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Evaluate the Effect of Acid Attack on Partial Replacement of Crumb Rubber with Coarse Aggregate

[1]YARLAGADDA SUMA, [2]Dr.B.SARITHA
[1]Research Scholar, Department of Civil Engineering, Bharath Institute of Higher Education and Research, Selaiyur, Chennai, Tamil Nadu 600126, India.
[2]Associate Professor, Department of Civil Engineering, Bharath Institute of Higher Education and Research, Selaiyur, Chennai, Tamil Nadu 600126, India.
Email ID: 2507suma@gmail.com, sarichaks@gmail.com

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Abstract:

Objectives: Implementing an experimental investigation on partial replacement of crumb rubber with coarse aggregate is the main objective of this project.

Methods: For a very long time, research was being done to find alternatives to disposing of waste tyres. Rubber from waste tyres can be recycled, which is one of these alternatives. The most common method is to use rubber from recycled tyres. Due to its energy absorption, low weight, elasticity, and properties, sound and heat insulation, recycled tyre rubber is a promising construction material. In this study, waste tyre rubber from recycled tyres was utilized to replacing the coarse aggregates by weights of 1.5% and 3%.

Findings: Due to having much greater compressive strengths than regular concrete, according to the findings, the concrete made from waste tyre rubber failed in a plastic, ductile manner rather than a brittle failure. In this nominal scale is compared with replacing the coarse aggregates by weights of 1.5% and 3%. So compared with nominal scale, 1.5% and 3% will give effective outcome.

Novelty: In this study, they used crumb rubber to replace coarse aggregate in normal concrete of grade M25 to identify the compressive strengths of the concretes.

Keywords: M25 concrete, Crumb Rubber, Coarse Aggregate, Recycle wasted Tyre Rubber**.**

1. Introduction

In today's world, civilization faces difficulties in putting sustainable development principles into practice across all economic spheres. The sustainable development paradigm has specific requirements for this waste management phase because it focuses not only on extending the product's "life-cycle" with recycled raw materials but also on reducing environmental consumption of non-renewable resources [1]. This study aims to determine how the various qualities of concrete are affected by adding crumb rubber. In the concrete mix, the crumb rubber is used in place of the aggregates. The tyre scraps are used to make crumb rubber.

Replacement over coarse aggregate to reduced on structure costs and pollution in the environment. Based on compression and flexural strength tests, various combinations of traditional coarse aggregate and crumb rubber were evaluated. This global issue can be reduced by integrating recycled tire rubber into concrete [2]. By partially replacing the natural coarse aggregate in nominal concrete, waste tire rubber can reduce course aggregate consumption and preserve these natural materials. If they take environmental protection into account, concrete turns out to be more cost-effective need that when the extent of crumb rubber in it is expanded. Every year, millions of tires are thrown away all over the world.

Because tires are non-biodegradable and have a long lifespan, disposing of waste tires is difficult. Stockpiling, illegally dumping, or disposing of tires in a landfill are the traditional waste tire management methods [3]. Recycling tires is a novel concept or approach in this analysis to address the growing environmental issue. Tire recycling is the process of recycling vehicles. Due to wear or irreparable damage including punctures, tyres that can no longer be used on vehicles.

The cracker mill process tears apart or reduces the size of tyre rubber by passing the material between rotating corrugated steel drums. Crumb rubber is a term used to describe these irregularly shaped, large-surface-area torn particles produced by this process. 2.68 million tons of rubber goods and 4.89 million tons of rubber tyres were delivered worldwide in 2015 [4]. In 2017, there was an increase of 2% in the production of rubber products, reaching 2.70 million tons and a 1% increase in the production of 4.94 million tons of car tyres. When looking at past years, it is important to note that the growth in production of rubber goods and car tyres is not a constant trend. However, the scale of production makes it difficult to manage rubber waste in today's society [5].

