MECHANICAL PROPERTIES OF FINE AND COARSE SIZE CRUMB RUBBER CONCRETE

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NOTATIONS

f'_c = Compressive strength of concrete made with stone aggregate plus certain percentage of crumb rubber aggregate after 28 days.

γ = Dry density of concrete made with stone aggregate plus certain percentage of recycled crumb rubber aggregate.

ASTM = American Society for Testing and Materials.

ACI = American Concrete Institute.

S.S.D. = Saturated Surface Dry

O.D. = Oven Dry

W/C = Water Cement ratio

F.M. = Fineness Modulus

MPa = Mega Pascal (N/mm^2)

psi = Pound per square inch

kN = Kilo Newton

kg = Kilogram

mm = Millimeter

cm = Centimeter

NCR = No Crumb Rubber

FCR = Fine Crumb Rubber (Retained on sieve no 30,50 and 100)

MCR = Medium Crumb Rubber (Retained on sieve no 8 and 16)

CCR = Coarse Crumb Rubber

WCR = Well Graded Crumb Rubber

CRC = Crumb Rubber Concrete

ABSTRACT

Disposing of waste tires globally has become a big environmental problem in recent years. Some studies and experiments were conducted on replacement by crumb rubber in concrete and resolve the problem of environmental concern. Waste tires partially replace the fine aggregate and coarse aggregate in regular concrete in crumb rubberized concrete (CRC). Hence, in the concrete mix sand and stone partially replace by crumb rubber both as fine aggregate and coarse aggregate of 0%, 5%, 10% and 15% in this study. To ascertain the behavior of crumb rubber concrete, all mixtures were compared with traditional concrete and also compared between coarse crumb rubber and fine crumb rubber which is replace instead of stone and sand. A total of 78 cylinders with a 100 mm diameter and 200 mm height were cast and put through testing. The M30 concrete mixture underwent testing for twenty days. Slump, the spilt tensile test, and compressive strength were four variables evaluated.

The research demonstrates that substituting some crumb rubber for sand and stone degrades concrete over time. According to the tests result, tensile strength, workability, and compressive strength declined as the amount of crumb rubber, both fine and coarse, rose. On the other hand, with increase the amount of coarse crumb rubber (CCR) the tensile strength was increased.

Although crumb rubber which is used in concrete decreased compressive and tensile strength, however up to 5% MCR increased the tensile strength 5.30% for 28 days curing. Compared between CRC coarse and fine crumb rubber, the fine crumb rubber provides 48.05% higher compressive than coarse crumb rubberized concrete and 24.1% higher tensile value. So, it is recommended that 5% of MCR is appropriate for application in concrete mixture.

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CHAPTER 1
INTRODUCTION

1.1 General

Large amounts of waste and recycling are produced and amassed, posing an ever-present threat to the environment. Rubber and plastic buildup might be regarded as non-decaying elements that affect the environment. To solve the environmental issues, recycled and waste materials are employed in concrete. The advancements Regarding the characteristics of concrete and the advantages for the environment brought about by the utilization of waste materials. One of the waste products that can be used in concrete is the rubber crumbs made from worn tires. European Tire and Rubber Manufacturers Association claims that (ETRMA). 2021 saw 470 million tires produced globally [1]. One of the major environmental issues over time is the disposal of tiers. The fast reduction in viable areas for trash disposal makes land filling intolerable. Utilizing tire rubber in concrete mixtures as a solution to concerns with creative disposal sites [2]. Aggregates made from tires are frequently utilized as the foundation for civil engineering projects. Concrete made of crumb rubber can be used in place of fine or coarse aggregate [3]. Concrete mixtures that contain crumb rubber are known as crumb rubber concrete (CRC). The primary distinction between CRC and regular concrete Is it possible to replace some of the coarse or fine aggregates with recycled tires that have been shred? Because it could have a negative impact on the mechanical qualities of concrete, using crumb rubber should be done with greater caution. We can use crumb rubber to lessen the amount of natural sand and stone that is required in concrete mixtures in addition to reducing the amount of fine and coarse aggregate used [4]. When crumb rubber is used in place of fine aggregate in concrete, the material's flexibility and ductility are improved. Compression, tension, and elastic modulus are all impacted by crumb rubber as well [5]. However, employing crumb rubber in concrete mix appears to reduce mechanical qualities such compression, tension strength, and elasticity modulus [10]. adhesion at the rubber-cement interface. The key factor for the loss of strength is the very low particle quality caused by the rubber particles' flat surface [7].

1.2 Purposes of the Research

The analysis of Crumb Rubber Concrete (CRC) results in the following two objectives:

1. To find out the optimum particle size and percentage of CR that may be used as a substitute of natural aggregate.
2. To lessen substantial environmental consequences through the use of rubber tires in concrete.

1.3 Outline Of The Methodology

The working methodology in this study is as follows:

a) Properly selection of materials.
b) Recycling of waste Crumb Rubber from rubber cutting mail.
c) Determination of materials properties.
d) Preparation of conventional concrete by using Portland cement, water, sand and stone aggregate.
e) Preparation of concrete using recycled as a partial replacement both as coarse aggregate and fine aggregate.
f) Curing of concrete.
g) Testing of concrete.
h) Results and analysis.
i) Conclusion and recommendations.

1.4 Scope of the Study

The current investigation involves replacing a volumetric amount of fine aggregate in concrete with recycled materials as fine and coarse aggregate at rates of 0%, 5%, 10%, and 15%. Compressive strength and Spilt Tensile Strength Test concrete have been identified as attributes. The variable in this investigation was the fine aggregate and coarse aggregate; all other factors remained constant. Over the course of the experiment, the water cement ratio was 0.47.

CHAPTER 2
LITERATURE REVIEWS

2.1 Introduction

The amount of solid trash is increasing alarmingly as industrialization accelerates. In both established and developing countries, there is an issue with such in every corner of the world. There are gathered a lot of tires every year. The ecosystem in Bangladesh and around the world is seriously threatened by used tires that are thrown in landfills because of their low density and sluggish rate of decomposition. Used tires offer major health dangers to people when they are unlawfully dumped or burned, which also makes fires more likely. Tires have a lifespan or safe duration that limits how long they can be used on cars. After that, the tires are disposed of in a number of ways. Tire buildup can cause serious environmental problems, one of which is the burning of sizable tire mounds, which emits carbon dioxide and other dangerous pollutants into the atmosphere. The construction industry might use crumb rubber (CR), produced from these old tire scraps, to produce building materials, helping to preserve natural resources and the ecological balance.

The rubber from scrap tires cannot be used entirely, but it can be replaced with fine and coarse material that significantly affect the qualities of concrete. In this study, we aim to workability, compressive strength, and tensile strength of concrete with partial replacement of fine aggregate and coarse aggregate. Crumb rubber is used as both fine and coarse aggregate, with sizes ranging from 4.75 to 0.075 mm and 50 mm to 9.5 mm, respectively.

2.2 Previous Study

Different experts have conducted numerous studies on crumb rubber concrete in various aspects. However, only a few researches have been done with different data, whereas most studies have used the same data. The majority of researchers conduct their studies in a variety of ways, using crumb rubber in some cases as fine aggregate and in others as course aggregate with varying percentages.

Assaggaf et al. (2021) work on this research that the mechanical, durability, thermal, and acoustic characteristics of concrete including both untreated and treated crumb rubber. In typical concrete, failure from fatigue and impact loads is an issue; the flexibility of the rubber particles may hold the solution. Utilizing waste materials sustainably through the use of crumb rubber concrete will conserve the environment and preserve natural aggregates. The researcher arranges extraordinary research that Due to the inclusion of a small amount of Crumb Rubber, several mechanical qualities of concrete, including abrasion resistance, impact strength, and toughness, increased. While the corrosion resistance Crumb Rubber Concrete was comparable to that of regular concrete, many of its durability characteristics, including chloride penetration, resistance to acid attack, depth of carbonation, freeze-thaw resistance, and electrical resistivity, were improved to a certain level of replacement of CR. The use of an inordinate number of CR can result in a significant degradation in the mechanical characteristics of CRC. Due to the lower density of CR, related entrapped air, and a weaker link between CR and cement mortar, the mechanical characteristics of CRC have decreased [1].

Siddique et al. (2004) did work on the use of used tires in Portland cement concrete provided. Additionally, they also emphasized the advantages of employing cement containing magnesium oxychloride as a binder for rubberized concrete mixes are discussed. Rubbery-rubber concrete offers various attractive features, including decreased density, increased toughness and impact resistance, improved ductility, and improved sound insulation. Magnesium oxychloride cement may also be used to create high-strength rubber concrete, which has higher rubber bonding properties. However, Concrete made with rubber aggregates has a lower compressive strength, which may prevent some structural applications from using it[2].

Siringi et al. (2013) worked on the Properties of Concrete with Crumb Rubber Replacing Fine Aggregates. The researcher conduct an exceptional research by comparing the compressive strength (ASTM C39), tensile strength (ASTM C78 and ASTM C496), failure patterns, energy absorption during loading, and workability of concrete reinforced with crumb rubber to ordinary concrete, the performance of both is examined. It is suggested that crumb rubber might sever as a lightweight alternative to fine aggregate in concrete. The findings indicate that with a little increase in the workability of the concrete, up to 15% of fine particles may be substituted with an equivalent volume of crumb rubber. Over 5% more compressive strength is added by using crumb rubber. As the amount of crumb rubber increases, the splitting tensile strength drops. However, it is noted that ductility, energy absorption, toughness, modulus, and strain at failure are all enhanced [3].

Al-Khuzaie et al. (2020) was work on mechanical characteristics of concrete pavement that contains tire crumb rubber. Rubberized concrete pavement with qualities similar to those of reference mix can be made using chemically treated CR. The pavement utilized in highway construction had appropriate qualities after replacement with 2% and 4%

CR. When compared to smaller particles, the coarser particles performed better in terms of mechanical qualities (as replacement from sand). Concrete treated with NaOH loses 7.6%, 15%, and 28% of its compressive strength for percentages of 2%, 4%, and 6% CR (from total aggregate), respectively. Since the zinc strata in the CR are not eliminated by water soaking, the compressive strength is reduced further. The CR negatively impacts concrete slump, particularly for high replacement rates of 8% and 10%, where the slump values were close to zero[4].

Manoharan et al. (2019) did worked on the characteristics of concrete using fine aggregate made from rubber crumb. In this investigation, the researcher of [5] used concrete with crumb rubber substitution in percentages of 3, 6, 9, 12, and 15. The purpose of this research is to demonstrate how crumb rubber may be used as a potential fine aggregate replacement in normal concrete. The result show that the greatest flexural strength value is attained when 9 percent crumb rubber is used. Up to a particular amount of crumb rubber is applied, compressive strength is higher (8%) than standard concrete. Up until a certain point, the amount of crumb rubber enhances the value of concrete's split tensile strength as well. Concrete made of crumb rubber is 11.2 percent more expensive than regular concrete with a 3 percent additive. Tensile strength was subsequently improved by 2.3 percent up to 9 percent [5].

