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Experimental Study and Analysis of Thermal Properties of Rice Husk Ash Based Concrete

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ABSTRACT: In this project composite material is prepared by using concrete(matrix) and Rice Husk Ash (filler). Now a day's utilization of cement increases day by day with more demand. Certain time its fail to meet the demand because of high expenses to face this problem Rice Husk Ash is used in concrete. By replacing certain amount of cement by rice husk ash than also concrete exhibit suitable character same as 100% cement used. It is very difficult to calculate and analyse the thermal behaviour of composites. To complete study of composite materials, the thermal behaviour of composite is also necessary for various application purpose. These composite materials are used in many engineering applications for economic growth and eco-friendly nature. India is a major rice producing country, the husk generated during milling is very large in quantity. This rice husk is used as a fuel in boilers for processing paddy. The dumping of Rice Husk Ash is one of the major concerns and challenge to the society, as the products are hazardous as well as proper method is to be followed for the dumping of waste. Reusing the waste product is one of the best solutions for dumping problems. In this project, the waste product reused is rice husk ash, the rice husk ash is sieved to obtain the desired grain size and are reinforced with the concrete and Moulded into a concrete slab with 20, 25, 30% fraction of rice husk ash. Experiments are conducted to determine the thermal properties such as thermal conductivity, coefficient of thermal expansion, specific heat and thermal diffusivity of the concrete slab. The results show the decrease in thermal conductivity, increase in specific heat, decrease in thermal diffusivity and decrease in thermal expansion for increase in the percentage of Rice Husk Ash. The Finite Element Method (ANSYS) analysis was carried out to know the temperature distribution across the composite.

KEYWORDS: Rice Husk Ash, Concrete, Specific Heat, Thermal Conductivity, Thermal Diffusivity, Coefficient of Thermal Expansion.

I. INTRODUCTION

Over the earlier periods, concrete technology is increases the usage concrete activities introduced Self consolidating concrete (SCC), High strength concrete (HSC) also called as Ultra High Strength Concrete (UHC). SCC was first developed during 1988 by Okamura to enhance the durability of concrete (Okamura and Ouchi [15]). The highest amount cement liberates maximum heat with water, which may cause cracking Kartin, [16]. Concrete created by man, it is a mixture of cement and water with aggregates as per code given. The strength, durability and additional properties of concrete depends upon the proportion of mix and its gradient properties including compaction method of curing age. The concrete has high compressive strength and its resistance to separation.

Concrete may be analysed in many ways, variables like strength in compression, tension, shear and flexural property. Mentioned variables are indicate the strength with respect to a specific method of analysing, when concrete breaks under a pressing load the failure is fundamentally a mixture of crushing shear failure.

Kartini,[16] reported the maximum usage RHA is reduces the in the compressive strength. However, 9-11 % replacement of cement with RHA reached the directed compressive strength, it may encourage the compressive strength and also durability in normal concrete.

1.1 Rice Husk Ash (RHA)

Rice industry releases a lot of husk during their process like milling of paddy. This husk is frequently used as a fuel in the paddy processing boilers. Rice husk is also used in power generation as a fuel. RHA is about 29% by weight of rice husk produced during boiler process. It is projected that about 71 million tons of RHA is generated yearly in global. This RHA is a great ecological threat may damage to the land and its surrounding area where waste is dumped.



1.2 Thermal Properties

To conduct this experiment following thermal properties are considered such as Thermal conductivity, Specific heat, Coefficient of thermal expansion and Thermal diffusivity.

1.3 Objectives of the Study

The main objective is to characterize concrete with RHA and Concrete are:

1. To produce different concrete specimens using 20, 25, 30 % proportions of rice husk ash and different grain size, which is an industrial waste.
2. Preparation of the test specimens.
3. To study the thermal properties of normal and rice husk ash-based concrete.

1.4 Justification of the Study

The study is appreciated in accepting the strengths of rice husk ash is used as a filler materials and partial replacement depends upon the behaviour of rice husk ash. The study is beneficial to engineers and investigators in the construction platform. It helps to replace the thermal variabilities of the concrete. Understanding of the thermal properties of concrete will create to establish the engineering usage of concrete in construction and industrial sector.

