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Investigating the Effects of Fly Ash, Rice Husk, and Sugarcane Ash on Concrete Properties: A Parametric Analysis Including Thermal Conductivity

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Abstract:

The construction of building, roads, bridge and canal, dam is only possible with the construction material. In this experimental work we are working with some sustainable green insulated material (SGIM) to improve its physical property and to reduce its thermal conductivity (TC). In this experimental work we used Rice husk ash (RHA), Sugar cane husk ash (SHA) and Fly ash (FA) in the percentage of 0%, 2.5%, 5%, 7.5% and 10%. With the partial replacement of Ordinary Portland cement (OPC). First, we did tests on material like fineness test, specific gravity test, water absorption test, workability test, compressive strength test, split tensile test and thermal conductivity test. We provided the coding of concrete based on percentage of insulated waste materials (IWM) used in the experiment. NCC is the normal cement concrete and for Modified cement concrete is MCC. After the modification of concrete when we used the insulated waste material, we got the slump value is gradually decreased by 22%-30%. In the case of compressive strength, it is slightly increased by 14.33%. In split tensile test it is increased by 22.2% to by its normal cement concrete. The main test is to be analyzed thermal conductivity test is reduced by 50.04% by to its normal thermal conductivity value. This value is taken from KD2 pro analyzer. For the future aspect we can use some types of insulated waste material for reduction of thermal conductivity and to enhance the physical property of materials.

Keyword: Sustainable green insulated material, thermal conductivity, normal cement concrete, modified cement concrete, workability, specific gravity, compressive strength.

1. INTRODUCTION

As we all know, know population of the world is continuously increasing, with the increase in population people need a comfortable living (standard lifestyle) style. There is a demand for houses for living at low cost and as well as economic in nature. People need to improve their lifestyle according to situation but now a day these houses are becoming more costly therefore researchers suggest the people make green buildings. Which means construction material should be ecofriendly, sustainable in nature, waste material, renewable material etc. for making greenhouse green material are necessary like wood, bamboo, glass, clay, eggshell,

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wool, fly ash, slag etc. to reduce the consumption of energy there should be better planning to design the building, there are manly three types of building construction-

- Load bearing wall construction,
- Framed types of structure,
- Composite type structure.

When all loads come on wall of the structure these types of structure are known as load bearing wall structure. These types of structure are generally made-up villages and where bearing capacity of soil is low, it will be maximum 2-3 stories building.

1.1 Building Construction Material (BCM) and Thermal Characteristics (TC)

During the design of any building there is the use of reinforced cement concrete (RCC) frame for better stability. That means beam, column, slab, and Flores are made up of RCC and walls are made up of bricks or stones. Which shows that 71% of homes have bricks masonry work and 65% homes have RCC work (Census: Planning commission, Govt. of India 2012). In any building there are four ways to energy enter any home and go outside heat to any house wall, roof, windows, and floors. For making building insulating, the panel of structure should be insulated. The roof and walls are the main portion where the heat enters the building and makes the building heat. For reducing the heat flow in wall and roof, material used in these panel are to be insulated in nature.

1.2 Power capacity in India

To fulfill the requirement of energy, India installed the power capacity as 31.5.2019 was 3,56,818 MW, which includes the 2,26,275 MW for thermal power, 6780 Mw for nuclear power, 45,785 Mw of hydropower and 78,349 Mw of renewable power (figure). The government of India (GOI) attempt to exploit the country massive for electricity production from renewable source of energy. The government of India must plan generation of renewable energy till March 2022 is 1,75,000 Mw.

1.3 Energy uses sector in India.

Energy consumption depends on per capita demand for any country. Per capita demand of India is 849 Mw, which is one of the lowest values in the world. Per capita demand of China is 4000 Mw and average per capita demand of USA is 2000 Mw. There are in India many sectors which are consumption of energy is accountable like industrial sector 46% of total, followed by domestic 22%, agriculture 19%, commercial 9% and others 5%.

