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Behaviour Of Fly Ash Concrete Slabs Containing Higher Levels Of Fly Ash

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Abstract:

The suitability of Fly ash concrete as a structural material can be accepted only when its behaviour along with embedded steel proves to be satisfactory. Earlier research works have been done on strength and durability aspects; however there are limited research studies on fly ash concrete slabs. A reinforced concrete two-way slab is an important structural element in civil engineering practice. The present investigations are conducted with a view to evaluate the behaviour of fly ash concrete slabs containing higher levels of replacement of cement by fly ash in comparison with normal concrete. Tests were conducted on two way square slabs of M40 grade concrete with 50% and 60% fly ash replacement, with simply supported and restrained end conditions. The results clearly demonstrated that the fly ash concrete need extended curing period. The slabs tested have shown enhanced load carrying capacity beyond the computed Johansen's load and all the slabs follow linear behavior up to 35% of the ultimate load with reduced stiffness after the cracking loads till ultimate failure.

Key words: *High volume fly ash concrete, simply supported slabs, restrained slabs,load deflection behaviour, cracking of slabs*

1.Introduction

Use of Fly ash as part replacement of cement and as an admixture has been recommended by IS: 456-2000 and IS: 3812-2003. The policy of replacing cement by industrial by-products such as Fly ash has manifold advantage; utilization of industrial waste in an economical way, preserving resources and improvements in the properties of concrete leading to sustainable development (Prabir C Basu et.al 2005). However concrete can never be used in isolation as a structural material (because of its low tensile strength) without incorporating reinforcing steel particularly when a structural component is subjected to tensile stresses where in tensile stresses are encountered in flexure or bending. In structures, we hardly find any structural component that is devoid of flexure. The suitability of Fly ash concrete as a structural material can be accepted only when its behaviour along with embedded steel proves to be satisfactory. Therefore the present work is taken up to study the Flexural behaviour of reinforced Fly ash concrete slabs.

The present study comprises of two parts. In the first part, mix design of high volume fly ash concrete of compressive strength of 40 MPa [150x150mm cubes] was taken up .This was done by replacing cement by fly ash with varying percentages (50% and 60% of fly ash). Studies were carried out on compressive strength at different ages.

The second part is concerned with the flexural behaviour of reinforced Fly ash concrete slabs. The experimental investigation has been carried out on Fly Ash concrete slabs for a particular design mix M40. Ten number of slabs(1000mm×1000mm×60mm) were casted by replacing cement by 0%, 50%, 60% fly ash. The slabs were tested under uniformly distributed load for both simply supported and fixed at all the edges and the behaviour was studied. The effective span of the square slab considered was 0.77 m. Test results are presented in terms of load deflection behaviour, crack width and crack propagation. It is hoped that the present investigation helps in better utilization of Fly ash concrete as a structural material.

2.Experimental Programme

Portland Cement Concrete proportioned to have 28 days strength of 40 Mpa was used as a reference mix and in addition to reference mix other two mixes are proportioned with incorporation of fly ash from Raichur thermal power plant to have cement replacement levels of 50% and 60%. Tests were planned to evaluate the behaviour of fly ash reinforced concrete slabs.

2.1. Materials Used

2.1.1.Cement

Ordinary Portland cement of 53 grade [Birla super plus] confirming to IS: 12269-1987 has been used. The results of the physical properties of the cement are tabulated in Table 1

Sl. No.	Properties	Values obtained	Requirements as per IS: 12269-1987
1	Fineness	2.5%	Not more than 10%
2	Soundness	1 mm	Not more than 10mm
3	Setting Time: Initial	80 min	Not less than 30 min
	Final	410 min	Not more than 600 min
4	Compressive strength: 3 days	41 N/mm^2	Not less than 27 N/mm^2
	7 days	45 N/mm^2	Not less than 37 N/mm^2
	28 days	56 N/mm^2	Not less than 53 N/mm^2
5	Standard consistency	31%	------
6	Specific gravity	3.15	------

Table1: Physical properties of cement

2.1.2 Fly Ash

Fly ash collected from the 6th hopper from the Raichur Thermal Power Plant was used. The chemical and physical composition of the fly ash was determined as per IS: 3812-Table 2.

