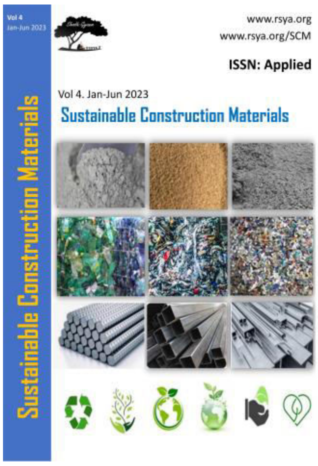

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Impact of Used Tire Rubber and Calcined Clay on Concrete with Regard to the Preservation of the Environment

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Abstract: Recycling used tyres is a very laborious process, which makes the disposal of discarded tyres a contemporary problem that poses a threat to public health. One of the most effective ways to recycle old tyres is to use them in the construction industry as a partial replacement for Portland cement. The purpose of this research is to determine the slump, compressive strength, splitting tensile strength, and water absorption of concrete made with rubber tyre (RT) and Calcined clay (CC) as partial substitutes for 30 percent of the cement. The purpose of this study is to determine the ideal ratio of reclaimed and recycled materials (RT and CC) to use in concrete mix in order to achieve the highest possible level of strength while simultaneously achieving the lowest possible level of water absorption (WA). In order to achieve this goal, numerous concrete mixtures, each with a unique combination of RT and CC in its make-up, have been produced. A mixture of RT and CC in varying proportions has been used to replace thirty percent of the weight of the cement. The findings suggest that the combined use of RT and CC in concrete improves the mechanical characteristics while simultaneously reducing cement consumption. This can help to lessen the negative environmental implications of cement manufacturing and helps to bring about a more sustainable environment.

Keywords: waste rubber tires, calcined clay, concrete mix, compressive strength

INTRODUCTION

The disposal of used rubber tyres has developed into a big environmental issue throughout the entirety of the world, posing a significant threat to the environment. One of the potential applications for recycled tyre rubber is to include it into concrete as a partial replacement for either the cement that is used or the natural aggregate that is used. By the year 2030, it is anticipated that an additional 5000 million tyres will be discarded on a regular basis, with an annual total of 1000 million tyres reaching the end of their functional life [1]. On the other hand, the production of Portland cement, which is regarded as the most important binder material in the production of concrete, has increased significantly as a direct result of the growing demand for concrete in the construction industry. This is due to the fact that concrete is increasingly being used in construction projects. The manufacturing of cement is another one of the major industrial sectors, and it is responsible for around 8 percent of the world's carbon dioxide (CO2) emissions [2]. These days, experts are interested in finding ways to reduce the amount of cement used in concrete products by using materials that are less harmful to the environment in engineering applications. [3] [4][5][6][7][8][9] . Chipped rubber, crumb rubber, ground rubber, and fibre rubber are the four different types of recycled tyre rubber that are classified according to their size. [10][11][12][9]. Rubber Tire that has been shredded or chopped after prolonged the shredding process results in the formation of tyre particles with a size ranging from 14 to 78 millimetres, which are referred to as "shredded particles." a significant number of researchers, in most cases, substitute sand for crumb rubber. Crumb rubber is produced in unique mills that tear large pieces of rubber down into smaller, more manageable pieces [13][14][15]. The mills that are utilised and the temperature that is maintained both play a role in the production of rubber particles of varying sizes. The production of particles with a high degree of irregularity in the range of 0.425–4.75 mm is accomplished by the use of a straightforward approach [9]. A chipped rubber tyre is another name for ground rubber, which is sometimes used as a potential substitute for cement. To obtain this rubber, the process of shredding tyres must be performed in two stages. At the end of the first stage, the length of the rubber should be between 300 and 430 mm, and the width should be between 100 and 230 mm. In the second stage, cutting brings the size down to between 100 and 150 millimetres. On used tyres, the processes of magnetic separation and screening are often carried out in two stages. Cement and concrete are using a growing variety of diverse procedures, each of which incorporates a different size proportion of rubber. The micro-milling method results in particles with a range of sizes, from 0.075 to 0.475 millimetres in diameter [16], [17]. The majority of the studies that were conducted came to the conclusion that one of the measures that might be done voluntarily to reduce cement use was to replace cement with ground tirerubber [18]. [19]. According to Sofi [1,] reducing the amount of rubber powder in concrete by 5, 7.5, or 10 percent results in a decrease in the material's compressive and flexural strengths while simultaneously increasing the percentage of water absorbed and abrasion resistance. It was observed by Shu and Huang[20] that putting rubber powder in concrete as a partial replacement for cement can increase the material's resilience to cracking as well as the melting and freezing cycles that it goes through. According to Bisht and Ramana [8,] there is a lack of consensus regarding the effect that crumb rubber has on the flexural strength of concrete. This may be because the size of the rubber that is used makes a difference in the outcome of the experiment. On the other hand, the size of the rubber particles has a substantial impact on the mechanical properties of the concrete [21][15][22]. In addition, the majority of studies show that adding crumb rubber to concrete makes it easier to work with [23]. Additionally, some researchers discovered that making a partial substitution of coarse and fine aggregate with crumb rubber and rubber chips, respectively, led to a significant increase in chloride-ion penetration [24].

