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Comparative Study on Effect of Fly Ash and Rice Husk Ash on Strength of Concrete

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ABSTRACT
The construction of concrete pavement is growing across the country due to its strength, durability, better serviceability & overall economy in long run. The need is to develop better quality pavement sections, which can bear heavy loads. This can be achieved by using high compressive strength concrete (>40MPa) made up of hydraulic cement having fine & course aggregates. In the work embodied construction work is done with the help of wastage from industry. Fly ash is a by-product of burned coal from thermal plants and Rice husk ash is the by-product of burned rice husk from paper plant. Considerably Fly ash and Rice husk ash are used as supplementary cementing materials to improve the properties of cement concrete.

The present study is done to develop pavement quality concrete by partially replacement cement with Fly Ash & Rice Husk Ash. The aim of study is to compare the strength characterises of pavement concrete which as achieved by concrete mixtures. The work done in this study shows the effects on the behaviour of concrete produced from cement with combination of FA and RHA at different proportions on the mechanical properties of concrete such as compressive strength, flexural strength. The replacement of cement were done at three levels is 10%, 20% and 30% with both Fly ash & Rice husk ash as well as combination of both Fly ash and Rice husk ash. The tests on hardened concrete were destructive in nature which includes compressive test on cube for size (150 x 150 x 150 mm) at 7 and 28 days of curing as per IS: 516 1959, Flexural strength on beam (150 x 150 x700 mm) at 28 days of curing as per IS: 516 1959. The samples were prepared with different water-cement ratio as 0.30, 0.35 & 0.40 for flexure design i.e. 5.5 MPa, 5.0 MPa & 4.5 MPa respectively. The result so obtained showed that it is possible to achieve saving in cement if replacement is done. The study proves to be beneficial in area where traffic load is less, also will use wastage released from thermal plants & rice mills also reduces economy as this materials is easily available. The waste material from industries is in bulk amount, as lesser amount of these used as supplementary cementing materials so these can be used as filling soil in subgrade of highway pavement

Keyword: *Rice Husk Ash, Aggregates, Fibers*

1.1 INTRODUCTION

Concrete is a composite material composed mainly of water, aggregate, and cement. Often, additives and reinforcements are included in the mixture to achieve the desired physical properties of the finished material. When these ingredients are mixed together, they form a fluid mass that is easily molded into shape.

Concrete is widely used for making architectural structures, foundations, brick/block walls, pavements, bridges/overpasses, highways, runways, parking structures, dams, pools/reservoirs, pipes, footings for gates, fences and poles and even boats. Concrete is used in large quantities almost everywhere mankind has a need for infrastructure.

The amount of concrete used worldwide, ton for ton, is twice that of steel, wood, plastics, and aluminum combined. Concrete's use in the modern world is exceeded only by that of naturally occurring water.

There are many types of concrete available, created by varying the proportions of the main ingredients below. In this way or by substitution for the cementations and aggregate phases, the finished product can be tailored to its application with varying strength, density, or chemical and thermal resistance properties [RS 2003].

From 1880 to 1996, the world's annual consumption of Portland cement rose from 2 million tons to 1.3billion tons. This was associated with major environmental cost include: a) cement manufacturing is the third2 2 largest CO producer and for over 50% of all industrial CO emissions (for every 1ton of cement produced,.25 ton of CO is released in the air); b) 1.6 ton of natural resources is consumed to produce 1 ton of cement(Muga, H., K. Betz, 2005). This calls for the use of sustainable binders. One of the most promising materialsis the rice husk ash (RHA).

Rice husk is an agricultural residue from the rice milling process. According to the United Nations FAO(2008), the annual world rice production for 2007 was estimated by 649.7 million tons, the Husk constitute approximately 20% of it. The chemical composition of Rice Husk is found to vary from sample to another dueto the differences in the type of paddy, crop year, climate and geographical conditions (Chandrasekhar, S., S. K. G. Pramada, 2003). Burning the husk under controlled temperature below 800< can produce ash with silicamainly in amorphous form (Chandrasekhar, S., S.K.G. Pramada, 2003; Zhang, M.H., V.M. Malhotra, 1996).

