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Experimental Investigation On Rubberised Green Concrete

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ABSTRACT

In order to produce rubberized green concrete, a sustainable building material, this study explores the possibility of adding rubber particles from recycled tires to green concrete. The study intends to address the large carbon footprint of conventional concrete production as well as environmental issues related to the disposal of waste tires. The mechanical and durability characteristics of concrete mixtures that substitute natural aggregates with varied percentages of rubber material are the main focus of the experimental inquiry. To evaluate the performance of rubberized green concrete, extensive tests are carried out, including assessments of durability, tensile strength, flexural strength, and compressive strength.

According to preliminary research, adding rubber particles to concrete weakens it overall but increases its flexibility, energy absorption, and impact resistance. The ideal balance strength for rubber content and durability are established, providing information about the real-world uses of rubberized green concrete in building. According to the study's findings, rubberized green concrete can be a practical substitute for some structural and non-structural applications, supporting waste management strategies and environmentally friendly building techniques. To optimize mix designs and investigate long-term performance in diverse environmental circumstances, more research is advised.

Introduction

General Introduction

When green concrete was first launched in Denmark in 1998, it marked a revolutionary shift in the concrete industry. Green concrete, despite its name, is about incorporating environmental factors into the manufacturing of concrete, from the selection of raw materials and mixture design to structural design, construction, and service life. Because green concrete uses waste materials to partially replace cement, it may be produced at a lower cost due to its capacity to reduce energy consumption during manufacturing, eliminate waste disposal fees, and improve durability.

Similar to regular concrete, green concrete uses less energy during manufacture and has a less environmental effect. Between 0.1 and 0.22 tons of CO2 are released for every ton of concrete that is produced. Nonetheless, given that concrete manufacturing accounts for around 5% of global CO2 emissions, the overall environmental effect is substantial given the enormous volume of concrete produced worldwide. The answer is in reducing the environmental effect of concrete rather than substituting it with alternative materials.

The use of green concrete has significant positive effects on society. It is feasible to create technologies that will reduce the CO2 emissions from the manufacture of concrete by half. As a result of society's growing awareness of the issues surrounding the disposal of leftover items in recent decades, demands, limitations, and levies have been put in place.

Essence of Green Concrete

Green concrete, sometimes referred to as eco-friendly concrete, is made with less of an adverse effect on the environment than regular concrete. The sustainable methods and materials used in green concrete are what make it so special—they reduce carbon footprints and preserve natural resources. Materials Recycled: The use of industrial waste as partial cement substitutes, such as fly ash, slag, or silica fume, lowers the overall carbon footprint and dependency on virgin resources. Conventional Portland cement manufacture is a major source of CO2 emissions and energy-intensive. To reduce these emissions, green concrete frequently includes additional cementitious ingredients or substitute binders. Compared to ordinary concrete, green concrete, also known as eco-friendly concrete, is produced with less of an impact on the environment.

Durability Studies of Green Concrete

The ability of concrete to resist weathering, chemical assaults, abrasion, and other types of deterioration is referred to as its durability. It also includes the effects of quality and serviceability of concrete when subjected to sulphate and chloride attacks. In addition to basic strength parameters, we also need to develop a concrete which has sufficient resistance against harsh environment and performs well in long run. Environmental conditions and exposure to aggressive chemicals affects the performance of concrete; spalling, disintegration and cracking can happen. Hence developing of concrete which performs well under different environmental conditions needs to be focused on. Green concretes have proven to be durable and the present study is aimed for this very purpose. Firstly green concrete of various grades is prepared and then its durability assessment is carried out. The resistance of the mortar is determined by measuring the relative decrease in compressive strength and mass of the materials following immersion in test solutions for varying durations.

Sustainability Benefits of GC

Supplementary cementitious materials (SCMs) like fly ash, slag, and silica fume are frequently used in green concrete, which lessens the demand for Portland cement, a significant contributor to CO2 emissions. Uses recycled materials and industrial by- products, such as rubber from old tires, fly ash, slag, and recycled aggregates, to divert waste from landfills and lessen environmental pollution. When compared to ordinary concrete, the energy required to produce green concrete is usually lower. Using alternative and recycled cementitious materials reduces the amount of energy used in the manufacturing process. When compared to ordinary concrete, the energy required to produce green concrete is usually lower. Using alternative and recycled cementitious materials reduces the amount of energy used in the manufacturing process. Lessens the need for natural raw resources such as aggregates and limestone.

Issues with Traditional Concrete:

Traditional concrete production significantly contributes to greenhouse gas emissions, with cement production accounting for about 8% of global CO2 emissions. The production of cement depends on non-renewable resources such as limestone and clay, leading to the depletion of natural reserves. Traditional concrete generates construction and demolition waste, contributing to landfill accumulation and environmental degradation.

Traditional concrete surfaces absorb and retain heat, exacerbating the urban heat island effect in densely populated areas. Conventional concrete is prone to cracking, impacting its long-term durability and necessitating frequent maintenance.

Potential Benefits of Rubberized Green Concrete:

Waste Utilization: Rubberized green concrete incorporates recycled rubber from discarded tires, reducing landfill waste and supporting circular economy practices.

Reduced Carbon Footprint: Replace a portion of cement with rubber particles reduces the carbon footprint of concrete production, as rubber has a lower environmental impact than cement.

Improved Flexibility and Crack Resistance: Rubber particles increase the flexibility of concrete, decreasing the likelihood of cracking and enhancing the overall durability of structures.

Durability: Rubberized concrete often exhibits enhanced durability due to the elasticity provided by rubber particles. It may have better resistance to freeze- thaw cycles and deicing salts, which can extend the lifespan of structures and reduce maintenance costs.

Sound Absorption: Rubberized concrete absorbs more sound than traditional concrete, making it useful for noise reduction in urban environments.

