International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 04 Issue: 08 | Aug -2017 www.irjet.net p-ISSN: 2395-0072

A Review study on the effect of addition of Crumb Rubber and Rice Husk Ash in concrete

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Abstract - For *the past few decades, concrete has been used extensively by construction industries. Being a part of every construction in large or small scale, the annual production of concrete in the world uses about 9 billion tons of aggregate and over 2 billion tons of cement. This is putting a lot of pressure on the natural resources as well as having adverse impacts on environment too. Being the major constituent of concrete, cement has its own social and environmental impacts and contributes largely to those of concrete as well. Portland cement production contributes More than 5% to the CO_2 outflow worldwide. So to meet the increasing demand of cement and also mitigate its impacts on environment, many researchers are trying to find ways to make concrete eco-friendly and also to find alternative materials to replace the constituent aggregates in concrete mixes. Wastes from different industries have been tested for their use in concrete and many of them have been proved to be effective. Among these wastes, crumb rubber recovered from scrap tyres and rice husk ash have been incorporated in concrete to make special concrete which possesses properties like Sound insulation, thermal insulation, and impact resistance, enhanced strength and workability. Also this practice of using waste in concrete solves another issue of safe disposal of these wastes which are being generated in a huge amount every year.*

Key Words: *crumb rubber, rice husk ash, waste disposal, sound insulation, impact resistance.*

1. INTRODUCTION

Concrete has been considered as the main element of nation's infrastructure because of its economic advancement, quality, and finally its serving period. The construction industry consumes huge amount of natural resources for carrying out different construction activities, such as calcareous and argillaceous materials (for cement production), sand and coarse aggregates etc. [1]. This practice is putting lot of pressure on environment and extensive use of concrete is also an issue of concern due to its high carbon footprint as compared to other materials. Continuous efforts are being made to mitigate these adverse impacts and to make the concrete "greener" or specifically an eco-friendly material [2]. The other alarming problem is about the disposal of industrial and agricultural waste that is being generated in huge amount every year. Most of the waste does not decay easily and the safe disposal of this waste has occurred to be a serious issue upfront. So the researchers are trying to solve both the problems by testing these waste materials to be used in making special concrete that shall help in conserving the natural resources and also resolve the problem of alternative raw materials as well as waste disposal. Accumulation of waste from different industries is a huge problem. A huge assortment of waste materials are viewed as plausible and can be used as a replacement of aggregates in concrete mixes. One of such waste is rubber waste from scrap tyres. The production of tyre in one year is estimated to be more than one billion around the world and equivalent number of waste tyres is also being generated. Examinations have demonstrated that rejected rubber tyres contain materials that don't deteriorate under ecological conditions and cause significant issues in its safe disposal. One solution for the decomposition is burning, however that would likewise bring about destructive contaminations. Rubber acquired from rejected tyres is considered as the latest waste materials which may be used in making special type of concrete. Rubber can be used as fine and coarse aggregates both. When the scrap tyre rubber or other rubber is shredded into uniform granules the material obtained is known as crumb rubber and it has been inspected in light of its indispensable use in the construction field. Somehow, incorporation of crumb rubber as a replacement of sand causes significant reduction in the strength of concrete. To avoid this reduction, there are certain methods like chemical treatment of rubber before its use in the concrete mix. These methods can help in attaining the desired strength. Industrial wastes which have pozzolanic qualities are also being practiced for a few decades. Just like the rubber tyre waste, rice husk ash, an agricultural waste, has been evolved as a new material which carries good pozzolanic properties and it is as fine as cement.

India contributes largely to the total rice production in the world. Approximately 600 million tons of rice paddy is being produced, further resulting in an annual production of 120 million tons of Rice Husk. Generally, this husk is either burnt or dumped as waste material. Being the second leading producer, India's production of rice is 132 million tons per year annually. Rice husk ash contains 90%-95% of reactive silica. Extensive research has been carried out on the use of amorphous silica in the manufacture of concrete [3]. Most of the researchers concentrated their studies on the effectiveness of RHA as a pozzolana by concentrating on the amount of ash present in the mix and on the enhanced characteristics resulting from its use. This practice of using RHA as a replacement of cement is not only helping in reducing the carbon emission due to concrete but also contributing in manufacturing of light weight concrete.