On this research **Faraz et al. (2015)** did work on Impact of Crumb Rubber on Concrete Mix. The purpose of this research is to investigate the effects of replacing 5% and 10% of coarse particles with rubber crumbs in Portland cement concrete. Rubber crumbs were added, which caused the weight of concrete from mixes 1, 2, and 3 to be reduced to 8.6, 8.3, and 8.1 kg, respectively. Compressive strength of mix 2 was reduced on average by 6%, 10.16%, and 7.04% during the course of 7, 14, and 28 days, respectively. While for7, 14 and 28 days, mix 2's compressive strength increased on average by 4 percent, 5.47 percent, and 6.34 percent, respectively. The major findings of this research are the workability increased. The compressive strength is increase firstly then reduce again we can consider it as a drawback. Therefore, on this paper the author improves workability but they didn’t emphasize on physical properties, such as density roughness we consider it as a limitation [6].

Sugapriya et al. (2018) worked on recycling Crumb Rubber to Improve Concrete's Damping Properties. Damping plays a major role in the design of roadside structures that gets affected due to vibrations transmitted from moving traffic. Fine aggregates were partially replaced with crumb rubber in concrete, at varying percentages of 5, 10, 15 and 20%. Scanning Electron Microscopy (SEM) analysis was conducted to analyze the micro structural bonding between rubber and concrete. The required target strength of M30 grade concrete was achieved in SET 3, whereas SET 1 and SET 2 had a loss of compressive strength. There was a reduction in the flexural strength up to 15% replacement, after which there was a slight increase in the strength. The cubes' compressive strengths at 7 and 28 days were evaluated. Compressive strength dropped as the quantity of rubber increased. As the rubber content increased, the flexural strength initially declined, but above 15% replacement, there was a little improvement in strength. With an increase in the rubber fraction in all sets, the damping ratio rose and the frequency values fell. Rubberized concrete, as opposed to non-rubberized concrete, provides greater insulating qualities, according to a research [7].

Selvakumar et al. (2015) worked on concrete made of crumb rubber with partially replaced fine aggregates has stronger properties. With a yearly consumption of 12.6 billion tons, concrete is the most commonly used building material in the world. The aggregate, in addition to the cement, makes up a significant portion of concrete. Sand and crushed stone/gravel are examples of aggregate. If there isn't a suitable replacement, using these materials in concrete will probably deplete resources. Concrete made with rubber from scrap tires holds promise as a potential new use for used tires. Crumb rubber has a weaker bonding capacity, which has an impact on the strength of the concrete. The strength of crumb rubber concrete is less than that of regular concrete when it comes to splitting tensile strength. The compressive strength of crumb rubber concrete with 5% replacement is 38.66 N/mm^2, which is greater than the strength of regular concrete (36.73N/mm^2) on 28^{th} days. While The acceptable strength of 33.47 N/mm^2 is provided by the compressive strength of crumb rubber concrete with 10% replacement. When compared to the strength of regular concrete, the flexural strength test on crumb rubber concrete reveals a weakness [8].

In this research **Mohammed et al. (2017)** worked on the influence of crumb rubber on rubbercrete's characteristics. By 2030, it is predicted that there will be 1.2 billion tonnes of scrap tires produced annually. Tire waste presents significant environmental, health, and aesthetic issues. The research on the properties of rubbercrete in both its fresh and hardened states is reviewed in this paper. Rubbercrete is easier to work with and is more resistant to freezing and thawing. Nano silica as a cementitious addition can be used to economically offset a decrease in rubbercrete's strengths. Rubbercrete can also be used to create components or products that enhance habitation quality [9].

Kaloush et al. (2005) did work on Crumb rubber concrete characteristics. Arizona State University and the Arizona Department of Transportation have started a number of crumb rubber concrete (CRC) test sections across the state. Used tires can be crushed and recycled to create crumb rubber. Finding a way to dispose of the rubber by encasing it in Portland cement concrete is the long-term objective of this research. According to a study, the flexural strength of a mix with a high rubber content (tennis court) was almost 50% lower than that of the control mix. The trapped air, which increased as the rubber content did, played a part in the reduction of strength. The tensile strength decreased as the rubber content rose, but the strain at failure also went up. A more rigid material will have a higher tensile strain at failure [10].

Guo et al. (**2019)** done work on quantitative cloud envision correlation for damage of recycled rubber concrete. When compared to regular concrete, recycled rubber concrete (RCRC) performed relatively better in terms of toughness (NC). For the purpose of examining the ductility and damage progression of RCRC, a unique quantitative cloud imagine correlation (QCIC) approach was employed. The study could support the use of this ecological material's best design in civil engineering. If the compressive strength is the same for both RCRC and NC, the latter may exhibit greater toughness performance. The rubber aggregate in concrete absorbs some of the strain and redistributes the tension inside the concrete since it is a form of super-elastic material. In order to prevent severe fractures from forming and to increase the plastic's ability to withstand fracture, the rubber aggregate provides deformation displacement for the inside of the concrete [11].

Liu et al. (**2016)** did work on experimental analysis of crumb rubber concrete's mechanical and durability characteristics. Incorporating used tire rubber into the aggregate will create crumb rubber concrete, which is made from recovered waste tires. In order to produce modified crumb-rubber concrete, this study serves as a reference. For crumb rubber concrete made using pretreatment rubber and synthetic resin, the strength loss ratio was lowered to 1.2% after 25 cycles of freezing-thawing. There was a reduction in the axial compressive strength, splitting tensile strength, compressive strength, and elastic modulus [12].

Shahjalal et al. (2019) [13] was done research on experimental study of mechanical characteristics of recycled aggregate concrete using polypropylene fiber and crumb rubber. Rubberized concrete reinforced with polypropylene fiber has greater toughness and ductility, indicating that it offers more forewarning before failure and has a greater ability to absorb energy. Increases in rubber content have the opposite effect on compression strength, flexural strength, and repeated drop-weight impact responses. In terms of compressive and flexural strength, R30C0F2 outperforms the control by 26.9% and 8.6%, respectively. As CR levels rise, the Poisson's ratio rises as well, although it falls as fiber percentages rise gradually.

Sofi et al. (2018) work on rubber from used tires has an impact on the mechanical and durability characteristics of concrete. Plastic bottles made of polyethylene terephthalate (PET) and tire rubber are two examples of the rapidly growing number of polymeric wastes. Every year, an estimated 1000 million tires are thought to reach the end of their useful life, and by 2030, an additional 5000 million tires are anticipated to be regularly disposed of. The control mix is less resistant to abrasion than high strength concrete with crumb rubber. As a result, concrete roadways, floors, and pavements may all use it. Concrete's flexural strength for both classes decreased when rubber was substituted for gravel or cement [14].

Batayneh et al. (2008) work on encouraging the application of crumb rubber concrete in underdeveloped nations. The recycling of rubber tires that amass each year in Jordan for use in concrete mixtures is discussed in the paper. According to test results, the crumb tires may still exceed the strength criteria for light weight concrete even if their compressive strength is lowered. It has been determined that modified concrete would help dispose of the scrap tires that aren't decomposing. The number of scrap tires amassing in developing nations has made it difficult to dispose of them, forcing the government to make investments to make it easier to employ waste tires in concrete. Similar to how conventional concrete is mixed, cast, and compacted, crumb rubberbased concrete may be mixed, cast, and compacted utilizing local resources [15].

Nadi et al. (2022) examining the characteristics of hardened mortars and their compactness while recycling construction and demolition waste (CDW). In coating mortars, concrete waste (CDW) can be used in place of natural sand, however the more CDW that is used, the more water the mortar will absorb. When replacing sand with more than 25% CDW, the mortar must include substantially more water. Although CDW can boost compressive strength and compaction levels, it cannot be used in amounts greater than 25%. Brazilian investigation has determined that the partial substitution of CDW for non-nutritioecological material (NS) in mortars could lead to a clean production mortar with a CDW composition of 25% being the most suitable for use in building construction. Leached and solubilized extracts are within national and international parameters in terms of the environmental evaluation, demonstrating that using these solid wastes won't have a substantial environmental impact [16].

Oluwaseunadeboje et al. (2019) work on engineering properties of concrete with sand and partially crumb rubber substitution. A study has shown that using crumb rubber in place of sand in concrete mixtures improved the mechanical qualities of the mixtures. Slump, bulk density, compressive strength, split tensile strength and energy dispersive spectroscopy tests were all improved. Tests were carried out on samples of concrete cubes that had been curing for 28 days. The substitution of 4 percent sand with crumb rubber lowered the slump from 45 mm for the control to 25 mm, but the workability of the concrete was unaffected. Crumb rubber-modified concrete produced normal weight concrete since its bulk density was in the range of 2,300 to 2,340 kg/m3[17].

Mohammed et al. (2017) did work on a review of crumb rubber's impact on rubbercrete's properties. Scrap tires are bulky, non-biodegradable, good breeding area for mosquitos and rodents and flammable materials. One of the most viable solution is to used crumb rubber from scrap tire as partial replacement to fine aggregate in concrete industry. By 2013, the United States had produced more than 3.8 million tons of discarded tires, with just around 5% of those tires being used in civil engineering. Complex elastomeric compositions composited with steel and fiber codes can be referred to as tires. Rubber create can be used to create components or products that improve the quality of life for residents because of its unique qualities in both its fresh and hardened states. Workability, air content, and unit weight are examples of fresh qualities; abrasion resistance, impact resistance, ductility, energy absorption, toughness, and fatigue qualities are among the characteristics of hardened materials [18].

Bisht et al. (2017) analyzing the mechanical and long-lasting qualities of crumb rubber concrete. In Portland pozzolana cement concrete, waste rubber, in the form of crumb rubber, is utilized as a fine aggregate replacement. For the various proportions (0%, 4%, 4.5%, 5% and 5.5 %), compressive strength, flexural strength, density, and durability characteristics including water absorption and abrasion resistance have been assessed. With a 4% substitution of fine aggregates by crumb rubber, the output of compressive and flexural strength shows a little drop. When substituting at the same amount, water absorption was only slightly impacted. In the current work, a microstructural analysis utilizing XRD, SEM, and optical microscopy was also completed. The strength achieved in PPC-based concrete with a 4 percent replacement level of crumb rubber is 33 N/mm^2, according to observations. Concrete with 5.5% crumb rubber showed less wear than was permitted by caudal regulations. An increase in substitution level has caused cavities and fissures, which have led to an increase in water penetration [19].

Alaloul et al. (2018) work on concrete's deformation properties when crumb rubber is used in particular place of fine aggregate. The construction industry uses fine aggregate and granulated tire crumb rubber to create rubbercrete. The use of Rubbercrete has certain significant disadvantages, including a gradual decline in its strength that will eventually restrict its application. This progress report will outline Rubbercrete production methods so that conventional concrete may be used to compare its compressive strength to Rubbercrete's. Rubbercrete's compressive strength will rise if Nano silica is added to the mixture, which will also improve concrete mixing. Due to the pozzolanic nature of fly ash, the percentage of modulus of elasticity drops when fly ash is introduced. It is necessary to reduce rubbercrete's deformities characteristics by adjusting variables like the water-cement ratio [20].