Sl. No.	Test Conducted	Results	Requirement as per IS:3812:2003			
			Part 1		Part 2	
			Siliceous Pulverized Fuel Ash %	Calcareous Pulverized Fuel Ash %	Siliceous Pulverized Fuel Ash %	Calcareous Pulverized Fuel Ash %
1.	Silicon dioxide (SiO_2) plus aluminium oxide ($Al2O_3$) plus iron oxide (Fe_2O_3), percent by mass,(Minimum)	94.68	70.0	50.0	70.0	50.0
2.	Silicon dioxide (SiO_2), Percent by mass, (Minimum)	61.90	35.0	25.0	35.0	25.0
3.	Magnesium oxide (MgO) percent by mass,(Maximum)	0.79	5.0	5.0	5.0	5.0
4.	Total sulphur as sulphur trioxide (SO3),percent by mass,(Maximum)	0.13	3.0	3.0	5.0	5.0
5.	Loss on ignition ,percent by mass, (Maximum)	0.47	5.0	5.0	5.0	5.0

Table2: Chemical Composition of Fly Ash

Sl. No	Test conducted	Results	Requirement as per IS:3812:2003	
			Part 1	Part 2
1.	Specific gravity	2.03	---	---
2.	Fineness–Specific surface in m^2/kg by Blaine's Air-permeability method,(Minimum)	469.0	320	200
3.	Lime reactivity –Average compressive strength in N/mm^2, (Minimum).	4.6	4.5	---
4.	Comparative Compressive Strength at 28 days, percent, [illegible]	90.0	Not less than 80% of the strength to plain [illegible]	---
5.	Soundness by Autoclave Test Expansion of specimens , percent,(Maximum)	0.0025	0.8	0.8
6.	Residue on 45 micron sieve, percent,(Maximum)	27.7	34	50

Table 3: Physical Composition of Fly Ash

2.1.3.<u>Fine Aggregates</u>

Natural river sand passing through IS sieve 4.75 mm was used .the specific gravity and fineness modulus was 2.60and 2.71

2.1.4.<u>Coarse Aggregate</u>

Crushed angular granite passing through 20 mm and retained on 10 mm sieve was used the specific gravity and fineness modulus was 2.7 and 6.816

2.1.5.<u>Superplasticizer</u>

To enhance workability Super plasticizer Conplast SP-430 a product from FOSROC chemicals conforming to IS: 9103-1999 has been used.

Mix	Cement (Kg/m^3)	Fine aggregates (Kg/m^3)	Coarse aggregate (Kg/m^3)	Water (Lts/m^3)
NM	370	629.27	1305	148
Ratio	1.00	1.70	3.53	0.40

Table 4: Mix proportion of Normal Concrete

Mix	Cement (Kg/m3)	Fly ash (Kg/m3)	Fine aggregate (Kg/m3)	Coarse aggregate (Kg/m3)	Water (Lts/m3)	Admixture SP-430 (Lts/m3)
M-1	268.25	268.25	664.07	1001.47	148	8.79
M-2	236.80	355.20	648.49	948.78	148	9.70

Table 5: Mix proportion Fly Ash Concrete

Grade	Age	Normal Concrete N/mm^2	M-1-50% N/mm^2	M-2-60% N/mm^2
M40	7 days	31.91	22.18	16.0
	28 days	47.32	40.26	29.06
	56 days	55.16	47.18	40.12
	91 days	58.22	54.62	48.36

Table: 6 Test Results of Cube Compressive Strength

3.Preparation And Testing Of Slab Specimens

3.1 Casting Of Slab Specimens For Flexural Test

To carry out experimental programme a total of 10 slab specimens were casted and moist cured using gunny bags for 91 days .The M40 grade concrete obtained from the mix design, mixed in hand driven concrete mixer. The form work used for casting of specimens was of wooden fabricated with accurate dimensions especially for the study as a first step installation of reinforcements into the formwork was completed as shown in the fig 5.3, and then the thoroughly mixed concrete was poured in layers and vibrated After each layer was poured it was compacted by hand. The top surface of the slab was finished using trowel. The concrete was allowed to set for 24 hours and then the formwork was removed carefully and the specimens was allowed for moist curing with gunny bags for a period of 91 days. Along with each slab together 12 cubes were casted from the same batch of concrete.

A total of 10 specimens were casted .All slabs were designed as 2 way slabs having same cross section area[1m×1m] with different reinforcement details for simply supported and fixed end conditions respectively.

