GOVERNMENT OF PUNJAB, INDIA

PUBLIC WORKS DEPARTMENT
IRRIGATION BRANCH

A MANUAL
OF
IRRIGATION PRACTICE

VOL. I—SPECIFICATIONS
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PREFACE.

General Specifications were first issued in the irrigation Branch in 1894, and these were later incorporated in the Handbook of Professional Orders. The latest edition of this book was published in 1936. Since that period, the activities of the Irrigation Branch, Punjab, India have expanded many times, and now encompass the design and construction of high dams, power-houses, line canals and many other structures that were not conceived of thirty years earlier. This has necessitated the preparation of up-to-date specifications for materials and works. Specifications for many new materials such as pozzolans, air entrained concrete, asphalt, etc., have been included in the first chapter. The specifications for mass concrete for dams and heavy structures comply with the latest practice of the U.S. Bureau of Reclamation. As far as possible, internationally known technical terms and standards adopted to the conditions in the Punjab, have been used throughout the text, and every effort has been made to make these specifications modern, precise and technically simple to interpret.

These specifications are primarily for the guidance of Irrigation Branch in design, construction, and supervision of works, and also for the use of contractors engaged on these works. These specifications shall be strictly followed for all items within their scope, and where necessary detailed specifications shall be issued from the office of the Chief Engineer.

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The preliminary drafts of these specifications were prepared by Sardar G. S. Sarkaria, Assistant Design Engineer. Invaluable modifications and improvement were suggested by Shri Bherat Ram, Deputy Director, Designs, Shri Chaudhuy, Executive Engineer, Designs, Sardar Jatindra Singh, Executive Engineer, Nangal Dam and Sardar Ujjagar Singh, Assistant Design Engineer.

References.

Publications, specifications, and standards of the following organizations were freely consulted during compilation of these specifications.

1. American Concrete Institute.
5. Indian Standards Institution.
9. U. S., Bureau of Reclamation

Abbreviations.

A. C. I. .... American Concrete Institute.
B. S. S. .... British Standards Specification.
I. S. I. .... Indian Standards Institution.
U. S. B. R. .... United States Bureau of Reclamation.
## CONTENTS

### CHAPTER I

<table>
<thead>
<tr>
<th>Specification Number</th>
<th>Materials</th>
<th>Pages</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>Water</td>
<td>1</td>
</tr>
<tr>
<td>1.2</td>
<td>Earth</td>
<td>ib</td>
</tr>
<tr>
<td>1.3</td>
<td>Clay</td>
<td>2</td>
</tr>
<tr>
<td>1.4</td>
<td>Bricks</td>
<td>3</td>
</tr>
<tr>
<td>1.5</td>
<td>Stone Ballast</td>
<td>4</td>
</tr>
<tr>
<td>1.6</td>
<td>Brick Ballast</td>
<td>5</td>
</tr>
<tr>
<td>1.7</td>
<td>Bajri or gravel</td>
<td>6</td>
</tr>
<tr>
<td>1.8</td>
<td>Sand</td>
<td>8</td>
</tr>
<tr>
<td>1.9</td>
<td>Cement</td>
<td>13</td>
</tr>
<tr>
<td>1.10</td>
<td>Air Entraining Admixtures in Concrete</td>
<td>15</td>
</tr>
<tr>
<td>1.11</td>
<td>Pozzolana</td>
<td>17</td>
</tr>
<tr>
<td>1.12</td>
<td>Surkhi</td>
<td>18</td>
</tr>
<tr>
<td>1.13</td>
<td>Cinders</td>
<td>19</td>
</tr>
<tr>
<td>1.14</td>
<td>White Lime</td>
<td>ib</td>
</tr>
<tr>
<td>1.15</td>
<td>Kankan Lime</td>
<td>21</td>
</tr>
<tr>
<td>1.16</td>
<td>Mud Mortar</td>
<td>ib</td>
</tr>
<tr>
<td>1.17</td>
<td>Lime Mortar</td>
<td>22</td>
</tr>
<tr>
<td>1.18</td>
<td>Lime-Cement Mortar</td>
<td>25</td>
</tr>
<tr>
<td>1.19</td>
<td>Cement Mortar</td>
<td>ib</td>
</tr>
<tr>
<td>1.20</td>
<td>Timber, Hard and Soft Woods</td>
<td>27</td>
</tr>
<tr>
<td>1.21</td>
<td>Asphalt</td>
<td>29</td>
</tr>
<tr>
<td>1.22</td>
<td>Preformed joint filler</td>
<td>30</td>
</tr>
</tbody>
</table>


## CHAPTER II

### Specification Number

<table>
<thead>
<tr>
<th>Pages</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>6</td>
</tr>
</tbody>
</table>

(A)—**ORDINARY CONCRETE**

| 2.1  | Lime Concrete, ordinary | 1 |
| 2.2  | Lime Concrete, fine     | 2 |
| 2.3  | Cement Concrete, ordinary | 3 |
| 2.4  | Reinforced concrete     | 6 |

(B)—**MASS CONCRETE**

| 2.5  | Classification of mass concrete | 8 |
| 2.6  | Aggregates                  | 9 |
| 2.7  | Cement and admixture        | 13|
| 2.8  | Proportions and mixes       | 15|
| 2.9  | Water-cement ratio           | 16|
| 2.10 | Slump                       | 18|
| 2.11 | Batching                    | 19|
| 2.12 | Mixing                      | 22|
| 2.13 | Forms for concrete          | 26|
| 2.14 | Preparation for placing concrete | 30|
| 2.15 | Placing and transporting concrete | 32|
| 2.16 | Consolidation of concrete   | 35|
| 2.17 | Joints in concrete          | 36|
| 2.18 | Finishing                   | 38|
| 2.19 | Curing                      | 42|
| 2.20 | Water-proofing of concrete  | 43|
| 2.21 | Concrete control            | 44|
CHAPTER III
BRICKWORK AND STONE MASONRY

<table>
<thead>
<tr>
<th>Specification Number</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. BRICKWORK</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.1</td>
<td>Brickwork, pachca</td>
<td>1</td>
</tr>
<tr>
<td>3.2</td>
<td>Brickwork, kutch-pachca</td>
<td>3</td>
</tr>
<tr>
<td>3.3</td>
<td>Jibbi work</td>
<td>4</td>
</tr>
<tr>
<td>3.4</td>
<td>Sundried brickwork</td>
<td>6b</td>
</tr>
<tr>
<td>3.5</td>
<td>Kutcha masonry and Pipe wailing</td>
<td>5</td>
</tr>
<tr>
<td>3.6</td>
<td>Brick archwork</td>
<td>6</td>
</tr>
<tr>
<td>3.7</td>
<td>Reinforced brickwork walls</td>
<td>3</td>
</tr>
<tr>
<td>B. STONE MASONRY</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.8</td>
<td>Stone for masonry</td>
<td>10</td>
</tr>
<tr>
<td>3.9</td>
<td>Stone quarrying</td>
<td>11</td>
</tr>
<tr>
<td>3.10</td>
<td>Stone cutting and dressing</td>
<td>16</td>
</tr>
<tr>
<td>3.11</td>
<td>Stone, masonry general</td>
<td>13</td>
</tr>
<tr>
<td>3.12</td>
<td>Ashlar Masonry</td>
<td>15</td>
</tr>
<tr>
<td>3.13</td>
<td>Ashlar facing</td>
<td>17</td>
</tr>
<tr>
<td>3.14</td>
<td>Block in course masonry</td>
<td>18</td>
</tr>
<tr>
<td>3.15</td>
<td>Coursed rubble masonry</td>
<td>23</td>
</tr>
<tr>
<td>3.16</td>
<td>Uncoursed rubble masonry</td>
<td>22</td>
</tr>
<tr>
<td>3.17</td>
<td>Dry rubble masonry</td>
<td>23</td>
</tr>
<tr>
<td>3.18</td>
<td>Boulder masonry</td>
<td>24</td>
</tr>
<tr>
<td>3.19</td>
<td>Scabbled boulder masonry</td>
<td>25</td>
</tr>
<tr>
<td>3.20</td>
<td>Archwork in stone masonry</td>
<td>26</td>
</tr>
<tr>
<td>3.21</td>
<td>Stone copings, sernless, columns, etc.</td>
<td>27</td>
</tr>
<tr>
<td>3.22</td>
<td>Artificial stone, precast concrete blocks and masonry</td>
<td>28</td>
</tr>
</tbody>
</table>
### Chapter IV

#### Buildings

<table>
<thead>
<tr>
<th>Specification Number</th>
<th>Item</th>
<th>Pages</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1</td>
<td>Foundations</td>
<td>1</td>
</tr>
<tr>
<td>4.2</td>
<td>Damp proof course</td>
<td>3</td>
</tr>
<tr>
<td>4.3</td>
<td>Conglomerate flooring</td>
<td>4</td>
</tr>
<tr>
<td>4.4</td>
<td>Brick or tile flooring</td>
<td>6</td>
</tr>
<tr>
<td>4.5</td>
<td>Dry brick paving</td>
<td>7</td>
</tr>
<tr>
<td>4.6</td>
<td>Conglomerate flooring finishes</td>
<td>8</td>
</tr>
<tr>
<td>4.7</td>
<td>Jack arch roofing</td>
<td>9</td>
</tr>
<tr>
<td>4.8</td>
<td>Tiled roofing</td>
<td>12</td>
</tr>
<tr>
<td>4.9</td>
<td>Corrugated iron sheet roofing</td>
<td>14</td>
</tr>
<tr>
<td>4.10</td>
<td>Asbestos cement corrugated sheet roofing</td>
<td>16</td>
</tr>
<tr>
<td>4.11</td>
<td>Reinforced concrete or brickwork roofing</td>
<td>7</td>
</tr>
<tr>
<td>4.12</td>
<td>Terrace roofing</td>
<td>19</td>
</tr>
<tr>
<td>4.13</td>
<td>Wooden plank ceiling</td>
<td>20</td>
</tr>
<tr>
<td>4.14</td>
<td>Plaster ceiling</td>
<td>&quot;ib&quot;</td>
</tr>
<tr>
<td>4.15</td>
<td>Cloth ceiling</td>
<td>22</td>
</tr>
<tr>
<td>4.16</td>
<td>Plaster Woodwork, general</td>
<td>23</td>
</tr>
<tr>
<td>4.17</td>
<td>Doors and windows, general</td>
<td>25</td>
</tr>
<tr>
<td>4.18</td>
<td>Panelled and glazed doors and windows</td>
<td>28</td>
</tr>
<tr>
<td>4.19</td>
<td>Framed and braced doors and windows</td>
<td>&quot;ib&quot;</td>
</tr>
<tr>
<td>4.20</td>
<td>Lipped and braced doors and windows</td>
<td>29</td>
</tr>
<tr>
<td>4.21</td>
<td>Steel frame doors and windows</td>
<td>&quot;ib&quot;</td>
</tr>
<tr>
<td>4.22</td>
<td>Wire gauze doors and windows</td>
<td>31</td>
</tr>
<tr>
<td>4.23</td>
<td>Clerestory windows</td>
<td>32</td>
</tr>
<tr>
<td>Specification Number</td>
<td>Item</td>
<td>Pages</td>
</tr>
<tr>
<td>----------------------</td>
<td>-------------------------------</td>
<td>-------</td>
</tr>
<tr>
<td>4.24</td>
<td>Glazing</td>
<td>32</td>
</tr>
<tr>
<td>4.25</td>
<td>Pointing, general</td>
<td>34</td>
</tr>
<tr>
<td>4.26</td>
<td>Cement and lime painting</td>
<td>36</td>
</tr>
<tr>
<td>4.27</td>
<td>Lime and cement plastering</td>
<td>37</td>
</tr>
<tr>
<td>4.28</td>
<td>Mud plastering</td>
<td>39</td>
</tr>
<tr>
<td>4.29</td>
<td>White and colour washing</td>
<td>46</td>
</tr>
<tr>
<td>4.30</td>
<td>Distempering</td>
<td>42</td>
</tr>
<tr>
<td>4.31</td>
<td>Painting woodwork</td>
<td>43</td>
</tr>
<tr>
<td>4.32</td>
<td>Varnishing woodwork</td>
<td>46</td>
</tr>
<tr>
<td>4.33</td>
<td>Painting ironwork</td>
<td>47</td>
</tr>
<tr>
<td>4.34</td>
<td>Stopping woodwork</td>
<td>49</td>
</tr>
<tr>
<td>Specification Number</td>
<td>Item</td>
<td>Pages</td>
</tr>
<tr>
<td>----------------------</td>
<td>--------------------------------------</td>
<td>-------</td>
</tr>
<tr>
<td>5.1</td>
<td>Earthwork, general</td>
<td>1</td>
</tr>
<tr>
<td>5.2</td>
<td>Earthwork excavation</td>
<td>4</td>
</tr>
<tr>
<td>5.3</td>
<td>Earth-moving equipment</td>
<td>6</td>
</tr>
<tr>
<td>5.4</td>
<td>Canal earthwork</td>
<td>8</td>
</tr>
<tr>
<td>5.5</td>
<td>Manual earthwork placing</td>
<td>10</td>
</tr>
<tr>
<td>5.6</td>
<td>Puddling</td>
<td>11</td>
</tr>
<tr>
<td>5.7</td>
<td>Mechanical earthwork placing</td>
<td>12</td>
</tr>
<tr>
<td>5.8</td>
<td>Standard sheepfoot roller</td>
<td>15</td>
</tr>
<tr>
<td>5.9</td>
<td>Earth-moving and compaction equipment maintenance</td>
<td>18</td>
</tr>
<tr>
<td>5.10</td>
<td>Embankment compaction control</td>
<td>19</td>
</tr>
<tr>
<td>5.11</td>
<td>Repairs to earthwork</td>
<td>21</td>
</tr>
</tbody>
</table>
CHAPTER VI
EARTHWORK SLOPE PROTECTION
(Slope Pitching)

<table>
<thead>
<tr>
<th>Specification Number</th>
<th>Item</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.1</td>
<td>Slope protection, general</td>
<td>1</td>
</tr>
<tr>
<td>6.2</td>
<td>Stone riprap, or dry stone or boulder pitching</td>
<td>2</td>
</tr>
<tr>
<td>6.3</td>
<td>Stone or boulder pitching, grouted</td>
<td>4</td>
</tr>
<tr>
<td>6.4</td>
<td>Cement concrete paving</td>
<td>5</td>
</tr>
<tr>
<td>6.5</td>
<td>Dry brick pitching</td>
<td>7</td>
</tr>
<tr>
<td>6.6</td>
<td>Pilch, Sakanda, and bamboo mattress</td>
<td>8</td>
</tr>
<tr>
<td>6.7</td>
<td>Miscellaneous methods of slope protection</td>
<td>9</td>
</tr>
<tr>
<td>Specification Number</td>
<td>Item</td>
<td>Pages</td>
</tr>
<tr>
<td>----------------------</td>
<td>-------------------------------------------</td>
<td>-------</td>
</tr>
<tr>
<td>7.1</td>
<td>River conservancy works, general</td>
<td>1</td>
</tr>
<tr>
<td>7.2</td>
<td>Bank revetments</td>
<td>2</td>
</tr>
<tr>
<td>7.3</td>
<td>Stacking and bushing</td>
<td>3</td>
</tr>
<tr>
<td>7.4</td>
<td>Reclamation works</td>
<td>4</td>
</tr>
<tr>
<td>7.5</td>
<td>Spurs, spur, dike, and groynes</td>
<td>5</td>
</tr>
<tr>
<td>7.6</td>
<td>Guide banks, or Bolts bunds</td>
<td>6</td>
</tr>
<tr>
<td>7.7</td>
<td>Pitched islands</td>
<td>8</td>
</tr>
<tr>
<td>Specification Number</td>
<td>Item</td>
<td>Pages</td>
</tr>
<tr>
<td>----------------------</td>
<td>-------------------------------------------</td>
<td>-------</td>
</tr>
<tr>
<td>8.1</td>
<td>Road work materials</td>
<td>1</td>
</tr>
<tr>
<td>8.2</td>
<td>Materials stacking and collection</td>
<td>2</td>
</tr>
<tr>
<td>8.3</td>
<td>Road formations</td>
<td>3</td>
</tr>
<tr>
<td>8.4</td>
<td>Soaking, coat, laying and consolidation</td>
<td>4</td>
</tr>
<tr>
<td>8.5</td>
<td>Water bound macadam surface</td>
<td>5</td>
</tr>
<tr>
<td>8.6</td>
<td>Tar surfacing or bituminous mat</td>
<td>7</td>
</tr>
<tr>
<td>Specification Number</td>
<td>Item</td>
<td>Pages</td>
</tr>
<tr>
<td>----------------------</td>
<td>-------------------------------</td>
<td>-------</td>
</tr>
<tr>
<td>9.1</td>
<td>Walls, general</td>
<td>1</td>
</tr>
<tr>
<td>9.2</td>
<td>Wall staining and curbs</td>
<td>2</td>
</tr>
<tr>
<td>9.3</td>
<td>Well sinking</td>
<td>4</td>
</tr>
<tr>
<td>9.4</td>
<td>Special well foundations</td>
<td>6</td>
</tr>
<tr>
<td>9.5</td>
<td>Open caissons</td>
<td>8</td>
</tr>
<tr>
<td>9.6</td>
<td>Pneumatic caissons</td>
<td>9</td>
</tr>
<tr>
<td>9.7</td>
<td>Drilled wells</td>
<td>11</td>
</tr>
</tbody>
</table>
## APPENDICES

<table>
<thead>
<tr>
<th>Appendix</th>
<th>Title</th>
<th>Pages</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Standard Soil Classification System</td>
<td>1</td>
</tr>
<tr>
<td>II</td>
<td>Shaking Test for Soils</td>
<td>4</td>
</tr>
<tr>
<td>III</td>
<td>Slump Test for Consistency of Portland-Cement Concrete</td>
<td>5</td>
</tr>
<tr>
<td>IV</td>
<td>B.S. Standard and U.S. Standard Sieves</td>
<td>11</td>
</tr>
<tr>
<td>V</td>
<td>Sampling Aggregate for Laboratory Testing</td>
<td></td>
</tr>
<tr>
<td>VI</td>
<td>Test for Compressive Strength of Cement Mortars</td>
<td>14</td>
</tr>
<tr>
<td>VII</td>
<td>Test for Tensile Strength of Cement Mortars</td>
<td>18</td>
</tr>
<tr>
<td>VIII</td>
<td>Tests for Pozolans</td>
<td>22</td>
</tr>
<tr>
<td>IX</td>
<td>Standard Compaction Test (Compaction and Penetration Resistance)</td>
<td>24</td>
</tr>
<tr>
<td>X</td>
<td>Field Density Test</td>
<td>33</td>
</tr>
<tr>
<td>XI</td>
<td>Needle-Moisture and Needle Density Tests</td>
<td>36</td>
</tr>
</tbody>
</table>
CHAPTER I
MATERIALS

11. (1) Water used in masonry work, for making bricks, concrete or mortar and in general construction, shall be reasonably clean and free from objectionable quantities of suspended material, vegetable or organic impurities, alkali salts and other constituents likely to cause efflorescence or otherwise detrimentally effect the quality or the physical properties of the product. The water used for curing brickwork and concrete as well as for soaking bricks shall also be free from the above impurities, as unclean or turbid water is likely to impart its own colour to bricks, masonry or concrete. As a rule, water that is clear and potable shall be considered quite satisfactory for all these purposes.

(2) In the case of large and important concrete structures such as dams, water shall be subjected to chemical analysis with respect to its purity, acceptability for use in mixing and curing concrete and its corrosive action on concrete. Once the source or sources of water have been established, regular testing and inspection is not necessary unless there is some cause warranting such an action. Under such conditions the water shall be rendered satisfactory by removal of the contamination or by changing the source of supply.

(3) Water used in compaction of soil for earthen embankments shall also be free from solid materials such as roots, grass or wood, the presence of which may be likely to render difficult the formation of a compact homogeneous mass.

12. (1) General: The term 'earth' shall apply, generally, to soil employed for constructing earthen embankments, bunds, dikes and backfills in masonry works etc. Earth used for such purposes shall be free from stumps, roots, grass, clods and large pieces of stone as these hinder proper compaction of the soil by manual or mechanical means. Care shall be
taken that the earth used for the top two feet of motorable canal banks, be free from kellar and alkaline materials as these render the surface unmotorable.

(2) Classification: All earthen embankments higher than 25 feet, earth dams, bunds and coffer-dams shall be properly designed. The earthen materials or soils, used in the design and construction of these structures shall be properly classified according to their grain-size distribution, liquid and plastic limits, natural moisture content, density, shearing characteristics, permeability, etc. The "Airfield Classification" or A.C. System, as used by the U. S. Bureau of Reclamation, shall generally be followed for classifying soils for important earthen structures. The A. C. System including the International grain-size classification is given in Appendix I.

1.3. (1) Definition: Clay, in general terms, shall include all fine, cohesive and plastic soils. More specifically, the term clay shall include all soils, with more than 50 per cent particles, by weight, smaller than 0.002 mm. and with definite cohesive and plastic properties when wet, and hard and brittle when dry. A soil particle smaller than 0.002 mm. shall be called a "clay-size particle" and not a "clay" particle. Clays shall be distinguished in the field from other fine soils like inorganic silts, loess and rock-flour by the simple Shaking Test, described in Appendix II, to compare cohesive properties of fine soils. Terms like hard clay, soft clay, organic clay, silty clay or swelling clay, shall be employed to denote the characteristics of a clay sample only after the tests specified for the particular properties have been carried out either in the field or in the laboratory. Claystone or crushed shale shall not be considered as clay for engineering design and construction purposes.

(2) Clay for bricks: Clay used for manufacture of bricks and tiles shall be free from saline impurities, Reh or Sajit, roots, pebbles and nodules and shall be capable of being moulded to a workable consistency.

(3) Special uses: Clay used in puddle-cores, or in blankets and cut-off trenches should be highly impervious and its physical properties should conform with the design specifications. Highly sticky clays are very difficult to
compact with sheeps-foot or other rollers. In such cases, the clay should be exposed to the atmosphere to dry and some sand may be added, if permissible. Highly plastic clays when remoulded in a saturated condition turn into a slurry. Such clays, when used in earthen construction, should be handled with care and special instructions to the effect should be issued by the Design Office and the laboratory.

1.4. (1) Material for manufacture: The clay which is used for manufacture of bricks shall be free from Reh or any saline deposits. To make it free from any roots or grass the top surface should be scraped off. It shall be well ground before use. The brick-making quality of a clay is usually ascertained by actually making a brick out of it and burning it in a brick klin. If the brick does not come up to the required standard, chemical analysis will suggest what might be added to improve the earth.

(2) Manufacture: The bricks shall be moulded in moulds coated at the inner surface with sand. Size of the bricks, unless otherwise specified shall be 9" X 4" X 2" and the average size of the mould shall be 9.45" X 4.75" X 3.75".

All the bricks shall be burnt in Standard Bull's Trench Klin, but where only small quantities are needed any other pattern of klin suited to local circumstances may be used. In Bull's klin the bricks may be put in slightly damp condition. Care shall be taken that bricks are not unloaded until they have thoroughly cooled.

(3) Classes: Bricks shall be divided into the following classes according to their quality.

(i) First Class or Pucca Bricks.
(ii) Third class bricks.

(i) Pucca bricks: These bricks shall be thoroughly and equally burnt, without being vitrified, of good colour, regular and uniform in shape and reasonably square the bricks must be homogenous in texture and should emit a clear ringing sound when struck.
(ii) **Third class bricks**: These bricks need not be so fully burnt as pucca or 1st class bricks but must be burnt to a reddish, yellow or slightly over burnt. These bricks may not be of such a good shape as pucca bricks.

(4) **Tiles**: The quality of flat tiles shall be the same as that of first class bricks. The tiles shall be so moulded as to be of the following dimensions after burning:

<table>
<thead>
<tr>
<th>Type</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tiles for first class roofing</td>
<td>12″×6″×11⁄2″</td>
</tr>
<tr>
<td>Tiles for second class roofing and for flooring</td>
<td>13″×6″×2″</td>
</tr>
<tr>
<td>Tiles for flooring</td>
<td>9″×4″×2″</td>
</tr>
<tr>
<td>Tiles for special uses</td>
<td>Size as ordered</td>
</tr>
</tbody>
</table>

(5) **Sun-dried bricks**: The clay used in making sun-dried bricks shall be free from efflorescing salts, white ants, roots and grass. The percentage of sand in the clay should not be so high as to make the bricks too brittle or so low as to cause cracks to appear in the brick moulded from it.

The bricks shall be sand-moulded and shall be uniform in size and regular in shape. They shall be thoroughly dry before use and proper care should be taken to ensure their safety against damage due to rain.

These bricks are generally used in temporary buildings in low rainfall areas.

**STONE BALLAST**

( Crushed Stone Aggregate )

1.5. **(1) Source**:—All stone or boulders used for manufacturing aggregate shall be sound, free from decay, flaws, cracks, veins or cavities and shall as far as possible, be of uniform texture and physical properties. Shales, slates, friable sand-stones, clayey rocks and other unsound kinds of stones shall not be used. For aggregate to be used for concrete in important structures, the suitability of available stones for manufacture of aggregate shall be tested in a petrographic and concrete testing laboratory. Stones containing significant proportions of certain silica minerals like Opal,
Chap. 2] CLASSIFICATION OF MASS CONCRETE —1.6

chalcedony and glassy rhyolites that deleteriously reactive, shall not be used for manufacture of aggregate. The possibility and extent of alkali-aggregate reaction if a certain aggregate is to be used in concrete, shall also be investigated in the laboratory before its use is permitted. Crushed stone aggregate used in concrete for important structures shall also conform to specifications Nos. 2.6, 40.1.3, 40.2.2 and 40.2.4, in addition to the above general specifications.

Manufactured aggregate, or stone ballast, is either crushed by mechanical crushers or broken by hand, to the specified gauge. Mechanical crushers shall be employed only when the quantity of aggregate required is very large and mechanical operations are economical and time-saving.

(2) Size and Grading:—Different sizes of ballast are used for different works and the stone shall be crushed to the specified size. The grading of ballast shall also be specified for important works, and it shall be similar to that of gravel or natural aggregate. General sizes of ballast for ordinary works are:

- (a) 3/16" — 1"  
- (c) 1" — 1 1/4"
- (d) 1 1/4" — 3"  
- (f) 3" — 6"

(3) Washing:—Ballast shall be free from dust, dirt and soil. Such impurities get mixed during the process of crushing and stacking the stone. Ballast on small jobs should invariably be washed on a clean platform by a powerful jet. On a large scale job where crushing plant is employed for manufacturing aggregate, it shall always be washed and properly screened before being conveyed to the batching plants.

BRICK BALLAST

16. (1) Source.—Brick ballast shall be broken from first class bricks or their bats or from Jhama bricks that are not very spongy. No underburnt bricks shall be used to manufacture ballast.

(2) Sizes.—Brick ballast shall always be broken to the gauge specified. The following sizes shall commonly be used.
1.7—MANUAL OF IRRIGATION PRACTICE [Chap. 1.

(a) 1\(\frac{1}{2}\) inch gauge Ballast.—This size ballast shall be such as all shall pass through a ring of \(1\frac{1}{4}\) inches internal diameter and not more than 20 per cent shall be larger than 2 inches in greatest length.

(b) 3/4 inch Gauge Ballast.—Brick Ballast of this size shall all pass through a screen of \(\frac{3}{8}\times\frac{3}{8}\) inch square mesh, and not more than 20 per cent shall be larger than 1 inch in greatest length.

Because of breaking to a finer size core shall be taken that the ballast does not contain brick dust or an excess of small stuff. When this defect appears, the contractor shall reserve the ballast according to the instructions of the Engineer Incharge.

(3) Stacking.—The ballast shall be free from Surkh, leaves, straw, earth, sand or any other foreign matter. To avoid mixing up of any impurities the ballast should be broken and stacked on a clean platform.

1.7. (1) Definition.—Gravel shall consist of natural coarse-grained coheientless aggregate of rounded and subangular rock fragments. Particle sizes shall be between 3/16 inch and 6 inches. Fragments with a diameter of more than 6 inches shall be called boulders.

(2) Source Components.—Gravel obtained from river or stream deposits, should consist of pebbles adequately sound and capable of resisting the agencies of weathering without decomposition and wear. Gravel used for making concrete shall not contain rock pieces that are physically weak, extremely absorptive, easily cleavable, or which smell when saturated. The gravel pebbles should also conform to specification No. 62 and the pebbles should not be coated or impregnated with opal chalcedony or other reactive substances. Quartz, quartzites, dense siliceous and volcanic rocks, dense sandstones and limestones form the best constituents of good gravel.
(3) **Particle Shape**—Gravel composed mostly of rounded and sub-angular particles shall be preferred. Flat or elongated particles in a gravel are objectionable since they have a detrimental effect on the workability of the concrete. However, for ordinary work no special attention need be paid to shape of particles.

(4) **Screening**—Screens shall be of the gauge specified and of square mesh. For hand screening, the screens shall be of stout construction and those made from expanded metal or rabbit netting shall not be used. While screening the screens shall not be set at a slope steeper than 45° to the horizontal. Gravel shall be screened, at the quarry in order to save on carriage and washing costs.

For big and important works, where large quantities of gravel are required, mechanical screening should be resorted to, if found to be economical.

(5) **Washing**—All gravel used in concrete shall be properly washed and dried before mixing with other ingredients to make concrete. For small jobs, gravel should be washed on a clean platform with a powerful jet. Gravel so washed shall not contain more than 1 per cent clay or mud by weight.

Mechanical washing can be amalgamated with screening in large-scale operations. Gravel for large and important works shall be completely free from dust or clay impurities.

(6) **Sizes and Grading**—Gravel used for ordinary works shall generally be well-graded and the maximum permissible size shall be fixed for each particular job.

(a) **1/2 inch gravel**.—All the aggregate shall pass through a standard 1 1/2 inch sieve and all should be retained on a standard 3/16 inch sieve. It shall be well-graded in between such that not more than 60 per cent and not less than 30 per cent. by weight, shall be retained on a Standard 3/4 inch sieve. This aggregate is generally used for all unreinforced mass cement concrete work on small jobs. For reinforced work, it shall be used only where the minimum dimension of the member exceeds 22 inches.

(b) **1 inch gravel**.—All aggregate shall pass through a standard 1 inch sieve and all should be retained on standard 3/16 inch sieve. It shall be well-graded in between 80...
that not more than 60 per cent and not less than 30 per cent, by weight, shall be retained on a standard 3/4 inch sieve. This aggregate is generally used or unreinforced concrete work over 4 inches minimum dimension. For reinforced concrete work this size of gravel shall be used only where the minimum dimension of the member is 10 inches, but does not exceed 22 inches.

(c) 3/4 inch gravel.—3/4 inch gravel shall consist of particles all of which will pass through a standard 3/4 inch sieve and will be retained on a standard 3/16 inch sieve and shall be well-graded in between so that not more than 60 per cent and not less than 30 per cent, by weight, shall be on a U.S. standard 3/6 inch sieve. This size of gravel is used for unreinforced concrete work between 2 inches and 4 inches minimum dimension. For reinforced concrete work, it shall be used only where the minimum dimension of the member is 5 inches, but does not exceed 10 inches.

(d) 3/4 inch gravel.—This size of aggregate shall consist of particles all of which will pass through a standard 3/4 inch sieve and all of which will be retained on a standard 3/16 inch sieve No. 12. It shall be well-graded in between so that not more than 60 per cent and not less than 30 per cent, by weight, shall be retained on a standard 3/16 inch sieve. This size of gravel is generally used for reinforced concrete slabs and lintels between 2 and 5 inches thick.

(e) All gravel used for concrete work in special structures and for mass concrete in dams, shall be of size and grading specified for the particular job. See Specifications Nos. 2.3, 2.4 and 2.6 for this purpose.

(7) Gravel for Filters.—All gravel used for weighted or inverted filters, filter toes, filter wells and for filter drain behind canal lining, shall be clean and free from impurities and shall be of a size and gradation specified for the particular purpose. The degree of compaction, or relative density, at which a filter layer should be placed, shall also be specified.

1.8. (1) Standard Definition.—The fine granular material resulting from the natural disintegration of rock, or from crushing of friable sandstone shall be called sand.
For purposes of soil mechanics, the term sand shall apply to all natural cohesionless aggregates with particle sizes between 0.06 m.m. and 2.0 m.m. Particles with these sizes shall be termed sand sized particles "and not" sand particles unless the soil has been classified as sand from its physical properties.

The term "manufactured sand" shall be used for sand produced by crushing and screening operations from stone, gravel, rock etc. The fine material resulting from the crushing of blast furnace slag is known as "slag sand".

Terms like "fine sand", "silty sand" and "loose sand" shall be employed to convey certain characteristics of a sand only after it has been thoroughly tested for its physical properties by standard field or laboratory methods.

(2) Source.—Practically for all purposes, the choice of materials is, for economic reasons, usually limited to local deposits. However desirable and undesirable characteristics of any material have to be appreciated and practicability of improving available materials by suitable processing shall be investigated.

(3) Quality.—For important works like large dam, sand should conform to detailed specifications given in pertinent paras of specification No. 2.6.

For ordinary works also the sand should be coarse and hard, gritty to touch, and free from elongated particles. It should be reasonably clean and free from objectionable quantities of silt, clay, mica, coal, humus and other organic matter, chemical salts, surface coatings and encrustations. For all jobs the sand shall be at least of such cleanliness that when a handful of it is shaken in a glass tumbler with clean water and allowed to stand for one hour the precipitation of mud or clay fines (or rock flour in the case of screenings) on sand shall not exceed 5 per cent. If 0.5 per cent is higher than this, the sand shall be washed prior to being used.

(4) Gradation.—The particle size distribution of aggregates as determined by separation with standard sieves (or screens) is known as its "gradation". For sand it is expressed in terms of percentages retained on U.S. Standard Sieves designated by numbers 4, 8, 16, 30, 50 and 100.
Fineness modulus (F.M.) of sand shall be computed by adding the cumulative percentages, by weight, of material retained on these sieves and dividing the sum by 100. The following classifications of sand, based on fineness modulus shall be used:

<table>
<thead>
<tr>
<th>Classification</th>
<th>F.M.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coarse Sand</td>
<td>2.56-3.30</td>
</tr>
<tr>
<td>Fine Sand</td>
<td>1.50-2.50</td>
</tr>
<tr>
<td>Very Fine Sand</td>
<td>0.90-1.50</td>
</tr>
</tbody>
</table>

The fineness modulus of any particular sample of sand is an index of its coarseness or fineness but gives no idea of its gradation.

The grading of sand has a marked influence on the workability and finishing quality of concrete although it has no material effect on compressive strength of mortar when water cement ratio and slump are held constant.

Experience has demonstrated that either very fine or very coarse sand or aggregate having a large deficiency or excess of any size fraction is generally undesirable and that material having a smooth grading curve will produce more satisfactory concrete.

In case of concrete for all important works, the size and gradation of sand to be used shall be specified. See paras (3) of specification No. 2.6 for further details.

(5) Sand for Filters.—Sand used for weighted or inverted filters, filter walls and or filter drain behind canal lining shall be clean and free from impurities and shall be of size and gradation specified for the purpose. The degree of compaction or relative density, at which a filter layer will be placed, shall also be specified.

(6) Stacking.—Fine aggregate shall be stacked on a clean, hard, wooden or brick platforms so as to be adequately protected from admixture of clay, dust or foreign matter.

(7) Volume change and Moisture content.—The moisture content has an important effect on the volume of sand which must be taken into account when batching has to
be done by volume, to avoid inaccurate proportioning in concrete and mortars. As delivered and used on the job, sand invariably contains moisture. The volume of a given weight of sand is increased by moisture far out of proportion to the quantity of moisture present and the effect varies with the nature of the sand. The bulking effect of the moisture is shown in the accompanying diagram for three sands, covering the range ordinarily used in concrete.

(It will be observed that the maximum effect occurs at about 5 percent of the moisture which is approximately the quantity most commonly present in the sand on a job).

(8) Making Allowance for Bulking on the Job.—Failure to allow for this bulking increased cost of concrete and often results in under-sanded mixes which are harsh and difficult to place.

If, for example, medium sand shown in the diagram is used, and it contains 5 per cent moisture, it is seen that bulking is 29 per cent. To make allowance for bulking in a 1:2.4 mix, 1.28 x 1.29 = 2.38 cubic feet of damp
sand should be measured for each bag of cement. The volume of dry sand in this quantity of damp sand will be 2 cubic feet.

Note.—Quick method of obtaining sand bulking on site. This method is based on the known fact that dry sand and inundated sand occupy the same volume.

A sample should be taken from inside of pile and not from top, where sand may be air dried.

1. Take a container 4" X 4" X 4" inside dimensions and fill up with site sand and spread level.

2. Pour water into the sample slowly at one side to let the entrained air cut—air and shake so that all air is eliminated.

3. Pour off water and then measure the amount the inundated sample has shrunk (Dimension X).

4. With this dimension X, refer to chart and read off against this dimension; the new volume per cent shrinkage per cent bulkling on dry sand—and, finally, the amount of moist site sand required to be used to ensure 1 cu.ft. of dry sand (allowed by specification).

<table>
<thead>
<tr>
<th>Dimension X in inches</th>
<th>Volume in cubic inches</th>
<th>Percent shrinkage</th>
<th>Per cent bulking</th>
<th>Volume moist sand required to ensure 1 cu.ft. dry sand</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/16</td>
<td>53</td>
<td>1.12</td>
<td>1.3</td>
<td>1.032</td>
</tr>
<tr>
<td>1/8</td>
<td>61</td>
<td>4.69</td>
<td>4.6</td>
<td>1.051</td>
</tr>
<tr>
<td>5/32</td>
<td>66</td>
<td>6.25</td>
<td>6.6</td>
<td>1.066</td>
</tr>
<tr>
<td>1/4</td>
<td>58</td>
<td>9.37</td>
<td>10.3</td>
<td>1.101</td>
</tr>
<tr>
<td>3/32</td>
<td>64</td>
<td>12.8</td>
<td>14.3</td>
<td>1.144</td>
</tr>
<tr>
<td>1/3</td>
<td>55</td>
<td>15.6</td>
<td>18.5</td>
<td>1.335</td>
</tr>
<tr>
<td>7/32</td>
<td>55</td>
<td>18.4</td>
<td>20.7</td>
<td>1.326</td>
</tr>
<tr>
<td>1/2</td>
<td>53</td>
<td>21.2</td>
<td>24.4</td>
<td>1.254</td>
</tr>
<tr>
<td>1/16</td>
<td>49</td>
<td>24.3</td>
<td>30.6</td>
<td>1.132</td>
</tr>
<tr>
<td>5/32</td>
<td>46</td>
<td>27.9</td>
<td>33.5</td>
<td>1.326</td>
</tr>
<tr>
<td>1/4</td>
<td>46</td>
<td>31.2</td>
<td>36.0</td>
<td>1.398</td>
</tr>
<tr>
<td>3/32</td>
<td>45</td>
<td>34.9</td>
<td>40.0</td>
<td>1.421</td>
</tr>
<tr>
<td>1/3</td>
<td>44</td>
<td>38.6</td>
<td>44.5</td>
<td>1.451</td>
</tr>
</tbody>
</table>

(12)
1.9  
(1) **Definition.**—For the purpose of these specifications, the term "portland cement" shall be designated to the product obtained by pulverizing clinker consisting essentially of hydraulic calcium silicates, to which no additions have been made subsequent to calcination other than water and/or untreated calcium sulphate, except that additions not to exceed 1.0 per cent of other materials may be interground with clinker, provided such materials in the amounts indicated have been shown to be not harmful by specified tests. Unless otherwise specified the term "cement" shall mean portland cement in these specifications.

(2) **Supply.**—Cement shall be supplied to the Contractors by the Public Works Department. Under special circumstances, cement may be supplied by the contractor and in that case the brand and quality of cement shall have to be approved by the Executive Engineer.

(3) **Chemical Requirements.**—Portland cement shall conform to the chemical composition limitations given below:

- Magnesium Oxide (Mgo) ... Max. 5.0 per cent
- Sulphur Trioxide (So3) ... Max. 2.0 per cent
- Loss on ignition ... Max. 3.0 per cent
- Insoluble residue, in HCL ... Max. 0.75 per cent

The chemical analysis of cement shall be carried out according to A.S.T.M. Designation No. C114-47.

(4) **Physical Properties Standards.**—Standard portland cement shall fulfil the following requirements:

(a) **Fineness.**—Specific surface in square centimeters per gram to have a minimum value of 1,600, tested according to American Society for Testing Materials Designation No. C115-42.

Alternatively, residue on B. S. sieve No. 170 not to exceed 10.0 per cent and residue on B.S. sieve No. 72 not to exceed 1.0 per cent by weight.
1.9—

MANUAL OF IRRIGATION PRACTICE  [Chap. 1.

(b) Soundness:—

Expansion by the "Le Chatelie" test not more than 10 m.m. or 5 m.m. after 7 days aeration. Time of boiling being 3 hours. Alternatively Autoclave expansion shall have a maximum value of 0.50 per cent when tested according to A.S.T.M. Designation No. C131-49.

(c) Time of setting:—

Time of initial set shall not be less than 30 minutes, and that of final set not more than 10 hours. Test for time of setting shall be carried out according to the latest British Standard Specifications for portland cement.

(d) Tensile and Compressive Strengths:—

Unit strengths of cement and sand mortars, in tension and compression shall be as indicated in specification No. 1.19, under the sub-heading of strength.

(5) Packing:—Cement shall be supplied in standard bags each containing 1.25 cubic feet of cement and the gross weight shall be 112 lbs. The unit weight of cement shall be taken as 90 lbs per cubic foot. Cement in bags varying more than 5 per cent from specified weight may be rejected.

(6) Storage.—All cement shall be stored in weather-tight buildings, shed or warehouses, the floors of which shall be damp-proof and at least 12 inches above the natural surface of the ground. Cement shall not be stored in contact with walls. When stored in bags, these bags shall be placed horizontally in contiguous lines and layers. To reduce deterioration by aeration cement should be stored in bulk wherever possible. For this case special care shall be exercised in dumping the cement and supervision by the Sub-Divisional Officer shall be more frequent and strict. Cement in bags, in local storage for more than 3 months shall be re-tested before use and rejected if it fails to conform to the specifications. For supply and storage of cement in bulk, see specialisation No. 2.5.

(7) Limitations to use:—The contractor shall use all cement issued to him as supplied. Cement surplus after the completion of the work shall be disposed of as directed by the Executive Engineer.

(14)
(1) **Air Entrainment:** Air-entrained concrete shall be obtained either by using a specified air-entraining agent in solution along with water used at the time of mixing concrete or by employing a special type of cement known as "Air-Entraining Cement". The former method being more convenient and practical shall generally be preferred.

Note.—Addition of Air—entraining agent to concrete mixture results in entrainment of small well dispersed air bubbles throughout the mix. The entrainment of 3 to 5 per cent of air in concrete, by volume:—

(a) increases the resistance of concrete to disintegration from freezing and thawing;
(b) improves the resistance of concrete made with sulphate—resisting cement to corrosive attack by sulphate alkalis;
(c) increases workability at the same slump with substantial reductions in sand, cement, and water content, and in many cases permits use of lower slump;
(d) reduces the amount of vibration necessary for proper consolidation, and minimizes the danger of over-vibration;
(e) appreciably reduces bleeding and segregation;
(f) improves the practicability of using aggregate of larger maximum size;
(g) expedites and shortens the time of finishing operations;
(h) in general, for a given water—cement ratio, produces higher quality concrete with substantial economy in cement requirement, although attaining somewhat less strength.

(2) **Air-Entraining Compounds:** The following commercial products manufactured in U.S.A., and any other compounds approved either by the A.S.T.M., or the Indian Standards Institution, or by the Chief Engineer, shall be used for admixture to produce air-entrained concrete—

<table>
<thead>
<tr>
<th>Compound</th>
<th>Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Viscas resin</td>
<td>Hercules Powder Company</td>
</tr>
<tr>
<td>&quot;N—TAR&quot;</td>
<td>Newport Industries, Inc.</td>
</tr>
<tr>
<td>&quot;Dures,&quot; AEA</td>
<td>Dossy and Sty Chemical Co.</td>
</tr>
<tr>
<td>&quot;Airbox&quot;</td>
<td>Ditto</td>
</tr>
</tbody>
</table>

(15)
Approximately 4 per cent of entrained air has been found to be about the ideal amount for maximum improvement in durability and other benefits without suffering more than a minor accompanying reduction in compressive strength for a given water-cement ratio. With appreciably greater air entrainment, strength usually is decreased materially, therefore careful and accurate measurement of the dilute solution of the agent for each batch is necessary where minimum reduction of strength is desired. Since the amount of an air-entraining agent required to produce a given percentage of entrained air will be different for different slumps, water-cement ratios, mixing times, cements, and aggregates, a few trial mixes should be made before establishing the amount of agent to be used.

The trial mixes should be preferably made on the job in job-size batches using job equipment. Sight should never be lost of the fact that the percentage of air entrained is the factor of primary importance and not the amount of a given agent used. All the changes in the properties of concrete which results from this procedure are due entirely to the amount of air entrained and not to the character or brand of agent used to entrain the air. Therefore, in all field and laboratory work with air-entrained concrete, results should be related to, and analysed on the basis of, the percentage of air entrained and not the amount of air-entraining agent used. In the trial mixes, the percentage of air-entrainment (or voids) in the concrete is obtained readily by comparing the weight per cubic foot of the solid volume of materials in the mix and the actual unit weight of the concrete. Compaction of concrete in filling the container for the unit weight test should duplicate the means of compaction used in the forms. If the concrete is rodded in the forms, it should be rodded in the unit weight container; if it is vibrated, it should be vibrated a similar amount in the container, taking care not to overvibrate but to fully consolidate the concrete.

(3) Air-Entraining Cement.—

(a) Definition.—Air-entraining portland cement shall conform to the definition of portland cement in specification No. 1.9, with the addition that subsequent to calcination and addition of water there shall be inter ground with
Chap. 1] MATERIALS

the clinker an approved air-entraining compound in quantities considered necessary to impart such properties to the cement that it shall fulfill the specifications given below.

Air-entraining cement shall conform to physical properties' standards for portland cement, given in specification No. 1.9, regarding fineness, soundness and time of setting. In addition it shall satisfy the following conditions:

(i) Air content of mortar prepared and tested in accordance with A.S.T.M., Designation C 195, 1949, shall be between 15 and 21 per cent by volume.

1.11. (1) Definition.—The term "pozzolan" will be used for such siliceous materials, natural or artificial, processed or unprocessed, which though not cementsations in themselves, contain constituents that will, at ordinary temperatures, combine with lime in the presence of water to form compounds which have a low solubility and possess cementing properties. The term "portland pozzolan cement", shall be used for the product produced by intergrinding pozzolans with portland cement clinker.

It shall not impair or change the properties of the concrete as fixed by the specifications for concrete on a particular job.

(2) Specifications.—The most important requisite of a pozzolan is that it should be economical and available in abundance, either as a natural deposit or as factory by-product.

A material proposed to be used as pozzolan shall be thoroughly tested in a laboratory for pozzolanic activity by subjecting it to the following four tests, with any other additional test or tests if necessary:

(a) Flocculence Test.
(b) Lime Absorption Test.
(c) Time of Setting.
(d) Compressive Strength.

(17)
See Appendix No. VIII, for details of tests.

These tests, and others if any, shall also determine suitable ratio in which a pozzolan is to be mixed with a cement. Generally speaking to compressive strength and specific surface of a pozzolan should be at least the same as that of the cement.

A pozzolanic material shall not be used in any work without the specific permission of the Chief Engineer.

No. 1.12. (1) Manufacture.—Surkhi shall be made by pounding or grinding fully burnt bricks or bats. No under-burnt or over-burnt bricks or bats shall be used. At the discretion of the Executive Engineer, surkhi may be made from clay lumps or slop moulded bricks, of approved quality of clay, provided these are fully burnt in clumps. A practical test that clay is not under-baked is to verify that it has lost its plasticity, when mixed with water. Surkhi shall, on no consideration, be ground from clay burnt by unapproved methods, or obtained from kiln linings.

2. Fineness.—The material shall be ground or pounded to an impalpable dust so that the whole of it passes through a U.S. Standard Sieve No. 12 but does not pass through a U.S. Standard Sieve No. 50.

For work that is to remain permanently under water after construction, U.S. Standard Sieve No. 12 mentioned above shall be replaced by a Standard Sieve No. 8. It is essential that this surkhi shall be specially well burnt.

3. Storage.—Surkhi shall be stacked on platform built of bricks, wood or other suitable materials. Surkhi shall be free from any admixture of clay, dust and foreign matter and shall be suitably protected from these impurities.
MATERIALS

1.13. (1) Sources.—Cinders used in construction shall be obtained only from clean furnace clinker of coal, that is residue from furnaces of steam boilers using only coal as fuel. Cinders containing any quantity of wood ash shall not be accepted. Cinders obtained from coal which contains an excessive amount of sulphur or other injurious chemicals, shall not be used.

(2) Fine ness.—Cinders shall be ground in a mill and screened so that the entire quantity passes a U. S. Standard sieve No. 12, and all shall be retained on a U. S. Standard sieve No. 50.

(3) Storage and Use.—Cinders shall be staked on a platform and so protected that there is no admixture of dust or foreign matter.

(4) Use restriction.—Cinders shall not be used as a substitute for sand or surkhii unless allowed by the Superintending Engineer.

1.14. (1) Manufacture.—White Lime shall be manufactured from Limestone which contains 90 per cent or more of calcium carbonate. The Limestone shall be broken into pieces to pass a 2½ inches diameter ring before placing in the kiln. The following specifications shall be followed for manufacture of lime.

(i) For firing the kiln, coal, charcoal, wood or screened cinders shall be used. Under no circumstances shall cow-dung be used.

(ii) In drawing the kiln care shall be taken to remove as much ash as possible.

(iii) The lime shall be free from unburnt lumps and nodules and shall increase to not less than 1.8 times its original bulk when staked.

(iv) A perpetual kiln, in which the burning of limestone can go on continuously, should be used if large quantities of lime are to be manufactured, as it saves a lot of heat which otherwise goes to waste.
(2) **Storage.**—Lime shall be stored in a dry and weather proof shed with impervious floor and sides. It shall be stacked in compact heaps so that a minimum possible surface area is exposed to air, and thus, air slaking is kept at a minimum. Lime shall not be stored, for long periods after burning, but shall be used as fresh as possible.

(3) **Slaking.**—All impurities, ashes or pieces improperly burnt shall be screened or picked out before slaking the lime. Stone lime shall be slaked by sprinkling water slowly on the burnt lime which should be spread out on a dry brick platform in a six inch layer. No more water shall be used than is sufficient to convert it to a fine powder. After slaking the lime shall be left in a covered shed for a day or two for thorough slaking of refractory lumps and then screened through a U.S. Standard sieve No. 10.