Jirjees et al. (2019) did work on behavior of concrete including tirederived crumb rubber aggregate. This research looks at how the mechanical and workability qualities of concrete are affected when recycled fine aggregate (RFA) is used in place of natural fine aggregate. Due to the rough surface of the crumb rubber aggregates' particles and the internal friction that develops between the components of the concrete, crumb rubber causes a reduced workability (slump) of the concrete. When compared to the reference mix, the compressive strength values for the mixes M10, M20, and M30 fell by 24%, 39%, and 46%, respectively (M0 mix) [21].

Youssf et al. (2016) worked on the mechanical performance of crumb rubber concrete is evaluated. When compared to traditional concrete, crumb rubber concrete (CRC) has several acknowledged mechanical performance drawbacks, particularly in terms of compressive strength. In order to evaluate the mechanical performance of a 20% rubber mix, this paper examines the mechanical characteristics of fifteen CRC blends. The slump, short- and long-term compression strength, and tensile strength of the rubber were measured, as well as the impact of the rubber pretreatment period, cement content, and cement content. When compared to ordinary concrete, rubber-based concrete (CRC) has demonstrated considerable improvements in slump, compressive strength, and ten-nanometer tensile strength. The concrete slump and compressive strength suffered when SF was used as a partial cement substitution. The increases in the compressive and tensile strengths after then were less significant and weren't economically beneficial. The authors intend to conduct a cost analysis of the suggested CRC assessment in further works [22].

Mohammed et al. (2012) work on the characteristics of concrete that uses rubber ash and rubber crumb to replace some of the sand. In this research concludes that due to reduced adhesion between cement paste and coarse aggregate; compressive strength and fracture decrease as the CR ratio increases. CRHCB can be produced as load-bearing hollow blocks with a maximum CR substitution of 6.5% and unloaded hollow blocks with a maximum CR substitution of 40. CRHCB can be manufactured as light to normal weight hollow blocks as required by ASTMC 90 and C129 subject to CR substitution percentage. CRHCB has better sound absorption with higher noise reduction factor than ordinary hollow concrete bricks. Although the STC for CRHCB decreased as the percentage of CR substitution increased, the decrease in STC was small and could be partially recovered by the inclusion of a higher percentage of silicon fume. CRHCB has a higher resistivity than ordinary hollow concrete bricks [23].

Shahidan et al. (2020) work on properties of concrete using rubber ash and rubber crumb in place of sand in part. This work concludes that ash and rubber crumbs in the concrete mix can reduce higher workability. While the presence of rubber ash and rubber crumbs in the concrete results in a significant reduction in the tensile strength of the concrete. Also, the substitution of rubber ash and rubber crumbs as natural aggregates in the concrete mix reduce the elastic modulus of the concrete. in this modulus of elasticity of the RAC is higher than RCC [24].

Abdurrahman et al. (2019) work on the characteristics of resistant pavement material made of concrete with crumb rubber and rice husk ash as additives in a peat environment. In this research crumb rubber and RHA added to OPC concrete to improve the concrete mechanical properties. The mechanical properties such as tensile strength, flexural and elastic modulus of OPC rubber were slightly higher than normal concrete. But compressive strength and porosity reduces. It can be concluded that OPC rubber with RHA has relatively better properties than OPC concrete [25].

Akinyele et al. (2015) work on rubber crumb's effect on concrete's mechanical and chemical properties. Research on the influence of rubber chips on mechanical and chemical properties shows that: The strength of concrete is generally reduced when more rubber chips are added to the concrete and these results support the findings of previous research on the mechanical properties of rubber coated concrete. Chemical analysis shows that the amount of very important elements such as iron (Fe), calcium

(Ca), silicon (Si), aluminum (Al) and oxygen (O2) in concrete is reduced due to high debris CR is added. into the concrete matrix, but the amount of carbon (C) and sulfur (S) in the mixture increases with the addition of rubber crumbs, mainly because tire rubber contains a lot of soot and sulfur, and this is reflected. shine in all rubber models [26].

Abd-Elaal et al. (2019) did work on a novel method of employing heat treatment to increase the strength of crumb rubber concrete. Study and compare the morphology of rubber granules before and after heat treatment. Mechanical properties, including compressive strength and tensile strength, were measured to check the effectiveness of the proposed method. Heating shredded rubber to a relatively high temperature before being added to the concrete mix has two main effects:(i) remove many impurities present on the surface of the shredded rubber, and (ii) create a hard shell on the surface of the rubber granules. Heat-treated rubber granules have a relatively strong bond to the concrete substrate, even after destructive compression tests.2. Rubber heat treatment recovers 93%, 60% and 47% of the compressive strength loss compared with ordinary concrete at 28 days, and recovers 106%, 82% and 57% of the tensile loss, respectively [27].

Bala et al. (2014) did work on impact of fly ash and rubber waste on the characteristics of composite concrete. The present work addresses the effects of fly ash and rubber particles from used tires on the workability, density, compressive strength and bond strength of composite concrete. The rubber content varies from 0 to 40% when replacing fine and coarse aggregates while fly ash varies from 0 to 30% when replacing cement. However, the maximum reduction was achieved with 0% fly ash and 40% alternative rubber. The compressive strength decreased by 96.5%, 96.4%, 96.3% and 96.2% at 0%, 10%, 20%, 30% and 40% rubber content at 0-30, respectively. The toughness of scrap rubber modified concrete is much higher than that of the control mixture [28].

Gupta et al. (2014) did work on evaluation of the mechanical and long-lasting qualities of concrete using scrap tires as fine aggregate. In this study, waste rubber tire particles in the form of rubber ash or in a combined form (10% rubber ash and different proportions of rubber fiber) were used to partially replace fine aggregate. The compressive strength of gum ash decreases with increasing percentage of gum ash at w/c of 0.35 and 0.45, while the compressive strength increases slightly at w/c ratio of 0.55. For modified concrete, compressive strength decreases with increasing percentage of rubber fibers at all selected w/c ratios. The density of both gum ash concrete and modified concrete decreases as the level of substitution increases the wear depth of gum ash concrete and modified concrete is affected by the incorporation of gum ash and gum fiber. Carbonation depth in gum ash concrete and modified concrete increases with increasing substitution level. Decreases in static and dynamic moduli indicate higher flexibility, which can be seen as a positive increase in rubberized concrete mixes. The concentration of chloride ions was very low in the downstream cells of each rubberized concrete mix [29].

Awan et al. (2021) work on experimental analysis of concrete-used crumb rubber that has been pretreated and untreated. In this studies CRC is treated with lime, NaOH, detergent and water. A 250% increase in slump and a 14% increase in compressibility were recorded when 20% CR was used instead of sand. The addition of CR increased the water absorption, with a maximum water absorption of 10.23% recorded after 7 days with 20% sand replacement, and decreased with increasing curing time, reaching a maximum of 8.69% at 28 days. did. The density of concrete decreased to 1869 kg/m3 and 1881 kg/m3 at 7 and 28 days, respectively, at 20% replacement. Lime treatment recovered 10.30% compressive strength after 28 days and 9.16% tensile strength after 28 days. The detergent treatment was found to be the worst treatment of all four treatment methods [30].

CHAPTER 3
EXPERIMENTAL METHODOLOGY

3.1 Introduction

In this chapter we discuss about different sorts of experiments which required to determine the characteristic of ingredient of concrete and to choose the properties of crumb rubber in concrete.

3.2 Properties of element of concrete

In our thesis work we not only used common element of concrete but also used crumb rubber partially both as coarse aggregate and fine aggregate.

1) Cement
2) Water
3) aggregate

(i) Coarse aggregate

- Stone chips
- Crumb Rubber

(ii) Fine aggregate

- Sand
- Crumb Rubber

3.2.1 Cement

A chemical substance called cement is used in construction because it hardens, sets, and adheres to other materials including stone, sand etc. In most cases, cement is used to bind sand and gravel (aggregate), not on its own. Inorganic cements are typically used in construction; they frequently have a lime or calcium silicate base. In our work we use Premier cement, which is Portland Composite Cement (PCC) CEM II/ B-M, Strength Class 42.5N, Clinker: 65-79%, Fly ash, Slag & Limestone: 21-35% and Gypsum: 0-5%. It is manufactured by premier cement mills PLC.

The one of a kind houses of cement is provided in Table 3.1

Table 3.1: Properties of Cement

Physical properties	***Test Results***
Standard Consistency	31%
Specific Gravity	3.15 g/cc
Initial Setting Time	30 min
Final Setting Time	600 min

3.2.2 AGGREGATE

In order to create mortar or concrete, granular materials called aggregate—such as sand, gravel, or crushed stone are combined with a hydraulic cementing agent. There are various types of aggregates, such as coarse and fine aggregate. For grading aggregate for use in concrete and other applications, sieve analysis is utilized.

i. Coarse aggregate
   a. Stone chips
   b. Crumb Rubber
ii. Fine aggregate
   a. Sand
   b. Crumb Rubber

3.2.2.1 Fine Aggregate

Fine aggregate is so small that it can pass through a 4.75mm sieve. In the construction sector, it is utilized to produce more concrete. Additionally, it uses materials that are less expensive. In this study we use both Sylhet sand and fine crumb rubber as fine aggregate and conduct all tests as per ASTM.

  

Fig.3.1 Discard Tires **Fig.3.2** Recycled Crumb Rubber **Fig. 3.3** Sand

3.2.2.2 Coarse Aggregate

Coarse aggregate is defined as aggregate with a size more than or equal to 4.75 mm on the IS Sieve. In this study we use hard stone chips and crumb rubber as coarse aggregate. And this material have been tasted according to ASTM.

 

Fig.3.4 Stone aggregate **Fig.3.5** Coarse Crumb Rubber

3.2.3 Water

Water is very crucial for mixing concrete mortar in a target strength. It all component fell effect on concrete strength so that is essential to use pure water in concrete mixing. In this study we use distill water.

3.4 Tests of Aggregate

The following tests were done to decide the properties of both fine and coarse aggregate:

Tests for Coarse aggregate:

(i) Sieve analysis of coarse aggregate.
(ii) Unit weight
  a) Dry
  b) SSD
(iii)Crushing test of stone aggregate

Test for fine aggregate:

i. Sieve analysis of fine aggregate.
ii. Unit Weight
  a) Dry
  b) SSD
iii. Specific Gravity

3.4.1 Sieve analysis of Coarse aggregate

Sieve analysis of coarse aggregate is use to classify the size distribution and fineness modulus of given coarse aggregate. This test method conforms as per the ASTM standard requirements of specification C136. The procedure is listed below:

Step 1:

At first, we take 2000gm and 500gm sand and crumb rubber respectively. And dry the sand at 110^0 C temperature for dry. After proper dry we measure.

