Study of ACI and DOE Mix Design Methods for High Strength Concrete using Crushed and Uncrushed Aggregate

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Abstract— The use of high strength concrete (HSC) has increased all over the world. Among the factors that justify this increased use is the strength increase for structural aspects and durability. High strength concrete is a concrete made with conventional concrete materials and admixtures such as fly ash, silica fume, blast furnace slag and superplasticiser, in varying proportions so as to give maximum strength and excellent performance in the various properties of concrete. This paper presents the result of mix design developed for HSC with fly ash and High range water reducing admixture (HRWR) with angular and rounded coarse aggregate. The study aims at comparing two methods of concrete mix design with angular and rounded coarse aggregate; The Department of Environment Method, UK and The American Concrete Institute Method, using different water to cementitious ratio (w/cm). In this research work 53 grades Ordinary Portland cement, the locally available river sand, 12.5mm angular and rounded coarse aggregate were selected based on IS 383:1970 standards for determining the relative quantities and proportions for different w/cm ratio. For design ACI 211.4R-08 and DOE guidelines are followed. 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.

Key words: High Strength Concrete, ACI 211.4R-08 Mix Design, DOE Mix Design, Water Cement Ratio, Compressive Strength

I. INTRODUCTION

For many decades, concrete has been largely used as a construction material, whether in moderate aggressive environments, or in strongly environments. It is obtained by mixing cement, fine aggregate, coarse aggregate and water in required proportions. The mixture when placed in forms and allowed to set hardens like rock. This hardening is caused by the chemical reaction between water and the cement which results to concrete growing stronger with age.

The strength, durability and other characteristics of concrete depend upon the properties of the constituent materials, proportions of mix, the methods of compaction and other control during placing, compaction and curing. Concrete mix design, involves the determination of proportions of the given constituents of concrete namely, cement, water, fine aggregate and coarse aggregate and admixtures if any [7]. It is the process of specifying the mixture of the ingredients required to meet anticipated properties of fresh and hardened concrete [8]. This proportioning is governed by the performance of concrete in two states, namely, the plastic (fresh) state and hardened state. If the plastic concrete is not workable, it cannot be placed and compacted, hence the property of workability becomes of very vital importance. Secondly, the compressive strength of the hardened concrete is generally considered to be an index of its other properties depending upon many other factors, namely, quality and quantity of cement, water and aggregates, mixing, placing, compaction and curing. A definition of HSC in quantitative term which is acceptable to everyone is not possible. As per IS 456:2000 [], the concrete mainly divided into three types: ordinary concrete (the concrete having strength up to 20MPa), standard concrete (the concrete having strength 25MPa and above up to 55MPa) and high strength concrete (the concrete having strength 60MPa and above up to 80MPa). As per Department of Environment [9], HPC is considered to be a concrete having a high strength at 28 days (typically >60 MPa in compressive strength) or a low water–binder ratio (<0.40). As per American Concrete Institute [3], HPC is supposed to be a special mixture, matching specific requirements that cannot be achieved on a routine basis. 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 HSC reduce the risk of corrosion of steel reinforcement and improve the durability of concrete structures. In addition, HSC can perform much better in extreme and adverse conditions, and 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 methods 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.

DOE and 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 with angular and rounded coarse aggregate, using different water cement ratio, and to determine how the different methods affect overall results.

II. EXPERIMENTAL PROGRAMME

A. Materials and Method

- Cement: The ordinary portland cement of 53 grades locally available is to be used conforming to IS 12269-1987. The properties of cement are according to Indian standards.
- Aggregates: Locally available Godavari river sand was used as a fine aggregate of size passing through the sieve 4.75mm and retained on the 75µ sieve. The two sources were intended to cover a wide range of aggregates commonly used in India in terms of shape and texture. The crushed aggregate of size passing through the 12.5mm sieve and the natural aggregate of shape rounded having size 12.5mm passing is to be used in the present study.
- Water: Potable water will be considered satisfactory for mixing concrete. Water should be free from organic impurities. Ordinary tap water will be used for concrete manufacturing in this work.
- Admixtures: Conplast SP 430 of FORSOC chemicals (India) Pvt. Ltd, Bangalore, was used as superplasticiser to get a workable mix. It confirms to IS 9103-1999.
- Cementitious materials: The processed low calcium fly ash of grade P100 produced by Dirk India Private Limited, Nasik is used in the experimental study.
- Slump test: This test was carried out to determine the consistency, wetness or fluidity of fresh concrete.
- Compressive strength test: This test was conducted to determine the hardness of concrete relative to its compressive strength. The compressive strength was determined from concrete cubes obtained using different mix proportions and then tested for 7 days and 28 days respectively. A total sixteen mix design casted and for each mix design five cubes were for each mix design and tested its strength respectively.

