

Experimental Study on Concrete Pavements by Partial Replacement of Cement with Industrial Wastes

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Abstract—Portland cement as a constituent in concrete is one of the main constituent broadly used exclusively in growing nations. Performance of concrete for pavement by replacing different percentage of industrial wastes by weight of cement for a controlled mix of M40 grade concrete and to analyze the effect of Admixtures on concrete. The scope for alternative binder or cement auxiliary materials is by using industrial derivatives and agricultural wastes.

The main scope of the investigation is to use limited substitution of cement in concrete pavement using different types of additives like Lagoon Ash, Rice Husk Ash are used which improve the Strength and Durability. In addition, it is also aimed to compare the mechanical properties of these Conventional mixes. The properties such as compressive strength, flexural strength, workability with initial tests on materials were performed and the principal advantages, major dis-advantages, principal applications in Indian construction industry were discussed & Cost Analysis of pavement also observed.

Keywords—Cement, Cost Effective Pavement, Lagoon Ash, Rice husk ash, Strength.

I. INTRODUCTION

The cost of concrete is reduced by replacing cement with pozzolanas. The increasing requirement for cement and concrete is resolved by partial cement replacement. Considerable energy and cost savings can result when industrial derivatives are utilized for the energy intense Portland cement. The disposal of large quantities of materials that pollute land, water and air are used as derivatives which generates eco-friendly atmosphere. Use of industrial derivatives in concrete leads to green environment and called as “Green Concrete”.

The most commonly used industrial waste to replace sand and cement in concrete are Fly Ash, Rice Husk Ash, Blast Furnace Slag, Pond ash, Red Mud.

Rice husk being the main agricultural residues obtained from the outer covering of rice grains during milling process. An approximation of 1,000 kg of rice grain produces 200 kg of Rice Husk after burnt. No useful application usually dumped into water streams resulting in pollution until it was known to be a useful mineral admixture for concrete.

The disposal of lagoon ash is a big challenge to all as concerning to their quantity which is increasing day by day. Hence worldwide investigation was performed to find

alternative use of this waste material and its use in concrete as a partial replacement of cement is one of the effective methods of utilization. The possibility of utilization of thermal power plant byproduct i.e. lagoon ash as replacement to cement in concrete is taken into consideration.

II. LITERATURE REVIEW

Obilade, I. O, (2004) This paper presents the results of the investigation carried out on the use of Saw Dust Ash (SDA) as partial replacement for Ordinary Portland Cement (OPC) in concrete. SDA was used to replace OPC by weight from 0 to 30% in steps of 5%. The results revealed that the Compacting factor decreased as the percentage replacement of OPC with SDA increased. The compressive strength of the hardened concrete also decreased with increasing OPC replacement with SDA.

K.M.Bagwan and S.S.Kulkarni (2006) has tested the pond ash concrete by partial replacement of cement with pond ash and tests were conducted for 7,28,56,90,150 days. Results have shown that later age strength of pond ash concrete has increased which creates sustainability in Construction field.

Yunfeng Li1, Fanying Kong1 and Rongqiang Du(2009).

Briefed The high performance concrete can be produced using mineral admixtures – steel slag powder and blast furnace slag. The recycling of steel slag can bring enormous economic benefit and environmental benefit.

XiaoluGuo, (2013) Briefed The feasibility of steel slag powder as a combined admixture with ground granulated blast-furnace slag (GGBFS) in cement based materials was explored. The effects of steel slag powder on the normal consistency water requirement, setting times, compressive strength, and hydration products of cement paste/mortar were studied. The results showed that the preferred additional content of steel slag powder in a combined admixture was less than 20%.

J.D.Bapat(2015) used 55% and 65% of lagoon ash as cement replacement and change in strength was observed over a period of 365 days and concluded that, the use of lagoon ash in high volume in dry lean concrete for road construction contributes problem solving of environmental pollution.

III. MATERIAL CHARACTERISTICS

A. Cement

Cement used is ordinary Portland cement confirming to IS: 12269-1987. The cement is fresh, uniform color and is free from lumps and foreign matter. The type of cement used throughout the experiment was Ordinary Portland Cement of grade 43 (OPC-43). This is the most common type of cement used in general concrete construction where there is no exposure to sulphates in the soil or in the ground water.

