

Ductility Behavior of reinforced high volume flyash concrete beams

R.Preetha, Joanna.P.S, Jessy Rooby,C.Sivathanu Pillai

Abstract— Ductility behavior of reinforced high volume flyash beams in comparison with reinforced ordinary Portland cement beams were studied experimentally. The ductility factors obtained experimentally are also compared with theoretical values .

Index Terms—Beam, Curvature ,Ductility, Displacement, Flyash Concrete, Rotation, Strain.

1 INTRODUCTION

Ordinary Portland cement (OPC) is one of the main ingredients used for the production of concrete. The utilization of industrial waste like fly ash in eco-friendly way along with cement, helps in preserving resources and also improves durability of concrete as it densifies the matrix. The enhanced durability of fly concrete is well documented; hence an attempt is made to study the structural behavior of reinforced flyash concrete beams in comparison with ordinary concrete beams. Beams are the structural elements in which large amount of seismic energy dissipation takes place, through stable flexural yield mechanism. In this paper ductility of reinforced flyash concrete beams is compared with reinforced ordinary Portland cement concrete beams. Ductility is the capacity to undergo inelastic deformation and absorb energy. These include curvature, displacement and rotational ductility.

2 MATERIAL & MIX DESIGN

The materials used in the mix were Ordinary Portland Cement (OPC), river sand, Fly Ash (F grade) and potable water. Beams are of M30 grade concrete(fig.1). Water-binder ratio of 0.45 and 0.75% conplast superplasticizer was used for OPC reinforced concrete beams(1:1.8:2.7). Water-binder ratio of 0.45 and 1.3% conplast superplasticizer was used for fly ash concrete beams(1:1.7:2.5). Fe 500 grade steel was used for longitudinal reinforcement and for stirrups.

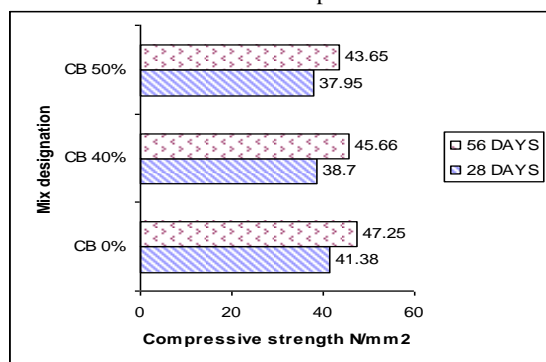


Fig.1 Compressive strength at 28 and 56 days

3 BEAM DETAILS & TEST SETUP

The beam span was 2500 mm and cross section 150mm x 250mm. The

specimens were designed as per IS 456:2000 (Table 1). Out of the twelve specimens tested, four specimens were cast without fly ash and the other eight specimens were cast with 40%&50% fly ash. Six specimens were tested at 28th day and six specimens were tested at 56th day from the date of casting.

TABLE 1
TEST BEAMS DETAILS

SL. No.	Beam Number	Testing of Beams (days)	Reinforcement in beams			
			Longitudinal		Stirrups	
			Top	Bottom	Diameter (mm)	Spacing (mm)
1	CB0%	28	2#10	2#12 + 1#16	8	120
2	CB40%	28	2#10	2#12 + 1#16	8	120
3	CB50%		2#10	2#12 + 1#16	8	120
4	CB0%		56	2#10	2#12 + 1#16	8
5	CB40%	56	2#10	2#12 + 1#16	8	120
6	CB50%		2#10	2#12 + 1#16	8	120

The testing was carried out in a loading frame of 400 kN capacity. TML strain gauge was fixed at the mid span of the tension bar and then protected using coating tape to avoid accidental damage during pouring of concrete[1]. Strain gauges were also attached to the concrete surface in the central region of the beam to measure the strain at different depths. The top surface of the beam was instrumented with strain gauge to measure the concrete compressive strains in the pure bending region. LVDTs were used for measuring deflections at several locations one at mid span, two directly below the loading points and two near the end supports .Strain gauges and LVDTs were connected to a data logger from which the readings were captured by a computer at every load intervals until failure of the beam occurred . The test was carried using a 400 kN hydraulic actuator and the beams were subjected to two-point loads under a load control mode (fig.2).

