Behavior of Rubberized Concrete under Flexural Loading

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DEDICATION

This Final Year Project is dedicated to our beloved

Parents

&

Teachers

ACKNOWLEDGEMENTS

All thanks go to Almighty Allah whose blessings gave me courage to undertake ability to accomplish this task. Indeed, it is He Who guides us in every matter and renders His support.

I am profusely thankful to my project supervisor **Lec. Asad Naeem** and HOD **Dr. Muhammad Rizwan** for their productive advice, valuable guidance, and kind supervision. I also extend my thanks to staff of Structure lab for their cooperation.

ABSTRACT

The process of rubber decomposition is extremely slow and time consuming, the disposal of wasted tire causes environmental issue and is very dangerous for public health. The addition of wasted rubber to make green concrete is beneficial to the environment. The aim of this research is to check flexural behavior of eco-friendly rubberized concrete. Five different mixes were made in which one mix contained no replacement of sand whereas four mixes were made by substituting (5%, 10%, 15%, and 20%) of sand by volume with rubber. The compressive strength and flexural strength and their load deflection curves were examined. The trend showed reduction in the compressive strength with huge reduction at higher percentages of rubber. The flexural strength tests were performed and the trend in the strength was towards reduction but there was slight reduction in the strength as the percentage of rubber was increased. Whereas ductility and failure mode under flexural loading was improved in specimens in which rubber was used and as the percentage of rubber was increasing the ductility was increased. The outcome of this novel approach of rubber addition provides an overview about the effect of rubber on the flexural strength of concrete and its correlation with compressive strength of normal strength rubberized concrete.

Table of Contents

List of Tables

List of Figures

Chapter 1: INRODUCTION

1.1 Concrete's Earliest Use:

Concrete and concrete-like substances have been used in the construction of the structures by cultures all over the world. It's difficult to estimate how long concrete has been existing because the substance has changed throughout time. It is known to have existed for thousands of years before the common period based on an approximate timeframe. Concrete has been utilized by several cultures throughout history:

6,500 B.C.: This is about the year when the first concrete-like structures were constructed. In modern-day Syria and Jordan, Bedouins built these antique concrete buildings. The early stages laid the groundwork for bettering procedures throughout time.

Around 700 B.C., the Bedouins discovered cement that hardens underwater and built kilns to make mortar. That mortar was utilized to help build floors, homes, and other constructions. During this time, they also began tamping the concrete mixture, knowing that if it became too wet, it would not function as effectively.

600 B.C.: The Greeks discovered a natural material that, when combined with lime, may be used to make concrete. While they made use of the material, they did not have as much experience with concrete techniques as other cultures.

In 1793, John Smeaton developed a more efficient way of manufacturing hydraulic lime. The product was used to aid in the setting of cement, and the updated manufacturing process made it easier to mix concrete and get it to set rapidly.

1824 was a pivotal year in the history of concrete since it was in this year that mason Joseph Aspdin invented Portland cement. Portland cement was a powerful kind of the construction material named from its resemblance to building stones in Portland, England. The cement was made by burning chalk and clay in a kiln by Aspdin. Later, he decided to make clinker by mixing limestone with clay.

1.2 What Has Changed in Concrete Over Time?

Concrete has evolved into a more efficient material over time. We progressed from employing natural chemicals that resembled cement to using man-made procedures to improve natural materials. Our techniques of creating concrete and cement evolved in tandem with technological advancements.

Individuals in Germany, France, and the United States developed steel-reinforced concrete at the same time in the late 1800s. It was initially utilized in industrial projects, but it would later be used in residential buildings and other structures.

The Portland cement invented by Joseph Aspdin is not identical to what we make today. While Aspdin didn't specify any ratios or temperatures for creating Portland cement, we know he couldn't have obtained the high temperatures we use to heat material today.

For Portland cement, we now have a standard formula. The American Society for Testing and Materials, in collaboration with the National Bureau of Standards, founded it in 1917. The uniform recipe ensured constant quality regardless of when or where the material was produced.

Builders started employing concrete in projects all around the world again even before we created a recipe for Portland cement. Concrete regained popular favor as a construction material in the early 1900s, with projects such as these being built:

1. In 1902, a Paris apartment building
2. In Ohio, the first concrete high-rise was built in 1904.
3. In 1911, a 328-foot bridge was built in Rome.

Ready-mix concrete was created because of these and other structures. The materials arrived in Baltimore, Maryland, in 1913. It improved job site efficiency by eliminating the need for personnel to mix concrete on the job. Instead, it was delivered pre-mixed from a mill in the forerunners of what we now know as cement trucks.

The concrete has evolved towards lightweight concrete, which results in the reduction of dead load of structure and increases the strength. To distinguish between normal weight and lightweight aggregates, the characterization of aggregate attributes, particularly density, is critical.

1.3 Environmental Hazards Due To Concrete:

Concrete's environmental impact, as well as its manufacturing and application, is complicate. Some impacts are negative, while others are positive. Many things are contingent on the situation. Cement is an important component, and it has its own environmental and social implications in addition to those of concrete.

Carbon dioxide, a strong greenhouse gas, is produced in large quantities by the cement industry. The most fertile layer of the land, the topsoil, is harmed by concrete. Concrete is used to provide hard surfaces, which contributes to surface runoff, which can result in soil erosion, pollution, and floods. Concrete, on the other hand, is one of the most effective instruments for flood control, since it can be used to dam, divert, and deflect flood waters, mud flows, and other natural disasters. Light-colored concrete can help to lessen urban pollution. Original vegetation, on the other hand, provides considerably more value. Building demolition and natural disasters may produce a lot of concrete dust, which is a major cause of harmful air pollution. Because of their toxicity and (typically naturally existing) radioactivity, various compounds in concrete, including both helpful and undesired additions, might create health risks. [3] Wet concrete is extremely alkaline, thus it should always be handled with caution. As a result of increased environmental consciousness, law, and economic factors, concrete recycling is on the rise. Concrete, on the other hand, reduces the usage of alternative building materials such as wood, which is a natural carbon sink.

1.4 General

A significant number of used tires are discarded each year after their natural lifetime of use. Several approaches have been explored to recycle used tires. In several instances, tire derived aggregates, which are typically large aggregates, have been used as raw materials for civil engineering projects. However, a significant fraction of used tires still finds their way into landfills, resulting in a public health and environmental hazard. Landfill facilities require tires to be shredded to minimize the extent of floating tires; the cost of shredding is dependent on the final particle size of the rubber, with finer particles being more expensive.

Concrete is widely used in the world as construction material. The concrete was introduced in 600 BC by the romans and the dawn of 200 BC saw unprecedented increase in the use of concrete for majority of construction works. The concrete is a mixture of cement, fine aggregate and coarse aggregate along with the admixtures. The foremost and important issue regarding the waste material disposal is worthy noticeable as it harms environment ecology worldwide. The Tire Industry Project (TRP) of the World Business Council for Sustainable Development published a research report on ELTs. Almost more than four billion end of life tires are accumulated in the world. Every country aims to get rid of these waste tires and they are following different techniques to dispose-off this waste. The world has tried different solution to eliminate this waste, but no solution was up to the mark. Moreover, the natural materials are consumed on larger scale in the construction industry which results in scarcity of these natural aggregates. For safety of environment and economy, one should introduce different techniques. One of the techniques is to use waste rubber as an alternative of natural fine material.

The astronomical use of sand in construction works is resulting in eradicating the mass from the planet. Since the origin of the sand and stones is river and mountains respectively, so by extracting it affects the beauty and environment on major scale. To get rid of this difficult situation replacement of sand with waste material like wasted tire rubber could be a great change in construction industry. The properties of rubber like its lightweight nature and flexibility, would help in the construction industry. It would be a great challenge to introduce rubber in construction works as different studies and research have been done on this revolution. Now, shedding some light on the properties of rubber that will affect the concrete. Firstly, homogeneous mixture from rubber is difficult to obtain. Secondly, the main factor of concrete that is strength is adversely reduced. Thirdly, the hydrophobic nature of the rubber results in the week bonding of particles. Different research and studies have proposed a variety of techniques to overcome these issues. In general, prior studies proposed a variety of strategies for modifying the surface of rubber particles, such as immersing them in a sodium hydroxide solution (NaOH) to increase their adherence to the cement paste. Moreover, the rubber surface can also be treated with the aid of waste quarry dust that is available in large amounts in Pakistan. Waste quarry dust is a global challenge that should be addressed as it harms environment and creates different health problems. The solution to this destructive problem is its reuse in the construction works. The usage of waste quarry dust in construction works involves in brick industry, as a replacement of sand in concrete as well as the replacement of cement in concrete.

1.5 Problem Statement:

- Waste tire is a global problem due to its fire catching potential and problems which results in environmental and health issues. In most countries it is used as a land fill It has become one of the most devastating problem all over the world especially in third world countries like Pakistan. Enormous volumes of discarded tires each year and due to their durability, scrap tires are one of the greatest and most significant forms of garbage in modern countries. When such tire dumps catch fire, extinguishing the fire is notoriously difficult and expensive. According to the IARC (International Agency for Research on Cancer), rubber contains carcinogenic compounds that might cause cancer.
- In addition, the construction sector is increasing the use of river sand as fine aggregate.
- Because old tire does not disintegrate, dumping them in a landfill just means that they will continue to pile up over time, taking up massive amounts of space. They also serve as breeding grounds for rodents and insects.
- This study is being conducted to discover an effective method for achieving sustainable development, environmental protection, and resource efficiency by recycling the rubber tires.

1.6 Objectives Of Research:

The most important objective of this research is to introduce the rubber in the construction industry and safety of environment and natural resources. The major disadvantage of usage of rubber is reduction of strength but this can be tackled with optimum percentages of rubber to be used in the concrete. This research has investigated following areas:

1. To investigate the optimum percentage of rubber to be used in concrete with minimum flexural strength reduction.
2. To compare the **flexural strength** of rubberized concrete at different percentages of rubber (5%, 10%, 15%, 20%) with ordinary concrete.
3. To check the load deflection curve and failure mode of rubberized concrete under flexural loading.

1.7 Scope of The Research:

The scope of the research includes the comparison between rubberized and natural aggregate concretes and post peak behavior of rubberized concrete. It also comprises of casting and curing of concrete specimens along with testing of specimens. The results are analyzed, and the stress strain curve will be observed of different sample contain (5 10 15 and 20) percentage of treated and untreated rubber after 28 days of curing. Sample size of cylinders are (diameter, 100xlong, 200) mm.

1.8 Research Significance:

The significance of this research is to use the waste rubber to solve different environmental and health issues and lessens the consumption of our natural resources. Due to unprecedented increase in the use of sand in construction works and due to continuous extraction of sand from the river is resulting in the environmental problems. The focus of this research is to produce a concrete that is eco-friendly.

1.9 Methodology

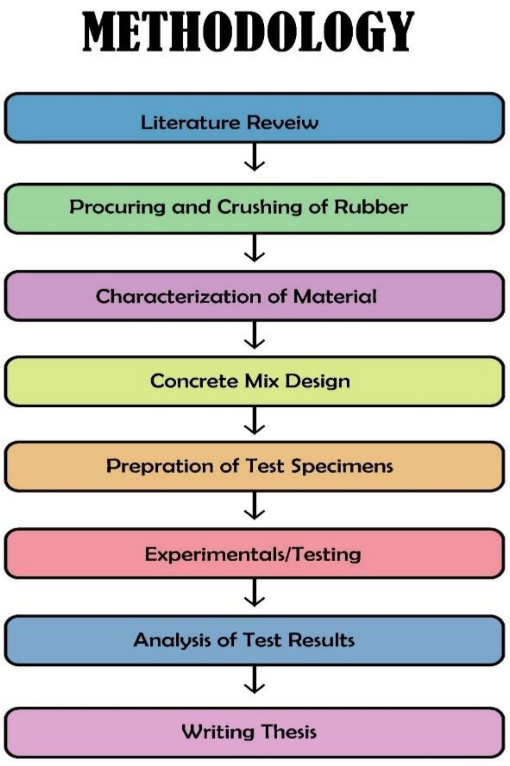


Figure 1- 1 Flow Chart for Methodology

Chapter 2: LITERATURE REVIEW

2.1 General

Researchers are looking for ways to improve the brittle behavior of Concrete because of the rising interest in using it due of its better durability, strength, and deflection control. Natural building materials are becoming increasingly scarce, necessitating the use of waste materials to reduce environmental impact. This is a global trend in the built environment.

Developed countries are looking into material recycling to achieve a variety of economic and environmental objectives. For example, the recycling of discarded tires has received a lot of attention. It is known that tires thrown on the ground as stockpiles are harmful to the environment and human health. Numerous studies, including the inclusion of used tires in the form of rubber particles into concrete, have been conducted to address this issue.

2.1.1 Rubberized Concrete:

In this type of concrete, some percentage of either course or fine aggregates are replaced with rubber by keeping all other constituent same. Rubber may be produced mainly from the tires which are of no use anymore(Sabahat, 2017). The flexibility of the rubberized concrete is higher than the ordinary concrete. Because of the rubber which is mixed in the concrete it is called as rubberized Concrete. The amount of rubber should be very low in the rubberized concrete because rubber has less strength and density than aggregate. The concrete mixes are prepared varying amount of rubber from 5-15%. Sand used for the experimental program was locally available material and conformed to Indian standard specifications IS 383-1970. Fine aggregate use was river sand. Specific gravity of fine aggregates is found 2.6 and water absorption is found to be 1.5%. The coarse aggregates are crushed with a maximum size of 20mm. The specific gravity of coarse aggregate is 2.67. Water absorption of coarse aggregate is 0.5%. All mix proportions are designed with a slump ranging from 25-30 mm keeping the water content constant at 190 kg/meter cube. The water cement ratio of 0.47 is kept constants for all mixes. Fine aggregate was replaced by crumb rubber varying from 5% to 15% by weight. Slump test and compression tests are performed on the various samples prepared(Khan et al., 2017).

