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COMPARATIVE STUDY ON EFFECT OF FLY ASH AND RICE HUSK ASH ON STRENGTH CHARACTERSTICS OF PAVEMENT QUALITY CONCRETE

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Abstract - There is growing interest in the construction of concrete pavements, due to its high strength, durability, better serviceability and overall economy in the long run. The thrust nowadays is to produce thinner and green pavement sections of better quality, which can carry the heavy loads. The high strength is a concrete having compressive strength greater than 40MPa, made of hydraulic cements and containing fine and coarse aggregates. The present study aims at, developing pavements quality concrete mixtures incorporating fly ash and rice husk ash partial replacement of cement. The aim is to the design of slab thickness of PQC pavement using the achieved flexural strength of the 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 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. It is found that it is possible to achieve savings in the cement by replacing it with fly ash. This study also shows that in view of the high flexural strength, high values of compressive strength the 20% replacement of cement with fly ash is ideal for design of Pavement Quality Concrete (PQC).

Keywords- Pavement, Compressive strength, Flexural strength,Fly ash, Rice husk ash, Water-Cement ratio

I. INTRODUCTION

The excessive global population growth brings high demand for building with higher levels of comforts and to low cost, but it is also generates the need of producing sustainable architecture in order to reduce energy consumption while lowering environmental impact [2]. The growing industries in India leads to the generation of large amount of wastes like rice mills industries generates a by-product known as husk. During milling of paddy about 78% of weight is received as rice, broken rice and bran, rest 22% of the weight of paddy is received as husk [1]. The husk to obtain is used as fuel to generate steam for parboiling process. The husk contain about 75% organic volatile matters and balance 25% of husk is converted into Ash during the firing process known as Rice Husk Ash [5].

Thermal power plants generates fly ash as a by-product waste in large amount which is such a big environmental concern. It has been observed that fly ash is very much similar to volcanic ashes used in production of earliest known pozzolan cement. Fly ash is the best known and one of one of the most commonly used pozzolan in the world. Fly ash being the most notorious waste product causing ill effects on agricultural land, surface & sub-surface waste pollution, soil & air pollution. So researchers have proposed few way to reduce fly ash in a cement replacement. Fly ash particles are mostly spherical in shape & this property is used to property mixed in materials [3].

The present study is conducted by using the waste materials from the both the industries like rice mills & thermal power plant. The study is done on techno-economic analysis for the compressive strength of cement concrete when cement was replace with fly ash and rice husk ash in different ratio. This research is to find environmental reuse of waste product also to finda substitute of cement where these industries are located so that is nearby areas these products could not cause pollution, water logging and diseases to mankind [4].

II. MATERIALS USED

A. Cement: The cement used was Ordinary Portland Cement of 43 grade. The properties obtained experimentally and as per IS 8112:1989 [12] shown in following table:

Sr. No.	Characteristics	Values Obtained Experimentally	Values Specified By IS 8112:1989
1	Specific Gravity	3.10	-
2	Standard Consistency	27%	-
3	Initial Setting Time, minutes	149	30 minutes (minimum)
4	Final Setting Time, minutes	257	600 minutes (maximum)
5	Compressive Strength 3 days 7 days 28 days	 27.8 N/mm^2 36.5 N/mm^2 48.6 N/mm^2	 23 N/mm^2 33 N/mm^2 43 N/mm^2

Table: 1: Showing characteristics of Ordinary Portland cement

B. Aggregates: The coarse aggregate used were a mixture of two locally available crushed stone of 20 mm and 10 mm size in 70:30 proportion. The specific gravity of coarse aggregates is 2.73 the aggregates were washed to remove dirt, dust and then dried to surface dry condition [9].In this experimental program**,** fine aggregates (stone dust) were collected from Jhelum Stone Crusher, Mirthal, Pathankot and conforming to grading zone II. It was coarse sand light grey in color.

C. Fly Ash: Fly ash used in the study was obtained from Guru Nanak Dev Thermal Power Plant, Bathinda. The fly ash, also known as pulverized fuel ash, Coal Fly ash (FA) is a by-product of the combustion of pulverized coal in thermal power plants. It is removed by the dust collection systems from the exhaust gases of fossil fuel power plants as very fine, predominantly spherical glassy particles from the combustion gases before they are discharged into atmosphere. The size of particles is largely dependent on the type of dust collection equipment. Diameter of fly ash particles ranges from less than 1 μm to 150 μm [6]. It is generally finer than Portland cement.