2. Literature Survey

V. K. Arachchi, J. Gamage and K. Selvaranjan.et.al [6], This article investigates the impact of using non-homogenous rubber aggregate on a developed concrete mix design. Identifying the dominant reasons and modifications to be made to improve the properties of rubberized concrete are discussed with respect to the diverse number of literatures. The recycled waste tire rubber particles were tested to identify the physical properties of rubber aggregate and twelve rubberized concrete cubes were tested in axial compression. The cubes were produced by replacing waste tire rubber with 1) 0% aggregate volume (Series 1) 2) 20% fine aggregate volume (Series 2) and 3) 10% coarse and 10% fine aggregates of the total aggregate volume

(Series 3). The results show a high-water absorption rate of 6-7% in rubber aggregate. The compressive strength of cubes reached up to 48.6 MPa, 32.4 MPa, and 37.5 MPa in Series 1, 2, and 3, respectively. Implementing 10% coarse and 10% fine rubber aggregate enhanced the compressive strength by 10.5%. There is clear evidence on improved mechanical properties of rubberized concrete with the addition of non-homogenous rubber aggregates.

M. A. Musarat, W. S. Alaloul, S. Ayub, M. B. Ali Rabbani, W. Farooq and M. Altaf.et.al [7], Concrete is susceptible to chemical attack and temperature changes, especially when exposed to extreme heat, which raises the internal pore water pressure. When used as a fine aggregate replacement in concrete, crumb rubber can help to avoid spalling by allowing the pore water pressure to escape when the temperature is high. However, research shows that when rubberized concrete is compared to ordinary concrete, its fresh properties degrade. To overcome the problem caused by material composition change, nanomaterials have been introduced as enhancing admixture. Concrete elements are exposed to a harsh environment such as acidic conditions. Hardened cementitious matrix undergoes deterioration when being attacked by different acids and various concentrations. When acids are being encountered with a cement-based matrix, the high solubility of salts is produced and induces a high amount of porosity, eventually producing shorter service life and increased expenditures**.**

M. U. Munir, A. Elnour, S. Huda and W. Zeiada.et.al [8], Rubber modified Asphalt Concrete utilizes Crumb Rubber (CR) that is acquired by shredding and grinding waste rubber tires. It is considered as a superior paving material that can cut down the required construction material and eventually save current depleting resources and CO2 emissions associated with the material transportation, construction, and production. Implementation of CR in AC mixtures however, requires modification in the asphalt mix plant by including a specific agitating tank required to blend the CR with the asphalt binder at high mixing temperature for 45 to 60 minutes. Unfortunately, local asphalt mix plants do not have this kind of agitating tanks which is the biggest obstacle to producing such superior AC mixes locally in UAE. Pre-treated crumb rubber is an emerging technology that offers a new method to produce rubber-modified AC mixtures in the field using traditional asphalt mix plants without any required modifications. A new crumb rubber modifier that is industrially recognized as Reacted and Activated Rubber (RAR) is an upcoming crumb rubber product whose purpose is to be used in a dry mixing process. RAR can be directly mixed with the hot aggregates without the need to be blended with the asphalt binders to simplify the mixing process with no additional modifications to asphalt mix plants. The main objective of this research is to study and assess the properties of asphalt binders modified with RAR compared to the traditional asphalt binders that are used in the UAE.

G. Zeng, H. Liu and F. Bai.et. al [9], In order to describe the random distribution law of mechanical properties of asphalt mixture, the Schapery nonlinear model and modified Schawartz model are employed to describe the viscoelastic and viscoplastic deformation respectively. A series of creep tests of multiple crumb rubber asphalt sand samples were carried out to determine the parameters samples. Based on the statistical analysis, the random parameter is determined and the normal distribution is used to describe the distribution law of the parameter to determine the random constitutive model. Finally, a random loading experiment was carried out to predict and verify the proposed model. The results show that the proposed the model parameter is more representative and can predict the deformation range of crumb rubber asphalt sand under other stress loading history. The proposed model can reflect the randomness of mechanical behavior and the dispersion of the material additionally.

