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Indian Standard

CODE OF PRACTICE FOR GENERAL
CONSTRUCTION OF PLAIN AND
REINFORCED CONCRETE FOR DAMS
AND OTHER MASSIVE STRUCTURES

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INDIAN STANDARDS INSTITUTION
MANAK BHAVAN, 9 BHADUR SHAH ZAFAR MARG
NEW DELHI 110002

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CODE OF PRACTICE FOR GENERAL CONSTRUCTION OF PLAIN AND REINFORCED CONCRETE FOR DAMS AND OTHER MASSIVE STRUCTURES

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Indian Standard
**CODE OF PRACTICE FOR GENERAL
 CONSTRUCTION OF PLAIN AND
 REINFORCED CONCRETE FOR DAMS
 AND OTHER MASSIVE STRUCTURES**

0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 22 March 1957, on approval by the Building Division Council of the draft finalized on 14 September 1956, by the Cement and Concrete Sectional Committee.

0.2 Cement concrete, both plain and reinforced, is being extensively used in the various multi-purpose projects of the Central Government and irrigation and power development schemes sponsored by the States. American and British practices are being generally followed in the execution of these works. Indian conditions differ in many ways from those found in UK or USA. The Cement and Concrete Sectional Committee felt it desirable that a code of practice which would take into consideration the variations obtained under Indian conditions would be a useful guide to engineers and their technical assistants in charge of such works. This code has been prepared with this object in view.

0.3 In the preparation of this standard, valuable assistance has been derived from the published materials of the Bureau of Reclamation, Tennessee Valley Authority and the American Society for Testing and Materials. This assistance is appreciatively acknowledged.

0.4 This standard forms one of a series of Indian Standards on concrete and reinforced concrete. Other standards in the series are:

*IS: 269-1951 SPECIFICATION FOR ORDINARY, RAPID-HARDENING AND LOW HEAT PORTLAND CEMENT

†IS: 383-1952 SPECIFICATION FOR COARSE AND FINE AGGREGATES FROM NATURAL SOURCES FOR CONCRETE

‡IS: 432-1953 SPECIFICATION FOR MILD STEEL AND HIGH TENSILE STEEL BARS AND HARD-DRAWN STEEL WIRE FOR CONCRETE REINFORCEMENT

*IS: 455-1953 SPECIFICATION FOR PORTLAND BLAST FURNACE SLAG CEMENT (*Tentative*)

§IS: 456-1957 CODE OF PRACTICE FOR PLAIN AND REINFORCED CONCRETE FOR GENERAL BUILDING CONSTRUCTION (*Revised*)

*Third revision in 1976.

†Second revision in 1970.

‡Second revision in 1966.

§Second revision in 1964.

*IS: 515-1959 SPECIFICATION FOR NATURAL AND MANUFACTURED
AGGREGATES FOR USE IN MASS CONCRETE
IS: 516-1959 METHODS OF TEST FOR STRENGTH OF CONCRETE

0.5 This Indian Standard Code requires reference to Indian Standard Specifications and Codes quoted under 0.4 and also to the following:

†IS: 226-1955 SPECIFICATION FOR STRUCTURAL STEEL (*Revised*)

‡IS: 460-1953 SPECIFICATION FOR TEST SIEVES

0.5.1 Wherever a reference to any Indian Standard mentioned under 0.5, except ‡IS: 460-1953, appears in this code of practice, it shall be taken as a reference to the latest version of the standard.

0.6 In pursuance of the decision of the Government of India to introduce uniform system of weights and measures throughout the country based on the metric system, as a first step, wherever possible, metric equivalents have been given. As the industry gets accustomed to the use of the metric units, it is intended to drop the foot-pound units altogether from the standard.

0.7 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with ‡IS: 2-1949 Rules for Rounding Off Numerical Values; the number of places retained in the rounded off value should be the same as those of the specified value in the standard.

0.8 This code is intended chiefly to lay down requirements regarding quality of material and the manner of their use, and it does not include all the necessary provisions of a contract.

1. SCOPE

1.1 This code covers general construction practices for plain and reinforced concrete used in dams and other massive structures and aims primarily at rigid control of concrete work with a view to ensuring durability, strength, impermeability and uniformity.

1.1.1 Provisions specified in this code are intended to secure for every part of the work homogeneous concrete, which when hardened shall have the desired properties.

1.2 This code requires to be supplemented by special instructions, if any, for each job.

*Since withdrawn.

† Fifth revision in 1975.

‡ Since revised.

2. TERMINOLOGY

2.0 For the purpose of this code, the following definitions shall apply.

2.1 Cement Factor — The weight of cement in kg per cubic metre (or lb per 100 cu ft) of concrete after compaction.

2.2 Concrete — A mixture of Portland cement, water, fine and coarse aggregates (and any admixture approved by the engineer-in-charge) mixed and placed in accordance with the code.

2.3 Consistency — The relative plasticity of freshly mixed concrete or mortar, and measure of its workability.

2.4 Cyclopean Aggregates — Stones of sizes 7.5 to 15 cm (3 to 6 in).

2.5 Engineer-in-Charge — The Chief Engineer-in-Charge of the works or his authorized representative.

2.6 Grout — A mixture of neat cement and water or cement, sand and water in fluid state.

2.7 Laitance — An extremely fine material of little or no hardness which may collect on the surface of freshly deposited concrete or mortar.

2.8 Mortar — A mixture of Portland cement, fine aggregate and water, and any admixture approved by the engineer-in-charge.

2.9 Plums — Large stones over 15 to 23 cm (or 6 to 9 in).

2.10 Slump — A measure of consistency in which subsidence of a core of freshly mixed concrete is determined in accordance with the method given in Appendix G of ***IS: 456-1957**.

2.11 Water-Cement Ratio — The ratio of the weight of water including surface moisture of aggregates, to the weight of cement used in the concrete mix. This ratio may also be expressed as the number of litres of water per 50 kg (or gallons of water per 112 lb) sack of cement.

3. MATERIALS

3.1 Cement — Portland cement and Portland blastfurnace slag cement used for plain and reinforced concrete work in dams and other massive structures shall comply with the requirements of **†IS: 269-1951** and **†IS 455-1953**, respectively. Special cements may also be specified for use in mass concrete.

3.2 Admixture — Admixture, including pozzolanas, air entraining agents, wetting agents, etc, shall be used only under specific authorization and wherever so permitted, the proportions and methods of use shall be specified by the engineer-in-charge.

*Second revision in 1964.

† Third revision in 1976.

3.2.1 Materials permitted as admixtures shall have established merit for improving any specific quality of the concrete without causing deleterious effects.

3.3 Water — Water for mixing concrete, grout, or mortar, and also for washing the aggregates and curing concrete, shall be clean and free from injurious quantities of acid, alkali, silt, oil, organic matter, or other impurities.

3.4 Aggregates

3.4.1 Aggregates for concrete shall conform to *IS: 383-1952 or †IS: 515.

3.4.2 The maximum size of coarse aggregate, as determined by the biggest square hole through which not less than 95 percent of the aggregate shall pass shall be as large as can be used practicably and economically under given conditions, but shall be not larger than any one of the following:

- a) one-fourth the narrowest dimension between the faces of forms,
- b) one-third the depth of any slab,
- c) three-fourths of the clear space between reinforcement bars, and
- d) three-fourths of the narrowest space through which the concrete shall have to be passed.

3.5 Reinforcement — Reinforcement shall be any of the following:

- a) Mild steel and high tensile steel bars and hard-drawn steel wire conforming to ‡ IS: 432-1953,
- b) Structural steel sections conforming to § IS: 226-1955,
- c) Cold twisted steel bars complying with the requirements of Appendix A of ¶ IS: 456-1957, and
- d) Such other reinforcement as may be proved suitable, having regard to the yield point stress, ductility, ultimate resistance to tension and other essential properties of the completed reinforcement as produced in readiness for use in reinforced concrete.

3.5.1 Mill scale and rust scale, if any, shall be removed from the reinforcement before use.

3.6 Storage of Materials

3.6.1 Cement shall be stored in a damp proof place. Handling and storage facilities shall be such that no cement is stored before use for more than 120 days counted from the date of despatch by the manufacturer.

*Second revision in 1970.

†Since withdrawn.

‡Second revision in 1966.

§ Fifth revision in 1975.

¶ Second revision in 1964.

Cement stored beyond 120 days but not exceeding 180 days shall be tested and rejected if found defective in any way. Cement stored beyond 180 days shall not be used for major construction. Cement shall be checked on the job for contamination or partial setting due to exposure to moisture during transit.

3.6.2 Aggregates shall be stored and handled in such a manner as to prevent the intermingling of various sizes of aggregates required separately for grading purposes. No foreign matter shall be allowed to be mixed up with the aggregates. Stockpiles shall be built in layers of uniform thickness.

3.6.3 Reinforcement shall be stored in such a manner as to minimize rusting of steel.

4. CONCRETE

4.1 General — The concrete used in dams and other structures may vary in character from mass concrete having a maximum size of aggregate from 10 cm (preferably 15 cm) to 23 cm [or 4 in (preferably 6 in) to 9 in] and a cement content ranging from about 150 to 235 kg per cu m (or 250 to 400 lb per cu yd) to heavily reinforced concrete having a maximum size of aggregate of 2 cm (or $\frac{3}{4}$ in) and a cement content of approximately 355 kg per cu m (or 600 lb per cu yd). To effect the greatest economy, the concrete should preferably contain the maximum size aggregate suitable for the place of use and giving the specified strengths.

4.2 Quality

4.2.1 The proportions of the ingredients in concrete shall be determined through preliminary laboratory tests on concrete made from representative samples of ingredients proposed to be used in the work. The tests shall be carried out in accordance with the procedure described in Appendix B of *IS: 456-1957. After the water content has been determined to suit the required consistency, the cement content shall be determined in the following manner:

A curve representing the relation between water-cement ratio and the average compressive strength of concrete at 28 days or earlier, at which the concrete is to receive its full working load, shall be established for a range of values at least 15 percent below and 15 percent above $1\frac{1}{4}$ times the required strength. The curve shall be fixed by at least four points, each point representing the average values of at least three test specimens. The water-cement ratio to be adopted on the work shall correspond to that strength on the curve which is $1\frac{1}{4}$ times the strength actually required.

*Second revision in 1964.