A state-of-the-art report on rice husk ash (RHA) was published by Mehta 1992, and contains a review of physical and chemical properties of RHA, the effect of incineration conditions on the Pozzolanic characteristics of the ash, and a summary of the research findings from several countries on the use of RHA as a supplementary cementing Pozzolanic material. Pozzolan- a siliceous or alumino-siliceous material that in itself possesses little or no Cementitious value but that in finely divided form and in the presence of moisture will chemically react with alkali and alkaline earth hydroxides at ordinary temperatures to form or assist in forming compounds possessing cementitious properties (ASTM, 1995). So far, according to the author's literature, RHA has not been utilized yet in the construction industry, except for some repairing works in the US where it was used in a dry-mix shotcrete to repair the Bowman Dam in northern California's Sierra Nevada Mountains, with positive results (Talend, D., 1997). The reason for not utilising this material may be probably due to lack of understanding of the RHA blended concrete characteristics. Many researchers have already published on the properties of the blended RHA concrete such as strength and durability. However, only few researches were found on the effect of RHA Average Particle Size (APS) on the properties of concrete.

1.2 OBJECTIVES

The objectives and scope of present study are

- To study the relative strength development of [RHA, FA, (RHA+FA)] concrete.
- Use of industrial waste in a useful manner.
- To conduct Compression Test on [RHA, FA, (RHA+FA)] concrete on standard IS specimen size (150X150X150) mm.
- To conduct Flexural Test on [RHA, FA,(RHA+FA)] and concrete on standard IS specimen size (150X150X700) mm.
- To provide economical construction material.
- Provide safeguard to the environment by utilizing waste properly.

1.3 RICE HUSK ASH

Completely burnt rice husk ash was brought from rice mills from Rajpura. Its physical and chemical properties are given in Table 3.9 and Table 3.10 respectively [RK 2013].

Table 1.1 Physical properties of rice husk ash

Physical property	Value
Colour	gray with slight black
Bulk density	104.9 kg/m^3
Specific gravity	1.96
Fineness	2775 cm^2/gm
Avg particle size	150.47µm
Mesopores	78%
Heating value	9.68 MJ/kg

Table 1.2 Chemical properties of rice husk ash

Component	%
Silica	92.1
Alumina	0.51
Iron oxide	0.40
Calcium oxide	0.55
Potassium oxide	1.53
Titanium di oxide	0.02
Manganese oxide	0.08
Phosphorous penta oxide	0.08
Sulphur tri oxide	0.12

2.1 RESULTS AND DISCUSSIONS:

2.1.1 Overview

The study was undertaken to investigate the compressive strength and flexural strength of concrete with different levels of replacement of cement with fly ash and rice husk ash in concrete mix. Cement was partially replaced by fly ash at three different levels of replacement i.e. 10%, 20% and 30% and same with rice husk ash. Concrete mixtures were also cast with combined replacements of fly ash and rice husk ash. Tests were performed after 7 and 28 days of curing of concrete. Cubes and beams were prepared for determining compressive strength and flexural strength of concrete with different water-cement ratio as 0.30, 0.35 and 0.40 for minimum required flexural strengths of 5.5N/mm2 5N/mm2 4.5N/mm2, respectively. Super-plasticizer was used in all the mixes at 1% level by weight of cementitious material.

2.1.2 Compressive Strength

It is the most common test conducted on hardened concrete as it is an easy test to perform and also most of the desirable characteristic properties of concrete are qualitatively related to its compressive strength. The compression test is carried out on specimens cubical in shape of the size 150 × 150 × 150 mm. The test is carried out in the following steps: First of all, the mould preferably of cast iron, is used to prepare the specimen of size 150 × 150 × 150 mm. During the placing of concrete in the mounds it is compacted with the tamping bar with not less than 35 strokes per layer. Then these mounds are placed on the vibrating table and are compacted until the maximum possible compaction is attained. After 24 hours, the specimens are removed from the mounds and immediately submerged in clean fresh water. The specimens can be tested at the end if 7, 14 and 28 days in compression testing machine.

2.1.3 General

In most structural applications, concrete is employed primarily to resist compressive stresses. When a plain concrete member is subjected to compression, the failure of the member takes place, in its vertical plane along the diagonal. The vertical crack occurs due to lateral tensile strains. A flow in the concrete, which is in the form of micro crack along the vertical axis of the member will take place on the application of axial compression load and propagate further due to the lateral tensile strains.