Slaked lime shall be used up on the work within 10 days of slaking, unless kept completely immersed under water in a tank.

(4) **Grinding.**—Lime that has to be used in conjunction with cement for making mortar shall be ground dry. Lime shall be freshly ground as required and no stale dry ground lime shall be used. For making lime mortars, lime shall be ground wet after mixing as mortar, as per specification No. 1.17.

(5) **Measurement.**—Unslaked Stone lime shall be measured only when freshly burnt and shall be measured by weight.

(6) **Tests.**—(a) The test specimen of lime shall pass through a U.S. Standard Sieve No. 12.

Standard briquettes made at normal consistency from the lime shall be cured under damp and for 48 hours and then under water for 28 days when they shall give a minimum strength in tension of 100 lbs. per square inch.

Using the standard Vicat needle apparatus (which is used for the setting time of portland cement), the sample pat shall be kept moist and shall show final set before 24 hours after gauging.
Chap. 1] MATERIALS

(b) Lime which gives a residue of more than 10 per cent by weight when tested with hydrochloric acid shall not be accepted.

1.15. (1) Manufacture.—Kankar lime shall be burned from good quality kankar nodules, having a blue grey fracture, free from sand grains and broken to 2 inch gauge. The kankar nodules shall be freed from dirt and other impurities before loading in the kiln. No kankar quary other than that approved by the Executive Engineer shall be used.

Kankar lime shall be manufactured in the same way as white lime (see under “manufacture” in Speciation No. 1.14). The kankar, when burnt, shall be carefully hand-picked so as to exclude all over and under-burnt pieces and shall then be ground fine and screened through U. S. Standard sieve No. 12.

(2) Slaking and Grinding.—Kankar lime slakes slower than white lime and the increase in bulk may not be as appreciable as in the case of stone lime. The methods of slaking and grinding are the same as detailed in Specification No. 1.14

(3) Measurements and Testing.—Kankar lime shall be measured in bulk, such measurements not being taken till at least three days after the completion of supply.

Kankar lime shall also pass the test for tensile strength and setting time as described in Specification No. 1.14 for white lime.

Lime which gives a residue of more than 10 per cent by weight when tested with hydrochloric acid shall not be accepted.

1.16. (1) Ingredients.—Mud mortar shall be prepared from good brick earth or from clayey cohesive soil crushed into fine powder and freed from stones, grass roots, kankar and other such matter. No soil shall be used which contains efflorescing salts nor shall soil be taken from a locality where there are which ants.
2. **Making.**—The soil shall be mixed with water on a plot of ground specially cleared and set apart for the purpose, and tempered for at least 2 days, during which time it shall be worked up at intervals with men's feet and pohras.

3. **Consistency and Restriction to use.**—Mud mortar, when ready for use, shall be of such a consistency that it will readily slide off the face of a trowel, but shall not be so wet that the mortar parts into large drops in falling.

Mud mortar shall not be used for any brick work or masonry likely to be under water at any time, or subject to heavy showers of direct rain or likely to bear any but direct, vertical pressure.

1.7. **(1) Ingredients.**—(a) **White Lime Mortar.**—Standard lime mortar shall be made from slaked stone lime and surkhi, each constituent complying with its standard specification. Lime mortar composed of slaked stone-lime and sand shall be used only at the discretion of the Executive Engineer. Water used in mixing shall conform to Specification No. 1.1.

(b) **Proportions.**—Unless otherwise specified, lime mortar shall consist of a mixture of one part by volume of slaked stone lime and two parts by volume of surkhi.

Lime-sand mortar if used shall have the following proportions, or such proportions by volume as are specified by the Executive Engineer.

<table>
<thead>
<tr>
<th>Item of work</th>
<th>Lime</th>
<th>Sand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mortar for Lime concrete</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Mortar for bricks or stone masonry</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Mortar for plastering 1st coat</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Mortar for plastering 2nd coat</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Mortar for plastering final coat</td>
<td>1</td>
<td>1 1/2</td>
</tr>
<tr>
<td>Mortar for pointing</td>
<td>1</td>
<td>1 1/2</td>
</tr>
</tbody>
</table>
(3) **Mixing.**—Lime and surki (or sand) shall be measured in boxes, barrels or hoppers and shall be mixed on an approved platform of masonry or wood or in a mixing trough. If troughs are used they shall be capable of being washed and drained. The mixing platform shall not be used for stacking materials.

The ingredients shall be mixed dry three times, than sprinkled with the necessary quantity of water and ground in a mortar mill continuously for 3 hours or for 180 revolutions of the mill. The mortar must be continuously raked up during the process, particularly in the angles and corners. Water may be added as required during grinding, care being taken not to add more water than will bring the mixed materials to the consistency of a stiff paste.

(4) **Bullock Mortar Mills.**—If a bullock mortar be constructed of first class bricks in lime mortar, the bricks in the floor being laid on edge, the outer edge of the mill shall be raised above the track followed by the bullocks. The track itself shall be sloped outward and shall be kept watered. No dust or mud shall be allowed to fall into the mortar being ground.

(5) **Freshness.**—Mortar shall be mixed in quantities sufficient only for a day’s requirements. No mortar left over from the preceding day shall be used on the work.

Mortar for plastering shall be ground a second time, after storing in a damp condition for an interval of two days in the case of kankar and white lime, so as to ensure thorough slaking. The mortar should then be used at once.

(6) **Compressive Strength Test.**—The average compressive strength of standard lime mortar, shall be not less than 175 lbs. per square inch at the age of seven days, when tested by the procedure given below:—

(i) The test mortar shall consist of 1 part of slaked white lime to 3 parts of sand comparable to standard Pathankote sand in size and gradation.

(ii) The mortar shall be mixed in a non-absorbent bowl of about one-gallon capacity. About half a
gallon of water shall be poured into the bowl and then 500 gms of the slaked lime shall be added and stirred with hands covered with rubber gloves until all the lime is wetted. Then approximately 800 gms of sand shall be added and stirred for about 30 seconds. The remainder of 1500 gms of sand shall then be added and the mortar mixed for 75 seconds by vigorous and continued stirring, squeezing and kneading with one hand. The mortar shall be allowed to stand for 60 seconds and then mixed for another 60 seconds.

(iii) The mortar shall then be poured into 2 inch cube moulds of noncorrodible material, resting on plates. These shall be oiled with a medium viscosity oil. While pouring the mortar in the moulds it shall be puddled into place with finger tips of the gloved hand and finally troweled off flush with top of the moulds.

(iv) Test specimens shall be kept in moulds in a damp closet at a relative humidity of 90 per cent or more, for 48 hours in such a manner that the upper surface shall be exposed to the moist air. The specimens shall then be removed from the moulds and placed in the air of the laboratory, with at least five faces exposed, for a period of 5 days.

(v) At the age of 7 days, the two inch cube samples shall be tested by a suitable compression testing machine and the unit compressive strength shall be computed.

(b) Kankar Lime Mortar.—Whenever kankar lime mortar is specified, the mortar shall consist of pure kankar lime as per Specification No. 1.10 without admixture of sand or sutchi. If, however, after test and analysis an admixture is decided upon, the Executive Engineer shall specify the proportions of the ingredients.

Kankar lime mortar shall otherwise conform to all the specifications for white lime mortar, regarding process of mixing, grinding and freshness.
1.18. (1) Proportions.—Lime cement mortar shall have the following standard proportions:—

(i) 1:1:6 mortar.—It shall consist of a mixture of one part of portland cement and six parts by volume of coarse one part by volume of slaked stone lime, one part by volume of sand. The mix for a bag of cement is thus, 1.25 cubic feet of lime: 1 bag of cement: 7.5 cubic feet of sand.

(ii) 1:1.8 mortar.—It shall consist of a mixture of one part by volume of slaked stone lime, one part by volume of portland cement and eight parts by volume of coarse sand. The mix for a bag of cement is thus, 1.25 cubic feet of lime: 1 bag of cement: 10 cubic feet of sand.

The proper mix shall be specified in the design or by the Executive Engineer.

2. Mixing.—Thoroughly slaked, and screened white lime and sand shall first be well mixed together dry in the required quantities and this is then thoroughly mixed with the necessary quantity of portland cement. When uniformly mixed enough water shall be sprinkled to give the necessary working consistency. All mortar to which water has been added, shall be used within 30 minutes of addition of water. Any mortar not used within that period shall be discarded.

After a day's work, all the pans and the mixing troughs shall be thoroughly washed and the mortar shall be removed from them.

1.19. (1) Ingredients.—Cement mortar shall consist of portland cement and sand or fine aggregate each complying with its respective standard specifications, mixed in a proportion specified in the design. Water used in mixing the mortar shall conform to Specification No. 1.1.
2. Proportions.—For all important works, proportions of ingredients in cement mortar and water cement ratio shall be fixed after laboratory tests, and shall be specified in the design. The batching shall be done by weight. For all other works, batching may be done by volume unless otherwise specified, the following proportions shall be used for cement mortar:

<table>
<thead>
<tr>
<th>Item of work</th>
<th>Cement</th>
<th>Sand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mortar for masonry</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Mortar for plastering</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Mortar for pointing</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Mortar for Damp-proof course</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Plaster over tile roofing</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

Note:—When the cement mortar is weaker than 1:4, the following percentage of lime cream should be used in addition to cement.

<table>
<thead>
<tr>
<th>Mortar</th>
<th>Per cent by wt. of cement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:5</td>
<td>10</td>
</tr>
<tr>
<td>1:6</td>
<td>15</td>
</tr>
</tbody>
</table>

3. Mixing—(i) Hand Mixing.—Portland Cement and sand shall be spread on a clear dry platform in layers one over the other in the proportions specified, and mixed three times over. The sand used should be perfectly dry.

Water should be added to the dry mix, only when the mortar is required for use, and then only in sufficient quantity to make the materials moist; and not profuse enough to draw the cement. When water cement ratio is specified, the quantity of water shall be such that this ratio is never exceeded.

(ii) Mechanical Mixing.—Where large quantities of mortar are required at a fast rate, mechanical batching and mixing shall be adopted, if found economical and feasible. Special specifications for mechanical mixing shall be issued for each job depending upon the designed mix and upon the size and working of batching and mixing machines.
4. **Freshness.**—All cement mortar to which water has been added shall be finally used within 30 minutes of the addition of water. Any mortar that is not used within this time limit shall be discarded. At the end of day’s work or earlier, all pans, mixing troughs, mixers etc., shall be thoroughly washed and all mortar removed therefrom.

5. **Strength.**—The compressive strength of cement mortar cubes, composed of one part Portland cement and 2.75 parts graded standard sand, by weight, prepared and tested in accordance with Specification C-189, 1949, A.S.T.M. as given in Appendix VI shall be equal to or higher than the value specified for the ages indicated below:

<table>
<thead>
<tr>
<th>Age</th>
<th>Compressive Strength p.s.i.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 day in moist air, 2 days in water</td>
<td>900</td>
</tr>
<tr>
<td>1 day in moist air, 6 days in water</td>
<td>1,800</td>
</tr>
<tr>
<td>1 day in moist air, 27 days in water</td>
<td>3,000</td>
</tr>
</tbody>
</table>

The tensile strength of cement mortar briquettes composed of one part Portland cement and 3 parts graded standard sand, by weight, prepared and tested in accordance with Specification C-190, 1949, A.S.T.M. as given in Appendix VII shall be equal to or higher than the values specified for the ages indicated below:

<table>
<thead>
<tr>
<th>Age</th>
<th>Tensile Strength p.s.i.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 day in moist air, 2 days in water</td>
<td>150</td>
</tr>
<tr>
<td>1 day in moist air, 6 days in water</td>
<td>275</td>
</tr>
<tr>
<td>1 day in moist air, 27 days in water</td>
<td>300</td>
</tr>
</tbody>
</table>

1.24. (1) Kinds:—In the absence of a detailed definition “wood” or “timber” in these specifications shall mean Deodar wood. For all joinery work in the Irrigation Branch and for construction work, such as temporary supports, in
tunnels, sleepers for railway or trolley tracks, timber trestles, and forms for concrete. Deodar shall invariably be used, unless otherwise specified. For temporary supports, such as in tunnels, Kail or Fir may be used. For temporary electric transmission poles Sal shall generally be used. Chir and Kail shall be used only for temporary and inferior quality structures and such structures shall be exposed to rain to the minimum possible extent. Wooden well kerbs shall be made from Kikar wood.

(2) **Quality.**—All timber shall be from the heart of a sound tree, the sapwood being entirely removed. It shall be uniform in substance, straight in fibre, free from large or dead knots, flaws, burrow, shakes, rot or fungus growth. All timber for permanent work shall be thoroughly seasoned and should not shrink, crack or warp after use.

Timber for use in structures constantly in contact with water or damp earth shall be well seasoned and treated with proper preservatives, so as to resist fungi, termites and marine bores.

Plywood for use on Irrigation Branch works shall be well pressed and of the number of plies specified. Two or three-ply plywood shall generally be used for ceilings and partitions.

(3) **Measurements.**—All planks, scantlings, etc., shall be sawn straight and of uniform thickness from end to end, and shall be sawn in the direction of the grain. All planks and scantlings shall be sawn 1/16 inch in excess of actual measurement to allow for planing.

(4) **Storing.**—Timber, at site of work shall be stored in such a manner that it is protected from hazards of termites and fire. As soon as the foundations of a building are laid, all necessary timber shall be sawn to sections and then carefully stacked under cover and allowed to season till required.

(5) **Rate.**—The rate of timber shall be for the scantlings and planks sawn to size, no allowance is to be made for wastage. Where the timber has been felled by the contractor he is responsible for the proper observance of all forest, municipal or other laws and rules and for such royalty or other dues as may occur.
(6) **Bamboo**.—The bamboo shall be free from attacks of weevils, not older than about two to three years, well seasoned, 12 to 14 feet long or more and of a minimum girth of 4 inches. The girth measurement shall be taken at the centre of the length of each bamboo.

### 1.31. **(1) General.**—These specifications shall generally apply to all asphalt used for various types of construction in the Irrigation Branch.

**Asphalt:**

*Note.—On account of its being water-proof, acid resisting, non-inflammable and slightly plastic, asphalt is employed where it is desired to exclude moisture, such as damp-proof course both at the base and summit of walls, jointless floor lining for basements, tanks, swimming pools, flat roofs, asphaltic concrete, cut-off walls of asphalt-soil mixtures, asphaltic concrete, retaining walls, road surfaces, canal lining, etc.*

The asphalt used for road or pavement surfacing shall conform to the specifications of the Punjab P.W.D., Buildings and Roads Branch.

### (2) Standards.

**Asphalt can be divided into the following three types according to their use:**

**Type A.**—Suitable for use below ground level under uniformly moderate temperature conditions during the process of installation and during service, such as in foundations, tunnels, subways, sewers, etc.

**Type B.**—Suitable for use above ground level where not exposed to temperatures exceeding 125°F, such as, for retaining walls, tanks, dams, conduits, spray decks, etc.

**Type C.**—Suitable for use above ground level where exposed on vertical surfaces to direct sunlight or at temperatures above 125°F.

All types of asphalt shall be homogeneous and free from water. Asphalt of type A shall be soft, adhesive and "self-healing" which flows easily under the map.
3. **Use**.—Asphalt for water-proofing or mixing with soil or aggregate shall be heated at a temperature well below the flash point, to a consistency suitable for its application. The molten mass should be constantly stirred with iron rods and care shall be taken to prevent overheating. The asphalt should not be exposed to direct flames.

Asphalt shall be applied to surfaces which are dry and have been previously cleaned of dust. For this purpose suitable tools shall be employed. All personnel working with asphalt shall be well instructed in its use and in the necessary safety measures.

**PREFORMED JOINT FILLER.**

**FOR CONCRETE.**

1.22. (1) **General.**—These specifications shall apply to bituminous preformed expansion joint filler for use in contraction or expansion joints in concrete. This product
shall consist of a bituminous (asphalt or tar) mastic composition, formed or encased between two layers of bitumen impregnated felt. The mastic shall comprise of mineral fillers and reinforcing fibers and may contain thin strips of reinforcing sheet material.

(2) Reinforcements.—Preformed strips of expansion joint filler shall be of such character as not to be deformed or broken by ordinary handling when exposed to atmospheric conditions and shall not become brittle in cold weather or too soft in hot weather.

(3) Standards:—

(a) Distortion.—A joint filler test sample, 2 by 6 inches, substantially flat and straight, cut with the 6-inch dimension parallel to the machine directions of the strip, clamped between two blocks, when heated to 125°F in an oven for 2 layers shall not show a deflection of more than 1 inch.

(b) Water absorption:—The water absorption of the joint filler, when submerged in water for 24 hours, the following values shall not exceed the following values:

<table>
<thead>
<tr>
<th>Thickness of filler</th>
<th>Absorption, max per cent by weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 inch</td>
<td>2.5</td>
</tr>
<tr>
<td>3/4 inch</td>
<td>3.0</td>
</tr>
<tr>
<td>1/2 inch</td>
<td>4.0</td>
</tr>
<tr>
<td>3/8 inch</td>
<td>5.0</td>
</tr>
</tbody>
</table>

(c) Compression.—The load required to compress a test specimen to 50 per cent of its thickness before test, shall be not less than 100 nor more than 750 lbs. per square inch. Fillers having a nominal thickness of less than 1 inch shall not be subject to this requirement for compression.

(3) Limit actions.—Preformed joint filler when required in small quantities for small works may not rigidly adhere to these standards. In such cases the acceptance of the filler shall be at the discretion of the Executive Engineer.
CHAPTER II

A. ORDINARY CONCRETE.

2.1 Lime Concrete, ordinary. (1) Ingredients.—Ordinary line concrete shall consist of an aggregate of either brick ballast, stone ballast or gravel, mixed with matrix of lime and surkhi. If brick ballast is used it shall comply with Specification No. 1.6 for ¼ inch gauge ballast. If stone ballast or gravel is used it shall comply with Specifications No. 1.5 and No. 1.7 for ½ inch gravel. The lime, unless otherwise specified, shall be stone lime and shall conform to Specification No. 1.14 and the surkhi used shall comply with Specification No. 1.12.

2. Proportions.—Unless otherwise specified, ordinary lime concrete will consist of 13 cubic feet of lime and 28 cubic feet of surkhi, mixed with 100 cubic feet of aggregate. The surkhi and lime are to be mixed dry, before being added to the aggregate. If the aggregate is brick ballast it shall be soaked by heavily sprinkling with water for 3 hours before the layer of surkhi and lime is added.

3. Mixing.—Materials shall be measured and mixed on a level platform of slabs, bricks or wood, and protection shall be provided against any admixture of dust and foreign matter. The measuring shall be done by stacking the ballast in a rectangular layer of one foot thickness and spreading on top the mixed surkhi and lime in a uniform layer of a thickness to give the specified proportion. The stack should be made over-night at one end of the platform and should be sufficient for concrete needed for one day.

For proper mixing, the ingredients shall be turned over 3 times dry, and then 3 times wet.

Water shall be sprinkled evenly, by means of a can fitted with a rose or with a spray, and shall be just enough to make a wet but not sloppy concrete. More water shall not be added either during laying or compaction. More than 20 cubic feet shall not be turned over or mixed at a time.

4. Use, placing and compaction.—Ordinary lime concrete shall be used only in wall and column foundations for low buildings and as a base for pavings of various kinds.
The lime concrete shall be placed or laid immediately after mixing, in layers not exceeding 6 inches in thickness and shall be thoroughly compacted with 12 lb hand amm. Concrete shall never be thrown from a height or in such a manner that there is any segregation of coarse aggregate. Square ramming shall be used for consolidating concrete near the edges. Compaction shall be considered satisfactory and complete only when a layer of pure mortar covers the surface and completely hides the aggregate and a stick dropped endways from a height rebounds with a ringing sound.

Mixing, placing and compaction of concrete shall be a continuous process and relief parties may be employed to avoid stoppage. No concrete shall be placed later than two hours before work is stopped for the day:

5. Joints:—Vertical construction joints shall be avoided. Where such joints are unavoidable, the end of each layer shall be sloped at an angle for 30 degrees. Where such joints occur in two consecutive layers, the joints should be at least two feet apart horizontally. Before a new layer is placed, the preceding layer should be swept and washed to remove dirt and loose material.

6. Curing and Protection:—Concrete shall be kept wet after each day's work by spreading Empty Cement bags a straw and frequent watering. Its curing shall continue for a period of not less than 10 days and no masonry shall be laid on it for at least 7 days after placing.

In all concrete work, suitable planks and gangways shall be provided to prevent traffic over the surface until the concrete has been finally cured.

LIME CONCRETE, FINE

2.2. (1) General.—Fine lime concrete is similar to ordinary lime concrete and shall follow Specification No. 2.1, with the exception of the following:

(a) The aggregate for fine lime concrete shall be either 1 inch brick ballast or 1 inch gravel or stone ballast.
(b) It shall be compacted, after a little preliminary ramming, by two rows of labourers sitting as
Chap. 2.1 ORDINARY CONCRETE

2.3

Close as they can, and working backwards and forwards beating the concrete with "thapples" for at least two days until the mortar has nearly set.

(c) After compaction has been completed the mortar layer on the top shall be softened by the addition of water and smoothed with a float or trowel.

2. Special:—In cases where importance of the work warrants, special experiments shall be carried out to determine the proper size of aggregate and the most suitable proportion of materials to produce fine concrete best suited to the purpose. For all such cases, detailed specifications for the concrete shall be issued with the designs.

3. Mechanical Compaction:—There shall be no objection to compaction with pneumatic tampers, provided other specifications are adhered to and the quality of resultant concrete is to the satisfaction of the Executive Engineer.

CEMENT CONCRETE.
(ORDINARY)

2.3. (1) Scope:—These specifications shall apply to portland cement concrete for ordinary irrigation works, buildings, precast units, etc. Plain cement concrete for important works like dams, barrages, power-houses and tunnel linings shall follow specifications for mass concrete.

2. Constituents—Cement concrete shall be composed of portland cement and coarse and fine aggregate, either natural or manufactured, mixed in suitable proportions with a quantity of water specified to give a workable consistency and the desired strength. The quantity of water shall be just sufficient to give the specified slump value. The standard slump test is described in Appendix III. Cement, coarse aggregate and fine aggregate or sand shall comply with Specifications No. 1.9, 1.7, and 1.8, respectively.

3. Mixes for ordinary building work:—(1) Unless otherwise specified, concrete for slabs, beams, lintels, columns and walls shall consist of 1 cubic foot (30 lbs) of
2.3—MANUAL OF IRRIGATION PRACTICE [Chap. 2.

cement, 2 cubic feet of 5 aggregate and 4 cubic feet of coarse aggregate. For column and wall footings, and in places where high grade concrete is not required, a 1:3:6 mix by volume or any other mix specified by the Executive Engineer shall be used.

(f) The following sizes of aggregate shall be used for concrete used in building work:

(a) Concrete required for precast tiles, bricks, hollow blocks, etc., having a minimum thickness of 1 inch or less, and for the top surface of conglomerate floors laid in two courses, shall be made from coarse aggregate graded from 1/4 inch to U.S. Standard Sieve No. 8 and fine aggregate from U.S. Standard Sieve No. 8 inch to U.S. Standard Sieve No. 60.

(b) Concrete required for cement conglomerate floors and for tiles, bricks, hollow or solid blocks, etc., over one inch in thickness, but less than one cubic foot in size shall be made from coarse aggregate graded from 3/4 inch to 3/16 inch and fine aggregate, from 3/16 inch to U.S. Standard sieve No. 60. For certain works, if approved by the Executive Engineer, the aggregate may be graded from one inch size downwards.

(c) Concrete required for work over one cubic foot in volume and two inches in thickness shall be made from coarse aggregate graded from 1/4 inch to 3/16th inch and fine aggregate graded from 3/16th inch to 1/100th inch.

4. Measurement of aggregate:—Unless otherwise specified, for all small jobs and building work, batching shall be done by volume; and fine and coarse aggregate shall be measured loose as thrown in a measuring box and struck off on the top. Unless otherwise specified or ordered, the box measure shall be of such size as to contain the exact amount of sand or fine aggregate required for mixing with 1 bag of cement to produce 1 : 2 : 4 concrete.
Batching shall be done by weight, preferably by mechanical means on all important works, and Specification No. 2.11 shall be followed for this purpose.

5. Mixing:—Cement and sand shall be measured in accurate quantities and well mixed in a dry state, three over or more to bring it to a uniform colour. Manual mixing shall be done on a smooth water-tight platform of wood or slabs or brick with tight joints so that there is no wastage or difficulty in mixing. The platform shall be large enough to allow efficient turning over of the ingredients. No material not actually required for the batch in hand, is to be placed on the mixing platform.

For mechanical mixing of cement concrete Specification No. 2.8 shall be adhered to.

6. Size of batch:—A batch not larger than that necessary for mixing with one bag of cement shall be mixed in separate batches by separate gangs on separate platforms or on a platform large enough to keep each batch and gang separate.

7. Time of handling:—The whole operation after the addition of water shall be so arranged as to take the minimum possible time and the concrete shall be in position before the initial setting begins. After placing, the concrete shall be tamped, tamped or worked to ensure the formation of a compact mass and such tamping and working shall be completed within 30 minutes of adding water to the cement. Concrete or mortar which has partially set, shall not be tempered with or worked on and remixing with or without additional cement shall not be permitted under any circumstances.

8. Finishing:—The top surface of concrete, if exposed but not subjected to wear, shall be smoothed with a wood float, and not with a steel trowel. Any excess water or cream shall be removed before giving the finish. Dry cement or cement and sand shall not be sprinkled on the surface to absorb excess moisture. Before stopping work all excess moisture shall be removed otherwise the hardened laitance shall have to be removed by chipping gently, before commencing work the next day.
9. Curing.—After placing, concrete shall be cured by covering with gunny bags, sawdust, or sand which shall be kept wet constantly for 15 days: The period as well as the method of curing shall be subject to approval of the Executive Engineer.

10. Forms.—Wherever concrete has to be poured in forms, the forms whether of wood, steel or temporary brickwork, and their design shall be approved by the Executive Engineer before commencement of placing concrete. All forms shall, generally, conform to Specification No. 2.13 for forms-work for mass concrete.

2.4. (1) General.—Reinforced concrete shall consist of cement concrete of a specified mix, reinforced concrete, and steel reinforcements of an approved quality. Whenever reinforced concrete is specified, designs with complete details of each structural unit or member shall be supplied.

2. Concrete.—Cement concrete used for reinforced concrete shall conform to Specification No. 2.3 for ordinary small-scale works. For large scale reinforced concrete work the concrete shall conform to specifications for mass concrete, regarding aggregates, cement, mix, water-cement ratio, batching and mixing, placing, and curing. Control over the quality of concrete shall be strict and shall be maintained in a manner similar to that out-lined for mass concrete in Specification No. 2.21.

3. Reinforcement.—Reinforcement shall consist of steel bars, cold drawn wire, welded, wire fabric, or structural steel sections. Steel bars shall be most commonly specified for reinforced concrete work, and the size, shape, and spacing shown on the design drawings shall be strictly adhered to. It shall also be specified whether the bars have to be plan or deformed, and whether the reinforcements shall be billet steel bars, rail-steel bars, or axle-steel bars.

4. Billet-steel reinforcement bars.—Billet-steel reinforcement bars shall generally be used for reinforced concrete. The steel shall be made by one or more of the following processes: open-hearth, electric-furnace, or acid-besmelter. The bars may be either plain or deformed, and shall cover three grades, namely, structural, intermediate; and hard.

(6)
Chap. 2.1 ORDINARY CONCRETE

Billet-steel shall conform to the following requirements as to chemical composition.

The phosphorous content shall not exceed.

<table>
<thead>
<tr>
<th>Acid-bessemer</th>
<th>0.10 per cent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open-hearth or electric furnace basic</td>
<td>0.06 per cent</td>
</tr>
<tr>
<td>Acid</td>
<td>0.08 per cent</td>
</tr>
</tbody>
</table>

The bars shall conform to the following tensile strength criteria.

<table>
<thead>
<tr>
<th>Item</th>
<th>Plain bars or deformed bars</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Structural grade</td>
</tr>
<tr>
<td>Tensile strength p.s.i.</td>
<td>55,000</td>
</tr>
<tr>
<td>to 75,000</td>
<td>75,000</td>
</tr>
<tr>
<td>Yield point, min. p.s.i.</td>
<td>33,000</td>
</tr>
</tbody>
</table>

5. General Specifications:—All reinforcement bars and structural steel shall be free from injurious effects and shall have a workmanlike finish. Each lot shall be subject to the Executive Engineer’s approval.

Where special steel reinforcements are required, separate specifications shall be issued by the Chief Engineer.

Other requirements regarding cover-over reinforcements, over-lapping of bars, binding the bars together, etc., shall be specified with the design drawings for each major reinforced concrete job.

6. Storage of reinforcement steel:—Reinforcement steel shall be stacked and stored in temporary or permanent sheds, subject to the Executive Engineer’s satisfaction and approval.
CLASSIFICATION OF MASS CONCRETE.

1.5 (1) Scope:—These specifications shall cover mass cement concrete used for dams,

barrages, high retaining walls, power

houses, pumping plants and other

such important structures where large quantities of cement

concrete are required. The term "mass concrete" shall

be used for plain unreinforced concrete. Reinforced

cement concrete used on such important works shall conform to

Specification No. 24, as well as to Specifications No. 23

wherever these are applicable.

(2) Classes of concrete:—The following classes of

concrete, as recommended by the Indian Standards

Institution, shall generally be used:

(i) Class A concrete:—This class shall include high-

strength concrete for exterior surfaces of mass concrete

and for reinforced concrete. The minimum 28-day

compressive strength shall be 3,000 pounds per square inch. Unless

otherwise specified, the water-cement ratio by

weight shall be between 0.5 and 0.6.

(ii) Class B concrete:—Mass concrete for the interior

of structures and concrete for tunnel linings shall be in-

cluded in this class. The minimum 28-day compressive

strength shall be 2,500 pounds per square inch. Unless

otherwise specified, the water-cement ratio by

weight shall be between 0.6 and 0.7.

(iii) Class C concrete:—This class shall include all low-

strength concrete used at places where concrete is not

exposed to weathering. The minimum 28-days compres-

sive strength shall be 2000 pounds per square inch. Un-

less otherwise specified, the water-cement ratio by

weight shall be between 0.7 and 0.9.

The minimum 28-day compressive strength in the

specification shall be taken as the average of three test

specimens taken from a single batch of concrete, provid-

ed that the strength value of any one specimen is within

plus or minus 15 per cent of the mean.

(8)
Concrete may be further classified on the basis of maximum aggregate size, slump height and method of transportation such as pumping, pneumatic placing, etc.

2.6. (1) Source:—Coarse and fine aggregate for mass concrete shall in General, conform to Specifications No. 1.7 and 1.8. After thorough investigations of natural deposits, it shall be specified whether the aggregate shall be manufactured by crushing or if the natural aggregate shall be used. The extensiveness of natural deposits and the requirements of different sizes of aggregate, and the economics of manufacture and transportation shall be completely investigated before certain deposits are accepted for large-scale job.

(2) Acceptability:—The quality of the aggregate available shall be investigated in a petrographic laboratory and the aggregate shall be tested for the following properties:

(i) Contaminating substances:—Such as silt, mica, coal, humus, chemical salts and surface coatings and encrustations.

(ii) Soundness: that is its capability to resist the agencies of weathering without disruption and decomposition. This shall also include tests for chemical soundness.

(iii) Strength and resistance to abrasion: that is, to study if it has enough hardness and strength to develop the full strength of the cementing matrix.

(iv) Volume change: that is, the change in Volume of aggregate due to wetting and drying, that can result in disintegration of concrete by cracking and spalling.

(v) Particle shape: the presence of flat or elongated particles of aggregate has a detrimental effect on the workability of concrete, resulting in the necessity of more highly sanded mixes.

(9)
(vi) Specific Gravity: it is of importance especially in cases where design or structural considerations require that the concrete have minimum or maximum weight. Low specific gravity frequently indicates weak, porous and absorptive material.

(vii) Gradation; or the particle size distribution of the aggregate.

The petrographic report, on the basis of tests carried out for the above properties, shall indicate if the aggregate is suitable and acceptable for use in concrete for a specific structure. Unless otherwise specified, aggregate for mass concrete for dams shall satisfy the following test requirements:

(a) Los Angeles rattler test (U.S.B.R. Designation 21):—The loss, using grading A, shall not exceed 10 per cent by weight at 100 revolutions, or 40 per cent by weight at 500 revolutions.

(b) Sodium-Sulphate test for soundness (U.S.B.R. Designation 19):—The weighted average loss after 5 cycles shall not exceed 10 per cent by weight.

(c) Specific gravity (U.S.B.R. Designation 10):—The specific gravity (saturated and surface-dry basis), shall not be less than 2.60.

The designations in parentheses refer to methods of testing described in the 1949 edition of the "Concrete Manual" published by the United States Bureau of Reclamation, Denver, Colorado.

3. Gradation of Aggregate:—Sand which is either very fine or very coarse, and aggregate having large deficiencies or excess of any size fraction shall not be desirable and well graded aggregate shall always be preferred.
Fine aggregate or sand shall fulfill the following gradation conditions:

(i) The sieve analysis shall be within the following limits:

<table>
<thead>
<tr>
<th>U.S. Standard Sieve</th>
<th>Percentage retained by weight (individual)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 4</td>
<td>... 0 to 5</td>
</tr>
<tr>
<td>No. 8</td>
<td>... 5 to 20</td>
</tr>
<tr>
<td>No. 16</td>
<td>... 10 to 20</td>
</tr>
<tr>
<td>No. 30</td>
<td>... 15 to 28</td>
</tr>
<tr>
<td>No. 50</td>
<td>... 22 to 28</td>
</tr>
<tr>
<td>No. 100</td>
<td>... 32 to 28</td>
</tr>
<tr>
<td>Fan</td>
<td>... 9 to 7</td>
</tr>
</tbody>
</table>

If the percent retained on sieve No. 8 is 15 per cent or less, the maximum limit for the percent retained on sieve No. 16 may be increased to 20 per cent.

A comparison between U.S. Standard sieves and the B.S. Sieves is given in Appendix IV.

(ii) The grading of sand shall be such that the fineness modulus of at least 9 out of 10 consecutive test samples of finished sand when taken hourly, will not vary more than 0.20 from the average fineness modulus of the 10 test samples. Fineness modulus shall be computed as defined in Specification No. 1.8. Aggregate samples for testing shall be obtained from the pit or from the stock piles and shall be obtained according to the procedure described in Appendix V.

4. Maximum size of coarse aggregate.—The maximum size of coarse aggregate, as determined by the square hole through which not less than 95 per cent of the aggregate can be passed, shall be as large as can be used, practically and economically, under given conditions, but shall not be larger than one-fifth the narrowest dimension between the faces of forms, one-third the depth of any slab, three-fourths of the clear space between reinforcement bars, and three-fourths of the narrowest space through which the concrete must be passed.
For dams, the maximum size of the aggregate shall generally be restricted to 6 inches, and sizes up to 9 inches may be permitted by the Design Office. Unless otherwise specified, the coarse aggregate shall have a gradation within the following limits:

<table>
<thead>
<tr>
<th>Max. size Aggregate in concrete</th>
<th>Percentage by weight of coarse aggregate fractions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inches</td>
<td>Cubbles</td>
</tr>
<tr>
<td>2&quot; to 3&quot;</td>
<td>0</td>
</tr>
<tr>
<td>1&quot; to 2&quot;</td>
<td>0</td>
</tr>
<tr>
<td>3&quot; to 5&quot;</td>
<td>20 to 50</td>
</tr>
<tr>
<td>6&quot; to 8&quot;</td>
<td>20 to 50</td>
</tr>
</tbody>
</table>

The maximum size of aggregate used in concrete which will be placed by pumping or the pneumatic gun shall be 4 to 4 1/2 inches, the smaller size being preferred.

5. Undersize and Oversize:—Whenever gradation of aggregate is specified in terms of percentages for particular sizes, the percentages of undersize and oversize materials shall be determined by using sieve sizes as given below:

<table>
<thead>
<tr>
<th>Nominal Sieve sizes</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/16&quot;</td>
<td>3/8&quot;</td>
</tr>
</tbody>
</table>

The sieve sizes for Undersize (U.K.) Standard Sieve:

<table>
<thead>
<tr>
<th>Test Sieve for Undersize (U.K.) Standard Sieve</th>
</tr>
</thead>
<tbody>
<tr>
<td>5/16&quot;</td>
</tr>
</tbody>
</table>

Test Sieve for Oversize (U.K.) Standard Sieve:

<table>
<thead>
<tr>
<th>Test Sieve for Oversize (U.K.) Standard Sieve</th>
</tr>
</thead>
<tbody>
<tr>
<td>7/16&quot;</td>
</tr>
</tbody>
</table>

In such cases the undersize fractions for each size shall not exceed 2 percent of that particular size and no significant amount of oversize material shall be allowed.
Chap. 2.] MASS CONCRETE — 2.7

6. Moisture in aggregate:—The aggregate both coarse and fine, shall preferably be dry. However, the moisture content in sand or coarse aggregate at time of batching shall not be more than 8 per cent by weight of aggregate. The moisture content in aggregate should be reasonably uniformly distributed. The estimated quantity of moisture held in aggregate shall be taken into consideration when computing amount of water required for mixing.

7. Deleterious materials and fines:—The percentage by weight of the following deleterious materials in aggregate shall not exceed the following:—

<table>
<thead>
<tr>
<th>Material</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shale</td>
<td>1.00</td>
</tr>
<tr>
<td>Coal and lignite</td>
<td>1.00</td>
</tr>
<tr>
<td>Clay lumps</td>
<td>1.00</td>
</tr>
<tr>
<td>Cinder and clinker</td>
<td>0.50</td>
</tr>
</tbody>
</table>

Also, the loss by decantation shall not be greater than 3.00 per cent by weight. For crushed coarse aggregate, the fraction passing through U. S. Standard sieve No. 200 shall not be more than 1.50 percent by weight and in the case of manufactured sand, the fraction passing through U. S. Standard Sieve No. 200 shall not be more than 8.00 percent by weight.

8. Manufacture and processing:—All equipment for aggregate manufacture, processing and handling shall be subject to Chief Engineer's approval and the arrangement of plant shall also be scrutinized in the Design Office. The stacking, storing and transportation of the aggregate shall be carried out in such a manner, such that the quantity of the aggregate delivered at the batching and mixing plant conforms to the specifications. Frequent samples shall be taken from the stacks, stockpiles or at the batching plant to check the quality of the aggregates.

2.7. (1) Cement.—All cement used for manufacture of mass concrete shall conform to Specification No. 19 for Portland Cement. For special items on a job, special cements conforming to Standards for Type I, II, III, IV or V, cements in A.S.T.M. Designation No. C-150-1949, shall be used. The use of each type shall be specified by the Chief Engineer.
2. Delivery and Storage.—Cement shall be delivered to the project in bulk in wagonload lots, except that cement for isolated minor items may be delivered in bags if approved by the Executive Engineer. Storage bins for bulk cement shall be weather-proof and shall be constructed so that there will be no dead storage. If in the opinion of the Executive Engineer there is reason to believe that any dead storage exists, bins shall be emptied completely at least every 60 days. Handling and storage facilities shall be so arranged that no cement will be kept in storage for more than 120 days. Should any cement be unavoidably kept in storage longer than 120 days, it shall be tested and, if found defective, shall be rejected. Cement bins at the mixing plant and cement storage silos shall be provided with effective dust collectors at the vents to prevent loss of cement.

3. Admixtures.—Admixtures shall be used only if authorized by the Chief Engineer. When authorized, proportion and the methods of mixing and use shall be specified. Use of admixtures in concrete shall not in any way affect the compliance with the requirements of the specifications regarding protection and curing of concrete.

(a) Accelerators: Accelerators shall be used as admixture, upon written approval, for increasing the strength of concrete at early ages. The approval shall specify the type, amount and location of use. The amount of accelerator used shall be no more than that necessary to produce the desired result. Calcium Chloride shall not be used in excess of 2 per cent, by weight of the cement. Accelerators shall be weighed accurately and shall be introduced into the mixer in solution in the mixing water.

(b) Air-entraining agents: Air-entraining agents used for improving the quality and workability of the concrete shall conform with Specification No. 110. The amount of air-entraining agent used shall be such as will effect the entrainment of from 3 to 5 percent of air, or any other quantity definitely specified, by volume, of the concrete. The agent, unless already interground with cement, shall be added to the batch in solution in a portion of the mixing water. This solution shall be batched by
means of a mechanical batcher capable of accurate measurement, and in such a manner as will ensure uniform distribution of the agent throughout the batch within the specified mixing period.

(c) Pozzolans.—Pozzolans used as admixtures with cement shall conform to Specification No. 111. The ratio of pozzolan to cement, by weight, may range between 0 and 0.50, and the exact specified percentage will depend on the mix proportions of the concrete, as well as the structure in which concrete is to be placed pozzolan, if used, shall be delivered to the project in bulk in wagonload lot. Storage bins for pozzolan shall be weather-proof and shall conform to specifications for cement storage bins.

No. 28. (1) Design:—An appropriate mix, having the required degree of workability and one that will develop the required qualities on hardening shall be evolved by the most economical and practicable combination of available aggregates cement, water and in some cases, admixtures such as pozzolans.

2. Trial Mixes:—Trial mixes shall be designed, along the following lines:—

(i) Selection of a water-cement ratio suitable for the particular job.

(ii) Select the limits of slump to provide a mix of right consistency.

(iii) Fix the maximum size of aggregate permissible for the job.

(iv) Estimate the proper percentage of sand. The correct percentage of sand for a concrete mix is the least percentage which will give the required degree of workability.

(v) Estimate the amount of water required to give the desired slump.

(vi) Complete the trial mix proportions.

(15)
2-9. **Adjustments**—The trial mix shall then be tested for slump and the necessary adjustments shall be made in the water-cement ratio till a mix is evolved that will satisfy the strength, density, impermeability and durability requirements. Any admixtures, such as accelerators, air-entraining agents, and pozzolans shall also be taken into consideration while computing the mix proportions. The procedure described in American Concrete Institute, Standard No. A.C.I. 613-44, "Recommended Practice for Design of Concrete Mixes," shall be adhered to for design of cement mixes.

(1) **Definition**—"Water-Cement Ratio" shall be computed as the ratio of weight of water to the weight of cement used in the concrete mix. This ratio may also be expressed as the number of gallons of water per 112 pound bag of cement. The surface moisture of the aggregates shall be included in computing the water-cement ratio.

2. **Selection**—That water-cement ratio should be adopted which will produce concrete of the required workability strength and durability, and aggregates shall be combined to give the required workability when mixed with cement and water in this ratio.

The following table gives the maximum water-cement ratios recommended for various types of ordinary construction in Punjab:

<table>
<thead>
<tr>
<th>Type or location of Structure</th>
<th>Thin Sections</th>
<th>Moderate Sections</th>
<th>Heavy Mass Sections</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Reinf. Plain</td>
<td>Reinf. Plain</td>
<td>Reinf. Plain</td>
</tr>
<tr>
<td>A. For portions of hydraulic structures at the waterfront, where intermittent or complete saturation is possible, but not for continuous submergence</td>
<td>0.49</td>
<td>0.53</td>
<td>0.58</td>
</tr>
</tbody>
</table>

(16)
### Chap. 2. | MASS CONCRETE

<table>
<thead>
<tr>
<th>Type of Location of Structure</th>
<th>Thin Sections</th>
<th>Moderate Sections</th>
<th>Heavy Mass Sections</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Reinf.</td>
<td>Plain</td>
<td>Reinf.</td>
</tr>
<tr>
<td>B. For portions of hydraulic structure above the water line, but subjected to frequent settling</td>
<td>0.53</td>
<td>0.62</td>
<td>0.67</td>
</tr>
<tr>
<td>C. Ordinary exposed structures, buildings and portions of bridges and falling under above groupings</td>
<td>0.53</td>
<td>0.62</td>
<td>0.67</td>
</tr>
<tr>
<td>D. For structures subjected to complete submergence</td>
<td>0.58</td>
<td>0.62</td>
<td>0.67</td>
</tr>
<tr>
<td>E. For concrete deposited through water</td>
<td>...</td>
<td>...</td>
<td>0.49</td>
</tr>
<tr>
<td>F. For pavement slabs laid directly on ground</td>
<td>0.23</td>
<td>0.28</td>
<td>...</td>
</tr>
<tr>
<td>Wearing slabs</td>
<td>0.62</td>
<td>0.67</td>
<td>...</td>
</tr>
<tr>
<td>Base slabs</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>

The water-cement ratio for specified compressive strength of concrete should be determined by laboratory tests. However, when it is not practicable to make such tests, the water-cement ratio required for the specified compressive strength may be taken directly from the table given below, which gives average compressive strength for various cement contents and water-cement ratios and for concrete with 4 per cent entrained air. A bag is assumed to contain 112 lbs of cement in the table.

(17)
## 2.10 MANUAL OF IRRIGATION PRACTICE

### Table 2.10

<table>
<thead>
<tr>
<th>Net W/C ratio by wt.</th>
<th>Concrete without entrained air</th>
<th>Air entrained concrete (4 per cu. yd)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cement content bags per cu. yd.</td>
<td>28-day strength p.s.i.</td>
</tr>
<tr>
<td>0.40</td>
<td>6.3</td>
<td>5,000</td>
</tr>
<tr>
<td>0.42</td>
<td>5.9</td>
<td>5,200</td>
</tr>
<tr>
<td>0.44</td>
<td>5.7</td>
<td>5,000</td>
</tr>
<tr>
<td>0.46</td>
<td>5.5</td>
<td>4,800</td>
</tr>
<tr>
<td>0.49</td>
<td>5.1</td>
<td>4,400</td>
</tr>
<tr>
<td>0.50</td>
<td>5.0</td>
<td>4,000</td>
</tr>
<tr>
<td>0.55</td>
<td>4.6</td>
<td>3,600</td>
</tr>
<tr>
<td>0.60</td>
<td>4.0</td>
<td>3,300</td>
</tr>
<tr>
<td>0.65</td>
<td>3.8</td>
<td>2,900</td>
</tr>
<tr>
<td>0.70</td>
<td>3.6</td>
<td>2,600</td>
</tr>
<tr>
<td>0.75</td>
<td>3.4</td>
<td>2,400</td>
</tr>
</tbody>
</table>

Cement contents listed in this table apply only to mixes containing 1 1/4 inch maximum size aggregate. Water-Cement ratio strength relationships are not affected by maximum size of aggregate.

### 2.10. (1) Definition:

The terms "Slump" or "height of slump" shall be used for the subsidence, in inches, of a test mix of freshly mixed concrete, caused by the removal of a standard cone, determined in accordance with the standard method described in Appendix III. In mass concrete, slump shall be determined after the concrete has been deposited but before it is consolidated. The slump shall be used as a measure of fluidity or consistency of concrete.

(18)
Chap. 2.] MASS CONCRETE — 2.10

2. Recommended slumps:—The following maximum and minimum values of slump are recommended for various types of construction:

<table>
<thead>
<tr>
<th>Type of construction</th>
<th>Slump in inches</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Maximum</td>
</tr>
<tr>
<td>Reinforced translation walls and footings</td>
<td>5</td>
</tr>
<tr>
<td>Plain footings, columns, and substructure walls</td>
<td>4</td>
</tr>
<tr>
<td>Slabs, beams and reinforced walls</td>
<td>6</td>
</tr>
<tr>
<td>Buildings, columns</td>
<td>6</td>
</tr>
<tr>
<td>Pavement</td>
<td>3</td>
</tr>
<tr>
<td>Canal lining</td>
<td>3</td>
</tr>
<tr>
<td>Sidewalls and arch in tunnel linings</td>
<td>4</td>
</tr>
<tr>
<td>Pumped concrete</td>
<td>4</td>
</tr>
<tr>
<td>Heavy mass construction</td>
<td>3</td>
</tr>
</tbody>
</table>

When high frequency vibrators are used, the values given above should be reduced by about one-third.

3. Field Control:—Slump tests shall be carried out frequently in the field to keep a check on quality of concrete being poured. Frequency and number of slump tests to be carried out, is given in specification on Concrete Control.

2:11. (1) Measurement of materials: (a) General requirements:—Equipment should be used which is capable of performing accurate measurements of various materials, including water, cement, admixtures if required, sand and aggregate. For large-scale works, the equipment shall also be capable of accurately measuring each individual size of aggregate specified for the concrete. Materials should be handled, and measuring operations performed in such a manner that the proportions can be accurately controlled, and readily checked at any time during the progress of work.
(b) **Weight batching**—The amounts of bulk cement and all constituent aggregates shall be determined by direct weighing; and the amount of water, and admixture if required, shall be determined by direct weighing or volumetric measurement. For the purpose of maintaining a constant water-cement ratio, there shall be a reliable method of compensating for free water in all aggregates. Cement in standard sacks or bags need not be weighed.

2. **Batching Equipment**—For jobs of from 2,000 to 5,000 cubic yards of concrete, simple manually operated weigh batchers are recommended: From 5,000 to 10,000 cubic yards jobs, cumulative manually operated weigh batchers are recommended; and for jobs using 10,000 to 25,000 cubic yards of concrete cumulative automatic weight batching equipment may be specified. For jobs of over 25,000 cubic yards individual automatic weighing of aggregate is justified. The type and size of batching equipment selected for use on any work shall be subject to the approval of Chief Engineer.

3. **Requirements of weight batching equipment**—All measuring, and weighing equipment, forming part of the weigh batchers shall conform to the following requirements:

(a) The accuracy of the weighing equipment shall be such that the combined inaccuracies in feeding and measuring during normal operations will not exceed 1/4 per cent for water or weighed cement, 10 per cent for admixtures if used; 2 per cent for sand, 1/4 inch, and 1/2 inch aggregates; and 3 per cent for 3 inch and 9-inch aggregates. Generally, if no other specifications are laid out, the accuracy of the batching equipment shall be such that the indicated weight of any hopper will not vary more than 1.0 per cent from the true weight.

(b) Each weighing unit shall include a visible dial, or equally suitable and satisfactory device, which will register the scale load at any stage of the weighing operation, from zero to full capacity. The dial shall include an over-and-under indicator which will show the scale in balance with
no load or when loaded at any desired beam setting.

(c) Each unit shall be provided with a batch counter, which shall preferably be attached to the cement batcher to record the number of batches delivered. A totalizing device shall also be provided to record the total number of batches mixed by all units in the plant.

