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Experimental Study on RC Beams Using High Volume Fly Ash

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ABSTRACT

The aim of this paper is to examine the flexural behaviour of structural beams made of high volume fly ash (HVFA) concrete with confined stirrups introduced in compression regions.Generally concrete is low tensile strength and poor ductile property. By confining compression regions introduced with closed stirrups which improves the ductility and load carrying capacity of beams. The introduction of stirrups to these regions would suppress the development of tensile stresses.Fly ash (FA) has been used in concrete and identified such a product as Eco smart or green concrete. In earth quake regions it becomes essential to construct the structures as a ductile one. Sudden failures due to poor workability of RC structures can be avoided, if critical sections are able to undergo large plastic deformations and to absorb large amount of strain energy.The results indicated that the confinement in the form of stirrups improves the ultimate strength and ductile behaviour of the concrete. It has been suggested that, the effective use of fly ash minimizes the disposal of fly ash , this HVFA concrete is easy to pump, consolidate and finish the surface, free from cracks, reduces carbon-dioxide emissions, superior environmental friendliness, reduction in stone mining since consumes less volume of Portland cement. The methodology adopted above which improves ductility, thus improving the ultimate load carrying capacity.

Keywords : Flyash, HVFA concrete, Plasticizer, Confinement, Profile

1.0 Introduction

The Civil Engineering community faces challenges to develop economic construction materials with minimum environmental impacts. Every year million tones of fly ash are obtained as waste product from thermal power stations. As it requires larger area for dumping and causes pollution it is replaced for certain percentage of cement content due to its cementing property therefore reduces the cost of cement and minimizes pollution.Portland cement concrete is a major construction material used in construction industry. The HVFA concrete is one specific type of fly ash concrete with higher fly ash contents that is above 50%, lower water cementitious materials ratio (0.4) and lower cement contents. This is to take full advantages of the increased workability and durability (IS:516- 1959) provided by fly ash. To produce workable concrete at such low water cementitious materials, the use of super plasticizer is most of the time is essential.

Producers of fly ash contend it is harmless and has much the same properties as soil. But according to the Environmental Protection Agency (EPA), fly ash contains heavy metals, created surface and groundwater contamination in the area hazardous nature. Additionally, traces of radioactive materials are present in fly ash. Given the large quantities of fly ash that are produced, In the past, fly ash produced from coal combustion was simply taken up by flue gases and dispersed into the atmosphere. This created significant environmental concerns and health risks. These days, most power plants are required by law to reduce their fly ash emissions to less than 1% of ash produced.

This collected ash either is sold for use in the cement/construction industry or disposed of in ash ponds or landfills. Recently, more fly ash is used beneficially, though more than 65% of fly ash produced from coal power stations is still disposed of.Using fly ash as partial replacement of cement in concrete could help to reduce the consumption of cement, economical, low unit weight, high strength, ease of compaction and durability (Bhanumathidas N. and Kalidas N. 2003) and more resistant to chemical attack. The major ill effects of these global processes is the production of large quantities of industrial waste and the problems related with their safe management and disposal,scarcity of land and materials.A large amount of flyash produced in the thermal power station plant needs to be disposed outside causes least disturbance causing several dosposal related problems.Globally,the level of utilization of fly ash was estimated to be less than 25%.

Durability of the concrete can be improved by introducing confined stirrups to the compression zone which provides shear resistance and suppress the development of tensile stresses.The longitudinal reinforcement used in concrete prevents the compression reinforcement from buckling.Sudden failure due to dynamic loads in earth quake regions can be avoided by considering critical sections. These sections are able to under go plastic deformations and minimize the brittle failure and redistribute the full moments. Only few researchers have attempted to utilize the stirrups in the design of structural concrete under static loading conditions without fly ash. Hence in this study the effect of confined 2 legged stirrups and deformation characteristic of confined concrete using HVFA (IS:3812-1981) concrete have been investigated and reported.

2.0 Materials used

Ordinary Portland cement 53 grade confirming to IS:12269-1989 (ResiS.S.and GargS.K,.1963) was used in this investigation. The fine aggregate (sand) confirming to zone II and crushed stone of nominal size 20mm of IS 383 -1970 were used for making concrete. Potable water has been used for mixing the concrete and to cure the cast specimens. The fly ash of class 'F'(Ravina.D, Methta.P,1986) obtained from Mettur thermal power station (Malhotra.V.M. 1999) was used to cast the cube and beam specimens. The reinforcement consist of main bars 10mm dia RTS and 8mm 2 legged vertical stirrups were used for beam specimens.

3.0 Mix Design

Concrete grade M20 (Sheikh S. A,1982) was proportioned by using I.S method confirming to IS: 10262- 2009 (Malhotra V. M.1989) of mix designing. The mix proportion arrived with water cement ratio 0.4. The cement and fly ash were thoroughly mixed in the dry state in a large size tray and poured over the fine aggregate. This mixer was thoroughly mixed and gently poured over the coarse aggregate and mixed again. Measured quantity of water was then added to the dry mixture. The entire mixing was carried in a large size tray. Slump test (Sheikh S. A.1982) are conducted and the results are shown in table-1.