2.1.2 Rubber as An Aggregate:

As fine rubber aggregate, finely ground tire rubber with the fabric and steel belts removed had a granular texture and ranged in size from very fine powder to sand-sized particles. As coarse rubber aggregate, truck tire rubber that has been chiseled into typical coarse aggregate size was employed. Rubber aggregate grading was compared to conventional fine and coarse aggregates for IS: 383 – 1970. Rubber aggregates reacted similarly to conventional aggregates. Rubber crumbs and chips have specific gravity of 1.14 and 1.16, respectively. Rubber crumbs and chips had fineness moduli of 5.35 and 7.68, respectively. (Vadivel et al., 2014)

2.2 Effects of Rubber In Concrete:

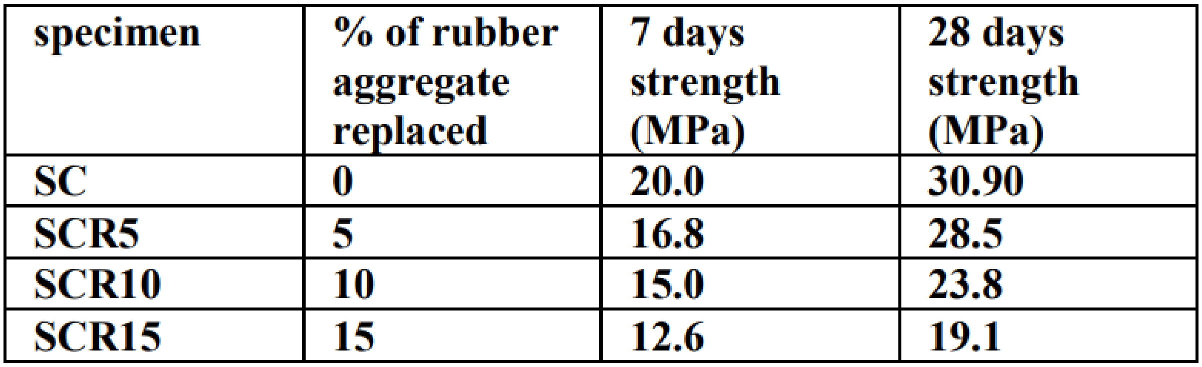
2.2.1 Compressive Strength:

The test was performed according to IS 516 – 2004. The cubes were made to be 150mm in diameter. Various quantities of leftover tire crumb were used to make the specimens. Rubber was tested at a concentration of 0%, 5%, 10%, 15%, 20%, and 25%. When compared to conventional concrete, the decrease in Split tensile strength with the addition of 5%, 10%, 15%, 20%, and 25% waste tire crumb rubber was 1.87 percent, 7.12 percent, 15,35 percent, 24.72 percent, and 44.94 percent at 7 days and 1.01 percent, 5.78 percent, 10.19 percent, 18.45 percent, and 32.50 percent at 28 days. When compared to conventional concrete, the compressive strength of M20 grade concrete with 5 percent, 10 percent, 15 percent, 20 percent, and 25 percent waste tire crumb rubber decreased by 2.67 percent, 9.37 percent, 17.85 percent, 30.80 percent, and 50 percent at 7 days and 2.61 percent, 6.21 percent, 12.41 percent, 23.20 percent, and 38.56 percent at 28 days (without rubber).(Antil, 2014)

In another experiment rubber was employed as a substitute for fine or coarse aggregate. The 25 percent, 50 percent, 75 percent, and 100 percent replacement rates were used. They used Edgar chips in 19 mm and 25 mm diameters as well as 38 mm Preston rubber was utilized, which was passed from a fine aggregate can be replaced with a 2 mm sieve. More than 200 cylinders were put through their paces in the lab. The diameter is 150 mm, and the height is 300 mm. The results showed that utilizing rubber as a substitute for the reduction of compressive strength was caused by coarse aggregate tensile splitting strength by 50% and strength by 85 percent. Depending on the percentage of rubber in the product. (Elshazly et al., 2020)

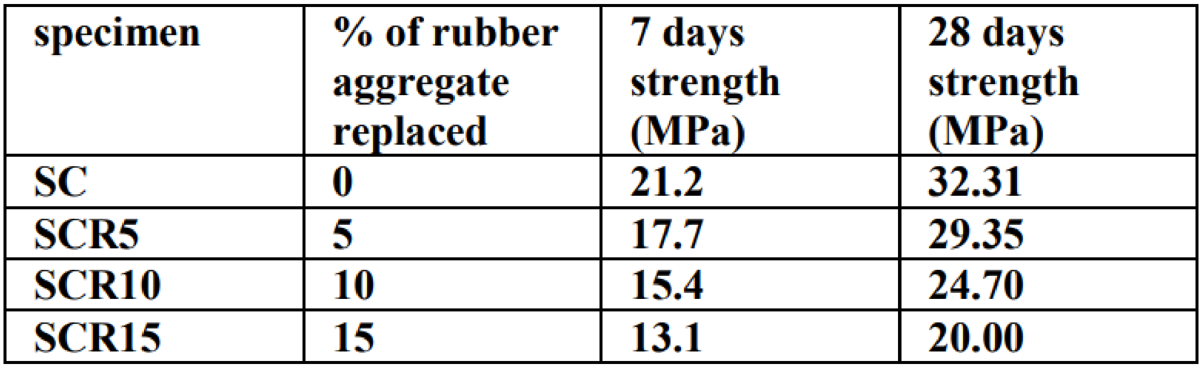
The compressive strength standard deviation ranged from 1.2 MPa when 0/1 fr. CR was added at 30% of the total aggregate quantity to 4.7 Mpa when ½ fr. And 20% CR were employed, respectively. It is possible to conclude that the CR additive has no effect on the standard deviation of concrete compressive strength. (Grinys et al., 2012)

The specimens' compressive strength was evaluated using a universal testing machine with a capacity of 200 tones and is listed below in Table 1 and Table 2(Grinys et al., 2012)



specimen	% of rubber aggregate replaced	7 days strength (MPa)	28 days strength (MPa)
SC	0	20.0	30.90
SCR5	5	16.8	28.5
SCR10	10	15.0	23.8
SCR15	15	12.6	19.1

Table 2- 1 Compressive Strength table *(Grinys et al.,2012)*



specimen	% of rubber aggregate replaced	7 days strength (MPa)	28 days strength (MPa)
SC	0	21.2	32.31
SCR5	5	17.7	29.35
SCR10	10	15.4	24.70
SCR15	15	13.1	20.00

Table 2- 2 Compressive Strength Table *(Grinys et al.,2012)*

2.2.2 Modulus Of Elasticity:

The stiffness of a structure influences its stability as well as the strength of its materials. Finally, the elastic modulus of rubberized concrete is another characteristic to consider when assessing its potential as a structural material. Although it has an impact on concrete strength and modulus of elasticity, adding rubber to structures helps prevent them from becoming too stiff, which is beneficial for earthquake resilience. (Ashar & Aleem, 2021)

The modulus of elasticity is the most difficult barrier to overcome for recycled concrete. The porosity, density, and aggregate content of concrete all play a role in determining the modulus of elasticity. The modulus of elasticity of mixtures with 1:3 and 1:4 binder/sand ratios is 1 Gpa and 0.82 Gpa, respectively. Despite the fact that these values are not typical of PC-based binders, they are similar to those reported by other authors for the same compressive strength.(Strivens, 1999)

Young’s Modulus and Modulus of Elasticity are the same thing. The elasticity modulus is constant. It is introduced by Robert Hooke. The Early Scientist Who Worked on Applied Mechanics was Robert Hooke (1635–1703). Young’s modulus, on the other hand, was given the letter “E” by Thomas Young in 1807. Thomas Young’s “Course of Lectures on Natural Philosophy and the Mechanical Arts” explains it in detail. Elasticity Characterization was a topic on which he did much research. The value of E, according to Robert Hook, is dependent on both the geometry and the substance under discussion. Physical testing is essential for any new component to determine the value of E According to Thomas Young, “the value of E is solely determined by the material, not its geometry.” As a result, he revolutionized engineering tactics. The elastic modulus of a little and large piece of rubber is the same. Elastic modulus is often referred to as tensile modulus or elastic modulus. Every material has a fundamental property that cannot be altered. Temperature and pressure, on the other hand, play a role. The Elastic Modulus is a measurement of a material’s stiffness. To put it another way, it’s a measurement of how easily a material can be bent or stretched. It is the stress and strain diagram’s slope up to the proportionality limit. It’s employed in both engineering and medical science. The elastic modulus can be used to determine how much a material will stretch as well as how much potential energy will be stored. The elastic modulus can be used to predict how a material will react under stress. Elastic modulus is also used to describe biological materials such as cartilage and bone.

(*Modulus of Elasticity - Definition, Measurement, Units, Formulas*, n.d.)

2.2.3 Flexural Strength:

The flexural strength test was carried out in accordance with IS 516 -2004. The beam specimens were subjected to two-point loading and the breaking loads were determined. The specimen's flexural strength was estimated using the breaking load. Figure 2.1 depicts the variances in test findings.

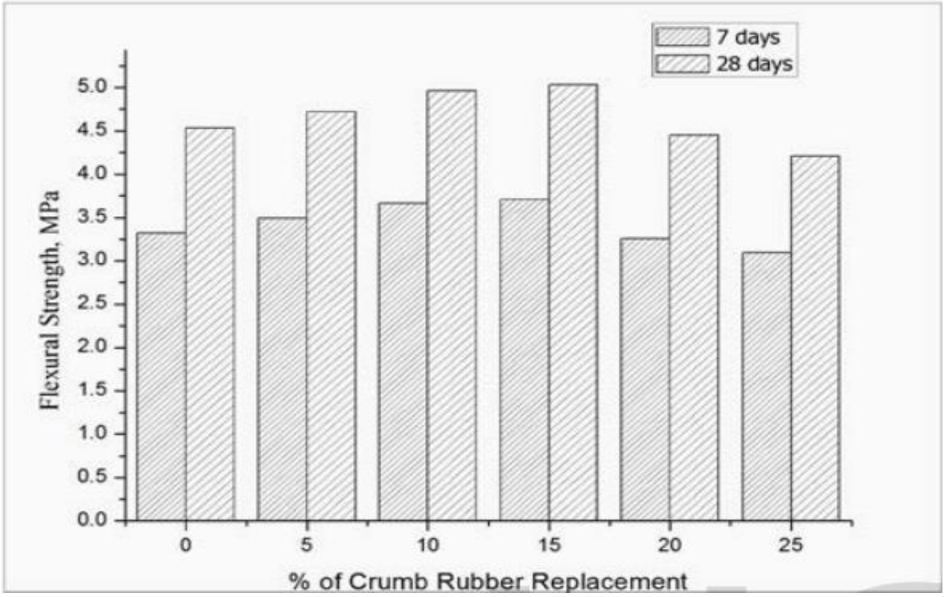


Figure 2- 1 Flexural Strength Chart for 7- and 28-days Curing(Antil, 2014)

Rubberized concrete's flexural strength was boosted by up to 15% when crumb rubber was replaced. The flexural strength was lowered by more than 15% when crumb rubber was replaced. The addition of crumb rubber to concrete increased the strength of the concrete by 5%, 10%, and 15% at 7 days, and 4.19 percent, 9.49 percent, and 11.04 percent at 28 days, respectively. The addition of 20% and 25% crumb rubber to concrete reduced the strength of the concrete by 1.84 percent and 6.92 percent at 7 days, and 1.76 percent and 7.06 percent at 28 days, respectively.(Antil, 2014)

In another experiment rubber particles were used to replace fine aggregate in a 20 percent ratio, resulting in a 12.8 percent reduction in flexural strength. They discovered that as the size of the rubber particles was reduced, the loss of flexural stiffness decreased. This was owing to the lower size of rubber particles in the rubberized concrete mix, which resulted in enhanced compaction.(Elshazly et al., 2020)

In an experiment flexure strength of concrete is obtained by using the fraction of CR. The obtained flexural stresses were used to calculate the test results' spread (Figure 2). The standard deviation values found varied from 0.11 to 0.48 Mpa. The tests revealed that when CR of ½ fr. Was added at 20% of the total aggregate amount, the standard variation of flexural strength was 0.48 Mpa, but specimens with CR of ½ fr. Added at 30% of the total aggregate amount had the lowest standard deviation of 0.11 Mpa. Because the standard deviation of the flexural strength is minimal, the obtained results can be said to be dependable.(Grinys et al., 2012)

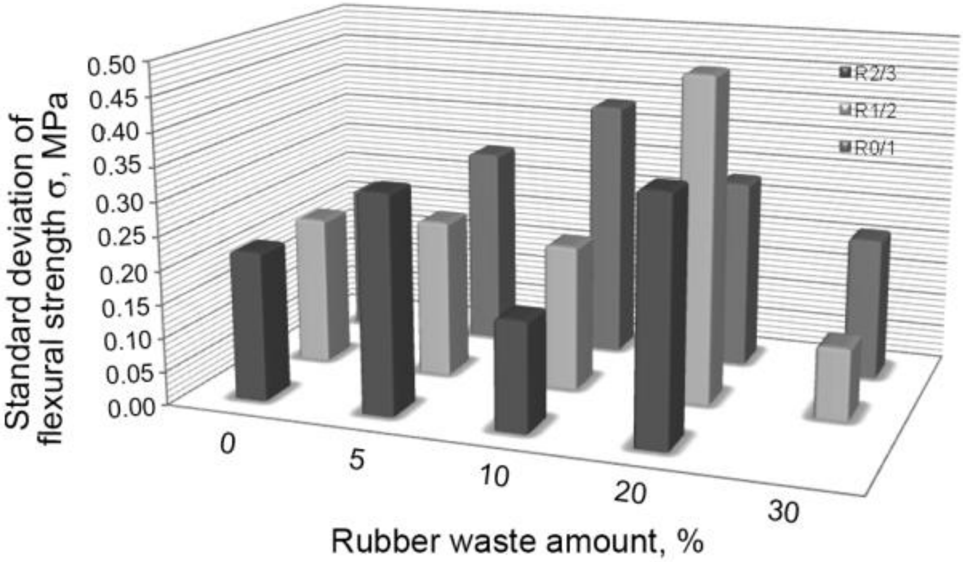


Figure 2- 2 Flexural Strength Graph*(Grinys et al., 2012)*

2.2.4 Impact Resistance:

Impact resistance is frequently misunderstood as impact strength, whereas in fact it has nothing to do with strength. Impact resistance is the energy necessary to shatter the sample into two or more pieces, while strength refers to a force. Impact resistance, like elongation to break, is affected by any particles, voids, or other in homogeneities that act as defects. Around the filler particles, stress concentrates. The greater the stress concentration, the larger the particle and the sharper the edges. As a result of the collision, the stress concentration surpasses the polymer's strength, resulting in micro cracks that quickly develop and finally lead to macroscopic failure. Impact causes de wetting and the creation of a void surrounding the filler particle for fillers with poor adherence to the polymer.

