Critical Analysis and Review of Existing Mix Design Procedures

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Synopsis

SYNOPSIS

Cement concrete is one of the important materials in Civil Engineering works. The strength of the concrete mix varies according to the ratio of the ingredients used and water cement ratio. The public do not know the importance of mix design in the quality control of concrete. There will be a definite advantage of designed mixes are adopted as against nominal mixes. In this investigation the aim is evaluate the reliability of the different methods of mix design.

In this investigation four methods are considered for analysis and their reliability compared. These methods are :-

1. Indian standard code method for mix design (IS 10262-1982).
2. American concrete institute method (ACI)
3. Road note No. 4 method.
4. Dr.Alexander method.

In each method two different workabilities are used and mixes designed for three water cement ratios, namely 0.4, 0.55 and 0.7. The coarse aggregate is of size 20 mm for the entire investigation. The materials are tested and their properties are considered for the design of various mixes.

Totally 96 cubes are cast and tested in compression after 28 days of curing.

The percentage error between the predicted value and the actual strength as calculated and presented in each case.

Excepting the A.C.I.Method all the other three methods are satisfactory for the purpose of design of mixes.

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CHAPTER I

Introduction

CHAPTER - I

INTRODUCTION

1. SIGNIFICANCE OF CONCRETE

Concrete is one of the most useful and important structural material since the beginning of the twentieth century. The concrete is used in the building for foundations, lintels, beams, columns and roof slabs etc. and it can be moulded into any shape. It has the unique distinction of being the only construction material actually manufactured at the site. Concrete requires careful proportioning of cement, sand, jelly and water. With good work manship and proper curing expected strength of the concrete can be obtained.

Mix Design

It can be defined as the process of selecting suitable ingredients of concrete and their proportions with the object of producing concrete of the expected strength and durability as economically as possible. Two aspects are important - One the strength of concrete and the other is cost of construction. The cost of concrete is due to material cost and the cost of labour. Since the cost of cement is comparitively more, attention is mainly directed to the use of minimum quantity of cement without affecting the required strength.Workability of the concrete mass is obtained by the lubricating effect of the paste and is influenced by the amount of water. Permeability of concrete is governed by the quality and quantity of the paste. The more dilute the paste, the greater the spacing between cement particles, and thus the weaker will be the ultimate paste structure . For workable mixes, the strength of concrete varies as an inverse function of the water cement ratio.

Methods available for proportioning of concrete mixes

1. The minimum void method
2. Fullers maximum density method
3. Tablot - Richard method
4. Abram's fineness modulus method
5. American concrete institute method
6. Road note No 4 method
7. I.S.Code method
8. Dr.Alexander method

Evolution of mix design

The terms workability, mix proportions, compaction etc which influence the strength and durability are of recent times. It is noted that the strength of concrete increased with increase in cement content and with good compaction. It was also thought that water was required only to make the concrete more plastic for easy workmanship and compaction. It was thought that the use of aggregate having less voids result in stronger concrete. Some of the earlier methods from item (1) to item (4) of mix design are based on the principles of minimum voids. The more recent A.C.I. method,Road Note No.4 method and I.S.Code methods are based on consideration of workability/ W/C ratio. But even these methods do not elimnate casting of trial mixes.

But the recent analytical method, of mix design developed by Dr.Alexander taking into account all factors, which influence the properties of concrete is capable of eliminating the casting trial mixes. This method is suitable for computerisation. Four important methods are taken for analysis and evaluation of their performance.

1. I.S.Code (10262 - 1982) method
2. A.C.I. Method
3. Road Note No 4 method
4. Dr.Alexander method

CHAPTER II

Mix Design - General

CHAPTER - 2

MIX DESIGN - GENERAL

The theory of brief description of the different methods of mix design as follows.

1. INDIAN STANDARD MIX DESIGN (IS 10262-1982)

(a) For any particular mean strength the water cement ratio is determined from the Fig. 1.

(b) The air content is estimated from table 3 for the maximum size of aggregate used.

(c) The water content and percentage of sand in total aggregate by absolute volume are selected from tables 4 and 5 for medium and high strength concrete respectively for the following standard reference conditions.

  (1) Crushed (Regular) Coarse aggregate.

  (2) Fine aggregate consisting of natural sand confirming to grading zone II of table 4 I.S. 383-1970 (13), in natural surface dry condition.

  (3) Water cement ratio of 0.6 and 0.35 for medium and high strength concretes respectively.

  (4) Workability corresponding to compacting factor 0.8.

(d) For other conditions of workability, water cement ratio, grading zone of fine aggregate and for rounded aggregates, adjustments in water content and percentage of sand in total aggregates are made as per table 6.

(e) The cement content is calculated from the water cement ratio and the final water content arrived after adjustment.

(f) With the quantities of water and cement per unit volume of concrete and the percentage of sand in the total aggregate already determined, the coarse and fine aggregate content per unit volumes of concrete are calculated from the following equation.

$$V = \left(W + \frac{C}{S_c} + \frac{1}{P} \times \frac{f_a}{S_{fa}}\right) \times \frac{1}{1000}$$

$$V = \left(W + \frac{C}{S_c} + \frac{1}{(1-p)} \times \frac{C_a}{S_{ca}}\right) \times \frac{1}{1000}$$

where

V	=	Absolute volume of fresh concrete
S_c	=	Specific gravity of cement
W	=	Mass of water in Kg/m^3 of concrete
C	=	Mass of cement in Kg/m^3 of concrete
P	=	Ratio of fine aggregate to total aggregate by absolute volume.
f_a, C_a	=	Total masses of fine and coarse aggregate in Kg/m^3 of concrete respectively.
S_{fa}, S_{ca}	=	Specific gravity of saturated surface dry fine aggregate and coarse aggregate respectively.

2. AMERICAN CONCRETE INSTITUTE - MIX DESIGN

(a) The water cement ratio, is selected for the required mean 28 days compressive strength from tables.

(b) The water content is selected from tables, for the desired slump and maximum size of coarse aggregate.

(c) The cement content is calculated from the water content and the water cement ratio.

(d) The coarse aggregate content is estimated from the tables with reference to the maximum size of the coarse aggregate and the fineness modulus of fine aggregate.

(e) The total weight of fresh concrete is taken from tables with reference to the max.size of coarse aggregate.

(f) The fine aggregate content is determined by subracting the sum of the weight of coarse aggregate, cement and water from the total weight of fresh concrete.

(g) Finally the proportion of the mix is calculated by comparing weights of cement, fine aggregate and coarse aggregate.

3. ROAD NOTE NO.4 METHOD

(a) Aggregate cement ratio is taken from table 11-13 considering the water cement ratio and workability.

(b) The water cement ratio is based on the 28 days strength.

(c) The fineness modulus of combined aggregate is determined from curve 1 of graph 1.

(d) The fine aggregate and the coarse aggregate are combined in a suitable proportion to get the desired overall fineness modulus.

(e) Knowing the total aggregate cement ratio, the actual ratio of fine aggregate and coarse aggregate can be determined to with respect to cement content.

4. Dr.ALEXANDER METHOD

This method of mix design is better than the other methods because it takes into account many parameters and giving the some what accurate results. It is an analytical method involving the use of number of semi-emphirical formulas. It leads direct solutions not requiring casting of trial mixes. This method takes into account properties of fresh concrete as well as hardened concrete and helps to evolve mix proportions in a systematic manner and is easily solved by the computer.

The following factors are consider for design

(a) Degree of consistency

(b) Softness

(c) Interspace

(d) Water cement ratio

(e) Harshness

(f) Wall effect

(g) Cement content

(h) Aggregate mortar ratio

(i) Mortar cement ratio

a) Degree of Consistency (K)

This is an important property of fresh concrete which determines the method of placement of concrete. The standard consistency and degree of consistency are defined as follows.

Standard Consistency

A mix is said to be of standard consistency when the water used in the mix is just sufficient to make a standard paste of the cement used in addition to wetting the aggregates. This type of mix is suitable for compaction by needle vibrator.

Degree of Consistency (K)

It is the ratio of the water actually used in a mix of given proportions to that required for a mix of standard consistency having the same proportion. It varies from 0.7 to 1.3 covering the entire range of practical mixes from semi dry mixes to mixes of flowing consistency.

(b) Softness

It is the amount of extra mortar in the mix over and above that required to fill the voids in the coarse aggregate.

(c) Interspace (t)

It is the minimum clear distance between adjacent particles of coarse aggregate which is termed as Interspace (t) and controls the cement of softness of mix. The standard interspace is taken as 1 mm for standard consistency.

(d) Water Cement Ratio

This will affect the strength of concrete. A well defined relationship between the strength and water cement ratio can be obtained only when the degree of workability is maintained constant.

(e) Harshness (h)

It is the complement of softness and refers to the proportion of rodded bulk volume of coarse aggregate in a given mix.

(f) Wall Effect

The quantity of mortar required to fill the space between the wall of the mould and the coarse aggregate particles is greater than that required in the interior of the mass. The extra mortar required at the surface is provided for by taking into consideration the surface volume ratio (r) of the mould and suitable shape factors P_i and P_s where P_i is solid proportion at the interior and P_s is solid proportion at the surface of coarse aggregate.

(g) Cement Content (Q)

Cement is an important ingredients of the concrete. The strength depends upon the cement content in the concrete. Higher cement content generally lends to higher strength and lower permeability.

(h) Aggregate mortar ratio (A)

It is the ratio of volume of coarse aggregate to the volume of mortar in a given mix.

