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Study on strength properties of concrete incorporating Slaked lime-rice husk ash-natural clay mixture in cement

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Abstract - *Concrete possess good compressive strength and more preferable in India for construction of structures. The properties of concrete are mainly controlled by type of cement used, properties of aggregates, environmental conditions and workmanship. The natural aggregates are well suitable materials for making concrete, but they are get depleted due to the international overexploitation throughout the world. Hence partial or full replacement of aggregates or cement using other source of materials is still researching from past two decades, for conserving the ecological balance. Cement is the binding material, which bind the aggregate together. The raw materials used for manufacturing of Ordinary Portland cement (OPC) are found naturally in the earth. The main objective of using other sources of raw materials in cement, optimize the mix to make excellent use of available raw materials. Slaked lime-Rice husk ash-Natural clay mixture is a blend of powdered forms of slaked lime, rice husk ash and natural clay at certain compositions. In this study for replacement levels 5%, 10%, 15% and 20% of ordinary Portland cement is done using Slaked lime-Rice husk ash-Natural clay mixture. The fresh properties like workability and density, mechanical properties such as compressive strength, split tensile strength and flexural strength of new concrete resulted by replacement of cement by Slaked lime-Rice husk ash-Natural clay mixture was studied.*

Key Words: **Blended Portland cement, Slaked lime, Rice husk ash, Natural clay, Compressive strength, Split tensile strength, Flexural strength**

1.INTRODUCTION

Ordinary Portland cement (OPC) is the most widely and commonly used cement around the world and which is a combined powdered form of calcareous, argillaceous ad siliceous raw materials. The source of raw materials of OPC is found naturally on earth, and they are continuously depleted from the initial years of cement manufacture. This making thought about the partial replacement of cement by naturally available waste materials which suits for exhibiting cement properties.

Concrete made from a lime mixture, sand and gravel is known as lime concrete. Lime concrete was widely used before the lime was replaced by Portland cement. Concrete made with lime cement is well known form more than 5000 years old. It was widely used in all over the world. After surveying different archaeological sites, it was proven. Lime is one of the most versatile chemical in the world [5].

Rice husk is an agricultural by-product generated from rice mills. This husk surrounds the paddy grain, which accounts for 22% of the 748 million tons of rice paddy produced annually worldwide. During milling of paddy, about 78% of weight is received as rice, broken rice, and bran and the remaining 22% of the weight is received as rice husk. Incineration of rice husk is a popular practice to reduce the volume of land filling. After the incineration process, about 25% rice husk ash (RHA), by weight of rice husk, is produced from the total rice husk. The ash produced from rice husk is rich in silica, and the silica is not easily decomposable when used as landfill. This disposal difficulty becomes an environmental hazard for rice-producing countries and ultimately leads to environmental pollution [11].

The Compressive strength of cement mortar specimen has increased after incorporating clay, compression strength reached a maximum at 10%, as it can be concluded that for replacement of cement to raw clay is efficiency, because the presence of Al_2O_3, Fe_2O_3 and calcium are present for the improves strength and pozzolanic activity [4].

In this study the cement is replaced with a new mix of locally available raw materials with some specific proportions of chemical contents. The new mixture contains slaked lime, rice husk ash and natural clay at certain contents. The mix, which is replaced in cement at various percentages, the fresh properties and mechanical properties of concrete are studied.

2.EXPERIMENTAL PLAN

2.1 Materials

In this study the cement used is OPC 53 grade. The properties regarding is provided in IS 12269:2013. The properties such as specific gravity, standard consistency and initial setting time was tested as per the codes IS 4031:1988 (Part II), IS 4031:1988 (Part IV) and IS 4031:1988 (Part V). Table 1 shows the test results of various properties of cement used in this study.

Table -1: Properties of cement used

Properties	Test results
Specific gravity	3.125
Standard consistency	30%
Initial setting time	30 minutes

The coarse aggregates used are crushed natural stone aggregates of maximum nominal size less than 20 mm. The properties such as specific gravity, water absorption and free moisture tested as per IS 2386 (Part III):1963. The properties of coarse aggregates are shown in Table 2.

