EXPERIMENTAL INVESTIGATION OF HIGH PERFORMANCE CONCRETE COLUMNS

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Abstract – High Performance Concrete is a concrete mixture, which possess high durability and high strength when compared to conventional concrete. This concrete contains one or more of cementitious materials such as fly ash, silica fume or ground granulated blast furnace slag and usually a super plasticizer. The term 'High Performance' is somewhat pretentious because the essential feature of this concrete is that its ingredients and proportions are specifically chosen so as to have particularly appropriate properties for the expected use of the structure such as high strength and low permeability. Hence High Performance Concrete is not a special type of concrete. It comprises of the same materials as that of the conventional cement concrete. The use of some mineral and chemical admixtures like Silica fume, Fly ash and Super plasticizer enhance the strength, durability and workability qualities to a very high extent. Hence with a view of these aspects this paper deals with the analysis of high performance short columns by adding admixtures and superplasticizers.

1. INTRODUCTION – American Concrete Institute defines High Performance Concrete as "A concrete which meets special performance and uniformity requirements that cannot always be achieved routinely by using only conventional materials and normal mixing, placing and curing practices". The requirements may involve enhancements of characteristics such as placement and compaction without segregation, long-term mechanical properties, and early age strength or service life in severe environments. Concretes possessing many of these characteristics often achieve high strength, but High Strength Concrete may not necessarily be of high performance.

High Performance Concrete works out to be economical, even though its initial cost is higher than that of conventional concrete because the use of High Performance Concrete in construction enhances the service life of the structure and the structure suffers less damage which would reduce overall costs.

High Performance Concrete can be designed to give optimized performance characteristics for a given set of load, usage and exposure conditions consistent with the requirements of cost, service life and durability. The High Performance Concrete does not require special ingredients or special equipment except careful design and production. High Performance Concrete has several advantages like improved durability characteristics and much lesser micro cracking than normal strength concrete.

2. OBJECTIVES

The main objectives of this project are as follows:

- To study the behaviour of High Performance Concrete Columns.
- To evaluate the Stiffness and Compressive strength.

- To find the load carrying capacity.
- To find the ductility parameters of the High Performance Short Columns.

3. MATERIALS IN HIGH PERFORMANCE CONCRETE

GENERAL

In conventional concrete the main ingredients are cement, fine aggregate (river sand), coarse aggregate and water. But in high performance concrete certain amount of cement is replaced with the cementitious materials/mineral admixtures such as silica fume, fly ash and GGBFS. In addition with this manufacturing sand as fine aggregate, coarse aggregate and chemical admixtures such as super plasticizers.

CEMENT

Cement is a binder substance that sets and hardens as the cement dries and also reacts with carbon dioxide in the air dependently, and can bind other materials together. There are two important requirements for any cement: (a) strength development with time and (b) facilitating appropriate rheological characteristics when fresh.

High C_3A content in cement generally leads to a rapid loss of flow in fresh concrete. Therefore, high C_3A content should be avoided in cements used for HPC. The total amount of soluble sulphate present in cement is a fundamental consideration for the suitability of cement for HPC. The fineness of cement is the critical parameter. Increasing fineness increases early strength development, but may lead to rheological deficiency. The super plasticizers used in HPC should have long molecular chain in which the Sulphonated group occupies the beta position in the poly condensate of formaldehyde and melamine sulphonate or that of naphthalene sulphonate. The compatibility of cement with retarders, if used, is an important requirement. The most important uses of cement are as an ingredient in the production of mortar in masonry and of concrete, a combination of cement and an aggregate to form a strong building material. The most common use for Portland cement is in the production of concrete. Concrete is a composite material consisting of coarse aggregate, fine aggregate, cement and water. In our project we used OPC 53 grade cement.

FINE AGGREGATE

Aggregates are the important constituents in concrete. They give body to the concrete, reduce shrinkage and economy. Earlier, aggregates were considered as chemically inert materials but now it has been recognized that some of the aggregates are chemically active and also that certain aggregates exhibit chemical bond at the interface of aggregate and paste. The mere fact that aggregates occupy 70-80 percent of the volume of concrete.

