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An Experimental Investigation of Mechanical Properties of M30 Grade Concrete by using ACI, DOE and IS Methods

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Abstract- **The increasing use of standard concrete for infrastructure and building projects selection of raw materials and mix proportion of concrete are very difficult task. This investigation is aim to decide the suitable mix design procedure for M30 grade concrete to get improved strength and workability. The three methods of mix proportioning were chosen ACI, DOE and IS. To compare best suitable method of mix proportioning in fresh state and hardened state properties of M30 grade concrete. The fresh state property was measured by slump method. The concrete specimens were cured for 7 and 28 days in curing tank. The slump, compressive strength, split tensile strength and flexural strength were examined. It was found that DOE method gives more realistic approach than ACI and IS methods. Hence, DOE method is a most suitable method to be adopted for M30 grade of concrete.**

Keywords— Mix proportioning; workability; strength

1. INTRODUCTION

Concrete is basically a mixture of Portland cement, water and aggregate which consolidates into a hard mass of any required shape due to hydration reaction between the cement and water called as binder medium. Each ingredients of the concrete has specific function. Cement and water combine act as a binder material whereas aggregate act filler material. Indian standard permits use of M20 grade concrete for the RCC members. The increasing use of concrete in construction industry such as high rise buildings and infrastructures are the need to improve its standard in terms of workability and strength which may need to go for higher grade M25 and above. For the improvement in the qualities of concrete proper mix proportioning of ingredients are required. There are different standards for the proportioning of concrete constituents such as ACI- American concrete institute method of mix proportioning, DOE- Department of Environment method of mix design United Kingdom (UK), IS- Indian standard method of mix proportioning and so on. Mix proportioning is the process of selecting suitable ingredients of concrete to determine their relative proportions with the object of producing certain prescribed mix of desired workability, strength and durability as economical as possible. Nowadays admixtures, mineral such as Fly ash, Metakaolin, slag and chemical such as plasticizers, super plasticizers etc., are also introduced in concrete to get better properties.

The current investigation is limited to find suitable method of mix proportioning for M30 grade of concrete in Indian Sub-Continent. The review of various literatures from codes, journals and papers are briefly discussed.

IS 456 – 2000 [1] Table 2 classify the grades of concrete as ordinary concrete, standard concrete and high strength concrete. In this code, the code has been recommended that the minimum grade of concrete shall not be less than M20 grade for reinforced cement concrete (RCC) work [1]. For the current investigation the M30 grade was selected keeping in mind the future capacity may increase minimum grade requirements due increase in high rise structures and infrastructure in Urban areas.

Aginam *et al* [3] were studied concrete mixes were designed to achieve a defined workability, strength and durability. Author's investigations revealed that the variation of concrete compressive strength with mix designed methods. Four common mix design methods were used namely: American Concrete Institute (ACI), Department of Environment (DOE), Road Note 4 (RN4) and CPIIO. The Ibeto brand of Portland cement was used in the research and a characteristic strength of 20N/mm^2 was designed for using the first four mix design methods. The concrete components used were tested for specific gravity; moisture content and grading were found suitable. Four sets of concrete cubes (150 x 150 x 150 mm) each were casted using four mix designs. Compressive strengths were evaluated at 7, 14, 21, and 28 days of curing. The 28 day strengths of the four sets of concrete were found to be 30.7 N/mm^2, 33.7 N/mm^2, 33.0 N/mm^2, and 35.1 N/mm^2 for ACI, DOE, RN4, and CP110 mix design methods, respectively.

Wadud and Ahmad [4] conclude concrete mix design by the ACI method requires various material properties as the input. The effect of variation of these input parameters on mix proportions had been studied, with reference to strength attainment in few cases. The sensitivity of the mix has been expressed by volume ratios of fine aggregate to coarse aggregate and cement to fine aggregate. It was found that inter-particle voids of coarse aggregates, a function of gradation, play a significant role in the prediction of mix proportions. The Authors works revealed that ACI method fails to rationally predict the proportion of the ingredients when coarse

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aggregates of higher voids was used in making the concrete. In such cases, the amount of fine aggregate was over estimated. That over estimation leads to a higher surface area to be covered by the same amount of cement, which was determined without any reference to aggregate grading. As a result, the mix fails to attain the design strength.