Table -2: Properties of coarse aggregates

Property	Test results
Specific gravity	2.85
Water absorption	0.25%

The fine aggregate used is M-sand and its particle size is less than 4.75 mm. The properties tested are given in Table 3. Manufactured sand (M-Sand) is a substitute of natural river sand for concrete construction, which is commonly using now. Manufactured sand is produced from hard granite stone by the process of crushing. The crushed sand is in cubical shape with grounded edges, washed and which is graded to as fine aggregate. The size of manufactured sand (M-Sand) is found to be less than 4.75mm. Tests such as specific gravity and water absorption was determined as per IS 2386:1963 (Part III).

Table -3: Properties of fine aggregate

Property	Test results
Specific gravity	2.85
Water absorption	2%
Grading zone	Zone II
Fineness modulus	3.6

The Slaked lime-Rice husk ash-Natural clay mixture contains a composition of 50% of slaked lime, 45% of rice husk ash and 5% of natural clay. The composition of the mix was decided based on the composition of ordinary Portland cement and the particle size of components of mixture was taken smaller than 90 micron. Slaked lime is obtained by the result of slaking of seashells which mostly contains Calcium hydroxide. RHA is obtained by burning of dried rice husk in high temperature. Clay which is used is naturally available clay found on paddy fields, which was oven dried to remove water. The specific gravity of the mix was found out using Lechatliers flask and it was calculated as 2.53. The chemical composition of slaked lime, RHA and Natural clay is shown Table 4. Figure 1 shows the Slaked lime-Rice husk ash – Natural clay mixture.

Table -4: Chemical composition of slaked lime, RHA and natural clay

Composition	Slaked lime	RHA	Natural clay
$Ca(OH)_2$	98%	-	-
CaO	-	0.49%	>0.01%
SiO_2	-	96.7%	78.71%
$CaCO_3$	0.25%	-	-
Al_2O_3	0.1%	1.01%	12.72%
Fe_2O_3	0.035%	0.05 %	4.49%
MgO	0.1%	0.19 %	0.33%
SO_3	-	-	>0.01%
Na_2O	-	0.26 %	0.31%
K_2O	-	0.91%	0.91%

Fig -1: Slaked lime-Rice husk ash-Natural clay mixture

The standard consistency test and initial setting time test of mixes with different percentages of slaked lime-rice husk ash-natural clay mix replaced in cement was done, and the results are shown in table 5. The standard consistency of the cement mixes with slaked lime-rice husk ash-natural clay mix was found to be increasing due to the good water absorption nature of mixes. The initial setting time was found to be increasing for mixes incorporated with slaked lime-rice husk ash-natural clay mix, which is due to the slow rate of reaction with cement at early ages.

Table -5: Properties of slaked lime-rice husk ash-natural clay mixture

Specific gravity	
slaked lime-rice husk ash-natural clay mixture	2.53
Standard consistency (%)	
100% cement	30
95% cement + 5% slaked lime-rice husk ash-natural clay mixture	34
90% cement + 10% slaked lime-rice husk ash-natural clay mixture	41
85% cement + 15% slaked lime-rice husk ash-natural clay mixture	46
80% cement + 20% slaked lime-rice husk ash-natural clay mixture	52
Initial setting time (mins)	
100% cement	30
95% cement + 5% slaked lime-rice husk ash-natural clay mixture	45
90% cement + 10% slaked lime-rice husk ash-natural clay mixture	60
85% cement + 15% slaked lime-rice husk ash-natural clay mixture	70
80% cement + 20% slaked lime-rice husk ash-natural clay mixture	85

