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Experimental and Analytical Study on High Strength Concrete Beams under Flexure

Bollineni Nithin Krishna[1],
[1]- IVYear B.E. Civil Engineering,
S. A. Engineering College,
Chennai.

Mr. M. Arvind,
M. Tech[2].
[2] – Asst. Professor,
Department of Civil Engineering,
S. A. Engineering College,
Chennai

***Abstract* - This paper presents the experimental program designed to study the fundamental characteristics of High Strength Concrete and flexural behaviour of simply supported high strength concrete beams under two point loading. The use of High Strength Concrete results in reduced dead loads in large span and taller structures. The current experimental study consists of casting 108 plain cement concrete specimenswhich includes cubes, beams and cylinders of grades M30, M60, M70 and M80. These specimens are tested for compressive strength and flexural strength over a period of 28 days, 56 days and 90 days. The results obtained from the tests on High Strength Concrete are compared with that of M30 grade plain cement concrete. The variables considered in this investigation were mainly the strength of concrete (60 MPa to 80 MPa) and the age of specimen. The specimens were analysed for ultimate load using the finite element software Robot Structure Analysis.**

I. INTRODUCTON

The use of high-strength concrete (HSC) has become a common practice worldwide. Inbridges, HSC could lead to longer spans and wider spacing of girders, resulting in reduction of the total number of supporting piers, construction time and overall cost of the bridges. Furthermore, the high durability of HSC could reduce the maintenance costs and increase the service life of the bridges.

This paper presents the findings of 108 unreinforced High Strength Concrete members with target concrete compressive strengths ranging from 68 to 88 MPa, tested under axial load and flexure. The stress-strain distribution in the compression zone of flexural members is evaluated. Stress-strain curves and stress block parameters for HSC were obtained, evaluated and correlated to the values that are obtained from analysing the specimens using the finite element software Robot Structure Analysis.

1. *High Strength Concrete*

High strength concrete (HSC) may be defined as concrete with a specified characteristic cube strength between 60 and 100 N/mm^2.High-strength concrete is made by lowering the water-cement (W/C) ratio to 0.35 or lower. To compensate for the reduced workability due to low W/C ratios, superplasticizers are commonly added to high-strength concrete mixtures. In bridges, HSC could lead to a reduction in number and depth of the girders as well as an increase in the span length. These features reduce the complexity of a project with reduced number of piers, construction time and cost. The enhanced durability of HSC could result in reduction of the maintenance costs and increase the service life of the structure.

2. *High Performance Concrete*

ACI defined high-performance concrete as a concrete meeting special combinations of performance and uniformity requirements that cannot always be achieved routinely using conventional constituents and normal mixing, placing, and curing practice. High Performance Concrete is being used in increasing volumes in recent years due to its long term performance and better rheological, mechanical and durability properties than Cement Concrete. The use of HPC in prestressed concrete construction makes greater span-depth ratio, early transfer of prestress and application of service loads. Low permeability characteristics of HPC reduce the risk of corrosion of steel and attack of aggressive chemicals. This permits the use of HPC in marine/offshore structures, nuclear power plants, bridges and places of extreme and adverse climatic conditions.

It is important to note the high-strength and high performance concrete are not synonymous."High performance" strictly relates to a concrete that has been designed to have good specific characteristics, such as high resistance to chloride ingress or high abrasion resistance. As a result it may also have a high strength, but this is not the main consideration.

3. *Superplasticizers*

Superplasticizers, also known as high range water reducers, are chemical admixtures used where well-dispersed particle suspension is required. Superplasticizers are used as dispersants to avoid particle segregation (gravel, coarse and fine sands) and to improve the flow characteristics in concrete. Dosage of 0.15–0.3% by cement weight allow a water reduction up to 40%, due to their chemical structure which enables good particle dispersion. At the start of the mixing process an electrostatic dispersion occurs but the cement particle’s capacity to separate and disperse. This mechanism considerably reduces the water demand in flowable concrete. The superplasticizer used in this

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project is Auramix 400. Auramix 400 combines the properties of water reduction and workability retention.

