DURABILITY ANALYSIS OF BLENDED CONCRETE AND BEHAVIOUR AT ELEVATED TEMPERATURE

A DISSERTATION

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OF

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IN

CIVIL ENGINEERING
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I, Pritam Chawla, Roll No. 2K21/STE/17 of M.Tech Structural Engineering, hereby declare that the project dissertation titled " Durability Analysis of Blended Concrete and Behaviour ate Elevated Temperatures " which is submitted by me to the Department of Civil Engineering, Delhi Technological University, Delhi in partial fulfilment of the requirement for the award of the degree of Master of Technology, is original and not copied from any source without proper citation. This work has not previously formed the basis for the award of any Degree, Diploma, Associateship, Fellowship, or other similar title or recognition.

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I hereby declare that the Project Dissertation titled “Durability Analysis of Blended Concrete and Behaviour ate Elevated Temperatures” which is submitted by Pritam Chawla, Roll No 2K21/STE/17 [Civil Engineering] Delhi Technological University, Delhi in partial fulfilment of the requirement for the award of the degree of Master in Technology, is a record of the project work carried by the student under my supervision. To the best of my knowledge this work has not been submitted in part or full for any Degree or Diploma to this university or elsewhere.

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ABSTRACT

Rubber & Sugarcane Bagasse Ash are few of the leading waste materials that needs to be recycled. Sugarcane Bagasse is being recycled into Plates & other utensils that are being used in many big brand restaurants but there is still a very huge gap between the waste disposal as well as the recycling. Not to count the Ash which is the by-product of the burning of Sugarcane Bagasse in the Sugar Industries which are either dumped in an open fil or in a pond, which in turn pollutes the air as well as the water.

Sugarcane Bagasse Ash, has good cementitious properties which can be used in the Construction Industry to replace the cement & reduce the pollution caused by it to some extent.

Waste Tyre Rubber is another material that is being used in this research. Out of 1.5 billion waste Tyres that are generated worldwide, about 6% of them are generated in India only. So, there is a gap in recycling here and there is a opportunity to benefit from it and use it as a replacement of Aggregates in the Concrete. Rubber has good Energy Absorption capacity, as well as high durability.

In this research the durability properties as well as the compressive strength of the concrete that is made by the replacement of Sugarcane Bagasse Ash with Cement & Waste Tyre Rubber Crumbs with Fine Aggregates has been examined.

For this, 15%, 20% & 25% replacement of SCBA & 10%, 20% & 30% replacement of Waste Tyre Rubber has been considered. Various tests like Mass Evaluation, Energy Absorption, Compressive Strength, Water Absorption, Chloride Attack, Carbonation, Sulphate Attack and Behaviour at Elevated Temperature on Hardened State of Concrete and Slump Test on Fresh Concrete hence achieving the optimum percentage replacement of both the materials and then the same tests were performed on the concrete made with the optimum replacement value of the materials replaced in the concrete.

From the research, it is concluded that the 20% Sugarcane Bagasse Ash & 20% Waste Tyre Rubber are the optimum percentage of replacement value for required durability of the concrete.

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Finally, I would like to thank the [Delhi Technological University] for providing me with the opportunity to pursue this research project. I am grateful for the resources and support that I have received, and I am excited to share my findings with the world.

Sincerely,

Pritam Chawla

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DEDICATED TO MY FATHER, MOTHER AND SISTERS

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CHAPTER 1

INTRODUCTION

1.1 OVERVIEW

The most popular man-made substance worldwide is concrete. Concrete contains a significant amount of Portland cement. The process of making cement uses a lot of energy and raw materials, and it also produces a lot of CO_2. The concrete industry's environmental effect has been reduced by trying to discover cement replacements in order to decrease carbon emissions. Large amounts of industrial and agricultural waste have been produced as a result of the quick development of both industries. The majority of these final wastes are disposed of in landfills, which not only shrink the amount of land that can be used for other purposes but also harm the environment.

Industrial by-products including blast furnace slag, silica fume, and coal fly ash have all been successfully incorporated into cementitious materials, and they have sufficiently benefited society and the environment. Currently, biomass fuel is primarily made from agricultural and forestry waste. The final waste produced, known as bottom ash or smoke ash, has garnered a lot of academic attention. [1]

It has been discovered that many different kinds of biomass ash, including rice husk ash, palm oil fuel ash, elephant grass ash, sugarcane bagasse, corncob ash, wood waste ash, bamboo boot ash, cow slurry ash, and paper mill ash, can be used as supplementary cementitious materials. According to earlier research, adding biomass ash to cementitious materials can keep or even boost the cementitious materials' mechanical performance. Additionally, incorporating biomass ash into cementitious materials can help cut the price of construction supplies, ease the burden of waste disposal, avoid soil and air pollution, and reduce greenhouse gas emissions created during cement manufacture.

One of the biggest causes of CO_2 emissions, which have a negative effect on the environment, is the production of cement. The primary cause of global warming is the release of CO_2 as a result of the heating of limestone ($CaCO_3$) to create calcium oxide (CaO), which is the major oxide in OPC as CO_2. Gases like CO_2 enter the atmosphere during the manufacturing of clinker and are estimated to make up 5 to 7 percent of all

CO2 emissions by weight. Supplementary cementitious materials (SCMs) are currently employed to make concrete with the necessary strengths in order to decrease or minimise the issue of global warming. [2]

1.2 SUGARCANE BAGASSE ASH

The by-product of the sugarcane industry known as sugarcane bagasse ash (SCBA) is created when bagasse, the fibrous residue left over after sugarcane juice extraction, is burned. SCBA is a fine, powdery material with a high silica content and other mineral elements. SCBA has come to light as a viable supplementary cementitious material (SCM) for concrete production in recent years.

Concrete has been proven to work well with SCBA as a partial replacement for cement. SBA can improve the mechanical qualities of concrete, such as its compressive strength, flexural strength, and durability, when combined with cement. The principal binder in concrete, calcium silicate hydrate (C-S-H) gel, is created when SCBA combines with calcium hydroxide in cement. Additionally, the concrete's porosity is decreased as a result of this reaction, enhancing its durability and chemical resistance.

SCBA is used in concrete because it offers many benefits. First off, it is a cheap and readily available material that can be sourced locally, lowering the cost of transportation and lowering carbon emissions. Second, by lowering the amount of cement used for concrete, the construction project's overall carbon footprint is reduced. Thirdly, it can make concrete more workable, making it simpler to finish and place. Fourth, it can improve concrete's durability, which lowers the need for upkeep and repairs.

The use of SCBA in concrete is not without its difficulties, though. The variability in ash quality, which can impact how well it performs in concrete, is one of the key problems. The type of sugarcane, the method of combustion, and the post-processing procedure are among of the variables that affect sugarcane bagasse ash quality. As a result, it's crucial to confirm that the bagasse ash used in concrete complies with all necessary requirements.[3]

The potential for alkali-silica reaction (ASR) in concrete when SBA is employed presents another difficulty. ASR is a chemical reaction between reactive silica in aggregates or additional materials and alkalis in cement that can lead to the expansion and cracking of concrete over time. Therefore, it's crucial to carry out appropriate testing and analysis to make sure that using SCBA doesn't cause ASR.

1.2.1 Production of Sugarcane Bagasse Ash

With sugarcane being farmed in more than 100 countries, the sugarcane business is one of the greatest agricultural sectors in the world. The sector is a significant producer of sugar as well as a number of byproducts, such as sugarcane bagasse ash (SCBA). Sugarcane Bagasse Ash is a fine, powdery byproduct of the burning of sugarcane bagasse, the fibrous byproduct left over after the extraction of sugarcane juice.

The harvesting of sugarcane and subsequent transportation to the sugar mill are the first steps in the manufacturing of bagasse ash. The sugarcane is crushed at the mill to extract the juice, which is then evaporated and cooked to create sugar crystals. The remaining bagasse from the sugarcane is then burned in boilers to create steam, which drives the mill and creates energy. Ash is created during the combustion process from the bagasse and is collected in hoppers for later use.

Sugarcane Bagasse typically includes significant concentrations of calcium, silica, and other minerals. Because the silica in SCBA is amorphous, it is highly reactive and has a large surface area. SCBA has a number of potential uses besides its use in concrete, such as wastewater treatment, soil stabilisation, and the adsorption of heavy metals. The mechanical and thermal properties of polymer composites can be enhanced by adding SCBA as a filler.[2]

1.3 WASTE TYRE RUBBER

The recycling of waste rubber tyres has become an increasingly important environmental issue in recent years. Tires are made from a combination of natural and synthetic rubber, as well as other materials such as steel and nylon. When tires reach the end of their useful life, they can pose a significant environmental hazard if not disposed of properly. One solution to this problem is to recycle scrap tires by using them as a partial replacement for fine aggregates in concrete.

According to projections, the number of discarded tyres is set to increase to 1.2 billion annually by 2030, with a total of 5 billion stored and discarded tyres. In India alone, it is estimated that 112 million tyres will be discarded annually after being retreaded twice. The disposal of used tyres can pose a significant risk to human health due to the presence of styrene, a highly toxic component in tire rubber. Therefore, recycling tire waste is crucial to mitigate this danger. In recent years, researchers have provided guidelines for recycling tire waste in various ways. The global tyre recycling market was worth USD 0.95 billion in 2016 and is expected to grow at a CAGR of 2.1% (Compound Annual Growth Rate) during the forecast period.[4]

The use of waste rubber tyres in concrete has several benefits. First and foremost, it provides a sustainable and environmentally friendly way to dispose of old tyres. By recycling tyres in this way, they are kept out of landfills and are instead repurposed for a useful application. Second, the addition of rubber to concrete can improve its mechanical properties. Rubber particles have high elasticity and can absorb energy, which can make concrete more durable and resistant to cracking.

The process of incorporating waste rubber tyres into concrete involves grinding them into small particles and adding them to the concrete mix in place of a portion of the fine aggregates. The amount of rubber that can be added depends on the specific application and the properties desired in the concrete. In general, up to 20% of the fine aggregates can be replaced with rubber without significantly affecting the strength or workability of the concrete.

Studies have shown that the addition of rubber to concrete can improve its properties in several ways. One study found that the use of rubber in concrete reduced its weight by up to 20%, which can be beneficial in applications where weight is a concern, such as in bridges or high-rise buildings. Another study found that the use of rubber in concrete reduced its water absorption and permeability, which can improve its durability and resistance to weathering. There are also some potential drawbacks to using rubber in concrete. One concern is that the rubber particles may absorb moisture and swell, which can lead to cracking or other damage over time. Additionally, the use of rubber in concrete may affect its fire resistance and may also impact its ability to be recycled at the end of its useful life.

Overall, the use of scrap rubber tires as a partial replacement for fine Aggregates in conc. is a promising application for recycled rubber. By diverting tyres from landfills and repurposing them for a useful application, this approach can have significant environmental benefits. While there are some potential drawbacks to consider, the use of rubber in concrete has shown promising results in improving its mechanical properties and durability.

1.4 OBJECTIVES

1. To determine the effect of the exposure condition on concrete with partial replacement of SCBA with Cement & Waste Tyre Rubber with Fine Aggregates.
2. To determine the Energy Absorption in concrete blended with Sugarcane Bagasse Ash & Waste Tyre Rubber
3. To determine the optimum percentage replacement of SCBA & Waste Tyre Rubber for the Blended Concrete.

1.5 ORGANIZATION OF THESIS

The thesis has been divided into 6 chapters. A brief description of each chapter has been given below:

Chapter 1: Deals with the introduction to the topic as well as the Waste Materials that are being used in this research for the partial replacement.

Chapter 2: It consists the Literature Review on the basis of reading of various papers and the research that has been carried by other researchers in the field regarding utilization of Waste Tyre Rubber & Sugarcane Bagasse Ash in the concrete.

Chapter 3: It describes the material properties of all the materials used as well as the methodology that has been followed by us during the research process.

Chapter 4: A detailed discussion has been done on the various tests that has been carried out in this research and all the experimental data have been tabulated in it.

Chapter 5: This chapter consists of the concluding remarks from the tests that that have been carried out and the end results that were inferred from the detailed experiments on the concrete specimen.

Chapter 6: References

CHAPTER-2

LITERATURE REVIEW

2.1 GENERAL

This chapter discusses the various research that have been undergone in past on the utilization of Sugarcane Bagasse Ash as well as Waste Tyre Rubber utilization in the concrete and what is their effect on the Durability as well as the Energy Absorption capacity of the concrete. Also, this will provide us with a base for the further discussion as well as a rock bottom for our further experimental work. All the experiment & the work done in this research are either branches of these research that were carried over the past or adding upon the already existing work done in the past & getting a solid result for our specific design mix, which is M40.

2.2 LITERATURE REVIEW

Ganesan et. al. (2007) studied the effect of the pozzolanic ingredients like sugarcane bagasse ash, wheat straw ash, hazel nutshell, and rice husk ash in the production of blended cements. However, the utilization of bagasse ash (SCBA) in cement mortars as a partial replacement material for cement has not been extensively studied. Consequently, a study was conducted to evaluate the impacts of varying levels of SCBA content on the physical and mechanical characteristics of cured concrete. The investigation encompassed a range of features such as compressive strength, splitting tensile strength, water absorption, permeability traits, chloride diffusion, and resistance to chloride ion penetration. The study's results demonstrated that SCBA is an effective mineral additive, with an optimum 20% cement replacement ratio being the ideal proportion.

Siddika et. al. (2019) emphasised on the emergence of rubberized cementitious composites and waste tyre rubbers, their composition, applications, serviceability, and durability. The research aims to provide an essential understanding of the integrated uses of rubberized concrete (RuC) composite materials, and their potential to advance construction techniques while increasing the environmental sustainability of concrete structures in the building sector. Recycled rubber aggregate (RA) has been found to have numerous advantages, including making concrete lighter, tougher, more resilient to fatigue, having better dynamic qualities, and being more ductile. Concrete made with recycled RA has performed well in both hot and cold climates and has demonstrated remarkable resistance to extreme circumstances and diverse loads. While RuC typically has low mechanical strength, specialised processing and the use of additives can reliably improve its capabilities.