Objective of Project

Examine the M30 and M40 rubberized green concrete's strength.

Examine how much water rubberized green concrete absorbs at various rubber percentages.

Rubber's contribution to green concrete's bulk density

Rubberized green concrete's durability was investigated.

MATERIALS AND METHODOLOGY

2.1 Materials

This section aims to describe the various materials utilized in the study. The materials employed include OPC, fly ash, GGBS, river sand, natural aggregates crushed to specific sizes, recycled coarse aggregates from concrete debris, water, and acidic solutions such as sulphuric acid.

2.1.1 Cement

Throughout the project, OPC grade 43 from the local brand Khyber, conforming to IS 8112:2013 standards, was utilized. The specific gravity of the cement was determined using the Le Chatelier flask method and was found to be 3.14. A visual representation of the cement powder is depicted in Figure 2.1.

Figure 2.1 Cement powder

2.1.2 GGBS

Blast furnace slag, a by-product of the iron industry, offers an eco-friendly alternative to traditional concrete. This material is created by rapidly cooling molten iron slag from blast furnaces using water or steam, resulting in a glassy texture. Once ground into a fine, off-white powder, it becomes denser than fly ash. By replacing a portion of cement (typically ranging from 20% to 60%), blast furnace slag enhances the durability of concrete. GGBS contains significant CaO content and exhibits hydraulic reactivity, allowing for a high replacement ratio of cement. Its chemical composition generally includes approximately 28-40% silica, 8-15% Al_2O_3, 30-50% CaO, and 1-15% MgO. The specific gravity of GGBS was measured at 2.82.

GGBS powder 2.2

2.1.3 Fly Ash

Fly ash, a residue from coal combustion that was previously disposed of in landfills, is now utilized in the production of eco-friendly concrete. Incorporating fly ash into concrete offers several benefits compared to traditional concrete, including reduced bleeding, improved strength, and minimized shrinkage. Additionally, fly ash helps to enhance concrete's resistance to alkali-silica reaction, a common cause of concrete deterioration. While the use of fly ash in concrete is widely accepted at lower replacement levels, typically up to 20%, there is often resistance to higher replacement levels (20% or more) due to concerns about potential impacts on early-age strength and durability. Engineers, architects, and contractors usually require incentives or mandates to specify higher replacement levels. The fly ash used in the current study is classified as class F fly ash, characterized by a specific gravity of 1.92. It contains significant amounts of silica and alumina, with lower quantities of calcium and iron oxide, and a notable amount of carbon as well.

Figure 2.3 Coal fly ash

2.1.4 Sand

The sand used was fine river sand conforming to IS 383:2016. The specific gravity was calculated employing IS 2386:1963 (Part 3) and was found out to be 2.72 and fineness modulus as 2.14. Sand was zone II sand

Figure 2.4 Sand

2.1.5 Crumb Rubber

Recycled truck and car tires are used to make crumb rubber. Granular rubber is produced during the recycling process by extracting steel and tire cord (fluff). It was established what the crumb rubber's density, specific gravity, and water absorption were.

Figure 2.5 Crumb rubber

2.1.6. Recycled coarse aggregate

The disposal of demolition waste from old structures poses a significant challenge. To address this issue, recycling concrete debris offers a practical solution by repurposing discarded concrete material and reducing the resources typically consumed in concrete production. In this study, recycled aggregates were obtained by crushing existing M20 concrete cubes at the college. Following crushing, the material was sieved according to IS standards. The specific gravity of the recycled aggregates was measured at 2.42, with a water absorption rate of 5.87%. These aggregates were utilized in a saturated surface dry state to account for their water absorption capacity.

2.1.7 Hydrochloric Acid

A 36% concentrated hydrochloric acid solution was diluted to prepare a 5% solution, in which concrete cubes were immersed and monitored for deterioration over a 28-day period. Examine weight loss and compressive strength reduction of the specimens.

2.1.8 Sulphuric Acid

A 98% concentrated sulfuric acid solution was diluted to prepare a 5% solution, in which concrete cubes were immersed and monitored for deterioration over a 28-day period. Similar to hydrochloric acid (HCL), the study focused on evaluating weight loss and compressive strength reduction of the specimens.