The preliminary tests shall be completed well before the beginning of concreting operations and a complete report on the concrete forming qualities and suitability of available aggregates as also recommendations for their use at the work shall be made and approved by the engineer-in-charge before actual concreting is started.

4.2.2 No substitutions in the materials used on the work or alterations in the established proportions shall be made unless additional tests have been conducted to show that the quality and strengths of the resulting concrete are satisfactory.

4.2.3 The engineer-in-charge may carry out check tests and order changes in the mix as may be necessary from time to time to maintain the specified quality of the work. No radical changes, substitutions and additions in the mix, shall be made without such check tests and subsequent approval.

4.3 Mix Proportions — The proportions of cement, water, aggregates and other ingredients, if any, necessary to produce concrete of the desired quality shall be determined as described under 4.2.1. The specified water-cement ratio shall be strictly adhered to for each class of concrete. Minor adjustments of the proportions of all ingredients may be made by the engineer-in-charge in accordance with field tests, specified under 7. Both the rate and the sequence of pouring shall be strictly regulated as laid down by the engineer-in-charge.

4.3.1 Determination of Surface Moisture — In the case of fine aggregates, the surface moisture shall be determined in accordance with the method prescribed in Appendix D of IS: 456-1957. In the case of coarse aggregates, percentage of free water shall be determined by weighing a representative sample, then surface-drying each particle individually with a clean towel and reweighing the surface-dry sample to determine the amount of water removed. In calculating the water-cement ratio, the total weight of water in the mixture including all free water in the aggregate but not including any absorbed moisture, shall be taken into consideration.

4.4 Workability — As far as possible the concrete shall be of uniform consistency and quality throughout any pour and for similar parts of the same structure. However, the consistency and composition shall be such that the concrete can be worked into all corners and angles of the forms and that the concrete surrounds completely the reinforcement and embedded metal without causing any segregation of the ingredients or collection of free water. To this end, the mix may be adjusted slightly as provided under 4.2, if necessary, to provide more workability under specific conditions, only if no change in the method of either placing or compacting will accomplish the desired result.

¹ Second revision in 1964.

4.5 Slump — The control of concrete under this code is based on maintaining a fairly uniform slump at the point of placement and on holding the water-cement ratio as closely as practicable to the standard ratio determined as specified under 4.2.1. Under no conditions shall the slump be greater than that required to provide proper placement and compaction of the fresh concrete within the forms.

The slump shall be measured in accordance with the method prescribed in Appendix G of IS: 456-1957. In the case of very small or zero slump, the consistency shall be measured by the use of Vee-Bee consistometer described in Appendix A. The allowable slump or consistency shall be determined by the engineer-in-charge, and no change in consistency shall be made without his approval.

4.6 Measurement of Materials

4.6.1 The method of measuring materials for concrete shall be such that the proportions are controlled and readily checked at any time during the progress of the work. Materials shall be measured as follows:

Each size of aggregate shall be weighed separately, the cement and admixtures, if any, shall be weighed in individual or multiple batches as approved by the engineer-in-charge.

4.6.2 Weigh Batches — All weighing devices shall be subject to approval and weigh batchers shall meet the following requirements:

- a) The accuracy shall be of the order set for the purpose and shall be such that the indicated weight of any hopper full of material does not vary more than one percent from the required weight.
- b) The weighing equipment shall be designed to permit ready and proper adjustment of the proportions of the mix.
- c) The equipment shall be capable of so controlling the rate of delivery of each kind and size of materials that the combined inaccuracy in feeding and measuring during normal operations does not exceed 3 percent for all aggregates, and 1 percent for water.
- d) The operating mechanism for measuring the amount of water shall be such that no leakage occurs with the valves closed. The filling and discharge valves shall not be opened before the filling valve is closed.
- e) Test scale weights shall be provided and periodic checks made of the accuracy of all weighing equipment.

4.6.2.1 In cases where weigh batchers are not available the specification expressing the mix in proportions of weight should be transformed into one measuring material by volume. This should be done in the field

• Second revision in 1964.

laboratories attached to each construction site. The co-efficients transforming weight into volume should be determined anew each time the aggregate is obtained from a different source.

4.6.3 Cement Content — Cement in standard packages or sacks need not ordinarily be weighed, but shall be periodically checked in the field. Bulk cement and fractional packages shall be weighed.

4.6.4 Water Content

4.6.4.1 The water-cement ratio established for each class of concrete shall be held within the limits specified under 4.2. The consistency of the concrete shall be varied only by increasing or by decreasing the amount of cement paste in each batch.

4.6.4.2 Water for mixing may be measured either by volume or by weight, and the measuring device shall be accurate to within one percent. A reliable method of compensating for free water shall be used for maintaining a constant water-cement ratio.

4.6.4.3 Whenever concrete is being conveyed over a long distance during hot or dry weather, an allowance may be made for probable evaporation during the period concrete is being transported.

4.7 Mixing

4.7.1 Machine Mixing at Site — The mixing of concrete shall be done in a batch mixer of such approved type as will ensure the homogeneous distribution of all ingredients. The plant shall be so designed and operated that all materials entering the mixer including water, can be accurately proportioned and readily controlled. The entire batch within the mixer shall be discharged before recharging. The volume of mixed material per batch shall not exceed the manufacturer's rated capacity.

4.7.1.1 Method of charging — The proper sequence of operations for the admission of aggregates into any type of mixer shall be ascertained by trial runs conducted in order to determine the method giving the best results. The following sequence of charging the mixer may be adopted:

- a) Five to ten percent of the total quantity of water required for mixing, adequate to wet the drum thoroughly, shall be introduced before the other ingredients in order to prevent any caking of cement on the blades or sides of the mixers.
- b) All dry ingredients (cement and both fine and coarse aggregates) shall be simultaneously ribboned into the mixer in such a manner that the period of flow for each ingredient is about the same.

Eighty to ninety percent of the total quantity of water required for mixing shall be added uniformly along with the dry ingredients.

- c) The remaining quantity of water shall be added after all the other ingredients are in the mixer.
- d) Cobbles or a portion of the coarsest aggregate, however, may be added last; this facilitates the clearance of the chutes and removes any fine aggregate or cement adhering to the sides.

4.7.1.2 Time of mixing

- a) Unless otherwise permitted, machine mixing of each batch shall continue for not less than the period indicated in Table I. During this period the drum shall be rotated at a speed recommended by the manufacturer. The mixing period shall be timed after all materials, including water, are in the drum. The efficiency of the performance of the mixer shall be periodically checked. For any one mix, the variation in the air-free unit weights of three samples taken from the front, centre and back of a batch of concrete in the mixer, shall not exceed the following:

| | |
|-----------------------|--|
| For one batch | 37.2 kg per cu m (or 2.3 lb per cu ft) |
| Average of 3 batches | 25.9 kg per cu m (or 1.6 lb per cu ft) |
| Average of 20 batches | 19.4 kg per cu m (or 1.2 lb per cu ft) |
| Average of 90 batches | 14.6 kg per cu m (or 0.9 lb per cu ft) |

TABLE I TIME OF MIXING

| CAPACITY OF MIXER | MINIMUM TIME OF MIXING | |
|--------------------------------|------------------------|----------------------------|
| | Natural Aggregates | Manufactured Aggregates |
| 3 cu m (or 3 cu yd) or larger | 2 minutes | 2½ minutes |
| 2 cu m (or 2 cu yd) | 1½ minutes | 2 minutes |
| 1 cu m (or 1 cu yd) or smaller | 1¼ minutes | 1½ minutes |

- b) Each mixer shall have a mechanically operated timing device for signalling the completion of the required mixing period. The actual time of mixing shall be checked at least twice during each shift and the timing device shall be adjusted if in error.
- c) The timing device shall be so interlocked with the discharge gate of the batch hopper that timing does not start until the discharge gate is fully closed and all ingredients are in the drum. A suitable record shall be kept of the average time consumed in charging, mixing and discharging a batch during each run.

- d) Excessive mixing, necessitating the addition of water to provide workability shall be avoided.

4.7.1.3 Discharging — The full contents of the drum shall be discharged quickly so as to avoid segregation

4.7.1.4 When the mixer is stopped, before placing again any ingredients in the mixer all hardened concrete or mortar shall be removed from the inner surface of the mixer.

4.7.2 Central Plant Mixing — Concrete mixing at the central plant shall be done in accordance with the requirements for machine mixing at site (see 4.7.1) before being loaded into the transporting vehicle.

4.7.3 Truck Mixing — Truck mixers, unless otherwise approved, shall be of the revolving drum type, so constructed that all materials in the concrete are kept uniformly distributed throughout the mass. The mixer shall be water-tight when closed. At the proportioning plant, all solid materials shall be accurately weighed and charged into the drum; the prescribed quantity of water may either be charged into the drum or measured and placed in the tank meant for carrying the mixing water. Truck mixers shall be provided with some device whereby the time of hauling, mixing, and introduction of water could be readily checked.

4.7.4 Hand Mixing — Hand mixing should be avoided in mass concrete construction. Hand mixing, if authorized for minor portions of the work, shall be done on a water-tight platform. The entire mass shall be turned over using shovels as many times as may be necessary to produce homogeneous concrete of uniform consistency.

4.7.5 Retempering — The retempering of partially hardened concrete or mortar requiring renewed mixing, with or without the addition of cement, aggregate or water, shall not be permitted.

4.8 Handling and Conveying

4.8.1 The handling and conveying of concrete from the mixer to the place of final deposit shall be done as rapidly as practicable and without any objectionable separation or loss of ingredients. Whenever the length of haul from the mixing plant to the place of deposit is such that the concrete unduly compacts or segregates, suitable agitators shall be installed in the conveying system. Where concrete is being conveyed on chutes or on belts, the free fall or drop shall be limited to 5 ft (or 150 cm) unless otherwise permitted. The concrete shall be placed in position within 30 minutes of its removal from the mixer

4.8.2 Handling Equipment

4.8.2.1 Buckets — Buckets, if used, shall be of the bottom-dump type, permitting an even, controlled flow into the forms or hopper without undue splashing or segregation. Cars, trucks and skips shall be designed to facilitate uniform delivery rather than quick dumping.