Impact resistance is a property of mortars that is determined by their deformability and compressive strength. As previously stated, age has an impact on deformability. In this way, ageing can reduce impact resistance, which can damage the render mortar's longevity. (Johnson et al., 2015)

The search for environmentally friendly building materials has reached a tipping point in terms of mitigating the harmful effects of climate change. It is vital to investigate the impact strength properties of eco-green construction materials and evaluate their performance for a variety of potential applications in the construction sector. There hasn't been any research done on the impact resistance of light weight geo grid reinforced concrete. The ability of concrete to sustain repeated impacts and absorb energy without breaking or spalling is referred to as impact resistance. Low velocity impact and high velocity impact are two types of impact scenarios. For varied OPS/ cement ratios, a good linear relationship for the initial and ultimate crack resistances against slab thickness is obtained. For varied OPS/cement ratios, the first and ultimate crack resistance rises with increasing number of supports at the boundary, reaching 29.8% for first crack resistance and 40.6 percent for ultimate crack for four (4) supports compared to two (2) supports border condition. The orientation of the geo grid in its main direction against its cross direction has no effect on the OPS concrete slab's first and final crack resistance. With a maximum ultimate crack resistance of 633.9 N/mm2, OPS geo grid reinforced slab offers good impact resistance qualities and can be used as a sustainable construction material.

(*IOP Conference Series: Earth and Environmental Science*, n.d.)

2.2.6 Shrinkage:

The results of 5% and 20% rubberized concrete mixes indicated a 35 percent and 95 percent increase in the length of the specimens, respectively, compared to standard concrete mixes. This could be due to the small size of rubber powder particles, which enables grains to serve as springs.(Elshazly et al., 2020)

Shrinkage of self-consolidating mortar specimens increased by 0%, 10%, 20%, 30%, 40%, and 50% when fine aggregate was partially replaced with scrap rubber particles (size 1–4 mm). With w/p = 0.51, the increase in 180-day shrinkage was approximately 1.74, 1.83, 1.96, 3 and 4 times higher, respectively, with 0%, 10%, 20%, 30%, 40%, and 50% rubber aggregate content. By raising the water-to-powder ratio, shrinkage can be increased. The use of crumb rubber granules (size 1.44–2.83 mm) to partially substitute fine aggregate in SCC mixes. Crumb rubber replacement, as evaluated by sand replacement volume, was 0%, 15%, and 15% for NaOH pre-treated rubber, respectively, and 25% for NaOH pre-treated rubber. Shrinkage increases as the rubber concentration rises. With 25 percent NaOH treated rubber content, 15 percent NaOH treated rubber content, and 15 percent untreated rubber content, the reduction alkali silica reaction (ASR) was 24 percent, 15 percent NaOH treated rubber content, and 7 percent untreated rubber content, respectively. SCC specimens shrank more when fine aggregate (sand) was partially replaced with tire rubber powder (size #30, #50) in volumes of 0 percent, 5 percent, 10 percent, 15 percent, and 20 percent. The average length change of the control specimen with 5% rubber powder content was 35% larger than the length change of the control specimen. The average length changes increased as the rubber powder content increased. The average length chance was 95 percent higher than the length change of the control specimen when 20 percent rubber powder was added (Figure 1). (Bušić et al., 2018)

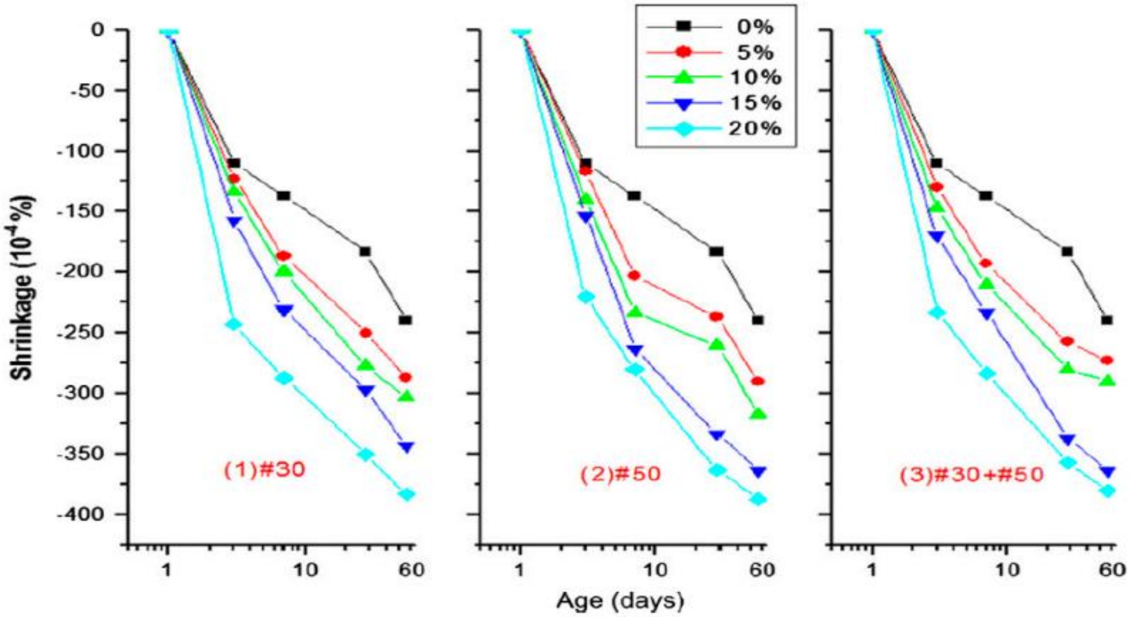
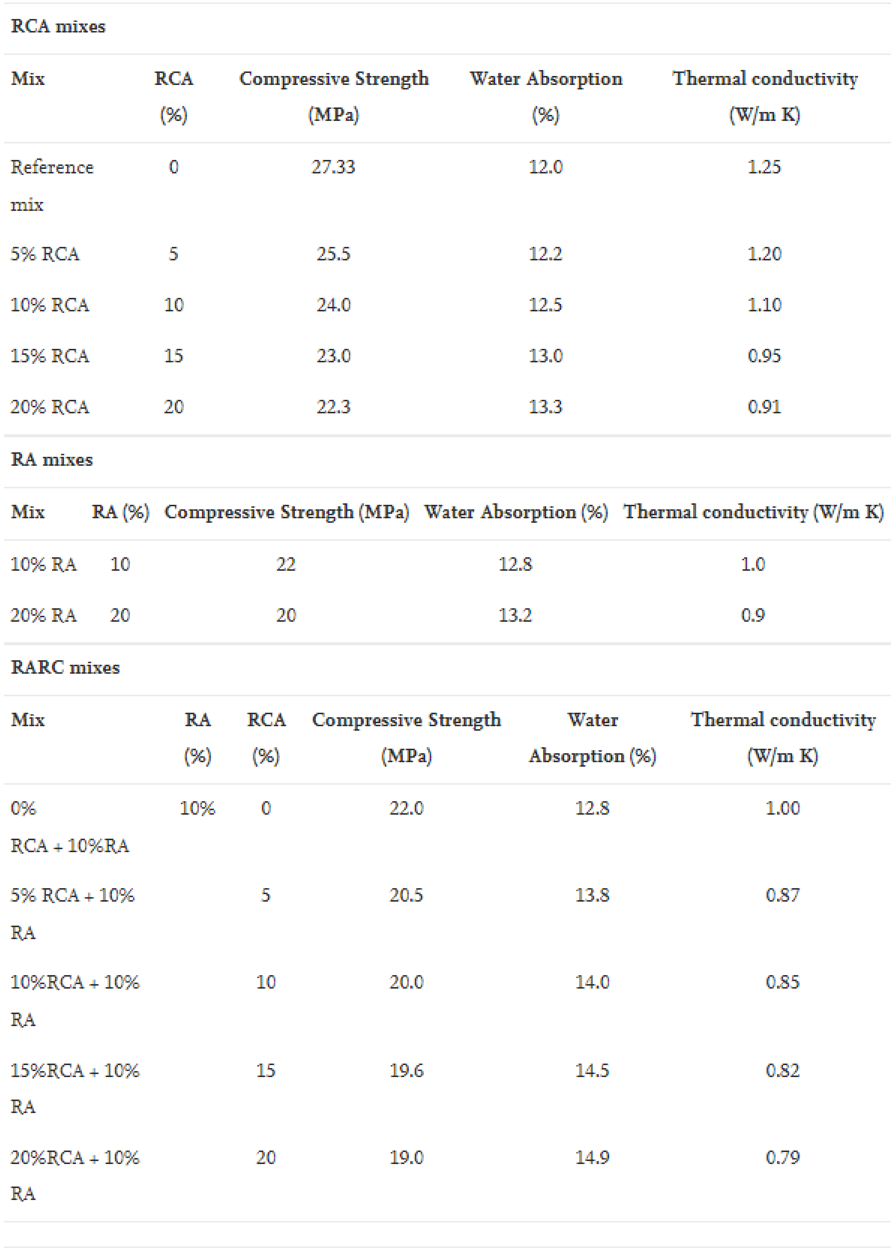


Figure 2- 3 Shrinkage Variation with time*(Bušić et al., 2018)*

2.2.7 Thermal Conductivity:

Rubberized concrete mixes have been exposed to temperatures as high as 400°C and 800°C. The color of the specimens changed from pink to light grey at 400oC and 800oC, respectively. Water in chemical bonds, free water in concrete capillary pores, and water in Calcium Silicate Hydrate (C-S-H) and sulphoaluminate evaporate at high temperatures. At 300oC, evaporation causes concrete to shrink. Above 400oC, C-S-H gels begin to breakdown. Anhydrite lime is formed when Ca(OH)2 is heated to 530°C. Concrete cracks and loses compressive strength as a result of high temperatures. As a result of the rubber burning that formed pores inside the concrete mix, high temperatures reduced the compressive strength of the rubberized concrete mix, and this loss in compressive strength grew as the rubber concentration rose. Rubber particles were used to replace 5%, 10%, 15%, 20%, and 25% of the coarse aggregate volume, respectively. In comparison to a typical concrete mix, 25 percent replacement of coarse aggregate with rubber particles lowered the thermal conductivity and specific heat capacity of the mix by 29.4% and 29.7%, respectively. Thermal resistance increased by 29.4 percent for the same rubberized concrete mix, but thermal diffusivity and thermal effectivity fell by 65.1 percent and 37.6 percent, respectively, as compared to conventional concrete mix. (Elshazly et al., 2020)

(Table 1) shows the thermal conductivity of all the created concrete combinations. The thermal conductivity values drop as the amount of RCA increases, according to the findings. Thermal conductivity values were found to be between 1.25 W/m °C for normal concrete and 0.79 W/m °C for 20 percent RARC. Thermal conductivity values published in the literature vary widely, but are typically in the range of 1.0–2.5 W/m °C. Furthermore, when compared to the control conventional concrete mixture, the thermal conductivity values of the hybrid RARC mix with 20% RCA decreased by 36.8%. The thermal conductivity is reduced by 37% when rubber particles are added to the cement matrix at a rate of 20%. The heat transmission capabilities of rubberized concrete are lower than those of regular concrete. The entrapped air, which increased with the rubber content due to the cement mortar’s poor adherence to the surface of the crumb rubber particles, led to a portion of the thermal conductivity drop. In hybrid RARC, as the RCA concentration increases, the thermal conductivity falls. However, to keep the compressive strength below acceptable ranges, the rubber content was limited to 10% and the RCA to 20%, as advised by several studies previously described. The porosity of the cement paste that is connected to the natural aggregates could be causing the decrease in thermal conductivity. Furthermore, the reduction in heat conductivity is linked to the presence of air in the concrete matrix, which results in a lower density. Table 2 lists the densities for all the different blends. According to Neville, the density of common concrete has little effect on its conductivity. However, when the amount of RCA in the RARC increased, the conductivity reduced due to the poor conductivity of air trapped on the surface of RA or RCA and the rubber itself. With a 10% inaccuracy, the density was connected to the thermal conductivity.