II. METHODOLOGY

Various materials are required to prepare test specimens like cement, fine aggregates, coarse aggregates, water and rice husk ash.

2.1 Mixing Procedure

Cement and aggregates were mixed rotated for two minutes in mixer in laboratory. The mixing process continued, about 80% of the water was added and the RHA were fed simultaneously to the concrete about 3–5 min while stirring. Finally, the remaining measured water was added and continue stirring for further 2min. The mould with half-filled fresh concrete was used and followed the compaction method. The specimens were casted and vertically vibrated for 30 to 60 seconds.

2.2 Method of Compaction

About 30 seconds mould with partially-filled concrete for casting and then entirely filled with additional concrete and vibrated extra for up to 60 seconds. This process of compaction was to line up the aggregate's usual to the direction of vibration.

2.3 Curing

After compaction, the specimen is exposed to the mould 24 hours after casting and dipped in water until analysis. The specimens were taken out from the water after soaked for 28 days.

2.4 Preparation of Composite Mould

PVC pipes were used to conduct experiment, cut into small sizes like as moulds for the specimen samples. The testing methodology for the composite essential that three sets of patterns should be shaped for required dimensions of the specimens. Glass sheets were used at the bottom to control volume for test specimen samples. The moulds were constructed to with +0.5mm to give allowable for machining, and the surfaces area rubbed with lubricating oil. Fig. 1 reflects the mould used for composite production. For these experiments, we considered rice husk ash.



Fig. 1: Mould used for specimen preparation Fig. 2: Specimens used to find the thermal conductivity

2.5 Dimensions of Specimens

Specimens are casted according to the sizes.

- Thermal conductivity

Fig. 2 Specimens used to find the thermal conductivity, dimensions are as follows

Diameter of the specimen = 100 mm, Thickness of the specimen = 8 mm

- Specific heat capacity

Fig. 3 Specimens used to find the specific heat capacity, dimensions are as follows

Diameter of the specimen = 50 mm, Thickness of the specimen = 10 mm

- Coefficient of thermal expansion

Fig. 4 Specimens used to find the thermal expansion, dimensions are as follows

Diameter of the specimen = 15 mm, Thickness of the specimen = 50 mm



Fig. 3: Specimens used to find the Specific heat Fig. 4: Specimens used to find Thermal expansion



III. EXPERIMENTAL WORK

With the help of experimental setup thermal conductivity, specific heat, thermal expansion, thermal diffusivity are measured and explained below.

3.1 Thermal conductivity

Electric flow diagram of the thermal conductivity set up shown in below Fig. 5

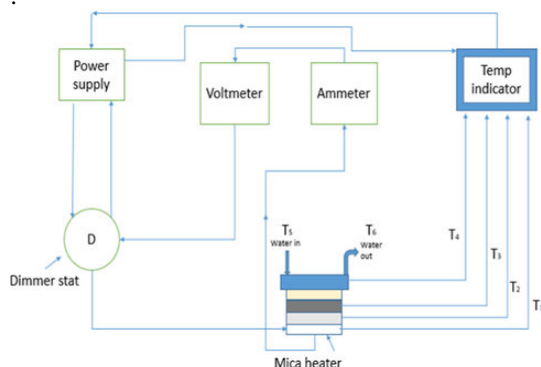


Fig. 5: Electric flow diagram of the thermal conductivity set up



Fig. 6: Test set up for the determination of specific heat

1. First all the connections are made according to the flow diagram, with this sensitivity of thermocouples are also checked. All the four thermocouples are placed between discs according to the requirements.
2. Water is made to flow through the cooling jacket so that proper cooling take place. During the conduction of experiment constant heat is supplied to the heater through dimmer stat so heat transfer will take place in composite slab.
3. Due to the presence of insulating material, one dimensional heat flow takes place. The temperatures are noted down with voltmeter and ammeter readings. Heat supplied is calculated by multiplying current and voltage readings.
4. Heat lost through the slab is calculated by taking water inlet and outlet temperatures.