4.8.2.2 Chutes — Where concrete is conveyed in chutes, the trough of the chutes shall be of such size and shape as to ensure a steady, uniform flow of material. The sections shall be made of, or lined with metal and all runs shall have approximately the same slope, not flatter than 1 vertical to $2\frac{1}{2}$ horizontal. The layout shall be such that the concrete will slide evenly in a compact mass without any separation or loss of ingredients. The required consistency of the concrete shall not be changed in order to facilitate chuting. Where it becomes necessary to change the consistency, the concrete mix shall be completely re-designed. Wherever there is a free fall within the conveying system, suitable baffle plates, splash boards or down spouts shall be provided to prevent segregation, splashing, or loss of ingredients. Wherever it is necessary to hold the discharge end of a chute more than 300 cm (or 10 ft) above the level of the fresh concrete, a flexible down spout shall be used to break the fall and confine the flow. The lower end of the spout shall be held close to the place of deposit. Wherever depositing is intermittent, a discharge hopper shall be provided. All chutes shall be thoroughly cleaned before and after each run. All wash water and debris shall be wasted outside the forms.

4.8.2.3 Pumping — Where concrete is permitted to be conveyed into place by the application of pressure, the pump and piping shall be suitably designed and shall be of adequate capacity for the work. Pumping shall be permitted only for conveying concrete containing aggregates less than 7.5 cm (or 3 in) maximum size. The operation of the pumping system shall be such that a continuous stream of concrete, without air pockets or interruptions, is delivered. At the end of the run, all concrete remaining in the pipe line shall be rejected in such a manner as to avoid any segregation or lack of uniformity. The pump and line shall be thoroughly cleaned and all wash water and debris wasted.

4.8.2.4 Belt conveyors — Where transportation by means of belt conveyors is permitted, a steady, uniform flow of concrete shall be maintained without any segregation or piling up on steep inclines or at transfer points. The conveyor shall be covered to prevent damage by rain, loss of heat during cold weather, evaporation or heating by the direct rays of the sun, or other deterioration of the concrete.

Concrete shall not be discharged directly into the forms, unless the discharge end of the conveyor or pipe can be readily moved about within the forms so as to place the concrete in even layers as specified under **4.10.2**,

and 4.10.10. Otherwise, suitable hoppers shall be provided, from which the concrete shall be dumped in place by means of buckets and short chutes or spouts.

4.8.3 Cleaning Equipment — At the end of each run and before again placing any concrete, all hardened concrete or mortar shall be removed from the inner surface of the conveying equipment. All conveying equipment shall be maintained in good order and kept reasonably free from deposits of stiff concrete and leakage of mortar.

4.9 Preparation for Placing Concrete

4.9.1 Before depositing any concrete for the next lift or pour, the forms shall not be retightened. The surface of contact shall be allowed to dry out between placing successive lifts of concrete. The top of the previously deposited concrete shall be thoroughly cleaned and prepared as specified under 4.10.5.

4.9.1.1 Where new concrete is to be bonded to hard concrete, unless otherwise ordered and in addition to the requirements specified under 4.10.5, the vertical and inclined surfaces which cannot be covered with mortar shall be given a heavy coat of neat cement grout, vigorously brushed into all interstices and hollows so as to provide the best possible conditions for bond and impermeability.

4.9.2 Rock Foundations — All rock surfaces against which concrete is to be placed shall be clean and free from mud, dirt, oil, organic deposits, or other foreign material which may prevent a tight bond between the rock and concrete. Seams shall be cleaned to a suitable depth and to firm rock along the side. Where excavation methods or the natural rock strata do not leave a sufficiently rough surface of contact, the bed shall be roughened by cutting steps, grooves, trenches, or keyways into the solid rock. Scaly coatings, hardened grout or concrete, construction debris, and other objectionable materials shall be removed. Seepage shall be properly controlled and diverted. The foundation bed and sides shall be carefully cleaned with stiff brooms, picks, jets of water and air applied at high velocity or other equally effective means, followed by thorough washing. After washing and before placing any concrete, water shall be removed from depressions and the rock surface shall be left uniformly damp.

4.9.3 All flat surfaces shall then be coated with mortar about 1.5 cm (or $\frac{1}{2}$ in) thick in the case of concrete surfaces and 2 cm (or $\frac{3}{4}$ in) thick on rock surfaces. The water-cement ratio for the mortar layer shall not exceed that for the regular concrete mixture, and the mortar shall be of such consistency that it can be spread evenly without flowing. It shall be

thoroughly broomed and worked into all irregularities, cracks and crevices. The manner of spreading and working shall be such as not to cause any segregation, and concrete shall be placed immediately upon the fresh mortar before its initial set.

4.9.4 On very rough or broken surfaces, the first few batches of concrete may, if so required, contain only about one-half the regular proportion of coarse aggregate.

4.9.5 No concrete shall be deposited until the foundation has been inspected and approved. Where the rock is dry enough to absorb water from the mortar layer, it shall be soaked for at least 24 hours prior to placing the concrete. Detailed instructions shall be issued for preparing scaly or cracked foundations requiring special treatment or grouting.

4.9.6 Earth or Shale Foundations

4.9.6.1 In the case of earth or shale foundations, all soft or loose mud and surface debris shall be scraped and removed. The surface shall be moistened to a depth of about 15 cm (or 6 in) to prevent the subgrade from absorbing water from the fresh concrete. Just before placing the concrete, the surface of the earth shall be tamped or otherwise consolidated sufficiently to prevent contamination of concrete during placing. In general, concrete shall be deposited only upon material lying in a natural, undisturbed state.

4.9.6.2 Foundations of porous or free-draining material shall be thoroughly compacted by flushing and by subsequent tamping or rolling, if necessary. The finished foundation surface shall then be blanketed with a layer of tar paper or closely woven burlap carefully lapped and fastened down along the seams so as to prevent the loss of mortar from the concrete.

4.9.6.3 Unless otherwise specified, the under-drainage system for all foundations shall be blanketed as specified under **4.9.6.2**.

4.10 Placing Concrete

4.10.1 No concrete shall be placed until the place of deposit has been thoroughly inspected and approved, all reinforcement, inserts and embedded metal properly secured in position and checked, and forms thoroughly wetted (except in freezing weather) or oiled. Placing shall be continued without avoidable interruption while the section is completed or satisfactory construction joint made.

4.10.2 Within Forms — Concrete shall be systematically deposited in shallow layers and at such rate as to maintain, until the completion of the

unit, a plastic surface approximately horizontal throughout. Each layer shall be thoroughly compacted before placing the succeeding layer. In general, the thickness of layers shall not exceed the following limits:

- a) Vibrated mass concrete 45 cm (or 18 in)
- b) Hand compacted mass concrete 30 cm (or 12 in)
- c) Reinforced concrete 25 cm (or 10 in)

The batches shall be deposited vertically in such a manner as to avoid segregation, air pockets, or damage to other recently placed concrete. The concrete shall not be caused to flow or be worked along the forms for any distance, but shall be compacted as close to the point of deposit as practicable. Wherever necessary, both the forms and reinforcement shall be protected against splashing, and all accumulations of partially set, dried, or caked mortar which may impair the bond or show in the finished faces shall be removed and wasted before commencing concreting operations.

4.10.3 No concrete shall be deposited at any time except in the presence of an authorized inspector, nor shall any concrete be placed outside regular working hours unless due notification thereof is given in sufficient time to make proper provision for inspection. Wherever concrete is being deposited at night or under artificial light, both the places of deposit and the mixing and conveying equipment shall be adequately illuminated so that all operations are properly observed and inspected.

4.10.4 *Temperature of Concrete* — When deposited in the forms, concrete shall have a temperature of not more than the maximum values as determined by concrete cooling studies, and appropriate measures shall be taken to attain this requirement. Such measures may include one or all of the following operations:

- a) Cooling of aggregates by spraying with water and air blasting,
- b) Cooling of water used in mixing by refrigeration,
- c) Use of cooling towers, and
- d) Arranging the placing of concrete during the cooler hours of the day.

In addition to the above, it may be necessary to control the temperature rise of the concrete after it has been placed by the one or more methods determined by temperature control studies. All lifts placed on rock foundation shall not exceed 75 cm (or 2½ ft).

4.10.5 *Cleaning Joints*

4.10.5.1 The joints shall be thoroughly cleaned so as to expose sound concrete surfaces. The method shall be by means of jets of air and water applied at high velocity with such additional roughening of the

surface by means of stiff-wire brushes as may be required. Brushing shall be done by jabbing and digging into the surface rather than by merely sweeping. The whole process shall be conducted in such manner as not to loosen the coarse aggregates but vigorously enough to 'expose' a fresh clean-cut concrete surface.

4.10.5.2 Should the next lift be delayed, the contact surface shall be kept wet and covered so as to minimize the evaporation of curing water which may cause an injurious coating on the joint. Where necessary all defective and undesirable concrete shall be removed by chipping and picking by hand or, if so required, by wet sand blasting the top to a depth just sufficient to expose a fresh, clean-cut surface over the entire area, which shall then be thoroughly flushed with water. Every precaution shall be taken to afford suitable bond for the succeeding lift.

4.10.5.3 Immediately before depositing fresh concrete, the contact surface shall again be gone over and thoroughly washed to remove all debris and loose material. The final pick-up of loose materials shall be made near the centre of the joint and away from the outside edges of the masonry. Dry contact surfaces shall be kept saturated with water for not less than 24 hours, but all standing water shall be removed from depressions before spreading the mortar layer. The joint shall then be covered with about 1.5 cm (or $\frac{1}{2}$ in) of mortar (in the same proportion as in the original concrete but not lower than 1:2) and the concrete immediately deposited thereon according to the manner specified under 4.9.2 for rock foundation.

4.10.5.4 Hardened surfaces of old masonry on which new concrete is to be placed shall, unless otherwise ordered, be prepared in the same manner as provided for rock foundations under 4.9.2.

4.10.6 *Pneumatic Placing* — The pneumatic method of placing concrete or mortar may be used for such special purposes as tunnel linings, under-pinning foundations, pressure grouting, etc, provided special permission has been granted and the method approved.

4.10.7 *Rate of Placing* — Concreting shall be continued without avoidable interruption until the structure or section is completed or until satisfactory construction joints can be made. Concrete shall not be placed faster than the placing crew can compact it properly. In placing concrete in thin members and columns, precautions shall be taken against too rapid a placement which may result in movement or failure of the form due to excessive internal pressure. An interval of at least 4 and preferably 24 hours should elapse between the completion of columns and walls and the placing of slabs, beams or girders supported by them in order to avoid cracking due to settlement. All concrete shall be placed in approximately horizontal lifts not exceeding 150 cm (or 5 ft) in thickness except to expedite the placing of embedded materials. The interval

between two lifts shall also be maintained as constant as possible, and the difference of elevation between any two adjacent blocks shall not be more than 900 cm (or 30 ft) and not less than 150 cm (or 5 ft). A period of 5 days for 150 cm (or 5 ft) of concrete laid shall be allowed before the next pour unless heat dissipation methods warrant otherwise.