2. CRUMB RUBBER CONCRETE

Rubber from scrap tyres can be incorporated in concrete either as coarse aggregates or fine aggregates and this rubber can be obtained from three types of tyres: passenger cars tyres, truck tyres and off-the road tyres. Approximately, 10 to 12 pounds of crumb rubber can be retrieved from a passenger tyre. Overall, a typical scrap tyre contains (by weight);

- 70 % recyclable rubber
- 15 % steel
- 3 % fibre
- 12 % additional material (e.g. inert fillers)

Waste rubber aggregates are classified in to four types on the basis of their particle size. This includes,
Shredded fibres
Shredded/chipped tyres (approximately 2 to 20mm)
Ground rubber (100% passing 0.425mm)
Crumb rubber (4.75-0.425mm)

Rubber can be extracted from scrap tyres by using following two methods:

- Mechanical grinding
- Cryogenic grinding

And to convert this rubber into crumb rubber, the following methods are used:

(i) Cracker mill process
(ii) Granular process
(iii) micro-mill process.

3. APPLICATIONS OF CRUMB RUBBER CONCRETE

Fine aggregate in concrete can be replaced by using ground rubber to make it cheaper and further this concrete can be used in the construction of reinforced pavements and bridge structures. This concrete is supposed to possess better resistance to ice thawing salts and frost action. The rubberized concrete is cost viable and can withstand more pressure, impact and temperature as compared to conventional concrete. Crumb rubber concrete remains intact even after failure which is a sign of good impact resistance. Due to this property, rubberized concrete can be utilized as a shock absorbing material in highway constructions, also in buildings as an earthquake shock-wave absorber and in sound barriers as sound absorber. Rubberized concrete also has high sound absorption coefficient (a), noise reduction coefficient (NRC) and less thermal conductivity coefficient (k) [4]. Hence, crumb rubber concrete exhibits superior thermal and sound properties than plain concrete. At present it has been used in precast side walk panel, non-load bearing walls in buildings and precast roof for green buildings. Since, it has low unit weight and it is not brittle in nature, so it can be used in roadways project, crash barriers, sidewalks, pavement blocks, recreational courts, pathways and skid resistance ramps and mostly where high strength is not required and in low unit weight structures [5,6].

However, studies show that the use of crumb rubber in concrete mixes affect the compressive and tensile strength significantly. With the increase in percentage of crumb rubber, strength properties are adversely affected [7,8]. Also rubberized concrete has more negative impact on being exposed to freeze and thaw conditions. So, the content of rubber in concrete mixes is restrained to certain limits. Various factors have been marked as the main reason behind the significant loss of strength in crumb rubber concrete such as the specific gravity of rubber and the other constituent materials of concrete, air void formation, lack of adhesion between rubber particles and the paste and low modulus of elasticity [9]. Some studies show that the reduction in the strength is not only due to the air entrapped but also due to poor bond between the cement paste and the rubber particles. Also the results from Freeze-thaw testing indicated that concrete mix having ground rubber behaved poorly under freeze-thaw, but the performance can be improved to some extent by using a defoamer [2]. Also the freeze-thaw performance can be enhanced when other materials like recycled aggregate and crushed glass are added to the mix. These materials are fine and fill the air gaps and make the mix more impermeable [1].

4. RICE HUSK ASH

India is a major **rice** producing country. The **husk** produced during milling is mostly used as a fuel in the boilers to produce energy through direct burning or gasification for processing paddy. About 75 % of this husk is a volatile organic matter and the rest 25 % of the weight of this husk gets converted into ash during the burning process and is known as rice husk ash (RHA). The annual production of RHA is estimated to be 20 million tonnes per year. This RHA is considered among those wastes which are a great threat to the environment. RHA causes damage to the land and the surrounding area in which it is dumped. Lots of ways are being thought of for disposing it off by using RHA commercially. RHA contains around 85 % - 90 % amorphous silica. When burning process of Rice Husk is carried under controlled temperatures below 700 degrees centigrade, the ash so generated is amorphous in nature and when this ash is exposed to high temperatures of above 850 degrees centigrade, the transformation of this amorphous state to crystalline state takes place.

Calcium silicate hydrate (CSH) gel is produced due to the hydration of cement which is responsible for the strength and cohesion in concrete. 60 % of hydrated cement paste volume is this CSH gel. The cement hydration liberates lime with which amorphous silica in RHA reacts to produce additional CSH gel that improves concrete strength and durability properties. The pozzolanic reaction of the amorphous silica, as well as the filler effect of the fine RHA particles in the concrete also improves strength at the interfacial transition zone (ITZ) between aggregate and the cement paste [10]. RHA is a good super-pozzolan and can be used as a substitute of cement in concrete mixes.IS-456-2000 (for plain and reinforcement concrete) does not specify the quantity RHA in concrete.

