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UTILIZATION OF INDUSTRIAL CERAMIC SLUDGE AND RECYCLED COARSE AGGREGATES FOR SUSTAINABLE GREEN CONCRETE

Manideep Pampadiga[1], Dr. Suresh Ranga[2], Dr. Aditya Kamineni[3],

[1,] M. Tech, student, Department of Civil Engineering, JB institute of engineering and technology (JBIET)

[2] Assistant professor, Department of Civil Engineering, JB institute of engineering and technology (JBIET)

[3] Associate professor, Department of Civil Engineering, JB institute of engineering and technology (JBIET)

ABSTRACT

This study aims to examine the environmental impacts of concrete, particularly in light of the significant expansion within the construction industry. A variety of new technologies have developed swiftly to address various challenges in the construction industry. Concrete is a critical material in the construction industry, standing out among all materials utilized for construction purposes. The manufacturing process of cement contributes approximately eight to ten percent of the total carbon dioxide emissions globally. The emission of greenhouse gases occurs during the crushing and heating of limestone and clays at elevated temperatures. In recent years, the recycling of waste and industrial by-products has gained popularity as a means to create environmentally friendly concrete, often referred to as Green Concrete. Green concrete is characterized by the incorporation of waste materials as a component, a production process that minimizes environmental impact, or the achievement of high performance and sustainability throughout its life cycle. This study presents an experimental investigation utilizing recycled coarse aggregates and industrial ceramic sludge material in M30 grade concrete. The proportions of ceramic sludge and recycled concrete aggregate are as follows: 0% ceramic sludge and 0% recycled concrete aggregate, 5% ceramic sludge and 5% recycled concrete aggregate, 10% ceramic sludge and 10% recycled concrete aggregate, 15% ceramic sludge and 15% recycled concrete aggregate, 20% ceramic sludge and 20% recycled concrete aggregate, and 25% ceramic sludge and 25% recycled concrete aggregate. The workability, including the sump and compaction factor, is assessed using various CS and RCA. The strength values, including compressive, split tensile, and flexural strength, are assessed using various percentages of CS and RCA.

Key words: Construction industry, cement, recycled coarse aggregates, industrial ceramic sludge, and green concrete

CHAPTER-I
INTRODUCTION

General

Color is unrelated to green concrete. Thinking and environment are considered in all aspects of raw material processing, from construction and mixture design to structural design and durability. Due to the use of recycled resources, green concrete is cheaper to make, reduces energy use, and increases durability. Sustainable building promotes long-term cost, durability, and efficacy above short-term economic reasons. Every stage of the building life cycle improves convenience, quality of life, environmental effect, and economic sustainability. Sustainable infrastructure decreases resource consumption throughout the building process, with green concrete playing a key role. The abundance of advantages has contributed to the growing popularity within the construction industry, particularly regarding emerging technologies in sustainable construction. Green concrete represents a significant advancement in contemporary construction and serves as a vital resource for future developments, particularly as natural resources face depletion.

The increasing interest in sustainable development has led engineers and architects to prioritize the selection of more sustainable materials. The choice of materials for concrete enhances sustainability and reduces environmental impact. Cement production contributes over 6% of total CO_2 emissions, significantly impacting global warming and greenhouse gas levels worldwide. India ranks as the third largest cement producer globally and is also among the largest consumers of cement on a per capita basis. India's consumption is approximately 1.2 tons per year per capita, compared to the world average of 0.6 tons per year per capita. CO_2 emissions associated with the

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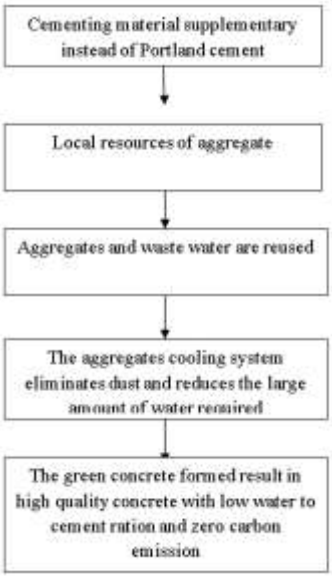
production of 1 ton of concrete range from 0.05 to 0.13 tons. Ninety-five percent of all CO_2 emissions associated with a cubic meter of concrete originate from the cement manufacturing process. Cement is one of the major components of concrete. The manufacturing process of one ton of cement results in the emission of one ton of CO_2 into the atmosphere. CO_2 is recognized as a greenhouse gas that plays a significant role in global warming. The decrease in CO_2 emissions from concrete can be accomplished through the partial substitution of cement with various supplementary cementitious materials. The incorporation of these cementitious materials has led to enhanced properties of concrete.