2. Background

Thermal comfort has a long history that dates to the beginning of humanity. They initially resided in caves before progressively moving into mud, stone, and wood structures. Eventually they started building buildings using synthetic materials such as clay blocks used to protect people from extremes of heat and cold. The National Gallery of Art is one of the structures that attest to this. Ancient Egypt's pyramids were constructed from mud and stones to keep people warm and shield them from the sweltering desert sun. Ancient Greeks and

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Romans reduced heat absorption by using cork. To stop the spread of heat and fire, asbestos was utilized. A cavity-filled double-wall construction, also known as a cavity wall, was created by the Greeks and is still in use today. Several insulating materials were developed during the industrial revolution in the middle of the 1700s, including cardboard, straws, sawdust, cotton, etc. Fiberglass and cellulose insulation have been developed to replace asbestos because it is a hazardous material. The use of polyurethane foam, which may cover gaps, is growing.

To find a better solution that offers higher thermal performance, it is best to go back, and study rejected products while weighing sustainability and environmental damage. (2015) (Davy et al. To reduce their energy expenses, modern commercial and residential buildings use insulation technologies. A possible study area would be the use of inexpensive, locally accessible garbage to shield buildings from the heat. A thorough review of the literature was done to learn about the many ways for increasing energy efficiency and to find original material development solutions for thermal insulation in buildings. The scope and goal of this research were framed by recent literature, which included experimental experiments to lessen heat penetration via the roof, the creation of an insulating mortar, and the assessment of the overall decrease in heat load in a structure.

Because of its 40% resource consumption in an industrialized country, buildings have a significant and growing negative influence on the environment. Around 12% of portable water and 70% of power are used (Lee & Chong 2016). Fostering long-term growth and development while preserving the environment and preventing the depletion of world resources is the main challenge of our period. The environmental effect of buildings throughout the course of their whole life cycles has received particular attention from the construction sector. Construction waste may be decreased by using energy-efficient technology and processes instead of more traditional ones. Energy use for heating, cooling, and lighting requirements may be greatly decreased by including a climate-sensitive strategy into the building design. Using solar energy effectively can lessen the environmental effects of supplying a building's energy demands with fossil fuels. As a result, energy efficiency issues must be considered while designing structures (Si et al. 2016).

India's construction energy usage trend is very similar to that of Western nations (Kalbar et al., 2018). According to the International Energy Outlook, this tendency will cause India's growth to pick up speed. Household energy consumption is rising at a comparable rate to China's, 3.7% annually, and business energy consumption in India is rising at an average rate of 2% annually. 5.4% is the yearly growth rate, which is like that of developed nations. As a result of its need for lighting and cooling, the commercial sector will account for up to 50% of a building's total cost by the turn of the century.

According to Liu et al. (2015), this tendency is directly related to the quick changes in lifestyles and the population's expanding need for comfort. The most popular form of air conditioning in structures is the conventional compression refrigeration system. (It represents 95% of the overall market share in the cooling industry) and is the main cause of environmental degradation. In India, buildings produce a lot of greenhouse gases and require

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a lot of energy. By 2050, they are expected to have grown by around 700% when compared to 2005 levels. (Ramachandran, 2015; colleagues, et al.)

Thermal insulation known as reflective insulation reflects the heat of radiation that strikes a surface and prevents heat transmission from the surface. This procedure reduces the quantity of heat transfer or solar heat gain because of the high reflecting (or low remittance) surface phenomena on the exterior. Zhang et al. (2015) and Li et al. (2016). The surface's temperature and reflectiveness both affect how much energy is radiated. Attics, roofing, and wall systems frequently use reflective insulation, which seals off air spaces with one or more low remittance reflecting surfaces. The airspace in the reflective insulation is faced by at least one reflecting surface.

3. Material and methodology

In this chapter we were to discuss the material which is used in the experimental work and the properties of that material. After the knowing properties of materials, prepared the design mixed of concrete with partially replacement of cement (OPC-43) with the fly ash (FA), Rice husk ash (RHA) and Sugarcane Husk ash (SHA).

3.1 Cement (Ordinary Portland Cement, OPC-43): Cement is a binding material, it will become hardened when comes to contact with water due to its chemical property. In civil engineering there are many types of cement used for construction, i.e. Pozzolana Portland cement, quick setting cement, rapid hardening cement etc. This cement is used in different types of construction work as per their necessity in that work.