- R.Preetha,Scientific officer,IGCAR,Kalpakkam,India. E-mail: predinesh@igcar.gov.in
- P.S .Joanna,Professor,Civil engineering department,Hindustan university,Chennai,India E-mail: joanna@hindustanuniv.ac.in
- Jessy Rooby,,HOD,,Civil engineering department,Hindustan university,Chennai,India E-mail: civil@hindustanuniv.ac.in
- C.Sivathanu Pillai,Associate Director,CEG,IGCAR,Kalpakkam,India Email: csp@igcar.gov.in

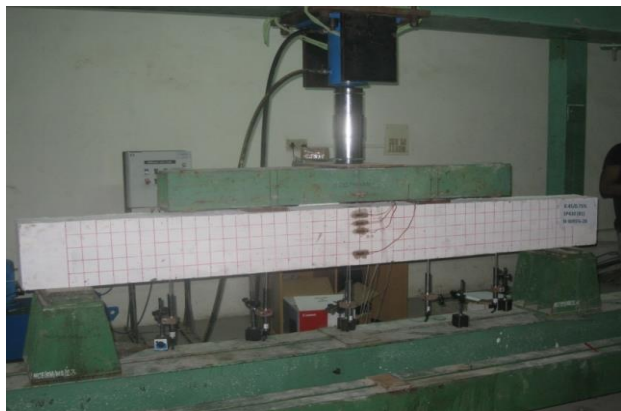


Fig 2. Test set-up

4 OBSERVATIONS

Vertical flexural cracks were observed in the constant-moment region and final failure occurred due to crushing of the compression concrete with significant amount of ultimate deflection[2]. When maximum load was reached, the concrete cover on the compression zone started to fall for both beams with and without fly ash. Crack formations were marked on the beam at every load interval at the tension steel level. It was noticed that the first crack always appeared close to the mid span of the beam. The cracks formed on the surface of the beams were mostly vertical, suggesting flexural failure in beams(fig.3).



Fig 3. Crack formations

5 DUCTILITY

Ductility is the capacity to undergo inelastic deformation and absorb energy. Several forms of ductility are often considered. These include curvature, displacement and rotational ductility. Displacement ductility(μ_Δ) is the ratio of ultimate (Δ_u) to first yield deflection (Δ_y). Based on idealized moment curvature ($M-\phi$) behavior, curvature ductility(μ_ϕ) is defined as the ratio of maximum curvature (ϕ_u) to curvature at first yield (ϕ_y). Similarly, rotational ductility(μ_θ) is the ratio of ultimate rotation (θ_u) to yield rotation (θ_y)[3].

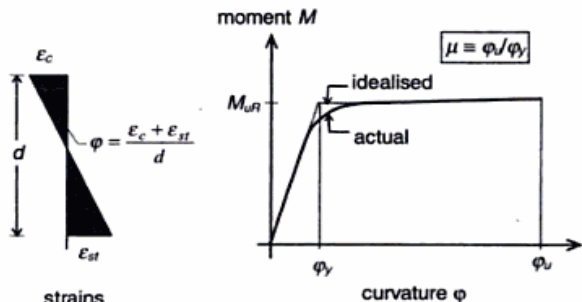


Fig.4 Moment curvature theoretical

5.1 Curvature ductility

Theoretical curvature ductility was arrived using the following equations and compared with the experimental values[4,5].

$$\phi_y = \frac{f_y}{E_s(1-k)d} \dots\dots\dots [1]$$

$$k = \sqrt{\left\{ (\rho + \rho')^2 n^2 + 2 \left(\rho + \left(\rho' \frac{d'}{d} \right) \right) n \right\} - n(\rho + \rho')} \dots\dots [2]$$

$$\phi_u = \frac{\epsilon_c \beta_1}{a} \dots\dots\dots [3]$$

$$a = \frac{A_s f_y - A'_s f_y}{0.85 f_c b} \dots\dots\dots [4]$$

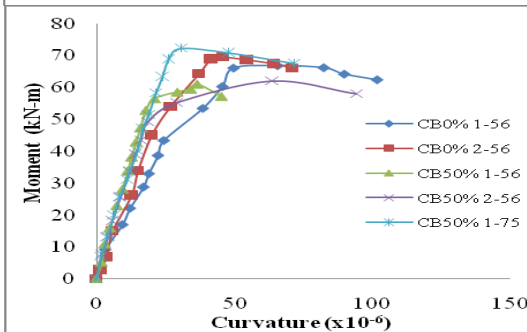
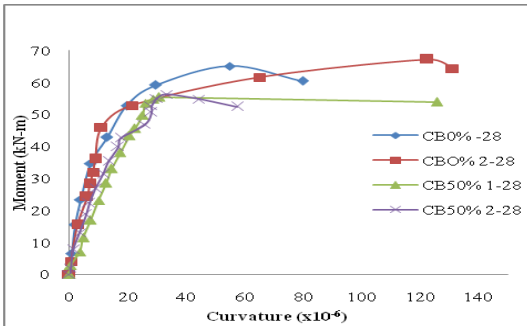
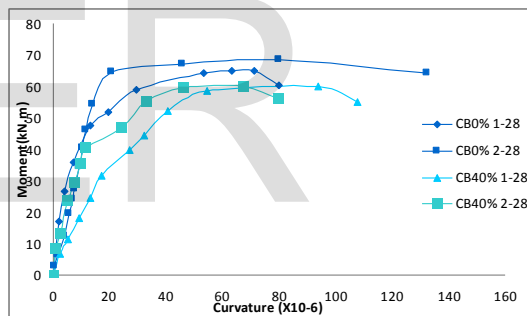
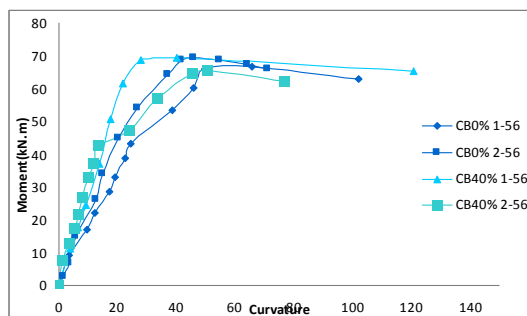
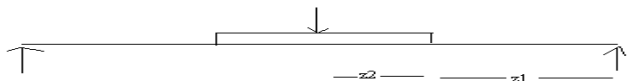


