Effect of High Volume Fly Ash Concrete on Instantaneous Deflection of RCC Beams

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Abstract— Fly ash is solid waste available all over the world and it is waste product obtained from thermal power plant. In my present work of interest I found short-time (instantaneous) deflection of high volume fly ash based RCC beams by different methods IS 456-2000, ACI 318-14, Bilinear, EN 1992, and Tension stiffing model and compared with experimental deflection and for same beams control approach has also been examined and the results are reported.

Key words: Analytical Methods, Comparisons, High Volume Fly Ash Concrete, Load Deflection Behaviour, Span-Depth Ratio

I. INTRODUCTION

As the foremost construction material across the world, concrete has a major determining role on the effects, good or bad, of construction on the environment. Concrete is the premier construction material across the world. Worldwide it is believed that up to 8% of carbon dioxide emissions are the result due to production of concrete. Every year in India 320 million tonne of cement, 12.6 billion tonne of raw materials and 115 million tonne of fly ash is produced. So clearly the production and use of concrete has a significant environmental impact such as global warming.

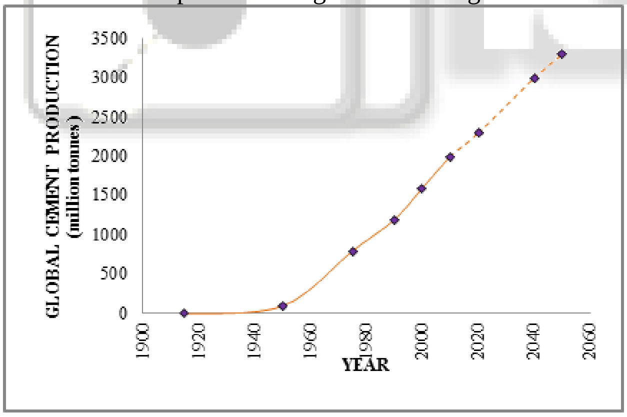

Fig. 1: Global hydraulic cement production (data from US Geological survey)

Global cement manufacture is growing, especially in developing countries and production, and the consequent energy requirement (fuel and electricity) and CO_2 emissions, could double by the middle of the century as shown in above figure.

Fly ash, like volcanic ash, is produced in, manmade small scale volcano like, furnaces of coal burning power plants. The fly ash has two types class F and class C, the costly and high carbon dioxide emission cement remains in the mix, the economic and environmental benefits associated with the utilization of fly ash. Use of these fly ash concrete improves the strength & durability then the normal concrete. This pozzolanic and cementitious material has very promising compressive strength, low carbon content, high glass content; higher electrical resistivity reduce the heat of hydration with finer particles. Use of this pozzolanic material save heavy amount of energy loss during the production of cement also economical and protect the environment by disposal the million tones of fly ash. By use this fly ash in concrete oppose the sulfate attack and thermal cracking, if concrete content more than 35% of fly ash then it is called as high volume fly ash HVFA concrete. Replacement with cement upto 60% done by some researchers and in India they replaced with cement upto 40% in road construction, present research shows we can replace cement upto 50% in structures.

In my present case of study is about how these normal concrete beam and high volume fly ash concrete beam behave under the action of loads, the structural performance of fly ash concrete beams (FA-CB), high volume fly ash concrete beams (HVFA-CB), Normal concrete beams (N-CB), subjected to pure-bending were studied and reported.

The fly as concrete beam (FA-CB), high volume fly ash concrete beam (HVFA-CB), Normal concrete beam (N-CB), are loaded under two point loads upto the failure. The fly ash content varied 0%, 10%, 20%, 30%, 40%, 50%, 60%, & 70% with replacement to cement and load verses deflection curves are determined.

The experimental data collected from different investigators Jinkyo F. Choo, Gum Sung Ryu, Sung Won Yoo (12-Beams)

- Mini Soman, Sobha.K (04-Beams)
- Sunilla George, Dr. R. Thenmozhi (18 Beams)
- B.K. Narendra, T.M Mahadeviah (30 Beams)

II. EXPERIMENTAL TEST PERFORMANCE

The experimental data collected for flexural behavior of HVFA concrete beams subjected to two point loads under the action of pure bending. For the beams under flexure find the load verses deflection curves for different beams of different percentage of steel and fly ash content.

III. ANALYTICAL METHODS

Five different methods of analysis using available codal practices and tension stiffening model are used. The computed deflections are compared with experimental data.

1) IS 456-2000 Method
2) ACI 318-14 Method
3) Bilinear Method
4) Euro code Method
5) Tension Stiffening Model

Span to effective depth ratio and depth require providing are calculated using the four different codes and these codes provides different parameters and equations.

1) IS 456-2000 METHOD

2) ACI 318-14 METHOD
3) BS EN 1992 METHOD
4) TSM METHOD

IV. RESULTS AND COMPARISON

Right away after getting experimental test results from different investigator for HVFA concrete beams. The load deflection curves were drawn for typical fly ash concrete beams and shown in figs 2-4.