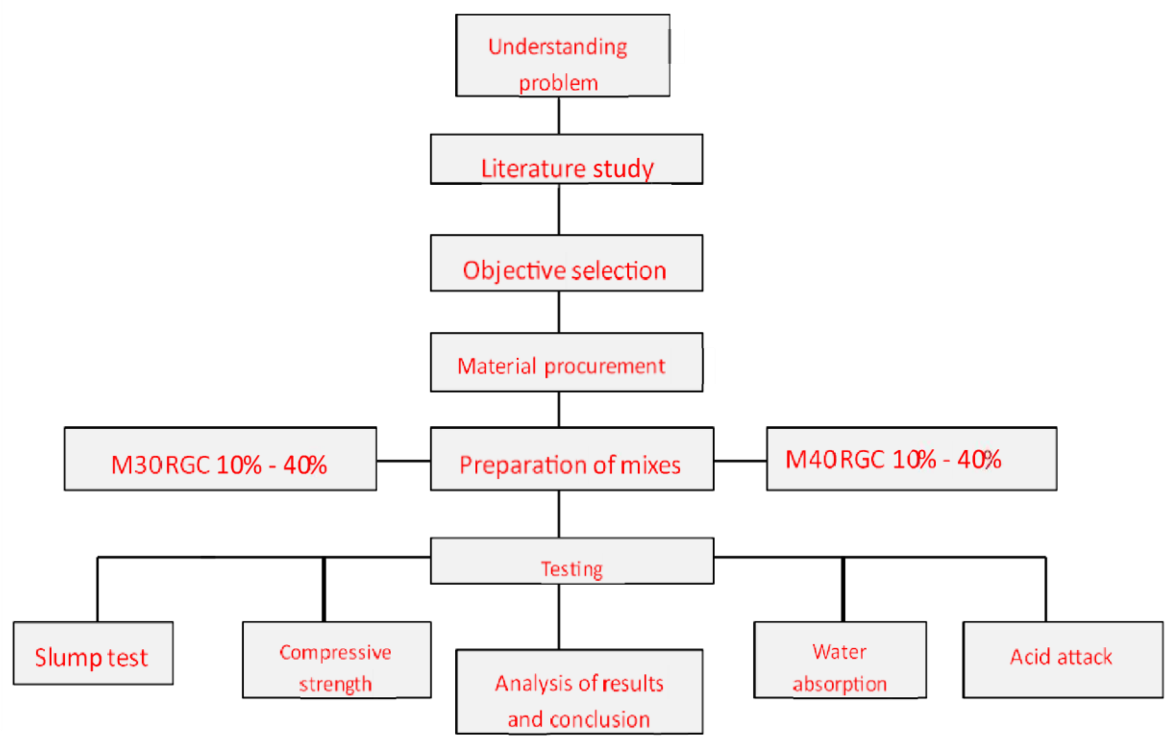
2.2 Methodology

This section describes the work flow of current study; what mixes were prepared with what proportions and how many cubes were casted. And what are the tests that were carried out and the equipment used to carry out those tests.

Table 2.2.1 Methodology table of M30 and M40

Mix proportion	No of cubes	Test carried out	Equipment required
M40R10 10%rubber and 90% sand as fine aggregate similarly M30R10 proportion	Eight cubes of 100mm x100mmx100mm	1) Slump test 2) water absorption 3)compressive strength test 4)acid attack(loss weight and strength)	1)compressive machine 2) weighing machine 3) slump cone 4)rod, hammer
M40R20 20%rubber and 80% sand as fine aggregate similarly M30R20 proportion it	Eight cubes of 100mm x100mmx100mm	1) Slump test 2) water absorption 3)compressive strength test 4)acid attack(loss weight and strength)	1)compressive machine 2) weighing machine 3) slump cone
M40R30 30%rubber and 70% sand as fine aggregate similarly M30R30 proportion it	Eight cubes of 100mm x100mmx100mm	1) Slump test 2) water absorption 3)compressive strength test 4)acid attack(loss weight and strength)	1)compressive machine 2) weighing machine 3) slump cone
M40R40 40%rubber and 60% sand as fine aggregate similarly M30R40 proportion it	eight cubes of 100mm x100mmx100mm	1) Slump test 2) water absorption 3)compressive strength test 4)acid attack(loss weight and strength)	1)compressive machine 2) weighing machine 3) slump cone

Flow chart of methodology



2.3 Tests carried out

2.3.1 Slump test: In accordance with ASTM C143, a slump test was conducted to gauge the concrete's workability.

2.3.2 Hardened concrete density :A concrete sample's volume is calculated by measuring its dimensions in order to ascertain its density. The mass and density of the sample are then computed using the weight and mass data.

2.3.3 Water absorption test : Following 28 days of water curing, water absorption tests were conducted on 100x100x100 mm concrete cubes in accordance with ASTM C642.

2.3.4 Compression Test : To evaluate the mechanical strength of the mixtures, tests of compressive strength were carried out seven and twenty-eight days after curing. The tests were conducted using a

CTM compliant with IS 14858:2000 and in accordance with the guidelines specified in IS 516 (Part 1/Sec 1):2021.

Figure

2.3.4 Compression machine

Figure 2.3.4 Compression machine

2.3.5 Acid attack: An acid resistance test was conducted following ASTM C267-97 over a duration of 28 days. Concrete samples measuring 100x100x100 mm were submerged in a solution containing 5% concentration of sulphuric acid and hydrochloric acid. The changes in weight and compressive strength were evaluated and compare to each other to study.

Figure 2.3.5 Concrete cube immersed in 5% in H2SO4

RESULTS AND DISCUSSION

3.1. Slump test

The workability of each mix was ascertained and compared since the rubber aggregate concentrations in each mix varied. Figure 3.1 displays the outcomes for Groups M40 and M30. Slump values for Group M40 showed just a very tiny rise with increasing rubber replacement, otherwise remaining almost the same for all combinations. The slump values for M40R20, M40R30, and M40R40 were 126 mm, 129 mm, and 130 mm, respectively, but the slump for the mix (M40R10) was 125 mm. Less than 10% separated the slump values of any rubber-containing combination. For all mixtures in Group M30, the slump had the same value of 80 mm.