Step 2:

Set the all sieves as decreasing order like 3in, 3/2in, 3/4in, 3/8in, #4, #8, #16, #30, #50, #100, and pan. After that we put the material on sieve.

Step 3:

We shake the sieve manually by hand around 15min. It is confirmed by us that we shake properly

(motion in all directions forward, backward, left, right, clockwise, counterclockwise and a lot of jolting).

Step 4:

After completing speaking we weighing the aggregate retained each sieve by digital balance to nearest 0.1%cof weight of sample. And we check the total weight after shaking and make sure it is close to its initial weight.

Step 5:

Then we explore the data and find fineness modulus using this formula-

$$FM= \frac{\sum \text{Cumulative \% weight of retained}}{100} \quad \text{………………. (3.1)}$$

The test data and graph of sieve analysis of fine aggregate are shown in appendix: Table A3.5 with Fig. A3.5 and A36 with Fig.A.3.6respectively.

3.4.2 Specific Gravity Absorption Capacity of Fine Aggregate

The specific gravity of aggregates must be carefully determined because they typically contain pores, both permeable and impermeable. Knowing each component's specific gravity allows for the conversion of its weight into a solid volume, which allows for the potential yield of concrete per unit volume to be estimated. In addition to the workability data, the specific gravity of the aggregate must be considered when computing the compacting factor. This test procedure complies with specification C128 of the ASTM standard.

The weight of the aggregate (oven-dry or saturated surface dry) divided by the weight in air of an equivalent volume of gas-free distilled water at the specified temperature is known as the bulk specific gravity. The weight of the aggregate dried in an oven at 100 to 110^{0}C for 24 hours divided by the weight of water filling a volume equivalent to that of the solid, including the impermeable pores, is the apparent specific gravity.

When weighing an aggregate, absorption values are used to determine how much water has been absorbed in the pore spaces of the constituent particles since the aggregate was dry.

Step 1:

At first, we take 40gm of Sylhet sand for test and dry it 24 hours in an oven at a constant temperature 110^0c. After complete dry we again measure it and find 37.46 gm.

Step 2:

Then we take the weight of empty pycnometer. After that we fill the pycnometer by sand and water up to calibration line and take the weight. Then take the weight of pycnometer which is fill by water. When all data were taken we find the specific gravity and absorption capacity of fine aggregate by the formula which write below:

Bulk Sp. gravity (OD) = $\frac{A}{B+S-C}$

Bulk sp. gravity (SSD) = $\frac{S}{B+S-C}$

Apparent sp. gravity = $\frac{A}{B+A-C}$

Here,

A = weight of oven-dry specimen in air, gm,

B = weight of pycnometer filled with water, gm,

S = weight of the saturated surface-dry specimen in air, gm and

C = weight of pycnometer with specimen and water to calibration mark, gm.

Absorption (%) = $\frac{S-A}{A} X100$

Fig.3.6 Determination of specific gravity

In appendix Table A3.9, the test results and calculations of Sylhet sand's specific gravity and water absorption capacity are presented. The values of specific gravity and water absorption capacity of Sylhet sand are given in the Table 3.2.

3.4.3 Unit Weight of Aggregate

The unit weight of compacted or loose fine and coarse aggregates can be determined using this test procedure. Values based on aggregates in a dry condition are produced by the technique. When choosing proportions for concrete mixtures, many procedures require the use of aggregate unit weight numbers. They can also be used to compute aggregate void percentages and establish mass/volume correlations for conversions. According to this test procedure, voids without any particles permeable or impermeable are not considered to be voids. This test method conforms to the ASTM standard requirements of specification C29.

Procedure:

In oven dry method we drying our material after tasting at a constant temperature 110^0c but in SSD method we didn’t. Measure one-third of the way full, then use your fingertips to smooth the top. 25 uniformly spaced tamping rod strokes should be applied to the layer of aggregate. Fill the measure two-thirds full, level it again, and rod it as before. Finally, fill the measure to the brim and rod once more in the method described earlier. With your fingers or a straightedge, level the aggregate's surface so that any tiny protrusions from the larger pieces of coarse aggregate roughly balance the larger voids in the surface beneath the top of the measure. Be careful not to forcefully strike the bottom of the measure when rodding the first layer. Use a lot of force when rodding the second and third layers, but avoid using enough pressure to allow the temping rod to pierce the layer of aggregate beneath. Record the figures to the closest 0.1lb and then calculate the mass of the measure plus its contents and the mass of the measure alone. Using this procedure, we find unit weight of all materials including sand, stone as well as crumb rubber both as fine and coarse aggregate. Then find the unit weight of aggregate by using this formula:

$$M = \frac{G-T}{V}$$

Where,

M= Unit weight of the aggregate, lb/ft3 (kg/m3),

G=Mass of the aggregate plus the measure, lb. (kg),

T= Mass of the measure, lb. (kg),

V=Volume of the measure, ft3 (m3)

Table 3.2 Properties of fine aggregate (Sylhet sand)

Properties	**Value**
Fineness Modulus	2.56
Specific Gravity	
Oven-Dry Basis (OD)	2.35
Saturated Surface-Dry Basis (SSD)	2.50
Water Absorption Capacity (%)	6.27%
Unit Weight	44.52 kg/ft^3

Table 3.3 Properties of fine aggregate (Crumb Rubber)

Properties		**Value**
Fineness Modulus	FCR	2.68
	MCR	4.43
	WCR	3.34
Unit Weight	FCR	13.18 kg/ft^3
	MCR	14.01 kg/ft^3
	WCR	13.6kg/ft^3

3.4.4 Sieve Analysis of Fine Aggregate

Through sieve evaluations known as aggregate grading, the particle length distribution of the aggregate is determined. If all of the aggregate's particles have the same length, the compacted mass will contain more voids, whereas an aggregate made up of particles of different sizes will result in a mass with fewer vacancies. A mass of mixture's particle length distribution must be such that the smaller debris fills the spaces between the larger debris. Dense concrete is produced by grading a mixture properly. In order to produce top-notch concrete, it is crucial that the coarse and superb mixture be nicely graded. Concrete is graded using percentages of weight maintained on or passing through a series of sieves used to simulate a fineness modulus test. The ASTM sieves come in sizes of #100, #50, #30, #16, #8, #4, 3/8 in., 3/4 in., and 1.5 in. The check method complies with specification C 136's popular ASTM requirements.

Procedure Of Sieve Analysis:

1. Take 1000gm sand and 300gm CR for testing. And dry the sand at a constant temperature 110±5^{0}C.
2. Then set all screen as sequence #4, #8, #16, #30, #50, #100 and pan and put all materials on sieve and shaking around 15min by hand.

3. Take data which is retained in each sieve by weighing by digital balance and find the FM of fine aggregate.

The test data and graph of sieve analysis of stone aggregate are shown in appendix: Table A3.3 and Fig. A3.3 respectively. Also the test data and graph of sieve analysis of crumb rubber aggregate are shown in appendix: Table A3.3 and Fig. A3.3 respectively. The values of F.M. of stone aggregate and crumb rubber aggregate are given in the Table 3.4.

Table 3.4 Properties of coarse aggregates

Common properties	**Stone Aggregate**
Fineness Modulus (F.M.)	6.95
Unit Weight	1736.56 kg/ft^3
Aggregate Crushing Value (%)	55.75%
Fineness Modulus of CCR (F.M)	7.29
Unit weight	700.2 Kg/ft^3

3.4.5 Aggregate Crushing Value

The aggregate crushing value provides a comparative assessment of an aggregate's resistance to crushing under a compressive load that is gradually applied. The result may be anomalous when the aggregate has an aggregate crushing value greater than 30, in which case the value for the ten percent penalty should be established.
Aggregate passing the 14.0 mm BS test sieve and remaining on the 10.0 mm test sieves constitutes the required material for the standard test. Before testing, the aggregate quality must be chilled to room temperature. By conveniently filling the cylindrical measure in three layers of almost equal depth and tamping each layer 25 times from a height of about 50 mm above the aggregate's surface, the right amount may be determined.

Procedure:

At first, we place the test apparatus' cylinder in place on the base plate, then add the test sample in thirds. Each third we give 25 strikes by the tamping rod, which will be dispersed equally across the layer's surface and will be dropped from a height of about 50 mm above the aggregate's surface. In order to prevent the plunger from jamming in the cylinder, we make sure the surface of the aggregate is level before inserting it so that it lies horizontally on it. After that we place the apparatus between the testing machine's plates with the test sample and plunger in place, and then load it gradually so that the necessary force is attained in 10 minutes. 400kN of force is provided. Then we holding the cylinder over a clean tray, pound on the outside with a good rubber mallet until the sample particles are sufficiently disturbed to allow the mass of the sample to fall freely into the tray. Then release the load and remove the crushed material. We use a stiff bristle brush to transfer any fine particles stuck to the base plate, the plunger's bottom, or the interior of the cylinder to the tray. On the 2.36 mm BS test sieve, sieve the entire material in the tray until no more appreciable amount passes in one minute. Calculate the percentage that passed the sieve. To prevent losing fines, we did all work with caution in all of these actions.

Percent of fines: $\frac{B}{A} * 100$

Here,

A is the mass of surface dry sample (gm)

B is the mass of the fraction passing the 2.36 mm BS test sieve (gm)

3.5 Concrete Mix Design

Concrete design is just the process of selecting the right components and figuring out how much of each is needed to produce high-quality concrete. The basic goal of concrete mix design is to create concrete that is strong enough to be useful. The most of the method of mix design are empirical relation basis, chart and graphs which are developed from experimental examinations. In our research, we use ACI mix design. For the purpose of working conveniently, the mix proportion was decided upon as 1:1.5:3 using the steps of the ACI technique of mixing proportioning for M35 grade concrete.

Table 3.5 Quantity of materials for each batch of mixing

Quantity of Materials for each batch of mixing							
	CR %	**Cement**	**Sand**	**CR**	**Stone**	**Water**	**Total**
		Kg	**Kg**	**Kg**	**Kg**	**kg**	**Kg**
FA	NCR-0%	1.63	3.24	0.00	11.07	0.766	15.94
	FCR-5%	1.63	3.08	0.16	11.07	0.766	15.94
	FCR-10%	1.63	2.92	0.32	11.07	0.766	15.94
	FCR-15%	1.63	2.75	0.49	11.07	0.766	15.94
	MCR-5%	1.63	3.08	0.16	11.07	0.766	15.94
	MCR-10%	1.63	2.92	0.32	11.07	0.766	15.94
	MCR-15%	1.63	2.75	0.49	11.07	0.766	15.94
	WCR-5%	1.63	3.08	0.16	11.07	0.766	15.94
	WCR-10%	1.63	2.92	0.32	11.07	0.766	15.94
	WCR-15%	1.63	2.75	0.49	11.07	0.766	15.94
CA	CCR-5%	1.63	3.08	0.16	11.07	0.766	15.94
	CCR-10%	1.63	2.92	0.32	11.07	0.766	15.94
	CCR-15%	1.63	2.75	0.49	11.07	0.766	15.94

3.6 Process Of Casting

Production of quality of concrete requires meticulous care exercised at every stage of manufacture of concrete. The quality of concrete can be controlled by following casting process properly.

