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"Experimental study on the properties of concrete made with alternate construction materials"

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Abstract: *Rapid increase in construction activities leads to active shortage of conventional construction materials due to various regions. Concrete is most widely used construction material. Cement, sand & granite stone are the constituents of the concrete. Researches were researching for cheaper materials that can be used as substitute for these materials. In this context an experimental study was carried out to find the suitability of the alternate construction materials such as, rice husk ash, sawdust , recycled aggregate and brickbats as a partial replacement for cement and conventional aggregates .For this concrete cubes of sixe 150mm x150mm were casted with various alternate construction materials in different mix proportion and with different water cement ratios. Their density, workability and compressive strengths were determined and a comparative analysis was done in terms of their physical properties and also cost savings. Test results indicated that the compressive strength of the OPC/RHA concrete cube blocks increases with age of curing and decreases as the percentage of RHA content increases.It was also found that the other alternate construction materials like saw dust, recycled aggregates and brick bats can be effectively used as a partial replacement for cement and conventional aggregates. The results showed that the compressive strength, of recycled aggregate are on average 70% to 80% of the natural aggregate concrete and the compressive strength of brick bat concrete and saw dust concrete was found to be in the range of 30-35% and 8-10% respectively. The compressive strength of rice husk ash concrete was found to be in the range of 70-80% of conventional concrete for a replacement of cement up to 20%.*

I. Introduction

Concrete is most widely used construction material today. Concrete has attained the status of a major building material in all the branches of modern construction. It is difficult to point out another material of construction which is as variable as concrete. Concrete is the best material of choice where strength, durability, impermeability, fire resistance & absorption resistance are required. Rice husk & saw dust are the waste products which are abundantly available & which can be used as a substitute for white cement.

I.1 Rice husk ash (RHA) concrete

Rice husk is an agro-waste material which is produced in about 100 million of tons. Approximately, 20 Kg of rice husk are obtained from 100 Kg of rice. Rice husks contain organic substances and 20% of inorganic material. Rice husk ash (RHA) is obtained by the combustion of rice husk. The burning temperature must be within the range of 600 to 800^{0}C. The ash obtained has to be grounded in a ball mill for 30 minutes and its appearance in colour will be grey. The most important property of RHA that determines pozzolanic activity is the amorphous phase content. RHA is a highly reactive pozzolanic material suitable for use in lime-pozzolana mixes and for Portland cement replacement. RHA contains a high amount of silicon dioxide, and its reactivity related to lime depends on a combination of two factors, namely the non-crystalline silica content and its specific surface. Research on producing rice husk ash (RHA) that can be incorporated to concrete and mortars are not recent. In 1973, investigations were done on the effect of pyroprocessing on the pozzolanic reactivity of RHA. Since then, a lot of studies have been developed to improve the mechanical and durability properties of concrete.

I.2 Previous Research Efforts

The following research efforts shed light on the research works on the utilization of rice husk and rice husk ash as a partial replacement material or stabilizing agent in building works. Tests were carried out on some characteristics of acha husk ash/ordinary Portland cement concrete. Test results indicated that the compressive strength for all the mixes containing AHA increases with age up to the 14-day hydration period but decreases to the 28-day hydration period while the conventional concrete increases steadily up to 28-day hydration period[1]. Tests were also carried on the use of rice husk ash in concrete. Test results indicated that the most convenient and economical temperature required for conversion of rice husk into ash is 500°C. Water requirement decreases as the fineness of RHA increases. The higher the percentage of RHA contents, the lower the compressive strengths [3]

I.3 Saw dust concrete

It is sometimes required to make nailing concrete & this may be achieved by using saw dust as an aggregate. Nailing concrete is a material into which nails can be driven & in which they are firmly held. The last stipulation is made because, for instance in some of the lighter light weight concrete nails, although easily driven, fail to hold. The nailing properties are required in some types of roof construction & pre cast unit for houses etc. because of its very large moisture movement, saw dust concrete should not be used in the situation where it is exposed to moistures (4).