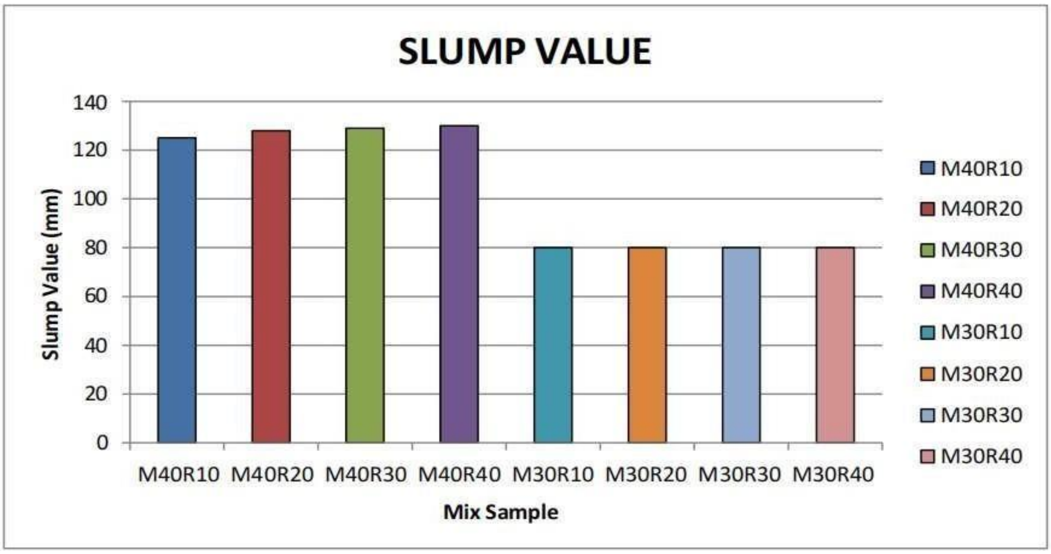


Figure 3.1 Slump value of M40 and M30 rubberize concrete

3.2. Hardened concrete density

Figure 3.2 illustrates how the volumetric replacement of rubber particles changed the concrete's density. At the same rubber replacement ratios, the loss in concrete density was nearly comparable for both groups. For instance, the density of concrete in Table 3.1 Group M30 decreased by 15.29% from 2307.59 kg/m³ with 10% rubber content to 1954.23 kg/m³ with 40% rubber content. Similarly, Group M40's density decreased by 13.19%, from 2352.51 kg/m³ to 2042.08 kg/m³.

Table 3.1 Hardened concrete density value

S.No	% of rubber	M30(Kg/m³)	M40(Kg/m³)
1	10%	2307.15	2352.51
2	20%	2189.51	2300.36
3	30%	2071.87	2176.72
4	40%	1954.23	2042.08

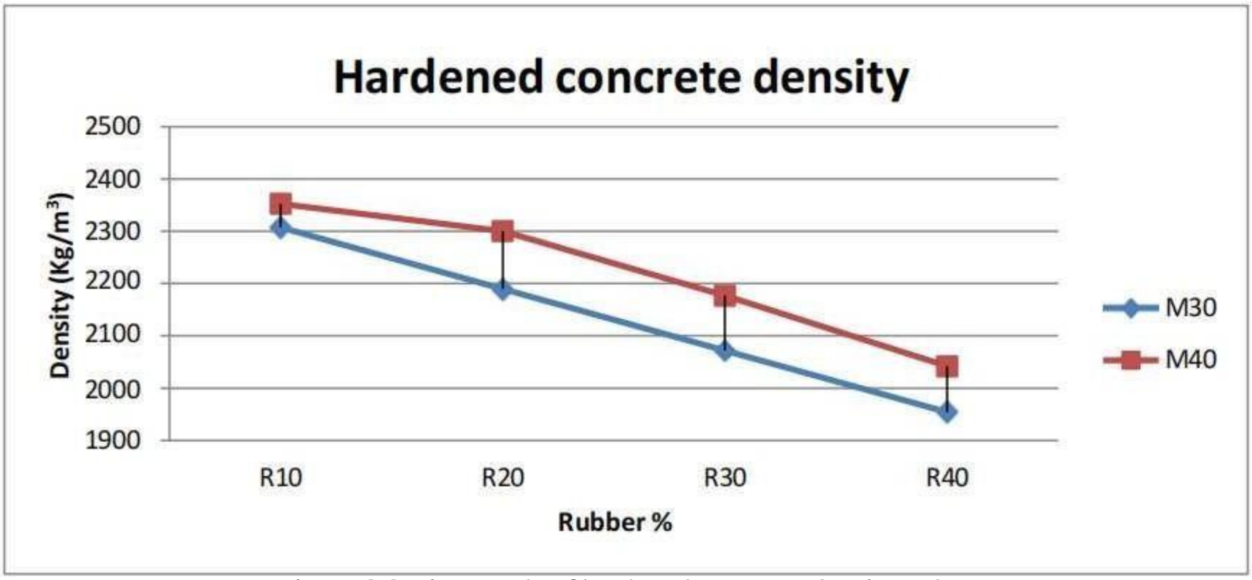


Figure 3.2 Line graph of hardened concrete density value

The concrete density decline seen in the results is consistent with other research reporting density reductions at varying rubber substitution percentages. Because rubber aggregates have a substantially lower density than natural aggregates, rubberized green concrete has a lower density. Rubber aggregates have a specific gravity of 1.15, which is significantly lower than that of natural fine aggregates (2.65). Another factor that decreased density was air trapped in the rubber's rough surface.

3.3. Water absorption

Figure 4.3 illustrates the slight change in the water absorption percentage of concrete for Group M40 and Group M30 when rubber particles are substituted for natural fine aggregates. The highest water absorption in Group M40 (table 4.2) was 2.49%; at 40% rubber content, this reduced to 1.69%, a 32.12% decrease. The highest water absorption in Group M30 was 3.57%; at 40% rubber content, this decreased to 2.46%, signifying a 31.09% reduction.