Sl. No.	Investigator	Name of beam	ΔWe mm	IS-456 ΔWc mm	ACI 318-14 ΔWc mm	Bilinear ΔWc mm	EN-1992 ΔWc mm	TSM ΔWc mm
1	Jinkyo F. Choo, Gum Sung Ryu, Sung Won Yoo	00-40-L	7.40	15.80	6.06	16.74	4.17	8.95
2		35-40-L	7.90	15.95	6.07	16.42	4.09	8.99
3		50-40-L	7.50	16.72	6.44	18.32	4.57	9.51
4		00-40-H	8.50	16.30	6.35	18.92	13.00	9.43
5		35-40-H	8.50	15.88	6.16	18.06	12.40	9.14
6		50-40-H	9.00	16.76	6.55	19.81	13.61	9.74
7		00-60-L	9.00	14.24	5.47	15.05	6.43	8.09
8		35-60-L	6.50	14.13	5.43	14.96	6.39	8.03
9		50-60-L	9.50	16.20	6.21	17.32	7.40	9.19
10		00-60-H	10.00	15.31	5.96	17.71	18.57	8.86
11		35-60-H	9.50	15.49	6.04	17.97	18.85	8.97
12		50-60-H	9.50	16.37	6.37	18.92	19.84	9.46

Table 1: Experimental to the calculated working deflection for first investigator

Sl. No.	Investigator	Name of beam	ΔWe mm	IS-456 ΔWc mm	ACI 318-14 ΔWc mm	BILINEAR ΔWc mm	EN-1992 ΔWc mm	TSM ΔWc mm
1	Mini Soman, Sobha.K	FU1	2.10	7.14	2.44	7.33	2.46	4.15
2		OU1	1.90	5.51	1.92	5.51	2.46	3.28
3		FB1	3.10	5.53	2.12	6.30	3.25	3.3
4		OB1	4.40	4.13	1.58	4.56	3.26	2.46

Table 2: Experimental to the calculated working deflection for second investigator

Sl. No.	Investigator	Name of beam	ΔWe mm	IS-456 ΔWc mm	ACI 318-14 ΔWc mm	BILINEAR ΔWc mm	EN-1992 ΔWc mm	TSM ΔWc mm
1	Sunilla George, R. Thenmozhi	0-B1C1	4.10	3.37	1.41	3.46	3.65	2.43
2		10-B1F1	3.30	1.87	0.90	1.97	3.52	1.53
3		10-B1AF1	2.20	2.90	1.27	2.97	3.66	2.18
4		0-B1C1	3.50	3.07	1.32	3.15	3.65	2.27
5		20-B1F2	4.60	1.85	0.89	1.94	3.54	1.52
6		20-B1AF2	2.00	2.88	1.26	2.94	3.66	2.17
7		0-B1C1	3.40	3.07	1.32	3.15	3.65	2.27
8		30-B1F3	5.20	2.62	1.14	2.73	3.55	1.94
9		30-B1AF3	2.70	3.44	1.44	3.52	3.68	2.49
10		0-B1C1	3.50	3.07	1.32	3.15	3.65	2.27
11		40-B1F4	6.00	1.74	0.85	1.83	3.51	1.45
12		40-B1AF4	3.50	3.88	1.58	3.96	3.68	2.72
13		0-B1C1	3.80	3.07	1.32	3.15	3.65	2.27
14		50-B1F5	6.00	1.44	0.75	1.53	3.49	1.28
15		50-B1AF5	5.50	5.37	2.05	5.48	3.68	3.52
16		0-B1C1	3.80	3.22	1.37	3.30	3.65	2.35
17		60-B1F6	6.00	1.62	0.81	1.71	3.48	1.37
18		60-B1AF6	2.40	3.04	1.31	3.11	3.66	2.26

Table 3: Experimental to the calculated working deflection for third investigator

Sl. No.	Investigator	Name of beam	ΔWe mm	IS-456 ΔWc mm	ACI 318-14 ΔWc mm	Bilinear ΔWc mm	EN-1992 ΔWc mm	TSM ΔWc mm
1	B.K. Narendra, T.M Mahadeviah	FC-3A-28	9.12	8.25	3.14	8.56	7.31	4.93
2		FC-3B-28	8.65	8.50	3.23	8.89	7.28	5.08
3		FC-3C-28	8.27	8.26	3.14	8.57	7.31	4.93
4		FC-3C-28-1	6.35	7.95	1.64	7.50	4.21	7.03
5		FC-3C-28-2	9.47	7.86	3.19	7.87	6.10	5.25