Table. 1 Test Results of M20 Grade Fresh Concrete

S.No	Grade of Concrete	% of Plasticizer	Slump value (mm)		
			FA 50%	FA 55%	FA 60%
1	M20	0	35	31	26
2	M20	0.5	38	34	30
3	M20	1.0	42	39	35
4	M20	1.5	46	43	40

4.0 Casting of cubes

For the experimental work casting of concrete cubes of 150mm x 150mm x 150mm size in the pre oiled mould was used. The test specimens were divided in to three groups. Each group consist of partial replacement of cement by fly ash at 0, 50 ,55 and 60% at 7,14 and 28days curing period. Cube specimens were cast for 7,14 and 28 days curing period. Cylinder and prism specimens were cast for 28days curing period. Super plasticizer SP 430 of 0,1,1.5 and 2% was added during casting the above specimens. All the specimens were demoulded after 24 hours and cured in water. The specimens were dried in air for one day before testing. The compression strength of cubes, splitting tensile strength **(**f_{sp}**)** and flexural strength (f_t) of HVFAC specimens are carried out as per IS:516-1959 (Phlip.L Ownes, 1979) and summarized and given in table-2.

Table .2 Test Results of M20 Grade Hardened Concrete

Cube ID	% of Flyash Replaced	Dosage of Plasticizer	Compressive Strength (MPa)			f_{sp} (MPa)	f_t (MPa)
			7 Days	14 Days	28 Days	28 Days	28 Days
A0	50	0	13.72	16.90	22.86	5.70	3.96
B0	55	0	12.90	15.20	20.54	5.42	3.60
C0	60	0	11.00	12.70	18.58	-	-

D	0	0	14.27	16.52	23.63	5.65	3.65
A1	50	1	13.82	16.01	21.90	5.34	3.37
B1	55	1	10.97	12.22	18.07	5.10	3.19
C1	60	1	06.85	08.04	12.69	-	-
A1.5	50	1.5	15.00	17.60	22.90	4.70	2.98
B1.5	55	1.5	10.35	12.00	16.57	4.61	2.76
C1.5	60	1.5	07.50	08.69	12.42	-	-
A2	50	2	11.76	13.91	19.05	4.98	3.20
B2	55	2	08.35	11.10	15.87	4.82	3.02
C2	60	2	06.00	06.79	11.80	-	-

The results are comparable with conventional concrete which further indicates the suitability for 50% replacement of cement by flyash with1.5% dosage of plasticizer gives the maximum compressive, splitting tensile and flexural strength in concrete.

5.0 Casting of beam specimens

For casting the beam specimens, steel moulds of internal dimensions 100 mm x 150mm x 1500mm were used. For easy removal of mould oil was smeared on the inner sides of the mould. 2 Nos of 10mm dia RTS bars were used as longitudinal reinforcement at bottom, 2numbers of 8mm diameter are bars provided at the top and another 2numbers are used at the middle to hold the confined hoops at 'd/2' depth. Concrete mix has been prepared by adding 0%, 50%, 55% and 60% replacement of cement by fly ash with 1.5 % of plasticizer. Accordingly 36 Nos of RC beams were cast for the above profiles out of which 27 beams are confined with closely spaced rectangular hoops. Figure 1 shows the details of the beam section without confinement as profile1(P1) and provided with 8mm dia 2 legged stirrups at a spacing of 0.75d at full depth. Figure 2 shows the details of the beam section with confinement of stirrup hoops in compression zone as profile2 (P2) and provided with hoops alternatively at half of 0.75d spacing. Figure 3 shows the details of the beam section with confinement of stirrup hoops in compression zone as profile3 (P3) and provided with hoops alternatively at 0.75d spacing. The reinforcement after fabrication was placed in the mould and plain cement concrete was placed layer after layer upto the bottom of the confining hoops and carefully compacted by poking rods uniformly to avoid honeycombing. The specimens were removed after 24 hours and cured in water tanks and dried in air for one day before testing.