Table 3.2 Water absorption values

S.No	% of rubber	M40(%)	M30(%)
1	10%	2.49	3.57
2	20%	2.10	3.18
3	30%	1.91	2.68
4	40%	1.69	2.46

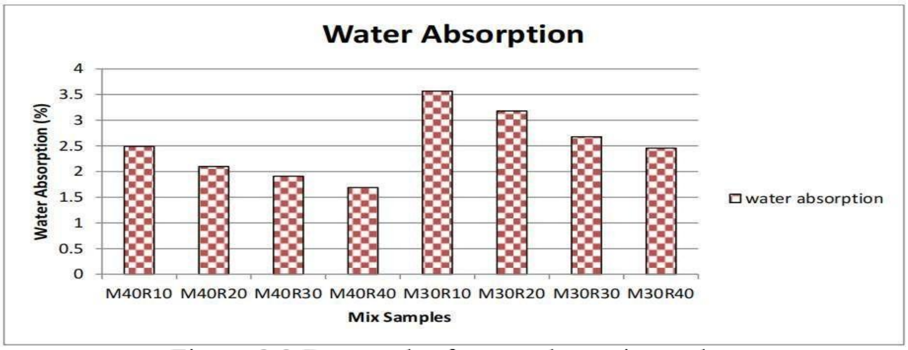


Figure 3.3 Bar graph of water absorption value

It was shown that both groups' trends in water absorption were somewhat declining as the rubber content rose. This might be the case due to rubber's lack of water absorption properties. Furthermore, the addition of fly ash to the mixture may be the cause of the reduced absorption rates. Fly ash can reduce water absorption in rubberized concrete by filling air spaces in the microstructure through its micro-filling capabilities.

3.4. Compressive strength

Tables 3.3 and 3.4 show the compressive strength values for various concrete mixtures after 7 and 28 days of curing. Despite the different concrete grades illustrated in fig 3.4, rubberized concrete specimens from Group M40 and Group M30 showed a constant drop in compressive strength with roughly comparable loss percentages. Group M30 experienced a decline in 7-day compressive strength of 21.05%, 29.63%, and 37.08%, while Group M40 experienced a loss of 23.99%, 31.49%, and 39.95%. when rubber was added at 20%, 30%, and 40% of the mixture. A mix (M30R10) had a 28-day compressive strength of 30.01 MPa; losses were seen for rubber replacement ratios of 20%, 30%, and 40%, respectively, of 12.79%, 22.05%, and 29.42%. The mix (M40R10) had a 28-day compressive strength of 36.87 MPa. At 20%, 30%, and 40% rubber replacement levels, the strength decreased by 14.32%, 23.05%, and 32.32%, respectively. With a compressive strength of 21.18 MPa for Group M30 and 24.95 MPa for Group M40, the specimens with 40% replacement in both groups fell within the predicted range for structural grade concrete.

Table 3.3 Compressive strength values of M40 rubberize concrete

S.No	% of rubber	7 days(MPa)	28 days(MPa)
1	10%	24.80	36.87
2	20%	18.85	31.59
3	30%	16.99	28.37
4	40%	14.89	24.95

Table 3.4 Compressive strength values of M30 rubberize concrete

S.No	% of rubber	7 days(MPa)	28 days(MPa)
1	10%	24.24	30.01
2	20%	19.16	26.17
3	30%	17.06	23.39
4	40%	15.25	21.18

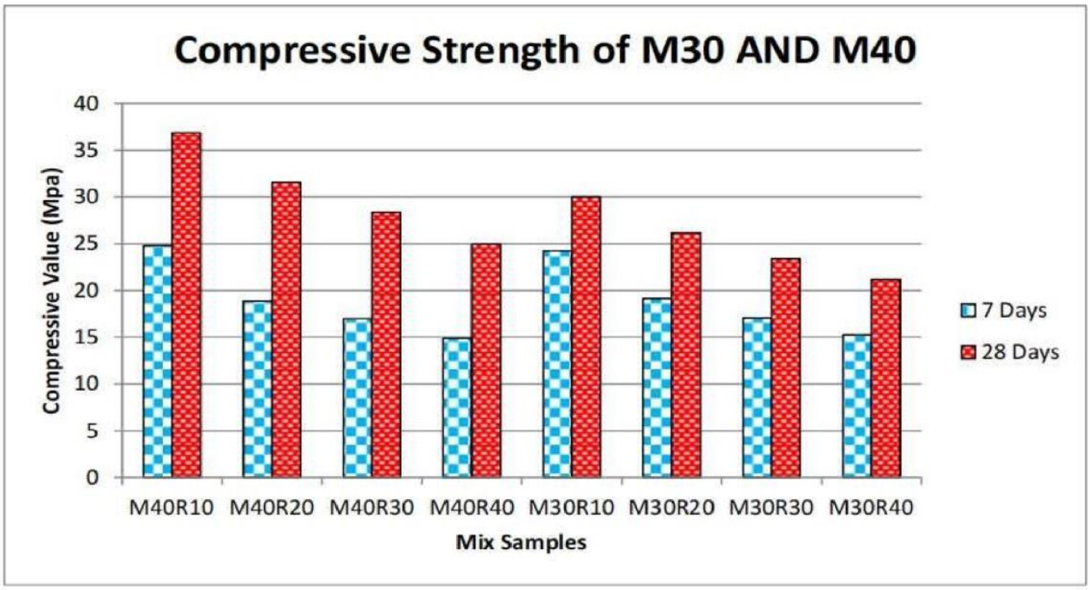


Figure 3.4 Bar graph of compressive strength of M40 and M30

There are several possible reasons for the reduction in compressive strength. Rubber particles are elastically deformable, which causes cracks to grow around them quickly. Failure occurs early in the loading process because the rubber particles are much softer and more elastic than the hard cement paste. Moreover, the cement paste has a weak adhesion to the smooth surface of rubber. Several researchers have used SEM to confirm the presence of a large and porous interfacial transition zone, which indicates poor bonding conditions. The loss of strength remains an issue notwithstanding these outcomes.

3.5. Acid Attack

3.5.1 Mass loss after acid attack

After 28 days of immersion in a acid solution, Figure 3.5 shows that the percentage loss in weight dropped as the amount of rubber aggregate replacement increased in the mix for each group. In table 3.3 the mix (M40R10) had a maximum weight reduction of 6.50%; this dropped to 6.48% for M40R20 and 5.85% for M40R30. At 2.57%, the M40R40 combination showed the least amount of weight loss. Likewise, the mix specimen (M30R10) had a maximum weight decrease of 5.55%. After then, the proportion fell to 5.17% for M30R30 and 4.68% for M30R20. At 4.35%, the M30R40 combination had the least amount of weight reduction. Similarly cubes immersed in HCL shown similar decrease in weight % as shown in table 3.4.