4.10.8 Placing 'Plums' in Concrete — Where plums are permitted to be used, they shall be washed and all dripping surface water removed before being embedded in the concrete. No stone shall be closer than 30 cm (or 12 in) to an exposed surface nor nearer than 15 cm (or 6 in) to an adjacent stone. The stones shall not be dropped in place, but each stone shall be laid and carefully embedded so as to avoid any injury to the forms or adjacent masonry and in such a manner that no planes of weakness of unnecessary seams occur in the structure.

4.10.9 Large Blocks — In placing concrete in large blocks, the work shall in general proceed from the low side to the high side so that the working face is never excessively steep nor long. However, for construction joints in dams, the work shall proceed from the high side to the low side so as to maintain an upward slope in the downstream direction, unless construction joints are otherwise shown on the drawings. Under no condition shall the slope be so steep as to cause the concrete to flow without working, or to cause any segregation. The concrete shall be deposited as nearly as practicable in final position and shall not be piled up in large masses at any point and then pushed, shovelled, or vibrated into space for long distances. It shall be brought up evenly around all large openings, conduits, or embedded metal so as to minimize unequal pressure and avoid displacement. For large blocks of concrete in dams and other massive structures, the sequence and rate of casting successive lifts and adjacent blocks shall be such as to facilitate the dissipation of the heat of hydration.

4.10.10 Rejected Concrete — All concrete of inferior quality shall be rejected and removed from the site of operations, if possible, before placing fresh concrete; where concrete has already been placed, if found inferior, it shall be dug out and removed from the forms. Any batch, too stiff for proper placement or in a such condition that it cannot be properly compacted, shall be removed.

4.11 Compacting

4.11.1 Method — Concrete shall be thoroughly compacted by means of suitable tools during and immediately after depositing. The concrete shall be worked around all reinforcement, embedded fixtures, and into the corners of the forms. Every precaution shall be taken to keep the reinforcement and embedded metal in proper position and to prevent distortion.

4.11.1.1 Compacting shall include rodding, spading, tamping, vibrating, treading, and such other operations except finishing, as are necessary to consolidate and mould the concrete properly. The rate of placing mass concrete or reinforced concrete in thin sections, whether mechanically or by manual labour, shall be clearly defined.

4.11.1.2 Accumulation of water on the surface due to bleeding, or other causes taking place during compacting shall be stopped as much as possible by adjustments in the mix. All free water on the surface shall be removed by sponging or mopping. Under no circumstances shall such accumulation of water be covered up with concrete, or dry concrete used to soak up excess water.

4.11.1.3 Unless otherwise permitted, all concrete shall be compacted by mechanical vibration. The number and type of vibrators shall be subject to the approval of the engineer-in-charge. In general, only vibrators of the internal type shall be used. However, in inaccessible places in the forms where spading, rodding, or forking is impracticable, the concrete may be gently worked into place and compacted by light vibrating or hammering the forms.

4.11.2 *Vibrating*

4.11.2.1 Wherever practicable, concrete shall be internally vibrated within the forms, or in the mass, in order to increase the plasticity as to compact effectively to improve the surface texture and appearance, and to facilitate placing of the concrete.

4.11.2.2 The intensity and duration of vibration shall be sufficient to cause complete settlement and compaction without any stratification of the successive layers or separation of ingredients. Preliminary experiments in vibrating shall be conducted under actual conditions of mix and placement in order to determine the optimum duration and method of vibration, as well as to develop the necessary skill.

4.11.2.3 Vibration shall be continued until the entire batch melts to a uniform appearance and the surface just starts to glisten. A minute film of cement paste shall be discernible between the concrete and the forms and around the reinforcement. Over vibration causing segregation, unnecessary bleeding or formation of laitance shall be avoided.

4.11.3 *Internal Type Vibrators*

4.11.3.1 Mass concrete shall be thoroughly compacted with the aid of high frequency, mechanical vibrators of the internal type, having

not less than 3 600 and preferably more than 5 000 impulses per minute. Immediately after depositing the concrete, the vibrators shall be inserted into each pile, operated from 10 to 20 seconds in one spot and then moved to another not over 90 cm (or 3 ft) away. The operation shall be repeated over until the entire mass is thoroughly compacted and the pile levelled down. Equal attention shall be paid to the edge of the pile and to the centre. A sufficient number of two-man vibrators shall be used to compact each batch properly before placing the next one. A sufficient number of reserve vibrators in good condition shall be kept on hand at all times so as to assure that there is no slackening or interruption in compacting.

4.11.3.2 The use of flexible shaft vibrators, if permitted, shall closely follow special instructions issued for the purpose.

4.11.3.3 Internal vibrators shall be allowed to penetrate as deeply as possible under their own weight and shall so consolidate the successive layers as to break up effectually all strata or seams. The vibrators shall be inserted and withdrawn slowly in such manner as not to leave voids in the plastic concrete. The entire operation shall be conducted in a systematic manner and each course or layer vibrated uniformly. The method of dumping or depositing the loads shall be so arranged as to keep the vibrators working continuously during placing operations. The courses shall be kept approximately level, and the concrete, even when deposited in thin layers, shall be as stiff as can be satisfactorily worked. However, concrete for which a slump greater than 10 cm (or 4 in) is specified shall not be vibrated unless otherwise ordered. Care shall be taken not to disturb a set of partially set layer. The vibrators shall be held vertical as far as possible.

4.11.3.4 Under no conditions shall internal vibrators strike the face of the forms, nor shall reinforcement steel or embedded metal be jarred with sufficient force to impair the bond between the concrete and the metal.

4.11.4 External Type Vibrators

4.11.4.1 Wherever so required, platform vibrators shall be used to embed all large stone or cobble projecting above the top of the lift, but such vibrators shall be used with caution and operated only in such manner as to avoid pulling excess mortar to the surface. The entire top of the lift for a depth of about 30 cm (or 1 ft) shall be thoroughly vibrated. Particular care shall be taken in making keyways and shear grooves. Where a raised key is required, the form shall be filled to overflowing and a platform vibrator used to compact the concrete and bond the key to the body of the lift.

4.11.4.2 Form vibrators shall be permitted only for special purpose specified under **4.11.1.3** and extreme care shall be exercised to avoid pumping air into the concrete.

4.11.5 Surface Voids — Large voids or air pockets, which may be left in the permanently exposed faces of the structure by vibration, shall be removed systematically spading the face in the following manner. Wherever practicable, a motor-driven, slowly revolving, square steel rod shall be held in a vertical position and moved slowly back and forth in short intervals along the entire face. Care shall be taken to avoid prolonging such spading to the point of leaving excess mortar in the face.

4.12 Depositing Concrete Under Water

4.12.1 Concrete shall not be deposited under water, if it is practicable to unwater the area and place the concrete in the regular manner. If it is found necessary to deposit any concrete under water, the method, equipment, materials and mix shall first be approved by the engineer-in-charge. Concrete shall not be placed in running water.

4.12.1.1 No concrete shall be placed in water colder than 2°C (or 35°F). When the water temperature is below 7°C (or 45°F), the temperature of the concrete when deposited shall be between 15 to 25°C (or 60 to 80°F). The difference between the temperature of water and temperature of concrete shall in no case exceed 5°C (or 40°F). The cement content shall be not less than 390 kg of cement per cu m (or 658 lb of cement per cu yd) of concrete. The limits for the slump shall be 10 cm and 18 cm (or 4 in and 7 in), the actual slump being decided by the engineer-in-charge.

4.12.1.2 Cofferdams or forms in running water shall be sufficiently tight to reduce the velocity of the water to less than 0.3 cu m (or 10 cu ft) per minute through the space to be filled with concrete. Cofferdams or forms in still water shall be sufficiently tight to prevent the loss of mortar. Pumping or bailing shall not be conducted while the concrete is being deposited, and within 24 hours after placing of the concrete.

4.12.2 Methods of Depositing Under Water — Concrete shall be deposited continuously until it is brought to the required height. While depositing, the top surface shall be kept as nearly level as possible and the formation of seams shall be avoided. The methods to be used for depositing concrete under water shall be one of the following:

- a) *Tremie* — When concrete is deposited under water by means of a tremie, the top section of the tremie shall be a hopper large enough to hold one entire batch of the mix or the entire contents of the

transporting bucket when one is used. The tremie pipe shall be not less than 20 cm (or 8 in) in diameter and shall be large enough to allow free flow of concrete and strong enough to withstand the external pressure of the water in which it is suspended, even if a partial vacuum should develop inside the pipe. Flanged steel pipe of adequate strength to sustain the greatest length and weight required for the job should preferably be used. A separate lifting device shall be provided for each tremie pipe with its hopper at the upper end. Unless the lower end of the pipe is equipped with an approved automatic check valve, the upper end of the pipe shall be plugged with a wadding of gunny sacking or other approved material, before delivering the concrete to the tremie pipe through the hopper. The plug of sacking or other material is forced out at the bottom end of the pipe by filling the pipe with concrete. It is necessary to raise slowly the tremie in order to cause a uniform flow of the concrete, but care shall be taken not to empty the tremie so that water enters above the concrete in the pipe. At all times, after the placing of concrete is started and until all the concrete is placed, the lower end of the tremie pipe shall be below the top surface of the plastic concrete. This causes the concrete to build up from below instead of flowing out over the surface and avoids formation of laitance layers. If the charge in the tremie is lost while depositing, the tremie shall be raised above the concrete surface, and unless sealed by a check valve it shall be re-plugged at the top end, as at the beginning, before being refilled for depositing concrete.

- b) *Drop bottom bucket* — The top of the bucket shall be open. The bottom doors shall open freely downward and outward when tripped. The bucket shall be filled completely and lowered slowly to avoid backwash. It shall not be dumped until it rests on the surface upon which the concrete is to be deposited and when discharged shall be withdrawn slowly until well above the concrete.
- c) *Bags* — Bags of at least 0.03 cu m (or 1 cu ft) capacity of jute or other coarse cloth shall be filled about two-thirds full of concrete, the spare end turned under so that bag is square ended and securely tied. They shall be placed carefully in header and stretcher courses so that the whole mass is interlocked. Bags used for this purpose shall be free from deleterious materials.