Ozbay et. al. (2010) determined the results regarding the addition of crumb rubber aggregate (CR) and ground granulated blast furnace slag (GGBFS) to concrete affected the material's physical characteristics, particularly its compressive strength, abrasion resistance, and energy absorption capability. In the experimental programme, the main parameters were the GGBFS content (0, 20, and 40%), CR content (0, 5, 15, and 25% by fine aggregate volume), and water-cement ratio (0.4). A total of 12 concrete combinations were created, and their physical characteristics were examined. The experiments' findings showed that adding CR aggregate to concrete reduced its compressive strength and abrasion resistance while significantly increasing its ability to absorb energy. The results point to the possibility of using CR aggregate as an additive in the creation of concrete, particularly in situations where energy absorption is a crucial factor.

Thomas and Gupta (2015) explained the change in the quality & behaviour of concrete if crumb rubber were used in place of the natural fine aggregate. Natural fine aggregate was substituted with crumb rubber at values ranging from 0% to 20% in steps of 2.5%. The resulting concrete samples underwent tests to determine its compressive strength, flexural tensile strength, pull-off strength, abrasion resistance, water absorption, and water penetration. The study found that while the rubberized concrete's abrasion resistance and water absorption (up to 10% substitution) were superior to the control mix concrete's, it had lower compressive strength, flexural tensile strength, pull-off strength, and depth of water penetration than the control mix. The results suggest that rubberized concrete may be suitable for use in structures where there is a risk of brittle failure. Furthermore, crumb rubber may be utilized in high strength concrete as a partial substitute for fine aggregate up to 12.5% by weight to achieve strengths greater than 60 MPa.

A Sofi (2017) presented a summary of several experiments performed to assess the durability and physical characteristics of concrete samples containing used rubber tyres. Utilising scanning electron microscopy (SEM), the compressive strength, flexural tensile strength, water absorption, and water penetration were assessed. The findings demonstrated that the rubberized concrete's compressive and flexural tensile strengths and the depth of water penetration were lower than those of the control mix. However, when discarded rubber tyres were substituted for up to 10% of the aggregate, the abrasion resistance and water absorption showed improved results. The study also examines the use of used tyre rubber in place of cement and gravel in concrete compositions.

Qing Xu et. al. (2018) explained the morphology, physical characteristics, chemical composition, and mineralogical composition of sugarcane bagasse ash (SCBA) are all covered in this paper's thorough overview of the current state of knowledge. Due to its potential as a pozzolanic material and its usage in the creation of alkali-activated binders, aggregates, and fillers for building materials, SCBA is recognised as a promising material for use in construction. The effects of SCBA on the physical characteristics, mechanical strength, microstructure, and durability of both fresh and hardened concrete are highlighted in the research. The temperature and time of calcination and recalcination, fineness, loss on ignition (LOI), and crystal silicon dioxide are key variables that control pozzolanic activity.

Reddy et. al. (2019) focused on to substitute cement with set amounts of bagasse ash and to examine the impact of magnesium sulphate on SCBA mixed concrete. The concrete mixture created by adjusting the ratios of bagasse ash cubes with a bagasse ash content of 0%, 5%, 10%, 15%, 20%, and 25% are cast, cured in normal water and 5% magnesium sulphate solution for ages of 7, 28, and 60 days, and their properties—such as slump cone testing, compaction factor testing, and compressive strength—are verified and the results are analysed

Ramakrishnan and Vignesh (2021) investigated the potential of using SCBA as a partial replacement for fine aggregate in M50 grade concrete. The SCBA is first calcined at 600 C for two days to enhance its silica content due to the presence of aluminium and silica ions. Five concrete mixtures, including one control, are prepared with varying replacement percentages of fine aggregate with SCBA, ranging from 0% to 20% in 5% increments. The concrete specimens are cured for 28 days and subjected to various tests. The results indicate that replacing fine aggregate with SCBA by 15% yields the strongest mechanical strength compared to other replacement levels. These findings suggest that SCBA can effectively be used as a substitute for fine aggregate in concrete to improve its performance.

Bahurudeen and Kanraj (2015) performed five separate tests to examine durability performance: the oxygen permeability test, the fast chloride penetration test, the chloride conductivity test, the water sorptivity test, the DIN water permeability test, and the Torrent air permeability test. The findings of this investigation demonstrate that adding sugarcane bagasse ash to concrete significantly improves its performance. Comparing bagasse ash blended concrete to control concrete, it was found that it had a lower heat of hydration, additional strength gains from pozzolanic reaction, a considerable decrease in permeability due to pore refinement, and similar drying shrinkage behaviour.

Fernandez et. al. (2018) The compressive behaviour of concrete mixtures including epoxy resin with and without hardener was studied in this work using ground rubber powder in place of cement. Distinct experimental mixtures were produced, each with a distinct polymer/cement mass ratio. While creating the combinations, a common design criterion was adopted in order to fairly compare polymer-cement and conventional concretes. Concrete mix design descriptions were based on mechanical and durability tests. Mechanical parts underwent tests for compression and flexure. Durability was evaluated through study on chloride penetration into the concrete matrix. The usage of polymer-cement concrete has an effect on the post-peak slope of the stress-strain curve, exhibiting enhanced ductility and being of special importance in earthquake engineering, according to the results.

Gupta et. al. (2021) evaluated the sugarcane bagasse ash (SCBA) as a partial replacement for ordinary Portland cement (OPC) in concrete in terms of its mechanical and durability properties. At the percentages of 5%, 10%, 15%, and 20% by weight of cement, the SCBA was partially replaced. Throughout the experiment's steps, a slump range of 130-150 mm was kept constant. Several tests on concrete specimens, including compressive strength, flexural strength, water absorption, water penetration, carbonation, and ultrasonic pulse velocity, were carried out to assess the behaviour of SCBA on concrete. The findings showed that after 120 days of curing, compressive strength for replacement levels of 5% and 10% rose by 2.6% and 1.7%, respectively.

Rerkipboon et. al. (2015) replaced the ordinary Portland cement (OPC) by up to 50% ground bagasse ash (GBA) as the binder in concrete to test its strength and durability. Investigations were done on the setting times, compressive strength, elastic modulus, chloride resistance, and expansion caused by a 5% Na2SO4 solution of concretes containing ground bagasse ash. In comparison to normal concrete the results showed that concrete containing 50% GBA produced at least 90% more compressive strength at the age of 28 days. The findings imply that using GBA up to 50% of the weight of OPC as a binder replacement can improve concrete's durability qualities, particularly its resistance to chloride penetration.

Suresh et. al. (2017) investigated the use of sugarcane bagasse ash (SCBA) as a supplementary cementing admixture in concrete, replacing Portland cement from 0 to 25% by mass fraction in increments of 5%. The concrete specimens were subjected to elevated temperatures of 300 °C, 400 °C and 500 °C, with exposure time of 2 hours at each temperature. The residual compressive and flexural strength were evaluated and compared with the reference performance at room temperature. The results demonstrate that the grain size distribution of SCBA is very similar to that of Portland cement. The compressive strength of the concrete decreased consistently at higher temperatures, but the inclusion of SCBA marginally mitigated this deterioration. The drop in strength was found to be less significant up to 20% cement substitutions. This study concludes that the use of SCBA as a supplementary cementing admixture can improve the resistance of concrete to elevated temperatures.

Marques et. al. (2013) studied the heat resistance of four different concrete compositions was constructed and tested. The first batch of concrete was a standard mix created with natural coarse aggregate. In the other three concrete mixtures, RA from used tyres was utilised to replace 5%, 10%, and 15% of the fine and coarse natural aggregate, respectively. After being heated in accordance with the ISO 834 time-temperature curve, the specimens were heated to 400 °C, 600 °C, and 800 °C for a duration of 1 hour. The compressive strength of the specimens was assessed and compared with reference values obtained before being exposed to fire after cooling to room temperature. The purpose of this research is to evaluate the possibility of RA as a concrete replacement for natural aggregates, particularly the durability of concrete at elevated Temperatures.

2.3 RESEARCH GAP

Based on the literature review, following limitations have been noticed in the earlier research done

1. To determine the durability properties of SCBA & Waste Tyre Rubber concrete under the aggressive deteriorating agents like Sulphates, Chlorides, Oxygen & Carbon Di-Oxide.
2. Even though it is well known that Rubber has good energy absorption, there has not been much studies exploring the energy absorption capacity of Rubber blended Concrete.
3. The effect of Waste Tyre Rubber on the Compressive Strength as well as the effect on the workability & cost effectiveness need to be studied.
4. The impact of SCBA on concrete production's environmental implications, including greenhouse gas emissions and the energy it embodies.

CHAPTER-3

MATERIAL & METHODOLOGY

3.1 OVERVIEW

In this chapter the material properties of the various materials used in the research as well as the mix design have been discussed. M40 is considered as the design mix for the research work where Cement has been replaced by Sugarcane Bagasse Ash and Fine Aggregates has been replaced by Waste Tyre Rubber. For each mix design casting of 20 cubes of dimension (150*150*150) has been done and various tests are performed including the Durability as well as Energy Absorption Tests. All the material properties that are discussed in this chapter are according to the Indian Standard Specifications. Various properties like Specific Gravity, Sieve Analysis, Compressive Strength, Initial Setting Time (IST) & Final Setting Time (FST), specific Gravity, Water Absorption Capacity were measured.

A flow chart has been prepared explaining briefly the methodology of the research work that was undertaken.

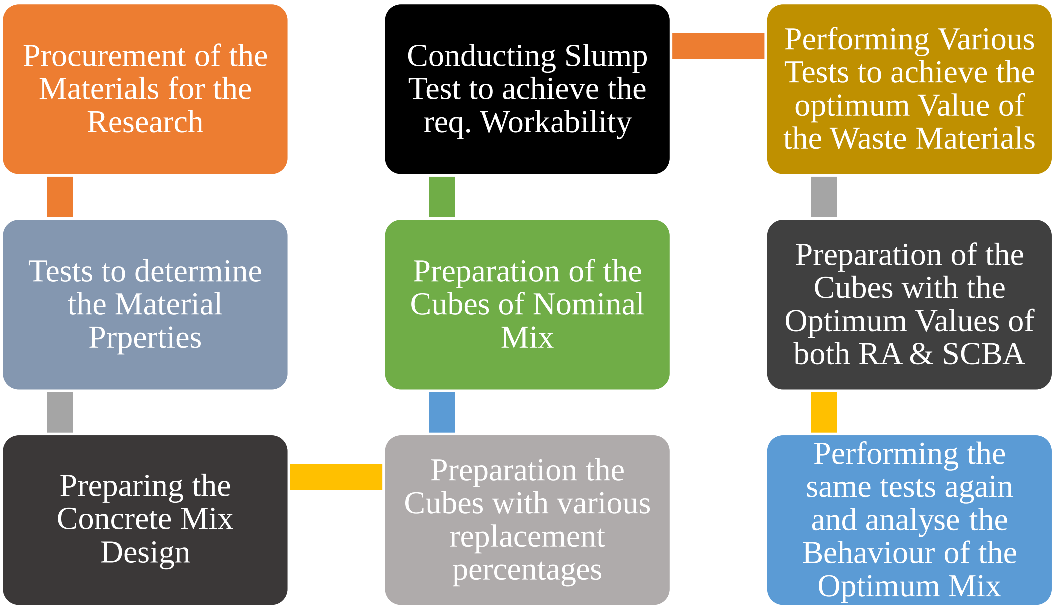

Figure 3.1 Methodology of the Research Work

3.2 MATERIAL PROPERTIES

In this study, test samples are prepared with cement, used tyre rubber, sugarcane bagasse ash, fine and coarse aggregates, super plasticizers, and water. The varied qualities of each and every material employed in the research have been discussed in the following topic. To generate the best concrete, the characteristics of each material employed in this study were carefully taken into account. Each material's characteristics have been covered separately.

3.2.1 Cement

OPC 53 was procured from the local market on special request of UltraTech Cement. It was stored away from moisture wrapped in a plastic bag to prevent the oxidation and formation of lumps in the cement. From the various tests that were performed on the cement, it performed well in the range provided by the Indian Standards and was passed to be used for the research work. Moreover, the cement was as per the IS 269-2015. The Physical & Chemical Properties of the OPC are tabulated in the Table 3.1 & 3.2 respectively.

Table 3.1 Physical Properties of Ordinary Portland Cement

S.No.	Properties	Results	Requirement as per IS:269-2020 [12]
1	Normal Consistency	31%	-
2	Initial Setting Time	75 minutes	Minimum 30 minutes
3	Final Setting Time	240 minutes	Maximum 600 minutes
4	Specific Gravity	3.14	-
5	Soundness	0.69 mm	Maximum 10mm

3.2.2 Aggregates

3.2.2.1 Fine Aggregates

Natural River Sand was used in the research which was procured from the Local Market in Rohini and which is also called as Badarpur. The sand conformed to the IS 2386-2021 & the results are mentioned in Table 3.3. Graphical Representation of the sieve analysis is also shown, also specific gravity & water absorption capacity of the sand was obtained using proper testing procedures which are tabulated.