3.2 Specific heat

Setup used for the measurement of specific heat capacity is shown in Fig. 6 It consists Of Hot air oven, thermocouples (0-250°C), temperature indicator (up to 1200°C), heater, insulated container etc.

1. Before the experiment, mass of all the specimens are noted.
 2. 250 ml of water is filled in the insulated container and its temperature was noted down.
 3. Specimen of specific heat is measured with the help of Hot air Oven (optimum 1000°C) for 24 hours of time.
 4. After 24 hours of time, the initial temperature of the specimen is taken. Then the specimen dipped in the insulated container.
 5. Time interval both specimen temperature and water temperature maintained same.
 6. Further calculation formula used given below specific heat capacity of specimen piece is calculated.
- $$Q = mC_p \Delta t \quad \text{J/s}$$

3.3 Coefficient of thermal expansion

Setup used for the measurement of Coefficient of thermal expansion capacity is shown Fig. 7 It consists of muffler heater, Digital Vernier calliper, heat gloves etc.

1. Before starting the experiment all the specimens are inspected for complete dried condition.
2. At normal temperature conditions, accurate length of the specimen is noted down by using digital Vernier scale.
3. To conduct the experiment these different temperatures are considered, 100, 200 and 500 °C.



Fig.7: Test setup for the determination of Thermal Expansion

4. The specimen is kept inside the heater and required temperature is set.
5. For every trial the specimen is kept for full 24 hours inside the heater to attain the constant temperature.

3.10 Thermal diffusivity

Thermal diffusivity of the materials is called as the thermal conductivity derived from density and specific heat capacity at constant pressure. Thermal diffusivity is denoted by “ α ” and expressed in SI unit (m^2/s). Thermal diffusivity for different specimens were calculated using this formula. The thermal diffusivity formula is given as:

$$\alpha = \frac{K}{\rho C_p}$$

Where,

K is thermal conductivity, W/m-K

ρ is density, kg/m^3

C_p is specific heat capacity, $\text{J}/\text{kg-K}$

3.4 Finite element method (Analysis)

Some of the assumption are made out in getting the results, are as follows. Both matrix and filler are homogeneous and isotropic. Thermal contact resistance between filler and matrix interface is very small. Composite is free from voids. Heat loss due to radiation and convection effect is neglected.

IV. EXPERIMENTAL RESULTS

Total 4 specimens were casted according to the sizes and 3 set of specimens were moulded for the experiments conducted namely S1 S2 S3 & S4 given in below Table-1

Table-1: List of Specimens

Specimen	% by weight of cement	% by weight of ash
S1	100	0
S2	80	20
S3	75	25
S4	70	30

4.1 Thermal conductivity of composite

From Fig.8, shows the Thermal conductivity of pure concrete is 1.541 W/mK. This is in the range 1.5-1.6W/mK of the Pure Cement Concrete given by the Kook-Han Kim. The greater are the porosity is pore size and lesser is the thermal conductivity. Figure, compared to normal cement concrete, RHA concrete showed reduction in thermal conductivity, which may be due to its porosity and pore size increase in RHA concrete.

4.2 Specific heat capacity of composite

From Fig.9, SHC is found as 0.79 J/g°C. From the figure it can be observed that SHC of composite is slowly increasing with increase in RHA percentage. It is chiefly because the RHA particle showed higher SHC. As a result of this SHC of concrete is increasing with the increase in RHA percentage.

4.3 Thermal diffusivity of composite

The thermal diffusivity is straight away proportional to specific heat and thermal conductivity, Fig. 10 predicts that the thermal diffusivity reduces with increase in the RHA percentage, since presence of the porosity, pore size of the RHA.

4.4 Coefficient of thermal Expansion

Fig. 11 depicts in the variation in thermal expansion of composite material with varied percentage of RHA particles. The neat cement specimen showed the maximum expansion, while the expansion reflects reducing capacity with the increase in percentage of the rice husk ash.