(i) Mortar Cement Ratio (M)

It is the ratio of volume of the mortar to the volume of cement in a given mix.

After considering all the above parameters finally the proportion of the concrete mix by weight is determined.

The actual method of mix design is as given in the example given in Chapter - 4.

CHAPTER III

Laboratory Tests on Materials

CHAPTER - 3

LABORATORY TESTS ON MATERIALS

For this analysis the following materials are used.

1. CEMENT

Sanker brand ordinary portland cement available in the laboratory was used for this investigation. The cement was fresh and packed in plastic bags of 50 kg capacity. The normal consistency of the cement was 0.3 and the specific gravity was 3.15 (assumed).

2. SAND

The sand used for this work is collected from Noyyal river which is 25 km from P.S.G.College of Technology. it is taken for tests in over dry condition and sieved through I.S.Sieve No. 480. The different properties of the fine aggregate was determined by experiments conducted in the laboratory. The experiments are as follows.

a) Specific Gravity of Sand

1. Weight of empty pycometer = 622 gms

2. Weight of pycnometer + dry sand = 1086 gms

3. Weight of pycnometer + sand + water = 1806.5 gms

4. Weight of pycnometer + water = 1520 gms

Weight of sand = 1086 - 622

= 464 gms

Weight of equal volume of water = (1520 - 622) -(1806.5 - 10.86)

= 898 - 720.5

= 177.5

Specific gravity of sand = $\frac{464}{177.5}$

= 2.614

b) Bulk Density of Sand

Weight of Emply Cylinder = 1.9 kg

Weight of cylinder + water = 3.74 kg

Weight of cylinder + compacted Sand (3 layer of each 25 blows) = 4.92 kg

Volume of water = 3.74 - 1.9

= 1.84

Bulk density of sand = $\frac{4.92 - 1.9}{1.84}$

= 1.64 gms/cc

Compact bulk density of sand = 1640 Kg/m^3

(c) Fineness Modulus of Sand

Sieve Size	Weight Retained	Percentage of Weight retained	Cumulative Percentage of retained
480	9.50	1.9	1.9
240	8.50	1.7	3.6
170	45.50	9.1	12.7
60	174.0	34.8	47.5
30	158.5	31.7	79.2
15	89	17.8	97.0
		Total	241.9

Weight of Sand taken for test = 500 gms

$$\text{Fineness modulus} = \frac{241.9}{100} = 2.419$$

3. COARSE AGGREGATE

20 mm mean size blue metal coarse aggregate is used for the tests. The 20 mm jelly was collected from local quorry near Coimbatore and stored in the laboratory. The coarse aggregate is hard, durable and used in an over dry condition. The different properties were determined in the laboratory.

(a) Specific Gravity of Coarse Aggregate

1. Weight of empty pycnometer	=	622 gms
2. Weight of pycnometer + C.A	=	1062 gms
3. Weight of pycnometer + waer	=	1519 gms
Weight of coarse aggregate	=	1062 - 622
	=	440 gms
Weight of water	=	1519 - 622
	=	897 gms
	=	1802 - 1062
	=	740 gms
Special Gravity $= \frac{440}{897 - 740}$	=	2.803 gms

(b) Bulk Density of Coarse Aggregate

1. Weight of empty cylinder	=	1.88 kg
2. Weight of cylinder + coarse aggregate (added 3 layers and 25 blows)	=	5.02 kg
3. Weight of cylinder + water	=	3.78 Kg
Weight of coarse aggregate	=	5.02 - 1.88
	=	3.14 kg
Equivalent volume of C.A.	=	3.78 - 1.88
	=	1.9 kg
Dry density $= \frac{3.14}{1.9}$	=	1.653 gm/cc
	=	1653 Kg/m^3

Normal Consistency test on cement

Weight of cement taken 500 gms

S.No.	Weight of Cement taken (gms)	Quantity of Water added		Penetration Index	Remarks
		%	gms		
1	500	28	140	2	-
2	500	30	150	39	-
3	500	29	145	34	Correct

The percentage of water required for obtaining cement paste of standard consistency : 29%.

CHAPTER IV

Calculations of Material Requirements

CHAPTER - 4

CALCULATION OF MATERIAL REQUIREMENT

I. I.S.CODE METHOD

Data

1.	Water Cement Ratio	:	0.4
2.	Workability	:	0.8
3.	Maximum size of aggregate	:	20 mm
4.	Degree of Quality Control	:	Good
5.	Specific Gravity of Cement	:	3.15
6.	Specific Gravity of Fine Aggregate	:	2.614
7.	Specific Gravity of Coarse Aggregate	:	2.803
8.	Grading of F.A.Zone	:	III
9.	Bulk Density of Cement	:	1440 Kg/m^3
10.	Bulk Density of Sand	:	1640 Kg/m^3
11.	Bulk Density of Coarse Aggregate	:	1650 Kg/cm^3

Considering Water Cement Ratio 0.4

From Fig. I. of I.S.10262 - 1982 target strength was determined 37 N/mm^2

Selection of Water and Sand Contents

Above M35 - From Table 5 for 20 mm nominal mix size aggregate and conforming to grade zone III.

Water content/m^3 of concrete : 180 Kgs. Sand as percent of total aggregate by absolute volume 25 percent.

Corrections are as follows

Refering table 6

For sand corresponding to zone III

Correction	-	1.5 percent + 1 percent
	-	- 0.5 percent
Required sand content	=	25 - 0.5
	=	24.5 percent

From Table 3

Air content for nominal 20 mm maximum size of aggregate : 2 percent of volume.

Water cement : 180 kg

Determination of cement content for W/C ratio 0.4

$$\text{Cement} = \frac{180}{0.4} = 450 \text{ Kg}$$

Determination of Coarse Aggregate and Fine Aggregate

Fine Aggregate

$$V = \left(W + \frac{C}{S_c} + \frac{1}{p} \times \frac{f_a}{S_{fa}}\right) \frac{1}{1000}$$

$$0.98 = \left(180 + \frac{450}{3.15} + \frac{1}{0.245} + \frac{f_a}{2.614}\right) \times \frac{1}{1000}$$

$$0.98 = 0.18 + 0.1429 + 0.00156\ f_a$$

$$0.6571 = 0.001627\ f_a$$

$$f_a = 421\ \text{Kg}$$

Coarse Aggregate

$$V = \left(W + \frac{C}{S_c} + \frac{1}{(1 - P)} \times \frac{C_a}{S_{ca}}\right) \frac{1}{1000}$$

$$0.98 = \left(180 + \frac{450}{3.15} + \frac{1}{(1 - 0.245)} \times \frac{C_a}{2.803}\right) \frac{1}{1000}$$

$$= 0.18 + 0.1429 + 0.0004725\ C_a$$

$$C_a = 1390\ \text{Kg}$$

Mix proportion by weight for 1 m^3 of concrete

Water	Cement	F.A.	C.A.
180	450	421	1390
0.4	1	0.935	3.09

Materials required for 4 cubes

Cube : Standard Size of Specimen	=	150 mm x 150 mm x 150 mm
Volume	=	$(0.15)^3$
	=	0.003375 m^3
Cement	=	0.003375 x 450 x 4
	=	6.075 Kg
Fine Aggregate	=	0.003375 x 421 x 4
	=	5.68 Kg
Coarse Aggregate	=	0.003375 x 1390 x 4
	=	18.76 Kg
Water	=	0.003375 x 180 x 4
	=	2.43 Kg

The same procedure of calculation is worked out for water cement ratio 0.55 and 0.7. The materials required for casting of cubes are tabulated.

And also calculated the quantity of material required for casting cubes of workability corresponding to compaction factor of 0.9 and the water cement ratio of 0.5, 0.55 and 0.7. The values are tabulated as shown.

I.S.Code Method

Low Workability corresponding to compacting factor 0.8 size of Cube 150 mm x 150 mm x 150 mm
Materials required for 4 cubes

W/C Ratio	Cement Kg	Fine Aggregate Kg	Coarse Aggregate Kg	Water Kg	Proportion
0.40	6.075	5.68	18.76	2.43	1 : 0.935 : 3.09
0.55	4.565	7.87	17.53	2.51	1 : 1.72 : 3.84
0.70	3.587	8.89	17.32	2.51	1 : 2.48 : 4.83

I.S.Code Method

Medium Workability Corresponding to compacting factor 0.9

Materials required for 4 cubes

W/C Ratio	Cement Kg	Fine Aggregate Kg	Coarse Aggregate Kg	Water Kg	Proportion
0.40	6.257	5.6	18.5	2.5	1 : 0.9 : 2.95
0.55	4.7	7.37	17.3	2.58	1 : 1.65 : 3.68
0.70	3.7	8.77	17.2	2.58	1 : 2.37 : 4.66

