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Indian Standard

RECOMMENDED GUIDELINES FOR CONCRETE MIX DESIGN

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RECOMMENDED GUIDELINES FOR CONCRETE MIX DESIGN

0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 30 July 1982, after the draft finalized by the Cement and Concrete Sectional Committee had been approved by the Civil Engineering Division Council.

0.2 Considerable need has been felt for formulating standard recommendations for guidelines on proportioning of concrete mixes. The need has been further emphasized by the importance given to design mix concrete according to IS : 456-1978*. Having recognized this need, Cement and Concrete Sectional Committee decided to evolve a standard recommended guidelines for concrete mix design.

0.3 The proportioning of concrete mixes consists of determination of the quantities of respective ingredients necessary to produce concrete having adequate, but not excessive, workability and strength for the particular loading and durability for the exposure to which it will be subjected. Emphasis is laid on making the most economical use of available materials so as to produce concrete of the required attributes at the minimum cost.

0.4 Concrete has to be of satisfactory quality in both the fresh and hardened states. The task of proportioning concrete mixes is accomplished by the use of certain established relationships which afford reasonably accurate guidance for selecting the best combination of ingredients so as to achieve the desirable properties of the fresh and hardened concrete. Out of all the physical characteristics of concrete, compressive strength is often taken as an index of its quality in terms of durability, impermeability and watertightness and is easily measurable. Therefore, the mix design is generally carried out for a particular compressive strength of concrete, coupled with adequate workability, so that the fresh concrete can be properly placed and compacted. In addition, the mix proportions are also checked against the requirements of adequate durability for the type of exposure condition anticipated in service.

*Code of practice for plain and reinforced concrete (*third revision*).

0.5 The basic assumption made in mix design is that the compressive strength of workable concrete is, by and large, governed by the water-cement ratio. Another most convenient relationship applicable to normal concretes is that for a given type, shape, size and grading of aggregates, the amount of water determines its workability. However, there are various other factors which affect the properties of concrete, for example, the quality and quantity of cement, water and aggregates; batching; transportation; placing; compaction; curing; etc. Therefore, the specific relationships that are used in proportioning concrete mixes should be considered only as a basis for trial, subject to modifications in the light of experience as well as for the particular materials used at the site in each case.

0.6 This standard does not debar the adoption of any other accepted methods of mix design.

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 : 2-1960. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

1. SCOPE

1.1 This standard lays down the recommended procedure for designing concrete mixes for general types of construction using the concreting materials normally available. The design is carried out for a desired compressive strength and workability of concrete, using continuously graded aggregates. This standard does not include the design of concrete mixes for flexural strength or when gap-graded aggregates or various admixtures and pozzolana are to be used.

1.2 All requirements of IS : 456-1978† and IS : 1343-1980‡, in so far as they apply, shall be deemed to form part of this standard except where otherwise laid down in this standard.

2. DATA FOR MIX DESIGN

2.1 The following basic data are required to be specified for design of a concrete mix:

a) Characteristic compressive strength (that is, below which only a specified proportion of test results are allowed to fall) of concrete at 28 days (f_{ck}),

b) Degree of workability desired,

*Rules for rounding off numerical values (*revised*).
†Code of practice for plain and reinforced concrete (*third revision*).
‡Code of practice for prestressed concrete (*first revision*).

c) Limitations on the water-cement ratio and the minimum cement content to ensure adequate durability (*see* Appendix A of IS : 456-1978*),

d) Type and maximum size of aggregate to be used, and

e) Standard deviation (s) of compressive strength of concrete.

NOTE — Standard deviation of concrete of each grade shall be determined separately according to IS : 456-1978*. When results of sufficient number of tests (at least 30) are not available, then, depending upon the degree of quality control expected to be exercised at the site, the value of standard deviation given in Table 1 may be adopted for guidance.

TABLE 1 SUGGESTED VALUES OF STANDARD DEVIATION

GRADE OF CONCRETE	STANDARD DEVIATION FOR DIFFERENT DEGREE OF CONTROL IN N/mm 2		
	Very Good	Good	Fair
(1)	(2)	(3)	(4)
M 10	2·0	2·3	3·3
M 15	2·5	3·5	4·5
M 20	3·6	4·6	5·6
M 25	4·3	5·3	6·3
M 30	5·0	6·0	7·0
M 35	5·3	6·3	7·3
M 40	5·6	6·6	7·6
M 45	6·0	7·0	8·0
M 50	6·4	7·4	8·4
M 55	6·7	7·7	8·7
M 60	6·8	7·8	8·8

NOTE — Appendix A provides guidance regarding the different degrees of quality control to be expected, depending upon the infrastructure and practices adopted at the construction site.

