



EXPERIMENTAL INVESTIGATION ON MIX DESIGN OF CONCRETE BY USING IS METHOD AND ACI METHOD

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ABSTRACT

The present work aims to examine the similarity and variation between concrete mix design by using the IS method and ACI method, also to suggest suitability of mix design through experimental investigation. In this research work 53 grade of OPC, locally available fine aggregate and coarse aggregate were selected, based on IS 456-2000 and IS 10262-2009 standards for determining quantities and proportion of concrete having grade M30. It was observed that water cement ratio was almost identical in the IS method and ACI method. The quantity of cement was highest used in IS method. Where, the percentage of FA was lowest in IS method and highest in ACI method. Compressive strength was determined at 7 days and 28 days curing period and finally, compare the results by checking strength and durability criteria.

Keywords- Mix design, IS method, ACI method, Compressive strength and Permeability test.

1. Introduction

Concrete is a homogeneous mixture of cement, aggregate and water, which is used in the various civil engineering fields. The basic building material is most popular because of good strength, durability and economical in use.

For tall buildings and pre-stressed concrete, use of higher grades of concrete is necessary to achieve the maximum strength. According to IS 456-2000 for durability considerations, we use highest grade of concrete for more severe exposure conditions. To increase the strength and durability of concrete use the mineral admixtures such as slag, fly ash, silica fume and meta kaolin are also added.

Concrete mix design methods are mostly based on graphs, charts, tables and on empirical relations which is developed by using available materials through experiments and investigations.

For Ordinary and Standard grades of concrete only IS method is used for different placing condition, for the specified slump value that ranges from 25mm to 150mm. Based on the nominal maximum size of aggregate, select

the maximum water content for range of 25 to 50 mm slump by using I.S. 10262:2009 (table 2). To design of normal and /or heavy concrete, and mass concrete mixes ACI method is applicable. Quality material gives better strength and durability to the concrete. Quality is a journey, not a destination, it is a continuous improvement.

2. Literature Review

This chapter includes the literature review on experimental investigation of mix design method of concrete by using IS 10262-2009 and ACI 211.1-91.

1. Anand B. Zanwar and Dr. S.S. Jamkar (2016)

This paper presents the result of mix design developed for high strength concrete with fly ash and High range water reducing admixture (HRWR). The study aims at comparing two methods of concrete mix design; In this research work 53 grade ordinary Portland cement, sand and aggregate were selected based on the ASTM C 127 standard for determining the relative quantities and proportions for different water cement ratio. Eight mixes with different water cement ratio were tested to determine compressive strength at curing period of 28 days.[1]

2. Abdul Aziz and A Ramakrishnaiah (2019)

This study investigates for determining the most suitable concrete mix in order to achieve the target mean strength. In this research work 43 grades of ordinary Portland cement, sand and aggregate were selected based on IS:456-2000 and IS 10262-2009 standard for determining quantities and proportions for concrete having grade M25. The specimen having size 150mm × 150mm × 150mm was tested at the age of 7 and 28 days of curing period.[2]

3. Jeevendra Kumar Chandrakar and S.P. Mishra (2012)

In this paper, a comparison of mix design procedures of IS method, BS method and, ACI method was presented and combining the test results of these methods, “function equations based design of normal concrete mixes” was proposed. To study water cement ratio, water-content, fine aggregate effect on the concrete. The mixes designed by IS method and ACI method achieved the target mean strength, which indicate that these methods were consistent. The proposed method was validated experimentally in the laboratory for concrete grades-15MPa, 20MPa, 25MPa, 30MPa and 35MPa, and achieved the target main strength.[4]

4. Kunal Bajaj And Sameer Malhotra (2018)

In this paper proportion of Ingredients and comparison of various ratios, i.e. amount of cement, water-cement ratio, total aggregate content by using IS, ACI and BS method were studied. The mixes designed by IS method and ACI method achieved the target mean strength, which indicate that these methods were consistent.[5]

5. K.Param Singh, U.Praveen Goud, S.Madan Mohan and Dr. S. Sreenatha Reddy (2016)

The main objective of the study was to design M25 concrete mix and find the compressive strength using different mix design methods like IS10262-1982 IS 10262-2009, ACI method and DOE method. The First object was to achieve the stipulated minimum strength and durability. The Second object was to make the concrete in the most economical manner. The basic assumption made in mix design was that the compressive strength of workable concrete was governed by the water cement ratio. We conclude that in above four methods minimum cement content used in DOE methods and it gives desire compressive strength of concrete economical way. [6]

3. Methodology

3.1 Objectives of Mix Design

The purpose of concrete mix design is to ensure the most optimum proportions of the constituent materials to fulfil the requirement of the structure being built. Mix design should ensure following objectives.