The various stages of casting of test specimens are:

(a) Batching
(b) Mixing
(c) Finishing
(d) Compacting
(e) Curing

3.6.1 Batching

Production of quality of concrete requires meticulous care exercised at every stage of manufacture of concrete. The quality of concrete can be controlled by following casting process properly.

The various stages of casting of test specimens are:

(a) Batching
(b) Mixing
(c) Finishing
(d) Compacting
(e) Curing

3.6.2 Mixing

The tilting type mixer was used in this investigation to mix the concrete. The mixer rotated at a rate of roughly 15 to 20 revolutions per minute. 5–6 minutes were spent mixing. Concrete mixing is depicted in Figs. 3.6 and 3.7.

Fig.3.7 Aggregates and cement

Fig.3.8 Mixer machine for mixing

3.6.3 Slump Cone Test Of Concrete

The concrete slump test can be used to gauge how workable or consistent fresh concrete is before it hardens. Concrete is poured into a cone-shaped mold for the test, and the amount the concrete "slumps" after the mold is removed is measured. The test method conforms to the ASTM standard requirements of specification C143. In Fig.3.8, a concrete slump cone test is displayed.

Procedure:

1. During steps 1 through 4, A person in group stand on the cone's two-foot pieces to keep it securely in place. Then fill the cone mold one third by concrete and give 25 tamping using a round, straight 16mm in diameter and 600mm long. He give the tamping uniformly over the concrete cross section.
2. After that, fill the cone to around two-thirds of its volume and rod 25 more times, each time only reaching the first layer, not previous layer. Apply even pressure while following Step one's instructions.
3. Then we fill the cone to the brim and then 25 more times with the rod, just piercing the second layer but not through it. Distribute your strokes equally once more.
4. After that with the steel rod, we remove any extra concrete from the cone's top so that it is completely level. Clear the overflow from the cone mold's base.
5. As soon as possible, we carefully lift the mold vertically away from the concrete. Raise the mold 300 mm in 5±2 seconds by steadily lifting it upward without any lateral or torsional movement. Complete the full test, from the beginning of the filling to the removal of the mold, without pausing, and in less than two and a half minutes. We measure the droop as soon as possible by figuring out the vertical distance between the mold's top and the specimen's top surface's original center that has been moved.

Table 3.6 Slump value for various % of Crumb Rubber

% of Crumb Rubber		Water Cement Ratio	Slump Value(mm)
CR	0%	0.47	82
Fine Aggregate	FCR 5%		57
	FCE 10%		73
	FCR 15%		87
	MCR 5%		50
	MCR 10%		72
	MCR 15%		62
	WCR 5%		93
	WCR 10%		55
	WCR 15%		73
Coarse Aggregate	CCR 5%		92
	CCR 10%		72
	CCR 15%		100

3.6.4 Compaction of Concrete

The process of compaction pushes the aggregate particles closer together and releases trapped air from freshly placed concrete, increasing the density of the concrete. It significantly strengthens concrete's ultimate strength and strengthens the bond with reinforcement.

3.6.5 Curing Of Concrete

Fresh concrete strengthens most quickly in the first few days and weeks after placement. On average, structural designs are based on 28 days of strength, of which about 70% is attained by the end of the first week. The moisture and temperature conditions during this initial period have a significant impact on the final concrete strength. Immersion of specimens in water is the best method for water curing because it satisfies all curing requirements, including hydration promotion, shrinkage elimination, and heat absorption during hydration. The specimens in the study were submerged in water for 28 days.

3.7.1 Compressive Strength Test

Using 100mm x 200mm cylinder specimens, the compressive strength test was decided in accordance with ASTM C 39/C 39M. The samples were tested after twenty-eight days of curing. Within the compression test, a Universal Testing Machine (UTM) with a 1000 kN load potential was used, and the loading rate was set to 1 kN/s. The specimen's maximum crushing load was applied using the compression machine. Fig. 3.9 illustrates the compressive power at its operational level. As shown in the following equation, the compressive force (cf) was computed by dividing the crushing load by the test specimen's contact area.

$$f_c' = \frac{P}{A_c} \qquad (3.2)$$

Where,

P = Crushing load (N)

A_c = Contact area of specimen (mm^2)

The values of compressive strength of concrete with various percentages of are given in appendix: Table A3.4.

Fig. 3.9 Compressive strength test set up

3.7.2 Spilt Tensile Strength Test

The capacity of concrete to withstand tensile stress or force is known as its tensile strength. The split cylinder test of the concrete method is used to determine the tensile strength of concrete. The units of force per cross-sectional area (Mpa) are used to calculate the tensile strength of concrete. As is common knowledge, concrete performs well under compression but poorly under stress. Concrete reinforcement has been added as a counterweight to this circumstance to stop cracks from forming. The test procedure complies with the cylinder specification C496 standards of the ASTM standard and use 4inch x 8inch cylinder specimens.

Calculate the splitting tensile strength of the specimen as follows:

$$T = \frac{2P}{\pi * ld}$$

Where,

T = Splitting tensile strength, psi [MPa]

P = Maximum applied load indicated by testing machine, lbf [N]

l = length, in. [mm]

d = diameter, in. [mm]

CHAPTER 4

TEST RESULTS AND ANALYSIS

4.1 General

A crucial task in monitoring and validating the quality of cement concrete work is testing hardened concrete. 39 of the 78 well-known cylinder specimens were evaluated to determine the compressive strength and modulus of elasticity in order to complete this examination of the entire set of 78 well-known cylinder specimens. In addition, 39 more pieces were looked at before the Spilt Tensile Strength Test was made. All of the cylindrical specimens underwent compressive strength, split tensile, and modulus of elasticity tests in ordinary water after twenty-eight days of curing.

4.2 Properties of The Recycled Concrete

4.2.1 Compressive Strength

Table 4.1 presents the test findings for compressive strength after 28 days of curing, a nd Fig. 4.1 shows the fluctuation in compressive strength of concrete with different a mounts of crumb rubber as fine and coarse aggregate. The compressive strength of N CR, FCR, MCR, WCR, and CCR specimens with different percentages of crumb rubb er demonstrates that at some point, the compressive strength of concrete stopped incre asing and began to decline. The WCR exhibits the maximum strength of all the speci mens, whilst the CCR exhibits the lowest strength. However, the rate of compressive strength loss is minimal, which may have been caused by a weakened bond between the waste's surface and the cement paste.

The compressive strength was tested using the procedure below:
Prior to testing, the samples were taken out of the water bath and let to air dry for 24 hours. After that, the cylinders were positioned underneath the UTM loading head and centered. The specimen received the load. When the cylinders fail, the UTM delivers the maximum load (kN). Recently, the machine was calibrated, and it was discovered to be 1% accurate. The results of the load were recorded, and by dividing the maximum load at failure by the typical cross-sectional area of the cylinder, the compressive strength of the concrete was estimated.

Fig.4.1 Cylinder under Compressive strength test in UTM

The information was finally gathered for analysis. Fig. 4.1 provides some images of the cylinder compressive strength test. Concrete testing enables us to assess concrete's capacity to withstand compressive stresses within structures, whereas axial and tensile stresses are addressed by reinforcing and other techniques. This allows us to concentrate on concrete's compressive strength.

Fig.4.2 Cylinder after compressive strength test

Table 4.1 Compressive strength of concrete with different % of crumb rubber

% of crumb rubber	Compressive Strength									
	NCR		FCR		MCR		WCR		CCR	
	Mpa	Psi	Mpa	Psi	Mpa	Psi	Mpa	Psi	Mpa	Psi
0	29.96	4305.1	-	-	-	-	-	-	-	-
5	-	-	26.28	3811.16	27.75	4023.6	26.36	3822.9	17.01	2466.19
10	-	-	24.30	3523.6	25.92	3758.7	24.73	3585.8	16.41	2379.8
15	-	-	21.49	3115.45	21.43	3107.7	21.51	3118.7	16.06	2329.14

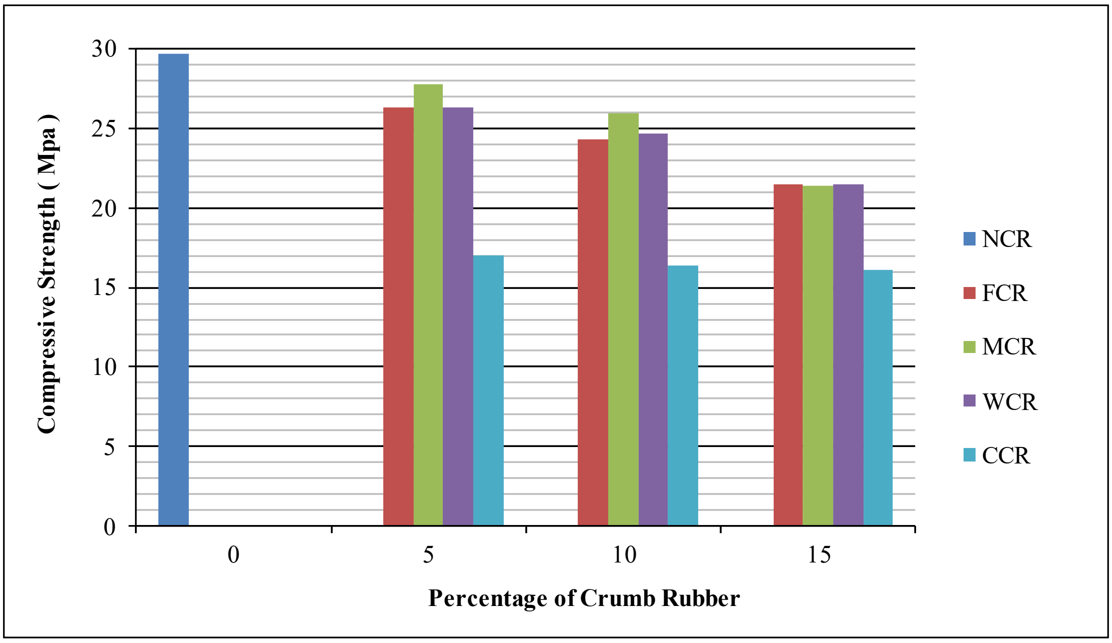

Fig. 4.3 Concrete's compressive strength varies with different percentages of crumb rubber.