E. Benavente-Huaman, M. Navarro-Cardenas and G. Duran-Ramirez.et .al [10], the reuse of discarded tires can reduce the great environmental problem associated with their inadequate final disposal. One way, is its addition in compacted soils that can provide solutions to the mechanical-geotechnical problems related to low shear strength. This study presents the behavior of silty sand reinforced with shredded rubber of discarded tires, through an experimental study. Physical characterization tests, Standard Proctor, direct shear test and consolidated undrained triaxial test (CU) were carried out in order to establish patterns of mechanical-geotechnical behavior that define the influence of the addition of rubber in this soil. The Direct shear and triaxial tests were performed on compacted soil samples at their maximum dry density and optimum moisture. The specimens tested were made with rubber contents of 0%, 5%, 10%, 15% and 20%, in relation to the dry weight of the soil. On the other hand, the triaxial test was carried out with specimens that content 0% and 5% shredded rubber. The results showed that the shear strength increased in samples with 5%, 10% and 15% of rubber with respect to soil. This addition of rubber is more effective for confinement tensions greater than 50 kPa and less than 300 kPa. It was concluded that the addition of 5% rubber is the one that provides higher shear strength.

3. Materials Used

Cement:
Hydraulic cement is used in regular Portland cement. When its chemical properties react with water, it is utilized in the production of concrete that has the ability to set and harden. A small amount of gypsum is mixed to a clinker and the mixture is finely processed to create the completed cement powders, which has the required setting properties. OPC (Ordinary Portland Cement) does not disintegrate in water because it sets and hardens in water. This project makes use of the grade OPC 53.

Fine Aggregate:
Fine aggregate is made from locally available sand that is nearly riverbed sand and is free of debris. The sand particles pack together to produce the lowest possible void ratio; a higher content of voids need for more water to be mixed. With the best cement content and less mixing water properties including void ratio, gradation specific surface, and bulk density must be evaluated.

Coarse aggregate:
Concrete's coarse aggregate is a chemically stable component. When coarse aggregate is present, drying shrinkage and other dimensional modifications made on by moisture movement are reduced. The interaction between coarse aggregate, which makes up the majority of conventional concrete, and the cement mix is porous, which adds to the heterogeneity of cement concrete. By limiting the aggregate and cement's maximum size, the concrete's strength and durability are significantly improved.

Water:
Given that it actively participates to the chemical reaction with concrete, it is a crucial component of concrete. The quantity and quality of water must be carefully considered because

it helps to the formation of the cement gel that provides strength. The proportions of undesirable organic or inorganic components in water should not be excessive. The Department of Civil Engineering provided the project with clean, usable water.

Crumb rubber:

Using mechanical or cryogenic processes, the tire is processed into fine granular or powdered particles. During this process, the tires steel and fabric components are also removed. Between 4.75mm and less than 0.075mm in size, the crumb rubber's particles come in a number of sizes. Scrap tires are typically transformed into crumb rubber in three ways.

4. Casting of Specimen

4.1 Mixing Concrete:

In order to prevent the loss of water or other materials, the concrete must be mixed by a machine. After molding the appropriate number of testing specimens, every batches of cement must be of a size that allows around 10% excess.

Fig. 1: mixing of materials

4.2 Casting of cubes:

Procedure for Casting of Concrete Cubes

1. All nuts and bolts should be properly tightened and the standard cube molds 6 No's should be carefully cleaned.

2.Apply oil to the mould’s entire contract surface.

3.During concreting, the mould’s size typically comes from the mixing location.

4.During concreting, collect the random sample from the mixing location.

5. Add three layers of concrete cubes.

6. Using a tamping rod, compact each layer with 35 stroke nodes.

7. After the final layer has been applied, use a trowel to finish the top surface.

8. To prevent water loss, immediately cover the mould with a damp hessian cloth.
9. Each specimen ought to be taken from various proposed concreting locations.
10. Take the specimen out of the mold after 24 hours.
11. While removing, take care to avoid breaking of edges.
12. Coding should be self-explanatory and show up on cubes by paint or maker.
13. Until the time of the test, submerged the specimen in clean, fresh water.

Fig. 2: Casting of cubes

4.3 Curing of Test Specimens:
The test specimens must be kept for 24 hours + ½ hour after the water has been added to the other substances in a location that is free from vibrations, under damp matting, sacks, or other similar material. The storage location must maintain a temperature between 220 and 320C. They must be labeled for future identification after the period of 24 hours, removed from the moulds and kept in clean water at a temperature of 240 to 300 degrees Celsius until tested, unless they are sent to the testing lab.