RCA mixes

Mix	RCA (%)	Compressive Strength (MPa)	Water Absorption (%)	Thermal conductivity (W/m K)
Reference mix	0	27.33	12.0	1.25
5% RCA	5	25.5	12.2	1.20
10% RCA	10	24.0	12.5	1.10
15% RCA	15	23.0	13.0	0.95
20% RCA	20	22.3	13.3	0.91

RA mixes

Mix	RA (%)	Compressive Strength (MPa)	Water Absorption (%)	Thermal conductivity (W/m K)
10% RA	10	22	12.8	1.0
20% RA	20	20	13.2	0.9

RARC mixes

Mix	RA (%)	RCA (%)	Compressive Strength (MPa)	Water Absorption (%)	Thermal conductivity (W/m K)
0% RCA + 10%RA	10%	0	22.0	12.8	1.00
5% RCA + 10% RA		5	20.5	13.8	0.87
10%RCA + 10% RA		10	20.0	14.0	0.85
15%RCA + 10% RA		15	19.6	14.5	0.82
20%RCA + 10% RA		20	19.0	14.9	0.79

Table 2- 3 Table for properties of Rubberized Concrete*(Elshazly et al., 2020)*

Construction and Building Materials Volume 133, 15 February 2017, Pages 514-524(Reference for tables and their description)

2.2.8 Sound Absorption:

Rubberized concrete sound absorption was more effective than standard concrete mix at all temperatures. Sound and shaking energy are effectively absorbed by rubberized concrete. Because of the porous nature of rubberized concrete, the ultrasonic modulus decreased as the rubber content and concentration increased. (Elshazly et al., 2020)

According to previous research, the absorption coefficients of materials containing crumb rubber range between 0.3 and 0.7, indicating that it is an excellent absorber. Combining it with concrete has the potential to improve sound absorption while lowering reflected sound levels. Previous research in this area indicated that adding crumb rubber to the mix improves sound absorption. Crumb rubber has also been mixed with concrete blocks to create a lighter, more flexible, and long-lasting absorbent substance that replaces 20% of the fine aggregate. According to research into the performance of CRC in various settings, the introduction of air entraining admixtures improves the durability of the material against freeze-thaw action.(Holmes et al., 2014)

The goal to increase the percentage of CR in self-consolidating rubberized concrete (SCRC) was that combinations with great potential for usage in high-impact resistance, energy dissipation, and sound absorption could be developed. CR percentage (0 to 50% by volume of sand), kind of supplemental cementitious materials (SCMs) (fly ash, slag, and metakaolin), binder content (500 to 550 kg/m3 [31.215 to 34.335 lb/ft3], coarse aggregate size (10 to 20 mm [0.39 to 0.79 in.]), and entrained air were also tested. Fresh properties, compressive strength, impact loading (drop weight on cylindrical specimens and flexural impact loading on small scale beams), ultrasonic pulse velocity, and acoustic emission measurements were among the tests carried out. The findings showed that it is possible to create SCRC mixes with optimal CR percentages, when compared to traditional concrete, this method produces concrete with improved energy absorption, acoustic insulation, and a lower self-weight. The impact energy required to induce the first visible crack and/or eventual failure crack of the tested cylindrical specimens increased by 30%, while the impact energy necessary to break the tested beams increased by 20%. On the other hand, when the CR grew, the sound absorption capability of the tested combinations increased as well. (Ismail & Hassan, 2016)

The study depicts processes and materials for reducing sound transmission loss through concrete without affecting mechanical qualities. Sound absorbing materials could be efficiently developed to 27inimize the harmful effects of noise pollution and to reduce the transmission of noises from streets to residential structures. This study evaluated several different combination designs to reduce sound transmission through concrete, including a control sample and three mixtures of recycled rubber with diameters ranging from 1mm to 3mm to limit sound transmission. Rubber is used to substitute sand aggregates in proportions of 5, 10, and 15%. The concrete's 7, 14, and 28-day strengths were measured first. The sound transmission losses through the samples were then measured using an impedance tube and the transfer function in the range of 63 Hz to 6300 Hz. The results suggest that samples containing 15% fine-grained crumbs had a loss of sound transmission of up to 190 percent, while samples containing 15% coarse-grained rubber had a loss of sound transmission of up to 228 percent. It has been demonstrated that using recycled rubber crumbs in concrete can successfully improve environmental noise absorption.(Chalangaran et al., 2021)

Chapter 3: Methodology

3.1 Initiation

The project's difficulty, scope, and objectives were determined once the project was chosen, and supervisor instructions were given. To have a clearer picture of what the study is about, the following stage was to collect data from other related research papers. That information has been mentioned in the "Literature Review" chapter. Typically, a literature review consists of books, thesis, research articles, and a wealth of online resources.

3.2 Materials

The materials used in the casting of specimens are following:

1. Portland Cement
2. Sand
3. Coarse Aggregates (5-10) mm
4. Coarse Aggregates (10-16) mm
5. Crumb Rubber (sieve # 4) passing.
6. Construction Chemical
7. Water

3.2.1 Portland Cement

Portland cement is the most popular form of cement used in concrete, mortar and sometimes in grout all over the world. It was created in England in the mid-nineteenth century from other varieties of hydraulic lime, and it mainly comes from limestone. It's a fine powder made by calcining limestone and clay minerals in a kiln, grinding the clinker, and mixing in tiny amounts of other ingredients. There are several varieties of Portland cement. Ordinary Portland cement (OPC), the most popular, is grey in color, however white Portland cement is also available. Because Portland cement is caustic, chemical burns can occur. The powder contains several dangerous components, such as crystalline silica and hexavalent chromium, and can cause irritation or lung cancer with prolonged exposure.

The significant energy consumption necessary to mine, produce, and transport cement, as well as the associated air pollution, including the discharge of greenhouse gases (e.g., carbon dioxide), dioxin, SO2, and particulates, are all environmental problems. Because of the low cost and broad availability of the limestone, and other naturally occurring elements used in Portland cement, it has become one of the most utilized materials in the previous century. Concrete made from Portland cement is one of the most flexible building materials on the market.

The cement utilized for this experimental program was OPC Type 1 for all the samples casted according to ASTM C150. The following properties were determined as per the ASTM C187-191.

Serial No.	**Properties**	**Values Obtained**	**Standard Ranges**
1	Setting Time – Initial	36 minutes	$\geq 30\ minute$
2	Setting Time – Final	306 minutes	$\leq 600\ minute$
3	Normal Consistency	30%	
4	Specific Gravity	3.15	OPC: 3.10 – 3.16
5	Fineness	4.5%	<10%

Table 3- 1 Cement Properties

3.2.2 Grading of Aggregates

Grading is the process of distributing aggregates according to the particle sizes present. The sieve analysis of fine and coarse aggregates is determined according to ASTM C136/ C136M. A typical sample of aggregate would be shaken through a series of sieves, starting with the biggest. In order of size, the largest apertures sieve on top and the smallest openings sieve at the bottom. The sieves set has the largest opening sieve on top and the smallest opening sieve at the bottom. Wires and meshes make up these sieves, which feature square openings. The material that passes through the smaller sieves above is collected in a closed pan at the bottom. Most of the time, separate sieves are used for coarse and fine materials. Fine aggregates or sand is the proportion of an aggregate that went through the 4.75 mm (No. 4) sieve and was largely retained on the 75 mm (No. 200) screen. The fraction of the aggregate that exceeds the above-mentioned threshold is referred to as coarse aggregate. Coarse aggregate is available in a range of sizes, from 37.5mm to 19mm (1-1/2 to ¾ in.). The simplified method is described in ASTM C33/C33M, Standard Specification for Concrete Aggregates, which includes a number of comparable size groups.

3.2.3 Sand

Sand is a granular substance made up of finely split rock and mineral particles that occurs naturally. It is distinguished by its particle size, which is finer than gravel but coarser than silt. Sand can also refer to a type of soil or a textural class of soil, such as one with more than 85 percent sand-sized particles by mass. Sand composition varies depending on local rock sources and circumstances, although silica (silicon dioxide, or SiO2), generally in the form of quartz, is the most prevalent ingredient of sand in inland continental settings and non-tropical coastal settings.

Calcium carbonate is the second most frequent type of sand, and it was largely formed during the last half billion years by diverse forms of life such as coral and shellfish. It’s the most common type of sand in places like the Caribbean beaches, where reefs have dominated the ecology for millions of years. Over human timeframes, sand is a nonrenewable resource, and sand suitable for concrete production is in great demand. Fine aggregates were used and tested according to ASTM C136 – 04 for grading and ASTM C128 – 04 for water absorption and fine aggregate specific gravity calculation.

Ser. No	Physical Property	Value Obtained
1	Specific Gravity	2.60
2	Water Absorption	1.28

Table 3- 2(Sand Properties)

3.2.3.1 Sieve Analysis of Sand

The sieve analysis for sand was obtained using modified ASTM C136. The fineness modulus of the sand used in this experiment was 2.3, and it was medium coarse. Table shows the data acquired from sieve analysis and figure 3-1 shows the gradation curve for sieve analysis of sand which is plotted on log scale with sample size on x-axis and percent passing on y-axis.

Sand					
Sieve no.	Sieve Size	Mass Retained	Cum Mass	Percent Cum Retained	Percentage Passing
4	4.75	1.5	1.5	0.197057278	99.80294
8	2	10.6	12.1	1.589595376	98.4104
16	0.85	43.6	55.7	7.317393589	92.68261
30	0.425	294.3	350	45.98003153	54.01997
50	0.25	274.3	624.3	82.0152391	17.98476
100	0.15	124.8	749.1	98.41040462	1.589595
200	0.075	1	750.1	98.54177614	1.458224
Pan		11.1	761.2	100	0

Table 3- 3 Table for sieve analysis of sand

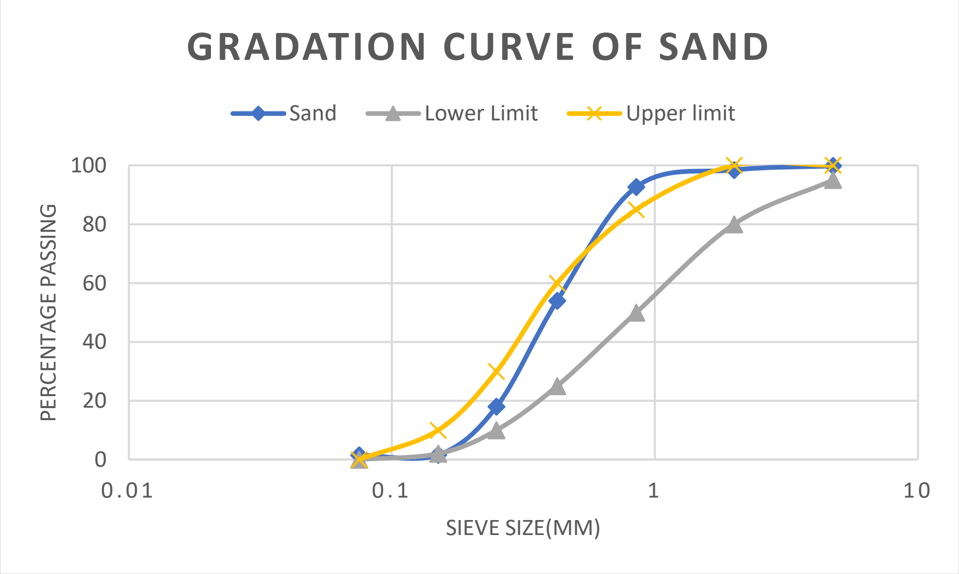


Figure 3- 1 Gradation Curve for Sand

3.2.4 Crumb Rubber

Crumb rubber is rubber that has been reclaimed from discarded tyres from cars and trucks. Steel and tyre cable (fluff) are removed during the recycling process, leaving granular tyre rubber behind. Continued granulator or cracker mill processing, maybe using cryogenics or mechanical techniques, decreases the particle size even more. Color is one of the parameters used to size and classify the particles (black only or black and white). Figure 3-2 and 3-3 show the crushed rubber of size less than 4mm which was replaced with sand in the design mix.

Figure 3- 2 Crumb Rubber

Figure 3- 3 Crumb Rubber

3.2.4.1 Gradation Curve of Crumb Rubber

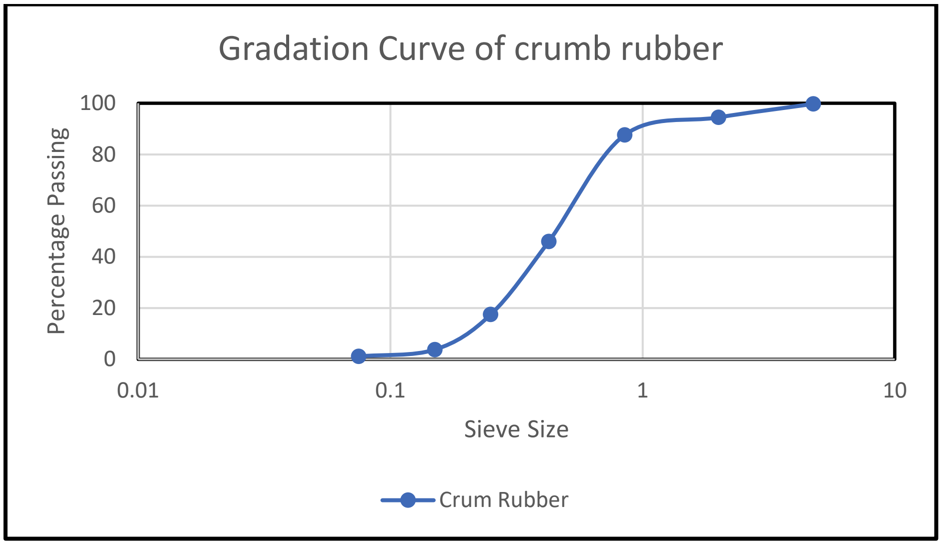


Figure 3- 4 Gradation Curve for Rubber

The Fig 3-4 shows the gradation curve of rubber. It is obtained by the sieve analysis of the rubber.