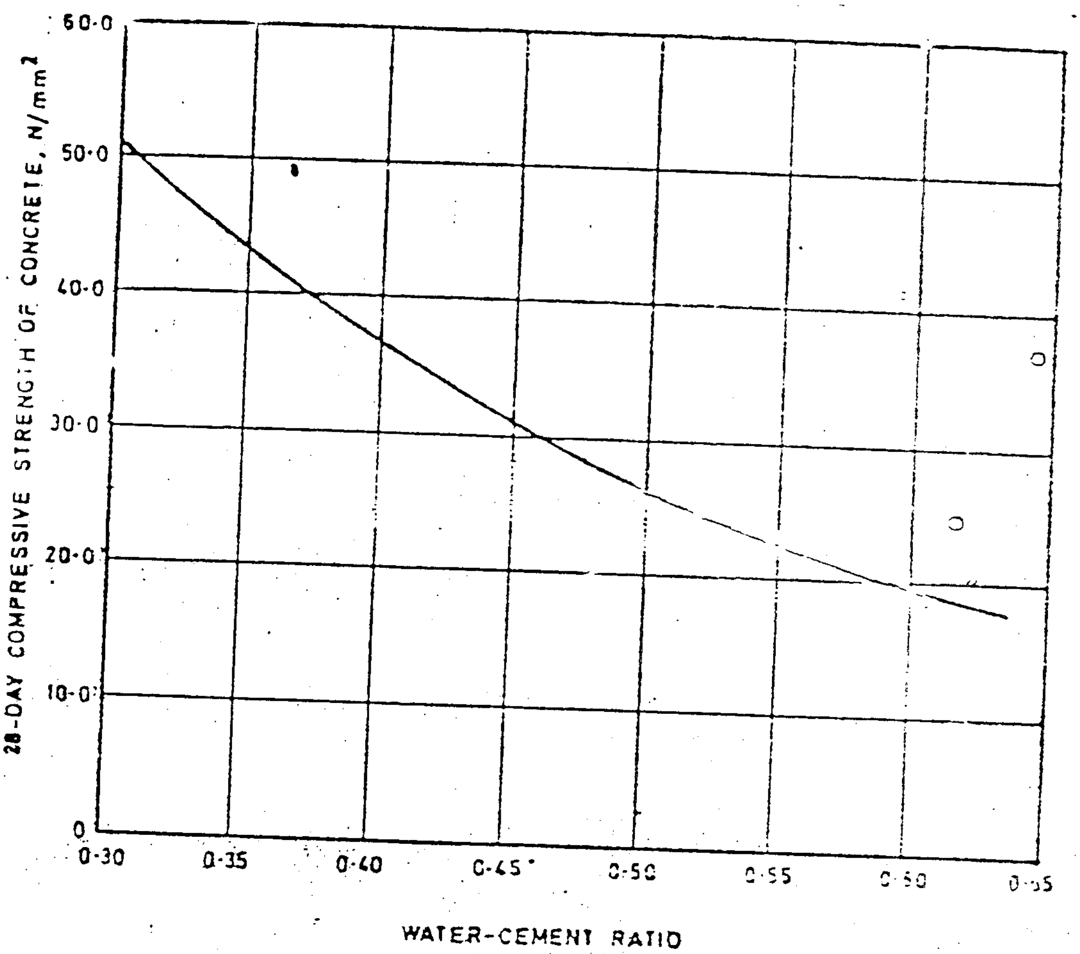

FIG. 1 GENERALISED RELATION BETWEEN FREE WATER-CEMENT RATIO AND COMPRESSIVE STRENGTH OF CONCRETE

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 mm	Water Content*, per Cubic Metre of Concrete kg	Sand as Percent of Total Aggregate by Absolute Volume
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 mm	Water Content*, per Cubic Metre of Concrete kg	Sand as Percent of Total Aggregate by Absolute Volume
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.

II. AMERICAN CONCRETE INSTITUTE METHOD (ACI METHOD)

Data Collected

1.	Workability	=	low (Slump 3 to 5)
2.	Water Cement Ratio	=	0.4
3.	Maximum size of Coarse Aggregate	=	20 mm
4.	Specific Gravity of Cement	=	3.15
5.	Specific Gravity of Fine Aggregate	=	2.614
6.	Specific Gravity of Coarse Aggregate	=	2.803
7.	Fineness Modulus of Fine Aggregate	=	2.419
8.	Bulk Density of Cement	=	1440 Kg/m^3
9.	Bulk Density of Coarse Aggregate	=	1650 Kg/m^3
10.	Bulk Density of Fine Aggregate	=	1640 Kg/m^3

Determination of Water

From Table 3 for 20 mm maximum size of Coarse Aggregate and the low workability of slump 3 to 5 cm.

Amount of Water = 185 kg

Using the water cement ratio the requirement of cement = $\frac{185}{0.4}$

Cement = 462.5 Kg

Determination of Coarse Aggregate

The volume of Coarse Aggregate is determined for the fineness modulus of Fine Aggregate 2.419 and the maximum size of Coarse Aggregate of 20 mm from the Table 4.

Volume of Coarse Aggregate = 0.658 m^3

Weight of Coarse Aggregate = 0.658 x 1650

= 1085.7 Kg

From Table 5, weight of fresh concrete when maximum size of coarse aggregate of 20 mm used.

Weight of concrete = 2355 Kg

Determination of Fine Aggregate

Weight of Fine Aggregate = 2355 - (1085.7 + 462.5 + 185)

Fine Aggregate = 621.8 Kg

Mix Proportion by Weight for 1 m^3 of concrete

Water	Cement	Fine Aggregate	Coarse Aggregate
185	462.5	621.8	1085.7
0.4	1	1.344	2.347

Material Required for 4 cubes

Cement	=	0.003375 x 462.5 x 4
	=	6.244 Kg
Fine Aggregate	=	0.003375 x 4 x 621.8
	=	8.394 Kg
Coarse Aggregate	=	0.003374 x 4 x 1085.7
	=	14.657 Kg
Water	=	0.003375 x 4 x 185
	=	2.498 Kg

The same procedure of calculation is worked out for water cement ratio 0.55 and 0.7. The material required for casting of cubes are tabulated.

And also calculated the quantity of material required for casting cubes of medium workability (Slumps 8 to 10 cm) and the water cement ratio of 0.4, 0.55 and 0.7. The values are tabulated as shown.

A.C.I. Method

Workability : Low (3 to 5 cm)

Material required fo 4 cubes

W/C Ratio	Cement Kg	Fine Aggregate Kg	Coarse Aggregate Kg	Water Kg	Proportion
0.4	6.244	8.394	14.657	2.498	1 : 1.344 : 2.547
0.55	4.54	10.097	14.657	2.498	1 : 2.22 : 3.228
0.70	3.568	11.07	14.657	2.498	1 :3.1 : 4.1

A.C.I. Method

Workability : Medium (8 to 10 cm)

Material required for 4 cubes

W/C Ratio	Cement Kg	Fine Aggregate Kg	Coarse Aggregate Kg	Water Kg	Proportion
0.4	6.75	7.69	14.66	2.7	1 : 1.14 : 2.17
0.55	4.9	9.53	14.66	2.7	1 : 1.94 : 3
0.70	3.86	10.58	14.66	2.7	1 : 2.74 : 3.8

DEPARTMENT OF CIVIL ENGINEERING

Recommended practice for selecting proportions for normal weight concrete.

Proposed revision of ACI 613-54

Reported by ACI committee 211 (1969)

TABLE 1- Relationship between cylinder compressive strength and water cement ratio

28 day strength kg/cm^2	Water cement ratio by weight
450	0.38
400	0.43
350	0.48
300	0.55
250	0.62
200	0.70
150	0.80

TABLE 2- Recommended slumps for various types of construction

Type of construction	Slump (cms)	
	Vibrated concrete	Unvibrated concrete
RCC foundation walls and footings	2 to 8	2 to 10
Plain footings and substructure walls	2 to 8	2 to 10
Beams, columns and walls	2 to 10	2 to 10
Pavements, slabs and mass concrete	2 to 8	2 to 10

TABLE 3- Mixing water requirements for different maximum size of aggregates

Slump (cms)	Water (kg/m^3 of concrete						
	Max. size of aggregate						
	10mm	12.5mm	20mmm	25mm	40mm	50mm	70mm
3 to 5	205	200	185	180	160	155	145
8 to 10	225	215	200	195	175	170	160
15 to 18	240	230	210	205	185	180	170
Approx.air content	3	2.5	2.0	1.5	1.0	0.5	0.3

TABLE 4- Volume of coarse aggregate per unit volume of concrete

Max.size of aggregate(mm)	Volume of dry rodded coarse aggregate for different fineness modulii of sand			
	2.4	2.6	2.8	3.0
10	0.50	0.48	0.46	0.44
12.5	0.59	0.57	0.55	0.53
20	0.66	0.64	0.62	0.60
25	0.71	0.69	0.67	0.65
40	0.76	0.74	0.72	0.70
50	0.78	0.76	0.74	0.72
70	0.81	0.79	0.77	0.75

TABLE 5- Weight of fresh concrete

Max.size of aggregate (mm)	Weight of concrete (kg/m^3)
10	2285
12.5	2315
20	2355
25	2375
40	2420
50	2445
70	2465

III. ROAD NOTE NO. 4 METHOD

Data Collected

1.	Workability	=	low
2.	Water Cement Ratio	=	0.4
3.	Maximum Size of Coarse Aggregate	=	20 mm
4.	Specific Gravity of Cement	=	3.15
5.	Specific Gravity of Fine Aggregate	=	2.614
6.	Specific Gravity of Coarse Aggregate	=	2.803
7.	Shape of Aggregate	=	Angular
8.	Fineness Modulus of Fine Aggregate	=	2.42
9.	Fineness Modulus of Coarse Aggregate	=	7.0

1. Aggregate cement ratio is taken from table 11-13 for the water cement ratio 0.4 of low degree of workability.

W/C Ratio	Aggregate/Cement Ratio			
	1	2	3	4
0.4	3.5	3.5	3.2	3

Select the aggregate/cement ratio 3.5 : 1

2. Proportion between the coarse and fine aggregate

From the graph I of curve (1) is considered for finding the fineness modulus of combined aggregate.