II. EXPERIMENTAL WORK

In this study, the mix design for High Strength Concrete was done using IS 10262 – 2009. The final mix proportions are as shown in Table 1. The material specifications used for the design mix are as following

1. *MATERIALS USED*

A. Cement

The Ordinary Portland Cement (OPC) of 53 grade confirming to Indian standard IS 12269-1987 was used. The specific gravity of the cement is 3.15. The compressive strength of cement at 7 days satisfies the 54.82 N/mm^2 requirement of IS 269-1989.

B. Fine aggregate

Fine aggregate used for this entire study of investigation for concrete was river sand confirming to zone-3 of IS: 383-1970. The specific gravity of the fine aggregate is 2.697 and the water absorption is 3.78.

C. Coarse aggregate

Crushed hard granite chips of maximum size 20mm were used in concrete mixes. The specific gravity of the coarse aggregate is 2.729 and the water absorption is 1.54.

D. Water

Potable water confirming to IS: 456-2000 was used for casting and curing.

E. Super Plasticizer

FOSROCAuramix 400 Aqueous solution of SulphonatedNaphthalene Formaldehyde Condensates was used.

2. *MIX DESIGN*

The control mixes were made for M30, M60, M70and M80 grade concretes. The mix proportions of the ingredients used in the mixes are as per table-1.

Table 1. Mix Proportions.

GRADE OF CONCRETE	WATER	CEMENT	FINE AGGREGATE	COARSE AGGREGATE
M30	0.42	1	1.43	3.17
M60	0.29	1	0.655	1.988
M70	0.26	1	0.565	1.7155
M80	0.23	1	0.475	1.4425

3. *BATCHING*

A proper mix of concrete is essential for the strength of the concrete. Before the concreting, all the mix material were weighed and kept ready for concreting as per design mix proportions.

Figure 1. Batching.

4. *CASTING OF SPECIMENS*

Casting of Specimens was done by batching of materials, preparation of moulds and placing of concrete in the moulds.

Figure 2, 3. Casting of Specimens.

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5. DEMOULDING

After levelling the fresh concrete in the moulds, it was allowed to dry for 24 hrs. The identification marks of concrete specimens were done with permanent markers and the specimens were removed from the moulds. The moulds were cleaned and kept ready for next batch of concrete mix.

Figure 5, 6. Demoulding.

6. CURING

Curing is an important process to prevent the concrete specimens from losing their moisture while they are gaining their required strength. All concrete specimens were cured in water at room temperature for 28 days, 56 days and 90 days. After curing, concrete specimens were removed from the curing tank and air dried to conduct tests on hardened concrete.

III. TESTS CONDUCTED ON HARDENED CONCRETE

***1.** COMPRESSIVE STRENGTH*

Three specimens of size 100 mm x 100 mm x 100 mm were used for compression testing for each batch of mix. Clean and surface dried specimens were placed in the testing machine. The platen was lowered and touched the top surface of the specimen, the load was applied gradually and maximum load was recorded.

Table 2 gives the details of average compressive strength of the high strength concrete cubes and cylinders for 28 days, 56 days and 90 days.

Figure 7. Compressive Strength Test.

Table 2. Average Compressive Strength

	COMPRESSIVE STRENGTH IN MPa		
MIX	28 DAYS	56 DAYS	90 DAYS
M30	36	39.3	40
M60	62	67.5	69.86
M70	74	79	80.49
M80	81	84.3	85.1

***2.** FLEXURAL STRENGTH*

The beams were tested to evaluate the flexural strength of the high strength concrete by two point loading. The beam dimensions are 500 mm x 100mm x 100mm.The beams were marked with the help of scale and marker, the location of supports, load points for placing in exact position. All the beams were tested under symmetrical two point loading on a simply supported span of 500 mm. Figure shows the test set up.

Figure 9. Flexural Test.

Table 3. Average Flexural Strength.

	FLEXURAL STRENGTH IN MPa		
MIX	28 DAYS	56 DAYS	90 DAYS
M30	3.64	3.91	4.03
M60	5.29	5.43	5.63
M70	5.91	6.04	6.17
M80	6.31	6.5	6.67

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IV. ANALYTICAL STUDY USING ROBOT STRUCTURE ANALYSIS

1. *ROBOT STRUCTURE ANALYSIS:*
2.