M sand is crushed aggregates produced from hard granite stones which is cubically shaped with grounded edges, washed and graded with consistency to be used as a substitute for river sand. M-Sand is superior quality fine aggregate with international standards. The most preferred alternative to river sand is the M-Sand got through processing the blue metal quarry dust. Fine and uniform granulation of quarry dust by floating it through pressurized water shower leading to the reduction of impurities gives us M-Sand.

COARSE AGGREGATE

The important parameters of coarse aggregate that influence the performance of concrete are its shape, texture and the maximum size. Since the aggregate is generally stronger than the paste, its strength is not a major factor for normal strength concrete, or for HES (High Early Strength) and VES (Very Early Strength) concretes. However, the aggregate strength becomes important in the case of high performance concrete. Therefore, it is general consensus that smaller size aggregate should be used to produce high performance concrete. It is generally suggested that 10 to 12 mm is the appropriate maximum size of aggregates for making high strength concrete.

MINERAL ADMIXTURES

Mineral admixtures form an essential part of the high-performance concrete mix. These are used for various purposes, depending upon their properties. More than the chemical composition, mineralogical and granulometric characteristics determine the influence of mineral admixture's role in enhancing properties of concrete. The fly ash (FA), the ground granulated blast furnace slag (GGBS) and the silica fume (SF) has been used widely as supplementary cementitious materials in high performance concrete. These mineral admixtures, typically fly ash and silica fume (also called condensed silica or micro silica), reduce the permeability of concrete to carbon dioxide (CO_2) and chloride-ion penetration without much change in the total porosity.

FLY ASH

Fly ash, also known as flue-ash, is one of the residues generated in combustion, and comprises the fine particles that rise with the flue gases. Ash which does not rise is termed as bottom ash. In an industrial context, fly ash usually refers to ash produced during combustion of coal. Depending upon the source and makeup of the coal being burned, the components of fly ash vary considerably, but all fly ash includes substantial amounts of silicon dioxide (SiO_2) and calcium oxide (CaO), both being endemic ingredients in many coal-bearing rock strata. In the past, fly ash was generally released into the atmosphere, but pollution control equipment mandated in recent decades now requires that it be captured prior to release.

2 SILICA FUME

Silica fume is a by product of producing silicon metal or ferrosilicon alloys. One of the most beneficial uses for silica fume is in concrete. Because of its chemical and physical properties, it is a very reactive pozzolan. Concrete containing silica fume can have very high strength and can be very durable. Silica fume is available from suppliers of concrete admixtures and when specified, is simply added during concrete production. Placing, finishing and curing silica-fume concrete require special attention on the part of the concrete contractor.

SUPER PLASTICIZERS

Super plasticizers, also known as plasticizers or high-range water reducers (HRWR) reduce water content by 12 to 30 percent and can be added to concrete with a low-to-normal slump and water-cement ratio to make high-slump flowing concrete. Flowing concrete is a highly fluid but workable concrete that can be placed with little or no vibration or compaction. The effect of super plasticizers lasts only 30 to 60 minutes, depending on the brand and dosage rate and is followed by a rapid loss in workability

4. LITERATURE REVIEW

LITERATURE REVIEW 1

"Experimental investigation on high performance reinforced concrete column with silica fume and fly ash as admixtures" published by P. Muthupriya, K. Subramanian, B.G.Vishnuram. In this study the investigations are carried on partial replacement of cement by fly ash and silica fume. Seven mixes M1 to M7 were cast with 0%, 5%, 7.5% and 10% replacement of silica fume along with 10% constant replacement of Fly ash to study the mechanical properties such as compressive strength, split tensile strength and flexural strength at different ages of concrete such as 3,7,28,56 and 90 days. The result shows that the optimum replacement of silica fume is 7.5%. If 10% of Fly ash is added then the optimum replacement of silica fume is 5%. Totally 7 seven columns were casted for mixes M1 to M7. The column specimens were tested in 1000kN loading frame at 28 days. The failed columns were rehabilitated with GFRP sheets with one or two layers and again tested in 1000kN loading frame. The results were then compared with the initial results.

