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Experimental Investigation on Pozzolanic Effect of Fly Ash in Roller Compacted Concrete Pavement Using Manufactured Sand As Fine Aggregate

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Abstract

Roller compacted concrete material for rigid pavement construction has been used in the recent past and gaining more importance over the past several years. Use of river sand in construction applications has become expensive and causes depletion of the natural resources. In this scenario, use of manufactured sand can be an alternative to natural river sand as fine aggregate in Roller Compacted Concrete Pavement. In this investigation, the pozzolanic effect of Fly ash in Roller Compacted Concrete has been studied with fly ash and with manufactured sand. Six levels of partial replacement of fly ash were considered viz., 10%, 20%, 30%, 40%, 50% and 60% and river sand was completely replaced with M-Sand (100%). The strength indices like specific strength ratio (R), index of specific strength (K) and contribution percentage of pozzolanic effect to strength (P) were examined. The research results indicates that i) at 90 days of curing, the contribution of fly ash effect to strength of RCC exceeds 50% ii) the strength at early ages like 3 days and 7 days of Fly ash Roller Compacted Concrete is poor.

Key words: RCC, Pozzolanic effect, M-Sand, Specific Strength, Specific strength ratio.

57. **Introduction**

Roller compacted concrete (RCC) as a pavement material, is a dry and stiff concrete with low water binder ratio, high strength and high density and compacted under heavy vibratory roller [6]. Fly ash is a residue collected from the coal thermal power plants and used in concrete for mainly in three aspects, i) morphologic effect ii) pozzolanic effect and iii) Micro aggregate effect. But the pozzolanic effect is the main effect of fly ash in which the oxides Sio_2 and Al_2O_3 in Fly ash can be activated by $Ca(OH)_2$ and produce more hydrated gel. As this gel fills the capillary pores in concrete, it therefore effectively contributed to concrete strength. [1]

Since the supply of River sand is limited and its continuous supply is not guaranteed, use of manufactured sand (M-Sand) as an alternative to River sand has become inevitable. ICAR (The international Center of Aggregates Research) research project work was showed that concrete can successfully be made using unwashed M-sand without modifying the sand. With the use of manufactured sand in concrete there was increase in flexural strength, improved abrasion resistance, increased unit weight and lowered permeability. [2]

Xincheng Pu[3] investigated the pozzolanic effect of fly ash in cement and concrete and reported that the contribution of pozzolanic effect to strength reached its maximum at 28 days of curing.

Cheng Cao[1], studied this effect of high volume fly ash in Roller compacted concrete, the test results showed that the fly ash effect towards strength at early age is low or negative and with increasing percentage of fly ash, the pozzolanic effect on HFRCC at 90 days age is more remarkable.

M. Madhkhan[4], found that with addition of pozzolans, the 28days compressive strength decreased. Although the 90day compressive strength was increased with using pozzolans, the rupture modulus decreased.

Ali Mardani[5], concluded that with increasing fly ash content in RCC, the strength values were decreased. At later ages the rate of strength development of mixtures where replaced with fly ash was very close and independent of the fly ash content of the mix.

1.1 Indices of pozzolanic Effect

1. Specific Strength of Roller Compacted Concrete (SP_{RCC}):

It is defined as the contribution of 1% cement to Roller Compacted Concrete strength which can be calculated as

$$SP_{RCC} = F / P_{cem},$$

Where,

F is the Strength of Roller Compacted Concrete,

P_{cem} is percent of cement to total amount of Binder

2. Specific Strength of pozzolanic effect (SP_{FA}):

It is the contribution of fly ash to the strength of concrete with fly ash and it can be formulated as

$$SP_{FA} = SP_{FRCC} – SP_{RCC}$$

Where,
SP_{FRCC} = Specific Strength of Fly ash RCC

3. Specific Strength Ratio (R):

Ratio of concrete strength in question to cement or mineral admixture percentage, is given by the following expression,

$$R= F/p$$

Where,
F= RCC strength, p is percentage of cementitious material

4. Contribution of the pozzolanic effect to RCC strength (R_P)

$$R_P = R_M-R_C$$

Where,
R_M is the contribution of unit mineral admixture to RCC strength
R_C is the contribution of unit cement to RCC strength without any mineral admixture

5. Index of Specific Strength (K):

It is the ratio of R_M to R_C and is given by the following expression, $K = R_M/R_C$

6. Percent contribution of pozzolanic effect to Strength (P)

It is given by the expression,

$$P= (R_P/R_M)x\ 100, \%$$

This paper presents the investigation on the pozzolanic effect of Fly Ash in Roller compacted concrete pavement. Seven RCC mixtures with various percent replacement levels of fly ash (0%,10%,20%,30%,40%,50% and 60%) were proportioned by soil compaction method [7].