Fig. 3: Curing of cubes

4.4 Acid Attack

The below figure (4) shows the acid attack obtained on concrete. Acid attack is the dissolution and leaching of acid-susceptible constituents, mainly calcium hydroxide, from the cement paste of hardened concrete. This action results in an increase in capillary porosity, loss of cohesiveness and eventually loss of strength. Chemical attack on concrete is a rather complicated subject since the chemistry of concrete itself is complex and the material is used in a very wide variety of environments. Of the types of degradation that are associated primarily with chemical changes occurring within the hydrated cement matrix, sulfate attack in its various guises is probably the most widespread threat to concrete durability, but acid attack can also take place in concrete sewers, silos, dairies, etc. and bacteria can mediate sulfate and acid attack in various environments.

Fig. 4: Acid attack on concrete

5. Results & Discussion

The below table (1) shows comparison of slump value mix type with nominal scale and rubber concrete. Compared with nominal scale, rubber concrete will give effective outcome.

Table: 1: Slump value of mix

Mix type	Slump value (mm)
nominal	85
rubcrete	53

Compressive strength of nominal mix:

The below table (2) shows compressive strength of nominal mix for 7 days and 28 days. For 7 days the compressive strength is 27.2 and for 28 days the compressive strength is 58.

Table. 2: Compressive strength of nominal mix

Curing period	Compressive strength (N/mm^2)
7 days	27.2
28 days	58

Compressive strength of rubber mixed concrete:

The below table (3) shows compressive strength of rubber mixed concrete of different replacements for 7 days and 28 days. For 7 days of 1.5% and 3% compressive strength is 22 & 25 and for 28 days of 1.5% and 3% compressive strength is 48.70 & 44.57.

Table. 3: Compressive strength of rubber mixed concrete of different replacements(N/mm^2)

Curing period	7 days	28 days
1.5%	22	48.70
3%	25	44.57

Acid attack on Portland cement concrete is not unexpected, since all of the phases in cement paste are basic, and many of them (for example, calcium hydroxide) are readily dissolved by acids. Typically, acid attack leads to loss of binder and strength in concrete and eventually to loss of section. Unlike acid attack, sulfate attack commonly involves expansive reactions which fracture the concrete leading to ongoing degradation, loss of strength and function. Several different processes may be involved and the literature on this subject has grown remarkably in recent years, prompting one reviewer to describe the current situation as more than a little confused. Here acid attack of 1.5% and 3% is compared with nominal scale. Compared with nominal scale 1.5% & 3% rubber weights will reduce gradually.

Table: 4 Weights of cubes of different mixes after being cured in Hcl acid (kg)

For nominal mix			
Conc of acid	0 days	7 days	28 days
2%	8.512	8.500	8.492
3%	8.600	8.584	8.572

For 1.5% replacement mix			
Conc of acid	0 days	7 days	28 days
2%	9.028	9.014	9.000
3%	8.892	8.855	8.844
For 3% replacement mix			
Conc of acid	0 days	7 days	28 days
2%	8.690	8.675	8.654
3%	9.124	9.075	9.046