To mitigate this environmental impact, green concrete is essential. Utilizing recycled or waste materials that are detrimental to the environment, such as fly ash and silica fume, as substitutes for cement can significantly decrease CO_2 emissions from concrete and mitigate its environmental impact. Consequently, green concrete is poised to become a significant solution in the future as natural resources face depletion.

Concept of green concrete

Green concrete uses eco-friendly ingredients to make structures more sustainable. Green Concrete is created from waste materials, saving energy and improving strength and durability. Dr. WG created Green Concrete in 1998.He created successful green concrete by combining mechanical, fire resistance, durability, strength, thermodynamic, and environmental features. India has invested heavily on fast roads, bridges, power projects, airports, and industries to satisfy globalization's needs. Concrete is essential for infrastructure building. Concrete is a cheap material used in industries, bridges, highways, roads, and homes. India produces around 170 million cubic meters of concrete annually in this century. The concrete industry emits around 7% of global CO_2. Green concrete may be made another way. There is no green tone to green concrete. One ton of cement produces one ton of carbon dioxide, according to recent studies. Researchers are replacing some cement with other cementitious materials to minimize concrete carbon dioxide emissions. These materials improve concrete.



Recycled coarse aggregates

The demolition or renovation of concrete structures often leads to the adoption of concrete recycling as a prevalent method for repurposing the resulting rubble. Concrete was previously transported to landfills for disposal; however, recycling offers several advantages that have made it a more appealing choice in today's context of heightened environmental consciousness, increased regulations, and the need to manage construction expenses effectively.

Concrete aggregates collected from demolition sites are processed using a crushing machine. Smashing offices recognize only uncontaminated solid, which must be devoid of debris, wood, paper, and similar materials. Metals, such as rebar, are recognized for their ability to be extracted using magnets and other sorting devices, and can be melted down for recycling purposes elsewhere. The total remaining lumps are organized by estimate. Larger lumps may undergo the crushing process again. Following the crushing process, various particulates are separated using a range of methods, including hand-picking and water buoyancy.

The use of mobile crushers at the actual construction site reduces development costs and minimizes pollution compared to transporting materials to and from a quarry. High-capacity street-convenient plants are capable of processing cement and asphalt rubble at a rate exceeding 600 tons per hour. These frameworks generally consist of a rubble crusher, side release transport, screening plant, and an arrival transport from the screen to the crusher gulf for the reprocessing of oversize materials. Smaller, independent crushers that can handle up to 150 tons per hour are also available, designed to fit into tighter spaces. As crusher connections related to various development equipment, such as excavators, become more prevalent, the trend towards local recycling with smaller volumes of material is rapidly gaining momentum. The connections encompass volumes of 100 tons per hour and below.

Need to use RCA

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Construction and demolition trash is one of the major in the EU, Asia, and other regions. Construction waste, defined as materials from destroyed buildings or structural engineering, is predicted to equal 180 million tons per year, or 480 kilograms per EU citizen. Sweden, Greece, and Ireland have below 200 kg per person per year, whereas Germany and the Netherlands have above 700 kg. The UK contributes 30 million tons each year, with an average of 500 kg per person, ranking second behind Germany. A CSIR Building and building Technology assessment found that South African landfills hold one million tons of building and demolition trash. Even if large amounts are illegally disposed of. Thus, development destruction and waste are worldwide issues that need sustainable solutions.

It is well accepted that recovering and reusing crushed trash in value-added applications may boost economic and environmental advantages. Because of this, recycling programs across the globe, including South Africa, turn low-value garbage into secondary building materials including aggregate levels, road materials, and aggregate fines. These materials are utilized for road construction, retaining wall inlays, low-grade concrete, drainage, and cheap housing masonry and block work. While improving RCA's usage in larger applications is important, the aggregate for robust applications must meet relevant criteria.