Table 3.5 Weights loss of cubes after H2SO4 attack

MIX	Initial weight (Kg)	Weight after H2SO4 (Kg)	Weight loss (gram)	Weight loss in percentage
M40R10	2.352	2.200	152	6.50
M40R20	2.300	2.151	149	6.48

M40R30	2.176	2.049	127	5.85
M40R40	2.042	1.990	52	2.57
M30R10	2.307	2.179	128	5.55
M30R20	2.189	2.076	113	5.17
M30R30	2.071	1.975	96	4.68
M30R40	1.954	1.870	84	4.35

Table 3.6 Weights loss of cubes after HCL attack

MIX	Initial weight (Kg)	Weight after HCL (Kg)	Weight loss (gram)	Weight loss in percentage
M40R10	2.352	2.227	125	5.33
M40R20	2.300	2.188	112	4.88
M40R30	2.176	2.083	93	4.29
M40R40	2.042	1.973	69	3.42
M30R10	2.307	2.197	110	4.80
M30R20	2.189	2.093	96	4.39
M30R30	2.071	1.989	82	3.99
M30R40	1.954	1.890	64	3.28

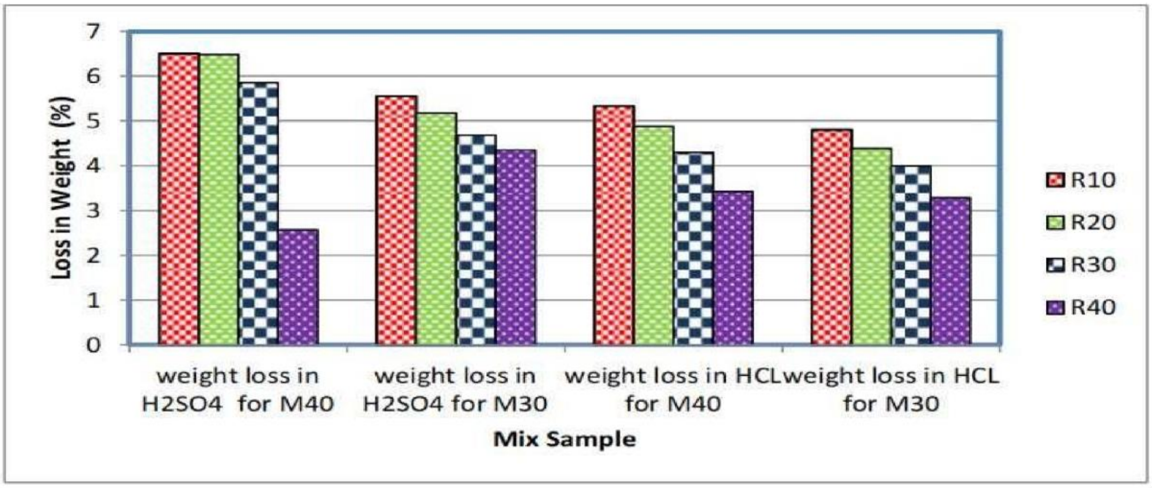


Figure 3.5 Bar graph of loss in weight of acid attack

Compared to specimens with larger rubber aggregate replacement percentages, the sample with the least amount of rubber aggregate has the lowest resistance to acid assault, according to a detailed examination of the degraded samples displayed in Figure 4.7. Specimens with a lower rubber content clearly lost more surface compounds than specimens with a greater rubber content. Out of all the samples, the specimens with 30% and 40% rubber aggregates had the nicest looks; they had smoother surfaces, less exposed parts, and less spalling.

3.5.2 Compressive strength after acid attack

When the amount of rubber grew, the specimens that were attacked by acid lost some of their compressive strength. The compressive strength ranged from 20.33 MPa for the mix (M40R10) to 16.98 MPa for M40R40 in Table 4.5 Concrete Group M40, and from 16.44 MPa for M30R10 to 13.96 MPa for M30R40 in Group M30. When comparing the percentages of residual compressive strength in specimens that were attacked by acid and those that were not, as seen in figure 4.6, a larger proportion of rubber aggregates was found to be beneficial. The blend (M40R10) had the lowest residual strength 55.8%. For M40R20, this proportion rose to 57.57%, and for M40R30, it grew to 64.74%. At 68.08%, the specimen with 40% rubber replacement showed the highest percentage of residual strength. Comparably, the initial residual strength in mix (M30R10) was 54.81%; this grew to 56.88% for M30R20 and to 63.90% for M30R30. With a percentage of 65.95%, the specimen including 40% substitution of rubber exhibited the most residual strength. Table 4.6 illustrates how cubes submerged in HCL increased the specimen's residual compressive strength.

Attacks with sulfuric acid cause large amounts of gypsum to accumulate close to the surface, which in turn causes mechanical strains and disintegration, which in turn causes spalling and the exposing of new internal surfaces. The chemical representation of the assault with sulfuric acid shows the processes that lead to these outcomes.

$$Ca(OH)2 + H2SO4 \rightarrow CaSO4.\ 2H2O$$

$$2CaO.\ 2SiO2.\ 3H2O + H2SO4 \rightarrow CaSO4.\ 2H2O + Si(OH)4$$

The chemical representation of the assault with hydrochloric acid as shown

$$Ca(OH)2 + 2HCL \rightarrow CaCl2 + 2H2O$$

Table 3.7 Compressive strength after sulphuric acid attack

Mix	Actual compressive strength(MPa)	Compressive H2SO4 immersion(MPa)	strength (%)
M40R10	36.87	27.94	75 8
M40R20	31.59	26.76	79.57
M40R30	28.37	24.98	84.74
M40R40	24.95	21.97	88.08
M30R10	30.01	22.79	75.97
M30R20	26.17	21.16	80.88
M30R30	23.39	20.09	85.90
M30R40	21.18	19.05	89.95