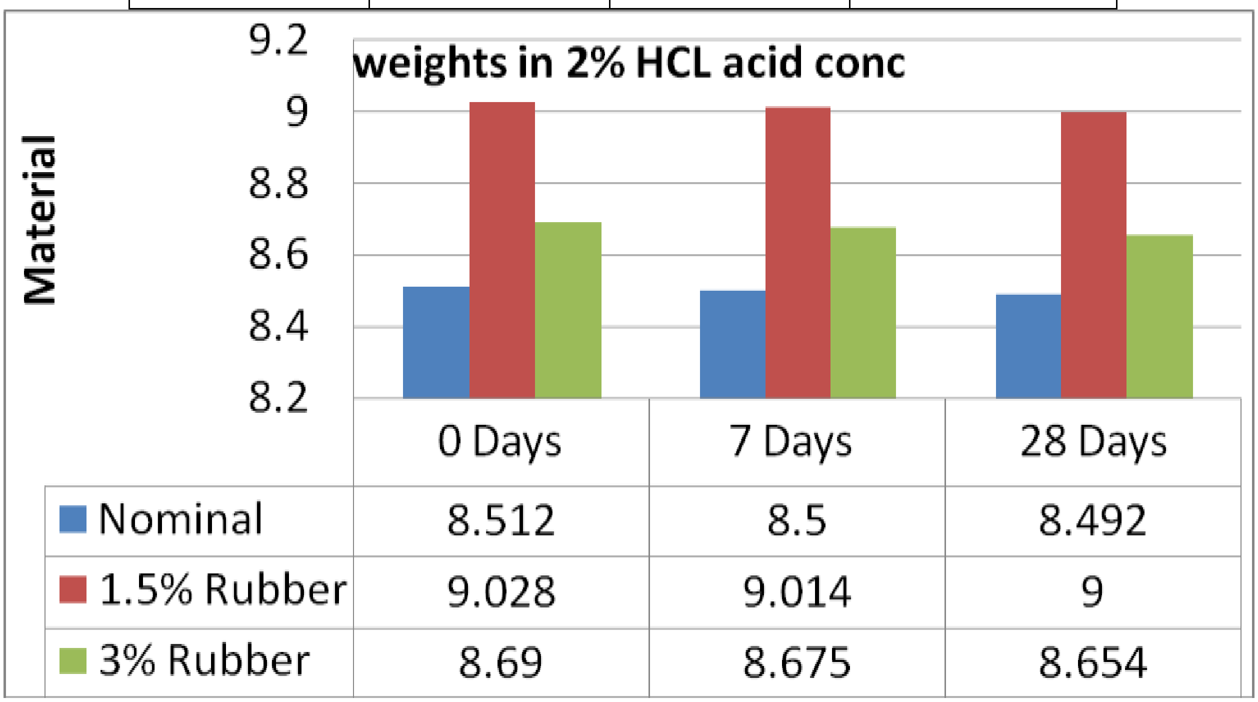


Fig. 5: Weights of cube after cured in 2%Hcl

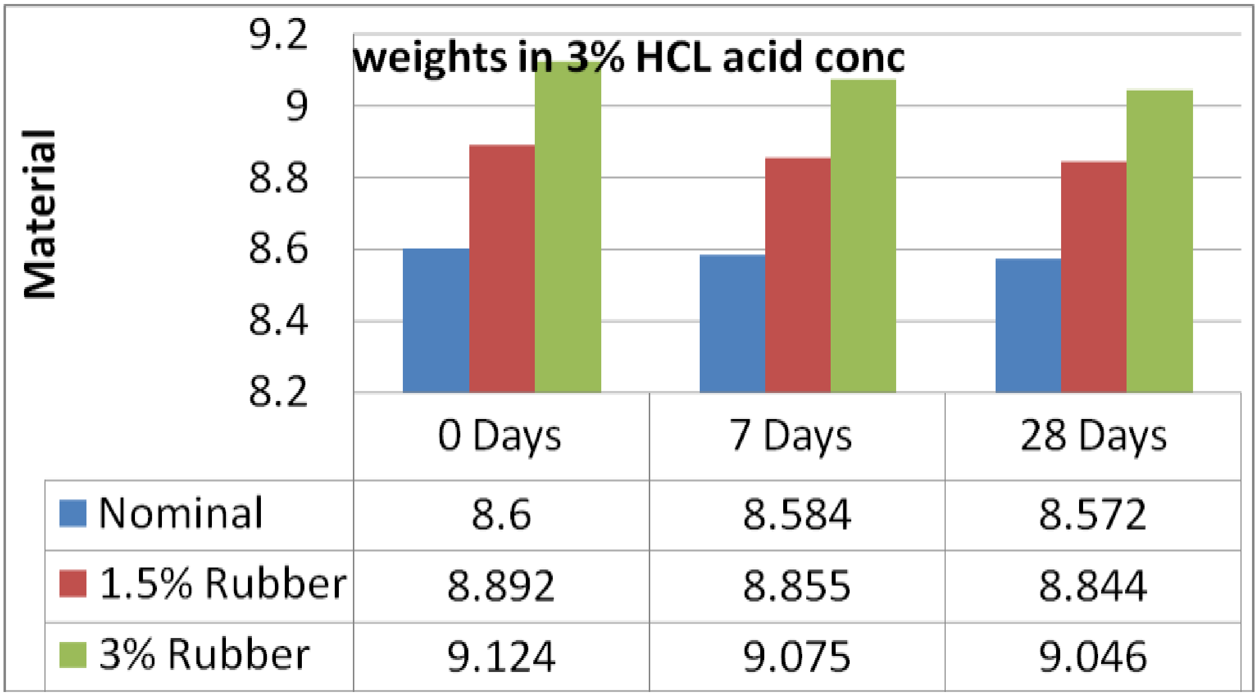