Constituent	**Component in %**
Silica (SiO2)	46.8
Alumina (Al2O3)	23.7
Ferric Oxide (Fe2O3)	13.2
Calcium Oxide (CaO)	1.2
Magnesia (MgO)	1.0
Loss on Ignition (LOI)	6.9
Specific gravity	2.10
Fineness	2840 cm^2/gm

Table: 2: Showing properties of Fly Ash

D. Rice Husk Ash: Rice husk ash used in this study obtained from Rice mill plant located in Rajpura, Punjab, India. Rice husk is one of the main agricultural residues obtained from the outer covering of rice grains during the milling process. It constitutes 20% of the 500 million tons of paddy produced in the world.IS 456- 2000 [13], recommends use of RHA in concrete but does not specify quantities. The rice husk ash had no useful application and had usually been dumped into water streams and caused pollution and contamination of springs until it was known to be a useful mineral admixture for concrete. Various experiments were carried out to determine properties of concretes incorporating optimum RHA. Tests include compressive strength, splitting tensile strength, workability, water permeability and flexural strength. In the case of RHA, the compressive strength of blended concrete structures has been shown to be enhanced and water permeability to be decreased chemically and physically.

Property	**Value**
Colour	Grey with slight black
Bulk density	104.9 kg/m^3
Specific gravity	1.96
Fineness	2775 cm^2/gm
Avg particle size	150.47µm
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

Table: 3: Showing properties of Rice Husk Ash

E. Superplasticizer: The superplasticizer “GLENIUM™ B233” procured from SIKA India Pvt. Limited was used in this study. The dosage of superplasticizer recommended is 0.6% to 2% by weight of cementitous material. 1% superplasticizer by weight of cementitious material was selected in this study to get the medium range of workability [7]. The technical data provided by manufacturer is given in Table:

Sr. No.	**Characteristics**	**Values**
1	Type	Poly carboxylic ether (PCE)
2	Form	Liquid
3	Colour	Light Brown
4	Specific Gravity	1.09
5	Relative density	1.09 ± 0.01 at 25^0C
6	PH Content	> 6
7	Setting Time	There may be mild extension of initial or final set

Table: 4: Showing properties of Superplasticizer

III. RESULTS AND DISCUSSION

Test specimens of size 150x150x150 mm were prepared for testing the compressive strength and specimen of size 150x150x700 mm for flexure strength with different ratios of materials with different flexure design and different water cement ratio. The compressive strength were tested for curing period of 7 and 28 days and flexure strength were tested for curing period of 28 days as per IS: 516-1959 [10]. Proper vibration was given to the mould with the help of table vibrator for removing voids in concrete cubes. 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.

3.1 Different Proportion of Cement, RHA and FA for testing:-

In this experimentation 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.
Following table shows the percentage variation of cement, fly ash and rice husk ash:

S. No.	Mould ID	Cement %	Fly Ash %	Rice Husk Ash %
1	FR00	100	0	0
2	FR10	90	10	0
3	FR20	80	20	0
4	FR30	70	30	0
5	FR01	90	0	10
6	FR02	80	0	20
7	FR03	70	0	30
8	FR11	80	10	10
9	FR21	70	20	10
10	FR12	70	10	20

Table: 5: Shows the percentage variation of cement, fly ash and rice husk ash in specimens

3.2 Test on Fresh Concrete

3.2.1 Compressive strength

For compressive strength test, cube specimens of dimensions 150x150x150 mm were cast for flexural design of 5.5, 5.0 & 4.5 MPa with different water cement ratio of 0.30, 0.35 & 0.40 respectively. The mould were prepared with different ratio of cement, RHA & FA. Vibration was given to moulds using table vibrator. After 24 hours the specimens were demoulded and were transferred to curing tank to cure for 7 and 28 days. After curing, these cubes were tested on digital compression testing machine as per IS 516-1959 [10]. The failure load was noted.

W/C = 0.30	7-Days	28-days	% increase
FR00	45.4562	60.6778	33.482
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	43.25	41.561
FR21	24.97	35.57	42.451
FR12	21.24	34.89	64.266

Table: 6: Compressive strength of 5.5 MPa flexure design (w/c = 0.30)

W/C = 0.35	7-Days	28-days	% increase
FR00	40.172	55.764	38.813
FR10	37.519	48.68	29.748
FR20	34.175	48.548	42.057
FR30	32.175	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	52.565
FR21	20.1948	31.214	54.565
FR12	17.274	29.45	70.487

Table: 7: Compressive strength of 5.0MPa flexure design (w/c = 0.35)

W/C = 0.40	7-Days	28-days	% 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

Table: 8: Compressive strength of 4.5 MPa flexure design (w/c = 0.4)

