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MECHANICAL EVALUATION OF RUBBERIZED CONCRETE INCORPORATING RICE HUSK ASH AS SUPPLEMENTARY CEMENTITIOUS MATERIAL

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ABSTRACT

The use of supplementary cementitious materials (SCMs) has increased over the years due to the carbon footprint associated with the production of cement, which contributes to 10% of the total global CO2 gas emissions. This causes an increase in global warming, and the exponential increase in demand for construction of concrete has caused depletion of natural resources.. Therefore, it has become necessary to reduce the CO2 emissions by reducing our dependency on cement as a binder and developing eco-friendly concrete using alternative binders from agro-industrial waste materials. This study utilizes Rice Husk Ash (RHA) as replacement of OPC .The cement content is replaced with 5%, 10%, 15%and 20% and Also Utilization of waste tyre as a material to improve elastic properties in rigid pavement construction in compost environment has not investigated yet. The rigid pavement in compost environment needs to be impermeable and posses high elastic properties. This thesis presents mechanical properties and workability of concrete incorporating crumb rubber as replacement in two different sizes in concrete mixture with a percentage of 10, 20, and 30 by fine aggregates and coarse aggregate. Replacement of natural aggregate with waste tyre rubber can have an undesirable influence on the mechanical properties of self-compacting concrete, i.e., compressive strength, flexural strength, splitting tensile strength, and modulus of elasticity, however. On the other hand, replacing natural aggregates (eg: FA/CA) with waste tyre rubber can improve impact resistance, ductility, resistance to cracking effect and fatigue resistance.

I. INTRODUCTION

Concrete is the most leading building material in the world, in terms of usage. Its popularity has been due to it being cost-effective, easy to produce anywhere, easy to mould into any shape desired and its relatively good resistance to environmental conditions. In spite of its importance to the socio-economic development of a country and its contribution to its GDP, construction leaves an environmental footprint due to the use of cement.

Whether traditional, self-compacting, or lightweight, cement is the sole binder in concrete. The cement industry is the leading energy intensive in the world, and it emits a lot of greenhouse emissions as well. It is estimated that 0.90 tonnes CO2 is released for each tonne of cement produced. In 2018, the cement industry produced over 4.1 billion tonnes of cement and emitted approximately 3.5 billion tonnes of CO2. The IEA [1] estimates that 33.1 Gt of CO2 gas was emitted in 2018, with the cement industry accounting for 10.57 percent of the amount[2].

To produce cement, large quantities of natural raw materials are required. In accordance with [3], the production of 1 ton cement requires approximately 1.5 tons natural raw materials. It has become vital to identify alternate methods to reduce the environmental impact. By enhancing energy efficiency, or by using other materials, the International Energy Agency [4] claims that concrete's negative environmental impact can be reduced (fuels or raw materials). Alternative cementitious materials (SCM) can be used to partially replace cement, especially if they are waste products. When used in concrete production, most SCMs are waste products[5].

Considering that cement is responsible for between 74% and 81% of concrete's total CO2 emissions [6], lowering cement's negative environmental impact by partially substituting it with SCMs has received a lot of attention. A concrete mixture contains 80 to 85 percent aggregates, which determine the concrete's compressive strength. However, they are also responsible for making concrete a non-renewable material for building constructions. River sand is mostly used as fine aggregates in concrete (FA). Essentially, it fills in any holes between bigger coarse aggregates, resulting in a denser structure. In spite of its scarcity, sand is the most mined mineral in the world, and yet, like all mined minerals, its presence is taken for granted [7]. As reported by UN [8], sand is the world's second most utilised natural resource after freshwater. High demand for sand, monetary incentives, and easy availability have led to an overabundance in the production. It causes erosion of coastal beaches and riverbanks, pollution and suspended particle levels to increase due to excavation activities and also decline in floral and faunal variety in river basins.

