Investigation on pozzolanic effect of Fly ash in Roller Compacted Concrete Pavement

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Abstract— **In the present experimental investigation the pozzolanic effect of fly ash in Roller Compacted Concrete (RCC) by partial replacement of cement (0%, 20%, 40%, 60%) was studied quantitatively with various strength indices viz., specific strength ratio(R), index of specific strength(K) and contribution percentage of pozzolanic effect to strength(P). Besides the mechanical properties these indices indicate that at early curing age, specific strength of Fly Ash Roller Compacted Concrete (FARCC) decreases with the increasing fly ash content. After 180 days of curing, the contribution of fly ash effect to strength of FARCC reaches to 50%.**

Keywords-Roller Compacted Concrete, specific Strength, pozzolanic Effect, specific strength ratio

I. INTRODUCTION

In Roller Compacted Concrete Pavements addition of active mineral admixtures like fly ash has great scientific significance. Fly Ash (FA) consists of SiO_2 and Al_2O_3, and has high potential activity. The main useful and significant effects of FA can be of three folds: Morphologic effect, pozzolanic effect, and Micro aggregate effect. [1].

The pozzolanic effect of FA is that combined oxides of SiO_2 and Al_2O_3 in FA can be activated by $Ca(OH)_2$ product of cement hydration and produce more hydration gel. This gel contributes more to the strength at later ages i.e long term strength.

Xincheng Pu [1] considered that the concrete strength consists of two parts; one came from the reaction of cement with water and other from the pozzolanic effect of the mineral admixture. The Pozzolanic effect of FA is mainly contributed towards the later age of hardening.

Cheng Cao et al. [2] investigated the effect the high volume Fly Ash Roller Compacted Concrete (HFRCC), results showed that the Fly ash effect at early ages is low or negative with increasing proportion of Fly ash, the pozzolanic effect on HFRCC at long curing age (90days) becomes more remarkable.

M. Madhkhan et al. [3], 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 et al.[4], 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.

In this investigation, the analysis of pozzolanic effect of FA on Roller Compacted Concrete pavement has been presented. The quantitative parameters of Strength indices are also presented, namely specific Strength ratio(R), index of specific Strength (K), and Contribution percentage of pozzolanic effect to Strength (P) have also been analyzed.

II. INDICES OF POZZOLANIC EFFECT

1. Specific Strength Ratio (R):

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

R= F/p
F= RCC flexural strength, p is percentage of cementitious material

2. Contribution of the pozzolanic effect to RCC strength (R_p):

$R_p = R_M - R_C$

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

3. Index of Specific Strength (K):

It is the ratio of R_M to R_C

$K = R_M/R_C$

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

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

III. EXPERIMENTAL INVESTIGATIONS

Materials:

The Cement used in RCCP was Ordinary Portland Cement (OPC) of 53 Grade, Conforming to IS 12269-1987.

Fine Aggregate Used was River sand with a fineness modulus of 2.65.

Coarse Aggregate of 19 mm NMSA was used. Both fine and Coarse Aggregate(Combined) grading curve is shown in Fig.1.

Fly-ash was obtained from VTPS, Ibrahimpatnam and its specific gravity was 2.2.

Water used in RCCP mix was potable and drinking water.

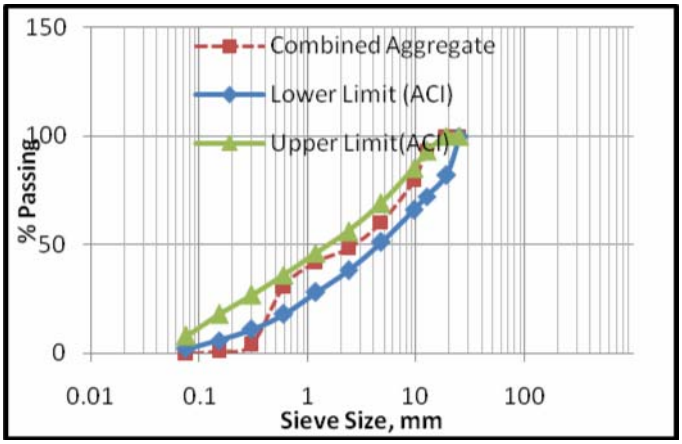

Figure 1 Particle Size Distribution Curve for Combined Aggregate

Concrete mixture proportioning:

Table1 gives the mixture proportions of Roller Compacted Concrete used in the present experimental work. Mixture proportioning was done using ACI 211.3R-02[5] specifications based on soil compaction method.

The identification of mixture and quantity of materials per one m^3 of concrete are given in Table 1. The mix was proportioned to a specified flexural Strength of 5 N/mm^2. The cement

content of control mix was 295 Kg/m^3. Cement was partially replaced with fly-ash at 20%, 40% and 60% levels.

Table1-Mixture Proportion of RCCP of 5 N/mm^2 flexural Strength.