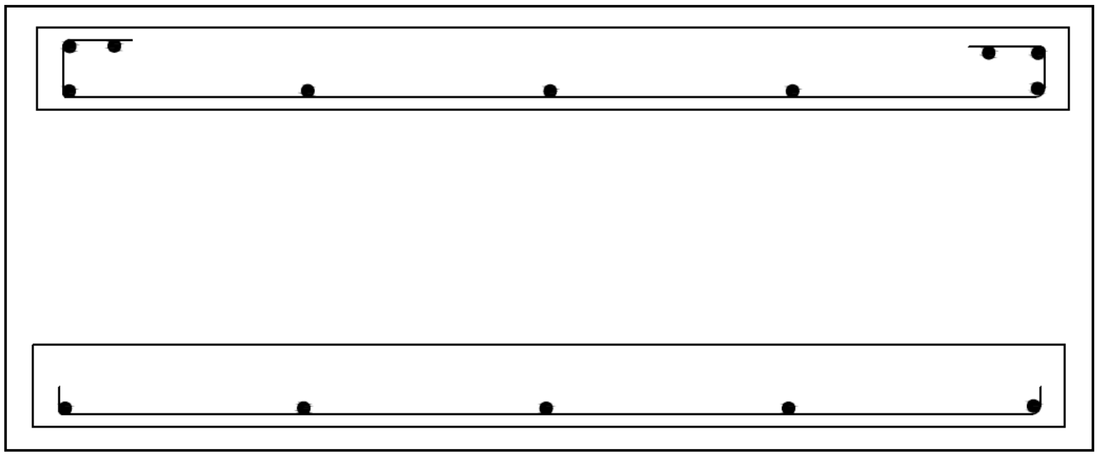

Figure 1: Reinforcement Details of Fixed and Simply supported Slabs

3.2.Testing Of Slab Specimens

Ten slab specimen of size 1000X1000X60mm with similar loading and different support conditions were designed using limit state concept. 5 numbers of 8mm dia bars were provided in both the directions and inclusive of edge strip only for fixed end conditions .All four edges were roller supports with bearing of 115 mm. The specimen was also painted with lime wash in order to easily note the crack pattern of the specimen. The setup was carried out with 25 Tonnes loading frame, a 100 tonnes loading jack was fixed on top of the specimen to apply load. A proving ring was also fixed above the loading jack which was connected to a measure the load increments. Set of angle sections were provided on top of the specimen to transfer the load from loading jack to the specimen uniformly. C-clamp and nut and bolt arrangement was used to achieve the fixity condition on all the four sides of the slab. The figure 5.4 and 5.5 shows the test setup for both support conditions.