Environmentalists have documented the amount of environmental damage caused by aggregate extraction. Natural resources are being consumed at a much faster pace than they can be replaced as well [9]. Because natural resources are depleting at an alarming rate, future generations and the construction industry will lack these materials [9]. As a matter of fact, sand is already in short supply in several regions [10], [11]. To protect the natural aggregate supply for future usage, it is necessary to explore alternative materials to lessen the excessive dependency of the construction trade. To solve this challenge, the use of agricultural and industrial wastes and by-products may have to increase [12]. Most academics nowadays are focused on finding ways to utilise agricultural and industrial wastes, which are produced in large numbers and cause environmental pollution and landfill problems since they take a long time to decompose, posing a severe health and environmental risk. Since agricultural waste can partially replace cement in the construction industry. Various agricultural wastes[2], [13], [14], [15], [16],[17] have long been used as partial cement substituting material. Similarly different waste materials have been used to partially replace fine and coarse aggregates content[18]. A combined use of wastes as a cement and sand/coarse replacement can be considered as more environmentally sustainable because it not only generates cleaner eco-friendly concrete, but also contributes greatly to reducing the waste being thrown in open landfills and depletion of natural resources. Taking this into consideration, the current study proposes to utilize two different wastes, RHA an agricultural waste as partial cement replacement and CR an automobile industry waste as a partial fine and coarse aggregate replacement in development of eco-friendly rubberized concrete. A combined use of wastes as a cement and sand/coarse replacement can be considered as more environmentally sustainable because it not only generates cleaner eco-friendly concrete, but also contributes greatly to reducing the waste being thrown in open landfills and depletion of natural resources. Taking this into consideration, the current study proposes to utilize two different wastes, RHA an agricultural waste as partial cement replacement and CR an automobile industry waste as a partial fine and coarse aggregate replacement in development of eco-friendly rubberized concrete. Rice is a significant agricultural commodity in Asia. The rapid increase in the demand of cement for usage and benefits provided using cement compelled the world to carry out experimental works, studies, and research to improve and enhance each and every cement aspect. This high amount production of cement causes heat emission. The properties and benefits of minerals as part of concrete consumes less quantity of cement with some particular characteristics, such as ecological and environmental benefits, very little energy consumption, lower emissions of CO_2 emission Therefore, it has become need of the hour to work on replacement materials. Pozzolanic materials are high siliceous possessing similar cementitious and chemical properties as OPC it is then brought into the field of cement replacement by several cementitious material. The materials commonly used as replacements are fly Ash, granulated blast furnace slag, sugar cane bagasse Ash, silica fume, coconut shell Ash and rice husk ash. Concrete is a brittle material therefore it is stronger in compression, but it is weaker in tension. The tensile strength of plain cement concrete is generally taken as 10% of its compressive strength. Just because of this lower tensile strength, the implementation of external loads and agents including shrinkage, temperature fluctuations and dead and live loadings on reaching tensile limit cannot be sustained perfectly. Because of that, the cracks are developed inside and on the surface of concrete. Furthermore, in conventional and non-prestressed concretes the crack formation is very usual because of less tensile strength and straining capacity. So, addition of cementations materials in concrete along with short length poly propylene fiber is an innovative technique for overcoming the tensile cracking and increase in straining capacity of concrete. But, in between of this, the selection of polypropylene fiber is very critical. These must have some characteristics such as chemically inert, corrosion free, fire resistant and water repellent behavior. The investigation was directed to reinforce a link between the two research topics, namely the incorporation of waste products in concrete and the demonstration of their relevance. Furthermore, RHA is not frequently employed throughout the Malaysian building industry. The fundamental goal of the study is to evaluate the behavior and performance of high-strength concrete incorporating RHA at various proportions ranging from 0% to 20%, as well as to promote the utilization of waste materials for a sustainable future. Various fresh properties including slump, compacting factor, density, compressive strength, splitting tensile strength, and flexural strength were all evaluated, and the strength properties were compared with conventional HSC. Furthermore, an environmental impact assessment of the produced HSC was investigated.

II. MATERIALS AND METHODOLOGY

It describes all the ingredients used in concrete such as cement, sand, crushed stones, rice husk ash and Rubberized concrete. The properties of concrete in fresh state and hardened state are briefed in it. Properties of concrete such as workability, density, compressive strength, and flexural tensile strength are elaborated. The effects of rice husk ash and Rubberized concrete are discussed in this chapter. The detailed methodology is mentioned in Figure 3.1. In this research the total number of beams casted is 102 for flexural tensile strength (three specimen per curing period per mix proportion, 2x3 x 17 = 102) and 102 cubes were casted for compressive strength tests (three specimens per curing period per mix proportion, 2 x 3 x 17 = 102). Total 204 specimens were prepared for this study.