Table 3.2 Grading Limit of Fine Aggregates as per IS 2386-2021

Seive Size (mm)	Percentage Passing	Percentage Passing for the Grading Zone II as per IS 2386-2021 [11]
4.75	92.3	90-100
2.36	85.1	75-100
1.18	70.8	55-90
0.6	54.6	35-59
0.3	27.5	8-30
0.15	6	0-10

Table 3.3 Sieve Analysis of Fine Aggregates

S.No.	IS Sieve Size (mm)	Weight Retained	Cum. Wt. Retained	Cum. %age of Wt. Retained	Cum. %age of Wt. Passing
1	4.75	110	110	11	89
2	2.36	97	207	20.7	79.3
3	1.18	153	360	36	64
4	0.6	139	499	49.9	51.1
5	0.3	291	790	79	21
6	0.15	168	958	95.8	4.2
7	Pan	42	1000	-	-
8	Total	1000		292.4	
9	Fineness Modulus	2.924			

Table 3.4 Specific Gravity of Fine Aggregates

Contents	Sample 1	Sample 2	Sample 3
Wt. of empty Pycnometer (W1)	451	451	451
Wt. of empty Pycnometer + Water (W2)	1503	1503	1503
Wt. of empty Pycnometer + Aggregate (W3)	961	957	971
Wt. of empty Pycnometer + Water + Aggregate (W4)	1821	1839	1805
Oven Dried Wt. (D)	481	494	476
Sp. Gvt. = [D/(W4-W2-W3+W1)]	2.521	2.905	2.183
Average	2.536		

Table 3.5 Physical Properties of Fine Aggregates

S.No.	Property	Results
1	Source	Local Market (Rohini)
2	Max. Coarse Size	4.75 mm
3	Specific Gravity	2.536
4	Water Absorption (%)	2.6%
5	Fineness Modulus	2.924

3.2.2.2 Coarse Aggregates

The maximum size of the Coarse Aggregate was taken to be 20mm. All the tests that were performed on the Coarse Aggregates as per the Indian Standard Specification IS: 2386-2021. All the results have been tabulated as well as the sieve analysis has been performed as per the Indian Guidelines & tabulated in Table 3.6 and Grading Analysis has been shown in Table 3.7. Physical Properties of Coarse Aggregates is mentioned in Table 3.9

Table 3.6 Sieve Analysis of Coarse Aggregates

S.No.	IS Sieve Size (mm)	Weight Retained	Cum. Wt. Retained	Cum. %age of Wt. Retained	Cum. %age of Wt. Passing
1	20	145	145	14.5	85.5
2	12.5	468	613	61.3	38.9
3	10	235	848	84.8	15.2
4	4.75	134	982	98.2	1.8
5	Pan	18	1000	-	-
6	Total	1000			
7	Fineness Modulus	2.588			

Table 3.7 Grading Limit of Coarse Aggregates as per IS 2386-2021

Sieve Size (mm)	Percentage Passing	Percentage Passing for the Grading Zone II as per IS 2386-2021 [11]
20	86.3	85-100
10	4.9	0-20
4.5	0.9	0-5

Table 3.8 Physical Properties of Coarse Aggregates

S.No.	Property	Results
1	Source	Local Market (Rohini)
2	Max. Coarse Size	20mm
3	Specific Gravity	2.82
4	Water Absorption	0.6%
5	Impact Value (%)	14%

3.2.3 Sugarcane Bagasse Ash (SCBA)

Sugarcane Bagasse Ash for the research work has been sourced from Triveni Chandanpur Sugar Unit located in Chandanpur, Gajraula, Uttar Pradesh. They had plenty of it and were keen on the research so that they can monetise the waste that is sitting idle in their backyard. Moreover, they also provided with some details like the temperature at which they burnt the ash and the Carbon Content which is expressed in the Table 3.10. SCBA is Dark Black in colour due to higher concentration of Carbon in it. Also, SCBA appears Dark Gray above temp 800℃ and white above 900℃. It is used as the partial replacement of Cement.

Table 3.9 Chemical Properties of Sugarcane Bagasse Ash

S. No.	Oxides Present	Percentage %
1	CaO (Calcium Oxide)	3.34
2	SiO_2 (Silicon Dioxide or Silica)	75.67
3	Al_2O_3 (Aluminium Oxide)	1.52
4	Fe_2O_3 (Ferric Oxide)	4.87
5	MgO (Magnesium Oxide)	1.87

6	SO_3 (Sulphur Tri Oxide)	-
7	K_2O (Potassium Oxide)	9.59
8	Na_2O (Sodium Oxide)	0.12

3.2.4 Waste Tyre Rubber

Waste Tyres are recycled to form Rubber Aggregates which are 2.36mm in size. Rubber is known to have high energy absorption capacity. This is helpful in the scenarios where it was required for concrete to absorb energy as much as possible. Few of the examples can be taken as in the Railway Sleepers, Foundation of Heavy Machines also it has high abrasion capacity, which is helpful in Tunnel Linings. Physical & Chemical Properties of Waste Tyre Rubber are shown in the Table 3.11 and 3.12 respectively. Crumb Rubber here in this research is used as the partial replacement of Fine Aggregates.

Table 3.10 Physical Properties of Rubber Aggregates

S.No.	Property	Results
1	Size	0-5 mm
2	Water Absorption	6.18%
3	Specific Gravity	1.10
4	Density	0.44

Table 3.11 Chemical Properties of Rubber Aggregates

S.No.	Compounds Present	Percentage %
1	Carbon Black	87.51
2	Oxygen	9.23

3	Zinc	1.76
4	Sulphur	1.08
5	Silicon	0.20
6	Magnesium	0.14
7	Aluminium	0.08

3.2.5 Admixture

For our research, Fosroc Auramix 400 has been used. This Super Plasticizer is known to have High Workability as well as High Water Reduction capacity & since the research deals with the waste materials which are known to decrease the workability, so it was chosen. With many trials on the workability as well as the cubes, it was observed that 1.4% is the optimum Super Plasticizer Content required for the adequate workability without compromising the strength. Variations performed were with 0.8, 0.9, 1.0, 1.1, 1.2 and finally 1.4% of Super Plasticizer content. At 1.4% Super Plasticizer content, optimum result was obtained and it was final. It was selected and tested conforming to all the guidelines of Annex G of IS 10262 [10]

3.2.6 Water

Tap water was used and it was free from any organic materials. Ph of the water used was tested and it was 6.

3.3 COST OF MATERIALS

Cost of the materials is an important factor while deciding the overall cost of the concrete. Since, Construction cost is increasing day by day, it is the need of the market that the materials are selected in such a way that the construction cost is significantly reduced. So, here comes the usage of the waste materials in the concrete. In this research 2 waste materials are used in the concrete, namely Sugarcane Bagasse Ash and Waste Tyre Rubber. In the Table 3.12 discussion on the cost of the materials used in our concrete is done. But all the cost of the materials in this discussion are excluding the cost of the transportation.

Table 3.12 Cost of Materials

Materials	Cost (Excluding Transportation Cost)
Cement (OPC 53)	₹ 400 per 50kg Bag
Fine Aggregates	₹ 6.5/kg
Coarse Aggregates	₹ 2.5/kg
SCBA	Zero
Rubber Aggregates	₹ 20/kg

3.4 Mix Design of Concrete of M40 Grade as per IS 10262:2019. [10]

1. Test Data for Material

a. Grade designation : M40

b. Maximum nominal size of aggregate : 20mm

c. Minimum cement content : 390 Kg

d. Exposure condition : Moderate

e. Type of aggregates : Crushed Angular Aggregates

f. Workability : 100 mm

g. Type of Cement : OPC 53

h. Chemical Admixture : Fosroc Auramix 400

i. Specific Gravity of Cement : 3.15

j. Specific Gravity of Coarse Aggregates : 2.82

k. Specific Gravity of Fine Aggregates : 2.536

l. Water Absorption of Coarse Aggregates : 2.82

m. Water Absorption of Fine Aggregates : 2.6%

n. Specific Gravity of SCBA : 1.91

o. Specific Gravity of RA : 1.07

2. Target strength for mix proportioning

f´ck = fck + 1.65 * s (3.1)

Where,

f´ck = target average compressive strength at 28 days,

fck = characteristic compressive strength at 28 days, and

S= standard deviation.

From Table I, standard deviation, s =5 N/mm

Therefore, target strength =40+ 1.65 x 5 =48.25 N/mm

3. Selection of water-cement ratio

From Table 5 of IS 456, maximum water-cement ratio =0.45.

Based on experience, adopt water-cement ratio as 0.38.

0.38< 0.45, hence O.K.

From Table 2, maximum water content for 20 mm aggregate = 186 Lt. (For 25 to 50mm slump)

Estimated Water content for 100mm Slump = 186 + (6*186)/100 = 197.16 lt.

But with trials, 1% of Super Plasticizer has been for 25% Reduction in Water Content= 197 * (100-25)/100 = 147.6 lt.

4. Calculation of cement content

Water-cement ratio=0.38

Cement Content= 148/0.38 = 390Kg

From IS 456, Minimum Cement Content for Moderate Exposure Condition is 300Kg/m^3

390 Kg/m^3 > 300 Kg/m^3. Therefore, Safe.

5. Volume of coarse aggregate and fine aggregate content.

Therefore, volume of Coarse Agg. = 0.62.

Corrected Proportion of Coarse Agg. = 0.62 + 0.02*2 = 0.66

Volume of fine aggregate content = 1-0.66 = 0.34

6. Mix calculations

The mix calculations per unit volume of concrete shall be as follows:

a) Volume of concrete = 1m^3

b) Volume of cement = 390/3.15 * 1/1000 = 0.123 m^3

c) Volume of water = 148/1000 = 0.148m^3

d) Volume of chemical admixture = 1% of total cement content

Mass of Admixture = 0.014*390 = 5.4Kg

Volume of Admixture = 3.9/1.08 * 1/1000 = 0.00361 m^3

e. Volume of Entrapped Air = 0.015 m^3

f. Volume of All in Aggregates = (1-0.015) – (0.123+0.148+0.00361) = 0.710 m^3.

g. Mass of Coarse Aggregates = 0.71*0.66*2.74*1000 = 1284Kg

h. Mass of Fine Agg. = 0.71*0.34*2.65*1000 = 640Kg

The Mix Proportion is tabulated Below for a Clear Idea in Table 3.14.

Table 3.13 Mix Proportion of Control Concrete Specimen

Constituents	Quantity (Kg)
Cement	390
Fine Agg.	640
Coarse Agg.	1284
Super Plasticizer	5.4

Water	148

In this mix, SCBA & Waste Tyre Rubber Aggregates are further added as a partial replacement of Cement & Fine Aggregates respectively. 3 mix of SCBA replacement at 15%, 20% and 25% & 3 of Rubber Agg. at 10%, 20% & 30% are prepared separately.

After optimization, 1 mix of 20% SCBA & 20% Rubber is made for further experimental studies. This has been Tabulated in Table 3.15 and 3.16 respectively. In Table 3.17, data has been tabulated the complete mix design of our samples for a better understanding.

Table 3.14 Replacement percentage of Cement with SCBA

Concrete Mix	Cement (Kg)	SCBA (Kg)
S0	390	0
S1	331.5	58.5
S2	312	78
S3	292.5	97.5

Table 3.15 Replacement percentage of Fine Agg. with Rubber Aggregates

Concrete Mix	Fine Agg. (Kg)	Rubber Agg. (Kg)
R0	640	0
R1	576	64
R2	512	128
R3	448	192

Table 3.16 Concrete Mix Design

Mix No.	**Cement (kg/m^3)**	**SCBA (kg/m^3)**	**SCBA (%age)**	**FA (kg/m^3)**	**Crumb Rubber (kg/m^3)**	**Crumb Rubber (%)**	**CA (kg/m^3)**		**w/c ratio**	**Super Plasticizer (kg/m^3)**
							10mm	*20mm*		*1.4%*
S1	331.5	58.5	15%	640	-	-	513.6	770.4	0.38	5.46
S2	312	78	20%	640	-	-	513.6	770.4	0.38	5.46
S3	292.5	97.5	25%	640	-	-	513.6	770.4	0.38	5.46
R1	390	-	-	576	64	10	513.6	770.4	0.38	5.46
R2	390	-	-	512	128	20	513.6	770.4	0.38	5.46
R3	390	-	-	448	192	30	513.6	770.4	0.38	5.46

3.5 PPEPARATION OF TEST SPECIMEN

All of the supplies utilised to make the concrete were tidy and dry. It was mixed with an electrically powered mixer. The method of mixing is crucial in determining the calibre of the concrete that is produced. Concrete of inferior quality will be produced if the components are not properly mixed. First, FA and coarse aggregates were added to the mixer and the mixture was thoroughly mixed. After some time of mixing, cement was added and stirred once more to thoroughly combine all three elements. When the mixture was uniform and homogeneous, water was added and thoroughly incorporated. For three to five minutes, the mixture was mixed in batches. The mixture was then put into a metal basin when mixing was finished. The settlement was examined right away once the mixing operation was finished. To release any trapped air, the resulting liquid was poured into the desired moulds and vibrated on a machine. All moulds were revised using a steel trowel after casting.

3.6 CURING BATCHING AND CASTING OF TEST SPECIMEN

Using a scale with a bigger capacity (for cement aggregates, etc.), the required amounts of all the materials were precisely weighed. The water and admixture were weighed together on a scale with a lower capacity (better precision). To produce the best outcome, the materials were dry-mixed in the concrete mix until the combination was uniform, and then water was added in a two-step mixing process.

After being prepared, the concrete was carefully lubricated before being poured in three layers into the moulds in accordance with IS 516-2018. Before adding the following layer, each one was completely compacted. After being completely filled, all test specimens were suitably vibrated. 30 seconds were spent shaking the table, and this time was the same for all manufactured specimens. After the compaction process, the test specimens' tops were smoothed with a trowel. The moulds were then left in the lab at room temperature unattended for 24 hours.

The specimens were demoulded and put in a curing tank for the proper curing procedure after being cast for 24 hours. Fresh tap water is present in the curing tank's water. Additionally, the water has been changed every seven days to maintain tank freshness and prevent the growth of organic matter.

CHAPTER-4

RESULTS & DISCUSSION

4.1 INTRODUCTION

This chapter includes various results of the tests done in this research. All the tests are done in 2 Phases. In 1st Phase, tests have been performed on the Cubes with partial replacement of Sugarcane Bagasse Ash and cubes with partial replacement of Rubber Aggregate separately. Then in the 2nd Phase same tests were performed on the cubes with the optimum percentage replacement of both the waste materials in a single specimen & that was the final of our research. The tests that have been performed are, Sulphate Attack, Chloride Attack, Carbonation Depth Test, Compressive Strength Test, Water Absorption Test & Energy Absorption Test. Workability of each & every replacement value specimen was measured. All the tests are described and discussed in their separate sub topics and are also represented in Tabular as well as Graphical Manner.

4.2 FRESH PROPERTIES OF CONCRETE

Fresh concrete qualities are those that are measured while the concrete is still in the green state. From the time it is mixed until it sets, the concrete remains in the green state. Concrete's fresh property controls many of its hardened qualities.

4.2.1 Workability

Workability is a property of plastic concrete that indicates its ability to be mixed, processed, transported and placed with minimal homogeneity. The workability of all the concrete mixes used in the work was determined by performing a Slump test. The results of the calculated value with different floor sections are shown in Figure 4.1. As the percentage of SCBA in the concrete mix increases, the slump value decreases with a fixed water-cement ratio of 0.38. The workability decrease can be overcome by adding water. The main reason in decrease in workability and increase in the water requirement can be attributed to the fact that the SCBA is even finer than cement, therefore it has more specific surface area as the particles are irregular in size and porous as well as they have high Carbon Content in them.