6		FC-3C-28-4	10.09	9.11	3.50	10.16	7.83	5.50
7		NC-30-28	11.28	8.19	3.12	8.49	7.31	4.90
8		NC-30-28-1	3.78	6.35	1.45	5.89	4.21	6.28
9		NC-30-28-2	6.57	7.03	2.94	7.02	6.11	4.87
10		NC-30-28-4	9.85	9.86	3.79	11.07	7.87	5.95
11		FC-4A-28	6.28	9.73	3.73	10.76	7.91	5.85
12		FC-4B-28	4.89	9.72	3.72	10.74	7.92	5.85
13		FC-4B-28-1	3.71	4.95	1.08	4.44	4.04	5.81
14		FC-4B-28-2	6.38	9.62	3.65	9.82	6.89	5.78
15		FC-4B-28-4	5.76	9.14	3.52	10.39	8.47	5.54
16		FC-4C-28	4.5	9.84	3.78	10.98	7.92	5.93
17		NC-40-28	8.55	9.74	3.73	10.78	7.91	5.86
18		NC-40-28-1	4.39	5.01	1.11	4.51	4.04	5.81
19		NC-40-28-2	6.62	9.64	3.66	9.85	6.89	5.79
20		NC-40-28-4	6.61	9.18	3.54	10.46	8.43	5.56
21		FC-5A-28	6.79	9.61	3.70	10.81	8.62	5.81
22		FC-5B-28	5.52	9.65	3.71	10.87	8.59	5.83
23		FC-5B-28-1	3.06	3.90	0.69	3.32	3.83	5.71
24		FC-5B-28-2	5.12	10.47	3.93	10.62	6.85	6.32
25		FC-5B-28-4	6.32	9.09	3.52	10.58	9.43	5.55
26		FC-5C-28	4.4	9.00	3.47	10.14	8.50	5.45
27		NC-50-28	6.96	10.33	3.97	11.69	8.64	6.24
28		NC-50-28-1	3.98	3.89	0.68	3.31	3.57	5.71
29		NC-50-28-2	6.91	10.49	3.94	10.65	6.93	6.32
30		NC-50-28-4	6.52	9.10	3.52	10.59	9.56	5.55

Table 4 Experimental to the calculated working deflection for fourth investigator

Sl. No.	**Investigator**	**Name of beam**	**ΔW_e**	**IS-456**	**ACI 318-14**	**Bilinear**	**EN-1992**	**TSM**
			mm	**$\Delta W_c / \Delta W_e$**	**$\Delta W_c / \Delta W_e$**	**$\Delta W_c / \Delta W_e$**	**$\Delta W_c / \Delta W_e$**	**$\Delta W_c / \Delta W_e$**
1	Jinkyo F. Choo, Gum Sung Ryu, Sung Won Yoo	00-40-L	7.40	2.13	0.82	2.26	1.87	1.21
2		35-40-L	7.90	2.00	0.77	2.12	1.75	1.13
3		50-40-L	7.50	2.11	0.81	2.23	1.84	1.19
4		00-40-H	8.50	1.86	0.71	1.97	1.63	1.05
5		35-40-H	8.50	1.86	0.71	1.97	1.63	1.05
6		50-40-H	9.00	1.76	0.67	1.86	1.54	0.99
7		00-60-L	9.00	1.76	0.67	1.86	1.54	0.99
8		35-60-L	6.50	2.43	0.93	2.58	2.13	1.38
9		50-60-L	9.50	1.66	0.64	1.76	1.46	0.94
10		00-60-H	10.00	1.58	0.61	1.67	1.38	0.90
11		35-60-H	9.50	1.66	0.64	1.76	1.46	0.94
12		50-60-H	9.50	1.66	0.64	1.76	1.46	0.94
			$\bar{X}$	**1.87**	**0.72**	**1.98**	**1.64**	**1.06**
			CV	**12.87**	**12.87**	**12.87**	**12.87**	**12.87**

Table 5: For first investigator ratios of calculated to the experimental deflection at working load

Sl. No.	**Investigator**	**Name of beam**	**ΔW_e**	**IS-456**	**ACI 318-14**	**Bilinear**	**EN-1992**	**TSM**
			mm	**$\Delta W_c / \Delta W_e$**	**$\Delta W_c / \Delta W_e$**	**$\Delta W_c / \Delta W_e$**	**$\Delta W_c / \Delta W_e$**	**$\Delta W_c / \Delta W_e$**
1	Mini Soman, Sobha.K	FU1	2.10	7.14	2.44	7.33	2.46	4.15
2		OU1	1.90	5.51	1.92	5.51	2.46	3.28
3		FB1	3.10	5.53	2.12	6.30	3.25	3.30
4		OB1	4.40	4.13	1.58	4.56	3.26	2.46
			$\bar{X}$	**5.58**	**2.01**	**5.92**	**2.86**	**3.30**
			CV	**19.12**	**15.47**	**17.19**	**13.88**	**18.09**

Table 6: For second investigator ratios of calculated to the experimental deflection at working load

Sl. No.	**Investigator**	**Name of beam**	**ΔW_e**	**IS-456**	**ACI 318-14**	**BILINEAR**	**EN-1992**	**TSM**
			mm	**$\Delta W_c / \Delta W_e$**	**$\Delta W_c / \Delta W_e$**	**$\Delta W_c / \Delta W_e$**	**$\Delta W_c / \Delta W_e$**	**$\Delta W_c / \Delta W_e$**
1	Sunilla George, R. Thenmozhi	0-B1C1	4.10	3.37	1.41	3.46	3.65	2.43
2		10-B1F1	3.30	1.87	0.90	1.97	3.52	1.53