B.S.Sieve (mm)	Percentage Retained
20.00	0
10.00	55
4.80	70
2.40	77
1.20	84
0.60	91
0.30	98
0.15	100
	575

Fineness modulus of combined aggregate = $\frac{575}{100} = 5.75$

Let n be the fraction of Fine Aggregate and (1-n) is fraction of Coarse Aggregate.

$$5.75 = 2.4\,n + 7.0\,(1 - n)$$

$$5.75 = 2.4\,n + 7 - 7n$$

$$4.6\,n = 1.25$$

$$n = \frac{1.25}{4.0} = 0.272$$

$$F.A. = 0.272$$

$$C.A. = (1-n) = 0.728$$

Total aggregate cement = 3.5 : 1

Fine Aggregate = 3.5 x 0.272

= 0.952

C.A. = 0.728 x 3.5

= 2.548

Proportion by Weight

Cement	Fine Aggregate	Coarse Aggregate	Water
1	0.952	2.548	0.4

Weight of Material required for 1 m^3 of Concrete

Finding absolute volume of material

Cement = $\frac{1}{3.15}$ = 0.317

Fine Aggregate = $\frac{0.952}{2.614}$ = 0.364

Coarse Aggregate = $\frac{2.548}{2.8}$ = 0.910

Water = $\frac{0.4}{1}$ = 0.400

2.091

Air Voids 2 Percentage = 0.042

2.133 cc

Material required for 1 m^3 of concrete

$$\text{Cement} = \frac{1 \times 10^3}{2.133} = 469 \text{ Kg}$$

$$\text{Fine Aggregate} = \frac{0.952 \times 10^3}{2.133} = 446 \text{ Kg}$$

$$\text{Coarse Aggregate} = \frac{2.548 \times 10^3}{2.133} = 1195 \text{ Kg}$$

$$\text{Water} = \frac{0.4 \times 10^3}{2.133} = 187.5 \text{ Kg}$$

Materials Required for 4 Cubes

Cement = 0.003375 x 4 x 469

= 6.33 Kg

Fine Aggregate = 0.003375 x 4 x 446

= 6 Kg

Coarse Aggregate = 0.003375 x 4 x 1195

= 16.13 Kg

Water = 0.003375 x 4 x 187.5

= 2.53 Kg

The same procedure of calculation is adopted for water cement ratio 0.55 and 0.7. The materials required for casting of cubes are tabulated.

Also calculated the quantity of material required for casting cubes of medium workability and the water cement ratio of 0.4, 0.55 and 0.7. The values are tabulated as shown.

Road Note No. 4 Method

Workability : Low

Material Required for 4 Cubes

W/C Ratio	Cement Kg	Fine Aggregate Kg	Coarse Aggregate Kg	Water Kg	Proportion
0.40	6.33	6.00	16.13	2.53	1 : 0.952 : 2.548
0.55	4.50	6.97	18.67	2.47	1 : 1.55 : 4.15
0.70	3.52	7.09	19.00	2.46	1 : 2.013 : 5.387

Road Note No. 4 Method

Workability : Medium

Material Required for 4 Cubes

W/C Ratio	Cement Kg	Fine Aggregate Kg	Coarse Aggregate Kg	Water kg	Proportion
0.40	7.17	6.05	16.19	2.87	1 : 0.843 : 2.257
0.55	5.13	6.56	17.56	2.82	1 : 1.278 : 3.422
0.70	4.04	6.81	18.25	2.83	1 : 1.686 : 4.514

Table 11·13

Aggregate/cement ratio required to give four degree of workability with different gradings and shapes of aggregate 20 mm angular aggregate[11.4]

Degree of Workability	*Very Low*				*Low*				*Medium*				*High*			
Grading of Aggregate (Curve No. on Fig. 3·4)	*1*	*2*	*3*	*4*	*1*	*2*	*3*	*4*	*1*	*2*	*3*	*4*	*1*	*2*	*3*	*4*
Water/cement ratio by weight																
0·35	3·2	3·0	2·9	2·7	2·7	2·7	2·5	2·4	2·4	2·4	2·3	2·2	2·2	2·3	2·1	2·1
0·40	4·5	4·2	3·7	3·5	3·5	3·5	3·2	3·0	3·1	3·1	2·9	2·7	2·9	2·9	2·8	2·6
0·45	5·5	5·0	4·6	4·3	4·3	4·2	3·9	3·7	3·7	3·7	3·4	3·3	3·5	3·5	3·2	3·1
0·50	6·5	5·8	5·4	5·0	5·0	4·9	4·5	4·3	4·2	4·2	3·9	3·8	×	3·9	3·8	3·5
0·55	7·2	6·6	6·0	5·6	5·7	5·4	5·0	4·8	4·7	4·7	4·5	4·3	×	×	4·3	4·0
0·60	7·8	7·2	6·6	6·3	6·3	6·0	5·6	5·3	×	5·2	4·9	4·8	×	×	4·7	4·4
0·65	8·3	7·8	7·2	6·9	6·9	6·5	6·1	5·8	×	5·7	5·4	5·2	×	×	5·1	4·9
0·70	8·7	8·3	7·7	7·5	7·4	7·0	6·5	6·3	×	6·2	5·8	5·7	×	×	5·5	5·3
0·75	—	—	8·2	8·0	7·9	7·5	7·0	6·8	×	×	6·2	6·1	×	×	5·8	5·7
0·80	—	—	—	—	—	—	7·4	7·2	×	×	6·6	6·5	×	×	6·1	6·0
0·85					—	—	7·8	7·6	×	×	7·1	6·9	×	×	6·4	6·3
0·90					—	—	—	—	×	×	7·5	7·3	×	×	×	6·7
0·95									×	—	8·0	7·6	×	×	×	7·0
1·00									×	×	—	—	×	×	×	7·3

Note : —Indicates that the mix was outside the range tested.
× Indicates that the mix would segregate.

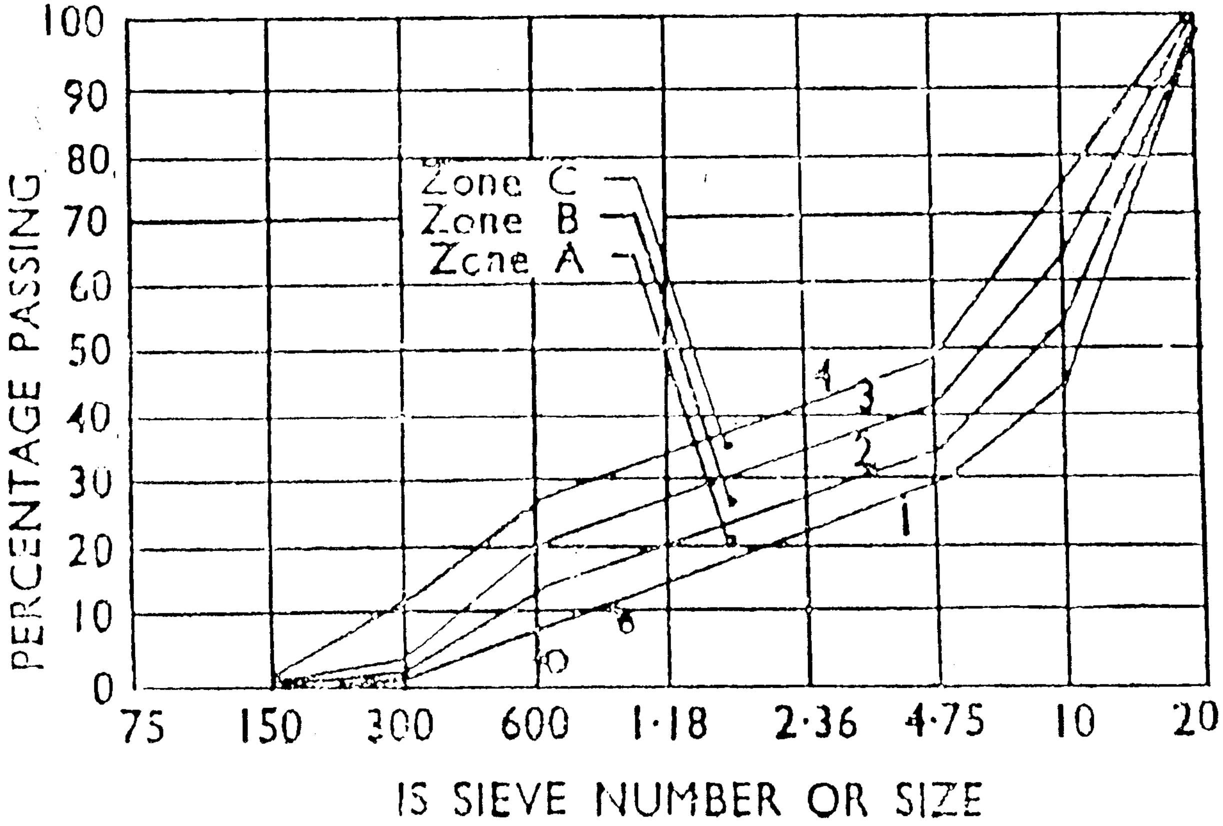

Fig. 3·4 Type grading curves for 20 mm aggregate

IV. Dr.ALEXANDER METHOD

Data

1. Low Workability (K) = 0.9
2. Water Cement Ratio = 0.4
3. Interspace = 0.1 cm

Cement

Normal Consistency N_c = 0.29

Specific Gravity, g_1 = 3.15

Bulk Density, D_1 = $\frac{315}{1 + 0.29 \times 315}$

= 1.646 gm/cc

Solid proportion P_1 = $\frac{1.646}{3.15}$

= 0.5225

Fine Aggregate

Fineness Coefficient Q = (6 - 2.419)