But when the Rubber Aggregate is mixed in the concrete as the partial replacement of Fine Aggregates, there was high reduction in the workability as the water Absorption is high in case of Rubber Aggregates & this can also be proved using the values in the Figure 4.1. The reason for the decrease in Slump value may be the extra fineness of the SCBA compared to the cement used. Increasing the fineness of SCBA increases its specific surface area, so that SCBA absorbs more water than cement. As SCBA absorbs more water, it makes the concrete mix drier as its replacement level increases and thus reduces workability.

There was enough workability present till the 25% replacement of SCBA with cement but the same cannot be said in case with Rubber Aggregates. The Workability was good when 10% & 20% replacement of Rubber Aggregates were used but at 30% replacement value, the workability was not good and there was a lot of difficulty in filling the cubes and even in some cases when the cubes were unmoulded, there were large voids present in the cubes, which made them unusable and there was a lot of wastage of the materials due to this.

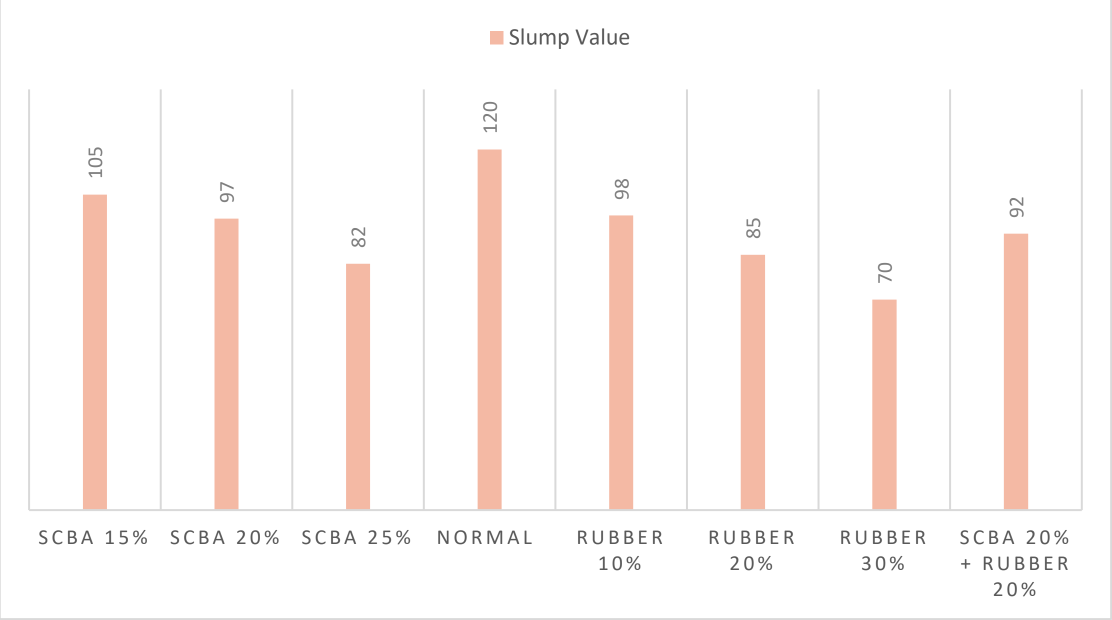

Figure 4.1 Slump Value of Various Concrete Mixes

4.3 TESTS ON THE HARDENED CONCRETE

4.3.1 Mass of Cube

Since, there are a total of 8 type of specimen prepared during the research, The weight of each type of specimen has been tabulated. From this, there is an general idea about the weight as well as the density of the different cubes prepared at different level of percentage replacement and how replacing cement and Fine Aggregates with the waste materials have affected.

Mass of all the cubes were taken after 28 days of full curing and leaving them in open air for 7 days more, so that the weight can be as realistic as possible and excess water can be evaporated.

From this test, there was noticed a general trend that there was not huge difference in the wight of the cubes on the partial replacement of Sugarcane Bagasse Ash but in the case of Waste Tyre Rubber, there was a large reduction in the weight of the concrete cubes upon the addition of Rubber Aggregates. In simpler words it can be said that weight of the cubes was inversely proportional to the amount of Rubber Aggregates added in the concrete. The data has been tabulated in Table 4.1, for a better understanding and clear representation. Mass of all the concrete mix was less than that of Nominal Mix.

Table 4.1 Mass of different Concrete mixes

MIX DESIGNATION	MASS OF CUBES (Kg)
Normal	8.71
SCBA 15%	8.585
SCBA 20%	8.382
SCBA 25%	8.106
Rubber 10%	8.252
Rubber 20%	8.005
Rubber 30%	7.623
SCBA 20% + Rubber 20%	8.194

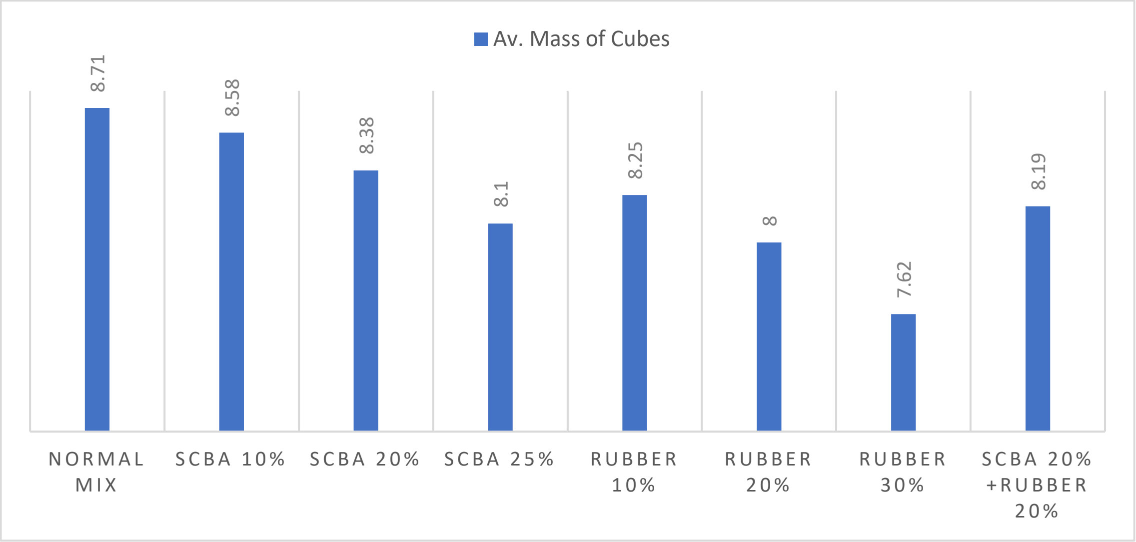

Figure 4.2 Average Mass of the Cubes

4.4 PHASE 1: TESTS ON THE SUGARCANE BAGASSE ASH AND WASTE TYRE RUBBER SAMPLES SEPARATELY

In this section, tests have been performed on the Sugarcane Bagasse Ash and Waste Tyre Rubber samples separately and with the help of these results, the optimum values have been decided for both the materials.

4.4.1 Effect of SCBA & Waste Tyre Rubber on Compressive Strength

At 28 days, the compressive strength of each mix with a distinct BA proportion was assessed. Figure 4.3 and Table 4.2 display the findings. When the replacement ratio was 15%, the compressive strength of sugarcane bagasse ash concrete initially declined, but then steadily increased. But for compressive strength, 20% was the ideal percentage. When compared to the compressive strength of normal concrete, the compressive strength with SCBA addition at all percentages decreased. In SCBA concrete samples, all of the specimens had a similar mode of failure. The outer layer of the concrete cubes chipped off initially & later they were having cracks which started from the corners & propagated towards the centre of the cubes.

The compressive strength of the Waste Tyre Rubber Concrete, there was a simple trend which can be noticed that the up to the replacement value of 20% there was not much change in the compressive strength as compared to the nominal mix, but a drastic decline in compressive strength at the replacement value of 30% has been observed. This is due to that rubber works as a void in the concrete matrix and reduces the density of such matrix, there is very little adhesion between rubber particles and cement paste. Rubber's smooth surface results in weak cement paste adherence. It was also observed that that all of the Rubber Specimen, cracked along with the Inter Transitional Boundaries between the Rubber Aggregates & Cement Paste.

Because RA rises to the upper surface of the mould when compacted because of its lower specific gravity this also lead in the reduction in the compressive Strength of the cubes with higher %age of Rubber in it. Additionally, pre-treating RA with a specialised solvent or modifier, like an emulsion or resin, has been shown to improve the binding between rubber and concrete. Rubber Aggregates for the research work has been pre-treated with NaOH (Sodium Hydroxide) for 24 hours before using the Rubber Aggregates in the concrete mix, this helped us to gain good compressive strength in the replacement values. From the results, it can be concluded that the 20% Rubber replacement and 20% Sugarcane Bagasse Ash performed well under the compressive load and displayed the best strength properties without much effect on the workability.

Table 4.2 Compressive Strength of SCBA & Rubber Concrete Samples

	Sugarcane Bagasse Ash			**Waste Tyre Rubber**		
Replacement Percentage	**15%**	**20%**	**25%**	**10%**	**20%**	**30%**
Weight (Kg)	8.705	8.406	8.106	8.252	8.007	7.623
Strength (N/mm^2)	37.72	59.05	40.16	44.58	46.93	17.38
Weight (Kg)	8.585	8.386	8.084	8.087	8.005	7.678
Strength (N/mm^2)	43.93	49.66	43.55	43.52	52.98	18.59
Weight (Kg)	8.480	8.382	8.212	8.293	8.093	7.665
Strength (N/mm^2)	42.36	48.87	45.385	42.01	46.58	17.27
`Average Weight (Kg)	8.59	8.391	8.134	8.21	8.035	7.655
Average Strength	41.33	52.52	43.03	43.37	48.83	17.74

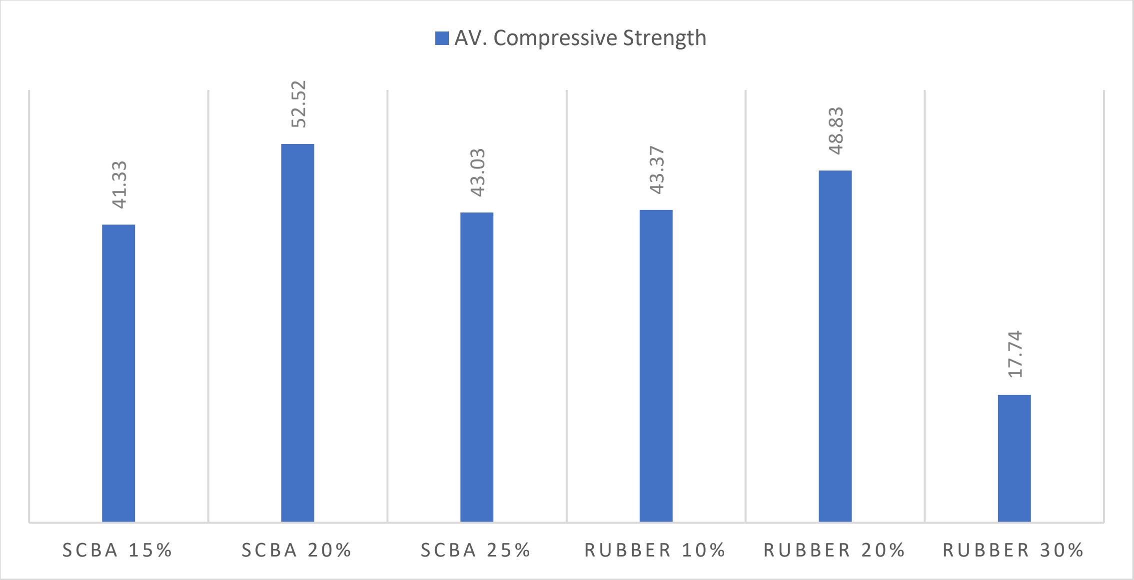

Figure 4.3 Average Compressive Strength at 28 days

4.4.2 Effect of Sulphate on the Compressive Strength (Sulphate Attack)

The hydrated cement's calcium hydroxide and alumina phase is more vulnerable to sulphate ion attack. The primary by-products of the chemical reaction between a sulphate-containing solution and the cement hydration products are ettringite and gypsum. Ettringite development is the cause of the expansion-related collapse of concrete in sulphate environments. The reaction of sodium sulphate (Na_2SO_4) or magnesium sulphate ($MgSO_4$) with calcium hydroxide {$Ca(OH)_2$} to generate gypsum and the reaction of the gypsum formed with calcium aluminate hydrates to form ettringite are the two main processes that cause sodium sulphate to attack concrete. Additionally, the calcium silicate hydrates [C-S-H] and magnesium sulphate both react with each other to generate gypsum and ettringite. When silica gel and magnesium hydroxide combine, a soft substance called magnesium silicate hydrate (M-S-H) is created that has an impact on the concrete's strength.

Additionally, it was noticed that there is a decrease in compressive strength when the SCBA content was increased to more than 20% as well as in waste tyre rubber when the percentage replacement was increased from 10% to 20% when the test is done at 14 days and 28 days after dipping them in the $MgSO_4$ solution. [5]

From these results it can be inferred that higher the permeability, more is the penetration of the Sulphates ions in the concrete and more is the decrease in the compressive strength. This can also be affirmed by the way the concrete cubes failed. So, all the cubes failed in the form of concrete chipping from the exterior of the cubes. The depth of penetration of the Sulphates varied between 1cm to 4cm increasing linearly with increase in the percentage replacement. This can be seen the photos attached below.

Chemical Reaction for Sulphate Reaction.