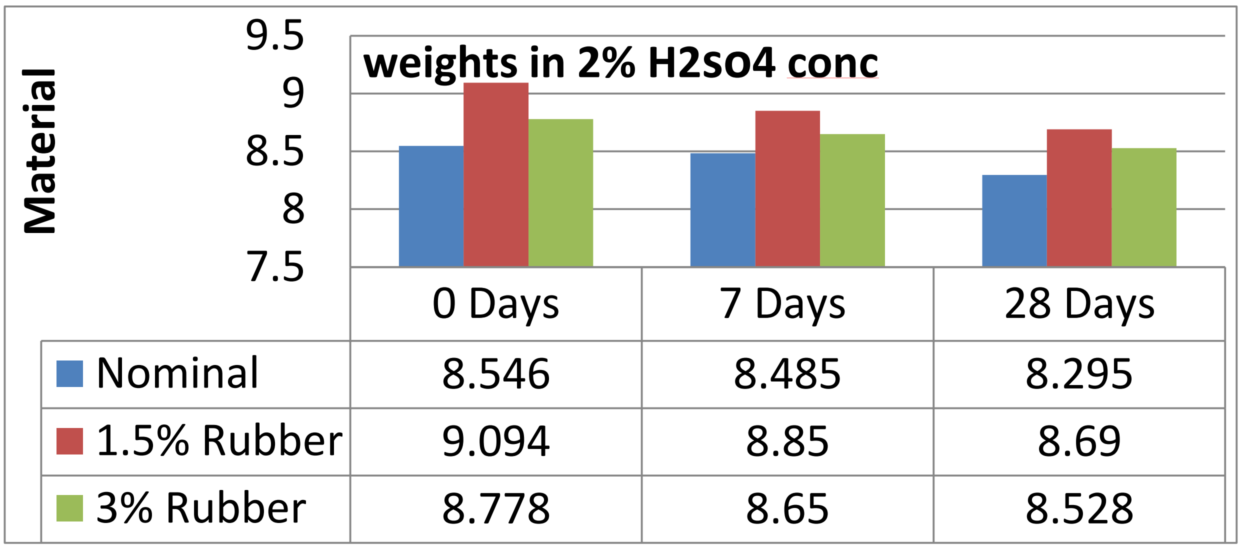


Fig. 6: Weights of cube after cured in 3% Hcl

Table: 5 Weight of cubes of different mixes after being cured in H2So4 acid (kg)

