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A STUDY ON MECHANICAL AND DURABILITY PROPERTIES OF CONCRETE WITH RICE STRAW ASH

Dr. M. Mohan Babu1, Dr. B. Damodhara Reddy1, Kiran Kumar Narasimhan1, Dr. S. Aruna Jyothy2, Panga Narasimha Reddy1, N. Gowtham3

1Department of Civil Engineering, Sri Venkateswara College of Engineering and Technology (Autonomous), Chittoor. A.P., India 2Department of Civil Engineering, Sri Venkateswara University College of Engineering, Tirupati, A.P., India.

3UG Student Department of Civil Engineering, Sri Venkateswara College of Engineering and Technology (Autonomous), Chittoor. A.P., India

Abstract:

Concrete is a ubiquitous construction material that is used extensively for various applications. However, the manufacturing of cement, primary constituent in concrete is associated with significant environmental impacts, including carbon emissions, energy consumption, and depletion of natural resources. One such sustainable alternative to cement is Rice Straw Ash (RSA), which is a product obtained on burning of rice straw. RSA has been found to have pozzolanic properties, which means that it can react with calcium hydroxide to form additional binding compounds in concrete. This property makes RSA a potential replacement for cement in concrete production. The study will focus on evaluating the compressive strength of concretewhen RSA used for partial replacement of cement. The study will also investigate the influence of RSA on the workability, durability (water absorption and RCPT). Finally In our experimental study we got the following variation of percentage when compare to control concrete. The chloride permeability is very low at replacement of 10%, 15% when compare to normal (control concrete) and 5% replacement. So, finally from the present observation we can conclude that 10% replacement of cement by RSA can be suggested as the best replacement based on mechanical, workability and durability aspects.

Keywords: Chloride Permeability, Concrete, Rice Straw Ash, Strength, Water absorption

1. Introduction

The Concrete is a manmadesubstance used in construction extensively for various applications. The cement production is causing lot of environmental hazards. Therefore, sustainable alternatives to cement in concrete production are sought. One such alternative is RSA, which is a material resulting after burning of rice straw. RSA has been found to have pozzolanic properties, which means that it can react with calcium hydroxide to form additional binding compounds in concrete. This project aims to investigate the use of RSA as an alternatematerial to cement in concrete. The study will focus on evaluating the mechanical, water absorptionand chloride penetrationproperties of concrete containing different proportions of RSA. The results of this study providedprecious intuitions into the possibility of using RSA in concrete. The findings of this study may provide a magnificent insight for the entire construction industry, specifically in the development of sustainable construction materials.

2. Review of Literature:

Mohamed A. EI-Sayed (2006) focused on evaluating the influence of RSA in different proportionsstarting with 5%, and incremented by 5% till 15%, by the weight of cement. The result shows that setting time, standard consistency increased and workability reduced when increasing the rice straw ash content of the concrete and mortar. El Damatty A.A. (2009) have carried out a study on a sustainable remedy to environmental hazards of RSA usingincineration technology resulting in increased silica content and can act as a mineral admixture for obtaining superior properties of concrete. In this experiment has used rice straw as a different percentages starting with 7.5%, and incremented by 2.5% till 12.5%, by the weight of cement. Torkittikul Pincha, (2010) have performed studies utilisingceramic waste as fine aggregate along with fly ash concrete to identify the possibility of using them to produce concrete. Without using fly ash and just using the CWA up to 50% enhancement in the compressive strength. But when it is increased to 100% reduction in both strength and workability in concrete is noticed. Demirel Bahar (2010) has performed studies on waste marble dust in the place of Natural sand in concrete and its influence onstrength of the concrete when marble dust is different percentages starting with 0%, and incremented by 25% till 100%, by the weight of sand. From the results the unit weight of the concrete and compressive strength increases with age and enhancement in proportions but reduction in porosity is noticed. Munshi Surajit (2013) have done investigation on the influence of RSAat different percentages starting with 5%, and incremented by 5% till 15%, by the weight of cementin mortar. Results depictsincrease in initial and final setting time,and compressive strength for 10% replacement levels are noticed with the increase of RSA.