$Na_2SO_4 + Ca(OH)_2 + 2\ H_2O \Rightarrow CaSO_4.2H_2O + 2NaOH$ (1)

$MgSO_4 + Ca(OH)_2 + 2\ H_2O \Rightarrow \mathbf{CaSO_4.2H_2O} + Mg(OH)$ (2)

(Gypsum)

$3CaO.\ Al_2O_3\ .12H_2O + \mathbf{3(CaSO_4.\ 2\ H_2O)} + 13H_2O \Rightarrow 3CaO.Al_2O_3.3CaSO_4.31H_2O$ (3) **(Ettrignite)**

$MgSO_4 + C\text{-}S\text{-}H \Rightarrow CaSO_4.\ 2H_2O + M\text{-}S\text{-}H$ (4)

From the above discussion & the results following things can be inferred,

1. There is significantly more loss in mass in Sugarcane Bagasse Ash samples as compared to Waste Tyre Rubber, either the values are taken at 14 days or 28 days.
2. Also, there has been greater loss in the compressive strength at 15% & 25% replacement of SCBA compared to the 20% replacement.
3. In case of Rubber, there is a gradual decrease in the compressive strength as the replacement percentage of Rubber is increased in the concrete either at 14 days or 28 days.
4. Also, to be noticed is that the compressive strength kept on decreasing steadily with increase in the days of submergence in $MgSO_4$ from 14 days to 28 days.
5. Failure pattern while doing the compressive strength was same in both of the specimens. As more & more $MgSO_4$ penetrated in the concrete specimens, the outer edge became weak and the failure occurred in the form of the chipping of the layer that was compromised with the penetration of the Sulphate. Also, a **Orange-Brown deposition** on the concrete can be observed on the concrete residue that chipped off in the interior parts, proving that the sample has been compromised with the penetration of $MgSO_4$ in it.

Table 4.3 Compressive Strength & Mass Loss after 14 days in the $MgSO_4$ Sol. of Sugarcane Bagasse Ash Blended Concrete Cubes

Replacement Percentage	**Sample No.**	**Initial Weight (Kg)**	**Final Weight (Kg)**	**Weight Loss**	**% Wt. Loss**	**Strength (N/mm2)**
15%	1	8.698	8.155	0.543	6.24	39.68
	2	8.512	8.244	0.268	3.14	38.34
	3	8.238	8.098	0.14	1.6	40.19
	Av.	8.482	8.165	0.317	3.66	39.4
20%	1	8.209	7.789	0.42	5.11	45.09
	2	8.376	7.967	0.409	4.88	39.01
	3	8.312	7.887	0.425	5.13	42.33
	Av.	8.299	7.881	0.418	5.04	42.14
25%	1	8.389	7.759	0.63	7.51	41.21
	2	8.348	7.741	0.607	7.27	37.39
	3	8.443	7.765	0.678	8.03	39.86
	Av.	8.395	7.755	0.638	7.603	39.48

Table 4.4 Compressive Strength & Mass Loss after 28 days in the $MgSO_4$ Sol. of Sugarcane Bagasse Ash Blended Concrete Cubes

Replacement Percentage	**Sample No.**	**Initial Weight (Kg)**	**Final Weight (Kg)**	**Weight Loss**	**% Wt. Loss**	**Strength (N/mm2)**
15%	1	8.771	8.432	0.339	3.86	45.12
	2	8.686	8.382	0.294	3.38	43.98
	3	8.612	8.367	0.245	2.84	45.14
	Av.	8.689	8.393	0.292	3.36	46.52

20%	1	8.791	8.680	0.111	1.26	46.8
	2	8.754	8.525	0.229	2.61	47.65
	3	8.759	8.598	0.161	1.83	48.13
	Av.	8.768	8.601	0.167	1.9	47.52
25%	1	8.68	8.4	0.28	3.22	43.55
	2	8.501	8.328	0.173	2.03	44.36
	3	8.654	8.355	0.299	3.45	42.18
	Av.	8.611	8.361	0.25	2.9	43.36

Table 4.5 Compressive Strength & Mass Loss after 14 days in the $MgSO_4$ Sol. of Waste Tyre Rubber Blended Concrete Cubes

Replacement Percentage	**Sample No.**	**Initial Weight (Kg)**	**Final Weight (Kg)**	**Weight Loss**	**% Wt. Loss**	**Strength (N/mm2)**
10%	1	8.519	8.481	0.038	0.04	46.48
	2	8.416	8.383	0.033	0.038	38.82
	3	8.523	8.429	0.094	0.011	42.67
	Av.	8.486	8.431	0.055	0.029	42.65
20%	1	8.093	8.040	0.053	0.0065	38.04
	2	8.067	7.961	0.106	0.013	37.12
	3	8.005	7.798	0.208	0.025	38.17
	Av.	8.055	7.933	0.122	0.0143	37.77
30%	1	7.908	7.794	0.11	0.013	23.46
	2	7.871	7.731	0.14	0.017	23.41

	3	7.675	7.587	0.088	0.011	24.09
	Av.	7.788	7.704	0.112	0.013	23.65

Table 4.6 Compressive Strength & Mass Loss after 28 days in the $MgSO_4$ Sol. of Waste Tyre Rubber Blended Concrete Cubes

Replacement Percentage	**Sample No.**	**Initial Weight (Kg)**	**Final Weight (Kg)**	**Weight Loss**	**% Wt. Loss**	**Strength (N/mm2)**
10%	1	8.543	8.416	0.127	1.42	23.22
	2	8.613	8.476	0.137	1.57	24.71
	3	8.669	8.501	0.168	1.90	25.82
	Av.	8.608	8.464	0.432	1.63	24.58
20%	1	8.350	8.208	0.142	1.73	29.28
	2	8.416	8.276	0.14	1.68	28.09
	3	8.327	8.174	0.153	1.81	27.68
	Av.	8.334	8.219	0.145	1.74	28.35
30%	1	7.965	7.730	0.235	2.93	23.16
	2	7.894	7.696	0.198	2.54	24.53
	3	7.944	7.768	0.176	2.21	25.57
	Av.	7.877	7.731	0.203	2.56	24.42

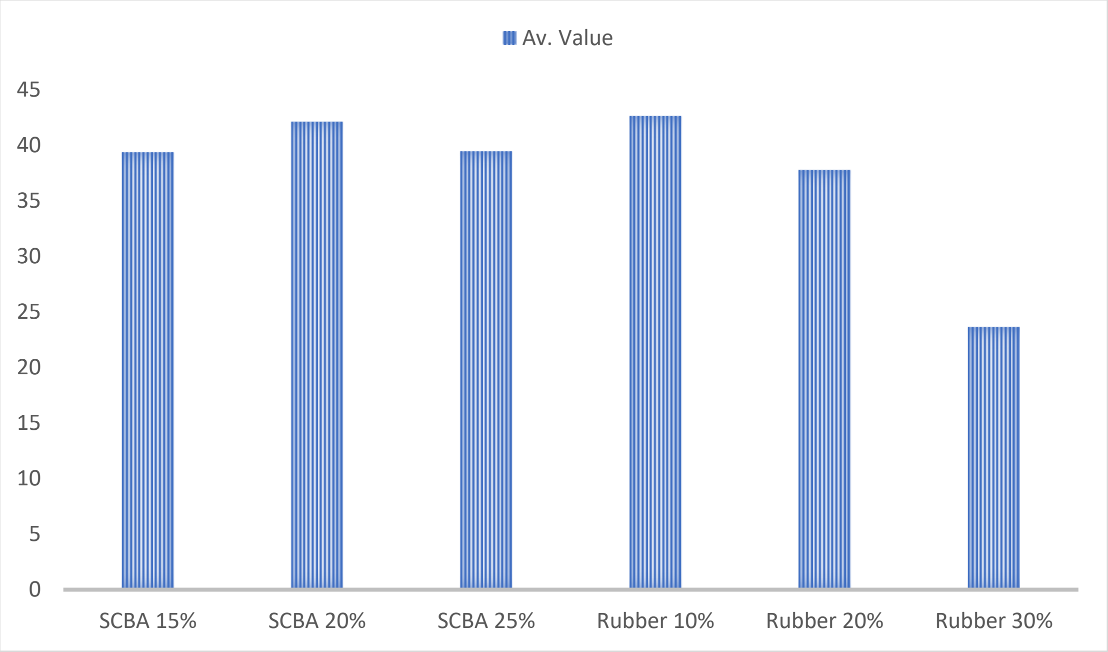

Figure 4.4 14 days Compressive Strength in the $MgSO_4$ Solution

Figure 4.5 28 days Compressive Strength under $MgSO_4$ solution

4.4.3 Effect of Chlorides on the Compressive Strength (Chloride Attack)

Six samples of each of the percentage replacement was immersed in the chlorine solution for a period of 14 days & 28 days. After each period, the compressive strength test was done & the results were not as expected. There was a reduction in the compressive strength at 15% replacement of SCBA, but surprisingly there was not much change in the compressive strength of 20% & 25%. Of, all the results of SCBA, it was noted that 25% SCBA had the least loss of strength as compared to others. So, from these results it can be inferred that increase in the %age replacement of SCBA increases the compressive strength of the concrete under Chloride Attack.

The finer SCBA particles are to be blamed for the decreased chloride permeability. Pozzolanic reactions precipitated additional C-S-H gel into the large pores. Smaller SCBA particles have the potential to reduce pore connection and pore solution conductivity by causing large pore dissociation.

Consequently, the results for chloride penetration dropped & therefore there is an increase in the compressive strength values, with increase in the SCBA addition as due to the fine size, it covered all the pores & prevented the ingression of the Chlorides in the concrete matrix.

But in the rubber replacement the decrease in the compressive strength was in 10% & 30% replacement values. 20% replacement of the rubber gave extraordinary strength gain. There is a need to examine this result further by doing the chemical analysis as well as the reactions & internal crystalline nature & mechanism that is going on with the reaction of Rubber & NaCl.

The results have been tabularised for a better understanding. Since there are fewer permeable gaps overall in Rubberized Concrete than in Nominal Concrete Mix, the former’s ability to absorb liquids is likewise less than that of Normal Concrete. The low internal packing density of Rubberized Concrete causes a reduction in the penetration resistance if replacement more than 20% is exceeded.

Due to the filler effects of the rubber content, the smaller particle size of RA causes a densely packed matrix. On the other hand, increasing the size of Rubber Aggregates can make them more porous, which will increase their capacity to absorb chemicals and water. Additionally, under acid exposure conditions, Rubberized Concrete experiences a smaller long-term loss in strength than Normal Concrete, and this loss in strength slows as the amount of rubber increases.

Moreover, the same as in Sulphate Attack, there was the chipping failure in this case too. More the penetration, more is the decrease in compressive strength and more depth of concrete chipped away during the compressive strength tests.

Table 4.7 Compressive Strength & Mass Loss after 14 days in the NaCl Sol. of Sugarcane Bagasse Ash Blended Concrete Cubes

Replacement Percentage	Sample No.	Initial Weight (Kg)	Final Weight (Kg)	Weight Loss	% Wt. Loss	Strength (N/mm2)
15%	1	8.414	8.395	0.019	0.0025	37.47
	2	8.5	8.569	0.082	0.0096	39.84
	3	8.467	8.418	0.049	0.0057	38.22
	Av.	8.463	8.46	0.05	0.00593	38.51
20%	1	8.309	8.254	0.055	0.0061	46.55
	2	8.129	8.08	0.049	0.006	43.96
	3	8.150	8.138	0.012	0.0014	45.67
	Av.	8.196	8.157	0.038	0.00456	45.39
25%	1	8.312	8.297	0.015	0.0018	55.21
	2	8.367	8.315	0.052	0.0062	53.28
	3	8.298	8.256	0.039	0.0046	50.19
	Av.	8.325	8.298	0.0353	0.0042	52.89

Table 4.8 Compressive Strength & Mass Loss after 28 days in the NaCl Sol. of Sugarcane Bagasse Ash Blended Concrete Cubes

Replacement Percentage	Sample No.	Initial Weight (Kg)	Final Weight (Kg)	Weight Loss	% Wt. Loss	Strength (N/mm2)
15%	1	8.512	8.372	0.14	1.64	21.88
	2	8.478	8.340	0.138	1.62	25.19
	3	8.481	8.376	0.105	1.23	23.89

	Av.	8.490	8.362	0.127	1.496	23.67
20%	1	8.430	8.236	0.194	2.30	48.11
	2	8.512	8.351	0.161	1.89	49.04
	3	8.459	8.290	0.169	1.99	51.67
	Av.	8.467	8.292	0.174	2.06	49.6
25%	1	8.613	8.406	0.207	2.40	46.28
	2	8.409	8.208	0.201	2.38	44.32
	3	8.532	8.316	0.216	2.53	43.97
	Av.	8.52	8.31	0.208	2.43	44.85

Table 4.9 Compressive Strength & Mass Loss after 14 days in the NaCl Sol. of Waste Tyre Rubber Blended Concrete Cubes

Replacement Percentage	**Sample No.**	**Initial Weight (Kg)**	**Final Weight (Kg)**	**Weight Loss**	**% Wt. Loss**	**Strength (N/mm2)**
10%	1	8.189	8.153	0.036	0.00438	38.05
	2	8.178	8.145	0.033	0.00435	39.02
	3	8.198	8.167	0.031	0.00431	38.77
	Av.	8.188	8.155	0.033	0.00434	38.61
20%	1	7.998	7.979	0.021	0.00262	50.47
	2	8.103	8.050	0.053	0.00654	53.48
	3	8.117	8.078	0.039	0.00484	50.09
	Av.	8.092	8.035	0.037	0.00466	51.34

30%	1	7.778	7.714	0.064	0.0082	16.81
	2	8.145	8.068	0.077	0.00945	28.91
	3	7.879	7.819	0.060	0.00769	23.64
	Av.	7.934	7.867	0.067	0.033	23.12

Table 4.10 Compressive Strength & Mass Loss after 28 days in the NaCl Sol. of Waste Tyre Rubber Blended Concrete Cubes

Replacement Percentage	**Sample No.**	**Initial Weight (Kg)**	**Final Weight (Kg)**	**Weight Loss**	**% Wt. Loss**	**Strength (N/mm2)**
10%	1	8.191	8.072	0.119	1.45	29.7
	2	8.167	8.054	0.125	1.89	31.89
	3	8.156	8.042	0.114	1.39	33.96
	Av.	8.171	8.056	0.119	1.563	31.85
20%	1	8.118	8.012	0.106	1.30	45.05
	2	8.017	7.919	0.098	1.22	42.91
	3	8.189	8.069	0.120	1.46	43.14
	Av.	8.108	8	0.108	1.326	43.7
30%	1	8.150	7.907	0.243	2.91	15.66
	2	7.967	7.691	0.276	3.46	16.12
	3	7.916	7.701	0.26	3.26	14.99
	Av.	8.011	7.7663	0.259	3.23	15.59

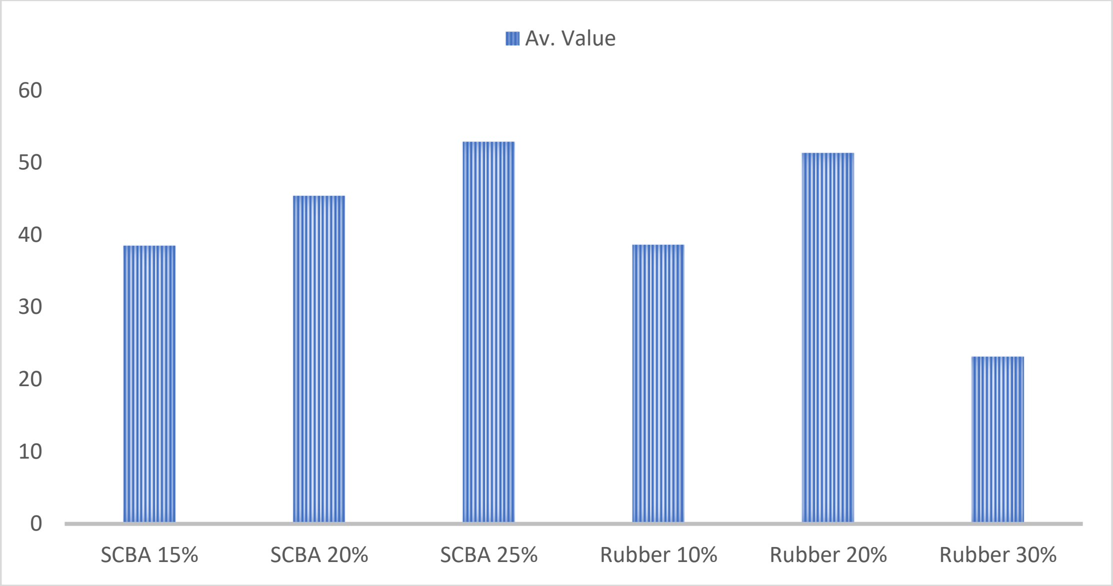

Figure 4.6 14 days Compressive Strength in NaCl Sol.