Property	Range/ Value
Consistency	30%
Initial setting time	90 min
Final setting time	700 min
Specific gravity (SG)	3.05

Table 3.1: Property of Ordinary Portland Cement (OPC-43)

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3.2 Sand:

S.N.	IS sieve No.	Wt. Retained in KG	%Weight Retained	% Weight Passing	Cumulative % Retain Weight
1	4.75 mm	0.036	3.6	96.4	3.6
2	2.36 mm	0.052	5.2	91.2	8.8
3	1.18 mm	0.342	34.2	57	43.0
4	600 microns	0.459	45.9	11.1	88.9
5	300 microns	0.084	8.4	2.7	97.3
6	150 microns	0.022	2.2	0.5	99.5
Sum					341.4%

Table 3.2: Gradation of sand

Fineness modulus of sand = Cumulative % of retained/ 100

= 341.4/100 =3.41

3.3 Aggregate: Fineness modulus of Aggregate = Commutative % of retained/ 100

= 743.68/100

SN	IS sieve No.	Wt. Retained in KG	%Weight Retained	% Weight Passing	Cumulative % Retain Weight
1	80mm	0	0	100	0
2	40mm	0	0	100	0
3	20mm	2.835	56.7	43.3	56.7
4	10mm	1.826	36.52	6.78	93.22
5	4.75mm	0.287	5.74	1.04	98.96
6	2.36mm	0.052	1.04	0	98.96
7	1.18mm	-	-	-	98.96
8	600micron	-	-	-	98.96
9	300micron	-	-	-	98.96
10	150micron	-	-	-	98.96
Sum					743.68

Table 3.3: Fineness modulus of Coarse aggregate

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- **Specific gravity of aggregate**

For calculating the S.G. of aggregate and water absorption of aggregate is, experiments were performed in the laboratory. The following experimental work is performed-

Taking wt. of saturated dry aggregate in air in kilo gram (W1) = 2 kg

Wt. of aggregate suspended in water in kg (W2) = 3,14 kg

Wt. of bulked suspended in water (W3) = 1.6 kg

Wt. of saturated aggregate in water (W2-W3) = 3.14-1.6 = 1.56 kg

Wt. of oven dry aggregate W4 = 1.997 kg

Calculation for specific gravity = W4/ (W1-W3)

= 1.997/ (2-1.6)

= **2.7**

Water absorption capacity of aggregate = W1-W4/ W4 *100

= 2-1.997/ 1.997 *100

= **0.15 %**

After the calculation we found the value of specific gravity of aggregate is 2.7 and the water abortion capacity is 0.15%.

3.4 Rice Husk Ash (RHA): Rice husk ash is an agricultural waste from occurring by plant and other organic matter. It is grayish black in color due to its unburned carbon. The burning temperature of RHA is 500- 750 C, and amorphous silica occurs where crystalline silica is formed on high temperatures. The specific gravity of RHA lies between 2.11 to 2.27. RHA is a material which is takes insulating property, it may resist the thermal conductivity which is flow in materials.

Physical Properties of Rice husk ash RHA

Mean particle size (µm)	Specific gravity (g/cm3)	Fineness passing 45 µm (%)	Specific surface area (m2/g)	References
6.27	2.08	91	36.47	Kannan et al. (2016)
5.7–15.6	–	–	22.36–25.21	Le et al. (2015)
39.34	2.24	–	0.37	Sua-Iam et al. (2013)
6	2.1	–	2.33	Safiuddin et al. (2012)
11.5–63.8	–	–	25.3–30.4	Abood Habeeb et al. (2010)
3.80	2.06	99	36.47	Ganesan et al. (2008)

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Table 3.4: Physical property of RHA

3.5 Sugarcane husk Ash (SHA): Sugar cane husk is also an agricultural waste which occurs from sugar cane, and it has property to reduce the thermal conductivity and enhancing the strength property to the composite materials. Sugar cane is a source of renewable source of energy a used in bioethanol industries. It can also be used in construction with the materials with partially replacement of main materials.

S N	Component	Amount %
1	Silica (Sio2)	60.94
2	Aluminum oxide ($Al_2O^{3)}$	14.83
3	Iron oxide (fe2O3)	12.81
5	Calcium oxide (Cao)	3.05
6	Potassium oxide (K2O)	3.71

Table 3.5: Property of Sugar cane husk ash

3.6 Test on Concrete and modified concrete: For the analyzing properties of concrete and modified concrete we must conduct many tests on it. To find the percentage of water and consistency limit of composite materials test were conducted in the laboratory with different mix and equipment. There are mainly four for the finding workability of concrete slump cone test, Vee-bee test, compaction factor tests etc. in this experiment we were used slump cone test and compaction factor test. Firs we do the dry mix of material, and the percentage of water will be for this experiment is 40%, 50%, 60% and 70%. In this experiment we used 50% water content for performing the workability of concrete. Cleaning all material that is used in experiment should be free from impurities.