<u>TEST</u>	<u>RESULT</u>	<u>RECOMMENDATIONS</u>
Fineness, m²/kg	99	225 minimum
Soundness, mm	5	10 maximum
Specific gravity	3.14	3.0 - 3.25
Setting Time, min	30,480	30,600 maximum
Compressive strength ,MPa 3 days	24 38 46	23 33 43

7 days		
28 days		

Table-1 Physical properties of cement

B. Coarse Aggregate

The maximum size of the aggregate maintained is 20 mm and it is qualified in all the tests as per IS 2386.

Specific gravity of coarse aggregate	2.86
Water absorption	0.5%
Aggregate impact value	26%
Aggregate crushing value	29%
Flakiness index	9%
Elongation index	12%

Table-2 Physical properties of coarse aggregate

C. Fine Aggregates

Fine aggregates used are hard, durable, clean, and are free from organic matter. The silt contents not exceeding 4% and Sand used is of Zone- IV of specific gravity of 2.6.

D. Lagoon Ash

Utilization of Thermal Power Plant by-product Pond ash, as replacement to cement in concrete is taken into consideration.

E. Admixture

Rebuild 522 is water reducing admixture .which was manufactured by D-BASF chemical company.

F. Rice Husk Ash

RHA is a good super-pozzolans. RHA can be used in a big way to make special concrete mixes low replacement will dramatically enhance the Workability, strength and impermeability of concrete mixes.

IV. MIX DESIGN

Mix	Cement	Fine Aggregat e	Coarse Aggregate	Water
Ratio	1	1.52	2.67	0.4

Quantity	450Kg/m ³	680Kg/m ³	1200Kg/m ³	180Lit
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Table-3 for M40 Grade Concrete: Is 456:2000

A. Mix Proportion

Admixture %	Cement Kg/m ³	F.A Kg/m ³	C.A Kg/m ³	Water Lit	w/c ratio	Rice husk ash Kg/m ³	Lagoon ash Kg/m ³
0%	450	680	1200	180	0.40	-	-
10%	405	680	1200	180	0.40	45	45
20%	360	680	1200	180	0.40	90	90
30%	315	680	1200	180	0.40	135	135
40%	270	680	1200	180	0.40	180	180
50%	225	680	1200	180	0.40	225	225
60%	180	680	1200	180	0.40	270	270

Table-4 Mix Contents for Admixtures

B. Preparation of Samples

In order to determine the mechanical characteristics such as compressive and flexural strengths different samples are prepared. Later they were tested on compressive testing machine and UTM. Samples are prepared with optimum dosage of Lagoon Ash & Rice Husk Ash.

The compressive strengths of concrete has been evaluated by testing cubes of size 150mmx150mmx150mm. The flexural strength of concrete have been evaluated by testing prisms of dimension 150mmx100mmx100mm. After casting of these specimens these are kept in moulds for 24hours at a temperature of 27 ± 2 degree Celsius. After 24 hours these are removed from the moulds and are put into curing tank and tested for 7, 28 days respectively.



Fig. 1. preparation of samples



Fig. 2. curing of samples

V. RESULTS AND DISCUSSION

Trial mixes were conducted for 7 days for different proportions of Lagoon Ash and Rice Husk Ash.

	0%	10%	20%	30%	40%	50%	60%
Lagoon Ash	28.1 Mpa	25.3 Mpa	28.12 Mpa	30.3 Mpa	32.2 Mpa	26.1 Mpa	28.3 Mpa
Rice Husk Ash	28.1 Mpa	28.7 Mpa	30.42 Mpa	29.8 Mpa	27.1 Mpa	25.6 Mpa	22.8 Mpa

Table-5 7-Days Compressive strength for Trial mixes

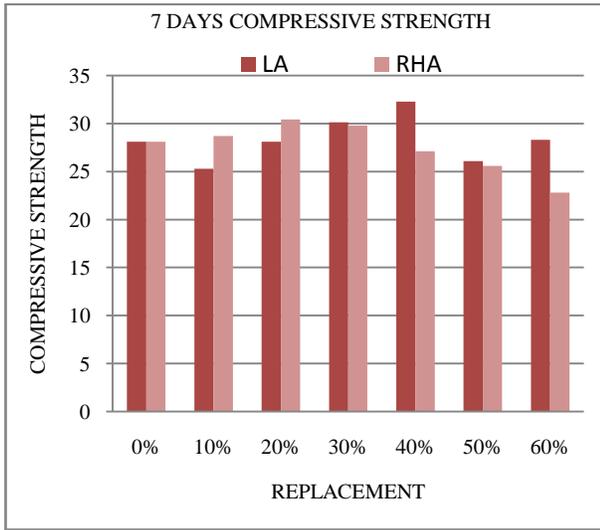


Fig. 3. Trial mix results of different concrete mixes at 7days

From the results attained Lagoon ash 40% & RHA 20% are found to be optimum.