- a) To achieve the desired workability in the plastic stage, minimum strength in the hardened stage
- b) Durability in the given environment conditions.
- c) To produce concrete as economically as possible.

3.2 Basic Considerations

The following point must be considered while designing concrete mixes

- a) **Cost** - The cost of concrete is made up of
 - Material Cost
 - Equipment Cost
 - Labour Cost
- b) **Specification** - The following point may be kept in mind while designing concrete mixes
 - Minimum Compressive Strength required
 - Minimum water/ cement ratio
 - Maximum cement content to avoid shrinkage cracks
 - Maximum aggregate / cement ratio
- c) **Workability**- The following points related to workability shall be kept in mind while designing concrete mixes.
 - The consistency of concrete should no more than that necessary for placing, compacting and finishing.
 - More workable concrete mean less strength which is depends on water cement ratio
- d) **Strength and Durability**- It is depends on only water cement ratio, to achieved max strength use suitable admixtures and quality materials.

3.3 IS method of Concrete Mix Design

Design **M30** concrete based on the provisions of IS-10262-2009 for the following data.

- | | |
|------------------------------------|--------------------------------------|
| a) Type of cement-OPC 53 | f) Specific gravity of F.A -2.65 |
| b) Exposure condition-Extreme | g) F.M of fine aggregate-2.80 |
| c) Maximum size of C.A-20mm | h) Sieve analysis zone –II |
| d) Specific gravity of cement-3.15 | i) Method of concrete placing-normal |
| e) Specific gravity of C.A -2.70 | j) Degree of supervision –good |

Step 1) Target mean strength of concrete

$$F_{ck} = f_{ck} + k_s = 30 + 1.65 \times 5 = 38.25 \text{ N/mm}^2$$

Refer IS-10262-2009, table 1, Standard deviation S=5

Step 2) Water cement ratio selection

Refer IS- 456-2000, table 5 For M-30 concrete, maximum w/c ratio=0.45

Step3) Water content selection

Refer IS 10262-2009, table 2

Maximum water content for 20mm aggregate=186kg/m³ (for slump 25 to 50mm)

Increase 3% of water content for every 25mm slump range

To attain maximum of 100mm slump range =6% increase in water content

$$\text{Estimated water content for 100mm slump} = 186 + \frac{6}{100} \times 186 = 197.16 \text{ kg/m}^3$$

Step 4) Cement content calculation

Water cement ratio=0.45

$$\text{cement content} = 197.16 / 0.45 = 438.13 \text{ kg/m}^3$$

According to IS-456-2000

For extreme exposure condition, Minimum cement content = 320 kg/m³

$$320 \text{ kg/m}^3 < 438.13 \text{ kg/m}^3, \text{ Hence Ok.}$$

Step5) Volume of CA and FA content

IS 10262-2009, table 3, volume of CA corresponding to 20mm size aggregate and

FA (Zone II), Volume of CA = 0.62, Volume of FA = 1 - 0.62 = 0.38

Step 6) Mix calculation

Volume of concrete = 1m³

$$\begin{aligned} \text{Volume of cement} &= \frac{\text{mass of cement}}{\text{specific gravity of cement}} \times \frac{1}{1000} = \frac{438.13}{3.15} \times \frac{1}{1000} \\ &= 0.139 \text{ m}^3 \text{ (for w/c ratio-0.45)} \end{aligned}$$

$$\begin{aligned} \text{Volume of water} &= \frac{\text{mass of water}}{\text{specific gravity of water}} \times \frac{1}{1000} = \frac{197.16}{1} \times \frac{1}{1000} \\ &= 0.197 \text{ m}^3 \end{aligned}$$

$$\begin{aligned} \text{Volume of total aggregate} &= (a - (b + c)) = (1 - (0.139 + 0.197)) \\ &= 0.67 \text{ m}^3 \end{aligned}$$

Mass of coarse aggregate

$$\begin{aligned} &= (d \times \text{Volume of coarse aggregate} \times \text{specific gravity of coarse aggregate} \times 1000) \\ &= 0.67 \times 0.62 \times 2.70 \times 1000 \\ &= 1121.58 \text{ kg} \end{aligned}$$

Mass of fine aggregate

$$= (d \times \text{Volume of fine aggregate} \times \text{specific gravity of fine aggregate} \times 1000)$$

$$= 0.67 \times 0.38 \times 2.65 \times 1000$$

$$= 674.69 \text{ kg}$$

Sr.No.	Grade of concrete	w/c ratio	Maximum water content	Cement	Fine aggregate	Coarse aggregate
			kg/m ³	kg/m ³	kg/m ³	kg/m ³
1	M30	0.45	197.16	438.13	674.69	1121.58

3.4 ACI method of concrete mix design

Design **M30** concrete based on the provisions of ACI 211.1 for the following data.