Mix Designations	**R0**	**R20**	**R40**	**R60**
Fly-ash (0%)	0	20	40	60
w/b Ratio	0.39	0.4	0.48	0.49
Cement (Kg/m^3)	295	231	168	110
Fly-ash(Kg/m^3)	0	58	112	165
Fine Ags(Kg/m^3)	801	791	767	758
Coarse Ags(Kg/m^3)	1209	1194	1158	1144
Water (Kg/m^3)	114	117	133	135

Note:

R0:Control concrete; R20: 20% Fly Ash; R40: 40% Fly Ash; R60: 60% Fly Ash

Tests Conducted

Compressive strength Test:

Cube specimens of size 150mmx150mmx150mm for each mixture were cast and tested under compressive load at the ages of 7days, 28days, 90days and 180days. All the test specimens were tested in SSD conditions. For each mix combination, three specimens were tested using CTM of 3000KN capacity and the compressive strength was calculated as per IS: 516-1959[6]. The test results are presented in Table 2-4.

Table2- Indices of pozzolanic effect of FARCC (3 days)

FA %	**Cement %**	**C.S at 3 days**	**R_M**	**R_p**	**K**	**P %**
0	100	18.67	0.1867	0.000	1.0000	0
20	80	12.22	0.1528	-0.034	0.8182	-22
40	60	9.11	0.1518	-0.034	0.8132	-23
60	40	6.00	0.1500	-0.036	0.8034	-24

Table 3- Indices of pozzolanic effect of FARCC (28 days)

FA %	**Cement %**	**C.S at 28days**	**R_M**	**R_p**	**K**	**P %**
0	100	43.2	0.4320	0.0000	1.0000	0
20	80	35.0	0.4375	0.0055	1.0127	1
40	60	24.0	0.4000	-0.032	0.9259	-8
60	40	16.8	0.4200	-0.012	0.9722	-3

Table 4- Indices of pozzolanic effect of FARCC (180 days)

FA %	**Cement %**	**C.S at 180day**	**R_M**	**R_p**	**K**	**P %**
0	100	53.4	0.5340	0.0000	1.000	0
20	80	44.6	0.5575	0.0235	1.044	4
40	60	36.1	0.6017	0.0677	1.126	11
60	40	26.7	0.6675	0.1335	1.250	20

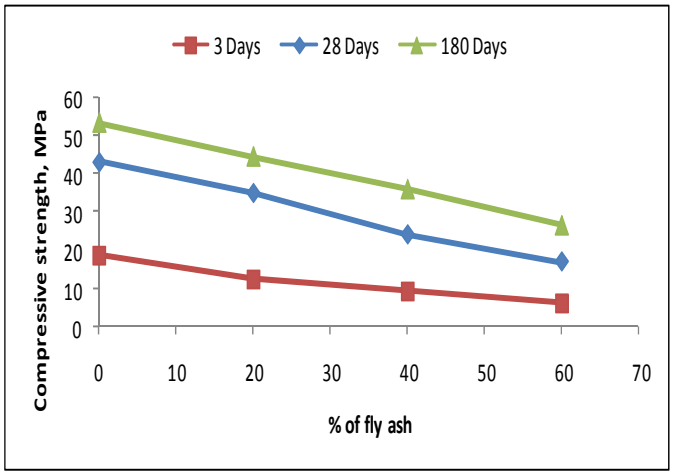

Figure 2.Change in compressive strength versus percent of fly ash in the mix

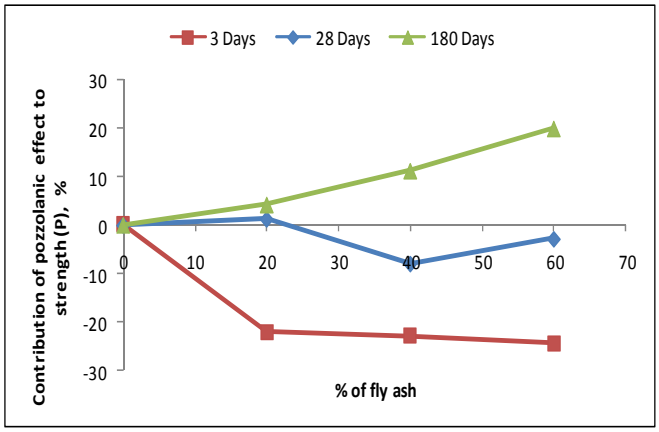

Figure3. Variation of P with fly ash content in RCC in Compression

Flexural Strength Test:

Beamsofsize500mmx100mmx100mm were cast and tested for each RCCP mix specimens for flexural strength at the ages of 7d,28d,90d,180d, according to IS:516-1959[6]. The test results are presented in Table 5-7.