4.12.3 To minimize the formation of laitance, great care shall be exercised not to disturb the concrete while it is being deposited.

4.12.4 If it is necessary to raise the water after placing the concrete, the level shall be brought up slowly without creating any waves or commotion tending to wash away cement or to disturb the fresh concrete in any way.

4.12.5 Concrete Exposed to Corrosive Water or Soils — Special cements shall be specified to be used in concrete to be deposited under these conditions. Extreme care shall be taken to secure maximum density and durability. The placing of any block shall continue without interruption until the concrete is at least 45 cm (or 18 in) above the ground water level. The corrosive waters or soils shall not touch the concrete during placement or for at least 72 hours thereafter.

4.13 Weather Conditions

4.13.1 Concrete operations shall be temporarily suspended during excessively hot, cold, or inclement weather, or whenever conditions are such that the concrete cannot be properly placed and cured.

4.13.2 During freezing weather, all aggregates shall be free from ice, snow, heavy frost and frozen lumps. Whenever the temperature is likely to fall below -7°C (or 20°F) within the subsequent 48 hours, concreting operations shall be suspended unless provision has been made to protect the concrete from freezing. Under such circumstances, the water used for mixing shall be heated and the temperature of concrete shall be kept at not less than 10°C (or 50°F) for at least 72 hours after placement.

4.13.3 During hot weather no concrete shall be deposited when the temperature within the forms is more than 50°C (or 120°F). Whenever necessary, exposed surfaces of fresh or green concrete shall be shaded from the direct rays of the sun and protected against premature setting or drying by being cured under continuous fine spray of water

4.13.4 During continued rainy weather or heavy downpours, all freshly placed concrete shall be covered and protected against surface wash. Special precautions shall be taken to prevent the formation of lean seams or sand streaks. Mortar coats for bonding construction joints as specified under **4.9.1**, **4.9.1.1** and **4.10.5** shall not be placed or left exposed if the rain is tending to increase the water-cement ratio of the mortar. Under no conditions shall concrete be placed in a pool or a sheet of water. The top of all badly washed or streaked surfaces shall be removed and wasted before depositing the next course.

4.14 Curing and Protection

4.14.1 All concrete shall be protected against injury. Exposed finished surfaces of concrete shall be protected against heating and drying from the sun for at least 72 hours after placement. Concrete shall, in general, be kept continuously (not periodically) moist for not less than 14 days. Construction joints shall be cured in the same way as other

concrete and shall also, if practicable, be kept moist for at least 72 hours prior to the placing of additional concrete upon the joint. Horizontal and approximately horizontal surfaces shall be cured by sprinkling or by covering with damp sand, or by the use of wet sacks which satisfactorily retain the required amount of water for curing purposes. Where damp sand or sack cover is used for curing, it shall be completely removed later. Water curing shall be used on all concrete in dams and shall be applied by means of sprays or sprinklers to cover the entire area of the concrete. Forms shall be kept sprinkled until removal. Concrete shall not be disturbed by workmen walking on it or by storing materials on the surface or otherwise for at least 10 hours after placing.

4.14.2 In special cases, such as powerhouses, the use of an approved, properly-applied sealing compound on limited areas shall be permitted. The curing compound shall be of the surface membrane type which shall thoroughly seal the concrete surface. Curing compound shall not be used on joints where bonding is required. The concrete surface shall be thoroughly wetted before applying the compound. All surfaces covered with curing compound shall be protected from traffic or injury of the sealing coat until expiration of the curing period. All methods used for curing shall leave the concrete free from any discolouration or damage to the concrete.

4.15 Repair of Concrete — Repair of all imperfections of the concrete surfaces necessary to produce surfaces that conform to the requirements shall be completed as soon as practicable after removal of forms and wherever possible within 24 hours after the removal of forms. Fins shall be neatly removed from surfaces for which finishes F2 and F3 (see 4.16.2) are required. Concrete that is damaged from any cause, and concrete that is honey-combed, fractured, or otherwise defective, and concrete, which because of excessive surface depressions, has to be excavated and built up to bring the surface to the prescribed lines, shall be removed and replaced with dry-patching mortar. Where bulges and abrupt irregularities protrude outside the required limits and where it is required to finish the surfaces with finishes F2 and F3, the protrusions shall be reduced by bush-hammering and grinding so that the surfaces are brought within the required limits. Drypack filling shall be used for holes having at least one surface dimension not greater than the hole depth, for holes left by removal of fasteners from the ends of form tie rods, for grout pipe recesses, and for narrow slots cut for repair of cracks. Filling of holes left by the removal of fasteners from the ends of the tie rods in surfaces for which F1 finish is specified, shall not be required. Dry-patching mortar shall consist of one part of cement to two parts of sand by volume, and just enough water to hold the ingredients together. The mortar shall be placed in layers of 2.5 cm (or 1 in) each layer thoroughly tamped, and the finishing layer shall be smoothed to form the surface continuous with

the surface of the holes and shall be sound and free from shrinkage cracks and surrounding concrete. All filling shall be bonded rightly to the hollow areas after the fillings have been cured and have dried.

4.16 Finishes and Finishing

4.16.1 Concrete surfaces shall be tested where necessary to determine whether surface irregularities are within the specified limits. Surface irregularities are classified as 'abrupt' or 'gradual'. Offsets caused by displaced or misplaced form sheathing or lining or form sections, or by loose knots in forms or otherwise defective timber forms shall be considered as abrupt irregularities, and shall be tested by direct measurement. All other irregularities shall be considered as gradual irregularities, and tested by use of a template, consisting of a straight edge or the equivalent thereof for curved surfaces. The length of the template shall be 150 cm (or 5 ft) for testing of formed surfaces and 300 cm (or 10 ft) for testing of unformed surfaces.

4.16.2 Formed Surfaces — The finish for formed concrete surfaces shall be of the following four classes:

- a) *Finish F1* — Finish F1 shall apply to formed surfaces upon which or against which backfill or concrete is to be placed. The surfaces require no treatment after removal of forms except removal and repair of defective concrete and the specified curing. Correction of surface irregularities shall be done only for depressions which when measured as described under 4.16.1 exceed 2.5 cm (or 1 in).
- b) *Finish F2* — Finish F2 shall apply to all permanently exposed formed surfaces for which finishes F3 and F4 are not specified. 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, measured as described under 4.16.1 shall not exceed 0.5 cm (or $\frac{1}{4}$ in) for abrupt irregularities and 1 cm (or $\frac{1}{2}$ in) for gradual irregularities.
- c) *Finish F3* — Immediately after removal of forms from surfaces designated for F3 finishes, all required patching, clean up and correction of major imperfections shall be completed and the surfaces shall be given a sack-rubbed mortar finish in the following manner:
The surfaces shall be thoroughly wetted and permitted to approach surface dryness before starting the sack rubbing. The surfaces shall be finished in areas sufficiently small to prevent complete drying of any part before the sack rubbing is completed for that area. The mortar used for the sack rubbing shall consist of one part of cement to two parts, by volume, of sand passing through IS Sieve 100, and enough water so that the consistency

of the mortar is that of thick cream. The mortar shall be rubbed thoroughly over the area with clean burlap or a sponge rubbed float, completely filling all pits and irregularities. While the mix in the holes is still plastic, a mixture of the dry ingredients of the mortar in the same proportions shall be rubbed over the area. After the mortar has stiffened adequately to prevent smearing, but before it has hardened, the excess mortar shall be removed by rubbing with clean burlap. After the final sack rubbing, a light fog spraying shall be applied to the coated surface, the moisture thus applied being just sufficient to damp the surface without allowing water to run down the face of the walls.

All sack-rubbed areas shall be kept continuously damp for at least 72 hours after the final sack rubbing, or until completion of the curing period for the concrete. When measured as described under 4.16.1, abrupt irregularities shall not exceed 0.5 cm (or $\frac{1}{4}$ in) for irregularities parallel to the direction of flow, and 0.25 cm (or $\frac{1}{8}$ in) for irregularities in other direction. Gradual irregularities shall not exceed 0.5 cm (or $\frac{1}{4}$ in). Irregularities exceeding these limites shall be reduced by grinding on a bevel of 1 to 20 ratio of height to length.

- d) *Finish F4* — Finish F4 shall apply to formed surfaces where absorptive form lining is used. Surfaces provided by absorptive form lining shall not be rubbed or treated in any way except for cleaning by wire brushing and grinding off thin fins or small projections.

4.16.3 Unformed Surfaces — The classes of finish for unformed concrete surfaces are designated by the symbols U1, U2 and U3. Interior surfaces shall be sloped for drainage where shown on the drawings. Surfaces which would be exposed to the weather and which would normally be level, shall be sloped for drainage. Unless the use of other slopes or level surfaces is specified, narrow surfaces, such as tops of walls and curbs, shall be sloped approximately 3 cm per metre (or $\frac{3}{8}$ in per ft) of width border surfaces, such as walks, roadways, platforms, and decks shall be sloped approximately 1.5 cm per metre (or $\frac{1}{4}$ in per ft). The classes of finish to be applied shall be as follows:

- a) *Finish U1 (screeded finish)* — shall apply to unformed surfaces that are to be covered by backfill or by concrete and surfaces of subfloors which will be covered by concrete floor topping. Finish U1 is also used as the first stage for Finishes U2 and U3. Finishing operations shall consist of sufficient levelling and screeding to produce even uniform surfaces. Surface irregularities, measured as described under 4.16.1 shall not exceed 1 cm (or $\frac{3}{8}$ in).
- b) *Finish U2 (floated finish)* — shall apply to unformed surfaces not permanently concealed by backfill or concrete or unformed surfaces for which Finishes U1 and U3 are not specified, and shall

include floors of sumps, tops of walls, parking areas, parapet walls, surfaces of gutters, sidewalks and outside entrance slabs. Finish U2 is also used as the second stage for Finish U3. Floating may be performed by use of hand- 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 screed marks and is uniform in texture. If Finish U3 is to be applied, floating shall be continued until a small amount of mortar without excess water is brought to the surface, so as to permit effective trowelling. Surface irregularities, measured as described under 4.16.1 shall not exceed 0.5 cm (or $\frac{1}{4}$ in). Joints and edges of gutters, sidewalks, entrance slabs, and other joints and edges shall be tooled where necessary.