The compressive strength test was conducted in Bhilai institute of technology Bhilai department of civil engineering. To this experiment knowing about the material strength with the help of compressive testing machine (CED/148) specification of the machine in 200-ton electricity cum manually operated with 3 dial gauge 0–200-ton, 0–100-ton, 0-50 ton, three phase. Mold is prepared with dimension 150 mm*150mm*150mm. test was conducted after curing 7 days and 28 days. Normal cement concrete and modified cement concrete were prepared with the help of rice husk ash, sugar cane husk ash and fly ash, the proportion is mentioned in below table.

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S. N	Concrete Code	Name/Material	Fly ash (%)	Sugar cane ash (%)	Rice husk ash (%)	OPC (%)
1	**NCC0**	Normal Cement Concrete	0	0	0	100
2	**MCC1**	Modified Cement Concrete	30	10	0	60
3	**MCC2**		30	0	10	60
4	**MCC3**		30	5	5	60
5	**MCC4**		30	2.5	7.5	60
6	**MCC5**		30	7.5	2.5	60

Table 3.6: Ratio for mixing of RHA, SHA, and FA for Compressive strength test.

Split tensile strength test is conducted of concrete. It is the most important test which is conducted on cylindrical concrete specimen to find out the cracking point of material. It has a great impact on the size of cracks.

Due to the brittleness of concrete, its tensile strength is generally weak and therefore it is not expected to withstand direct tensile forces. Therefore, a tensile strength test must be performe d to determine the load to be broken. Cylinder splitting tensile test is a method used to determ ine the tensile strength of concrete samples. The study is based on ASTM C496 code like IS: 5816-1999 code. The mold for cylinder is made of steel which is 3mm thick, the internal diameter of mold is 15cm and the height is 30 cm, provided metal base plate and mold should be coated with oil before use for resistance of adhesion of concrete.

Thermal conductivity is the property of material which is used in construction. It is about the amount of heat resist by materials or building component. The normal material has more heat passing property than the green material and sustainable material used in the construction. For using that type of material people feel pleasure to living in house and it reduced the electricity cost of building i.e. building or construction becomes low cost and economic. For measuring thermal conductivity, we can use two types of instruments: the first one is the thermal conductivity flow analyzer Lamba series and second one is the K-D 2 pro analyzer. These are the two instruments available in NIT Raipur department of mechanical department. In this experiment we used the K-D 2 pro analyzer for measuring the thermal conductivity TC, resistivity, diffusivity, and volumetric specific heat. With the help of this equipment, we can measure all four readings. After the test of compressive strength and split test we can use these specimens for the thermal conductivity test.

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Figure 3.1: Compressive strength of NCC and MCC, Split tensile test for Normal cement concrete and modified cement concrete, Thermal conductivity TC rest performance with KD2 Pro Analyzer

4. Result and Discussion

4.1 Result analysis of workability for Concrete and Modified concrete: After the experimental work result is analyzed for the workability of concrete and modified concrete, and compressive strength of concrete and modified concrete, split tensile test of concrete and thermal conductivity test of concrete. It is already discussed in chapter 3. First, we analyzed the workability of concrete and modified concrete. After that the compressive strength of concrete and modified concrete and then the split tensile test will be analyzed and at last, we must find out the thermal property of concrete and modified concrete.

For the workability of concrete, the amount of cement will be 12.3 kg, sand 23.37 kg and the aggregate will be 38.13 kg. This material is required for the 6 no. of cylinder. The ratio of material mixed is 4.10:7.79:12.71. Then we divide the percentage of fly ash as per requirement. We replace the cement with fly ash in the percentage of 2.5%, 5 %, 7.5% and 10 % respectively. We find the workability value from experiment for slump value, Vee-Bee value and compaction factor value shown in below fig. 4.1.

In this experiment we used the concrete code for normal cement concrete (NCC) and for the modified cement concrete (MCC). We also used some other concrete code MCC1, MCC2, MCC3, MCC4, MCC5 and NCC for percentage of materials which is used in the experiment.