I.4 Recycled aggregate concrete

Lots of construction activities are going on in & around the world & lots of demolition of old concrete works are also taking place. This demolished concrete, if it can be recycled & used as recycled aggregate concrete their disposal which is gigantic task can never be problem. Shanker and Ali(5) have studied engineering properties of rock flour and reported that the rock flour can be used as alternative material in place of sand in concrete based on grain size data. Nagaraj and Banu(9) have studied the effect of rock dust and pebble as aggregate in cement and concrete. It has been reported that crushed stone dust can be used to replace the natural sand in concrete. Sahu, et al (2) have reported that sand can be replaced by rock flour up to40% without affecting strength and workability. Kanakasabai and Rajashekaran(10)investigated the potential of ceramic insulator scrap as coarse aggregate in concrete. It has been reported that the crushed ceramic aggregate can be used to produce lightweight concrete, without affecting strength

I.5 Obstacles in Use of recycled aggregate

The acceptability of recycled aggregate is impeded for structural applications due to the technical problems associated with it such as weak interfacial transition zones between cement paste and aggregate, porosity and transverse cracks within demolished concrete, high level of sulphate and chloride contents, impurity, cement remains, poor grading, and large variation in quality (8). Although, it is environmentally & economically beneficial to use RCA in construction, however the current legislation and experience are not adequate to support and encourage recycling of construction & demolished waste in India. Lack of awareness, guidelines, specifications, standards, data base of utilization of RCA in concrete and lack of confidence in engineers, researchers and user agencies is major cause for poor utilization of RCA in construction. (7)

I.6 Brick bat aggregate concrete

Bricks bats one of the types of aggregates used in certain places where natural aggregates are not available or costly. Where ever brick bats aggregates are used the aggregates are made from slightly over burnt bricks. This will be hard & absorb less water.

II. Experimental Investigations

II.1 Introduction

The experimental investigations includes the casting of cube with various alternative construction materials & the tests were conducted to study the various physical properties such as density, slump, 7days & 28 days compressive strength. A total of 168 specimens were cast & tested in the laboratory to evaluate their compressive strength.

II.2 Materials and Methods

II.2.1 Materials

- **Cement-** Cement used in this study is "43 Grade" which is available under the commercial name " Rajashree Cement".
- **Sand -** River sand confirming to zone -2 and with a fineness modulus of 2.4 was used in this study.
- **Rice Husk Ash -**The rice husk ash was obtained from N.K.Enterprises ,Jharsuguda, Orissa, India . Here rice husk was burnt approximately 48 hours under uncontrolled combustion process. The burning temperature was within the range of 600 to 800^{0}C. The ash obtained was grounded in a ball mill for 30 minutes and its appearance in colour was grey.
- **Coarse aggregate -** From near by quarry.
- **Saw dust -** from nearby saw mill
- **Brick bats** –Collected locally and then broken into pieces of 40mm size, mechanically sieved through 4.75mm sieve to remove the finer particles.
- **Recycled aggregates** The recycled aggregate are collected from the source demolished structures. The concrete debris were collected locally from different sources and broken into the pieces of approximately 80 mm size with the help of hammer .The foreign matters were sorted out from the pieces. Further, those pieces were mechanically sieved through sieve of 4.75 mm to remove the finer particles. The recycled coarse aggregates were washed to remove dirt, dust etc. and collected for use in concrete mix.

II.3 Material tests (As per I S 456-2000)

II.3.1 Cement and rice husk ash

- Initial setting time of cement – 95 min
- Final setting time of cement – 420 min
- Specific gravity of cement – 3.12
- Specific gravity of rice husk ash -2.14
- Fineness of cement – 1.35%
- Setting Times-The comparison of setting times of cement and rice husk ash is presented in table -1

The initial and final setting times increases with increase in rice husk ash content. The reaction between cement and water is exothermic leading to liberation of heat and evaporation of moisture and consequently stiffening of the paste. As rice husk ash replaces cement, the rate of reaction reduces, and the quantity of heat liberated also reduces leading to late stiffening of the paste. As the hydration process requires water, greater amount of water was also required for the process to continue.