CEMENT

In this research work, the ordinary Portland cement of 53 Grade is used. Cement was bought from Lucky manufacturing company. All the physical tests and safety measures were taken to protect and store cement bags in airtight containers to prevent them from weathering agencies and adverse atmospheric effects. The chemical composition of cement is in accordance with following standards:

Table 1: Depicts test values of cement

S. No.	Characteristic	Value
1	Normal consistency	35mm
2	Fineness of cement	93.5%
3	Initial (Minutes) Final (Minutes)	85 240
4	Compressive Strength 3 Days 7 Days 28 Days	29.0 MPa 39.95 MPa 55.1 MPa

AGGREGATES:

Aggregate are the prime solid constituents. They structure basic assortment of solid, it diminishes the material shrinkage and influences the economy of the blend. By realities the aggregates have inhabitance over 70% to 80% of solid body(Kumar et al., 2011). Totals majorly affect various properties of cement. Totals prior were known as artificially non-responsive (latent) material yet later not many of the aggregates have been perceived synthetically dynamic and furthermore specific totals show compound holding properties at total surface and glue. Right now, totals utilized can be found at quarry site near to rohri of district Sukkur, Sindh

Coarse Aggregate:

Throughout the investigations, crushed coarse aggregates of 20mm procured from the local crushing plants were used. The aggregate was tested for its physical requirements such as gradation, fineness modulus, specific gravity, and bulk density etc.

Fine Aggregate:

Aggregate having sizes lesser than 4.75 mm and retained on 600 µm sieve are fine aggregate which satisfied the required properties for experimental work and conforms to zone as per the specification of IS: 383-1970. Aggregates were tested & values were obtained for physical properties like specific gravity, fineness modulus, bulk modulus, and gradation.

RICE HUSK ASH:

Rice Husk (RH) was collected from local market and it was burnt approximately between 600ºC to 700ºC and after burning it was grinded and finally powder of Rice Husk Ash was got by passing it from # 325 sieve. Rice husk ash is a Pozzolanic material, utilized in this experimental work as a cement replacement material. Rice Husk is a waste product of agricultural industry, disposed in bulk amount causes numerous adverse problems(Bawankule et al., 2015). As 1 ton of paddy production dumps 200 kg of rice husk. That huge amount of agricultural waste is then converted into ash by controlled burning process. Rice Husk Ash when blended with cement increases the durability of material along with strengthening concrete.

Crumb Rubber:

Rubberized concrete (RC) is a concrete mix that includes crumb rubber particles as a replacement of fine or coarse aggregate. The rubber waste additives in RC act as an absorber and balance all internal stresses in concrete. RC may be used in highway construction as a shock absorber, in sound barriers and as a sound boaster, and also in buildings as an earthquake shock wave absorber. The crumb rubber consists of two sizes e.g: as passing from 4.75mm sieve and retained on 4.75mm sieve respectively.

WATER:

Concrete preparation demands a top quality of water, specifically it's quoted that concrete should be fed with purified drinking water. thanks to unavailability of purified water the water utilized in concrete sample preparation was bored water safe for drinking, and hence considered safe for concrete production(Domke, 2012). The water utilized in this experimental work was water free morpheme organic materials and oil mixtures, a Graduated jar was wont to measure the quantities of water per each mix and added to the batched mix with it. The water test results were obtained from a hunt that "The results revealed that pH ranged from 6.16- 8.6, most of the groundwater possess a pH value of 7.

ADMIXTURE:

Concrete mix preparation causes improper mixing thanks to incorporation of RHA thanks to its high-water absorption properties, which directly affects the binding, strength, and hardness of concrete. it should also lead to early age shrinkage of concrete revealing cracks over surface of concrete(Magnani et al., 2014). Therefore, to counter this problem and produce a workable, strong, and crack free concrete a super plasticizer was won't to handle concrete.