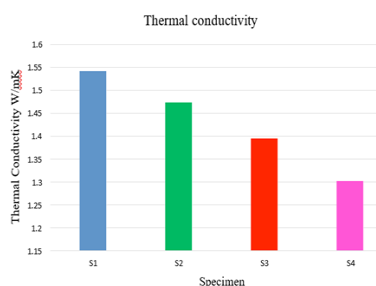


Fig. 8: Thermal conductivity for different composition of rice husk ash

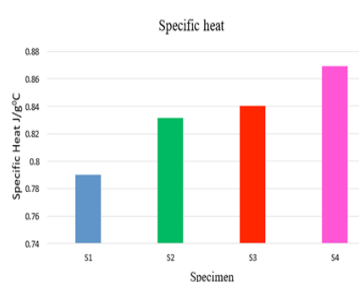


Fig.9: Specific heat capacity for different composition of rice husk ash

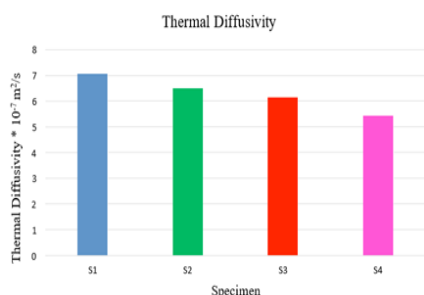


Fig.10 Thermal diffusivity for different composition of rice husk ash

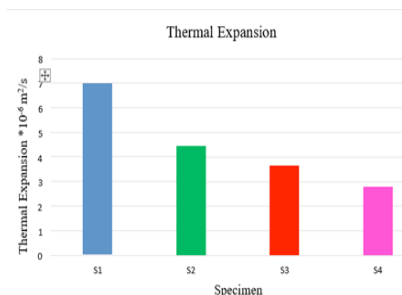


Fig.11 Coefficient of thermal expansion of different composition of rice husk ash

4.5 Finite Element Method (Analysis)

The finite element method is a numerical analysis technique for obtaining approximate solutions to a wide variety of engineering problems. Because of its diversity and flexibility as an analysis tool, it is receiving much attention in engineering fields and in industries. In more and more engineering situations today, we find that it is necessary to obtain approximate numerical solutions to problems rather than exact, closed form solution. Below figure shows the contour plot for temperature distribution along the composite.

Fig.12 Contour plot temperature distribution along the composite (0% RHA Concrete). The temperature distribution of 0% RHA Concrete for given the input temperature of 36 °C the output temperature is 51.2 °C and the thermal conductivity is 1.542 W/m °C.

Fig.13 Contour plot temperature distribution along the composite (20% RHA Concrete)
The temperature distribution of 20% RHA Concrete for given the input temperature of 33.2 °C the output temperature is 49.2 °C and the thermal conductivity 1.4736 W/m °C.

By observing both experimental and analytical results we can come to know that ANSYS gives ± 20 temperature variation from experimental value.

Fig.14 Contour plot temperature distribution along the composite (25% RHA Concrete)
The temperature distribution of 25% RHA Concrete for given the input temperature of 32.1 °C the output temperature is 49 °C and the thermal conductivity is 1.3946 W/m °C.

Fig.15 Contour plot temperature distribution along the composite (30% RHA Concrete)
The temperature distribution of 30% RHA Concrete for given the input temperature of 31 °C the output temperature is 48.5 °C and the thermal conductivity is 1.2 463W/m °C.

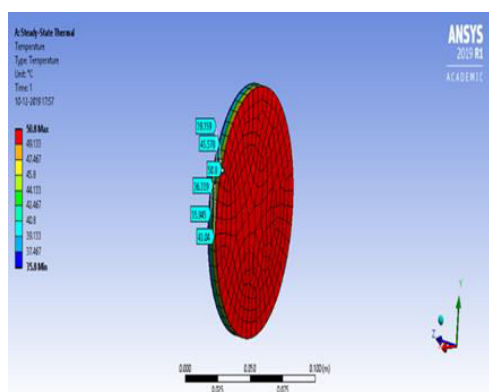


Fig.12 Contour plot temperature distribution along the composite (0% RHAConcrete)

