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Evaluation of Mechanical Performance of Concrete through the Integration of Crumb Rubber and Plant Residue

Raja Shujahat Zahoor Khan[1,*], Raja Wajahat Zahoor Khan[1], Anwar Khitab[2], Muhammad Asad[2]

[1] Department of Civil Engineering, University of Engineering and Technology, 47050 Taxila, Pakistan

[2] Department of Civil Engineering, Mirpur University of Science and Technology, 10250 Mirpur, Pakistan

*Corresponding Author: shujahatkhan277@gmail.com

ABSTRACT

Crumb Rubber Concrete can help to avoid pollution and overcome the issue of discarding utilized tires. It decreases the formation of cracks and expands which helps to bear greater tensile loads. This concrete got significant attention due to the expanding request for predominant auxiliary properties. The present work is based on the effect of partial replacement of sand with 5% and 10% rubber crumbs and 0.5% plant residue in Portland cement concrete. The mechanical properties, such as compressive and tensile strength, are evaluated in the hardened state. The study observes a significant decrease in compressive strength with increasing ratios of crumb rubber, as well as a gradual reduction in split tensile strength as the proportion of crumb rubber in the concrete mix increases. The samples containing the replacement with rubber by 5% and 10% and 0.5% plant residue showed 47% and 61% reduction in compressive strength when samples were tested at 28 days respectively. Study shows that there has been a 33% (0.5% plant residue & 5% rubber) and 37% (0.5% plant residue & 10% rubber) reduction in split tensile strength and 37% (0.5% plant residue & 5% rubber) and 58% (0.5% plant residue & 10% rubber) reduction in flexural strength when concrete samples were tested at 28 days.

KEYWORDS: Aggregates, Crumb rubber concrete, Compressive strength. Lantana Camara

1. INTRODUCTION

Around 1 billion waste tires are discarded worldwide. It is difficult to manage because it takes up space, is troublesome to compress and the combustion of tire discharges exceedingly toxic substance into the environment. Consequently, most of them conclude up within the landfill, as past investigation information evaluated that currently 4 billion waste tires can be found in landfills.

In recent years, 35% of waste tires were recycled, 50% were used to produce fuels derived from tires, and the remaining 15% were burned or decomposed in landfills [1]. A conceivable arrangement for this issue is to include waste tire rubber in cement items. Rubberized concrete has been inspected to be appropriate for paving and structure construction applications [1].

Lightweight concrete can also be delivered with the correct utilization of rubberized material. Past work represents that the substitution of crumb rubber in concrete affects compressive and flexural strength [2]. In addition, appropriate handling and treatment of rubberized material and the addition of polarized plants limit the shortcomings brought about by the addition of crumb rubber. Lantana camara (common lantana) is a species of flowering plant within the Verbena family (Verbenaceae). L. camara can outcompete local species, leading to a lessening in biodiversity. It can cause issues on the off chance that it attacks rural zones as a result of its harmfulness to animals, as well as its capacity to create thick shrubberies which, in case cleared out unchecked, can significantly diminish the efficiency of farmland.

The excessive use of cement and natural aggregates poses a threat to global warming. There is no proper disposal method for waste tires in developing countries like Pakistan. The use of crumb rubber might have the potential to replace aggregates that could help to reduce environmental impact. The main purpose of this research is to evaluate the properties of concrete by the partial sand replacement of 5% and 10% of finely ground crumb rubber, and cement replacement with 0.5% polarized plant (Lantana Camara). The strength of concrete is studied at 3 days, 7 days, and 28 days. Several tests are performed to study the consistency and strength of concrete. This research will help to determine the possibility of replacing aggregates and binders with crumb rubber and plant residue and pave new ways to develop sustainable concrete.