3		10-B1AF1	2.20	2.90	1.27	2.97	3.66	2.18
4		0-B1C1	3.50	3.07	1.32	3.15	3.65	2.27
5		20-B1F2	4.60	1.85	0.89	1.94	3.54	1.52
6		20-B1AF2	2.00	2.88	1.26	2.94	3.66	2.17
7		0-B1C1	3.40	3.07	1.32	3.15	3.65	2.27
8		30-B1F3	5.20	2.62	1.14	2.73	3.55	1.94
9		30-B1AF3	2.70	3.44	1.44	3.52	3.68	2.49
10		0-B1C1	3.50	3.07	1.32	3.15	3.65	2.27
11		40-B1F4	6.00	1.74	0.85	1.83	3.51	1.45
12		40-B1AF4	3.50	3.88	1.58	3.96	3.68	2.72
13		0-B1C1	3.80	3.07	1.32	3.15	3.65	2.27
14		50-B1F5	6.00	1.44	0.75	1.53	3.49	1.28
15		50-B1AF5	5.50	5.37	2.05	5.48	3.68	3.52
16		0-B1C1	3.80	3.22	1.37	3.30	3.65	2.35
17		60-B1F6	6.00	1.62	0.81	1.71	3.48	1.37
18		60-B1AF6	2.40	3.04	1.31	3.11	3.66	2.26
			$\bar{X}$	**2.86**	**1.24**	**2.95**	**3.61**	**2.13**
			CV	**32.07**	**24.89**	**31.11**	**1.94**	**25.19**

Table 7: For third investigator ratios of calculated to the experimental deflection at working load

Sl. No.	**Investigator**	**Name of beam**	**ΔW_e**	**IS-456**	**ACI 318-14**	**Bilinear**	**EN-1992**	**TSM**
			mm	**ΔW_c / ΔWe**	**ΔW_c / ΔWe**	**ΔW_c / ΔWe**	**ΔW_c / ΔWe**	**ΔW_c / ΔWe**
1		FC-3A-28	9.12	8.25	3.14	8.56	7.31	4.93
2		FC-3B-28	8.65	8.50	3.23	8.89	7.28	5.08
3		FC-3C-28	8.27	8.26	3.14	8.57	7.31	4.93
4		FC-3C-28-1	6.35	7.95	1.64	7.50	4.21	7.03
5		FC-3C-28-2	9.47	7.86	3.19	7.87	6.10	5.25
6		FC-3C-28-4	10.09	9.11	3.50	10.16	7.83	5.50
7		NC-30-28	11.28	8.19	3.12	8.49	7.31	4.90
8		NC-30-28-1	3.78	6.35	1.45	5.89	4.21	6.28
9		NC-30-28-2	6.57	7.03	2.94	7.02	6.11	4.87
10		NC-30-28-4	9.85	9.86	3.79	11.07	7.87	5.95
11		FC-4A-28	6.28	9.73	3.73	10.76	7.91	5.85
12		FC-4B-28	4.89	9.72	3.72	10.74	7.92	5.85
13		FC-4B-28-1	3.71	4.95	1.08	4.44	4.04	5.81
14		FC-4B-28-2	6.38	9.62	3.65	9.82	6.89	5.78
15	B.K. Narendra, T.M Mahadeviah	FC-4B-28-4	5.76	9.14	3.52	10.39	8.47	5.54
16		FC-4C-28	4.5	9.84	3.78	10.98	7.92	5.93
17		NC-40-28	8.55	9.74	3.73	10.78	7.91	5.86
18		NC-40-28-1	4.39	5.01	1.11	4.51	4.04	5.81
19		NC-40-28-2	6.62	9.64	3.66	9.85	6.89	5.79
20		NC-40-28-4	6.61	9.18	3.54	10.46	8.43	5.56
21		FC-5A-28	6.79	9.61	3.70	10.81	8.62	5.81
22		FC-5B-28	5.52	9.65	3.71	10.87	8.59	5.83
23		FC-5B-28-1	3.06	3.90	0.69	3.32	3.83	5.71
24		FC-5B-28-2	5.12	10.47	3.93	10.62	6.85	6.32
25		FC-5B-28-4	6.32	9.09	3.52	10.58	9.43	5.55
26		FC-5C-28	4.4	9.00	3.47	10.14	8.50	5.45
27		NC-50-28	6.96	10.33	3.97	11.69	8.64	6.24
28		NC-50-28-1	3.98	3.89	0.68	3.31	3.57	5.71
29		NC-50-28-2	6.91	10.49	3.94	10.65	6.93	6.32
30		NC-50-28-4	6.52	9.10	3.52	10.59	9.56	5.55
			$\bar{X}$	**8.45**	**3.06**	**8.98**	**7.02**	**5.70**
			CV	**21.77**	**33.35**	**26.76**	**24.48**	**8.31**

Table 8: For fourth investigator ratios of calculated to the experimental deflection at working load

Sl. No.	**Investigator**	**Number of beams**		**IS-456 Method**	**ACI 318-14 Method**	**Bilinear Method**	**EN-1992 Method**	**Tension Stiffening Model**
1	Jinkyo F. Choo,	12	$\bar{X}$	1.87	0.72	1.98	1.64	1.06