Table 5- Indices of pozzolanic effect of FARCC (3 days)

FA %	Cement %	F.S at 3 days	R_M	R_p	K	P %
0	100	3.8	0.04	0	1.00	0
20	80	3.2	0.04	0.00	1.05	5
40	60	2.8	0.05	0.01	1.23	19
60	40	1.3	0.03	-0.01	0.86	-17

Table 6- Indices of pozzolanic effect of FARCC (28 days)

FA %	Cement %	F.S at 28 days	R_M	R_p	K	P %
0	100	6.8	0.07	0.00	1.00	0
20	80	6.1	0.08	0.01	1.12	11
40	60	5.4	0.09	0.02	1.32	24
60	40	4.2	0.11	0.04	1.54	35

Table 7- Indices of pozzolanic effect of FARCC (180 days)

FA %	Cement %	F.S at 180 days	R_M	R_p	K	P %
0	100	7.5	0.08	0	1.00	0
20	80	6.6	0.08	0.01	1.10	9
40	60	6.2	0.10	0.03	1.38	27
60	40	6	0.15	0.08	2.00	50

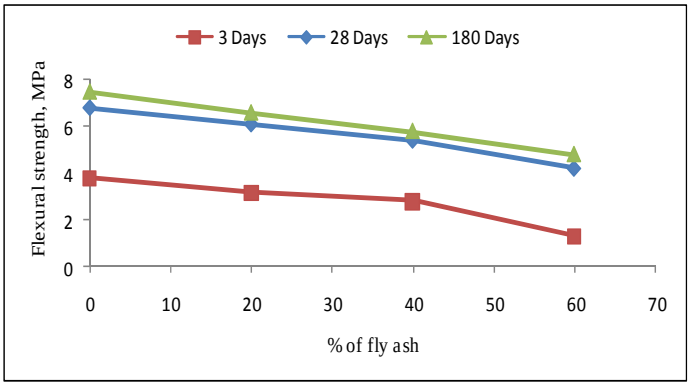

Figure 4. Change in flexural strength versus percent of fly ash in the mix

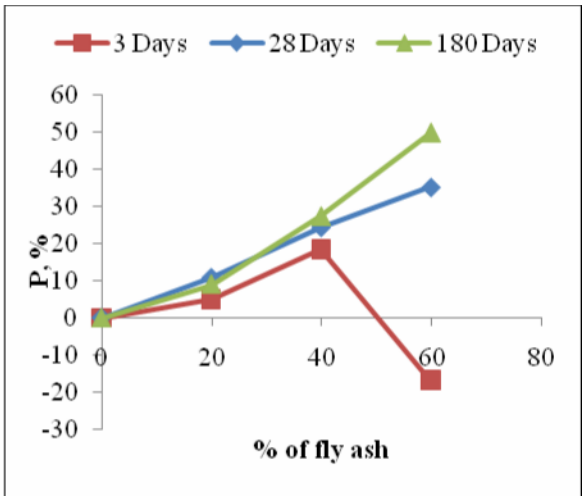

Figure.5 Variation of P with fly ash content in RCC

IV. RESULTS AND DISCUSSIONS

Variation of pozzolanic effect with Fly ash content:

The mixture proportions were presented in Table 1. The Compressive strength results were presented in Tables 2-4. The pozzolanic indices are summarized in Tables 2-4. Also the flexural strength results were presented in Tables 5-7. In the Table 2 and Table 3 the indices of pozzolanic effect(R_p and P) of compressive strength at 3 days and 28 days of curing are showing negative values when fly ash content is more than

20%. But in Table 5 these indices are improved with increase in fly ash content at 180 days of curing.

In Table 5 the indices of pozzolanic effect (R_p and P) of flexural strength at 3 days of curing are showing negative value only at 60% of fly ash replacement. In Table 5 and Table 6 these indices are greatly improved with increase in fly ash content at 28 days and 180 days respectively.

Increase in pozzolanic effect with curing age:

From Tables 2-4 and Tables 5-7, also from Figures 2-5, it is clear that the compressive strength and flexural strength of RCC and indices of pozzolanic effect are increased with curing age. During early period of 3 days curing the pozzolanic effect of fly ash is minimal. The longer the curing age, greater be the contribution of pozzolanic effect of fly ash to RCC strength. This implies that curing age is an important factor on the pozzolanic effect of Fly ash for RCC.

V. CONCLUSION

From the experimental investigation following conclusions were drawn.

1. The pozzolanic effect of the fly ash in Roller Compacted Concrete was quantitatively examined through various indices like specific strength ratio(R), Index of specific strength (K) and contribution percentage of pozzolanic effect to Strength (P).
2. The strength of FARCC is very poor at early curing ages. But strengths were developed rapidly for longer periods of curing.

3. Fly ash effect in FARCC is positive after 28 days of curing age. The contribution of fly ash in FARCC with 180-day curing age to strength approaches 50% at 60 percent replacement of cement with fly ash, and is more remarkable for flexural strength than compressive strength.

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