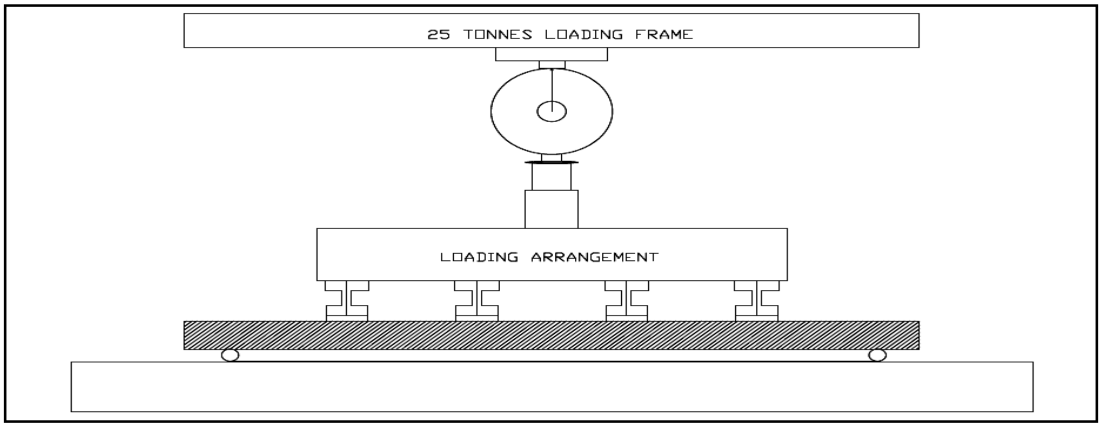

Figure 2: Details of Test Setup

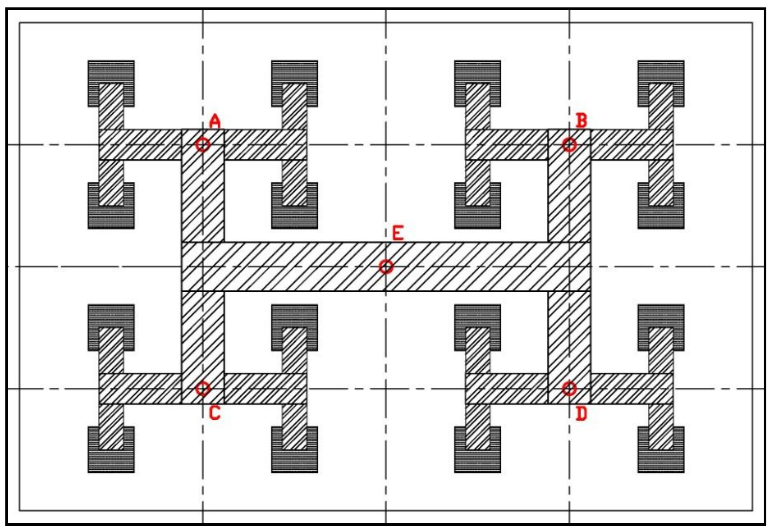

Figure 4: Dial Gauge Arrangement

3.3.Testing Of Slab Specimens

Ten slab specimen of size 1000X1000X60mm with similar loading and different support conditions were designed using limit state concept. 5 numbers of 8mm dia bars were provided in both the directions and inclusive of edge strip only for fixed end conditions .All four edges were roller supports with bearing of 115 mm. The specimen was also painted with lime wash in order to easily note the crack pattern of the specimen. The setup was carried out with 25 Tonnes loading frame, a 100 tonnes loading jack was fixed on top of the specimen to apply load. A proving ring was also fixed above the loading jack which was connected to a measure the load increments. Set of angle sections were provided on top of the specimen to transfer the load from loading jack to the specimen uniformly. C-clamp and nut and bolt arrangement was used to achieve the fixity condition on all the four sides of the slab. The figure 5.4 and 5.5 shows the test setup for both support conditions.

Figure 5: Test Setup for Simply Supported Condition

Figure 6: Test Setup For Fixed End Condition

4.Results And Conclusions

4.1.Compressive Strength Development

Grade	Age	Normal Concrete N/mm^2	M-1 50% Cement Replacement N/mm^2	M-2 60% Cement Replacement N/mm^2
M40	7 days	31.91	22.18	16.0
	28 days	47.32	40.26	29.06
	56 days	55.16	47.18	40.12
	91 days	58.22	54.62	48.36

Table:7 Test Results of Cube Compressive Strength

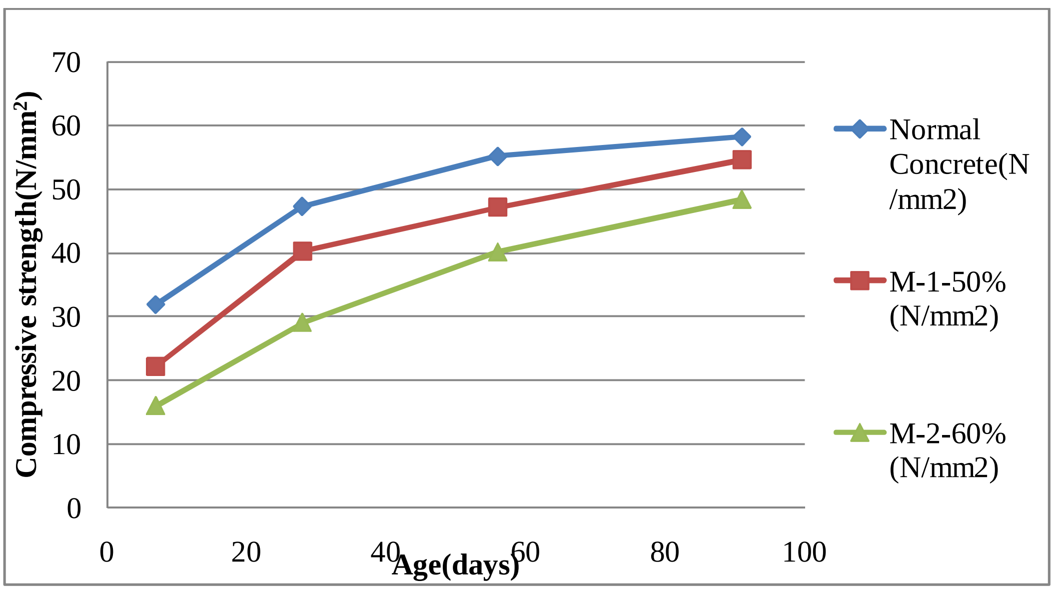

Figure 7: Variation of Compressive Strength of All Mixes

Slab	Fly ash	Support	Johansen's	Load at	Ultimate	Deflection(mm)

Notation	content (%)	Condition	Yield Load, P_j kN/m^2	first Crack kN/m^2	Load kN/m^2	At first Crack load	At Ultimate Load
S1	0	Simply Supported	116.40	38	130	5.304	12.714
S2	0	Restrained	164.40	40	172	4.857	13.729
S3	50	Simply Supported	115.98	38	128	5.618	14.832
S4	50	Simply Supported	115.98	38	126	6.449	14.738
S5	50	Restrained	163.89	38	170	4.083	15.14
S6	50	Restrained	163.89	38	168	4.39	15.051
S7	60	Simply Supported	115.12	36	126	4.793	14.629
S8	60	Simply Supported	115.12	34	126	4.936	14.655
S9	60	Restrained	162.93	36	166	4.776	15.323
S10	60	Restrained	162.93	38	166	4.008	15.285

Table 8: Results of Experimental and Theoretical Ultimate Loads and their Deflections