A. Workability of Concrete Test

Slump cone test was performed to determine the workability of the concrete mixes. The slump values for different mixes tabulated below

Mix Type	Slump(mm)
Conventional concrete(CC)	65
Lagoon Ash concrete(LAC)	39
Rice Husk Ash Concrete(RHAC)	42

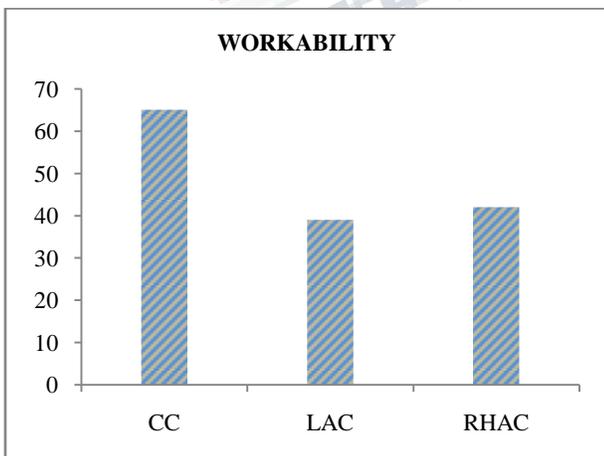


Fig. 4. Workability of concrete mixes

From above results we observe that workability is reduced for lagoon Ash concrete compared to conventional concrete.

B. Compressive Strength

Compressive strength of 40% Lagoon Ash & 20% Rice Husk Ash concrete mix at 7&28 days

Mix	7 days (MPa)	28 days (MPa)
CC	28.12	42.26
LAC	32.27	48.35
RHAC	30.42	39.07

Table-7 Compressive strength

From the table-7 it is observed that rate of increment in compressive strength of the cc at age of 28 days is 50% compared to 7 days, compressive strength of the LAC at age of 28 days is 49% increment compared to 7 days, & RHAC is 29% increment at age of 28days compare to 7 days. It is also observed that rate of increment in compressive strength of the LAC is 15% and 24% compared at age 28 days of CC & RHAC respectively.