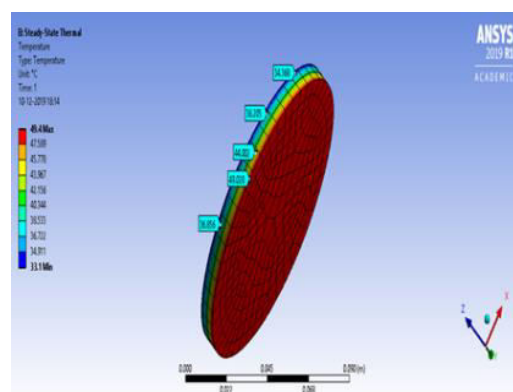


Fig.13 Contour plot temperature distribution along the composite (20% RHA Concrete)

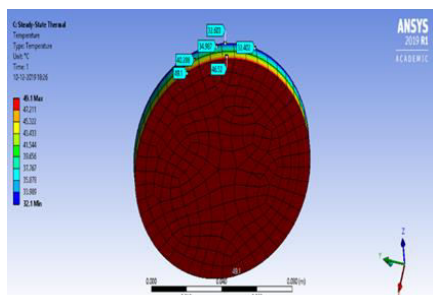


Fig.14 Contour plot temperature distribution along the composite (25% RHA Concrete)

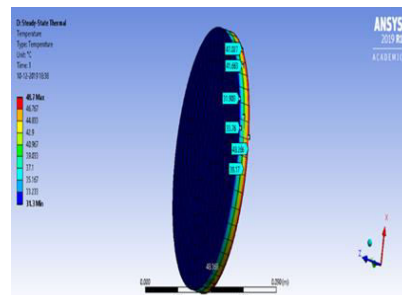


Fig.15 Contour plot temperature distribution along the composite (30% RHA Concrete)

V. CONCLUSION

The experimental results of thermal properties of RHA concrete composite have the following conclusions. The results obtained from the experimental setup are in close with the values attained using FEM simulation by ANSYS. It is seen that the FEM can be gainfully adopted for estimation of thermal behaviour like heat flux, heat flow rate and distribution of temperature distribution of the composite walls.

1. It is indicated that the mixture of RHA particles decrease in the thermal conductivity with respect to that of pure cement. A maximum reduction in thermal conductivity of concrete 8% is noticed. Increase of RHA in the cement percentage in concrete composite there by encourages its thermal insulation capacity. The reduction capacity in the thermal conductivity is extensively established in the Engineering applications.

2. The Specific Heat Capacity of composite with RHA particles display higher specific heat producing capacity than that of pure concrete. For pure cement concrete it is around $0.7908 \text{ J/g}^\circ\text{C}$ and for concrete with maximum weight fraction RHA composite it is noticed as $0.8691 \text{ J/g}^\circ\text{C}$. Higher RHA content in concrete composite maximum will be the heat carrying capacity of the composite.

3. Thermal diffusivity of composite with various fractions of RHA is calculated. In this work thermal diffusivity of normal concrete is observed as $7.041 \times 10^{-7} \text{ m}^2/\text{s}$, for 20% ash $\alpha = 6.495 \times 10^{-7} \text{ m}^2/\text{s}$, for 25% ash $\alpha = 6.126 \times 10^{-7} \text{ m}^2/\text{s}$ and for 30% $\alpha = 5.411 \times 10^{-7} \text{ m}^2/\text{s}$. Thermal diffusivity is reduced with addition of RHA, thus its ability to collect the thermal energy will enhanced with increase in the RHA percentage.

4. It is noticed that the thermal expansion is significantly influenced with the mixture of RHA particles. Co-efficient of thermal expansion of normal concrete is $6.203 \times 10^{-6} / ^\circ\text{C}$ at temperature range of around $100 - 500^\circ\text{C}$, for 20% $\beta = 4.445 \times 10^{-6} / ^\circ\text{C}$, for 25% $\beta = 3.643 \times 10^{-6} / ^\circ\text{C}$ and for composite with 30% RHA, thermal expansion is $2.840 \times 10^{-6} / ^\circ\text{C}$.

5. In practice it reflects that with increasing the rice husk ash percentage in concrete decreases the thermal expansion.

6. From above results, we can conclude that the concrete with RHA greater than 20% is acceptable for construction keeping the thermal properties

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