2.2 Casting of specimens

Concrete specimens of 150×150×150 mm cubes were cast with different replacement levels of cement by slaked lime-rice husk ash-natural clay mix at 0%, 5%, 10%, 15%, and 20% for compressive strength test. Concrete specimens of 150 mm diameter and 300 mm long cylinders were cast with different replacement levels of cement by slaked lime-rice husk ash-natural clay mix similar to compressive strength test specimens for split tensile strength test. Concrete specimens of 100 x 100 x 500 mm beams were cast with different replacement levels of cement by slaked lime-rice husk ash-natural clay mix similar to compressive strength test specimens for flexural strength test. After 24 hours the specimens were demoulded and subjected to curing in ordinary tap water. The mix design for M25 grade concrete was done by the guidelines of IS 10262-2009 and the water cement ratio adopted is 0.48. The Table 6 shows the mix designations and their compositions.

Table -6: Mix designations

Mix	Cement (kg)	Slaked lime (kg)	Rice husk ash (kg)	Natural clay (kg)
NM	438.13	-	-	-
MR05	416.22	10.95	9.86	1.10
MR10	394.32	21.90	19.71	2.19
MR15	372.41	32.86	29.57	3.28
MR20	350.50	43.813	39.43	4.38

2.3 Experimental investigations

The fresh property such as slump and density was tested. The slump test was done according to IS 1199-1959. The density of fresh and hardened concrete has effect on durability, strength and resistance to permeability. Density is obtained by dividing the weight by volume occupied. Here the density of fresh concrete is determined by taking the weight of fresh concrete mix in mould which is made for casting of cubes divided by the volume of mould itself. The density of different mix proportions with a number of samples are found out.

The tests conducted on hardened concrete at the ages of 7, 28 and 56 days are compressive strength, split tensile strength and flexural strength. The compressive strength and flexural strength of concrete was carried out as per IS 516-1959. The Split tensile strength of concrete was carried out as per IS 5816-1999.

3.TEST RESULTS AND DISCUSSIONS

3.1 Fresh Properties

Slump

Fig -2: Slump test

From the slump test results it is clear that, slump value decreases. The mix NM has high slump of 86 mm and the mix

MR20 shows lower slump of approximately 3 mm. The results indicate that, as the percentage of replacement of cement with slaked lime-rice husk ash-natural clay mixture increases the slump decreases. The mixture incorporated in cement absorbed water and it caused difficulty in mixing. The observations of experiment are shown in Table 7, Fig. 2 shows the slump test of concrete and Chart 1 shows the variation in slump of different mixes.

Table -7: Observations of slump test

Mix designation	Slump (mm)
NM	86
MR05	65
MR10	40
MR15	18
MR20	3.3

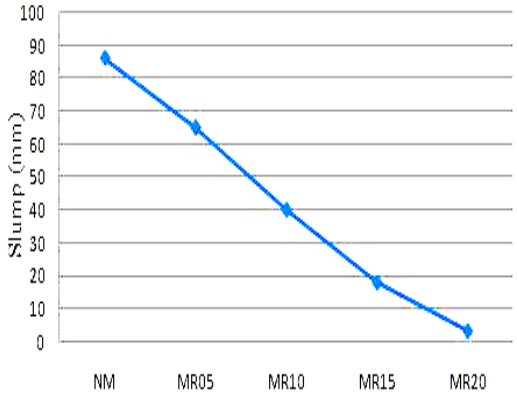

Chart -1: Variation in Slump

Fresh density

From the observations it is found that, density of fresh concrete increases as the replacement percentages of cement increases. The mix NM has 2493.79 kg/m^3 and mix MR20 has 2595.55 kg/m^3 density at fresh state. The increase in density is due to the bulky nature of slaked lime-Rice husk ash-Natural clay mixture. Chart-2 shows graphical representation of variation in fresh density of concrete and Table 8 shows the density of different mixes.