Revathi S (2015) evaluated mechanical of the mortar when groundnut husk ash (GHA) in different percentages starting with 0%, and incremented by 10% till 60% is performed to replace Natural sand. The results depict that GHAcontent increases the compressive strength, sorptivity and water absorption. Munshi Surajit (2016) attempted to analyse the physical, mechanical and durability properties using X-ray Diffraction, Compressive Strength, and Water absorption, of the concrete by using RSAat different percentages starting with 5%, incremented by 5% till 15%by the weight of cement. The test result depicts that the mechanical properties improved till10% replacement levels in comparison tonormal concrete, and also the permeability of RSA mortar improved withconcrete age. Dabai M. U (2017) have performed on mortar cubes with RSA at different proportions starting with 0%, with increment of 2%, till 10% by weight of cement to check compressive strength for different age of 3, 7 and 28 days. And improved results were noticed till 6% replacement of cement with RSA. Kabeer Ahmed Syed. K.I (2018) have studied on marble powder based mortar with marble powder replacing natural sand between 0% to 100% to prepare eco friendly material and also reduce the overall cost of project. And the result shows that at 20% replacement levels workability, drying shrinkage, and compressive strength, improved a lot. There was also increase in density, water absorption, and dynamic Young's modulus. Pandey Arunabh (2019) carried out studies showing the physical, chemical properties like SEM, XRD and XRFby using RSA and micro silica in difference percentage of RSA starting from 5%, with an increment of 5% till 30% and Silica fume starting with 2.5%, with an increment of 2.5%, till 10% by the weight of cement. Results depicted improved setting, compressive strength and durability properties of concrete. However there is a decrease in the permeability.

3. Materials & Methods:

Materials:

Ordinary Portland Cement (43 GRADE)

In India popularly used ordinary Portland cement is of 43 grade cement for constructions. It is called "43 grade" as it possess a compressive strength of 43 MPa after subjected to curing for 28 days. This means that the cement can withstand a high amount of stress or pressure before it starts to crack or fail. 0% PC (Portland cement) is a term that refers to thesesupplementary cementaneous material (SCMs) include materials such as fly ash, silica fume, and Metakolin. The use of SCMs in concrete mixtures reduces load on environment by avoiding usage of cement which cause carbon dioxide emissions.

Fine Aggregate

Naturally the natural sand is consists of oxide, the variety of quartz, that is chemical inactive. The sand is free from suspended matter, the dimensions of sand adopted for this study is between 4.75 mm and 150 microns. The natural on the market watercourse sand having relative density 2.63 and orthodox to Zone-II supported grain size distribution was taken to organize the concrete as per code IS: 2386-1963.

Coarse Aggregate

The coarse aggregate is free from suspended matter and is tested for relative density, in accordance with IS: 2386-1963. The size of coarse aggregate in the form of gravel or crushed stone is up to 20mm size with angular shape. However, in huge structures, like dams, the coarse aggregate used may be of larger boulders.

Water

The water utilized for the study is free from acids, organic matter, suspended solids, alkalis and impurities that once could have adverse impact on the strength of concrete. Water is a crucial ingredient of concrete that not solely actively participates within the association of cement however additionally contributes to the workability of recent concrete. Cement could be a mixture of complicated compounds, the reaction of cement with water ends up in its setting and hardening. All compounds form within the cement are anhydrous however once brought into contact with the water they get hydrolysed, forming hydrous compounds. Ocean water is not appropriate to be used in concrete preparation especially when steel is used as replacement as steel may be subjected to corrosion.