II.3.2 Chemical analysis of rice husk ash as supplied by the supplier

Table shows the chemical composition of rice husk ash. The total percentage composition was found to be 73.77% This value is within the range of required value of 70% minimum for pozzolonas. The loss of ignition obtained was 17.71% which is slightly more than 12%max required for pozzolonas. It means that rice husk ash contains little unburnt carbon and this reduces the pozzolonic activity of ash.

Content	% age composition
Fe2O3	0.91%
SiO2	65.3%
CaO	1.31%
Al2O3	4.4%
MgO	1.85%

Loss of ignition	17.71%

The specific gravity of rice husk ash was found to be 2.14.The value is well within the range of pulverised fuel ash which is in between 1.9 and 2.4 as reported in (6)

II.3.3 Fine aggregate tests

Specific gravity of sand – 2.61
Fineness modulus of sand – 2.54
Fineness modulus of saw dust – 2.67
Specific gravity of saw dust -2.12

II.3.4 Coarse aggregates tests

II.3.4.1 Conventional aggregate

Specific gravity of coarse aggregate – 2.70
Fineness modulus of coarse aggregate – 7.133
Crushing strength – 16.1%
Specific gravity of brick bats -2.34

II.3.4.2 Recycled Concrete Aggregate

(a) Specific Gravity and Water Absorption

The specific gravity (saturated surface dry condition) of recycled concrete aggregate was found to be 2.28 which is lower as compared to natural aggregates. Since the RCA from demolished concrete consist of crushed stone aggregate with old mortar adhering to it, the water absorption found to be 2.95% which is relatively higher than that of the natural aggregates.

(b) Bulk Density

The rodded & loose bulk density of recycled aggregate is lower than that of natural aggregate. The lower value of loose bulk density of recycled aggregate may be attributed to its higher porosity than that of natural aggregate.

(c)Crushing and Impact Values

The recycled aggregate is relatively weaker than the natural aggregate against mechanical actions. As per IS 2386, the crushing and impact values for concrete wearing surfaces should not exceed 45% and 50% respectively. The crushing & impact values of recycled aggregate satisfy the BIS specifications

II.4.4.3 Super plasticizer

Product - Roff block master
Description – It is an admixture for making concrete blocks and pre cast concrete products- to achieve homogeneous highly workable mix to give high early strength & to reduce breakages.
Typical applications – For manufacture of concrete blocks, products such as pipes, pole, manhole covers, concrete jails etc.
Consumption – 140ml/bag of 50 Kg cement
Application – Dry mix cement & aggregate, add 140ml roff block master in gauging water, mix thoroughly & cast as per standard practice, permits use of leaner mixes.

II.5 Specimens

A total of 168 specimens of size 15cm x 15cm x 15cm were casted with different alternative construction materials with varying mix proportion & water cement ratio is given in table -2

III. Comparison of results

III.1.Rice husk ash concrete with conventional concrete

Nearly 60 specimens were casted with the mix proportion of 1:2:4 with different water cement ratios 0.56,0.58,0.60 and 0.62 and with different percentages of Cement and rice husk ash .It was found from that when the rice husk ash percentage was increased from 50% onwards the mix was becoming harsh ,so a higher water cement ratio was adopted for the mixes with increased rice husk ash percentages The comparison of compressive strength of conventional and rice husk ash concrete cubes are given in table -3