RCA should be progressively included into basic cement to narrow the gap between these interests. Waste processing, including organizing, pounding, separating, and assessing the total for solid development, requires careful management. Waste is recycled as fill, drainage, and sub-base materials in several wealthy countries C and D. Many opportunities exist for increasing this market and using these materials. Implementing efficient C and D waste management strategies and facilitating recycling for value-added applications requires prompt administrative action.

Industrial ceramic sludge

Rapid industrial expansion depletes natural aggregates and generates large amounts of building and demolition trash worldwide. Utilizing garbage may help solve this problem. All countries create trash, with building and demolition waste making about 75% of worldwide waste. The majority of building and demolition trash is ceramic, at 54%.

Kilns fire ceramics, paraffin, rubber,

plastic, paper, and artificial marble. This method lets them be formed into several shapes and is heat-resistant and durable. Ceramics work well as insulators for these reasons. High-voltage insulators shatter, generating a lot of ceramic insulator trash, according to the electrical board. The broken ceramic insulator debris has not been reused. This study uses ceramic waste instead of fine or coarse aggregate.

Environmental issues and studies

The history of construction demonstrates that the construction industry grows alongside advancements in development. However, the substantial volume of raw materials utilized in construction has had an impact on the environment. A significant volume of waste is produced in the construction industry, leading to ongoing generation of waste materials and pollution associated with construction development. It is essential to repurpose waste materials for various applications to mitigate environmental impact.

The continuous increase in infrastructure development has also led to a corresponding rise in environmental impact. The extensive use of cement and other raw materials negatively impacts sustainability, as the significant quantities of cement utilized in the construction industry result in substantial carbon dioxide emissions during the manufacturing process. CO2 has increased greenhouse gases, contributing to the global warming effect. Global warming is a significant challenge facing the world, necessitating efforts to manage this issue along with other environmental concerns.

Research has used garbage in concrete to reduce environmental effect. Fly ash, silica fume, and other waste products are used in construction. Research is also using more ceramic insulator trash. Due to high disposal costs and rising environmental requirements, waste manufacturers worldwide are recycling and reusing. Controlled landfills may be needed for ashes containing cadmium and lead. Finding methods to use this trash is critical because recycling technologies that transform combustion waste oxide into value-added goods are profitable. It reduces permeability, preventing groundwater recharge. These particles may pollute the air, harming people, animals, flora, and equipment. They replace fine and coarse aggregate in concrete. Ceramic waste in concrete helps the ecology and ecosystem.

Strength of concrete

The strength of concrete is its resistance to rupture. Strength is measured by compression, tension, shear, or flexure. Compressive strength is critical to concrete. Hardened concrete quality is measured qualitatively. Compressive strength evaluates concrete mix components. Concrete strength depends on water-to-cement ratio, cement quality and amount, chemical composition, cement-to-aggregate ratio, age and curing conditions, aggregate grading, surface texture, form, size, strength, and stiffness. The chemical makeup and particle size of cement impact concrete strength. Fuel usage, kiln operation, clinker output, and cement performance depend on chemical composition. Increased cement fineness improves early concrete strength.

Objectives of the study

The objectives established for the current study are as follows

1. Assess the workability, overall strength, and rate of strength gain for concrete incorporating ceramic waste and recycled materials.
2. Evaluate the performance of concrete made with industrial ceramic sludge and recycled coarse aggregates in comparison to a traditional mix.
3. To assess the strength values with different proportions of ceramic sludge and recycled coarse aggregates.
4. To create green concrete utilizing an M30 grade concrete mix

Summary

Green concrete involves the utilization of environmentally friendly materials in concrete production to enhance the sustainability of infrastructure. Green Concrete is cost-effective to produce as it utilizes waste materials, resulting in reduced energy consumption while enhancing strength and durability. Green Concrete was initially developed by Dr. WG in 1998. In recent years, India has undertaken significant initiatives to enhance its infrastructure, including express highways, bridges, power projects, airports, and industries, to meet the demands of globalization.

In the current century, India generates over 170 million cubic meters of concrete each year. Globally, concrete industries contribute to over 7% of carbon dioxide emissions. An alternative technique exists for the production of green concrete. Green Concrete is not related to its color; it does not possess a green hue. Recent research indicates that the production of one ton of cement generates approximately one ton of carbon dioxide in the atmosphere.