Rice Straw Ash (RSA)

It is a by Product of burning rice straw, which is the remaining stalks of the rice plant after the grains have been harvested. Rice straw is a major agricultural waste product in many parts of the world, and its disposal can be an environmental and economic burden. However, RSA can be repurposed as a valuable material in construction. RSA has been found to have pozzolanic properties, which means that it can react with calcium hydroxide ($Ca(OH)_2$) in the presence of moisture to form calcium silicate hydrate (C-S-H), the primary binding agent in cement. This property makes RSA a potential supplementary cementitious material (SCM) in concrete production. The chemical composition of RSA is primarily silica (SiO_2), which is a key component of cement, along with small amounts of potassium (K), calcium (Ca), magnesium (Mg), and other trace elements. The particle size of RSA is similar to that of cement, making it a suitable replacement for some of the cement in concrete mixes. The use of RSA as an SCM in concrete offers several benefits, including: 1. Environmental Sustainability: Repurposing rice straw waste as RSA can reduce the environmental impact of rice straw disposal. Additionally, using RSA as an SCM in concrete can reduce the overall amount of cement needed for the mix, resulting in significant environmental benefits. RSA is typically less expensive than cement, which can result in cost savings for construction projects. Additionally, using RSA as an SCM in concrete can further reduce costs by decreasing the overall amount of cement needed for the mix. The addition of RSA to concrete can improve its performance characteristics, such as strength, durability, and resistance to cracking. However, there are also some limitations to the use of RSA as an SCM in concrete. For example, the properties of RSA can vary depending on the method of production and the characteristics of the rice straw used. Additionally, the pozzolanic activity of RSA may be influenced by factors such as temperature, humidity, and curing time.

Methods

Compressive Strength Test

To evaluate the hardened properties of concrete,compression test is conductedon cubical specimens of 150mm x 150mm x 150mm and for cylinder is 150mm x 300mm were casted with various concrete mixtures. After casting are stored in water tank for curing for different ages like 7, 14, 28 and 56 days. Then the compressive strength test is conducted for the specimens. The water and grit on the cubes and cylinders were removed before testing the cubes. After curing specimens were removed from water and they are dried for about one

hour. The cubes are placed in the testing machine and before placing the bearing surface of the machine is test machine is cleaned. Then the load will be applied on the smooth casting side of the specimen placed at centre on the base plate of machine. The movable portion is rotated by hand up to the top surface of the specimen touches. Then the load will be applied continuously without shock at the rate of 140kg/cm2/minute until the specimen fails. Then to observe the maximum load at failure of the cube and they are recorded for each sample, two specimens should be tested for accuracy results. After conducting the test for each sample two specimen crushing values are obtained and then these values are averaged to obtain the crushing strength. For the hardened properties of concrete to conduct the most common test is compressive strength. It is one of the tests for the design requirements of the structure and to calculate the structure resistance of the load. By using destructive test the strength of the cube and cylinder compression can be examined. This test is done by using standard specification of BS1881 Part 116: 1983. The concrete specimens are kept on the compression testing machine when the machine starts the load applies on the specimen slowly and it will break the specimen at higher load. For this purpose the compression testing can be tested. The variation of the specimen sizes and also the strength of the compression is varied. The size of the specimen is increased then the strength will be reduced because that specimen contains week elements and it has a greater porosity. Thus larger sizes start failure early as compared to the smaller size specimens because of weak bond between cement and aggregate. To calculate the strength of the specimen is the ratio of total Load applied onto the cross sectional area of the specimen and ascertain that specimens are properly dried before subjecting to test on CTM. Place the concrete cube in the center of loading area. After curing specimens were removed from water and they are dried for about one hour. The cubes are placed in the testing machine and before placing the bearing surface of the machine is test machine is cleaned. The loading should be applied axially on specimen with none shock and increased at the speed of 140kg/sq. cm/min until the specimen collapse. When test cube fails, maximum load applied shall be noted. Similarly the remaining samples were tested. Compressive strength (Maximum load /Cross sectional area).

Water Absorption Test

The water absorption of concrete specimens is collected before and after subjecting concrete specimens to 24 hours curing. The water absorption of aggregate generally ranges from 0.1 to 2.0 %.