Table 3.8 compressive strength after hydrochloric acid attack

Mix	Actual compressive strength(MPa)	Compressive after HCL immersion(MPa)	Residual strength (%)
M40R10	36.87	28.64	77.69
M40R20	31.59	26.10	82.63
M40R30	28.37	24.78	87.36
M40R40	24.95	22.63	90.74

M30R10	30.01	23.68	78.91
M30R20	26.17	22.21	84.87
M30R30	23.39	20.88	88.93
M30R40	21.18	19.69	92.98

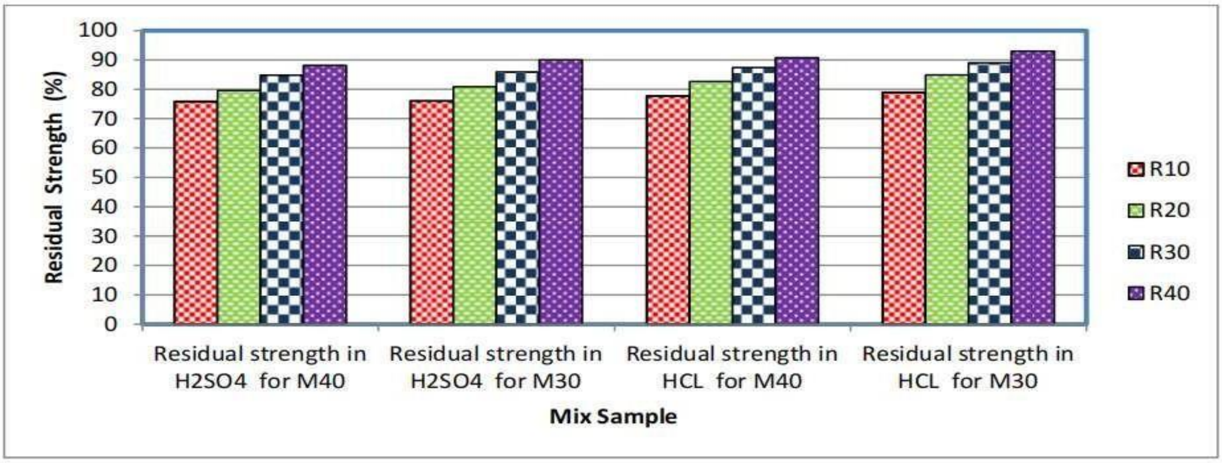


Figure 3.6 Bar graph residual compressive strength percentage of H2SO4 and HCL of concrete cubes

The compressive strength of every concrete mix was observed a decrease in the acid curing as shown in Fig. 4.6. Rubber aggregates were added to both Group M40 and Group M30 mixes up to 40%, which strengthened the mixtures' defences against acid assault. Sulphoaluminate, which resembles ettringite, is created when sulfuric acid combines with the results of concrete hydration. Significant internal pressure is produced in the concrete when a substantial amount of ettringite forms, weakening the surface layer and causing mass loss. Rubber aggregate-containing mixes feature gaps in their microstructure, which gives ettringite additional room to develop without increasing internal pressure in the concrete. Since rubber is elastic, it may absorb the ettringite-induced expansion energy, reducing structural failure and improving compressive loading performance somewhat.

Additionally, gypsum, which appears as a white paste on the concrete samples, is produced by the reaction of sulfuric acid and calcium hydroxide in concrete. This top layer of gypsum paste is washed away from the sample surface during weight measurements, which causes mass loss.

In HCL case C-S-H bond is dissolve due to chlorine but rubber aggregate acts as shield to prevent penetration of HCL to the concrete further from surface since rubber is resistance to corrosive behaviour of acid therefore improving compressive strength in the specimen. The expose modes depicted in Figure 4.7 demonstrate the strong ductility of concrete cubes with rubber component even after deterioration. Because the rubber particles are resilient, they are able to withstand the corrosive effects of sulfuric acid and hydrochloric acid also while retaining their structural integrity. This helps prevent cracks from forming through the concrete matrix.

Figure 3.7 Showing spalling in cubes after sulphuric acid attack

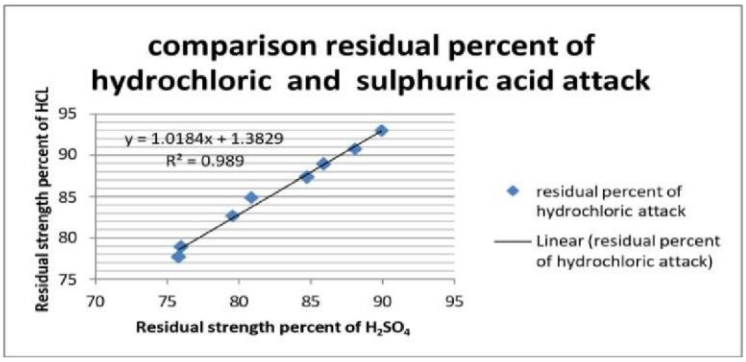


Figure 3.8 Line regression graph of residual percent of HCL and H2SO4

The relationship between residual strength percent of both HCL and H2SO4, as well as the quantity of crumb rubber utilized, is depicted in figure 4.8. It also gives the equation that characterizes this relationship. For specimens with varying percentages of crumb rubber, a linear relationship is shown by the examination of the regression coefficients shown in these graphs

CONCLUSION

Before applying crumb rubber (CR) to pavements and other structures, one must take into account how CR affects the physical and mechanical properties of the concrete.