	Gum Sung Ryu, Sung Won Yoo		CV	12.87	12.87	12.87	12.87	12.87
2	Mini Soman, Sobha.K	4	$\bar{X}$	5.58	2.01	5.92	2.86	3.30
			CV	19.12	15.47	17.19	13.88	18.09
3	Sunilla George, R. Thenmozhi	18	$\bar{X}$	2.86	1.24	2.95	3.61	2.13
			CV	32.07	24.89	31.11	1.94	25.19
4	B.K. Narendra, T.M Mahadeviah	30	$\bar{X}$	8.45	3.06	8.98	7.02	5.70
			CV	21.77	33.35	26.76	24.48	8.31
For all Investigators		64	$\bar{X}$	1.36	0.51	1.45	1.23	0.91
			CV	43.52	43.48	45.01	35.64	41.50

Table 9: Abstract of total 64 beams

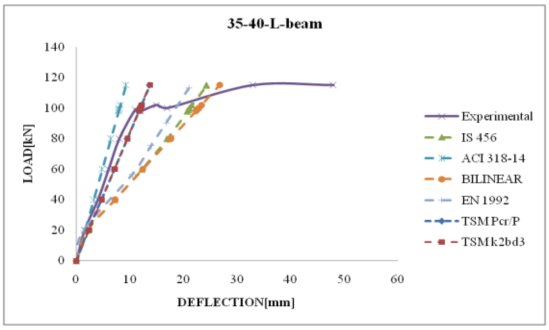

Fig. 2: Comparison of deflection at working load from various codes

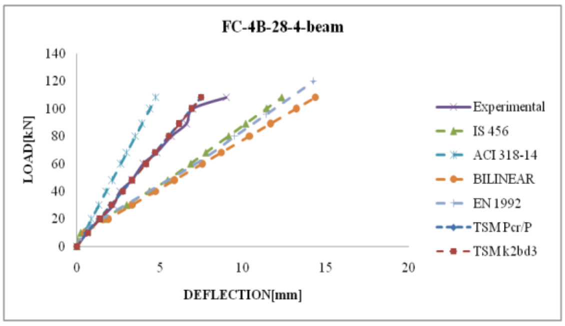

Fig. 4: Comparison of deflection at working load from various codes

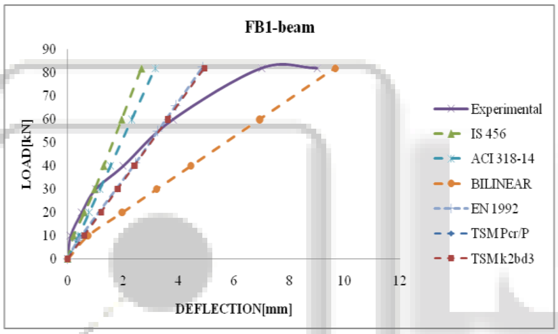

Fig. 3: Comparison of deflection at working load from various codes

Sl. No.	Investigator	Name of beam	l/d Provided	l/d required using IS-456	l/d required using ACI 318-14	l/d required using EN-1992	l/d required using TSM
1	Jinkyo F. Choo, Gum Sung Ryu, Sung Won Yoo	00-40-L	12.80	19.00	16.18	13.98	6.53
2		35-40-L	12.80	19.00	16.18	14.86	6.72
3		50-40-L	12.80	19.00	16.18	13.32	6.22
4		00-40-H	12.80	16.00	16.18	12.80	6.44
5		35-40-H	12.80	16.00	16.18	13.32	6.68
6		50-40-H	12.80	16.00	16.18	12.39	6.21
7		00-60-L	12.80	18.00	16.18	14.42	7.04
8		35-60-L	12.80	18.00	16.18	14.32	7.03
9		50-60-L	12.80	18.00	16.18	14.74	6.82
10		00-60-H	12.80	16.00	16.18	13.18	6.91
11		35-60-H	12.80	16.00	16.18	13.12	6.86
12		50-60-H	12.80	16.00	16.18	13.39	6.82

Table 10: l/d ratio for first investigator

Sl. No.	Investigator	Name of beam	l/d Provided	l/d required using IS-456	l/d required using ACI 318-14	l/d required using EN-1992	l/d required using TSM
1	Mini Soman, Sobha.K	FU1	8.15	16.00	16.12	20.49	6.10
2		OU1	8.15	16.00	16.12	20.72	6.61
3		FB1	8.15	18.00	16.12	15.22	6.20
4		OB1	8.15	18.00	16.12	15.32	6.84