2.1.4 Test Procedure and Results

Test specimens of size 150mm x 150mm x 150mm were prepared for testing the compressive strength (FR00, FR10 & FR20 etc.). The mix was done manually. The cement and fine aggregate were first mixed dry to uniform colour and then coarse aggregate was added and mixed with the mixture of cement and fine aggregates. Water was then added and the whole mass mixed. The interior surface of the moulds and the base plate were highly oiled before concrete was placed. After this the specimens were removed from the moulds and placed in clean fresh water at for 28 days curing. For testing in compression, no cushioning material was placed between the specimen and the plates of the machine. The load was applied axially without shock till the specimen was crushed. Test results of compressive strength test at the age of 7 days & 28 days are given in the Table 2.1, Table 2.2 and Table 2.3 respectively.

Table 2.1 Compressive strength (w/c = 0.4)

w/c = 0.4	7 Days		28 Days	
	Avg. Load (KN)	f_c (N/mm²)	Avg. Load (KN)	f_c (N/mm²)
Controlled **(FR00)**	855.03	37.92	1142.66	51.22
10% F.A. **(FR10)**	843.63	37.54	1096.33	47.84
20% F.A. **(FR20)**	768.633	34.4524	1011.1	45.36
30% F.A. **(FR30)**	652.366	28.3268	931.133	40.9826
10% R.H.A. **(FR01)**	503.97	22.55	729.36	32.44
20% R.H.A **(FR02)**	435.9	19.7522	641.133	28.4137
30% R.H.A. **(FR03)**	363.2	15.8511	570.9	24.8955
10% F.A. 10%R.H.A. **(FR11)**	468.2	20.7677	722.933	31.7525
20% F.A. 10% R.H.A **(FR21)**	365.17	16.45	615.3	26.9688
10% F.A 20% R.H.A. **(FR12)**	354.63	15.47	577.56	25.79

**fc = Compressive strength*
FR = Mould No.
F.A = Fly Ash
R.H.A. = Rice Husk Ash

Table 2.2 Compressive strength (W/C = 0.35)

w/c = 0.35	7 Days		28 Days	
	Avg Load (KN)	f_c (N/mm²)	Avg Load (KN)	f_c (N/mm²)
Controlled **(FR00)**	920.5	40.712	1279.66	55.764
10% F.A. **(FR10)**	850.933	37.519	1120	48.68
20% F.A. **(FR20)**	791.666	34.175	1083.33	48.548
30% F.A. **(FR30)**	734.466	32.142	963.3	41.713
10% R.H.A. **(FR01)**	543.86	24.77	758.56	32.71
20% R.H.A **(FR02)**	486.833	21.547	712.633	30.762
30% R.H.A. **(FR03)**	435.533	18.258	604.166	25.841
10% F.A. 10%R.H.A. **(FR11)**	537.766	22.758	786.633	34.661
20% F.A. 10% R.H.A **(FR21)**	470.133	20.1948	724.833	31.214
10% F.A 20% R.H.A. **(FR12)**	411.233	17.274	685.5	29.45

**fc = Compressive strength*
FR = Mould No.
F.A = Fly Ash
R.H.A. = Rice Husk Ash

Table 2.3 Compressive strength (W/C = 0.3)

w/c = 0.30	7 Days		28 Days	
	Avg Load (KN)	f_c (N/mm^2)	Avg Load (KN)	f_c (N/mm^2)
Controlled **(FR00)**	1047.66	45.4562	1388	60.6778
10% F.A. **(FR10)**	954.433	41.4092	1199.33	52.2374
20% F.A. **(FR20)**	999.8	43.4455	1193.66	52.0518
30% F.A. **(FR30)**	738.233	31.8102	1039.73	45.2104
10% R.H.A. **(FR01)**	601.67	25.74	995.67	43.25
20% R.H.A **(FR02)**	526.73	22.45	725.7	32.8583
30% R.H.A. **(FR03)**	480.2	20.3421	609.8	26.102
10% F.A. 10%R.H.A. **(FR11)**	739.566	30.87	938.667	43.7
20% F.A. 10% R.H.A **(FR21)**	582.333	24.97	850.933	37.57
10% F.A 20% R.H.A. **(FR12)**	482.03	21.24	786.633	34.89