IS: 10262 [2, 5] treats normal mixes (up to M35) and high strength mixes (M40) and above differently. This is logical because richer mixes need lower sand content when compare with leaner mixes. The method also gives correction factor for different W/C ratio, workability and for rounded coarse aggregate. In IS method, the quantities of fine and coarse aggregate are calculate with help of yield equation, which is based on specific gravities of ingredients. Thus plastic density of concrete calculate from yield equation can be close to actual plastic density obtained in laboratory, if specific gravities are calculated accurately. Thus actual cement consumption will be close to that targeted in the first trial mix itself. The water cement ratio was calculated from cement curves based on 28 days strength of cement. That can be time consuming impractical at times. The IS method gives separate graphs using accelerated strength of cement with reference mix method This greatly reduces the time required for mix design.

For the current investigation of mix proportioning for M30 grade of concrete three methods of mix proportioning are considered ACI, DOE and IS methods to decide best suitable method of mix proportioning.

2. EXPERIMENTAL PROGRAMME

The experimental work is designed to meet the objective to decide best suitable method of mix proportioning for M30 grade of concrete by comparative study of mechanical properties of M30 grade of concrete using ACI, DOE and IS.

3. PROPERTIES OF MATERIAL USED

In the present experimental work the basic materials are used such as cement, sand as fine aggregate, coarse aggregate and water. The properties of materials and their relative proportions are as follows.

3.1 Cement

Cement use in the work was Ultra-tech 53 Grade Ordinary Portland Cement. The properties of cement used are presented in Table 1.

Table 1 properties of cement

Properties	Result	Permissible limits
Initial setting time (min)	34	IS 4031-PART 5-1988
Final setting time (min)	-	
Specific gravity	3.15	
Consistency (%)	34	IS 4031-PART 11-1988

3.2 Water

Potable water is used for mixing and curing of concrete.

3.3 Aggregate

Locally available river sand is used as fine aggregate and crushed basalt of nominal maximum size of 20mm are used as coarse aggregates. The properties of aggregates are given in Table 2 and details of grading of fine and coarse aggregates are given in Tables 3 and 4 respectively.

Table 2 Properties of Coarse and Fine Aggregate

Sr. No	Property	Coarse aggregate	Fine aggregate
1	Type	Crushed, Angular	River sand
2	Maximum size	20 mm	4.75 mm
3	Specific gravity	2.78	2.62
4	Water absorption	1%	0.61%
5	Moisture content	Nil	Nil
6	Bulk Density	1.62 kg/lit	------
7	Fineness modulus	------	2.75

Table 3 Sieve Analysis of Fine Aggregates

Sieve size	Weight retained (gm.)	Cumulative wt. retained	Cumulative % wt. retained	Remark
4.75 mm	0	0	0	Zone II sand as per IS 383: 1970
2.36 mm	100	100	10	
1.18 mm	250	350	35	
600μ	350	700	70	
300μ	200	900	90	
150μ	100	1000	100	

4. MIX DESIGN

The three different mix design procedure were adopted for the present experimental work. The calculated proportions for 1m³ are as follows.

4.1 ACI method

The concrete mix design was done by using American concrete Institute (ACI) method for M30 grade of concrete. The calculated proportion for 1m³ is given in Table 4

Table 4 Mix calculation for 1m^3 by ACI method

Material	Quantity in Kg/m^3
Cement	394
Water	185
Fine aggregate	803
Coarse aggregate	992
Water cement ratio	0.47

4.2 DOE method

The concrete mix design was done by using Department of Environment (DOE) method for M30 grade of concrete. The calculated proportion for one cubic meter (1m^3) is given below.

Table 5 mix calculation for 1m^3 by DOE method

Mix proportion	Quantity in Kg/m^3
Cement	302
Water	160
Fine aggregate	787
Coarse aggregate	1181
Water cement ratio	0.53

4.3 IS method

The concrete mix design was done by using Indian standard (IS) method from code IS 10262-2009 for M30 grade of concrete. The calculated proportion for 1m³ is given below

Table 6 Mix calculation for 1m³ by IS method.

Mix proportion	Trial in Kg/m³
Cement	438
Water	197
Fine aggregate	636
Coarse aggregate	1098
Water cement ratio	0.45

5. RESULTS AND DISCUSSION

This section presents the results of workability and strength of M30 grade concrete.

5.1 Results on Workability

The mix id and test result on workability using slump as measure of workability are presented in Table 7.