Table 11: l/d ratio for second investigator

Sl. No.	Investigator	Name of beam	l/d Provided	l/d required using IS-456	l/d required using ACI 318-14	l/d required using EN-1992	l/d required using TSM
1	Sunilla George, R. Thenmozhi	0-B1C1	8.33	18.00	16.12	15.69	7.04
2		10-B1F1	8.33	18.00	16.12	14.26	7.85
3		10-B1AF1	8.33	18.00	16.12	15.81	7.32
4		0-B1C1	8.33	18.00	16.12	15.69	7.20
5		20-B1F2	8.33	18.00	16.12	14.37	7.89
6		20-B1AF2	8.33	18.00	16.12	15.90	7.34
7		0-B1C1	8.33	18.00	16.12	15.69	7.20
8		30-B1F3	8.33	18.00	16.12	14.40	7.29
9		30-B1AF3	8.33	18.00	16.12	16.05	7.05
10		0-B1C1	8.33	18.00	16.12	15.69	7.20
11		40-B1F4	8.33	18.00	16.12	14.18	7.96
12		40-B1AF4	8.33	18.00	16.12	16.09	6.84
13		0-B1C1	8.33	18.00	16.12	15.69	7.20
14		50-B1F5	8.33	18.00	16.12	14.09	8.26
15		50-B1AF5	8.33	18.00	16.12	16.12	6.29
16		0-B1C1	8.33	18.00	16.12	15.69	7.12
17		60-B1F6	8.33	18.00	16.12	14.04	8.06
18		60-B1AF6	8.33	18.00	16.12	15.85	7.24

Table 5.12: l/d ratio for third investigator

Sl. No.	Investigator	Name of beam	l/d Provided	l/d required using IS-456	l/d required using ACI 318-14	l/d required using EN-1992	l/d required using TSM
1	B.K. Narendra, T.M Mahadeviah	FC-3A-28	10.00	19.00	16.12	15.22	6.51
2		FC-3B-28	10.00	19.00	16.12	15.08	6.42
3		FC-3C-28	10.00	19.00	16.12	15.21	6.51
4		FC-3C-28-1	10.00	28.00	16.12	44.94	7.00
5		FC-3C-28-2	10.00	22.00	16.12	18.31	6.70
6		FC-3C-28-4	10.00	18.00	16.12	14.14	6.19
7		NC-30-28	10.00	19.00	16.12	15.23	6.53
8		NC-30-28-1	10.00	28.00	16.12	45.40	7.28
9		NC-30-28-2	10.00	22.00	16.12	18.52	6.89
10		NC-30-28-4	10.00	18.00	16.12	14.22	6.04
11		FC-4A-28	10.00	18.00	16.12	14.72	6.17
12		FC-4B-28	10.00	18.00	16.12	14.75	6.18
13		FC-4B-28-1	10.00	28.00	16.12	53.11	7.61
14		FC-4B-28-2	10.00	20.00	16.12	16.71	6.35
15		FC-4B-28-4	10.00	17.00	16.12	14.05	6.27
16		FC-4C-28	10.00	18.00	16.12	14.42	6.09
17		NC-40-28	10.00	18.00	16.12	14.70	6.17
18		NC-40-28-1	10.00	28.00	16.12	52.23	7.59
19		NC-40-28-2	10.00	20.00	16.12	16.66	6.34
20		NC-40-28-4	10.00	17.00	16.12	13.97	6.25
21		FC-5A-28	10.00	17.00	16.12	14.73	6.32
22		FC-5B-28	10.00	17.00	16.12	14.63	6.29
23		FC-5B-28-1	10.00	28.00	16.12	70.52	7.91
24		FC-5B-28-2	10.00	20.00	16.12	18.27	6.35
25		FC-5B-28-4	10.00	16.00	16.12	13.93	6.45
26		FC-5C-28	10.00	17.00	16.12	14.37	6.38
27		NC-50-28	10.00	17.00	16.12	14.77	6.18
28		NC-50-28-1	10.00	28.00	16.12	70.69	7.91
29		NC-50-28-2	10.00	20.00	16.12	18.22	6.34
30		NC-50-28-4	10.00	16.00	16.12	13.92	6.45

Table 13: l/d ratio for fourth investigator

Sl.	Investigator	Name of	l/d	l/d required	l/d required	l/d required	l/d required

No.		beam	Provided	using IS-456	using ACI 318-14	using EN-1992	using TSM
1	Jinkyo F. Choo, Gum Sung Ryu, Sung Won Yoo	00-40-L	250.00	168.42	197.71	228.82	489.91
2		35-40-L	250.00	168.42	197.71	215.39	476.54
3		50-40-L	250.00	168.42	197.71	240.31	514.10
4		00-40-H	250.00	200.00	197.71	250.05	496.93
5		35-40-H	250.00	200.00	197.71	240.19	479.23
6		50-40-H	250.00	200.00	197.71	248.17	515.00
7		00-60-L	250.00	177.78	197.71	221.93	454.59
8		35-60-L	250.00	177.78	197.71	223.42	454.93
9		50-60-L	250.00	177.78	197.71	217.14	469.47
10		00-60-H	250.00	200.00	197.71	242.76	463.30
11		35-60-H	250.00	200.00	197.71	243.89	466.50
12		50-60-H	250.00	200.00	197.71	239.07	469.17

Table 14: Effective Depth d for first investigator

Sl. No.	Investigator	Name of beam	l/d Provided	l/d required using IS-456	l/d required using ACI 318-14	l/d required using EN-1992	l/d required using TSM
1	Mini Soman, Sobha.K	FU1	135.00	68.75	68.26	53.70	180.30
2		OU1	135.00	68.75	68.26	53.08	166.42
3		FB1	135.00	61.11	68.26	72.29	177.54
4		OB1	135.00	61.11	68.26	71.79	160.73