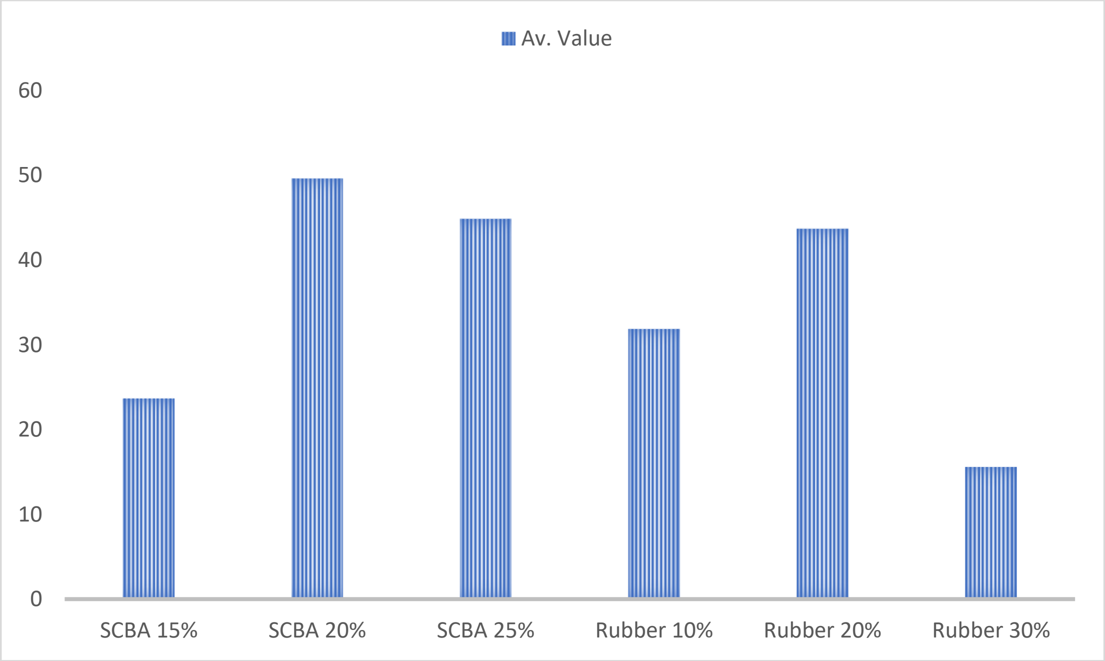

Figure 4.7 28 days Compressive Strength in NaCl Sol.

4.4.4 Carbonation Depth Analysis

Carbonation Test was performed to analyze the reaction of hydrated cement minerals with carbon dioxide (CO_2) in the presence of moisture. This was conducted by evaluating the depth of the carbonated zone in the concrete sample.

A solution of 3.5 gram phenolphthalein indicator was mixed with 350ml Ethyl Alcohol (Ethanol) & 500ml Water and The solution was poured into a container fitted with a nozzle. [2]

The solution was sprayed on the broken surface of the samples & the color change as well as penetration was recorded after 30 seconds. The test result was surprisingly good as there was little to no penetration of CO_2 in the samples.

Rubber Samples had a little of about 1cm but there was none on SCBA samples. Talking about the results, there was little to no carbonation of our samples even after being in the open air for more than 28 days. The reason behind no Carbonation in SCBA mix, is the fineness of the Sugarcane Bagasse Ash, due to its smaller size, it occupies the pores between the cement & aggregates leaving no space for Carbon Di-Oxide to penetrate in the sample & hence making the concrete more resistant to Carbonation attacks & increases the durability against them. But in contrast with the Rubber Mix, since Rubber is hydro plastic in nature its tendency is to repel Cement paste, but since the Rubber has been pre-treated with NaOH, so there was adequate adhesion present in the cement Rubber paste & this is the reason why there is less Carbonation Effect on our Rubber Samples. But generally, it is indicated that Rubberized Concrete contained more gaps and fissures that allowed carbon dioxide to easily enter the interior concrete. Rubber Mix compacted and tightly packed matrix constantly helps to reduce the carbonation depth. Because a larger Rubber Aggregates results in a more porous mix, the size and content of the Rubber Agg. Also cause an increase in carbonation depth.

So, from the test results it can be inferred that the concrete blended with SCBA & Waste Tyre Rubber will not go under Carbonation if the Rubber is pre-treated with NaOH for 24 hours before hand.

4.4.5 Energy Absorption Test / Impact Resistance Test

The energy absorption test was performed using a 0.4 kg steel ball &150mm cube specimen. The test was performed by dropping the ball from a standard height of 1 m onto the mid-point of the sample cube faces. After dropping the ball onto the sample, its rebound height was recorded with a camera. The energy absorption capacity was computed by measuring the potential Energy before dropping the ball (P1) & after dropping the ball (P2). Energy Absorption Capacity= (P1- P2).[6]

For this test, the slow motion mode on the mobile camera has been used, to measure the rebound height with most accuracy. Energy Absorption capacity increases with increase in the Rubber content as more the rubber content more energy is absorbed by the concrete, surprisingly Sugarcane Bagasse Ash blended concrete also did a great job in energy absorption test and also absorbed most of the potential energy but lesser than the Rubber.

From, these results it can be inferred that with increase in the Rubber Content the energy absorption capacity of the concrete increases. Rubber Blended Concrete can be used in the areas where more energy absorption is required like areas where Machine Foundation is there as well as areas where high impact load is present like in roads, footpaths as well as in the case of Railway Sleepers, as they are designed to carry & dissipate Vibrational Loads as well as Impact Loads occurred due to continuous movement of Wagons & Locomotives over them. Also, Sugarcane Bagasse Ash also increased the Energy Absorption Capacity of the concrete but it did not follow any specific pattern.

Table-4.11 Energy Absorption Capacity of Concrete Specimen

	Sugarcane Bagasse Ash			**Waste Tyre Rubber**		
	15%	20%	25%	10%	20%	30%
Initial Ht.	1m	1m	1m	1m	1m	1m
Initial Potential Energy (P1)=m*g*h	3.924 Kg/s^2	3.924 Kg/s^2	3.924 Kg/s^2	3.924 Kg/s^2	3.924 Kg/s^2	3.924 Kg/s^2
Rebound Ht.	0.2m	0.22m	0.18m	0.15m	0.12m	0.09m
Final Potential Energy (P2)=m*g*h	0.784Kg/s^2	0.863Kg/s^2	0.706 Kg/s^2	0.588 Kg/s^2	0.470 Kg/s^2	0.353 Kg/s^2
Energy Absorption Capacity (P1-P2)	3.14 Kg/s^2	3.061 Kg/s^2	3.218 Kg/s^2	3.336 Kg/s^2	3.454 Kg/s^2	3.571 Kg/s^2

4.4.6 Water Absorption Capacity

After 28 days of curing, the cube specimen is heated to 110°C for 24 hours in an oven. After being taken out of the oven, the specimen is allowed to cool in the air at room temperature before being weighed (Wa). The specimens are submerged in water for at least 48 hours at a temperature of roughly 25°C after final drying and cooling. After being surface-dried by absorbing the surface moisture with a towel (Wb), the specimens weight is recorded. The average absorption of 3 samples was determined as the water absorption capacity of the each %age replacement value. Water Absorption (%) = {(Wb -Wa)/Wa } * 100

Table 4.12 Water Absorption of SCBA & Rubber Concrete Samples

	Sugarcane Bagasse Ash			**Waste Tyre Rubber**		
%age Replacement	**15%**	**20%**	**25%**	**10%**	**20%**	**30%**
Oven Dried Wt. (Wa)	8.212	8.130	8.313	8.191	8.118	8.150
Sat. Surface Dried Wt. (Wb)	8.616	8.898	8.561	8.6	8.75	9.04
Water (%) Absorption	4.93	3.32	2.98	4.99	7.78	10.92
Oven Dried Wt. (Wa)	8.398	8.029	8.167	8.178	8.103	7.845
Sat. Surface Dried Wt. (Wb)	8.772	8.3	8.556	8.596	8.747	8.635
Water (%) Absorption	4.46	3.38	3.03	5.12	7.95	10.08

Oven Dried Wt. (Wa)	8.312	8.559	8.454	8.369	8.127	7.944
Sat. Surface Dried Wt. (Wb)	8.701	8.873	8.664	8.863	8.779	8.836
Water (%) Absorption	4.68	3.67	2.49	5.91	9.23	11.98
Av. Oven Dried Weight (Wa)	8.307	8.239	8.311	8.246	8.116	7.982
Av. Sat. Surface Dried Wt. (Wb)	8.696	8.706	8.593	8.686	8.758	8.837
Av. Water Absorption	4.69	3.45	2.83	5.34	8.32	10.99

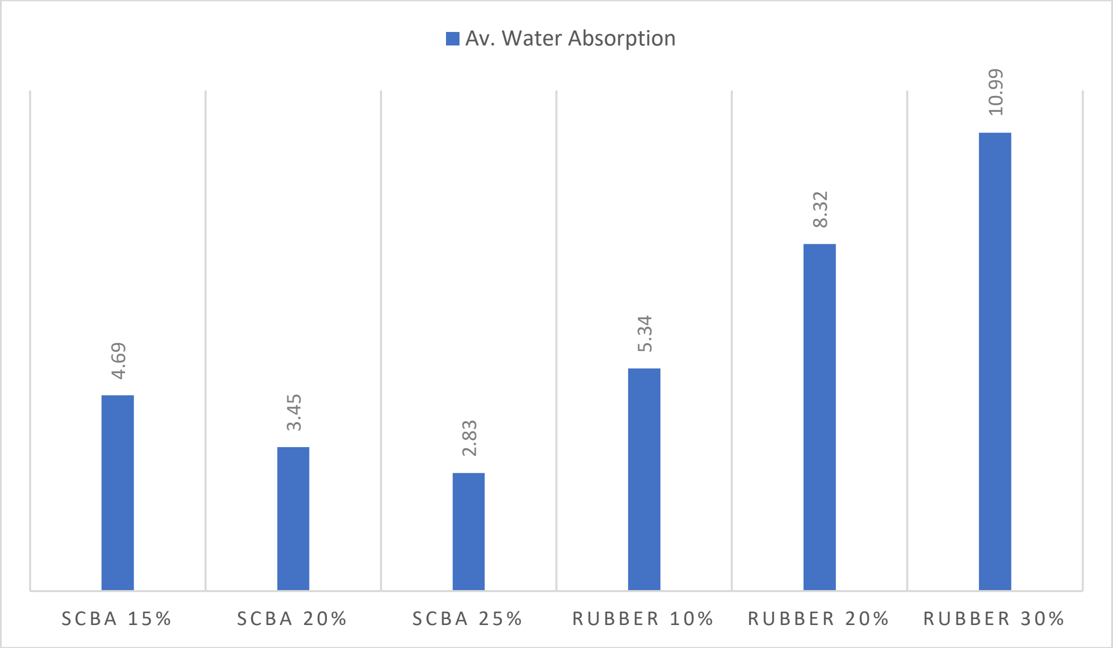

Figure 4.8 Average Water Absorption Capacity

From the above analysis it can be inferred that the Water absorption capacity of the concrete decreases with increase in the replacement of Sugarcane Bagasse Ash as, SCBA is finer than the cement particles so it occupies the pores present in the concrete matrix & hence it decreases the water penetration in the concrete cubes.

In the Rubber matrix, since Rubber acts as voids & it has cement repealant properties so, the concentration of voids increases in the rubber & also as Rubber is known to absorb water, therefore there is an increasing trend in the water absorption capacity. Moreover, it is also observed from the literature review that when replace the Rubber Aggregates with Coarse Aggregates instead of Fine Agg, there is more increase in the water absorption capacity, so it is advisable to use Rubber as Fine Agg. not as Coarse Agg. This also shows the fact that Rubber Aggregates, can be in future used to design pervious concretes.

4.4.7 Effect on Compressive Strength due to Concrete being exposed to Elevated Temperatures

This test analyses the performance of the Specimen under the action of elevated temperature. From the literature review, three temperature ranges have been selected for the specimen to be tested, Tests have been performed on the 2 samples each for all the replacement percentages of Rubber and Sugarcane Bagasse Ash

The temperature ranges selected are 200℃, 300℃ & 400℃ for both Sugarcane Bagasse Ash as well as Waste Tyre Rubber. From the tests at 200℃, there were a few takeaways. There were visible signs of cracks in the concrete with 20% & 30% Rubber content, this proved that the inclusion of Rubber had an expansion effect on the concrete. Also, when these samples were tested for Compressive Strength, there was not significant decrease in compressive strength up to 20%, but a sharp decrease in the compressive strength has been noticed when the Rubber replacement was 30%. The values came around 10N/mm^2.

