Comparative Study of Mix Proportioning of High Strength Concrete using DOE and ACI Method

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***Abstract*:- 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; The Department of Environment Method, UK and The American Concrete Institute Method, using different water cement ratio. In this research work 53 grade ordinary portland cement, the locally available river sand, 12.5mm graded coarse aggregate were selected based on ASTM C 127 standard for determining the relative quantities and proportions for different water cement ratio. For design ACI 211.4R-08 and DOE guidelines are followed. Totally eight mixes were designed with different water cement ratio. The compressive strength values were determined at the age of 28 days curing period respectively. It was found that ACI 211.4R-08 method gives high strength as compared to DOE method. The ACI 211.4R-08 method did not make provision for uncrushed aggregate in its design method, implying that comparison could not be made in that regard.**

Keywords: High strength concrete, ACI 211.4R-08 Mix Design, DOE Mix Design, Water cement ratio, Compressive strength

1. INTRODUCTION

For many decades, concrete has been largely used as a construction material, whether in moderate aggressive environments, or in strongly environments. This is due to the fact that it possess excellent water resistance, can be moulded in a variety of shapes and sizes, and for being cheaper and more easily available in the field. To illustrate such statement, Mehta and Monteiro [10] estimate that world consumption of concrete reaches the order of 5.5 billion tonnes a year. However development of high compressive strengths characterized by mechanical properties that considerably differ from those of normal concretes. Presently High strength concretes are intensively used in the construction of high responsibility structures such as bridges, tall buildings, dams, etc. which gives the better rheological, mechanical and durability properties. This is because most of the rheological, mechanical and durability properties of these material are better than those of conventional concretes. High strength is made possible by reducing porosity, in homogeneity and micro cracks in concrete and transition zones. This can be achieved by using superplasticizers and supplementary cementing materials such as fly ash, silica fume, granulated blast furnace slag, and natural pozzolans. Fortunately, most of these materials are industrial by-products and help in reducing the amount of cement required to make the concrete less costly, more environmental friendly, and less energy intensive.[11]

A definition of high strength concrete in quantitative term which is acceptable to everyone is not possible. In North American practice, high strength concrete is usually considered to be a concrete with 28 day compressive strength of at least 42 MPa. In a recent CEB-FIP state of art report on high strength concrete, it is defined as a concrete having a minimum 28 days compressive strength of 60 MPa. In many developed countries, the concrete producers arbitrarily defined the high strength concrete as the concrete having the 28 day cube strength of above 45 MPa when the normal weight aggregate is used. Clearly then, the definition of high strength concrete is relative; it depends upon both the period of time in question, and the location.[10]

The use of high strength concrete results in many advantages, such as reduction in beam and column sizes and increase the building height with many stories. In pre-stressed concrete construction, a greater span-depth ratio for beams may be achieved with the use of high strength concrete. In marine structures, the low permeability characteristics of high strength concrete reduce the risk of corrosion of steel reinforcement and improve the durability of concrete structures. In addition, high strength concrete can perform much better in extreme and adverse conditions, and can reduce the maintenance and repair costs.[10]

All developed countries as well as many developing countries, have standardized their concrete mix design methods are mostly depend on empirical relations, charts, graphs and tables developed as an outcome of extensive experiments and investigations of locally available materials and all of those standards and methods follow the same basic trial and error principles.

The British Department of Environment (DOE) method of concrete mix design is used in the united kingdom and many other parts of the world. The methods originate from the "Road-note" which was published in Greek Britain in 1950. The DOE method utilizes British test data obtained at the building research institute, the Transport and Road Research Institute and the British cement Association. The aggregates used in the test conform to BS812 [8] and cement to BS12 [7].

The American Concrete Institute (ACI 211.4R-08) mix design method is one of the numerous method of concrete mix design available today. It is widely used in US and in continually updated. Both methods are somehow similar, but with major difference in the method of estimating the relative proportion of fine and coarse aggregates.

The British Department of Environment (DOE) and American Concrete Institute (ACI 211.4R-08) methods are two different method of concrete mix design amidst other methods, for construction work (Highway & Building) [12]. The aim of this research work is to examine the comparison between the ACI 211.4R-08 and DOE methods of concrete mix design, using different water cement ratio, and to determine how the different methods affect overall results.

2. EXPERIMENTAL PROGRAMME:

2.1 Material Used:

Ordinary portland cement of 53 grade, confirming to IS 12269-1987 [5] is used in the investigation. locally available river sand as fine aggregate confirming to IS 383-1970 [6] and coarse aggregate of size 12.5mm down size confirming to IS 383-1970 [6] were used in the present investigation. Potable water was used in the present investigation for both casting and curing both the concrete. Superplasticizer (chemical admixture) sulphonated napthalene formaldehyde CONPLAST SP 430 confirming to BIS 9103-1999 is used as workable agent. Fly ash (Mineral admixture) procured from Dirk India private. Ltd , Nasik under the trade name Pozzocrete 100 is used in present investigation. The preliminary investigation of material for concrete mix proportioning as per IS2386- part-III specific gravity, water absorption and moisture content of different sample are investigated shown in table 1

Table 1: Preliminary properties of Materials required for concret

Sr No	Types of Material	Specific gravity	Water absorption	Fineness modulus
1.	Coarse aggregate	2.83	1.2%	6.32
2.	Fine aggregate	2.507	0.65%	3.40
3.	Cement	3.15	-	-
4.	Cementitious material (fly ash)	2.25	-	-
5.	Superplasticizer (SP 430 Conplast)	1.26	-	-

2.2 Mix proportions of HSC:

For HSC there is no specific method of design mix. In the present investigation ACI 211.4R-08 method and DOE method are used. In order to achieve high strength lower w/c ratio is adopted and to achieve good workability superplasticizer is used. From the trial mix proportions of the concrete the high strength is achieved at a replacement of cement by cementitious material at a 10%. Hence in the present investigation the fly ash of 10% is used as a replacement of cementitious material. The trial mix proportions of concrete as shown in table 2 and 3. In the present investigation determination of compressive strength of four series of water cement ratio i.e. (0.35, 0.3, 0.25, 0.2) by using the different mix design process i.e. ACI 211.4R-08 and DOE.