2. EXPERIMENTAL PROGRAME

2.1 Sampling and Testing Method

After the collection of the plant (Lantana Camara), the plant is dried and ground. The next process was to burn it in a tube furnace. The temperature is set in the tube furnace at 650^{o}C, which we obtained from TGA (Thermogravimetric Analysis). After the plant is burned at a given temperature, it is collected from the outlet tube. The plant is grinded in a ball mill machine for 30 min and the machine is set for 35 rev/min. After the grinding of the plant, this residue is passed through sieve # 200. The concrete mixer, along with a few molds for the casting of beams and cylinders for various tests, was used to carry out the machine mixing for batching the concrete. To create a workable concrete with the necessary strength, the concrete materials were estimated and mixed by weight or volume following the preferred mix design. Here, batching for the M15 was done by weight and using ratio (1: 2: 4). Concrete must be mixed in batches to achieve the desired strength of 15 N/mm^2, and crumb rubber and plant residue must be replaced partially. All casting is done according to a pattern where samples for the control are cast first, followed by specimens and beams for 5% and 10% as partial sand replacements. A portion of the crumb rubber is substituted with fine aggregate (sand). 0.5% of the plant residue is used to replace cement. The split tensile strength and flexural strength of concrete samples is determined according to the specifications of ASTM C496/C496M-17 [6], and ASTM C78/C78M [8] respectively.

Figure 1: Casting of specimens.

Figure 2: Concrete specimens of different mixes.

2.2 Materials & Mix Proportions

C53 cement grade is used in this research. The initial setting time of this cement is 35 minutes. Whereas the final setting time of this cement is 600 minutes (10 hours). Their particle size ranges from 1-50 micrometers. We utilized Lawrencepur sand for our project. The aggregate we use for making concrete is from Margala Crush which has an angular shape appearance and gray color. It is formed by the decomposition of Margala Rock. The size of the coarse aggregate we use is from 19mm to 4.75mm. Sieve analysis of fine aggregates was done according to the guidelines of ASTM C136/C136M-19. The plant we are using in the partial replacement of cement is Lantana Camara. It is used as 0.5% cement. Crumb rubber is regarded as a replacement for natural aggregates that are utilized as fillers in the matrix of the concrete.

The concrete mix design used to determine the required design strength is M15, which is (1:2:4). The ACI requirements for carrying out the mix design are followed during design [3]. The partial cement replacement is done with plant residue and sand replacement with rubber crumbs. Following ACI 211.1-91 for the batching of concrete, the values for the necessary test are cross-checked, and all the values are accurate and exactly in line with the batched concrete.

Table 1: Mix proportion of concrete mixes.

Mix	w/c	Water	Cement	Sand	Coarse Agg.	Plant residue	Rubber crumb
		(L)	Kg	Kg	Kg	Kg	Kg
M1	0.62	7.44	12	24	48	-	-
M2	0.62	7.44	11.40	22.80	48	0.60	1.20
M3	0.62	7.44	11.40	22.80	48	0.60	2.4

3. RESULTS

3.1 Compressive Strength Test

After the concrete specimens had been in the curing tank for 3, 7, and 28 days, the compressive strength of the concrete was determined according to ASTM C 39/C 39M-03. The compressive strength of the concrete at 3, 7, and 28 days of curing is shown in the graph below. These values are compared to those of the control unit and reflect the fractional replacement of crumb rubber with sand at 5%, 10%, and plant residue at 0.5%. The control unit displays the maximum strength (10.23MPa,14.23MPa, and 20MPa at 3, 7, and 28 days. The bonding between the concrete mix was affected when the sand was partially replaced with crumb rubber, which resulted in the rapid loss of the concrete in compression. The compressive strength for mix design 2 was 4.56MPa, 6.2MPa, and 10.53MPa at 3, 7, and 28 days. The bonding weakens significantly as 10% crumb rubber was added to the concrete mixture; this indicates that the crumb rubber lacks the stiffness to support the same stresses as the control unit, which provides the strength in compression. The compressive strength for mix design 3 was 4.2MPa, 4.3 MPa, and 7.73MPa at 3, 7, and 28 days. Study shows that there has been a 56% reduction in compressive strength due to the replacement with 0.5% cement and 5% sand. The samples containing the replacement with rubber by 0.5% cement and 10% sand showed a 69% reduction in compressive strength at 7 days. Similarly, there was a 47% and 61% reduction in compressive strength when samples were tested at 28 days respectively. This addition significantly reduced the concrete's compressive strength because it has an extremely uneven surface texture, traps spaces, and creates free spaces that lead to the production of air voids. Similar results were obtained in the study conducted by Jamal et al. [4] when 20% crumb rubber was added to concrete. The maximum strength of 22.53Mpa was achieved by the addition of 10% crumb rubber by Akbar et al. [5]. Similarly, studies on the addition of crumb rubber revealed that doing so significantly affects the compressive strength of concrete, and many other researchers came to the same conclusion. The compressive strength of concrete decreases as more crumb rubber is added to any concrete mix design.