3.2.4.2 Comparison

This graph shows the comparison of gradation curve of rubber and sand. These both the materials have almost same fineness modulus and because of this rubber can be replaced by sand as fine aggregate in the design mix.

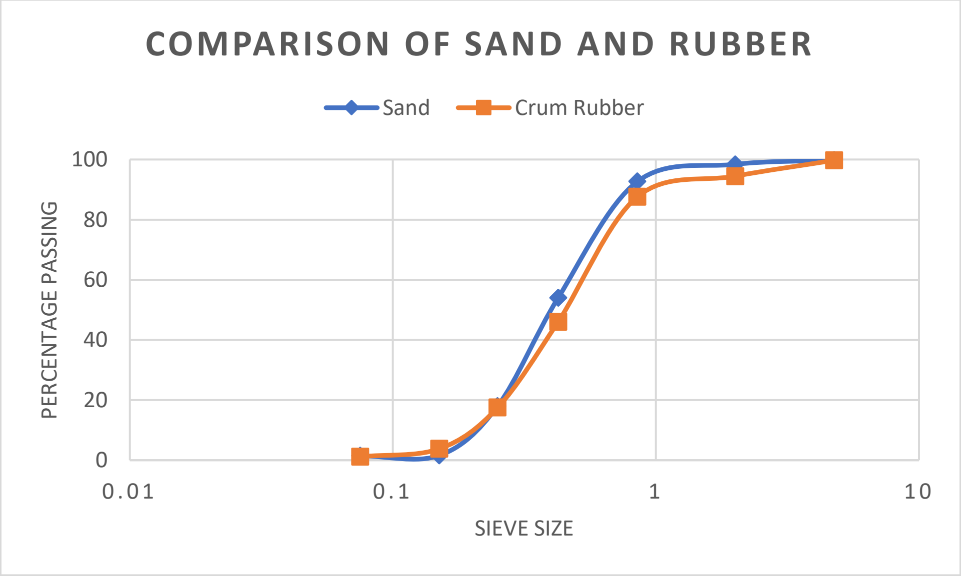


Figure 3- 5 Gradation Curve Comparison

3.2.5 Coarse Aggregate

The coarse material utilized in the experiment was crushed aggregate from Margalla. Coarse aggregate with a maximum size of 12.5 mm (1/2 in) was employed in all the specimens. ASTM C136 – 04 was used to conduct the sieve analysis. The specific gravity and percentage of water absorption were calculated using ASTM C 128-04.

The coarse aggregate was crushed stone from the Margalla Hills geological formations. These 40-million-year-old rock formations are rich in minerals and include vast amounts of limestone. The following aggregate parameters were determined using conventional procedures based on ASTM C-127 before casting the sample.

3.2.5.1 Crushing test of Course Aggerate

The aggregate crushing value test' determines how resistant an aggregate is to crush when subjected to a progressively applied compressive stress. The proportion by weight of crushed (or finer) material achieved when test aggregates are exposed to a particular load under regulated conditions is described as aggregate crushing value, and the strength of aggregate used in road building is denoted by numerical index.

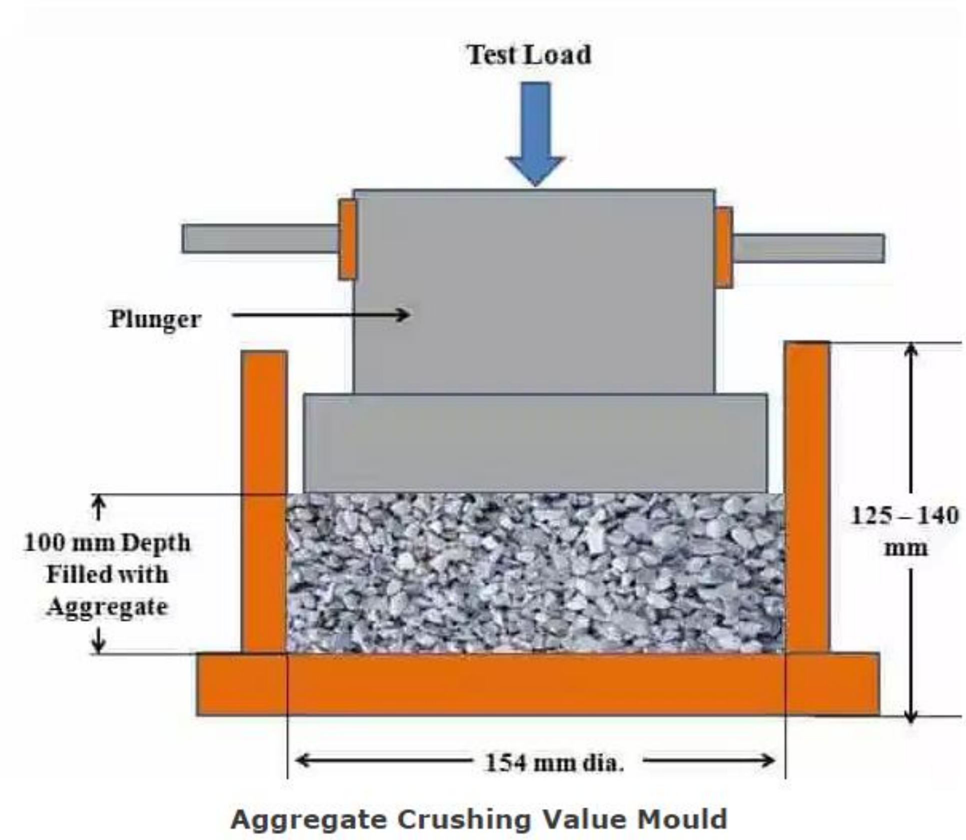


Figure 3- 6 Aggregate Crushing Mold *(Researchgate.com)*

Calculations:

Aggregate crushing value = (X/Y) *100 %

X = weight of fraction passing through 2.36 mm sieve = 485 grams

Y = weight of surface dry sample taken in mold = 2875 grams

Crushing value = (502/2968) *100 = 16.91

3.2.5.2 Impact value of Coarse Aggregate

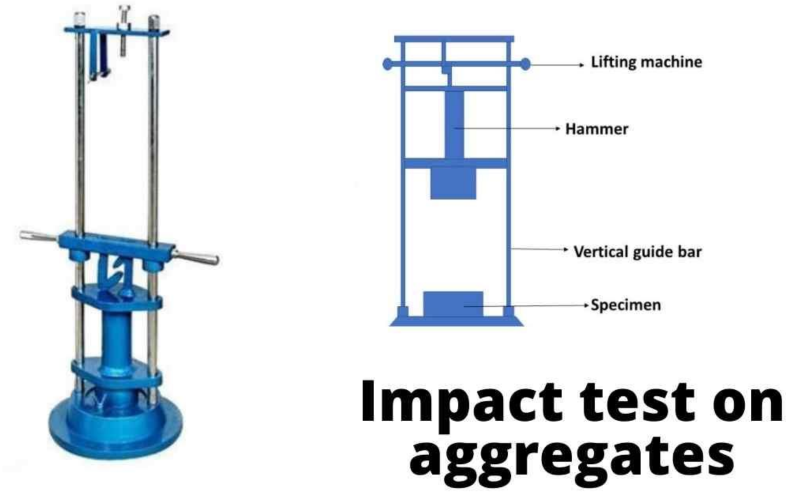


Figure 3- 7 Impact testing apparatus *(Researchgate.com)*

The aggregate impact test is used to measure how resilient aggregates are to impact or sudden loads. The size of the aggregates used in the test should be between 10 and 12.5 mm. This test is performed in a mold with a depth of 50 mm and a diameter of 102 mm. The hammer that delivers the impact load on the aggregates weights 13.5-14 kg and has a drop of 380 mm. A total of 15 blows are delivered to the aggregates. To calculate the aggregates' impact value, the material passing through a 2.36 mm sieve is represented as a percentage of total aggregate.

Calculations:

Aggregate Impact value = (X/Y) *100 %

X = weight of fraction passing through 2.36 mm sieve = 25 grams

Y = weight of surface dry sample taken in mold = 350 grams

Crushing value = (25/350) *100 = 7.14%

Ser. No	**Physical Properties**	**Obtained Value**
1	Specific Gravity	2.68
2	Water Absorption Percentage	0.58%
3	Impact Value	6.34%
4	Crushing Value	17.56%

Table 3- 4 Coarse Aggregate Properties

3.2.5.3 Water Absorption And Specific Gravity Test

Concrete is made using two very important aggregate properties: specific gravity and water absorption. Two kg of dry aggregates are immersed in water for 24 hours. Finding the aggregate sample weight in water yields the buoyant weight. Before being weighed, the same aggregates are baked for around 24 hours at a temperature of 100-110 C.

The specific gravity is calculated by dividing the dry weight of aggregates by the weight of an identical amount of water at a certain temperature. Aggregate specific gravity ranges from 2.6 to 2.9. Water absorption is the proportion of water absorbed in terms of oven dried weight of aggregates. Water absorption should be less than 0.6 percent of total weight of aggregate.

3.2.7 Water

Water in concrete serves two purposes. The hydration of cement to link the ingredients comes first, followed by the concrete's workability. Potable water devoid of hazardous substances, salts, and chlorides is required by ASTM C1602/C1602M Standard Requirement for Mixing Water Used in the Production of Hydraulic Cement Concrete (2018). (Active Standard). All of the samples were made with Risalpur drinking water, and they were also cured with the same water.

Test	Material	Standards
Sieve Analysis	Sand and Coarse Aggregate	ASTM C33 / C136
Cement Properties	Cement (OPC)	ASTM C187-191
Crushing Value	Coarse Aggregate	BS 812 :110
Specific Gravity	Sand and Coarse Aggregate	ASTM C127-07
Absorption Capacity	Sand and Coarse Aggregate	ASTM C127

Table 3- 5 Standards for Material Testing

3.3 Batching and Casting of Concrete

The weight proportions of the elements that make up concrete were used to batch the mix design. Several samples were cast according to the mix designs stated previously. Based on the literature research, replacement percentages were calculated using 05 percent, 10%, 15%, and 20% Crumb rubber with sand. The aggregate substitution percentages were used to name the samples. To blend all the components, a concrete pan mixer was employed. To manufacture high-strength concrete, all the ingredients (cement, sand, aggregates, and silica fume) were combined in the mixer 20 pan (HSC). A carefully calculated amount of water was thrown in the mixer after some time when the batcher started rotating. In a mixing bowl, the superplasticizer was dissolved in water and poured in. The quantity of superplasticizer was kept 100ml. The mixer was spun for 3 minutes. For casting molds according to our required dimensions were used. But before pouring the mixture into the molds they were properly lubricated with mobile oil. So that after drying out of the samples they do not get struck into the mold and could easily be taken out. After that the samples were kept in water for 7 and 24 days. To avoid any kind of voids in the sample the mold was placed on the vibrator as soon as they were filled in the molds. The vibration times ranges from 5 to 8 seconds. Table 3-6 shows the casting scheme upon which samples were casted for testing. 6 cylinders and 6 prims were casted for each percentage of rubber. From each of the 6 specimens 3 were tested after 7 days and 3 were tested after 28 days of curing.

Serial No.	Sample	Cylinder	Prisms
1	Control	6	6
2	5% Rubber	6	6
3	10% Rubber	6	6
4	15% Rubber	6	6
5	20% Rubber	6	6
		30	30
TOTAL		60	

Table 3- 6 Casting Scheme

3.4 Design Mix

The standards for concrete are complicated, but the end goal is to develop the most cost-effective combinations of concrete ingredients that meet the performance requirements. Physical characteristics of a correctly built concrete mixture include:

1. It must be sufficiently functional while still in its plastic condition.
2. The specified strength criteria must be reached.
3. For a concrete pavement, durability means the capacity to endure imposed pressures and factors like traffic abrasion.
4. Permeability and aesthetics are two more attributes that vary in importance depending on where concrete is used in a construction.

The mix design ratio was chosen for this project based on the targeted strength using the mix design procedure in ACI 211.1. Our mix design had a cement, sand, and aggregate ratio of **1:2.5:3.6**. And the chosen water cement ratio was **0.58**. The control specimens will compute the intended strength for each of these tests.

Also, the quantity of rubber was replaced in design mix by volume as there is huge difference in the densities of sand and rubber, so the amount of rubber added was according to its volume in the batch.

Design Mix Table (lb/yd^3)

Mix type	**Cement**	**Sand**	**Coarse Agg.**	**Rubber**	**W/C**
Control	517	1294	1892	0	0.58
5%	517	1229.3	1892	31.15	0.58
10%	517	1164.6	1892	62.30	0.58
15%	517	1099.9	1892	93.45	0.58
20%	517	1035.2	1892	124.6	0.58

Table 3- 7 Design Mix Table

3.5 Molds Used For Casting

3.5.1 Cylinders

The cylinder has a diameter of 152mm and a height of 305mm. The cylinder's total capacity is now 0.0053m^3. This cylinder was used for casting of specimens for compression testing. Concrete is poured in the cylinder and after 24 hours specimen is taken out of mold. Before pouring the concrete in cylinder the inner side of the mold is greased with mobile oil in order to avoid any kind of friction.