LITERATURE REVIEW 2

"Behaviour of high performance fibre reinforced concrete columns" (2012), published by Wasan Ismail Khalil, Ikbal Naeem Gorgis and Zeinab Raad Mahdi. In this the experimental work has been made to study the behaviour of high performance fibre reinforced short columns with different aspect ratios and volume fractions of steel fibres with different volumetric ratios of longitudinal and lateral reinforcement. The addition of fibres to normal strength concrete (NSC) and high performance concrete (HPC) columns increases the maximum strength. The percentage increase for HPC columns containing 0.75% steel fibres is about 42% and 21% for specimens with short fibres and long fibres respectively. The stress-strain relationship extends beyond the peak load for HPC columns containing long steel fibre with volume fraction 0.75% and reinforced with longitudinal bars with diameters 10mm and 12mm. The deformability of steel fibre high performance concrete columns after concrete cracking increases as the fibres aspect ratio is increased.

LITERATURE REVIEW 3

"Steel fibre reinforced high performance concrete beam-column joints subjected to cyclic loading" published by N.Ganesan, P.V.Indira and Ruby Abraham. This paper describes the experimental results of ten steel fibre reinforced high performance concrete (SFRHPC) exterior beam-column joints under cyclic loading. The M60 grade concrete used was designed by using a modified ACI method suggested by Aitcin. Volume fraction of the fibres used in this study varied from 0 to 1% with an increment of 0.25%. Joints were tested under positive cyclic loading and the results were evaluated with respect to strength, ductility and stiffness degradation. Also an attempt has been made to compare the shear strength of beam-column joints obtained by using the models proposed by Tsonos and co-workers, Bakir and co-workers, and Jiuru and co-workers. The proposed model was found to compare satisfactorily with the test results.

LITERATURE REVIEW 4

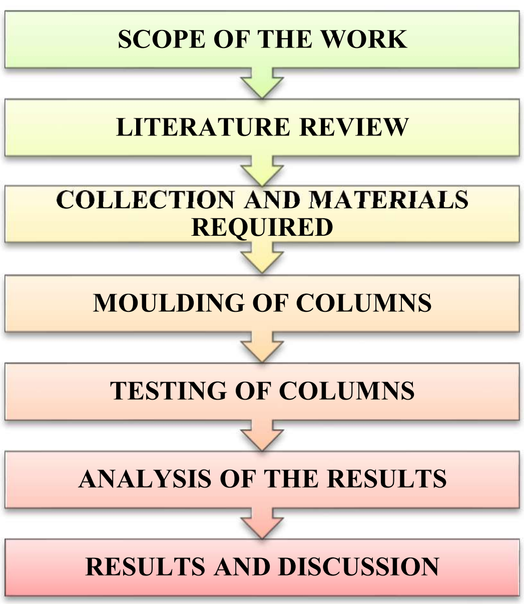
"Behaviour of ultra high performance concrete structures" published by Adel A. Al-Azzawi, Ahmed Sultan Ali and Husam K.Risan. In this a study has been made through this investigation to understand the behaviour of UHPC members with steel fibres by using two approaches: experimental investigation of concrete mixes and simulation of the problem studied by other researchers using finite elements. Experimental investigation is carried out to obtain the mechanical properties for two types of UHPC mixes, namely, the type of pozzolanic admixtures in addition to use three different values of steel fibres volume fraction. The finite element method through the ANSYS computer program is used. The eight node brick element is used to model the UHPC beams with embedded steel fibres. The experimental data obtained from the researchers is compared with the finite element solution and good agreement between the results is obtained. Higher values of compressive strength have been achieved using UHPC mixes with Silica Fume in comparison with UHPC mix with High Reactivity Metakaolin.