EXPERIMENTAL PROCEDURE

The concrete mix that was used in this research study consisted of Ordinary Portland Cement, Rubber Tire (RT), Calcined Clay (CC), Fine Aggregate, Coarse Aggregate, Superplasticizer, and Water. All of these components were combined together.

Table 1 Chemical properties of constituents.

Material	Cao	SiO2	Al2O3	Fe2O3	MgO	SO3	K2O	Na2O	L.O.I.
Cement	64	21.3	4.1	3.4	1.4	1.2	0.4	0.1	1.01
Calcined Clay	1.2	51.1	35.62	2.41	0.9	1	0.42	0.51	1.76

Table 2 Physical Characteristics of constituents.

Properties	Specific Gravity (g/cm3)	Bulk Density (kg/m3)	SSD absorption (%)	Fineness Modulus
Fine Aggregate (Sand)	2.54	1615	4.4	3.1
Coarse Aggregate (Gravel)	2.58	1625	0.92	-

ORDINARY PORTLAND CEMENT (OPC)

Cement is a binder made by mechanically grinding limestone and other materials in a cement production plant. Cement employed in the investigation was ordinary Portland cement having grade 43, which was procured from a local vendor and offered by GLA University, Mathura. In this investigation, rubber tire and calcined clay embedded concrete was prepared using Ordinary Portland Cement having specific gravity of3.10 in compliance with IS: 8112-2013 [25].

CALCINED CLAY

Dolomite and calcium-rich limestone are the two main components of calcined clay, which results in a white clay. Calcined clay, in comparison to cement, is made up of particles of a much finer size [26][27][28]. The primary goal of replacing cement with calcined clay is to improve the characteristics of cement concrete specimens by utilising pozzolans. This can be accomplished through the use of Pozzolans. Using calcined clay as a weight substitution for cement in concrete specimens can result in significant reductions in CO2 emissions [29]. Calcined clay can be used in place of cement. Calcined clay (CC) and ordinary portland cement are broken down into their component chemicals and displayed in Table 1. (OPC). The use of calcined clay in concrete, in addition to improving the micro properties of the concrete, helps to reduce the harmful effects of carbon dioxide emission on the environment and minimises the problem of waste disposal [30].

RUBBER TIRE

Rubber Tire (RT) is a product that is derived from waste vehicle tyres, which are then mechanically shredded into pieces that range in size from 0.14 to 0.28 millimetres and have a specific gravity of 1.15 grammes per cubic centimetre [31]. This product is used as a partial substitution for cement in the range of 0 to 30 percent by weight.

SUPERPLASTICIZER

In each of the designs, a superplasticizer composed of polycarboxylate at a concentration of 0.5 percent was used.

FINE AGGREGATE

In this experiment, we used sand that was readily available in the surrounding area and that had previously been sieved using an IS device with a size of 2.36 mm. The GLA University in Mathura went to a neighbourhood shop to buy the sand that they needed. The outcomes of the tests on the fine aggregate properties that were carried out in accordance with IS 383:2016 [32] are presented in Table 3. The sand was pristine and free of any impurities, including plants, leaves, and muck, amongst other potential contaminants. In mortar specimens, fine aggregate serves the purpose of a filler ingredient and contributes to the solidity of the construction as a whole.