5. APPLICATIONS OF RICE HUSK ASH

Being a fine material, RHA improves workability and stability of concrete mix. Since, it is rich in silica, it causes less heat evolution, as a result of which thermal cracking and plastic shrinkage are reduced to some extent. RHA modifies the pore structure and blocks the large pores in the hydrated cement paste through pozzolanic reaction and improves Impermeability and durability.

FOR STRENGTH:

RHA is cheaper than silica fume or micro silica (another substitute for cement) and it has the ability to be used as a substitute for cement without compromising with the quality. Since, RHA has particle size finer than cement, hence, even using it in low replacement percentages can enhance the workability, strength and impermeability of concrete mixes, while making the concrete resistive to chemical attacks, abrasion and reinforcement corrosion which leads to a strong concrete mix.

FOR WATER PROOFING:

RHA fineness makes it excellent in resisting water penetration and it is used in waterproofing compounds to have better results. It can reduce the water penetration by as much as 60 %.

FOR BETTER CONCRETE IN MARINE ENVIRONMENT:

Adding RHA improves the durability of concrete by reducing chloride ion penetration by as much as 50 % into the structure.

FOR LOWER HEAT OF HYDRATION:

Adding RHA to concrete can lower the heat of hydration by as much as 30 %. It reduces the crack formation in structure.

6. RICE HUSK ASH CONCRETE

The incorporation of rice husk ash in concrete convert it into an eco-friendly supplementary cementitious material. RHA concrete is less susceptible to drying shrinkage and facilitate durability of the concrete mix. For concrete incorporating RHA, bleeding and segregation problems are negligible. The reduction in the permeability of concrete structure also helps in reducing the penetration of chloride ions, thus avoiding the disintegration of the concrete structure. RHA concrete possesses higher chloride and sulphate attack resistance. The rice husk ash in concrete react with the calcium hydroxide to bring more hydration products. The consumption of calcium hydroxide will enable lesser reactivity of chemicals from the external environment [11]. The low specific gravity of RHA leads to the reduction in the mass per unit volume. Incorporation of finer RHA increases the density of concrete mix and this concrete mix possesses higher strength than the concrete with coarser RHA. Concrete made with RHA is supposed to be more compacted than the controlled mix [12]. RHA concrete can be considered as "green" and high performance concrete**.**

7. METHODOLOGY ADOPTED FOR THE DEVELOPMENT OF RUBBER MODIFIED CONCRETE

Malek k. batayneh et al. (2008) [7], focused its investigation on utilising crumb rubber as substitution for natural aggregates used in concrete mix in Jordan. Size of the crumb rubber used in testing ranged from 4.75 to 0.15 mm. The replacement is done in different percentages by volume (20%, 40%, 60%, 80% and 100%). Type 1 ordinary Portland cement was used. The grade for normal concrete used in the study was M25. Effect on workability, unit weight, compressive strength and split tensile strength were studied, and also, stress strain relationship analysis was also done.

S. Selvakumar et al. (2015) [1], studied the viability of rubber as substitute for fine aggregate and utilized the crumb rubber extracted from the tyres in concrete. Concrete specimens with various percentage of replacement (5%, 10%, 15% and 20%) were prepared and tested. M30 grade of concrete was used as control mix concrete. Flexural, compression and splitting tensile test were conducted.

Nadim A. Emira and Nasser S. Bajaba (2012) [5]**,** studied the viability of addition of waste rubber tyre aggregate as a replacement for natural aggregates in concrete and the effects of curing time on the engineering properties of concrete were studied. Different concrete groups were made using plain Portland concrete, crumb rubber as replacement for fine aggregates (0%, 10%, 20% and 30%) by volume. Various sizes of crumb rubber were used which has been divided into three groups namely; (0.01-1.5) mm, (0.5-2) mm, and (2-3) mm. The specimens of all the different groups were examined after different curing time namely; 7, 14, 21 and 28 days. The grade for normal concrete used in the study was M25.