*fc = Compressive strength
FR = Mould No.
F.A = Fly Ash
R.H.A. = Rice Husk Ash

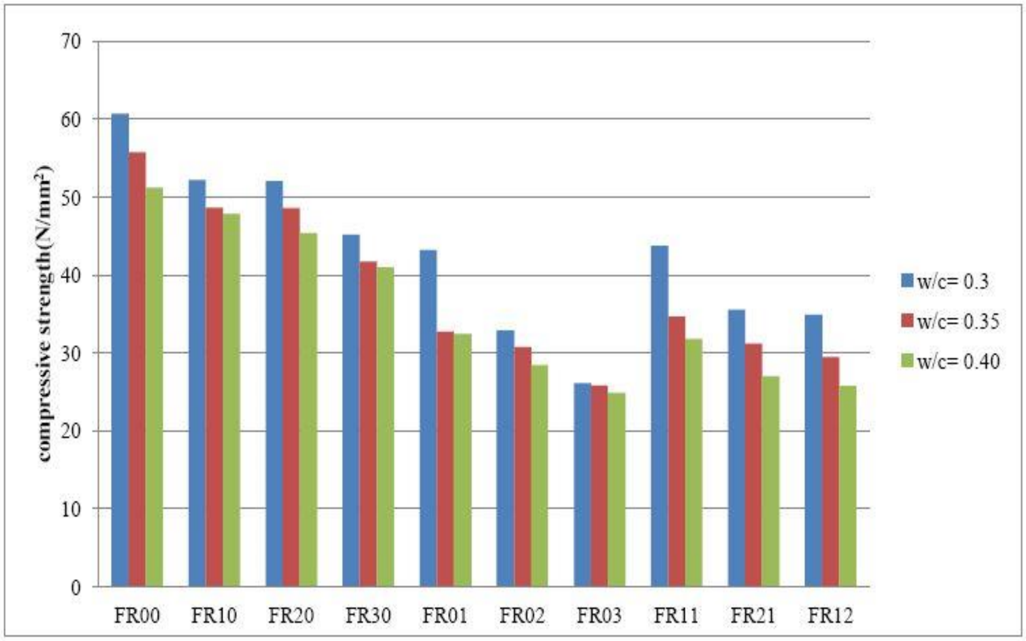

Fig 2.1: 28-day compressive strengths for all water cement ratios

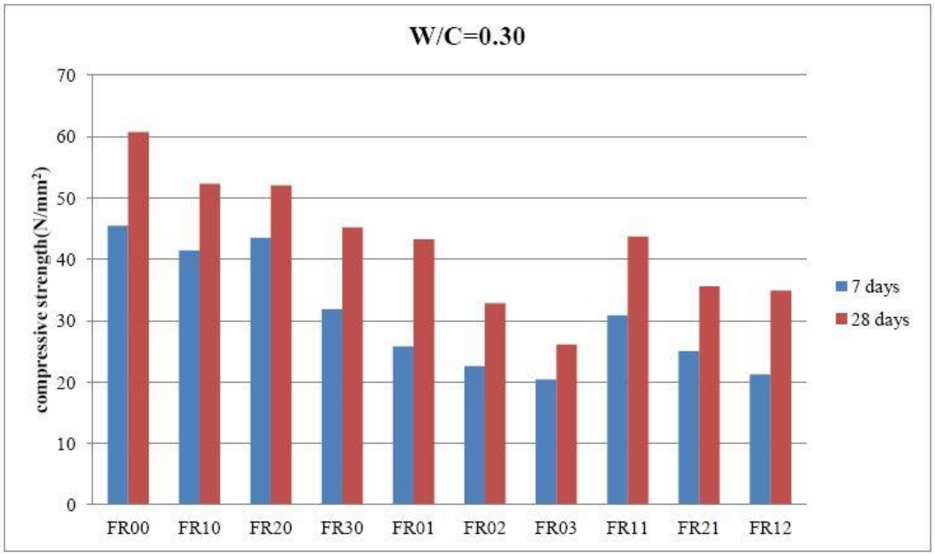

Fig 2.2: 7-day and 28-day compressive strengths with w/c = 0.30

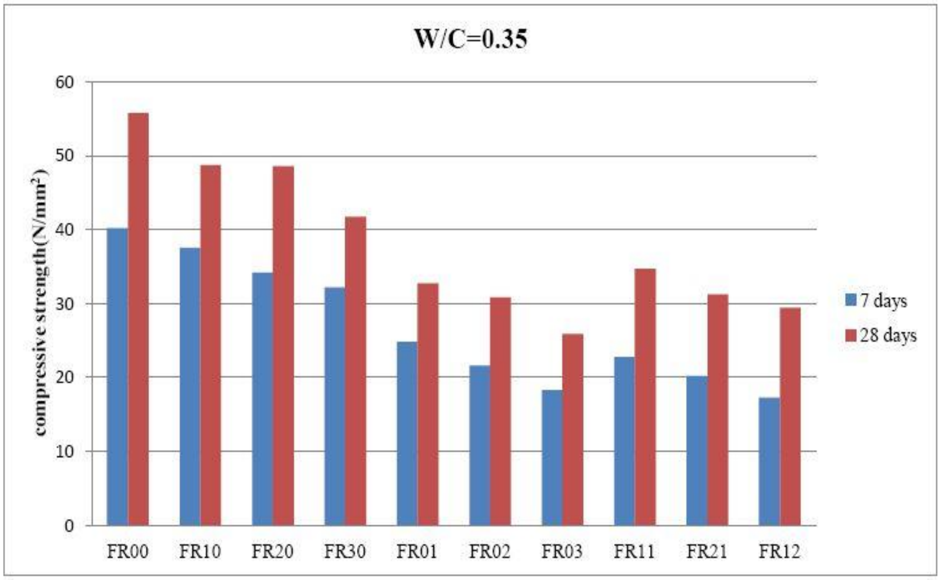

Fig 2.3: 7-day and 28-day compressive strengths with w/c = 0.35

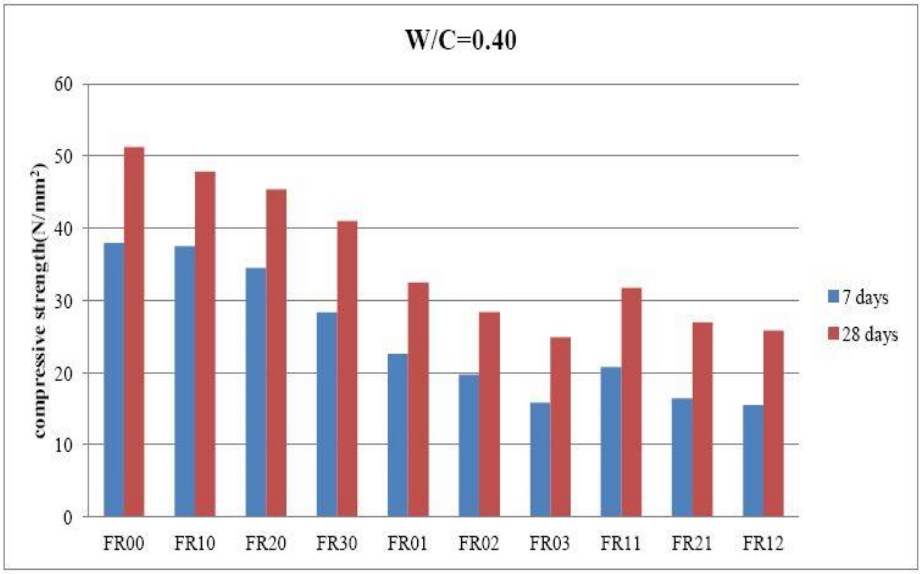

Fig 2.4: 7-day and 28-day compressive strengths with w/c = 0.40

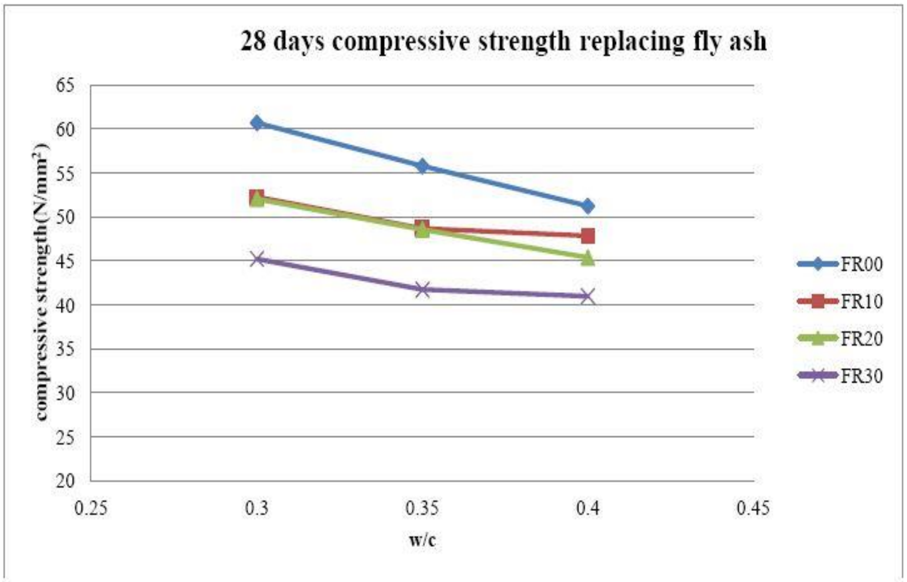

Fig 2.5: 28-day compressive strength replacing Fly ash

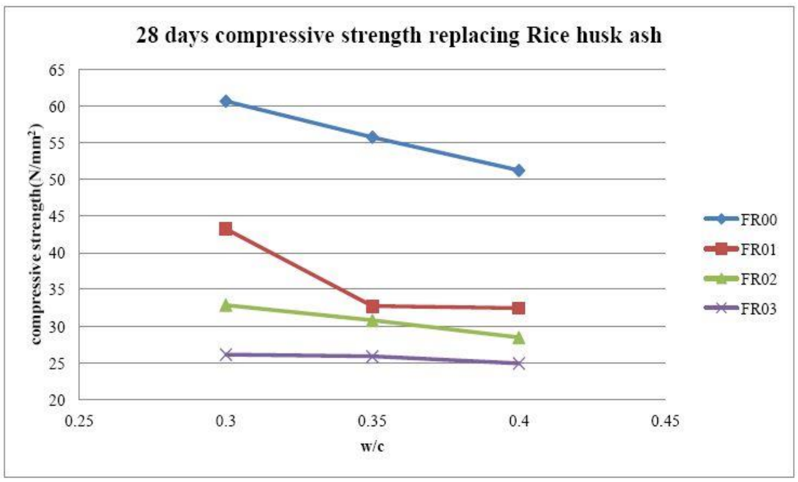