Table 15: Effective Depth d for second investigator

Sl. No.	Investigator	Name of beam	l/d Provided	l/d required using IS-456	l/d required using ACI 318-14	l/d required using EN-1992	l/d required using TSM
1	Sunilla George, R. Thenmozhi	0-B1C1	180.00	83.33	93.08	95.60	213.16
2		10-B1F1	180.00	83.33	93.08	105.16	191.20
3		10-B1AF1	180.00	83.33	93.08	94.87	205.02
4		0-B1C1	180.00	83.33	93.08	95.60	208.37
5		20-B1F2	180.00	83.33	93.08	104.40	190.22
6		20-B1AF2	180.00	83.33	93.08	94.36	204.42
7		0-B1C1	180.00	83.33	93.08	95.60	208.37
8		30-B1F3	180.00	83.33	93.08	104.15	205.90
9		30-B1AF3	180.00	83.33	93.08	93.45	212.86
10		0-B1C1	180.00	83.33	93.08	95.60	208.37
11		40-B1F4	180.00	83.33	93.08	105.79	188.45
12		40-B1AF4	180.00	83.33	93.08	93.25	219.21
13		0-B1C1	180.00	83.33	93.08	95.60	208.37
14		50-B1F5	180.00	83.33	93.08	106.44	181.64
15		50-B1AF5	180.00	83.33	93.08	93.05	238.41
16		0-B1C1	180.00	83.33	93.08	95.60	210.79
17		60-B1F6	180.00	83.33	93.08	106.83	186.07
18		60-B1AF6	180.00	83.33	93.08	94.61	207.19

Table 16: Effective Depth d for third investigator

Sl. No.	Investigator	Name of beam	l/d Provided	l/d required using IS-456	l/d required using ACI 318-14	l/d required using EN-1992	l/d required using TSM
1	B.K. Narendra, T.M Mahadeviah	FC-3A-28	225.00	118.42	139.62	147.87	345.51
2		FC-3B-28	225.00	118.42	139.62	149.19	350.27
3		FC-3C-28	225.00	118.42	139.62	147.96	345.68
4		FC-3C-28-1	225.00	80.36	139.62	50.07	321.30
5		FC-3C-28-2	225.00	102.27	139.62	122.92	336.01
6		FC-3C-28-4	225.00	125.00	139.62	159.11	363.73
7		NC-30-28	225.00	118.42	139.62	147.70	344.62
8		NC-30-28-1	225.00	80.36	139.62	49.56	309.07
9		NC-30-28-2	225.00	102.27	139.62	121.51	326.45
10		NC-30-28-4	225.00	125.00	139.62	158.24	372.33

11		FC-4A-28	225.00	125.00	139.62	152.81	364.40
12		FC-4B-28	225.00	125.00	139.62	152.49	363.91
13		FC-4B-28-1	225.00	80.36	139.62	42.37	295.71
14		FC-4B-28-2	225.00	112.50	139.62	134.63	354.56
15		FC-4B-28-4	225.00	132.35	139.62	160.15	358.68
16		FC-4C-28	225.00	125.00	139.62	156.05	369.59
17		NC-40-28	225.00	125.00	139.62	153.07	364.81
18		NC-40-28-1	225.00	80.36	139.62	43.08	296.39
19		NC-40-28-2	225.00	112.50	139.62	135.04	355.09
20		NC-40-28-4	225.00	132.35	139.62	161.05	360.23
21		FC-5A-28	225.00	132.35	139.62	152.77	356.28
22		FC-5B-28	225.00	132.35	139.62	153.78	357.82
23		FC-5B-28-1	225.00	80.36	139.62	31.91	284.59
24		FC-5B-28-2	225.00	112.50	139.62	123.12	354.20
25		FC-5B-28-4	225.00	140.63	139.62	161.49	348.73
26		FC-5C-28	225.00	132.35	139.62	156.59	352.83
27		NC-50-28	225.00	132.35	139.62	152.30	364.36
28		NC-50-28-1	225.00	80.36	139.62	31.83	284.50
29		NC-50-28-2	225.00	112.50	139.62	123.51	354.67
30		NC-50-28-4	225.00	140.63	139.62	161.69	349.08