2.2 Target Strength for Mix Design — In order that not more than the specified proportion of test results are likely to fall below the characteristic strength, the concrete mix has to be designed for a somewhat higher target average compressive strength (f_{ck}). The margin over the characteristic strength depends upon the quality control (expressed by the standard

*Code of practice for plain and reinforced concrete (*third revision*).

deviation) and the accepted proportion of results of strength tests below the characteristic strength (f_{ck}), given by the relation:

$$\bar{f}_{ck} = f_{ck} + t \times s$$

where

$\bar{f}_{ck}$ = target average compressive strength at 28 days,

f_{ck} = characteristic compressive strength at 28 days,

s = standard deviation, and

t = a statistic, depending upon the accepted proportion of low results and the number of tests; for large number of tests, the value of t is given in Table 2.

NOTE — According to IS : 456-1978* and IS : 1343-1980†, the characteristic strength is defined as that value below which not more than 5 percent (1 in 20) results are expected to fall. In such case, the above equation will reduce to:

$$\bar{f}_{ck} = f_{ck} + 1{\cdot}65\ s$$

TABLE 2 VALUES OF t

(*Clause* 2.2)

ACCEPTED PROPORTION OF LOW RESULTS	t
1 in 5	0·84
1 in 10	1·28
1 in 15	1·50
1 in 20	1·65
1 in 40	1·86
1 in 100	2·33

3. SELECTION OF MIX PROPORTIONS

3.1 Selection of Water Cement Ratio — Since different cements and aggregates of different maximum size, grading, surface texture, shape and other characteristics may produce concretes of different compressive strength for the same free water-cement ratio, the relationship between strength and free water-cement ratio should preferably be established for the materials actually to be used. In the absence of such data, the preliminary free water-cement ratio (by mass) corresponding to the target strength at 28 days may be selected from the relationships shown in Fig. 1.

*Code of practice for plain and reinforced concrete (*third revision*).
†Code of practice for prestressed concrete (*first revision*).