In the Sugarcane Bagasse Ash mix, initially Compressive Strength increase from 15% to 20%, but later declined at 25% with very fine cracks starting to appear at 25% replacement. 25% replacement of the SCBA gave the worst result as the values dropped down under the 40KN/m^2 value. Coming to the 20% replacement, it was concluded that only 20% replacement was suitable for further temperature tests, therefore proceeded with it at higher temperatures.

Table 4.13 Compressive Strength at exposure temperature of 200 °C

	Sugarcane Bagasse Ash			**Waste Tyre Rubber**		
%age Replacement	**15%**	**20%**	**25%**	**10%**	**20%**	**30%**
Sample No.	**Compressive Strength** (N/mm^2)			**Compressive Strength** (N/mm^2)		
1	43.32	47.81	37.78	43.08	48.46	11.58
2	41.95	56.93	36.42	37.67	45.14	9.09
3	39.40	51.26	35.09	35.41	43.98	10.11
Av. Compressive Strength	41.55	52	36.43	38.72	45.86	10.26

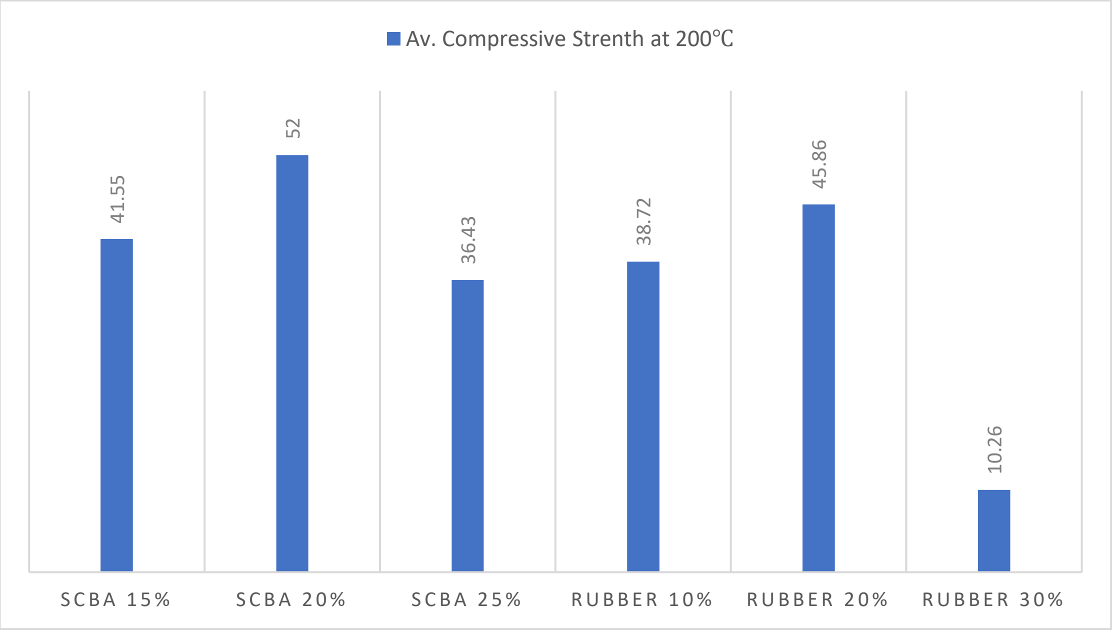

Fig. 4.8 Average Compressive Strength at 200°C

It was noticed that the Waste Tyre Rubber samples cracked in the pre-heating process before putting the samples in the furnace for further testing. They were kept in the oven at 110°C for 48 hours so as the excess moisture can be evaporated, but after taking out the samples from the oven major cracks were observed on the surface itself.

Also, in Sugarcane Bagasse Ash, the values of the compressive strength dropped under 40N/mm^2 when tested at 300℃, this was way under our Target compressive strength requirement of 45.33 N/mm^2. The results of the Sugarcane Bagasse Ash are shown in the graph below.

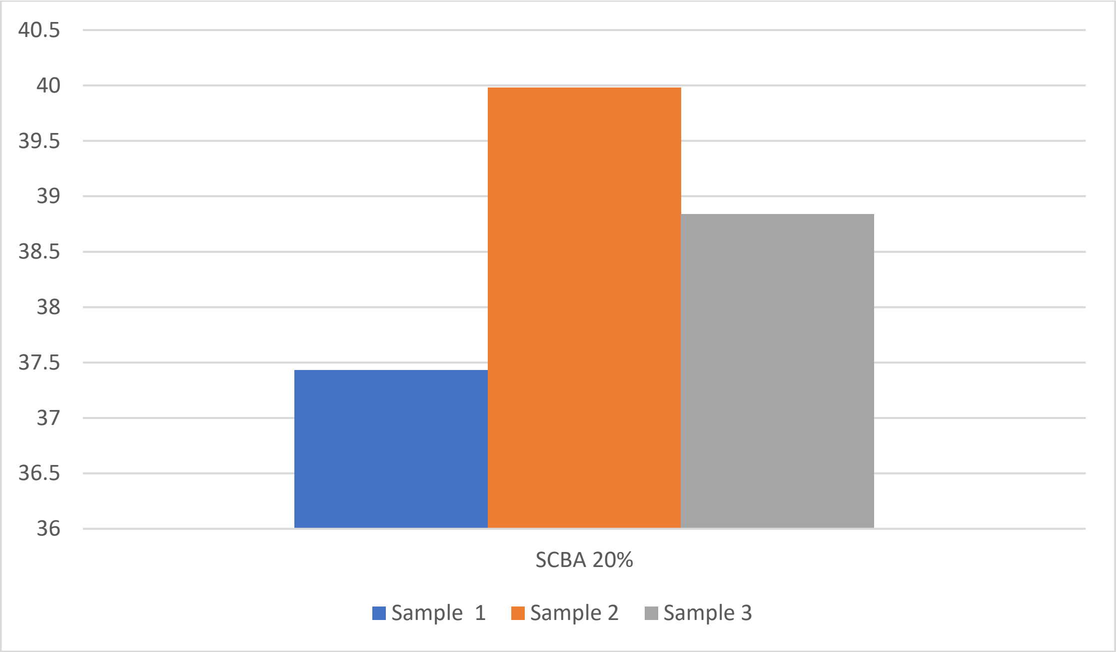

Figure 4.9 Compressive Strength of 20% SCBA replacement Cubes at 300℃

4.5 PHASE 2: TESTS ON THE OPTIMUM MIX AND NORMAL MIX

From the tests above which mainly comprised of Compressive Strength, Sulphate Attack, Chloride Attack, Energy Absorption & Water Absorption Test, it was concluded that 20% replacement value for the Sugarcane Bagasse Ash and Waste Tyre Rubber gave the best strength with adequate Energy Absorption Capacity & Water Absorption. So, now the optimum mix has been prepared by incorporating the optimum values of both the materials and the tests will be performed on the specimens of the Nominal Mix. This will give us a clear-cut understanding of the effect of utilization of both of these materials on the Durability of the Concrete Structures that are to be constructed with the help of these Waste Materials.

4.5.1 Effect of SCBA and Waste Tyre Rubber on Compressive Strength

Compressive Strength test has been performed on the Nominal Mix and the Optimum Mix & the results have been compared. The target mean strength of our mix was 45.33 N/mm^2 but the Optimum Mix achieved a strength of 50.4 N/mm^2. This shows that the materials perform well under the compressive load and can be used.

Table 4.14 Compressive Strength Values of Nominal Mix & Optimum Mix

	Nominal Mix			SCBA 20% + Rubber 20%		
Sample No.	1	2	3	1	2	3
Weight (Kg)	8.698	8.734	8.767	8.206	8.044	8.332
Strength (N/mm^2)	57.06	62.08	60.77	52.31	48.82	50.09
Average Weight (Kg)	8.733			8.194		
Average Strength (N/mm^2)	59.95			50.406		

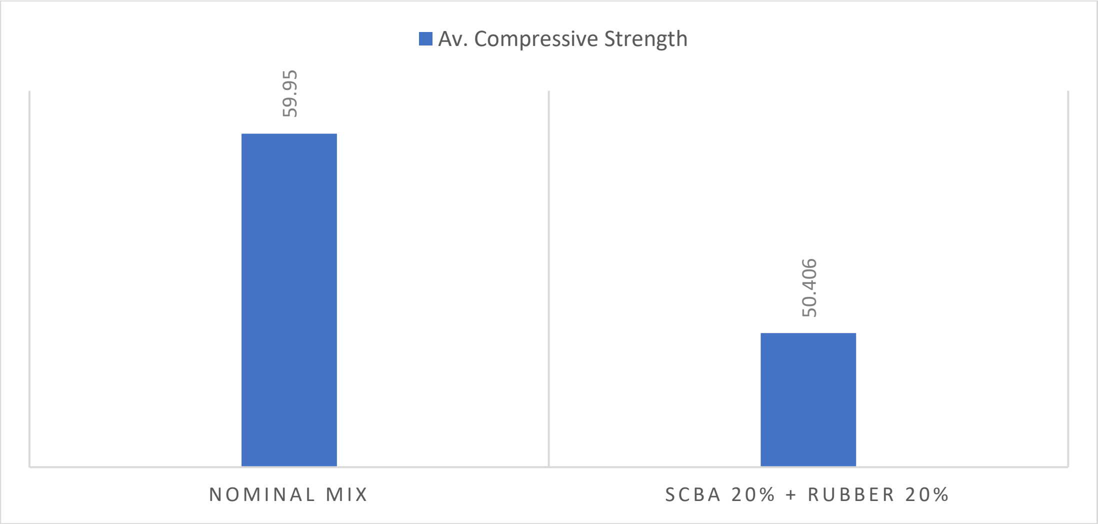

Figure 4.10 Compressive Strength Values of Nominal Mix & Optimum Mix

4.5.2 Effect of Sulphate on the Compressive Strength (Sulphate Attack)

Nominal Mix and the optimum value have been submerged in the $MgSO_4$ solution for 28 days. After 28 days, the compressive strength tests have been carried out & the results are tabulated. There is decrease in the compressive strength by 13% in the Optimum Mix as compared to the Nominal Mix.

Table 4.15 Compressive Strength of Normal Mix & Optimum Mix in MgSO4 Sol.

	Nominal Mix			SCBA 20% + Rubber 20%		
Sample No.	1	2	3	1	2	3
Initial Weight (Kg)	8.658	8.684	8.732	8.106	8.229	8.151
Final Weight(Kg)	8.412	8.398	8.404	7.921	7.963	7.842
Strength (N/mm^2)	48.06	45.08	50.77	43.57	44.76	42.89
Av. Initial Weight (Kg)	8.691			8.162		
Av. Final Weight (Kg)	8.404			7.908		
Av Strength (N/mm^2)	50.63			43.74		

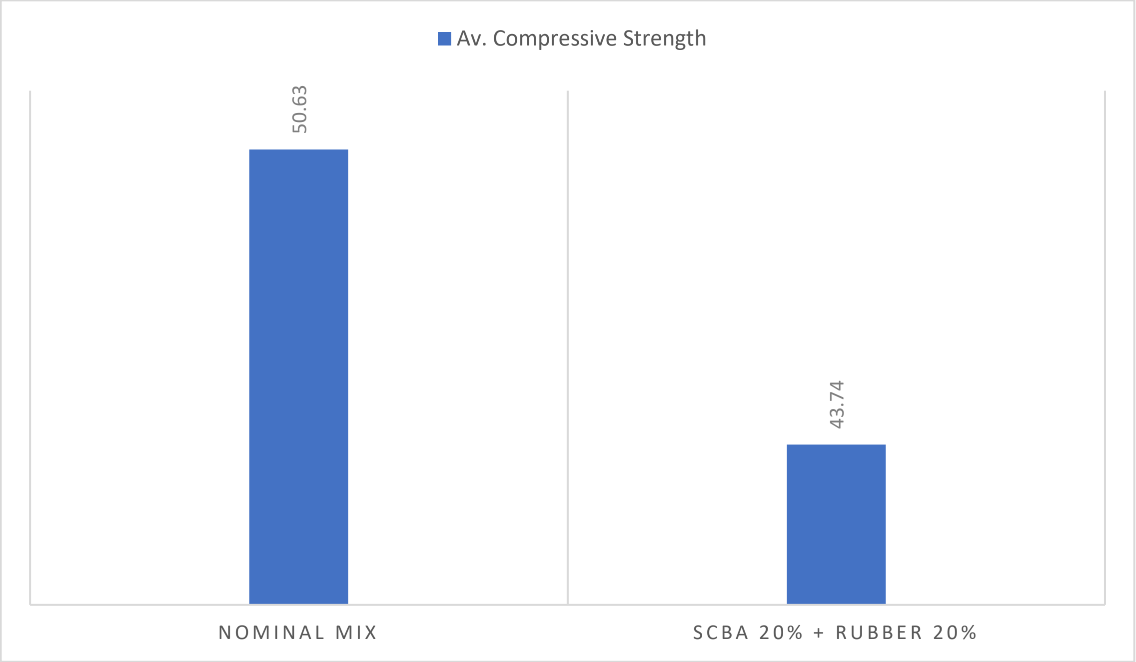

Figure 4.11 Compressive Strength of Nominal Mix & Optimum Mix in MgSO4 So

4.5.3 Effect of Chlorides on the Compressive Strength (Chloride Attack)

Nominal Mix and the optimum value have been submerged in the NaCl solution for 28 days. After 28 days, the compressive strength tests have been carried out & the results are tabulated. There is decrease in the compressive strength by 6.74% in the Optimum Mix as compared to the Nominal Mix.

It can be noticed that the Optimum Mix has lower loss in strength when submerged in NaCl solution as compared to the samples which have been submerged in the $MgSO_4$ solution.

It can be concluded that the Rubber & Sugarcane Bagasse Ash performs better when exposed to conditions where there are Chlorides, like in Sea Water as well as Under Water Construction.

Table 4.16 Compressive Strength of Nominal Mix & Optimum Mix in NaCl Sol.