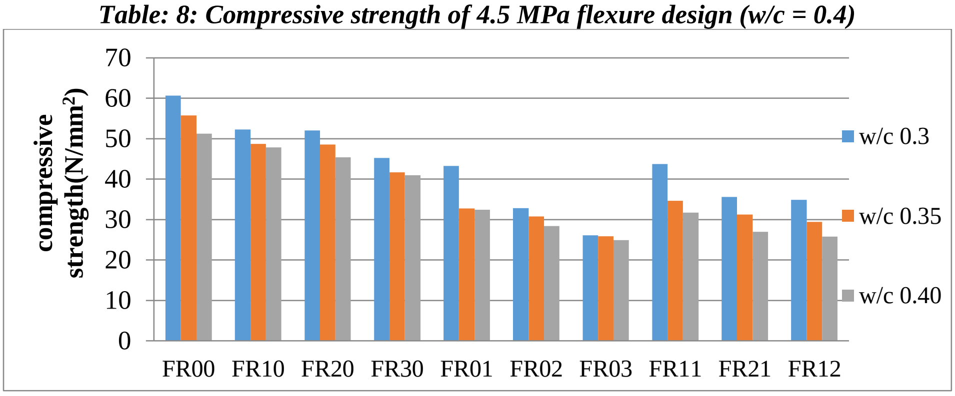
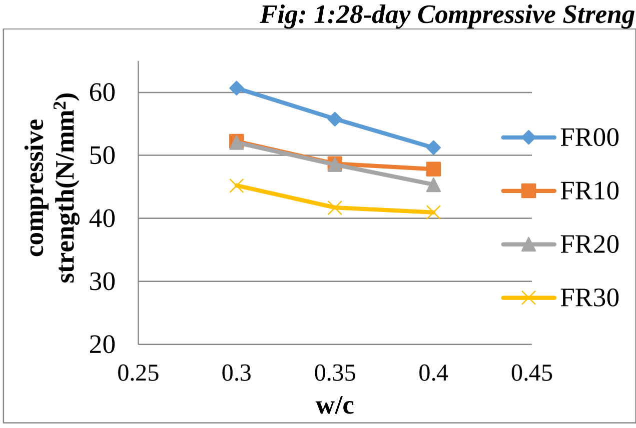


Fig: 1:28-day Compressive Strengths for all water cement ratios



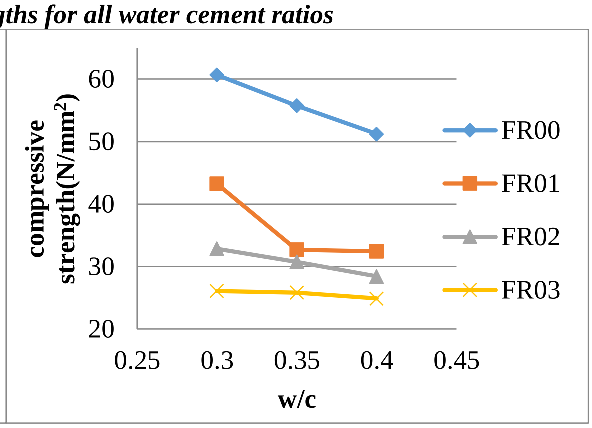


Fig: 2:28-day Compressive Strength replacing Fly Ash

Fig: 3:28-day Compressive Strength replacing Rice Husk ash

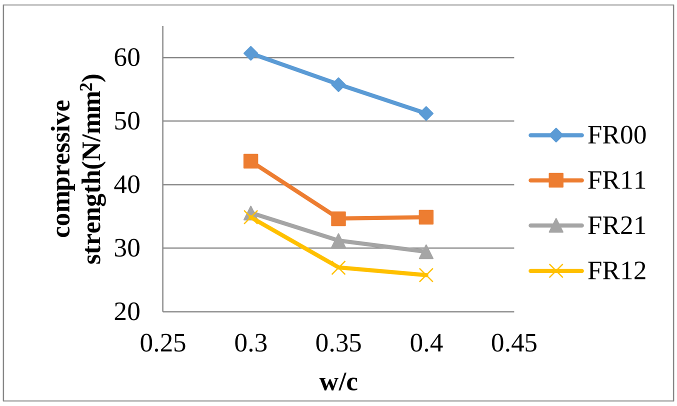


Fig: 4:28-day Compressive Strength replacing Rice Husk ash + Fly Ash

3.2.2 *Flexural Strength*

Test specimens of beam size 150×150×700 mm were prepared for testing the flexural strength. The beam moulds containing the test specimens were placed in moist air for at least 90% relative humidity and a temperature of $27^0 \pm 2^0$ C for 24 hours $\pm 1/2$ hour from the time of addition of water to the dry ingredients. After this the specimens were removed from the moulds and placed in clean fresh water at a temperature of $27^0 \pm 2^0$ C for 28 days curing. After 28 days of curing the specimens were tested in flexure on a Universal Testing Machine [8]. Loads were applied at the one third points at a constant rate of 30 kg/minute. The distance between the centres of two rollers was kept 20cm.If the fracture occurred within the central one-third of the beam, the flexuralstrength was calculated on the basis of ordinary elastic theory.