According to the correlation illustrated in Fig. 4.3, the compressive strength of concrete formed with stone aggregate and fine aggregate decreases as the percentage of crumb rubber increases. Compared FCR with NCR the strength of concrete replacement 5% and 15% is decreased 1.75% and 8.84% respectively. Whereas use rubber as FCR 10% is rise to 4.5%. As well as MCR 5%, 10% and 15% gives the strength value higher than NCR to 40% 31.5% and 7.5% respectively. Again, compare the strength of WCR with

NCR the compressive strength is increased by 29.8%,25.5% and 5.8%. Using crumb rubber as CCR the strength is decreased 17.5%, 17% and 24.5% for 5%, 10% and 15% of CCR which is compared with NCR. Compared with over all fine aggregate and coarse aggregate the strength value of concrete which partially replace by crumb rubber as fine aggregate gives higher strength than which is replace by coarse aggregate up to 43.5%.

4.2.2 Spilt Tensile Strength Test

The splitting tensile test evaluates the concrete's direct tensile strength in an indirect manner. The findings of the splitting tensile strength tests for concrete containing various percentages of crumb rubber as fine and coarse aggregate are summarized in Table 4.2. As can be observed, as the amount of crumb rubber used increases, consequently the splitting tensile strength are increased. On the other side, as crumb rubber content increases, some spots' tensile strength also decreases. It is important to note that employing MCR at 5% in conventional concrete results in the maximum tensile strength of 3.38 Mpa. The lowest, which is 1.70 Mpa, is produced by CCR 5%.

The spilt tensile strength was tested using the procedure below:

We made the concrete mix for casting the cylindrical specimen at the first step. Then we give grease the interior of the mold, then pour the mixture into it in layers. Then we tamp down each layer with a rod. 15 taps on each layer. We remove any extra concrete by giving the mixture a uniform stroke. After that we out the specimen from the mold and submerged in freshwater. After 28 days of curing, concrete's splitting tensile strength has been tested. We remove the specimen from the water and wipe it dry before beginning the test. Next, we record the specimen's size and weight. We attach plywood to the specimen's top and bottom. Next, set the sample on the testing device. Apply load then gradually between 0.7 and 1.4 MPa/min. We Keep track of the specimen's breaking load.

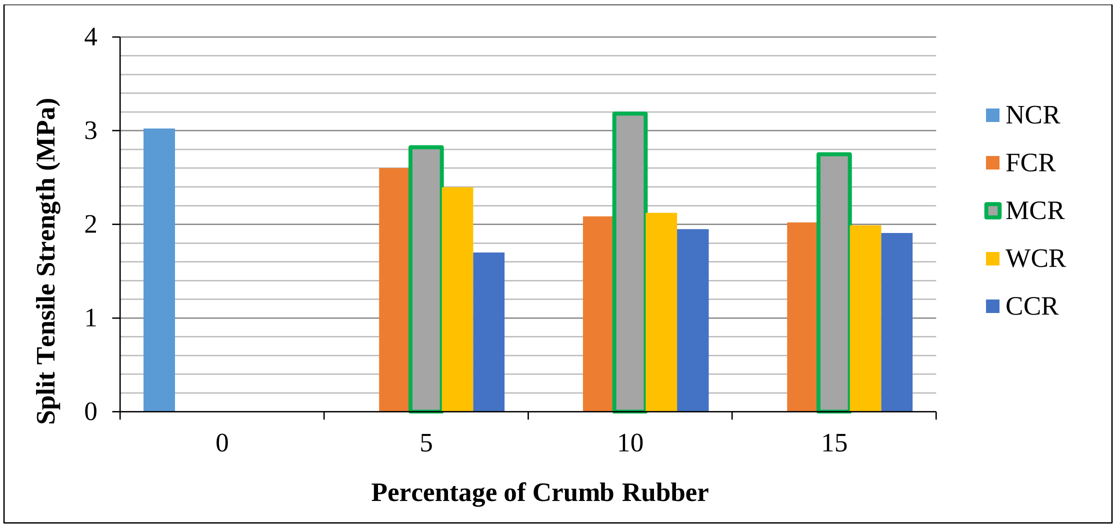

Fig. 4.4 Variation of spilt tensile strength of concrete with various % of Crumb Rubber.

The Spilt tensile strength of concrete built with partial replacement with stone aggregate and with sand has been shown in Fig. 4.4 to occasionally decrease and occasionally rise with an increase in the percent of crumb rubber (0%, 5%, 10%, 15%). Compared FCR with NCR the tensile strength of concrete replacement 5%,10% and 15% is decreased by1.12% and 820.68% and 23% respectively. As well as 5% , 10% and 15% of MCR gives the strength value higher than NCR to 7.94% 28.48% and 4.82% respectively for MCR 5%,10% and 15%. Again, compare the strength of WCR with NCR the compressive strength is increased by 29.8%,25.5% and 5.8%. Using crumb rubber as CCR the strength is decreased 17.5%, 17% and 24.5% for 5%, 10% and 15% of CCR which is compared with NCR. Compared with over all fine aggregate and coarse aggregate the strength value of concrete which partially replace by crumb rubber as fine aggregate gives higher strength than which is replace by coarse aggregate up to 43.5%.

Table 4.2 Spilt tensile strength of concrete with different % of crumb rubber

% of crumb rubber	**Spilt Tensile Strength Test**									
	NCR		**FCR**		**MCR**		**WCR**		**CCR**	
	Mpa	Psi	Mpa	Psi	Mpa	Psi	Mpa	Psi	Mpa	Psi
0	3.02	438.29	-	-	-	-	-	-	-	-
5	-	-	2.60	377.04	2.82	409.33	2.40	347.34	1.70	246.21
10	-	-	2.09	302.44	3.18	461.56	2.12	307.70	1.95	282.84
15	-	-	2.02	293.26	2.75	398.47	1.99	288.45	1.91	276.91

CHAPTER 5
DISCUSSION AND CONCLUSION

5.1 General

The goal of this study was to assess the workability parameters of fresh concrete mixes with FCR, MCR, WCR as well as CCR as well as the strength performance of mortar mixes containing various amounts of crumb rubber, both as fine aggregate and coarse aggregate. After 28 days, the qualities of the mixtures were assessed. These mixtures were created in 1:15:3 ratios and contained varying amounts of crumb rubber including FCR, MCR WCR and CCR. The characteristics of compressive strength and tensile strength were examined. awareness of environmental concerns and a balance between the economy and utilizing sand and stone from natural mines. As a result, leftover crumb rubber is now used as a component of concrete mixtures. The study has suggested using crumb rubber in place of fine and coarse aggregate in concrete.

5.2 Conclusion

From the test results and analysis, the following conclusion has been drawn for recycled crumb rubbers as different type of fine aggregate coarse aggregate in concrete:

a) Compressive strength of concrete reduced with the increased the all type of waste crumb rubber in traditional concrete.

b) The different size of crumb rubber particles has significant impact on mechanical properties of CRC. In term of performance, crumb rubber use as replacement of sand provide better performance than use as coarse aggregate as replacement of stone. In this study, the practical which retain on sieve #8 and #16 i.e. MCR behave better than which retain on sieve #30, #50 and #100 i.e. FCR.

c) In term of CRC, MCR provide better value than other CR particle used as fine and coarse aggregate, however using crumb rubber both as fine aggregate and coarse decreased the compressive strength compared with normal concrete. After 28 days the value of compressive strength was 27.75 Mpa, 25.92 Mpa and 21.43 Mpa for 5%, 10% and 15% replacement the concert by MCR. On the other hand NCR showed 29.69 Mpa which is higher then all compressive strength. When we partly replace stone by crumb rubber (CCR) it gives us low compressive strength compare with normal concrete and CRC which is replaced by fine crumb rubber to 17.01 Mpa, 16.41 Mpa, and 16.06 Mpa for 5%, 10% and 15% of CCR. When we use

WCR in concrete partially it provides 11.20%, 16.70% and 27.56% lower compressive strength than traditional concrete for 5%, 10% and 15% of WCR replacing.

d) In addition, in many case CRC use in concrete reduce the spilt tensile strength of concrete if we compare with normal concrete except MCR which is seen to a gradual increase. After 28 days curing the NCR give 3.02 Mpa tensile strength which is 26.02%, 3.46%, 28.24% and 38.70% higher than FCR, MCR, WCR and CCR respectively. Although, overall decrease was observed but only except while we use MCR 10% it produce higher value than NCR that is 5.30%. Overall with increasing the percent of crumb rubber both as fine and coarse aggregate the tensile strength decreased. So, it is concluded that 5-10% replacement of MCR appropriate for application to structures.

5.3 Recommendations For Further Studies

It is strongly advised to conduct additional research and testing on crumb rubber concrete to determine its strengths and suitability for use in structures. Following are some suggestions for additional research:

- In terms of, it is possible to employ an additive to boost CRC's strength and look at the characteristics of concrete.
- Different water/cement ratios can be utilized to explore the qualities of concrete because they have a significant impact on the strength of concrete.
- It is also advised to conduct additional research and laboratory testing to better understand the properties of recycled crumb rubber, such as flexural strength, air content in concrete, water absorption capacity, and creep of concrete.
- To obtain varied results, more experiments with various particle sizes, treated and untreated rubber, and percentages of recycled crumb rubber are advised.

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APPENDIX

Table A3.1 Grain size analysis of sylhet sand

Sieve No.	Sieve size (mm)	Wt. of retained (gm)	% wt of retained	Cumulative % wt. of retained	% of finer	F.M
#4	4.75	18.11	1.811	1.811	100	2.564
#8	2.36	82.66	8.266	10.077	89.923	
#16	1.18	116.55	11.655	21.732	78.268	
#30	0.6	201.85	20.185	41.917	58.083	
#50	0.3	430.56	43.056	84.973	15.027	
#100	0.15	127.622	12.7622	97.74	2.26	
#200	0.075	22.65	2.265	100	100	
Total		**1000**		**256.43**		

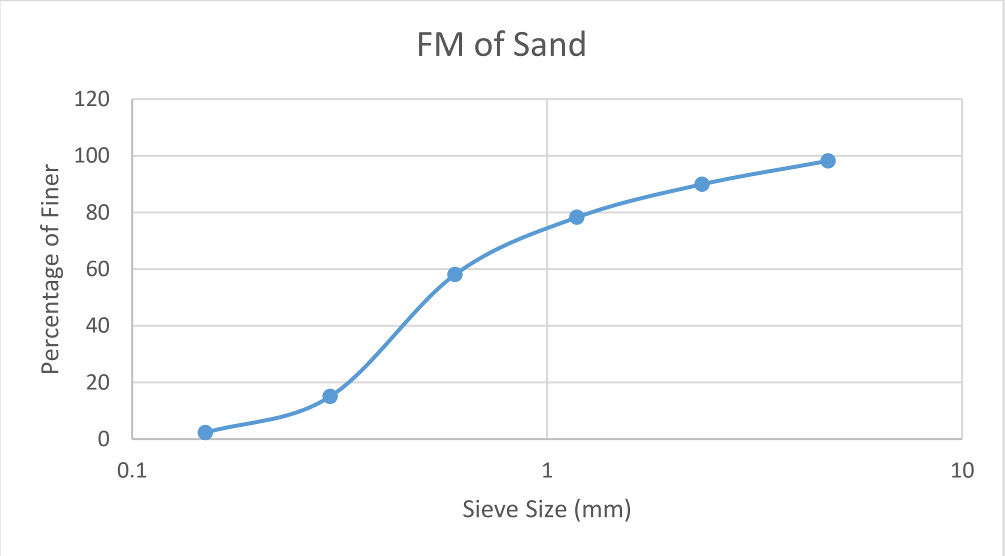

Fig. A3.1 Grain size distribution curve of Sylhet sand

Table A3.2 Grain size analysis of FCR

Sieve No.	Sieve size (mm)	Wt. of retained (gm)	% wt of retained	Cumulative % wt. of retained	% of finer	F.M
#4	4.75	0	0	0	100	2.68
#8	2.36	0	0	0	100	
#16	1.18	0	0	0	100	
#30	0.6	222.75	74.25	74.25	25.75	
#50	0.3	60.21	20.07	94.32	5.68	
#100	0.15	15.82	5.27	99.593	0.467	
#200	0.075	1.24	0.41	100	0	
Total		**300**		**268.163**		