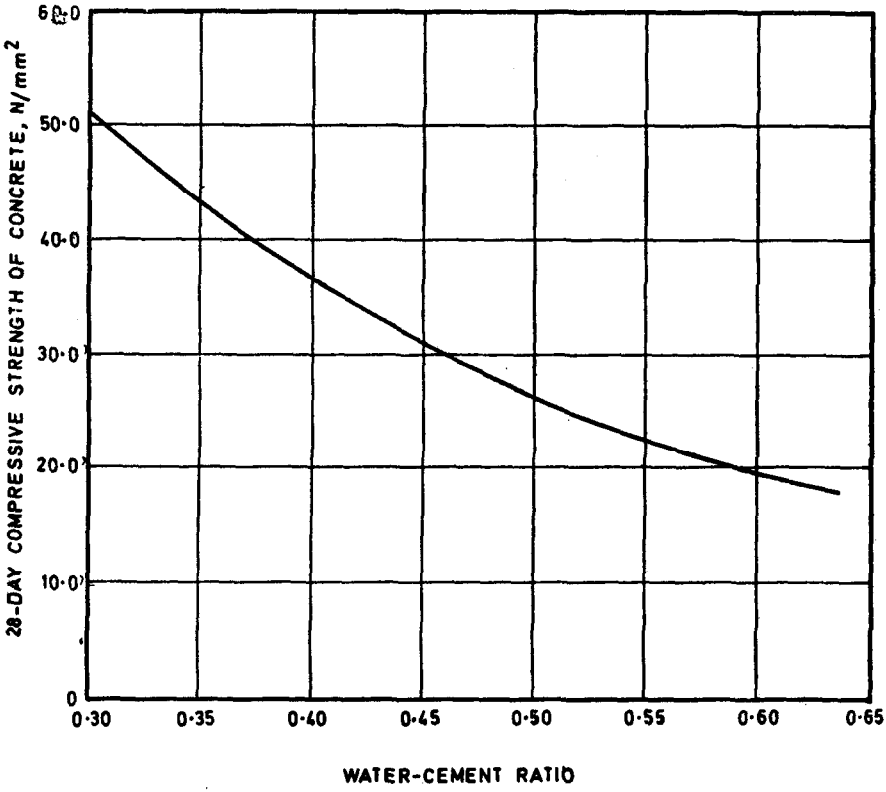
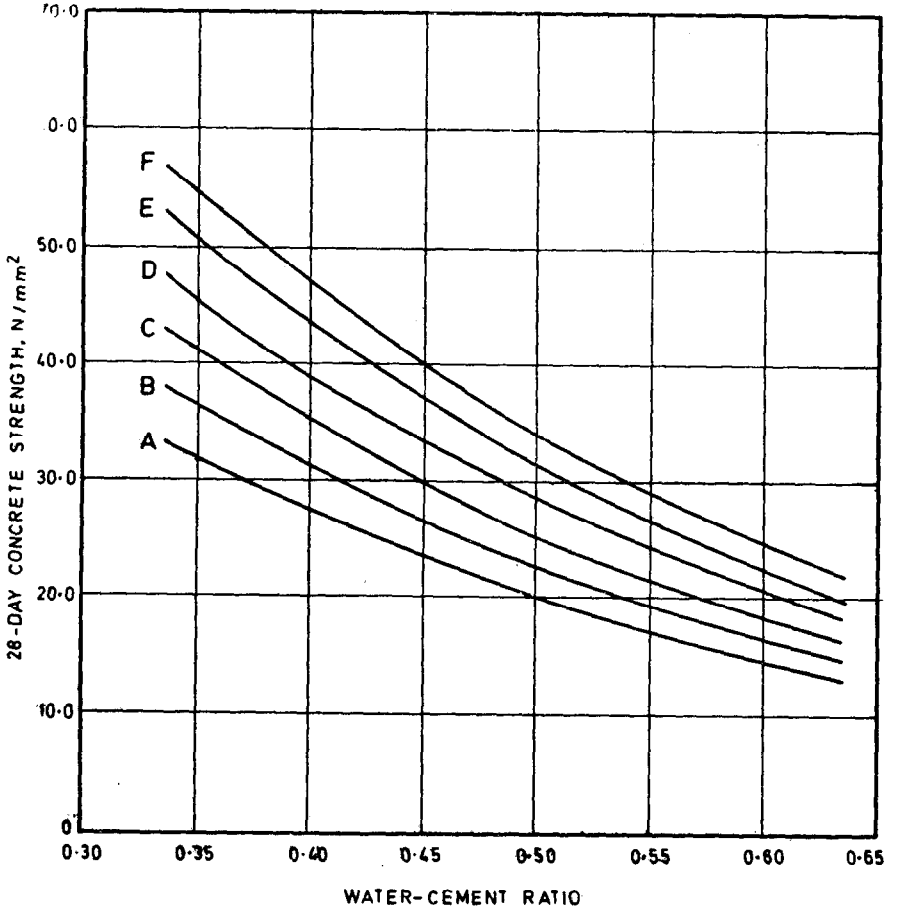


FIG. 1 GENERALISED RELATION BETWEEN FREE WATER-CEMENT RATIO AND COMPRESSIVE STRENGTH OF CONCRETE

3.1.1 Alternately, the preliminary free water-cement ratio (by mass) corresponding to the target average strength may be selected from the relationships shown in Fig. 2 using the curve corresponding to the 28 days cement strength to be used for the purpose.

NOTE — The method described in Appendix B involving determination of compressive strength of concrete cubes cured by accelerated method, may be used for rapid estimation of free water-cement ratio.

3.1.2 The free water-cement ratio selected according to **3.1** or **3.1.1** should be checked against the limiting water-cement ratio for the requirements of durability, and the lower of the two values adopted.



28-Day Strength of Cement, Tested According to IS : 4031-1968

A = 31·9-36·8 N/mm² (325-375 kg/cm²)
B = 36·8-41·7 N/mm² (375-425 kg/cm²)
C = 41·7-46·6 N/mm² (425-475 kg/cm²)
D = 46·6-51·5 N/mm² (475-525 kg/cm²)
E = 51·5-56·4 N/mm² (525-575 kg/cm²)
F = 56·4-61·3 N/mm² (575-625 kg/cm²)

FIG. 2 RELATION BETWEEN FREE WATER-CEMENT RATIO AND CONCRETE STRENGTH FOR DIFFERENT CEMENT STRENGTHS

3.2 Estimation of Air Content — Approximate amount of entrapped air to be expected in normal (non-air-entrained) concrete is given in Table 3.