Table 17: Effective Depth d for fourth investigator

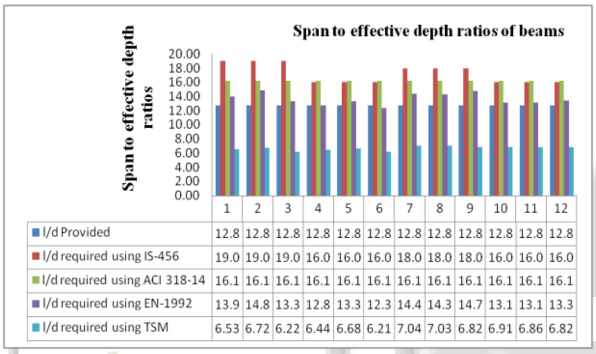

Fig. 5: Span to effective depth ratios for first investigator

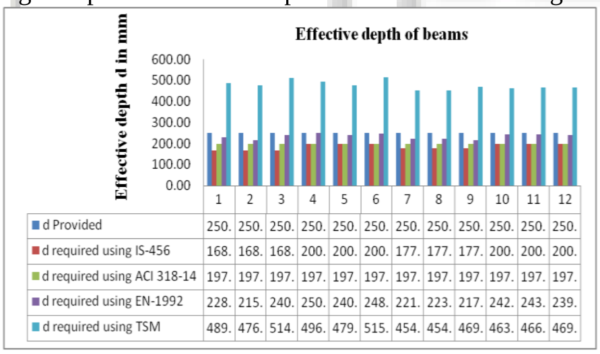

Fig. 6: Effective depth d for first investigator

From figure above it can be concluded that effective depth provided is more than required calculated from IS 456-2000, ACI 318-14, EN-1992 but from TSM it is quite large because as it is does not provide any clarification regarding use of percentage of steel or grade of steel in the equations used by TSM.

It is found that effective depth d provided is greater than required depth calculated from different method except TSM which is quite high because as it does not give clarification regarding the grade of steel or percentage of steel in the equations.

From table 9 it can be concluded that tension stiffening model (TSM) is the best method to calculate deflection at working load, because the average ratio $\overline{X}$ is 0.91 and covariance CV is 0.4150 compare to other methods.

From fig 2-4 as it can be clearly seen that the TSM curve is close to experimental curve, in other word experimental deflections are very close to theoretically calculated deflections by TSM method compare to other methods.

V. CONCLUSIONS

This analytical study evaluates effect of high volume fly ash (HVFA) on the flexural performance of RCC beams which intern affect on instantaneous deflection of RCC beam at service load same is compared with experimental results, total 64 beams data collected from different investigators with varying percentage of fly ash, tensile steel ratio, grade of concrete, grade of steel and structural configuration. L/d ratio and effective depth d is calculated for same 64 beams. The following conclusions drawn from the analytical and experimental results.

– An experimental data collected from different investigators who done research on flexural behaviour of HVFA concrete beams.
– Five different methods are used (IS 456-2000, ACI 318-14, Bilinear method, EN 1992, and Tension Stiffening Model) to study load-deflection of HVFA concrete beams,
– Four different methods are used (IS 456-2000, ACI 318-14, EN 1992, and Tension Stiffening Model) to calculate Span by depth ratios and effective depth.
– Comparing experimental and analytical results of short-time deflection of HVFA concrete beams, it can be concluded that the Tension Stiffening Model is best method to calculate the deflection at service load.
– It is also predicted that TSM is very close to experimental data collected at various load levels.
– It is also predicted that in TSM by replacing M_{cr}/M_w by P_{cr}/P_w in the effective moment of inertia equation we get well defined non-linear curve.

– Same deflection equations are used to calculate deflection of HVFA concrete beams as used for normal concrete beam, no separate equations are needed.

REFERENCE

[1] Jinkyo F. Choo, Gum Sung Ryu, Sung Won Yoo "Evaluation of the effect of the HVFA on the flexural behavior of RCC beams" Construction and Building Materials-2015. Vol. 47 PP. 1132-1144
[2] T Srinivas and N V Ramana Rao "A Study on Flexural behaviour of RCC beams containing HVFA" Journal of mechanical and civil engineering – 2015. Vol. 12 Issue4 Ver V (Jul-Aug 2015) PP. 35-40
[3] Mini Soman Sobha.K "Strength and Behaviour of HVFA concrete" International journals of innovation research in science, engineering and technology – 2014. Vol.3 Issue 5 May 2014 PP 12416-12424
[4] B.K. Narendra, T.M Mahadeviah " Flexural behavior of Reinforced FA Concrete in comparison to reinforced normal concrete beam in term of load deflection" International journals of Engineering and Advance Technology, volume 4, Issue-2 December 2014. PP 45-51
[5] Abins Aziz, Jessy Rooby, P.S Joanna "Effect of superplasticizer on the behavior of FA concrete beam in flexure" International journals for Science Research & Development Vol. 2, Issue 01 2014, PP. 152-155
[6] Putte Gowda B.S, Aswath M.U, and Muthu K.U " Experimental study on flexural behaviour of FA concrete beams' International journals of Advanced Scientific and Technical Research Issue 3 Volume 2 March-April 2013, PP. 184-199
[7] N Gurumoorthy, C Jaideep, "Performance Evaluation of Critical J-Integral J1c With High Volume Fly Ash Concrete" International journals of Engineering Trend and Technology, Volume 4 Issue 4 April 2013, PP. 815-820
[8] Sunilla George, R. Thenmozhi " Flexural behaviour of activated fly ash concrete" International journals of Engineering Science and Technology, vol. 3 No. 10 October 2011. PP. 7633-7642
[9] Narendra H, Muthu K.U, VijayAnand M, and Ganesh S, "Short-term Deflection of SCC beams using tension stiffening model" Innovation in Building Materials, Structural Designs and Construction Practices, IBMSDCP-08 Sathyamangalam, May 2008 PP. 952-957
[10] Arivalagan S, "Flexural behaviour of Reinforced fly ash concrete beams" International journals of Structural and Civil Engineering, Volume 1 Issue 1 PP.11-17