Robot Structural Analysis Professional structural engineering software includes advanced building simulation and structural analysis abilities for both simple and complex structures. Structural engineers can more quickly perform simulation and analysis on a variety of structures with a smoother workflow and more succinct results.

The specimen geometry and testing conditions are generated in the software for analysing.

Figure 10. Geometry.

In Robot Structure Analysis the advantage is that we can apply the desired material property to the element we need to analyse.

The loads at which the actual beams failed in the experimental procedure is applied along with the ddead load of the beam.

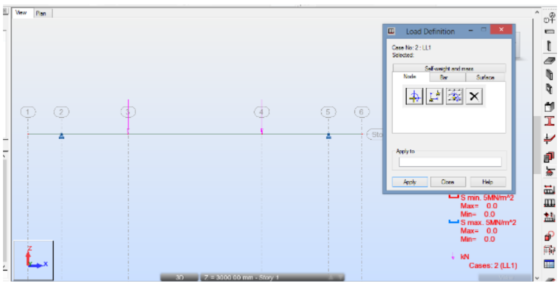

Figure 11. Load Definition.

Once the geometry and the load combinations are set we can analyse the elemnt and we can get the desired result diagrams. The result diagrams for M60, M70 and M80 grade concrete are as shown below.

Figure 12. Result diagram for M60 grade concrete beam.

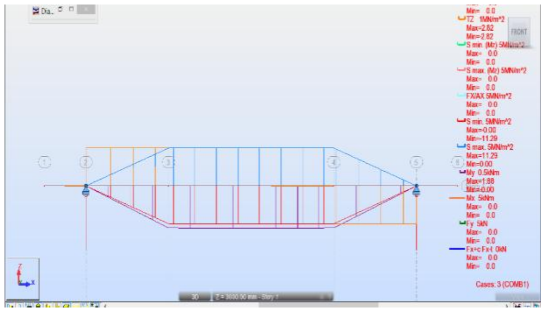

Figure 13. Result diagram for M70 grade concrete beam.

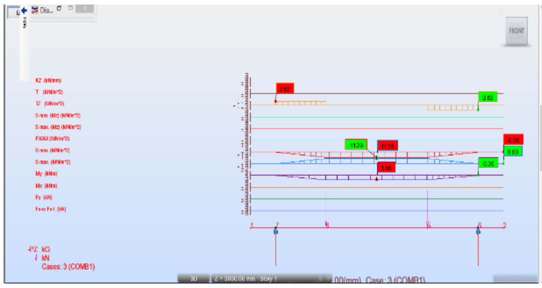

Figure 14. Detail Result diagram for M70 grade concrete beam.

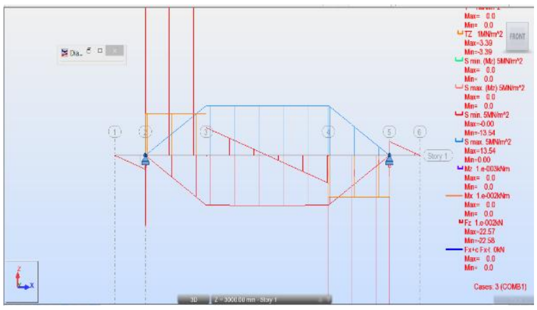

Figure 15. Result diagram for M80 grade concrete beam.

V. CONCLUSIONS

Based on the experimental studies conducted the following conclusions are drawn.

i. In development of high strength concrete, the aggregate of smaller size play very important role. In the present mix design, the aggregate of 20 mm size is being used.
ii. Fineness modulus of aggregate play very important role in development of high strength concrete. It affects the strength greatly. In the present mix design, the fineness modulus of coarse aggregate and coarse sand is 6·7 and 2·89 respectively.
iii. 0.6 % Auramix high range water reducer by weight of cement is added.
iv. Compressive strength of concrete had shown an increasing trend with the increase of curing period.
v. The flexural strength of High Strength concrete is increased on an average of 6% compared to normal concrete.

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