TABLE 7 RESULT ON WORKABILITY

Mix id	Water content in kg	W/C	F.A. in (kg)	C.A. in (kg)	Slump in (mm)
1	2	3	4	5	6
ACI	185	0.47	803	992	120
DOE	160	0.53	787	1181	135
IS	197	0.45	636	1098	140

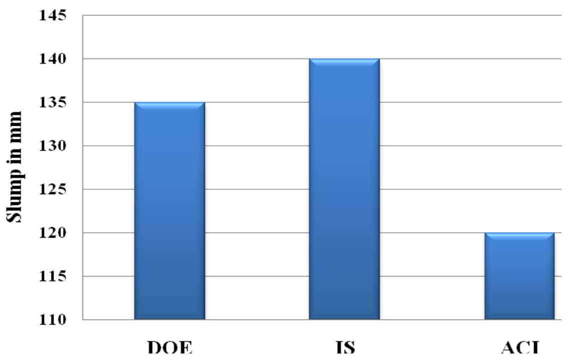

Fig. 1. Slump in mm for M30 Grade concrete

Column 1 of table 7 shows method of mix design, while water content, water to cement ratio (w/c) by mass, quantity of fine aggregate, and quantity of coarse aggregate are presented in column no. 2, 3, 4 and 5 respectively for each mix. Workability is measured using slump cone test as per IS 1199: 1959 and results of workability are presented in column no.6. From figure 1, it is clear that IS method of mix design gives better workability than ACI and DOE methods of mix design. But from the results of workability present in column 6 of Table 7 we observed that w/c ratio for IS method is lower than other two methods but still the workability is on higher side. Hence from the results of workability we also observe that water content alone is not responsible for workable mix, cement content and aggregate content is also similar importance. We observed from the results that here fine aggregate content plays major role for the workable mix. Higher the fine aggregate content lower will be the slump, because finer particles mean large surface area. Larger the surface area means more water require in a mix for better workability in terms of slump.

5.2 Results on Compressive strength

The mix id and test result on compressive strength of concrete are presented in Table 8. The mix id of mixes is presented in column 1. For each mix, cement content and w/c ratio by mass are presented in column 2 and 3 respectively. The result of compressive strength was obtained by taking average strength of three cubes for each mix. The result of compressive strength for 7 days and 28 days are presented in column 4 and 5 respectively.

Table 8 Compressive strength of M30 grade of concrete

Mix id	Cement Content in kg	Water / Cement ratio	Compressive strength at 7 days in N/mm²	Compressive strength at 28 days in N/mm²
1	2	3	4	5
ACI	394	0.47	29.24	43.03
DOE	302	0.53	21.24	32.43
IS	438	0.45	32.82	40.98

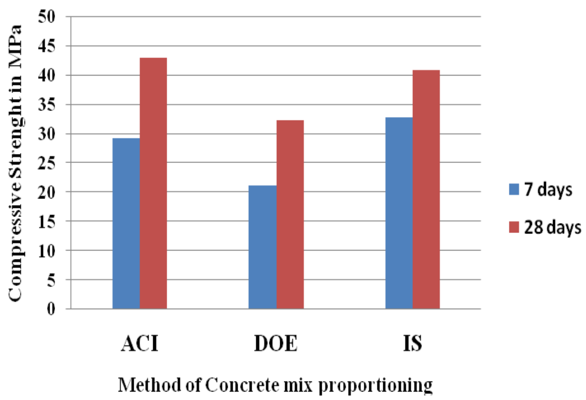

Fig. 2. Compressive strength in N/mm² for M30 Grade concrete

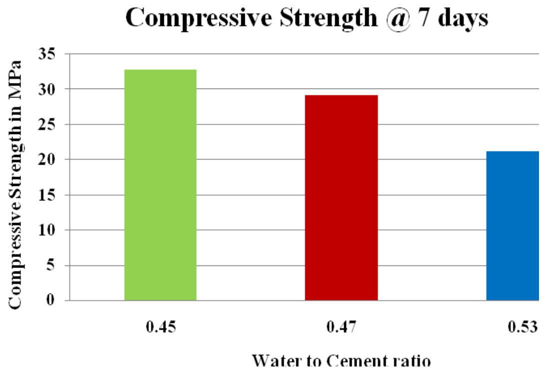

Fig. 3. Compressive strength in N/mm² v/s w/c ratio

From Fig. 3 and Table 8, we observed that the water to cement ratio (w/c) plays important role on strength of concrete. We observed that the compressive strength of concrete at 7 days is 32.82 N/mm² by IS method whereas for ACI and DOE compressive strength is 29.24 N/mm² and 21.24 N/mm² respectively. The result on compressive strength shows that increase in w/c ratio the strength of concrete decreases. Similar pattern where observed for 28 days strength as shown in Fig. 2.