Fig 2.6: 28-day compressive strength replacing Rice husk ash

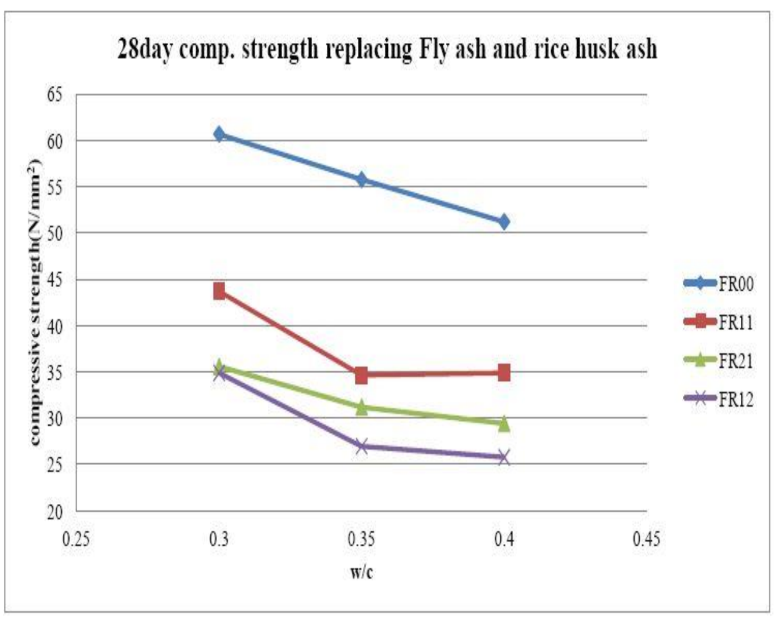

Fig 2.7: 28-day compressive strength replacing fly ash and rice husk ash

2.2 Discussion Of Results

2.2.1 Effect of Fly ash and Rice husk Ash Replacement on Compressive Strength of Concrete

a) Effect of age on compressive strength

Fig. 4.1 to 4.7 and Tables 4.1 to 4.3 show the variation of compressive strength of Quality Concrete due to variation in the replacement levels of fly ash and rice husk ash, individually as well as in combinations, at the curing ages of 7 and 28 days.

The Tables 4.7 to 4.9 and Figures 4.12 to 4.14 show the percentage increase in values of compressive strengths with age (from 7 to 28 days) for all the replacement combination concrete mixes with w/c ratios of 0.30, 0.35 & 0.40 respectively. From the data as presented, it can be seen that the mixes with only fly ash replacement has a lesser rate of increase in strength from 7days to 28 days though they have high initial strength, than the mixes with rice husk ash replacement only and mixes with both fly ash and rice husk ash as replacement of cement. The mixes with the inclusion of both rice husk ash and fly ash as replacement material show the highest rate of increase of strength for all water to cement ratios indicating that pozzolanic activity initiates early for such mixes.