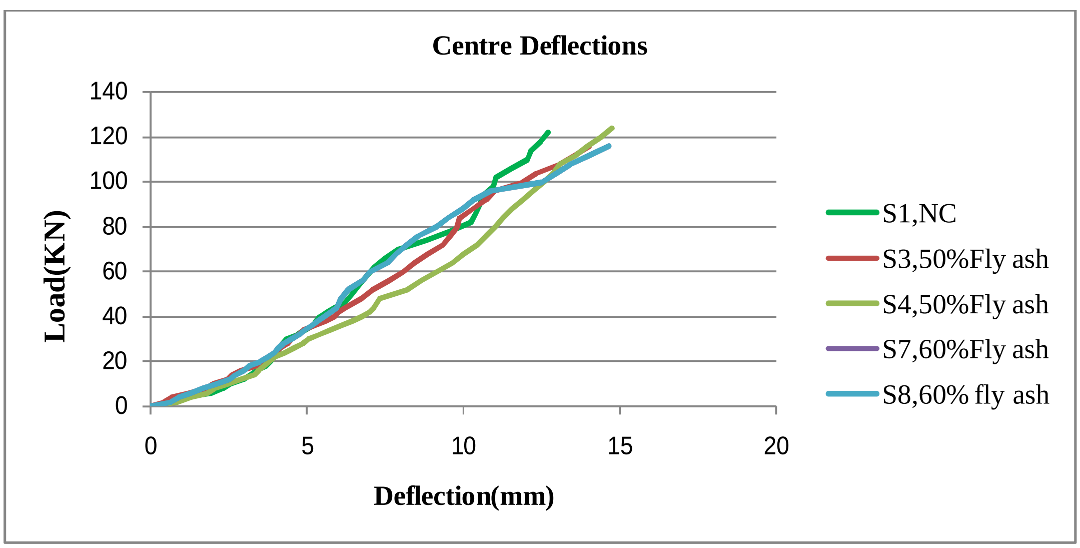

Figure 8: Comparison of simply supported Load v/s mid span Deflection

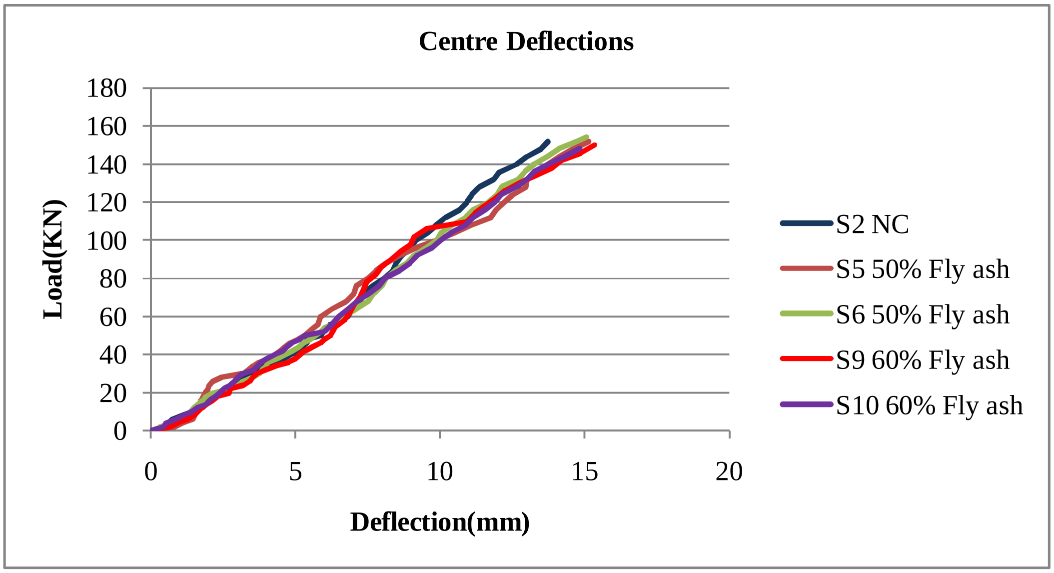

Figure 9: Comparison of restrained Load v/s mid span Deflection

4.2.Comparison Of Intensity Of Ultimate Load And Intensity Of Johansen's Yield Load For Simply Supported And Restrained Slabs

SLAB ID	Pcr kN	Pw kN	Pu kN	δcr mm	δw mm	δu mm	δu/D
S1	38	77.6	130	5.304	7.949	12.714	0.212
S3	38	77.32	128	5.618	9.342	14.832	0.247
S4	38	77.32	126	6.449	10.723	14.738	0.245
S7	36	76.75	126	4.793	8.01	14.629	0.244
S8	34	76.75	126	4.936	7.755	14.655	0.244