LITERATURE REVIEW 5

"Experimental tests performed on concrete columns with ultra-high performance fibre reinforced cores" published by M.Popa, H.Constantinescu, R.Zagon, Z.Kiss, Geanina Bolca. This paper describes experimental tests performed on 12 compound square columns. The columns had an inner core made of Ultra-High Performance Fibre Reinforced Concrete (UHPFRC), class C150 and a steel reinforced outer layer (shell) which was cast using C50 class concrete. The object of the research program was to determine the efficiency of this type of elements when subjected to centric compression and the possibility of reducing the cross section of column in structures. The experimental program described in this paper shows that using UHPFRC cores is an effective means of reducing columns cross sections.

5. METHODOLOGY

This represents the methodological framework used for collecting of materials and testing the columns for high performance concrete.



6. MIX DESIGN FOR M60 CONCRETE

STEP 1: Target mean strength

Target strength = $60 N/mm^2$

Target mean strength = fck+1.5s

= 60 + 9.7

Size of aggregate = 12.5mm

Specific gravity of cement = 3.15

Specific gravity of fine aggregate =2.65

Specific gravity of coarse aggregate =2.84

Bulk density of fine aggregate= $1537 kg/m^3$

Bulk density of coarse aggregate= $1315 kg/m^3$

STEP 2: Selection of maximum size of coarse aggregate

The size of aggregate is 12.5 to 10 mm for greater than 62 MPa.

STEP 3: Estimation of free water content if saturation point of the super plasticizer

Not known, assume 145 l/m^3

STEP 4: Super plasticizer dosage

1% trial

STEP 5: Estimation of air content

Assume 1.5 since it is HPC

STEP 6: Selection of coarse aggregate

Particle shape is average. Coarse aggregate content is 1050 kg.

STEP 7: Selection of water binder ratio

0.30 to 0.36. Select 0.33

STEP 8: Calculation of binder content

B = 145/0.33

= 439.39 kg. Say 440 kg

STEP 9: Super plasticizer content

Msol =CxD/100

=440 x 1/100

=440 kg

Vliq =Msol x 100/S x S_s

=4.4/(4/100) x 1.21

=9.09 l/m^3

V_w =Vliq x Ss[100 – S/100]

=9.09 x 1.21 x [100 – 40/100]

=6.60 l/m^3

V_{sol} = V_{liq}-V_w

= 9.09-6.6

=2.49 l/m^3.

STEP 10: Estimation of fine aggregate content

The absolute volume of sand in liters per unit volume of concrete (m^3).

V_{fa}=1000-[145+440/3.15+1050/2.84+2.48+15]

=1000-[145+139.68+369.71+2.48+15]

= 328.12 l/m^3.

Fine aggregate content = 328.12 x 2.65

= 870 Kg.

STEP 11: Moisture adjustments

Moisture content present in the coarse aggregate = 0.1%

Moisture content present in the fine aggregate = 0.4%

(Assume that there is no need of correction will be made because of smaller quantity)

FINAL COMPOSTION:

The necessary volume of mixing

Water = 145 l/m^3

Fine aggregate = 870 Kg/m^3

Coarse aggregate = 1050 Kg/m^3

Binder/cement = 440 Kg/m^3

Super plasticizer = 9.32 l/m^3

Table 5.1 Mix Proportion

CEMENT	FINE AGGREGATE	COARSE AGGREGATE	W/C RATIO
440	870	1050	0.33
1	1.97	2.39	0.33

7. TEST PROCEDURE

The load was applied by using a load cell of 500 kN capacity. An initial set of 5kN was applied to seat the specimen in position in each test and then the instruments were normalized and initial readings were observed. For short columns, the loads were applied as axial and the axial deformations were measured at mid span of the specimen on all four faces. The average value was used to plot the load versus axial deformation curves. Deflections were measured at mid height using linear variable differential transducers (LVDTs).

The load was applied gradually and the deflection was measured at various load stages at regular intervals, at the same time strain values were also measured and observations of initial of crack and propagation of cracks at different stages of loading, ultimate load to failure and mode of failure were taken.