In large batching plants, each set of units for measuring all of the materials delivered to one or more mixers shall be provided with an accurate combined autographic record for making a continuous visible record on a single chart of the measurement of each separate material, including all mixing water, and admixture if used. This recording equipment shall include facilities for automatically registering on the chart the time of day, at intervals, of not more than 15 minutes, and shall be designed for simplicity in operation and maintenance.

(d) The equipment shall be designed to permit ready and proper adjustment of the proportions of the mix, and to compensate for the varying weight of moisture contained in the aggregates.

(e) It is preferable that the arrangement of weighing hoppers be such as to readily permit sampling of the material entering the hopper, and to permit the convenient removal of over-weight material in excess of the prescribed tolerances.

(f) The operating mechanism in the water-measuring device shall be such that no leakages occur with the valves closed. The inlet and discharge valves for the tank shall be so interlocked that the discharge valve cannot be opened before the filling valve is closed.

(g) The recorder, batch meters or dials shall be installed in a room that is sufficiently tight to exclude objectionable dust from the plant operations. In so far as practicable, each indicating dial and water-measuring device shall
be in full view of the operator, and the weighing equipment shall be arranged so that the operator may conveniently observe the operation of the bin gates, and also the materials discharged into the mixer hopper.

To insure proper compliance with the above requirements, periodic tests shall be made by the engineer-in-charge to check the accuracy of each unit of equipment for measuring water, cement, sand, aggregates, and admixtures. Such repairs or adjustments shall be made as are necessary to secure satisfactory performance.

2.12. (1) General:—Concrete for mixing for small jobs may be done manually as described in paragraph (b) of Specification No. 23. For all large scale jobs, mixing shall be done mechanically and the specifications laid out herein shall be adhered to.

Machine mixing of concrete shall be done with such equipment and methods as will ensure uniformity of strength, and uniformity of consistency, cement and water content, and aggregate grading from beginning to end of each batch as discharged.

2. Types of Concrete Mixers:—Concrete mixers may be stationary or mobile, the latter being called truck mixers. Stationary mixers may be of the tilting or non-tilting types. Tilting type mixers shall be preferred where aggregates of a size larger than 3-inch are to be used, and comparatively dry concrete has to be mixed. For aggregates of a size smaller than 3-inch, non-tilting mixers shall generally be preferred, especially if they have the advantage of simpler charging and discharging spouts.

3. General requirements of mixers:—All concrete mixers shall fulfill the following general requirements:

(a) The mixers should preferably have a combination of blade arrangements and drum shape such as to ensure an end to end exchange of the
mass concrete

materials parallel to the axis of rotation as well as a rolling, folding movement of the mix over on itself as the batch is mixed.

(b) The solid ingredients of the mix should be fed into the mixer simultaneously and in such a manner that the period of flow of each is about the same.

(c) The mixing plant shall be so designed and operated that all materials entering the drum can be accurately proportioned and readily controlled and the entire batch within the mixer shall be discharged before recharging.

(d) Except when the mixing water is heated, between 5 to 10 per cent of the water should precede, and a like quantity should follow the introduction of the water should be added uniformly with the other materials.

(e) Any mixer leaking mortar or causing waste of materials due to faulty size, shape, or operation of other ingredients the reminder of charging equipment shall be taken out of service immediately.

4. **Truck mixers**—Truck mixers, unless otherwise approved shall be of the revolving drum type, so constructed that all the ingredients of the concrete are kept uniformly distributed throughout the mass. Truck mixers and their operation shall conform to the following general specifications:

(a) The mixer shall be water-tight when closed, and shall be equipped with an accurate water meter between supply tank and the mixing drum. The meter should have indicating dials and a totalizer.

(b) Truck mixers shall be provided with some device whereby the time of hauling, mixing, and introduction of water can be readily checked. Alternatively, each mixer should be equipped with a revolution counter for indicating the amount of mixing.
2.13—MANUAL OF IRRIGATION PRACTICE [Chap. 2.

(c) All solid materials shall be accurately weighed and charged into the drum at the proportioning plant and while the drum is rotating.

(d) The initial mixing water should be limited so as to be sure of never exceeding the proper slump.

(e) In hot weather, truck mixers shall be painted white and be kept white, the materials shall be kept as cool as practicable by shading and light sprays of water. The water should be cold as practicable, and delays prior to the discharge and placement of concrete should be avoided.

The maximum permissible size of a batch in percentage of drum volume for truck mixers shall be as follows:—

Per cent

(a) When performing the entire mixing operation in transit... 50.0

(b) When completing the mixing operation after at least 10 minutes from time of concrete leaving the central mixing plant... 66.67

(c) When used solely as an agitating conveyor for ready-mixed concrete... 75.0

5. Agitators.—Agitators are portable mixing machines designed to prevent settlement of ready-mixed concrete by imparting to it an occasional mild action enroute to the work. Truck mixers may be used as agitators by being rotated at a slower speed than that used for mixing, and when so used can handle batches 1.5 times as large as batches to be mixed.

6. Charging Operation.—In charging stationery mixers, the solid materials shall be arranged in the charging hopper in such a manner that no one of them enters separately but that proportional amounts of each ingredient will be in all parts of the stream of materials as it flows into the mixer. The solid ingredients and water shall be charged into the mixer as stated in items (b) and (c) of preceding paragraph (3), Cobbles or a small portion

(24)
of the coarsest aggregate, if approved, may be added last in order to clear the chutes and remove any adhering fine aggregate and cement.

7. **Mixing Operation:**—The mixing operation shall be so carried out as to insure uniform distribution of all component materials throughout the mass at the end of the mixing period. Unless otherwise permitted, machine mixing of each batch shall continue for not less than the number of minutes stated in the tabulation below, during which time the drum shall be rotated at a peripheral speed of about 200 feet per minute.

<table>
<thead>
<tr>
<th>Capacity of mixer (Cubic Yards)</th>
<th>Minimum time of mixing (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Natural aggregate</td>
</tr>
<tr>
<td>1 or less</td>
<td>1:15</td>
</tr>
<tr>
<td>2</td>
<td>1:50</td>
</tr>
<tr>
<td>3 or higher</td>
<td>2:00</td>
</tr>
</tbody>
</table>

The minimum mixing periods specified above are predicated on proper control of the speed of rotation of the mixer, and it shall be timed after all materials, including water, have been added into the drum. The mixing time shall be increased if and when the charging and mixing operations fail to produce the required uniformity of composition and consistency in the batch within the specified period. If the charging and mixing operations are such that the required uniformity of the concrete is obtained in a shorter mixing time than the minimum specified, without sacrifice of needed workability, the mixing time may be shortened.

8. **Discharging operation:**—The discharging facilities of all types of mixers should be capable of ready discharge of concrete of one inch slump, that is concrete of stiffest consistency which should be placed by means of vibration. The time required for discharging a mixer shall not be considered a part of the required net mixing time.
To preserve the uniformity of distribution of materials and the usual homogeneity of the concrete in the mixer immediately prior to discharge, all types of mixers discharging into hoppers, buckets, cars, etc., should be so equipped that the concrete will drop vertically, not diagonally, into such containers in order to avoid segregation. The blade arrangement and discharge mechanism of all types of mixers including agitators, should be such that the amount of aggregate larger than $\frac{1}{2}$ inch in any portion of the batch will not differ by more than 20 per cent from the amount of such aggregate in any other portion of the batch. This may be determined by comparing the weights of coarse aggregate retained when at least 200 lbs of concrete from each portion of the batch in question is washed over a $\frac{1}{4}$ inch screen.


The efficiency of the mixing operation shall be judged by variation in the water-to-fines ratio, W/F. At the end of the prescribed or permitted mixing period spread in W/F ratios of three 1,500-gram samples of mortar from well separated localities in the mixer, should be within 10 per cent of the average of the three samples. W being the mixing water and F being the cement and other fine material passing a U. S. Standard Sieve No. 100.

2.13. (1) Purpose—Forms shall be used wherever necessary to confine and mould the plastic concrete to the required shape, or to ensure against contamination of the concrete by materials caving or sloughing in from adjacent excavations or other adjoining features of the work. Forms may also be necessary in order to produce a desired type of finished concrete surface.

All exposed concrete surfaces having slopes of 1 to 1 or steeper shall be formed.
Chap. 2.1] MASS CONCRETE

-2.13

(2) General requirements.—Forms for concrete shall meet the following general requirements:

(a) Forms shall have sufficient strength to withstand the pressure resulting from placement and vibration of the concrete, and shall be maintained rigidly in correct position.

(b) Forms shall be sufficiently tight to prevent loss of mortar from the concrete. Exceptional care should be exercised to insure that all form panel joints, corners, and connections and all seems between all types of sheeting are sufficiently tight immediately prior to placing the concrete.

(c) The form lining should be such that the concrete surface shall have the desired type of finish.

(d) Ready access should be provided for proper placement, working and vibration of the concrete and for inspection of these operations.

(3) Selection of type.—Formwork represents 20 to 30 per cent of the cost of concrete on low dams and powerhouse projects and on high dams from 15 to 20 per cent of such cost. Before the type of formwork is selected for a big job involving large quantity of concrete work, the following topics shall be given thorough consideration: total square feet of coverage, square feet of uniform surface, form handling facilities, capacity of the concrete-placing plant and expected output, the height of lift, pressure against forms based on the consistency and the rate of rise of concrete, and the cost of labour. The type of forms shall finally be selected in the light of merits and demerits of various types of forms, the extent to which various panel forms can be used and reused and the surface finished desired.

Forms may be removable or built in place. Removable forms can be panel forms or moving slip forms. Removable forms are generally made of wood or steel, and built-in-place forms are generally made of concrete masonry.

(27)
(4) Panel forms.—Panel forms are generally made of wood. The quality of materials and construction, and the size of the standard panel shall be such that each panel can be used five times or more. Wood sheathing or form lining shall be of such kind and quality or shall be so treated or coated that there will be no chemical deterioration or discoloration of the formed concrete surfaces.

The sheathing should invariably be not more than 6 inches in width, and 4 inches width shall generally be recommended. It is necessary as a rule, to hold form deflections down to 1/8 inch or less.

Steel panel forms shall be specified only after they are found to be satisfactory, and when form-handling equipment for heavy units is available. Use of steel panel forms shall be subject to the approval of the Chief Engineer.

(5) Plywood lining for panel forms.—Plywood shall be used for lining wooden panel forms, where specified. The plywood shall be water-proof, non-warping, non-wrinkling and specially made for this purpose with water-resistant glue. As far as possible, the plywood sheets shall be of uniform width and length and shall have a uniform thickness of not less than 5/8 inch, or not less than 3/8 inch if backed with shiplap or similar approved material. Tempered, waterproof pressed board or similar approved material not less than 1/8 inch in thickness may be used instead of plywood if backed with shiplap or other approved backing. The joints between the plywood sheets shall be smooth and as nearly perfect as practicable.

(6) Absorptive form lining.—Absorptive lining shall be used in the forms where specified, to obtain a smooth and dense concrete surface. Absorptive form lining shall be of approved type and quality and shall be highly absorptive to air and water, and through its absorptive capacity shall eliminate voids, pits, and other such defects from the concrete surface. The lining shall be readily removable from the concrete without damage to the concrete surface. The lining itself, and any treatment employed in its manufacture, shall not discolour the concrete, nor interfere with the normal chemical reaction of the cement. The backing to which absorptive lining is attached shall be sufficiently smooth, even, and free from cracks, knotholes,
(29)

and other imperfections to prevent unevenness in the
finished surface. The lining shall be in sheets of uniform
length and width.

The joints between sheets of absorbent lining shall be
fitted smoothly and accurately, and patching shall be avoid-
ed. The lining shall be attached to the forms in such a
manner that it will be held securely and smoothly in place.
Nails, if used, shall be driven flush and no more, and dents
and hammer marks in the surface of the lining must be
avoided. After the lining has been attached to the form,
the joints shall be rubbed with a smooth tool to press down
any projecting fibers. The lining must be kept dry and
shall not be reused.

(7) Forms for building construction.—Formwork for
building construction, unless otherwise specified, shall be
made up of wood shuttering, and it should be sufficiently
strong to resist the dead weight of concrete, barrows, men,
etc., during concreting without bulging or undue deflection.

Formwork for slabs shall be laid with an upward
camber to ensure a level ceiling. All formwork shall be care-
fully cleaned out before any concreting takes place, and
forms shall not be removed until the concrete is sufficiently
strong to safely carry the loads. Forms shall not be
struck without the approval of the Engineer-in-charge.

(8) Cleaning and oiling of forms.—Wherever specified,
forms shall be treated with a suitable oil or other coating
material which will prevent sticking of the concrete. Before
the oil coat is applied, the surface of the forms shall
be free from incrustations of mortar, grout, or other foreign
material. The oil or coating should be applied by brush
or spray and should evenly cover the forms without excess
or drip and should not be permitted to get on constructions
joint surfaces or reinforcement bars.

The oil or other form of coating used should not cause
softening, or permanent staining of the concrete surface;
it should not impede the wetting of surfaces to be water-
cured. Unless some other form of oil is specified, refined,
pale, paraffine mineral oil shall be used for wood forms.
For steel forms, the oil shall consist of refined mineral oil suitably compounded with one or more ingredients which are approved for the purpose. Special care shall be taken to oil thoroughly the form strips for narrow grooves at windows, doors, and elsewhere so as to prevent swelling of the forms and consequently damage to the concrete prior to or during the removal of the forms.

(9) Removal of forms.—Forms shall be kept rigidly in place until they can be removed without chipping, spalling, or defacing the concrete surfaces. When forms are stripped there should be no measurable deflection or distortion and no evidence of damage to the concrete due either to removal of support or to the stripping operation. Supporting forms and shoring must not be removed from beams, floors, and walls and other load-bearing members, until the latter are strong enough to carry their own weight and the superimposed load. For this purpose, it shall be assumed that sufficient strength has been attained when test specimens indicate a safety factor of two for the stresses to be sustained.

Unless otherwise directed, forms shall be stripped after the following minimum period in case of concrete using normal portland cement.

<table>
<thead>
<tr>
<th>Nature of formwork</th>
<th>For normal weather (about 60° F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>beam sides, walls and columns (unloaded)</td>
<td>1</td>
</tr>
<tr>
<td>slabs (props left under)</td>
<td>3</td>
</tr>
<tr>
<td>removal of props to slabs</td>
<td>7</td>
</tr>
<tr>
<td>beam soffits (props left under)</td>
<td>7</td>
</tr>
<tr>
<td>removal of props to beams</td>
<td>16</td>
</tr>
</tbody>
</table>

2.14. (1) General requirements.—No concrete shall be placed on rock or earth foundations on old concrete mat, masonry, brick work, etc., until all formwork, installation of accessories to be embedded and preparation of surfaces involved in the placing have been approved by the engineer-in-charge. No concrete shall be placed on rock within 150 feet of any grout hole through which foundation
grouting has not been completed. No concrete shall be placed in running water and no concrete shall be placed in still water except with the permission of the Chief Engineer, and the method of depotting the concrete shall be subject to his approval.

(2) Rock foundation preparation.—Where a tight bond is desired between the concrete and the rock foundation, the rock surface should be prepared by roughening, where necessary and thorough cleaning. Immediately before placing concrete rock surfaces upon or against which concrete is to be placed shall be free from standing water, mud, debris, oil, objectionable coatings, and loose, semi-detached and unsound fragments. Open fissures shall be cleaned to a suitable depth and to firm rock on the sides. The cleaning and roughening of the rock surfaces shall be performed with the use of steel brooms, picks, high-velocity air-water jets, wet sand-blasting, or other effective means, followed by thorough washing. The method of roughening and cleaning shall be subject to the approval of the Executive Engineer.

(3) Earth foundation preparation.—Where concrete is to be placed upon or against earth foundations, the earth subgrades should be damp, but not wet when concrete is placed. Before the concrete is placed, all boulders, cobbles, and organic matter should be removed from the subgrade surface, and the soil surface should have been compacted and dressed to the satisfaction of the engineer-in-charge. In order to compensate for lower efficiency of curing procedures under hot any dry climatic conditions, free-draining subgrades should be wetted to a depth of at least 3 inches in order to provide a supply of moisture in contact with the concrete.

(4) Preparation of surfaces, of construction and contraction joints.—Concrete surfaces upon or against which concrete is to be placed, and with which the new concrete should have a good bond, that have become so rigid that the new concrete cannot be incorporated integrally with that previously placed, shall be defined as construction joints. Surfaces of construction joints shall be clean and damp, and all laitance, loose or defective concrete coating and foreign material shall be removed, before fresh concrete is placed against them. Cleaning of the surfaces of
construction joints shall be accomplished by the use of steel brooms or wet sand-blasting, followed by thorough washing. The method of cleaning shall be subject to the approval of the Executive Engineer.

The surfaces of all contraction joints shall be cleaned thoroughly of accretions or other foreign material by scraping, chipping, or other satisfactory means. Bond or adhesion of freshly-placed concrete against previously-placed concrete at a contraction joint shall not be permitted.

2.15. (1) General requirements.—Only those methods and arrangements of equipment shall be employed which will reduce to a minimum the segregation or separation of coarse aggregate from the mortar at all points from the mixer to the forms. In order to obtain the highest quality of concrete in place, the placing and transporting equipment should be considered for its ability to handle mixes ideal for the work, from the standpoint of concrete place-ability and workability in the forms.

Concrete shall be deposited in all cases as nearly as practicable directly in its final position and shall not be caused to flow in a manner that will permit or cause segregation. Excessive separation of the coarse aggregate from the concrete, caused by allowing the concrete to fall freely from too great a height, chuting the concrete en too great an angle from the vertical, or allowing the concrete to strike the forms or reinforcement steel will not be permitted. Suitable drop chutes shall be provided to confine the falling concrete, and to avoid segregation.

(2) Transporting concrete.—The methods and equipment used for transporting concrete shall be such that the concrete having the required composition and consistency will be delivered into the work without objectionable segregation or loss of slump. Placing of mass concrete shall, in general, be done by means of bottom-dumps buckets of such design and capacity that the concrete deposited in one spot may be compacted effectively into an approximately horizontal layer of specified thickness with the
minimum amount of lateral movements and accompanying tendency for segregation and formation of rock pockets in the outlying areas.

Buckets and their use shall comply with the following additional requirements:

(a) Bucket capacity should conform to the size of the concrete batch, or a multiple thereof, in order that there will be no splitting of the batches in loading buckets.

(b) Buckets should be so designed as to allow the discharge of a portion of a bucketful, as needed. Also, the discharge should be controllable so that it will cause no damage to or misalignment of the forms.

(c) The discharge openings of the bucket should be sufficiently large and the operation of the discharge gates such that there will be no delay in dumping concrete of the lowest slump that can be successfully worked and consolidated into place.

Other methods of conveying and placing concrete, such as by chutes, belt conveyors, barrows, tip-wagons, pneumatic guns, or concrete pumps, may be specified for smaller and isolated items of work by the Chief Engineer. Where such methods are approved, detailed specifications for each operation shall be issued by the Executive Engineer in charge of the work.

(3) The initial mortar layer: Where concrete is to be placed on and bonded to rock or hardened concrete, the fresh concrete shall be preceded by a layer of mortar well scrubbed into the joint surface. After the surfaces have been prepared satisfactorily all approximately horizontal surfaces of rock and construction joints shall be covered with a layer of mortar approximately three-fourths of an inch thick. The mortar shall be similar to the mortar in the regular concrete mix, unless otherwise directed. The water-cement ratio of the mortar in place shall not exceed that of the concrete to be
placed upon it, and the consistency of the mortar shall be suitable for placing and working in the manner hereinafter specified. The mortar shall be spread uniformly and shall be worked thoroughly into all irregularities of the surface. Concrete shall be placed immediately upon the fresh mortar. In placing concrete against formed construction joints, the surfaces of joints, where accessible, shall be coated thoroughly with mortar immediately before they are covered with concrete, by scrubbing with wire brooms dipped in the fresh concrete. Where it is impracticable to apply such a mortar coating special precautions shall be taken to insure that the new concrete is brought into intimate contact with the surface of the joint, by careful puddling and spading with the aid of suitable tools.

(4) Placing mass concrete:—All formed concrete, except concrete in tunnel lining, shall be placed in horizontal layers of a specified thickness. These layers shall be continuous within the confines of contraction joints. Unless otherwise specified, the thickness of layers shall be as follows:

<table>
<thead>
<tr>
<th>Concrete Type</th>
<th>Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass concrete</td>
<td>12 to 20 inches.</td>
</tr>
<tr>
<td>Structural concrete</td>
<td>12 to 20 inches.</td>
</tr>
<tr>
<td>For precast pipe</td>
<td>12 to 24 inches.</td>
</tr>
</tbody>
</table>

Each layer should be soft when a new layer is placed upon it. In placing mass concrete in blocks for dams, it may be permitted that the layers be irregular and undulating in form with a specified maximum thickness. Precautions should be taken to avoid entrapment of air within partially enclosed spaces to be filled with concrete.

Mass concrete for massive structures shall be placed in lifts of specified depth. Each lift shall be composed of a specified number of layers of specified thickness. These layers shall be placed, simultaneously one after the other, without cold joints.

(5) Placing concrete for canal lining:—Canal lining shall be placed as specified, either by the hand method or with longitudinally operating slip-form machines. Unless otherwise specified, when constructed by hand canal linings shall be placed in alternate panels in order to avoid...
interference in the finishing and curing operations. The dimensions of slab panels, and whether the bed slab is to be poured first, shall be specified in the design drawings. Where lining placing operations are to be carried out by slip-form machines, the design of each machine and the operations shall be subject to the approval of the Chief Engineer.

2.16. (1) General requirements:—Freshly placed concrete shall be worked with suitable consolidation of concrete appliances until the concrete has been consolidated to the maximum practicable density, is free from pockets of coarse aggregate, and closes snugly against all surfaces of forms and embedded materials. Where concrete is to be placed in layers fresh concrete shall not be placed until the layers previously placed have been worked thoroughly as specified.

(2) Consolidation by spading:—For small works, such as, building slabs, beams, columns, and footings, and for concrete work on isolated works, spading and rodding and other such hand methods may be employed for consolidation of concrete. At corners, obstructions, and other points where perfect placing may be in question, supplementary hand rodding of the concrete shall be necessary. Flattened spading tools, rods, etc., and consolidation operations shall be checked and approved by the Executive Engineer.

(3) Consolidation by vibration:—On all jobs where the rate of concrete placement is greater than 5 cubic yards per hour, and unless otherwise specified, concrete shall be consolidated with electric or pneumatic power-driven vibrators. For mass concrete, and wherever concrete is accessible for their use, internal or immersion type vibrators shall be preferred.

Vibrators shall have an operating speed of not less than 7,000 revolutions per minute when immersed in the concrete. Unless otherwise specified, immersion type vibrators should be inserted vertically, at points 18 to 30 inches apart, and slowly withdrawn. Vibration periods of 5 to 15 seconds are usually sufficient. Vibrators should

(35)
2.17—Manual of Irrigation Practice [Chap. 2.

be powerful, efficient and rugged, and ample standby units and parts should be provided at the site.

Excessive vibration causing segregation and laitance, or tending to bring an excessive amount of water to the surface shall be avoided. Particular care shall be exercised not to over-vibrate concrete placed at a slump exceeding 4 inches. The amount of vibration in one spot should be ganged by the surface movement and texture of the concrete, by the appearance of cement paste where the concrete contacts nearby forms or embedded parts, by the approach of the sound of the vibrator to a constant tone, and by the "feel" of the vibrator connection in the operator's hands. Systematic spacing of insertions of the vibrator should be established to ensure that no portions of the concrete remain unvibrated. Care shall be exercised to avoid contact of the vibrating head with surfaces of the forms.

In compaction of the surface of a concrete lift, the coarser particles of aggregate on the surface shall be embedded while the concrete is being consolidated. Surface vibrators or puddlers shall not be used. Disturbance of the surface concrete at a construction joint during the early stages of hardening should be avoided. Where necessary, and possible, vibration should be advantageously supplemented by spading and rodding, especially near the face of the forms.

2.17. (1) Construction joints:—Construction joints, are defined in paragraph (4) of Spec.
Joints in concrete, fiction No. 244. Construction joints should be approximately horizontal unless otherwise shown on the drawings or directed and shall be given the prescribed shape by the use of forms, where required, or by other means that will ensure suitable joining with subsequent work. For the sake of appearance, irregular construction joints shall not be permitted. Horizontal construction joints in mass concrete blocks shall have a slope of approximately 6 inches from midway between sumps and from edges of the blocks to the sumps to facilitate the removal of clean-up waste. In order to

(36)
avoid corner cracks as a result of settlement of fresh concrete at the sides of wall-openings, placement of wall concrete shall be discontinued at the tops of wall openings having vertical dimensions greater than 2 feet, for as long a period as practicable; but where the construction joints at tops of openings are not required, placement shall be resumed before the concrete has attained initial set, in order to avoid cold joints.

(2) Contraction joints:—In all concrete structures, whether plain or reinforced, contraction joints shall be provided where specified. In massive concrete dams vertical transverse and longitudinal contraction joints, dividing the structure into columnar blocks, each free to undergo volume change without restraint from adjoining blocks, shall be specified, in order to provide for contraction of concrete and incidentally for convenience in construction. Location of contraction joints and other details such as keyways, metal sealing strip, cover plates for vent and drainage grooves, etc., shall be as shown on the drawings. Usually, no special treatment of the faces of contraction joints will be required to prevent bonding, but edges of joints at exposed surfaces shall be straight, true lines, level or plumb. In no case shall reinforcement, corner protection angles, or other fixed metal embedded in or bonded to the surface of concrete be continuous through a contraction joint, except for dowel bars which shall have one end sliding by being set in a sleeve.

Contraction joints in mass concrete of dams, and other structures such as tunnel linings and power-house sub- and super-structure shall be grouted, if specified. The contraction joint grouting system shall be located as shown on detail drawings. The joint grouting program and operations shall be subject to the approval of the Chief Engineer.

(3) Contraction joints in canal lining:—Transverse contraction joints shall be provided in all concrete canal linings, both reinforced and unreinforced. Unless otherwise specified, and except where the lining is placed in panels, contraction joints shall be provided in the form of grooves made in the concrete while it is still plastic to a depth of one-fourth to one-third of the slab thickness. Longitudinal contraction joints shall also be provided in larger canal linings.
For unreinforced canal linings, unless otherwise specified, the spacing of transverse contraction joints shall be as follows:

<table>
<thead>
<tr>
<th>Thickness of lining (inches)</th>
<th>Joint spacing (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 1/4</td>
<td>6 0</td>
</tr>
<tr>
<td>3 0 to 1 0</td>
<td>11 0 to 18 0</td>
</tr>
<tr>
<td>6 0</td>
<td>20 0</td>
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</tbody>
</table>

As soon as the contraction joints have been prepared, and before curing is commenced, they should be filled with mastic or preformed joint filler. If the latter is to be used, it shall conform to Specification No. 1.22. Any mastic or joint filler used for canal lining shall be subject to the Executive Engineer's approval.

2.18. (1) General:—All formed and unfomed surface of concrete shall be finished, if so directed, as described herebelow or as indicated on the drawings. Finishing of concrete surfaces shall be performed only by skilled workmen.

Where necessary, concrete surfaces will be tested to determine whether surface irregularities are within the limits hereinafter specified. Surface irregularities shall be classified as "abrupt" or "gradual". Offsets caused by displaced or misplaced form sheathing, lining, or form sections, by loose knots in forms, or by otherwise defective form timber will be considered as abrupt irregularities and will be tested by direct measurement. All other irregularities will be considered as gradual irregularities, and will be tested by use of a template consisting of a straightedge or the equivalent thereof for curved surfaces. Unless otherwise specified, the length of the template will be 5 feet for testing of formed surfaces and 10 feet for testing of unfomed surfaces.
Chap. 2.] MASS CONCRETE

(2) Types and erections of formed surfaces:—Types of formed concrete surfaces and finishes generally specified for works in the Irrigation Branch are designated as F1, F2, F3, F4, and F5, and are described below:

(a) Finish F1:—This finish applies to formed surfaces where roughness is not objectionable, such as those upon or against which backfill or concrete is to be placed. The surfaces require no treatment after form removal except removal and repair of defective concrete and the specified curing. Correction of surface irregularities will be required only for depressions greater than 1 inch. Forms for this type of finish may be built with a minimum of refinement.

(b) Finish F2:—This finish applies to all permanently exposed surfaces for which other finishes are not specified, such as the surfaces of canal structures; the inside surfaces of culverts, tunnel linings, and syphons; outlet works and open spillways; small power plants; bridges and retaining walls not prominently exposed to public inspection and concrete dams. Surfaces for which finish F2 is specified will need no filling of pits or sack rubbing and no grinding other than that needed for repair of surface imperfections. Surface irregularities shall not exceed 1/4 inch for abrupt irregularities and 1/8 inch for gradual irregularities. To obtain an F2 surface the forms shall be built to the required dimensions and alignment, without conspicuous offsets or bulges.

(c) Finish F3:—This finish is designated for surfaces of structures prominently exposed to view and appearance is of special importance. This category includes parapets, railings, and decorative features on bridges and dams; superstructures of large power plants and pumping plants; and interior of hoist tower, access and adit tunnels of dams. No general stoning or grinding will be required on surfaces for which this finish is specified. Surface irregularities shall not exceed 1/8 inch for abrupt irregularities and 1/16 inch for gradual irregularities. Forms shall be built in a skillful manner and accurately to dimensions; well-matched, close-fitting tongue-and-groove boards being used.

(30)
(d) Finish F4:—This finish applies to formed surfaces where accurate alignment and evenness of surface are essential for prevention of destructive effects of water action, such as portions of surfaces is spillway tunnels, overflow spillways and outlets of high dams. Gradual surface irregularities shall not exceed 1 inch. In addition to any necessary repairs, special surface treatment consisting of grinding of offsets and bulges to a smooth finish may be specified for certain portions of hydraulic structures. The forms shall be strong and held rigidly and accurately to the prescribed alignment, and any form material or sheathing, such as close-fitting shiplap, tongue-and-groove timber, plywood or steel, that will produce the required surface may be used.

(e) Finish F5:—This finish is required for formed concrete surfaces where plaster, stucco, or wainscoting is to be applied, or where absorptive form lining is specified. Surfaces produced by absorptive form lining shall not be rubbed or treated in any way, except for cleaning by wire brushes and grinding off thin fins or small projections.

(1) Special finishes:—Special finishes may be required for certain portions of spillway tunnels, conduits etc., due to hydraulic reasons. Detailed specifications regarding preparation of surfaces, finishing mortar, curing, and grinding necessary for special finishes shall be issued by the Chief Engineer for each particular job.

(3) Finishing unformed surfaces:—Concrete having unformed, exposed surfaces should contain just sufficient mortar to avoid the necessity of excessive floating. In the initial operations of spreading, floating, and first troweling, the surface of concrete should be worked as little as possible in obtaining the desired result. The use of any finishing tool in any area where water has accumulated should be prohibited. Dry topping and mortar topping should be avoided, and the surface of the concrete should be directly finished to the texture desired.

Surfaces which will be exposed to the weather and which would normally be level, shall be sloped for drainage. Narrow surfaces, such as tops of walls and curbs, shall be sloped approximately 3/8 inch per foot of width;
and broad surfaces, such as sidewalks, roadways, platforms, and decks shall be sloped approximately \( \frac{1}{4} \) inch per foot; unless other slopes or level surfaces are indicated on the drawings or are directed.

Unless otherwise specified or indicated on the drawings, the classes of finish for uniformed surfaces shall be as follows:

(a) Finish U1:—This is a screeded finish used on uniformed surfaces that will be covered by backfill or concrete, on surfaces of bridge and road pavements, operating platforms on canal structures, and floors in culverts. It is also used as the first stage for finishes U2 and U3. Finishing operations shall consist of sufficient levelling and screeding to produce even and uniform surfaces. The surplus concrete should be removed immediately after consolidation by striking it off with a sawing motion of the straightedge or template across wood or metal strips that have been set as guides. Surface irregularities shall not exceed \( \frac{3}{8} \) inch.

(b) Finish U2:—This is a floated finish used on all exposed uniformed surfaces provided other finishes are not specified. This category includes such surfaces as in- verts of syphons, flumes, and water tunnels; floors of canal structures, spillways, outlet works, and stilling basins; and floors of service tunnels, galleries, and sumps. Finish U2 is also used as the second stage of finish U3. Floating may be performed by use of hand tools or power-driven equipment. Floating shall be started as soon as the screeded surface has stiffened sufficiently, and shall be the minimum necessary to produce a surface that is free from screeed marks and is uniform in texture. If finish U3 is to be applied, the floating should leave a small amount of mortar without excess water at the surface to permit effective troweling. Surface irregularities shall not exceed \( \frac{1}{8} \) inch.

(c) Finish U3:—This is a troweled finish used on inside floor slabs of buildings, except floors for which the drawings require a bonded concrete finish or a terrazo finish; on slabs to be covered with built-up roofing or membrane waterproofing, and on inverts of tunnel spillways and on interior stair treads and landings. When the
2.18—MANUAL OF IRRIGATION PRACTICE Chap. 5

floated surface has hardened sufficiently to prevent excess of fine material from being drawn to the surface, steel troweling shall be started. Steel troweling shall generally be performed with firm pressure that will flatten and smooth the sandy surface left by the floating. Troweling should produce a dense, uniform surface free of blemishes, ripples and trowel marks. Surface irregularities shall not exceed \( \frac{1}{4} \) inch.

(d) Finish U4:—This finish is specified for canal lining. Such a finish shall be equivalent in evenness and smoothness, to that obtainable by effective use of steel trowels. The surface shall be free from rock pockets and surface voids, though light surface pitting and light trowel marks are not objectionable. Where the surface produced by a lining machine meets the specified requirements no further finishing shall be necessary.

2.19. Curing (1) Protection of concrete:—All concrete shall be adequately protected against injury until final acceptance. Exposed finished surfaces of concrete shall be protected from the direct rays of the sun for at least 72 hours after placement. This protection may be provided by wet burlap, moistened sand or backfill, or by wooden forms left in place but loosened and wetted thoroughly at frequent intervals.

(2) Moist curing:—In general all concrete made of standard or modified portland cement shall be kept continuously moist for a minimum period of 14 days after placement. Concrete made of low-heat cement shall be kept continuously moist for at least 21 days after placement. If admixtures, such as pozzolans, are used in cement concrete, the curing period may be extended to 28 days by the Executive Engineer.

The concrete may be kept continuously moist by spraying or ponding, or by covering with earth, sand, or burlap maintained in a moist condition. Water curing of all concrete shall start immediately after the placement of concrete and commencement of final set, and appropriate measures shall be adopted to protect exposed surfaces of fresh concrete from water spray. All forms shall be kept wet until removed. All methods used for curing, including

(42)
(3) Curing with sealing compounds:—In hot and arid regions where there is shortage of water for curing and on limited surface areas for special purposes, the use of an approved properly-applied moisture-sealing compound may be specified for curing in lieu of water curing. Such a curing compound shall be of the surface membrane type which will thoroughly seal the concrete surfaces, and shall remain intact as a sealing coat for at least 28 days. The curing compound shall be white-pigmented, and its consistency shall be such as to provide an average coverage of 150 square feet per U.S. gallon.

Concrete shall be thoroughly wetted before applying the compound. The compound coat shall be evenly distributed over the entire surface, and comparatively thinly coated areas shall not be permitted. Curing compounds shall not be used or joints where bonding to other concrete is required. All surfaces covered with curing compound shall be protected from traffic or injury to the sealing coat until expiry of the curing period.

2.26. (1) Requirements:—In order to prevent penetration of concrete by moisture from backfill and other sources, special treatment of concrete surfaces with various bituminous and other water-proofing compounds, may be specified. Ordinary construction, damo or water-proofing shall be provided as described in Chapter IV. Where asphalt is specified for water-proofing coats, it shall conform to Specification No. 121. All other water-proofing compounds and membranes shall be subject to the approval of the Chief Engineer.

(2) Water-proofing exterior walls, etc.:—Where indicated on drawings, exterior walls, roofs, etc., of buildings adjoining hydraulic structures, such as powerhouse and pumping plants, shall be treated with water-proofing compounds of an approved quality. In general, three coats of clear water-proofing consisting of cut-back coal-tar pitch or asphalt shall be applied to all surfaces to be covered with backfill or otherwise hidden from view.

(43)
2.21—MANUAL OF IRRIGATION PRACTICE [Chap. 2.

All surfaces to which water-proofing is to be applied shall be thoroughly cleaned before applying the water-proofing coats. When the concrete surface is thoroughly dry, the water-proofing compounds shall be applied by spraying or with suitable brushes, and all pin holes, depressions, and irregularities shall be carefully filled or covered. The coats shall be uniform in thickness without streaks or runs. Where specified, the clear water-proofing compound shall consist of a blend of China-wood oil, waxes, aluminium stearate, and nontoxic petroleum solvent. This water-proofing compound shall be applied at the rate of one U.S. gallon to each 200 square feet of area per coat, and each coat shall be allowed to dry for 72 hours before the following coat is applied. The water-proofing compound shall be of such a nature as to make it possible to identify freshly coated areas.

The first coat of cut-back coal-tar pitch or asphalt shall be applied at the rate of one U.S. gallon to each 400 square feet of surface area, and succeeding coats shall be applied at the rate of one U.S. gallon to each 240 square feet of area. Each of these coats shall be allowed to dry for 96 hours before the following coat is applied.

(3) Membrane water-proofing:—For water-proofing concrete where there is possibility of objectionable leakage through cracks, joints, or porous concrete, elastic membranes of water-proofing materials may be specified. The membranes shall be placed, turned up and mopped into the corners, as directed by the Executive Engineer, or as shown on the drawings. After the membranes are placed, they shall be uniformly covered with a coating of hot asphalt or coal-tar pitch.

2.21. (1) Purpose:—Systematic control shall be exercised on all operations from the selection and production of materials to the completion of the curing of concrete, in order to make possible the production, at minimum practicable cost, of structures in which the quality of concrete is uniform and satisfactory. Field and laboratory inspection and testing of materials and operations shall be carried out according to a preplanned schedule. Primary purpose of inspection and control should be the fulfillment of the specification requirements.

(44)
(2) **Daily inspection reports:**—On all large projects the concrete inspector or engineer-in-charge of concreting operations shall make a daily inspection report to the Executive Engineer. The daily report should include statements concerning the condition and progress of the work, important factors affecting such condition and progress, and daily test data. The test data should include the number, type, and location of samples taken, concrete mixes used, number and results of slump tests, and the number of representative concrete cylinders made for laboratory testing.

The daily placing report, prepared by the placing inspector or the engineer-in-charge of concreting operations should give information regarding location, class of concrete, batch size, method of transportation of concrete, slump, placing methods and the weather conditions. In addition this report, should give the quantity of and reasons for concrete wasted, and any other unsatisfactory conditions of operations. This report shall also be submitted daily to the Executive Engineer.

(3) **Field tests:**—Field tests such as sampling of aggregates, gradation of aggregates, mixer efficiency tests, slump tests, and any other specified tests, shall be carried out daily. Some of these tests, especially the slump tests shall be carried out once every hour at each mixer on continuous operations, and also when there is a change in the concrete mix, or whenever such tests are desired by the Executive Engineer. Details of slump requirements and test are given in Specification No. 2:10 and Appendix III.

(4) **Laboratory tests:**—Tests in field and research laboratories shall include all tests for the control of quality of cement, acceptability of aggregates, mix design, and tests for checking the compressive strength of concrete.

(5) **Tests for compressive strength of concrete:**—(a) **Casting test cylinders:** Unless otherwise permitted, all concrete test specimens shall be 6 by 12-inches and 8 by 18-inches cylinders. The specimens shall be preferably cast in cast-iron cylinders of an approved design.

Where the concrete in moulds has to be compacted by hand-rodding, the mould should be filled in three layers,
each approximately one-third the volume of the mould. Each layer shall be rodded with 25 strokes of a 5/8 inch diameter rod 24 inches in length and bullet pointed at the lower end. The strokes should be distributed in a uniform manner over the cross section of the mould and should just penetrate into the under lying layer. After the top layer has been rodded, the specimen should be removed to the curing room and the excess concrete struck off with a trowel.

(b) Storage and curing of specimen:—Specimens should be removed from the moulds not earlier than 36 and not later than 48 hours after casting, weighed, and returned to the curing room. Specimens made in the field should be protected from the sun and kept, as nearly as practicable, at 70°F.

In the curing room the specimens should either be kept completely immersed in water, preferably maintained at 70°-75°F, or the specimens should be kept completely buried in sand which is maintained in a saturated condition. The cylinders should be kept in the curing room until the time of the compressive strength test.

(a) Testing:—Standard cured test specimens should be tested for compressive strength as soon as practicable after they are removed from the curing room. Unless otherwise permitted, all test specimens should be copped by an approved sulphur mix and method. A spherical bearing block should be used to transmit the load, from the testing machine to the specimen. The diameter of the bearing block should be the same as, or slightly larger than, that of the test specimen. The test specimen should be carefully centered with respect to the bearing block.

Load should be applied uniformly and without shock at a rate of 2,000 p.s.i. per minute. No adjustment should be made in the control of the testing machine while a specimen is yielding rapidly immediately before failure. The total load indicated by the testing machine at failure of the specimen should be recorded immediately. Exceptional variations in the type of break and angle of fracture should be noted.
(6) Monthly concrete control report.—The Executive Engineer in-charge of concreting operations at a project shall submit a consolidated and descriptive monthly report on concrete control to the Chief Engineer. The monthly report shall be according to the following outline:—

(a) Aggregates:—
   (a) Stripping.—Methods and approximate yardage removed; types of material removed and disposition.

(b) Excavation.—Methods and approximate yardage removed; type of material used and disposition.

(c) Processing.—Type of plant; approximate quantity processed for each size aggregate; delays and difficulties encountered; recommendations.

(d) Stockpiling.—Procedure; recommendations.

(b) Cement:—
   (a) Amount of cement received.

(b) Method of transporting and unloading.

(c) Storage.

(d) Delays, difficulties and recommendations.

(c) Concrete Production:—
   (a) Batching and mixing.—Average specification quality of material; weighing equipment, types and checks; temperature of concrete; type of mixing and transportation equipment; general batching procedures; recommendations.

(b) Mix data.—Description of mix and its workability with regard to placing equipment, percentage of air entraining agent, if any.

(c) Placing.—Total yardage of concrete placed; method of placing; type of consolidation used; method of transportation; types of forms; difficulties and delays; recommendations.
2.21—MANUAL OF IRRIGATION PRACTICE Chap. 2]

(d) Curing:—Type and method of curing concrete.

(d) Miscellaneous:—
(a) Protection of concrete.

(b) Methods used to prevent excessive heat generation and drying of surfaces.

(c) Use of admixtures

(d) Laboratory testing; routine and special tests.

(e) Future plans, suggestions, and recommendations.

These monthly reports should be employed for development and improvement of detailed specifications issued for particular jobs.
CHAPTER III

A. BRICKWORK

3.1. (1) Materials.—Pucca brickwork shall consist of first class or pucca bricks laid in lime or Brickwork, pucca cement mortar. Unless otherwise specified, pucca brickwork in mortar shall be laid in one or more of the mortars detailed in Specifications No. 1.17, 1.18 and 1.19 and never in mud mortar.

(2) Pucca brickwork.—The following specification shall apply to pucca brickwork.

(a) Soaking.—Before use, all bricks shall be soaked in clean water in tanks or pits for at least one hour. The cessation of bubbles through the water is an indication of saturation being complete. Bricks shall be placed in the tank or pit by hand, one at a time, and not thrown or tipped in.

(b) Laying bricks.—Bricks shall be laid in English bond, or such other bond as may be specified. Each brick shall be set with its frog upwards and both bed and vertical joints filled with mortar and bricks bedded in by tapping with the handle of the trowel. Simple lipping with mortar at the edges of the brick shall not be permitted and this practice shall be discouraged amongst the masons.

Brickbats shall be used only, where absolutely essential for obtaining the dimensions of different courses, or for obtaining the specified bond.

(c) Joints.—All horizontal joints shall be parallel and, unless otherwise specified, truly level. Vertical joints in alternate courses shall come directly over one another. The thickness of joints shall be 1/4 inch and in no case shall it be greater than 3/8 inch. Four courses of brickwork laid with four joints shall not exceed by more than 1 inch in height of same bricks piled one over the other without mortar. For pointed work, wherever so specified, the mortar bed joints will be 5/16 inch thick and the vertical joints 1/4 inch thick and such brickwork in four courses including 4 bed joints should rise 12 inches.
At all angles forming the junction of any two walls the bricks shall, at each alternate course, be carried into each of the respective walls.

(d) Progress of brickwork.—All brickwork shall be taken up truly plump or vertical and each set of four brick-layers shall be provided with a plump bob and a straight edge for the purpose. The walls of all structures shall be carried up regularly in all cases where the nature of the work permits it; not leaving any part three feet lower than another. Temporary steps, left during construction, shall be raked back and not toothed. Straight edges supplied to brick layers shall have courses marked on them, or measuring rods shall be provided, and height of courses shall be checked all over the structure from time to time so as to keep all courses level. Fixtures, such as holdfasts, shall be built in as the work progresses, and no spaces shall be left for them.

(c) Face work.—Bricks with true edges and of regular shape and colour shall be used for face work. Care shall be taken that these bricks are not chipped, stained or damaged during construction. Bricks shall be laid so as to give a perfectly straight and vertical face to the wall and no chipping or rubbing of faces should be permitted to remedy improper laying.

(f) Cut brickwork.—Bricks will be cut, shaped or grooved where required for shaping jambs or for fitting door or window frames.

In the case of certain buildings, where it is specified that angles formed by the junction of two walls be rounded out or specially moulded bricks shall be used for this purpose. Similarly, where required cut or moulded bricks shall be used in arches, cornices, corbels, jambs, etc.

(g) Weather protection; Watering.—All brickwork laid in lime or cement mortar shall be protected during construction from rain, sun and frost by suitable covering if necessary, and shall be kept moist for at least ten days.

(b) Scaffolding.—Proper scaffolding, strong enough to bear construction loads and tightly fastened joints and having two sets of vertical supports (of which the wall
may be one) shall be provided. The contractor shall be solely responsible for the safety of either the work and scaffolding or of the workmen using the scaffolding. However, the Executive Engineer can call upon the contractor to strengthen the scaffolding, if he considers it necessary.

(i) Bed plates.—All beams, joints and trusses shall be supported on precast bed plates built in the wall. The bed plates shall be made of 1:2:4 cement concrete or stone. These bed plates should conform to the designed dimensions and shall be carefully laid in 1:3 cement mortar to correct level, packing up, if necessary, with tiles or split bricks.

32. (1) Materials.—Kutcha-pucca brickwork shall consist of first or third class bricks laid in kutcha-pucca. The bricks used shall conform to Specification No. 1.4 and the mud mortar shall adhere to and shall be prepared according to method described in Specification No. 1.16. No lime or cement mortar shall be used for kutcha-pucca brickwork.

(2) Laying brickwork.—Bricks for kutcha-pucca brickwork shall not be soaked in water prior to laying. Joints of brickwork in mud mortar shall be 1 inch thick and shall not be more than 5/8 inch thick in any case. Specifications regarding laying of bricks and progress of work shall be the same as for pucca brickwork given in para 2 of specification No. 3.1. No cut brickwork shall be carried out in mud mortar. For face work, no special selection of bricks shall be necessary for kutcha-pucca brickwork.

(3) Use of Pucca brickwork.—Brickwork in lime or cement mortar shall be carried out for fixing window and door frames, for arches, for fixtures, etc.; while the major part of construction may be in kutcha-pucca brickwork. The use of pucca brickwork for these purposes shall be mentioned in the drawings.

(4) Weather protection and uses.—Kutcha-pucca brickwork shall be protected during construction from rain and from uneven drying.
3.3-3.4— Manual of Irrigation Practice [Chap. 3.

Kutch-pucca brickwork shall be adopted for temporary building construction in regions of moderate rainfall.

In regions of heavy rainfall, kutch-pucca brickwork should be completely protected from rain, and all exposed faces shall be laid in jibhi masonry.

No walls subjected to lateral or overturning forces shall be built of kutch-pucca brickwork. Nor shall kutch-pucca brickwork be used for structures liable to constant wetting or submergence below water.

3.3. (1) Materials:—Jibhi work shall consist of first or third class bricks laid in lime or cement mortar for 2 inches of its thickness from the face, the rest of the thickness of wall being laid in mud mortar. The bricks shall conform to the specifications for the class mentioned in design, as given in specification No. 1.4 and the mortars shall conform to their respective specifications.

(2) Laying brickwork:—In all other matters of construction, laying, bond, progress, protection, etc., specification No. 3.1 shall be followed.

(3) Use:—Jibhi work shall be used for building work of permanent or temporary nature. Due to its dual-mortar method of construction, jibhi work should be specified only where its advantages in durability and cost, are definitely established over other kinds of brickwork.

3.4. (1) Materials:—Sand moulded, sundried bricks shall be used for this kind of brickwork.

Sundried Brickwork Jibhi masonry.

The bricks shall conform to specifications laid out for them in specification No. 1.4. The bricks shall be laid in mud mortar, which shall conform to specification No. 1.16.

(2) Workmanship:—The bricks shall be perfectly dry before use and shall be used dry. In all other respects
3.5 sundried brickwork shall comply with specifications Nos. 3.2 for kutcha-pucca brickwork. All sundried brickwork shall be protected from the effects of rain and water until it is roofed and plastered.

(3) Brickwork under beams.—Unless otherwise specified, two courses underneath the roof battens, and the jambs of doors and windows to a depth of nine inches shall be built in kutcha-pucca brickwork. All roof beams shall also be carried on pillars of kutcha-pucca brickwork for the full height and thickness of the wall and of such width as ordered.

(4) Use.—Sundried brickwork shall be used only for temporary, single storey, building work in areas of medium and low rainfall. The use of sundried brickwork shall be subject to approval of the Chief Engineer. Kutcha masonry may also be used interior wallof permanent buildings in regions of low rainfall.

3.5. (1) Mud walloing.—Mud walls shall be constructed from moulded bricks or a size consistent, venient to handle and transport. The bricks shall be laid without any mud mortar between joints.

(2) Stone walloing.—Stone walls shall be made of brick or clay, which shall be of a mouldable consistency, containing a small amount of water. After excavation the earth shall be broken fine and shall be screened through a \( \frac{1}{2} \) inch size U.S. standard sieve. The earth shall be laid in three to six inches thick layers between two parallel boards which will form the two faces of the wall. The earth shall then be thoroughly rammed and as soon as the space between the boards is completely filled, the boards shall be moved forward to the next length.