For each mix, M-sand was used as fine aggregate and coarse aggregate of NMSA of 19mm was used in all mixtures. Flexural and compressive strengths were examined at various ages (3d, 7d, 28d, and 90 day). The quantitative parameters of strength indices are also determined [15].

2 Materials

2.1 Cement:

Ordinary Portland cement (OPC) of 53 Grade was used. It was tested as per IS 4031:1988[12] properties are given Table. 1

Table 1 Physical Properties of OPC 53

S.NO	Property	Result
1	Standard Consistency	28.5%
2	Initial setting Time	120min
3	Final setting Time	280min
4	Fineness by sieving	3.5%
5	Soundness	1mm
6	Compressive strength	
	i) 3 days	39.0 N/mm^2
	ii) 7days	44.0N/mm^2
	iii)28 days	57.0N/mm^2
7	Specific Gravity	3.15

2.2 Fly ash

Fly ash was obtained from Narla TataRao Thermal Power Station (NTTPS) at Ibrahimpatnam, Vijayawada, AP, India was used in this experimental program. It was tested as per IS 1727:1967[14] and results of tests are given in Table 2.

Table 2 Physical Properties of Fly ash

S.No	Property	Result
1	Fineness(Retained on 45µm sieve)	8%
2	Specific Gravity	2.5
3	Specific surface(Blaine m^2/Kg)	359

2.3 Fine Aggregate

Manufactured sand (M-sand) was used as fine aggregate and was tested as per IS 383[13]. It was collected from V.N.S Ready Mix plant, Vijayawada, India. The specific gravity of M-sand was 2.713. Its particle size distribution was shown in Fig 1.

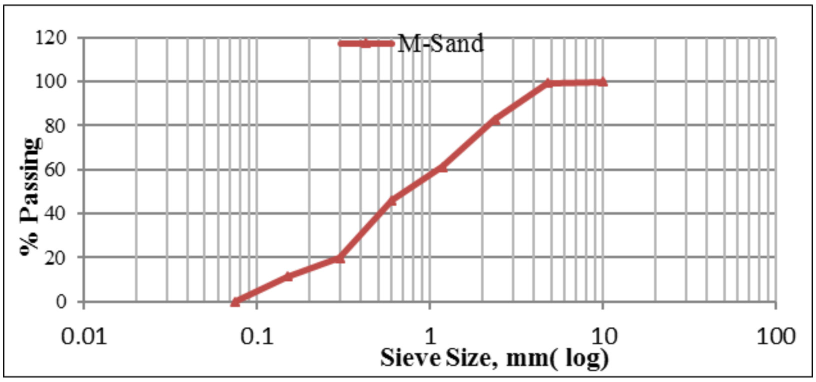

Fig.1 Particle Size Distribution curve of M-Sand

2.4 Coarse Aggregate

Crushed angular stone aggregate with NMSA of 19mm and downgraded was used. The specific gravity was 2.87. coarse aggregates passing 20mm 10mm and 6mm sized were combined (40:40:20). The combined grading is given in Table 3.[8]. Particle size distribution curve is shown in Fig. 2

Table 3 Sieve Analysis of All in Aggregate

Sieve Size	% Passing			
	M-sand (40%)	Combined coarse Aggregate (60%)	Combined Grading	As Per ACI 211-3R
25mm	100	100	100	100
19mm	100	100	100	82-100
12.5mm	100	88.8	93.28	72-93
9.5mm	100	65.94	79.56	66-85
4.75mm	99.30	33.78	59.98	51-69
2.36mm	82.70	14.76	41.93	38-56
1.18mm	61.15	7.02	28.67	28-46
0.600mm	45.90	4.86	21.27	18-36
0.300mm	19.85	2.62	9.51	11-27
0.150mm	11.40	0.98	5.14	6-18
0.075mm	2.60	0.12	1.11	2-18