TABLE 3 APPROXIMATE AIR CONTENT

Nominal Maximum Size of Aggregate	Entrapped Air, as Percentage of Volume of Concrete
mm	
10	3·0
20	2·0
40	1·0

3.3 Selection of Water Content and Fine to Total Aggregate Ratio

3.3.1 For the desired workability, the quantity of mixing water per unit volume of concrete and the ratio of fine aggregate to total aggregate by absolute volume are to be estimated from Tables 4 or 5 as applicable, depending upon the nominal maximum size and type of aggregates.

TABLE 4 APPROXIMATE SAND AND WATER CONTENTS PER CUBIC METRE OF CONCRETE FOR GRADES UPTO M 35

Nominal Maximum Size of Aggregate	Water Content*, per Cubic Metre of Concrete	Sand as Percent of Total Aggregate by Absolute Volume
mm	kg	
10	208	40
20	186	35
40	165	30

*Water content corresponding to saturated surface dry aggregate.

TABLE 5 APPROXIMATE SAND AND WATER CONTENTS PER CUBIC METRE OF CONCRETE FOR GRADES ABOVE M 35

(*Clauses* 3.3.1, 3.3.3, 3.3.4 and *Table* 6)

Nominal Maximum Size of Aggregate	Water Content*, per Cubic Metre of Concrete	Sand as Percent of Total Aggregate by Absolute Volume
mm	kg	
10	200	28
20	180	25

*Water content corresponding to saturated surface dry aggregate.

3.3.2 Table 4 is to be used for concretes grade up to M 35 and is based on the following conditions:

a) Crushed (angular) coarse aggregate, conforming to IS : 383-1970*,

b) Fine aggregate consisting of natural sand conforming to grading zone II of Table 4 of IS : 383-1970*,

c) Water-cement ratio of 0 6 (by mass), and

d) Workability corresponding to compacting factor of 0·80.

3.3.3 Table 5 is to be used for concretes of grades above M 35 and is based on the following conditions:

a) Crushed (angular) coarse aggregate conforming to IS : 383-1970*,

b) Fine aggregate consisting of natural sand conforming to grading zone II of Table 4 of IS : 383-1970*,

c) Water-cement ratio of 0 35 (by mass), and

d) Workability corresponding to compacting factor of 0·80.

3.3.4 For other conditions of workability, water-cement ratio, grading of fine aggregate, and for rounded aggregates, certain adjustments in the quantity of mixing water and fine to total aggregate ratio given in Tables 4 and 5 are to be made, according to Table 6.

NOTE — Aggregates should be used in saturated surface dry (SSD) condition. If otherwise, when computing the requirement of mixing water, allowance shall be made for the free (surface) moisture contributed by the fine and coarse aggregates. The amount of mixing water obtained from Tables 4 and 5 shall be reduced by an amount equal to the free moisture contributed by the coarse and fine aggregates. On the other hand, if the aggregates are dry, the amount of mixing water should be increased by an amount equal to the moisture likely to be absorbed by the aggregates. The surface water and percent water absorption of aggregates shall be determined according to IS : 2386 (Part III)-1963†.

3.4 Calculation of Cement Content — The cement content per unit volume of concrete may be calculated from the free water-cement ratio (*see* **3.1** and **3.1.1**) and the quantity of water per unit volume of concrete (*see* **3.3.1**).

The cement content so calculated shall be checked against the minimum cement content for the requirements of durability and the greater of the two values adopted

*Specification for coarse and fine aggregates from natural sources for concrete (*second revision*).

†Methods of test for aggregates for concrete : Part III Specific gravity, density, voids, absorption and bulking.

TABLE 6 ADJUSTMENT OF VALUES IN WATER CONTENT AND SAND PERCENTAGE FOR OTHER CONDITIONS

(*Clauses* 3.3.4 and 4.1)

Change in Condition Stipulated for Tables 4 and 5	Adjustment Required in	
	Water Content	Percent, Sand in Total Aggregate
(1)	(2)	(3)
For sand conforming to grading Zone I, Zone III or Zone IV of Table 4 of IS : 383-1970*	0	+ 1·5 percent for Zone I − 1·5 percent for Zone III − 3·0 percent for Zone IV
Increase or decrease in the value of compacting factor by 0·1	± 3 percent	0
Each 0·05 increase or decrease in free water-cement ratio	0	± 1 percent
For rounded aggregate	− 15 kg/m³	− 7 percent

*Specification for coarse and fine aggregates from natural sources for concrete (*second revision*).