Table 3: Result properties of fine aggregates

Physical Properties	Results
Specific gravity	2.67
Bulk density	1640
Fineness modulus	2.45
Water absorption	1%
Passing through IS sieve	4.75mm

COARSE AGGREGATE

In this study, 10 mm and 20 mm coarse aggregates were employed. The coarse particles utilized had a clean surface and were sub-angular in form. The coarse aggregate requirements followed IS 383 [33].

WATER

Cement and pozzolanic particles can only hydrate with the presence of water. The strength and durability attributes of the specimen are significantly influenced by the quality of the water that was used in the process. This experiment only used water that was free of any impurities that could have originated from other sources. For the purpose of this investigation, sterile drinking water was obtained from GLA University in Mathura, India. This water had a total dissolved solids content of up to 1665 ppm and a pH of 7.2 on average. The qualities of the curing water are outlined in Table 4, which can be found here.

Table 4: Quality parameters of water.

Properties	Specific Gravity (g/cm3)	Bulk Density (kg/m3)	SSD absorption (%)	Fineness Modulus
Fine Aggregate (Sand)	2.54	1615	4.4	3.1
Coarse Aggregate (Gravel)	2.58	1625	0.92	-

METHODOLOGY

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$$\text{Water Absorption } (\%) = (W2-W1)/W1*100$$

Table 5: Chemical properties of constituents.

Mix ID	Cement(kg/m3)	RT(kg/m3)	CC(kg/m3)
RT00CC00	350	0	0
RT10CC20	245	35	70
RT20CC10	245	70	35
RT30CC00	245	105	0
RT00CC30	245	0	105

RESULTS AND DISCUSSIONS

SLUMP VALUES

Cement and pozzolanic particles can only hydrate with the presence of water. The strength and durability attributes of the specimen are significantly influenced by the quality of the water that was used in the process. This experiment only used water that was free of any impurities that could have originated from other sources. For the purpose of this investigation, sterile drinking water was obtained from GLA University in Mathura, India. This water had a total dissolved solids content of up to 1665 ppm and a pH of 7.2 on average. The qualities of the curing water are outlined in Table 4, which can be found here.