Table 9: Deflections at Ultimate Loads for Simply Supported Slabs

SLAB ID	Pcr kN	Pw kN	Pu kN	δcr mm	δw mm	δu mm	δu/D
S2	40	109.6	172	4.857	8.464	13.729	0.228
S5	38	109.26	170	4.083	8.604	15.14	0.252
S6	38	109.26	168	4.39	9.3	15.051	0.251
S9	36	108.62	166	4.776	8.698	15.323	0.255
S10	38	108.62	166	4.008	9.552	15.285	0.254

Table 10: Deflections at ultimate loads for restrained slabs

Slab ID	P_U kN/m^2	P_j kN/m^2	Le=[(PU- Pj)×100]/ P_j %
S1	130	116.4	11.68
S3	128	115.98	10.36
S4	126	115.98	8.64
S7	126	115.12	9.45
S8	126	115.12	9.45

Table 11: Load Enhancements for Simply Supported Slabs

Slab ID	P_U kN/m^2	P_j kN/m^2	Le=[(P_U- Pj)×100]/ P_j %
S2	172	164.4	4.62
S5	170	163.89	3.73
S6	168	163.89	2.51
S9	166	162.93	1.89
S10	166	162.93	1.89

Table 12: Load Enhancements for Restrained Slabs

Slab ID	$P_{0.3cr}$ kN/m^2	P_j kN/m^2	FOS Cracking $P_{0.3cr}$ /(2/3× P_j)
S1	94	116.40	1.21
S3	90	115.98	1.16
S4	86	115.98	1.11
S7	86	115.12	1.12
S8	82	115.12	1.06

Table 13: Partial Safety Factors for Simply Supported Slabs

Slab ID	$P_{0.3cr}$ kN/m^2	Pj kN/m^2	FOS Cracking $P_{0.3cr}$ /(2/3× P_j)
S2	136	164.4	1.24
S5	130	163.89	1.11
S6	128	163.89	1.17
S9	124	162.93	1.14
S10	126	162.93	1.16

Table 14: Partial Safety Factors for Restrained Slabs

4.2.Load Deflection Behaviour For The Tested Slabs

Both Normal concrete slabs and Fly ash concrete slabs showed a linear behaviour at initial stages and beyond this a non linear behaviour was observed . The experiments show that in most of the cases Fly ash concrete slabs showed more deflection than the Normal concrete slabs at a given load. This is expected behaviour only which validates the conduction of experiments.

4.3.Comparison Of Intensity Of Ultimate Load & Intensity Of Johansen's Load

Experiments conducted showed that the intensity of ultimate load is higher than the computed intensity of Johansen's yield line loads. It has been well established that the discrepancy in estimating the ultimate loads is due to the membrane action. The present study shows that the load enhancement changes with each test specimen. Therefore to obtain an economical design which includes the membrane action, the present investigation points out that designers have to use less percentage of fly ash.

4.4.Partial Safety Factors With Respect To Limiting Crack Width

Many codes of practices limit the width of the crack to be 0.3 mm. In case of water retaining structures this value has been reduced to 0.21 mm. The ratio of the load corresponding to the limiting crack width of 0.3 mm is obtained from the test data. The partial safety factors with respect to cracking is taken as the ratio of service loads(2/3 of Johansen's yield line load) to the above load. This range from 1.06 to 1.21 for simply supported slabs & from 1.14 to 1.24 for Restrained slabs. This illustrates that the recommended value of the codes of practice of 1.5 is conservative and can be adopted.

4.5.Deflections At Ultimate Loads

Many theoretical models to predict the load deflection behaviour for normal slabs are available. As most of the above analysis are the extension of rigid plate analysis, the theoretical load deflection curve do not give directly the ultimate loads. A suitable deflection at ultimate loads has to be assumed and the theoretical load corresponding to this is considered as the ultimate load. In order to have an idea of the above, the ratio of the deflection at ultimate loads to its thickness is calculated. For Simply supported slabs it ranges from 0.212 to 0.244, while in case of restrained slabs it ranges from 0.228 to 0.255. Hence this data can be used in the theoretical formulation to estimate the ultimate loads.

5.Conclusion

The slabs were tested after 91 days of curing. During testing the cracking loads, load deflection behaviour of individual slabs and their ultimate strength were observed from the investigation and the following conclusions can be drawn:

- The experimental investigation clearly demonstrated that fly ash concrete requires more curing period than control concrete.
- All the slabs follow linear behaviour up to nearly 35% of the ultimate load with reduced stiffness after the cracking loads till ultimate failure.
- Ultimate loads of simply supported fly ash concrete two way slabs is lesser compared to control concrete, same is implied to restrained slabs which is generally expected behaviour of structural members.
- The slabs showed enhanced load carrying capacity beyond the computed Johansen’s load.