= 3.581

Proportion of Solid martor P_2 = 0.6666

Specific Gravity g_2 = 2.614

Bulk Density D_2 = $P_2 \times g_2$

= 0.6666 x 2.614

= 1.7424 gms/cc

Mould

Surface volume ratio (r) $= \frac{2}{15} + \frac{2}{15} + \frac{2}{15}$

(r) $= 0.4$

Coarse Aggregate

Mean Aggregate Size (a) $= 2.0$ cm

Fineness Index (F) $= (\frac{4}{a})^{1/3}$

$= (\frac{4}{2})^{1/3}$

$= 1.2599$

Specific Gravity g_3 $= 2.8$

Fine Cubical Solid of Size $= 15 \times 15 \times 15$ cm

Solid proportion at interior P_i $= 0.634$

Solid proportion at surface P_2 $= 0.4755$

Mean Solid proportion $(P_3) = P_i - \frac{(P_i - P_s)}{2} \times a \times r$

$= 0.634 - (\frac{0.634 - 0.4755}{2}) \times 0.4 \times 2$

$P_3 = 0.5706$

Bulk Density D_3 $= 0.5706 \times 2.8$

$= 1.5977$ gm/cc

2. Determination of Water Cement Factors

For Cement

Rich mix $W_1 = N_c \, D_1$

$= 0.29 \times 1.646$

$= 0.4773$

Lean Mix $W_1^1 = 0$

For Sand

Rich Mix $W_2 = 0.03 \times \phi$

$= 0.03 \times 3.581$

$= 0.1074$

Lean Mix $W_2^1 = 1 - 0.6666$

$= 0.3333$

For Coarse Aggregate

$W_3 = 0.033 \times F$

$= 0.033 \times 1.2599$

$= 0.04157$

3. Determination of Critical Value (f)

(Fine Aggregate proportion in the mix)

$$f = f_{cr} \text{ (Critical)}$$

$$f_{cr} = \frac{W_1}{(W_2^1 - W_2)}$$

$$= \frac{0.4773}{0.3333 - 0.1074}$$

$$= 2.113$$

4. Determination of Harshness (h)

$$h = \frac{1 - 0.63\ t\ r}{(1 + (\frac{t}{a})^3}$$

$$= \frac{1 - 0.63 \times 0.1 \times 0.4}{(1 + (\frac{0.1}{2.0})^3}$$

$$= 0.8421$$

5. Determination of Aggregate Mortar ratio (A)

$$A = \frac{h}{(1 - P_3 h)}$$

$$= \frac{0.8421}{(1 - 0.5706 \times 0.8421)}$$

$$= 1.6241$$

6. Determination of Mix Volume Co-efficient

Rich Mix

For Cement $M_1 = P_i + K\ W_1$

$= 0.5225 + 0.9 \times 0.4773$

$= 0.9521$

For Sand $M_2 = P_2 + K\ .\ W_2$

$= 0.6666 + 0.9 \times 0.1074$

$= 0.7633$

For Coarse Aggregate $M_3 = P_3 + K\ W_3$

$= 0.5706 + 0.9 \times 0.04157$

$= 0.608$

Lean mix

For Cement $M_1^{\ 1} = P_i \doteq 0.5225$

For Sand $M_2^{\ 1} = P_2 + K\ W_2^{\ 1}$

$= 0.6666 + 0.9 \times 0.3333$

$= 0.9666$

For Coarse Aggregate $M_3^{\ 1} = P_3 + K\ .\ W_3$

$= 0.57067 + 0.9 \times 0.04157$

$= 0.608$

7. **Determination of Critical Water Cement Ratio**

$W_0\ C_r = W_2^{\ 1}\ f_{cr}$

$= 0.3333 \times 2.113$

$= 0.7043$

$M_{cr} = M_1 + M_2\ f_{cr}$

$= 0.9521 + 0.7633 \times 2.113$

$= 2.565$

$M_{cr} = K(W_{0cr} + W_3\ A\ M_{cr})$

$= 0.9\ (0.7043 + 0.04157 \times 1.6241 \times 2.565)$

$= 0.7897$

$$W^{1}_{cr} = \frac{W_{cr}}{D_1} = \frac{0.7897}{1.646} = 0.4798$$

$$0.4 < 0.4798$$

$$W < W_{cr}^{1}$$

Hence the mix is rich

8. Determination of Mix Proportion

$$\text{Rich Mix } W_v = W \times D_1$$

$$= 0.4 \times 1.644$$

$$= 0.6584$$

$$f_v = \frac{\left(\frac{W_v}{K} - W_1 - W_3\ A\ M_1\right)}{W_2 + W_3\ A\ M_2}$$

$$= \frac{\frac{0.6584}{0.9} - 0.4773 - 0.04157 \times 1.6241 \times 0.9521}{0.1074 + 0.04157 \times 1.6241 \times 0.7633}$$

$$f_v = 1.22$$

$$C_v = A\ (M_1 + M_2\ f_v)$$

$$= 1.6241\ (0.9521 + 0.7633 \times 1.22)$$

$$= 3.058$$

Mix proportion by volume

Cement	f_v	C_v	W_w
1	1.22	3.058	0.4

Mix Proportion by Weight

$$f_w = f_v \times \frac{D_2}{D_1}$$

$$= 1.22 \times \frac{1.7424}{1.646}$$

$$= 1.291$$

$$C_w = C_v \times \frac{D_3}{D_1}$$

$$= 3.088 \times \frac{1.5977}{1.646}$$

$$= 2.968$$

$$W_w = 0.4$$

Proportion

Cement	f_w	C_w	W_w
1	1.291	2.968	0.4

9. **Determination of Quantity of Material for 1 m^3 of Concrete**

$$C_0 = M_1 + M_2 f_v + M_3 C_v$$

$$= 0.9521 + 0.7633 \times 1.22 + 0.608 \times 3.058$$

$$= 0.9521 + 0.9312 + 1.8592$$

$$= 3.742$$

$$\text{Cement } Q = \frac{D_1}{C_0} = \frac{1.646}{3.762}$$

$$= 0.44 \text{ gm/cc} = 440 \text{ Kg/m}^3$$

Fine Aggregate = $Q \times f_w$

= 0.44 x 1.291

= 0.568

= 568 Kg/m^3

Coarse Aggregate = $Q \times C_w$

= 0.44 x 2.968

= 1.306 gm/cc

= 1306 Kg/m^3

Water = 0.44 x 0.4

= 0.174

= 174 Kg/m^3

10. Material required for 4 Cubes

Cement = 0.003375 x 4 x 440

= 5.94 Kg

Fine Aggregate = 0.003375 x 4 x 568

= 7.67 Kg

Coarse Aggregate = 0.003375 x 4 x 1306

= 17.63 Kg

Water = 0.003375 x 4 x 176

= 2.38 Kg

The same procedure of calculation is adopted for water cement ratio 0.55 and 0.7. The materials required for casting of cubes are tabulated.

Also calculated the quantity of material required for casting of cubes of concrete of medium workability (K = 1) and water cement ratio 0.4, 0.55 and 0.7. The values are tabulated as shown.

Dr.Alexander Method

Workability (K) = 0.9 (low)

Material required for 4 cubes

W/C Ratio	Cement Kg	Fine Aggregate Kg	Coarse Aggregate Kg	Water Kg	Proportion
0.40	5.94	7.67	17.63	2.38	1 : 1.291 : 2.968
0.55	3.70	10.14	17.64	2.04	1 : 2.742 : 4.77
0.70	3.00	10.54	17.66	2.09	1 : 3.52 : 5.89

Dr.Alexander Method

Workability (K) = 1 (Medium)

Materials required for 4 cubes

W/C Ratio	Cement Kg	Fine Aggregate Kg	Coarse Aggregate Kg	Water Kg	Proportion
0.40	7.20	5.41	17.59	2.88	1 : 0.753 : 2.444
0.55	4.13	9.5	17.55	2.27	1 : 2.30 : 4.28
0.70	3.36	9.90	17.52	2.35	1 : 2.95 : 5.216

I. MATERIALS REQUIRED FOR 4 CUBES I.S.CODE MIX DESIGN

Workability	Water/Cement Ratio	Cement Kg	Fine Aggregate Kg	Coarse Aggregate Kg	Water Kg	Proportion
Low (0.8)	0.40	6.075	5.68	18.76	2.43	1 : 0.935 : 3.09
Low (0.8)	0.55	4.565	7.87	17.53	2.51	1 : 1.72 : 3.84
Low (0.8)	0.70	3.587	8.89	17.32	2.51	1 : 2.48 : 4.83
Medium (0.9)	0.40	6.257	5.60	18.50	2.50	1 : 0.9 : 2.95
Medium (0.9)	0.55	4.700	7.37	17.30	2.58	1 : 1.65 : 3.68
Medium (0.9)	0.70	3.70	8.77	17.20	2.58	1 : 2.37 : 4.66
Total		28.884	44.18	106.61	15.11	