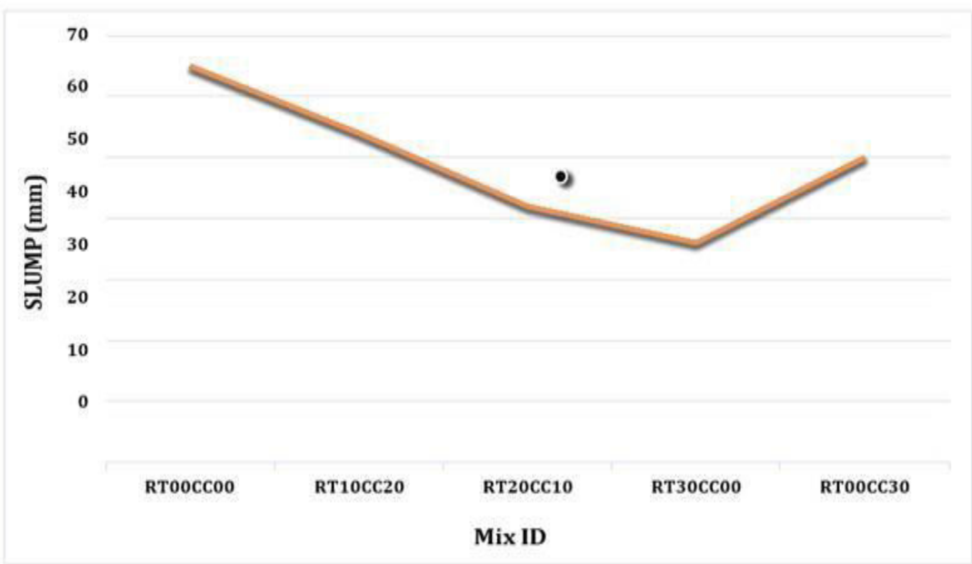

Fig. 1 Slump values of different mix having RT and CC

COMPRESSIVE STRENGTH

The impact that RT and CC content have on the compressive strength of concrete is illustrated in Figure 2. According to the findings of the experiments, an increase in RT results in a decrease in the compressive strength of the concrete. A reduction in compressive strength occurred as a direct result of the formation of voids, which may have originated as a result of the fine nature of RT. It is common knowledge that a rise in the RT content leads to an increase in the development of voids within the mixture, which in turn results in concrete that has a low density and poor strength. Reduced compressive strength, which in turn leads to the development of microcracks and poorer bonding in the concrete mixture, has been identified as one of the causes of reduced bond formation between RT particles and cement paste. [3] [15] This has been recognised as a cause of reduced compressive strength. A cumulative impact of calcined clay and rubber tyre has resulted in a modest rise in compressive strength, which can be seen illustrated in figure 5. This increase in compressive strength has been noted. In spite of the fact that the addition of rubber tyre resulted in a sizeable weakening of the concrete's compressive strength, the combinations that included both rubber tyre and calcined clay shown a sizeable improvement in that property. The maximum compressive strength of the RT10CC20 mixes is 34.26 MPa, which is higher than the strength of the reference mix. It is believed that the filler effect in CC and pozzolanic reaction products are responsible for the densification of the cement matrix and the enhancement of the grounded rubber cement mix. However, the rate of strength development slowed down when the amount of rubber tyre in the combination climbed to more than 10 percent substitution.