Khalid Battal Najim (2013) [8], experimentally determined the effect of varying w/c at constant cement content and aggregate specific surface area, on the fresh state properties and hardened state properties of rubberized concrete. Feasibility of designing rubber modified concrete with acceptable workability level was assessed. High strength Portland cement was used; fine aggregates, coarse aggregates and (coarse + fine) aggregates was replaced with rubber tyre particles for different percentages of 10, 20, 30 and 50% (by weight).

S.Talukdar et al. (2011) [2], this study investigated the use of waste materials such as crushed glass, ground tyre rubber, and recycled aggregate in concrete. Compressive strength and elastic modulus were the main objectives of this study. The main interest of the study was to examine the effectiveness of using a defoamer to reduce the air in rubber modified concrete mixes. Once the air content is reduced, above mentioned materials such as recycled aggregate and crushed glass were mixed properly with ground tyre rubber so as to reduce the carbon footprint. Four concrete mixes were prepared and further investigated. Percentage of replacement of coarse aggregate (by mass) by ground rubber was 15% that produced 25% more of fresh concrete by volume. The specific gravity of ground tyre rubber was 1.1 and maximum nominal size of its particle was 9.5mm. Ten standard 100mm × 200mm cylinder were casted for a total of 40 cylinders for each mix. Moist curing adopted for the specimens for at least 28 days and then tested for compressive strength. From each mix, five specimens were tested after 7 days, and the rest five were tested after 28 days. For the tests at 28 days, elastic modulus values were also determined.

8. METHODOLOGY ADOPTED FOR THE DEVELOPMENT OF RICE HUSK ASH CONCRETE

Ghassan Abood Habeeb et al. (2010) [12], in this study rice husk ash (RHA) used was produced by using a ferro-cement furnace and its properties were studied. Ordinary Portland Cement (OPC) was used in this study. The samples were casted and placed in the curing tank after 24 hours until the testing time at the age of 1, 3, 7, 28 days. In this study, cement was replaced with three grades of RHA at various 5, 10, 15, and 20% percentages (F1, F2 and F3, i.e. 180, 270 and 360 minutes of grinding respectively).

Md. Akhtar Hossain et al. (2011), in this paper an overview of the work carried out on the use of RHA as partial replacement of cement in concrete is discussed. The Rice Husk Ash used in this study was produced in laboratory by simply burning rice husk over a steel box of 1.5 m X 1.5 m in dimension without controlling the burning temperature and time. Ordinary Portland cement was used in this work. The mixes were prepared to achieve the target mean strength of 40 MPa for the OPC control mixture.

A. E. Abalaka (2013) [10], in this paper Strength and durability properties of concrete containing rice husk ash (RHA) consisting of amorphous silica at a specific surface of 235 m^2/kg produced using a charcoal incinerator were determined. Natural sand was used as fine aggregate; for coarse aggregate, granite crushed to 20 mm maximum size with specific gravity of 2.63 was used. The cement used was OPC. Drum mixer was used for mixing concrete and the process carried for 3 min. After 24 hours, all samples were cured in water at 21˚C. For the casting of the cubes, 100 mm steel moulds were used. Compaction of cubes was done manually. For determining split tensile strength of the concrete mixes, concrete cylinders were cast in 150×9×300 mm steel moulds. Milled RHA was used dry for cement replacement in the concrete mixes.