- c) *Finish U3 (trowelled finish)* — shall apply to unformed surfaces, such as slabs to be covered with built-up roofing or membrane water-proofing and stair treads. When the floated surface has hardened sufficiently to prevent excess of fine material from being drawn to the surface, steel trowelling shall be started. Steel trowelling shall be performed with firm pressure, so as to flatten the sandy texture of the floated surface and produce a dense uniform surface, free from blemishes and trowel marks; light steel trowelling will be permissible on surfaces of slabs to be covered with built-up roofing or membrane waterproofing, in which light trowel marks are not considered objectionable. Surface irregularities measured as described under 4.16.1 shall not exceed 0.5 cm (or $\frac{1}{4}$ in).

5. FORMS FOR CONCRETE

5.1 General — Forms shall be used wherever necessary to confine concrete and shape it as required. All exposed concrete surfaces having slopes of one to one or steeper shall be formed, unless otherwise directed. Where the character of the natural material cut into to receive a concrete structure is such that it can be trimmed to the prescribed lines, the use of forms shall not be required. The forms shall have sufficient strength and rigidity to hold the concrete and to withstand the necessary pressure, ramming, and vibration without excessive deflection from the prescribed lines. The surfaces of all forms in contact with the concrete shall be clean, rigid, tight and smooth. Suitable devices shall be used to hold corners, adjacent ends, and edges of panels or other forms together in accurate alignment.

5.1.1 Metal forms or metal-lined forms shall be permitted for permanently exposed surfaces only when an entire surface is to be built

completely with such forms. Curved and special forms shall be of a character that would give smooth concrete surfaces. They shall be so designed and constructed as not to warp or spring during erection or placing concrete. Forms to be used more than once shall be maintained in serviceable condition, and shall be thoroughly clean and smooth before being reused. Where metal sheets are used for lining forms, the sheets shall be placed and maintained on the forms with the minimum amount of wrinkles, bumps, or other imperfections. The use of sheet metal to correct imperfections in the lining of timber faced forms for surfaces that are to be permanently exposed to view shall not be permitted. Where plywood is used for form lining, the joints between the sheets shall be smooth and as perfect as practicable, and no patching of the plywood shall be permitted for permanently exposed surfaces. Minor imperfections in the plywood shall be corrected by the use of plastic wood, secured firmly in place and sand-papered smooth after it has hardened.

5.2 Absorptive Form Lining — Absorptive form lining, where directed to be used, shall be of the type and quality approved by the engineer-in-charge. The form lining shall be highly absorptive to air and water, and through its absorptive capacity be able to eliminate voids, pits and other common defects from the concrete surface. The lining shall be readily removable from the concrete without damage to the surface. It shall produce a dense concrete surface of uniform and satisfactory texture and colour. 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, knot holes, and other imperfections to avoid unevenness in the finished surface. The lining shall be in sheets of uniform length and width. Location and direction of the joints shall be approved by the engineer-in-charge. The joints between sheets shall be fitted smoothly and accurately, and patching shall be avoided. Edges shall be brought to light contact, but shall not be pressed tightly together. Cutting and trimming shall be true and shall be done with tools well adapted to this work so that sharp, smooth, square edges are produced. The lining shall be attached to the forms in such a manner that it is held securely and smoothly in place. Nails or tacks, if used, shall be spaced in uniform pattern, and shall be driven flush. Dents and hammer marks in the surface of the lining shall 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 fibres. Where absorptive form lining is in contact with the face of a previous pour, care shall be used in setting and sufficient pressure shall be applied in tightening form anchors to produce continuity and evenness at the face, free from offsets, sand streaks, and other irregularities. The lining shall be kept dry and shall not be reused.

5.3 Form Ties — The use of metal rods or other similar devices embedded in the concrete for holding forms shall be permitted if the ends of the rods are omitted or subsequently removed to a depth of not less than 5 cm (or 2 in) from the surface of the concrete without injury to the concrete, provided that for walls subjected to water pressure on one side and required to be watertight, the rods shall not be taken through the wall. Complete removal of embedded rods shall not be permissible. Removal of embedded fasteners on the ends of the rods shall be done so as to leave holes of regular shape for reaming. All holes left by the removal of fasteners from the ends of the rods shall be immediately reamed with suitable toothed reamers so as to leave the surfaces of the holes clean and rough and completely filled with dry patching mortar, and the surface shall be finished to match the adjacent concrete. Wire ties shall be permitted only where specifically approved, and shall be cut off flush with the surface of the concrete after the forms are removed. Wire ties shall not be used where permanently exposed finished surfaces are required.

5.4 Erection of Forms — Before placing concrete, the surfaces of all forms, except those lined with absorptive form lining, shall be oiled with a suitable non-staining oil, and, immediately before concrete is placed, precautions shall be taken to see that all forms are in proper alignment and that all form anchors and ties are thoroughly secure and tight. Special care shall be taken to oil thoroughly the form strips for narrow grooves so as to prevent swelling of the forms and consequent damage to the concrete prior to or during the removal of forms. Where forms for continuous surfaces are placed in successive units, the forms shall fit tightly over the completed surface so as to prevent leakage of mortar from the concrete and to maintain accurate alignment of the surface. Care shall be taken to see that the construction joints formed are smooth, free from sharp deviations, projections, or edges. Particular attention shall be given in setting and tightening the form, so that the construction joint surfaces are plumb and accurately aligned.

5.5 Removal of Forms — Removal of forms shall never be started until the concrete has thoroughly set and has aged to give it sufficient strength to carry twice its own weight plus the live load which is likely to come on the structure during the course of construction. The length of time, the forms would remain in place, shall be decided with reference to weather conditions, slope and position of the structure or structural member and the nature and amount of dead and live loads.

5.5.1 In no case should forms be removed until there is assurance that their removal is possible without chipping, spalling or defacing the concrete surface. Furthermore, heavy loads shall not be permitted until after the concrete has reached its designed strength. All forms shall be entirely removed from a lift to permit inspection before the forms for the next lift are set.

6. CONSTRUCTION JOINTS

6.1 Location of Joints — The location and type of all construction joints shall be shown on the drawings, and no other joints or type of joints shall be built unless specifically approved by the competent authority.

6.2 Horizontal Joints — The stipulations of 4.10.5 for cleaning masonry joints and bonding new concrete to old shall apply to all horizontal construction joints. Keyways or dowels for resistance to shear shall be carefully formed and placed as shown on the drawings. At least 2 hours shall elapse after depositing concrete in columns or supporting walls before placing the concrete in the floor system. All joints shall be finished to present a sharp level, straight line in the exposed face.

6.3 Vertical Joints — Vertical construction joints shall be built with essentially the same care as other exposed surfaces. The break between the adjoining sections of masonry shall be complete, unless otherwise detailed on the drawings.

6.4 Water-tight Joints

6.4.1 Where horizontal construction joints are subject to water pressure, special care shall be taken to bond the next lift of concrete. The consistency of the concrete shall be carefully controlled so as to avoid sand streaking; and after compaction no free water shall show anywhere along the joint. The surface shall be carefully cured as specified under 4.15 and shall be protected from mechanical injury. Before placing the next lift, the joint shall be cleaned and prepared as specified under 4.10.5.

6.4.2 In casting vertical joints required to be water-tight, care shall be taken not to injure or displace the grout piping, water stops, or seals called for on the drawings.

6.5 Emergency Joints — Wherever placing is interrupted long enough for the concrete to take its final set, the working face shall be so formed and finished as to provide union with subsequent work equal to that specified for regular construction joints.

7. TESTS

7.1 Field Tests — Field tests of all concrete being placed shall be regularly conducted. In general, as a reliable indication of other physical properties, the quality of the concrete being produced shall be judged by a comparison of the compressive strengths developed within a given period.

7.2 Laboratory Test— A properly equipped testing laboratory to control the quality of the concrete shall be operated on the work site. The laboratory shall be fully equipped with apparatus for conducting all the usual physical tests for concrete. The compression-testing machine shall have a capacity of not less than 100 metric tonnes (or 100 tons) and shall be capable of applying the test load at a uniform rate of application.

7.3 Test Records— A complete record shall be kept of all operations. An accurate daily record shall be made of the location, mix, compressive strength, water-cement ratio and other physical data pertaining to the concrete placed in each part of the structure.

7.3.1 The density, durability, imperviousness, generation and loss of heat, expansion and other physical characteristics of the concrete shall be tested as often as may be required to maintain the required properties.

7.4 Test Pieces— In general, not less than one sample shall be taken from approximately each 380 cu m (or 500 cu yd) of mass concrete and from 190 cu m (or 250 cu yd) of reinforced concrete placed and for each class of concrete deposited in any one day's run. Three cylinders or test beams shall be made from each sample. The normal number of control specimens, however, may be changed at the discretion of the engineer-in-charge. Samples for compression test shall be taken in the field in accordance with Appendix E of *IS : 456-1957. All specimens shall be moulded immediately after the sample is taken. They shall be stored in a protected place under a moist condition at $27 \pm 2^{\circ}\text{C}$ (or $81 \pm 4^{\circ}\text{F}$) without being disturbed or moved for at least 24 hours after being cast.

7.4.1 For standard 15×30 cm (or 6×12 in) cylinders, all aggregate having a maximum dimension of more than 4 cm (or $1\frac{1}{2}$ in) shall be removed by wet-screening the sample just before moulding the test pieces. For large cylinders, the maximum size of aggregate left in the sample shall not be more than one-fourth the diameter of the cylinder. Occasional specimens as large as can be tested in the field laboratory shall be cast without removing any aggregate. Such specimens shall be tested to establish the relation between unscreened and normally screened samples. The corrective factor thus determined shall be applied to the tested strength of screened specimens in recording the average daily unit strength of the concrete placed in the structure.

7.4.2 For dams and other large structures, all field specimens shall be finally cured under moist conditions at a constant temperature of $27 \pm 2^{\circ}\text{C}$ (or $81 \pm 4^{\circ}\text{F}$) and at 85 percent relative humidity. For small jobs where a moist room is not available, the specimens shall be cured in accordance with the standard methods of making and storing compression test specimens in the field.

*Second revision in 1964.

7.4.3 *Age of Specimens* — Regular tests shall be run at the age of 7 and 28 days, with occasional tests of representative specimens at 14 days and at 3, 6 and 12 months.