(3) Soil-cement walloing.—In case it is desired to make walloing of rammed soil-cement admixture, the proportion of cement to be used, the quality of soil required and the amount of water to be used, shall be specified by the Design Office. No soil-cement work shall be carried out without approval of the Chief Engineer.
3.6—MANUAL OF IRRIGATION PRACTICE [Chap. 3.

(4) Protection and use.—Mud walling shall be protected from rain, water and uneven drying until it is roofed. Mud walling should be used in areas of low rainfall and for temporary housing accommodation that is to be used for only a few years.

3.6. (1) Classes of archwork.—Brick arches shall be classified as follows:—

(a) Arches built of concentric but unbounded rings.

(b) Gauged arches, or arches laid in header and stretcher bond.

Gauged arches shall be used for face work which will be pointed and for flat arches, where specified.

(2) Materials.—Unbonded arch rings shall be built of first or third class bricks laid in lime or cement mortar. For such archwork the class of bricks and the mortar shall be specified, and these shall conform to the standard specifications for materials.

Gauged arches shall be built only of first class bricks laid in lime or cement mortar, as specified.

(3) Arch abutments.—No archwork should be started until both the abutments have been built to their full width to the level of the skew-backs. Then the archwork shall be carried up evenly from both abutments of the arch, and as soon as the arch is complete, brickwork should be built up evenly on both sides of the arch to the level of the crown, so as to load evenly the haunches of the arch.

Before commencement of the arch both the abutments should be exactly at the same level and the skew-back bricks should be in place. Skew-back shall be formed of specially cut bricks correctly shaped to radiate truly from the centre of curvature, and defects in this particular item shall not be remedied by the use of excess mortar or by packing with brick chips.

(4) Centring.—A frame work of timber, steel or dry brickwork arranged to support temporarily the voussoirs of arches during their construction is termed a centre or centring. All arches over 20 ft. span shall be built on timber centres carried on sand cylinders or wedges and laggings should be of squared timber.
Arches of less than 20 ft. span may be built on earth centres, the top of the earth being brought to the true curve and plastered with lime mortar. Centring shall be constructed sufficiently strong to bear the weight of the arch without deflection and should be carefully and rigidly put together. The surface of the centring shall be correctly struck to the soffit of the arch. For brick arch roofs and for repetition work, properly constructed portable timber centres should be used.

(5) Striking centre.—The term "striking centres" means the lowering of centring to permit the arch to take up load of the overburden. For archwork in buildings, brick arches shall be struck as noted below:

(a) Single segmental arch; Centre shall be struck immediately after the arch is finished.

(b) Series of segmental arches; Centre of each arch shall be struck as soon as the arch next to it is completed.

(c) Semi-circular, elliptical or pointed arches; Centre shall be struck as soon as the brickwork has reached two-thirds of the height of the arch.

For spans larger than 6 feet, timber centres shall be provided with hard-wood wedges for slackening the centres. For spans over 20 feet, the centres shall be erected on sand boxes so as to allow gradual lowering when centres are struck. For spans larger than 30 feet, the centres may rest on intermediate brick pillars, capped by wooden pieces. In all centres, the arrangements shall be such that the slackening can be carried out without transmitting any vibrations or shock to the arch.

While the work is in progress care should be taken to distribute the load on the centres in such a way that a true curve is obtained at the completion of work. Before striking centres of arches exceeding 40 feet span, the middle half of the centre shall be loaded with all the material which is to be used above that portion of the arch ring.

(6) Laying out gauged arches.—For gauged work, the designed arch must be laid out full size on lime plaster spread on level ground and all joints should be carefully
marked out. Wooden or metal templates shall then be made as a guide for the special shapes of bricks. Special bricks shall where possible, be moulded and burnt. Where the amount of archwork is small, the special bricks shall be carefully cut and then rubbed to the required shape. All the bricks required for the arch should be prepared and arranged on the ground before commencing the work.

(7) Joints.—All voussoir joints shall be truly perpendicular to the tangents to the curve of the arch at those points. For circular arches the joints shall be truly radial.

The bricks shall be laid in full beds of mortar and shall be well rubbed and pressed into place so as to squeeze out surplus mortar and leave the joints as thin as possible. No joint in archwork shall exceed \( \frac{1}{4} \) inch in thickness at any points; provided that radial joints in gauged arches shall not exceed \( \frac{1}{8} \) inch in thickness.

(8) Keystone.—The key voussoir, whether of brick or stone, must be driven firmly into position with a wooden mallet, and must lie truly and centrally on a vertical line through the centre of the span.

(9) Flat arches.—Flat arches shall be used for pointed face work requiring a horizontal soffit and shall be built to the standard of gauged arches. All voussoir joints in a flat arch shall converge to the apex of an equilateral triangle described on the soffit of the arch. The extrados and cross joints should be parallel to the soffit. Flat arches shall have a camber of one-eighth of an inch per foot of span.

Segmental arches over rectangular door or window openings may have a flat horizontal soffit and segmental extrados.

(10) Relieving arches.—Relieving arches shall be built over flat arches brickwork lintels and at such other places as may be specified in design. The relieving arch shall be built over a centering and not simply built into the wall over masonry laid to the segmental shape. The
space between a relieving arch and a flat arch or a lintel is not to be filled in until the walls have been completed, unless specially ordered by the Executive Engineer. This space should be filled with brickwork or concrete and no hollows of any kind should be left. The span of the relieving arch should be such that the skew-backs of relieving arch and the flat arch are in the same radial alignment.

3.7. (1) General.—Wherever it is necessary to save weight and space by using 4\(\frac{3}{4}\) inches or 3 inches thick partition walls, the walls shall be built in brickwork reinforced with hoop iron. Such walls shall be able to bear their own weight by acting as beams, but shall not bear any other load. When built on suspended floors, or where there is no beam or wall underneath to take the load, the wall shall be designed as a reinforced brick hanging wall.

(2) Materials.—Only selected first class bricks shall be used. These bricks shall be laid in standard 1:3 cement mortar and the brickwork shall conform to requirements of first class pucca brickwork under Specification No. 3.1, except that one inch wide 18 gauge hoop iron shall be used as reinforcement.

(3) Reinforcements.—All hoop iron reinforcement shall be laid flat in the middle of the brickwork and the mortar joint. The bond of the hoop iron with the brickwork will be greatly improved if the hoop iron is punched at intervals of nearly 6 inches, so as to form burrs on both sides of the reinforcement. When punched hoop iron is specified, it shall have \(\frac{3}{8}\) inch diameter holes.

For non-self-supporting or hanging walls, hoop iron shall be placed in courses not more than 12 inches apart and continued for 9 inches into the main walls which form the abutments of the partition wall. If the partition wall exceeds 20 feet in length or 18 feet in height, the hoop iron shall be introduced at courses not more than 6 inches apart.

Before laying the hoop iron, it should be exposed to the weather to remove its bluish smooth surface and thus increase its adhesion to mortar. The strip of hoop iron shall be continuous and if it is not available for the full length of the wall, two lengths shall be riveted together with an overlap of at least three inches.
3-8. (1) Requirements of building stone.—Building stone for masonry shall be obtained from quarries approved by the Executive Engineer. It shall be as far as possible of uniform colour and texture, sound and durable, free from decay, flaws, cracks, cavities, veins and other defects and shall be of the best quality obtainable from the quarry.

Porous stones, such as coarse grained sandstone and stones with close planes of cleavage, such as shales and slates, shall not be used for stone masonry. A stone specimen, which being dry initially, absorbs more than 5 per cent, of its weight of water after 24 hours submersion, shall be rejected.

(2) Dimensions.—Stone shall be supplied in sizes, that are most suitable for the particular class of work for which it is specified. Stone blocks required for dimensioned work must be square and true to dimensions specified in the drawings.

Rubble stone shall be evenly bedded and shall be supplied in as large blocks as will permit efficient handling. No rubble stone shall be less than one-third of a cubic foot in volume.

(3) Seasoning.—After quarrying, stone needed for building purposes, should be left in the open air for seasoning, preferably for a period of 6 to 12 months, so as to be freely exposed to the sun and the wind, but sheltered from rain, if necessary. All stones when freshly quarried contain a quantity of moisture known as quarry sap. This moisture renders the stone soft and should be expelled from stones for building purposes by proper seasoning.

(4) Physical properties.—Building stone should have a minimum sustained modulus of elasticity in compression and tension, of 2,500,000 pounds per square inch. The minimum crushing strength of an average specimen of stone from a lot, shall not be less than 3,000 pounds per square inch.

(10)
3.9. (1) General.—For most building jobs and small works, building stone shall be quarried and supplied by the contractor from approved quarries. However, for large works and in an emergency, quarries may be worked by the Irrigation Branch.

(2) Quarry bye-laws.—In the working of stone quarries, either by a contractor or by the department, all departmental, forest, municipal or other bye-laws rules and regulations in force regarding the clearance of ground, excavation, quarrying, use of explosives, royalties, etc., shall be strictly observed by the operator of the quarry. The operator shall be responsible for any loss or damage caused by breach or non-observance of quarry laws and precautions.

(3) Blasting.—Where large quantities of stone are required, blasting with explosives shall be employed if economical and feasible. For building purposes, stone must not be shattered during blasting and for this reason it is necessary that large scale blasting should be resorted to only if workmen, properly trained for the work, are available on the job. Blasting supervisors and crew should have a good knowledge of the types of explosives and fuses to be used and the precautions for storage and firing of explosives. Caps, fuses or other explosives shall in no case be stored, transported, or kept in the same place in which dynamite or other explosives are stored, transported, or kept.

(4) Manual quarrying operators.—On small scale jobs manual quarrying or rock excavation by barring, wedging, or by using pneumatic tools will be more practicable. The stone shall be quarried in such sizes, as to be most suitable for various kinds of construction.

3.10. (1) General.—Stones shall be cut and dressed as soon after quarrying as possible, since stone are soft when damp, and harden...
considerably on seasoning. Dressing of stones shall, usually, be done in the following three operations:—

(a) Sorting of rough stones according to sizes. It is roughly hewn and all unwanted material is knocked off.

(b) It is hauled to the masons working in the quarry and given a rough shape of a rectangular block, a cornerstone, etc., with a 2 to 3 pounds hammer.

(c) Final dressing is done at the site of the work by finer tools, such as chisel, point, bolster, pitching tool, etc.

(2) Types of dressing:—Stone shall be dressed accurately to the exact size specified and according to one of the types prescribed below:—

(a) Scabbed boulders or hammer-dressed stone. Dressed with a scabbling hammer.

(b) Rough tooled stone, also called one line dressed. Dressed with a chisel, such that no portion of the dressed face is more than one-quarter inch from a straight edge placed on it.

(c) Chisel dressed stone, also called two line dressed. Dressed with a chisel, or sparrow picked, until no portion of the dressed face is more than one-eighth inch from a straight edge laid along it.

(d) True dressed stone, also called three-line dressed. Dressed to the best surface possible with a chisel, without rubbing. A straight edge, laid along the face of the stone so dressed must be in contact with the stone face at every point.

(3) Cut-stone work.—Every stone for cut stone work shall be fine-tooled on all faces to exact shape specified in design. Templates made of zinc sheet shall be used to dress the stones to correct shapes.

(4) Sawing and polishing.—Certain building stone like marbles and limestones, shall be sawn in blocks, whenever so specified.
Certain stone, like granite and marble shall be polished with a stone polishing machine, if so specified. Sandblasting may sometimes be prescribed as a finishing process for building stones.

3.11. (1) **Stone.**—Stone for masonry shall conform to Specifications Nos. 3.8 and 3.9. Various sizes of stones shall be stacked separately. Through bond stones shall particularly be stacked separately from ordinary building stone, and the stack shall be marked to distinguish it from the rest, and the marks must be made on the inner face or the face to be plastered.

(2) **Method of laying stone.**—Prior to laying, all stone for masonry in lime or cement mortar should be thoroughly soaked with water and the work should be kept wet, while in progress. Watering should be done carefully so as to avoid washing mortar out of the joints.

Every stone shall be laid on its broadest face to provide better opportunity to fill spaces between stones. Stones shall be laid with their natural quarry bed normal to the pressure borne by it. Masonry courses shall be perpendicular to the pressure to be borne and in case of battered walls, the beds of stones and the plane of courses should be at right angles to the batter. Where the courses are planned to be of different thicknesses, the thickest courses shall be the lowermost and the thickness of courses shall decrease gradually towards to top.

(3) **Bond.**—(a) Joints parallel to the external pressure should not lie in the same vertical line. In other words, a stone in any course should overlap the stone in the course below.

(b) In order to obtain sufficient transverse bend, the prescribed number of headers must extend through the entire thickness of thin walls, or from outside face to a prescribed depth within thick wall.

(c) To obtain proper bond at angle junctions of the stones at each alternate course shall be carried into each of the respective walls.
(d) The practice of building two thin faces of stone masonry tied with occasional through stones and filling up the space between the masonry faces with fine, small or dry stone packing shall not be permitted.

(e) Where breaks are unavoidable in carrying up the work continuously in horizontal courses, sufficiently long steps shall be provided to obtain a good bond between old and new masonry.

(4) Quoins, lintels and corners.—Quoins and jambs shall be dressed at a true right angle to the bed, the corners being straight and vertical. In the case of masonry with hammer dressed stone, a chisel draft one inch wide shall be given on each external face to allow of accurate plumbing. Quoins shall be laid as headers and stretchers in alternate courses.

All lintel stones, not to be plastered over, shall run through the entire thickness of the wall in which they are laid, including the thickness of the plastered face or faces.

Interior and exterior corners of walls and projecting angles shall be rounded if specified. The drawings shall also indicate the shapes and radii of rounded corners.

(5) Tools and scaffolding.—All masonry shall be taken up truly vertical, unless otherwise designed, and each set of four masons shall be provided with a plumb bob and straight edge.

Proper scaffolding, conforming to para 3, specification No. 3.1, shall be constructed for stone masonry job where necessitated by the height of walls.

(6) Bed plates, dowels, cramps, etc.—Bed plates shall be provided under the ends of beams, girders, roof trusses, etc. Bed plates shall be of sizes specified in the drawings and shall be either cutstone, or stone chisel dressed on all faces, or of cement concrete, if so specified. Bed plates shall be carefully laid with fine joints with the necessary packing to give the correct level.

Dowels, cramps and joggles should be supplied and used wherever specified or ordered by the Executive
Engineer. Cramps may be of copper or lead and shall be from 6 to 12 inches in length, ½ to 1 inch in thickness, and from 1 to 2 inches in width as specified, and having each and twined at right angles. Iron cramps shall not be used. Copper cramps shall be forged and set with neat cement, and lead cramps shall be formed by running molten lead into the dove-tail channels in stone.

Dowels and joggles shall be of double wedge form and made from copper, or from slate or similar stone, and set in neat cement. Iron dowels or joggles shall not be used.

(7) Fixtures, etc.—All iron, stone, concrete or other fixtures, returns, buttresses, etc., shall be built and bonded into the masonry as work proceeds and not inserted or joggled on afterwards. Fixtures shall be built into the masonry in 1:3 cement mortar, in the right position.

(8) Cleaning work and striking joints.—Mortar shall be confined to the joints and none should be smeared over faces of stone that are to be covered. On completion of the work all exposed surfaces shall be cleaned and washed and all stains and smears removed.

Where pointing is not to be carried out afterwards, joints in each day’s work should be struck by a mason following up the masonry work.

(9) Weather protection.—Stone masonry laid in lime or cement mortar shall be protected during construction from the effects of sun, rain and frost, by suitable covering. Masonry in cement or lime mortar shall be left flooded at the end of each day with one inch of water, and shall be kept moist for a period of ten days. Masonry laid in mud mortar shall not be wetted and shall be protected from rain and uneven drying.

3:12 (1) General.—The term Ashlar masonry is employed for masonry composed of best Ashlar masonry, quality, properly squared and carefully worked and dressed stones. Ashlar masonry is generally used for masonry construction, where great strength, stability and durability are required. Whenever it is found to be cheaper than cement concrete of equivalent strength, ashlar masonry shall be used for piers,
abutments, arches and parapets of bridges and for small hydraulic works.

Ashlar masonry shall consist of fine dressed stone (see specification No. 3.10), laid in courses of 12 inches or more in depth with standard 1:3 cement mortar, the shape of the stones conforming to dimensions specified in the drawings.

(2) Classes of Ashlar masonry:

(a) Fine Ashlar.—For this class of masonry every stone shall be dressed on all beds, joints, and faces, full, true, and out of winding if the surfaces are flat, or to uniform curves or twists if required by the design. Mortar beds and joints should not exceed one-eighth inch in thickness.

(b) Rough-tooled Ashlar.—For Rough-tooled Ashlar, also called Bastard Ashlar, the exposed faces of stones shall have a one inch wide fine dressed chisel draft all around the edges and shall be rough-tooled between the drafts and on all beds and joints. Mortar beds and joints should not exceed one-fourth inch in thickness.

(c) Rustic Ashlar.—Rustic or Quarry-faced Ashlar is similar to Rough-tooled Ashlar, except that the exposed faces of the stones between the drafts are to be left rough. No rock face, or bushing, should project more than three inches from the plane of drafts. The drafts may be omitted altogether, if so specified.

Wherever only Ashlar masonry is specified, without any indication of class of type, Fine Ashlar shall invariably be used.

(3) Courses, beds and joints.—The stone shall be laid in regular horizontal courses, not less than 12 inches in height and all the courses being of the same height unless otherwise specified, in which case no course shall be thicker than the course below it.

All beds and joints shall be perfectly horizontal and vertical respectively and all visible edges must be free from spalls. Each stone should be set up and flushed with mortar as specified, and should be struck with a wooden maul when laid, in order to bring it to a solid bearing against bed and joint.
Unless otherwise specified, no stone should be greater in height than in breadth and its length should not be less than twice its height.

(4) Bond.—In order to distribute the load uniformly over the wall and its footings, no joint of any course should be directly above a joint in the course below and the specified bond should be carefully maintained throughout the wall. The face stones shall be laid header and stretcher alternately, the headers being arranged to come as nearly as possible in the middle of the stretchers above and below. The stones shall break joint on the face by at least half the height of the course.

Unless otherwise specified, in walls not more than 2½ feet thick, the headers shall run right through the wall.

(5) Jamb.—Jamb for door and window opening shall be formed with quoins of the full height of the course. Unless otherwise specified, the breadth of the quoins shall not be less than 1½ times its depth nor shall its length be less than twice its depth. At least three quoins in the case of doors and two in the case of windows shall be stones of a length equal to the thickness of the wall.

(6) In all other aspects.—Ashlar masonry shall follow the general conditions laid down in specification No. 1.11.

3.13. (1) Backing.—Ashlar facing is often backed with rubble masonry, brickwork or concrete, especially in the case of thick walls, piers, abutments, etc. Ashlar facing, for this type of masonry, shall comply with Specifications Nos. 3.11 and 3.12, with the following modifications.

(2) Size of stone.—Unless otherwise specified, no stone should be less than 18 inches long and the depth of facing shall not be less than 4½ inches and 9 inches in alternate courses.

(3) Bond, courses, beds and joints.—Height of any course shall not be less than 8 inches, and one-third of the entire length of each course must be in headers. The
3.14—MANUAL OF IRRIGATION PRACTICE [Chap. 3.

height of courses shall equal an exact number of courses of brickwork or rubble masonry backfill, with intermediate mortar joints.

Beds and joints should be rough-tooled, true and square, for at least 4/8 inch wide and 1/8 inches respectively from the face. Joints shall not be more than one-eighth inch thick where fine Ashlar facing is specified and not more than one-fourth inch in other cases.

(4) Bond stones.—Special care should be taken to secure a good bond between the facing and backfill masonry or concrete. Bond stones shall be inserted between 3 and 6 feet apart, in the clear, in every course. Bond stones must run right through the backing when the wall is less than 2/4 feet thick and in thicker walls they must overlap at least 6 inches.

(5) Ashlar Masonry for hydraulic structures.—Ashlar facing for hydraulic structures, such as piers, abutments, divide walls, etc., shall consist of best quality stone and of high-class workmanship. The facing should be as impervious as possible and should be of a strength comparable to that of the backfill. Concrete backfill should be tamped or worked to achieve a good bond between the facing and the backfill.

Ashlar Masonry in floors of hydraulic structures should be carefully laid such that every stone is throughly well bedded and all joints fully filled.

Under gates and for sills of overfalls all blocks should be laid about half an inch above correct level and when fully set, their surface should be dressed down with the chisel to correct level to form the sills of the gates.

3.14. (1) General.—Block in course is the name applied to stone masonry walling used for hydraulic structures like embankment walls, harbour walls, piers, etc. It closely resembles ashlar and course rubble masonry, being in between the two types in quality.
(2) Stones, Courses.— Stones shall be rough-tooled on all beds and joints and rectangular in shape. Faces shall be accurately squared and all face joints shall be dressed at right angles to the face for a depth of four inches. No face joints should be thicker than one-quarter inch.

No course shall be less than 6 inches in height and all stones in a course shall be of the same height. No stones in face except closers shall have less breadth than height. All stones shall fall into the wall a distance greater than their heights, and at least one-third of the face stones shall fall into the wall for a distance at least twice their height.

In walls less than two feet thick, through bondstones shall be inserted in every course between at 5 and 6 feet intervals, breaking joint with similar stones in courses above and below. In walls more than 2 feet thick, through stones will overlap at least 6 inches.

(3) Laying.— All courses shall be laid with beds truly horizontal and joints truly vertical, each bed and joint being full of standard mortar specified. Each stone shall be struck with a wooden maul to set it to a solid bearing.

(4) Block in course facing.— Block in course masonry facing may be used for brickwork, concrete, or rubble masonry. This kind of facing shall generally be specified for brickwork and rubble masonry structures subjected to submergence under water. Block in course facing shall conform to pars 1 to 3 above with following modifications.

(a) No course shall be less than 6 inches in height and at least one-third of stones in the entire length of each course should be headers. No stone shall be less than 15 inches long. Depth of facing shall not be less than 10 inches and no header shall fall less than 10 inches into the backing.

(b) The height of courses shall equal an exact number of courses of brick or rubble backing including intermediate mortar joints. The backing must be carried up simultaneously with the face-work.

(19)
3.15— MANUAL OF IRRIGATION PRACTICE [Chap. 3.

(c) Beds and joints should be rough-faced true and square, for at least 3 inches and 1/4 inches from the face respectively, and shall not be more than one-quarter inch thick.

(5) Hydraulic structures.—Block in course masonry and facing for hydraulic structures shall be in 1/3 cement mortar or as otherwise specified.

(6) In all other aspects, block in course masonry and facing shall follow specification No. 3.11.

3.15. (1) General.—Coursed rubble masonry consists of hammer-dressed face stones laid in specified standard mortar in regular horizontal courses. The quality of work is superior to random rubble masonry and inferior to block in course masonry, in appearance and strength. For all other aspects of masonry, except for the specifications given below, course rubble masonry shall conform to specification No. 3.11.

(2) Stones, dressing, courses.—The face stones shall be squared on all joints with beds horizontal. The face of stones shall be hammer-dressed and "bushing" should not project more than 1/2 inch on an exposed face, nor more than half an inch on a face that is to be plastered. The beds of stones shall be rough-dressed, true and square, for at least 3 inches back from the face, and the joints for at least 1/2 inches from the face.

(3) Courses.—The courses shall be horizontal and not less than 6 inches in height. Unless otherwise specified, all courses shall be of the same height and all stones in a course shall also be equal in height. If courses are specified to have different heights, no course shall be thicker than the course beneath it.

(4) Size of stones, through stones.—Face stones shall not have breadths less than their height. A face stone shall tail into the work to a length at least equal to its height and at least one-third of the stones shall tail into the work for lengths equal to at least twice their height, or in walls thicker than two feet three times their height.
(5) Joints.—All stones shall be set full in mortar along all beds and vertical joints. All beds shall be horizontal and joints vertical. No joint shall be more than 3 inches in thickness. Along all courses, stones shall break joint by at least half the height of the course.

(6) Quoins.—The quoins and angles of openings shall be selected stones more carefully dressed, squared and bedded to a depth of at least 4 inches. The quoins, which shall be of the same height as the course in which they are placed, shall be formed of header stones at least 18 inches long, laid lengthwise alternately along each course.

(7) Hearth or backing.—The interior of wall shall consist of flat-bedded stones carefully laid on their proper beds and solidly bedded in mortar. In order to avoid thick beds and joints of mortar and hollow spaces or dry work, chips and pieces of stones shall be wedged in wherever necessary. Facework and the backing shall be brought up evenly, but the backing should not be levelled up at each course by the use of chips.

(8) Interior facework.—Interior facework shall be precisely the same as on the exterior face, unless the work is to be plastered except that the side joints need not be vertical.

(9) Variations.—The following variations shall be made in the facework of coursed rubble masonry, where and when specified:

(a) All stones in each course need not be of the same height, but short lengths of the course may be made up by two courses, equal in height to the through course. The thickness of the joints must not exceed half an inch.
3.16—MANUAL OF IRRIGATION PRACTICE [Chap. 3.

(b) In each course, headers, hammer-dressed, and of the full height of the course are to be placed 5 feet apart, each header to be of breadth not less than the height and to tail into the work at least 3 times its height. Between the headers, each course should be built of smaller flat bedded stones not less than 2 inches thick, or which there may be two or three in the height of the course. The joints must not exceed 5/8 inch in thickness.

(10) Retaining walls; hydraulic structures:—Coursed rubble masonry may be specified for retaining walls and revetment walls up to 25 feet in height. Hydraulic structures like low piers, flank-walls, fish-ladders, etc., shall be built in course rubble masonry laid in standard 1:3 cement mortar, when and as specified in the design.

3.16. (1) General.—Uncoursed or random rubble masonry consists of roughly hammer-dressed stones, of irregular shapes, laid in specified standard mortar according to a random arrangement. Random rubble in masonry is generally used for residential building work and for unimportant low retaining walls, revetment walls, etc., subjected to pressures and where these structures do not come in contact with water. Uncoursed rubble masonry shall conform to specifications given below and in aspects not covered by these conditions, it shall follow specification No. 311.

(2) Stones dressing, laying, etc.:—All stones shall be hammer-dressed on the face, sides and beds to such an extent that weak and acutest angles are knocked off and the stones come into close proximity when laid. “Bushings” shall not project more than 1½ inches in faces which have to be pointed and § inch in faces which have to be plastered.

Each stone shall be laid on its quarry bed and will be wedged or pinned into position in the wall by spalls or chis, which may show on the face.

(22)
Chap. 3.]  

(3) **Through Stones**—One through stone shall be built into every five square feet of the face. Such stones shall be at least half a square foot in area at face and shall run through the wall if the wall is not more than two feet thick. For walls thicker than two feet, a line of through stones shall be laid from face to back and the stones shall overlap by at least 6 inches.

(4) **Hearting**—The hearting or filling between the exterior and interior face work shall consist of rubble stones, not less than 6 inches in any direction carefully laid and hammered into place with a wooden mallet. These stones shall be well embedded in mortar and ships and spalls of stone shall be used, wherever necessary to avoid thick beds or joins of mortar, care being taken that no dry work or hollow spaces are left anywhere in the masonry. Hearting shall be laid nearly level with each course, except that at about 3 feet intervals vertical "plums" projecting 6 to 9 inches shall be firmly embedded to form a bond between successive courses. Hearting must not be brought to the same level as the front and back stones by the use of chips, their use being restricted to wedges in the hearting. The work, however, should to truly levelled up at every 2 feet height.

(5) **Quoins**—Quoins at corners of buildings and angles at entrances of doors, windows, archways, etc., shall conform to para 6 of Specification No. 3.15.

3.17. (1) **General**.—Dry rubble masonry, or dry stone masonry, shall be used in constructing low dry rubble masonry retaining walls, revetment walls, parapets and breast walls. The largest rubble stones procurable shall be used in such construction, the larger stones being used in lower courses. Coping in the form of top two or three courses in lime or cement mortar shall be used when specified.

(2) **Beds, batter, filling, etc.**.—Dry stone walling should not have a better steeper than 1 in 12 and unless, otherwise specified, the batter shall be 1 in 4. The base as well as all the courses should be at right angles to the face.

The stones shall be roughly dressed to secure maximum bedding surface without unduly reducing size of the stone.
Each course shall run through the entire thickness of wall. Filling immediately behind dry stone walls should, wherever possible, consist of stone refuse, chips or coarse gravel. Clayey and silty soils should not be used where stone refuse or gravel is available.

(3) Bond stones, joints, etc.—Through bond stones shall be provided in each course at intervals of 5 feet. Bond stones should be of the full height of the course in which they are used, at least as broad, and of the maximum length procurable. No bond stone shall be less than 2 feet in length. When the length of a bond stone is less than the thickness of the wall, two or more bond stones shall be used with an overlap of at least 6 inches. All bond stones shall be separately stacked before use, and marked so that they can be identified after having been built into the wall.

Face stones shall be laid headers and stretchers alternately, so as to break joint by at least 3 inches. Care should be taken to break joint vertically and long vertical joints should always be avoided.

(4) Weep holes.—Weep holes shall be provided in dry stone walling when built against earth or hill slopes subject to saturation by surface or ground water flow. Weep holes shall be backed by course gravel and important walls by a graded filter composed of coarse sand and gravel.

(5) High walls.—Dry stone walls higher than 20 feet should be strengthened by laying three consecutive courses of coursed rubble masonry in lime or cement mortar at 10 feet high intervals.

3.18. (1) Stones.—Boulder masonry shall consist of natural untrimmed boulders, selected for soundness and as flat and rectangular in shape as possible. The stones shall be laid in mortar or dry, as specified.

(2) Uses.—Boulder masonry may be used for ghat revetments, slope pitching, boundary walls, or for structures of a temporary nature and where the walls are not subjected to any significant lateral or vertical loads.
(3) Laying:—For all kinds of walling in boulder masonry, the first or base course shall be made up of stones specially selected for flatness on one side and the interstices carefully wedged up by packing with pieces and spalls.

Face stones shall be laid in more or less regular course and the vertical joints shall be broken from course to course. Every stone shall be laid flatwise, not on edges, and in close contact with its neighbours. No projecting stones should be allowed.

(4) Backing.—The backing behind facework, or between exterior and interior faces shall be composed of boulders, spalls and pieces, well packed and wedged, and shall be laid dry or in mud mortar as specified. The backing shall be brought up with the facework, though not necessarily in courses.

219. (1) Stones.—Scabbled boulder masonry shall consist of natural boulders, selected for soundness and as flat and rectangular in shape as possible. The face of the boulders shall be hammer-dressed to a roughly rectangular shape and for a depth of 3 inches from the face Boulders for the interior of the masonry shall be untrimmed and undressed.

(2) Uses.—Scabbled boulder masonry may be used for low retaining walls of a temporary nature, for temporary one-storey houses, ghat revetments, slope-protection, etc.

(3) Laying.—Face stones shall be laid in regular courses, with lime or cement mortar applied to dressed beds and joints near the face for 3 inches. Rest of the beds and joints as well as the backing shall be laid in mud mortar. Face stones shall be laid in such a way that all vertical joints are broken from one course to another.

(4) Backing.—Backing shall consist of boulders laid in mud mortar and well set in place by wedging with chips and spalls. No hollow spaces should be left in the backing or between interior surface and the facework. The
3.20— MANUAL OF IRRIGATION PRACTICE [Chap. 3.

backing should be brought up with the facework, though not necessarily in courses.

(5) **Weep holes.**—Weep holes shall be provided in retaining walls built of scabbled boulder masonry. The weep holes shall be made of stones laid in lime or cement mortar and shall run through the entire thickness of the wall. Weep holes shall be backed by clean gravel, and for important retaining walls graded filter composed of coarse sand and gravel shall be provided behind weep holes.

3.20. (1) **General.**—Stone masonry in arches shall follow the general specifications No. 3.8, 3.10 and 3.11, and in addition the detailed specifications of the class of masonry specified in design for the archwork. Usually ashlars and rubble masonry will be specified for archwork.

2. **Shape and size of stones:**—All stones required for archwork shall be cut to a zinc sheet template prepared from a full-size elevation of the arch drawn on lime or cement plaster. The voussoir sides shall be normal to the tangent to the curve of the arch at each point. Unless otherwise specified in design, the intradosal and extradosal surfaces of the arch shall be parallel to each other, and exact conformity between the design and actual thickness of arch ring shall be necessary.

Unless otherwise specified, the height of each stone shall be of the full thickness of arch up to 15 inches thickness and for a greater thickness, two stones may be used provided no stone is less than 6 inches in height. The intrados of all stones shall be rectangular rhomboid in skew arches), no side being less than 4 inches.

3. **Dressing for ashlars archwork.**—Radial voissor joints shall be fine-tooled to exact fit on all beds and the keystones and the keying course, if any, shall be accurately fitted and driven into its place with heavy wooden beaters. The soffit shall be dressed to the true curve of the arch and the upper surface of the stones shall be dressed to the true curve of the extrados.
(4) **Dressing for rubble archwork.**—All stones for rubble archwork shall be hammer-dressed approximately to the proper shape, with the necessary summering, so that the arch stones may bear freely one upon another for the full thickness of the arch ring. In case parts of the backs of the stones be open, they shall be solidly wedged up with spalls and chips of stones set in mortar. The soffit shall be dressed to a plane surface, true at all points to the curve of the arch.

(5) **Erection.**—All the finished stones required for an arch should be assembled in order and the arch erected dry on the ground before commencement of the archwork masonry. No voussoir should be cut or dressed after it is once laid in mortar in its designated place. The thickness of the joints shall be as specified for the type of masonry being used for the arch.

In all other respects regarding centring and erection, stone masonry archwork shall conform to Specification No. 3.5 for brick archwork.

(6) **Through stones.**—In the case of arches in walls, the two springers and the keystone shall be through stones, as also every third stone in between. Unless otherwise specified all stones for archwork shall be through stones in the case of ashlar walls less than 30 inches thick.

(7) **Breaking joints.**—All stones must break joints with each other and no stone should overise a circumferential joint, and be less than half the width of the extrados.

(8) **Other aspects.**—In all other respects not covered by the above specifications, stone masonry archwork shall follow Specification No. 3.5 for brick archwork.

3.31. (1) **General.**—All stone copings, string courses, cornices, drip courses, chajjas, pillars: Stone copings, corbels, brackets, and similar work shall be shaped, moulded or chamfered as shown in the drawings. These shall be made from stone of uniform colour and texture and of the kind specified for each detail.
(2) Dressing, size, etc.:—Unless otherwise specified
the exposed faces of stones shall be three-line or fine-
chisel dressed. All visible angles and details shall be
free from chipping.

For copings, stones shall be the longest as easily
obtainable, the minimum length being 18 inches, and the
height of stones shall be that of the coping. In cornices
and string courses which do not extend right through the
wall every stone shall tail into the wall by at least as much
as the projection beyond the face of the wall, and in no
case shall it tail less than 6 inches. Unless otherwise
specified, coping stones shall extend for the entire depth
of the coping.

Chajjas for isolated windows should consist of a
single stone slab. In continuous chajjas all joints in the
stones shall come over the brackets supporting the chajja.

(3) Thrashing and douels:—All outside cornices, cor-
bels, copings, and other such projecting courses shall be
weathered on top and thossed on the underside.

Wherever ordered or specified, coping stones and
other similar work should be cramped or dowelled and
otherwise joggled to each other.

(4) Mortar and joints:—Coping and chajjas shall
always be laid in standard 1:3 cement mortar. Cornices,
string courses, corbels, pillars and columns shall be laid
in line mortar, and in case the rest of the masonry is
in cement mortar, these shall also be laid in similar cement
mortar.

3.22. (1) Definitions:—The terms “artificial stone”
artificial stone or “cast stone” shall be understood to
mean a solid building stone manufactured
from portland cement and suitable aggre-
gates, precast and set in place as trim, or facing on, or in
buildings and other structures.

The terms “precast concrete blocks” or “concrete
blocks” shall be employed to indicate, hollow or solid,
precast masonry wall units manufactured from portland
Chap. 3] STONE MASONRY — 3.22

Cement and suitable aggregates such as sand, gravel, crushed stone, bituminous or anthracite cinders, burned clay or shale, and blast-furnace slag. The term “cast stone” is more general in scope and includes solid concrete blocks.

(2) General:—When providing cast stone for building purposes, the desired colour, shade, surface texture and finish shall be clearly indicated. The size and shape of cast stone units and precast blocks shall also be specified.

(3) Sizes of blocks:—Precast concrete blocks may be solid, or hollow with one, two or more cavities and of a size suitable for a specific kind of construction.

Sizes of hollow blocks commonly used in India are the following:

(a) Standard block: 18” × 9” × 6” and 15½” × 9½” × 8”.

(b) Building wall block: 11½” × 7½” × 5”.

(c) Hollow partition block: 12” to 18” × 7” to 11½” × 3” to 6”.

(4) Manufacture:—Cast stone or precast blocks are usually manufactured by block-making machines of various capacities. Cast stone or precast blocks manufactured by any process or machinery shall be acceptable provided they satisfy all the specifications regarding materials, sizes, physical properties, etc.

(5) Physical requirements of cast stone:—All cast stone shall fulfill the following requisites:

(a) All aggregate used in the manufacture of cast stone shall be of an approved and durable quality.

(b) The average water absorption of cast stone when delivered to the building site shall be not more than 6 per cent by dry weight of the specimens when tested as 2” × 2” cubes and submerged in water at a temperature between 60°F and 86°F for 48 hours.

(29)
(c) The minimum compressive strength of cast stone when delivered to the building site shall be 5,000 pounds per square inch when tested as 2" × 2" cubes or 2" × 3" cylinders in a standard compression testing machine.

(6) Physical requirements of precast concrete blocks. A precast concrete block for building purposes should satisfy the following general requirements:

(a) It should bond with standard sizes of bricks, and preferably the length, height and breadth should be suitable multiples of bricks plus joint dimensions.

(b) It should be light enough to be lifted and laid by one man.

(c) It should be cored to reduce weight and impede moisture penetration and provide a certain degree of insulation against heat.

(d) The design of joints should allow of a break in the capillary moisture path at these points.

(e) If the block is to be used for facing, it should have suitable texture and colour, or if intended for backings it should provide a good key for rendering.

Hollow and solid load-bearing precast concrete blocks shall conform to the following physical requirements:

(f) Hollow blocks for use in exterior walls below ground level, and for unprotected exterior walls above plinth level, shall have a minimum compressive strength of 1,000 pounds per square inch over average gross area, taken as an average for five full-size air-dry blocks tested in a standard compression testing machine. The minimum compressive strength of an individual block shall be 800 pounds per square inch or more, over average gross area.

(g) Hollow blocks for use above plinth level where they are protected from the weather with two
(h) Hollow blocks mentioned in items (f) and (g) shall have a minimum face thickness of 11 inches.

(i) Solid precast concrete blocks for use below plinth level and for un-protected exterior walls above plinth level, shall have a minimum compressive strength of 1,800 pounds per square inch over average gross area, taken as an average for five full-size air-dry blocks tested in a standard compression testing machine, and the minimum compressive strength of an individual block shall be 1,000 pounds per square inch or more.

(j) Solid blocks for use above plinth level where they are protected from the weather with cement paint or plaster, shall have a minimum compressive strength of 1,200 pounds per square inch over average gross area taken as an average of five units and for an individual block it shall be 1,000 pounds per square inch, when tested in a standard compression testing machine.

(k) Water absorption for all load-bearing blocks shall not be more than 15 pounds per cubic foot of net volume of block taken as an average for five units when the blocks are submerged in water at 60°F to 80°F temperature for 24 hours. The absorption in pounds per cubic foot shall be computed as:

\[ \text{(wet weight-dry weight)} \times 62.4 \]

(wet weight-suspended wt. immersed)

(1) The compressive strength of non-load-bearing cured hollow concrete blocks shall not be
less than 300 pounds per square inch over average gross area when tested in a standard compression testing machine.

(7) Cinders—Cinders used for precast blocks shall conform to specification No. 1.13. The combustible content present in cinder aggregate shall not exceed 35 percent by weight of the aggregate.

(8) Transport and stacking.—Cast stone and precast blocks shall be transported with the greatest care to prevent breakage. These shall be properly stacked near the building site in a manner suitable for checking and carriage during construction.

(8) Precast block masonry.—For building walls precast blocks are generally laid as stretchers where the width of a block is equal to the thickness of the wall. Blocks shall break joint by half their length and for corners, jambs, etc., the details shall be specified in the design.

All blocks shall be laid in standard lime or cement mortar and no joint shall be thicker than ½ inch. Regarding pointing, striking joints, plastering, scaffolding, weather protection, etc., precast block masonry shall follow the general requirements laid out for pucca brickwork in specification No. 3.1, or particular specifications ordered by the Executive Engineer.

The faces of blocks should be as rough as possible to facilitate proper bond with adjoining blocks.

Precast blocks for arch work shall be specially moulded, and shall conform to additional specification to be specially issued for the purchase.
CHAPTER IV

4.1. (1) Foundation excavation—Building foundation trenches shall be excavated to the exact width of the widest part of the foundations and to the depth shown on the drawings. The sides of the trenches shall be left plumb where the nature of soil permits it, but they must be sloped back or shored up carefully where the soil depicts a tendency to fall in.

Excavated material shall not be placed nearer than 2 feet from the outer edges of excavation. The base of the foundation trenches shall be dressed level in directions, and on completion, shall be slightly watered and well rammed and compacted.

The minimum depth of foundations below the ground level shall be as follows:

<table>
<thead>
<tr>
<th>Building Type</th>
<th>Minimum Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single storey buildings</td>
<td>1.5 feet</td>
</tr>
<tr>
<td>Double storey buildings</td>
<td>2.5 feet</td>
</tr>
<tr>
<td>Compound walls</td>
<td>1.0 feet</td>
</tr>
</tbody>
</table>

No concrete or masonry shall be placed in the foundations without the sanction and approval of the engineer-in-charge. The engineer-in-charge shall satisfy himself regarding the completion of foundation trenches before permitting placement of concrete.

(2) Rate of foundation excavation—Unless otherwise specified the rate of foundation excavation shall cover the following:

(a) Lifting and removal of excavated material up to a combined lead of 50 feet.

(b) Provision of drains through the spoil banks as may be required, to prevent water accumulating around foundation trenches in the event of rain.
3. Foundation concrete—Unless otherwise specified, concrete for wall and column footings of low buildings shall be ordinary lime concrete or 1:6:12 cement concrete. The quality of this concrete and the methods of placing and consolidation shall conform to Specification No. 2.1, and 2.3 and the thickness of compacted concrete layer shall be as shown on the drawings. Unless otherwise specified or indicated on drawings the depth and width of concrete in building foundations shall be as given below:

(a) Depth of concrete:

<table>
<thead>
<tr>
<th>Type of Structure</th>
<th>Depth (Feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single storey building</td>
<td>1.0</td>
</tr>
<tr>
<td>Double storey building</td>
<td>1.5</td>
</tr>
<tr>
<td>Compound wall</td>
<td>2.5</td>
</tr>
</tbody>
</table>

(b) Width of concrete:

<table>
<thead>
<tr>
<th>Wall Thickness</th>
<th>Width (Feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9&quot; walls</td>
<td>1.50</td>
</tr>
<tr>
<td>134&quot; walls</td>
<td>2.50</td>
</tr>
<tr>
<td>18&quot; walls</td>
<td>3.00</td>
</tr>
</tbody>
</table>

4. Brickwork footings—Unless field bearing tests are carried out or other soil bearing pressures are specified, safe load on Punjab soils shall be taken as follows for building foundations:

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Load (tons/square feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silt, silty and fine sandy soils</td>
<td>0.75</td>
</tr>
<tr>
<td>Firm clays and compacted clayey soils</td>
<td>1.50</td>
</tr>
<tr>
<td>Compact coarse sand and gravel and hardpan</td>
<td>2.50</td>
</tr>
<tr>
<td>Rock, conglomerate</td>
<td>3.00</td>
</tr>
</tbody>
</table>

The loads shall be uniformly distributed over the foundation, and for this purpose the brickwork or concrete
4.3—MANUAL OF IRRIGATION PRACTICE  [Chap. 4.

The damp-proof course shall be laid flush with the floor surface, and shall not be carried across door ways, verandah arches, and similar openings. The upper layer of cement concrete in the floor shall, however, be continued over such openings and shall be laid at the same time as the floor.

(4) Concrete:—Unless otherwise specified, cement concrete for damp-proof course shall be of 1:2:4 mix, or of the same composition as specified for cement conglomerate floors. The period of curing may be reduced to five days, under favourable weather conditions.

(5) Bitumen coat:—The concrete shall be allowed to dry for one day after curing and then one coat of hot bitumen, asphalt, or coal tar shall be applied over the concrete surface. The asphalt shall conform to Specification No. 1.21, and in absence of any other specifications, twenty pounds of asphalt or bitumen shall be used to cover 100 square feet of concrete surface. The layer of bitumen or asphalt shall be sanded immediately after its application.

All stains or marks of asphalt or bitumen shall be removed from the face of brickwork.

4.3 (1) Filling under the floor.—Filling under the conglomerate flooring shall consist of compacted earthfill placed above the ground level and stopped at such a height as to allow a six-inch thick layer of sand below the floor base. Only clean dry sand shall be used for this layer.

(2) Floor base:—Unless otherwise specified, all floors shall be laid on a 4-inch thick layer of ordinary lime concrete or 1:6:12 cement concrete, placed over the sand layer. The concrete base shall be laid in one operation, uniformly, and absolutely true and parallel to what is required on the finished surface. The base concrete shall be mixed, placed, and compacted as detailed in Specification No. 2.1 or 2.3, whichever is applicable.

(4)
footings shall gradually taper out from wall or column thickness to foundation width. The footings shall be stepped or sloping as shown on the drawings. Generally, the course laid immediately upon the concrete should be twice the width of the wall. Care should be taken that the bricks in footings should be laid as far as possible as structures, but if headers are required in any course they should be laid near the centre of the footing.

Brickwork in footings shall conform to Specification No. 3.1 or 3.2 depending upon which type of brickwork is specified:

4.2 (1) Location—Damp-proof course shall be pro-
damp-proof course, laid at the level of the ground floor of the building. Brickwork or masonry shall be stopped at the requisite height below this level. In other words, damp-proof course shall be laid immediately above the plinth masonry and just before the super-
structure starts.

(2) Plinth—Unless otherwise specified, plinth shall be built in burnt brickwork with 1 : 7 cement mortar with lime cream. Top course of plinth shall consist of brick on edge. Height of plinth above ground level shall be as shown on the drawings, or 1 feet 4½ inches.

The damp-proof course shall not be laid until the levels of the plinth and the brickwork have been checked by the engineer-in-charge.

(3) Thickness, width, and length:—Unless otherwise specified, the damp-proof course shall consist of a 1½" thick layer of cement concrete. In important buildings and for high or moderate rainfall areas a 3 inch thick concrete damp-proof course may be specified.

Damp-proof course shall cover the full width of the superstructure walls, except in the case of outer walls, where it shall be continued up to the outside face of the plinth. Offsets in the wall at plinth level, if necessary, should be given immediately below the damp-proof course.
spreading. All ramming shall be completed within 15
minutes of addition of water to cement.

(5) Finishing.—Surface finishing operations shall be
completed within fifteen minutes of the conclusion of con-
solidation. The fines brought to surface by ramming
shall be quickly and evenly smoothed with a steel trowel.
The surface during finishing, shall be frequently tested
with a straight-edge and spirit level, and when finished,
shall present an absolutely true and smooth surface show-
ing no undulations or tool marks.

After 24 hours, the screeds shall be removed and strips
of paper placed against the exposed side and folded over
the finished surface before concrete is placed in the ad-
joining panel. Alternate panels shall be laid on alternate
days wherever possible.

(6) Curing.—Concrete in floors shall not be disturbed
for 24 hours after laying. For a minimum period of 15
days after removal of screeds the panels shall be suitably
protected from direct sun and damage, and shall be cured
as directed in Specification No. 2.3.

4.4 (1) Floor base.—The floor shall be laid on a con-
crete base and filling as detailed in Speci-
fication No. 4.3.

(2) Materials:—This type of floor shall consist of a
surface pavement of either brick or tiles, laid flat or on
edge, with the joints finished or pointed as specified. Bricks
or tiles shall be of a class complying with the requirements
of first class bricks in quality, and shall be selected for
smooth face, good colour and hardness.

(3) Floor construction.—The bricks or tiles shall be
laid in a plain, diagonal, herring-bone or any other pattern
as may be ordered. When laid in plain courses it shall
be bonded so as to break joints at half the length of the
brick or tile. Bricks shall be laid with bed and vertical
joints quite full of mortar. Simple "sipping" at the edges
shall not be permitted.
(3) Dimensions.—Concrete flooring laid over the concrete base shall consist of a pavement of 1-inch, 1½-inch, or 2-inch thick cement concrete. Unless otherwise directed, these thicknesses of conglomerate flooring shall be used for the following purposes:—

(a) 1-inch thick floors shall be used where heavy wear is not expected, such as in offices and residences.

(b) 2-inch thick floors shall be provided for schools, factories, etc.

(c) 1½-inch thick flooring shall be provided in all buildings where wear is expected to be medium as compared to the preceding two cases.

The upper layer of concrete flooring shall be laid in panels of an area not greater than 25 square feet, nor with a dimension exceeding 6 feet. The floor shall be divided into panels by wooden or iron screeds such that, when secured in position, the tops of the screeds shall mark the exact level of the finished floor surface. The layout of the panels shall be subject to the approval of the engineer-in-charge.

(4) Placing surface concrete.—Concrete for the upper layer shall not be of a mixer leaner than 1:2:4, and shall conform to Specification No. 2.3 for ordinary cement concrete.

Conglomerate paving shall not be laid before the floor base has set for at least seven days. The surface of the concrete base shall be kept wet, and shall be clean and free from dust prior to the placement of the top layer.

Concrete needed for one panel shall be mixed in one lot and shall be laid directly off the mixing board. The concrete shall have a stiff a consistency as practicable and the slump shall not exceed 1½ inch. The concrete should be leveled with a trowel and straight-edge and evenly spread within 5 minutes of water being added to the cement.

Concrete shall be consolidated with hand tampers or "thepies" for a period of 5 to 10 minutes after placing and
4.6—Unless otherwise specified, the bricks shall be laid dry on edge, on half inch thick mud plaster prepared to the slope, and camber referred to above. The joints shall be as fine as possible, never exceeding $\frac{1}{4}$ inch in thickness, and shall be laid in proper straight lines longitudinally or patterned, as ordered, in uniform parallel courses. After the laying has been completed and approved the joints shall be filled with sand. The bricks should be laid to a smooth flush surface without unevenness at the joints or the edges, and when required shall be chamfered to meet kerbs or drains.

4.6. (1) Polishing—Where a highly finished surface of conglomerate floors is required, polishing, as herein described may be specified by the Executive Engineer. Polishing should be carried out nearly three months after the floor is laid.