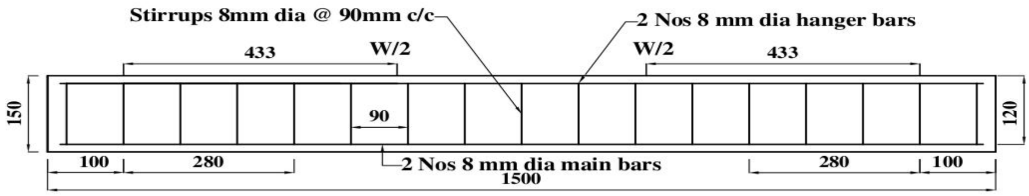


Fig - 1 Longitudinal section for profile 1

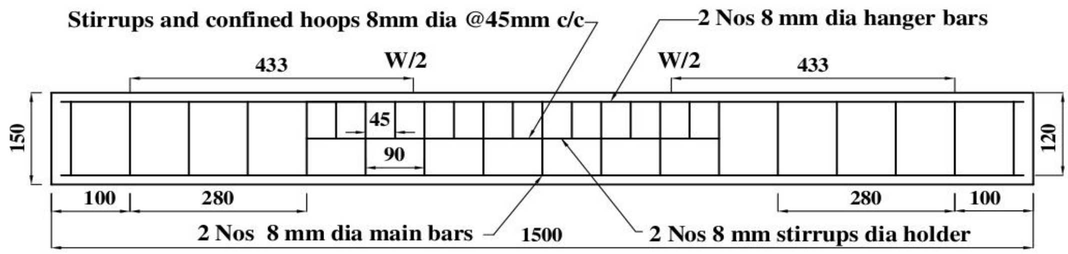


Fig - 2 Longitudinal section for profile 2

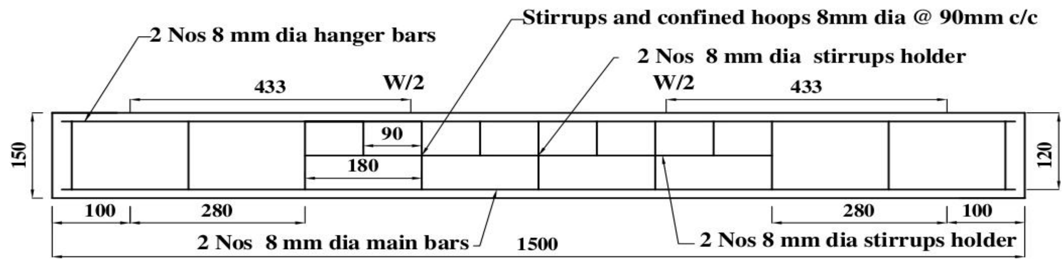
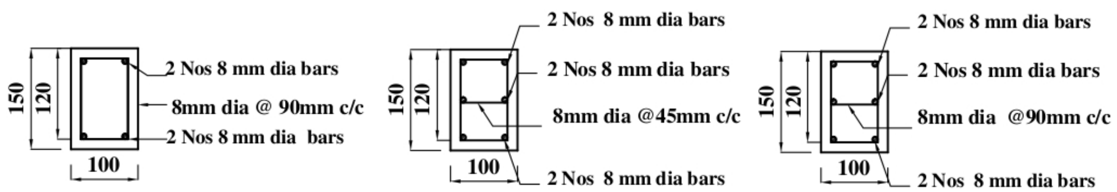


Fig - 3 Longitudinal section for profile 3



(a) Profile - P1 **(b) Profile - P2** **(c) Profile - P3**

Fig - 4 Details of cross sections of various profiles

6.0 Testing of Beam Specimens

A 100 ton capacity reaction frame mounted over strong floor was used to test the beams. The beams were simply supported over an effectively span of 1.3 meter. Two point loads were applied at one fourth distances from each support. The load was applied gradually and in increments. The test was continued until the load droped about 80% of ultimate load for both confined and unconfined concrete specimens. All the beams were tested till it reaches their full flexural capacity. The behaviour of the beam was keenly observed from the begning to till collpse. The dial gauges with a least count of 0.01mm having a travel of 50mm was used to record the vertical deflection at the bottom of the beam.Large deflections are observed in confined beams which indicate the ductile behaviour of beams. The confined beam failure took place either due to crushing or shear failure in compression zone and failed with sufficient warning before collapse. The introduction of stirrups resisted load considerably even at the maximum load. It has been observed that hairline cracks developed in the lower part of beam and as loading continues, cracks widened and extended upwards towards neutral axis. At this stage shear cracks are noticed.

The following equations were used for moment (M) and curvature (1/R):
Moment (M)=Wl/6, Curvature (1/R) =M/EI

The flexural strength of beam specimens are carried out and the observations are summarized and given in table-3.

Table. 3 Test Results of Beams - M20 Grade Concrete

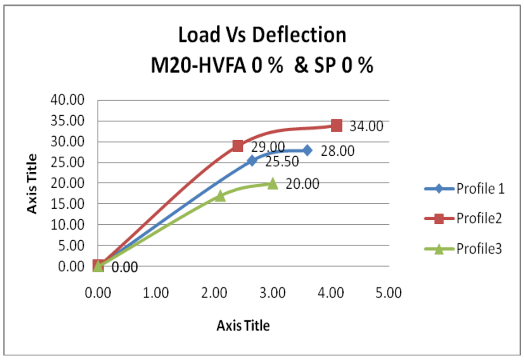
Fly ash	**Load - (W) x10^{3}N**		**Deflection - Δmm**		**Curvature - (1/R) x10^{-6}mm**		**Moment - (M) x10^{6}Nmm**		**Flexural Rigidity- (EI) x10^{12}Nmm^2**	
Profile	Yield	Ultimate	Yield	Ultimate	Yield	Ultimate	Yield	Ultimate	Yield	Ulti mate
OPCC-P1	25.50	28.00	2.65	3.60	7.36	10.00	5.53	6.07	0.75	0.61
OPCC-P2	29.00	34.00	2.40	4.10	6.67	11.39	6.28	7.37	0.94	0.65
OPCC-P3	17.00	20.00	2.10	3.00	5.83	8.34	3.68	4.33	0.63	0.52
50%-P1	23.00	26.00	2.50	3.65	6.95	10.14	4.98	5.63	0.72	0.56
50%-P2	28.50	33.00	3.10	4.70	8.61	13.06	6.18	7.15	0.72	0.55
50%-P3	16.00	17.50	2.35	2.87	6.53	7.97	3.47	3.79	0.53	0.48
55%-P1	22.50	25.00	2.90	3.80	8.06	10.56	4.88	5.42	0.61	0.51
55%-P2	24.00	27.00	2.72	3.52	7.56	9.78	5.20	5.85	0.69	0.60
55%-P3	14.00	16.00	2.10	2.95	5.83	8.20	3.03	3.47	0.52	0.42
60%-P1	20.00	23.50	1.50	2.40	4.17	6.67	4.33	5.09	1.04	0.76
60%-P2	25.00	25.50	2.00	3.00	5.56	8.34	5.42	5.53	0.97	0.66
60%-P3	15.00	19.00	1.00	1.85	2.78	5.14	3.25	4.12	1.17	0.80