Table 2.4 - Effect of Age on Compressive Strength of Concrete W/C = 0.3

W/C = 0.3	7-DAY	28-DAY	% INCREASE
FR00	45.4562	60.6778	33.486
FR10	41.4092	52.2374	26.149
FR20	43.4455	52.0518	19.809
FR30	31.8102	45.2104	42.125
FR01	25.74	43.25	68.026
FR02	22.54	32.8583	45.778
FR03	20.3421	26.102	28.315
FR11	30.87	43.7	41.561
FR21	24.97	35.57	42.451
FR12	21.24	34.89	64.266

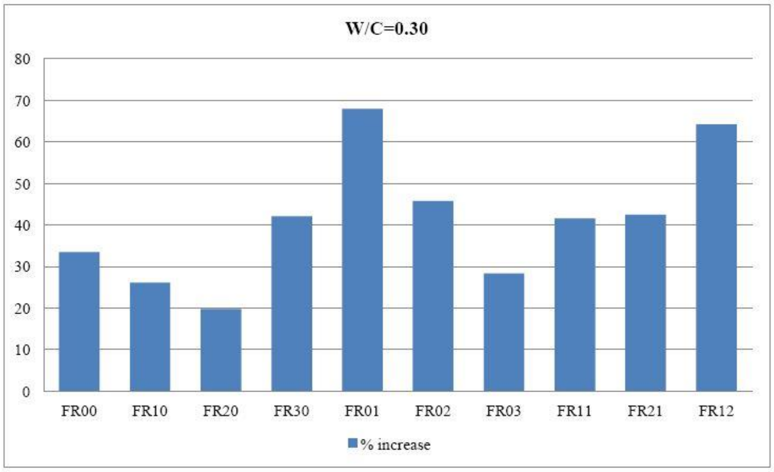

Fig 2.8 Percentage increase in compressive strengths of 7days to 28 days W/C = 0.30

Table 2.5 - Effect of Age on Compressive Strength of Concrete W/C = 0.35

W/C = 0.35	7-DAY	28-DAY	% INCREASE
FR00	40.172	55.764	38.813
FR10	37.519	48.68	29.748
FR20	34.175	48.548	42.057
FR30	32.142	41.713	29.777
FR01	24.77	32.71	32.055
FR02	21.547	30.762	42.767
FR03	18.258	25.841	41.532
FR11	22.758	34.661	52.302
FR21	20.1948	31.214	54.565
FR12	17.274	29.45	70.487

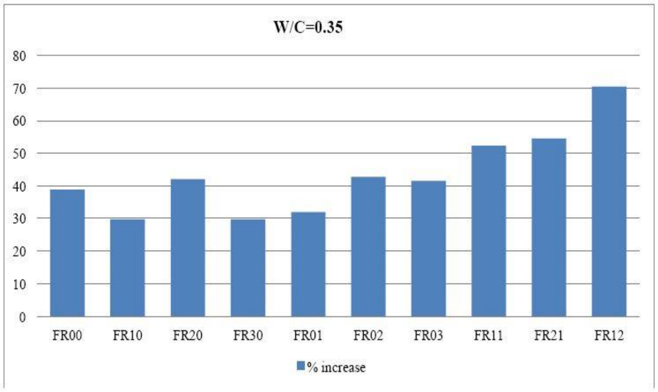

Fig 2.9 Percentage increase in compressive strengths of 7days to 28 days W/C= 0.35

Table 2.6 - Effect of Age on Compressive Strength of Concrete W/C = 0.40

W/C = 0.40	7-DAY	28-DAY	% INCREASE
FR00	37.92	51.22	35.074
FR10	37.54	47.84	27.437
FR20	34.4524	45.36	31.660
FR30	28.3268	40.9826	44.678
FR01	22.55	32.44	43.858
FR02	19.7522	28.4137	43.851
FR03	15.8511	24.8955	57.059
FR11	20.7667	31.7525	52.901
FR21	16.45	26.9688	63.944
FR12	15.47	25.79	66.710