MATERIALS BATCHING:

Quantity of materials including cement, fine aggregates, coarse aggregates, rice husk ash, Crumb rubber, water, and admixture were respectively measured in keeping with the values obtained from mix design, sensitive measurements taken using weigh balances of Kilogram and gram units so as to stay the top-quality concrete.

MIX PROPORTIONS AND CASTING OF CONCRETE:

A total of 17 mix proportions divided into 5 batches are to be prepared. The details of the mix proportions and the % of replacement are tabulated.

Table 2: Mix Proportions and % of Replacement

Mixes		Binders		Natural Aggregates		Crumb Rubber	
		OPC	RHA	Fine	Coarse	Fine	Coarse
Batch 1	OPC	100%	0%	100%	100%	0%	0%
	5RHA	95%	5%	100%	100%	0%	0%
	10RHA	90%	10%	100%	100%	0%	0%
	15RHA	85%	15%	100%	100%	0%	0%
	20RHA	80%	20%	100%	100%	0%	0%
Batch 2	OPCRF10	100%	0%	90%	100%	10%	0%
	OPCRF20	100%	0%	80%	100%	20%	0%

	OPCRF30	100%	0%	70%	100%	30%	0%
Batch 3	OPCRC10	100%	0%	100%	90%	0%	10%
	OPCRC20	100%	0%	100%	80%	0%	20%
	OPCRC30	100%	0%	100%	70%	0%	30%
Batch 4	XXRHARF10	100% - XX	XX %	90%	100%	10%	0%
	XXRHARF20	100% - XX	XX %	80%	100%	20%	0%
	XXRHARF30	100% - XX	XX %	70%	100%	30%	0%
Batch 5	XXRHARC10	100% - XX	XX %	100%	90%	0%	10%
	XXRHARC20	100% - XX	XX %	100%	80%	0%	20%
	XXRHARC30	100% - XX	XX %	100%	70%	0%	30%

III. RESULTS AND DISCUSSION

WORKABILITY

Fig: No.1 shows the value of slump of controlled mix plain concrete without RHA and values of slump by replacing the cement with RHA with various percentages of 05%, 10%, 15% & 20% by weight of cement and Crumb Rubber in two sizes used as fine and coarse aggregate replacement with 10, 20 and 30 percentages in both fine and coarse aggregates along with optimum 10% of RHA used as cement replacement. The maximum slump value obtained was 59mm for control mix, on addition of RHA as cement replacement the value of slump decreases up to 40mm on 20% of RHA. In batch 2 the value of slump starts from 25mm and decreases by adding Crumb Rubber as replacement of fine aggregates at 10, 20 and 30 percentages to 15mm. Third batch shows the results of slump obtained from Crumb Rubber used as coarse aggregate as replacement on various percentages of 10, 20, and 30 ranges from 42 to 27mm. Batch 4 show the results of 10% optimum percentage of RHA with Crumb Rubber as fine aggregates replacement, the values obtained on 10, 20 and 30 percentages are as 36, 32 and 27mm respectively. And the last batch which contains 10% RHA as cement replacement with Crumb Rubber as coarse aggregates replacement with different percentage of 10, 20 and 30 ranges from 30 to 14 mm. The study showed that on addition of Crumb Rubber as fine and coarse aggregates replacement the values of slump decreases on each increment.