III. 2. Saw dust concrete with conventional concrete

Some properties of concrete with sawdust ash (SDA) as a replacement for conventional fine aggregate are investigated The cube specimens were casted under 2 mix proportions.1:2:4 and 1:1.5:3.Sawdust and river sand were taken in the ratio 1.5:0.5 for 1:2:4 concrete and 1:0.5 and 1.25:0.25 for 1:1.5:3 concrete. The water cement ratio adopted earlier was found harsh for this concrete. So the mixes are made in a water cement ratio of 0.7,0.75 and 0.8 respectively.. The compressive strength of specimens with replacement levels shown above cured for periods of 7-28 days showed a decreasing strength with higher saw dust content. The comparison of compressive strength of conventional and saw dust concrete cubes are given in table -4

III.3. Recycled aggregate concrete with conventional concrete

Three different mix proportions 1:1.5:3, 1:2:4, and 1:3:6 with water cement ratio 0.5 & 0.6 and 0.7 were made with natural aggregate concrete and recycled aggregate concrete with and without plasticizer. Due to the higher water absorption capacity of RCA as compared to natural aggregate, both the aggregates are maintained at saturated surface dry (SSD) conditions before mixing operations. The ordinary Portland cement of 43 grade and natural river sand were used throughout the casting work. The maximum size of coarse aggregate used was 20 mm in both recycled and natural aggregate concrete. A total of 54 cube specimens were casted . The comparison of compressive strength of conventional and recycled aggregate concrete cubes are given in table -5

III.4 Brickbat concrete with conventional concrete

Here the conventional stone aggregates were replaced with brickbats and the specimens were casted in the ratio 1:2:4.1:1.5:3 and 1:3:6. The comparison of compressive strength of conventional and brick bat aggregate concrete cubes are given in table -6

IV. Cost analysis

A cost comparison was done with concrete made up of alternate construction materials and conventional concrete was done the same was presented in table 7 &8

IV.1 Analysis of results obtained

IV.1.1 Suitability of Material Used

- The rice husk ash used was found to be pozzolonic in nature.The specific gravity of rice husk ash was found to be 2.14.The setting time of Ordinary Portland cement and rice husk ash paste increases as rice husk ash content increases
- The fineness modulus of saw dust was 2.67 and that of sand was 2.54. This infers that the saw dust contains more coarse particles in comparison to sand. Hence, saw dust may be considered as fine aggregate in concrete.
- The specific gravity of the brick bat aggregates (2.34) is about 0.86 times as that of conventional aggregate (2.7). As the specific gravity of brick bat aggregates is less than that of the conventional aggregates, the concrete produced using the brick bat aggregate will be of low density.
- Recycled aggregate and brick bat aggregates can be partially used to replace conventional coarse aggregates (10% to 20%), without affecting its structural significance

V. Conclusion

- The compressive strength of rice husk ash concrete was found to be in the range of 70-80% of conventional concrete for a replacement of cement up to 20%.
- The study shows that the early strength of rice husk ash concrete was found to be less and the strength increased with age.
- The rice husk ash concrete occupies more volume than cement for the same weight. So the total volume of the rice husk ash concrete increases for a particular weight as compared to conventional concrete which results in economy.
- Due to the lower density of RHA concrete the self weight of structure gets reduced which results in overall savings.
- From the cost analysis it was found that the cost of RHA concrete was less compared to conventional concrete
- Recycled aggregate posses relatively lower bulk density, crushing and impact values and higher water absorption as compared to natural aggregate.
- The compressive strength of recycled aggregate concrete was found to be in the range of 70 to 80 % of conventional concrete..
- The compressive strength of brick bat concrete was found to be nearly 35 % of conventional concrete... The compressive strength of saw dust concrete was found to be nearly 10 to 15% of conventional concrete. So the concrete made with alternate construction materials like brick bats and saw dust can be used for partition & filling purposes & nailing purposes where the strength is not the criteria.
- Wherever compressive strength is not a criteria, the concrete made with alternate construction materials can always be preferred.

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Table -1 Comparison of setting times of cement and rice husk ash under various replacement levels.

