Improvement in Robustness of M40 Grade Concrete through Partial Replacement of Cement with GGBS and Corn Cob Ash (CCA)

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Abstract:

Given the quick pace of urbanization today, the construction industry relies heavily on natural resources and is a significant source of carbon dioxide emissions and pollution. This study looks at employing industrial and agricultural by-products as ecologically friendly replacements in concrete manufacture to help alleviate the two concerns of pollution from cement-related waste and limited resources.

This study indicates that Corn Cob Ash, when effectively combined with GGBS, acts as an effective, ecologically friendly, and cost-efficient supplementary cementitious ingredient that helps to minimize cement consumption, repurpose garbage, and generate high-robustness sustainable concrete. The combination of GGBS and CCA's pozzolanic activity led in a thicker microstructure and a stronger long-term strength. Partial substitution of ordinary Portland cement with Ground Granulated Blast-Furnace Slag (GGBS) and Corn Cob Ash (CCA) is the subject of this study, which tries to increase the robustness (mechanical and durability properties) of M40-grade concrete. Prepared by controlled burning of cleansed Corn Cob at 600 °C followed by considerable crushing, CORN COB ASH (CCA) is another agro-waste resource that may be utilized as a supplemental cementitious ingredient. It helps lessen the environmental effect of concrete manufacturing and may be partly replaced for cement.

In the experimental setting, Corn Cob Ash was added in increasing quantities of 0%, 3%, 6%, 9%, 12%, and 15%, while GGBS was held constant at 15% by weight of cement. Six different concrete mixes were prepared and then compared: a control mix with 0% CCA + 0% GGBS and five modified mixes with 3% CCA + 15% GGBS, 6% CCA + 15% GGBS, 9% CCA + 15% GGBS, 12% CCA + 15% GGBS, and 15% CCA + 15% GGBS. The studies reveal that at 7,14 and 28days, compressive, split tensile, and flexural strength all rise.

Keywords— Robustness, M40 Grade, Ground Granulated Blast-Furnace Slag (GGBS), Corn Cob Ash (CCA), sustainable concrete

I. INTRODUCTION

1.1 THE STORY BEHIND THE MATERIALS USED IN CONCRETE:

The building industry is always changing, constantly seeking improved methods to enhance the strength and environmental friendliness of structures. Recently, there has been a shift towards using new materials rather than the conventional cement. Cement is crucial as it provides concrete with the necessary durability and longevity for buildings. However, producing traditional cement consumes a lot of energy and releases a significant amount of carbon dioxide, which harms the planet. Because of these issues, scientists have been exploring more eco-friendly alternatives.

Corn Cob Ash (CCA) and Ground Granulated Blast Furnace Slag (GGBS) have gained traction as they help lower carbon emissions and enhance concrete's quality. Research indicates that incorporating brick dust can increase the strength of concrete and reduce its tendency to leak, potentially extending its lifespan. Furthermore, utilizing this type of waste aids in decreasing the volume of waste sent to dumps, highlighting the effectiveness of recycling in the construction field. GGBS, created by quickly cooling the slag produced during iron and steel manufacturing, serves as a substitute for a portion of cement, enhancing the durability of concrete.

It possesses unique traits that allow it to combine with calcium hydroxide when wet, forming more cement-like substances that strengthen the material. Concrete mixed with GGBS generates less heat during production and offers improved resistance to damage from sulfates, making it suitable for harsh conditions.

1.2 WHAT IS CORN COB ASH (CCA)?

Corn Cob Ash (CCA) is a pozzolanic material obtained by burning corn cobs (the central core of maize after removing grains) under controlled conditions and then grinding the ash into fine powder. It is commonly used as a partial replacement for cement in concrete and mortar.

1.3 WHAT IS GROUND GRANULATED BLAST FURNACE SLAG (GGBS)?

Ground Granulated Blast-furnace Slag, known as GGBS, is a leftover material from making steel. The granulation process involves rapidly cooling hot iron slag from a blast furnace using water or steam, and then crushing the cooled substance into a smooth powder. In concrete production, GGBS is often substituted for a portion of the Portland cement.