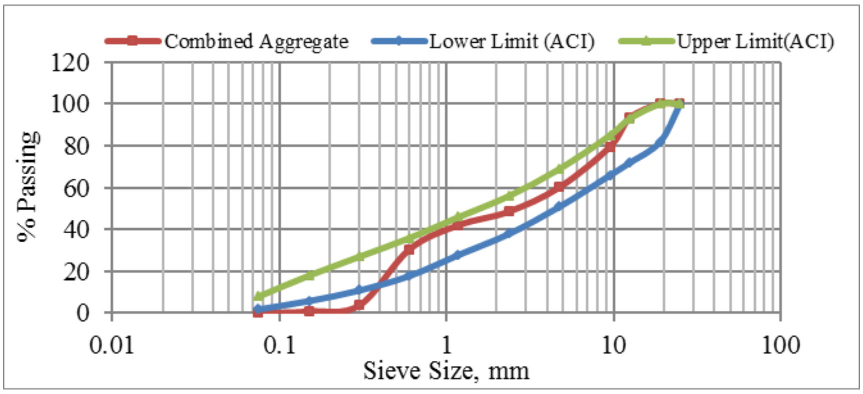

Fig.2 Particle Size Distribution curve of All in Aggregate

3. Mix Proportioning

3.1 Mix proportioning of RCCP was done using ACI 211 3R-02-2004[7] method. This method was developed for Roller compacted concrete pavements of Rigid pavement category and it is limited to mix design with nominal maximum size of aggregate of 19mm as per ACI 325.10R-99[6].The RCCP mix was proportioned for specified target flexural strengths of 5.0N/mm^2[8-10]. The cement content of control mix of RCC was 295kg/m^3. In six RCCP mixtures 10, 20, 30, 40, 50 and 60% by weight of cement were replaced with fly ash. Using six different water/binder ratios six mixtures were prepared. The identification of mix proportions and quantity of material are given in Table 4.

Table 4. Quantities of materials per one m^3 of Roller Compacted Concrete Pavement of 5 N/mm^2 Flexural Strength

Mix Designation	F0	F10	F20	F30	F40	F50	F60
Cement (Kg/m^3)	295	265.5	236	206.5	177	147.5	118
Fly Ash (Kg/m3)	0	29.5	59	88.5	118	147.5	177
W/b Ratio	0.39	0.40	0.42	0.44	0.48	0.49	0.50
M-Sand(Kg/m^3)	801	801	801	801	801	801	801
Coarse Aggregate(Kg/m^3)	1209	1209	1209	1209	1209	1209	1209
Water (Kg/m^3)	114	118	123.9	129.8	141.6	144.55	147.5

3.2 Preparation, casting and Testing of specimens

3.2.1 Compressive strength studies.

Cube specimens of size 150mmx150mmx150mm were casted for measuring compressive strength. Concrete is placed and compacted with modified proctor rammer. After 24 hours, the specimens are demoulded and kept in water for curing.

Then compression loading tests were conducted on a compression testing machine of capacity 3000KN. For this test, a loading rate of 2.5KN/S was applied as per IS:516-1959[11].The tests were performed at 3d,7d,28day and 90days. Test results were shown in Table 5

Table 5 Compressive Strength results of 150 mm cubes

Mix Designation	Description	Compressive Strength, N/mm^2			
		3 days	**7 days**	**28 days**	**90 days**
F0	Control Mix	18.67	22.22	33.74	45.2
F10	10% Fly Ash	16.8	20.0	30.88	41.41
F20	20% Fly Ash	14.7	17.88	28.5	38.5
F30	30% Fly Ash	12.8	15.7	24.4	36.0
F40	40% Fly Ash	10.6	13.6	21.3	33.78
F50	50% Fly Ash	8.8	11.7	18.9	30.2
F60	60% Fly Ash	6.6	8.67	16.68	28.69

3.2.2 Flexural strength studies

Beam specimens of size 500x100x100 mm were used for measuring flexural strength in beam moulds and compacted with modified proctor’s rammer. They were demoulded and kept for curing after one day. Then Flexural strength test were conducted on UTM of capacity 1000 KN by center point loading at 3,7,28 and 90 days[11]. The test results were presented in Table 6.

