Experimental And Analytical Investigation of High Performance Beam Column Joint Under Monotonic Loading Using Foundry Sand And Fly Ash

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Abstract- *High performance concrete appears to be a better choice for a strong and durable structure. In this thesis, investigations are carried out on strength properties and durability properties such as compressive strength, split tensile strength, flexural strength, saturated water absorption test, acid attack, carbonation and alkalinity measurement of M75 grade of HPC mixes with different % replacement of 10%, 20%, and 30% of foundry sand with fine aggregate and 10%, 20%, and 30% of cement by fly ash by adopting water-binder ratio of 0.3. Conplast SP430 is based on Sulphonated Napthalene Polymers and can be used as a super plasticiser for better workability for high performance concrete.*

The HPC mix, grade M75 concrete is designed as per ACI 211.4R-93 "Guide for selecting proportions for high strength concrete with Pozzolana Portland cement and other cementitious materials". Mechanical characteristics like Compressive strength, Split-tensile strength, Flexural strength will be examined. The durability study will be done by conducting the tests such as saturated water absorption test, acid attack, and carbonation and alkalinity measurement. A mathematical model was conducted using ANSYS 14.0 software. The predicted mathematical model for beam column joint will be tested to get accurate results for the respective ages and compared with the experimental results. Based on the results obtained, the replacement of 30% foundry sand and fly ash with 3% of super plasticiserwith superior characteristics will be found.

I. INTRODUCTION

High performance concrete (HPC) is a concrete that meets special combinations of performance and uniformity requirements which cannot always be achieved routinely using conventional constituents and normal mixing and placing and curing practices. To produce high performance concrete it is generally essential to use chemical and mineral admixtures in addition to the same ingredients, which are generally used for normal concrete. In recent times, many researches are going on for improving the properties of concrete with respect to strength, durability, and performance as a structural material. There are many materials like fly ash, furnace slag, foundry sand and silica fume etc. One among these special concrete is the foundry sand which is new emerging as one of new generation construction material in producing high strength and performance concrete for special structures. The interest in fly ash and foundry sand started in enforcement of air pollution control in many countries. This implies that the industry had to stop releasing fly ash and foundry sand into the atmosphere. To find solution to this problem studies were initiated and after some investigations, it was found that the fly ash and foundry sand could be used as a very useful material in concrete. Foundry sand in concrete for quite some time in countries like Norway and U.S very high strength concrete is being produced using this fine highly reactive industrial by product. In India, improved Foundry sand and fly ash is finding its use now a day.

II. LITERATURE REVIEW

HIGH PERFORMANCE CONCRETE: Oral buyukozturk and denvid lau (2000), They carried out the experimental investigated that the difference between the normal concrete and high strength concrete, stress strain relationship under biaxial and triaxial loading are described. These criteria are analysed such as strength, permeability and cracking resistance. The microstructure of HPC and its influence on concrete performance is also presented. In manufacturing the material the use of dignified small particle systems contribute to the high strength and low permeability of HPC .Fly ash, silica fume and super plasticizer are important ingredients to manufacture high strength concrete. In order to create durable HPC, it is necessary to use a proper mix design and apply an effective curing. It is suggested that three criteria should be considered to produce durable concrete. Because of its advantageous characteristics, HPC is now widely used in tall building construction.

FOUNDRY SAND: Ishatpreet Kaur (2006), They investigated on mechanical properties of concrete incorporating used foundry sand and effect of foundry sand as fine aggregate replacement on the compressive strength, split tensile strength and modulus of elasticity of concrete having mix proportions of 1:1.45:2.20:1.103 was aggregates were replaced with three percentages of foundry sand. The percentages of replacements were 10, 20 and 30 % by weight of fine aggregate

FLY ASH: P.Nath and P.Sarker (2011), They conducted test on effect of Fly Ash on the Durability Properties of High Strength Concrete concluded that Fly ash in concrete decreased drying shrinkage when the w/c ratio and the binder content were adjusted to achieve the same 28-day strength of the control concrete. Incorporation of fly ash reduced the segregation of concrete in early age and it decreased further at six months. The fly ash concretes yielded better resistance to chloride ion penetration both at 28 and 180 days