7.0 Behaviour of the Beam Specimen

In all the beams when the load increases, cracks appeared in the flexural span. Further increase of load caused additional cracks on either side of the crack which occured in the initial stages. The cracks have been probogate and at this stage some shear cracks also developed. Incase of confined beams, the failure took place either due to crushing of concrete in compression zone or shear compresion failure. These beams are failed all of a sudden as and when peak load is reached. Incase of confined RC beams it has been noticed that the formation of cracks are also similar to unconfined beams, these beams resisted the load considerably even during post peak load. Also large deflections were observed which indicate the ductile behaviour of these beams.

8.0 Test results and discussion

The load was increased gradually in the initial stages upto 80% of the peak load and then increased at slower rate until the peak load was reached. Such that the beam was just at the verge of collapse. In the case of specimen with confined stirrups it was observed that the lateral expansion was small at the begining stages of loading, when axial stress is increased further, the specimen began to crush and lateral expansion increased rapidlly. As the confined stress was very large it was observed that vertical cracks appeared on the surface at this stage. As the load on the specimen increased the number of cracks also increased and cracks started widen. At about 90% of the peak load, spalling of concrete was noticed and it was severe after the crossing of peak load. In general the values of ultimate load were found to increase as the confinement increases.The following figures 5 to 8 is the load- deflection curve and figures 9 to 12 is the moment-curvature graphs were drawn based on the observations.



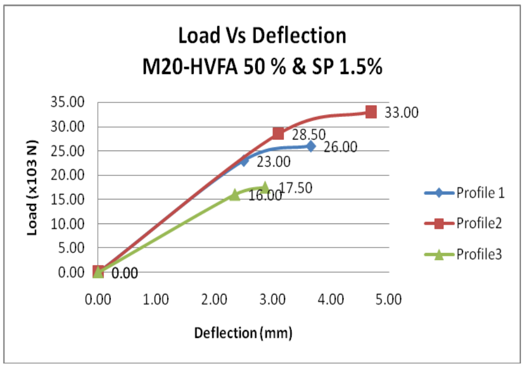
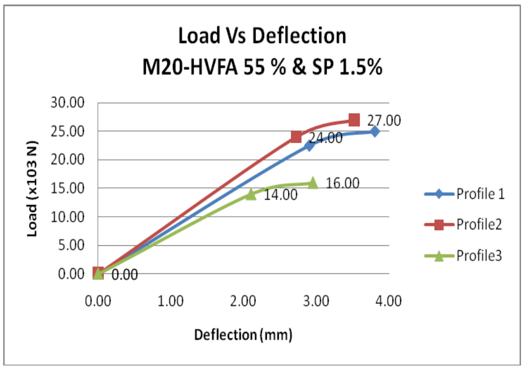


Fig - 5 LOAD VS DEFLECTION CURVE **Fig - 6 LOAD VS DEFLECTION CURVE**

OPCC **50% flyash & 1.5 %Sp**



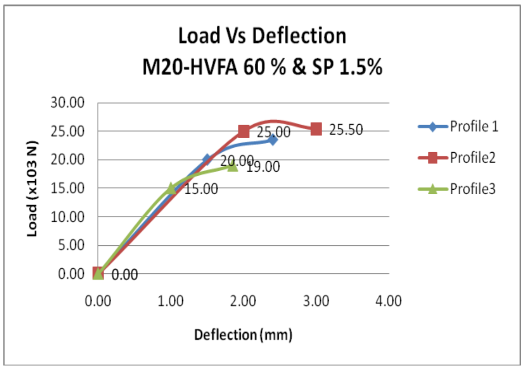
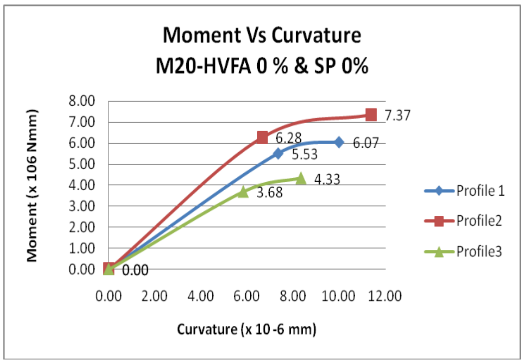