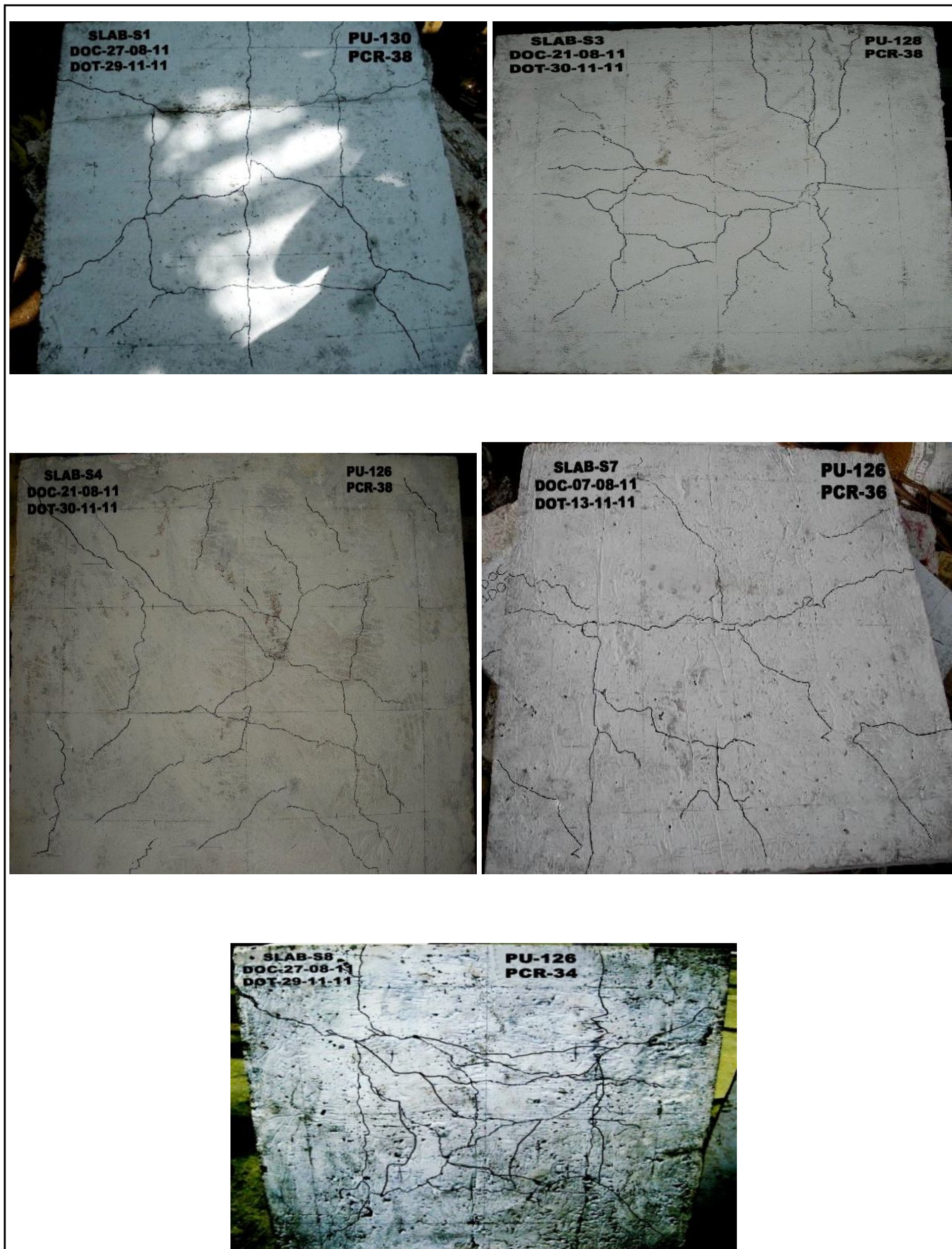

Figure 10: Crack Pattern of Simply Supported RNC and RFAC Slab (Tension Side)