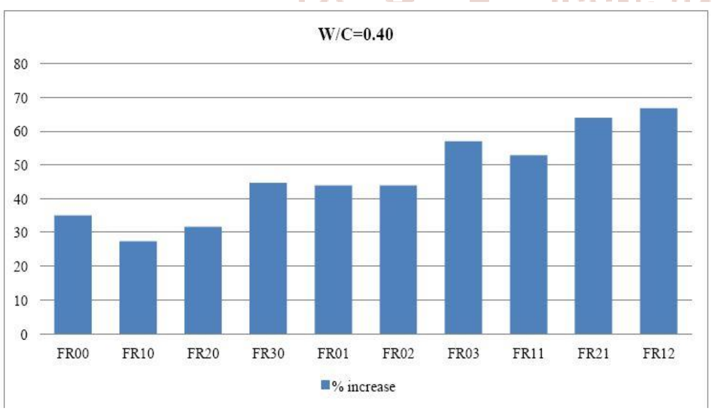

Fig 2.10 Percentage increase in compressive strengths of 7days to 28 days W/C = 0.40

b) Effect of replacement levels of mineral admixtures on compressive strength of Concrete

The Tables 4.12 to 4.14 and Fig. 4.15 to 4.20 show the percentage variation in compressive strengths of the mixes with fly ash and rice husk ash as replacement materials, individually as well as in combination, as compared to the strength of the control mix specimen and also relative to the minimum required design compressive strength for PQC mixes (as per MoRTH standards the value is 40MPa). The variations are shown for all the three water to cement ratios of 0.30, 0.35 and 0.40. It is observed that for all the water-cement ratios none of the concrete mixes, with partial cement replacement with fly ash and rice husk ash, could achieve the compressive strength value of the control mix in 28 day curing period. The mixes containing only 10% fly ash could achieve 85% of the control strength, whereas, the mixes containing only 30% rice husk as replacement achieved only 45% of the target controlled strength. When compared with the minimum required design compressive strength for PQC mixes (as per MORTH standards the value is 40MPa), it is observed that all the mixes with fly ash replacement showed higher compressive strengths than required for PQC for all replacement levels and for all water to cement ratios. The concrete mixes with replacement of cement by rice husk ash only, could not achieve the desired PQC strength for water to cement ratios 0.35 and 0.40, but with 10% replacement of rice husk ash and combined replacement of 10% each of fly ash and rice husk ash with a water-cement ratio of 0.3 higher compressive strengths were observed as compared to the minimum required for quality Concrete.

3.1 CONCLUSIONS

The study was undertaken to investigate the effect of partial replacement of cement with fly ash and rice husk ash on compressive strength and flexural strength of concrete mix. Cement was partially replaced by fly ash at three different levels of replacement i.e. 10%, 20% and 30% and same with rice husk ash as well as with combined replacements of fly ash and rice husk ash. Tests were performed after 28 days of curing of concrete. Cubes and beams were prepared for determining compressive strength and flexural strength of concrete with different water-cement ratio as 0.30, 0.35 and 0.40 for min required flexural designs 5.5 MPa, 5 MPa & 4.5 MPa respectively. Super-plasticizer was used in all the mixes at 1% level by weight of cementations material.

From the experimental results, the conclusions of compressive strength, flexural strength and the pavement quality concrete slab thickness are concluded as under:

3.1.1. Workability of concrete

The amount of SP requirement of mixtures for achieving a desired slump in the range of (80–100 mm) is shown in Table 2. To attain the desired slump, the concretes containing RHA required higher water content than those containing only Portland cement. This is due to the high specific surface area and high carbon content of RHA [1, 12]. Therefore, the SP content of RHA concrete mixtures is higher than that of the control mixture. The SP content increases along with the RHA percentage.

3.1.2 Compressive Strength

- The mixes with only fly ash replacement has a lesser rate of increase in strength from 7days to 28 days despite the fact that they have high initial strength, than the mixes with rice husk ash replacement only. The mixes with the inclusion of both rice husk ash and fly ash as replacement material show the highest rate of increase of compressive strength for all water to cement ratios which indicates indicates that pozzolanic activity initiates early for such mixes.
- Concrete mix with up to 20% percent replacement of cement with fly ash for 0.40 w/c ratio have higher compressive strengths than minimum required as per MoRT&H specifications.
- Concrete mixes with replacement of rice husk ash in all water-cement ratios have lesser compressive strengths than minimum required as per MoRT&H specifications.
- Combined replacement of fly ash and rice husk ash in w/c= 0.3 & 0.35 showed higher compressive strengths than only replacement of concrete mixes with rice husk ash.
- Concrete mixes with combined replacement of fly ash and rice husk ash in all water-cement ratios have lesser compressive strengths than minimum required as per MoRT&H specifications.

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