RHA replacement of OPC (%)	0	10	20	30	40	50
Initial Setting Time (minutes)	90	172	183	285	324	389
Final Setting Time (minutes)	240	313	490	525	712	790

Table -2 Specimens casted with different alternate construction materials and with different water Cement ratios.

Sl No	Types of concrete	Proportions	W/C ratio	Density (Kg/cum)
1.	Conventional concrete	1:2:4	0.4,0.5,0.6	2520
2.	Concrete with rice husk ash	1:2:4(80%cement and 20%rice husk ash)	0.4,0.5,0.6	2418
4.	Recycled concrete without plasticizer	1:1.5:3,1:2:4,1:3:6	0.5,0.6,0.7	2488
6.	Saw dust concrete	1:(1.5+0.5):4	0.7,0.75,0.8	1980
7.	Concrete using brick bat	1:2:4	0.5,0.6,0.7	2215

Table -3 Comparisons of compressive strength of conventional and rha concrete cubes.

Sl No	Types of concrete	Mix	Cement : RHA	W/C	Compressive strength in Kg/cm^2		
					3 days	7 days	28 days
1	Conventional concrete	1:2:4	100% :0%	0.56	118.57	166.00	298.06
2	RHA concrete	1:2:4	90%:10%	0.56	98.69	138.57	234.39
3	RHA concrete	1:2:4	80%:20%	0.56	89.69	124.62	197.98
4	RHA concrete	1:2:4	70%:30%	0.56	71.02	104.00	157.90
5	Conventional concrete	1:2:4	100% :0%	0.58	122.3	168.22	276.67
6	RHA concrete	1:2:4	90%:10%	0.58	100.79	144.74	237.15
7	RHA concrete	1:2:4	80%:20%	0.58	89.05	128.93	198.57
8	RHA concrete	1:2:4	70%:30%	0.58	78.50	106.26	158.12
9	Conventional concrete	1:2:4	100% :0%	0.60	101.67	154.15	277.86
10	RHA concrete	1:2:4	90%:10%	0.60	101.12	146.15	239.33
11	RHA concrete	1:2:4	80%:20%	0.60	91.47	132.98	199.76
12	RHA concrete	1:2:4	70%:30%	0.60	79.66	108.59	161.33
13	Conventional concrete	1:2:4	100% :0%	0.62	120.55	160.43	248.33
14	RHA concrete	1:2:4	90%:10%	0.62	84.05	112.79	216.71
15	RHA concrete	1:2:4	80%:20%	0.62	78.28	107.05	198.81
16	RHA concrete	1:2:4	70%:30%	0.62	61.26	85.09	164.62
17	RHA concrete	1:2:4	50%:50%	0.98	49.4	57.31	75.09
18	RHA concrete	1:2:4	40%:60%	1.07	35.57	55.33	59.28
19	RHA concrete	1:2:4	30%:70%	1.20	25.57	39.52	41.5
20	RHA concrete	1:2:4	20%:80%	1.35	15.81	23.71	25.69

Table-4 Compressive strength test results of conventional concrete and saw dust concrete.

Sl No	Types of concrete	Prop	W/C	Compressive Strength (7days) Kg/cm^2	Compressive Strength (28days) Kg/cm^2
	Conventional concrete	1:2:4	0.56	166	328
	Saw dust concrete	1:(1.5+0.5):4	0.7	18.89	31.11
	Saw dust concrete	1:(1.5+0.5):4	0.75	19.09	32.36
	Saw dust concrete	1:(1.5+0.5):4	0.8	17.78	30.35
	Saw dust concrete	1:(1+0.5):3	0.7	20.12	42.11
	Saw dust concrete	1:(1+0.5):3	0.75	20.26	43.22
	Saw dust concrete	1:(1+0.5):3	0.8	19.19	39.32
	Saw dust concrete	1:(1.25+0.25):3	0.7	18.11	30.33
	Saw dust concrete	1:(1.25+0.25):3	0.75	18.63	30.44
	Saw dust concrete	1:(1.25+0.25):3	0.8	18.42	30.14

Table-5 Compressive strength test results of conventional concrete and recycled aggregate concrete.