	Nominal Mix			SCBA 20% + Rubber 20%		
Sample No.	1	2	3	1	2	3
Initial Weight (Kg)	8.678	8.709	8.749	8.279	8.218	8.309
Final Weight (Kg)	8.354	8.466	8.585	8.129	8.125	8.169
Strength (N/mm2)	47.91	49.18	48.84	46.18	44.49	45.41
Av. Initial Weight (Kg)	8.712			8.268		
Av. Final Weight (Kg)	8.468			8.141		
Av. Strength (N/mm^2)	48.64			45.36		

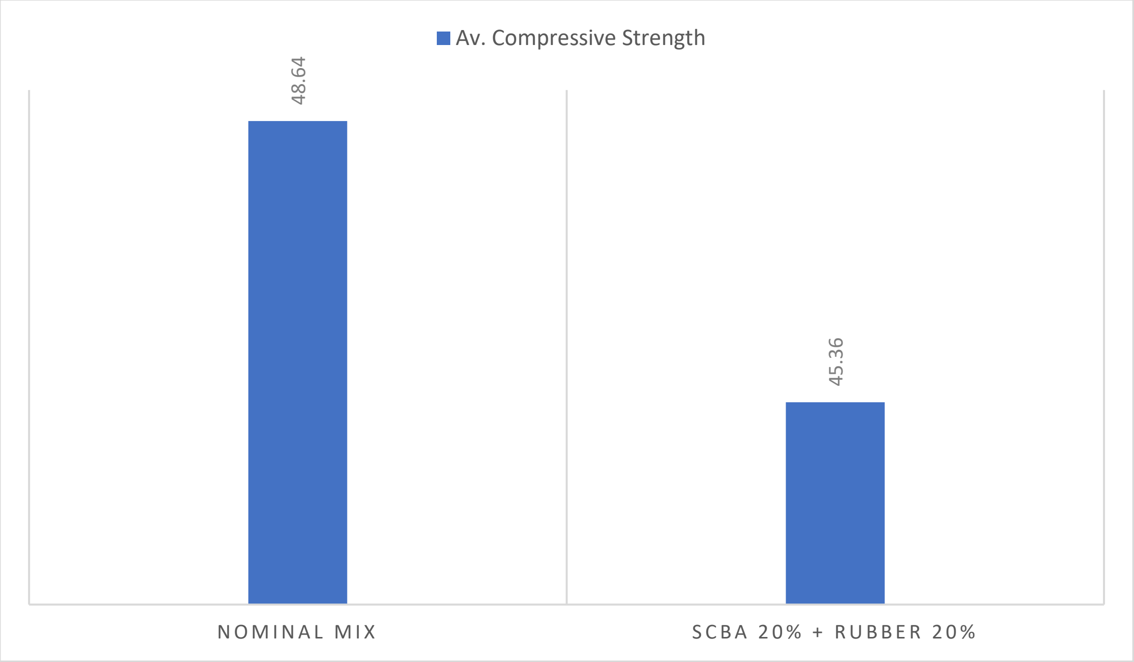

Figure 4.12 Compressive Strength of Nominal Mix & Optimum Mix in NaCl Sol.

4.5.4 Energy Absorption Test / Impact Resistance Test

From the test results, it can be inferred that due to the addition of Rubber in the concrete matrix, the Energy Absorption Capacity of the specimen have improved & this shows that our optimum mix can be used as the machine foundation for better energy dissipation.

Table 4.17 Energy Absorption Capacity of Nominal Mix & Optimum Mix

	Nominal Mix	**Optimum Mix (SCBA 20% + Rubber 20%)**
Initial Ht.	1m	1m
Initial Potential Energy (P1) = m*g*h	3.924 Kg/s^2	3.924 Kg/s^2
Rebound Ht.	0.31m	0.16m
Final Potential Energy (P2) = m*g*h	1.216 Kg/s^2	0.627 Kg/s^2
Energy Absorption Capacity (P1-P2)	2.708 Kg/s^2	3.297 Kg/s^2

4.5.5 Water Absorption Capacity

The Optimum Mix, has lower water absorption as compared to the Nominal Mix. This is due to the fact that Sugarcane Bagasse Ash have filled up the pores which decreased the voids in the concrete matrix and hence decreasing the concrete matrix.

This can be concluded that the Optimum Mix of Sugarcane Bagasse Ash & Waste Tyre Rubber have less permeability as compared to the nominal mix & it can be used as in the areas where lower permeability is required like in the lining of Tunnels & Dams.

Table 4.18 Water Absorption Capacity of Nominal Mix and Optimum Mix

	Nominal Mix			SCBA 20% + Rubber 20%		
Sample No.	1	2	3	1	2	3
Oven Dried Wt. (Wa)	8.509	8.458	8.558	8.106	8.206	8.218
Sat. Surface Dried Wt. (Wb)	8.982	9.112	8.938	8.44	8.556	8.588
Water (%) Absorption	5.56	6.21	5.68	4.13	4.27	4.51
Av. Oven Dried Weight (Wa)	8.508			8.176		
Av. Sat. Surface Dried Wt. (Wb)	9.01			8.528		
Av. Water Absorption	5.81			4.303		

CHAPTER-5

CONCLUSION

5.1GENERAL

This research has been performed in 2 phases. In Phase 1 Cement has been replaced with Sugarcane Bagasse Ash & Fine Aggregates with Crumb Rubber & various tests are performed to get the optimized value of both the materials. In Phase 2 both the optimum values of the materials are combined in a single concrete matrix & the test have been performed again to understand the change in property and effect of each of the materials on the concrete behaviour. A comprehensive study has been done in the research to make use of these waste materials so that cost of the concrete can be reduced as well as it might help in reducing the generation of waste products in the environment & the pollution produced by the construction industry can be controlled. Compressive Strength, Test Slump Test (Workability), Mass Test (Density), Chloride Attack, Sulphate Attack, Carbonation Resistance, Water Absorption Energy, Absorption (Impact Resistance) & Behaviour at Elevated Temperatures are the tests that have been performed on the concrete samples.

5.2 CEMENT REPLACED WITH SUGARCANE BAGASSE ASH

- The mass of the cube for the mix with no partial replacement was 8.71Kg, while the mass kept on decreasing continuously as the replacement percentages of Sugarcane Bagasse Ash increases. The reduced mass of the mix with 20% of Sugarcane Bagasse Ash and Waste Tyre Rubber stands at 8.194Kg which is approximately 6% less. It can be concluded that replacing the waste materials can reduce the overall dead weight of the concrete. The reason behind this is that Sugarcane Bagasse Ash and Waste Tyre Rubber are lighter as compared to Cement and Fine Aggregates.
- Workability of the Normal Concrete was 120mm which was well within the codal provisions and the Workability was high, but with increase in the percentage of Sugarcane Bagasse Ash there was a decrease in Workability but it is still workable and the values are 105mm, 97mm and 82mm for 15%, 20% and 25% respectively.

- There is an increase in the compressive strength by 21% when the Sugarcane Bagasse Ash value is increased from 15% to 20% but there is decrease in the compressive strength when 25% replacement with Cement is done. This suggests that Ash is finer than OPC & it occupies the voids & pores present between the cement and makes a strong bond between the two which increases the compressive strength.
- The Compressive Strength values of 20% Sugarcane Bagasse Ash replacement is 12.39% less than that of Nominal Mix, while for the Optimised mix it is 15.91% lesser than the Nominal Mix. The value is 50.406 N/mm^2 which is greater than the Target Mean Strength of 45.33 N/mm^2.
- In the Sulphate Attack Test, initially there is a decrease in the Compressive Strength at 14 days due to the formation of Gypsum in the concrete and the mean value is obtained as 40.34N/mm^2 but after 28 days, the $MgSO_4$ become unreactive and the formation of Ettringite as the precipitate occurred which increased the mean compressive strength value by 12.11% to 45.9N/mm^2. This is also verified by the literature review.
- The Chloride Attack test concluded that at 14 days the compressive strength of the 15% replacement of Sugarcane Bagasse Ash starts to decrease but the 20% and 25% replacement does not show any major change as the values remains 45.39 & 52.89 N/mm^2 respectively. When the tests are done after 28 days the same trend continues but 25% Sugarcane Bagasse Replacement has more loss of strength and the mean value was 44.85 N/mm^2 as compared to 49.6 N/mm^2 for 20% replacement. This is due to the fact that SCBA is very fine which decreases the penetration of Chlorides in the concrete specimen.
- SCBA cubes, had no effect of CO_2 (Carbonation of Concrete Samples) due to the fine nature of SCBA.
- For the Energy Absorption Test, the mean values of the Energy Absorption obtained are 2.708 Kg/s^2, 3.139 Kg/s^2 3.453 Kg/s^2 and 3.297 Kg/s^2 for Nominal Mix, Sugarcane Bagasse Ash, Rubber and Optimized Mix respectively. It can be concluded that Rubber has the best Energy Absorption Capacity and Sugarcane Bagasse Ash has slightly increased Energy Absorption as compared to Normal Concrete.

- Water Absorption Capacity decreases with replacement of Sugarcane Bagasse Ash with cement by 37.11%. This suggests that Sugarcane Bagasse Ash makes the concrete matrix free from voids.
- At Elevated Temperature, at 200°C, the compressive strength of the 15% ,20% & 25% replacement mix, are 41.55 N/mm^2, 52 N/mm^2 and 36.63 N/mm^2, but there was visibility of minor cracks at the 25% replacement values at 25% and the 15% replacement had a lesser compressive strength. This is due to the presence of Un-Burnt Carbon in the Sugarcane Bagasse Ash which decreases the compressive strength at elevated temperatures. Also, when heated at 300°C, the 20% replacement of Sugarcane Bagasse Ash had a lower strength of 38.73 N/mm^2 which is less than the Target Mean Strength. This concluded that the Sugarcane Bagasse Ash is not well suited of Structures that are prone to elevated temperatures.

5.3 FINE AGGREGATES REPLACED WITH CRUMB RUBBER

- The Slump Value of Waste Tyre Rubber Replacement at 10%, 20% and 30% are 98mm, 85mm and 70mm respectively. This shows that Rubberized Concrete has low workability. The main reason behind the decrease in the workability is the high absorption capacity of Rubber and hydrophobic nature of Rubber Aggregates.
- Rubberized Concrete has lower density than the Sugarcane Bagasse Ash concrete mix as the weight of the cubes for the same replacement percentage are 8.252Kg, 8.005Kg and 7.623Kg at 10%, 20% and 30% respectively while Sugarcane Bagasse Ash had 8.585Kg, 8.382Kg and 8.106Kg for 15%, 20% and 25% replacement respectively.
- Concrete's mechanical qualities can generally be decreased by adding rubber, and this tendency gets worse as rubber quantity and size rise. Due to the weak adherence of rubber to cement paste, a wide and porous ITZ (Inter Transitional Zone) was seen in Rubberized Concrete. Rubber is being pre-treated as a result. This is the reason of the decrease in the compressive strength of the Rubberized Concrete. The compressive strength of the 30% Rubber Replacement was 17.74 N/mm^2 which proves the statement.
- In the Sulphate Attack test, it was found that there is a gradual decrease in the compressive strength as the percentage of the Rubber is increased in the concrete

either at 14 days or 28 days. At the 14 days mark, the compressive strength of 10%, 20% & 30% Rubber replacement were 42.65 N/mm^2, 37.77 N/mm^2 & 23.65 N/mm^2 respectively, while at the 28 days mark these were 24.58 N/mm^2, 28.35 N/mm^2& 24.42 N/mm^2. This shows that the Rubber Particles react with $MgSO_4$ and due to the voids in the concrete matrix due to rubber replacement, Sulphates were able to penetrate the matrix and weakened the bond between Cement and Aggregates which leads to decrease in the compressive strength. This problem was overcome by adding Sugarcane Bagasse Ash in the matrix and there was gain in the compressive strength to 43.78 N/mm^2.

- It is observed that the samples had an Orange-Brown colour deposition in the interior as well as the exterior of the Rubber specimen, proving that there has been ingress of Sulphates in the concrete matrix.
- In Chloride Attack test, there was extraordinary strength gain at 20% replacement. The compressive strength values obtained at 10%, 20% and 30% replacement at 14 days were 23.67 N/mm^2, 49.6 N/mm^2 & 44.85 N/mm^2 while at 28 days were 38.61 N/mm^2, 51.34 N/mm^2 & 23.12 N/mm2. The reason behind this is that the Rubber make the concrete porous, it is easy for chemicals and water to penetrate the concrete easily which decreases the durability of the Rubberized Concrete
- In the Carbonation Analysis, it was observed that there has been slight Carbonation effect on the concrete samples till 1-2cm depth in the specimen. This illustrates that Rubber Concrete is susceptible to Carbonation.
- For Energy Absorption, Rubber performed extremely well. It absorbed almost 80% of the Impact Energy. The normal Concrete absorbed 70% of the Potential Energy of the ball while the Rubberized Concrete with 30% rubber replacement absorbed 91% of the total Potential Energy and the Optimum mix with 20% Sugarcane Bagasse Ash and Rubber each absorbed 85% of the total potential Energy. This is due to the fact that Rubber Aggregates are soft in nature so, they are able to compress. This is also proved during the compressive strength test, when the test was performed and the pressure was released, the cubes tried to retain their original shape before the application of load.
- In the test of Elevated Temperature, the 30% replacement of Rubber revealed surface cracks and the strength also came 10.26 N/mm^2, also, during the pre-heating process itself, Rubber specimen with replacement values of 10% and 20%

manifested surface cracks so, it can be concluded that Rubber Aggregates are not suitable for high temperatures.

5.4 FUTURE SCOPE OF WORK

- Behaviour of Rubber aggregates, when replaced with Coarse Aggregates need to be studied also if they can be made into powdered form, their behaviour when replaced as a cement is to be explored.
- Effect of freezing temperature on the strength of the Rubber Concrete has to be explored so as to understand their utilization in the colder regions.
- For Sugarcane Bagasse Ash, there is a need to study more about the Carbon content in the SCBA as well as its effect on the concrete compressive strength and the efficacy of the Ash in the concrete, so as this ever-generated waste material can be brought in the cement industry as soon as possible. The most important thing to notice is that SCBA shares a lot of properties with Fly Ash, but the quality of SCBA depends on the burning temperature of Sugarcane Bagasse.
- Furthermore, its effect on the Concrete's compressive strength at lower temperatures as well as its behaviour when it is used as filler need to be studied.

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