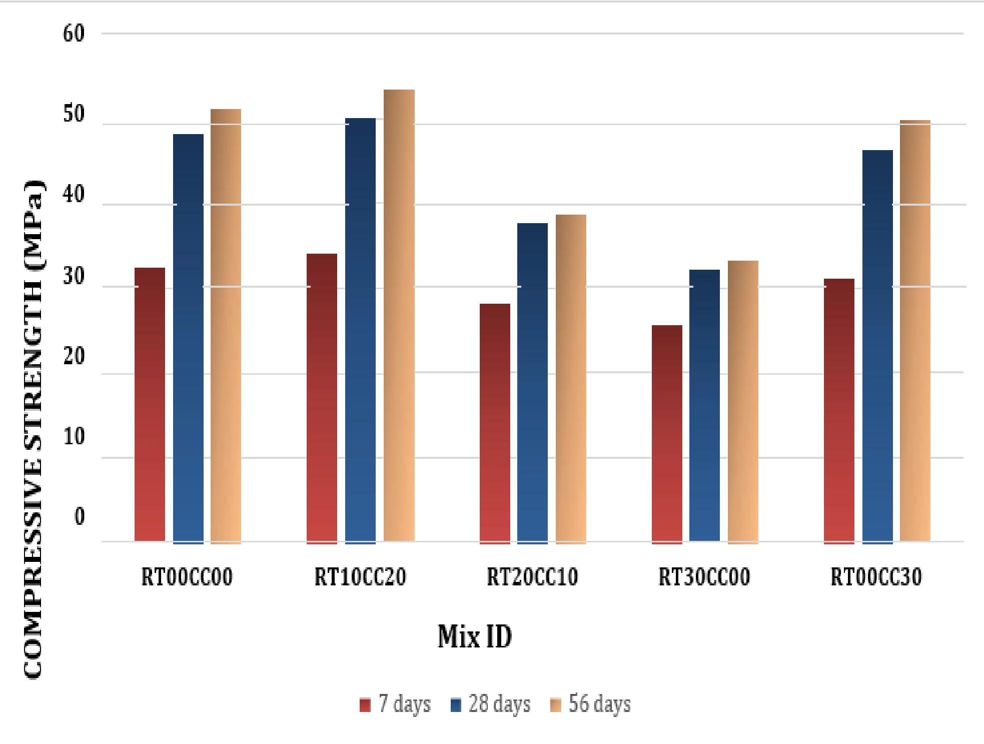

Fig. 2 Compressive Strength of different mix having RT and CC

TENSILE STRENGTH

The values for the splitting tensile strength of the concrete sample are shown in Figure 6. The splitting tensile strength of the specimens falls as the concentration of RT in the test solution increases. This could be due to an insufficient connection between the RT and the cement matrix, which would result in the formation of fissures. A higher RT content was associated with an increased likelihood of the development of micro-cracks, and the linking together of these micro-cracks under load application resulted in the production of a larger crack at a lower load value. In addition to this, a stress concentration is formed around the RT as a result of the greater deformations that the RT undergoes in comparison to the matrix [42]. The splitting tensile strength will decrease as the concentration of RT in the material increases. Clay that has been calcined and rubber, when used together, provide a material that is significantly more robust. According to the findings of the experiments, the RT10CC20 mix had the greatest strength after 7 days, 28 days, and 56 days; its value was 3.25 MPa, 4.28 MPa, and 4.29 MPa, respectively.

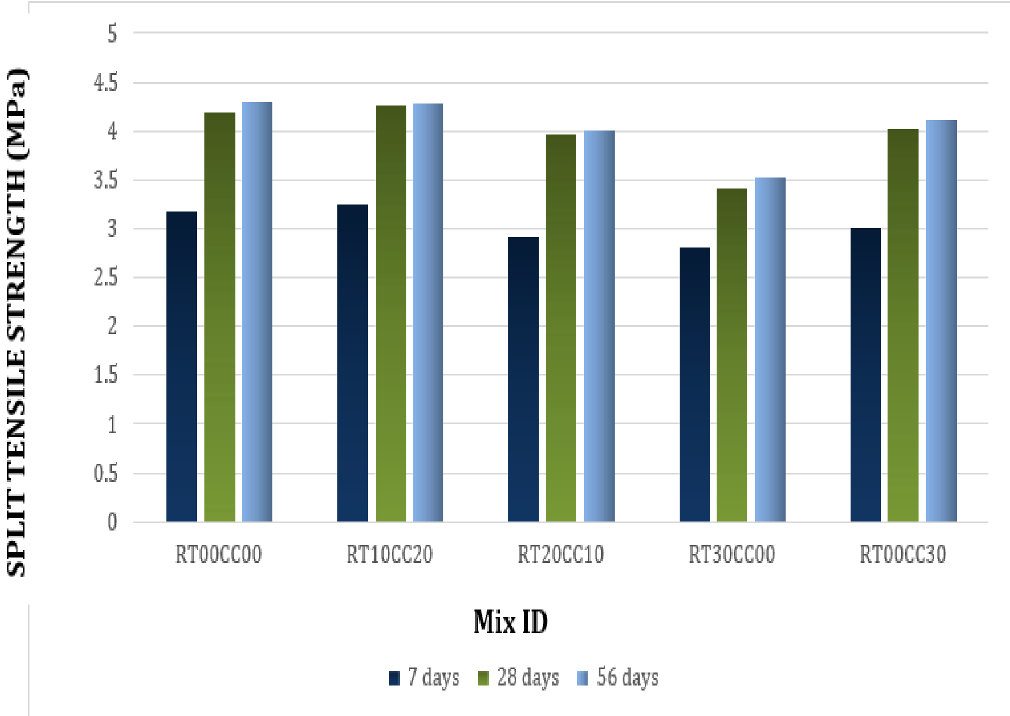

Fig. 3 Tensile Strength of different mix having RT and CC

WATER ABSORPTION

In order to determine whether or not water could penetrate the concrete, an experiment measuring water absorption was carried out over the course of 7, 28, and 56 days. Experiments were done to visually represent the increase in percentage. According to Figure 4, the proportion of water that was absorbed into the rubber tyres increased as the amount of replacement tyres increased. The percentage of water absorbed by the mixtures that contained calcined clay and rubber tyres ranged from 3.0 to 4.0 percent. In contrast, the incorporation of calcined clay into mixtures resulted in a reduction in the amount of water that was absorbed by the specimens, which was between 3.80 and 4.0 percent. The larger void content of rubberized concrete may be attributed to characteristics such as the tendency of crumb rubber to float in mixes in conjunction with the elastic nature of the composite material. This may have led to the higher void content.