Table 6 Flexural Strength results of 500x100x100 mm beam

Mix Designation	Description	Flexural Strength, N/mm^2			
		3 days	**7 days**	**28 days**	**90 days**
F0	Control Mix	3.8	4.4	6.8	8.6
F10	10% Fly Ash	3.49	3.96	6.35	8.36
F20	20% Fly Ash	3.12	3.55	5.8	7.73
F30	30% Fly Ash	2.5	3.16	5.61	7.38
F40	40% Fly Ash	2.1	2.77	5.5	7.2
F50	50% Fly Ash	1.77	2.37	5.05	7.05
F60	60% Fly Ash	1.38	1.98	4.68	6.98

4. Results and Analysis

4.1 Specific Flexural Strength of Fly Ash Roller Compacted Concrete (SP_{RCC}):

In figure 3 the development of flexural strength of FRCC with curing age was shown. In the early ages of 3 days, with the increase in fly ash content, SP_{RCC} decreases at all levels of replacement. When it cured for more than 28 days, the contribution of fly ash to flexural strength in FRCC is significant.

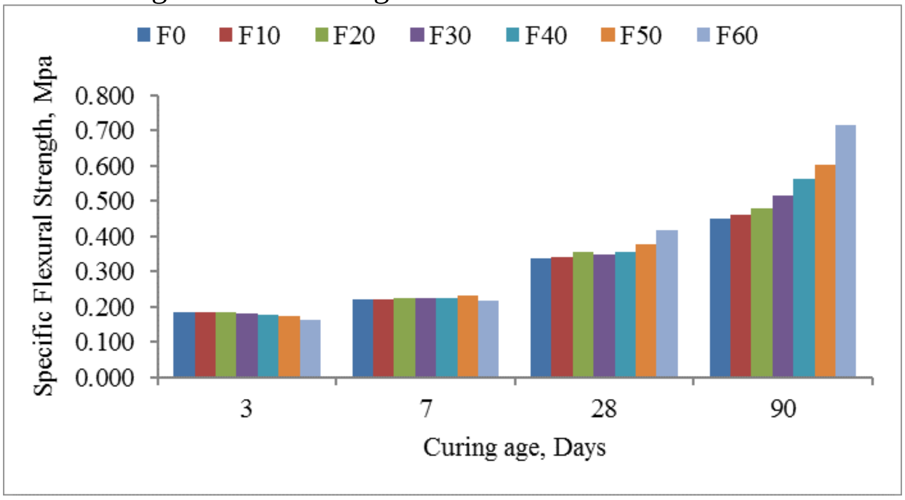

Fig. 3 Flexural Specific Strength of FRCC with Curing Age

4.2 Specific Strength of pozzolanic effect of fly ash in FRCC (SP_{FA}):

Figure 3 shows the trend of Flexural Specific Strength of pozzolanic effect of fly ash in FRCC. At initial ages of 3 days and 7 days, the pozzolanic effect of fly ash is very low or negative (at 3 days for all mixes and at 7 days for R60), but it is increasing very rapidly at 90 days with increase in fly ash content. In the long term curing age, fly ash even at 60 % replacement level provides effective contribution to strength.

