SHORT TERM DEFLECTION OF FLY ASH CONCRETE BEAMS

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***Abstract*— Fly ash is the most available supplementary cementing material worldwide. A few studies are available in the literature on the ultimate strength of fly ash concrete beams. The reported studies on deflection characteristics of fly ash concrete beams are very few. Also methods are required to estimate the short term deflections of such beams. In the present work, various codes of practices viz ACI 318-14, IS: 456-2000, Bilinear and EN 1992 were used to predict the load deflection behaviour of fly ash concrete beams and normal strength concrete beams. The predictions, suitability and their variations are presented.**

***Key words:* Analysis, Codes, Comparison, Fly Ash concrete, Load deflection behaviour, Ordinary Portland cement, Statistics, Tests.**

I. INTRODUCTION

Construction activity in India and the world over during the last decades has more than doubled. The concrete industry in India is to meet the demands posed by enormous infrastructure needs due to rapid industrialization and urbanization. Due to the continuous usage of the materials for making concrete there will be heavy shortage of natural resources. It is learnt that for every tonne of ordinary Portland cement produced, about one tonne of carbon dioxide is released into the atmosphere adding to global warming. The ingredients of the concrete are modified using fly ash, which will improve the existing property of concrete, these includes the slower rate of setting, hardening and other physical properties. FLY ASH is obtained by burning the powdered coal and it is collected from the bunkers. Continuous research studies by various engineering research laboratories revealed its varied usefulness as an additive for enhancing the various qualities of concrete including its workability, strength and durability if handled and cared properly. Partial replacement of cement with fly ash in concrete save much of the energy required for production of OPC and also facilitates the economical disposal of millions of tons of fly ash. At present most of the fly ash blended cements commercially produced in India has 18 to 25% fly ash by weight and addition of fly ash to this extent has a beneficial effect on the workability and economy of concrete. This beneficial aspect of fly ash can be advantageously used with cement. This leads to replacing cement with larger percentages of fly ash. Fly ash content greater than 35% can be considered as high volume replacement or high blending. HVFA system has proven to be economical construction material which can be mixed, placed and consolidated with conventional concrete construction equipment including pumping and shortcrete.

II. PRESENT WORK

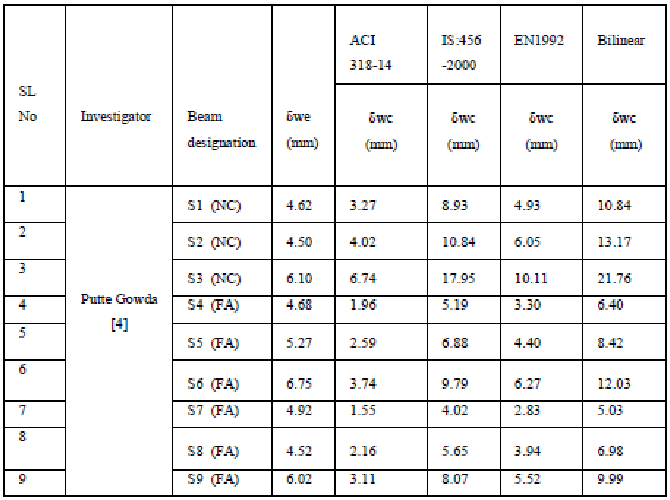
The present work is carried out to understand the flexural behaviour of simply supported Reinforced Fly ash Concrete (RFAC) beams in comparison to identical Reinforced Normal Concrete (RNC) beams subjected to pure bending. Fly ash concrete is obtained by replacing a fraction of cement by a known amount of Fly ash such that the total cementitious content of a particular grade of concrete remains the same in Fly ash concrete (FAC) and Normal Concrete (NC). The load deflection behaviour of reinforced Fly ash concrete simply supported beams was studied and results were compared with normal concrete beam specimens. The test data of 53 beams available in literature have been used. The data base consists of thirty beams of Narendra [1], nine beams of Putte Gowda et.al [4] and Fourteen beams of Kode Venkata Ramesh [8]. The flexural behaviour of fly ash concrete beams made with class F fly ash which was used as cement replacement material. The present work focuses on load deflection response. The short term deflection of beams was calculated using ACI 318-14, IS:456-2000, EN1992 and Bilinear method. The above methods have been used to compute the short term deflections of fly ash concrete beams, also a similar study on traditionally vibrated concrete beams have been made. The results are compared and presented.