Fig - 7 LOAD VS DEFLECTION CURVE **Fig - 8 LOAD VS DEFLECTION CURVE**

55% flyash & 1.5%Sp

60% flyash & 1.5%Sp



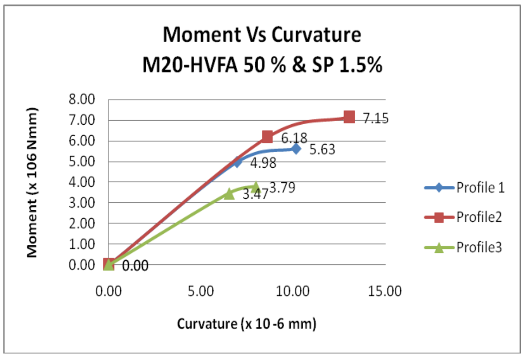
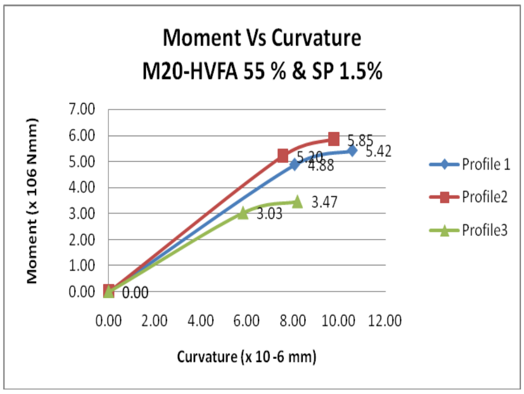


Fig - 9 MOMENT VS CURVATURE
OPCC

Fig -10 MOMENT VS CURVATURE
50% flyash & 1.5% Sp



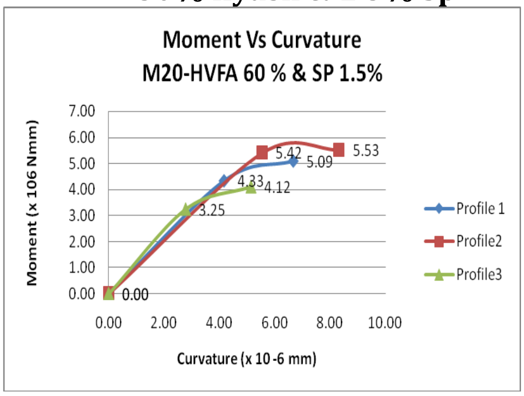


Fig - 11 MOMENT VS CURVATURE
55% flyash & 1.5% Sp

Fig -12 MOMENT VS CURVATURE
60% flyash & 1.5% Sp

From the test results shown in table-1, it is observed that the slump value of concrete has low degree of workability measured in accordance with IS: 1199 -1959 and placing conditions of concrete are light reinforced section in slabs,beams,columns,walls,floors,canal lining etc., When we increase the percentage of flyash content the slump value of concrete is decreasing proportionately.

From the test results shown in table-2, it has been observed that the compressive strength of 50% fly ash concrete cubes (A1.5) with 1.5% of plasticizer at 28 days is almost nearer to the strength of ordinary concrete (D). Further observations reveal that rate of development of compressing strengh at the age of 7 & 14 days is not high for fly ash based concrete. This may be due to slower pozzolanic reaction of fly ash at early ages. However at the age of 28 days the increase in pozzolinic activity of fly ash was suffcient to contribute to the compressive strengh.

From the test results shown in table-3, it is observed that the flexural strength of the specimens confined with stirrups at 90mm C/C with 50% fly ash replacement of cement (profile-2) has been almost same while comparing the test results of the specimens made in conventional concrete without fly ash at 90mm C/C stirrups (profile-1). Specimens confined with stirrups shows a higher increase in confined strength than unconfined specimens. It has been observed that the strength and ductility of the confined concrete specimen increases as the lateral confinement increases. These beams resisted the load considerbly even during the post peak load.

9.0 Moment of Resistance Equation

A moment of resistance equation has been developed for singly reinforced rectangular beam (SRRB) with high volume fly ash as an ingredient and test results were compared with IS: 456-2000 equations and found correct.

The moment carrying capacity of rectangular beam with steel reinforcement is calculated by the equations available in IS:456-2000.These equations are obtained from stress and strain block parameters developed both above and below the neutral axis of the beam. According to the code IS:456-2000, the characteristic compressive stress and strain relationship of concrete is considered as parabolic at initial stage and further rectangular till its ultimate failure. This phenomenon is applicable only if the concrete mix designing done using standard ingredient as per the code recommendations (cement, fine aggregate, coarse aggregate and water). Whenever these ingredient replaced by any other material, it is obvious to get the parabolic curve as like a nominal mix. Due to which stress strain behavior of concrete may change. In nominal mix, the stress strain block of the concrete is considered as parabolic as per IS: 456-2000 where as in the case of special concrete the stress block may be either parabola or triangle at initial stage further it is rectangular. Hence the equations developed in this paper may be applicable for any type concrete provided in compression zone along with steel reinforcement in a tension zone. The result obtained from the developed equations is compared with is IS:456-2000 equations and the percentage error were analyzed.