STRENGTH AND DURABILITY: Siddique et al (2009), They investigated that compressive strength and modulus of elasticity of concrete mixtures made with and without foundry sand was determined at 7, 28, 56, 91, and 365 days of curing. They concluded that (i) there was marginal increase in the compressive strength of concrete mixtures with the inclusion of foundry sand as partial replacement of regular sand. At 28 days, Control Mixture M-1(0% WFS) achieved a compressive strength of 28.5 MPa, whereas Mixtures M2 (10% FS), M-3 (20% FS), M-4 (30% WFS) achieved a compressive strength of 29.7, 30.0 and 31.3 MPa respectively; an increase of 4.2%, 5.2% and 9.8% in comparison with the strength of Control Mixture M-1 (0% WFS). Compressive strength of concrete mixtures also increased with age. With the increase in age (from 56 to 365 days), percentage increase in compressive strength for control mixture (0% WFS) was between 8 to 18%, between 11.4 to 18.8% for mixture M-2, between 12 to 20% for mixture M-3, and between 12.4 to 20% for mixture M-4. Increase in the compressive strength of concrete 11 mixes incorporating used foundry sand indicated that foundry sand could be successfully used in making concrete as partial replacement of fine aggregate

BEAM-COLUMN JOINTS: Ganesan and Indira (2007), They investigated 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 Aïtcin. 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. Test results indicate that the provision of SFRHPC in beam-column joints enhances the strength, ductility and stiffness, and is one of the possible alternative solutions for reducing the congestion of transverse reinforcement in beam column joints.

ANALYTICAL INVESTIGATION: Amer Ibrahim et al (2009), They investigated the Analysis model is presented for reinforced concrete beams externally reinforced with fiber reinforced polymer (FRP) laminates using finite elements method adopted by ANSYS. The results obtained from the ANSYS finite element analysis are compared with the experimental data for six beams with different conditions from researches (all beams are deficient shear reinforcement). The comparisons are made for load deflection curves at mid-span; and failure load. The results from finite element analysis were calculated at the same location as the experimental test of the beams. The accuracy of the finite element models is assessed by comparison with the experimental results

III. METHODOLOGY AND MATERIALS

This chapter deals with the study of various materials used like PPC , Fine aggregate, Coarse aggregate, foundry sand , fly ash, Superplasticizer, and water. Its properties and functions are described in this chapter.

The methodology for this thesis work is followed below:

- Selection of appropriate title
- Literatures regarding the study
- Primary testing of materials
- Trial mix design
- Workability studies
- Mechanical properties
- Durability studies
- Experimental investigation on beam column joint
- Stiffness vs deflection characteristics
- Analytical investigation result
- Results and discussions
- Conclusion

Materials

1 CEMENT: Pozzolana Portland cement used for casting all the specimens. To produce high performance concrete the utilization of high strength cements is necessary. Different types of cement have different water requirements to produce pastes of standard consistence. Different types of cement also will produce have a different rates of strength development. The choice of brand and type of cement is the most important to produce a good quality of concrete. The type of cements affects the rate of hydration, so that the strengths at early ages can be influenced by the mineral admixtures with cement

2 FINE AGGREGATE: Clean and dry river sand available locally will be used. Sand passing through IS 4.75mm sieve was used for casting all the specimens.

3 COARSE AGGREGATE Crushed granite aggregate with specific gravity of 2.6 and passing through 12.5mm sieve and will be used for casting all specimens. Several investigations concluded that maximum size of coarse aggregate should be restricted in strength of the composite. In addition to cement paste- aggregate ratio, aggregate type has a great influence on concrete dimensional stability.