III. METHOD OF ANALYSIS

This section includes different methods used to calculate the short term deflection of beams. The short term deflection of beams was calculated using ACI 318-14, IS:456-2000, EN1992 and Bilinear method. The effective moment of inertia concept has been used in ACI 318-14 and IS: 456-2000 methods, mean curvature concept used in EN1992, and curvature concept used in bilinear method. Cracked and uncracked sections are treated separately.

IV. RESULTS AND COMPARISON

An attempt has been done to bring about a comparative study between the experimental data and the different methods used to calculate the short term deflection of beams at service loads. The short term deflection of beams was calculated using ACI 318-14, IS:456-2000, EN1992 and Bilinear method. The load deflection behaviour, summary of statistical data of different investigations and the relevant tables and graphs are discussed.The results of experimental and calculated deflection of beams at service loads and at service loads the ratios of experimental and calculated deflection of beams are presented in the following tables.



SL No	Investigator	Beam designation	δwe (mm)	ACI 318-14	IS:456 -2000	EN1992	Bilinear
				δwc (mm)	δwc (mm)	δwc (mm)	δwc (mm)
1	Putte Gowda [4]	S1 (NC)	4.62	3.27	8.93	4.93	10.84
2		S2 (NC)	4.50	4.02	10.84	6.05	13.17
3		S3 (NC)	6.10	6.74	17.95	10.11	21.76
4		S4 (FA)	4.68	1.96	5.19	3.30	6.40
5		S5 (FA)	5.27	2.59	6.88	4.40	8.42
6		S6 (FA)	6.75	3.74	9.79	6.27	12.03
7		S7 (FA)	4.92	1.55	4.02	2.83	5.03
8		S8 (FA)	4.52	2.16	5.65	3.94	6.98
9		S9 (FA)	6.02	3.11	8.07	5.52	9.99

Table. 1 Experimental and Calculated Deflections at service Loads of 9 Beams using various codes.

SL NO	Investigator	Beam designation	δwe (mm)	ACI 318-14	IS:456 -2000	EN 1992	Bilinear
				δwc (mm)	δwc (mm)	δwc (mm)	δwc (mm)
1	Kode Venkata Ramesh [8]	HVA	0.46	0.18	0.47	0.76	0.42
2		HVB	0.44	0.27	0.70	1.16	0.71
3		HVC	4.82	3.50	9.89	6.61	8.97
4		HVD	5.11	3.95	12.62	7.61	11.06
5		HVE	10.6	5.72	19.96	12.64	18.25
6		HVF	7.83	5.42	18.45	12.53	17.44
7		HVG	8.73	5.46	18.34	13.23	17.82
8		OA	0.41	0.16	0.47	0.79	0.43
9		OB	0.46	0.27	0.72	1.21	0.74
10		OC	4.16	3.33	8.95	6.35	8.46
11		OD	4.30	3.56	10.73	6.85	9.66
12		OE	8.79	6.32	18.91	14.01	20.16
13		OF	6.50	5.10	15.23	11.79	16.26
14		OG	7.39	5.41	16.12	13.02	17.54

Table. 2 Experimental and Calculated Deflections at service Loads of 14 Beams using various codes.