Table 2: Mix proportions of concrete by ACI 211.4R-08

w/c ratio	Quantity of materials					
	Cement	FA	CA	Water	Fly ash	SP (by wt of cement)
0.35	481.58	604.30	1080.52	187.28	53.5	1%
0.30	561.86	534.02	1080.52	187.28	62.5	1%
0.25	674.22	434	1080.52	187.28	74.9	1.5%
0.20	842.8	285	1080.52	187.28	93.6	2%

Table 3: Mix proportions of concrete by DOE

w/c ratio	Quantity of materials					
	Cement	FA	CA	Water	Fly ash	SP (by wt of cement)
0.35	477.76	707.625	1016.64	182.667	53.08	1%
0.30	552.42	677.29	973	182.667	61.38	1%
0.25	654.72	635.81	913.4724	182.667	72.74	1.5%
0.20	803.52	575.36	826.63	182.667	89.28	2%

2.3 Curing and casting :

The ingredients of the mixes were weighed and casting was carried out using a tilted drum type concrete mixer. Precaution were taken to ensure uniform mixing of ingredients. The specimens were cast in steel moulds and compacted on table vibrator. Cube specimens of size 150x150x150 mm were cast for cube compressive strength. Curing was done for 28 days by keeping the specimens completely immersed in water. All the test results reported in the paper represent the average value obtained from a five specimens.

3. RESULTS AND DISCUSSION:

3.1 Workability of fresh concrete:

Table 2 and 3 shows the dosage of superplasticiser which was necessary for mixes containing different level of w/c ratio to have a constant slump of high workability according to BS 1881: part 102:1983. It can be observed that the mixes incorporating lower water cement ratio tended to require higher dosage of superplasticiser.

Table 4: Compressive strength (MPa)

w/c ratio	Mix design	
	ACI 211.4R-08	DOE
0.35	55	57
0.30	65	63
0.25	77	74
0.20	86	82

3.2 Compressive strength:

For concrete stored in water, the development of compressive strength at 28 day is shown in table 4. The development of compressive strength for different water cement ratio are shown in figure.1

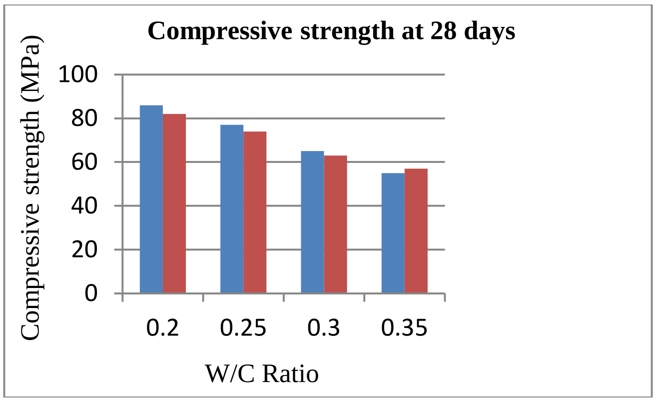

Fig 1: Comparison of compressive strength for different mixes

For all mixes were tested at a period of 28 days. It is observed that the compressive strength at the age of 28 days for different water cement ratio i.e. 0.35,0.30,0.25,and 0.20 are maximum for ACI 211.4R-08 as compared to DOE method. For 0.35 water cement ratio the compressive strength of DOE is maximum as compared to ACI 211.4R-08 but for remaining the compressive strength of ACI 211.4R-08 is maximum

4. CONCLUSION:

1. Both DOE and ACI 211.4R-08 methods are based on the empirical relation and derived from extensive experiments done in each of the countries with locally available materials, implying that both methods extensively uses tables and graphs during the design process, and follow logical determination of the ingredients, by establishing the target strength of the structural concrete and the statistical analysis to ensure that the mix design meets or exceed the design strength, to which is related to statistical of the quality control.
2. Once the target strength is established both methods advance the process with the determination of the water/cement ratio. It is also common to both methods that the cement content is determined from a relationship of two parameter; the w/c ratio and the amount of water and is checked against the limited values in order to satisfy durability requirement. While the DOE method uses the 28 days cube strength to arrive at the target strength, the ACI 211.4R-08 method uses 28 days cylindrical strength.
3. Though both method utilize the standard deviation to calculate the target strength, the technique employed by both the methods is absolutely different. While the DOE method suggest the value of the standard deviation, the ACI 211.4R-08 method recommends empirical values to determine the standard deviation.
4. While British DOE method uses compaction factor as a measure of workability, the American ACI 211.4R-08 method uses the slump. Though the DOE method discusses the air entrainment, the selection of the w/c ratio is a sole function of the target strength whereas in ACI 211.4R-08 method, the determination of w/c ratio, is a combination of both the target strength and the type of concrete (whether Air entrained or Non Air entrained)
5. In the DOE method, determination of the water content is depend on the target strength, whereas in ACI 211.4R-08 method, water content could be determined independent of target strength. The DOE method considers whether the coarse aggregate is crushed or uncrushed, but in the ACI 211.4R-08 method, consideration is not made for uncrushed aggregate.
6. Generally it could be seen that ACI 211.4R-08 method gives the higher strength as compared to DOE method.

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