3.5 Calculation of Aggregate Content

3.5.1 With the quantities of water and cement per unit volume of concrete and the ratio of fine to total aggregate already determined, the total aggregate content per unit volume of concrete may be calculated from the following equations:

$$V = \left[W + \frac{C}{S_c} + \frac{1}{p} \cdot \frac{f_a}{S_{fa}} \right] \times \frac{1}{1\,000}, \text{ and}$$

$$V = \left[W + \frac{C}{S_c} + \frac{1}{1-p} \cdot \frac{c_a}{S_{ca}} \right] \times \frac{1}{1\,000}$$

where

V = absolute volume of fresh concrete, which is equal to gross volume (m³) minus the volume of entrapped air,

W = mass of water (kg) per m³ of concrete,

C = mass of cement (kg) per m³ of concrete,

S_c = specific gravity of cement,

p = ratio of fine aggregate to total aggregate by absolute volume,

f_a, c_a = total masses of fine aggregate and coarse aggregate (kg) per m³ of concrete respectively, and

S_{fa}, S_{ca} = specific gravities of saturated surface dry fine aggregate and coarse aggregate respectively.

3.6 Combination of Different Coarse Aggregate Fractions — The coarse aggregate used should conform to IS : 383-1970*. Coarse aggregates of different sizes should be combined in suitable proportions so as to result in an overall grading conforming to Table 2 of IS : 383-1970* for the particular nominal maximum size of aggregate.

3.7 Calculation of Batch Masses — The masses of the various ingredients for concrete of a particular batch size may be calculated.

3.8 An illustrative example of concrete mix design is given in Appendix C.

4. TRIAL MIXES

4.1 The calculated mix proportions shall be checked by means of trial batches. Quantities of materials worked out in accordance with **3.1** to **3.7** shall comprise Trial Mix No. 1. The quantity of materials for each trial shall be sufficient for at least three 150 mm size cube concrete specimens and concrete required to carry out workability test according to IS : 1199-1959†.

Workability of the Trial Mix No. 1 shall be measured. The mix shall be carefully observed for freedom from segregation and bleeding and its finishing properties. If the measured workability of Trial Mix No. 1 is different from the stipulated value, the water content shall be adjusted according to Table 6 corresponding to the required change in compacting factor. With this adjusted water content, the mix proportions shall be recalculated keeping the free water-cement ratio at the pre-selected value which will comprise Trial Mix No. 2. In addition, two more Trial Mixes No. 3 and 4 shall be made with the water content same as Trial Mix No. 2 and varying the free water cement ratio by $\pm$ 10 percent of the pre-selected value. For these two additional Trial Mixes No. 3 and 4, the mix proportions are to be recalculated for the altered condition of free water-cement ratio with suitable adjustments in accordance with Table 6.

The procedure for trial mixes is explained by an illustrative example in Appendix D, where the starting mix is arrived at according to **3**. Mix No. 2 to 4 normally provides sufficient information, including the relationship between compressive strength and water-cement ratio, from which the mix proportions for field trials may be arrived at. Using the relationship so obtained between the compressive strength and water-cement ratio, any change needed in the water-cement ratio to get the required target compressive strength may be easily obtained. The concrete mix proportions shall, however, be recalculated for this changed water-cement ratio, taking

*Specification for coarse and fine aggregates from natural sources for concrete (*second revision*).

†Methods of sampling and analysis of concrete.

the water content same as that determined in Trial Mix No. 2. If the size and special requirement of the work so warrant, the trial may be extended to cover larger ranges of mix proportions as well as other variables, such as alternative sources of aggregates, maximum sizes and grading of aggregates, and different types and brands of cements.

APPENDIX A

(*Note Below Table* 1)

DEGREE OF QUALITY CONTROL EXPECTED UNDER DIFFERENT SITE CONDITIONS

Degree of Control	*Conditions of Production*
Very good	Fresh cement from single source and regular tests, weigh-batching of all materials, aggregates supplied in single sizes, control of aggregate grading and moisture content, control of water added, frequent supervision, regular workability and strength tests, and field laboratory facilities.
Good	Carefully stored cement and periodic tests, weigh-batching of all materials, controlled water, graded aggregate supplied, occasional grading and moisture tests, periodic check of workability and strength, intermittent supervision, and experienced workers.
Fair	Proper storage of cement, volume batching of all aggregates allowing for bulking of sand, weigh-batching of cement, water content controlled by inspection of mix, and occasional supervision and tests.