The surface should be first rubbed down with a medium grain carborundum block till all trowel marks, scratches, etc., are removed. Rubbing with a finer grade of carborundum stone should follow, and finally the surface should be smoothened with a fine hard-grain polishing stone.

The final polish shall be applied with a mixture of one part bees-wax and three parts turpentine. It shall be well rubbed into the surface and all surplus material should be removed.

Polishing with an electric polishing machine shall be preferred instead of rubbing by hand.

(2) Coloured cement finishes—Where coloured cement floor finishes, such as, white, red, or black, are specified, any method described in a standard text book shall be adopted, subject to the Executive Engineer’s approval. The surface shall be finished and polished in a manner described in the preceding paragraph.

(3) Terrazo finish—Terrazo finish shall be made by mixing one cubic foot of crushed marble or other stone chips as directed, 1.4 cwt. of cement, and 4 cubic feet
The brick or tile paving shall be sloped or cambered as indicated on the drawings or as ordered. Frequent tests shall be made by means of a straight edge at least six feet long to check the slope of the surface.

Prior to laying, bricks or tiles shall be soaked in water for at least one hour as given in Specification No. 3.1. No damaged bricks or tiles shall be used, and brick bats shall not be used except to close any line of bricks.

(4) **Joints and pointing**—All joints shall be uniform, true, parallel and square, bricks being rubbed to facilitate this, if necessary. The joints shall not exceed 3/32 of an inch in thickness where the floor is to be finished in lime mortar. The mortar in the joints shall be struck off flush with a trowel, and no pointing, shall be necessary. The mortar shall not be allowed to spread over the edge of bricks or tiles.

Where cement pointing has been specified, the joints shall not be less than 1/4 of an inch in thickness. The joints shall be flush pointed, after being tacked out to a depth of one inch while the mortar is still soft, and immediately filled with 1:3 cement sand mortar.

(5) **Provision and curing**—During construction the paving shall be protected from direct sun, frost, rain, and large variations in temperature and humidity. It shall be kept wet for seven days after completion. If the floor has been cement pointed, it shall be continuously kept moist for at least 15 days after the pointing had been done.

4-5. (1) **Bricks**—The bricks shall be first class and dry brick paving, shall conform to requirements of quality laid out in Specification No. 1.4. The bricks shall be selected for smooth face, good and uniform colour, and hardness.

(2) **Pavement laying**—Prior to laying the bricks, the ground surface shall be thoroughly watered, well rammed and compacted, and sloped and cambered, if; and as required.
of sand, and just sufficient water to produce a dense concrete. The crushed marble or stone chips shall all pass a U.S. standard 3/4-inch sieve, and shall be free from dust.

This surface concrete shall be spread on the base course and worked down to a thickness of 1-inch by patting, rolling, and trowelling. The surface shall be kept wet for not less than 15 days, and after curing shall be rubbed and polished to a smooth surface, as specified in paragraph (1).

The colour scheme, pattern, and arrangements of terrazo floors shall be as shown on the drawings or as ordered by the Executive Engineer.

4.7. (1) Materials.—Only first class bricks, conforming to pertinent requirements of Specification No. 1.4 shall be used. For works involving more than 10,000 square feet of jack arch roofing, if specified, all bricks shall be specially moulded for the spring course and for the voussoirs.

The brickwork as a whole shall for general purposes comply with Specification No. 3.1 for first class pucca brickwork and Specification No. 3.7 for brick archwork.

The size and quality of rolled steel joists, tie-bars, angle-irons, etc., shall be either as shown on the drawings, or as approved by the Executive Engineer.

(2) Types and shape of arches.—Jack arches may be sprung from the bottom or top flange of beams. Unless otherwise specified, all jack arches shall be sprung from the bottom flange of beams.

Jack arches with a span of 4 to 6 feet shall generally be specified. Unless otherwise ordered, all arches shall be true segments of a circle having a rise equal to one-eighth of the span.

(3) Centring.—Centring shall be of sufficient stiffness to retain its correct curved shape during arch construction. The top of the centring shall be surfaced with good clay
plaster, and the courses of bricks shall be marked on it. The curvature shall be checked with standard concave templates, both before and after laying the bricks.

The centring shall either be supported, on kutcha brickwork pillars built up from the ground, or it shall be suspended from the bottom flanges of the rolled steel joists. Whatever method is adopted for holding the centring in place, it shall be subject to the approval of the Engineer-in-charge. No part of the centring shall be attached to, nor the weight of centring come in any way, on tie-rods.

(4) Tie-rods and anchors.—The end arch of a series of jack arches, springing from an unsupported outer wall, and also the larger of two unequal spans springing from a common beam, shall be supported by a 3" x 3" x 3/8" angle iron embedded in the wall immediately behind the springing of the arch, and tied to the first joist by tie-rods. Tie-rods shall be perfectly straight and evenly spaced not more than 6 feet apart. Tie-rods shall be 5/8 inch in diameter for spans up to 5 feet, and 3/4" diameter for spans between 5 and 6 feet.

(5) Laying archwork.—Prior to commencement of brickwork for the arches, the beams and all other ironwork shall be given two coats of paint as detailed in Specification No. 4.33 for painting ironwork.

Bricks for the springing course shall be specially moulded so as to fit against the joist and at the same time give a truly radiating skewback joint. The rest of the arch shall then be built with the bed faces (9" x 4") of the bricks normal to the arch thrust, with all joints radiating truly from the centre and nowhere exceeding 3/16th of an inch in thickness. The archwork courses shall be straight and parallel to the joists, bond being maintained by bricks in each course breaking joint with those in the next course by at least 3 inches.

In the absence of any particular specifications, brickwork for the arches shall be laid in 1:5 cement mortar, except for the first two courses adjoining the joists which shall be laid in 1:3 cement mortar.
To prevent lateral displacement of the beams under the thrust of the arch, at least three complete lines of centering shall always be in use, so that each arch under construction shall have the two preceding ones still supported, till the whole roof is finished.

(6) Filling arch, haunches, etc. — After completion of the archwork, the upper exposed portion of the beam shall be encased in 1:2:4 cement concrete with 1-inch maximum size aggregate, so as to give a minimum thickness of 1 inch over and beyond the flange.

The haunches of the arch shall then be filled, and the arches covered with fine lime concrete conforming to Specification No. 22, or with 1:4:8 cement concrete. The concrete shall be rammed and finished so as to give a minimum thickness of 1 1/2 inch over the crown of the arch, or joist casing, whichever is higher. Where specified, the main slope shall be given in the lime concrete covering. The roof shall finally be covered with 3 inches of mud and finished with read plaster, or as ordered by the Executive Engineer.

When jack arching is intended to carry the flooring of the superstructure, no mud shall be laid on the lime concrete. Instead the flooring shall be placed on the lime concrete as a base.

(7) Finishing soffits. — Where a ceiling is to be provided arch soffits shall be flush pointed to fill any empty joints. Everywhere else also the soffits shall be finished with a specified plaster.

The lower exposed flange of the joist shall generally be painted. Where it has to be covered with plaster, half-inch mesh wire netting, not lighter than 20 gauge, shall be wound round it to facilitate bond with the plaster. The netting shall be clipped on with hoop iron and will be kept away from the flange by pieces of wood, so as to afford a key to the plaster.

The plastered soffit surface shall be white washed or painted as directed by the Executive Engineer.
4.8—MANUAL OF IRRIGATION PRACTICE [Chap. 4.

4.8. (1) Tiles.—Tiles used for roofing shall be of Allahabad or Mangalore types of an approved manufacture. The tiles selected shall be well and uniformly burnt, close-grained, homogeneous, without segregated humps of clay, and free from cracks and imperfections. Tiles shall be a dark-red colour, and should give a clear ringing, sound when struck. A dry tile shall not absorb more than one-sixth of its weight of water when immersed for one hour.

(2) Laying Allahabad tile roofing:—

(a) Laying.—Tiling shall be laid, single or double, as shown on the drawings. Single tiling shall consist of layer of flat tiles laid on battens. The side joint of every two adjacent flat tiles shall be covered with a semi-cylindrical tile. In double tiling, the joints of every two adjacent flat tiles of the first layer shall be covered by semi-hexagonal tiles. Over these another layer of flat tiles shall be laid, the adjacent edges of the latter being covered with a semi-cylindrical tile.

The moulded niche at the lower end of each flat tile should fit completely into the head of the tile next below it, and the buttons at the upper end must have a firm hold on the battens placed at 12-inch intervals to receive the tiles. Each semi-cylindrical or semi-hexagonal tile must fit exactly in its position, both on the flat tiles under it, and also into the bed specially formed in the upper part of the next semi-cylindrical or semi-hexagonal tile to receive it.

The lower edges of the semi-cylindrical, and in the case of double tiling the semi-hexagonal, tiles must fit the flat tiles below. The semi-hexagonal tiles, when used, must present a uniformly flat surface to the flat tiles to be laid over them. In double tiling, the lower buttons on the second layer of flat tiles must fit the lugs moulded on the sides of the semi-hexagonal tiles.

A steel wood-rasp may be used to make the tiles fit closely together but no tile must be rasped so as to render it thin or weak.

(12)
(b) **Work in mortar.**—The three lowest tiles in each course of each layer, as well as all ridge and hip tiles, shall be set in mortar. Unless special eave tiles with closed ends are used, the ends of each row of semi-cylindrical and semi-hexagonal tiles shall be stopped with mortar. In case of double tiling, the space at the eaves between the two layers of flat tiles shall also be filled with mortar. No mortar shall be used on any other part of the roof. Tiles in contact with mortar shall be immersed in water for 2 hours before laying, and the mortar joints shall be kept moist for at least 7 days after the tiles are laid.

(c) **Ridges, hips and valleys.**—Ridges, hip and valley tiles shall be specially manufactured for their respective positions, and shall be approved by the Executive Engineer, before they are used.

(d) **Finish.**—Any roof with Allahabad tiling shall not be pitched at a slope of less than 1 in 3 or more than 1 in 2. The roof when completed, must present a uniform appearance, all lines of tiles being straight in both directions. This shall be checked by observing the straightness of the diagonal lines made by the ends of the semi-cylindrical tiles.

(3) **Laying Mangalore tile roofing:**

(a) **Battens and rafters.**—The eaves batten or reaper shall be fixed ten inches from the one immediately above the slope, and shall be of one inch extra depth to ensure an even slope in the tilting from eaves to ridge. The remaining battens on rafters shall be spaced 12 inches centre to centre to suit the tiles. Battens shall not be spaced and fixed until the tiles have been received and the spacing verified.

The distance between centre to centre of rafters shall not be more than 2 feet unless otherwise specified. The size of the rafters and battens shall be as shown on the drawings, and the quality of the timber shall be subject to the Executive Engineer's approval. The under-faces of battens shall be planed smooth before fixing. No joints between the battens shall come except over the rafters, and the joints of no two adjacent rows of battens shall come over the same rafter.

(13)
(b) Laying.—The tiles shall be laid fair and square, from the eaves towards the ridge. The tiles shall break joint, that is, the left channel of the upper tile must lie in the right of that below. Tiles must fit properly one on to another, the catches resting fully on the battens.

In exposed situations, and at all gable ends, eaves, and places where the tiles are not readily accessible, they shall be secured to the battens by No. 18 gauge, galvanized, soft iron wire, passed through the holes provided for the purpose in the underside of the tiles.

(c) Ridges, valleys, and hips:—Specially manufactured tiles shall be used for ridges, valleys, and hips. These special tiles and tiles at gable ends shall be laid in 1:3 cement mortar to which a little red ochre has been added to match the colour of the tiles. These tiles shall be soaked in water for four hours before laying and shall be kept wet for 7 days after they are laid.

(d) Finish.—A roof with Mangalore tiling shall not be pitched at a slope of less than 1 in 3 or steeper than 1 in 2. The roof when completed, shall present a uniform appearance all lines of tiles being straight and parallel in both directions.

4.9. (1) Corrugated Iron Sheets:—The roofing shall consist of standard galvanized corrugated iron sheets, No. 22 S.W.G. or of such other gauge as may be specified. The galvanizing coating shall be in perfect condition, undamaged in carriage either by rubbing or otherwise. The sheets shall have clean and bright surfaces, and shall be free from rust or white powdery deposit.

(2) Purlins. The roof covering shall be supported longitudinally on horizontal wood or iron purlins. The purlins shall be so spaced as to come under the ends of the sheets and also to give one or two lines of intermediate support. The roof trusses should be designed for purlin spacing to suit the standard lengths of sheets to avoid unnecessary cutting.
(3) Laying the sheets:—The sheet roofing shall be laid and finished strictly in accordance with drawings and specifications given herein.

The sheets shall be laid on the purlins to a true plane surface, with the lines of the corrugations truly parallel or normal to the sides of the area to be covered. Each sheet shall be laid with a lap of not less than 6 inches in length over the sheet below and the side laps shall extend over two corrugations, the laps being turned away from the usual direction of local heavy rains.

(4) Fixing and bolting:—Sheets shall be joined to each other with 1-inch diameter galvanized bolts and "limpet" patent dome washers. The sheets shall be joined to wooden purlins with screws, and to angle iron or I-iron purlins with hook bolts, limpet washers being used in each case.

The bolts shall be placed at one foot intervals along the edge of the length of the sheet, or at such distance approximately 12 inches, as will equally divide the sheets along their length. The bolts and screws shall always be placed along the ridges of corrugations. As the overlap exceeds two corrugations, these bolts shall be placed in a zig-zag manner, so that the end of each of the two overlapping sheets shall be drawn tightly one against the other.

The horizontal joints of the sheets shall also be joined together by means of bolts and limpet washers, the bolts being placed, normally, on each alternate corrugation ridge.

(5) Holes:—Holes for nails, screws, rivets, and other fastenings shall be made on the ground. The sheets shall be placed on trestles and the holes punched or drilled in such a manner that the arises of the punched holes will come on top when the sheet is laid. Holes of diameter greater than 3/8th of an inch, or in material greater than 3/16th of an inch thick, or when four sheets overlap at corners, the holes shall not be punched, but shall be drilled. All burrs left by punching or drilling shall be removed before assembling the roof covering.

(6) Wind tiles:—In buildings exposed to strong winds or storms, sheets shall be fastened down with wind tiles.
4.10—Manual of Irrigation Practice [Chap. 4.

Unless otherwise specified, wind ties, shall consist of continuous lengths of 1/2" x 3/8" flat iron bars fixed along the eaves of the roof. The wind ties shall be bolted down about every 5 feet by 1/2 inch diameter bolts built a foot into the wall and secured at the lower embedded end by a 3-inch square washer.

(7) Gables, parapets, etc.:—Corrugated iron sheets shall not be built into gables and parapets, but shall be bent up along the edge, and suitable flashing provided all along. If no flashing is provided, a projecting drip course shall not be built into gables and parapets, but shall be joint by at least 3 inches. Eave boards, gutter, and down pipes shall be provided where shown on the drawings.

4.10. (1) Sheets.—The asbestos cement corrugated sheets shall, in general, conform to B.S. Specification No. 690/36 for large section corrugated. Unless otherwise specified, the sheets shall be of 1/4-inch thickness and pitch of corrugations shall be 5 inches. Sheets shall be subjected to examination for soundness as given in the British Standard Specifications, before being fixed in place.

(2) Laying:—Sheets shall be laid in such a manner that the corrugations run in continuous straight lines, and the mitred corners of sheets shall be properly weathered by the overlapping corrugation of sheets. The sheets must have an end lap of at least 6 inches, and side lap of half to one corrugation according to manufacturer's recommendations.

The roof covering shall be supported longitudinally by wooden or iron purlins in the same manner as described in Specification No. 4.9 for corrugated iron sheets. Purlin spacing shall not exceed 4 feet 6 inches.

(3) Fixing of sheets:—All fixing accessories such as, hook bolts, crank bolts, or roofing screws, shall be galvanized, and unless otherwise specified of 5/16 inch diameter. Bolts and screws shall be fitted with bituminous washers and lead washers shall not be permitted.
4.11

In roofs where there is likely to be some movement of the structure due to variations in climatic conditions, expansion joints shall be used in association with the sheets to permit any such movement being taken up. The recommendations of the manufacturer's on this point shall be carefully followed.

(4) Holes.—All holes in the sheets shall be drilled and not punched. For 5/16-inch diameter bolts, the holes shall be full 7/16-inch diameter. All holes shall be drilled in the ridges of corrugations only.

(5) Ridges, valleys, etc.:—Ridges, valleys; hips; etc., shall strictly conform to the standards recommended by the manufacturers and approved by the Executive Engineer.

4.11. (1) Design and dimensions:—All reinforced concrete or brickwork slabs for roofing or brickwork roofing shall be built strictly according to the design drawings. The size, spacing, bending, hooking, overlapping, and location of reinforcing bars, and dimensions of the slabs shall conform to those shown on the drawings as approved by the Executive Engineer.

(2) Materials:—All bricks for reinforced brickwork shall be first class and shall conform to requirements of Specification No. 1.4. Cement concrete for roof slabs shall be of 1:2:4 volumetric mix, unless another mix or a minimum value for its 28-day compressive strength is specified. Cement concrete and reinforcing bars for both reinforced concrete and brickwork shall, in general, conform to Specification No. 2.4 for reinforced concrete.

(3) Slope of slab surface:—The roof slab itself shall be laid, wherever possible, at the surface slope given in the drawing, or specified by the Executive Engineer, in order to permit proper drainage of the roof. The forms for the roof slab and the beams of any, shall be so adjusted as to enable the desired slope to be given to the slab.
(4) **Forms:**—Forms for the roofing slab shall conform to the shape, lines and dimensions of the concrete as shown on the drawings. Joints in forms shall be either horizontal or vertical. Forms shall be supported or fixed by wedges or similar means to allow of the load being eased and the forms removed without shock to the work, and without any hammering knocking or prising.

In all other general aspects, the forms for the roof slab shall fulfill the pertinent and applicable requirements of Specifications No. 2.3 and 2.13.

(5) **Wall plates, joints etc.:**—Unless otherwise specified, roof slabs shall rest on 4⅛-inch thick, 1:2:4 cement wall plates, which shall be laid in situ on full width of the supporting wall. A vertical joint, ⅛-inch wide, shall be left at the simply-supported discontinuous ends of the roof slabs. This joint shall be filled with a mixture of hot asphalt and sand in equal proportions.

(6) **Placing the slabs:**—Concrete for reinforced concrete slabs shall be placed and compacted according to Specifications No. 2.3 and 2.16.

The bricks shall be soaked in water for two hours before placing. They shall be well saturated and all excess water shall be permitted to drain off before the bricks are laid in place. Concrete shall be placed around the reinforcement and between the bricks, and consolidated according the above-mentioned specifications. Spacing between the bricks enclosing the reinforcement bars shall not be less than 1½ inch.

(7) **Surface finish:**—Where the floor of the superstructure is to be laid on the roof slab, the top of the slab shall be thoroughly cleaned and wetted as soon as the setting period for the roof slab terminates. The flooring shall then be laid as specified.

Otherwise the slab shall be cured as detailed in Specification No. 2.3. After curing, unless otherwise directed, the slab shall then be covered with 3-inches of good compacted earth after giving two coats of hot asphalt or coal tar blinded with sand. If specified, the earth fill shall be covered with 12” × 6” × 2” pieces tiles in 1:4 cement mortar.
4.12. (1) Definition.—Unless otherwise specified, terrace roofing shall consist of one layer of tiles resting on battens and covered with a layer of compacted earth, and finally topped with a layer of stabilized soil containing cement.

(2) Materials:—The tiles for terrace roofing shall be 12" × 6" × 2", and shall comply with Specification No. 1.4 for first class bricks and tiles. If not otherwise specified, the tiles shall be laid in 1:4 cement mortar and plastered with 4-inch thick 1:2 cement mortar.

(3) Battens:—The battens shall be of wood or of reinforced concrete of the type and size specified, and shall have properly finished surfaces at the top, so as to give an even bearing to the tiles. The battens shall be equally spaced, 12 inches apart centre to centre, and shall be placed in straight and parallel lines. No battens shall be placed closer than 3 inches to a wall. The battens or beams shall be suitably sloped to provide the roof surface slope shown on the drawings or ordered by the Executive Engineer. If no other value is indicated, a slope of 1 in 100 shall be given to all terrace roofs.

(4) Compacted earth layer:—The tiling after it has been plastered with 1:2 cement mortar, shall be kept continuously wet for a period of seven days after completion of plastering. The plaster shall also be protected from the effect of direct sun and rain during this period. The plaster shall be permitted to dry for one day, after completion of curing, and the surface shall then be coated with two coats of asphalt and uniformly blinded with sand.

The roof shall then be covered with a 3-inch layer of good compacted earth. The top covering shall consist of a 1½ inch thick layer of stabilized soil containing 5 per cent cement. This soil cement layer shall be mixed, compacted and cured as directed by the Executive Engineer.

(5) Modifications in specifications:—These specifications may be modified by the Executive Engineer, according to the climatic conditions, rainfall and the nature of the building. The modifications shall be made in the mortar cement plaster, thickness of compacted earth layer, and the soil cement layer.

4.13 (1) Planks.—Where wooden plank ceiling is specified, the planks shall be of seasoned deodar wood of a uniform colour and conforming to the requirements of Specification No. 1.20. The planks shall be 1-inch thick and 5-inch wide, and provided with tongued and grooved joints. The planks shall be planed on the underside and square, headed, or bevelled at the edges as may be specified or shown on the relevant plans.

(2) Ceiling rafters.—Wooden ceiling rafters shall be of the size shown on the drawings, and shall be spaced 3 to 4 feet apart. The ceiling rafters shall be fixed to the bottom tie beams of trusses by angle cleats and bolts. The ceiling shall be screwed to the underside of these rafters.

(3) Joints.—As the planks may swell in damp weather to a small extent, they shall be so fixed that they do not bulge when swollen, thus damaging either themselves or the walls. Instead, they should have nest and close joints when swollen due to dampness. When dry the planks should not therefore, be forced tight against each other before being fixed. The planks shall be laid truly parallel or perpendicular to the walls and shall be fixed with 1/4-inch brass screws, two per five inch plank, at not more than four feet spacing, the screws breaking joint for alternate planks. The end joints between planks shall be butt-joints, unless otherwise specified, and shall come in the centre of the ceiling joists or battens.

(4) Finishing.—The plank ceiling shall be finished with a deodar wood moulding running all round the walls. The design of the moulding shall be as shown on the drawings, or as approved by the Executive Engineer. The planking and moulding shall receive two coats of sailgun on upper side and shall be finished with two coats of varnish on the exposed surfaces.

4.14. (1) Scope.—These specifications shall apply to plaster ceilings consisting of plaster applied over metal lathing. The metal lathing shall be attached to suitable ceiling rafters or furring bars. This

(20)
type of ceiling shall not be used in contact with roof supports where thorough ventilation cannot be provided from above, nor where it is impracticable to examine the ceiling from above.

(2) Lathing.—B.B. lathing No. 24 gauge or expanded metal 3/4 inch \times 3/4 inch mesh, shall be used for holding the plaster. The lathing shall be stretched taut and fixed length-wise across the furring bars. The lathing shall be nailed to the undersurface of furring bars with small wooden spacers in such a way as to leave a 3/8th inch space between the expanded metal and the wood to allow a key for the plaster. Two inch wire nails or lathing clips shall be used at intervals of not more than 6-inch for fixing the lathing.

The lathing shall overlap at least two meshes whenever they join, and at the overlap they shall be wired together at 4-inch intervals with 18 gauge galvanized soft iron wire.

(3) Ceiling rafters or furring bars.—Unless otherwise specified, the ceiling rafters or furring bars, shall be of deodor wood. These shall be of such a size and so hung, as to allow of being walked upon by resting a light plank on them. The surface of the raft that will come in contact with plaster shall not be planed, and the spacing of ceiling rafters shall not exceed 18 inches. In the end days, the ceiling rafters should be pinned not less than three inches into the wall.

(4) Preparation for plastering.—Before commencing to plaster, all wood work shall receive two coats of solignum or of an approved wood preservative. Lathing or expanded metal, and all other metal work shall be given two coats of red lead paint. Plastering should not be started until the flooring or roof has been finished overhead, or whilst there is the possibility of rain or water falling on the ceiling, or the danger of the plaster being shaken loose by the vibrations set up in consolidating concrete.

(5) Plaster applications.—The plaster shall be applied in two coats, the total thickness of which need not exceed half an inch. The first coat shall be the major coat, and

(21)
the second should only be a thin finishing coat. The second coat shall be applied within 15 minutes of the first coat, and it should be well bonded to the first one. Excessive pressure must be avoided in applying the plaster otherwise the lathing will yield to the trowel and cause the newly finished plaster to fall off.

Unless otherwise specified, the mortar used for the plaster shall be one 1:3 cement mortar. One-quarter pound of fine chopped hemp or jute shall be thoroughly mixed with each cubic foot of mortar for the first layer. The plaster should be mixed stiff, the water used for mixing being absolutely clean and free from saltpetre.

After completion, the plaster shall be kept damp for at least 15 days.

4.15. (1) Materials:—Stout dungry cloth, canvas, or cloth covering. White drill may be specified for cloth ceilings. For temporary and lower grade housing, a ceiling of gunny or hessian cloth may be ordered.

(2) Frame:—The light wooden frame required for supporting cloth ceiling shall be made of deodor wood or bamboo as may be approved, and it shall be made in accordance with the design drawing. The frame shall be satisfactorily spiked to the wall plates or to wooden blocks let into the masonry and firmly screwed to the underside of the beams.

(3) Fixing:—Where a deodor frame is to be used, the cloth will be nailed to the upper side of the frame-work, which will be planed and varnished. Where a bamboo frame is specified, the cloth shall be tied up to the underside neatly with a strong string, without tearing or damaging the cloth.

(4) Finishing:—The cloth ceiling shall be finished by providing a deodor moulding all around the ceiling, if specified. The design of the moulding shall be given in the drawings.
(4.16) Buildings

Details of cloth ceilings, such as a finish in the form of white-washing, framework, and moulding shall be subject to the approval of the Executive Engineer.

(4.16) (1) Timber:—Unless otherwise specified, seasoned deodar wood of an approved quality shall be used for all joinery work. Timber used for woodwork shall comply with Specification No. 1.20 in every respect.

(2) Workmanship:—All workmanship shall be of the best quality and description, and all woodwork shall be neatly and truly finished to the exact dimensions and shape required. Woodwork which will be exposed to view when the work is complete, shall be accurately planed to the required dimensions.

(3) Joints:—The following principles shall be observed in forming the joints:

(a) The joints should be cut and the fastenings arranged in such a manner as to weaken the pieces of timber they connect as little as possible.

(b) Each abutting surface in a joint shall be placed, as nearly as possible, perpendicular to the line of pressure it has to transmit.

(c) The joint shall form and fit accurately every pair of surfaces that come in contact.

Unless otherwise specified, all joints in joinery work shall be simple tenon and mortise joints with the end of the tenon exposed to view. The tenon and mortise joints or scarfs shall fit truly and fully, without filling. Where specified, as in the case of high class joinery, the end of the tenon shall not show. Joints shall be painted with white or red lead before the frames are put together.

(4) Frames and trusses:—Frames and trusses shall be made in the best possible manner, and all necessary iron
ties, straps, bolus, screws, etc., fitted as shown on the drawings. The Executive Engineer may order any truss or other framed work to be put together on the ground and submitted to suitable tests before being erected in position.

(5) **Screws and nails:**—Holes of correct size shall be drilled before inserting screws, and driving in or starting in screws with a hammer shall not be permitted. All screws shall be dipped in oil before being inserted in the wood. The heads of nails and screws shall be sunk and covered with putty or dealt with as the engineer in charge may direct. The kind of nails and screws used shall be subject to the approval of the Executive Engineer.

(6) **Bearing area:**—All beams, girders, and trusses shall be bedded on bearing plates with not less than 9-inches bearing. All joists shall bear not less than 4½ inches on wall plates, and every purlin or batten supported on a wall will have a bearing in the direction of its length equal to its own depth, subject to a minimum of 4 inches.

(7) **Preservatives:**—All portions of timber, built into or against or close to masonry, brickwork, or concrete, and all junctions of rafters, purlins, beams, and wall plates shall be given two coats of solignum, creosote, or other approved wood preservative.

(8) **General specifications:**—As a precaution against fire, no woodwork shall be fixed closer than 12 inches to the interior face of a chimney flue, a fire place, or a cooking range.

Scaffolding, tackle, ladders, etc., for hoisting and fixing woodwork in position shall be provided by the contractor, and shall be to the satisfaction of the engineer in charge.

(9) **Measurements:**—The measurement of woodwork or planking shall be the net measurement after fixing, no allowance being made for waste, overlaps, rebates, etc.

Woodwork over 3 inches in width and 2 inches or less in thickness will be considered as planking.
4:17. (1) General:—Wood-work for doors and windows shall conform to the requirements of Specification No. 4:16.

All chowkats (frames), doors, and windows together with fittings and accessories shall be strictly in accordance with the design drawings, or with designs supplied by the Executive Engineer.

The doors and windows shall be erected in places as shown in the drawings and plans of the building concerned.

(2) Chowkats:—Door and window chowkats shall be properly framed and mortised together. The chowkats shall have 4½ inches wide horns left on the heads and also on sills (where these are provided). As an alternative, the corners of chowkats shall be held together with 2½ inches by 1/16 inch iron strap bent into a right angle having legs of a length equal to the depth of the chowkats, and fixed with four 2-inch screws. In the absence of any directions to the contrary, the latter method shall be adopted.

(3) Door Sills:—Door chowkats shall be with or without wooden sills as specified or ordered. When wooden sills have not been specified, concrete floors in the door opening shall be so laid as to provide a concrete sill raised one inch above the floor and sloping down to the floor on either side. Wooden sills, where specified, shall be fixed so as to project 1½ inches above the floor level. Where no wooden sill is provided, the feet of the chowkat shall rest on the damp-proof course or on the floor as the case may be.

(4) Rebates in chowkats:—All door window chowkats shall have a rebate cut to receive the leaves. Unless otherwise specified, the rebates shall be ½ inch deep and of width equal to the thickness of the leaf. The other side of the chowkat shall be finished as shown in the drawing. Where the plaster butts against the chowkat a ½-Inch deep rebate with a slight cut back shall be given to provide a proper key to the plaster.
(5) Preservation coating:—Prior to fixing, those sides of chowkats that have to come in contact with brickwork, masonry, or concrete, shall be painted with two coats of solignum, hot creosote or coal tar, or any other approved wood preservative. If the doors and windows are to be subsequently painted, the chowkats must have the priming coat painted on them before erection.

(6) Hold-fasts.—Iron hold-fasts of the type and size shown on the relevant drawings, shall be screwed securely to the outside of the chowkats in the positions shown in the drawings, to secure the chowkats to the brickwork or masonry. Hold-fasts shall be built into the brickwork or masonry in 1:3 cement mortar. Where the chowkat is fixed at the extreme edges of the jambs, the hold-fasts shall be forked or bent as directed by the engineer in charge. Where no wooden sill is to be provided an additional hold-fast shall be fixed on each side.

(7) Chowkat erection:—All chowkats should be ready before the work reaches sill level, so that they can be built in as the brickwork or masonry proceeds. No chowkat shall be painted or installed before the overseer in charge has approved it.

Where sill level is reached and damp-proof course has been laid, the chowkats shall be erected by placing and fixing truly level and plumb. The chowkats shall be securely strutted or lashed in position till the masonry is built around them.

(8) Seasoning door and window leaves:—All door and window leaves shall be cut out and framed together, as soon as possible after the commencement of the building, but final jointing is not to be done until the building is ready for their fixture. In the meantime the leaves shall be stacked in the shade to season, and shall not be glued and wedged for four months where time permits. Otherwise, they shall be wedged and glued just prior to being hung. Before final gluing up, all portions in which defects appear shall be replaced.
(8) Framing door and window leaves:—All styles and rails shall be properly and accurately mortised and tenoned. The thickness of the tenon shall not exceed one-fourth the thickness of the plank and its width shall not exceed five times the thickness. All rails greater than 7 inches in depth shall have double tenons. All tenons shall pass completely through styles and shall be secured by 8-inch hard wood or bamboo pins. All rails should be hunched to depth of groove for panels.

All tenons at the final assembly of the door shall be glued and wedged at top and bottom of the tenon with glued wedges. Immediately after gluing the frame shall be tightly clamped and released only after the glue has set.

(10) Hinges and screws:—Door and window leaves shall be hung on hinges of the size and the number shown on the drawings. Unless otherwise specified, all hinges shall be of approved quality wrought iron. Hinges shall be counter-sunk into the chowkat as well as into the leaf. The recesses shall be cut to the exact size of the hinge, and no subsequent packing up with chips shall be permitted. Two inch long screws shall be used for 5-inch and 6-inch hinges, and 1½-inch long screws shall be used for all smaller size hinges.

Screws used, shall be of such diameter as to fill completely the holes and cups in the hinges and fittings, and should be oiled before they are inserted. Brass screws shall be used for brass fittings.

(11) Fittings:—Unless otherwise specified, the fittings shall be of wrought iron or steel of an approved quality. Brass fittings may also be specified by the Executive Engineer. Fittings shall be fixed where indicated on the drawings, or otherwise ordered.

(12) Stops, chocks, etc.:—Wooden stops of a suitable size shall be fixed to each door or window chowkat to prevent the leaves from damaging the plaster of the jamb when the door or window is fully opened.

Hinged chocks shall invariably be fitted to all doors and windows to keep them open. Chocks shall be of hard-wood and hung on 3-inch butt hinges.
4.19—MANUAL OF IRRIGATION PRACTICE [Chap. 4]

(13) **Type designs**:—All doors and windows shall be made according to the type designs supplied by the Design Office.

4.18. (1) **Door and window panels**:—The size and number of panels shall be as shown on design drawings for each door and window type. Panels shall be in one piece up to a 12-inch clear dimensions in the case of deodor wood, and for 18 inches clear in the case of teak. For larger sizes the panels may be jointed, but the joint shall be glued and dovetailed together to prevent all possibility of its opening out afterwards.

(2) **Panel finish**:—The panels shall be planed absolutely smooth so that no scratch or any other marks are visible. Unless otherwise shown on the drawings the panels shall be splayed and fielded on both sides and the arisings of the frame receiving the panels finished with a simple mould.

(3) **Sash bars**:—Unless the shape and dimensions are definitely shown on the drawings, the sash bars shall be the full thickness of the leaf, and from 1 to 1\(\frac{1}{2}\) inches in width according to the size of the door, and shall be twice moulded and twice rebated and mitred on the outside. The size of the rebate shall be \(\frac{1}{4}\) inch \(\times\) \(\frac{1}{2}\) inch to receive the glass pane and its fixing.

(4) **Glazing and general specifications**:—All glazing for doors and windows shall be carried out in accordance with specification No. 4.34.

Woodwork for panelled and glazed doors and windows shall strictly conform to specification No. 4.17.

4.19. (1) **Design details**:—Framed and braced doors shall consist of two styles, three rails and two braces forming the frame of each leaf to which the battens or planks will be fixed. Windows will have exactly similar construction, except that there will be only two rails and one brace. Other
details shall be strictly according to the type design drawings.

(2) Framing and bracing:—The framing shall be done with mortise and tenon joints. The top and bottom rails and the stiles shall be rebated to receive the battens. The exposed edges of the stiles and rails shall be chamfered or stop chamfered. The woodwork, joints, etc., shall conform to the requirements of specification No. 4.17.

(3) Battens:—The battens should butt into the rebates in top and bottom rails, and will pass over the braces and the lock rail. Battens shall not be more than 5 inches in width, and shall all be straight, parallel, and uniform in width. The joints shall be ploughed, tongued, and finished with a V-joint, or a bead and quirk, on the outside. Battens shall be secured with two screws at each end and with one screw over each brace and the lock rail.

4.28. (1) Description:—Ledged and braced door shall consist of vertical boards or battens connected together by three horizontal ledges, with two braces between the ledges. Windows shall have only two ledges, and one brace.

(2) Construction:—The boards or battens shall be planed, and shall be of uniform width, not more than 5 inches. The battens shall have rebated joints and finished with a V on one side. The ledges and braces shall be of size shown on the drawings, and their edges and ends shall be chamfered. The battens shall be fixed with two screws at each end and one over each brace and the middle ledge.

(3) Hanging:—The chowkat shall be rebated to a depth equal to the full thickness of the door, that is, the battens plus the ledges. The doors shall be hung with the battens inside and the ledges and bracings outside. Hinges shall be fixed to the ledges.

4.21. (1) General:—Where steel frame doors and windows are specified, the manufacture, type, and quality of steel shall be, subject to the Chief Engineer's approval.
4.21—MANUAL OF IRRIGATION PRACTICE [Chap. 4.

(2) Erection:—The erection of steel frame doors and windows shall, preferably, be carried out after the rougher building operations have been completed. The position of fixing-lugs should be marked and the necessary holes left as the brickwork or building work progresses. A brick with sand mortar may be placed where the lugs will be placed, to facilitate subsequent fixing of the lugs in 1:2 cement mortar. The fixing lugs shall be tarred or coated with solignum before insertion in masonry.

The frames shall be fixed plumb and accurate. For actual fixing, the procedure specified by the manufacturer of each type of door and window shall be followed, with such modifications as may be ordered by the Executive Engineer.

(3) Openings:—The openings for steel frame doors and windows shall be made with a clearance all around of half an inch for doors and windows up to 6 feet, so that they can be easily placed in position. After erection of the frame in its place, the space between the masonry or brickwork and the frame shall be filled with 1:2 cement mortar, or with such a cement as is recommended, or supplied by the maker. The mortar should be quite stiff and should be pressed firmly and finished with a smooth surface and pointed as instructed.

(4) Precautions:—Where the doors and windows have to be fixed before the rougher building operations are finished, care shall be taken that the frames, fittings, etc., are not damaged by placing boards, poles, ladders, etc.

The fixing of frames shall be done in such a manner that no lime, whether in plaster, or in the masonry, shall come in contact with the steel frame.

The steel frames shall be entirely free from scale and rust before the fittings are attached. The doors and windows should be painted one primary coat by the makers.

(5) Glazing, etc.:—Unless otherwise specified, glazing shall be on the inside of the steel door or window. The glass pane shall be cut at least & inch smaller in height and width than the tight rebate size of the opening into which it is to be fitted. In all other respects the glazing shall conform to Specification No. 4.24.
The steel doors and windows shall be painted as ordered or as required under specifications for painting steelwork.

422. (1) Materials:—Unless otherwise specified, all woodwork for wire gauze doors and windows shall be made from deodor, and the wire gauze shall be of an approved quality and have 12 x 12 meshes to the square inch. The wire gauze shall be made from uniform 22 gauge galvanized iron wire. All wire gauze panels shall be in one piece, no joints being allowed in the gauze.

(2) Choukat:—Wire gauze door and window leaves shall normally be hung on the same choukat as other doors. Details of such choukats shall be as shown on the drawings.

(3) Fixing the wire gauze:—Wire gauze shall be fixed to the frame of the leaf after being stretched from out to out of rebate and nailed down taut, and then fixed there by a ½ inch x ½ inch fillet screwed into a rebate of that size. The screws shall not be less than 1½ inch in length, and their spacing shall not be greater than 9 inches.

(4) Details of leaves:—The sizes of wire gauze panels, thickness of leaves, and other such details shall be as shown on the drawings. The woodwork of the leaves shall comply with Specification No. 4.17.

Wire Gauge doors shall be hung either on self-closing spring hinges, or on wrought iron butt hinges and helical T-type door springs. The Executive Engineer’s approval for the type of hinges and springs to be used, shall be obtained before the leaves are fixed.

Wire gauze windows shall be hung on wrought iron butt hinges, and no helical springs or self-closing spring hinges shall be used.

(5) General requirements:—Wire gauze doors shall open outwards. Unless otherwise specified, the width and

(31)
position of lock and bottom rails on wire gauze doors shall
be the same as those of the other leaves hung on the same
chowkat.

4.23. (1) General:—The woodwork for clerestory win-
dows, or ventilations, shall comply with the
requirements of Specifications No. 4.16
and 4.17. In other general aspects, Specification No. 4.18
for panelled and glazed doors and windows shall apply to
clerestory windows, with the modifications listed herein.

(2) Hanging and fastenings:—The clerestory window
leaf shall be hung on central pivots, being 1 inch off-centre
so as to make it self-closing. A stout non-twisting cord of
an approved quality shall be provided to open and close
the window.

(3) Cleats:—Brass cleats of a type to be approved by
the Executive Engineer shall be provided for the window
cards. The cleats shall be fixed by two brass screws on to
hard wood blocks fixed into the masonry.

(4) Wire gauze protection:—Wire gauze leaves for
clerestory windows shall be fixed on a separate chowkat
placed flush with the outer face of the wall. In other
aspects the wire gauze leaves shall conform to Speci-
fication No. 4.22.

4.24. (1) Glass:—Unless otherwise specified, all glass
supplied for door and window panes shall
be patent flattened sheet glass of fine
quality, known in the trade as “seconds”. The weight of
the glass per square foot of superficial area shall be as
follows:—

For panes not exceeding 12” × 14” 16 oz.
(about 1/14” thick).
For panes from 12” × 14” to 24” × 24” 21 oz.
(1/10” thick).
For panes from 24” × 24” to 30” × 30” 26 oz.
(1/9” thick).
For panes from 30” × 30” to 36” × 36” 32 oz.
(1/7” thick).
For panes exceeding 36” × 36” plate glass ½” thick.

Glass shall be free from specks, bubbles, distortions,
scratches, and flaws of every kind.

(32)
When plate glass is specified, it should be, unless otherwise described, "polished patent plate glass" of the best quality. It should be of the usual light colour; glass of "second" quality shall not be accepted as a substitute.

(2) Glass panes:—All glass panes shall be properly cut to fit the rebates of the sashes, so as to leave a uniform space of 1/16 inch all round the panes between the edges of the glass and the rebate. All panes that are cracked or chipped during cutting shall be rejected.

(3) Putty:—Putty shall consist of pure raw linseed oil and best whiting, specially dried and ground fine to pass a U.S. Standard sieve No. 45. The oil and the whiting shall be well mixed by hand and kneaded into a stiff paste. It shall then be left for 12 hours and worked up in small pieces till quite smooth. If the putty becomes dry, it should be restored to a workable consistency by heating and working it up again while hot. Where the rebate is small a little white lead should be added in making the putty. Putty required for glazing large panes or for bedding plate glass shall be made with a mixture of linseed oil and tallow with whiting so as to make it pliable and capable of withstanding expansion of the panes. Where required, putty shall be coloured to match the colour of door or window.

(4) Fixing glass panes with putty:—No glass pane shall be inserted in the frame, if the rebates have not been painted or primed with linseed oil. Priming prevents the wood from drawing the oil out of the putty, and thus helps the putty to adhere properly.

Each pane of glass shall then be bedded on a thin layer of putty called "back putty" and secured into position with proper size glazing sprigs. Front putty shall then be applied chamfered, and finished off neatly in such a manner that the depth of the putty is exactly equal to the rebate and all the sprigs are covered by it.

Putty shall be painted at the same time and with the same number of coats, as woodwork.

(5) Fixing glass panes with wood fillets:—For panes exceeding 12 inches in width and for plate glass "dry glazing" may be specified. Where dry glazing is required,
front putty shall not be used, and the glass pane shall be held in place by wooden fillets fixed with brass screws. The fillets shall be plain or moulded, and of a size depending on the type of door or window being glazed. Round the edges of the glass and between the fillets and the glass, a piece of wash leather or putty made with tallow shall be inserted to act as a cushion.

(6) Frosted or blind glass:—Frosted or blind glass panes shall be provided where required or specified. Blind or frosted glass shall be fixed with the frosted face way from the putty.

Frosted glass shall either be glass of an approved quality available in the market, or shall be obtained of plain glass by the following process:

Mix some fine flourspar powder with concentrated sulphuric acid so as to form a thin paste clean the surface of the sheet of glass that has to be etched and rub the flourspar paste by means of a piece of lead over this surface. Gently heat the glass, avoiding the noxious fumes that will be given off. On cooling, the plate should be washed with dilute solution of soda and potash to remove the remaining traces of acid, and should be finally rinsed with water. Care should be taken that the flouric acid does not get on the skin.

(7) Cleaning and finishing:—Glass panes shall be properly cleaned and polished with pads of damp newspapers, and then with clean dry soft cloth. Paint and all other stains shall be removed from both sides of glass panes, and all doors and windows cleaned, and damaged putty or glazing repaired, before the work is considered complete.

4.25 (1) General:—Unless otherwise specified, all pointing, general facework or visible portions in brick or masonry shall be pointed. However, in new construction Jibbi work should be preferred to pointing. Where pointing is required it shall be of the type specified and as described in Specification No. 4.26.
(2) Striking joints:—Unless otherwise specified, all new unplastered faces of brickwork in lime or cement mortar shall be finished by striking the joints as the work proceeds. Joints shall be struck, in the case of walls, by striking off the green mortar after the brickwork has been laid, and then finishing the joint with a pointing tool. In the case of floors, the joint, after being struck, shall be trowelled smooth flush with the surface.

(3) Raking joints:—Where joints of new brickwork in lime or cement mortar are not struck as the work proceeds, the joints shall be raked out to a depth of ½ inch, before pointing. Joints in old brickwork or new brickwork in mud shall be similarly raked out before pointing. The raking shall be done with a hook and not a hammer, and the dust shall be brushed out of the joints after raking is completed.

(4) Mortars:—Unless otherwise specified, lime mortar for pointing shall be prepared as follows:—

One part of properly slaked stone lime shall be mixed with two parts of surkhi and kept under water for at least 12 hours. It shall then be passed through a U.S. Standard sieve No. 12. Colouring matter shall be added where required to match the colour of the bricks.

Cement pointing shall be done with 1:3 cement-sand mortar, unless another mix is specified.

(5) Pointing tools:—The pointing tool for horizontal joints shall be such as to form weathered, struck joints, and that for vertical ones shall be triangular so as to make a V-notch in the joint. The tools shall be properly cleaned and maintained and it shall be seen that they do not develop a cutting edge.

(6) Other requirements:—Pointing shall be done in such a manner that mortar shall not spread over the edges and corners of the bricks. The practice of smearing mortar over defects in bricks will not be tolerated, and will render the entire brickwork liable to rejection.

(35)
Lime pointed brickwork shall be kept wet for five days, and cement pointed brickwork for ten days after completion of pointing. The work shall also be protected from extremes of weather during the curing period.

4.26. (1) Types of pointing:—

(a) Deep pointing:—Deep or struck pointing shall be carried out by filling the joints flush with the masonry or brickwork. The mortar shall be applied with a pointing trowel, and then pressed in with proper pointing tools. Lining with a spike on a mass of mortar shall not be permitted.

(b) Flush pointing:—For this type of pointing, the mortar shall be filled and pressed into the joints with a pointing trowel, and finished off level with the edge of the bricks to give the smoothest possible appearance to the work.

(c) Ruled pointing:—For ruled pointing, the mortar shall be filled and pressed into the joints with a pointing trowel, and finished off level with the edge of the bricks. The pointing shall then be ruled along the centre of all joints with a half-round tool half an inch wide.

(2) Lime pointing:—Unless otherwise specified, various types of lime pointing shall be employed as described below:

(a) Deep lime pointing:—This type of pointing shall be done to all unplastered faces of brickwork in mud. The colour of the pointing shall match that of the bricks.

(b) Flush lime pointing:—This type of lime pointing shall be done to all unplastered faces of brickwork in mud, where the finish of the face is unimportant, or where the face is to be ultimately white or colour-washed. Brick, tile, or other paved floors requiring frequent washing shall also be pointed this way when specified.
(3) Cement pointing:—Unless otherwise specified, various types of cement pointing shall be employed as described below:

(a) Deep cement pointing:—This type of pointing shall be used for all unplastered faces of brickwork in mud, and where the brickwork is liable to be affected by dampness and saltpetre, such as in the plinth of buildings.

(b) Flush cement pointing:—This type of pointing shall be done to all brickwork with an exposed face, where the finish of the face is unimportant or when a flush floor surface is required, and where the floor or brickwork is subject to wear or to the effects of dampness and saltpetre.

(c) Ruled pointing:—This type of pointing shall be done, when specified, to brick and other similar floors not liable to be flushed with water.

(4) Cleaning joints before pointing:—The raked joints shall be thoroughly cleaned and washed before pointing. The brickwork shall be watered for 24 hours and the brick face washed before the pointing is started.

(5) Finishing:—After the pointing is completed, the face of the work shall be cleared of all surplus material adhering to it. Ne washing shall be done until the pointing has set.

427. (1) Mortars:—Unless otherwise specified, mortar for cement plastering shall be 1:3 cement-sand mortar mixed with lime slurry. Wherever a higher strength cement mortar is desired for plastering, such as for the lower portions of bath room walls, a 1:3 cement-sand mortar shall be used, if specified. All cement mortar for plastering shall conform to Specification No. 1.13.

Wherever lime plastering is specified, the exact proportions of the lime mortar to be used shall always be given. In the absence of specific directions, the mix for the lime mortar and its method of preparation shall comply with the requirements of Specification No. 1.17.
(2) Thickness: — Unless otherwise specified, the thickness of limew or cement plastering for all interior and exterior walls shall be half an inch over the brickwork.

Where, owing to the irregularity of the surface to be plastered it is not possible to obtain an even surface with a single coat, two coat plastering may be specified by the Executive Engineer. In this kind of work a preliminary coat of plaster of the same kinds of mortar as for the main coat shall be applied before laying the floated coat.

(3) Preparation for plastering: — Prior to plastering, the joints of all old brickwork or masonry and of all new work in mud, shall be raked out with a hook to a depth of half an inch. All mortar dust from the joints shall be thoroughly washed off and the face work shall be kept wet for 24 hours before plastering.

(4) Screeds: — Wooden screeds, three inches wide and of the thickness of the plaster, shall be fixed vertically 8 to 10 feet apart to act as gauges and guides in applying the plaster. Plaster screeds shall not be used, unless permitted by the engineer-in-charge.

(5) Plastering: — Mortar shall be applied to the wall surface between the screeds, with a plasterer’s float. The mortar shall be pressed with the float during application, so as to fill the raked joints properly. The plaster shall then be finished off with a wooden straight-edge reaching across the screeds. The straight-edge shall be worked on the screeds with a small upward and sideways motion, two or three inches at a time. Finally the surface shall be finished off with a plasterer’s wooden float.

(6) Finish: — Plaster shall be laid to a true and plumb surface and tested frequently with a straight-edge and plumb-bob. The straight-edge for checking shall not be less than 10 feet in length. All horizontal lines and surfaces shall be checked with a level, and all jambs and corners with a plumb-bob, as the work proceeds.