CHAPTER- II

LITERATURE REVIEW

1**. Title:** "Utilization of Ceramic Waste in Sustainable Concrete Manufacturing"
Authors: John D. Wilson and Maria L. Rivera
Summary: Wilson and Rivera investigated the feasibility of utilizing ceramic waste as a partial substitute for cement in concrete. The experimental research indicated that the processing and incorporation of ceramic sludge in precise proportions enhanced the durability and minimized the carbon footprint of concrete. A comprehensive analysis of the pozzolanic properties of ceramic waste was conducted, establishing its contribution to the enhancement of concrete's compressive strength. Furthermore, their study provided data on the energy savings realized through this replacement.

2. **Title:** "Evaluation of Recycled Aggregates in Sustainable Concrete"
Authors: Ahmed H. Khalil and Sarah E. Morgan
Summary: Khalil and Morgan conducted an evaluation of the mechanical properties of concrete incorporating recycled coarse aggregates (RCA). The study emphasized that recycled concrete aggregates could substitute natural aggregates by as much as 50% without notably compromising the structural integrity of concrete. The team conducted comprehensive durability testing, which included freeze-thaw resistance and abrasion assessments, highlighting the environmental and economic advantages of RCA in minimizing construction waste.

3. **Title:** "Utilization of Industrial Byproducts in Sustainable Construction Materials"
Authors: Priya Sharma and Ramesh Gupta
This study analyzed the chemical properties of industrial byproducts, including ceramic sludge, and their effects on the resistance of concrete to chloride penetration. Sharma and Gupta's findings highlighted the dual benefit of minimizing landfill waste while enhancing the durability of concrete structures. A comparative cost analysis was also included, indicating substantial savings for the construction industry.

4. **Title:** "Mechanical and Durability Properties of Concrete Incorporating Recycled Aggregates and Ceramic Waste"
Authors: Li Wei and Zhou Ming
Summary: Wei and Ming examined the integrated application of RCA and ceramic waste, exploring their collaborative effect

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on enhancing concrete performance. The research indicated that a blend comprising 30% RCA and 10% ceramic sludge yielded the best outcomes regarding compressive strength and durability in challenging environmental conditions. Their work encompassed long-term monitoring data, rendering it valuable for practical applications.

CHAPTER-III

MATERIALS AND METHODOLOGY

3.1 GENERAL:-

An experimental investigation has been structured to assess the effects of industrial ceramic sludge and recycled coarse aggregate on concrete by varying the proportion of coarse aggregates. Six distinct concrete mixtures were formulated, one of which was a nominal mix. Nine cubes, nine cylinders, and nine beams were produced for each mix and subjected to curing periods of 3, 7, and 28 days. Specimens underwent evaluations to assess the variations in concrete strength. The execution of this experimental program has been structured into four distinct phases.
Phase 1: Procurement of materials followed by testing procedures.
Stage 2: Evaluation of concrete mixing and workability parameters.
Stage 3: Molding of specimens and subsequent curing process.
Phase 4: Assessment of the specimen.

3.2 DESCRIPTION OF MATERIALS USED:-

3.2.1. Cement:

Portland cement requires calcareous solids like limestone or chalk and argillaceous ingredients like shale or clay. Wet and dry processes exist. This categorization is dependent on whether raw ingredients are mixed and ground wet or dry. Cement is made from lime, silica, alumina, and iron oxide. The oxides react in the kiln at high temperatures, leading to the creation of increasingly intricate compounds. The process by which cement reacts with water, leading to chemical transformations, is known as cement hydration. The hydration of cement can be characterized in two distinct manners. The initial process involves a dissolution mechanism where cement dissolves to create a supersaturated solution, resulting in the subsequent precipitation of hydrated products. Water progressively deteriorates cement compounds, first at the surface and penetrating interior over an extended duration. The interaction between cement and water generates heat. The reaction

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produces a substantial amount of heat. The phenomenon of heat release is termed the heat of hydration.
This investigation utilized 53-grade Ordinary Portland cement (ACC cement), procured specifically for this purpose. The examinations conducted on this item produced a result of 4.3.