From the results of compressive strength of concrete at 28 days it is observed that for M30 grade concrete by DOE method of mix design gives more realistic value of compressive strength than ACI and IS method as shown in Fig. 2. It is also seen that both ACI and IS methods require more cement content than DOE method hence DOE method is more economical than ACI and IS methods. Since cement is the major material that will impact on the cost of the project. Hence it is recommended that DOE method of mix design to be adopted for mix proportioning of M30 grade of concrete.

5.3 Results on split tensile strength and Flexural strength

The mix id and test result on split tensile and flexural strength of concrete are shown in Table 9. Column 1 shows mix design method for M30 grade of concrete. The w/c ratio of three mixes is presented in column 2. The results of split tensile strength and flexural strength are shown in fig.4 and fig.5. From the results of split tensile strength and flexural strength it is seen that as the water to cement ratio increases tensile as well as flexural strength reduces. It is also notice the split tensile strength and flexural strength are higher strength in ACI and IS method as compare to DOE method. Since cement content were more in both ACI and IS method which gives higher strength than DOE method of mix proportioning. Due to more the finer particles in a mix, means larger surface area and less voids which gives better particle packing of mixes and leads to better strength.

Table 9 Result of Split tensile and Flexural strength of M30 grade of concrete

Mix id	W/C	Split Tensile Strength Ft (Mpa)	Flexural Strength Fcr (Mpa)
1	2	3	4
ACI	0.47	3.3	5.81
DOE	0.53	3.19	5.77
IS	0.45	3.7	6.08

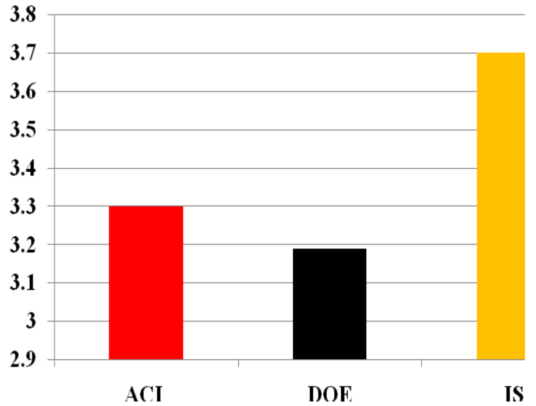

Fig. 4. Split Tensile strength in N/mm² for 28 days curing by different methods of mix design

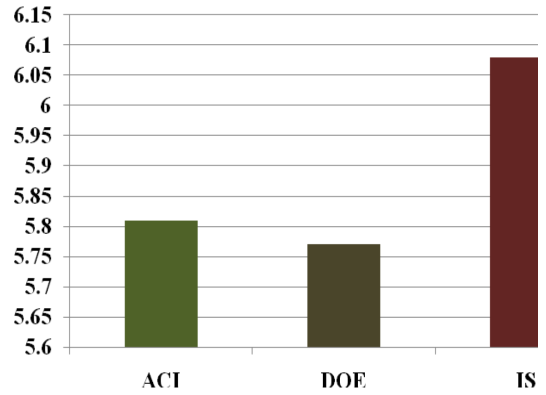

Fig. 5. Flexural strength in N/mm² for 28 days curing by different methods of mix design

6. CONCLUSIONS

The conclusions drawn from experimental work as discussed in the previous section are as follows.

1. The workability of concrete increases as water content increases.
2. The workability of concrete decreases as the quantity of fine aggregate increases.
3. The strength of concrete reduces as water to cement ratio increases.
4. The strength of concrete is more in ACI and IS methods as compare to DOE method.
5. For M30 grade of concrete mix proportioning DOE method gives more realistic compressive strength as compare to ACI and IS methods.
6. DOE method consumes less cement than ACI and IS method. Hence it is recommended that DOE method is more suitable for M30 grade of concrete mix proportioning.

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