Figure 3- 8 Casting Cylinder *(Researchgate.com)*

3.5.2 Prism

The prism has a total length of 500mm and a width and height of 100mm. The prism's overall volume will be 0.005 m^3.

Figure 3- 9 Casting Prism *(Researchgate.com)*

3.6 Curing of Samples

The casted samples were kept in the molds for 24 hours before being unmolded and put in a room temperature water bath the next day. The samples were cured to suit the test's standards.

3.7 Tests To Be Performed On Concrete

3.7.1 Compression Strength Test

Hardened concrete was tested for compressive strength (ASTM C39). Hardened concrete tests are essential for assessing how concrete performs when mixed properly or when certain criteria are met. The next sections of this experimental inquiry detail the tests done on hardened concrete.(ASTM C39/C39M, 2003)

3.7.2 Flexural Strength Test

Flexural Strength of Concrete (Using Simple Beam with Center-Point Loading) was tested according to ASTM standards, with the designation C293 – 02. The modulus of rupture of specimens prepared and cured in accordance with Practices C 31 or C 192 is determined using this test method. Where there are changes in specimen size, preparation, moisture condition, or curing, the strength determined will vary. The results of this test method can be utilized to determine specification compliance or as a foundation for proportioning, mixing, and placing procedures. This test technique yields flexural strength results that are much greater than Test Method C 78.

3.7.2.1 Apparatus Arrangement

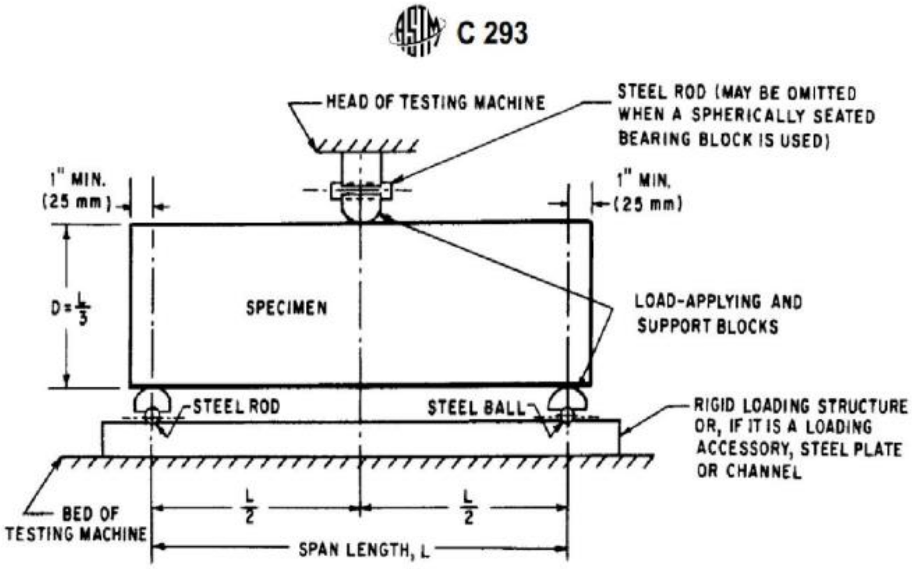


Figure 3- 10 Flexural testing Assembly *(ASTM-C293)*

Calculations

Calculate the modulus of rupture as follows:

$R = 3*P*L/2*b*d^2$

where:

R = modulus of rupture, psi, or MPa

P = maximum applied load indicated by the testing machine, lbf, or N

L = span length, in., or mm

b = average width of specimen, at the fracture, in., or mm

d = average depth of specimen, at the fracture, in., or mm.

Chapter 4: Results and Discussions

4.1 Compressive Strength

The targeted compressive strength was 3500psi and the achieved compressive strength of control sample was 3825 psi. The compressive strength of rubberized concrete decreased as the percentage of rubber was increased in the design mix. It is deduced form the results that at 5% and 10% replacement of fine aggregate with rubber of size less than 5mm was done there was not significant reduction in the strength but when percentage of fine rubber was increased from 10% to 15% and 20% the strength of rubber was reduced more significantly and almost 45% of strength of concrete was lost at 20% replacement. The pattern in strength reduction is exactly same as that of previous studies. The reason behind the abrupt change in strength when the percentage of rubber is increased further from 10% is that the rubber particles entrain air in mix after certain percentage of rubber and do not comply with water in concrete due to which segregation and pore formation happens in concrete which results in reduction in the strength of concrete. Also, during the casting of samples of 20% rubber replacement when concrete was vibrated on shake table the cement along with water started leaking from casting cylinder due to segregation.

Figure 4- 1 Testing on CTM at 15%

Figure 4- 2 Testing on CTM at 20%

4.1.1 Comparison

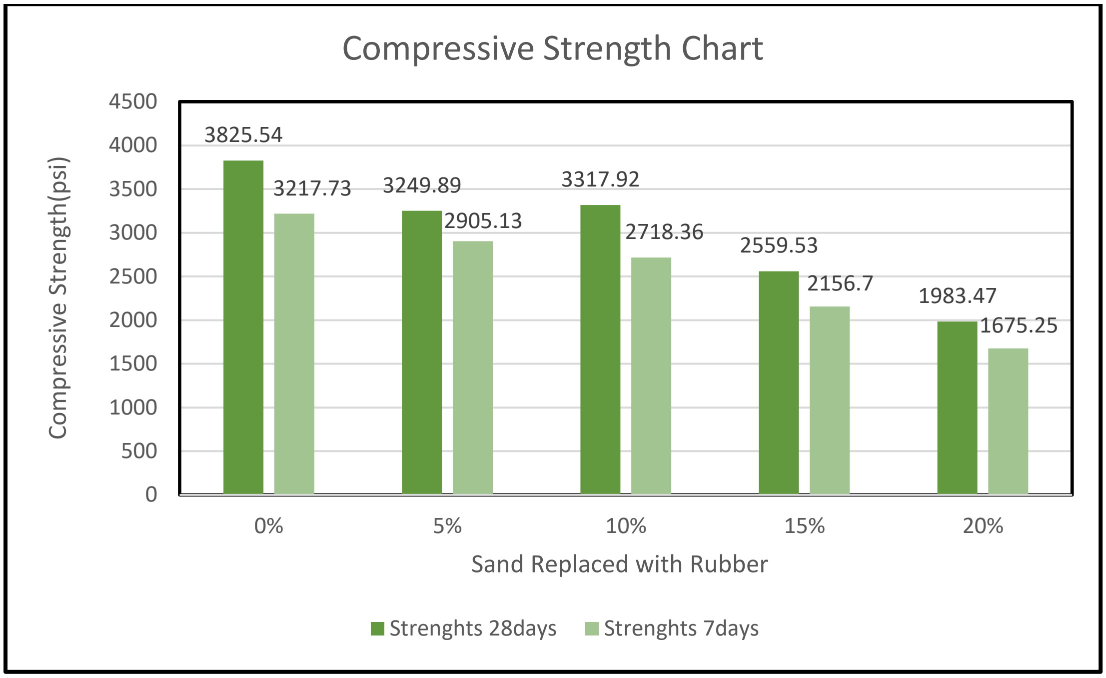


Figure 4- 3 Compressive Strength Chart

4.2 Flexural Strength

The flexural strength for different percentages of rubber is shown in the bar chart given below. The bar charts show the values of flexural strength for different percentages of rubber replacement in concrete. This chart shows that there is slight reduction in the strength of concrete with gradual increase in the percentage of rubber. From the given analysis the result which can be concluded is that instead of huge reduction in the strength with increase in percentage of rubber there is slight decrease in the flexural strength which is almost negligible. This behavior shows that unlike the compressive strength with optimal amount of rubber used almost equal flexural strength as that of concrete can be achieved. The bar chart shows that the maximum flexural strength after 28 days of curing is 6.3Mpa and the lowest flexural strength after 28 days of curing at 20% rubber replacement is 5.4Mpa and there is not much difference which concludes that flexural strength can be achieved by adding rubber instead of sand.

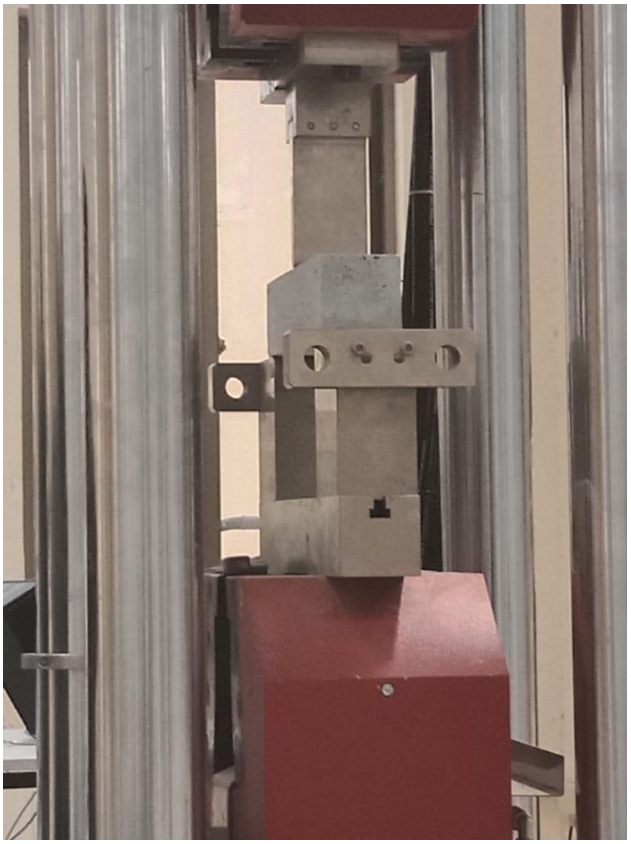


Figure 4- 4 Flexural testing on UTM

Figure 4- 5 Flexural testing on UTM

4.2.1 Flexural Strength at 7 Days:

As shown in figure 4-6, the flexural strength comes out to be 4.61 MPa for control sample. As percentage pf rubber increases the flexural strength Is decreasing as indicated in figure 4-7 to figure 4-10. By comparing the flexural strengths of control sample with 5%, 10%, 15% and 20% replacement, the strengths are decreased by 3.7%, 9.1%, 13.7% and 20.4% respectively. The maximum decrease in flexural strength is 20.4% for 20% rubber replacement as compared to control sample.

Figure 4-6 shows the flexural strength after 7 days with 0% crumb rubber and strength of each sample is illustrated with their average strength in the histogram. The flexural strength of each sample is obtained from UTM and expressed in MPa.

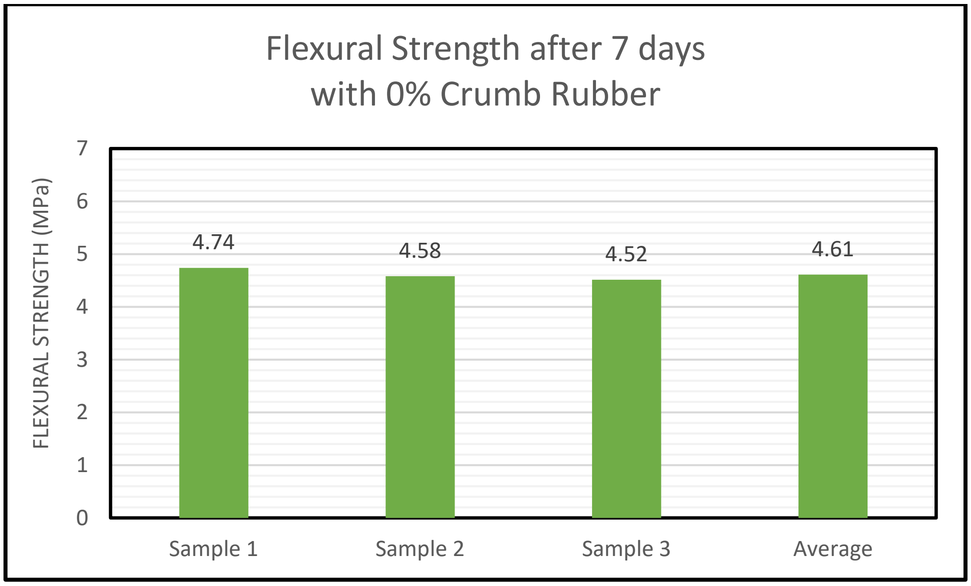


Figure 4- 6

Figure 4-7 shows the flexural strength after 7 days with 5% crumb rubber and strength of each sample is illustrated with their average strength in the histogram. The flexural strength of each sample is obtained from UTM and expressed in MPa.

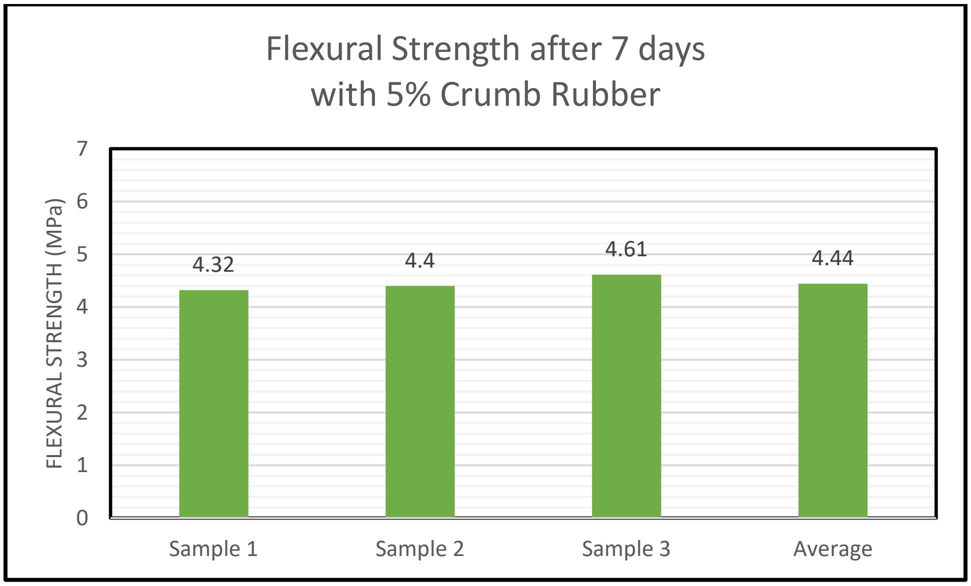


Figure 4- 7

Figure 4-8 shows the flexural strength after 7 days with 10% crumb rubber and strength of each sample is illustrated with their average strength in the histogram. The flexural strength of each sample is obtained from UTM and expressed in MPa.