II. MATERIALS REQUIRED FOR 4 CUBES - A.C.I. MIX DESIGN

Workability	Water/Cement Ratio	Cement Kg	Fine Aggregate Kg	Coarse Aggregate kg	Water Kg	Proportion
Low	0.40	6.244	8.394	14.657	2.498	1 : 1.344 : 2.347
Slump (3 to 5 cm) Low	0.55	4.540	10.097	14.657	2.498	1 : 2.22 : 3.228
Low	0.70	3.568	11.070	14.657	2.498	1 : 3.31 : 4.1
Medium	0.40	6.750	7.690	14.660	2.700	1 : 1.14 : 2.17
Slump (8 to 10 cm) Medium	0.55	4.900	9.530	14.660	2.700	1 : 1.94 : 3.0
Medium	0.70	3.860	10.580	14.660	2.700	1 : 2.74 : 3.8
Total		29.862	57.361	87.95	15.600	

III. MATERIALS REQUIRED FOR 4 CUBES - ROAD NOTE NO. 4 METHOD

Workability	Water/Cement Ratio	Cement Kg	Fine Aggregate Kg	Coarse Aggregate Kg	Water Kg	Proportion
Low	0.40	6.33	6.00	16.13	2.53	1 : 0.952 : 2.548
Low	0.55	4.50	6.97	18.67	2.47	1 : 1.55 : 4.15
Low	0.70	3.52	7.09	19.00	2.46	1 : 2.013 : 5.387
Medium	0.40	7.17	6.05	16.19	2.57	1 : 0.843 : 2.257
Medium	0.55	5.13	6.56	17.56	2.82	1 : 1.278 : 3.422
Medium	0.70	4.04	6.81	18.25	2.83	1 : 1.686 : 4.514
Total		31.22	40.08	105.8	15.68	

IV. MATERIALS REQUIRED FOR 4 CUBES - Dr.ALEXANDER METHOD

Workability	Water/Cement Kg	Cement Kg	Fine Aggregate Kg	Coarse Aggregate kg	Water kg	Proportion
Low (0.9)	0.40	5.94	7.67	17.63	2.38	1 : 1.291 : 2.968
Low (0.9)	0.55	3.70	10.14	17.64	2.04	1: 2.742 : 4.77
Low (0.9)	0.70	3.00	10.54	17.66	2.09	1 : 3.52 : 5.89
Medium (1.0)	0.40	7.20	5.41	17.59	2.88	1 : 0.753 : 2.444
Medium (1.0)	0.55	4.13	9.50	17.55	2.27	1 : 2.30 : 4.28
Medium (1.0)	0.70	3.36	9.90	17.52	2.35	1 : 2.95 : 5.216
Total		27.33	53.16	105.59	14.82	

CHAPTER V

Calculation of Theoretical Values

CHAPTER - 5

CALCULATION OF THEORETICAL VALUE

PREDICTED STRENGTH OF CONCRETE

I. I.S.CODE METHOD

I. Workability Corresponding to Compacting Factor 0.8

(a) Considering Water Cement Ratio 0.4

From Figure I of I.S.Code 10262 - 1982 target strength of Concrete = 37 N/mm^2

(b) For Water Cement Ratio 0.55

The Target Strength = 23 N/mm^2

(c) For Water Cement Ratio 0.7

The Target Strength = 18 N/mm^2

II. Workability Corresponding to Compacting Factor 0.9

(a) Water Cement Ratio 0.4

From Figure I of I.S.Code 10262 - 1982

Target Strength of Concrete = 37 N/mm^2

(b) For Water Cement Ratio 0.55

Target Strength of Concrete = 23 N/mm^2

(c) For Water Cement Ratio 0.7

Target Strength of Concrete = 18 N/mm^2

II. A.C.I.METHOD

1. Workability - Low (Slump 3 to 5 cm)

(a) Water Cement Ratio 0.4

The cylinder Strength from Table I

Water/Cement Ratio	Strength
0.38	450 Kg/cm^2
0.43	400 Kg/cm^2

For 0.4 Water Cement Ratio = 430 Kg/cm^2

Control Factor 0.6

= 430 x 0.6

= 278 Kg/cm^2

Cylinder Strength = 0.82 times the cube strength

Cube Strength = $\frac{278}{0.82}$ = 339 Kg/cm^2

= 33.9 N/mm^2

(b) Water Cement Ratio 0.55

The Cylinder Strength from Table I

= 300 Kg/cm^2

Control Factor 0.6

= 300 x 0.6

= 180 Kg/cm^2

Cylinder strength 0.82 times the cube strength

$= \frac{180}{0.82}$

= 219.5 Kg/cm^2

= 21.95 N/mm^2

(c) Water Cement Ratio 0.7

The cylinder strength from Table I

= 200 Kg/cm^2

Control Factor 0.6

= 200 x 0.6

= 120 Kg/cm^2

Cylinder Strength = 0.82 times cube strength

Cube Strength $= \frac{120}{0.82}$

= 146.3 Kg/cm^2

= 14.63 N/mm^2

II. Workability Medium (Slump 8 to 10)

(a) Water Cement Ratio 0.4

Cube Compressive Strength = 33.9 N/mm^2

(b) Water Cement Ratio 0.55

Cube Compressive Strength = 21.95 N/mm^2

(c) Water Cement Ratio 0.7

Cube Compressive Strength = 14.63 N/mm^2

III. ROAD NOTE NO. 4 METHOD

I. Workability : Low

(a) Water Cement Ratio 0.4

Refer Figure 11.3 for Water Cement Ratio 0.4 the designed strength for 28 days curing = 480 Kg/cm^2

Desigh strength = $S_{min} + K . \sigma$

Where S_{min} = Minimum Strength

K = Himsworth Constant

From Table 11.3 K is taken 2.33

σ = Standard deviation

From Table 11 - 2. σ is taken 13

480 = S_{min} + 2.33 x 13

480 = S_{min} + 30.3

= 449.7 Kg/cm

Minimum Comp. Strength = 44.97 N/mm^2

(b) Water Cement Ratio 0.55

Figure 11-3 Design Strength = 320 Kg/cm^2

Minimum Compressive Strength = 320 - 30.3

= 288.7 Kg/cm^2

= 28.87 N/mm^2

(c) Water Cement Ratio 0.7

Figure 11.3 Design Strength	=	220 Kg/cm^2
Minimum Compressive Strength	=	220 - 30.3
	=	189.7 Kg/cm^2
	=	18.97 N/mm^2

The Same value for medium workability

For 0.4 Water Cement minimum Strength = 44.97 N/mm^2

For 0.55 Water Cement Minimum Strength = 28.87 N/mm^2

For 0.7 Water Cement Minimum Strength = 18.97 N/mm^2

IV. Dr.ALEXANDER METHOD

General Designed Strength Equation

$$A = 20\ [7 + 2\ F.M. - 6\ K]$$

$$B = 1050\ Kg/cm^2$$

Where A depends on F.M. of fine aggregate and degree of workability (K).

Where B - Constant - Theoretical Strength at zero Water Cement Ratio.

$$\sigma = B\ \left(\frac{A}{B}\right)^W$$

where σ = Designed Strength

W = Water Cement Ratio

I. Workability (K) = 0.9

(a) Water Cement Ratio 0.4

F.M. = 2.419

A = 20 [7 + 2 x 2.419 - 6 x 0.9]

= 128.76

$= 1050 \left(\frac{128.76}{1050}\right)^{0.4}$

$= 453.5\ Kg/cm^2$ or $45.35\ N/mm^2$

(b) Water Cement Ratio 0.55

$= 1050 \left(\frac{128.76}{1050}\right)^{0.55}$

$= 331.07\ Kg/cm^2$ or $33.11\ N/mm^2$

(c) Water Cement Ratio 0.7

$= 1050 \left(\frac{128.76}{1050}\right)^{0.7}$

= 231.65 Kg/cm or 23.16 N/mm

II. Workability (K) : 1

(a) Water Cement Ratio 0.4

A = 20 [7 + 2 x 2.419 - 6 x 1]

= 116.76

B = 1050

$$\sigma = 1050 \left(\frac{116.76}{1050}\right)^{0.4}$$

$$= 436.13 \text{ Kg/cm}^2 \text{ or } 43.61 \text{ N/mm}^2$$

(b) Water Cement Ratio 0.55

$$= 1050 \left(\frac{116.76}{1050}\right)^{0.55}$$

$$= 313.7 \text{ Kg/cm}^2 \text{ or } 31.37 \text{ N/mm}^2$$

(c) Water Cement Ratio 0.7

$$= 1050 \left(\frac{116.76}{1050}\right)^{0.7}$$

$$= 225.66 \text{ Kg/cm}^2 \text{ or } 22.56 \text{ N/mm}^2$$

THEORETICAL STRENGTH OF CONCRETE

I. I.S.Code Method

Workability	Water/Cement Ratio	Strength N/mm^2
Low (0.8)	0.40	37
	0.55	23
	0.77	18
Medium (0.9)	0.40	37
	0.55	23
	0.70	18

II. A.C.I.Method

Workability	Water/Cement Ratio	Strength N/mm^2
Low Slump 3 to 5	0.40	33.90
	0.55	21.95
	0.70	14.63
Medium slump 5 to 8	0.40	33.90
	0.55	21.95
	0.70	14.63

III. Road Note No. 4 Method

Workability	Water/Cement Ratio	Strength N/mm^2
Low	0.40	44.97
	0.55	28.87
	0.70	18.97
Medium	0.40	44.97
	0.55	28.87
	0.70	18.97