3.2.2. Aggregates:

Aggregates are essential to concrete. They improve concrete structural integrity, shrinkage, and cost-effectiveness. Aggregates are inert granular solids like sand, gravel, or crushed stone made from simpler elements. Concrete formulation relies on their essential function. An effective concrete mix requires clean, durable, and sturdy aggregates without absorbed chemicals or clay and other fine elements, which may degrade cement. Size divides aggregates into two types. coarse aggregate fine aggregate

3.2.2.1.coarse aggregate

Coarse aggregates are particles bigger than 4.75 mm, usually 9.5–37.5 mm. These materials may be main, secondary, or recycled. Primary aggregates are terrestrial or marine. Gravel is coarse gravel from marine and terrestrial sources. Gravel and crushed stone make up coarse aggregates. Gravels make up most of concrete's coarse aggregate, while crushed stone makes up the rest.
The study uses 20- and 12-mm coarse aggregate with nominal sizes.

3.2.2.2. Fine aggregate:

Fine aggregates are usually terrestrial or marine sands. The bulk of fine aggregates, usually natural sand or broken stone, pass through a 4.75mm screen. Figure 4.4 shows that this investigation used local river sand as fine material. Initial evaluations gave these resources a 4.3 grade.

3.2.3. Water:

Concrete relies on water to react with cement. Water amount and quality greatly impact the strength-enhancing cement gel formation. C3S needs 24% water by weight, C2S 21%. Average 23% water by weight of cement is needed for chemical interaction with Portland cement compounds. Twenty-three percent of water interacts chemically with cement, making it bonded. Saturating gel-pores requires 15% cement by weight.
Cement needs 38% water by weight to complete chemical reaction and fill gel-pore gaps. Water purity and quality affect strength, thus it's important to assess it. Mixing concrete using potable water is typical. Potassium, sodium, and bicarbonates impact cement setting.

Manganese, tin, zinc, copper, and lead salts considerably weaken concrete. A 2000-ppm turbidity threshold is proposed.

For mixing and curing, this experimental program used locally provided drinkable fresh water without pollutants or organic debris.

Industrial ceramic waste

Ceramics, along with other insulating materials such as paraffin, rubber, plastic, paper, and synthetic marble, are subjected to fire in a kiln. These materials can be molded into diverse configurations, offering exceptional thermal resistance and endurance. Consequently, ceramics have been utilized as insulators and execute their roles effectively. The electrical board has recognized a significant production of ceramic insulator waste due to the fracture of high-voltage insulators.

4. EXPERIMENTAL INVESTIGATION

4.1 Scheme of experimental program:

Sl. No	% CS+%RCA	Compressive strength of concrete			Split tensile strength of concrete			Flexural strength of concrete		
		7days	14days	28days	7days	14days	28days	7days	14days	28days
1	0%CS+0%RCA	3	3	3	3	3	3	3	3	3
2	5%CS+5%RCA	3	3	3	3	3	3	3	3	3
3	10%CS+10%RCA	3	3	3	3	3	3	3	3	3
4	15%CS+15%RCA	3	3	3	3	3	3	3	3	3
5	20%CS+20%RCA	3	3	3	3	3	3	3	3	3
6	25%CS+25%RCA	3	3	3	3	3	3	3	3	3
total		54 Cubes			54 cylinders			54 Prisms		

Each batch consisted of 3 cubes, 3 cylinders, and 3 prisms. A total of 54 cubes, 54 cylinders, and 54 prisms were produced over the entire experiment.

Shape and Dimensions of the Blocks

The table below lists block shapes and dimensions for various tests.
Table 4. 2: Block Shape and Dimensions

Type of test	Shape of block	Length(m)	Breadth(m)	Height(m)	Diameter(m)	Volume of block (m^3)
Compressive strength	Cube	0.15	0.15	0.15	--	0.00375
Split tensile strength	Cylinder	--	--	0.30	0.15	0.00530
Flexural strength	Square prism	0.1	0.1	0.7	--	0.00700