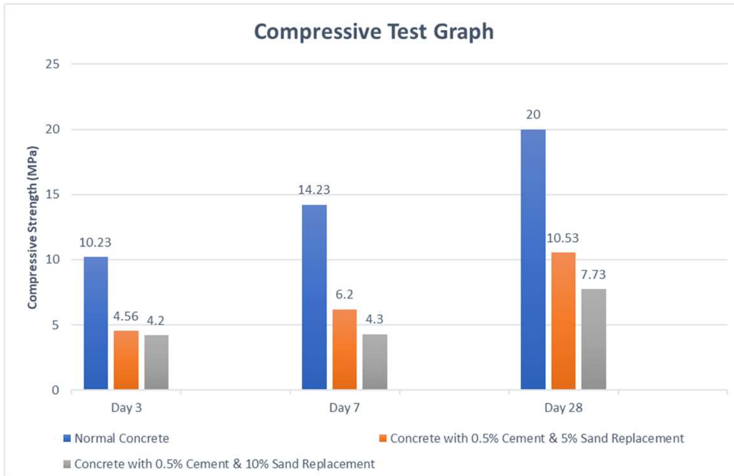

Figure 3: Compressive strength of concrete specimens.

3.2 Split Tensile Strength

The results of split tensile strength obtained from testing cylindrical specimens. The specimens were constructed following ASTM C 496/C 496 M-04 [6]. The tensile strength is seen to decline linearly for the specimens when the crumb rubber fractions were replaced with sand in the concrete mix. The findings indicate that the specimens' split tensile strength has dropped slightly but not as much as in the compressive strength tests. The cylinders' split tensile strength has somewhat decreased. It might be because the crumb rubber's extremely tiny particle size causes it to absorb water, trap gaps between aggregates, and create air voids. Therefore, the strength of the concrete decreases as the percentage of crumb rubber increases. Similarly, researchers have determined that concrete's strength has decreased. At 3 and 7 days, respectively, the control unit exhibits the maximum strength of all specimens of 1.44 MPa and 1.85 MPa. Study shows that there has been a 33% (concrete with 0.5% cement & 5% sand replacement) and 37% (concrete with 0.5% cement & 10% sand replacement) reduction in split tensile strength at 28 days. The Split Tensile Strength of the concrete at 3, 7, and 28 days of curing is shown in the graph below.

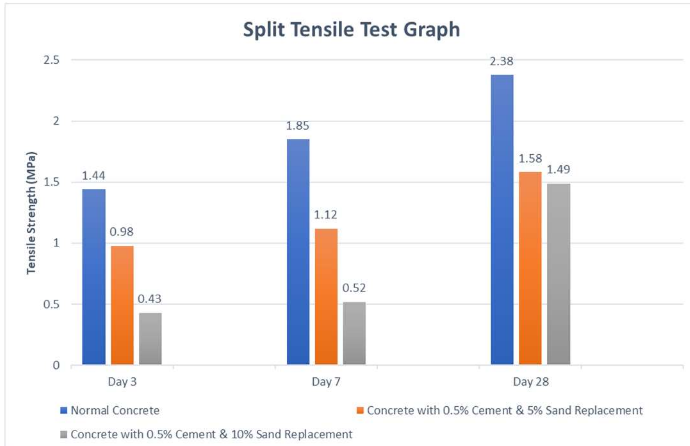

Figure 4: Split Tensile strength of concrete specimens.

