EXPERIMENTAL STUDY ON COMPRESSIVE STRENGTH OF CONCRETE CONTAINING WASTE TIRE RUBBER AND BRICK AGGREGATES

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ABSTRACT

Coarse aggregate is one of the indispensable elements of concrete that occupies a major portion of its volume and weight. However, using huge amounts of this ingredient creates a great demand for coarse aggregate globally. Alternative sources have become crucial to limit the consumption of raw natural aggregates as well as to ensure sustainable development. As a consequence, BurntClay Brick (BCB) chips are one of the alternatives to stone aggregates especially found in this Indian sub-continent. Though BCB provides good performance, there are still some environmental issues associated with its production. On the other hand, discarded vehicle tires have drawn concern as construction materials, because an enormous amount of waste tires is generated all over the world. Therefore,this research aims to utilize BCB chips and recycled tire rubber combined as alternatives to coarse aggregates inconcrete. Systematic experimental investigations were carried out to evaluate the rheological, mechanical, and durability performance of concrete with crumble tire rubber as a partial replacement (0%, 10%,20%,30%) of BCB aggregates. In this paper, some properties including workability, unit weight, and compressive strength have been reported.It was found that the workability decreased by 11%, 15%, and 23% than the control specimen with the addition of RA by 10%, 20%, and 30% respectively. Besides, the unit weight decrease was recorded maximum of 9% by adding 30% rubber content. In the case of compressive strength, the 7 days strength was found 22.23 MPa, 18.95 MPa, 11.93 MPa, and 7.37 MPa for the concrete with 0%, 10%,20%, and 30% rubber contents respectively. In overview, the produced concrete tended to become lightweight, but the strength was alsoreducedparallelly. Therefore, furtherresearch is ongoing for other properties of concrete with brick chips and waste tire rubber in different aspects.

Keywords:*concrete, brick chips, waste tire rubber, compressive strength, unit weight.*

1. INTRODUCTION

High strength, workability, durability, and water resistance are the main features of concrete that make it the most consumed construction material all over the world. It is also economical since it is produced with low-cost raw ingredients.Coarse aggregate is one of the essential elements which occupies a major portion of concrete volume. Due to enormous consumption, a great demand for coarse aggregate has been observed globally. This demand for construction aggregates exceeds 26.8 billion tons per year. The demand for coarse aggregate in many nations, including Bangladesh, is met by imports, which has led to the indiscriminate mining of natural rocks. So, alternative sources have become crucial to limit the consumption of new natural aggregates and ensure sustainable development. Burnt clay brick chips are one of the alternatives to stone aggregates especially used abundantlyin Bangladesh. Especially in rural construction work, most of the concrete structuresutilize brick chips as an alternative to stone aggregates. The inclusion of brick chips in concrete improves the mechanical properties of the material, such as strength and durability, and adds a unique appearance.The production of Brick Chips(BC) involves collecting clay, cleaning,molding,burning bricks, and crushing bricks into chips.(Rasel et al., 2011)stated that BC is becoming an important building component in rural areas as well. High Brick demand is rising quickly because of rising costs or a lack of other building materials including stones, and iron sheets. According to Bangladesh House Building Research Institute (HBRI) Report 2022, Over 8000 brick kilns in Bangladesh are in operation which are producing 17.5 billion bricks annually.These vast amounts of clay bricks consume 45 million tons of clay, 3.5 million tons of coal, and 2 million tons of firewood annually. The report also mentioned thatCoal burning by kilns releases pollutants (CO_2, NO_X, PM etc) into the atmosphere, leading to harmful effects on health and agricultural yields and contributing to global warming and climate change. In addition, in Bangladesh annually 9.8 million tons of CO_2 is emitted due to the burning of bricks and 42000 acres of agricultural land is being diminished annually due to unplanned brick fields and the collection of clay from agricultural topsoil. Consequently, the Bangladesh government is imposing a law to reduce kiln brick production for environmental concerns.