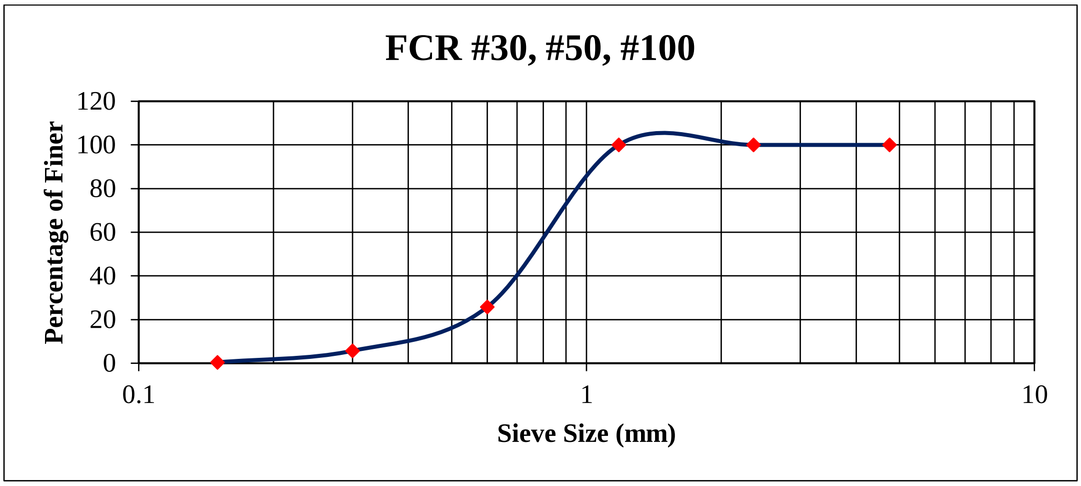

Fig. A3.2 Grain size distribution curve of FCR

Table A3.3 Grain size analysis of MCR

Sieve No.	Sieve size (mm)	Wt. of retained (gm)	% wt of retained	Cumulative % wt. of retained	% of finer	F.M
#4	4.75	0	0	0	100	4.43
#8	2.36	129.21	43.07	43.07	56.93	
#16	1.18	170.79	56.92	100	0	
#30	0.6	0	0	100	0	
#50	0.3	0	0	100	0	
#100	0.15	0	0	100	0	
#200	0.075	0	0	100	0	
Total		**300**		**443.07**		

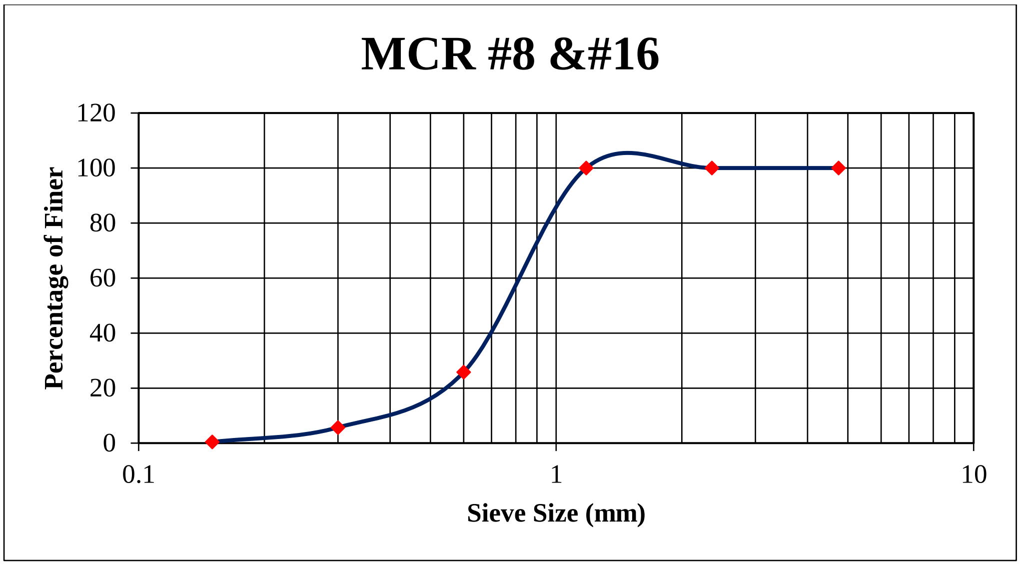

Fig. A3.3 Grain size distribution curve of MCR

Table A3.4 Grain size analysis of WCR

Sieve No.	Sieve size (mm)	Wt. of retained (gm)	% wt of retained	Cumulative % wt. of retained	% of finer	F.M
#4	4.75	0	0	0	100	**3.341**
#8	2.36	33.05	11.02	11.02	88.98	
#16	1.18	131.53	43.84	54.86	45.14	
#30	0.6	60.13	20.04	74.90	25.097	
#50	0.3	57.47	19.16	94.065	5.94	
#100	0.15	15.62	5.21	99.27	0.733	
#200	0.075	1.59	0.53	100	100	
Total		**300**		**334.11**		

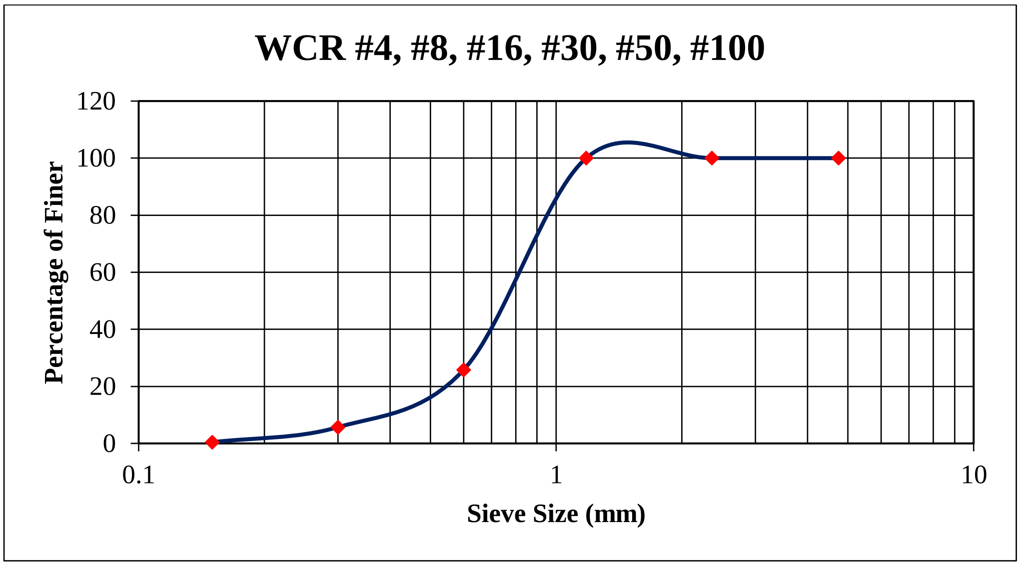

Fig. A3.4 Grain size distribution curve of WCR

Table A3.5 Gradation of coarse aggregate (stone)

Sieve No.	Sieve size (mm)	Wt. of retained (gm)	% wt of retained	cumulative % wt. of retained	% of finer	F.M
3”	50	0	0	0	100	6.95
3/2”	37.5	0	0	0	100	
¾”	19.5	104.37	5.2185	5.2185	94.7815	
3/8"	9.5	1700.21	85.011	90.229	9.771	
#4	4.75	195.37	9.77	99.9975	0.0025	
#8	2.36	0.05	0.0025	100	0	
#16	1.18	0	0	100	0	
#30	0.6	0	0	100	0	
#50	0.3	0	0	100	0	
#100	0.15	0	0	100	0	
Pan	-	-	-	-	-	
Total		**2000**		**695.445**		

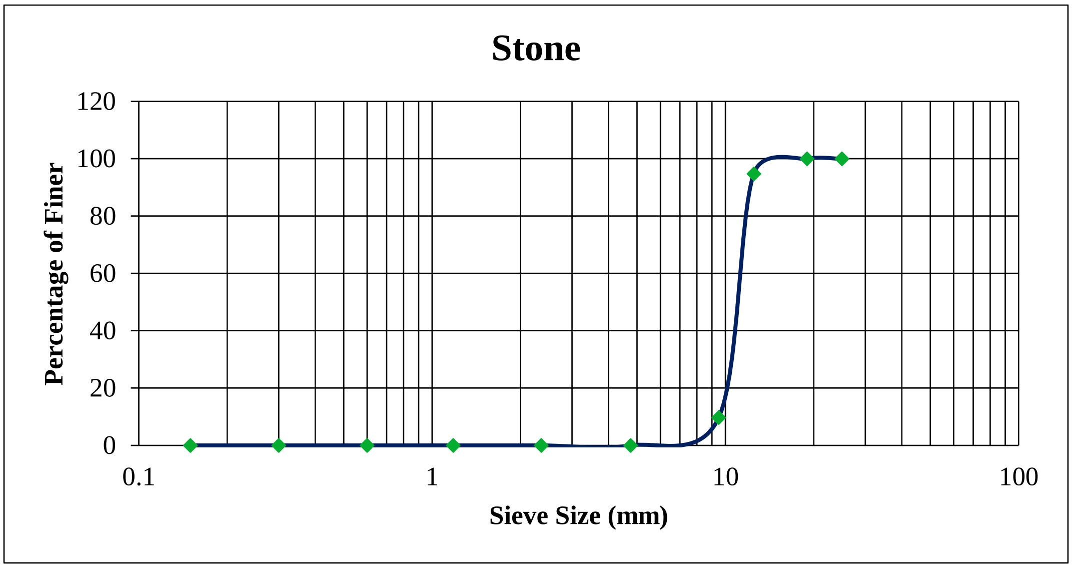

Fig. A3.5 Grain size distribution curve of stone aggregate

Table A3.6 Gradation of coarse aggregate (CCR)