IV. Dr.Alexander Method

Workability	Water/Cement Ratio	Strength N/mm^2
0.9	0.40	45.35
	0.55	33.11
	0.70	23.16
1.0	0.40	43.61
	0.55	31.37
	0.70	22.56

Table 11·3

Value for the Factor K Himsworth Constants[11.1]

Percentage of results allowed to fall below the minimum	*Value K*
0·1	3·09
0·6	2·50
1·0	2·33
2·5	1·96
6·6	1·50
16·00	1·00

Table 11·2

Values of the Standard Deviation for Different Conditions of Placing and Mixing Control

Placing and Mixing condition	*Degree of control*	*Standard Deviation* σ (*kg/cm*^{2})
Dried aggregates, completely accurate grading, exact water/cement ratio, controlled temperature curing.	Laboratory Precision	13
Weigh-batching of all materials, control of aggregate grading, 3 sizes of aggregate plus sand, control of water added to allow for moisture content of aggregates, allowance for weight of aggregate & sand displaced by water, continual supervision.	Excellent	28
Weigh-batching of all materials, strict control of aggregate grading, control of water added to allow for moisture content of aggregates, continual supervision.	High	35
Weigh-batching of all materials, control of aggregate grading, control of water added, frequent supervision.	Very good	42
Weighing of all materials, water content controlled by inspection of mix, periodic check of workability, use of two sizes of aggregate (fine & coarse) only, intermittent supervision.	Good	57
Volume batching of all aggregates allowing for bulking of sand, weigh batching of cement, water content controlled by inspection of mix, intermittent supervision.	Fair	65
Volume batching of all materials, use of all in aggregate, little or no supervision.	Poor	70
	Uncontrolled	85

CHAPTER VI

Experimental Values

CHAPTER - 6

EXPERIMENTAL VALUES

Casting of cubes, curing and compression testing are carried out in structures and materials laboratory.

Moulds

Steel cubical moulds of size 15 x 15 x 15 cms are used for casting of cubes.

Casting

The material of concrete is weighed in the weighing machine according to the mix design proportion. Hand mixing is adopted for mixing of concrete in view of the small quantity involved The concrete is mixed thoroughly and uniformly. Casting is done immediately and compaction is also done by needle vibrator.

Curing

The cube specimans were demoulded after 24 hours of casting and were placed under water in the water taken till the day of testing.

Testing

The concrete cube specimens were taken from the water after 28 days curing, and wiped with wet cloth. Then the cubes are weighed and tested in the compression testing machine. The rate of loading was 140 Kg/cm^2/minute. The loading is gradually applied upto failure. The maximum load at which failure occured was noted. The strength and weight of concrete specimens are given in tables.

Method : I.S.Code Method
Size of Specimen : 15 x 15 x 15 cms
Type of Test : Compression
Age of Testing : 28 days curing
Mean Aggregate Size : 20 mm

Date of Casting : 3.9.90
Date of Testing : 1.10.90

Workability	Water/Cement Ratio	Mix Proprotion by Weight 1 : f_w : C_w	Weight of Specimen Kg	Strength of Specimen Tonnes	Strength Kg/cm²	Mean Strength kg/cm²	Mean Strength N/mm²
Low (0.8)	0.40	1 : 0.935 : 3.09	9.00	88.80	394.66	393.38	39.34
	0.40		8.98	88.72	394.31		
	0.40		8.93	88.52	393.42		
	0.40		9.15	88.00	391.11		
Low (0.8)	0.55	1 : 1.72 : 3.84	8.92	50.00	222.22	243.89	24.39
	0.55		9.15	59.00	262.22		
	0.55		8.91	57.50	255.56		
	0.55		8.88	53.00	235.55		
Low (0.8)	0.70	1 : 2.48 : 4.83	8.90	40.00	177.78	185.55	18.56
	0.70		9.04	44.00	195.55		
	0.70		8.71	41.00	182.22		
	0.70		8.79	42.00	186.66		

Mix Design Method : I.S.Code Method
Size of the Specimen : 15 x 15 x 15 cm
Type of Test : Compression
Age of Testing : 28 days curing
Mean Aggregate Size : 20 mm

Date of Casting : 4.9.90
Date of Testing : 2.10.90

Workability	Water/Cement Ratio	Mix Proportion by Weight 1 : f_w : C_w	Weight of Specimen Kg	Strength of Specimen Tonnes	Strength Kg/cm²	Mean Strength Kg/cm²	Mean Strength N/mm²
Medium (0.9)	0.40	1 : 0.9 : 2.95	8.91	98.50	437.78		
			9.16	100.50	444.44		
			9.05	95.00	422.22	437.77	43.78
			9.19	100.50	446.66		
Medium (0.9)	0.55	1 : 1.65 : 3.68	8.96	51.50	228.88		
			9.21	61.00	271.00	272.20	27.22
			8.90	66.50	295.55		
			8.92	66.00	293.33		
Medium (0.9)	0.70	1 : 2.37 : 4.66	9.07	46.50	206.66		
			8.82	44.50	197.78		
			8.73	42.00	186.67	200.55	20.06
			8.96	47.50	211.11		

Method : A.C.I.Mix Design
Size of the Specimen : 15 x 15 x 15 cm
Type of Test : Compression
Age of Testing : 28 days curing
Mean Aggregate : 20 mm size

Date of Casting : 6.9.90
Date of Testing : 4.10.90

Workability	Water/Cement Ratio	Mix proportion by Weight 1 : f_w C_w	Weight of Specimen Kg	Strength of Specimen Tonnes	Strength Kg/cm²	Mean Strength Kg/cm²	Mean Strength M/mm²
Low Slump 3 to 5	0.40	1 : 1.344 : 2.347	8.96	104.5	464.44	471.66	47.17
			8.90	111.0	493.33		
			8.92	103.5	460.00		
			9.08	105.5	468.88		
Low Slump 3 to 5	0.55	1 : 2.22 : 3.228	8.82	75.0	333.33	308.33	30.83
			8.59	69.0	306.66		
			8.83	65.5	291.11		
			8.70	68.0	302.22		
Low Slump 3 to 5	0.70	1 : 3.31 : 4.1	8.89	43.0	191.11	193.88	19.39
			8.91	47.5	211.11		
			8.70	43.0	191.11		
			8.57	41.0	182.22		

Method : A.C.I.Mix Design

Size of the Specimen : 15 x 15 x 15 cm

Type of Test : Compression

Age of Testing : 28 days curing

Mean Aggregate : 20 mm

Date of Casting : 7.9.90

Date of Testing : 5.10.90

Workability Slump in cm	Water/Cement Ratio	Mix Proportion by Weight $1 : f_w : C_w$	Weight of Specimen Kg	Strength of Specimen Tonnes	Strength Kg/cm^2	Mean Strength Kg/cm^2	Mean Strength M/mm^2
8 to 10	0.40	1 : 1.14 : 2.17	8.90	102.5	455.55	455.05	45.51
			9.10	105.5	468.88		
			8.78	98.0	435.55		
			8.98	103.5	460.22		
8 to 10	0.55	1 : 1.94 : 3.0	9.12	55.5	246.66	258.88	25.89
			8.98	58.0	257.77		
			9.00	60.5	268.88		
			8.86	59.0	262.22		
8 to 10	0.70	1 : 2.74 : 3.8	9.18	40.5	180.00	180.55	18.06
			8.88	42.0	186.66		
			8.90	38.0	168.88		
			9.10	42.0	186.66		

Method of Mix Design : Road Note No. 4
Size of the Specimen : 15 x 15 x 15 cm
Type of Test : Compression
Age of Testing : 28 days curing
Mean aggregate Size : 20 mm

Date of Casting : 10.9.90
Date of Testing : 8.10.90

Workability	Water/Cement Ratio	Mix Proportion by Weight $1 : f_w : C_w$	Weight of Specimen Kg	Strength of Specimen Tonnes	Strength Kg/cm²	Mean Strength Kg/cm²	Mean Strength M/mm²
Low	0.40	1 : 0.952 : 2.548	8.94	104.0	462.22		
			9.10	108.0	480.00		
			9.31	100.0	444.44	455.55	45.56
			8.96	98.0	435.55		
Low	0.55	1 : 1.55 : 4.5	9.28	54.5	242.22		
			9.04	53.0	235.55		
			9.22	54.5	242.22	237.77	23.78
			9.30	52.0	231.11		
Low	0.70	1 : 2.013 : 5.387	9.00	42.5	188.88		
			8.96	38.5	171.11		
			9.06	41.5	184.44	178.32	17.83
			9.09	38.0	168.88		

Method of Mix Design : Road Note No. 4
Size of the Specimen : 15 x 15 x 15 cm
Type of Test : Compression
Age of Testing : 28 days curing
Mean Aggregate Size : 20 mm

Date of Casting : 14.9.90
Date of Testing : 12.10.90

Workability	Water/Cement Ratio	Mix Proportion by Weight $1 : f_w : C_w$	Weight of Specimen Kg	Strength of Specimen Tonnes	Strength kg/cm^2	Mean Strength Kg/cm^2	Mean Strength N/mm^2
Medium	0.40	1 : 0.843 : 2.257	9.12	109.5	486.66	491.66	49.16
			9.02	112.0	497.77		
			9.08	108.0	480.00		
			9.48	113.0	502.22		
Medium	0.55	1 : 1.278 : 3.422	9.22	52.5	233.33	245.00	24.5
			9.08	56.0	248.88		
			9.24	55.0	244.44		
			9.08	57.0	253.33		
Medium	0.70	1 : 1.686 : 4.514	9.00	36.5	162.22	163.33	16.33
			9.24	38.5	171.11		
			9.14	36.5	162.22		
			8.92	35.5	157.77		