7.5 Compression Tests

7.5.1 For compression tests, the regular size of cylinder and cubes and the manner of moulding, capping and testing the specimens shall be in accordance with Appendices B and E of *IS: 456-1957* except that an approved method of vibration may be used for compacting the concrete.

7.5.2 Wherever required, representative 15 cm (or 6 in) cores shall be drilled from the completed structure and shall be prepared, capped and tested in accordance with Appendix B. The ultimate compressive strength and soundness of such specimens shall be compared with the results of similar tests on standard test cylinders taken from the same run.

7.6 *Flexure Tests* — For flexure tests, the size and shape of specimens and the manner of moulding and testing shall be in accordance with Appendix C.

7.7 *Failure to Meet Requirements* — Should the test specimens fail to show the desired uniform quality and characteristics, the directions given by the engineer-in-charge to improve such concrete, shall be strictly followed.

APPENDIX A

(Clause 4.5)

DETERMINATION OF CONSISTENCY OF CONCRETE BY VEE-BEE CONSISTOMETER METHOD

A-1. SCOPE

A-1.1 This appendix deals with the determination of consistency of concrete using a Vee-Bee Consistometer, which determines the time required for transforming, by vibration, a concrete specimen in the shape of a conical frustum into a cylinder.

A-2. APPARATUS

A-2.1 The Vee-Bee Consistometer (*see Fig. 1*) consists of:

- a) A vibrator table resting upon elastic support;
- b) A metal pot;

*Second revision in 1964.

- c) A sheet metal cone, open at both ends; and
- d) A standard iron rod.

A-2.2 The vibrator table (G) is 380 mm long and 260 mm wide and is supported on rubber shock absorbers at a height of about 305 mm above floor level. The table is mounted on a base (K) which rests on three rubber feet, and is equipped with an electrically operated vibrometer mounted under it operating on either 65 volts or 220 volts, three phase, 50 cycles alternating current. A sheet metal cone (B) open at both ends is placed in the metal pot (A) and the metal pot is fixed on to the vibrator table by means of two wing-nuts (H). The sheet metal cone is 30 cm high and its bottom diameter is 20 cm and top diameter 10 cm. A swivel arm holder (M) is fixed to the base and into this is telescoped another swivel arm (N) with funnel (D) and guide-sleeve (E). The swivel arm can be readily detached from the vibrating table. The graduated rod (J) is fixed on to the swivel arm and at the end of the graduated arm a

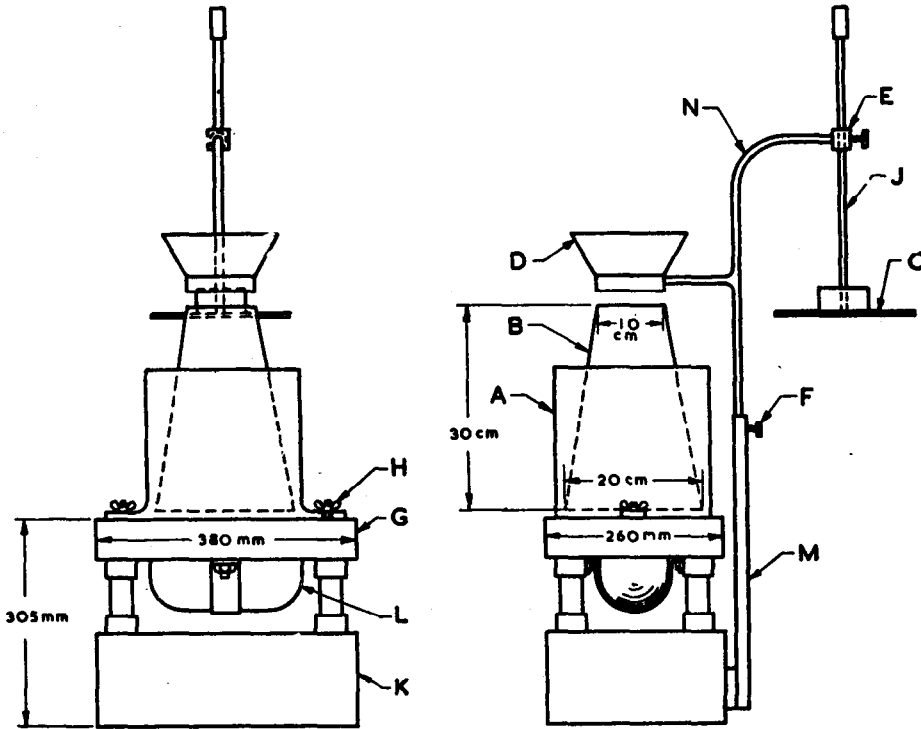


FIG.1 VEE-BEE CONSISTOMETER, TYPE VBR

glass disc (C) is screwed. The graduation of the scale on the rod records the slumps of the concrete cone in centimetres and the volume of concrete after vibration of the cone in the pot. The standard iron rod is 20 mm in diameter and 500 mm in length. The electrical equipment mounted on the base of the consistometer consists of a fixed plug and connector for



FIG. 2 VEE-BEE CONSISTOMETER

the electric supply cable, plug and socket contacts for the detachable cable connected to the vibrometer and a control switch. A photograph of the apparatus under operation is given in Fig. 2.

A-3. PROCEDURE

A-3.1 A slump test as described in Appendix G of *IS: 456-1957 is performed in the sheet metal cylindrical pot of the consistometer. The glass

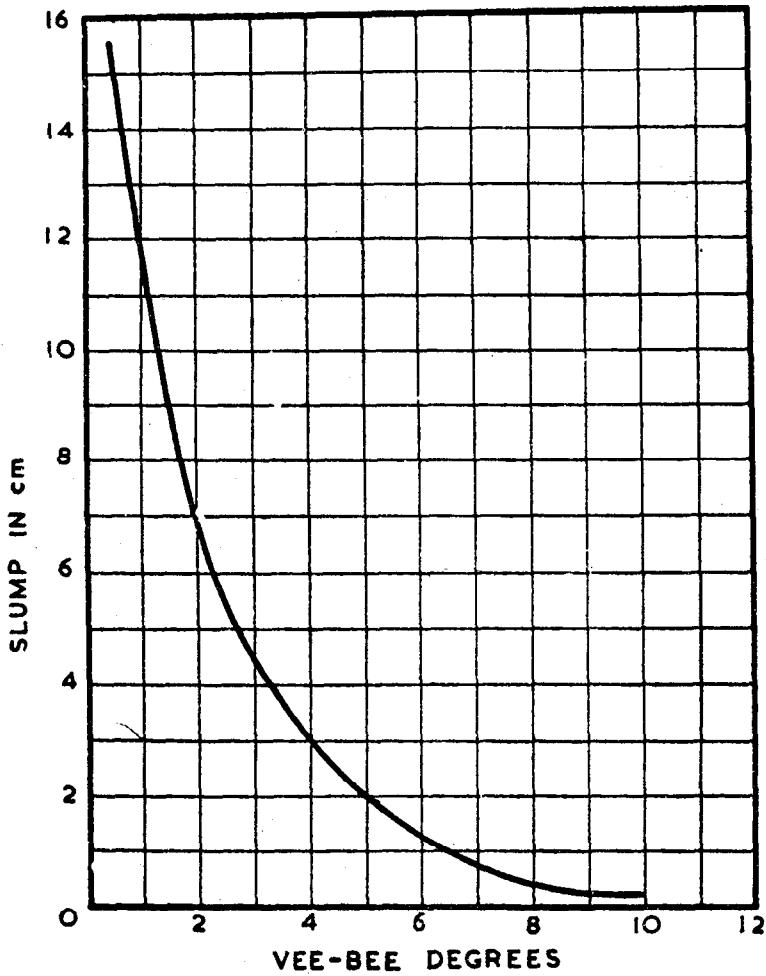


FIG. 3 RELATION BETWEEN SLUMP IN CM AND VEE-BEE DEGREES

*Second revision in 1964.

disc attached to the swivel arm is moved and is placed just on top of the slump cone in the pot and before the cone is lifted up the position of the concrete cone is noted by adjusting the glass disc attached to the swivel arm. The cone is then lifted up and the slump is noted on the graduated rod by lowering the glass disc on top of the concrete cone. The electrical vibrator is then switched on and the concrete is allowed to spread out in the pot. The vibration is continued until the whole concrete surface uniformly adheres to the glass disc as indicated in Fig. 2 and the time taken for this to be attained is noted with a stop-watch. The time is recorded in seconds.

A-4. RESULT

A-4.1 The consistency of the concrete is expressed in Vee-Bee degrees which are equal to the time in seconds under **A-3.1**.

A-4.2 The required slump is obtained on the basis of the consistency scale given in Table II.

A-4.2.1 The curve in Fig. 3 indicates the relationship between slump in cm and the degrees covered by the consistency scale given in Table II.

TABLE II CONSISTENCY SCALE

| CONSISTENCY | NUMBER OF VEE-BEE DEGREES | CHARACTERISTICS |
|-------------|---------------------------|---|
| Moist earth | 40 to 25 to 20 | Particles of coarse aggregate in the concrete are adhesive, but concrete does not clot. Risk of segregation. |
| Very dry | 20 to 15 to 10 | Concrete has the consistency of very stiff porridge, forms a stiff mound when dumped, and barely tends to shake or roll itself to form an almost horizontal surface when conveyed for a long time in, say, a wheel-barrow |
| Dry | 10 to 7 to 5 | Concrete has the consistency of stiff porridge, forms a mound when dumped, and shakes or rolls itself to form a horizontal surface when conveyed for a long time in, say, a wheel-barrow. |
| Plastic | 5 to 4 to 3 | Concrete can be shaped into a ball between the palms of the hands and adheres to the skin. |
| Semi-fluid | 3 to 2 to 1 | Concrete cannot be rolled into a ball between the palms of the hands, but spreads out even though slowly and without affecting the cohesion of the constituents so that segregation does not occur. |
| Fluid | More fluid than 1 | Concrete spreads out rapidly and segregation takes place. |

APPENDIX B*(Clause 7.5.2)***METHOD OF SECURING HARDENED SPECIMENS OF
CONCRETE FROM THE STRUCTURE****B-1. SCOPE**

B-1.1 This method covers the procedure for securing, preparing and testing specimens of hardened concrete from structures and pavements.