Sieve No.	Sieve size (mm)	Wt. of retained (gm)	% wt of retained	cumulative % wt. of retained	% of finer	F.M
3”	50	0	0	0	100	7.29
3/2”	37.5	0	0	0	100	
¾”	19.5	147.43	29.486	29.486	70.514	
3/8"	9.5	352.57	70.514	100	0	
#4	4.75	0	0	100	0	
#8	2.36	0	0	100	0	
#16	1.18	0	0	100	0	
#30	0.6	0	0	100	0	
#50	0.3	0	0	100	0	
#100	0.15	0	0	100	0	
Pan	-	-	-	-	-	
Total		**500**		**729.486**		

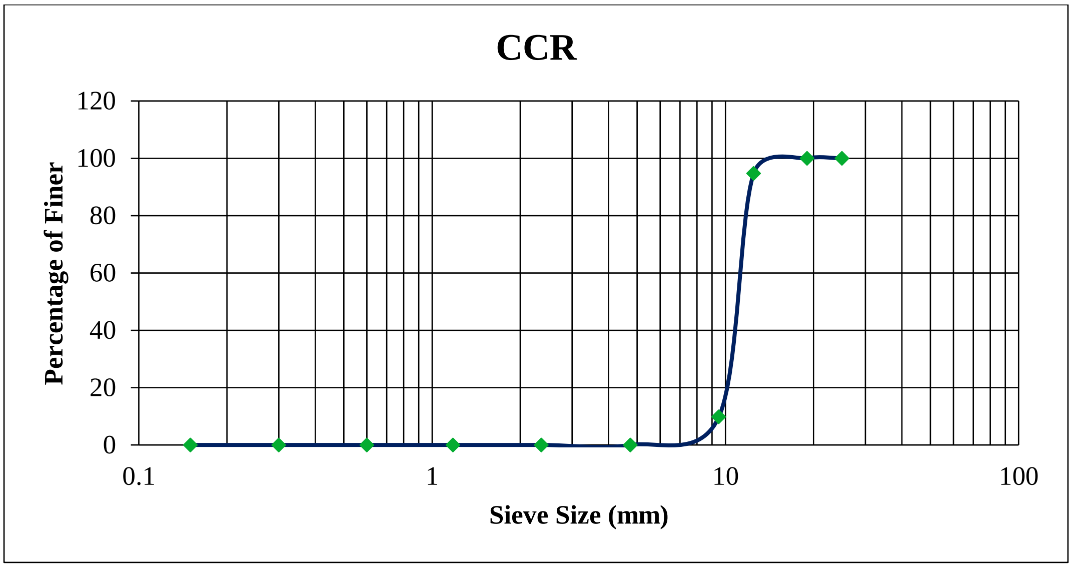

Fig. A3.6 Grain size distribution curve of coarse aggregate(CCR)

Table A3.7 Compressive strength of concrete with different % of crumb rubber

% of CR	NCR						
	sample	**dia** cm	**area** sqmm	**load** KN	**strength** Mpa	**avg. strength** Mpa	psi
0							
	NCR	10.1	8011.9	216.03	26.96	**29.69**	**4305.09**
	NCR	10	7854.0	254.869	32.45		
	NCR	10	7854.0	232.92	29.66		

% of CR	FCR						
	sample	**dia** cm	**area** sqmm	**load** KN	**strength** Mpa	**avg. strength** Mpa	psi
5	FCR5	10	7854.00	199.1517	25.36	**26.28**	**3811.16**
	FCR5	10	7854.00	217.9598	27.75		
	FCR5	10.1	8011.87	206.2536	25.74		
10	FCR10	10.1	8011.87	195.7908	24.44	**24.30**	**3523.56**
	FCR10	10.1	8011.87	205.2458	25.62		
	FCR10	10.2	8171.30	186.6814	22.85		
15	FCR15	10	7854.00	165.2817	21.04	**21.49**	**3115.45**
	FCR15	10.1	8011.87	186.6814	23.30		
	FCR15	10	7854.00	157.9653	20.11		

% of CR	MCR						
	sample	**dia** cm	**area** sqmm	**load** KN	**strength** Mpa	**avg. strength** Mpa	psi
5	MCR5	9.9	7697.71	211.5598	27.48	**27.75**	**4023.65**
	MCR5	10	7854.00	220.5646	28.08		
	MCR5	10.2	8171.30	226.1926	27.68		
10	MCR10	10	7854.00	205.9318	26.22	**25.92**	**3758.75**
	MCR10	10.1	8011.87	207.0574	25.84		
	MCR10	10.1	8011.87	205.9318	25.70		
15	MCR15	10.2	8171.30	176.662	21.62	**21.43**	**3107.69**
	MCR15	9.9	7697.71	163.159	21.20		
	MCR15	9.8	7542.98	162.0334	21.48		

% of CR	WCR						
	sample	dia cm	area sqmm	load KN	strength Mpa	avg. strength Mpa	avg. strength psi
5	WCR5	9.9	7697.71	223.9414	29.09	**26.36**	**3822.89**
	WCR5	10	7854.00	205.9318	26.22		
	WCR5	10.2	8171.30	194.3328	23.78		
10	WCR10	10	7854.00	180.043	22.92	**24.73**	**3585.85**
	WCR10	10.1	8011.87	209.3086	26.12		
	WCR10	10.1	8011.87	201.4294	25.14		
15	WCR15	10	7854.00	205.9318	26.22	**21.51**	**3118.69**
	WCR15	9.9	7697.71	180.043	23.39		
	WCR15	9.8	7542.98	112.507	14.92		

% of CR	CCR						
	sample	dia cm	area sqmm	load KN	strength Mpa	avg. strength Mpa	avg. strength psi
5	CCR5	9.9	7697.71	120.386	15.64	**17.01**	**2466.19**
	CCR5	10	7854.00	131.642	16.76		
	CCR5	10	7854.00	146.275	18.62		
10	CCR10	10	7854.00	133.893	17.05	**16.41**	**2379.77**
	CCR10	10.1	8011.87	131.642	16.43		
	CCR10	10	7854.00	123.763	15.76		
15	CCR15	10	7854.00	127.14	16.19	**16.06**	**2329.14**
	CCR15	10	7854.00	137.27	17.48		
	CCR15	10	7854.00	114.067	14.52		

Table A3.8 Spilt tensile strength of concrete with different % of crumb rubber

% of CR	NCR						
	sample	di a cm	height cm	load KN	strength Mpa	avg. strength Mp a	avg. strength psi
0							
	NCR	9.9	20.80	81.875	2.53	**3.02**	**438.29**
	NCR	10	20.30	101.47	3.18		
	NCR	9.9	20.40	106.42	3.35		

% of CR	FCR						
	sample	dia cm	height cm	load KN	strength Mpa	avg. strength	
						Mpa	psi
5	FCR5	10	20.10	92.246	2.92	**2.60**	**377.04**
	FCR5	10.1	20.10	78.739	2.47		
	FCR5	10	20.80	78.739	2.41		
10	FCR10	10	21.00	53.976	1.64	**2.09**	**302.44**
	FCR10	10.1	20.90	78.739	2.37		
	FCR10	10	20.40	71.985	2.25		
10	FCR15	9.9	20.70	60.729	1.89	**2.02**	**293.26**
	FCR15	10	20.10	58.478	1.85		
	FCR15	9.9	20.50	74.237	2.33		

% of CR	MCR						
	sample	dia cm	height cm	load KN	strength Mpa	avg. strength	
						Mpa	psi
5	MCR5	10.2	20.90	105.75	3.16	**2.82**	**409.33**
	MCR5	10.1	20.80	76.49	2.32		
	MCR5	10	20.10	94.5	2.99		
10	MCR10	10.2	20.10	111.39	3.46	**3.18**	**461.56**
	MCR10	10.2	20.50	94.497	2.88		
	MCR10	10.1	20.30	103.5	3.21		
10	MCR15	10	20.40	83.24	2.60	**2.75**	**398.47**
	MCR15	10	20.60	112.51	3.48		
	MCR15	9.9	20.00	67.483	2.17		

% of CR	WCR						
	sample	dia cm	height cm	load KN	strength Mpa	avg. strength	
						Mpa	psi
5	WCR5	10.4	20.90	67.483	1.98	**2.40**	**347.34**
	WCR5	9.9	20.80	69.734	2.16		
	WCR5	9.8	20.10	94.497	3.05		
10	WCR10	9.9	20.10	65.23	2.09	**2.12**	**307.70**
	WCR10	9.9	20.50	58.48	1.83		
	WCR10	10.1	20.30	78.739	2.44		
10	WCR15	9.9	20.40	53.98	1.70	**1.99**	**288.45**
	WCR15	10	20.60	58.478	1.81		
	WCR15	9.9	20.00	76.488	2.46		

% of CR	CCR						
	sample	dia cm	height cm	load KN	strength Mpa	avg. strength	
						Mpa	psi
5	CCR5	10.4	20.90	44.971	1.32	**1.70**	**246.21**
	CCR5	9.9	20.80	53.976	1.67		
	CCR5	9.8	20.10	65.232	2.11		
10	CCR10	10	20.10	58.478	1.85	**1.95**	**282.84**
	CCR10	9.9	20.50	58.478	1.83		
	CCR10	10.1	20.30	69.734	2.17		
10	CCR15	10.3	20.40	71.98	2.18	**1.91**	**276.91**
	CCR15	10	20.60	53.976	1.67		
	CCR15	9.9	20.00	58.478	1.88		

Table A3.9 Specific gravity and water absorption capacity of Sylhet sand

Name of the item	**Quantity**	**Bulk specific gravity**		**Absorption capacity**
		SSD	**OD**	
Weight of oven-dry specimen, A	37.64 gm	2.50	2.76	2.04%
Weight of pycnometer filed with water, B	352.72 gm			
Weight of pycnometer with specimen and water, C	376.72 gm			
Weight of the saturated surface-dry specimen, S	40 gm			

Calculation:

Bulk specific gravity (Oven-Dry Basis), S_d

$$S_d = \frac{A}{(B+S)-C}$$

$$S_d = \frac{37.64}{(352.72 + 40) - 376.72} = 2.76$$

Bulk specific gravity (Saturated Surface-Dry Basis), S_s

$$S_s = \frac{S}{(B+S)-C}$$

$$S_s = \frac{40}{(352.72+40)-376.72} = 2.50$$

Absorption Capacity

$$A\% = \frac{S-A}{A} \times 100 .$$

$$A\% = \frac{40 - 37.64}{37.64} \times 100 = 6.27\%$$

Table A3.10 Aggregate Crushing Value (Stone)

AGGREGATE CRUSHING VALUE		
Weight of cylinder	587.75	gm
Weight of cylinder with materials	953.28	gm
Total materials, A	365.53	gm
Fines, B	103.75	gm
% of fines	55.74098	%
Weight retain materials	261.78	gm

Percent of fines: $\frac{B}{A} * 100$

Percent of fines: $\frac{103.75}{365.53} * 100$= 28.38%