Method of Mix Design : Dr.Alexander Method

Size of the Specimen : 15 x 15 x 15 cm

Type of Test : Compression

Age of Testing : 28 days curing

Mean Aggregate Size : 20 mm

Date of Casting : 17.9.90

Date of Testing : 15.10.90

Workability (K)	Water/Cement Ratio	Mix Proportion by Weight 1 : f_w : C_w	Weight of Specimen Kg	Strength of Specimen Tonnes	Strength Kg/cm²	Mean Strength Kg/cm²	Mean Strength N/mm²
0.9	0.40	1 : 1.291 : 2.968	9.25	111.0	493.33		
			9.02	106.0	471.11		
			9.03	108.00	480.00	480.00	48.00
			9.20	107.0	475.55		
0.9	0.55	1 : 2.742 : 4.77	9.31	71.5	317.77		
			9.04	64.5	286.66		
			9.10	67.5	300.00	309.44	30.94
			9.59	75.0	333.33		
0.9	0.70	1 : 3.57 : 5.89	9.28	47.0	208.88		
			9.12	43.5	193.33	198.32	19.83
			9.17	41.5	184.44		
			9.08	46.5	206.66		

Method of Mix Design : Dr.Alexander Method

Size of the Specimen : 15 x 15 x 15 cm

Type of Test : Compression

Age of Testing : 28 days curing

Mean Aggregate Size : 20 mm

Date of Casting : 18.9.90

Date of Testing : 16.10.90

Workability (K)	Water/Cement Ratio	Mix Proportion by Weight $1 : f_w : C_w$	Weigth of Specimen Kg	Strength of Specimen Tonnes	Strength kg/cm²	Mean Strength Kg/cm²	Mean Strength N/mm²
1.0	0.40	1 : 0.753 : 2.444	9.08	93.0	413.33	411.10	41.11
			9.20	98.0	435.55		
			9.03	90.0	400.00		
			9.01	89.0	395.55		
1.0	0.55	1 : 2.30 : 4.28	9.39	66.5	295.55	292.77	29.28
			9.20	70.5	313.33		
			8.99	63.5	282.22		
			8.88	63.0	280.00		
1.0	0.70	1 : 2.95 : 5.216	9.24	42.5	188.88	194.44	19.44
			8.78	41.0	182.22		
			8.82	47.5	211.11		
			9.25	44.0	195.55		

CHAPTER VII

Comparison of Different Methods

CHAPTER - 7

COMPARISON STATEMENTS

In each method, the theoretical compressive strength is compared with the actual compressive strength as obtained from tests. The error and percentage of error are calculated and the comparison is tabulated.

Method : I.S.Code Method

Size of the Specimen : 15 x 15 x 15 cm

Type of Test : Compression

Mean Aggregate Size : 20 mm

Workability	Water Cement Ratio by Weight	Mix Proportion by Weight 1 : f_w : C_w	Theretical Strength N/mm²	Tested Strength N/mm²	Error	Percentage of Error
(0.8) Low	0.40	1 : 0.935 : 3.09	37	39.34	+ 2.34	6.3
0.8 (Low)	0.55	1 : 1.72 : 3.84	23	24.39	+ 1.39	6.0
0.8 (Low)	0.70	1 : 2.48 : 4.83	18	18.56	+ 0.56	3.1
0.9 (Medium)	0.40	1 : 0.9 : 2.95	37	43.78	+ 6.78	18
0.9 (Medium)	0.55	1 : 1.65 : 3.68	23	27.22	+ 4.22	18.3
0.9 (Medium)	0.70	1 : 2.37 : 4.66	18	20.06	+ 2.06	11.4

Method : A.C.I.Method

Size of the Specimen : 15 x 15 x 15 cm

Type of Test : Compression

Mean Coarse Aggregate : 20 mm

Workability Slump in cm	Water Cement Ratio by Weight	Mix Proportion by Weight $1 : f_w : C_w$	Theoretical Strength N/mm^2	Tested Strength N/mm^2	Error	Percentage of Error
3 to 5	0.40	1 : 1.344 : 2.347	33.90	47.17	+ 13.27	39.0
3 to 5	0.55	1 : 2.22 : 3.228	21.95	30.23	+ 8.28	37.7
3 to 5	0.70	1 : 3.31 : 4.1	14.63	19.39	+ 4.76	32.5
5 to 8	0.40	1 : 1.14 : 2.17	33.9	45.51	11.61	34.0
5 to 8	0.55	1 : 1.94 : 3.0	21.95	25.89	+ 3.94	18.0
5 to 8	0.70	1 : 2.74 : 3.8	14.63	18.06	+ 3.43	23.4

Method : Road Note No. 4

Size of the Specimen : 15 x 15 x 15 cm

Type of Test : Compression

Mean Aggregate : 20 mm

Workability	Water Cement Ratio by Weight	Mix Proportion by Weight $1 : f_w : C_w$	Theoretical Strength N/mm^2	Tested Strength N/mm^2	Error	Percentage of Error
Low	0.40	1 : 0.952 : 2.548	44.97	45.56	+ 0.59	1.3
Low	0.55	1 : 1.55 : 4.5	28.87	23.78	- 5.09	17.6
Low	0.70	1 : 2.013 : 5.387	18.97	17.83	- 1.14	6.0
Medium	0.40	1 : 0.843 : 2.257	44.97	49.16	+ 4.19	9.3
Medium	0.55	1 : 1.278 : 3.422	28.87	24.50	- 4.37	15.0
Medium	0.70	1 : 1.686 : 4.514	18.97	16.32	- 2.47	13.0

Method : Dr.Alexander Method
Size of the Specimen : 15 x 15 x 15 cm
Type of Test : Compression
Mean Aggregate Size : 20 mm

Workability (K)	Water Cement Ratio by Weight	Mix Proportion by Weight $1 : f_w : C_w$	Theoretical Strength N/mm^2	Tested Strength N/mm^2	Error	Percentage of Error
0.9	0.40	1 : 1.291 : 2.968	45.35	48.00	+ 2.65	5.5
0.9	0.55	1 : 2.742 : 4.77	33.11	30.97	- 2.14	6.9
0.9	0.70	1 : 3.57 : 5.89	23.16	19.83	- 3.33	- 16
1.0	0.40	1 : 0.753 : 2.444	43.61	41.11	- 2.50	6.0
1.0	0.55	1 : 2.30 : 4.28	31.37	29.28	- 2.09	7.1
1.0	0.70	1 : 2.95 : 5.216	22.56	19.44	- 3.12	- 16

CHAPTER VIII

Conclusion

CHAPTER - 8

CONCLUSION

The object of this project is to find out which method is giving reliable and good result when comparing the theoretical values with tested values. In this project 4 different methods are considered for comparison. Now each method is analysed separately regarding their results and the final conclusions are given.

1. I.S.CODE METHOD

1. When water cement ratio increases the strength decreases. The water cement ratio and strength are inversely proportional.

2. The strength is increases with workability in all water cement ratios.

3. The weight of the specimen is almost equal in all cases.

4. The aggregate cement ratio increases with water cement ratio.

5. When comparing the theoretical results and tested results the error is always positive. 6 percent to 18 percent. That is the tested results are more than predicted values. This method is some what reliable for design works.

II. A.C.I.METHOD

1. The water cement ratio is inversely proprotional to strength.

2. The workability and the strength are inversely proportional.

3. The weight of the specimen is almost equal.

4. The aggregate cement ratio increases with water cement ratio.

5. The proportion of sand is generally higher than that in I.S.Code method for comparative mix.

6. When comparing to the theoretical results with tested results, the error is positive ranging from 18 to 39 percent. The actual values are more than the theoretical values. This method is not reliable for design work.

III. ROAD NOTE NO. 4 METHOD

1. The water cement ratio is inversely proportional to strength.

2. Medium workability is giving more strength than low workability for all water cement ratios.

3. The weight of the specimen is almost equal.

4. The aggregate cement ratio increases with water cement ratio.

5. Comparing the theoretical results with tested results the error is both negative and positive ranging from 9 to 17 percent. This method is some what reliable for design work.

IV. Dr.ALEXANDER METHOD

1. The water cement ratio is inversely proportional to the strength.

2. The workability is also inversely proportional to the strength for any water cement ratio.

3. The weight of the specimen is almost equal in all water cement ratio but slightly more than other methods.

4. The aggregate cement ratio increases with water cement ratio.

5. When comparing the theoretical results with tested results the error is almost negative ranging from 5.5 to 16 percent. Hence this method is reliable for design works.

GENERAL CONCLUSION

After analysis of all four methods in all aspects the following conclusions are arrived.

1. This fact of water cement ratio being inversely proportional to the strength is common to all methods.

2. Dr.Alexander method, IS Code method and Road Note No.4 Method give good and reliable results. That is the predicted strength and the tested strength of specimens are closer to each other and the percentage of error is also minimum. This percentage of error is less than the percentage of error in the ACI method. In Dr.Alexander's method the consumption of cement is the lowest.

This report recommends that Dr.Alexander method Mix design is more reliable than the other methods.

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