Rapid Chloride Permeability Test

The transporting and placing of concrete is very important because if proper care is not taken at this level due to intrusion of aggressive material like chlorides into concrete due to corrosion by altering pore structure. The most essential concrete property, apart from permeability, is chloride diffusion (passing through pores or voids). This test on concrete specimens is performed after subjecting these specimens to 28 days curing as per ASTM C1202. In the Rapid chloride penetration test, a concrete specimen of 50-mm thick and 100- mm diameter is exposed to a 60 V applied DC voltage for 6 hours, permeability cell, two reservoirs (NaCl, NaOH solutions) and copper mesh usedas electrode.

4. Results and Discussion

Test Results on Cement

The Physical and Chemical properties of ordinary Portland cement adopted for the study is shown in Table 1 and Table 2 as shown below. The results obtained are in accordance to code IS 8112:1989(%).

Table 1: Chemical Properties of Ordinary Portland cement

Chemical properties	Result obtained (%)	Requirements as per IS 8112:1989(%)
CaO	63.24	60–67
SiO_2	21.07	17–25
AI_2O_3	5.65	3–8
Fe_2O_3	4.05	0.5–6
MgO	1.16	0.5–4
NaO_2	0.20	0.3–1.2
K_2O	0.45	0.3–1.2
SO_3	2.15	2–3.5

Table 2: Physical properties of ordinary Portland cement

S.No.	Property	Ordinary Portland Cement (OPC)	
		Results	Requirement as per IS:4031(part 5):19881
1	Special gravity	3.15	3.10–3.15
2	Normal consistency	31.5 %	30–35%
3	Setting times (Initial)	35 Minutes	30 minimum
	Setting times (Final)	380 Minutes	600 maximum

4	Fineness	4%	<10%

Water Absorption Results

Table 3: Water Absorption

S.No	W1 (grams)	W2 (grams)	Water absorption (%)
1	2385	2379	0.252
2	2277	2277	0.22

The Table 3 clearly depicts the water absorption test results on concrete specimen.as per IS 1124-1974.

RCPT Results

Table 4: RCPT Standard Values

Permeability class	**Electric charge passed as per ASTM C1202 (Coulombs)**	**Chloride migration diffusion coefficients as per concrete society, united kingdom (m2 / s)**
High	>4,000	$> 5\times10^{-12}$
Moderate	2,000 – 4,000	1 to 5×10^{-12}
Low	1,000 – 2,000	$< 1\times10^{-12}$
Very low	100 – 1,000	-
Negligible	< 100	-

The test results are typically reported in terms of coulombs passed or coulombs per square meter of surface area. Lower values indicate better resistance to chloride ion penetration and, therefore, better durability. The specific threshold values for "passing" or "failing" the RCPT test can vary depending on the project's requirements and specifications. It's important to note that the RCPT is just one of many tests used to evaluate concrete durability and resistance to chloride ion penetration. Other tests, such as the Rapid Chloride Migration test (RCM), are also commonly used and may provide additional information. It's essential to consult with a qualified engineer or materials testing professional to determine the appropriate tests to use for a specific project and to interpret the results accurately. The RCPT results for the concrete specimens are summarized in Table 5 and are in accordance with permissible values shown in Table 4. The average charge passed per unit surface area was 1215 coulombs/m², which falls within the moderate range according to ASTM C1202 - 19.

Table 5: RCPT Obtained Values

Concrete mix	**RCPT values (columbs)**	**Chloride permeability (ASTM C1202)**
Normal	2475	(2000–4000)-Moderate
5%	1124	(1000–2000)-Low

10%	870	(100–1000)-Very Low
15%	836	(100–1000)-Very Low

Compressive Strength Results

The concrete specimens of size 150 x 150 x 150 mm and are subjected to compression test after exposing to curing for different ages (3,7 and 28 days.) with the help of 200 T compression testing machine (CTM) as per IS 516-1959. The results were shown in Table 6 and plotted below in, Figure 1, Figure 2 and Figure 3.