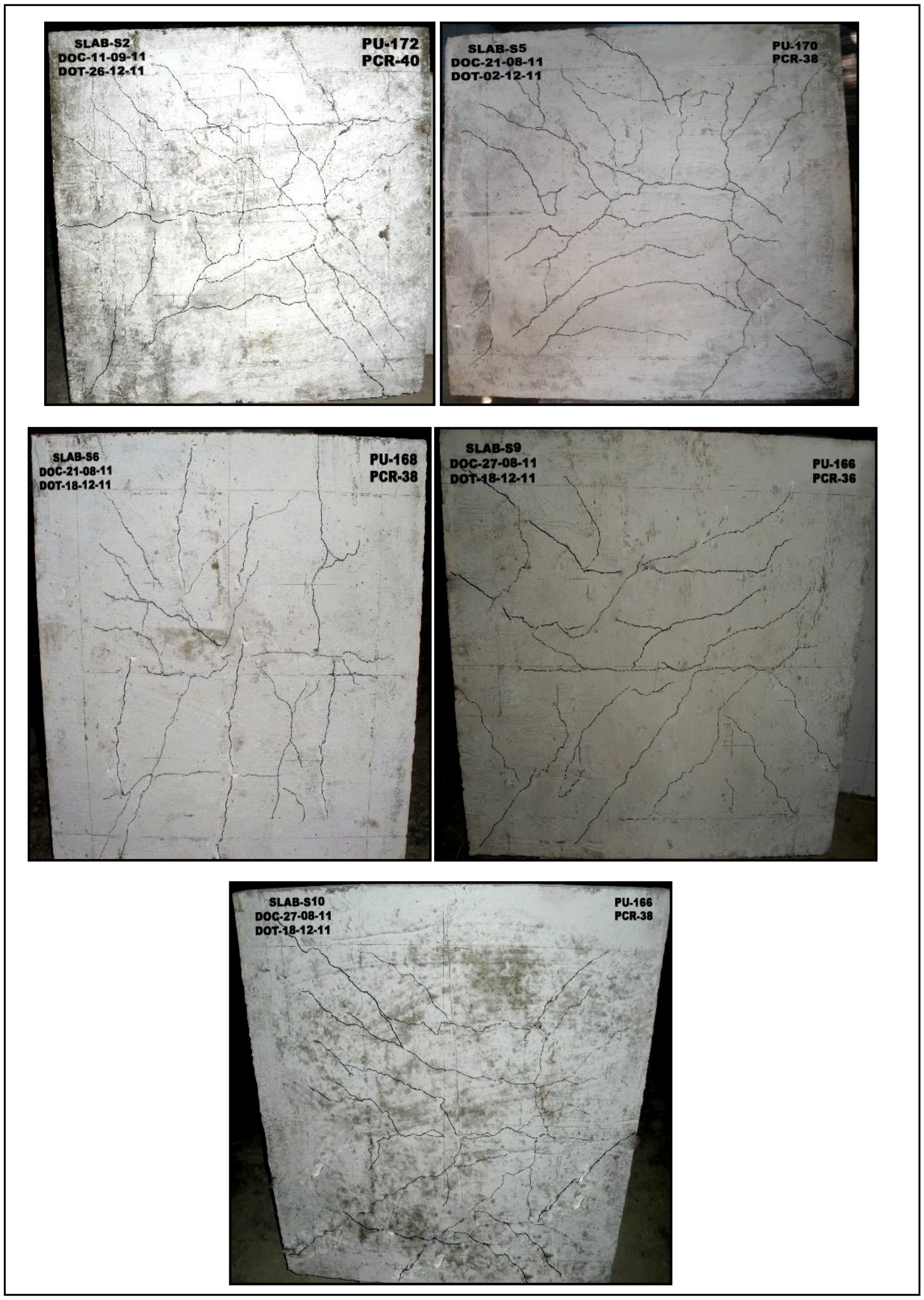

Figure 11: Crack Pattern of Restrained RNC and RFAC Slab (Tension Side)

6.Reference

1. Dr. Yashpal Singh(2011) Fly Ash utilization in India Wealthy waste.com
2. Desayi P and Kulkarni, A.B. (1997) " Load deflection behavior of restrained reinforced concrete slabs,"Journal of structural division, ASCE,103,ST2,405-419.(Discussion 104,ST1,231).
3. Braestrup, M.W. Dome(1980) ."Effect in RC slabs: rigid – plastic analysis, "Journal of structural division, ASCE, 106, ST6, 1237-1253. (Discussion 107,ST4,714-716,ST5,1017-1019,ST7,1380-1384,108,479-480).
4. N.A.Lloyd. and b.Vijaya Rangan (2009) "Shear Design of reinforced concrete beams ,Slabs and walls to Australian Standard 3600 : Proceedings of the Seventh structural Engineering Convension,Annamalai University ,December -2010 pp-29-44
5. Taylor R,(1965), "A note on a possible basis for a new method of ultimate load design of reinforced concrete slabs ",Magazine of concrete research ,vol 17,no.53,183-186.
6. Alan,Hun,GEOFF TAPLIN,RIADH AL MAHAIDI,(2005) "strength of reinforced concrete bridge deck under compressing membrane action", ACI journal, volume 102
7. Baily, (2008), "Simplified and advanced analysis of membrane action of concrete slabs",ACI structural journal , 30-40
8. Fournier.B , D.Lu, J.P.Charland and J.Li (2004), "Evaluation of Indian Fly ashes for using High volume fly ash concrete:part1: Characterisation "Indian concrete Journal ,Vol78 ,No.11, PP: 22-30.
9. V.Sivasundaram(2004), "Evaluation of Indian fly ashes for the HVFA concrete.Part 2:Behaviour in concrete" ICJ Nov 2004 PP:41-49