CHAPTER-V

RESULTS AND ANALYSIS

Workability of concrete

Slump cone test

S. No	%CS+%RCA	Slump in mm

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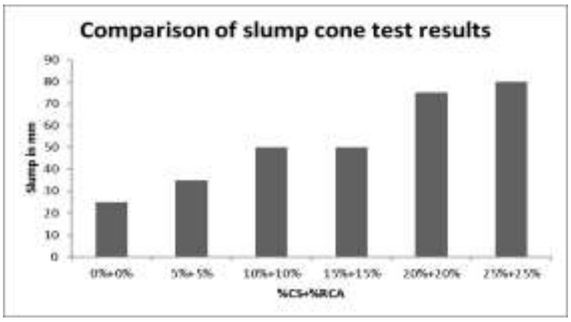
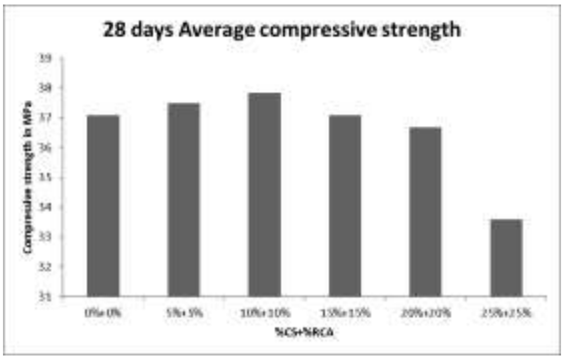
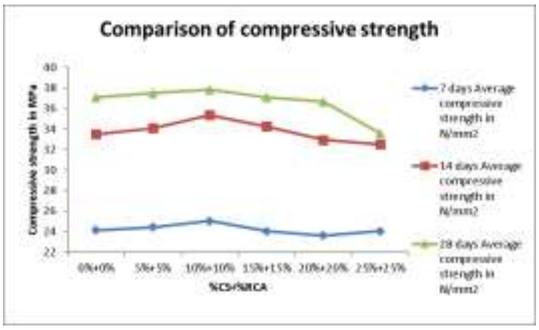
1	0%+0%	25
2	5%+5%	35
3	10%+10%	50
4	15%+15%	50
5	20%+20%	75
6	25%+25%	80