W/C = 0.30	F.S (N/mm^2)	% variation in F.S relative to that of control specimen	% variation in F.S relative to the minimum design strength (MORTH standard for PQC) of 5.5 MPa
FR00	5.95	0.0	8.18
FR10	5.721	-3.8	4.02
FR20	5.369	-9.8	-2.38
FR30	4.941	-17.0	-10.16
FR01	4.582	-23.0	-16.69
FR02	3.618	-39.2	-34.22
FR03	3.152	-47.0	-42.69
FR11	3.667	-38.4	-33.33
FR21	3.401	-42.8	-38.16
FR12	3.168	-46.8	-42.40

Table: 9: Flexural strength of 5.5 MPa flexure design (w/c = 0.30)

W/C = 0.35	F.S (N/mm^2)	% variation in F.S relative to that of control specimen	% variation in F.S relative to the minimum design strength (as per MORTH standard for PQC) of 5.0MPa
FR00	5.62	0.0	11.03
FR10	5.482	-2.5	8.79
FR20	5.243	-6.7	4.63
FR30	4.744	-15.6	-5.40
FR01	4.451	-20.8	-12.33
FR02	3.586	-36.2	-39.43
FR03	2.977	-47.0	-67.95
FR11	3.646	-35.1	-37.14

FR21	3.274	-41.7	-52.72
FR12	2.993	-46.7	-67.06

Table: 10: Flexural strength of 5.0 MPa flexure design (w/c = 0.35)

W/C = 0.40	**F.S (N/mm^2)**	**% variation in F.S relative to that of control specimen**	**% variation in F.S relative to the minimum design strength (as per MORTH standard for PQC) of 4.5MPa**
FR00	5.362	0.0	19.15556
FR10	5.179	-3.4	15.08889
FR20	5.097	-4.9	13.26667
FR30	4.572	-14.7	1.6
FR01	4.481	-16.4	-0.42222
FR02	3.487	-35.0	-22.5111
FR03	3.016	-43.8	-32.9778
FR11	3.562	-33.6	-20.8444
FR21	3.463	-35.4	-23.0444
FR12	3.032	-43.5	-32.6222

Table: 11: Flexural strength of 4.5 MPa flexure design (w/c = 0.4)