- a) Type of cement-OPC 53
- b) Exposure condition-Moderate
- c) Standard deviation-4MPa
- d) Design mix slump target-75-100mm
- e) Maximum size of C.A-19mm
- f) Dry rodded bulk density of C.A-1600 kg/m³
- g) F.M of fine aggregate-2.80
- h) Gravity of F.A -2.65
- i) Specific gravity of C.A -2.70
- j) Air entrained-2%
- k) Specific gravity of cement-3.15

Step 1. Choice of Slump (ACI-211.1-7. Table No.- 6.3.1)

Range 25-75 category (75-100mm)

Step 2. Choice of Maximum Size of Aggregate (ACI – 211. 1 Table No. – 6. 3. 3)

20 mm, From Table the MAS= 19 mm

Step 3. Estimation of Mixing Water and Air Content

(ACI – 211.1 . Table No. – 6. 3. 3)

W=205 kg/m³ (For75-100mm slump) and entrapped air = 2%

Step 4. Selection of Water/Cement or Water/ Cementitious Materials Ratio

(ACI – 211. 1 , Table No. – 6. 3. (a) OR Table No. – 6. 3. 4(b))

For target strength of 35.82 MPa, w/c from Table of ACI 211.1 = 0.47.

This is limited to 0.55 from durability.

Step 5. Calculation of Cement Content

$$= \frac{\text{weight of water}}{w/c} = \frac{205}{0.47} = 436 \text{ kg/m}^3$$

Steps 6 . Estimation of Coarse Aggregate (ACI – 211. 1 . Table No. – 6. 3. 6)

Volume of C.A per unit volume different for aggregate F.M (Aggregate size-19mm)

$$V_{CA} = 0.62$$

$$Mass_{CA} = 0.62 \times 1000 = 992 \text{ kg/m}^3$$

Steps 7 . Fine Aggregate Contents

F.A- It can be determined by subtracting volume of CA, Cement, water and entrapped air from total volume.

$$= 1 - V_{\text{Coarse agg.}} - V_{\text{Water content}} - V_{\text{Cement}}$$

$$= 1 - \frac{992}{2.7 \times 1000} - \frac{205}{1 \times 1000} - \frac{436}{3.15 \times 1000} = 2\%$$

$$V_{FA} = 1 - 0.36 - 0.2 - 0.138 - 0.02 = 0.282$$

$$Mass_{FA} = 0.282 \times 2.65 \times 1000 = 747 \text{ kg/m}^3$$

Sr.No.	Grade of concrete	W/c ratio	Maximum water content	Cement	Fine aggregate	Coarse aggregate
			kg/m ³	kg/m ³	kg/m ³	kg/m ³
2	M30	0.40	205.00	436.00	747.00	992.00

Table no-01- Concrete Ingredients Properties

Sr.No.	Method of mix. design	Concrete grades	Free water cement ratio	Free water content	Cement content	C.A content	F.A content	Total agg. content	Total aggregate cement ratio
				kg/m ³	kg/m ³	kg/m ³	kg/m ³	kg/m ³	
1	IS Code	M20	0.50	197.6	394.32	1159.61	669.50	1829.10	4.63
2		M25	0.50	191.6	383.20	1151.72	638.12	1789.24	4.68
3		M30	0.45	197.6	438.13	1108.10	643.93	1752.03	4.00
4	ACI Code	M20	0.55	205.0	372.72	992.00	800.30	1792.30	4.80
5		M25	0.50	205.0	410.00	992.00	768.50	1760.50	4.29
6		M30	0.47	205.0	436.00	992.00	747.00	1739.00	3.98