4 SUPER PLASTICIZER Conplast SP430 is based on Sulphonated Napthalene Polymers and is supplied as a brown liquid instantly dispersible in water. Conplast SP430 has been specially formulated to give high water reductions up to 25% without loss of workability or to produce high quality concrete of reduced permeability

5 FOUNDRY SAND Foundry sand is high-quality uniform silica sand that is used to make moulds and cores for ferrous and nonferrous metal castings. Foundry sand is a by-product of the castings industry typically comprising uniformly sized sands with various additives and metals associated with the specific casting process. Foundry sand is the most essential raw material and its importance is sometimes forgotten amongst Foundry personnel. Foundry sand is as used by Foundries is desired for its thermal resistance and availability. Most metal casting sand (FS) is high quality silica sand with uniform physical characteristics. It is a by roduct of the ferrous and nonferrous metal casting industry, where sand has been used for centuries as a moulding material because of its unique engineering properties. In modern foundry practice, sand is typically recycled and reused through many production cycles. Industry estimates are that approximately 100 million tons of sand are used in production annually. Of that, four (4) to seven (7) million tons are discarded annually and are available to be recycled into other products and industries.

6 FLY ASH Fly ash is finely divided residue resulting from the combination of ground or powered coal. They are generally finer then cement and consist mainly of glassy spherical particles as well as residue of hematite and magnetite, char and some crystalline phases formed during cooling.

7 WATER Casting and curing of specimens were done with the potable water that is available in the college premises. Water is used for both mixing and curing shall be clean and the amounts of deleterious materials and such as Viz oils, acids, alkalis, salts, sugar, organic materials or other substances that may be deleterious to concrete or steel. Potable waters are generally satisfactory for mixing and curing concrete. In cause of doubt, the suitability of water for making concrete shall be ascertained by the compressive strength and initial setting time test specified in IS.456– 2000.

IV. RESULTS AND DISCUSSIONS

1. WORKABILITY STUDIES

SLUMP CONE TEST The slump value plays a major role in HPC. By the value of slump it is possible to know the effectiveness in HPC. Due to low water/binder ratio the slump value should be minimum. The slump values also determine the robustness of the mix, segregation, bleeding in the mix. The minimum value of slump is to be 40mm and a maximum of 80mm for a fresh HPC.

Table 4.1 Slump flow

Mix proportions (%)	Slump (mm)
M1	55
M2	50
M3	45
M4	43

2. MECHANICAL PROPERITES

The compressive, split and flexure studies at different ages of 7, 14 and 28 days. When compared to that of the control mixture increasing amounts of mineral admixtures generally increase the strength. In this mix 30% replacement of fly ash with cement and foundry sand with fine aggregate behaves better in mechanical properties of concrete

Table 4.2 Compressive, Split and Flexural Strength results

Mix proportions (%)	Compressive Strength (MPa)			Split Tensile Strength (MPa)			Flexural Strength (MPa)		
	7 Days	14 Days	28 Days	7 Days	14 Days	28 Days	7 Days	14 Days	28 Days
M1	35	43	75	3.345	4.512	6.015	3.2	4.5	6.012
M2	37	45	75	3.445	4.834	6.040	3.4	4.5	5.999
M3	37	50	77	3.344	4.545	6.022	3.2	4.6	6.022
M4	42	54	79	3.433	4.656	6.055	3.5	4.7	6.030

3 DURABILITY STUDIES

SATURATED WATER ABSORPTION The results of the saturated water absorptions (SWA) tests of various high performance concrete mixes at the age of 28, 56 and 90 days

Table 4.3 Saturated Water Absorption Test Result

Mix proportions (%)	Average reduction in weight (%)		
	28 days	56 days	90 days
M1	3.63	3.45	3.28
M2	3.31	3.21	3.12
M3	3.00	2.87	2.74
M4	2.64	2.48	2.32

POROSITY The results of the porosity tests of high performance concrete mixes at the age of 28, 56 and 90 days. The porosity for high performance concrete with replacement of cement with Fly ash of 10%, 20%, 30%, and fine aggregate by foundry sand.

Table 4.4 Porosity Test Result

Mix proportions (%)	Effective porosity (%)		
	28 days	56 days	90 days
M1	6.70	6.43	6.26
M2	6.36	6.11	5.92
M3	5.76	5.62	5.48
M4	5.35	5.24	5.02

ACID ATTACK The weight and the compressive strength of the specimens were found out for the age of 28, 56 and 90 days. The average percentage of loss of weight and compressive strengths were calculated for acid test.