Table 6: Compressive Strength

Mix	3 Days (Mpa)	7 Days (Mpa)	28 Days (Mpa)
Normal	9.26	18.56	31.43
RSA+ (5%)	11.3	21.46	32.8
RSA+ (10%)	14.53	24.7	38.23
RSA+ (15%)	11.96	22.66	34.26

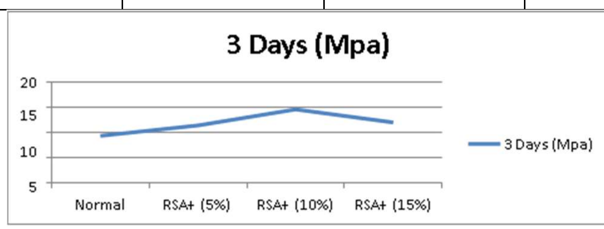

Figure 1: Compressive strength graph for 3 days

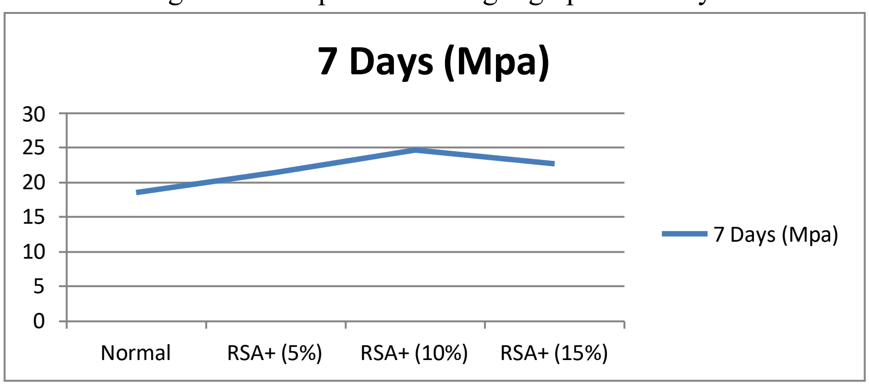

Figure 2: Compressive strength graph for 7 days

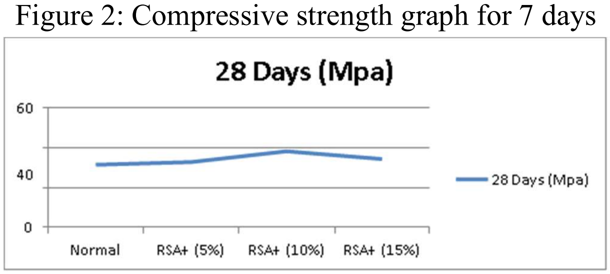

Figure 3: Compressive strength graph for 28 days

5. Conclusion

Based on the results obtained from the study, we can presume that using rice straw ash (RSA) in the place of cement in concrete has both positive and negative effect on mechanical and durability properties. The increase in RSA content in concrete improved slightly compressive strength of the concrete when compared to normal concrete but quite an improvement in durability of concrete is noticed.

Overall, the use of RSA in concrete can be a sustainable solution to reduce the environmental impact of concrete production by utilizing agricultural waste.Finally In our experimental study we got the following variation of percentage when compare to control concrete. The incremental percentage between control concrete and replacement of 5% RSA is 4.36%.The incremental percentage between control concrete and replacement of 10% RSA is 21.65%. The incremental percentage between control concrete and replacement of 15% RSA is 9%. The chloride permeability is very low at replacement of 10%, 15% when compare to normal (control concrete) and 5% replacement. So, finally from the present observation we can conclude that 10% replacement of cement by RSA can be suggested as the best replacement.

6. Scope of Further Study

The further research is needed to determine the quality and the properties of RSAin different regions and to evaluate its suitability in concrete and further study is required to investigate the influence of RSA on the long-term performance of concrete.

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