The review's general conclusions are: As the size and amount of rubber aggregate grow, the workability of crumb rubber concrete increase by 2-3 mm. There are instances where workability stays constant. Therefore, the inclusion of rubber had no discernible effect on workability. According to literature, the density of RGC falls at the rate of 3.82% of density as the amount of rubber increases since rubber aggregates have a lower specific gravity. Because of this, rubberized concrete may be used for lightweight constructions as long as the compressive strength is maintained.

It is advised to maintain the amount of rubber aggregate above 20% for compressive strength in order to prevent noticeably lower strength. Compressive strength RGC reduce by 9-12% of actual compressive strength.

Durability of rubberized green concrete increase in the sense of residual compressive strength of the sample because as the rubber content increase Residual strength increase by 4-7%.

Scope of Future Research

The mechanical characteristics of high-performance and high-strength rubberized concrete require more research.

Pre-casting concrete structures with waste materials like crumb rubber is an interesting field for further research due to the restricted mechanical qualities and workability.

Credit authorship contribution statement

Syed Suhaib Farooq: Investigation,writing – original draft. **Ajay Vikram:** Supervision, Resources and concepualization

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REFERENCES

1. AbdelAleem, B.H., Hassan, A.A.A., 2019. Influence of synthetic fibres' type, length, and volume on enhancing the structural performance of rubberized concrete. Construct. Build. Mater. 229, 116861.
2. Abdelmonem, A., El-Feky, M.S., Nasr, E.-S.A.R., Kohail, M., 2019. Performance of high strength concrete containing recycled rubber. Construct. Build. Mater. 227, 116660.
3. Abdulameer Kadhim, A., Mohammed Kadhim, H., 2021. Experimental investigation of rubberized reinforced concrete continuous deep beams. J. King Saud Univ. - Eng. Sci.
4. Abed, M., Nemes, R., Tayeh, B.A., 2020. Properties of self-compacting high- strength concrete containing multiple use of recycled aggregate. J. King Saud Univ.-Eng. Sci. 32 (2), 108–114.
5. Adeboje, A.O., Kupolati, W.K., Sadiku, E.R., Ndambuki, J.M., Kambole, C., 2020. Experimental investigation of modified bentonite clay-crumb rubber concrete. Construct. Build. Mater. 233, 117187.
6. Al-Tayeb, M.M., Abu Bakar, B.H., Akil, H.M., Ismail, H., 2013. Performance of rubberized and hybrid rubberized concrete structures under static and impact load conditions. Exp. Mech. 53 (3), 377–384.
7. Al-Tayeb, M.M., Zeyad, A.M., Dawoud, O., Tayeh, B., 2020. Experimental and numerical investigations of the influence of partial replacement of coarse aggregates by plastic waste on the impact load. Int. J. Sustain. Eng. 1–8.
8. Alaloul, W.S., Musarat, M.A., Tayeh, B.A., Sivalingam, S., Rosli, M.F.B., Haruna, S., Khan, M.I., 2020. Mechanical and deformation properties of rubberized engineered cementitious composite (ECC). Case Stud. Construct. Mater. 13, e00385.
9. Alawi Al-Sodani, K.A., Al-Zahrani, M.M., Maslehuddin, M., Baghabra Al- Amoudi, O.S., Al-Dulaijan, S.U., 2021. Chloride diffusion models for Type I and fly ash cement concrete exposed to field and laboratory conditions. Mar. Struct. 76, 102900.
10. Almeshal, I., Tayeh, B.A., Alyousef, R., Alabduljabbar, H., Mohamed, A.M., 2020a. Ecofriendly concrete containing recycled plastic as partial replacement for sand. J. Mater. Res. Technol. 9 (3), 4631–4643
11. Mehta P.K. and Ravina D., —Compressive strength of low cement/high fly ash concrete, Cement and Concrete Research, 18(4), 1988,Pp. 571-583.
12. Malhotra, V.M., High-Performance, —High-volume Fly Ash Concretell, Concrete Experimental investigation of durability properties of rubberized concrete

13. Nouran Yasser, Amr Abdelrahman, Mohamed Kohail, Ayman MoustafaInternational, 24 (7), 2002, Pp. 30-34 Experimental investigation of durability properties of rubberized concrete
14. Brito J, Saikia DN. Recycled Aggregate in Concrete: Use of Industrial, Construction and Demolition Waste, 2012; 54.
15. Mehta PK. Durability – Critical Issues for the Future. Concr. Int., 19(7).
16. Ahmad F, Jamal A, Mazher KM, Umer W, Iqbal M. Performance evaluation of plastic concrete modified with e-waste plastic as a partial replacement of coarse aggregate. Materials (Basel) 2022;15(1):pp. doi: https://doi.org/ 10.3390/ma15010175.
17. Ali B, Qureshi LA, Shah SHA, Rehman SU, Hussain I, Iqbal M. A step towards durable, ductile and sustainable concrete: Simultaneous incorporation of recycled aggregates, glass fiber and fly ash. Constr Build Mater 2020;251:. doi:
18. Tamanna N, Tuladhar R, Sivakugan N. Performance of recycled waste glass sand as partial replacement of sand in concrete. Constr Build Mater 2020;239:. doi: https://doi.org/10.1016/j.conbuildmat.2019.117804117804
19. ASTM C143/C143M-12: Standard Test Method for Slump of Hydraulic-Cement Concrete Significance and Use
20. ASTM C642-21: Standard Test Method for Density, Absorption, and Voids in Hardened Concrete
21. IS 516 (Part 1/Sec 1):2021 is a standard for compressive, flexural, and split tensile strength of concrete.
22. ASTM C 267-97, —Standard Test Methods for Chemical Resistance of Mortars, Grouts, and Monolithic Surfacing and Polymer Concretes.