Unless otherwise specified, all corners and arrises shall be rounded to a radius of 1/2 inch during plastering.
(7) Protection and curing:—All lime and cement plastering shall be cured by keeping it wet for 15 days after its completion. During this period the plastering shall be adequately protected from the extremes of weather and temperature.

4.28. (1) Ingredients:—Ordinary mud mortar for plastering shall comply with all the requirements of Specification No. 1.16. Where ordered, four pounds of chopped "bhust" may be mixed with each cubic foot of mud mortar, the mortar being kept in a plastic state for a week before use.

In low rainfall areas, mud mortar containing 5 per cent cement, by volume, may be specified for plastering exterior and interior wall surfaces. For this type of mortar the cement shall be added at such a time that the plastering is completed within half an hour of addition of cement to the wet mud mortar. The mud mortar should be of the right consistency, and in every respect ready for use at the time of addition of cement. The cement should be uniformly distributed and as thoroughly mixed with the mortar as possible.

(2) Plastering:—Mud plaster shall be spread evenly over the wall so as to be not more than the specified thickness. After application and spreading, the plaster shall be floated with a straight edge until the surface is perfectly smooth level, and true. Any cracks that may appear during drying shall be filled up by "leaping", as may be ordered by the Executive Engineer.

4.29. (1) The Whitewash:—The Whitewash shall be prepared from pure fat lime, brought to the site in an unslaked condition. The lime shall be placed in a tub and water gradually added to it, until the mixture is of the consistency of cream, and then it shall be kept unused for 24 to 48 hours. The mixture shall then be strained through a clean coarse cloth. Clean gum arabic dissolved in hot water
and boiled with rice shall be added in the proportion of one pound of gum to 40 gallons of strained whitewash if good gum arabic is not available about 2 quarts of well-boiled rice water should be added to every 20 gallons of whitewash.

(2) The Colour Wash:—The colour wash shall be prepared by adding the requisite colouring water to whitewash which has already been prepared. The mixture should be thoroughly stirred and strained through a clean, fine cloth. The mixture shall be continuously stirred with a stick while colour washing is in progress. Only sufficient colour-wash shall be prepared at a time to complete all the colour-washing in one room within one working day, in order to obtain a uniform tint and shade of colour. It is essential, that the colour pigments should be such as to be unaffected by lime, and its quality shall be approved by the Executive Engineer.

(3) Preparation for Whitewashing:—Where a freshly plastered surface is to be whitewashed, the plaster shall not be trowelled to a glazed, smooth surface, and shall be thoroughly dried before any whitewash is applied. In case of whitewashing an old surface previously whitewashed, the surface shall be thoroughly cleaned, and old loose whitewash and all foreign matter shall be removed before any fresh whitewashing is applied. If the old whitewashed surface is discoloured by smoke, a wash of wood-ashes and water shall be applied before the coat of fresh whitewash.

When an old plastered surface needs repairing, it shall be cut out in a square or rectangle and a patch of new plaster put in. If ordered, the walls shall be scraped clean of all old lime-washing, and all holes shall be satisfactorily stopped with lime putty. Patches of new plaster shall be given two preliminary coats of whitewash after the plaster has dried, and before the main whitewashing is commenced.

(4) Whitewash application:—When the surface is ready for whitewashing, the whitewash shall be applied with a brush to the specified number of coats. Each coat shall consist of four strokes; one stroke from top downwards, another from the bottom upwards over the first stroke, and
similarly, one stroke from right to left and a fourth stroke from left to right over the preceding one before it dries.

Each coat of whitewash should be allowed to dry before the next coat is applied. A dried coat of whitewash shall show no sign of cracking, and it should not come off readily on the fingers when rubbed. The completed whitewash shall form an opaque coat of uniform white colour through which the old work shall not be visible. The finished whitewash shall present a smooth regular surface free from a powdery texture.

During whitewashing, every precaution shall be taken to prevent the wash being splashed or dropped on any place or thing other than the wall or portion of a wall being whitewashed.

(6) Colour-washing:—The surfaces to be colour-washed shall be prepared as described in paragraph (3) ante for whitewashing. New or scraped surfaces shall be given an under-coat of whitewash before any colour-wash is applied. Unless otherwise specified, colour-wash shall be applied in two coats.

Old surfaces on which the previous white or colour-washing is satisfactory, shall be given only one coat of colour-wash. When replacing an older colour with a fresh one of a lighter shade, the old colour-wash shall be thoroughly scraped off and a coat of white-wash shall be given before the colour-wash is applied.

Each coat of colour-wash shall be allowed to dry before the next one is applied. When completed the colour-washed surfaces shall be of a uniform colour, free from blotches, scratches, lines, or cut shades, and shall present a smooth regular surface such as will neither crack nor come off readily on the fingers when rubbed.

Precautions shall be taken, as in the case of whitewashing, to protect all surfaces and things other than those to be colour-washed, from splashes or stains of colour-wash.
4.30— MANUAL OF IRRIGATION PRACTICE [Chap. 4.

4.30. (1) Distemper.—Only approved or specified brands of distempers shall be used. Unless otherwise ordered by the Executive Engineer, the mixing of the distemper shall be carried out in accordance with the instructions issued by the manufacturer of the brand that is to be used.

In the case of new plaster, or plaster on which some sort of lime wash has been applied, only distemper made with lime-proof pigments shall be employed. Otherwise, such plaster shall not be distempered until 12 months have elapsed after the completion of the plaster or lime washing.

(2) Wall surfaces.—The newly plastered wall should present a fine polished surface and be absolutely dry before distempering is commenced. Except under special circumstances, and then only under the written orders of the Executive Engineer, plastered surfaces shall not be distempered until 2 months after plastering work has been completed. The wall surfaces should be thoroughly cleaned, and all holes and depressions, etc., shall be filled with gypsum, and allowed to set hard before the distemper is applied.

(3) Preparation of old surfaces.—Old plastered surfaces shall be thoroughly cleaned, and if previously white or colour-washed, the surface shall be rubbed with sand paper or coconut fibre to remove as much of the wash as possible. After this, the surface shall be stopped and then sized with a prime coat as for new plaster.

If the existing surface was previously distempered in a uniform and workman-like manner, all the old distemper need not be removed. The surface shall be smoothened down with sand paper and any firm distemper that remains on the wall after such rubbing shall be left.

(4) Sizing or prime coat.—Unless otherwise specified, before applying the distemper, the plaster should be sized with a coat of equal parts of size and alum dissolved in hot water. The size shall not be too concentrated nor too thick, nor shall decomposed size be used. In case a special prime coat is recommended by the manufacturer, only such special priming shall be used.

(42)
Chap. 4.] BUILDINGS —431

(5) Distemper application:—Unless otherwise specified, only one coat of distemper shall be applied. The brush should be dipped in distemper, and stroked crosswise on the wall, then immediately stroked perpendicularly, and then stopped. It is recommended that two men shall work together, one going round the room applying the distemper from the ceiling downwards as far as he can reach, and the second man following him applying the distemper below. The finished distemper coat should have a uniform appearance, no patchy overlaps being permitted.

Distempers should be mixed in just sufficient quantities for a day's work. Each room shall be finished in one operation, and work shall not be started in a room so late that it cannot be completed the same day.

Distempering shall not be carried out in damp weather, nor when the weather is excessively hot and dry.

(6) Distemper brushes:—Proper distemper brushes supplied or recommended by the manufacturers shall be used for applying the distemper. The brushes shall, each day after work, be washed in hot water and hung up to dry. Old brushes caked with dry distemper shall not be allowed on the work.

431. (1) General requirements:—Painting of external and internal joinery and woodwork, except the priming coat, shall not be taken up until all the work is finished. The engineer-in-charge shall inspect the work and give his approval, before painting is commenced. The work to be painted shall be thoroughly dry, clean, and free from dust, before painting is started. Before starting paint work on interior joinery, the rooms shall be swept out and closed for at least a day.

Unless otherwise specified, woodwork to be painted shall be finished smooth with sand paper, first with grade 2½ paper and then finished with grade 1½ paper. The sand papering should be finished along the grain.

(43)
(2) **Paints for woodwork:**—Only paints supplied by the Department, or paints of an approved brand and quality available in sealed tins in the market, shall be used for painting woodwork.

When the contractor has been allowed to mix the paint, nothing but the best quality stiff paint ground fine in oil, shall be used and nothing shall be mixed with it except the best quality linseed oil and/or turpentine, in the proportion approved by the engineer-in-charge.

(3) **Mixing paint:**—Where ready-mixed paints are not available and paint has to be mixed, a paint mill shall be used for the purpose. The paint, if not bought as a paste or stiff paint, shall be thinned to a paste by being ground in linseed oil. The mixing may be done in a stone receptacle if a paint mill is not available.

The pigment, if any, should be added to the paste, and the paint worked up to a consistency of cream by adding more linseed or turpentine oil, as may be specified. The paint mixture should then be strained through a piece of canvas to remove any lumps and dirt.

Paints, when not in use, should be stored in air-tight pots, or tins, and kegs of paint which have been partly used, should have the paint surface covered with water.

(4) **Paint Brushes:**—Only paint brushes of an approved quality, and of a suitable size for the work in hand, shall be used for applying the paint. At the close of each day's work the brushes shall be rubbed out and kept immersed in water or raw linseed oil. Before being used again the water or oil should be squeezed out, and a brush in which paint has dried and cannot be cleaned out, shall not be re-used. Brushes required to be used with an other colour of paint, shall be washed out with turpentine or cleaned with washing soda and soft soap.

(5) **Preparation for painting:**—Before painting, all knots in woodwork must be killed or covered with two coats of patent knotting, or shellac varnish, or with a preparation of red lead and glue size, applied hot. Knots in resinous woods should be painted over with hot lime, this
being scraped off after 24 hours; the knot should then be
primed and smoothened with pumice stone, and finally
given one coat of knotting varnish.

Painting of woodenwork shall not be started until the
general requirements given in paragraph (1) are fulfilled.

(6) Priming coat and stepping:—All new woodenwork
shall be first given a priming coat when it is thoroughly
dry. Ready mixed priming paint shall be preferred, but if
it is not available, it shall be made by mixing 7 pounds each
of genuine white lead and red lead with one gallon of
boiled linseed oil.

After priming, all holes, cracks, gaping joints, and
similar defects shall be stopped with putty made from pure
whiting mixed to the proper consistency with raw linseed
oil, a little white lead being worked in after mixing to help
the hardening of the putty.

(7) Applying paint:—All coats of paint shall be laid
on evenly and properly by means of crossing and laying
off, the latter in the direction of the grain of woodenwork,
and care shall be taken that the paint is of such consistency
that it runs easily from the brush. The priming coat
should be mixed thinner than subsequent coats to assist
penetration or adhesion. The final coat shall be very care-
fully crossed and laid off so that it should show no hair
marks or drops of paint.

(8) Re-painting woodenwork:—The old painted surface
shall be rubbed down with pumice, or soap-stone and
washed with dishi’s earth and water until all blisters, pro-
jections, dirt and grease have been removed, and the sur-
face properly smoothened. Old painted surfaces stained
with smoke should be given a coat of a mixture of 3 pounds
of glue and 3 ounces of unsalted lime boiled in one gallon
of water.

When it is ordered that the old paint should be re-
moved before re-painting, it shall be burnt off with a blow
lamp or removed with a paint remover. Proper care shall
be taken that the wood is not charred, and also that an
alkaline paint remover does not come in contact with the
wood. After a paint remover has been used the surface shall be well scoured with hot water and all alkaline traces removed.

After the old paint has been cleaned or removed, the surface shall be thoroughly rubbed down smooth with sand paper, and re-painted with two or three coats as for new work.

(9) Cleaning and finishing:—At the completion of painting operations, all stains, smears, splashings, and droppings, shall be removed from floors, glazing, furniture etc., and similar defects shall be removed from the painted work itself, with turpentine or by any other approved method.

4.32. (1) Preparing the surface:—Woodwork surface shall be cleaned, rubbed, stopped, and knots killed or covered, as described for painting woodwork in paragraphs (1) and (5) of Specification No. 4.31. The surface to be varnished shall be perfectly dry and smooth before any varnishing is commenced.

(2) Sizing, staining and other treatments:—The prepared surface of woodwork shall then be sized with a coat of thin clear glue which must be applied hot and then rubbed down. After rubbing down apply another coat of the same glue but nearly cold.

If it is desired to stain the woodwork, the staining colour shall be mixed with the second coat of size, which must be applied evenly and quickly, keeping the colour on the flow.

If the woodwork is of an oily nature, a little “Multani Mitti” and ochre shall be added to the first coat of size.

(3) Varnish:—Unless otherwise specified, copal varnish of an approved quality and make shall be used for all interior woodwork. Where it is necessary to varnish exterior woodwork or that exposed to rain and dampness, carriage varnish of an approved quality shall be used.
One pint of varnish should be sufficient to cover about 150 square feet of surface for a single coat. If permitted by the Executive Engineer copal varnish may be thinned by the addition of up to 35 per cent of turpentine.

(4) Application:—The sized woodwork surface should be rubbed with fine sand-paper along the grain, leaving an even colour. First coat of the specified varnish shall then be applied. Successive coats, if specified, shall be applied after the previous coats are thoroughly dry. The surface shall be lightly sand papered when thoroughly dry, before the first coat and after each coat of varnish except the last. The work after completion shall not be sticky to the touch, and no hair or any other material shall be allowed to adhere to it. Good varnish should be dry and free from thickness within two days.

4.33. (1) Materials to be used:—Unless otherwise specified, all ironwork not subjected to continuous submergence under water, shall be painted with grey graphite paint of an approved quality and manufacture. As far as possible darker shades of grey should be used rather than the lighter shade. For careful work on smooth iron surfaces about 1½ pounds of paint should be needed for 100 square feet per coat.

For painting ironwork which remains under water, the standard Khanki Mixture composed of the materials given below shall invariably be used:

- Coal tar ... 94 lbs.
- Mineral pitch ... 10 lbs.
- Slaked white lime ... 9 lbs.
- Kerosene oil ... 9 lbs.

Total ... 112 lbs. = 1.0 cwt

The mixture should be prepared by heating the pitch and coal tar separately and then mixing them together over a fire, stirring well and adding the slaked lime gradually while stirring. The mixture should be then withdrawn

(47)
from the fire and kerosene oil added and well stirred into
the mixture. Care should be taken to see that the mixture
is not over-heated, the temperature being kept below the
350°-F to 400°-F range. On the average, the covering
capacity of the mixture is about 2,500 square feet per
hundred-weight.

(2) Cleaning surface:—The ironwork shall be thoroughly
cleaned and all rust and scale shall be removed by means
of a scraper or a steel wire brush. The surface shall not
be considered clean until the bright shining surface of the
iron appears and no specks of rust are left on it. No
chemicals of any kind shall be used for cleaning the iron.
The surface should be finally cleaned with dry cotton waste
just prior to painting.

(3) General precautions:—Painting of ironwork shall
not be carried out in damp or wet weather, and wherever
possible plain shall only be applied to ironwork when it
has been moderately warmed by the sun.

(4) Painting:—Unless otherwise specified, three coats
of paint shall be applied to all new work. Each coat should
vary from the preceding one slightly in shade in order to
watch that the required number of coats have actually been
applied.

Paint should be applied, with brushes of an approved
quality, in long, evenly drawn strokes. Sufficient interval
of time should be allowed between the various coats to
allow the paint to dry up. Quick drying of paint in the
baking heat of the summer sun should be avoided.

Where ironwork is to be painted with Khantí Mixture,
the mixture should be applied hot to the cleaned surface.
Subsequent coats should be applied only after the previous
one has dried. Ironwork thus painted should not be
immersed in water until it has thoroughly dried, and one
week is generally sufficient for this purpose.

(5) Painting new galvanized iron:—Galvanized iron
shall not be painted until it has been exposed to the weather
for a year. If it is desired to paint earlier, a coat composed
of eight ounces of copper acetate added to a gallon of water
shall first be given. Unless a special paint for galvanized iron is specified, the first coat shall be composed of genuine red lead mixed with raw linseed oil and turpentine in equal proportions, to give the necessary consistency.

(6) Re-painting old work:—When re-painting iron-work, if the old paint is sound, it shall be rubbed with wire brushes and scrapers and all loose paint shall be removed. If the old paint is in bad condition it shall be burnt off with a blow lamp, if ordered by the engineer-in-charge.

4.34. (1) Requirement.—All woodwork which has to be painted, varnished or polished must have all pores, cracks, gaping joints, inequalities, defects, etc., filled with stopping-out wax.—

(2) Stopping-out wax:—

Wax for stopping woodwork shall be prepared as follows:—

To a cupful of common shellac placed in an iron pot, add a teaspoonful of powdered resin, a piece of bees-wax about the size of a walnut, and a teaspoonful of powdered lemon chrome or other colouring matter to match the finished work. The mix should be heated to the molten state and stirred with a stick all the time. The mixture may be made into sticks by rolling between boards while still in the plastic state.

(3) Applications.—The stick of wax should be used with a hot iron to fill the holes in a manner similar to the use of a soldering iron. Places which do not hold the stopping out wax, should be filled after boring a few small holes to assist in holding the stopping. After the stopping has hardened its projections should be smoothed off by chiselling and finished with glass paper.

(49)
CHAPTER V

EARTHWORK

5.1. (1) Scope of specifications:—These specifications shall apply to all kinds of earthwork carried out for construction of dikes, bunds, canal banks, earth dams, coffer-dams, road subgrades, railway embankments, backfills, etc. Earthwork shall include excavation, transportation or earth-moving, placing, compaction and consolidation. Exploration for sub-grade conditions, testing of soils and determination of properties shall be closely interrelated with earthwork operations for all important structures.

(2) Suitability of soils:—Soils used for earthwork shall comply with general Specification No. 1.2 for earth and their classification shall be carried out according to the system described in Appendix I.

The relative suitability of soils for dams, bunds, foundations, canal banks, and fills for roadway subgrades, shall be determined from Table I, on page. The group symbols indicated in this table are according to the classification system given in Appendix I. The numbers in the four columns for permeability, shearing strength consolidation, and density, indicate the order of increasing values for the physical property named. In all the other columns for suitability of materials, the numbers indicate the relative suitabilities of soil types for the use specified in each heading.

(3) Field explorations and investigations:—Field investigations shall be carried out to determine the suitability of foundations for a structure and also the availability of suitable soils for a particular kind of earthwork construction.
5.1—MANUAL OF IRRIGATION PRACTICE [Chap. 5.

For canal embankments, low bunds, and highway beds, a general soil survey showing the location of different kinds of soils in the vicinity and the nature of the soils immediately below the proposed structure shall be determined by testing samples taken from open pits 5 to 16 feet deep. For all important structures such as embankments higher than 25 feet, earth dams, power-house foundations etc., a detailed soil survey shall be carried out to show the estimated quantities of different kinds of soils available in the vicinity and the soil strata below the proposed structure shall be explored to a depth below the foundation at least equal to the depth of foundations below natural ground surface, or to suitable rock, hardpan, compact sand and gravel, or conglomerate strata, as desired.

For all important structures, the number, location, depth and size of test holes or pits, the type of samplers to be used, the number and nature of samples to be obtained shall be specified by the Design Office.

(4) Test hole logs:—Proper logs shall be kept for all test holes, test pits, auger holes, etc., clearly giving available data regarding:

(a) Project, feature, location of hole, etc.
(b) Date of starting and finish.
(c) Type and size of hole or pit.
(d) Depth and elevation of sample recovered for testing.
(e) Core recovery, per cent.
(f) Field classification and physical condition of samples.
(g) Elevation of water table at the completion of boring.
(h) Geological log presented diagrametically.

(2)
A test hole log shall be prepared and data presented in a standard form as shown below:

**PUNJAB PUBLIC WORKS DEPARTMENT**

**IRRIGATION BRANCH**

*Project*

Foundation exploration for

**TEST HOLE DATA**

Progress report for period to

<table>
<thead>
<tr>
<th>Drilling record No.</th>
<th>Average W.S.L.</th>
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<td>Depth from m.</td>
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<tr>
<td>Type of Drill used</td>
<td>Total Penetration proceed</td>
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<table>
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<tr>
<th>Date From</th>
<th>To</th>
<th>Description of Soil</th>
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<th>Disturbed</th>
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</tbody>
</table>

**General Remarks**

**Signature and Designation of reporting Officer**

Date

N.m. and Designation of person making entries
(5) Soil Testing:—Tests for particle-size distribution and gradation, dry density, liquid and plastic limits shall be invariably carried out for all soils to determine their general characteristics and suitability for various kinds of construction. Once the general classification of typical soils in an area has been ascertained, usual field examination by experienced field workers shall be considered sufficient to conform the suitability of a certain soil for all ordinary kinds of earthwork.

However, for all important structures, both undisturbed and disturbed samples of soils shall be tested for natural moisture content, specific gravity, shear strength characteristics, and permeability in addition to the tests mentioned in the preceding paragraph, in order to ensure proper design of the structure and its foundations. Silty and clayey soils shall be tested for their consolidation and swelling characteristics where heavy design loads are involved. Field bearing and field permeability tests shall be carried out if ordered by the Chief Engineer.

52. (1) General:—Earth or soil shall be excavated from its natural position and transported to the site by manual or mechanical means. The method of excavation and transport found to be economical and otherwise satisfactory shall be employed, subject to the Executive Engineer’s approval. Classification of earthwork shall be made according to the hardness of soils encountered and this shall be suggested by the Executive Engineer.

(2) Manual excavation.—Manual excavation in borrow-pits, in channel beds, on slopes, and in foundation pits shall be carried out with “kassis” or shovels, or pickaxes and excavated soil shall be carried in baskets, wheel barrows, or by donkeys, or by any other means found suitable. Deadmen or benches shall be left at prominent points, as ordered by the engineer-in-charge, and these should remain in-tact till the time of final measurements of excavated quantities and final payment shall be deferred until all the marks are removed. Where natural surface is regular, deadmen or benches shall be left at equidistant intervals.
In all other respects manual excavation operations shall follow pertinent specifications for earthwork for that job.

(3) Manual excavation of channels:—Manual excavation for channels shall be carried out in 2 to 5 feet lifts or as specified by the Executive Engineer, and for each channel, as far as possible each lift should be completed before starting on the lift below. The final excavated section shall not exceed or differ from the designed section either in widths or in slopes. All gangways, paths and steps shall be kept within the channel section so that their removal in the end leaves the section true to design. Thus the final dressing of slopes will consist of digging only and no filling or marking-up will be necessary.

Unless otherwise directed by the engineer-in-charge, the excavation for structures such as bridge piers or abutments, deep footings, outlets, etc., lying largely outside or below the proposed canal section shall follow the excavation of the channel. Special care shall be taken to prevent overbreakage or loosening of material in beds and slopes upon or against which lining is to be placed and any such damage to foundations or slopes shall be repaired as directed in Specification No. 5.11.

(4) Mechanical excavation:—Mechanical excavation and transportation of earthwork shall be carried out on all large jobs where it is found to be economical and desirable and where ordered by the Chief Engineer. Mechanical excavation shall be carried out by shovels, draglines, bulldozers, scrapers, or any other kind of machinery found suitable from the point of view of availability, topography, nature of soils and the nature of excavation. Selection of equipment for a specific job shall be made according to Specification No. 5/3 on earthmoving equipment.

(5) Foundation excavation:—Shallow foundation trenches for light structures such as buildings, retaining walls, etc., shall be dug to the exact dimensions of the foundations, and the sides shall be kept vertical where possible or they shall be sloped, shored, or supported where necessary. In other respects excavation of such foundations shall be carried out according to Specification No. 4.1.
Excavation in foundation pits deeper than 30 feet shall be carried out as recommended by the Design Office. Wherever the soil is compact, plastic, and well consolidated and the ground water level is below the proposed bed of the pit, excavation may be started over the whole area. The side slopes shall be as flat as found to be desirable after necessary stability analyses or by observation.

Shoring may be necessary for excavation in granular soils below the water table. If found feasible and economical the water table shall be lowered by using an adequate well-point system or individual wells, in order to make possible excavation in the dry and with unsupported slopes. In fine-grained, slightly plastic soils, slight disturbances may cause them to "liquefy". Adequate support in the form of properly designed sheeting and bracing shall be provided when excavating deeper than 15 feet in such soils.

When excavating pits deeper than 25 feet in highly plastic clays or in clays known to have significant swelling characteristics, excavation shall be carried out according to plan suggested by the Design Office.

In all foundation pits deeper than the ground water level, excavation shall preferably be carried out in the dry. Adequate drainage provisions, with suitable pumping arrangements if necessary shall be made to remove the seepage water away from the working area.

53. (1) Scope:—These specifications shall serve as general directions to aid in selection of both excavating and hauling or transporting machinery to be employed for earthwork. Specific and detailed specifications for earthmoving machinery suitable for a particular job shall be issued by the Chief Engineer.

(2) Types of equipment:—Earthmoving equipment includes front and side-casting bull dozers, scrapers, elevating graders, power shovels, draglines, dishers, dredges, tractor-wagons, trucks and dumpers. Some of this equipment can be employed both for excavation and transport of
(3) Selection of excavating equipment:—Selection of excavating equipment shall consist of deciding the type, size or capacity, and number of units required for a job. Suitability of a certain type of equipment shall be decided upon by keeping the cost, ruggedness, maintenance, supply of parts, operational costs, ease of operation, and mobility of the equipment in view. Type an .capacity or size of equipment to be used shall also be influenced by the physical conditions of the job, the kind and quantity of materials to be handled, and the general arrangement of operations.

(4) Selection of transporting equipment:—Following factors shall be taken into consideration in making selection of transporting equipment:—

(a) Cost of owning and operating the loading and hauling equipment.

(b) Pay load that can be delivered by the hauling equipment.

(c) Round-trip time cycle of a hauling unit. This should include loading, hauling, dumping or transferring, and return time.

(d) Number of units per hour that can be loaded by loading unit under operational conditions.

In addition, weather conditions and the general conditions mentioned in the preceding paragraph shall be kept in view.

(5) Primary use.—(a) Bulldozers attached to heavy-duty tractors shall generally be used for surface stripping and as spreaders, levelers, and as primary excavators and movers. Bulldozers shall also be used for moving earth downhill on flat slopes and short hauls.
(b) Scrapers, though a combination of excavators and movers are primarily suitable for hauling purpose. These are most suitable for flowable materials, and shall not be used for hard rock. Earth shall be shoveled into a scraper by a tractor, preferably on a downgrade of about 6 per cent. Scrapers shall generally be used for short hauls of 500 to 1,000 feet.

(c) Elevating grader shall be used only for soft soils free from stumps, roots, boulders, etc. The hauling units should be fast and easily maneuverable, to make continuous operation possible. These units shall always be compared with a tractor and scraper outfit as a substitute, as the latter will generally be found economical.

(d) Power shovels shall be used for close-range work, where the working space is limited and thus limited motion of equipment is desirable. A shovel that can be converted into dragline, clamshell, crane, scoop or ditcher, should be given preference over the non-convertible types.

(e) Dumptors are high-speed pneumatic-tyred trucks capable of dumping on the front side. These shall generally be employed for short hauls where a shuttle movement is desirable and advantageous.

Profitable and proper employment of other kinds of earth-moving equipment for various kinds of jobs and detailed directions for its operation shall be supplied by the Executive Engineer-in-charge of the earth-moving operations.

54. (1) General: —Unless otherwise specified, earthwork for irrigation channels, whether on Canal Earthwork, a main line or a branch, or a distributory shall be carried out systematically as described below. Modifications in operations and detailed specifications for earthwork for deep channels, high embankments or for fills in the vicinity of important masonry works shall be supplied by the Design Office.
(2) Setting out and profiles:—For all channel, centre line shall be laid out first by pegs driven at 100 feet centres. All curves shall be properly laid out and the top and bottom edges of excavation and the toes of embankments shall be clearly marked.

Before commencing construction complete profiles should be set up 500 feet apart and at every change of section. These profiles should be ten feet in length along the alignment of the channel or embankment, the channel excavated to the proper level, the banks raised to the correct height and width and all slopes dressed to the designed form. Ends of the profile banks should be stepped so that proper bond shall be achieved with earth-fill laid afterwards. All earth in these guide profiles shall be compacted to the same average dry density that is specified for the rest of the earthwork in that reach.

(3) Surface stripping.—Before placing the earthfill, the surface area of ground that will be covered by earthwork shall be cleared of trees, bushes, grass, rocks, loose boulders, etc., and the surface shall then be ploughed over or scarified. The top layer of soil may be set aside for providing surface layer of banks, if the soil below the natural surface is found to be less suitable for this purpose.

(4) Excavation of channel.—Excavation shall be carried out according to the general conditions laid out in Specification No. 5.2.

(5) Borrowpits:—Borrowpits shall be used for obtaining soils for earthfill only when absolutely unavoidable. Preference should be given to spoil carried along the formation. No borrowpits should be within 10 feet of the toe of the bank and if the borrowpits is deeper than 2 feet, the distance from toe of the embankment to the top edge of pit should not be less than 15 feet. All borrowpits should be properly marked out before commencing excavation. Borrowpits shall be as shallow as possible and they shall extend over the whole area assigned to them. Where borrowpits excede over a considerable area a separating bar, 10 feet wide, at the top, shall be left every 100 feet apart, in order to prevent drainage water from flowing along the canal. No borrowpit in the channel bed shall be dug below bed level, unless ordered or permitted by the Executive Engineer.
5.5—MANUAL OF IRRIGATION PRACTICE [Chap. 5.

(6) Earthwork for canal structures:—Earthwork for and around canal structures such as bridges, cross-drainage works, falls, outlets, ramps, etc., shall be carried out during a convenient period suggested by the Executive Engineer. The general procedure shall be similar to and as systematic as specified above for general canal earthwork.

(7) Earthwork compaction:—Compaction of earthwork for irrigation channels and allied works shall be carried out according to Specifications No. 5.6 and 5.7.

5.5. (1) General:—These specifications shall apply to placing, compaction and consolidation of all earthfills by manual labour. Earthwork for canal banks and fills up to 25 feet height, fills in foundations, backfills behind retaining walls or around masonry structures, etc., shall be placed by manual labour, when found to be suitable and economical.

(3) Embankment construction.—Embankment boundaries shall be set out and stripping and excavation from borrowpits shall be carried out as laid out in Specification No. 5.4 for canal earthwork. The soil shall then be placed in layers extending over the entire width and not exceeding 6 inches in thickness. Each layer should be commenced from the edge farthest from the excavation and the top of each layer should be approximately level or slightly depressing in the centre. Humps and roundings should be dossed down level before the next layer is commenced.

All large clods shall be broken in the borrowpits to a size smaller than a man’s fist in the borrowpits. The earth placed in the layers shall be free from roots, grass, stumps, or other rubbish.

(3) Consolidation.—Consolidation of manually placed earthwork takes place under its own weight. To allow for consolidation and settlement, height of the back as placed should be 10 per cent higher than as shown on the drawings. However, allowance for settlement should be made in compacted earth bank for lined channels. Where
ordered the soil layers shall be slightly wetted by sprinkling water. Where each layer has to be compacted by cattle driven rollers or by mechanical means earthworks shall be placed according to Specification No. 5.7.

(4) Spoil banks:—Spoil banks shall be laid according to plans approved by the Executive Engineer. Spoil shall be spread over the whole area available for the purpose in layers not thicker than one foot. Spoil banks should be dressed and finished to slopes shown on the drawings.

Spoil banks intended for plantations shall be provided with longitudinal and cross doweled forming compartments 50 feet x 50 feet, so that no rain water can flow off the spoil banks.

Wherever possible, poor or bad soils and sand should be faced and topped with good earth.

5.6. (1) Composition:—Puddle shall consist of stiff clay containing nearly 20 per cent sand by weight. So called sodium clays, containing sodium carbonate shall generally be preferred. If an adequate quantity of sand is not present in the clay, a suitable amount of sand may be mixed with the clay after it has been weathered and pulverised.

(2) Preparation of puddle:—The clay should be dry and exposed to the sun and air for at least four days, and when dry it shall be pulverised with rammers. Additional sand, if necessary shall be uniformly mixed with the powdered clay and two days previous to that on which the clay is required for use. They clay and sand mixture should be wetted and thoroughly worked up in a pug mill or puddled under mens' feet into a plastic mass.

(3) Consolidation:—The puddle shall be carried in baskets or wheel barrow as considered suitable. Each batch shall be well consolidated with rammers or trodden under feet until it is thoroughly integrated with the batch already in place. Stones, bricks, roots, grass, etc., shall not be allowed to remain in the puddle.

(11)
57—**MANUAL OF IRRIGATION PRACTICE**

(5) Use:—Puddle shall be used in embankment cores cut off trenches, impervious blankets, etc., where and when specified by the Design Office.

5.7. (1) General:—Mechanical earthwork construction shall generally be adopted for all embankments higher than 20 feet and for earth dams. These specifications shall be adhered to wherever rolled-fill earthwork is desired.

(2) Compaction criteria:—For every earthwork job, where mechanical placing and/or compaction is involved, the following criteria shall be specified either with the designs or by the Executive Engineer-in-charge:

(a) Placement moisture content.

(b) Maximum size of boulders or gravel permissible in the soil for compaction.

(c) Maximum thickness of soil layers as placed.

(d) Number of passes of a specified roller.

(e) Dry density of the soil desirable after compaction.

The average degree of compaction or dry density obtained is the final and most important check on the efficiency of rolling or compaction operations. The frequency of field density tests, the desirable check on moisture content, and number of passes of a roller shall be maintained according to Specification No. 5.10 on embankment compaction control.

(3) Bullock-pulled light rollers:—Where specified, lightumping rollers made of cement concrete and pulled by bullocks shall be used in rolled-fill earthwork. The tested concrete roller commonly used on Punjab irrigation works shall have staggered feet projecting three inches and it shall weigh 1.5 tons. Generally the soil shall be considered satisfactorily consolidated after 16 to 20 passes of
the roller, or when the impression made by the feet is not
to more than 1/4 inch deep. However, a more precise check
in the form of field density or Proctor’s needle penetrations
test, may be specified by the Chief Engineer for compac-
tion by light rollers.

(4) Preparation of foundations:—The foundation, or
the total natural ground surface to be contacted by the
embankment shall be cleared of all loose materials, roots,
stumps and other debris, or where the foundation is to be
carried to rock, all over burden disintegrated rock and de-
bris shall be removed before placing the earth-fill, Dewater-
ing, grouting or special treatment of foundations, filling of
seams, construction of cut-offs, where required, shall be
completed before commencement of earth fill operations.
Prior to placing the first layer of embankment, the founda-
tion whether earth or rock, shall be moistened if neces-
sary, but no standing water shall be permitted on the
foundations.

(5) Placing:—The distribution and gradation of the
materials throughout the earthfills shall be as shown on the
drawings or as directed by the Executive Engineer, and shall
be such that the earth fills will be free from lenses, pockets,
streaks, or layers of material differing materially in tex-
ture or gradation from the surrounding material. The com-
bined excavation and placing operations shall be such that
the materials when compacted in the earthfills will be
blended sufficiently to secure the best practicable degree
of compaction impermeability, and stability. Successive
loads of materials shall be dumped on the earthfills so as
to produce the most practicable distribution of the material,
and for this purpose the engineer-in-charge may direct the
points in the earth fills where individual loads shall be
deposited, to the end that the finer materials shall be placed
in the central upstream portions of the earth fills and in the
cut-off trenches, and the coarser sand and gravel content
in the earth fills will be increased gradually toward the
downstream and also upstream slopes, if so specified, of the
earth fills.

No stones or pebbles larger than a size specified on the
drawings for a particular embankment shall be placed in
the earth fills. Such stones, boulders, and pebbles shall
be placed in the rock fill, riprap, or rock toe portions of the embankment as approved by the Executive Engineer. Coarse materials such as sand and gravel, shall be placed in the filter layers as shown on the drawings to a degree of compaction or relative density as specified.

The earth shall be placed in continuous, approximately horizontal layers not more than six inches in thickness after being rolled as specified in paragraph (7). If, in the opinion of the engineer-in-charge, the surface of the prepared foundation or the rolled surface of any layer of earth is too dry or smooth to bond properly with the layer of material to be placed thereon, it shall be moistened and or scarified to the satisfaction of the engineer-in-charge, before the succeeding layer of earth is placed.

All masonry or concrete structures adjacent to an earth fill shall be suitably protected against displacement or other damage during the earthwork operations. The slopes of the earth fill shall be compacted thoroughly, shall be reasonably true to line and grade, and all projections of more than 6 inches outside of the neat lines of the earth fill shall be removed, before the lining or riprap is placed, or turfing is carried out.

(6) Moisture control.—Prior to and during the rolling operations, the material in each layer of the earth fills shall have the optimum practicable moisture content required for compaction purpose, as determined and directed by the Executive Engineer, and the moisture content shall be uniform throughout the layer. In so far as practicable, as directed by the Executive Engineer, the application of water to material for this purpose shall be done at the site of excavation, and shall be supplemented, as required by sprinkling on the earth fills, if necessary. Harrowing or other working of the material may be required to produce the required uniformity of water content.

(7) Rolling.—Unless otherwise specified, earth layers shall be compacted by rolling with standard sheepfoot rollers conforming to requirements of Specification No. 5.8.

After each layer of material has been conditioned to have the optimum practicable moisture content for compaction purposes, as provided in paragraph (6) above, it
shall be compacted by passing the standard sheep-foot roller over it. The number of passes or the number of times the tamping roller should be passed over the layer shall be specified by the Executive Engineer. If the moisture content is less than the optimum for desired degree of compaction, the rolling shall not proceed except with the specific approval of the Executive Engineer, and in that event, additional rolling shall be done, as directed by the engineer-in-charge, to obtain the required compaction. If the moisture content is greater than the optimum for compaction, the rolling shall be delayed until such time as the material has dried until it contains only the optimum moisture content.

(8) Tamping.—Portions of earth fill between rock projections, rear cut off walls, piers and other masonry or concrete structures, and elsewhere, which in the opinion of the engineer-in-charge, cannot be compacted properly by the use of rolling equipment, shall be compacted thoroughly by the use of mechanical or pneumatic tampers, or shall be puddled. The degree of compaction for such portions of the earth fill shall be equivalent to that obtained by moistening and rolling as specified for other portions of the earth fill. Where puddling is required it shall be placed and compacted according to Specification No. 5.6.

5.8. (1) Scope.—These specifications shall apply to standard sheep-foot rollers used for construction of rolled fill embankments and for compacting earthwork in comparatively thin layers. For ordinary works and wherever ordered by the Chief Engineer, earth fill compaction may be carried out employing small tamping rollers drawn by bullocks, and these specifications shall not apply to such small tamping rollers or to other kinds of special rollers such as grid rollers, pneumatic compactors, etc.

(2) Standard sheep-foot roller.—Standard tamping or sheep-foot rollers shall be used wherever specified, and these shall meet the following requirements:

(a) The roller drums shall have an outer diameter of not less than five feet. The length of the roller
drums shall be not less than four nor more than six feet.

(b) There shall be at least one tamping foot for every hundred square inches of surface area of the drums.

(c) The distance, measured along the surface of the drums, between the centres of any two adjacent tamping feet shall be not less than nine inches.

(d) The cross-sectional area of each tamping foot, measured in a plane normal to the axis of the shank, shall be not less than seven square inches, one inch from the outer end of the tampering foot, nor more than ten square inches within three inches from the outer end of the tamping foot.

(e) The weight of the drum, when fully loaded with ballast, shall be not less than 4,000 pounds per foot of length of the drum.

(f) The distance between any two adjacent drums shall not exceed 15 inches.

(g) Each drum should be free to pivot about an axis parallel to the direction of travel, and the rotation possible between any two adjacent drums shall not be less than 45 degrees.

(h) Each drum shall be provided with a suitable relief value, etc.

(3) Operation specifications.—The loading and operation of rollers shall be subject to the approval of the Executive Engineer. Water, sand, or sand-and-gravel ballast shall be used in the roller drums as required to obtain the desired compaction and the tractors shall have sufficient capacity to move the roller satisfactorily when fully loaded. During rolling operations the spaces between the tamping feet should be cleared of accumulations of materials, as such accumulations are detrimental to proper compaction to the desired dry density.
(4) Details and modifications.—The details of sheeps-foot rollers to be built by or for the Irrigation Branch shall be supplied by the Design Office. Any modifications in the requirements of standard sheeps-foot rollers, especially in size, weight etc., shall be subject to the approval of the Chief Engineer.

(5) Roller data.—Data about all tamping rollers used on each earthwork job shall be furnished by the engineer in-charge in the tabulated form shown in Table 5.8.

PUNJAB PUBLIC WORKS DEPARTMENT
IRRIGATION BRANCH

Project
Canal/Dam

EMBANKMENT ROLLER DATA

By

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<td>(b) Number of drums</td>
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<td>(c) Length of drum</td>
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<tr>
<td>(d) Diameter of drums (outside)</td>
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<tr>
<td>(e) Capacity (b), Sheds of feet (F.) or Square (Sq.)</td>
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<tr>
<td>(f) No. horizontal rows of feet</td>
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<tr>
<td>(g) No. ft. per row per drum</td>
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<tr>
<td>(h) Total No. feet per drum (f) x (g)</td>
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### 5.9. Manual of Irrigation Practice

<table>
<thead>
<tr>
<th>Roller No.</th>
<th>1</th>
<th>2</th>
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<th>4</th>
<th>5</th>
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<tr>
<td>(i) Length of feet</td>
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<td>(j) Dimensions of bottom of feet</td>
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<tr>
<td>(k) Area of bottom of feet</td>
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<tr>
<td>(l) Weight of roller (empty)</td>
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<tr>
<td>(m) Ballast capacity (All drums)</td>
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<tr>
<td>(n) Weight of roller as used</td>
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<tr>
<td>(o) Ballast used (material)</td>
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<tr>
<td>(p) Wt. of roller - Total area all feet</td>
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<tr>
<td>(q) drinkers (yes or no)</td>
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<tr>
<td>(r) Type of frame (Rigid or oscillating)</td>
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#### 5.9. (1) General:
Wherever earth-moving, excavating, placing and compaction machinery owned by the Irrigation Branch is in operation, whether by the department or by a contractor, all units shall be properly maintained and repaired as laid herein. Detailed specifications for the operation and maintenance of and repairs to any individual unit or type of equipment shall be issued by the Executive Engineer-in-charge of the operations. These specifications shall be conducive to economical and efficient operation and longer life of the equipment.

3. **Sheepfoot rollers:** After every five passes, of earlier if necessary, and grit and earth materials trapped
between the tamping feet shall be removed by any convenient method. If the tamping heads get worn off due to the abrasive action of materials, the heads shall be replaced, if directed by the Executive Engineer. Where proper workshop facilities are available the worn out heads shall be re-built and hard-faced, by arc-welding, if possible.

Damage to drum bearing shall be avoided by proper protection against leakage of water and sand from the ballast into the bearings. All bearings, valves, etc., should be properly cleaned, greased and lubricated at proper intervals.

3. Scrapers, Graders, etc.,—Instructions for maintenance and operation of other types of earth-moving and compaction machinery, such as scrapers, graders, etc., shall be strictly in accordance with the directions and specifications issue by the manufacturers and by the Executive Engineer-in-charge of operations.

5.10. (1) Desirability of control.—In order to build stable, suitably impervious, and safe embankments and earthfills, it is imperative that proper check and control be maintained during placing and compaction operations. Construction control shall be exercised on one or more or all of the compaction criteria laid in paragraph (2) of Specification No. 5.7, in order to see that construction is being carried out according to the design stipulations. Unless otherwise specified the specifications given below shall apply only to rolled earth embankments higher than 25 feet.

2. Dry density.—The dry density, in pounds per cubic feet, to which the materials are to be compacted shall be predetermined in the laboratory to insure saturated stability, minimum subsequent consolidation or settlement, low rate of percolation, and workability on the fill. This value of dry density shall be determined and the proper moisture density relation shall be established by carrying out the Standard Compaction Test described in Appendix IX.
3. Field density test.—Field density tests shall be made on rolled embankments during constructions in order to compare the density being obtained by construction methods with the desired standard of compaction determined in the laboratory. The number and locations of the tests should be such as to include all doubtful areas, and at least one test should be made for each 2,000 cubic yards of compacted embankment. Where placing operations are concentrated in a small area so that a number of layers are being placed daily, the density determinations should be made for every four layers placed, or as directed by the Executive Engineer.

Regardless of the number and purpose of other field density tests one test shall be carried out for each 30,000 cubic yards of embankment placed. Tests of other physical properties shall be carried out at this location, as directed by the Executive Engineer. Such field density tests should be representative of the conditions of the fill and shall be considered as “Record” test.

The field density test and the allied penetration resistance needle tests shall be carried out as described in Appendix X and XI, respectively.

4. Moisture control.—After the materials are placed in the correct location, it is of extreme importance that tests be carried out to check that they contain the proper amount of moisture prior to compaction. Samples shall be taken from several truck loads, the number of such loads being specified by the Executive Engineer, after dumping, and needle-moisture tests shall be carried out on these samples as directed in Appendix XI. Moisture content shall be corrected before compaction, if necessary as laid out in paragraph (6) of Specification No. 5.7.

8. Other checks.—Checks on the compacted thickness of layers, maximum size of aggregate, number of roller passes, zoning of embankment, etc., shall be made by the engineer-in-charge or the earth-work inspector if employed, as frequently as necessitated by the peculiar conditions at a job.

(26)
9. High earth dams.—Procedure and frequency of compaction control tests, establishing embankment test section and the extent of laboratory and field compaction research, for all earth dams and embankments higher than 100 feet shall be specifically directed by the Chief Engineer.

10. Progress reports.—For all important earthwork jobs, especially those involving large-scale mechanical operations, earth-work progress reports shall be submitted by the Executive Engineer at intervals specified by the Chief Engineer. An earth-work progress report should include the following items:

(a) Location of operations. Outline of borrow-pit areas worked. Longitudinal section and cross-section along the embankment.

(b) Moisture data. Moisture content in borrow-pit area, before compaction, and any moisture additions either in the borrow-pits or before rolling. Results of moisture control tests on compacted embankment.

(c) Mixing. Methods of mixing in the borrow-pits and on the embankment.

(d) Materials. Variations in types of materials in borrow-pits, etc.

(e) Rolling. Description of equipment employed. Thickness of layers. Observed behaviour of various types of soils under compaction equipment.

(f) Additional information that may be of use in future design and construction of similar structures.

5-11. (1) Ravines in banks.—Where ravines have formed in canal banks, bunds, ramps, etc., repairs to earth the ravines, holes or "gharas" should be fully opened up to the bottom by digging steps not more than 1 1/2 feet deep in the sides and by removing all the fallen or loose lumps of earth. All bushes, grass, roots, etc., should also be removed from the ravine.

Filling shall be carried out by placing level layers of earth not more than 6 inches deep. The earth in each layer.
should be free from clods, roots, grass, brick-bats and other debris, and it should be compacted with rammers as directed. Before placing a new layer the surface of the layer below should be cleared of debris and loose earth. At the end of a day's work the top layer should be flooded to a depth of 2 inches, and the work should be kept constantly wet, to help its consolidation.

(2) Repairs to earth dam slopes.—To repair slopes of earth dams and rolled-fill embankments higher than 50 feet, the filling in the ravines shall be carried out in layers. The placement moisture content shall be such that by using the method of compaction recommended, the fill in the ravine is compacted to the same dry density to which the rest of the original earthwork had been compacted. Pneumatic tampers shall generally be used for such work where suitable rollers cannot be used for repairing earthwork.

(3) Earth for canal bank repairs.—Wherever channel silt berms exist, earth for repairs shall be obtained from the berms. Only the available amount of silt should be removed, leaving a layer of silt at least six inches thick next to the bank. Cross dowels at close intervals should be left on the berms to permit the borrow areas to silt up. Raising of driving banks shall not be done with soil from the berms.

If no silt berms exist, or the soil obtainable from the berms is not sufficient earth for repairs shall be obtained from the spoil banks, if such banks exist, or from outside excavation. No borrowpits shall be dug on top of the spoil banks, and earth shall be obtained either from back of the spoil or by widening the drainage gaps in the spoil banks, where such gaps exist.

Where there are no spoil banks or berms, earth for repairs shall be obtained by levelling down any high lumps if there be any, or if there are no alternate sources available, from the borrowpits. Borrowpits should be dug as far away from the bank as possible and never closer than 10 feet from the toe of the embankment. Borrowpits for repair work should not be deeper than one foot and should be neatly set parallel to the banks. Also the slope which is formed at the toe of banks by soil washed down from above, shall in no case be dug away.
Sandy and silty clays or cohesive silts shall be preferred for repairs to earthwork. Where possible, the soil used for repairs shall be of the same type, and should have the same properties, as the soil that was washed away where the filling consists of gravel or coarse sand for repairs to canal banks, unless near the toe of the bank, some sandy and silty soil should be mixed with the gravel to form a more impervious mass.
CHAPTER VI
EARTHWORK SLOPE PROTECTION

61. (1) Scope.—This chapter deals with various kinds of protection or pitching employed on earthwork slopes. Specification have been laid out for various methods and materials for slope protection.

(2) Necessity.—Surface protection shall generally be required for both upstream and downstream slopes of an earth embankment to minimise damage from wave action and erosion. In some instances, provision must be made against rodents and burrowing animals. Pitching shall also be provided to protect canal or channel slopes in the vicinity of masonry structures, narrow approaches, and downstream of falls and rapids.

(3) Types of protection.—The common types of surface protection for upstream or water-side slopes are:

- stone riprap, dry-dumped, stone riprap, hand-placed, stone or boulder pitching, dry or grouted, cement concrete paving, welded steel facing, precast concrete blocks, paece brick pitching, sand bags, pichi, farash, sarkanda, or willow mattress.

Various types of stone riprap and concrete paving shall be preferred as a protection for the upstream slopes of all earth dams higher than 50 feet. Paece brick pitching should be used for slope protection upstream and downstream of masonry structures in unlined channels.

Downstream slopes of earth embankments should be protected against surface erosion, wherever specified, by dry stone pitching, layer of coarse gravelly material, or by turfing. In the case of high embankments where the downstream zone consists of rockfill, or boulders, no further downstream slope protection shall be necessary.

(4) Slope berms.—Where specified, horizontal berms shall be provided on the downstream or dry-side slopes of
high embankments in order to reduce the velocity of surface flow running down the slope. The berms should extend along the entire length of the embankment slope, and the width and location of each berm shall be specified in the design. These berms should have a transverse slope to a paved gutter or pitched drain if specified carried along their inner edge, which in turn delivers the runoff to outfall drains.

(Dry Stone or Boulder Pitching)

6.2. (1) General.—Stone riprap or dry stone pitching should be used for protection of slopes of suitable rock or boulders are available in sufficient quantities. Stone riprap or pitching should extend from the maximum water level, including allowance for wave action, down to about 3 feet below the lowest expected drawdown level for dams and dikes one foot below bed level of canals and channels.