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8 RESULTS AND DISCUSSION

The short columns were cast for the w/b ratio of 0.32 and tested for axial load in the loading frame of capacity of 1000kN and the test results for the columns cast with w/b ratio of 0.32 are shown in the table 8.1. the comparison of first crack load vs ultimate load for w/b ratio 0.32 As shown in fig 8.1

Table 8.1 Compression test results on columns

S.No	Mix ID	First crack load (kN)	Ultimate load (kN)	Deflection (mm)
1	M1	162	194	0.84
2	M2	145	190	0.88
3	M3	190	234	1.3
4	M4	166	222	0.99
5	M5	185	228	1.32
6	M6	168	220	1.03
7	M7	154	187	0.63

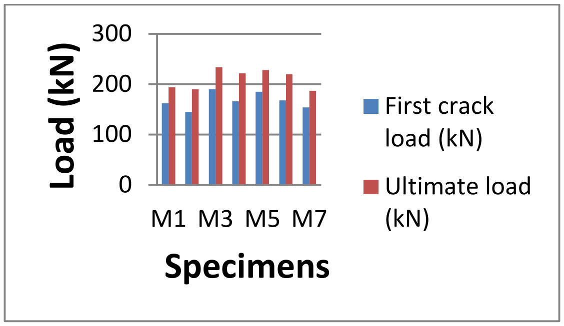

Fig 8.1 Comparison of first crack load and ultimate load

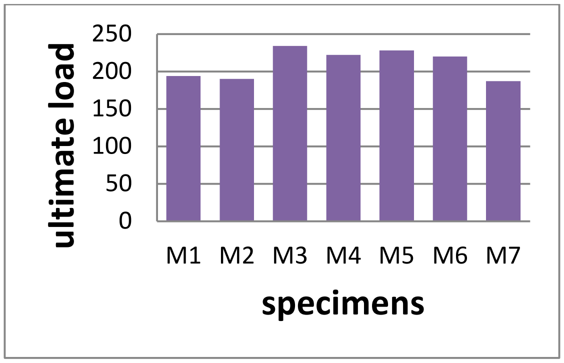

Fig 8.2 Chart for comparison of ultimate load

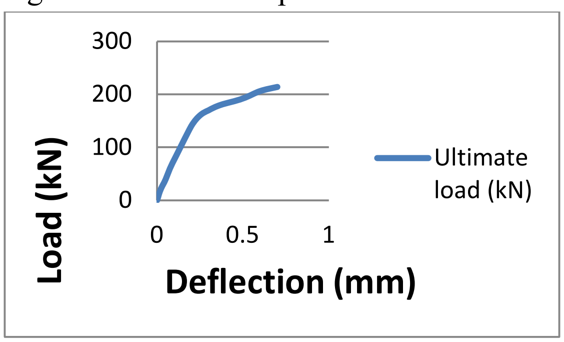

Fig 8.3 Comparison of P - Δ curves for mix M4

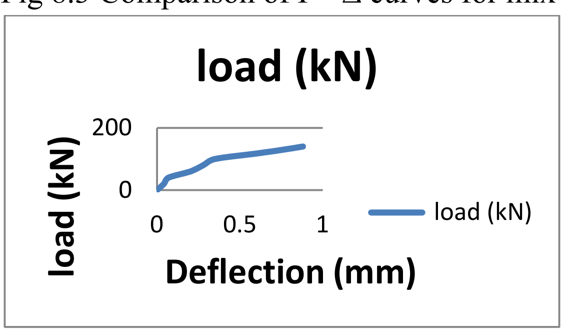

Fig 8.4 Comparison of P - Δ curves for mix M5

9. CONCLUSION

The short column test specimen M3 with 7.5% of silica fume had the ultimate load carrying capacity of 234kN. This is 1.2 times higher than the load carrying capacity of control column M1. The deflection at ultimate load for M3 is also 1.72 times higher when compared with the control column M1. The column M5has the ultimate load carrying capacity of 228kN. This is 1.17 times higher than the control column M1. It was observed that the columns cast with SF and SF with FA showed higher load carrying capacities compared to control column except M2 and M7. An increased value for deflection was recorded for specimens M3 and M5. The increase in ultimate load carrying capacity for other short columns when compared to the control column is 21.4%, 14.78%, 17.34%, 13.7%, for M3, M4, M5,M6 respectively compared with M1.

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