APPENDIX B

(*Clause* 3.1.1)

METHOD OF RAPID ESTIMATION OF WATER-CEMENT RATIO

B-1. Use of Fig. 2 will necessitate testing of the cement for its 28 day compressive strength according to IS : 4031-1968* and another 28 days are needed to obtain the compressive strength of concrete according to the trial mixes. As an alternative, a rapid method of concrete mix design which will take only 3 days for trials is described in **B-2.** The procedure is based on the use of accelerated curing (boiling water) method for determination of compressive strength of concrete according to IS : 9013-1978†.

B-2. PROCEDURE

B-2.1 Determine the accelerated strength (boiling water method) of a 'reference' concrete mix having water-cement ratio = 0·35 and workability (compacting factor) = 0·80 with the cement proposed to be used, on 150 mm cube specimens. The nominal maximum size of aggregate of the 'reference' concrete shall be 10 mm and fine aggregate used shall conform to Zone II of Table 4 of IS : 383-1970‡.

B-2.2 Corresponding to this accelerated strength, determine the water-cement ratio for the required target strength of the concrete mix from Fig. 3.

B-2.3 Work out the remaining mix proportions according to **3.2** to **3.7** and check the workability of the trial mix.

B-2.4 Determine the accelerated compressive strength of the trial mix (boiling water method) and estimate the 28 day compressive strength with the help of correlations between accelerated and 28 day strengths of concrete, of the type of Fig. 2 of IS : 9013-1978†.

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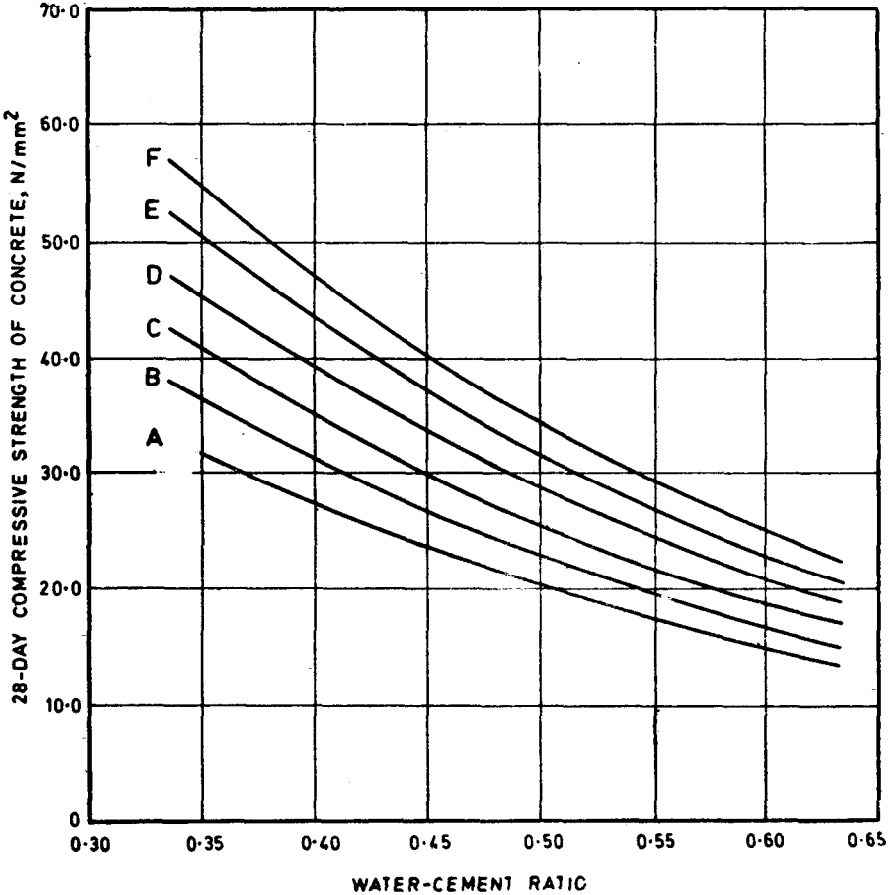
*Methods of physical tests for hydraulic cement.

†Methods of making, curing and determining compressive strength of accelerated-cured concrete test specimens.

‡Specification for coarse and fine aggregates from natural sources for concrete (*second revision*).