Table -8: Fresh density of mixes

Mix	NM	MR05	MR10	MR15	MR20
Density (kg/m^3)	2493.9	2495.7	2535.3	2541.2	2595.5

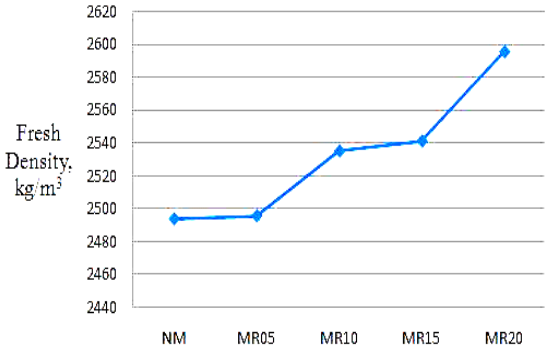

Chart -2: Variation in fresh density of mixes

3.2 Mechanical Properties

Compressive strength

The compressive strength test of cubes of size 150mm conducted at the age of 7 days shows that, the strength was more for mix MR10 (25.33 N/mm^2). The mix NM has 24.44 N/mm^2, the increase in strength of MR10 as compared to NM is 0.89 N/mm^2. At the age of 28 days the results show that, the strength was more for mix MR10 (45.86 N/mm^2). The mix NM has 43.40 N/mm^2, the increase in strength of MR10 as compared to NM is 2.46 N/mm^2. The compressive strength test of cubes conducted at the age of 56 days shows that, the strength was more for mix MR10 (46.07 N/mm^2). The mix NM has 43.56 N/mm^2, the increase in strength of MR10 as compared to NM is 2.51 N/mm^2.

Hence the optimum replacement level of cement with slaked lime-rice husk ash-natural clay mixture was found to be 10%. After increasing replacement percentage, the strength is reducing both the cases of 7, 28 and 56 days results. The mix is combination of various ingredients which is similar to cement with high silica and calcium hydroxide, hence will resulted in increase in compressive strength. The Table 9 shows the compressive strength results of specimens. The Fig -3 and chart-3 shows the compression test and variation in compressive strength.

Table -9: Compressive strength results

Mix designation	Compressive strength(N/mm^2)		
	7 days	28 days	56 days
NM	24.44	43.40	43.56
MR05	24.88	44.44	44.81
MR10	25.33	45.86	46.07
MR15	23.55	45.70	45.77
MR20	20.88	41.33	42.70