Table 4.5 Acid Resistance Test Result

Mix proportions (%)	Average reduction in weight (%)			Average loss of compressive Strength (%)		
	28 days	56 days	90 days	28 days	56 days	90 days
M1	3.94	4.54	5.62	10.6	12.10	13.20
M2	2.16	3.71	4.88	6.70	7.80	8.66
M3	1.83	3.28	4.32	5.90	7.21	8.02
M3	1.61	2.89	3.96	5.35	6.51	7.43

CARBONATION DEPTH The depths of carbonation were determined by spraying on a freshly broken surface with 1% of phenolphthalein in the solution of 70% ethyl alcohol. The phenolphthalein solution is colorless. It was used as an acid–base indicator. The color of the solution was changed to purple when pH was higher than the range of approximately nine. When the solution was sprayed on a broken specimen surface, the carbonated portion was colorless and non-carbonated portion was purple.

Table 4.7 Alkalinity Measurement Results

Mix proportions (%)	pH		
	28 days	56 days	90 days
M1	11.80	11.61	11.42
M2	11.60	11.07	10.55
M3	10.40	10.11	9.82
M4	9.64	9.54	9.44

4 EXPERIMENTAL INVESTIGATION ON BEAM COLUMN JOINT

Specimens were tested in a hydraulic jack of 500 kN capacity. A constant load of 150 kN (or 1.5 t), which is about 20% of the axial capacity of the column, was applied to the column for holding the specimens in position and to simulate column axial load. A hydraulic jack of 500 kN (or 5 t) capacity was used to apply load at the beam

Fig 4.10 Beam Column Joint Test Set Up

Fig 4.11 Crack Pattern

Table 4.8 Load-Deflection Behaviour of Specimens

M1-control specimen		M2-10% replacement		M2-20% replacement		M2-30% replacement	
Beam load kN	Deflection (LVDT) mm	Beam load kN	Deflection (LVDT) mm	Beam load kN	Deflection (LVDT) mm	Beam load kN	Deflection (LVDT) mm
0	0	0	0	0	0	0	0
10	1.23	10	1.18	10	0.45	10	1.05
20	2.08	20	1.86	20	1.17	20	1.70
30	**3.12**	30	2.24	30	1.75	30	2.50
40	3.48	**40**	**2.89**	**38**	**2.30**	40	3.75
50	5.17	50	4.65	40	2.70	**50**	**4.96**
60	6.93	60	5.96	50	4.05	60	6.30
70	7.61	70	7.45	60	5.43	70	7.58
72	**8.61**	**73**	**8.11**	70	6.75	**80**	**8.90**
				78	**7.82**		

Table 4.9 Deflection results

Mix proportions (%)	Load at First Crack (kN	Load at First Crack (kN	Ultimate load (kN)	Deflection at Ultimate load (mm
M1-0	30	3.12	72	8.61
M2-10	40	2.89	73	8.11
M3-20	38	2.30	78	7.82
M4-30	50	4.96	75	8.96

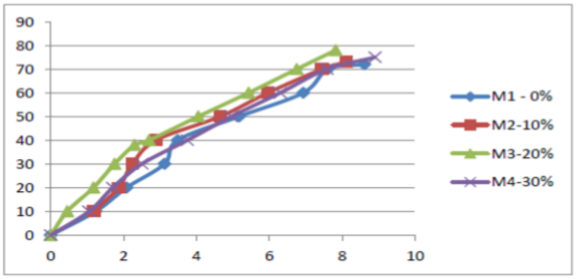

Fig 4.16 Load Vs Deflection Behaviour

5.STIFFNESS VS DEFLECTION CHARACTERISTICS

In the Stiffness vs Deflection characteristics, stiffness at ultimate load was compared with each specimen. As the stiffness of the specimen is increased, density will be more for the specimens and strength of the specimens will be high and high ultimate carrying capacity. The Stiffness vs Deflection graph is shown below. From the graph, stiffness values are higher for the specimens with Fly ash and foundry sand in the HPC mix