3.3 Flexural Strength Test

The beams of concrete were used to determine the flexural capacity of concrete and the variation in flexural strength of different mixes is represented in the graph below. The specimens were constructed following ASTM C78. At 3 and 7 days, respectively, the control unit exhibits the maximum strength of all specimens of 3.76 MPa and 4.8 MPa. The tensile strength is seen to decline linearly for the specimens when the crumb rubber fractions were replaced with sand in the concrete mix. The results indicate that the beams' flexural strength has dropped slightly. It was calculated that there was a 37% (concrete with 0.5% cement and 5% sand replacement) and 58% (concrete with 0.5% cement and 10% sand replacement) reduction in flexural strength when concrete samples were tested at 28 days. A similar study conducted by Gravina et al. [7] recommends the maximum use of crumb rubber should not be more than 20%, however, there is limited literature on this topic. The beams' split tensile strength has somewhat decreased. It might be because the crumb rubber's extremely tiny particle size causes it to absorb water, trap gaps between aggregates, and create air voids. Therefore, the strength of the concrete decreases as the percentage of crumb rubber increases.

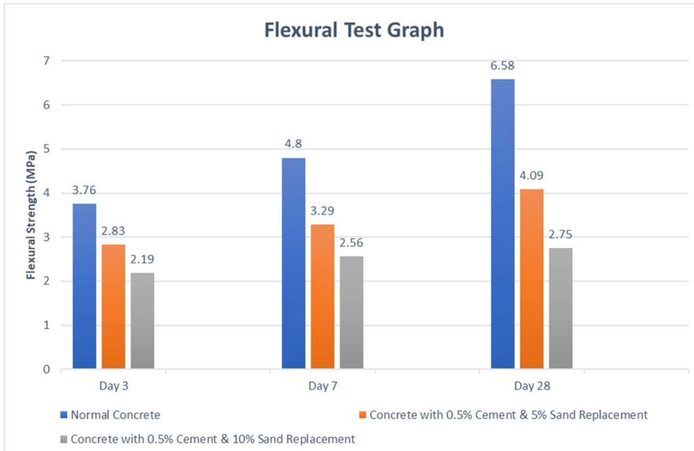

Figure 7: Flexural strength of concrete specimens.

4. CONCLUSIONS

Adding crumb rubber to the concrete mixture reduces the strength of the concrete. When rubberized concrete of 5% and 10% sand replacement were tested after 7 and 28 days of curing a significant reduction in the compressive strength of rubberized concrete was observed. The following conclusions can be drawn from the conducted study:

1. In Experiments that are performed in the hardened start of rubberized concrete, the declining behavior is observed in mechanical properties that the decrease in compressive strength, tensile strength, thermal conductivity, porosity, and shrinkage.

2. After 28 days, the samples with 5% and 10% rubber replacement and 0.5% plant residue demonstrated a 47% and 61% decrease in compressive strength, respectively. After 28 days, the study revealed that there was a reduction in split tensile strength of 33% (0.5% plant residue & 5% rubber) and 37% (0.5% plant residue & 10% rubber) Similarly there was 37% (0.5% plant residue & 10% rubber) and 58% (0.5% plant residue & 10% rubber) reduction in flexural strength when samples were tested at 28 days. Crumb rubber traps voids and is inert to cement, leaving air voids in concrete which makes the specimen weak in compression.

3. As rubber is an elastic material and its tensile strength is greater, it was assumed that the addition of crumb rubber in the concrete mix would be greater. However, when the experiment, i.e., the tensile strength test was performed, an analysis of its results showed that less reduction of tensile strength in rubberized concrete due to the inert reaction of Crumb rubber. A slight reduction in tensile strength is observed, unlike a drastic reduction in compressive strength.

5. RECOMMENDATIONS

The study suggests that a high proportion of crumb rubber is not a viable option especially where the strength of concrete is a priority. This study only incorporated crumb rubber at 5% and 10%, however, the behavior of concrete can also be checked by adding a small proportion of crumb rubber. In addition, microstructural analysis can be conducted in the future to have a better understanding of the interaction between crumb rubber and aggregates.

6. ACKNOWLEDGMENT

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