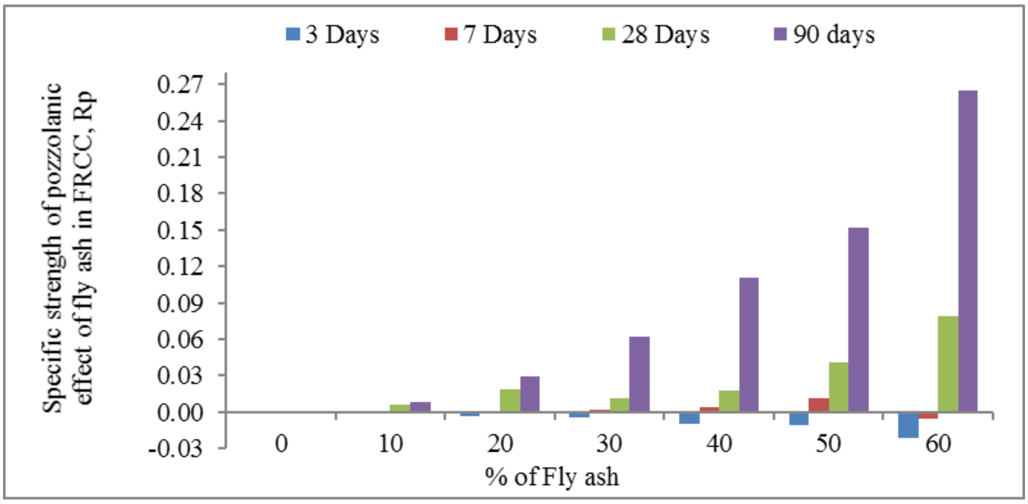

Fig. 4Flexural Specific Strength of pozzolanic effect of Fly ash with % Fly ash

4.3 Variation of pozzolanic effect with Fly ash content:

The pozzolanic indices for flexural strength were calculated and presented in Tables

7-9. Similarly for compressive strength the pozzolanic indices were presented in Tables 10-12. In the table 7 it was shown that the indices of pozzolanic effect (R_P and P) of flexural strength at 3 days of curing age are showing negative values when fly ash content is more than 20%. But in Table 8 and Table 9, these indices are showing improved values with increase in fly ash content at 28 days and 90 days of curing. Similar trend has been observed in Compressive Strength indices also (Table 11 and Table 12).

Table 7 Indices of pozzolanic effect of FRCC (3 days) Flexural Strength (N/mm^2)

FA %	Cement %	F.S @3 days	R_M	R_P	K	P %
0	100	3.8	0.0380	0.0000	1.0000	0
10	90	3.49	0.0388	0.0008	1.0205	2
20	80	3.07	0.0384	0.0004	1.0099	1
30	70	2.17	0.0310	-0.0070	0.8158	-23
40	60	1.78	0.0297	-0.0083	0.7807	-28
50	50	1.35	0.0270	-0.0110	0.7105	-41
60	40	0.9	0.0225	-0.0155	0.5921	-69

Table 8 Indices of pozzolanic effect of FRCC (28 days) Flexural Strength (N/mm^2)

FA %	Cement %	F.S @28 days	R_M	R_P	K	P %
0	100	6.8	0.0680	0.0000	1.0000	0
10	90	6.35	0.0706	0.0026	1.0376	4
20	80	5.8	0.0725	0.0045	1.0662	6
30	70	5.61	0.0801	0.0121	1.1786	15
40	60	5.5	0.0917	0.0237	1.3480	26
50	50	5.05	0.1010	0.0330	1.4853	33
60	40	4.68	0.1170	0.0490	1.7206	42

Table 9 Indices of pozzolanic effect of FRCC (90 days) Flexural Strength (N/mm^2)

FA %	Cement %	F.S @90 days	R_M	R_P	K	P %
0	100	8.6	0.0860	0.0000	1.0000	0
10	90	8.36	0.0929	0.0069	1.0801	7
20	80	7.73	0.0966	0.0106	1.1235	11
30	70	7.38	0.1054	0.0194	1.2259	18
40	60	7.2	0.1200	0.0340	1.3953	28
50	50	7.05	0.1410	0.0550	1.6395	39
60	40	6.98	0.1745	0.0885	2.0291	51

Table 10. Indices of pozzolanic effect of FRCC (3 days) Compressive Strength (N/mm^2)

FA %	Cement %	C.S @3 days	R_M	R_P	K	P %
0	100	18.67	0.1867	0.0000	1.0000	0.00
10	90	16.8	0.1867	0.0000	0.9998	-0.02
20	80	14.7	0.1838	-0.0030	0.9842	-1.61
30	70	12.8	0.1829	-0.0038	0.9794	-2.10
40	60	10.6	0.1767	-0.0100	0.9463	-5.68
50	50	8.8	0.1760	-0.0107	0.9427	-6.08
60	40	6.6	0.1650	-0.0217	0.8838	-13.15

Table11 Indices of pozzolanic effect of FRCC (28 days) Compressive Strength (N/mm^2)