Fig.5 Moment curvature experimental

Moment-Curvature diagrams were generated for all the beams based on the concrete strain and steel strain(fig.5). The experimental results showed 80-95% of theoretical curvature ductility.

5.2 Displacement ductility

Theoretical displacement ductility was arrived using the following equations and compared with the experimental values[3].



$$\Delta_y = \phi_y \frac{z_1^2}{3} + \phi_y z_2 \left(z_1 + \frac{z_2}{2} \right) \dots\dots\dots [5]$$

$$L_p = 0.08 z_1 + 0.022 d_b f_y \dots\dots\dots [6]$$

$$\Delta_u = \phi_y \frac{z_1^2}{3} + \phi_u z_2 \left(z_1 + \frac{z_2}{2} \right) + (\phi_u - \phi_y) L_p \left(z_1 - \frac{L_p}{2} \right) \dots\dots\dots [7]$$

Table 2. Performance details of fly ash concrete beams and OPC concrete beams.

BeamID /testing day	Deflection at yield (mm)	Max. deflection (mm)	Displacement ductility
CB0% -28	4.8	20.0	4.17
CB0% -28	5.4	27.5	5.09
CB40% -28	5.0	20.6	4.12
CB40% -28	5.8	25.2	4.35
CB0% -56	4.6	24.6	5.34
CB0% -56	3.5	22.0	6.28
CB40% -56	6.2	28.6	4.61
CB40% -56	4.9	21.7	4.43
CB50% -28	5.0	19.3	3.86
CB50% -28	5.0	22.2	4.44
CB50% -56	5.0	21.6	4.32
CB50% -56	4.0	20.5	5.13
CB50% -75	4.3	27.0	6.30

The experimental results showed 80-100% of theoretical displacement ductility.

5.3 Rotation ductility

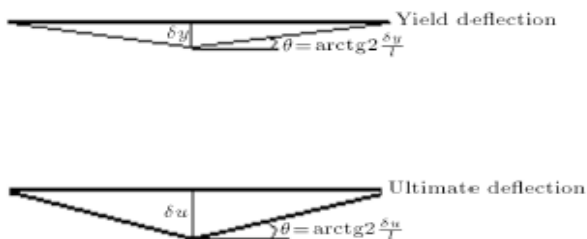


Fig.6 Yield & Ultimate rotation theoretical

Theoretical rotational ductility was arrived from equation shown in fig.6 and compared with the experimental values.