SL NO	Investigator	Beam designation	δwe (mm)	ACI 318-14	IS:456-2000	EN 1992	Bilinear
				δwc (mm)	δwc (mm)	δwc (mm)	δwc (mm)
1	Narendra [1]	FC-3A-28	9.12	3.11	8.26	5.83	10.13
2		FC-3B-28	8.65	3.22	8.50	6.08	10.44
3		FC-3C-28	8.27	3.12	8.26	5.83	10.14
4		FC-3C-28-1	6.35	2.54	7.24	6.20	14.70
5		FC-3C-28-2	9.47	3.17	7.81	6.05	10.88
6		FC-3C-28-4	10.09	3.50	9.13	8.30	11.26
7		NC-30-28	11.28	3.10	8.32	6.19	10.07
8		NC-30-28-1	3.78	1.98	5.85	5.59	13.12
9		NC-30-28-2	6.57	2.85	7.18	5.42	10.08
10		NC-30-28-4	9.85	3.79	9.86	7.73	12.18
11		FC-4A-28	6.28	3.73	9.73	7.64	12.00
12		FC-4B-28	4.89	3.72	9.73	7.62	11.98
13		FC-4B-28-1	3.71	1.62	4.94	5.62	12.14
14		FC-4B-28-2	6.38	3.65	9.65	7.00	11.93
15		FC-4B-28-4	5.76	3.52	9.14	7.26	11.32
16		FC-4C-28	4.50	3.78	9.83	7.75	12.15
17		NC-40-28	8.55	3.73	9.73	7.71	12.01
18		NC-40-28-1	4.39	1.53	5.04	5.31	12.16
19		NC-40-28-2	6.62	3.66	10.22	7.00	11.95
20		NC-40-28-4	6.61	3.54	9.18	7.26	11.36
21		FC-5A-28	6.79	3.69	9.61	7.90	11.88
22		FC-5B-28	5.52	3.71	9.65	7.87	11.93
23		FC-5B-28-1	3.06	1.00	3.65	4.89	11.96
24		FC-5B-28-2	5.12	3.93	10.71	3.24	13.05
25		FC-5B-28-4	6.32	3.52	9.09	7.85	11.30
26		FC-5C-28	4.40	3.46	9.00	7.32	11.14
27		NC-50-28	6.96	3.97	10.37	8.45	12.77
28		NC-50-28-1	3.98	0.99	3.63	4.89	11.96
29		NC-50-28-2	6.91	3.93	10.52	3.24	13.06
30		NC-50-28-4	6.52	3.52	9.10	7.85	11.31

Table. 3 Experimental and Calculated Deflections at service Loads of 30 Beams using various codes.

SL NO	Investigator	Beam designation	δwe (mm)	ACI 318-14	IS:456-2000	EN 1992	Bilinear
				δwc/ δwe	δwc/ δwe	δwc/ δwe	δwc/ δwe
1	Putte Gowda [4]	S1 (NC)	4.62	0.71	1.93	1.07	1.98
2		S2 (NC)	4.50	0.89	2.41	1.34	2.54
3		S3 (NC)	6.10	1.10	2.94	1.66	3.25
4		S4 (FA)	4.68	0.42	1.11	0.70	1.20
5		S5 (FA)	5.27	0.49	1.31	0.83	1.43
6		S6 (FA)	6.75	0.55	1.45	0.93	1.66
7		S7 (FA)	4.92	0.32	0.82	0.57	0.92
8		S8 (FA)	4.52	0.48	1.25	0.87	1.42
9		S9 (FA)	6.02	0.52	1.34	0.92	1.57
			$\bar{x}$	**0.61**	**1.62**	**0.99**	**1.77**
			CV	**38.65**	**39.74**	**31.58**	**38.47**

Table. 4 Ratios of Experimental and Calculated Deflections at service Loads of 9 Beams using various codes.

SL NO	Investigator	Beam designation	δwe (mm)	ACI 318-14	IS:456-2000	EN 1992	Bilinear
				δwc/ δwe	δwc/ δwe	δwc/ δwe	δwc/ δwe
1	Kode Venkata Ramesh [8]	HVA	0.46	0.39	1.01	1.66	0.92
2		HVB	0.44	0.62	1.59	2.64	1.62
3		HVC	4.82	0.73	2.05	1.37	1.86
4		HVD	5.11	0.77	2.47	1.49	2.16
5		HVE	10.6	0.54	1.88	1.19	1.72
6		HVF	7.83	0.69	2.36	1.60	2.23

7		HVG	8.73	0.63	2.10	1.52	2.04
8		OA	0.41	0.40	1.14	1.92	1.04
9		OB	0.46	0.60	1.56	2.62	1.60
10		OC	4.16	0.80	2.15	1.53	2.03
11		OD	4.30	0.83	2.49	1.59	2.25
12		OE	8.79	0.72	2.15	1.59	2.29
13		OF	6.50	0.78	2.34	1.81	2.50
14		OG	7.39	0.73	2.18	1.76	2.37
			$\bar{x}$	**0.66**	**1.96**	**1.74**	**1.90**
			CV	**20.37**	**23.08**	**66.03**	**24.30**

Table. 5 Ratios of Experimental and Calculated Deflections at service Loads of 14 Beams using various codes.