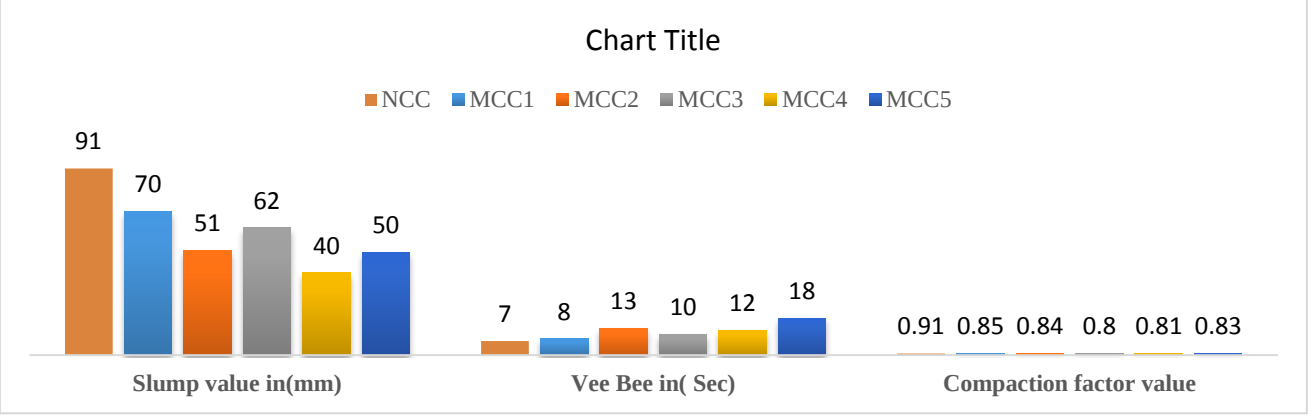

Figure 4.1 : Workability of Normal cement concrete and Modified cement concrete of Slump value, Vee-Bee Value and Compaction factor value

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4.3 Result analysis for Compressive strength of Normal cement concrete (NCC) and Modified cement concrete (MCC): After the workability test of concrete (NCC and MCC), cube test was performed of normal cement concrete and modified cement concrete as per the IS 456:2000. The test was performed after the 7 days and 28 days curing. The comparison of normal cement concrete and modified cement concrete was done according to performance of material and percentage use in the concrete. The test value is mentioned in fig. 4.2.

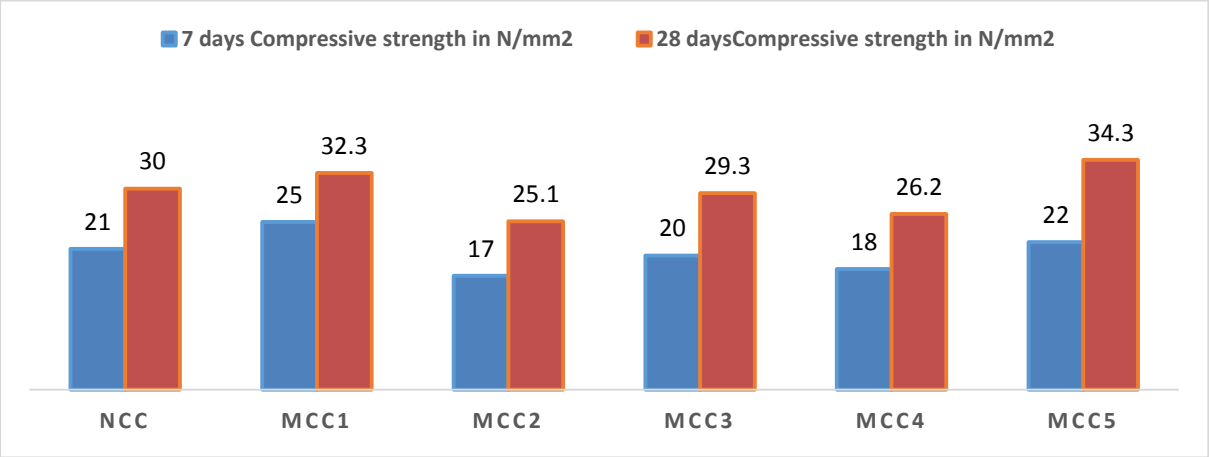

Figure 4.2: Compressive strength of Normal cement concrete and modified cement concrete after 7 days and 28 days.