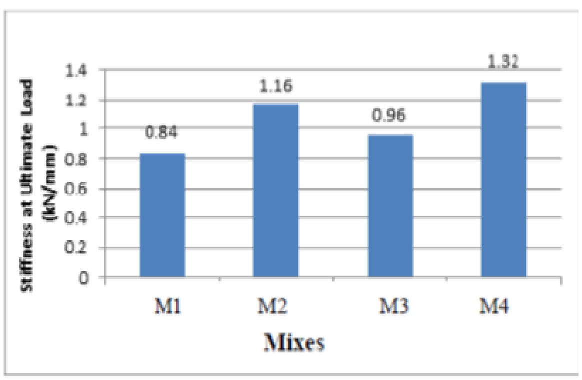

Fig 4.17 Comparison of Stiffness of each specimens

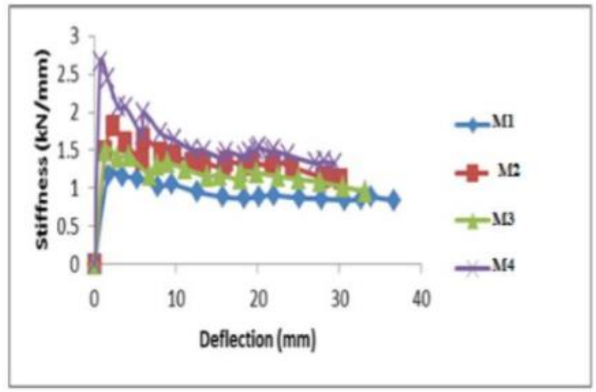

Fig 4.18 Stiffness vs Deflection Graph

6 ANALYTICAL INVESTIGATION RESULT

The modelled beams were analyzed up to the ultimate load. For that corresponding ultimate load the different plots such as deflection plot, strain plot and stress plot had taken and the results were discussed.

COMPARISONS OF EXPERIMENT STUDY AND BEAM ANALYSIS: Experimental results are compared with FEM model analysis in ANSYS, the behavior of the exterior beam column joint are similar. Maximum stresses are occurred at the junction for the ultimate loading at the beam tip.

ULTIMATE LOAD AND DEFLECTION: Load-displacement relationships for monotonic loading in the finite element model of specimens. are shown below. The analytical results are compared with the experimental results. In general the analytical loaddisplacement curves agree quite well with the experimental data. The first cracking load for the finite element analysis is 20 kN for the control mix which are higher than the load of 22 kN from the experimental results by 16.66%. After the first cracking, the finite element models are found stiffer than the tested specimens. The yield load for the control mix is 75 kN which is higher than the experimental results by 6.66%. The ultimate load carrying capacities of the four models subject to monotonic loading are compared. It is observed that the load carrying capacities are improved in M3 and M4 Compared to M1 and M4. The maximum load observed is 79kN using ANSYS and 78 kN in the case of experiment for Mix-3. The specimen failed at 7.5mm displacement in ANSYS and 7.82mm in experiment. Results indicates that the analytical behavior closely predicts the experimental behavior

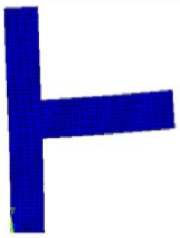

Fig 4.19 Deflection Plot of beam column M1

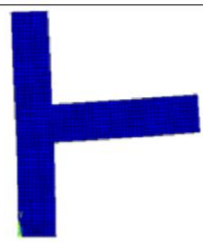

Fig.4.20 Deflection Plot of beam column M2

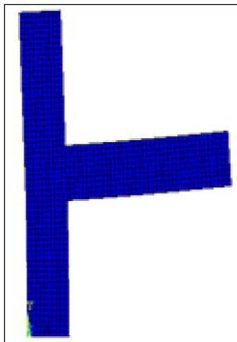

Fig 4.21. Deflection Plot of beam column M3

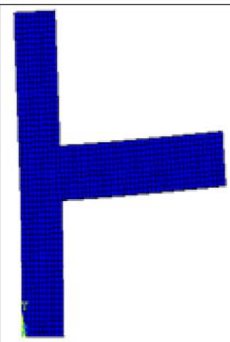

Fig 4.22. Deflection Plot of beam column M4

Table 4.10 Comparison Table of Ultimate Load and Deflection

Mix	**Ultimate Load (kN)**		**Deflection for Ultimate Load(mm)**	
	Experimental	**Analytical**	**Experimental**	**Analytical**
M1	72	71	7.6	5.07
M2	73	76	8.06	5.36
M3	78	79	8.42	5.64
M4	75	77	7.68	5.21