Sl No	Types of concrete	Prop.	W/C	Compressive Strength (7days) Kg/cm^2	Compressive Strength (28days) Kg/cm^2
1	Conventional concrete	1:2:4	0.5	166	296
2	Conventional concrete	1:1.5:3	0.5	198	346
3	Conventional concrete	1:3:6	0.5	136	196
4	Recycled concrete without plasticizer	1:2:4	0.5	101.44	177.56
5	Recycled concrete without plasticizer	1:2:4	0.6	104.67	187.78
6	Recycled concrete without plasticizer	1:2:4	0.7	114.44	192.22
7	Recycled concrete without plasticizer	1:1.5:3	0.5	119.23	218.11
8	Recycled concrete without plasticizer	1:1.5:3	0.6	122.89	221.56
9	Recycled concrete without plasticizer	1:1.5:3	0.7	129.28	228.33
10	Recycled concrete without plasticizer	1:3:6	0.5	81.88	118.66
11	Recycled concrete without plasticizer	1:3:6	0.6	87.78	121.22
12	Recycled concrete without plasticizer	1:3:6	0.7	92	128.78
13	Recycled concrete with plasticizer	1:2:4	0.5	134.44	234.56
14	Recycled concrete with plasticizer	1:2:4	0.6	136.67	241.78
15	Recycled concrete with plasticizer	1:1.5:3	0.5	148.23	258.13

16	Recycled concrete with plasticizer	1:1.5:3	0.6	152.78	272.11
17	Recycled concrete with plasticizer	1:3:6	0.5	109.11	152.06
18	Recycled concrete with plasticizer	1:3:6	0.6	111.43	154.11

Table-6 Compressive strength test results of conventional concrete and brick bat concrete.

Sl No	Types of concrete	Prop.	W/C	Compressive Strength (7days) Kg/cm^2	Compressive Strength (28days) Kg/cm^2
1	Conventional concrete	1:2:4	0.56	166	328
2	Concrete using brick bat	1:2:4	0.5	58.12	91.11
3	Concrete using brick bat	1:2:4	0.6	62.89	108.89
4	Concrete using brick bat	1:2:4	0.7	59.67	102.89
5	Concrete using brick bat	1:1.5:3	0.5	64.12	122.33
6	Concrete using brick bat	1:1.5:3	0.6	69.67	132.11
7	Concrete using brick bat	1:1.5:3	0.7	66.78	128.44
8	Concrete using brick bat	1:3:6	0.5	42.89	66.67
9	Concrete using brick bat	1:3:6	0.6	43.22	72.22
10	Concrete using brick bat	1:3:6	0.7	41.08	68.34

Table -7 Cost comparisons between rice husk ash concrete specimens and conventional concrete specimens.

Sl No	Types of concrete	Cement:RHA	Prop.	Percentage w.r.t conventional concrete
1	Conventional concrete	100% :0%	1:2:4	--
2	RHA concrete	90%:10%	1:2:4	4.23%
3	RHA concrete	80%:20%	1:2:4	5.93%
4	RHA concrete	70%:30%	1:2:4	14.31%
5	RHA concrete	50%:50%	1:2:4	17.9%
6	RHA concrete	40%:60%	1:2:4	19.74%
7	RHA concrete	30%:70%	1:2:4	23.6%
8	RHA concrete	20%:80%	1:2:4	27.6%

Table-8 Cost comparison between other alternate construction material specimens and conventional Concrete specimen.

Sl No	Types of concrete	Prop	%age of saving w.r.t to conventional concrete
1.	Conventional concrete	1:2:4	--
2	Recycled concrete without plasticizer	1:4	28.1%
5.a	Recycled concrete with plasticizer	1:4	25.2%
6.a	Saw dust concrete	1:(1.5+0.5):4	30.1%
7.a	Concrete using brick bat	1:2:4	15.42%