Sr. No	Types of aggregate	Specific gravity	Water absorption	Fineness modulus
1.	Angular aggregate	2.83	1.2%	6.32
2.	Rounded aggregate	2.65	0.57%	6.10
2.	Fine aggregate	2.507	0.65%	3.40

Table 1: Properties of Aggregate

B. Mix proportions of HSC

For HSC there is no specific method of design mix. In the present investigation ACI 211.4R-08 and DOE method are used. From the literature review it can be observed that most of the HSC is covered for low w/cm ratio in the range of 0.20 to 0.35.In order to achieve high strength lower w/c ratio is adopted and to achieve good workability superplasticiser is used. The optimum content of fly ash and dose of superplasticiser are finalized based on trial mix design. Hence in the present investigation the fly ash of 10% is used as a replacement of cementitious material. The mix proportions of concrete as shown in table II, III, IV and V. In the present investigation determination of compressive strength of four series of water cement ratio i.e. (0.20, 0.25, 0.30, 0.35) by using the different mix design process i.e. ACI 211.4R-08 and DOE with angular and rounded coarse aggregate.

w/c ratio	Quantity of materials (Kg)					
	Cement	FA	CA	Water	Fly ash	SP
0.20	842.8	285	1080.52	168.55	93.6	18.73
0.25	674.22	434	1080.52	176.05	74.9	11.23
0.30	561.86	534.02	1080.52	181.04	62.5	6.24
0.35	481.58	604.30	1080.52	18728	53.5	5.35

Table 2: Mix Proportions of Concrete by ACI 211.4r-08 with Angular Aggregate

w/c ratio	Quantity of materials (Kg)					
	Cement	FA	CA	Water	Fly ash	SP
0.20	820.26	408.82	1006.4	167.82	91.14	14.46
0.25	656.22	540.16	1006.4	173.30	72.90	8.98
0.30	546.70	627.55	1006.40	177.08	60.70	5.00
0.35	468.8	683.40	1006.40	182.58	52.00	4.28

Table 3: Mix Proportions of Concrete by ACI 211.4r-08 with Angular Aggregate

w/c ratio	Quantity of materials (Kg)					
	Cement	FA	CA	Water	Fly ash	SP
0.20	803.52	523.96	887.20	164.81	89.28	17.86
0.25	654.72	610.70	952.01	171.76	72.74	10.91
0.30	552.42	655.27	1000.75	176.54	61.38	6.13
0.35	477.76	708.26	1017.56	182.67	53.08	5.30

Table 4: Mix Proportions of Concrete by Doe with Angular Aggregate

w/c ratio	Quantity of materials (Kg)					
	Cement	FA	CA	Water	Fly ash	SP
0.20	774.19	541.51	858.6	163.10	86.02	12.90
0.25	630.82	623.86	910.67	167.59	70.09	8.41
0.30	532.25	669.86	957.98	171.27	59.13	4.73
0.35	460.33	722.62	972.17	176	51.14	4.09

Table 5: Mix Proportions of Concrete by ACI 211.4r-08 with Angular Aggregate

III. CURING AND CASTING

The ingredients of the mixes were weighed and casting was carried out using a tilted drum type concrete mixer. Precautions were taken to ensure uniform mixing of ingredients. The specimens were cast in steel mould 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.

IV. RESULTS AND DISCUSSION

A. *Workability of Fresh Concrete*

Table II, III, IV and V shows the dosage of superplasticiser (SP) which was necessary for mixes containing w/cm ratio 0.20 to 0.35 at the interval of 0.05 for high degree of workability. Both methods give the high degree of workability i.e. 60 to 180mm as per DOE method.

W/C Ratio	Mix design	
	ACI 211.4R-08	DOE
0.20	45	40
0.25	70	60
0.30	80	70
0.35	110	80

Table 6: Degree of Workability with Angular Aggregate

W/C Ratio	Mix design	
	ACI 211.4R-08	DOE
0.20	180	160
0.25	190	165
0.30	160	130
0.35	220	180

Table 7: Degree of Workability with Rounded Aggregate

B. *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

W/C Ratio	Mix design	
	ACI 211.4R-08	DOE
0.20	88	84
0.25	79	73
0.30	66	64
0.35	55	57

Table 8: Compressive Strength (Mpa) with Angular Aggregate

W/C Ratio	Mix design	
	ACI 211.4R-08	DOE
0.20	77	73
0.25	68	64
0.30	57	55
0.35	49	47

Table 9: Compressive Strength (Mpa) with Rounded Aggregate

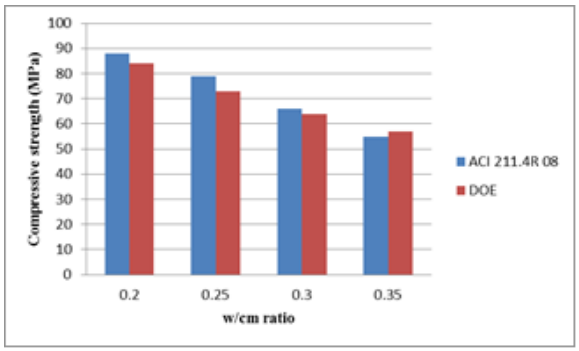

Fig. 1: Comparison of compressive strength for mix proportioning of high strength concrete with angular aggregate