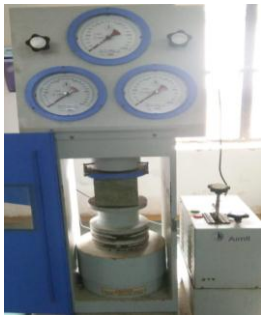

Fig -3: Compression test

Fig -4: Split tensile test

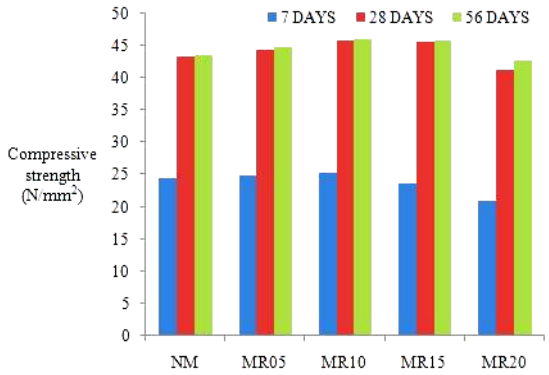

Chart -3: Variation in compressive strength

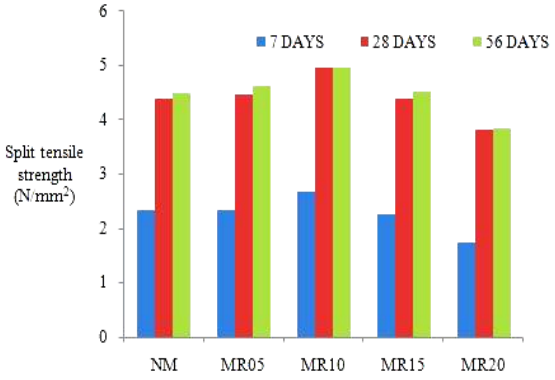

Chart -4: Variation in split tensile strength

Split tensile strength

The split tensile strength test conducted at the age of 7 days shows that, the strength was more for mix MR10 (2.68 N/mm²). The mix NM has 2.33 N/mm², the increase in strength of MR10 as compared to NM is 0.35 N/mm². The test conducted at the age of 28 days shows that, the strength was more for mix MR10 (4.95 N/mm²). The mix NM has 4.38 N/mm², the increase in strength of MR10 as compared to NM is 0.57 N/mm². The test conducted at the age of 56 days shows that, the strength was more for mix MR10 (4.97 N/mm²). The mix NM has 4.50 N/mm², the increase in strength of MR10 as compared to NM is 0.47 N/mm².

Table -10: Split tensile strength results

Mix designation	Split tensile strength (N/mm²)		
	7 days	28 days	56 days
NM	2.33	4.38	4.5
MR05	2.35	4.47	4.62
MR10	2.68	4.95	4.97
MR15	2.26	4.38	4.52
MR20	1.74	3.81	3.84

Hence the optimum replacement level of cement with slaked lime-rice husk ash-natural clay mixture was found to be 10%. After increasing replacement percentage, the strength is reducing both the cases of 7, 28 and 56 days results. The Fig 4 shows the split tensile test and chart 4 shows variation in split tensile strength. Table 10 gives the split tensile strength results of specimens.

Flexural strength

The flexural test conducted at the age of 7 days shows that, the strength was more for mix MR10 (3.53 N/mm²). The mix NM has 1.73 N/mm², the increase in strength of MR10 as compared to NM is 1.80 N/mm². The test conducted at the age of 28 days shows that, the strength was more for mix MR10 (5.80 N/mm²). The mix NM has 3.6 N/mm², the increase in strength of MR10 as compared to NM is 2.2 N/mm². The test conducted at the age of 56 days shows that, the strength was more for mix MR10 (6.46 N/mm²). The mix NM has 5.56 N/mm², the increase in strength of MR10 as compared to NM is 0.9 N/mm².

Hence the optimum replacement level of cement with slaked lime-rice husk ash-natural clay mixture was found to be 10%. After increasing replacement percentage, the strength is reducing both the cases of 7 days and 28 days results. The variation in compressive and flexural strength shows similar trend. The Fig 5 and chart 5 shows the flexural strength test and variation in flexural strength. Table 11 shows the results of flexural strength test.

Table -11: Flexural strength results

Mix designation	flexural strength (N/mm²)		
	7 days	28 days	56 days
NM	1.73	3.6	5.56
MR05	2.53	4.26	5.93
MR10	3.53	5.8	6.46
MR15	2.93	4.66	6.45
MR20	1.6	3.46	5.31