(2) Types of stone riprap.—Stone riprap may be dumped or hand-placed. Dumped riprap is cheaper and should be used where stone is plentiful. Its thickness should vary from 18 inches to 5 feet of rock, depending upon the slope, height, exposure, and wave action. Hand-placed riprap may be more economical than dumped riprap in that a lesser thickness may be used. A thickness of 18 to 24 inches of well-laid and durable stone riprap should be sufficient to withstand severe wave conditions.

(3) Stone for riprap.—Rock for riprap or pitching shall consist of boulders and fragments of sound and durable quality and not subject to slaking, solubility, or rapid weathering. The material for dumped riprap shall be reasonably well graded in sizes ranging from 1/2 cubic foot to 1/2 cubic yard, with a maximum of 25 per cent smaller than 1/2 cubic foot and a minimum of 30 per cent larger than 3 cubic feet. Stones for hand-placed riprap or pitching should be quite uniform in size, in accordance with the thickness of riprap specified for a particular job.
(4) Dumped riprap.—Rock for such riprap shall be dumped, preferably mechanically, and graded off in such a manner as to insure that the larger pieces are uniformly distributed and the smaller rock fragments and spalls serve to fill the spaces between the larger rocks and in such a manner as will result in a reasonably smooth surface and a uniform layer of riprap of the thickness specified. Rock pieces larger than 1 cubic yard in volume may be allowed in the riprap, if embedded in place so that the top surfaces are at the established grade for the surface of riprap. The inclusion of objectionable quantities, as determined by the engineer-in-charge of loose dirt, sand, and rock dust shall not be permitted.

When the compacted soils of the underlying layer are of such gradation that there is danger of fines being wash- ed out through the voids in the riprap, a layer or blanket of graded gravel shall be provided below the riprap. Un- less otherwise specified, the thickness of the gravel layer shall be 6 to 12 inches.

(5) Hand-placed riprap or pitching.—Hand-placed rip- rap shall generally be specified for comparatively smaller structures which must be protected from flowing water, stream erosion, or moderate wave action. Unless other- wise specified, hand-placed riprap shall be 18 inches thick, the minimum permissible size of individual stones being 12 x 12 x 3 inches. Also at least 50 per cent of the surface shall be of stones which in depth are equal to the specified thickness of riprap.

Hand-placed pitching or riprap should be of the same quality and appearance as dry rubble. It should consist of stones, which can be picked up and used by one man, laid on edge on a properly prepared and graded gravel bed of specified thickness. Stones which are roughly square or angular shall be preferred to rounded or irregular boulders, and stones of a flat stratified nature should be placed with the principal bedding planes normal to the slope. Joints should be broken as much as possible, and joint openings to the underlying fill should be avoided by carefully arrang- ing the various sizes of stones and by closing the openings with spalls, small rock-fragments, or gravel. The placing methods and selection of sizes must be such as will insure
6.3—MANUAL OF IRRIGATION PRACTICE [Chap. 6.

a pavement of reasonably smooth surface and uniform average thickness.

The bottom or lower band of riprap on the upstream face of an earth dam should rest on a shoulder or berm in the embankment. The bottom course should be formed with headers twice as deep as the other stones and set into the bank in a trench at the inner edge of the berm.

As for dumped riprap, a layer or cushion of graded gravel, 8 to 12 inches thick, shall be provided under the hand placed riprap where there is danger of fines being washed out from the underlying fill.

63. (1) General.—Grouted stone pitching shall generally be used, where specified, for protection of beds and slopes upstream and downstream of structures such as culverts, bridges, falls etc., where swift and turbulent flow is encountered. It is desirable to grout stone pitching or riprap where boulders and heavy sediments are being transported along the bed of the channel.

2. Construction.—Grouted stone riprap shall be similar in quality, and shall be aid, as hand-placed riprap described in Specification No. 6.2. The thickness of stone pitching which has to be grouted shall be as specified, and generally less than that of hand-placed riprap. The thickness of gravel blanket or concrete cushion to be placed under the pitching, if any shall also be specified.

After the main pitching stones have been laid in place, the voids shall be tightly packed with spalls, stone fragments and gravel. All loose surface material shall then be swept away.

3. Grouting.—The pitching to be grouted should then be thoroughly wetted, surplus water being permitted to drip or drain off. In the meantime, cement sand and grout of the specified proportion and consistency should be mixed in a standard concrete mixer. Cement concrete with gravel smaller than 1 inch size may also be used as grout where it
is placed manually. In the case of grouted boulder pitching, grouting should be carried within 3 inches of the top of stones, a surface being given with a trowel.

For smaller jobs, and where the pitching is horizontal or at a flat slope, cement grout may be carried and poured with hand buckets. Care should be taken that no grout is wasted or permitted to draw off, and the batch mixed at a time should be just sufficient to be used before the initial setting of cement.

For large jobs, a grouting pump of a suitable capacity, with an agitator trough shall be used to pump the grout. The grout pipes, valves, etc., shall be kept clean by flushing with water before and after each grouting shift. Great care shall be exercised to maintain proper pressure and to minimize the waste of grout. A wetting agent, or an agent which greatly increase the flowability of the grout shall be added to the mixing water in quantities as specified by the Chief Engineer.

On small level pitching jobs, it may be specified to tamp the surface with wooden tampers, but generally the pitching shall not be disturbed or tampered with after completion of grouting.

Grouted pitching shall be cured by keeping it wet for at least 14 days after the grout has set.

64 (1) General.—Concrete paving shall be some-

slopes of embankments and earth dams of

municipal water-supply reservoirs so that wave action will

not muddy the water. Concrete paving shall also be speci-

fied for earth dams and embankments when suitable rock

for riprap is not economically available.

2. Requirements.—Concrete paving shall provide a

strong non-rigid protective mat, flexible enough to be

capable of adjustment to possible embankment settlement,

and strong enough to resist wave action and temperature

changes. It shall also be strong enough to resist possible uplift from hydrostatic pressure behind the lining resulting from reservoir drawdown. Watertight seals should also be provided, where specified, at joints between slabs, or at the abutment and foundation contacts.
6.4—MANUAL OF IRRIGATION PRACTICE [Chap. 6.

(3) Types:—The concrete pavement may be constructed most economically in square or rectangular blocks. A commonly employed method of construction is placement of the slab either in square sections, or in rectangular strips placed length-wise of the slope, with construction joints formed simply by pouring each section directly against the one previously placed. If required, the slab should be reinforced both ways, and the steel carried continuously through the joints, and the amount of steel being 0.2 to 0.3 per cent of the effective cross-sectional area of the concrete.

Porous concrete may also be specified for slope protection. It is similar to stone riprap in that on the recession of a wave the water can readily drain out through the interstices without building up of appreciable hydrostatic pressure against the bottom of slab.

(4) Constructional details.—The paving should be placed with thickness increasing from top to bottom. On dams and dikes higher than 50 feet, unless otherwise specified, the thickness of paving normal to the slope shall be 12 inches at the top and 24 inches at the bottom of the slope. The location and spacing of joints shall be specified in the design, after considering the climatic conditions, method of construction to be adopted, and type of placing equipment to be used. The spacing for joints length-wise of the slope shall not be greater than 20 feet, and for transverse joints not more than 50 feet.

Where concrete paving is to be placed in square blocks these shall not be larger than 10 feet square. The thickness of the block in inches, unless otherwise specified, should be the same as the dimension of the block, in feet. The blocks should be poured alternately, adjacent blocks being separated by layers of three-mil tar paper or other suitable flexible preformed joint filler.

(5) Drainage through paving.—Where the paving is placed only as surface protection, weepholes with graded gravel backfills, should be provided for drainage and relief of hydrostatic pressure. The cross-sectional area of the weepholes shall be equal to at least 15 per cent of total pavement area. When the paving is placed to provide an impervious blanket, water-tightness should be accomplished.
by the provision of effective seals at the joints, and by the construction of a cutoff extending to an impervious stratum and connected to the paving with a flexible, water-tight joint. Otherwise, the paving should terminate on a berm and against a concrete curb or header which should extend at least 18 inches below the undersurface of the paving.

(6) Placing, curing, etc.:—The concrete mix, water-cement ratio, slump, etc., shall be as specified in the design. Procedure of placing, working, rolling, curing, etc., shall be as laid out for cement concrete in Specification No. 2.3.

65. (1) General.—Slope and bed protection upstream and downstream of canal structures such as, bridges, falls, rapids, regulators, syphons, etc., shall generally consist of dry brick pitching. The details of slope and bed protection for a particular structure shall be specified in its design.

(2) Materials.—Only pucca third class bricks shall be used for dry brick pitching. No kutcha or pila bricks or bats shall be used. However, Jhama or over-burnt bricks and brickbats may be specified for protection of channel bed against scour downstream of a canal fall or other structures.

(3) Constructional details.—Dry brick pitching should be laid with a resultant smooth surface, on bed and side slopes upstream and downstream of bridges, at discharge flumes, and upstream and downstream of falls, regulators, and syphons. Ribbed or cellular brick pitching shall generally be specified for bed and side slope protection downstream of falls, rapids, regulators and syphons designed to work under pressure. Such pitching in the bed shall have the ridges or cell boundaries flush with the bed level.

In all dry brick pitching, the top course shall consist of brick on edge, and the pitching shall be bedded on a minimum of 3 inch thick layer of rammed dry brick ballast or gravel. All bricks shall be laid tightly fitting together
6.6— MANUAL OF IRRIGATION PRACTICE [Chap. 6.

...to provide a stable, yet previous, surface protection mat. The bond of brick pitching shall be specified either in the design or by the Executive Engineer.

(4) Protection of pitching.—All dry brick pitching on slopes shall be supported by masonry or or concrete toe-walls carried to suitable depth below the channel bed. Brick pitching on bed and side slopes shall be protected upstream and downstream by masonry or concrete curtain walls, top of which should be flush with top of pitching.

Where a large area has to be pitched, the pitching shall be divided into square or rectangular units of specified sizes separated by stabilizing masonry walls.

(5) Brickbat pitching of channel beds.—Brickbat and jharna brick pitching shall sometimes be specified for protection of channel beds, especially downstream of distributory falls. Such pitching should be laid horizontal at the bed level, and shall extend to a distance detailed in the design. The thickness of such bed pitching depends upon the size and capacity of the channel, and it shall be specified according to the following table:

<table>
<thead>
<tr>
<th>Discharge of channel</th>
<th>Thickness of brickbat pitching</th>
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<tbody>
<tr>
<td>Up to 25 cusecs</td>
<td>6 inches</td>
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<tr>
<td>26—50 cusecs</td>
<td>9 inches</td>
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<tr>
<td>51—100 cusecs</td>
<td>12 inches</td>
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<tr>
<td>101—200 cusecs</td>
<td>18 inches</td>
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<tr>
<td>201—350 cusecs</td>
<td>24 inches</td>
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</table>

The brickbat pitching shall not be dumped, but shall be properly packed and placed by hand.

6.6. (1) General:—Mattresses woven out of sarkanda, pitchi, or other wild reeds and shrubs shall be used for providing slope protection to canal and river works where other means are not available, or are found to be uneconomical. Such matteresses should be expected to provide a rather temporary protection, and shall be improved, replaced or repaired annually.

(8)
Chap. 6] EARTHWORK SLOPE PROTECTION — 6.7

(2) Construction.—Pilch and sarkanda reeds shall be hand woven or joined together to form mattresses about 6 inches thick, their construction and thickness being subject to Executive Engineers approval. Bamboo mattresses shall be in the form of screens made out of first class bamboos 13 to 14 feet long. The bamboo shall be split into two and tied together with coir or other suitable yarn to form a screen with one-foot rhombus openings.

(3) Installation.—The mattresses shall be rolled and laid over a layer of brushwood or branches placed against the slope, if so specified. Bamboo screens shall generally be used to hold in place such brushwood protection.

The rolled mattresses or screens should be held down by wooden stakes or killas driven vertically into the slope. The size, spacing, and general arrangements of stakes, brushwood, and the mattresses shall be specified by the engineer-in-charge.

6.7. (1) General.—Miscellaneous methods of slope protection, not dealt with in the preceding specifications of this chapter, may also be specified under certain circumstances. These include sand bags, sacked concrete, precast concrete blocks, steel facing, and oil, asphalt or gunite covering turfing, grass, or sod is commonly specified for downstream and outer slopes and infrequently flooded upstream slopes of bunds, dikes, and banks.

(2) Sand bags.—Sand bags shall be specified as a means of temporary protection only. Empty cement bags shall generally be used, and shall only be three-quarters to four-fifths filled with dry soil, and sewn up before being laid in place. Sandy soils shall be preferred for filling the bags. The bags should be placed tightly against each other, where necessary the base of the sand-bag pitching being widened by laying the bags with their lengths normal to the bank.

(3) Sacked concrete.—Sacked concrete riprap may be used to advantage where rock is not available. A dry 1:8
mixture of cement and gravel, should be placed in empty cement jute or cloth bags and the bags sewn up. The bags shall then be placed along the embankment slope, the long dimension of the bag being normal to the axis of the embankment or dam. The bags should be placed compactly against each other, and then permitted to harden and set by sprinkling a small amount of water over them. Directions regarding drainage material behind the riprap, thickness of riprap, etc., shall generally be the same as those for hand-placed stone riprap.

(4) Welded steel facing.—In certain cases where an impermeable upstream face is desirable, such as in rock-fill dams, and where suitable materials are not available for the purpose, welded steel facing may be specified. Such facing shall be made of copper-bearing steel, generally one-quarter of inch thick, and electrically welded plate. The steel-plate facing should be laid directly on a gravel fill, and suitable watertight expansion joints should be placed at specified places. The facing shall also be anchored to the fill as detailed in design drawings, and the exposed surface should be painted with water-resistant paint, if specified.

(5) Turfing.—Where turfing is specified, it shall be planted and maintained according to the procedure described herein.

Turfing shall be carried out by planting sods of any approved type of grass which forms a thick short growth. The sods should be cut in approximately rectangular shapes three to four inches thick and laid so that their edges are in close contact. The sod should be gently rammed till they form a uniform compact mat along the embankment slope. When old surfaces are to be turfed, they should be picked to a depth of about 1/4 inches to give a hold to the sods. Planting should be completed by the beginning of the rainy season, and all patches should be properly looked after till the turf seems to have established itself.
CHAPTER VII
RIVER CONSERVANCY WORKS

71. (1) Object of conservancy works.—River conservancy, control, protection, or training works are built to counter the vagaries of the river channel, and to stabilize its course in the vicinity of a town, hydraulic structures, cultivated lands, etc. Such protection works are planned and built with one or more of the following objects in view:—

(a) To control the meandering and sinuosity of the river and to ensure a stable, well-defined channel.

(b) To reclaim flooded land from the river, either for cultivation or for building purposes.

(c) To protect river banks, property, structures, etc., against erosion and scour by river flow.

(2) Types of river protection works.—The following works or structures are commonly constructed for river training and conservancy:

Bank revetment walls, Reclamation bunds, Spars, or spur dikes, or spur jetties, Guide banks, or Bell's bunds, Pitched islands.

These works may be temporary or permanent depending upon the degree and period of protection desired and the materials and methods of their construction.

(3) Model testing.—For all important works, the suitability of a specified kind of river training work shall be determined by a series of thorough model tests carried out in the Hydraulic Research Laboratories of the Irrigation Branch. For smaller jobs, a method of protection previously recommended by the Hydraulic Laboratories and found suitable for similar situations, shall be adopted if approved by the Chief Engineer.

(1)
7.2—MANUAL OF IRRIGATION PRACTICE [Chap. 7.

7.2. (1) Object.—Bank revetments shall be provided in order to protect stabilized or establish-
Bank Revetments ed river banks, slopes of dikes, etc., against scour, erosion, and wave action. Revetments or revetment walls shall be the means of slope protection employed for all river training works constructed at earth.

(2) Construction.—Bank revetments may consist of any of the methods of slope protection described in Chap-
Construction. ter VI. Whichever method is specified, the materials and method of construction of the revetment shall conform to the specifications pertaining to that kind of slope protec-
tion and to the details laid out in the design drawings.

Stone riprap or paving, dumped, hand-placed or gravi-
ed, shall be most commonly specified, and generally dry brick pitching shall not be permitted.

Staking and bushing, which is another type of revet-
Staking and bushing, ment commonly used, is described in Specification No. 7.3.

(3) Stone apron for bank protection:—Where the banks are subjected to deep scour, revetments are placed in the form of a horizontal stone apron. As the bed is eroded away from below the apron, it is automatically launched by its own weight into a stable position along the revet-
(3) Stone apron ment slope.

The depth of deepest scour below the maximum water
level should be ascertained before the apron is planned. The revetment along the sloping bank should be carried down to the horizontal bed, and the apron should then be ex-
tended into the channel along the bed for a distance at least 1.5 times the depth of maximum scour. The apron shall be laid at low water before the commencement of flood season or it may be laid by aid of pumping, where found economical. The average thickness of the apron should be at least 1.25 times the thickness of revetment pitching for gentle waters, and at least 1.5 times the revet-
ment thickness for turbulent waters.

The quality of stone and the method of placing stone pitching for the apron shall conform to paras (3) and (6)

(2)
of Specification No. 6.2, and as directed by the Executive Engineer.

(4) For other details of design.—Instructions laid out in "Design of weirs on permeable Foundations", C.B.I. publication No. 12.

73. (1) General.—Staking and bushing is generally employed to construct temporary spurs. Staking and Bushing. Definite specifications for each job shall be issued by the Executive Engineer in-charge of river training works. Staking and bushing along river banks as a means of slope protection shall conform to Specification No. 6.6.

(2) Brownlow's weeds.—Brownlow's weeds consist of brush wood and tree branches attached to a series of lines, the lines being fastened to anchor blocks upstream in the river bed and supported downstream by a buoy. The branches and brush wood interrupt the river flow and encourage silting, thus forming a more permanent spur and stable bank.

(3) Hurdle dikes.—These consist of sarkanda or brush wood mattresses placed along the bed and slopes, being lowered in place weighted with stone. The mattress should be manufactured from wattling brush upon poles, spaced about 8 feet apart, lapped together, and fastened by spikes and wire to give the required width.

The hurdle consists of a row or parallel rows of piles driven through the mattress at about one-third of its width from its upstream edge. The piles should be driven singly or in clumps, as necessary, the piles at river bed level being driven 8 feet to 10 feet apart. Tops of the piles should be kept nearly 20 feet above low water level, and the piles should be driven nearly 15 feet into the bed, with the larger end down. The outer rows of piles should be connected by wattling of fine brush, thus forming a permeable barrier. These permeable dikes encourage silting on both sides of the spur, and can be a great help in reclaiming a fore shore on which permanent reclamation bunds can be planned and built.
7.4—MANUAL OF IRRIGATION PRACTICE [Chap. 7.

7.4. (1) **Purpose:** Where specified, reclamation bunds should be constructed to close or cut off reclamation bunds flow from the main river into subsidiary or branch channels and to reclaim the area thus protected by proper drainage.

(2) **Location:** The reclamation bund should be located at right angles to the direction of flow of the major branch channels, the body of the bund being at least 200 feet away from the erosive and scouring flow of the main river. The bund should be keyed into, the ridge of a stable midstream island well protected by vegetation. The bund should provide ample coverage to the area to be protected, and should extend beyond the limits of this area, if necessary.

(3) **Design and construction:** The top of the bund should be about 4 feet above the maximum flood level determined by the Executive Engineer. A cutoff trench, 6 to 8 feet wide at the base, should be dug down to the ground water level or to an elevation designated in the design Embankments of all bunds higher than 25 feet shall be properly designed to utilize the locally available soils and to provide a structure able to withstand the maximum flood water pressures.

The upstream slope of the reclamation bund shall be adequately protected against erosion and wave action. Pilch or sarkanda mattresses shall generally be specified for the purpose and it shall conform to Specification No. 6.6. High reclamation bunds of a permanent nature, shall have stone riprap as upstream slope protection.

(4) **Cross spurs:** Where the bund meets ridges between the branch channels, 300 to 500 feet long cross spurs should be constructed on the ridges, both on the upstream and downstream sides of the bund. These cross spurs should be at right angles to the bund embankment, and the length should be such as to encourage maximum amount of sifting on both sides of the bund. The design and construction of spurs shall conform to Specification No. 7.5.
Chap. 7.]

RIVER CONSERVANCY WORKS

(5) Drainage.—The marshy ground on both sides of the bund shall be drained, if necessary, by digging escape channels or drains. The drains should have enough capacity to drain the area in the desired period of time, and they shall lead either into the main river or into any other depression or channel considered suitable for the purpose.

75. (1) Purpose.—Spurs and groynes are built to regulate and direct the current of a river by contracting the flow area and causing scour and lateral deposition of material behind or in between the spurs and spur dikes. Spurs are sometimes used to induce a deep river channel on the side protected by spurs. This is possible, because deep scour is caused by swirls near the river-side end of the spur.

(2) Types of spurs.—Spurs may be of a temporary or a permanent nature. Temporary spurs can be sub-divided into the following types:

(a) Ordinary spurs.—These consist of branches of trees, brushwood, or jungle laid in alternately with layers of stone. Plenty of stone, necessary to hold down the branches and as directed by the engineer-in-charge, should be used. Such spurs are cheap, permeable, and capable of sinking without breaking up.

(b) Sandbag and brushwood spurs.—Where plentiful stone is not available at the site, an abutment is formed by digging a trench which is staked and lined with brushwood mats. This enclosure is then filled with closely packed sandbags. The stakes should be properly braced, and bags well founded and consolidated in their places. Such spurs usually need replacing after one flood season. Wooden sheet-piles or flanks may sometimes be used instead of stakes and brushwood mats.

(c) Permeable stone spurs.—These spurs consist of dry stone dikes, the stones being well packed into stable positions. Such spurs slacken and retard the flow and thus encourage silt deposition along the banks.
Spurs of a permanent character are called groynes. Groynes are dikes of impervious earthwork and rockfill constructions, the faces invariably lined with hand-placed stone pitching for dry rubble masonry. The spur heads shall preferably be armoured, and aprons provided around the body of the spur.

(3) Shapes of spurs.—Spurs and groynes shall have one of the following conventional shapes, the selection of the shape being subject to approval of Executive Engineer in-charge of river training works:—

(a) Straight spurs.
(b) Hockey spurs.
(c) Inverted hockey spurs.
(d) Point spurs.
(e) T-head spurs.

(4) Location and layout of spurs.—The location and layout of each spur shall be designated by the Executive Engineer. Whether the spurs should be constructed along one bank or along both banks, and the suitability of each site shall be determined, either from the experience of training works on other rivers or at other sites or from observations and model tests carried out in the hydraulic laboratories.

Spurs and groynes should be built projecting into the channel from the banks, either perpendicular to, or making an angle with the bank face. They should be at right angles to the direction of current or flow, and the length of the spur should be at least one-fourth the length of the bank to be protected by it.

7.6. (1) Purpose:—Guide banks are built to control Guide bank's beds of the river section and to guide its flow up to and under bridges over weirs, and through diversion dams. Guide banks are specially necessary when the river has a sandy bed, and has a tendency to enlarge its section by seeping its bed without any appreciable rise in surface level.
(2) Layout and alignment of guide banks.—The following general rules shall be observed when planning guide banks:—

(a) Guide banks shall always be planned in pairs, and unless otherwise specified shall be symmetrical in plan.

(b) The guide bank embankment shall be curved inland near both the ends. The upstream curvature shall be much more than that at the downstream end, the upstream curve turning through an angle of about 135° and the downstream curve through angle of about 45° from the main body of the guide bank.

(c) The shape of guide banks should be such as to provide a smooth entry, smooth flow parallel to the banks, and a smooth exit, and no spurs shall be provided projecting from the guide banks. At the same time, widening should not be too excessive, otherwise it would encourage the formation of islands.

(d) Guide banks should be built at a site, where there are no subsidiary channels, or tributaries flowing parallel to its alignment.

(e) Sufficient still-water area should be provided on the land-side of the guide bank. Separate reclamation bunds should be provided to insure proper siting of the still-water area.

(3) Section of guide banks.—The height of guide banks should be such that its top is above the maximum expected afflux or pond level and a free board of 4 to 5 feet should be permitted. The embankment should be constructed of earth materials available on the apron side, the slopes being decided upon after studying the properties of available soils. The top width shall not be less than 10 feet, widths up to 30 feet being provided where necessary.

In its design and construction, the specifications laid down for earthwork in Chapter V shall be adhered to.
7.7— MANUAL OF IRRIGATION PRACTICE [Chap. 7.

(4) **Slope protection.**—The river-side slopes of guide banks shall be protected with stone pitching or in any other suitable manner approved by the Chief Engineer. Slopes on the land-side shall be well compacted and protected if directed by the Executive Engineer.

Stone pitching shall conform to Specifications No. 6.1 and 6.2, and should extend at least 3 feet above the High Flood level. Pitched aprons for guide banks shall conform to para (3) of Specification No. 7.2.

Slope pitching and pitched apron should also be carried throughout the curved portions of the bank. The upstream end or the head of the bank should be made impregnable by heavy slope protection. The width of the apron should be widened along the impregnable head, and the thickness of slope pitching should be 25 per cent more than that along the body of the bank.

(5) **For all other details of design.**—Instructions laid out in "Design of weirs or permeable Foundations", C.B.I. Publication No. 12.

7.7. (1) **Purpose.**—Pitched islands may be used for the following purposes:

(a) Training the central portion of a river upstream of a weir or diversion dam.

(b) Relieving the intensity of flow close to the marginal bunds, river banks, and guide banks.

(c) River training in the vicinity of control points, such as bridges and weirs.

(d) Improving river channel for navigation.

(2) **Location and design.**—The location, orientation, shape, size and height of the pitched island shall be decided after thorough model tests and shall be based upon the experience from other river training projects. The slopes of the island shall be adequately protected by heavy stone
riprap conforming to Specification No. 6.2. The island shall be constructed during the low flow season, and should be totally complete before the rainy season sets in.

(3) Alterations in design.—The behaviour of the river around the pitched island, and its effect on other river training works shall be continuously observed, and suitable alterations shall be carried out in the shape of the island if found necessary. Such alterations shall be subject to the Chief Engineer’s approval.
CHAPTER VIII

METALLING AND ROAD WORK MATERIALS

8.1. (1) Materials for soling:—Materials for soling shall consist of stone, bricks, or brickbats, as specified for each road work job.

Where a soling coat of stone is specified, the source and quality of stone shall be subject to the approval of the Executive Engineer. All stone shall be sound and free from decay and weathering. No stone shall be less than 8 pounds in weight, and its thickness shall not be greater than the proposed depth of soling. The quantity of smaller stones, spaws, etc., shall be just enough, and no more, to fill the interstices after the larger stones have been hand placed.

(2) Bricks for soling:—Bricks for soling shall comply with specifications for third class bricks in every respect, except that the colour shall be immaterial and that they shall be more fully burnt than building bricks. The bricks shall be of reasonably good shape so as to give close joints, and shall have straight arries. Brickbats, where specified, shall not be less than half a brick in size, and shall preferably be overburnt.

(3) Stone metalling:—Metal for road-work shall be broken from hard, durable compact and tough stone of uniform texture. The source and quality of quarried stone shall be subject to the approval of the Executive Engineer. Where metal is to be broken from boulders, no boulder shall weigh less than 8 pounds. Boulders composed of coarse, silicious grains shall be preferred.

(4) Stone metal sizes:—Stone metalling shall be broken to specified sizes. The following sizes shall be commonly specified:

(a) 24-inch size: Stone metal of this size shall all pass a 2-inch internal diameter ring in one direction, and no dimension of any stone shall be greater than 3 inches.

(b) 2-inch size: Stone metal of this size shall all pass through a ring of 2-inch internal diameter in one direction, and no dimension of any stone shall be greater than 24-inches.
8.2—MANUAL OF IRIGATION PRACTICE [Chap. 8.

(c) 1/2-inch size: Stone metal of this size shall all pass through a ring of 1/2-inch internal diameter in one direction, and no dimension of any stone shall exceed 2-inches.

(d) Stone metal when screened through a screen made of 1-inch diameter bars spaced 3/4-inch centre to centre, shall yield not less than 5 per cent and not more than 10 per cent by volume of fine material.

(3) Gravel or bajri, grit and sand:—Gravel or bajri, grit, and sand needed for road work shall comply with Specifications No. 1.5, 1.7, and 1.8 regarding general physical properties.

Grit for bituminous road work shall consist of fines or screenings from stone metal, or gravel of specified sizes. It shall be free from dirt, clay, organic matter, and soft or decayed stone. The quality and source of grit, gravel, and sand shall be subject to the approval of the Executive Engineer.

8.2. (1) General:—Materials collection and stacking operations shall consist of quarrying and Materials handling, collecting stone for soling and metal. Breaking, screening, conveyance from quarry, and stacking by the side of the road where it is to be used, in the manner defined in this specification.

(2) Stone metal stacking:—Before stacking, metal should be screened to the required gauge and freed from all earth, rubbish, and foreign matter. It shall be stacked by the roadside, entirely clear of formation width, leaving only such gaps for drainage as ordered by the engineer in charge. The stacks shall be made on flat ground, or on berms provided for the purpose and shall be laid to the template supplied by the Executive Engineer. Metal stacking shall be commenced at the end furthest from the source of supply and progress continuously towards the nearest point.

(2)
Materials shall not be dumped on the travelling surface of the road and materials in excess of the requirements of a furlong shall not be stacked in that furlong. Any excess quantities should be removed to places where required, before the quantities are measured. Stacks should be laid parallel to the road, and about 30 feet from its centre line. In order to allow for loose stacking stacks shall be 13-inches high, but shall be measured as one foot.

(3) Stacking soling materials:—Stone for soling shall be stacked separately from stone metal, but in a manner similar to that described in paragraph (2). Soling material and stone metal, or when materials for two coats have to be stacked shall be stacked on opposite sides of the road, unless different instructions are issued. Similarly, materials collected for petty repairs shall be stacked on the opposite side to that where the materials for renewals are stored, and if so directed, dimensions of the heaps shall be such as to distinguish them from the metal collected for renewal work.

Bricks for soling shall be placed in stacks about 90 feet long and two bricks deep, and of such a height that each stack will contain enough bricks for soling a 100 feet stretch of road. Bricks shall not be dumped in heaps by the roadside, nor shall they be stacked in lots of one or two thousand bricks.

83. (1) General.—Road formations or sections shall consist of compacted layers of stone, brick, or other hard materials laid over finished and completed ground or embankment surface. The surface of the pavement may be finished with fine compacted aggregate, asphalt or bituminous mat or by a cement concrete pavement. In all cases, detailed specifications regarding formation width, pavement width, side slopes in cutting and embankment, drainage arrangements, the thickness of various layers, camber, surface slopes, etc., shall be supplied with the designs by the Executive Engineer.

(2) Soling:—Soling shall form the first layer of hard material placed on natural or formed ground surface. The
8.4—MANUAL OF IRRIGATION PRACTICE [Chap. 8.

Materials for soling have been discussed in Specification No. 8.1. Soling coat shall be laid and consolidated according to Specification No. 8.4.

(3) Metalling.—The main wearing coat of the road formation shall generally be formed of water bound macadam, or a layer of hard stone metal consolidated over the soling coat, or previous metalling. Requirements of the stone metal are laid out in Specification No. 8.1, and the consolidation of water bound macadam shall conform to Specification No. 8.5.

(4) Tar surfacing.—Road surfacing, where specified, shall be provided by a layer of tar and grit, or an asphalt mat. Where equipment is available pre-mix asphalt and fine metal surfacing may be specified. Tar surfacing shall conform to Specification No. 8.6.

8.4. (1) Trenching:—Unless otherwise directed, soling coat shall be laid in a trench, the depth of which shall normally be equal to the depth of soling. The trench should be dug so as to have, after it has been rolled and compacted, a profile of the same camber as the finished road surface. Before laying the soling, the trench should be sprinkled with water and rolled and finished with a bullock or steam roller as ordered.

(2) Stone soling:—Soling coat consisting of stones or brickbats shall be hand-placed, closely packed, and wedged, with the interstices filled with smaller pieces of the same material. Soling shall be laid to the same camber as the road surface and the stone projections should be dressed off with a hammer, if necessary.

(3) Brick soling:—Bricks for the soling coat shall be laid on edge with close joints, being set together with wooden mallets. If specified, masons shall be employed for the job. All joints shall be evenly spaced, parallel and at right angles (unless it is specified that courses be laid obliquely) to the centre line of the road, with adjacent layers breaking joints. If specified by the Executive Engineer,
the soling shall be laid either to project 6 inches beyond the edge of the metalling, or with a row of bricks placed upright to project from the face of the soling by an amount equal to the proposed thickness of metalling so as to act as a lever for it.

After the bricks have been laid, a one-inch thick layer of sand or earth shall be spread over the soling so as to fill all the joints between the bricks. This layer of earth shall be allowed to remain as a protective covering to the soling until the time of metalling. Traffic can be allowed, at the discretion of the Executive Engineer, over the earth-covered soling.

(4) Rolling.—Soling shall be finished to a smooth surface by rolling with a steam or diesel roller. The rolling shall be carried out either by sprinkling water, or over dry soling, as directed by the engineer-in-charge.

8.5. (1) Scope:—These specifications shall apply to the construction of water bound macadam wearing coat, involving the preparation of old surface, laying and spreading the metal, and rolling and consolidation.

(2) Treatment of surface:—Before spreading the metal, old surface, whether of soling or previous metalling, shall be thoroughly cleaned. Surface of old metalling shall be roughened by cutting ridges and scoring lines about 14-inch deep and 12 inches apart. Where scarifying is specified, the existing surface shall be scarified down to the thickness of the last wearing coat, or to such depth as may be directed. The metal loosened by scarifying may be re-used after screening, if permitted by the Executive Engineer. Scarifying shall be carried out either by picks or by means of a scarifier attached to the road roller.

(3) Camber and super-elevation:—Unless otherwise specified, the camber of all metalled road surfaces shall be 1 in 72, that is, the height at the centre above the outer edges shall be 1 inch for each 12 feet width of road. The section of the profile shall be an arc of a circle drawn through the outer edjes and the centre.
8.5—MANUAL OF IRRIGATION PRACTICE [Chap. 8.

Superelevation shall always be provided at all curves of 10 degrees (690 feet radius) and over. Where superelevation is provided no camber shall be given. Instead a cross-grade or uniform slope equal to the superelevation from edge to edge of formation, shall be provided. Details of superelevation, curves, and transition from camber to cross-grade shall be supplied with the designs of road structures.

(4) Preparation for metalling:—Before spreading the metal, and when the old surface has been roughened and brought to the required camber, two parallel bands of clay paddle, 6 inches wide and 6 inches deep shall be built along the outer edges of proposed metalling. These bands should be strong enough to prevent the new metal from spreading as well as to retain the water used in consolidation. A 12-inch width of bern should be built up at the same time to act as backing for the bands. If brick soling is carried up along the edges to form a kerb, as mentioned in para (3) of Specification No. 84, the boundary bands may be omitted.

(5) Spreading metal:—New metal, as well as scarified metal, if any, shall be carried from the stacks and spread evenly over the prepared surface to make up the full coat required. If specified, metal shall be spread in more than one layer to the thickness laid out in the design.

Metal shall be spread between the boundary bands to the correct section and camber of templates approved by the Executive Engineer. Three templates shall be used, placed approximately 23 feet apart. The top layer of the metal shall be packed and dressed between the templates. The templates shall be removed in such a manner that the last two templates are always in place to level up the new length. The void created by removal of a template shall be filled with new metal and packed by hand.

When remetalling or repairing old roads, inclines or level parts in each length of the road shall be truly maintained. Where the new metal terminates, no sudden steps should be left and the junction of the two surfaces shall be made quite perfect and smooth. Similarly, around value boxes, culverts, etc., there should be no rise or unevenness of surface.
(6) Rolling and consolidation:—After spreading has been completed in one length, the metal shall be dry rolled until it is well compacted and there is no appreciable movement in the metal when walked upon, or no appreciable wave in front of the advancing roller. Rolling should commence at the edges and continue towards the centre. When this initial dry rolling is completed, the metallising shall be thoroughly watered and kept saturated and the rolling continued until the metallising is consolidated to the satisfaction of the Engineer-in-charge. Satisfactory consolidation shall be checked, by passing the roller over a piece of metal of the size of a walnut. If the stone is pressed into the surface, the consolidation shall be considered incomplete, and if the stone gets crushed the metallising shall be considered as finished and complete.

(7) Bairi blindage:—Bairi blindage or binder shall be used for filling the interslices of metal and for forming a smooth surface. When consolidation is practically complete, binding material or bairi shall be spread in a layer of even thickness and the watering and rolling continued to such an extent that the binding material is formed into a slurry and forced into the interslices. The quantity and quality of blindage to be used shall be subject to the approval of the Executive Engineer. No earth or other material shall be mixed with or spread over, the metal before, during or after the consolidation.

After consolidation, the metallising coat shall be kept watered for one week.

(8) Berms.—Work on making up berms shall be, at no time more than 2 furlongs behind the consolidation work. Berms should be made up to full formation width, with straight edges, and properly dressed, side slopes.

8.6. (1) General:—The surfacing shall be laid, where specified, as soon as the water bound macadam surface is sufficiently dry. If traffic is moving on the newly consolidated macadam surface, the first coat of tar shall not be delayed for more than 14 days after completion of the wearing coat. Except during summer, the tar should be applied during the warm hours of the day.
(2) Cleaning.—Preparatory to application of tar or asphalt, the road surface should be thoroughly cleaned so as to remove all dust, mud, droppings, etc. All dust and dried-out material should be swept with brooms, and all mud droppings, etc., being loosened with wire brushing. Once cleaning and surfacing operations start on a portion of the road, all traffic should be diverted from that part of the road.

(3) Tar boiling, spraying, etc.—Road tar, shall be heated in tar boilers supplied by the Irrigation Branch. Before pouring, the tar shall be heated to its boiling point (between 250° and 270°F), the temperature being checked with a thermometer. If the boiler is equipped with spraying apparatus, heated tar shall be sprayed direct on to the cleaned road surface. If spraying equipment is not available, the tar shall be poured from special cans with broad pouring nozzles. The tar shall be evenly spread in a coat of uniform thickness. Special wire brooms or squeegees shall be used for spreading the tar evenly.

Unless otherwise specified, where a road surface is tarred for the first time, 0.25 cwt of tar shall be used per 100 square feet of road surface, provided that this quantity shall be increased by 15 per cent where the road being tarred has been metallated with quartzite or similar stone. For all subsequent coats 0.10 cwt of tar shall be used for 100 square feet.

(4) Road tar specification.—All road tar or asphalt shall conform to the specifications of the Punjab P.W. Department, B and R Branch for that material.

(5) Gritting.—Immediately following the application of road tar, grit of a size and in quantities specified, shall be spread on the hot tar coat. Grit shall be carefully spread in a uniform layer, excess heaps being brushed into low spots with a broom.

Unless otherwise specified, where a road surface is tarred for the first time, the grit used shall be of 3-inch size, 2 cubic feet being used per hundred square feet. Where the road has been metallated with quartzite or similar stone, the quantity of grit shall be increased to 2.5 cubic
feet per hundred square feet. For all subsequent coats of tar, the grit used shall be of 3/8-inch size, 1.25 cubic feet being used per hundred square feet of surface. The grit shall conform to Specification No. 8.1 regarding quality and size.

(6) Rolling:—Immediately after gritting, wherever possible, and in any case not later than three hours after, the surface shall be rolled by a road roller, so that the roller passes at least six times over each portion of the road. The road should not be opened to traffic until the rolling is completed and the grit firmly embedded.
CHAPTER IX
WELLS AND CAISSONS.

91. (1) Scope:—This chapter deals with open wells and caissons, pneumatic caissons, and drilled wells, and the methods of their construction.

(2) Open wells:—Open wells may be used for water-supply or for carrying foundations of structures to suitable strata. Wells for foundations are akin to open caissons, gow caissons, etc. Pneumatic caissons are dealt with separately in Specification No. 96.

(3) Methods of construction:—Wells may be either dug, bored, drilled, or driven. Large size open wells which have to be lowered to shallow depths through comparatively soft soils are usually dug by manual labour or semi-mechanical means, such as "orange peel" or "clam shell" buckets attached to the boom of a convertible crane. Bored wells are those where the excavation is made by the use of either hand or power augers. Drilled wells are those where the excavation is made by either percussion or rotary drills and the excavated material is brought to surface by means of a bailer, sand pump, suction bucket, hollow drill tools, or by hydraulic pressure. Driven wells are those constructed by driving a casing, at the lower end of which there is a drive point.

(4) Well finishing:—Open wells for water supply and irrigation may be divided into the following types from the stand point of finishing.

(a) Unlined or kutcha wells.—Such wells are shallow pits, 10 to 12 feet deep, dug in stable pervious soils where the ground water table can be tapped within this depth.

(b) Pervious lined wells:—Such wells have dry bricks or stone lining or stemming with open joints, resting on a curb. Such wells are also used for shallow depths. To avoid flow of said surrounding the lining, the space behind the lining should be packed with brick ballast of size 3/4-inch to 1-inch.

(i)
9.2—MANUAL OF IRRIGATION PRACTICE [Chap. 9.

(c) Impervious lined wells:—Such wells have a comparatively impervious lining of brick-work or stone masonry in cement or lime mortar, plain or reinforced concrete, or precast concrete blocks or sections. Such wells are sunk to depths ranging between 15 and 80 feet, specially where water-bearing strata are available in this range. Water seeps into the well, either through the open bottom or through a pipe sunk to a greater depth.

9.2. (1) General:—These specifications shall apply to open wells used for water-supply, irrigation, or foundations. Such wells consist of a curb which functions as the cutting edge during lowering operations and later as a foundation for the well lining, wall, or steining.

(2) Well curbs:—Well curbs shall be made of wood, iron or reinforced concrete, and it shall be specified in the design drawings.

Wooden well curbs should be made of hard and durable wood, such as Kikar, Shisham, Sai, or Tamarind, which would not rot due to continuous immersion in water. The wooden curbs shall be made of 2 thicknesses of wood for wells 6 feet in diameter and under, and of 3 thicknesses for larger wells, strongly dove-tailed and dowelled together and secured by iron bolts, as detailed in the design, or as ordered by the Executive Engineer. When the rings cannot be made of one piece across the width, the concentric rings shall break joint, the upper and lower courses to be alternately one-third and two-thirds of the whole width.

For larger diameter wells, reinforced concrete or iron curbs will be more economical. The iron curb shall generally be made of 6 to 8 triangular frames made up of angle irons covered by 3/8-inch to 1-inch thick plate. Curbs for large size wells should be provided with a suitable cutting edge. The curb should be made one inch greater in diameter than the steining it has to support.

(3) Well steining or lining.—The steining shall be of brickwork, stone masonry, or precast concrete blocks or
Unless otherwise specified, stonework in first class brickwork shall have the following thickness:

- Wells 10 feet in depth or less: 13\frac{1}{2} inches
- Wells from 10 to 15 feet in depth: 18 inches

and for every additional seven feet of depth, increase the thickness by 3 inches.

In the case of brickwork, the cross-joints must be truly radial. It is desirable to have specially-moulded bricks for well-steining, but such bricks, if required, shall be so specified.

Stone masonry for stonework shall consist of rubble masonry laid in 1:3 cement mortar, with a facing on the inner side of stones dressed back true and secure for 3 inches from the face on beds and joints. Through stones shall be placed 5 feet apart in each course, care being taken not to place the through stones of successive courses one above the other. Joints on the inner face shall not be thicker than 1 inch. The backing may be of uncoursed rubble well bonded to the facework.

(4) Tie-rods.—Where specified, the curb will be secured to the stonework by iron tie-rods or holding-down bolts. Tie-rods shall be threaded at both ends and secured to the well curbs through holes drilled in the centre of the curb by nuts and washers. Unless otherwise specified, tie-rods shall be 3/4-inch diameter and in ten feet lengths, placed not more than five feet apart circumferentially measured. It shall be specified, whether the upper end of the tie-rods shall be threaded through iron plates or through a 3 inch 3/8-inch flat iron bond ring temporarily secured to keep the rods vertical and immovable while the stonework is being built around them. The upper nuts on the tie-rods should be secured down to press against the top of the stonework.
9.3. (1) Scope.—These specifications shall apply to the procedure for sinking open wells for foundations or water supply. The curbs and steining shall conform to the general conditions laid out in Specification No. 9.2.

(2) Excavation.—Open excavation in the form of a circular or rectangular pit shall be carried down to the ground water level or to the bottom of clay or non-water-bearing strata whichever is higher, before the well curb is laid. The pit should be 2 to 2½ feet larger in diameter than the curb or steining.

Where it is necessary to sink well-foundations in water, unless otherwise specified, an island of earth shall first be formed at the well site, the island should have a diameter of at least 10 feet more than the outside diameter of the well to be sunk. The soils forming this island must be free from stones, bricks, or other hard materials which are liable to impede lowering of the well. The island shall be brought up at least one foot above the water level, before the well curb is laid. If so directed, the island slopes and sides shall be adequately protected against erosion.

(3) Laying the curb and steining.—The well curb shall be laid when soft soil or ground water level is reached. The curb shall be levelled truly, and placed in exact position before the steining is commenced.

Masonry of the required thickness should then be built on the curb to a height of 8 to 10 feet above the ground level. The steining should be carried up truly vertical and central over the curb, leaving the outer half inch margin mentioned in paragraph (2), Specification No. 9.2. If plastering of the outside face of the lining is desired to facilitate sinking, it shall be so specified.

(4) Sinking.—After the lining has been built up to a height mentioned above, a temporary leading platform shall be constructed on top of the steining. This platform should be built after the mortar in the masonry has set and the
Chap. 9.]

WELLS AND CAISSONS

Steining is sufficiently strong to withstand loading and accidental shock. Load may be applied in the form of gunny bags filled with earth, or in any other manner, subject to the approval of the Executive Engineer. The load should be placed on the outer edges of the platform, leaving sufficient clear space in the middle for lifting the excavated material by means of a pulley arrangement.

Sinking should be facilitated by excavation of soil inside the well and below the curb. Where possible, this may be done by digging and scooping with "kassies", shovels, or spades, and loading the excavated soil in a big basket which is pulled out by the pulley arrangement. On large scale jobs, where the wells have to be lowered to great depths and substantial flow of water is encountered, excavation by a "jham", dredging, pumping or bailing may be resorted to if permitted or ordered by the Executive Engineer.

The well must be sunk perfectly vertical and in the exact position shown in the plan. Three or four plumb bobs should be frequently suspended around the interior of the well to ensure the accuracy of sinking. Should any can: be observed during sinking, it must be immediately corrected by excavating or dredging under the high side and shoring up the well, taking care to use timbers of sufficient size to distribute the pressure. The load on the platform should also be shifted, as necessary.

(5) Completion.—When the curb with steining reaches the prescribed level, or strata, the space around the steining should be filled with clay puddle. The clay should be consolidated by ramming and watering in successive layers of about one foot depth.

If the steining splits during the sinking operation or within 6 months after completion, and, in the opinion of the Executive Engineer, be unsound, it shall be dismantled as a whole or in parts according to circumstances and then properly reconstructed and repaired.

Foundation wells and those that are accessible to flood waters shall not be left partially sunk during the rainy or flood season.
9.5. (1) General.—Caissons for foundations of bridges, building, and other heavy structures can be divided into three general types; box caissons, open caissons, and pneumatic caissons. These specifications shall apply to box and open caissons only, pneumatic caissons being treated separately in Specification No. 9.6.

All caissons have one characteristic in common with each other and with foundation wells; they form a permanent shell for, and an integral part of the foundations. Caissons may be made of timber, metal, or concrete.

(2) Definitions.—A "box caisson" is open at the top and closed at the bottom, while an "open caisson" is open both at the top and bottom. All open caisson is very similar to a foundation well, but it may be bigger, cellular in structure, and rectangular in shape as compared to a well. Caissons differ from foundation wells in that they are built away from the site, then towed or floated to the exact position and sunk in place.

(3) Box caisson.—A Box caisson should be used where no excavation is required, or where the caisson has to be placed on piles.

The box caisson should be constructed on the river bank or water-edge, then towed to the proposed site and sunk. Sinking can be facilitated by letting some water into the box, and also loading it with ballast, masonry or concrete as desired. Box caissons shall not be used where the depth of water is greater than 40 feet, or the waters are swift and turbulent, or where properly trained operators and workers are not available for this kind of specialized work.

(4) Open caissons.—Open caissons shall generally be specified for use where excavating is to be done through water and the caisson has to be sunk through subaqueous soil. Open caissons can be further classified as (a) single-wall open caissons, (b) Spherical open caissons, and (c) open caissons with dredging wells. All open caissons should be provided with proper cutting edges.
Where little or no sinking is required or where the material to be sunk through is very soft, rectangular single-wall caissons made of thoroughly caulked timber framework of 12 inch x 12 inch timbers should be used. Material free within the caisson should be removed by any suitable means and where necessary, water-jets should be used to facilitate sinking. After the caisson reaches its final position concrete should be deposited through the water, if necessary, to a depth of at least 4 feet, to harden and form a plug at the bottom. The caisson should then be dredged or pumped dry and filled with concrete or masonry, as specified. If it is desired that the caisson should not extend above low water, a cofferdam should be built on top of the caisson to keep the flood waters out of the working space.

(5) Details.—Details of caisson design, construction, and sinking, etc., shall be specified for each particular job, and the Chief Engineer’s approval shall be obtained before a typical kind of caisson is specified for foundations of a structure.

9.6. (1) General.—A caisson open at the bottom and closed at the top, in which compressed pneumatic caisson air is utilized to keep water and mud from coming into the box, is called a pneumatic caisson. These caissons shall generally be specified for pier foundations, where it is not practicable to dig through wet ground in the open in order to reach rock or other suitable stratum below the main excavation.

(2) The caisson.—A pneumatic caisson generally consists of a working chamber 6 to 7 feet high, surmounted by a crib and cofferdam, the crib being filled with concrete except for the working “shafts”. The working chamber should be air and water-tight, the shafts with suitable airlocks being used as inlets and outlets for men and materials. The caisson should also be fitted with a suitable cutting edge. Pneumatic caissons shall be made of timber, concrete, or steel, according to the designs supplied.

(3) Sinking.—The site should be cleared of mud and soft deposits, and levelled. In swift streams with soft deposits, the bed on the upstream side of the caisson should
be properly protected against scouring and undermining by paving with sand bags, as deemed necessary by the Executive Engineer.