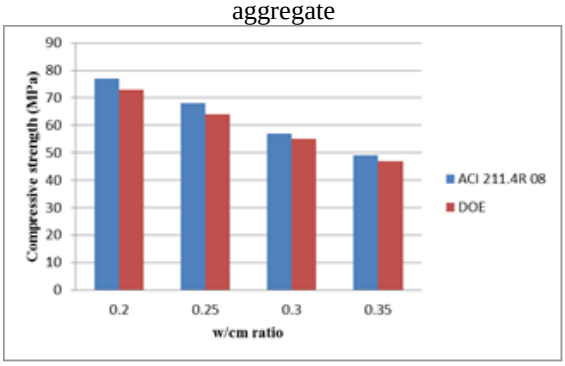

Fig. 2: Comparison of compressive strength for mix proportioning of high strength concrete with angular aggregate

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. 0.20 to 0.35 at the interval of 0.05 were maximum for ACI 211.4R-08 as compared to DOE method with angular and rounded aggregate. For 0.35, w/cm ratio the compressive strength of DOE is higher as compared to ACI 211.4R-08 with angular aggregate but for remaining the compressive strength of ACI 211.4R-08 is higher. Both the methods give the approximately 10% higher compressive strength for angular aggregate in comparison to rounded aggregate.

V. CONCLUSION

1) It can be conclude that when HSC are proportioned as per ACI 211.4R 08 method, the achieved compressive strength of concrete cubes at 28 day are higher than the DOE method
2) The DOE method uses the compaction factor as a measure of workability whereas ACI 211.4R 08 method uses slump.
3) From the result as mentioned in Table VI and VII, the degree of workability of ACI 211.4R 08 have higher workability for same dose of superplasticiser in comparison to DOE method.
4) The DOE method considers whether the coarse aggregate used is crushed or uncrushed, but in the ACI method, consideration is not made for crushed or uncrushed aggregate.
5) Generally, it could be seen that at lower target strength, the DOE method gives the higher compressive strength than the ACI 211.4R 08 method, but reverse was at 0.35 w/cm ratio for rounded aggregate.

6) From the results as mentioned in Table VIII and IX, the Compressive strength required for ACI 211.4R 08 method is maximum in comparison to DOE method.
7) ACI 211.4R 08 not only give higher strength but also required higher ingredients of concrete as compared to DOE method.

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REFERENCES

[1] A. Annadurai and A. Ravichandran, "Development of mix design for high strength concrete with Admixtures", IOSR Journal of Mechanical and Civil Engineering", vol.10 (5), pp.22-27, 2014.
[2] ACI committee 363R-92 (Reapproved 1997) State-of-the-Art Report on High-Strength Concrete
[3] ACI. Committee. 211 (211 - 4R - 08.) "Guidelines for Selecting Proportions for High strength Concrete with Portland Cement and Fly Ash American concrete Institute, Detroit, Michigan
[4] Aitcin. P.C. "High performance concrete, E & FN Spon, London, 1998.
[5] BIS: 12269-1987 (reaffirmed 1999) "Specification for 53 grade Ordinary Portland Cement", New Delhi
[6] BIS: 383-1970 (reaffirmed 1997) "Specification for Coarse and Fine Aggregates from Natural Source for Concrete", New Delhi.
[7] BS 12 (1978). Specification for Portland cement. British Standards Institution.
[8] BS 812: Part 1 (1975). Methods of Determination of particle size and shape
[9] British Department of the environment method, "Design of normal concrete mixes", 2nd edition, 1988
[10] IS 2386 (Part III) – 1963 "Methods of test for aggregates for concrete," Bureau of Indian Standards, New Delhi, Eleventh Reprint, 1997.
[11] Mehta, P. K. and Monteiro, P. J., Concrete: Structure, Properties, and Materials,
[12] Nawy EG. Fundamentals of high strength high performance concrete. UK: Longman; 1996
[13] Neville AM. Properties concrete. 4th ed. New York: Wiley; 1997
[14] Prentice-Hall, Englewood Cliffs, N.J., 2nd ed, 1993.
[15] Jeenu G., Vinod P., and Mangal L., "Packing characteristics of aggregates for High performance concrete", International Journal of Emerging Science and Engineering, vol. 5 (1), pp. 1424-1431, 2012
[16] Sarita Singla, "Mechanical properties of high strength performance concrete", International Conference on Advances in Civil Engineering, 2012