Fig -5: Flexural strength test

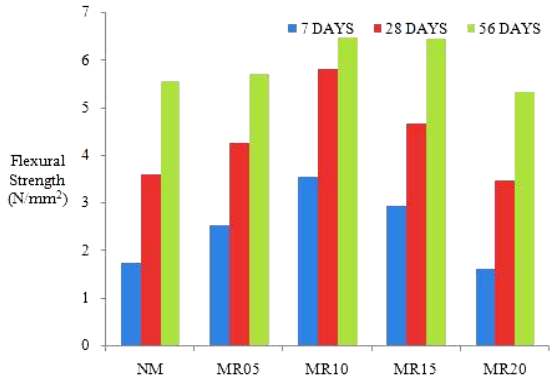

Chart -5: Variation in flexural strength

3.3 Relation Between Compressive Strength And Flexural Strength

There are many studies and guidelines across the globe showing the relationship between compressive and flexural strength of natural aggregates concrete. IS: 456 use the following relation $f_b = 0.7\sqrt{f_{ck}}$ (where f_b is flexural strength and f_{ck} is characteristic compressive strength) to predict the flexural strength of concrete mixes from corresponding characteristics compressive strength results. Since, the utilization of slaked lime-rice husk ah-natural clay mixture for concrete structures is a new practice and an attempt has been done to establish a relationship between the compressive and flexural strength of concrete mixes. For M25 grade concrete the flexural strength can be calculated using IS Code equation, $f_b = 0.7\sqrt{f_{ck}} = 3.5$ N/mm². The equation given by IS 456 predicted the flexural strength at 28 days, it was found to be lesser when compared with the actual experimental results. Chart 6 and 7 illustrates the relationship between flexural strength and compressive strength of the specimens containing slaked lime-rice husk ash-natural clay mix.

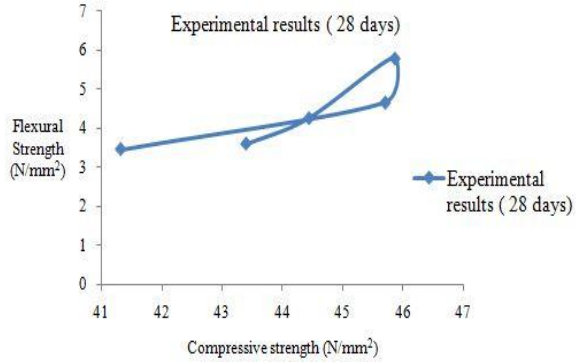

Chart -6: Relation between compressive strength and flexural strength of 28 days experimental results

The established equation is typically a linear equation. The obtained regression equations was found to have a high co-relation factors (R^2) which shows that flexural strength of concrete incorporated slaked lime-rice husk ash-natural clay mix upto 10% can be predicted from the corresponding compressive strength.

The relation obtained from the 28 day experimental results is given below. The linear equation y= 0.905x-35.80 which having a co relation factor $R^2 = 0.981$ can be used to predict the 28 day compressive strength of concrete incorporated with slaked lime-rice husk ash-natural clay mixture upto 10%.

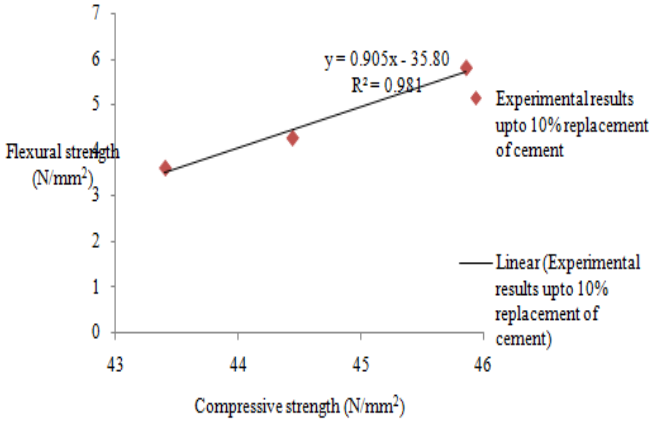

Chart -7: Relation between compressive strength and flexural strength at 28 days

4.CONCLUSIONS

From the test results obtained, following conclusions were made

- The slump test conducted to determine the fresh property of concrete shows that reduction in slump at higher replacement levels of cement with slaked lime-rice husk ash-natural clay mix. Reduction in slump is due to the absorption of water by the slaked lime-rice husk ash-natural clay mixture. The mix MR20 shows approximately 3 mm slump.
- The fresh density of concrete was increased when the replacement percentages of cement by slaked lime-rice husk ash-natural clay mixture. The bulky nature of slaked lime-rice husk ash-natural clay mixture caused the increase in fresh density.
- Mechanical property studies showed that the slaked lime-rice husk ash natural clay mix provided a significant increase in compressive, split tensile and flexural strengths when used as a modifier in concrete with varying amounts. When slaked lime-rice husk ash-natural clay mix replaces the cement it was noticed that the strength of concrete is higher up to 10% gives higher strength than that of the plain concrete, for w/c ratio 0.48.

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