Accelerated Strength (Tested According to IS : 9013-1978) of Reference Mix

A = 12·3-15·2 N/mm² (125-155 kg/cm²)
B = 15·2-18·1 N/mm² (155-185 kg/cm²)
C = 18·1-21·1 N/mm² (185-215 kg/cm²)
D = 21·1-24·0 N/mm² (215 245 kg/cm²)
E = 24·0-27·0 N/mm² (245-275 kg/cm²)
F = 27·0-29·9 N/mm² (275-305 kg/cm²)

FIG. 3 RELATION BETWEEN FREE WATER-CEMENT RATIO AND COMPRESSIVE STRENGTH OF CONCRETE FOR DIFFERENT CEMENT STRENGTHS DETERMINED ON REFERENCE CONCRETE MIXES (ACCELERATED TEST-BOILING WATER METHOD)

APPENDIX C

(*Clause* 3.8)

ILLUSTRATIVE EXAMPLE ON CONCRETE MIX DESIGN

C-0. An example illustrating the mix design for a concrete of M 20 grade is given below:

C-1. DESIGN STIPULATIONS

a) Characteristic compressive strength required in the field at 28 days	20 N/mm^2
b) Maximum size of aggregate	20 mm (angular)
c) Degree of workability	0·90 compacting factor
d) Degree of quality control	Good
e) Type of exposure	Mild

C-2. TEST DATA FOR MATERIALS

a) Cement used—ordinary Portland cement satisfying the requirements of IS : 269-1976*	
b) Specific gravity of cement	3·15
c) Specific gravity	
1) Coarse aggregate	2·60
2) Fine aggregate	2·60
d) Water absorption	
1) Coarse aggregate	0·5 percent
2) Fine aggregate	1·0 percent
e) Free (surface) moisture	
1) Coarse aggregate	Nil (absorbed moisture also nil)
2) Fine aggregate	2·0 percent
f) Sieve analysis	
1) Coarse aggregate	

*Specification for ordinary and low heat Portland cement (*third revision*).

IS Sieve Sizes mm	*Analysis of Coarse Aggregate Fraction* (*Percent Passing*)		*Percentage of Different Fractions*			*Remark*
	I	II	I	II	Combined	
			60 percent	40 percent	100 percent	
20	100	100	60	40	100	Conforming to Table 2 of IS : 383-1970*
10	0	71·20	0	28·5	28·5	
4·75		9·40		3·7	3·7	
2·36		0				

2) Fine Aggregate

IS Sieve Sizes	*Fine Aggregate* (*Percent Passing*)	*Remark*
4·75 mm	100	Conforming to grading Zone III of Table 4 of IS : 383-1970*
2·36 mm	100	
1·18 mm	93	
600 micron	60	
300 micron	12	
150 micron	2	

C-3. TARGET MEAN STRENGTH OF CONCRETE

C-3.1 For a tolerance factor of 1·65 and using Table 1, the target mean strength for the specified characteristic cube strength is $20 + 4·6 \times 1·65 = 27·6$ N/mm².

C-4. SELECTION OF WATER CEMENT RATIO

C-4.1 From Fig. 1, the free water-cement ratio required for the target mean strength of 27·6 N/mm² is 0·50. This is lower than the maximum value of 0·65 prescribed for 'Mild' exposure in Appendix A of IS : 456-1978†.

C-5. SELECTION OF WATER AND SAND CONTENT

C-5.1 From Table 4, for 20 mm nominal maximum size aggregate and sand conforming to grading Zone II, water content per cubic metre of concrete = 186 kg and sand content as percentage of total aggregate by absolute volume = 35 percent.

*Specification for coarse and fine aggregates from natural sources for concrete (*second revision*).

†Code of practice for plain and reinforced concrete (*third revision*).

For change in values in water-cement ratio, compacting factor and sand belonging to Zone III, the following adjustment is required:

Change in Condition (*Ref Table 6*)	*Adjustment Required in*	
	Water Content Percent	Percentage Sand in Total Aggregate
For decrease in water-cement ratio by (0·60 — 0·50) that is 0·1	0	— 2·0
For increase in compacting factor (0·9 — 0·8) that is 0·10	+ 3	0
For sand conforming to Zone III of Table 4 of IS : 383-1970	0	— 1·5
Total	+ 3 percent	— 3·5

Therefore, required sand content as percentage of total aggregate by absolute volume = 35 — 3·5 = 31·5 percent

$$\text{Required water content} = 186 + \frac{186 \times 3}{100} = 186 + 5{\cdot}58 = 191{\cdot}6 \text{ l/m}^3$$

C-6. DETERMINATION OF CEMENT CONTENT

Water cement ratio = 0·50

Water = 191·6 l

$$\text{Cement} = \frac{191{\cdot}6}{0{\cdot}50} = 383 \text{ kg/m}^3$$

This cement content is adequate for mild exposure condition, according to Appendix A of IS : 456-1978*.