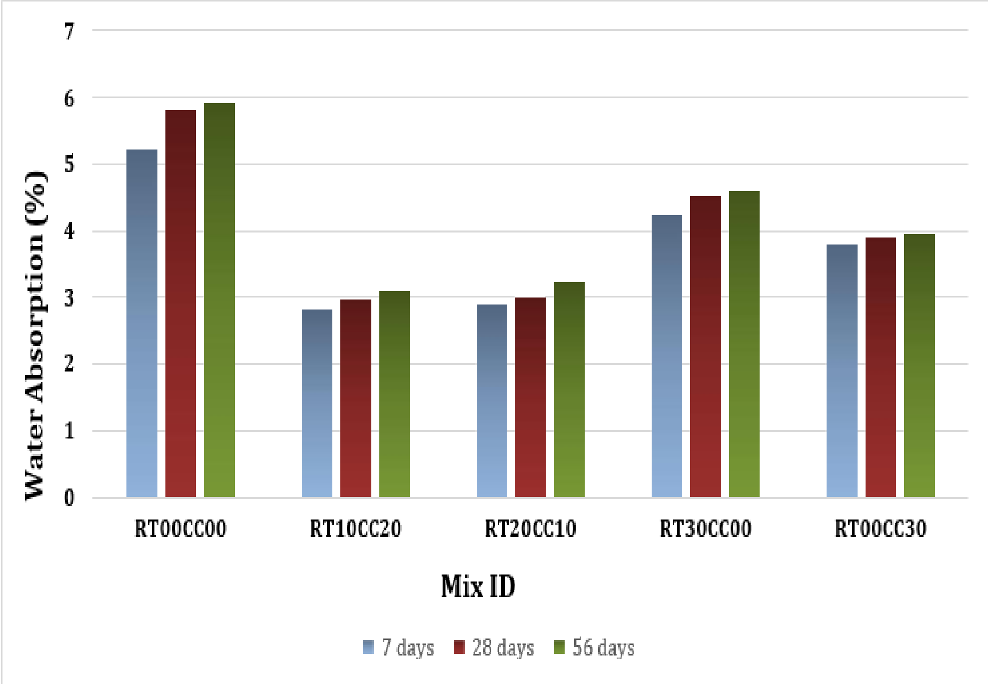

Fig 4: Water Absorption

CONCLUSION

In this line of research, an investigation was carried out to investigate the effects on the mechanical characteristics of concrete by using pulverised rubber tyre and calcined clay as a cement substitute. The following inferences can be drawn from the findings of the experiments that have been reported:

- The presence of rubber tyres has a detrimental effect on the workability. According to the findings of the tests, conventional concrete RT00CC00 mix has a larger slump value of 65 millimetres, but the replacement of rubber tyre with cement at a rate of 30 percent resulted in the lowest value of slump, which was 36 millimetres.
- The compressive strength was somewhat increased by the addition of RT and CC to the mix. Because of the synergy that exists between limestone powder and calcined clay, these mixes were able to outperform the reference combination while using 10 percent RT and 20 percent CC as substitutions for cement. At 7, 28, and 56 days after mixing, the RT10CC20 mix has a maximum compressive strength of 34.26 MPa, 50.26 MPa, and 53.48 MPa, respectively. An increase in the concentration of rubber tyres in concrete results in a reduction in the material's compressive strength. When compared to a standard sample, the compressive strength of the composite material significantly improved thanks to the synergistic action of calcined clay and recycled rubber tyres.
- According to the findings of the tensile strength test, the combined effect of calcined clay and rubber resulted in an increase in strength. According to the findings of the experiments, the RT10CC20 mix had the greatest strength after 7 days, 28 days, and 56 days; its value was 3.25 MPa, 4.28 MPa, and 4.29 MPa, respectively.

- The use of calcined clay in the appropriate concentrations leads to considerable improvements in both the water absorption and mechanical properties of concrete. The inclusion of calcined clay boosts the concrete's mechanical strength to some degree, but it also reduces the concrete's capacity to absorb water.

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