B-2. PRECAUTIONS

B-2.1 A specimen to be tested for strength shall not be removed from the structure until the concrete has become hard enough to permit its removal without disturbing the bond between the mortar and the coarse aggregate. In general the concrete shall be 14 days old before the specimens are removed. Specimens that show abnormal defects or that have been damaged in removal shall not be used.

B-3. APPARATUS

B-3.1 Core Drill — A core drill shall be used for securing cylindrical core specimens. For specimens taken perpendicular to a horizontal surface, a diamond drill shall be used.

B-3.2 Saw — A saw shall be used for securing beam specimens from the structure or pavements for flexural strength tests. The saw shall have a diamond or silicon carbide cutting edge and shall have adjustments that will permit cutting specimens which conform to the dimensions prescribed under **B-4.2**.

B-4. SPECIMENS

B-4.1 Core Specimen — A core specimen for the determination of pavement thickness shall have a diameter of at least 10 cm (or 4 in). A core specimen for the determination of compressive strength shall have a diameter at least three times the maximum nominal size of the coarse aggregate used in the concrete, and in no case shall the final diameter of the specimen be less than twice the maximum nominal size of the coarse aggregate. The length of the specimen, when capped, shall be, as nearly as practicable, twice its diameter.

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B-4.2 Beam Specimen — A beam specimen for the determination of flexural strength, in general, shall have a cross-section of 15×15 cm (or 6×6 in). The specimen shall be at least 53 cm (or 21 in) in length but when two tests for flexural strength are desired for one beam specimen, it shall be at least 84 cm (or 33 in) in length.

NOTE — In many cases, particularly with prisms cut from pavement slabs, the width shall be governed by the size of the coarse aggregate and the depth by the thickness of the slab.

B-5. PROCEDURE

B-5.1 Core Drilling — A core specimen taken perpendicular to a horizontal surface shall be located, when possible, so that its axis is perpendicular to the bed of the concrete as originally placed. A specimen taken perpendicular to a vertical surface, or perpendicular to a surface with a batter, shall be taken from near the middle of a unit of deposit, i.e., 380 cu m (or 500 cu yd) of mass concrete and from 190 cu m (or 250 cu yd) of reinforced concrete placed in any one day's run.

B-5.2 Slab Removal — A sufficiently large slab shall be removed so that the desired test specimens may be secured without the inclusion of any concrete which has been cracked, spalled, undercut, or otherwise damaged.

B-5.3 Beam Sawing — The sawing operation shall be so performed that the concrete will not be weakened by shock or by heating. The sawed surfaces shall be smooth, plane, parallel, and free from steps, ridges and grooves. Care shall be taken in handling sawed beam specimens to avoid chipping or cracking.

B-6. COMPRESSIVE STRENGTH

B-6.1 End Preparation — Core specimens to be tested in compression shall have ends that are essentially smooth, perpendicular to the axis, and of the same diameter as the body of the specimen. The ends of specimens which have projections of 0.5 cm (or $\frac{1}{4}$ in) or more above the normal plane, or which depart from perpendicularity to the axis by more than 5 degrees, or whose diameter departs from the mean by more than 0.25 cm (or $\frac{1}{8}$ in) shall be sawed or tooled until they conform to these tolerances.

B-6.2 Moisture Conditioning — Test specimens shall be completely submerged in water at room temperature for 40 to 48 hours immediately prior to the compression test. Specimens shall be tested promptly after removal from water storage. During the period between removal from the water storage and testing, the specimens shall be kept moist by covering with a wet burlap or blanket. They shall be tested in a moist condition.

B-6.3 Capping — Before making the compression test, the ends of the specimen shall be capped in order to meet the requirements given in Appendix E of IS: 456-1957.

B-6.4 Measurement — Prior to testing, the length of the capped specimen shall be measured to the nearest 0.25 cm (or 0.1 in) and its average diameter determined to the nearest 0.25 cm (or 0.1 in) from two measurements taken at right angles near the centre of the length.

B-6.5 Calculation and Report — The direction of the application of the load with reference to direction of compaction of the concrete in the structure shall be reported. The compressive strength of each specimen shall be calculated in kg per sq cm (or lb per sq in) based on the average diameter of the specimen. If the ratio of length to diameter of a specimen is appreciably less than two, allowance for the ratio of length to diameter shall be made by multiplying the compressive strength by the applicable correction factor given in the following table. Values not given in the table shall be determined by interpolation.

| RATIO OF LENGTH OF CYLINDER TO DIAMETER | STRENGTH CORRECTION FACTOR |
|--|-------------------------------|
| 1.75 | 0.98 |
| 1.50 | 0.96 |
| 1.25 | 0.94 |
| 1.10 | 0.90 |
| 1.00 | 0.85 |
| 0.75 | 0.70 |
| 0.50 | 0.50 |

APPENDIX C

(Clause 7.6)

FLEXURAL STRENGTH OF CONCRETE (USING SIMPLE BEAM WITH THIRD-POINT LOADING)

C-1. SCOPE

C-1.1 This method of test covers the procedure for determining the flexural strength of concrete by the use of a simple beam with third-point loading.

C-2. APPARATUS

C-2.1 The third-point loading method shall be used in making flexure tests of concrete employing bearing blocks which shall insure that forces

applied to the beam are vertical only and applied without eccentricity. A diagram of an apparatus which accomplishes this purpose is shown in Fig. 4.

NOTE — Sometimes methods of load application other than the one described in this appendix are used in the field. If such methods are used, the results should be correlated with those obtained with the method described in this appendix.

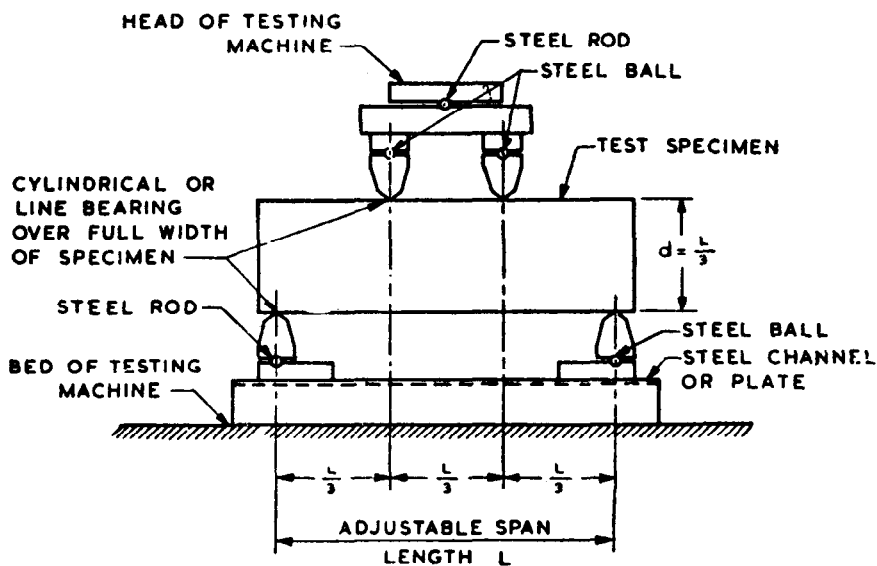


FIG.4 DIAGRAMMATIC VIEW OF APPARATUS FOR FLEXURE TEST OF CONCRETE BY THIRD-POINT LOADING METHOD

C-2.2 Apparatus for making flexure tests of concrete should be designed to incorporate the following principles:

- a) The distance between supports and points of load application should remain constant for a given apparatus;
- b) The load should be applied normal to the loaded surface of the beam and in such a manner as to avoid eccentricity of loading;
- c) The direction of the reactions should be parallel to the direction of the applied load at all times during the test;
- d) The load should be applied at a uniform rate and in such a manner as to avoid shock; and
- e) The ratio of distance between point of load application and nearest reaction to the depth of the beam should be not less than one.

C-2.2.1 The directions of loads and reactions may be maintained parallel by judicious use of linkages, rocker bearings, and flexure plates. Eccentricity of loading can be avoided by use of spherical or roller bearings.

C-3. TEST SPECIMEN

C-3.1 The test specimen shall have a span as nearly as practicable three times its depth as tested.

C-4. PROCEDURE

C-4.1 The test specimen shall be turned on its side with respect to its position as moulded and centred on the bearing blocks. The load-applying blocks shall be brought in contact with the upper surface at the third point between the supports. If full contact is not obtained between the specimen and the load-applying blocks and the supports, due to the surfaces of the specimen being out of plane, the surfaces of the specimen where they are in contact with the blocks or supports shall be capped to meet the requirements given in Appendix E of IS: 456-1957. The load may be applied rapidly up to approximately 50 percent of the breaking load, after which it shall be applied at such a rate that the increase in extreme fibre stress does not exceed 10 kg per sq cm (or 150 lb per sq in) per minute.

C-5. MEASUREMENT OF SPECIMENS AFTER TEST

C-5.1 Measurements to the nearest 0.25 cm (or 0.1 in) shall be made to determine the average width and average depth of the specimen at the section of failure.

C-6. CALCULATIONS

C-6.1 If the fracture occurs within the middle third of the span length, the modulus of rupture shall be calculated as follows:

$$R = \frac{Pl}{bd^2}$$

where

- P = modulus of rupture in kg per sq cm (or pounds per square inch),
- R = maximum applied load indicated by the testing machine in kg (or lb),
- l = span length in cm (or in),
- b = average width of specimen in cm (or in), and
- d = average depth of specimen in cm (or in).

NOTE — Weight of the beam is not included in the above calculation.

*Second revision in 1964.

C-6.2 If the fracture occurs outside the middle third of the span length by not more than 5 percent of the span length, the modulus of rupture shall be calculated as follows:

$$R = \frac{3Pa}{bd^2}$$

where

a = distance between line of fracture and the nearest support measured along the centre line of the bottom surface of the beam in cm (or in.) and other symbols have the same significance as given under **C-6.1**.

C-6.3 If the fracture occurs outside the middle third of the span length by more than 5 percent of the span length, the results of the test shall be discarded.

C-7. REPORT

C-7.1 The report shall include the following:

- a) Identification number,
- b) Average width to the nearest 0.25 cm (or 0.1 in).
- c) Average depth to the nearest 0.25 cm (or 0.1 in),
- d) Span length in centimetres or inches,
- e) Maximum applied load in kilograms or pounds,
- f) Modulus of rupture calculated to the nearest 0.4 kg per sq cm (or 5 lb per sq in),
- g) Defects in specimen, and
- h) Age of specimen.


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