The compressive strength value was recorded after 7 days, and 28 days was 30 N/mm2 and 35.5 N/mm2 respectively for the normal cement concrete. In other hand the strength value was recorded for modified cement concrete was for MCC1, MCC2, MCC3, MCC4 and MCC5 is 32.3 N/mm2, 25.1 N/mm2, 29.3 N/mm2, 26.2 N/mm2 and 34.3 N/mm2 respectively after 28 days. After the adding admixture insulating material MCC2 and MCC3 were found better result for the strength as compared to other mixing percentage of insulated materials.

4.4 Analysis of Split Tensile Strength test of NCC and MCC: We prepared the cylindrical mold of cement sand and aggregated with some insulating material like sugar cane husk ash, rice husk ash and fly ash with the different proportion. The normal cement concrete mold we got the value of 2.0 N/mm2 and 4.5 N/mm2 after the 7 days and 28 days. In other hand the modified cement concretes the concrete code MCC1 and MCC5 we recorded the value of split tensile value is increased of 2.3 N/mm2 and 5.3 N/mm2 and 2.8 N/mm2 and 5.5 N/mm2 after 7 days and 28 days respectively. The test value is shown in fig. 4.3. We are seen in the test value of split tensile the value of concrete cube is slightly increase in 7 and 28 days.

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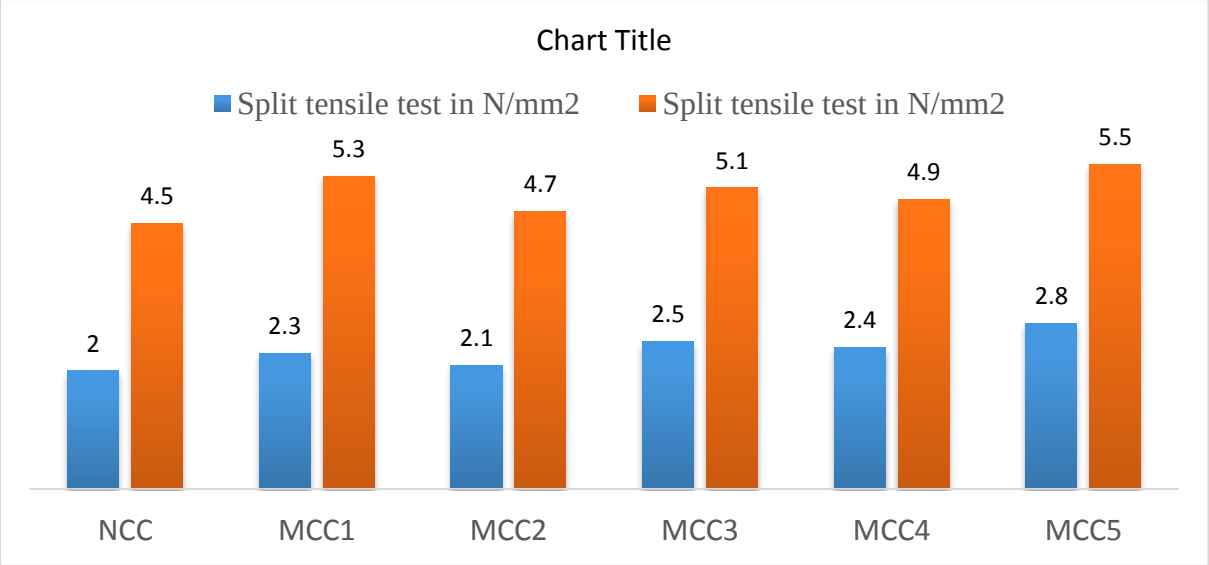

Figure 4.3: Analysis of Split Tensile test for NCC and MCC

4.5 Analysis of thermal conductivity of NCC and MCC: in this experiment we were to use some insulating materials i.e. rice husk ash RHA, sugar can husk ash SHA and fly ash FA to reduce the thermal conductivity of materials. We also take care of its compressive strength and workability as well as its split tensile strength also. We take the specimen national institute technology Raipur for the thermal conductivity test. After the doing test, we found the value of thermal conductivity of normal cement concrete is about 2.25 w/mk. This value is for concrete material is at room temperature. After the modification of concrete with partially replacement of cement on concrete we prepared the modified concrete that is MCC1, MCC2, MCC3, MCC4 and MCC5. This is the concrete code. Details are written below after below fig.4.4. After the test we found the value of thermal conductivity is reduced of all the modified concrete materials. MCC1 code of concrete we find the best suited material for thermal conductivity property. In this code we add 7.5% sugar cane husk ash, 2.5 sugar can husk ash insulating waste material and 30% fly ash with 60% of OPC.