4. Results

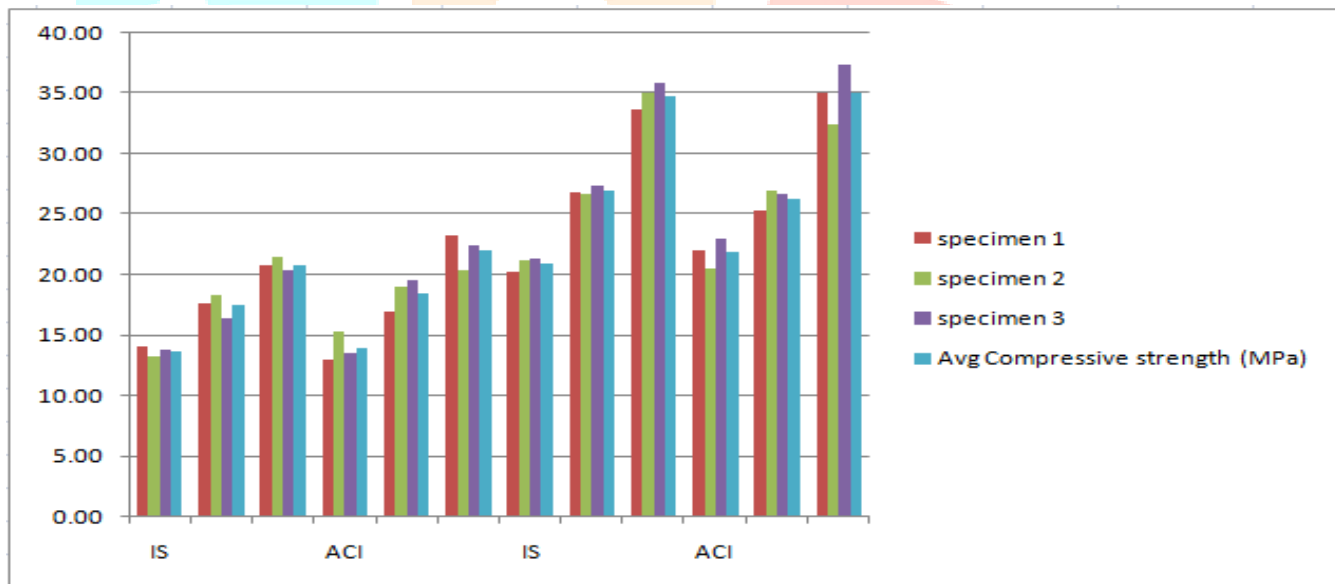
Compressive strength of various grades of concrete was tested at 7 and 28 days curing period. Also, check the durability of concrete by using Permeability test. Following experimental test results were obtained.

4.1 Compressive strength

To determine compressive strength of various grades of concrete specimen by using digital compression testing machine (CTM).

Table No-02- The following results were obtained from compressive strength test

Sr. No.	Method of mix design	Curing period	Concrete grades	Specimen 1	Specimen 2	Specimen 3	Avg Compressive Strength (MPa)
1	IS	7 days	M20	14.08	13.33	13.87	13.76
			M25	17.68	18.39	16.41	17.49
			M30	20.77	21.52	20.38	20.89
2	ACI	7 days	M20	13.08	15.37	13.54	13.99
			M25	16.98	19.05	19.64	18.55
			M30	23.24	20.38	22.53	22.05
3	IS	28 days	M20	20.21	21.17	21.35	20.91
			M25	26.86	26.72	27.33	26.97
			M30	33.68	35.03	35.87	34.86
4	ACI	28 days	M20	22.03	20.56	23.03	21.87
			M25	25.29	27.02	26.69	26.33
			M30	35.08	32.49	37.43	35.00

**Chart 1- Test Results for Compressive Strength**

4.2 Permeability test

The test was performed to study the durability of concrete when designed as per IS and ACI methods. The test was performed on M20, M25 and M30 grades of concrete. The test was set about by applying a pressure of 5 kg/cm² and gradually increasing up to 17.04 kg/cm². The observations are tabulated in table 3.

Table No. 03 - Water Permeability Test Results

Sr. No.	Method of mix design	Coefficient of Permeability (in 10^{-12} m/sec)		
		M20	M25	M30
1	IS Code	Nil	Nil	Nil
2	ACI Code	Nil	Nil	Nil

5. Conclusions

The following conclusions were drawn from the investigation.

1. The IS method (IS 10262:2009) is nearly in line with the ACI method (ACI 211.1-91). It is applicable to design of ordinary and standard grades of concrete only, also applicable to design of light weight and heavy weight concrete. For durability requirements with all, types of exposure conditions, provisions of IS 456:2000 are applicable.
2. IS method gives minimum strength as a comparison of ACI method.
3. ACI method of mix design and mix proportioning are applicable, for design of normal concrete, heavy concrete and mass concrete mixes, 28-days cylinder compressive strength of 45MPa and slump ranges of 25 to 100 mm.
4. ACI method is most suitable for medium as well as high strength concrete, air- entrained concrete and as plum concrete.
5. The ACI method is based on determining FM of sand and the CA content based on dry rodded CA bulk density. This method also gives separate tables for air-entrained concrete, sand and water content for maximum size of aggregate up to 150 mm and separate values for 12.5 & 25 mm down coarse aggregate.

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