SL NO	Investigator	Beam designation	δwe (mm)	ACI 318-14	IS:456 -2000	EN 1992	Bilinear
				δwc/ δwe	δwc/ δwe	δwc/ δwe	δwc/ δwe
1	Narendra [1]	FC-3A-28	9.12	0.34	0.91	0.64	0.94
2		FC-3B-28	8.65	0.37	0.98	0.70	1.03
3		FC-3C-28	8.27	0.38	1.00	0.70	1.04
4		FC-3C-28-1	6.35	0.40	1.14	0.98	1.18
5		FC-3C-28-2	9.47	0.33	0.82	0.64	0.83
6		FC-3C-28-4	10.09	0.35	0.91	0.82	1.01
7		NC-30-28	11.28	0.27	0.74	0.55	0.75
8		NC-30-28-1	3.78	0.52	1.55	1.48	1.56
9		NC-30-28-2	6.57	0.43	1.09	0.83	1.07
10		NC-30-28-4	9.85	0.38	1.00	0.78	1.12
11		FC-4A-28	6.28	0.59	1.55	1.22	1.71
12		FC-4B-28	4.89	0.76	1.99	1.56	2.20
13		FC-4B-28-1	3.71	0.44	1.33	1.51	1.20
14		FC-4B-28-2	6.38	0.57	1.51	1.10	1.54
15		FC-4B-28-4	5.76	0.61	1.59	1.26	1.80
16		FC-4C-28	4.50	0.84	2.19	1.72	2.44
17		NC-40-28	8.55	0.44	1.14	0.90	1.26
18		NC-40-28-1	4.39	0.35	1.15	1.21	1.03
19		NC-40-28-2	6.62	0.55	1.54	1.06	1.49
20		NC-40-28-4	6.61	0.53	1.39	1.10	1.58
21		FC-5A-28	6.79	0.54	1.42	1.16	1.59
22		FC-5B-28	5.52	0.67	1.75	1.43	1.97
23		FC-5B-28-1	3.06	0.33	1.19	1.60	1.09
24		FC-5B-28-2	5.12	0.77	2.09	0.63	2.07
25		FC-5B-28-4	6.32	0.56	1.44	1.24	1.67
26		FC-5C-28	4.40	0.79	2.05	1.66	2.30
27		NC-50-28	6.96	0.57	1.49	1.21	1.68
28		NC-50-28-1	3.98	0.25	0.91	1.23	0.83
29		NC-50-28-2	6.91	0.57	1.52	0.47	1.54
30		NC-50-28-4	6.52	0.54	1.40	1.20	1.62

			$\bar{x}$	**0.51**	**1.36**	**1.09**	**1.44**
			CV	**30.51**	**28.15**	**32.07**	**31.35**

Table. 6 Ratios of Experimental and Calculated Deflections at service Loads of 30 Beams using various codes.

SL. NO	Investigator	Number of beams		ACI 318-14	IS:456 -2000	Bilinear	EN1992
1	Narendra [1]	30	$\bar{x}$	0.51	1.36	1.44	1.09
			CV	30.51	28.15	31.35	32.07
2	Putte Gowda [4]	9	$\bar{x}$	0.61	1.62	1.77	0.99
			CV	38.65	39.74	38.47	31.58
3	Kode Venkata Ramesh [8]	14	$\bar{x}$	0.66	1.96	1.90	1.74
			CV	20.37	23.08	24.30	66.03
4	All Investigations	53	$\bar{x}$	0.56	1.56	1.62	1.24
			CV	32.25	33.49	33.52	37.61

Table. 7 Summary of statistical data of different investigations.

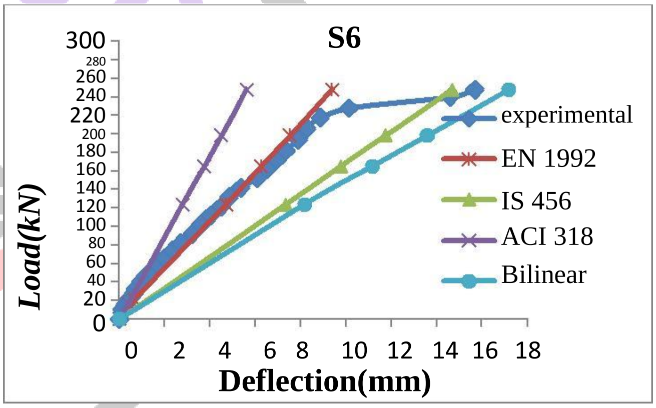


Fig.1 Comparison of service load deflections by various methods-S6.