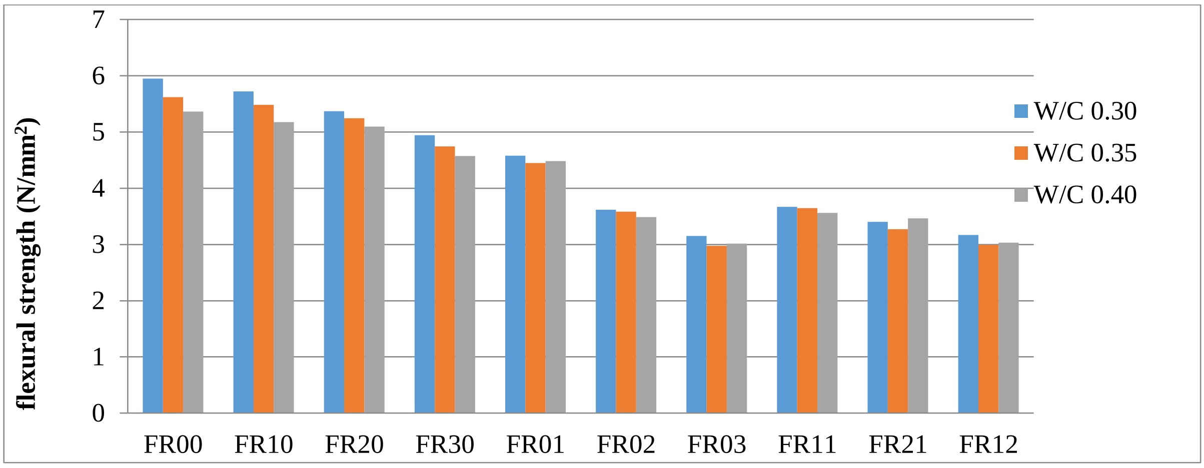


Fig: 5: 28-day Flexural Strengths for all water cement ratios

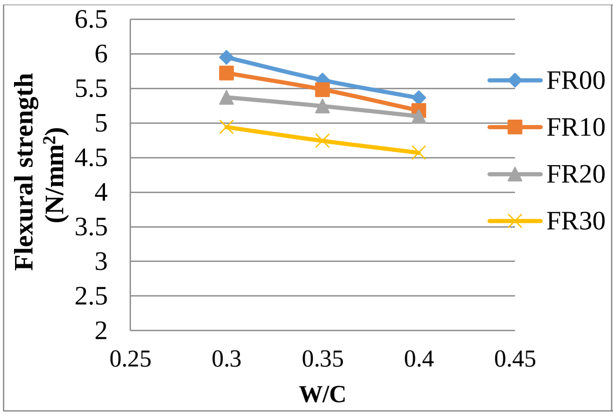


Fig: 6:28-day Flexural Strength replacing Fly Ash

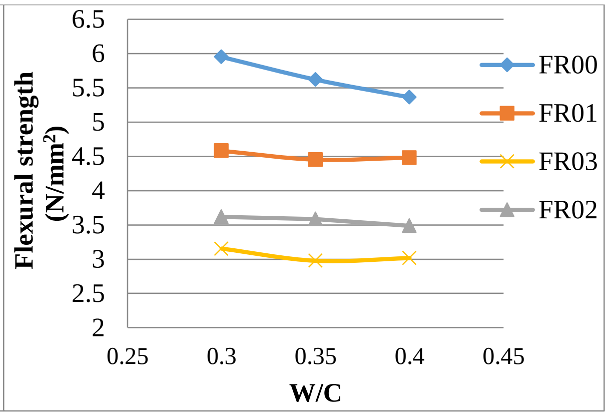


Fig: 7:28-day Flexural Strength replacing Rice Husk ash

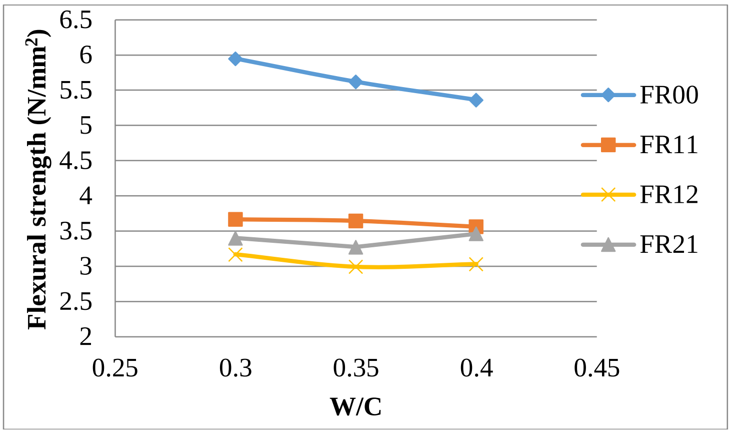


Fig: 8:28-day Flexural Strength replacing Rice Husk ash + Fly Ash

IV. CONCLUSIONS

A. Compressive strength

1. 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.
2. 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.
3. 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.
4. 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.
5. 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.

B. Flexural strength

6. The mixes containing only fly ash could achieve 85 to 95% of the control strength, whereas, the mixes containing only 30% rice husk as replacement achieved only 55% of the target controlled strength.
7. Fly ash up to 10 to 25% replacement for all the water-cement ratios showed higher flexural strengths than minimum required flexural strengths as per PQC design standards. Thus, cement replacement by fly ash can be used in designing pavement quality concrete mixes with significant saving in cost.
8. Partial replacement of cement along with rice husk ash does not significantly contribute to gain in flexural strengths for all the replacement levels and for all water to cement ratios.
9. Mixes with combination of fly ash and rice husk ash were unable to achieve desired flexural strengths.

V. FUTURE PROSPECTS

1. Rice husk ash is showing lesser compressive strength than fly ash, industrial waste it can further be utilized as strength material of sub grade soil in highway pavements.
2. The result so obtained proves that fly ash is providing more strength than rice husk ash but lesser than cement, so it can be utilized as supplementary cementing material in pavement concrete of less traffic load.
3. The industrial waste, if left unutilized cause environmental problems like burning cause pollution, mixing with water causes choking & blockage. It is better to use waste in an effective & environmentally sound manners.

4. Partial replacement of FA & RHA reduces the environmental effects, produces economical & eco-friendly concrete.

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