The Stress exerted at extreme fiber is considered as maximum and its value was obtained by testing the concrete experimentally. The moment of resistance of the beam is derived by limiting these stress value to certain limit. The resultant forces acting at a cross section of the beam both in compression and tension zone were evaluated and equated for equilibrium. The moment of resistance of the beam can be obtained by multiplying lever arm distance between these forces. The resultant compressive force Fc = Area of stress block above neutral axis (Ac) X breadth of the beam (b).The Ac value can be calculated from shape of the stress block above the neutral axis of the beam .The stress strain behavior can be analyzed from the various experimental test for the concrete manufactured according to IS: 456-2000. The resultant forces exerted below the neutral axis of the beam can be calculated directly from characteristic yield strength of the steel rod. However the bonding strength between the steel reinforcement and concrete is achieved as like a usual case. The shear reinforcement also provided according to the code recommendation in order to avoid shear failure. The concrete mix designing, manufacturing process, casting of cubes, curing process and testing methods everything is done according to the code standard IS: 456-2000 for both nominal and HVFA concrete.

The moment of resistance of the SRRB with nominal concrete:

The elements of stress block for the SRRB is shown in figure 13.The stress strain behaviors of nominal mix concrete were found experimentally and shown figure 14.This satisfies the code IS: 456-2000.

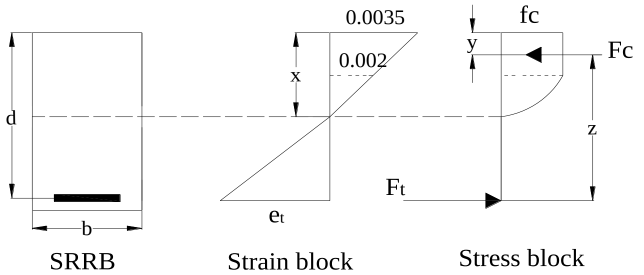


Fig- 13 Elements of stress block

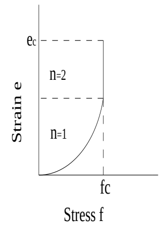


Fig- 14 Stress- strain diagram

The moment of resistance of the SRRB as per IS: 456-2000 equations are,

Mc= 0.36 fck b xumax (d- fy Ast /fck b) and

Mt = 0.87 fy Ast d (1- fy Ast/bd fck)

The material parameters of SRRB is chosen for satisfying Mc =Mt, hence it is the balanced section. Let Mc = Mt = M.

The moment of resistance of the above beam (SRRB) is also calculated by a newly arrived equation M_T.

$$\mathbf{M_T = f_t A_{st} d + [(f_t^2 A_{st}^2) / (f_c b T_2)] [T_1 / T_2 - e_c]}$$

$$\mathbf{T_1 = \Sigma [A_n C_n (e_{nt} - e_{nb})^2 + A_n e_{nb} (e_{nt} - e_{nb})] \quad and \quad T_2 = \Sigma [A_n (e_{nt} - e_{nb})]}$$

Where,

M_c & Mt = Moment of resistance by compression and by tension fiber.

f_c & f_t = Maximum allowable Stress of the material in the compression and tension zone respectively.

e_c & e_t = Maximum allowable strain of the material in compression and tension zone

A_{st} = Area of tension reinforcement,

b = Breadth of the beam,

d = Effective depth of the beam.

C_n = Centriod factor of n^{th} element of stress block {Cn=1/2 for Rectangle,Cn= 5/8 for Parabola,Cn = 2/3forTriangle.}

A_n = Area factor of n^{th} element of Stress block {An=1 for Rectangle, An= 2/3 for Parabola, An = 1/2 for Triangle.}

e_{nt} = Strain at end of n^{th} element of stress block. , e_{nb} = Strain at beginning of n^{th} element of stress block.

T_1 & T_2 are the stress block parameters obtained from the different shapes of stress block above the neutral axis of the beam. In order to find the T_1 & T_2 values, the continues cube test of certain concrete with stress strain relationship are necessary. Hence M_T = M. Therefore the moment of resistance of the SRRB with nominal concrete using IS: 456-2000 equation is equal to M_T. It is noted that way of calculating moment of resistance using M_T is considering the shapes of the stress block parameters.

The moment of resistance of the SRRB with HVFA concrete:

The concrete mix designing was done as per code standard IS: 456-2000 and cement was replaced by HVFA partially. The stress strain behaviors of HVFA concrete were found experimentally and shown figure 13.This is not satisfies the code IS: 456-2000. Even if we can get the design strength of the concrete cubes, the frequency of stress strain behavior quite vary from nominal mix concrete due to inter molecular resistance.

The moment of resistance of the above beam (SRRB) is also calculated by equation M_T. T_1&T_1 are the stress block parameters obtained from the different shapes of stress block above the neutral axis of the beam. Here MT ≠ M. It is because of the parabolic shape only considered in IS: 456-2000 equation where as the real shape is considered. Since the equation M_T is derived based on the real shape of the stress block of concrete, it can be used for any type concrete made with fly ash sand, fibers etc.

10.0 Finite Element Analysis (FEA)

FEM models were developed to simulate the behavior of full-size beams from linear through nonlinear response and up to failure. ANSYS package version 14.5 was used and comparisons were made for load-deflection plots at mid span for ultimate loads at failure. Modeling simplifications and assumptions developed during this research are presented. Comparisons between the experimental data and the results from FE models showed good agreement.