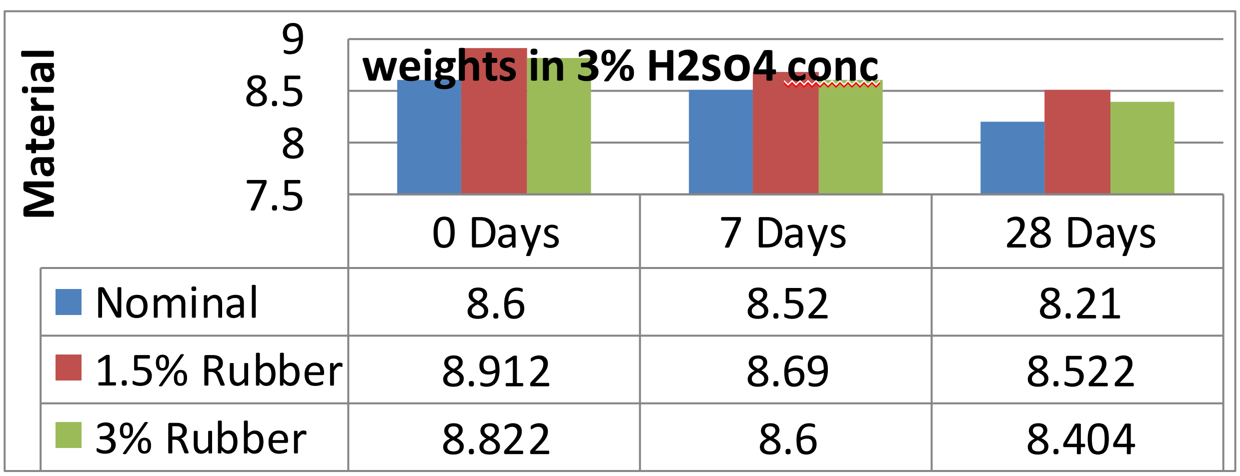
For nominal mix			
Conc of acid	0 days	7 days	28 days
2%	8.546	8.485	8.295
3%	8.600	8.520	8.210
For 1.5% replacement mix			
Conc of acid	0 days	7 days	28 days
2%	9.094	8.850	8.690
3%	8.912	8.690	8.522
For 3% replacement mix			
Conc of acid	0 days	7 days	28 days
2%	8.778	8.650	8.528
3%	8.822	8.600	8.404

The below figure (7) shows the 2% Sulphuric acid attack. Sulphuric acid attack causes extensive formation of gypsum in the regions close to the surfaces, and tends to cause disintegration and mechanical stresses which ultimately lead to spalling and exposure of the fresh interior surface. Normally, the chemical changes of the cement matrix are restricted to the regions close to the surfaces because of less penetration of the Sulfuric acid in concrete. However, in some cases it is observed that scaling and softening of the concrete occurs due to the early decomposition of calcium hydroxide and the subsequent formation of large amount of gypsum.



	0 Days	7 Days	28 Days
Nominal	8.546	8.485	8.295
1.5% Rubber	9.094	8.85	8.69
3% Rubber	8.778	8.65	8.528

Fig. 7: Weights of cube after cured in 2% H2SO4



	0 Days	7 Days	28 Days
Nominal	8.6	8.52	8.21
1.5% Rubber	8.912	8.69	8.522
3% Rubber	8.822	8.6	8.404

Fig. 8: Weights of cube after cured in 3% H2SO4

The below table (4) shows the Compressive strength of cubes of different mixes after being cured in H2SO4 acid (N/mm^2) for nominal scale, 1.5% & 3%.

Table. 4: Compressive strength of cubes of different mixes after being cured in H2SO4 acid (N/mm^2)

Concentration of acid	(nominal) 0%	1.5%	3%
2%	27.33	41.57	43.90
3%	17.43	27.05	29.46

6. Conclusion

This analysis suggests that crumb rubber can partially take the place of coarse aggregates. Although rubber-based concrete has good toughness and deformability, concrete becomes weaker as crumb rubber number increase. Because toughness and deformability are more important than strength in structures like bridge barriers and road foundations, concrete types that can be used. Because rubber-based concrete has reversible elasticity, this type of concrete can also be used to increase vibrations at the structure's base. As the amount of crumb rubber in the concrete increased, the compressive and flexural values gradually increased.

- Concrete of the M25 grade with a coarse aggregate content of 1.5% and 3% crumb rubber exhibits greater strength.
- A stronger connection between the cement paste and the rubber tire aggregate was the primary factor in the strength increase.
- In addition, it was discovered that when compared to using 3% crumb rubber as a coarse aggregate by volume, 1.5% crumb rubber has a relatively higher strength. It demonstrates that the strength of the concrete continues to decrease when the amount of rubber is increased.
- After acid attacks there is a relative decrease of compressive strengths of all concretes when compared to normal compressive strengths and we can observe a very small reduction of strengths for replaced concrete even after acid attacks when compared with conventional concrete.

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