TABLE 1. EFFECT OF CRUMB RUBBER AND RICE HUSK ASH ON THE PROPERTIES OF FRESH AND HARDENED CONCRETE

PROPERTIES	RUBBERISED CONCRETE	RICE HUSK ASH CONCRETE
Compressive strength	When rubber aggregates were added to the normal concrete mix, there was decrement in the compressive strength of concrete and this decrement kept on increasing with increase in rubber content and it was found more when coarse aggregates were replaced. Following were the reason concluded: 1) Significant difference between the specific gravity of rubber and other constituent Materials of concrete. 2) Rubber particles are hydrophobic in nature and entrap air, causing increase in air content, this leads to the reduction of concrete strength. 3) Significant difference between the elastic modulus of rubber and other constituents. 4) Low adhesion or week bond between the cement matrix and the rubber particles, which results in crack propagation through rubber-cement paste interface, when load acts upon the concrete [9].	Concrete with 10% RHA had a significant increase in compressive strength, and for up to 20%, cement could be replaced by RHA without compromising with the strength properties. With the increase in fineness of RHA the strength of concrete also increases. One study have further shown that, the low specific surface RHA used, could replace 15 % of OPC at w/b ratio of 0.50 without reduction in both compressive and tensile strength of concrete.
Flexure Strength	It reduces as the content of rubber aggregate increases. Flexural strength of CR concrete mix is significantly less as compared to conventional mix.	During the 7 days to 28 days period, the development rate of the flexural strength is high. After 28 days, till 56 days a slight increase is observed. A comparative increase in flexural strengths of RHA concrete was found at higher curing period. Results shows that the incorporating RHA to concrete can increase the flexural strength. RHA concrete mix having finer RHA was found to have higher flexural strength due to the increased pozzolanic reaction and the packing ability of the RHA fine particles.
Split Tensile Strength	Incorporating rubber aggregates affects the split tensile strength adversely but the failure of the specimens was not brittle.	Some studies results show that the low specific surface RHA can replace 15 % of OPC at w/b ratio of 0.50 without reducing both compressive and tensile strength of concrete [10].
Workability	Poor workability. Concrete mixes with crumb rubber content were harsh for manual mixing and compaction and zero or negligible slump was observed.	Bleeding and segregation were found to be very less or negligible in RHA concrete mixes. The low specific gravity of RHA was the sole reason behind it. Due to low specific gravity a reduction in the mass per unit volume was found. But to maintain workability the SP content had to be increased along with the increase in RHA fineness and percentage because the high specific surface area of RHA can increase the water demand [11].

Unit weight	Unit weight of concrete decreases with the increasing percentage of rubber content. Up to 12% replacement (by weight) of coarse aggregate and 20% (by volume) of fine aggregate meet the criteria for light weight concrete. Reduction in weight was more when coarse aggregate are replaced [5,7].	The low specific gravity of RHA causes reduction in mass per unit volume. It makes the concrete lighter. More over denser mixes are achieved by the addition of RHA.
toughness	Incorporating waste rubber tyre aggregates in concrete mix enhanced the impact resistance of the concrete. The ability to support load even after the propagation of cracks, was also increased on addition of rubber aggregates in concrete. The failure was gradual instead of brittle. Rubber concrete mix has higher flexibility due to which it was able to absorb high energy [6,7].	RHA particles are finer than cement particles. Above that RHA has low specific gravity which reduced the mass per unit volume. The permeability of concrete is reduced and a denser mixes are achieved. This resulted in better impact resistance than conventional mix.

9. CONCLUSIONS

[1] Concrete becomes ductile when rubber aggregates are incorporated in it and the failure of specimen is gradual. Above that rubberized concrete have the ability to support load even after the propagation of cracks at peak load.

[2] Properties like impact resistance and toughness are enhanced and rubber modified concrete shows more resilience as compared to conventional concrete mix.

[3] Strength properties like compressive, flexure and tensile are reduced when rubber aggregates are used in concrete mixes. Also the reduction rate increases with the increase in rubber content and it is found more in case of coarse aggregates replacement.

[4] Rubberized concrete mixes are harsh for mixing and compacting manually. But if the content of rubber is restricted to limits, workable mixes can be prepared. Slump observed is zero or negligible in some of mixes.

[5] The unit weight of rubber modified concrete is less as compared to conventional mix and hence light weight concrete can be prepared by replacing natural aggregates up to 20% to 30% (by volume) with rubber aggregates.

[6] OPC has been used in most of the research works. The viability of rubber aggregates with PPC or other cements has not been investigated.

[7] The RHA is efficient as a pozzolanic material. It is rich in amorphous silica (85-90%). Increasing RHA fineness increases its reactivity. The cement hydration liberates lime with which amorphous silica in RHA reacts to produce additional CSH gels that improves concrete strength and durability properties.

[8] The compressive strength of the concrete mix having 10% RHA, has been increased significantly, and for up to 20% RHA could replace cement without affecting the strength adversely. Increasing RHA fineness enhances the strength of concrete.

[9] The mechanical properties in terms of flexural and tensile strength have been significantly improved with the addition of RHA, with the coarse RHA showing the least improvement.

[10] The usage of Rice husk ash in concrete as a replacement for cement can decrease the emission of green-house gases to a larger extent which automatically increases the possibility for gaining more number of carbon credits.

[11] Rubber particles are hydrophobic in nature and entrap air, causing increase in air content leading to the reduction of concrete strength. In this case, being a finer material RHA can be used in rubber modified concrete mixes to check whether it reduces the permeability of concrete mix or not. Further, light weight concrete mix can be prepared for desired strength with the help of RHA without affecting the strength properties of concrete mix.

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