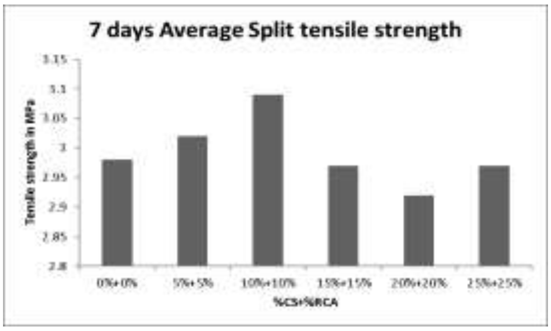


Comparison of compressive strength values

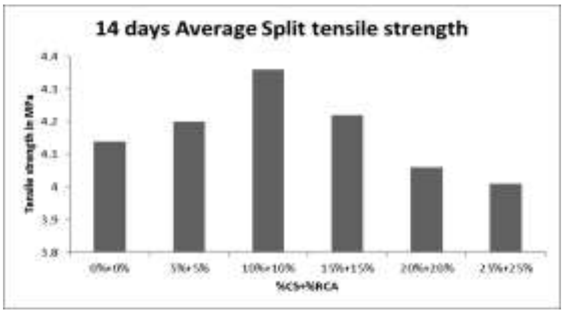


Split tensile strength

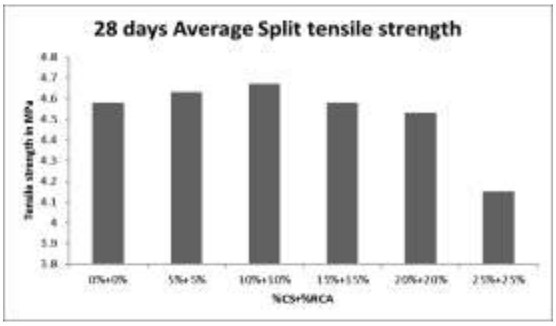
7days



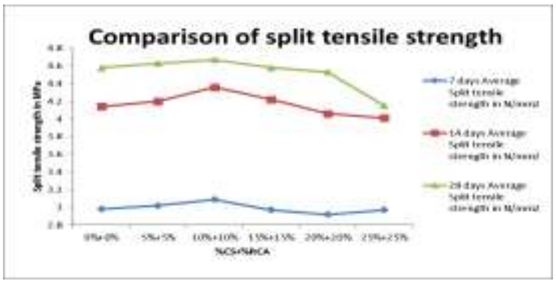
14days



28 days

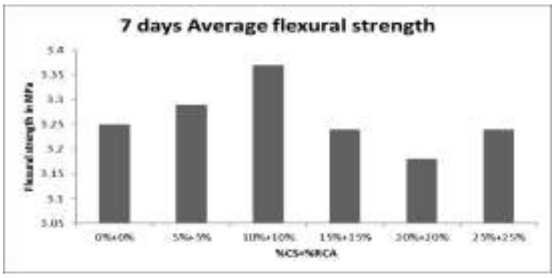


Comparison of split tensile strength values

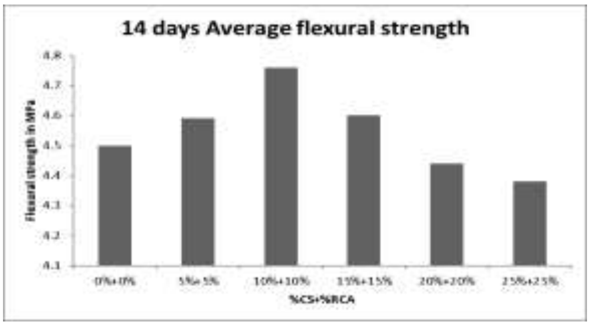


Flexural strength

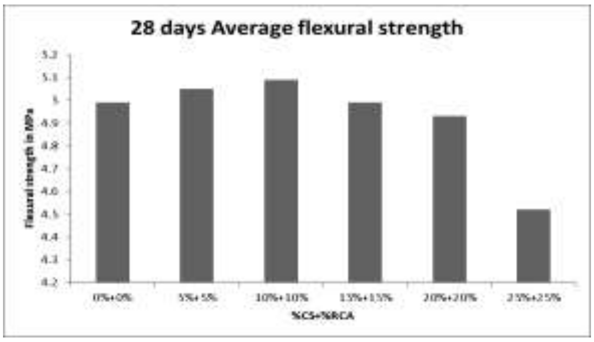
7days



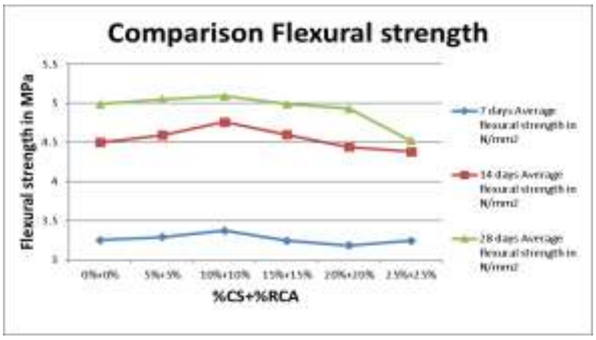
14days



28 days



Comparison of flexural strength values



CHAPTER-VI

CONCLUSON

The following conclusions were drawn from this study.

1. The necessity for sustainable construction is evident. Therefore, to achieve sustainable construction, the concept of green concrete is implemented.

2. By utilizing Green Concrete Technology, we can preserve natural materials for future generations and ensure their sustainability over an extended period.

Green concrete has significantly lowered environmental impact, achieving a 30% reduction in CO2 emissions from the concrete industry. Green concrete exhibits excellent thermal and fire resistance properties.

4. The utilization of waste materials, including ceramic wastes and recycled aggregates, has led to a 20% increase in the concrete industry's adoption of waste products. Therefore, green concrete utilizes less energy and proves to be cost-effective in application.

5. The slump values obtained from the use of ceramic waste and recycled concrete waste increase from 0% to 50% for M30 grade concrete, while the compaction factor decreases from 0% to 50% in the concrete. The highest values of compressive, split tensile, and flexural strength are achieved with 10% ceramic sludge and 10% recycled aggregates in M30 grade concrete across all curing periods of 7 days, 14 days, and 28 days.

Therefore, green concrete utilizes less energy and is more cost-effective. The utilization of concrete products, such as green concrete, in the future will significantly decrease CO2 emissions and environmental impact while also being cost-effective to produce.

The utilization of recycled aggregate in construction leads to substantial savings in both energy and transportation costs associated with natural resources and excavation. This consequently minimizes the effect of waste material on the environment.

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