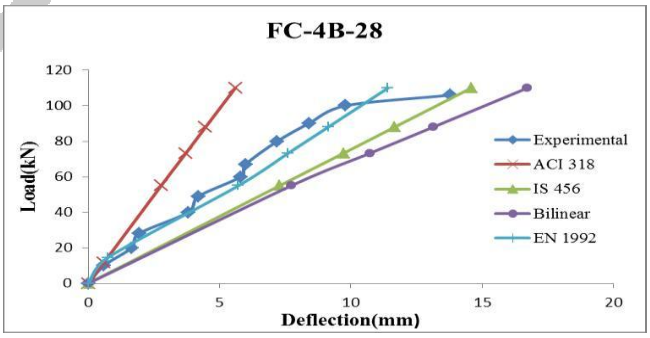


Fig.2 Comparison of service load deflections by various methods- FC-4B-28.

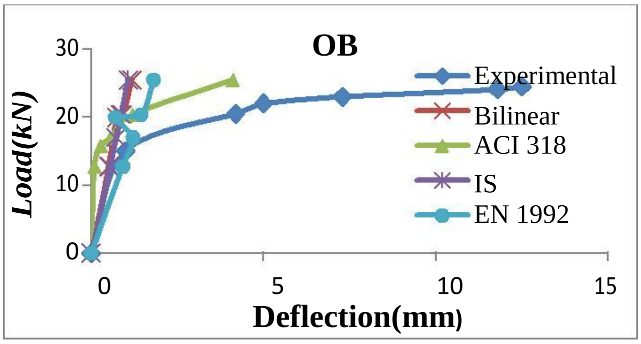


Fig.3 Comparison of service load deflections by various methods-OB.

In case of Control and Fly ash beams the deflections was estimated by using ACI 318, IS 456, Bilinear method, EN 1992 was shown (Table 1,2&3). It is noted that the ACI 318, IS 456, Bilinear method over estimates the deflections of the beams when compare to EN 1992. And the average ratios of theoretical to experimental values of deflections was calculated separately for 30 beams[1], 14 beams[8] and 30 beams[1] along with co-variance was shown in table 4,5 and 6 and the Summary of statistical data of different investigations was shown in Table 7. It can be inferred that EN1992 can be used to calculate the deflections of both control and Fly ash beams.An evaluation of computed and experimental load-deflection curves shows that the suggested method (EN1992) is able to predict actual trend of the experimental load deflection curve in all 53 beams. In a few cases a slight deviation from the experimental curve is noted in case of FC-5A-28,FC-5B-28, FC-5C-28, NC-50-28,HVE,HVF,HVG,OE,OFandOG and in a very few beams the load deflection curve predicted are to be terminated at cracking load, as the theoretical prediction shows that they are uncracked (HVA,HVB,OA and OB) .Typical load deflection curves were plotted using ACI 318-14 , IS:456-2000, EN 1992 and Bilinear methods.

The deflections at service loads were computed and compared with the experimental data of 53 beams (wide Table:1-6). Table 7 shows that EN1992 is able to predict satisfactorily the deflection at service load and the average ratios of theoretical to experimental values is 1.24 with covariance 0.38 when compared to ACI 318-14, IS:456-2000 and Bilinear methods.

V. CONCLUSION

From the study reported herein on short term deflections at service loads of high volume fly ash concrete beams and control beams was computed using different methods, and we can conclude that.

1. A program was designed to study the load-deflection behaviour of high volume Fly ash concrete beams and control beams under flexure.
2. The available codal equations were used to estimate the structural characteristics of the tested beams which include the load-deflection behaviour and short term deflections at service loads.
3. All the available formulae in various codes of practices including ACI 318, IS 456, Bilinear and EN1992 under estimate the deflections.
4. However, EN1992 method is able to estimate satisfactorily the deflection at service load and the average ratios of theoretical to experimental values is 1.24 with co-variance 0.38 when compared to ACI 318-14, IS:456-2000 and Bilinear methods.
5. Also the present study shows that the codal formula available for normal concrete beams can be applied for Fly ash concrete beams with a reasonable acceptance and no separate equations are necessary from the designer's point of view.
6. Thus the present study pointed out that the Fly ash can be used as replacement material in concrete for structural applications with a reasonable acceptance. And Fly ash can be effectively utilized as a structural material (up to 35 percent) in future.

7. The present field scenario demands sustainable technology .This is possible with the use of marginal materials like fly ash.
8. The present study endorses that fly ash can be used as a cement replacement.

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