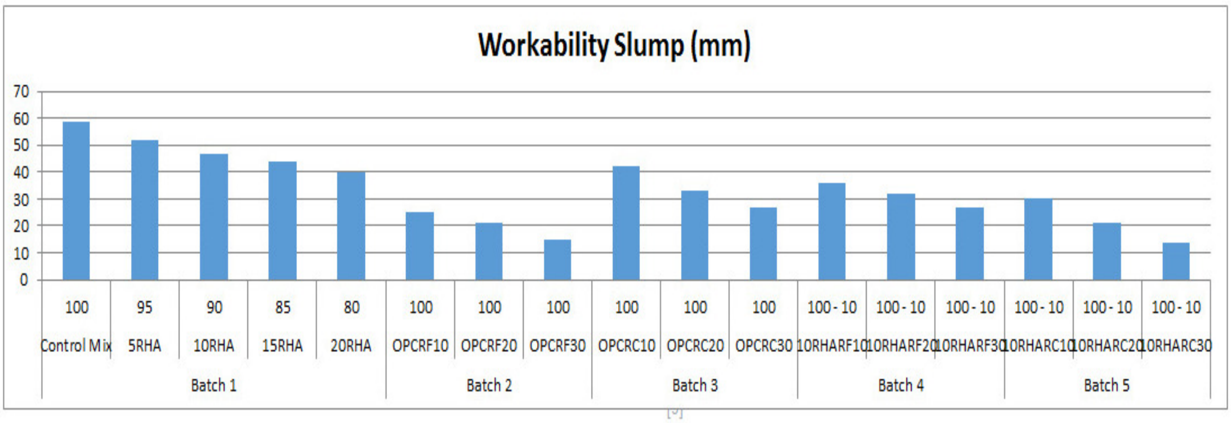

Fig: No.1 Showing Workability Slump (mm) Of Concrete

COMPRESIVE STRENGTH

Fig: No. 2 shows the value of compressive strength of control mix without RHA and values of compressive strength by replacing the cement with RHA with various percentages of 05%, 10%, 15% & 20% by weight of cement and Crumb Rubber in two sizes used as fine and coarse aggregate replacement with 10, 20 and 30 percentages in both fine and coarse aggregates along with optimum 10% of RHA used as cement replacement. The maximum compressive strength obtained was 18.50 and 25.70 MPa on 7 and 28 days for control mix, on addition of RHA as cement replacement the value of compressive strength increases. The optimum strength obtained on 10% RHA is 29.31 MPa. In batch 2 the value of compressive strength ranges from 22.75 MPa to 16.25MPa and it shows decrease by adding Crumb Rubber as replacement of fine aggregates at 10, 20 and 30. The optimum value obtained at 28 days was 22.75MPa on 10% RHA which was also lesser than that of control mix. Third batch shows the results of compressive strength obtained from Crumb Rubber used as coarse aggregate as replacement on various percentages of 10, 20, and 30 ranges from 11.79 to 10.14 MPa, optimum values obtained was 11.79 MPa on 28 days curing on 20% CR coarse replacement. Batch 4 show the results of 10% optimum percentage of RHA with Crumb Rubber as fine aggregates replacement, the strength values obtained on 10, 20 and 30 percentages are as 16.27, 15.18 and 17.22 MPa respectively. And the last batch which contains 10% RHA as cement replacement with Crumb Rubber as coarse aggregates replacement with different percentage of 10, 20 and 30 ranges from 17.71, 18.87 & 16.98 MPa. The study showed that on addition of Crumb Rubber as fine and coarse aggregates replacement the values of compressive strength has negative effect but other properties are improved.