C-7. DETERMINATION OF COARSE AND FINE AGGREGATE CONTENT

C-7.1 From Table 3, for the specified maximum size of aggregate of 20 mm, the amount of entrapped air in the wet concrete is 2 percent. Taking this into account and applying equations from **3.5.1**,

$$0{\cdot}98 \text{ m}^3 = \left(191{\cdot}6 + \frac{383}{3{\cdot}15} + \frac{1}{0{\cdot}315} \cdot \frac{f_a}{2{\cdot}60}\right) \times \frac{1}{1\,000}$$

$$\text{and } 0{\cdot}98 \text{ m}^3 = \left(191{\cdot}6 + \frac{383}{3{\cdot}15} + \frac{1}{0{\cdot}685} \cdot \frac{c_a}{2{\cdot}60}\right) \times \frac{1}{1\,000}$$

$$\text{or } f_a = 546 \text{ kg/m}^3, \text{ and}$$

$$c_a = 1\,187 \text{ kg/m}^3$$

*Code of practice for plain and reinforced concrete (*third revision*).

The mix proportion then becomes:

Water	*Cement*	*Fine Aggregate*	*Coarse Aggregate*
191·6 l	383 kg	546 kg	1187 kg
or 0·50	1	1·42	3·09

C-8. ACTUAL QUANTITIES REQUIRED FOR THE MIX PER BAG OF CEMENT

C-8.1 The mix is 0·50 : 1 : 1·42 : 3·09 (by mass). For 50 kg of cement, the quantity of materials are worked out as below:

a) Cement = 50 kg

b) Sand = 71·0 kg

c) Coarse aggregate = 154·5 kg (Fraction I = 92·7 kg, fraction II = 61·8 kg)

d) Water

1) For water-cement ratio of 0·50 quantity of water = 25·0 litres

2) Extra quantity of water to be added for absorption in case of coarse aggregate, at 0·5 percent by mass = (+)0·77 l

3) Quantity of water to be deducted for free moisture present in sand, at 2 percent by mass = (—) 1·42 l

4) Actual quantity of water to be added = 25·0 + 0·77 — 1·42
= 24·35 l

e) Actual quantity of sand required after allowing for mass of free moisture = 71·0 + 1·42
= 72·42 kg

f) Actual quantity of coarse aggregate required:

1) Fraction I = 92·7 — 0·46 = 92·24 kg

2) Fraction II = 61·8 — 0·31 = 61·49 kg

Therefore, the actual quantities of different constituents required for the mix are:

Water : 24·35 kg
Cement : 50·00 kg
Sand : 72·42 kg
Coarse aggregate: Fraction I = 92·24 kg
Fraction II = 61·49 kg

APPENDIX D

(*Clause* 4.1)

DETAILS OF TRIAL MIX

D-1. A typical test programme to establish concrete making properties of materials obtained from the site of construction by means of laboratory trials is given below:

Mix No. 1 (derived according to procedure given in **3**) consists of the calculated batch quantities required per m^3 of concrete. Since in actual trial, the mix did not have the desired workability of 0·90 in terms of compacting factor, and the mix was undersanded with 31·5 percent sand, adjustments in water and sand contents have been made in subsequent Mix No. 2. Mix No. 3 and 4 have higher and lower water-cement ratio than Mix No. 2 (by $\pm$ 10 percent), but the water content is held constant. Details of the four trial mixes and observations on the mixes are given in Table 7.

TABLE 7 TYPICAL TEST RESULTS OF TRIAL MIXES

Mix No.	Quantities of Materias per Cubic Metre of Concrete					Concrete Characteristics		
	Cement	Water	Sand	Coarse Aggregate Type		Workability in Terms of Compacting Factor	Visual Observation for the Mix	28-day Compressive Strength
				I	II			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	kg	l	kg	kg	kg			N/mm²
1.	383 (W/C* = 0·50)	191·6	546 (31·5 percent)	712	475	0·80	under-sanded	—
2.	394·6 (W/C* = 0·50)	197·3	564 (33 percent)	687	458	0·91	Cohesive	28·8
3.	358·7 (W/C* = 0·55)	197·3	591 (34 percent)	688	459	0 90	Cohesive	26·0
4.	438·4 (W/C* = 0·45)	197·3	535 (32 percent)	682	455	0·89	Cohesive	31·2

*Water-cement ratio.

Continued from page 2

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