On the other hand,a vast amount of tire waste is generated per year all over the world.Areport by the World Business Council for Sustainable Development (WBCSD) in 2019, it is estimated that the global tire waste generation rate is between 1.1 to 1.5 billion tires per year, with only about 20% being recycled or recovered. The report also noted that the tire waste generation rate is expected to increase due to the growing demand for vehicles and mobility.Proper waste tire management is now crucial to prevent environmental hazards and promote sustainable development. The waste tires can cause land, water, and air pollution, which can harm human health and the environment.(Raffoul et al., 2017)highlighted that tire waste is directly proportional to tire production, with over 2.9 billion tires produced globally in 2017. This waste poses environmental risks since it doesn't decompose and takes up considerable space. Burning tires for fuel can emit toxic fumes that are harmful to both the environment and people. Therefore, one of the solutionsfor waste tire management was found to use them as construction materials.Over the decades, extensive research, on the properties of concrete using waste tire rubberhas been studied. That research introduced it as an emerging construction material considering the economic and environmental aspects. The discarded tire rubber has been used in concrete in different forms like granular particles, powder, and fibre(Islam et al., 2022). However, very few studies have concentrated on the use of rubber content replacement of coarse aggregates.

Considering those above concerns, this research worked on the properties of concrete utilizing both brick chips and waste tire rubber as coarse aggregates. A systematic experimental investigation is carried out to evaluate therheological, mechanicaland durability performance of concrete with crumble tirerubber as a partial replacement (0%, 10%,20%,30%) of BCB aggregates. This report highlighted only the workability, unit weight and compressive strength of concrete. The research is still ongoing, rest of the result on other properties will be published later.

2. METHODOLOGY

All the materials were collected from locally available sources. Physical properties of materialswere determined according to ASTM standard and the final mix design was fixed by trial. The sample preparation and testing procedures were also performed according to ASTM standards.

2.1 Materials

For this experiment. The list of materials includes- Brick Chips (BC), Sylhet sand (FA), Ordinary Portland Cement (OPC), potable water and waste tire Rubber Aggregate (RA) were collected from local source of Khulna Bangladesh.In case of binder, OPC from Seven Rings Cement Company in Bangladesh served as the only binder for the concrete mixtures. The OPC complies with ASTM C150, Type-I, CEM-I, 52.5 N. The manufacturer stated that this cement is composed of 95–100% clinker and 0–5% gypsum. The specific gravity of cement is 3.15. The properties of aggregates are shown in table 1. The rubber aggregate was produced locally by collecting and crumbling discarded tire of truck.

Table 1:Physical Properties of Aggregates

Properties	FA	BC	RA
Fineness Modulus (FM)	2.85	-	-
Unit Weight, Υ_{bulk} (kg/m^3)	1686	1024	602
Bulk Specific Gravity, G_{sb}	2.51	2.1	1.1
Absorption (%)	2.46	17.01	1.7

The BC were also collected from local vendor. The gradation of both BC and RA was performed according to ASTM C 136. The gradation result of coarse aggregates was shown in figure 1.

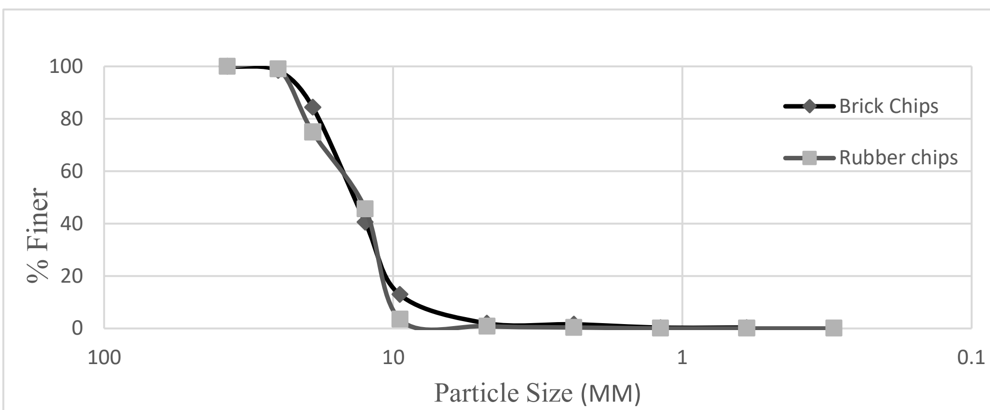

Figure 1: Particle size distribution of coarse aggregates

Figure 2:Brick chips (left) and Rubber Aggregates(right)