Comparisons of results were made on load-deflection plots at mid span from the ANSYS finite element analysis with the experimental data for full the full size beams. Also discussed are the summaries of the maximum stresses occurring in the composite beam for the FE models. The data from the FE analyses were collected at the same locations as the load tests for the full size beams. The following results were obtained from ANSYS for the yield and ultimate loads beam specimens.

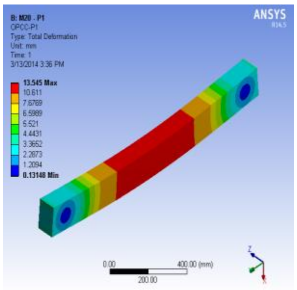
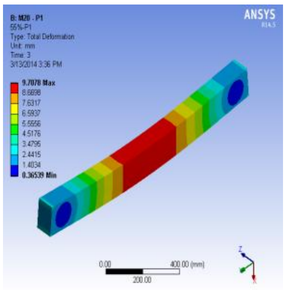
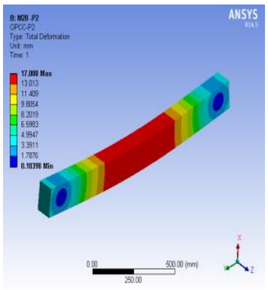
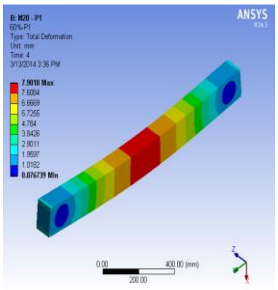
Table- 4 compares the results obtained using the proposed FE model with those obtained from the experiment tests for P1 ,P2 and P3 series beams respectively. It is evident the results shows that the numerical analysis can predict both the failure load and the displacement up to service load of the new system with the acceptable accuracy.

Table .4 Results from ANSYS for P1,P2 and P3 series beams

Sl. No.	Profile	Strength at 28 days	Beam ID	Failure load (kN)			Total Deformation (mm)		
				Expt.	FEA	P_{FEA} / P_{EXP}	Expt.	FEA	$\Delta_{FEA}/\Delta_{EXP}$
1	P1	23.63	OA11	33.50	34.20	1.02	12.50	13.54	0.92
2		22.90	AP11	24.00	25.00	1.04	9.00	9.03	0.99

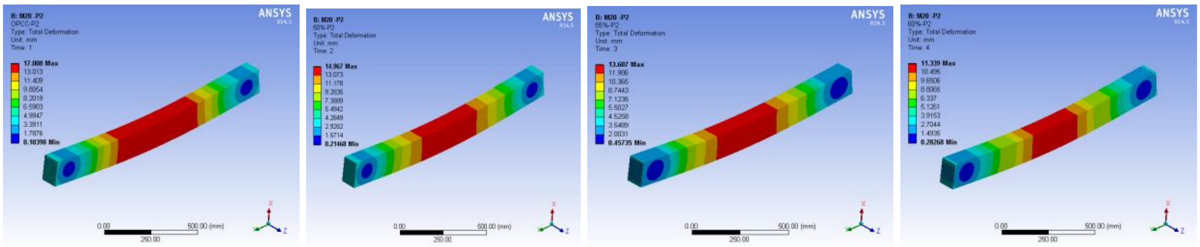
3		16.57	AP12	24.50	23.40	0.95	9.50	9.70	0.97
4		12.42	AP13	23.50	23,00	0.97	8.90	7.90	1.12
1	P2	23.63	OA12	39.00	38.00	0.97	16.20	17.00	0.95
2		22.90	AP21	39.50	40.00	1.01	14.50	14.96	0.96
3		16.57	AP22	29.00	30.00	1.03	12.70	13.60	0.93
4		12.42	AP23	27.50	29.00	1.05	10.20	11.33	0.90
1	P3	23.63	OA13	35.00	34.10	0.97	13.50	13.56	0.99
2		22.90	AP31	25.50	25.00	0.98	11.30	12.54	0.90
3		16.57	AP32	26.50	26.00	0.98	11.80	12.43	0.94
4		12.42	AP33	25.50	25.00	0.98	9.50	10.17	0.93

The total deformation contours of beams of M20 grade concrete for the three percentage replacement levels of cement by FA namely 50%, 55% and 60% for the three profiles P1,P2 and P3 are given in Figures 15 (a-d), 16(a-d) and 17 (a-d) respectively.