All the four exterior beam-column joint experimental results are compared with analytical results as shown in Figure below. From the load vs deflection characteristics have predicted that, analytical deflection values are higher than the experimental deflection values. From the analytical results concluded that, deflection value was increased by 7.55% while compared to analytical deflection value in M1 specimen. In M2 specimen, experimental deflection value was increased by 8.52% and in the M3 specimen, experimental deflection value was increased by 11.91%. In the M4 specimen, experimental deflection value was increased by 14.79%. From the load vs deflection characteristics have predicted that, analytical deflection values are higher than the experimental deflection values. From the analytical results concluded that, deflection value was increased by 7.55% while compared to analytical deflection value in M1specimen.

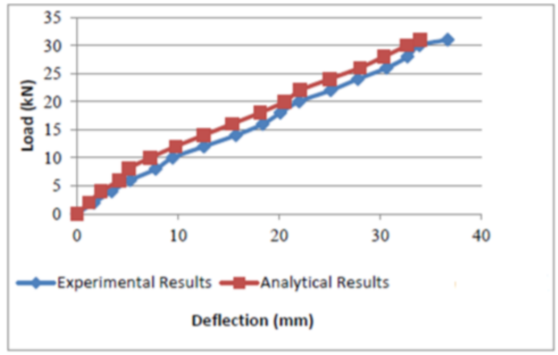

Fig 4.23 Load vs Deflection Graph for M1 Specimen

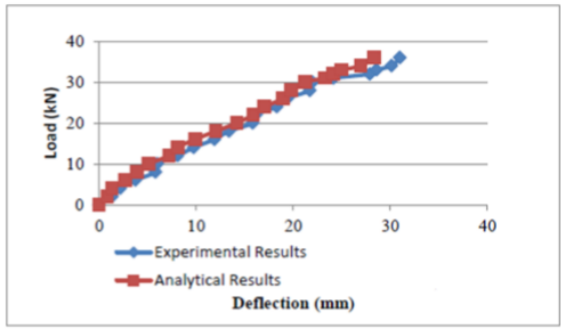

Fig 4.24 Load vs Deflection Graph for M2 Specimen

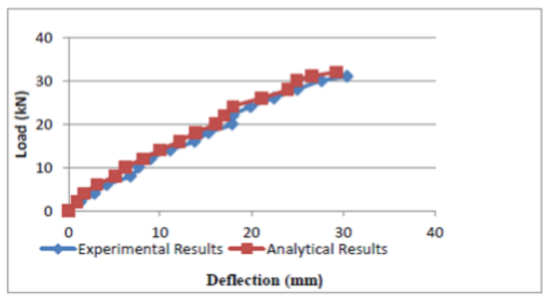

Fig 4.25 Load vs Deflection Graph for M3 Specimen

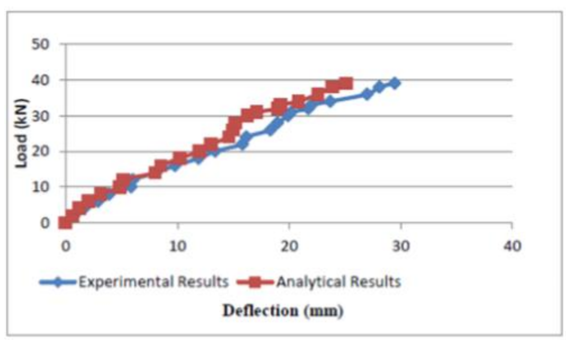

Fig 4.26 Load vs Deflection Graph for M4 Specimen

V. CONCLUSIONS

In this project, the Concrete Mix M75 has been designed as 1:1.03:1.973:0.26. The concrete with optimum replacement percentage of 30% replacement of cement by fly ash and 30% replacement of fine aggregate by foundry in concrete mix quantities also arrived and the performances of exterior beam-column joint with Indian standard codes are examined experimentally. The following conclusions are arrived from this study.