1.4 MANUFACTURING PROCESS OF CONVERTING CORN COB INTO ASH:

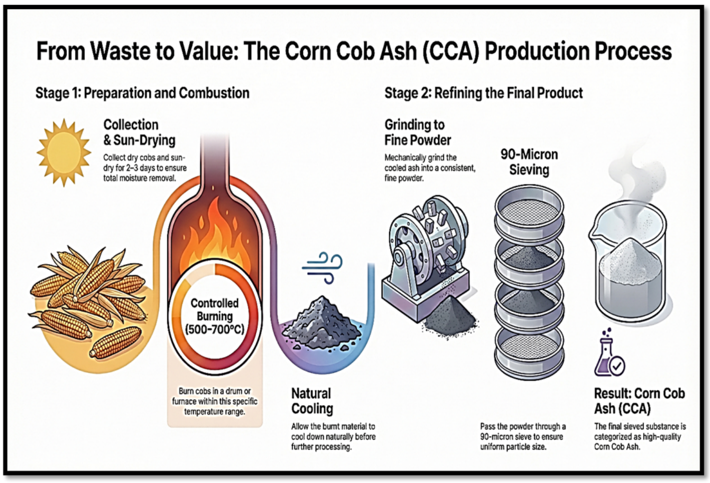

Fig 1: The procedure of manufacturing Ash from CCA

II. LITERATURE REVIEW

The growing demand for environmentally friendly materials in building is leading to the search for new ways to make cement. Combining Corn Cob Ash (CCA) and ground granulated blast furnace slag (GGBS) with natural materials and industrial leftovers might help lessen the harmful effects of cement production on the environment. This study explores using CCA and GGBS as partial replacements for cement, showing both the benefits and challenges of this method in building with concrete.".

- Antonio et al (2014): CCA can be used up to 10%; it retains structural stability; it enhances compressive strength and workability in mixtures (when solely using CCA).
- Kamau J and Ahmed A (2017): Maize cob ash (CCA) utilised at 5-20%; the best compressive strength observed is 63. 5 N/mm² at 7. 5% (after 91 days); all mixtures exceed 25 N/mm² after 28 days except for 20%; strength rises as it ages. Workability is greater with more CCA; it has lower density and is darker; it displays superior resistance to sulfates (length change of 15%; less fluctuation than conventional concrete (CCA with RHA).
- Mallikarjuna Prasad P, Vanam Sameer Kumar (2025) The objective is to reduce dependence on Portland cement, and improve the sustainability of concrete. The GGBS & BD both are replaced in place of cement by maintaining GGBS as constant with 15% and BD with ascending follows from 0%, 3%, 6%, 9%, 12% & 15% an expansion of plasticizer with a steady rate 1% within the volume of concrete in M35 Solid. Combining 9% BD with 15% GGBS yields the optimal compressive, ductile, and flexural strengths according to the analysis of the data. The highest compressive strength seen after 28 days is 43.47 MPa. The peak tensile strength is 4.53 MPa and the flexural strength comes out to 8.45 MPa. The presence of recovered demolition waste BD helps one to classify this mix as green. https://doi.org/10.55248/gengpi.6.0325.1276
- Bolledula Bhanu Prakash , Vanam Sameer Kumar (2025) The focus of the project includes both Ground Granulated Blast Furnace Slag (GGBS) and onion peel ashes (OPA) have been investigated as partial substitutes for cement in concrete. The objective is to reduce decrease dependence on Portland cement, and improve the sustainability of concrete. The GGBS & OPA both are replaced in place of cement by maintaining GGBS as constant with 15% and OPA with ascending follows from 0%, 4%, 8%, 12%, 15% & 20% in M30 Solid. Based on results as considered the compressive quality, ductile quality & flexural quality attained maximum strength at percentage of replacing 12%OPA+15%GGBS. The maximum Compressive strength quality gained for 28 days is 38.53 MPa. The maximum Tensile strength quality gained for 28 days is 3.02 MPa. The maximum Compressive strength quality gained for 28 days is 6.08 MPa. It can be referred as green concrete due to the replacement of agro based waste OPA. https://www.doi.org/10.58257/IJPREMS39567

III. METHODOLOGY

The Methodology describes the proxies used in place of cement done over this paper:

- The study explores the application of ground granulated blast furnace slag (GGBS) at a fixed ratio of 15% to cement and Corn Cob Ash (CCA) at proportions of 3%–15%.
- Compressive strength characteristics for 150 x 150 x 150 mm cubes are evaluated.
- Tensile strength characteristics for cylinders of 150 mm in diameter and 300 mm in height are examined.
- Evaluation of 500 x 100 x 100 mm beams' bending strength characteristics.
- Perform a carbonation test over 28 days to check the durability of concrete cubes.