(a) Beam ID- OA11 **(b) Beam ID- AP11** **(c) Beam ID- AP12** **(d) Beam ID- AP13**

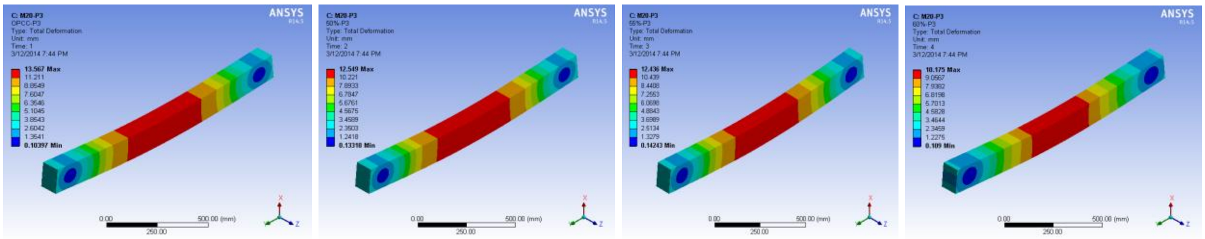
Figure 15 (a-d) Total deformation contours of beams - profile 1



(a) Beam ID- OA12 (b) Beam ID- AP21 (c) Beam ID- AP22

(d) Beam ID- AP23

Figure 16 (a-d) Total deformation contours of beams - profile 2



(a) Beam ID- OA13 (b) Beam ID- AP31 (c) Beam ID-AP32

(d) Beam ID- AP33

Figure 17 (a-d) Total deformation contours of beams-profile 3

By comparing the ultimate loads obtained from the ANSYS modeling for the test specimens were higher than the corresponding specimens tested in laboratory.

From the above results, it has been observed that the concrete grade M20 with 50% replacement of fly ash of profile 2 has of maximum failure load of experimental value with ANSYS in the maximum ratio of 1.51, having a corresponding deflection 14.967 mm **(**Beam -ID AP2).

11.0 Conclusions

The effective use of fly ash in concrete for present and future use minimise the disposal of fly ash and free from pollution. High volume fly ash in concrete mix allows a lower water cement ratio and tends to increase in compressive strenghth and rich in cocrete mixes.HVFA concrete mixtures are sustainable because they consume less portland cement , large volume of industrial waste and produce a highly durable product. Increase in substitution of fly ash for OPC tends towards a reduction in compressive strength. By using fly ash in concrete ,considerable reduction in stone mining will save the natural resourses.It is understood that fly ash is not a waste ,but highly potential building material.Higher value of cement replacement with fly ash will require lower water cement ratio to achieve the same compressive strength. The complete usage of fly ash in concrete works double the benefit by giving pollutionless environment and rich concrete mixes.

It has been observed that workability of concrete decreases as the percentage of fly ash increases for the same water cementitious materials ratio 0.4. It has been concluded that the 50% fly ash replacement of cement and 1.5% super plasticizer added to the HVFA concrete achieved better compressive strength, split tensile strength and flexure strength compare to other categories. The Flexural strength of profile-2 beam by 50% fly ash replacement of cement and 1.5% super plasticizer added to the concrete was found to be higher than ordinary portland cement concrete beam of profile-1. Confining the concrete compression regions with closed stirrups improves the ductility and load carrying capacity of beams and reduction flexural capacity of the beams due to the presence of shear. Large deflections were observed in profile-2 beams which indicate the ductile behavior and the confinement improves both the strength and deformation characteristics of concrete.

The results shows that HVFA concrete is an exellent material with later age properties superior to conventional concrete,namely-compression strength ,flexural strength etc.,From the view point of sustainable development,it is a strongly viable solution as a building material in the years ahead.

12.0 Acknowledgements

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13.0 References

[1] Bhanumathidas N. and Kalidas N. (2003),"Fly ash the resourses for construction Industry", Indian Concrete Journal, April,Vol. 77,No. 4, pp. 997-1004.

[2] IS:516- 1959, "Method of test for strength of concrete", edition 1.2 (1991-07) , Bureau of Indian Standard, New Delhi.

[3] IS :3812-1981, "Specification for fly ash for use as pozzolana and admixture", (first revision), Bureau of Indian Standard, New Delhi.

[4] IS:12269-1987, "Specification for 53 grade OPC", Bureau of Indian Standard, New Delhi.

[5] IS:456 - 2000, "Plain and Reinforced concrete- Code of Practice " (fourth revision), Bureau of Indian Standard, New Delhi.

[6] IS:10262-2009, "Concrete Mix Proportioning-Guidelines", Bureau of IndianStandard, New Delhil.

[7] Malhotra. V.M. (1999)," Making concrete with fly ash,"Indian concrete journal, Vol.73(10): pp. 609-614.

[8] Mark Reivier and Kevins Rens, (2006), "High volume fly ash concrete; analysis and application Practice ",Periodical on structural design and construction @ ASCE,2006.

[9] Phlip.L Ownes, (1979),"Fly ash and its usage in concrete",Concrete International,Vol-24, July, pp. 21-26.

[10] Ravina.D, Methta.P, (1986),"Properties of fresh concrete containing large amounts of flyash",Cement and Concrete research, Vol,16,PP227-238, pp. 211-217.

[11] ResiS.S.andGargS.K,.(1963)",Evaluation of Indian Fly ashes", Indian Concrete Journal, June 1963.

[12] Sheikh S. A,(1982), "Comparative study of confinement models", ACI journal, july-Aug, pp. 296-306.

[13] Wilbert S. Langgley,George S G Carette and Malhotra V. M. (1989),"Structural Concrete incorporating high voume of astm class F flyash",ACI Materials journal, Vol-86, Sep-Oct,pp. 507-514.