2.2 Sample Preparation

Fourdistinct mixes were prepared with variable proportions of coarse aggregate (BC+RA) to achieve a goal strength of 24 MPa (3500 psi) for 28 days control specimen. In each mix,four replacement ratios of brick chips by rubber aggregate (0%, 10%, 20%, and 30%) were prepared for Rubberized Concrete (RuC). Every concrete mix has the same proportion of water to cement that was 0.45.For each mix, three sample of 100 mm x 200 mm (diameter x height) was casted. The mix portion of each ingredient are shown in table 2.After mixing, the fresh property of concrete including slump and unit weight was measured. Further, after seven days of curing, three cylinders from each mix were put through a compressive load test.

Table 2:Quantity of Materials for Different Concrete Mixes

Batch Name	Cement (kg/m^3)	Coarse Aggregates (kg/m^3)	% RA	Rubber Aggregates (kg/m^3)	Fine Aggregates (kg/m^3)	Water (kg/m^3)	Admixture (kg/m^3)
R0	415.5	831	0%	0	623	187	0.35
R10	415.5	748	10%	83	623	187	0.35
R20	415.5	165	20%	166	623	187	0.35
R30	415.5	581	30%	250	623	187	0.35

3. RESULT AND DISCUSSION

3.1 Workability

Before to pouring the concrete into the standard Moulds, the slump values of the freshly mixed concrete were measured to assess its workability. Figure 3 displays the slump values for freshly mixed concrete. It was found that the slump was 103 mm for control specimen whereas the workability decreased by 11%, 15%, and 23% with the addition of RA by 10%, 20% and 30% respectively. In this study, the slump reduction is attributed by hydrophilic nature of brick chips as its water absorption is much higher. Moreover, Rough surface of rubber and brick chips caused stiffer concrete mix thereby the slump value got reduced. This phenomenon is explained by the hydrophobic nature of tire rubber, which may result in the generation of slightly stiffer mixes(Ince et al., 2022). Slump value reductions of around 19% to 93% were observed by (Siddika et al., 2019b) at replacement levels of 20% to 100% rubber.

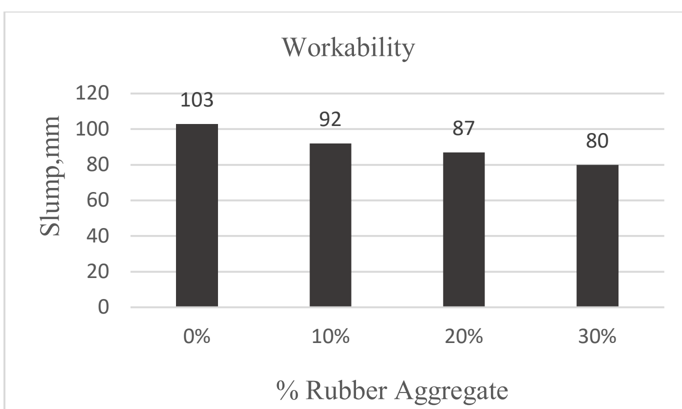

Figure 3:Variation of Slump with RA

3.2 Unit Weight

The density was measured in fresh concrete immediately after mixing. As shown in the figure, the density decreased with the addition of waste tire rubber aggregate. The unit weight found for the control specimen is 2242 kg/m^3 where around a maximum of 9% weight is reduced by adding 30 % crumb rubber. Previous studies found that the decrease in the unit weight of rubberized concrete is due to two main reasons i.e., one is the lower specific gravity of tire rubber than the normal aggregates and another reason is that the rough surface of rubber particles tends to repel water and attract air, raising the proportion of crumb tire to increase the air content. As shown in the figure, the density decreased with the addition of waste tire rubber aggregate. The porosity caused by air bubbles is less than the water's unit weight (Li et al., 2019).