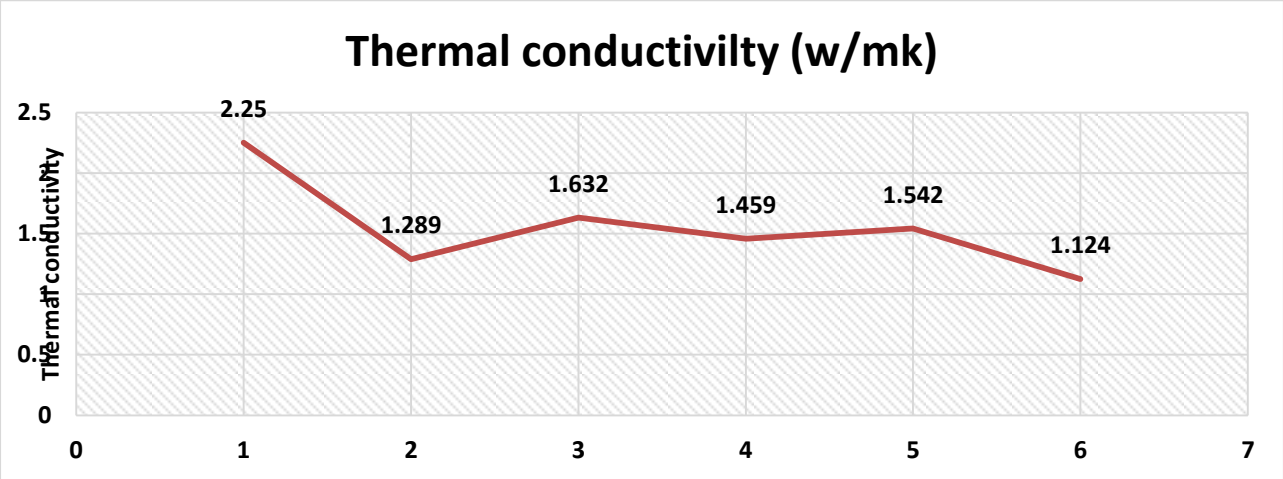

Figure 4.4: Thermal conductivity analysis of NCC and MCC

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5. CONCLUSION

The following conclusion was recorded after the test conducted-The workability of normal cement concrete (NCC) is recorded 91 mm and the slump value of MCC and MCC3 is 70 mm, 62 mm respectively. Which gradually decreased by 22.07% and 30.86% respectively.

Compressive strength of normal cement concrete is recorded after 7 days, and 28 days is 21 N/mm2 and 30 N/mm2 and the modified cement concrete MCC1 25 N/mm2 and 32.5 N/mm2 after 7 days and 28 days. But the concrete code MCC5 slightly increased the compressive test by MCC1 after 28 days that is 34.3 N/mm2. The compressive strength is increased by 7.66% and 14.33% after 28 days for MCC1 and MCC.

The value for split tensile value is recorded for normal cement concrete is 2.0 N/mm2 and 4.5 M/mm2 after 7 days and 28 days. The modified cement concrete (MCC5) has recorded values of 2.8 N/mm2 and 5.3 N/mm2. Which slightly increased in 7 days and 28 days. Which increased by 22.2%.

The Thermal conductivity value is recorded with KD2 Pro analyser, and we found the conductivity of normal cement concrete is 2.25 w/mk. All the modified cement concrete is recorded value is less than the normal cement concrete. The concrete code MCC5 is reduced by 50.04 % thermal conductivity and code MCC1 is reduced by 42.11% of TC.

Overall, when we used 7.5% of sugar cane husk ash (SHA), 2.5% of rice husk ash (RHA), 30% of fly ash (FA) and 60% of ordinary Portland cement (OPC) we will get the best material for building construction and 10% SHA and 30% FA and 60% OPC is also give better TC.

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