FA %	Cement %	C.S @28 days	R_M	R_P	K	P %
0	100	33.74	0.3374	0.0000	1.0000	0
10	90	30.88	0.3431	0.0057	1.0169	2
20	80	28.5	0.3563	0.0189	1.0559	5
30	70	24.4	0.3486	0.0112	1.0331	3
40	60	21.3	0.3550	0.0176	1.0522	5
50	50	18.9	0.3780	0.0406	1.1203	11
60	40	16.68	0.4170	0.0796	1.2359	19

Table 12 Indices of pozzolanic effect of FRCC (90 days) Compressive Strength (N/mm^2)

FA %	Cement %	C.S @90 days	R_M	R_P	K	P %
0	100	45.2	0.4520	0.0000	1.0000	0
10	90	41.41	0.4601	0.0081	1.0179	2
20	80	38.5	0.4813	0.0293	1.0647	6
30	70	36	0.5143	0.0623	1.1378	12
40	60	33.78	0.5630	0.1110	1.2456	20
50	50	30.2	0.6040	0.1520	1.3363	25
60	40	28.69	0.7173	0.2653	1.5868	37

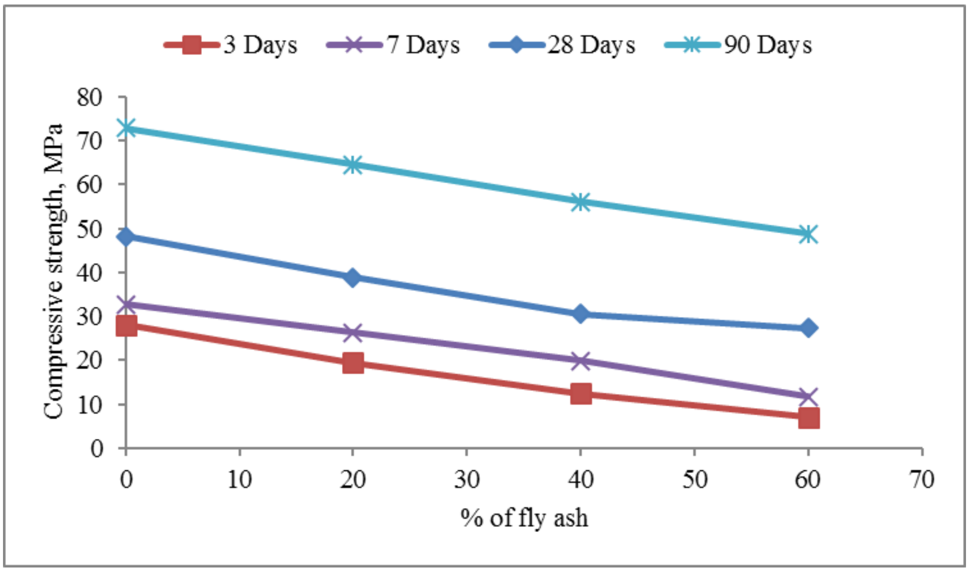

Fig. 5 Change in compressive strength versus percent of fly ash in the Mix

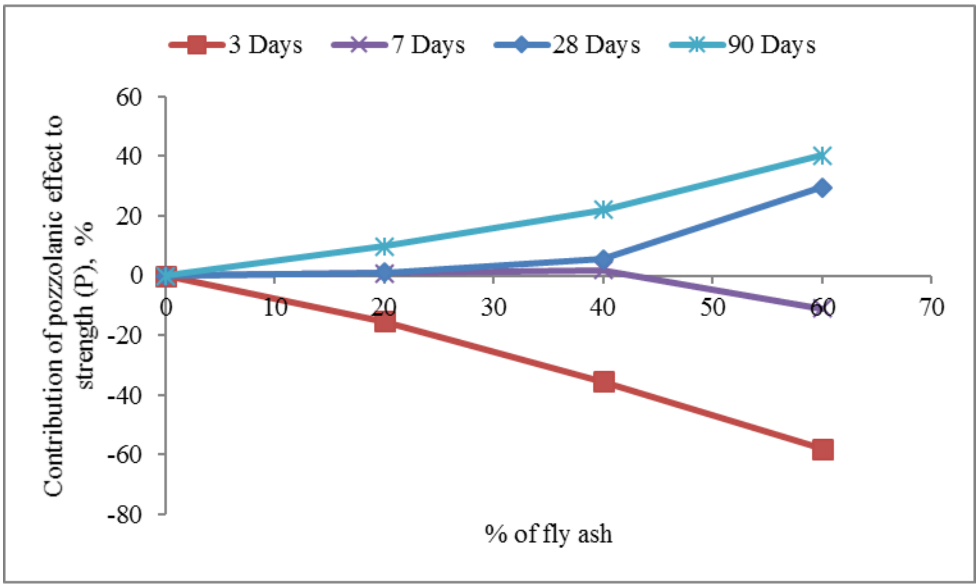

Fig. 6 Variation of P with fly ash content in RCC (Compressive Strength)