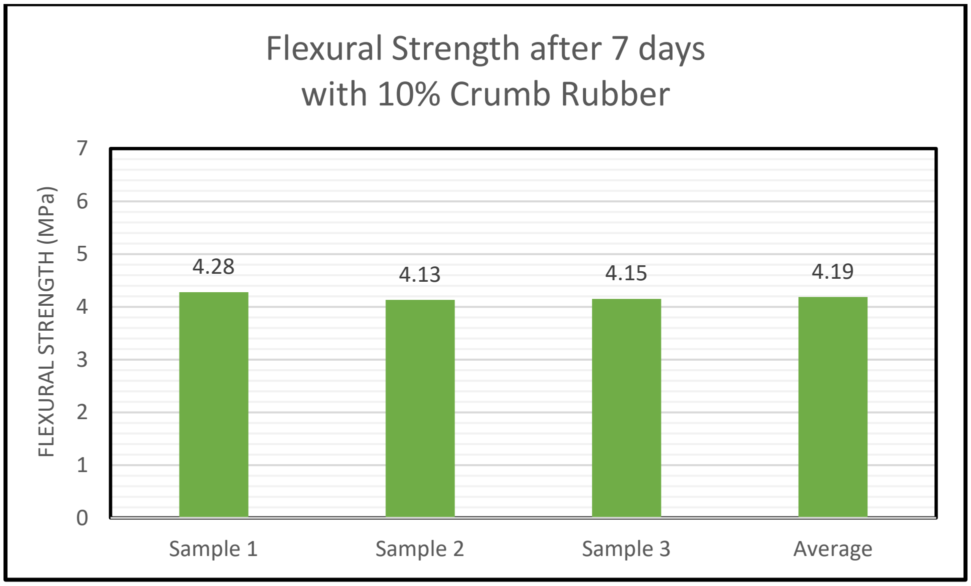


Figure 4- 8

Figure 4-9 shows the flexural strength after 7 days with 15% crumb rubber and strength of each sample is illustrated with their average strength in the histogram. The flexural strength of each sample is obtained from UTM and expressed in MPa.

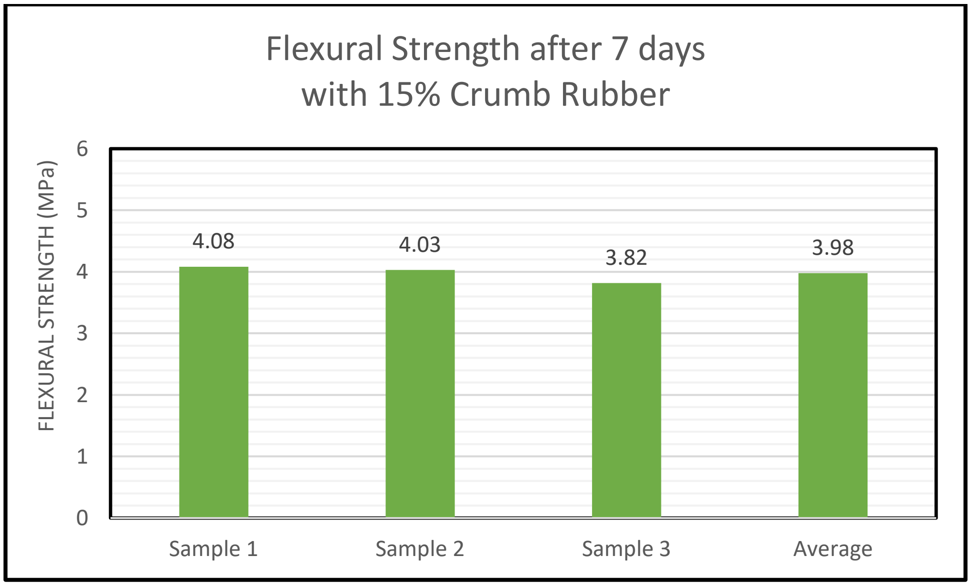


Figure 4- 9

Figure 4-10 shows the flexural strength after 7 days with 20% crumb rubber and strength of each sample is illustrated with their average strength in the histogram. The flexural strength of each sample is obtained from UTM and expressed in MPa.

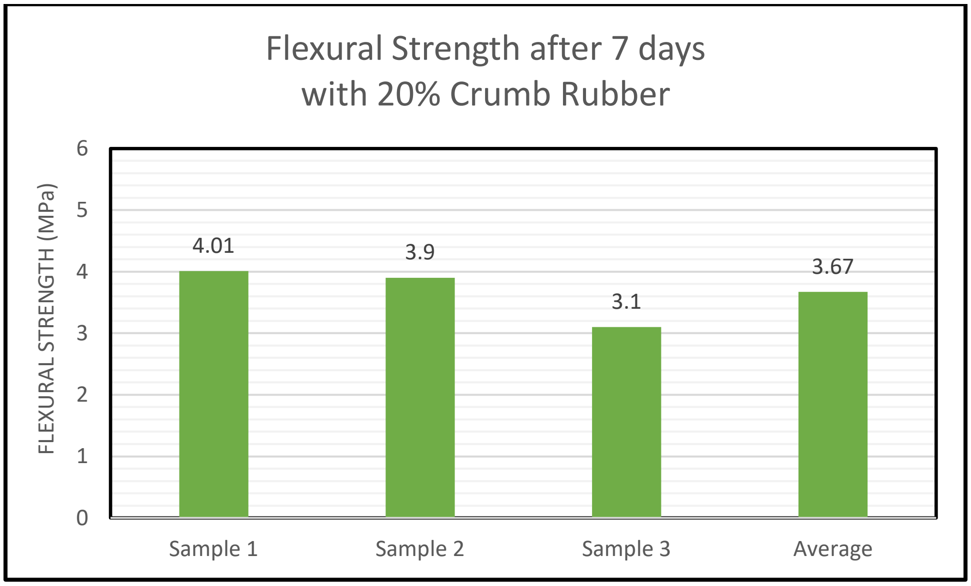


Figure 4- 10

3.2.2 Flexural Strength at 28 Days

As shown in figure 4-11, the flexural strength comes out to be 6.14 MPa for control sample. As percentage pf rubber increases the flexural strength Is decreasing as indicated in figure 4-11 to figure 4-15. By comparing the flexural strengths of control sample with 5%, 10%, 15% and 20% replacement, the strengths are decreased by 2.3%, 9.6%, 10.1% and 10.7% respectively. The maximum decrease in flexural strength is 10.7% for 20% rubber replacement as compared to control sample.

Figure 4-11 shows the flexural strength after 28 days with 0% crumb rubber and strength of each sample is illustrated with their average strength in the histogram. The flexural strength of each sample is obtained from UTM and expressed in MPa.

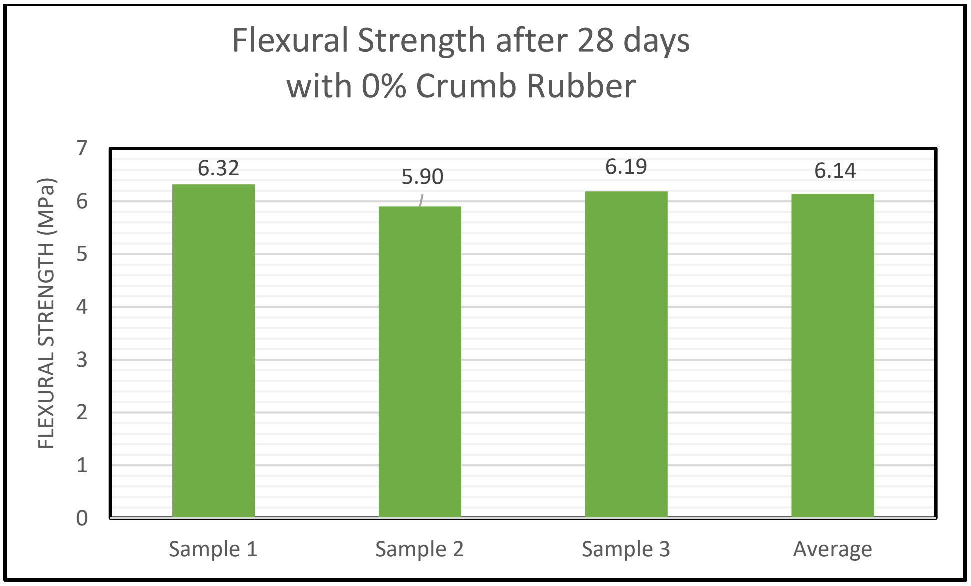


Figure 4- 11

Figure 4-12 shows the flexural strength after 28 days with 5% crumb rubber and strength of each sample is illustrated with their average strength in the histogram. The flexural strength of each sample is obtained from UTM and expressed in MPa.

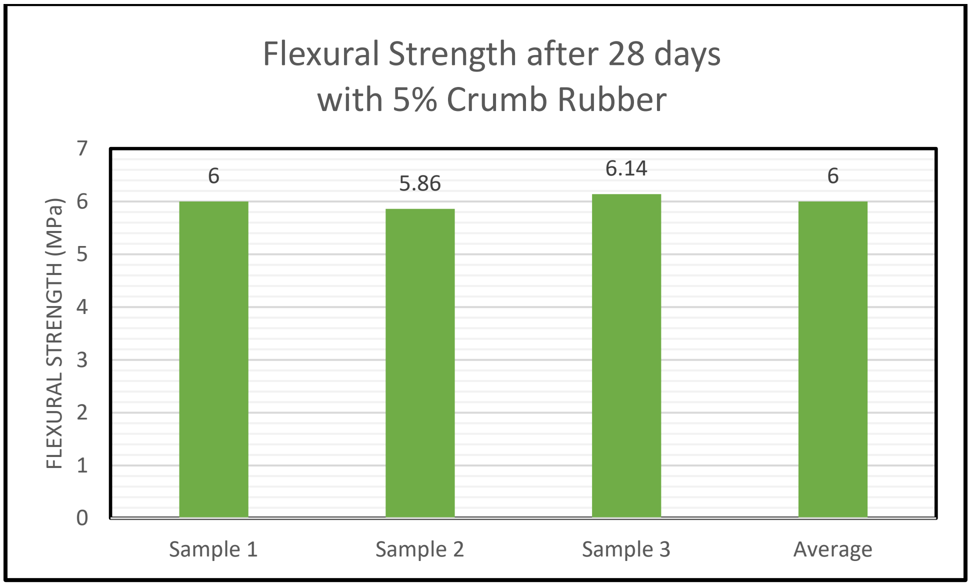


Figure 4- 12

Figure 4-13 shows the flexural strength after 28 days with 10% crumb rubber and strength of each sample is illustrated with their average strength in the histogram. The flexural strength of each sample is obtained from UTM and expressed in MPa.

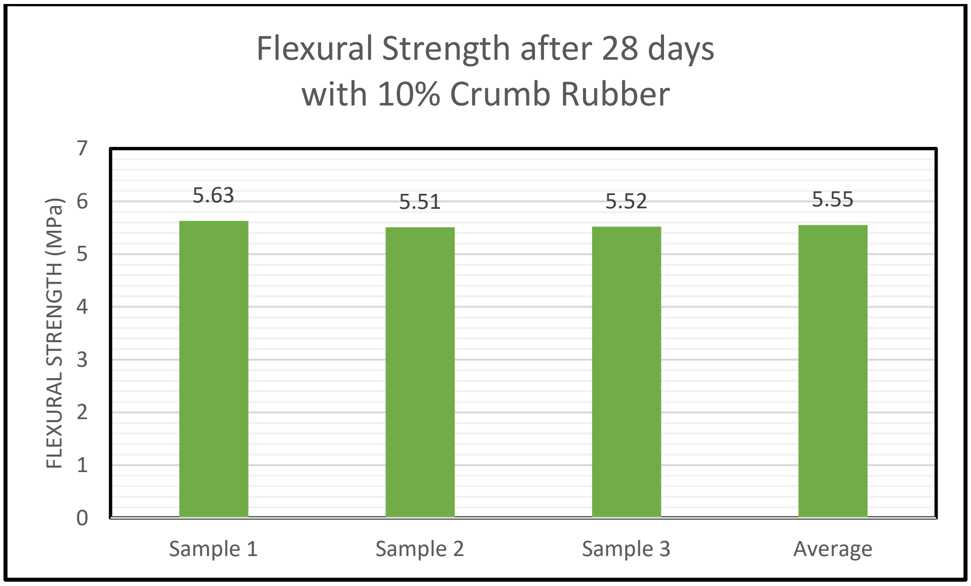


Figure 4- 13

Figure 4-14 shows the flexural strength after 28 days with 15% crumb rubber and strength of each sample is illustrated with their average strength in the histogram. The flexural strength of each sample is obtained from UTM and expressed in MPa.