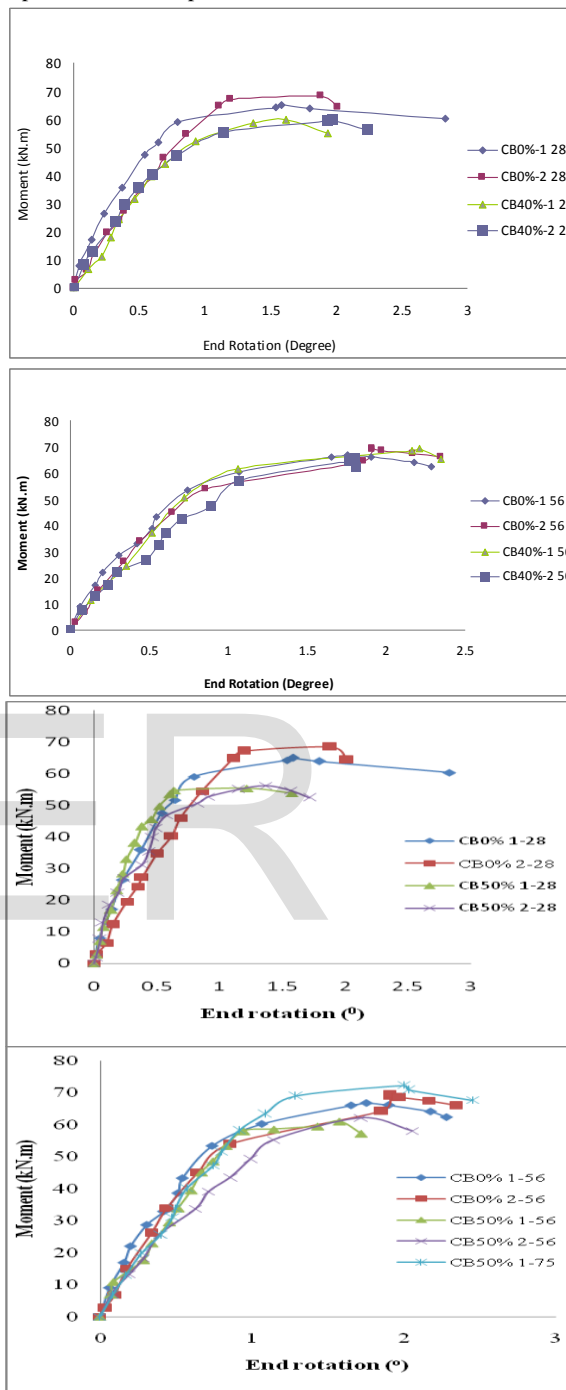


Fig.7 Moment rotation experimental

The experimental results showed 70-90% of theoretical rotational ductility.

5.4 Comparison of different types of experimental ductility factors

Comparison of different measures of ductility was made with the experimental results. It is seen from fig.8 that the behaviour of beams with and without flyash are similar and within -10% to +10% range of each other. Curvature ductility is the measure of the cross section, hence it is seen as significant than other two measures of ductility. In general

high ductility ratios indicate that a structural member is capable of undergoing large deflections prior to failure.

deflections prior to failure. Thus indicating that the flyash concrete reinforced beams can be considered for structural members subjected to large displacement such as sudden forces caused by earthquake.

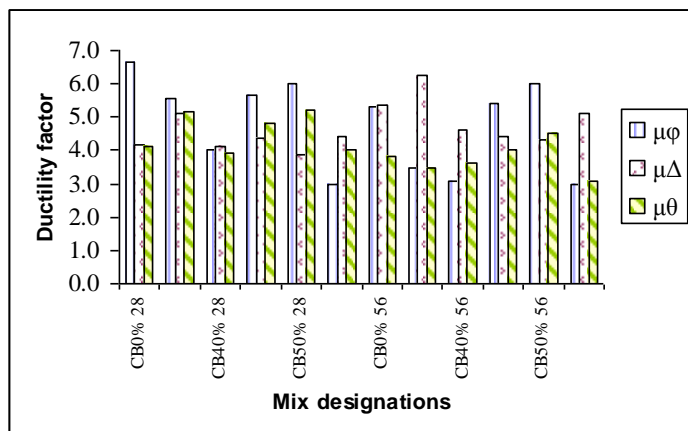


Fig.8 Comparison of different ductility

6 CONCLUSIONS

Total of twelve reinforced beams specimens were tested under two point loading and following inferences were made.

- Vertical flexural cracks were observed in the constant-moment region and final failure occurred due to crushing of the compression concrete with significant amount of ultimate deflection.
- The cracks formed on the surface of the beams were mostly vertical, suggesting flexural failure in beams
- The ductility factors ie. Curvature, displacement and rotational of beams with and without flyash are similar and within -10% to +10% range of each other.
- The experimental and theoretical ductility factors are very close to each other.
- The reinforced concrete beams cast with high volume flyash as designed in the experiment are capable of under going large

REFERENCES

- [1] Effect of Replacement of Cement with FA on the Strength and Durability Characteristics of HPC, *Indian Concrete Journal*, 2011, p. 335-341. Gopalakrishnan S, Rajamane NP, Neelamegam M, Annie Peter J, Dattatrya JK.
- [2] Assessment of High-Volume Replacement Fly Ash Concrete-Concept of Performance Index, *Construction and Building Materials*, 2012. Obada Kayali, Sharfuddin Ahmed M.
- [3] Ductility of High Strength Concrete Heavily Steel Reinforced Members, A.A. Maghsoudi and Y. Shari, *Transaction A: Civil Engineering* Vol. 16, No. 4, pp. 297{307c Sharif University of Technology, August 2009.
- [4] Reinforced concrete design, S.Unnikrishna Pillai, Devdas Menon.
- [5] *Earthquake resistant structures*, Andreas Kappos, G.G.Peneles.