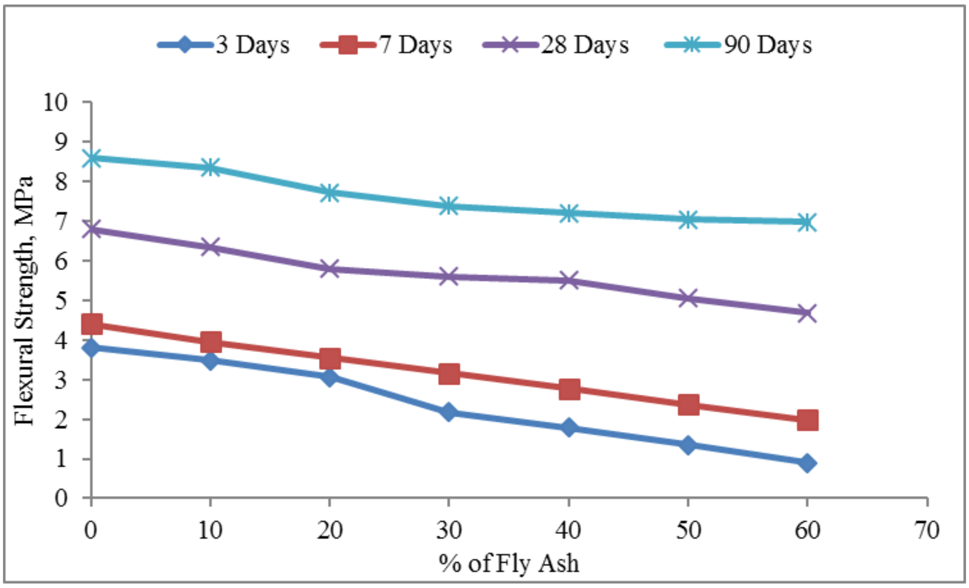

Fig. 7 Change in Flexural strength versus percent of fly ash in the Mix

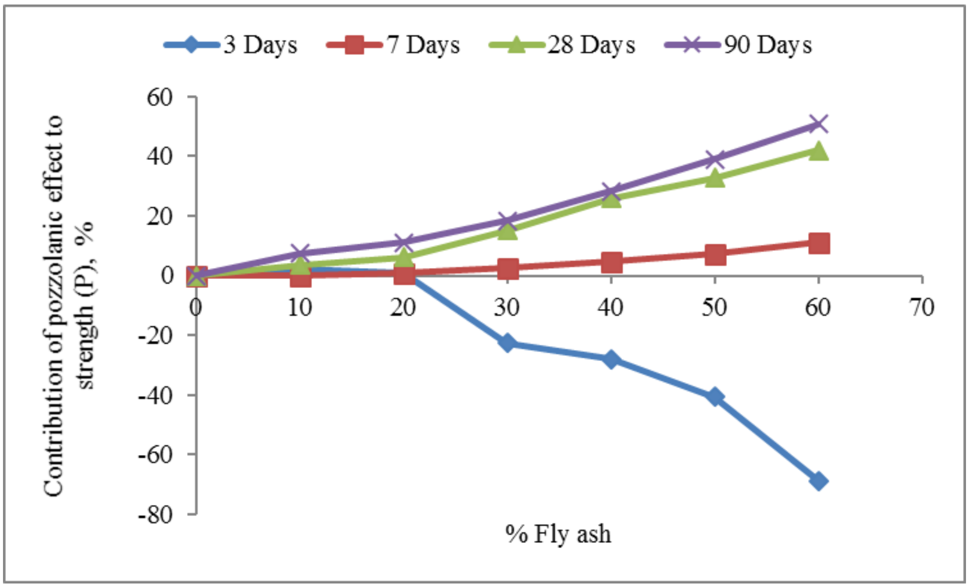

Fig. 8 Variation of P with fly ash content in RCC (Flexural Strength)