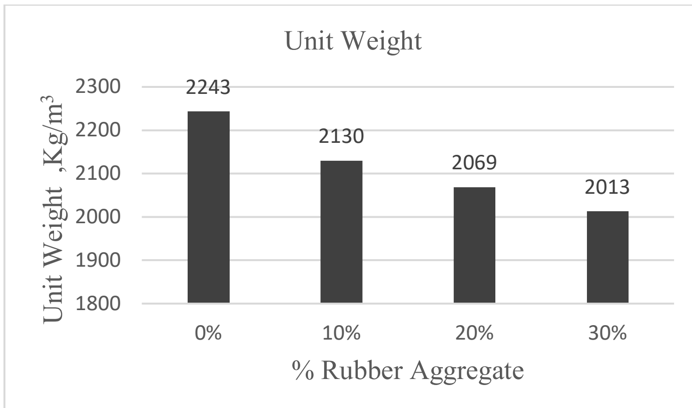

Figure 4:Change of Density with Rubber Content

RA have a specific gravity compared with natural aggregates, and the replacement of stone by rubber can lessen the weight of concrete. The weak bond between rubber and cement paste as well as voids of rubber in concreteincreases the porosity, thereby caused a low unit weight (Siddika et al., 2019b). The variation of unit weight with additon of rubber content are shown in figure 4.

3.3 Compressive Strength

The samples for compressive strength were examined after 7 days water curing. From the figure 5, it was observed that the average compressive strength of normal brick chips concrete was found 22.23 MPa.However, the strength decreased significantly by the inclusion of tire rubber crumble. The compressive strength was found to be 18.95 MPa, 11.93 MPa, and 7.37 MPa with the addition of rubber content by 10%, 20%, and 30% respectively. The strength was decreased around 14.75%, 46%, 66% at the inclusion of 10%, 20%,30% rubber content respectively. In line with prior study, adding 10% and 15% more rubber chips resulted in strength reductions of 35% and 50%, respectively (Jalal et al., 2019). When Natural Coarse Aggregate (NCA) was replaced entirely with waste chip rubbers, there was a noticeable 85% drop in compressive strength (Siddique & Naik, 2004). Another study showed that significant reduction in compressive strength was occurred up to 80% with 50% replacement of natural aggregate with recycled rubber(Martauz&Vaclavik, 2021). Shape, size, mechanical characteristics, composition, surface treatment, and replacement percentages of rubber aggregates are the primary factors that contribute to a reduction in RuC strength. The presence of voids and gap in Interfacial Transition Zone (ITZ) between the rubber and cement paste, thereby indicating a weak bonding condition (Siddika et al., 2019a). This weak ITZ is also another reason for this lower compressive strength. However, (Ramezanianpour et al., 2015) found that inclusion of pozzolans such as silica fume and zeolite can improve ITZ and enhance the bonding between rubber and binder that can reduced strength loss.

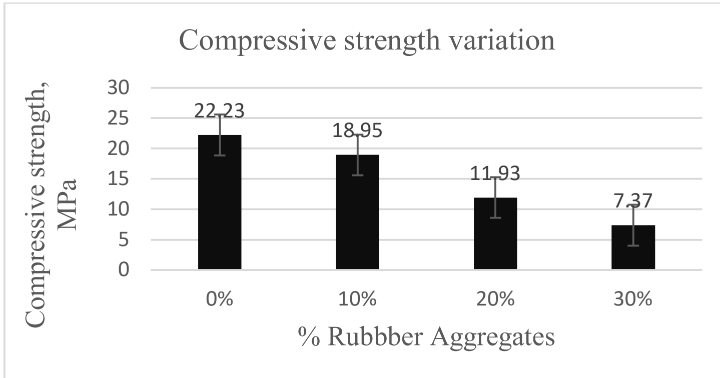

Figure 5: Variation of Compressive Strength with inclusion of Rubber Aggregate.

4. CONCLUSIONS

In conclusion, It was found that the addition of RA causes the concrete mix slightly stiffer than the control mix, thus the workability got reduced with the amount of RA. Further, the density was found to be decreased with the inclusion of RA. Around 10% of the unit weight has been reduced from the control mix with the addition of 30%RA. Thus, RA helps to produce relatively lightweight concrete. In the case of compressive strength, it was found that the compressive strength decreased around significantly by 14.75%, 46%, and 66% at the inclusion of 10%, 20%, and 30% rubber content respectively.The weak ITZ bond and compressibility of RA are the main reason for this lower compressive strength. However, this result was part of a project. Research is still ongoing on this rubberized concrete for other properties in different aspects of mix. Further result and analysis will be published later.

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