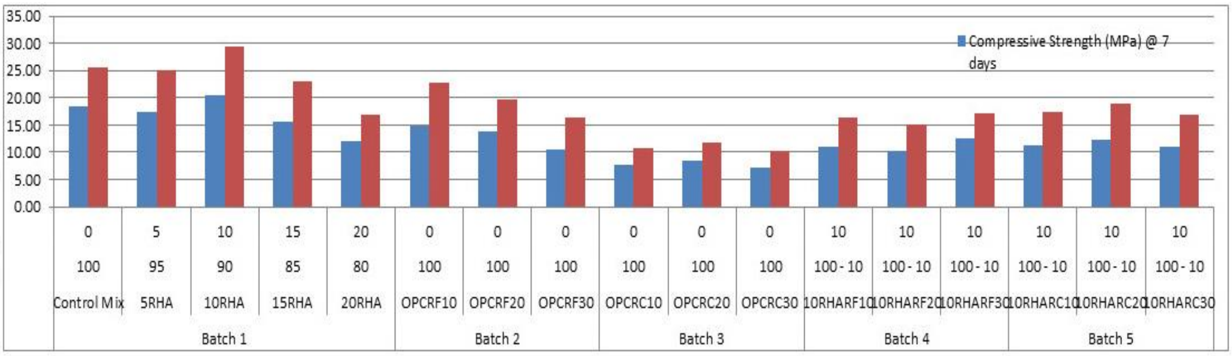

Fig: No. 2 Showing Compressive Strength (MPa) Of Concrete

FLEXURAL STRENGTH

Fig: No. 3 shows the value of flexural strength of control mix without RHA and values of flexural strength by replacing the cement with RHA with various percentages of 05%, 10%, 15% & 20% by weight of cement and Crumb Rubber in two sizes used as fine and coarse aggregate replacement with 10, 20 and 30 percentages in both fine and coarse aggregates along with optimum 10% of RHA used as cement replacement. The maximum flexural strength obtained was 3.86 MPa for control mix, on addition of RHA as cement replacement the value of compressive strength increases up to 3.50MPa on 05% of RHA. In batch 2 the value of flexural strength starts from 3.41 to 2.43 MPa and decreases by adding Crumb Rubber as replacement of fine aggregates at 10, 20 and 30 percentages to 2.43MPa. Third batch shows the results of compressive strength obtained from Crumb Rubber used as coarse aggregate as replacement on various percentages of 10, 20, and 30 ranges from 2.12 to 1.25MPa. Batch 4 show the results of 10% optimum percentage of RHA with Crumb Rubber as fine aggregates replacement, the values obtained on 10, 20 and 30 percentages are as 2.44, 2.60 and 2.89 MPa respectively. And the last batch which contains 10% RHA as cement replacement with Crumb Rubber as coarse aggregates replacement with different percentage of 10, 20 and 30 ranges from 3.41 to 3.13MPa. The study showed that on addition of Crumb Rubber as fine and coarse aggregates replacement the values of flexural strength improves.

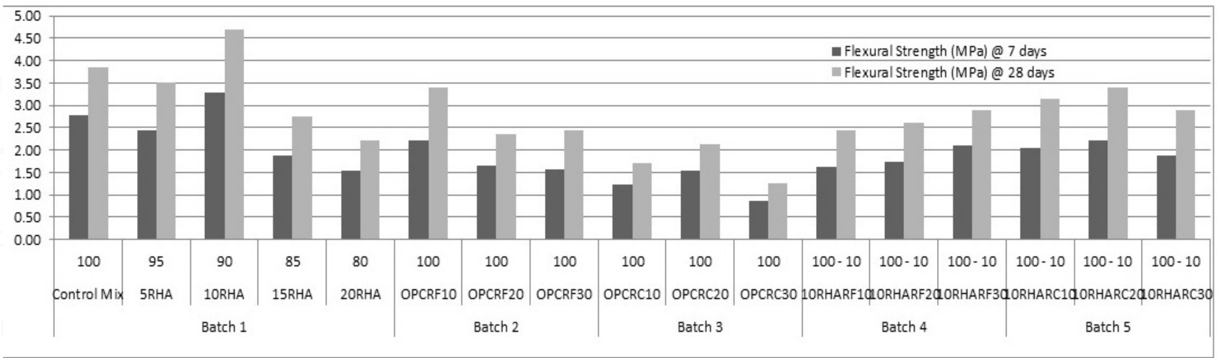

Fig: No. 3 Showing Flexural Strength (MPa) Of Concrete

IV. CONCLUSION

Based on conducted research, it can be concluded that:

- It is concluded that this experimental work by replacing 10% fine aggregate with crumb rubber aggregate, slightly decreases to 22.75 as compared to control mix which is 25.70 MPa. The value was further decreased on replacement on addition of optimum RHA to 17.22 MPa.
- The compressive strength on replacement as CR coarse aggregate, maximum value found was 11.79 MPa and by using optimum RHA the value slightly increases to 18.87MPa which is positive impact on strength.
- Flexural strength is improved for crumb rubber fine aggregate replacement volume ratio comprises 10%. Addition of Rice Husk Ash is increases flexural strength on 10 percentage.
- Rubberized cement composite is an effective absorber of sound, resistance to cracking and shaking energy.
- The addition of rubber particles reduces composites sensitivity to water. This water absorption resistance offers a better protection against corrosion. Also water absorption is better with addition of Rice Husk Ash.
- The study showed that on addition of Crumb Rubber as fine and coarse aggregates replacement the values of slump decreases on each increment.

V. RECOMMENDATION

It is further recommended that this study may be extended to examine the other various properties of concrete containing crumb rubber as fine and coarse replacement with optimum 10% RHA.

The properties like wet density, specific gravity, and long term curing ages strength may be studied further.

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