4.4 Increase in pozzolanic effect with curing age

From Table 7-9 and Table 10-12, also from figures 5-6 and figures 7-8, it is clear that the flexural strength and compressive strength of FRCC and indices of pozzolanic effect are increased with curing age. During early period of curing at 3 days the pozzolanic effect of fly ash is minimum. As the curing age increases the contribution rate of pozzolanic effect of fly ash also increases. This implies that curing age is an important factor on the pozzolanic effect of Fly ash for RCC.

5. Conclusion

From the experimental investigation following conclusions were drawn.

1. The pozzolanic effect of the fly ash in Roller Compacted Concrete Pavement with Manufactured sand as fine aggregate was quantitatively examined through various strength indices like Specific Strength Ratio (R), Index of Specific Strength (K) and Contribution percentage of pozzolanic effect to Strength (P).
2. With the increase in Fly ash content in FRCC the strength decreases. Although the strength is very low at early curing ages of 3 days and 7 days, but it develops rapidly with increase in curing age. The strength at longer ages is exceeding with that of control concrete mix without fly ash.
3. The specific strength of FRCC decreases with increase in Fly ash Content at early age of curing.
4. Fly ash effect in FRCC is positive after 28 days of curing age. The Contribution of fly ash in FRCC with 90 days curing age to Strength exceeds 50 %, and is more remarkable for flexural strength than compressive strength.

References:

[1] Cao, Cheng, Wei Sun, and Honggen Qin. "The analysis on strength and fly ash effect of roller-compacted concrete with high volume fly ash." *Cement and concrete research* 30.1 (2000): 71-75.

[2] ICAR 102 Final Report-"An experimental study on the guidelines for using higher contents of Aggregate Micro fines in Portlan Cement Concrete", Research Report ICAR 102-1F, By Namshik Ahn and David W. Flower

[3] Pu, Xincheng. "Investigation on pozzolanic effect of mineral additives in cement and concrete by specific strength index." *Cement and Concrete Research* 29.6 (1999): 951-955.

[4] Madhkhan, M., R. Azizkhani, and ME Torki Harchegani. "Effects of pozzolans together with steel and polypropylene fibers on mechanical properties of RCC pavements." *Construction and Building Materials* 26.1 (2012): 102-112.

[5] Mardani-Aghabaglou, Ali, and Kambiz Ramyar. "Mechanical properties of high-volume fly ash roller compacted concrete designed by maximum density method." *Construction and Building Materials* 38 (2013): 356-364.

[6] ACI 325.10R-95 "Report on Roller-Compacted Concrete Pavements" Reported by ACI Committee 325

[7] ACI 211 3R-02, Guide for Selecting Proportions for No-Slump Concrete, 2002

[8] KrishnaRao, S., T. ChandraSekharRao, and P. Sravana. "Effect of Manufacture sand on Strength Characteristics of Roller Compacted Concrete." *International Journal of Engineering Research and Technology*. Vol. 2. No. 2 (February-2013). ESRSA Publications, 2013.

[9] Pavan, S., and S. Krishna Rao. "Effect of Fly ash on Strength Characteristics of Roller Compacted Concrete Pavement." Volume 11, Issue 6 Ver. II (Nov- Dec. 2014), PP 04-08, IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)

[10] S.Krishna Rao, P.Sarika, P.Sravana, T.ChandraSekhara Rao. "Evaluation of Properties of Roller Compacted Concrete Pavement (RCCP)" IJEAR Vol. 4, Issue Spl-2, Jan - June 2014

[11] IS 516 (1959): Method of Tests for Strength of Concrete

[12] IS 4031:1988 Method of physical tests for cement

[13] IS 383: Specification for Coarse and Fine Aggregates From Natural Sources For Concrete

[14] IS 1727:1967 Methods of test for Pozzolanic Reactivity

[15] Yu, L-H., H. Ou, and L-L. Lee. "Investigation on pozzolanic effect of perlite powder in concrete." *Cement and Concrete Research* 33.1 (2003): 73-76.