1 MECHANICAL PROPERTIES

- The slump value for M75 grade using foundry sand and fly ash is reduced. For 30% replacement, the fresh properties observed were good as compared to 10%, 20% replacement.
- Hence fly ash and foundry sand replacement is effective for HPC in order to attain high strength. Compare to ordinary concrete M75 grade concrete attain good strength by using lower water/binder ratio. Hence segregation and bleeding occurs in the concrete can be reduced.
- Foundry sand substitution generally results in favorable outcomes and is highly recommended for all HPC mixes. The strength of concrete structures using foundry sand is always similar to conventional concrete. • The percentage increase in compressive strength at 28 days of 30% replacement of cement by fly ash and fine aggregate by foundry sand compare to other specimens.
- The percentage increase in split tensile strength at 28 days of 30% replacement of cement by fly ash and fine aggregate by foundry sand over control specimen without fly ash and foundry sand.
- The percentage increase in flexural strength at 28 days of 30% replacement of cement by fly ash and fine aggregate by foundry sand over other specimen.

2 DURABILITY PROPERTIES

- The water absorption percentage and the porosity percentage were found to be slightly higher for high performance concrete than those for continuously moist cured conventional concrete.
- Acid resistance capacity increases when 30% replacement of cement by fly ash and fine aggregate by foundry sand compare to other specimens in high performance concrete
- The carbonation depth for high performance concrete at the age of 28, 56 and 90 days was found. It can be observed that the carbonation depth is decreased when fly ash is increased.

3 BEAM COLUMN JOINT

- The behaviour of exterior beam-column joint specimens in which the reinforcement designed as per IS 456-2000 under monotonic loading were studied.
- The test specimens with fly ash and foundary sand in High Performance Concrete mix showed better performance in both the reinforcement detailing as per IS 456- 2000 with cross diagonal bars at the joint exhibiting higher strength with minimum cracks in the joint.
- The test specimens with fly ash and foundary sand in High Performance Concrete mix showed increased ultimate load carrying capacity and lesser deflection than the control specimens with High Performance Concrete mix.
- The ultimate load carrying capacity of specimens with fly ash and foundary sand for reinforcement detailing were increased compared to the control specimens with similar reinforcement detailing.
- Specimens with fly ash and foundary sand in the HPC mix have higher stiffness values compared to the specimens with HPC mix by 30%, The finite element model of exterior beam-column joint was developed by using ANSYS 10.0 software.

VI. APPENDIX

MIX DESIGN: Mix Design is the process of selecting suitable ingredients of the concrete and determining their relative proportion with object of producing concrete possessing certain minimum desirable properties like workability in fresh state minimum desirable strength and durability in hardened state. To obtain the required strength properties of concrete in HPC, a higher proportion of ultra-fine materials and the incorporation of chemical admixtures are necessary. The mix design has been adopted as per ACI 211 4R-93. The concrete used in this study was proportioned to attain strength of 75 MPa. ACI Committee recommendation has been used for M75 design. The mixes M1 is the conventional mix and M2, M3, M4 were obtained by replacing 10, 20, and 30 percent of the mass of cement by fly ash and 10, 20, 30 percent of the mass of fine aggregate by foundry sand.

MIX RATIO the mix ratio adopted is, 1:1.03:1.973:0.26

Table. 1 Mix proportions

MIX	%FOUNDARY SAND	%FLY ASH	MIX PROPORTIONS
M1	0	0	1:1.03:1.973:0.3
M2	10	10	1:1.03:1.973:0.3
M3	20	20	1:1.03:1.973:0.3
M4	30	30	1:1.03:1.973:0.3

Table. 2 Mix proportions details

MIX	CEMENT Kg/m3	FOUNDRY SAND Kg/m3	FLY ASH Kg/m3	FA Kg/m3	CA Kg/m3	WATER Lit/ m3
M1	583	0	0	601	1151	151
M2	524.6	60.135	58.341	583.41	1151	151
M3	466.318	120.27	116.682	481	1151	151
M4	407.977	180.405	175.023	420.73	1151	151

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