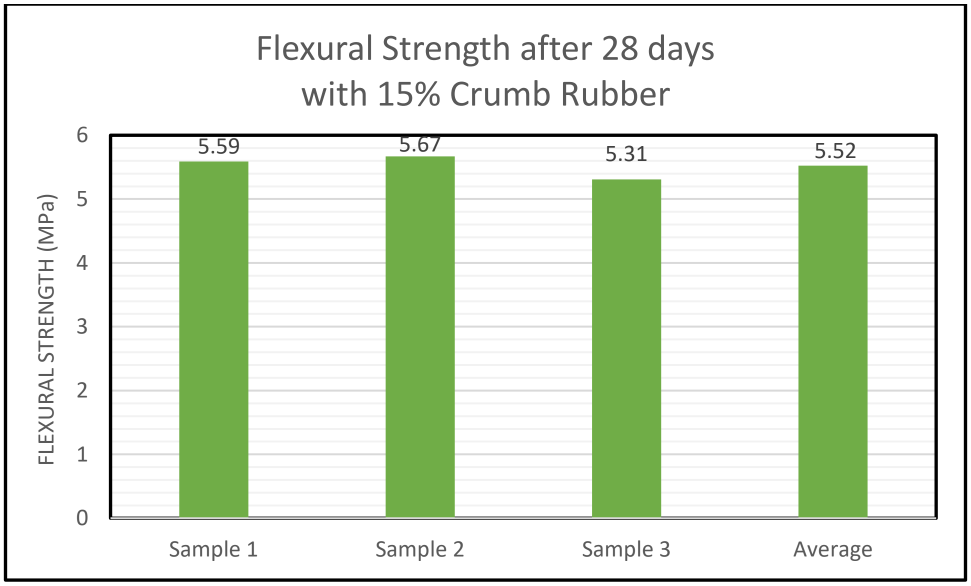


Figure 4- 14

Figure 4-15 shows the flexural strength after 28 days with 20% crumb rubber and strength of each sample is illustrated with their average strength in the histogram. The flexural strength of each sample is obtained from UTM and expressed in MPa.

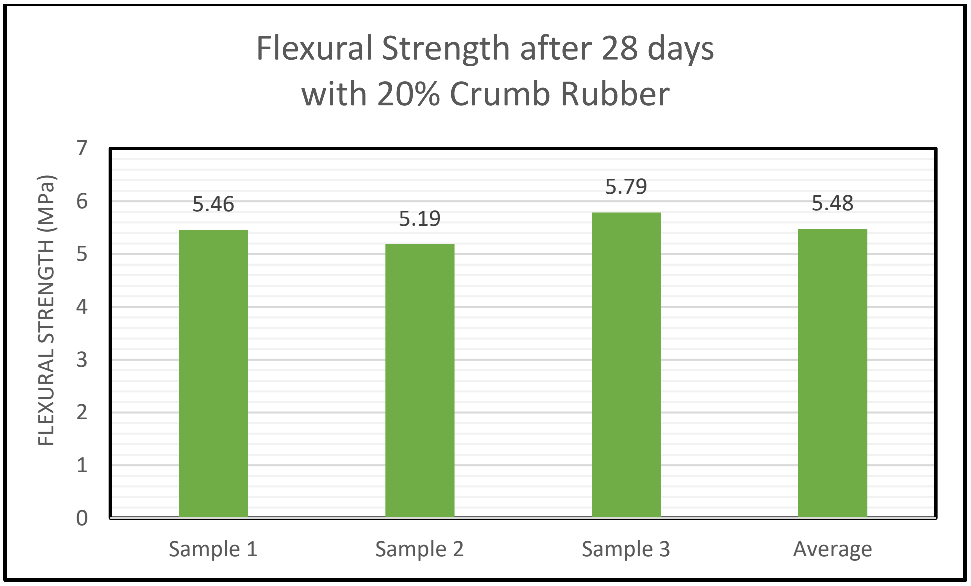


Figure 4- 15

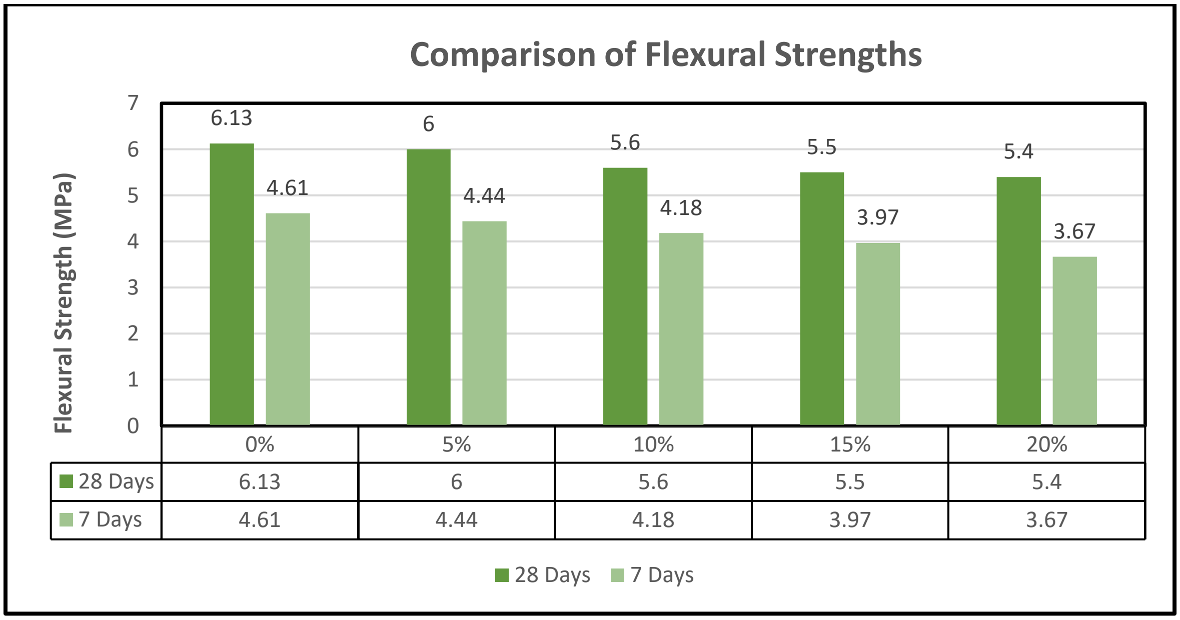


Figure 4- 16 Flexural Strength Comparisosn Chart

By comparing the flexural strengths of specimens after 7 days of curing control sample with 5%, 10%, 15% and 20% replacement, the strengths are decreased by 3.68%, 9.32%, 13.88% and 20.39% respectively.

By comparing the flexural strengths of specimens after 28 days control sample with 5%, 10%, 15% and 20% replacement, the strengths are decreased by 2.12%, 6.52%, 8.15% and 9.78% respectively.

3.2.3 Flexural Test Graphs Comparison

The graph given below is the comparison of load deflection curves of at different percentages of rubber in concrete. The comparison is done to show the behavior of rubberized concrete under flexural loading. The graph shows that the normal concrete has highest strength, but the failure mode is brittle which normal concrete always have, but as the percentage of rubber is increased in concrete the failure mode is changing form brittle to ductile and this behavior continuous as the percentage of rubber is increased which means that ductility and failure mode of concrete is enhanced with the addition of rubber. Brittle behavior of concrete was always a problem which was enhanced by reinforcing the concrete but to increase the ductility of plain concrete used in structure and make failure mode its more ductile rubber can be very helpful to be used in concrete under optimum percentages which lead to the minimum reduction in the in compressive strength also.

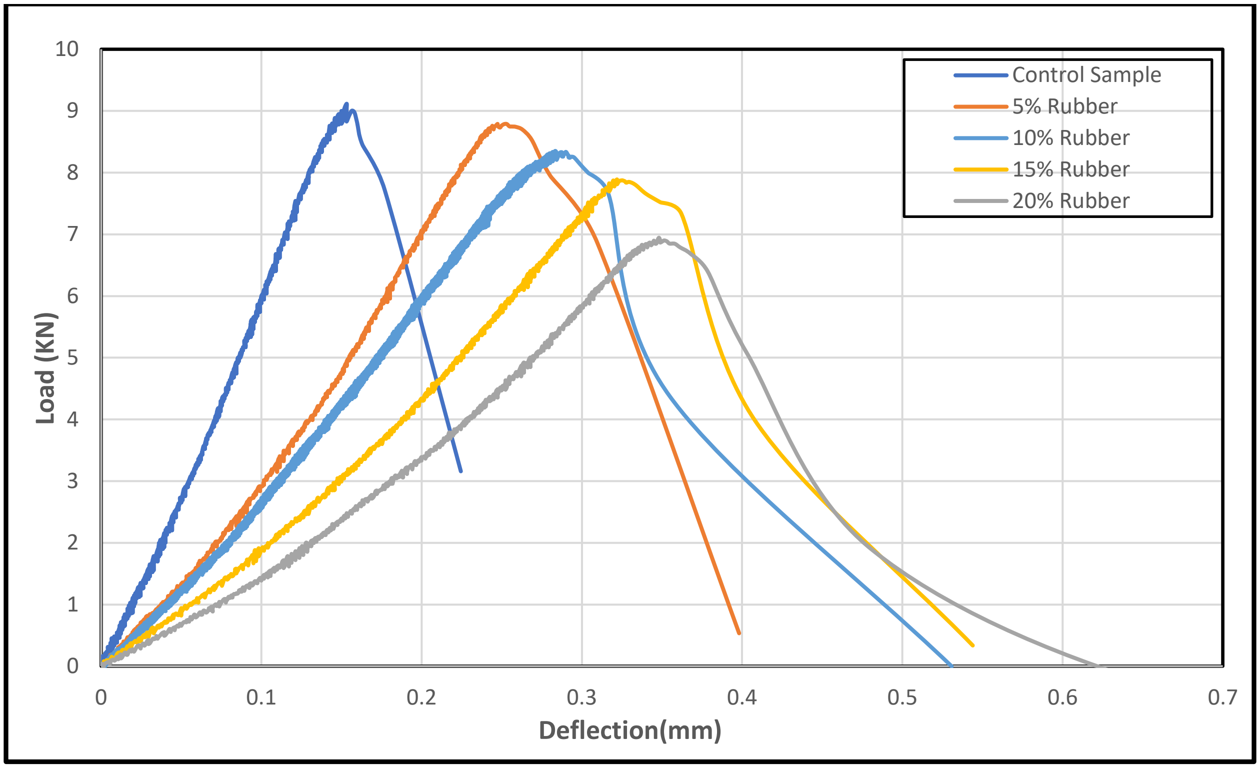


Figure 4- 17 Load Deflection Curves Comparison Chart

Chapter 5: Conclusion and Recommendations

5.1 Conclusion

Following conclusions are made from the research:

- The rubberized concrete has shown a ductile behavior under flexural loading rather than brittle behavior.
- The percentage decrease of flexural strength of 5%, 10%, 15% and 20% rubberized concrete which is cured for 7 Days compared to control sample is 3.68%, 9.32%, 13.88% and 20.39% respectively.
- The percentage decrease of flexural strength of 5%, 10%, 15% and 20% rubberized concrete which is cured for 28 Days compared to control sample is 2.12%, 6.52%, 8.15% and 9.78% respectively.
- The optimum percentage of rubber used in concrete should be between 5-10% for minimum reduction in flexural strength
- At higher percentages of rubber i.e., 15-20% more air got entrapped due to which pores are created, and it also causes reduction in the flexural strength.
- As the percentage of rubber increases the specimen shows more ductile behavior as compared to the control sample under flexural loading.
- The pouring and casting of rubberized concrete same as normal concrete when percentage of rubber in concrete is less than 15% but if rubber is more than 20% fresh concrete is very flowable and pouring and casting is not an easy job.

5.2 Recommendations

For further research following are the recommendations

- Reinforced beams should be used under flexural loading to find the actual flexural strength.
- Rubberized concrete should be confined in plastic pipes and checked under compression loading to be used as column.
- Research for the cheap and readily available treatment of rubber that makes rubber stiffer and makes its use in concrete more efficient.

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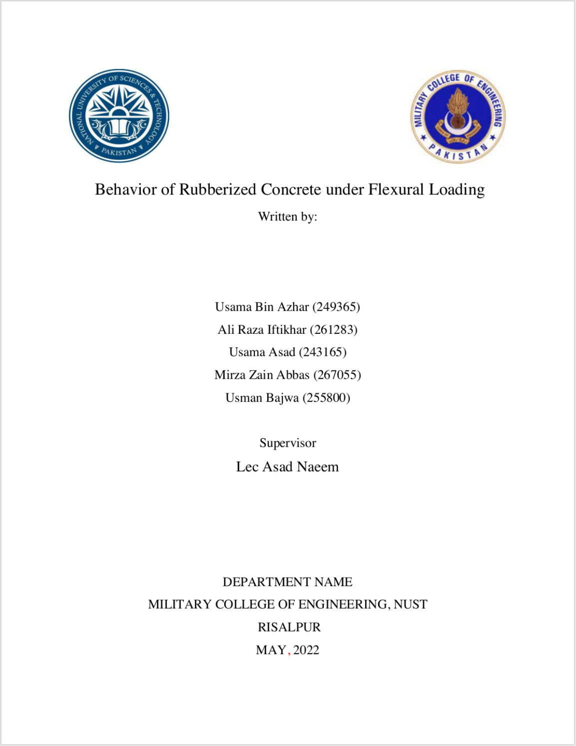

Behavior of Rubberized Concrete under Flexural Loading

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