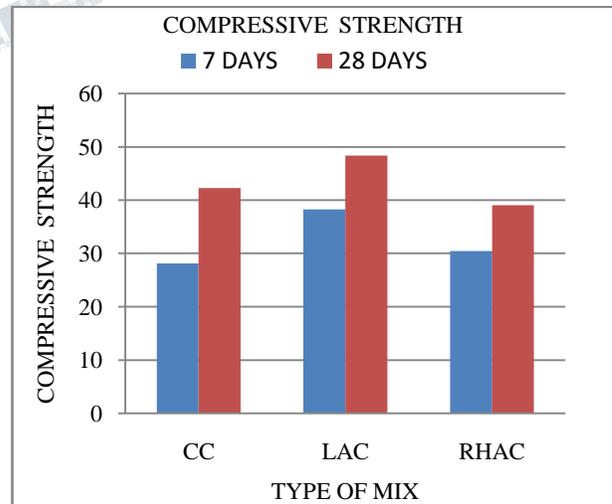


Fig. 5. Compressive strength of concrete mixes at 7&28 days



Fig. 6. Cube Testing

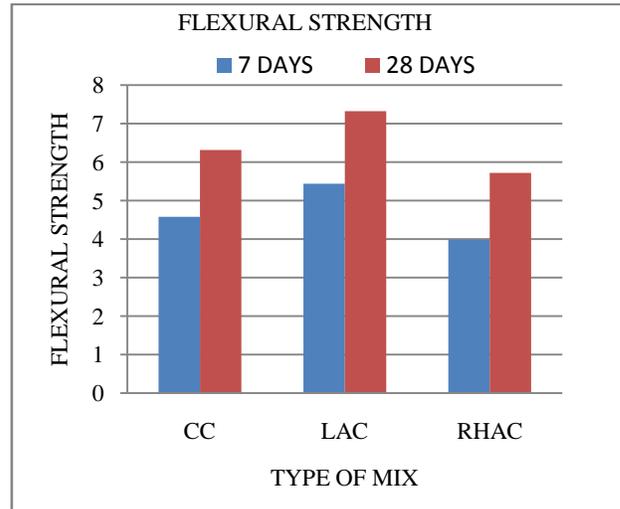


Fig. 7. Flexural strength values of different mixes at 7&28 days



Fig. 8. Prisms Testing

C. Flexural Strength

Mix	7 days (MPa)	28 days (MPa)
CC	4.58	6.31
LAC	5.44	7.32
RHAC	3.98	5.72

From the table-8 it is observed that rate of increment in flexural strength of the cc at age of 28 days is 38% compared to 7 days, flexural strength of the LAC at age of 28 days is 35% increment compared to 7 days, & RHAC is 43% increment at age of 28days compare to 7 days. It is also observed that rate of increment in flexural strength of the LAC is 16% and 27% compared at age 28 days of CC & RHAC respectively.

VI. DESIGN OF SLAB THICKNESS

The design parameters values taken from IRC-58:2002, except traffic data, axle load survey and temperature differential.

Flexural strength of cement concrete = 64.43kg/cm²

Effective modulus of subgrade reaction of the DLC sub-base = 8 kg/cm³

Elastic modulus of concrete = 3×10⁵kg/ cm²

Poisson's ratio = 0.15

Coefficient of thermal expansion of Concrete = 10×10⁻⁶/0C

Tyre pressure	=	8 kg/cm ²
Rate of traffic increase	=	0.05
Spacing of contraction joints	=	4.5 m
Width of slab	=	3.5 m
Design life	=	30 years
Present traffic	=	2891 cvpd

Quantity and cost of each material estimated for a stretch of 1m length and 3.5wide pavement. Unit cost of materials per kg of the materials is shown in table.11. Cost of the pavement with various thicknesses for CC and LAC & RHAC were determined and was compared to Conventional concrete to know the cost benefits of using Lagoon Ash & Rice Husk Ash. The cost of the pavement for two types of concrete is shown in table-12.

The unit cost of the materials per kg taken from COMMON SCHEDULE OF RATES AS PER A.P. REVISED STANDARD DATA FOR THE YEAR 2015-16.

Single Axles		Tandem Axles	
Load in tonnes	Expected repetitions	Load in tonnes	Expected repetitions
20	175268	36	52580
18	368063	32	52580
16	858814	28	105160
14	1963003	24	315480
12	2769237	20	262902
10	2804290	16	87634
Less than 10	3855900	Less than 16	350536

Table-9 Expected repetitions for single and tandem axle loads

Taking the above design parameters and expected repetition values into considerations and design the slab thickness according to IRC-58:2002 for conventional, & Lagoon Ash, Rice Husk Ash, concretes.

Grade of Concrete (M40)	Flexural strength (Kg/cm ²)	Slab thickness (cm)	Fatigue life consumed	Corner stress (Kg/cm ²)
CC	64.5	25	0.013	23.5
LAC	74.6	23	0.016	27
RHAC	58.5	25	0.61	23.5

Table-10 Slab thickness design

Cost Comparison of Pavements

S.no.	Material	Rate per kg in Rs.
1	Cement	6
2	Fine aggregate	0.45
3	Coarse aggregate (20mm)	0.8
4	Super plasticizer	50
5	Lagoon ash	0.1
6	Rice Husk Ash	0.2

Table-11 Cost analysis

Pavement type	Thickness (cm)	Cost (rupees)
CC	25	3516
LAC	23	2263
RHAC	25	2995

Table-12 Cost analysis of CC&LAC,RHAC pavements

From the above calculation we can save 1253 /- Rs per 1m length by using Lagoon Ash replacing Cement & 521 /- Rs per 1m length by using Rice Husk Ash replacing Cement. The construction cost of the pavement is reduced by 55 % by using Lagoon Ash & 18 % by using Rice Husk Ash.

CONCLUSION

[1] From the test results 40% replacement of cement with Lagoon Ash, 20% replacement of cement with Rice

Husk Ash in concrete improves concrete mechanical properties compared to conventional concrete. Hence it is the optimum replacement of the cement by Lagoon Ash & Rice Husk Ash.

[2] It is evident that from the results flexural strength of Lagoon Ash concrete increases 17% at age of 28 days compared to conventional concrete.

[3] It is evident that from the results flexural strength of Rice Husk Ash concrete decreases at age of 28 days compared to conventional concrete.

[4] It is observed that the optimum dosage of LA in concrete reduces the pavement thickness by 9% & the construction cost of the pavement was reduced up to 55%.

[5] It is observed that the optimum dosage of RHA decreases the construction cost of the pavement was up to 18%.

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