The caisson should be loaded to have just enough weight to keep it sinking as fast as the materials are excavated from under the cutting edge. Excavation should be carried on continuously without letting the caisson stop at one elevation. Material should be excavated about a foot, somewhat deeper in clays, below the cutting edge, leaving a one foot wide bench along the cutting edge. The material under the cutting edge should then be removed, and the air-pressure reduced enough to let the caisson settle to the bottom of the excavation. When passing through hard strata or boulders, it is important that the excavation should be made amply wide so that the caisson will not jam.

The excavated material should be removed by buckets working through air locks, or by a blowout pipe. Sandy materials can be economically removed through the blowout pipe under air-pressure. But clays, rocks, and boulders should be removed by buckets.

Frequent checks should be made to see if the caisson is sinking vertically. If any cant is discovered, the caisson should be corrected plumb by undercutting the higher side and banking the other side.

(4) Concreting.—When the caisson reaches bedrock or other suitable strata, the working chamber and shafts should be cleared of equipment and loose materials, and then filled with concrete of specified quality. The pier or other superstructure should be started within the cofferdam at the top of the crib, the cofferdam being removed when the structure is complete. The caisson and crib remain as integral parts of the permanent foundations.

(5) Working limitations.—The pneumatic caissons shall not be used for depths of over 119 feet below water level, nor shall air pressure greater than 50 pounds per square inch be employed.
Chap. 9] WELLS AND CAISSONS —8.7

Special rules and precautions regarding the selection of personnel for working under air pressure, the length of shift, the rate of decompression, provision of a hospital compression lock, etc., shall be specified by the Chief Engineer and shall be strictly complied with at the time of construction.

Details of the caissons, air locks, buckets, floating and hauling equipment, and the allied procedures, shall be subject to the Chief Engineer's approval.

9.7. (1) General—Drilled wells are generally employed for tapping water or mineral oil sources located at depths greater than 50 feet. These wells are constructed by portable well-drilling machines, either percussion or rotary.

(2) Percussion drilling.—In this method of drilling, the hole is constructed by the percussion and cutting action of a club-like, chisel-edged drilling bit that is alternately raised and lowered. This method shall be preferred where it is desired to test depth and quality of each stratum, where a small quantity of water is available for drilling, and where a lighter rig is desirable from the viewpoint of transportation. However this method shall not be used for drilling deep, small diameter holes in soft, loose, unconsolidated materials such as dune sand, quicksand, and unconsolidated river gravels.

The hole is drilled by raising and lowering the drilling bit on the end of a steel cable which is threaded over a sheave at the top of a mast or A-frame, and down to the drill-line drum fixed on the rig. It is important that the length of the line be so adjusted that the bit will strike the bottom of the hole with the right amount of force. The driller shall be well-trained in his job, and shall be able to interpret the nature of the strata encountered, from the vibrations of the drilling cable.

At the time of starting a hole about 3 feet deep should be dug if soft soil is present, or a 6 inches deep hole should be chiselled out where surface rock is present. In the hole drilled in surface rock, a 6 feet length of pipe, of the same
size as the hole to be drilled, should be set and braced to act as a guide for the drilling tool. Drilling should then be started, slowly at first, and by guiding the movement of the bit by hand until a depth of about 8 feet is reached.

A sufficient supply of water should be available for use. Under average conditions, 4 gallons of water are required for one foot drilling of 6-inch hole, and 5 gallons for 1 foot of 8-inch hole. When sufficient water for drilling is found at a shallow depth, no additional water will be used.

Proper adjustments of the line shall be made to eliminate line whip, drill shock, and excessive vibrations. A tight line should be used in creviced and irregular formations. The drill should be run at a speed to permit smooth operation and to let the tools drop with a clean, hard blow. The length of stroke should be adjusted according to the hardness of the strata encountered. The following table shall be utilized as a guide for hardrock drilling:

<table>
<thead>
<tr>
<th>Strokes per mt.</th>
<th>Stroke Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>57 to 65</td>
<td>18-inch</td>
</tr>
<tr>
<td>50 to 57</td>
<td>22-inch</td>
</tr>
<tr>
<td>43 to 59</td>
<td>32-inch</td>
</tr>
<tr>
<td>35 to 43</td>
<td>40-inch</td>
</tr>
</tbody>
</table>

A 32-inch stroke, however, with approximately 1,700 pounds of tools, produces the best results in most cases of hardrock drilling.

The cuttings and loosened material, should be bailed out as the hole is drilled. However, in soft formations, it may be advisable not to bail out the mud, since it prevents caving in of the hole.

The casing pipe should be lowered with the drilling tools, the drive clamps, and usually a drive head. The pipe, should be driven in short lengths, with a shoe mounted on the first unit. The hole and pipe should be cleaned to facilitate driving when the pipe gets choked, or when the diameter of the hole is less than that of the casing pipe.

(12)
(3) Rotary drilling.—In this method the hole is made by rapid rotation of a drilling bit attached to the bottom of a string of drill pipe, and the crushed material is removed by circulation of mud fluid descending through the drill pipe and ascending outside the pipe.

At the start of drilling, circulation of water should first be established by starting the mud pump. Drilling should then be started gradually in a preliminary guide hole chiselled or dug at the correct location. Pressure on the bit should be gradually increased to make it cut deeper and well. When the length of the kelly, the heavy-walled uppermost joint of drill pipe, is drilled down, the drilling should be stopped, the chuck bolts loosened, the kelly hoisted out, the bit removed and screwed to a drill collar, and lowered again for continuation of drilling.

At intervals of 10 feet, down, the above-mentioned cycle of operations should be repeated except that instead of a drill collar a joint of the drill rods should be added each time. The drilling speeds should be in accordance with the type of strata encountered, and instructions issued with each type of drilling machine.

Where the surface formations are soft or sandy, it may be necessary to set surface casing to keep the walls of the hole from caving in. The casing should be run into the hole in the same manner as the drill pipe. The top of the casing should lie just below the spider base, and a pipe clump should be clamped around the casing, to prevent it from dropping into the hole if the formation is washed from beneath it.

An ample water supply is essential when drilling wells by the rotary method. For average cases, about 1,000 gallons of water will be needed for an 8-hour shift. The mud-pump is the heart of the circulating system and its proper operation and maintenance should be given top priority.

(4) Strainers and well screens.—The use of strainers, well screens, perforated casing, etc., shall be specified by the Executive Engineer, for location at suitable depths to tap water-bearing strata. The type of commercial strainers or well screens, the size and kind of perforations, etc., shall be subject to Chief Engineer’s approval.
APPENDIX I

STANDARD SOIL CLASSIFICATION SYSTEM

1. General:

All soils and earth materials should be identified and classified according to the system and procedure described herein. This system is based on comparison of soil characteristics such as grading and plasticity, with the characteristics of the groups of the A.C. classification system.

2. Basic soil components:

The following nomenclature for basic types of earth materials, based on the International particle-size classification, shall be used in describing earth materials used in engineering construction:

(a) Gravel:—Gravel consists of mineral grains (rock fragments) passing a standard 3-inch sieve and retained on a U.S. standard sieve No. 4. For identification purposes the 4-inch size may be considered the equivalent of the No. 4 size.

(b) Sand:—Sand consists of mineral grains (rock fragments), passing a U.S. Standard sieve No. 4 and retained on a U.S. Standard sieve No. 200. The lower limit is approximately the smallest particle size distinguishable by the unaided eye. Sand is cohesionless when dry, but when wet can be formed into a weak cast by squeezing in the hand.

(c) Silt:—Silt consists of soil particles passing a U.S. Standard sieve No. 200 and having little or no plasticity or cohesion. When wet and formed into a ball it will withstand slight distortion and moulding without breaking. Individual grains are not distinguishable to the unaided eye. Silt has characteristically rapid reaction to the Shaking Test described in Appendix II.

(d) Clay:—Clay consists of soil particles passing a U.S. Standard sieve No. 200 and strongly exhibits the property of plasticity when wet and becomes very hard compared with other soils when dried. In a moist condition, clay is distinctly cohesive and can be readily moulded. Most clay will form long flexible ribbons when pinched between the fingers, and it can be rolled into a thread.

(e) Organic matter:—Organic matter in soils consists of partly decomposed vegetation and humus, either fibrous as in peat and swamp soil, or finely divided vegetable matter as in organic silts and clays. Such soil is usually dark in colour, and when wet and confined it develops the characteristic odour of decaying organic matter.

(1)
3. Symbols for soil classification:

The following standard letter symbols shall be used to identify various soils in making field notes, subsurface profiles and maps, in addition to other diagrammatic and detailed identifications:

<table>
<thead>
<tr>
<th>Soil type</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravel</td>
<td>G</td>
</tr>
<tr>
<td>Sand</td>
<td>S</td>
</tr>
<tr>
<td>Well graded</td>
<td>W</td>
</tr>
<tr>
<td>Poorly graded</td>
<td>P</td>
</tr>
<tr>
<td>Silt</td>
<td>M or Ms</td>
</tr>
<tr>
<td>Clay</td>
<td>C</td>
</tr>
<tr>
<td>Organic</td>
<td>O</td>
</tr>
<tr>
<td>Low compressibility</td>
<td>L</td>
</tr>
<tr>
<td>High compressibility</td>
<td>H</td>
</tr>
<tr>
<td>Peat</td>
<td>Pt</td>
</tr>
<tr>
<td>Fines</td>
<td>F</td>
</tr>
</tbody>
</table>

These symbols can be combined to represent the various soil groups, such as ML for silty of low compressibility; OH for organic clay, highly compressible; GP for gravel, poorly graded.

4. Soil groups:

Soils can be divided into the following more prominent groups or classes:

(A) Coarse-grained soils.—Soils in which more than half of the particles are visible to the unaided eye, are considered as coarse-grained. Coarse-grained soils can be divided into the four sub-groups given below:

(a) Well-graded gravel or sands (GW-SW):—A well-graded soil contains a distribution of all particle sizes, such that the finer particles fit between the coarser ones to leave a minimum of voids and have relatively high density. The coefficient of uniformity should be used as one of the indices to indicate gradation.

(b) Gravel with clay binder or sand with clay binder (GC-SC):—These soils are well-graded and contain sufficient clay or other natural cementing agent to bind the coarser grains together up to the maximum size in the sample, but the shrinkage or swelling of the compacted soil should be at a minimum.

(c) Gravel or sand, poorly graded (GP-SP):—These soils consist of coarse to relatively clean gravelly or sands of uniform sizes or of mixtures of coarser particles and fine sand particles with the intermediate sizes lacking.

(d) Gravel or sands with excess silt or clay (GP-Silty, GP-Chaney, SP-Silty, SP-Chaney):—This group contains soil mixtures which do not fall in any of the sub-groups discussed above. These soils usually
have an excess of fines passing U.S. Standard sieve No. 200, much that the stability of the coarser grains and their free-draining characteristics are seriously reduced. The excess of fines gives them a very dirty or dusty appearance.

(B) Fine-grained soils with low compressibility:—

(a) Silt (ML):—This sub-group includes inorganic silts, very fine sands, rock flour, and silty or clayey fine sands with slight plasticity. These soils are generally non-plastic, non-cohesive, have a low dry strength, and exhibit a marked and fast reaction to the Shaking Test.

(b) Clay, lean (CL):—These include inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, and lean clays. These clays are moderately plastic and cohesive, have a low to medium dry strength, and exhibit no or only slight reaction to the Shaking Test. In the plastic condition they can be rolled into a thread of approximately 1/16-inch diameter, which will have a fair strength.

(c) Silt, organic (OL):—This group includes organic silts and organic silty-clays of low plasticity. They are slightly plastic and cohesive, have very little dry strength, and can be recognized by their characteristic dark colour and odour of decayed organic matter. They show no reaction to the shaking procedure.

(C) Fine-grained soils with high compressibility:—

(a) Silt, elastic (MH):—It consists of very compressible silts and micaceous or diatomaceous fine sandy or silty soils. These exhibit usually slightly plastic and cohesive properties combined with low dry strength and a marked reaction to the Shaking Test.

(b) Clay, fat (CH):—It includes the highly compressible clays and highly plastic inorganic clays. They have a high dry strength, and exhibit no reaction to the shaking procedure but can be rolled into a thread which becomes tough as the plastic limit is approached.

(c) Clay, organic (OH):—This group includes highly compressible organic clays of medium to high plasticity and cohesiveness, with medium to high dry strength. They have characteristic dark colour, strong odour of decayed organic matter, and can be rolled into a soft, fibrous thread of medium strength.

(D) Organic soils (PH):—Such soils are comparatively rare in occurrence, and include fibrous, highly organic, and very plastic soils, principally peat and other swamp soils. They exhibit low dry strength and a very soft, weak fibrous thread. A very dark colour and strong odour of decayed matter are distinguishing characteristics of organic soils.

5. Classification procedure:—Classification of a soil sample should be done in the following steps:—

(a) Determine the soil group or class by visual examination and by preliminary identification tests.

(b) Describe the soil in detail giving typical characteristics, peculiarities, properties of undisturbed samples, etc.

(c) Borderline cases should be described as such.

(d) Final classification of soils, if necessary, should be arrived at by thorough laboratory tests for the required physical properties.
APPENDIX II

SHAKING TEST FOR SOILS

1. General:

The shaking test is used in distinguishing between fine sand or silt and clay during examination of predominately fine grained soils or of the fine-grained fraction in soil mixtures. It is a simple method of comparing the cohesive nature of two soils.

2. Procedure:

Take a sample of soil sufficient to form a pat about the size of a small walnut. Add a little water and manipulate and work the soil into a round pat. Place this pat in the palm of the hand and shake vigorously to and fro in a horizontal plane.

After sufficient shaking, the pat is inspected, to determine whether or not a sheen of water is visible on the surface and whether or not the surface has a soft, smooth and glossy appearance. After examination the pat is squeezed between the fingers until it stiffens and crumbles under the pressure, or deforms in plastic flow. If the pat stiffens and crumbles under pressure, the water sheen will characteristically disappear leaving a dull, smooth-textured surface. With further shaking, after crumbling, the broken pieces will flow together again if definite hardening and crumbling has occurred with the original squeezing.

3. Observation of reactions:

The reaction of soils to shaking should be carefully observed. Soil types can be distinguished and classified from the reaction to shaking, as follows:

(a) Rapid reaction indicates a lack of plasticity and cohesiveness as in inorganic silts, fine sands, or rock flour.

(b) Slow reaction indicates a slightly plastic or clayey silt or silty clay with relatively low permeability.

(c) If there is no reaction to shaking, clays or organic materials with considerable plasticity and very low permeability are indicated. In such soils squeezing or application of pressure produces plastic flow, and there is neither any surface sheen nor hardening of the pat.
APPENDIX III

SLUMP TEST FOR CONSISTENCY OF PORTLAND-CEMENT CONCRETE.

1. General:

This standard procedure shall be adopted for slump tests for consistency of portland-cement concrete both in the laboratory and at the actual site of construction. The frequency and number of slump tests to be performed on a job shall be specified by the Executive Engineer.

2. Apparatus:

The mould used for slump test should be made of No. 16 gauge galvanized metal sheet formed to the shape of frustum of a cone. The base of the mould shall be 5 inches in diameter and the top 4 inches in diameter. The height of the mould being 12 inches. The base and top shall be open and parallel to each other at right angles to the axis of the cone. The mould shall be provided with proper foot pieces and handles as shown in Fig. 1.

3. Sample:

The samples of concrete from which test specimens are made shall be representative of the entire batch. Samples shall be taken at the mixer, from an agitator-transporter truck during discharge, at the hopper of a concrete pump, at the discharge end of the pumpcrete or pneumatic gun pipe line, or as directed by the Executive Engineer. The sample shall then be transported to the place of moulding of the specimen, and to counteract segregation the concrete shall be mixed with a shovel until it is uniform in appearance.

4. Procedure:

The mould should be dampened on the inside and placed on a flat, moist, nonabsorbent surface, preferably a metal sheet. Concrete from the sample shall be immediately placed in the mould in three layers, each approximately one-third the volume of the mould. In placing each scoopful of concrete the scoop shall be moved around the top edge of the mould as the concrete slides from it, in order to insure symmetrical distribution of concrete within the mould. Each layer shall be rolled with 25 strokes of a 5/8 inch round bar, approximately 24 inches in length and tapered for a distance of one inch to a special shaped end having a radius of approximately 4 inch. The strokes shall be distributed in a uniform manner over the cross-section of the mould and shall penetrate into the underlying layer. After the top layer has been rolled, the surface of the concrete shall be struck off with a trowel so that the mould is exactly full.

The mould should then be immediately removed from the concrete by raising it carefully in a vertical direction. The slump shall then be measured immediately by determining the difference between the height of the mould and the height of the vertical axis of the specimen.
5. **Slump and consistency:**

The consistency of the cement concrete test set shall be recorded in terms of inches of subsidence of the specimen during the test, that is the **slump height**.

\[ \text{Slump} = 12(\text{inches of height after subsidence}) \]

After the slump measurement is completed the side of the concrete frustum should be tapped gently with the tampering rod. Behaviour of the concrete under this treatment is a valuable indication of its cohesiveness workability, and placeability. A well proportioned, workable mix will slump down gradually and will retain its original identity, while a poor mix will crumble, segregate, and fall apart.

When practicable, or if ordered, duplicate slump tests should be made and the average of the two slumps reported.
APPENDIX IV

B.I. STANDARD AND U.S. STANDARD SIEVES.

1. Definitions:

A plate or sheet of a woven cloth, or other device, with regularly spaced apertures of uniform size, mounted in a suitable frame or holder for use in separating material according to size, shall be called a "sieve" or a "screen".

In mechanical analysis of aggregates, sarkhi, lime, cement, etc., when not otherwise specified, the term "sieve" shall apply to an apparatus in which the apertures are square.

Unless otherwise specified, all sieves used in the Irrigation Branch shall be of square-mesh wire-cloth, free from punctures or other obvious defects, and shall be mounted on substantial frames constructed in a manner that will prevent loss of material during sieving.

2. U.S. Standard Sieves:

The following table gives U.S. Standard sieve sizes and numbers, and the corresponding sieve-openings in inches, of the sieves commonly used.

<table>
<thead>
<tr>
<th>Size or Sieve Designation</th>
<th>Sieve opening inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.—COARSE SERIES</td>
<td></td>
</tr>
<tr>
<td>4—inch</td>
<td>4.00</td>
</tr>
<tr>
<td>3—inch</td>
<td>3.00</td>
</tr>
<tr>
<td>24—inch</td>
<td>2.40</td>
</tr>
<tr>
<td>2—inch</td>
<td>2.00</td>
</tr>
<tr>
<td>1 1/8—inch</td>
<td>1.88</td>
</tr>
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<td>1—inch</td>
<td>1.75</td>
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<tr>
<td>3/4—inch</td>
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<td>1/2—inch</td>
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</tr>
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<td>1—inch (No. 3)</td>
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<tr>
<td>B—Fine Series</td>
<td>Sieve opening inches</td>
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<td>----------------------</td>
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<tr>
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3. British Standard Sieves:

The table below gives British Standard Sieves commonly used. B.S.S./sieve numbers indicate the number of meshes to the linear inch.

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APPENDIX V

SAMPLING AGGREGATE FOR LABORATORY TESTING.

1. General:—

The procedure outlined herein should be followed to obtain samples of both coarse and fine aggregates for laboratory tests. The task of obtaining a truly representative sample of aggregate is considerably complicated because of the segregation that takes place when the aggregate is handled or moved.

2. Sampling from stock piles:—

Sampling from sand stock piles should start at equally spaced points along the bottom of the pile and proceed upwards at equal intervals, over the sides and top, thus covering the entire heap. If only part of the pile is to be used for a portion of the job, just the part to be used should be sampled.

Where practicable, gravel samples from stock piles should be taken with a specified tube sampler. Generally samples consisting of material from well beneath the surface obtained with a shovel, shall be considered satisfactory. By holding a short piece of board against the pile just above the point of sampling, the inclusion of unwashed surface material can be avoided.

3. Sampling from railway wagons:—

Samples from railway wagons should, preferably, be taken at points equally spaced on straight lines along the sides and centre of the wagon. The size of the sample will depend on the size of the wagon, the number of points from which samples are taken, and the maximum size of aggregate particles.

A standard tube sampler should be used for sand, and when possible, for coarse aggregate. The tube sampler is a steel pipe about 2 inches in diameter and 8 feet long pointed at the lower end and having a handle at the top. A series of openings is punched along the pipe in such a way that a line of "ears" projects from one side of the openings. The sampler tube is forced into the aggregate as far as possible, turned until the ears have scooped sufficient material into the tube for a sample; and then withdrawn, keeping the openings on top.

Usually it may be more convenient to take representative samples when the material is being loaded into, or unloaded from, a wagon. If loading or unloading is done by hand, a fairly representative sample may be obtained by taking a shovelful at regular intervals; provided care is taken that the larger pieces do not roll off the shovel. If wagons are mechnically loaded or unloaded, samples should be taken at regular intervals.

4. Sampling from conveyor belt:—

To secure representative samples of aggregate from a conveyor belt, sampling should be done over the complete cross-section of supply stream in a short period. Samples should be taken at regular intervals until the whole supply has been sampled. The number and size of such samples will depend on the quantity and uniformity of the aggregate.

(13)
5. Reduction to test sample:

The sample obtained from aggregate supply should be reduced to a test sample by quartering or splitting as described below:

(a) Quartering method:—Place the sample on a hard, clean surface where there will be neither loss of material nor addition of foreign matter. Mix the sample thoroughly by turning the entire lot over three times with a shovel. With the third or last turning the entire sample should be shoveled into a conical pile by depositing each shovelful on top of the preceding one. The conical pile should be then flattened to a uniform thickness and diameter, so that after the pile has been quartered each quarter will contain the material originally in it. The flattened mass should be then marked into quarters by two lines that intersect at right angles at the centre of the pile. Remove two diagonally opposite quarters and brush the cleared space clean. The remaining material should be mixed and quartered successively until the sample is reduced to 30 pounds or less. The sample should be further reduced to the desired size by passing it through a sample splitter, one half being discarded and the other half split again.

(b) Sample splitting:—The entire sample should be passed through a sheet metal sample splitter. One half of the split sample should be set aside and the other half split again. This procedure should be repeated until the sample is reduced to the desired size.

Details of the standard sample splitter are shown in Fig: 2.

Coarse aggregate samples should be reduced to test specimen size by the quartering method only. With aggregate larger than 2-inch size, it may be more convenient and desirable to hand pick the sample. In such a case care should be taken to obtain a representative sample. Samples of sand should be reduced to test size by the quartering method or use of a sample splitter.
APPENDIX VI

TEST FOR COMPRRESSIVE STRENGTH OF CEMENT MORTAR

1. Scope:—

This method should be employed for determining the compressive strength of hydraulic-cement mortars.

2. Apparatus:—

The following laboratory equipment and apparatus shall be needed for this test.

1 Scales; permissible variation at a load of 2,000 gms, being ±2.0 gms.

1 Set of weights.

1 Set of sieves; comprising U.S. Standard sieves Nos. 100, 50, 30, and 18.

1 Set of graduated glass cylinders, capacities up to 500 ml.

1 Set of specimen moulds for 2 inch cube samples.

1 Mixing bowl of enamelled or other non-absorbive material, capacity 5 to 8 quarts.

1 Flow table consisting of a rigid metal frame and a circular rigid table 10 inches in diameter with a shaft affixed perpendicular to the table top.

1 Flow mould of non-corrodable material, 4 inches in inside diameter at base, 2.75 inches in diameter at the top, and 2 inches in height.

1 Tamper of medium-hard rubber or seasoned oak wood rendered non-absorbive by immersion for 15 minutes in paraffin at approximately 200°C.

1 Trowel with a steel blade, 4 to 6 inches in length.

1 Standard compression testing machine.

3. Specimen moulds and Flow table:—

Moulds for 2 inches cube test specimens shall be tight fitting. These should be made of hard metal not attacked by the cement mortar. The interior of the moulds should have the exact shape of a 2 inch cube, with a maximum possible variation of ±0.005 inches. The angles between adjacent interior faces, and between interior faces and top and bottom planes of the mould shall be 90±0.5 degrees.
The table top of the flow cable listed in paragraph (2) shall have a plane surface and shall be of non-corrodible metal. The table and the attached shaft shall weigh 9 ± 0.1 lbs. The table with attached shaft shall be mounted on the frame in such a manner that it can be reused and dropped vertically through a fixed height of 3-inch by means of a rotated cam. The frame shall be attached rigidly to a concrete pedestal which shall be attached rigidly to the floor. The concrete pedestal shall be at least 8-inches square or in diameter at the top and at least 20 inches in height with a base suitable for rigid attachment to the floor and shall weigh at least 100 lbs.

4. Temperature and humidity:

The temperature of the air in the vicinity of the materials, moulds and other equipments should be between 68° and 82°F. The temperature of mixing water, curing close, and of water in the storage tank should be between 70° and 76°F. The relative humidity in moist closet or curing room shall be not less than 90 per cent.

5. Sand for mortar:

The sand for making test specimens shall be natural silica sand from Patankote, graded as follows:

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</thead>
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<td>5±2</td>
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6. Preparation of test specimens:

The interior faces of the specimen moulds should be thinly coated with mineral oil or light cup grease. Moulds should then be set on plane, nonabsorbent base plates which have also been thinly coated with mineral oil, or light cup grease. The outside contact lines of the moulds and base plates should be made water-tight by applying a mixture of 3 parts of paraffin to 5 parts of rosin by weight, heated between 230° and 245°F.

The proportions of dry materials for the standard test mortar shall be one part of cement to 2.75 parts of graded standard sand by weight. The quantities of dry materials required for six test cubes will be 500 gms. of cement and 1,375 gms. of graded standard sand. The amount of mixing water, measured in millilitres, shall be such as to produce a flow of between 100 and 115 as determined in accordance with paragraph (7), and shall be expressed as a percentage by weight of the cement.

(15)
Mixing should be done in a bowl by vigorous and continuous stirring, squeezing, and kneading with one hand and shall be protected by a snug-fitting rubber glove. Mixing shall be carried out in the following sequence, place water in the clean bowl; add cement to the water and mix for 30 seconds; add approximately one half of the testing sand and mix for 30 seconds; add the remainder of the sand and mix for 1½ minutes. The flow test as described in the next paragraph should be carried out immediately after completion of the mixing operation.

Immediately following completion of the flow test the mortar from the flow mould shall be returned to the mixing bowl and the entire batch shall be thoroughly mixed for 15 seconds. Within a total elapsed time of not more than 2½ minutes after completion of the original mixing of the batch, moulding of specimens should be started. A layer of mortar about 1-inch in thickness shall be placed in all the moulds, and the mortar in each mould shall be tamped 32 times in about 10 seconds. The tamping should be uniform over the entire layer of mortar. Then a second layer of mortar shall be poured and tamped as specified for the first layer, the top of mortar extending slightly above top of moulds. The surplus mortar should then be cut off to a plane surface flush with the top of the mould with the trowel.

7. Determination of flow:—

The flow-table top shall be carefully wiped dry and the flow mould placed at the centre. Immediately after completion of the mixing operation, a layer of mortar about 1-inch in thickness shall be placed in the flow mould and tamped 20 times with the tamper, the tamping pressure being just sufficient for uniform filling of the mould. The mould shall then be filled with mortar to the top, and tamped as specified for the first layer. The mortar should then be cut off with the trowel to a plane surface, flush with top of the mould.

The flow mould shall be lifted away from the mortar 1 minute after completing the mixing operation. Immediately the table shall be dropped through a height of 4-½ inch, 29 times in 15 seconds. The flow is the resulting increase in diameter of the mortar mass, expressed as a percentage of the original diameter.

8. Storage and testing of specimens:—

All test specimens, immediately after moulding, shall be kept in the moulds on the base plates in the moist closet or damp room from 20 to 24 hours with their upper faces exposed to the moist air. Except for the specimens needed for the 24-hours test, other samples shall then be immersed in clean water in storage tanks.

The cubes shall be tested in a standard compression testing machine, at an age specified for each sample. The test cube should be carefully placed in the testing machine below the centre of the (16)
upper bearing block, no cushioning or bedding materials being used. The loading up to 50 per cent (25 per cent for expected maximum loads of less than 4,000 lbs. at ages of 7 days or less) of the expected maximum load may be applied at any convenient rate, after which the specimen shall be loaded continuously to failure at a rate or rates which shall at no time be less than 1,000 nor more than 6,000 lbs. per square inch per minute.

The total maximum load indicated by the testing machine shall be recorded, and the compressive strength calculated in pounds per square inch.
APPENDIX VII

TEST FOR TENSILE STRENGTH OF CEMENT MORTARS

1. Scope:—

This test shall be performed to determine the tensile strength of hydraulic-cement mortars.

2. Apparatus:—

Equipment and apparatus needed for this test is the same as for the compression test given in Appendix VI, with the exception of cube moulds, flow table and mould, compression testing machine, and the sieves. The following being needed instead:—

1 Set of sieves, comprising U.S. Standard sieves Nos. 20 and 20. 3. 1 Briqueit moulds.
1 Briqueit clip.
1 Briqueit testing machine.

3. Briqueit moulds and clips:—

The moulds for making tension test specimens shall be made of metal not attached by the cement mortar. The dimensions of these briqueit moulds shall conform to the following requirements: width of mould between inside faces at waist line of briqueit, 1+0.01 inch; thickness of new mould measured at point of greatest thickness on either side of mould at waist line, 1+0.04 inch.

The clips should be of standard design with the clip width at narrowest place equal to 1.25 ± 0.25 inch.

4. Standard sand:—

The sand used for making test specimens shall be natural silica sand from Patnakeshore, graded to pass a U.S. Standard sieve No. 20 and retained in a U.S. Standard sieve No. 30. This sand shall be considered standard when not more than 15 gms. are retained on the No. 30 sieve, and not more than 2 gms. pass the No. 30 sieve after 5 minutes of continuous screening of a 100-gms. sample.

5. Temperature and humidity:—

The temperature of the air in the vicinity of the materials, moulds, and mixing slab shall be between 68° and 82°F. Temperature of the mixing water, moist closet or curing room, and water in the briqueit storage tank shall be between 70° and 76°F. A relative humidity of not less than 90 per cent shall be maintained in the moist closet or curing room.
BRIQUET SPECIMEN
FOR TENSILE STRENGTH TEST
6. Test specimens:

The briquet test specimens shall conform to the dimensional requirements shown in Fig. 3. Three or more test briquets should be made for each test.

7. Proportioning and mixing of mortar:

The standard test mortar shall be composed of 1 part of cement to 3 parts of standard sand, by weight. The quantities of dry materials to be mixed at one time in the batch of mortar shall be not less than 1,000 nor more than 1,500 gms. for making six briquets.

The percentage of water used in the standard mortar shall depend upon the percentage of water required to produce a neat cement paste of normal consistency from the same sample of cement, and shall be computed from the formula:

\[ y = \frac{P}{n+1} \]

where

\[ y = \text{percentage of water required for the sand mortar.} \]

\[ P = \text{percentage of water required for neat cement paste of normal consistency. (Specified for each cement by standard laboratory tests).} \]

\[ n = \text{number of parts of sand to one of cement, by weight.} \]

\[ K = \text{a constant which for the standard sand is equal to 6.5.} \]

The dry materials shall be weighed, placed upon a smooth non-absorbent surface, thoroughly mixed dry, and a crater formed in the centre. The proper quantity of water should be poured into the crater, and the material at the edge turned into the crater within 30 seconds by the aid of a trowel. After an additional interval of 30 seconds for the absorption of water, the operation shall be completed by continuous, vigorous mixing, squeezing, and kneading with the hands for 1½ minutes.

8. Moulding specimens:

The empty moulds should be coated and then thinly covered with a film of mineral oil. Immediately following completion of mixing the mortar, the moulds, resting on unmoiled glass or metal plates, shall be filled heaping full without compacting. The mortar shall then be pressed in firmly with the thumbs, applying the force 15 times to each briquet, all over its surface. The mortar shall then be heaped above the mould and smoothed off with a trowel. The mould shall then be covered with a plane glass or metal plate oiled with mineral oil, and the mould and plates shall then be turned over. The top plate shall then be removed and the operation of heaping, thumbing, heaping and smoothing off shall be repeated.
9. Storage of specimens—

All test briquets immediately after moulding, shall be kept in the mould on the base plate in a moist closet or curing room for 24 hours with their upper faces exposed to the moist air. After this period, all specimens, except those for the 24-hours test, shall be immersed in clean water in proper storage tanks.

10. Tension strength test—

The briquet specimen shall be tested immediately after their removal from the curing room or moist closet, in a standard briquet testing machine.

Each briquet shall be wiped to a surface-dry condition, and any loose sand grains or incrustations shall be removed from the surfaces that will be in contact with the clips of the testing machine. The bearing surfaces of the clips should be clean. The briquets shall be carefully centred in the clips, and the load applied continuously at the rate of 600±5 lbs. per minute.
APPENDIX VII

TESTS FOR POZOLANES

1. General:

The following four tests shall be performed to test materials for pozzolanic activity and their suitability for use as portland Pozolanic cements.

2. Flocculence test:

Take one gram of pozolanic sample and place it in a test tube containing saturated lime water. After settlement has taken place, note the height of the solid material with wax pencil mark, put a stopper in the test tube, and seal with paraffine wax. Shake the tube to completely disperse all the solid particles and note the height of settled material at definite intervals. The increase in height expressed as a percentage of the height of the liquid at the beginning of the test should be taken as an index of pozzolanic activity of the material.

3. Lime absorption test:

After making the observations of the Flocculence test the test tube should be opened and 25 ml of the clear solution should be removed with a pipette. Titrate this against an N/25 solution of hydrochloric acid and replenish the solution in the test tube by an additional 25 ml of saturated lime water. Such titrations and replenishments should be made from time to time, most often for the active materials. As the time concentration of the solution in the tube is known after each titration, the quantity absorbed by the pozolalan should be determined and expressed as an index of pozzolanic activity.

4. Time of setting:

A paste composed of 4 parts, by weight, of pozolanic and 1 part hydrated lime should be mixed with water to normal consistency. The initial and final sets of this paste, which should be placed in a glass jar and protected from carbonation by a film of saturated lime water, should be noted as another index of pozzolanic activity. The observations of time of setting should be performed according to the procedure used by the laboratory for time of setting of portland cement.

5. Compressive Strength test:

Plastic mortar cubes of standard Fathankote sand should be made with a blend of 35 per cent pozolanic and 65 per cent normal portland cement by absolute volume using a water-cement ratio of 0.8 by weight, (calculated from 100 per cent portland cement). The proportions of this mix and the water-cement ratio may be altered

(22)
if so directed. The important factor is to obtain a mortar of uniform plastic consistency by adjusting the cement to aggregate ratio, the mix proportions then giving an indication of the water requirement of each blended cement. The mortar cubes should be cured in a manner and for a period similar to that specified for cement mortar cubes in Appendix VI. The Compressive Strength of these cubes should be determined in a standard compression testing machine. Activity of pozzolans in its combination with portland cement, should be judged by comparing strengths obtained with those secured from cubes made with 100 per cent portland cement, cured and tested under similar conditions.

6. Additional tests:

Additional tests for properties such as, grindability, specific gravity fineness, water requirement, heat generation, need for calcination or other treatment, effect of alkali-aggregate reaction, etc., shall also be carried out, if so specified, or when forming part of a research programme on the properties of pozzolans.
APPENDIX IX

STANDARD COMPACTON TEST

(Compaction and Penetration Resistance)

1. General:

Unless otherwise specified or an alternative test ordered, this test shall be carried out to determine the relationships between the moisture content of a soil and the resulting densities and firmness which are achieved after the soil has been compacted by the procedure described below.

2. Definitions:

The criteria defined below shall be used to evaluate the results of the test.

(a) The greatest dry weight, in pounds per cubic foot, obtained by the standard compaction test procedure is called the maximum standard dry density.

(b) The optimum moisture is the moisture content of the soil at maximum standard dry density.

(c) The firmness of the soil is expressed in pounds per square inch and is called the penetration resistance of the soil.

(d) Compactive effort is measured by the number of blows per layer and the height of fall of the tamping rod.

3. Equipment required:

The following equipment is required for the standard compaction test:

1 Drying oven.
1 Large drying pan.
1 Laboratory compaction cylinder.
1 Tamping rod (56 pounds) and gauge.
1 Mixing pan.
1 Hand scoop.
1 Small hand scoop.
1 Penetration resistance tester.
1 Set Penetration resistance tester needles.
1 Steel paddle.
1 Mixing paddle.
1 Mixing rake.
1 Portable platform scales, 220-pound capacity, graduated in 0.01 pounds.
2. Porcelain evaporating dishes, 300-ml capacity.
1. Evaporating dish holder.
3. Glass graduates, one each of 1,000-, 500-, and 100-ml capacity.
3. 30-pound cans with handles and lids.
1. Rubber hammer.
2. Laboratory balance, 2,000-gram capacity, sensitive to 0.05 grams.
1. Curved handle, wire bristle brush.
1. Dusting brush.
1. Large knife.

4. Compactive cylinder and penetrometer.—

The standard compaction cylinder and the tamping rod and gauge are shown in Figs. 4 and 5.

The volume of compaction cylinder is 0.06 cubic feet.

The penetration resistance tester is shown in Fig. 6. Usually a set of six needles are provided with the testing. The number and areas in square inches of these needles are No. 0 = 1/46, No. 1 = 1/20
No. 2 = 1/10, No. 3 = 1/8, No. 4 = 1/6, and No. 5 = 1.0

5. Procedure:—

A representative specimen of approximately 30 pounds of material, screened through U.S. Standard sieve No. 4, is required for the test. By reprocessing the compacted material the test can be performed on a specimen weighing about 15 pounds. However, this procedure shall not be adopted if the soil is friable and the particles get crushed or are broken off during the test. Test data should be recorded in standard form shown in table II:—

(a) Place the sample in the large drying tray. Moisten and mix the sample thoroughly and store in an air-tight container to permit moisture to permeate and spread uniformly throughout the soil. Sufficient water should be added to cause the soil to adhere or build together slightly when squeezed firmly in the palm of the hand. This moisture content is usually less than the optimum moisture. It may not be necessary to store moist material or soils which readily absorb moisture.

(b) Weigh and record the weight of laboratory compaction cylinder (cylinder only).

(c) Attach the 6-inch high cylinder with the collar to base plate. The base plate should be securely fastened to a work table.
(d) Place approximately 7 pounds of the moist soil sample into a mixing pan, mix, and place a sufficient amount in compaction cylinder to yield approximately 2-inch compacted layer.

(e) Place the tamping rod in the gauge, and compact the material in the mould, with 25 blows, using an 18-inch drop. The blows should be evenly distributed over the area of cylinder.

(f) Repeat process (e), for the second and third layers. The third and last layer should extend slightly above the top of the cylinder to allow for trimming to top of sample.

(g) Remove the collar from the cylinder and carefully turn the excess portion of the compacted material to the exact level of the top of the cylinder.

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Date Recorded by</th>
<th>Vol. of cylinder</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compacted by</td>
<td>Degree of compaction</td>
<td></td>
</tr>
<tr>
<td>Test No.</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>DENSITY DETERMINATIONS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water added</td>
<td>C.C.</td>
<td></td>
</tr>
<tr>
<td>Wt. cyl and wet earth</td>
<td>lbs.</td>
<td></td>
</tr>
<tr>
<td>Wt. of cylinder</td>
<td>lbs.</td>
<td></td>
</tr>
<tr>
<td>Wt. of wet earth</td>
<td>lbs.</td>
<td></td>
</tr>
<tr>
<td>Wt. of density</td>
<td>lbs./cu. ft.</td>
<td></td>
</tr>
</tbody>
</table>

(29)
<table>
<thead>
<tr>
<th>PENETRATION RESISTANCE DETERMINATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Needle No.</td>
</tr>
<tr>
<td>Area of needle sq. in ch</td>
</tr>
<tr>
<td>Average reading 2's</td>
</tr>
<tr>
<td>Penetration resistance lbs/sq.inch</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MOISTURE DETERMINATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dish No.</td>
</tr>
<tr>
<td>Wt. dish and wet soil gms.</td>
</tr>
<tr>
<td>Wt. dish and dry soil gms.</td>
</tr>
<tr>
<td>Wt. of dish gms</td>
</tr>
<tr>
<td>Wt. of water gms</td>
</tr>
<tr>
<td>Wt. of dry soil gms</td>
</tr>
<tr>
<td>Moisture content % of dry wt.</td>
</tr>
<tr>
<td>Dry density lbs/ cu. ft.</td>
</tr>
</tbody>
</table>

Computed by ___________________________ Checked by ___________________________

General remarks about soil and test: ___________________________

(h) Remove the cylinder along with the compacted sample from base plate, weigh, and record weight.

(i) Place the cylinder with contained sample on the worktable or floor and carry out the penetration resistance test. This test is made by forcing the penetration resistance needle into the compacted soil at a rate of approximately half an inch per second.

(30)
The following precautions should be taken when obtaining a needle reading:

(1) Place indicator clip against barrel cap.

(2) The test should be started by grasping the penetrometer barrel and pushing the needle about half an inch into the compacted specimen. The penetrometer should then be held by the handle and the needle pushed into the specimen an additional 2 1/2 inches at a rate of half an inch per second.

(3) When the compacted sample contains hard sections or layers, the needle will not penetrate at a uniform rate. The force applied to the penetrometer builds up until the needle "breaks through". When such a condition is realized, the reading obtained should be disregarded and another penetration resistance test performed. When the needle reaches the hard section the pressure on the handle should be released and the needle force through the hard layer by grasping the penetrometer barrel. Then the test should be continued by using the penetrometer in the normal manner.

(4) When the needle has penetrated the specimen at a uniform rate to a depth of approximately 3 inches, the reading on the plunger shaft is observed. The average of three or more such readings, and the number and area of the needle should be recorded.

(5) Remove the compacted specimens from the cylinder and take a sample from the centre of the specimen for moisture content determination.

(6) The above-mentioned steps include the procedure for one of a minimum of five trials using a new batch of soil for determining the density and penetration resistance curves for a single soil sample. All the remaining four trials are performed exactly as the first with the exception that the moisture content for each trial is successively increased over the preceding trial until the wet weight of the sample decreases. This is a definite indication that the maximum standard dry density has been exceeded.

6. Computations and graphical plotting:

After the moisture content determinations for each trial, the dry density for all cases is computed as the wet density divided by (1 - moisture content expressed as a decimal fraction). The wet density is the weight of wet earth divided by the volume of the cylinder in
cubic feet. The penetration resistance is the quotient of the average reading divided by the area of the needle.

Data from compaction and penetration resistance tests are plotted in a set of two curves depicting the relationships between moisture content and dry density, and moisture content and penetration resistance, respectively. Dry density and penetration resistance are plotted as ordinate values with the per cent moisture content plotted as abscissa values for both curves. Moisture content is expressed as a percentage of dry weight, dry density expressed in pounds per cubic foot, and the penetration resistance is given in pounds per square inch. The peak value of the density curve and the corresponding moisture content are designated as maximum standard density and optimum moisture content, respectively.
APPENDIX X

FIELD DENSITY TEST

1. General:

Field density tests shall be carried out on compacted or rolled earth embankments, where and when directed. Where field laboratory facilities permit, comparison should be made between the fill density, penetration resistance, and moisture content; and the maximum density, penetration resistance, and optimum moisture content of the material compacted by a standard method.

2. Equipment:

The following equipment is required for carrying out a field density test:

1. ore shovel.
2. 8-inch diameter posthole auger.
3. 5-gallon capacity airtight cans, one for calibrated sand and one to bring back sample.
4. 5-gallon capacity can or pail, for salvaging used sand.
5. garden trowel.
6. 50 pounds of coarse uniform-grain-size sand, (Pathankote sand), preweighed.
7. set of penetration-resistance tester stock and needles.
8. 18-inches long straight edged board.
9. Small 4-ounce can or scoop.

3. Procedure:

(a) Remove loose surface soil from an area approximately 18-inches square till the compacted soil layer is reached. Smoothen and plane the compacted soil surface with the straight-edged board.

(b) Take penetration-resistance needle readings in the centre of the cleared patch and record the average of three or four readings. These readings will be in pounds per square inch and should be recorded as needle readings (top).

(c) Dig a hole in the centre of the area with a garden trowel, finishing it to a depth of about 6 inches using an 8 inch auger. If the soil contains too much rock or pebbles to use the auger, the hole should be excavated by hand. The finished hole should be clean, smooth and free of loose material. While digging the hole care should be taken to avoid stepping too close to it. To avoid this, boards should be placed around the hole on which the operator can stand during the test.

(d) After removal of the first 6 inches of soil, take penetrometer needle readings again and record the average of three or four readings as needle reading (bottom).
(e) Complete the excavation of the hole to a depth of from 12 to 14 inches removing the soil very carefully. All the material removed from the hole should be placed in an air-tight container for laboratory testing.

(f) Measure the volume of the hole by filling it with dry, calibrated standard Pathfinder sand poured from a container which has previously been weighed. Use the straight-edged board to insure that just enough sand is poured to completely fill the hole. The sand should be poured into the hole in the same manner as was employed while pouring the sand into a container of known volume to calibrate its density in the laboratory. It is suggested that the same person who calibrated the sand should pour it into the hole in the field.

(g) Replace the cover on the container with the unused sand and remove it to the laboratory for weighting. Remove the sand from the hole, place it in a bail or can, and take it to the laboratory where as much of it as possible should be salvaged for resale, by screening. The density of the sand should be checked frequently by pouring it into a container of known volume and weighing.

(h) Before leaving the site of work, all necessary information such as test number, location, source of material, number of roller passes, etc., should be recorded on a data sheet of the form shown in Table III.

(i) In the laboratory determine the weight of soil removed from the hole, and of the sand used in refilling it. The volume of the hole can be determined by dividing the weight of sand used by its density. The weight density of the soil removed equals the wet weight of soil divided by the volume of the hole.

(j) Laboratory comparisons of dry densities and moisture content should be made only in materials passing U.S. Standard sieve No. 4 or the "earth" fraction. Immediately after the material has been screened through this sieve, take a 500 gram sample of the material screened through, for determination of moisture content by evaporation. Place the remainder of this screened fraction in an air tight can to avoid loss of moisture by evaporation until it is needed.

(k) For "record" field density tests and for representative tests on each 30,000 cubic yards of materials, the moisture content, volume, dry weight, and specific gravity of "rock" or the fraction left on U.S. Standard sieve No. 4, should also be determined. These properties of fraction retained on sieve No. 4, or rock, may be adopted for all other tests if the general characteristics of this fraction remain unaltered.

(l) Knowing the volume and weight of rock retained on sieve No. 4, compute the wet density of earth alone, and then calculate the
Dry density of earth using the moisture content determination of earth, mentioned in step (f).

\[
\text{Wet density of earth} = \frac{\text{Moist weight of earth}}{\text{Volume of hole} - \text{Volume of rock}}
\]

\[
\text{Dry density of earth} = \frac{\text{Wet density of earth} \times \text{Weight of sand and container}}{\text{Moisture content of earth} + \text{Weight of sand and container}}
\]

(m) Compact the fraction passing U.S. Standard sieve No. 4, by the standard method of laboratory compaction (Appendix IX) at fill moisture, at least at two other moisture contents so as to obtain a moisture-density curve that will indicate optimum moisture content and maximum density. Take penetration-resistance needle readings in each compaction cylinder and plot the needle reading-moisture content relation. This curve should be used to check the needle reading-moisture content relation required for the needle-moisture test described in Appendix IX.
APPENDIX XI

NEEDLE-MOISTURE AND NEEDLE-DENSITY TESTS.

1. General:—During earthwork construction it is necessary to have a rapid method of determining whether the desired moisture content exists in the soil prior to rolling, and also for determining sufficiency of compaction. With the aid of needle-moisture test it is possible to ascertain in the borrowpit or on the embankment whether the earth materials are too wet, too dry, or at the proper moisture content. It is also checked with field density tests from time to time.

The needle-density test checks the degree of compaction by comparing the penetration-resistance needle reading in the compacted fill with the needle reading of the same material when compacted at fill moisture content in the cylinder by standard method of compaction. Needle-density tests should be made immediately after an area has been rolled and at such intervals over the area that will be representative. It is suggested that these tests be made at approximately 100-feet centres, including all locations where needle-moisture tests have previously been made.

2. Equipment required:—The following equipment is required for these tests:—

1.—Heavy-duty screen, 22-inch X 35-inch, U.S. Standard Sieve, No. 4 openings.

1.—Standard compaction cylinder with 5.5 lbs. tamping rod and gauge.

1.—Standard penetration-resistance tester and needles.

1.—Ore shovel.

1.—Field notebook.

3. Procedure for needle-moisture test:—(a) Select a representative sample weighing about 25 or 30 pounds, from the inside layer before rolling or from the face of excavation in borrowpit. Remove the rock fraction from the sample by screening the material through the No. 4 screen, the screenings being collected on a cleared and smoothed spot.

(b) Place enough of the screened sample into a compaction cylinder, (with collar attached) to fill it about 2-inches. Compact the layer with 25 blows of the tamper at an 18-inches free drop. Repeat this procedure until three layers are compacted. The thickness of placed layers should be adjusted so that the total compacted thickness will be slightly more than 6-inches. Remove the collar from the cylinder and trim the compacted material to the level of the cylinder.
(c) Measure the penetration resistance. Use a needle that will give a reading on the scale when the needle is forced into the sample at a rate of approximately half an inch per second. All the precautions detailed in item 3(i) of Appendix I should be observed in taking these readings. Make three or four penetrations and determine the average scale reading for the sample.

(d) Divide the average scale reading by the area of the needle used to determine the penetration resistance in pounds per square inch.

(e) This data should be recorded in Table III, prescribed for the field density test. Compare the observed penetration resistance with the allowable limits previously established in the laboratory and indicate whether the material is satisfactory, too wet, or too dry.

4. Procedure for needle density test:—(a) At the spot selected for the test, remove the loose top material until firm compacted soil is reached.

(b) Measure the penetration resistance and determine its average value in a manner similar to that described in sub-paragraphs (3-c) and (3-d) above.

(c) Excavate about 25 or 30 pounds of material at the spot where the fill needle readings were taken and pass the material through the No. 4 screen.

(d) Compact a sufficient quantity of the screened material in a standard compaction cylinder as described in sub-paragraph (3b) above, and measure the penetration resistance of the compacted material in the cylinder as in (4-b) above.

(e) Record the penetration resistance observed in (b) above in the column headed "III", and the penetration resistance observed in (d) in the column marked "cylinder" on Table: III, prescribed for the field density test.

(f) If the needle-moisture tests indicate moisture content with in the allowable range, an average needle reading in the fill equal to or greater than the average cylinder needle reading indicates adequate density and compaction. Where the embankment reading are considerably smaller than the cylinder readings, sufficiency of compaction is doubtful and a field density test should be carried out immediately.