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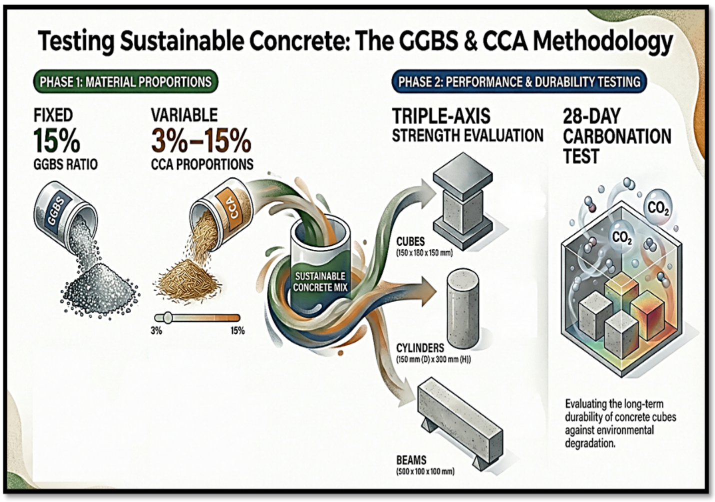
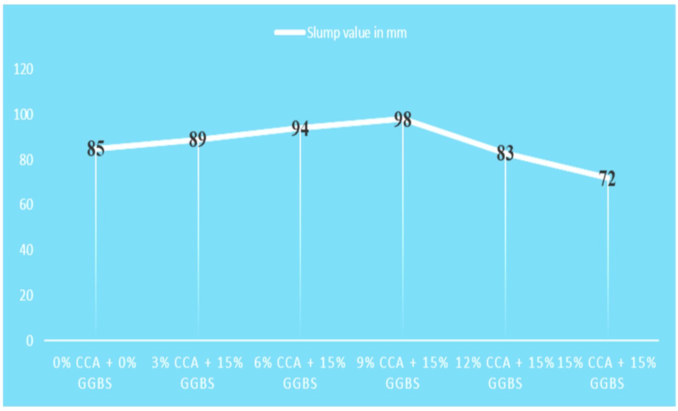


Fig 2: Steps involved in methodology of with respect to proxies

IV. RESULTS

Table no 1 Slump Cone values

Mix % Replacement	Slump value in mm
0%CCA + 0%GGBS	85
3% CCA + 15%GGBS	89
6% CCA + 15%GGBS	94
9% CCA + 15%GGBS	98
12% CCA + 15%GGBS	83
15%CCA + 15%GGBS	72



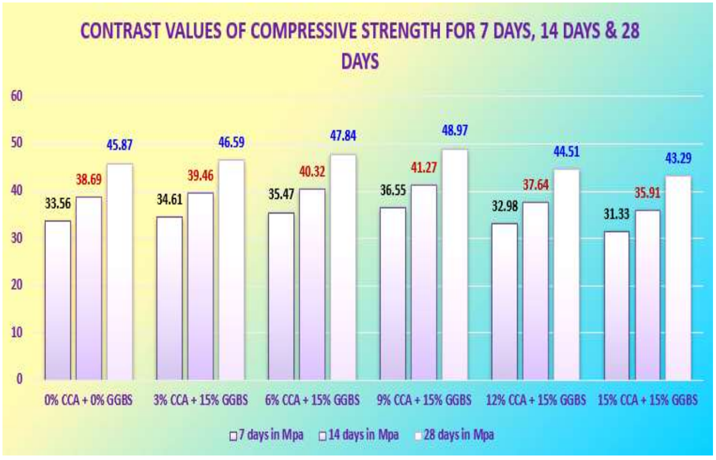
Graph no 1 Slump Cone values

Table no 2: Mix proportion of M40

Grade	**M40**
Proportion	**1:1.96:2.65**
W/C ratio	**0.39**
Cement	**381.6**
Fine Aggregate	**748.44**
Coarse Aggregate	**1013**
Water	**165**

Table no 3 Test results of Compressive Strength at 7 days, 14 days & 28 days:

Mix % Replacement	7 days in Mpa	14 days in Mpa	28 days in Mpa
0% CCA + 0% GGBS	33.56	38.69	45.87
3% CCA + 15% GGBS	34.61	39.46	46.59
6% CCA + 15% GGBS	35.47	40.32	47.84
9% CCA + 15% GGBS	36.55	41.27	48.97
12% CCA + 15% GGBS	32.98	37.64	44.51
15% CCA + 15% GGBS	31.33	35.91	43.29



Graph no 2 Compressive Strengths at 7,14 & 28 days

Table no 4 Test results of Split Tesile Strength at 7 days, 14 days & 28 days:

Mix % Replacement	7 days in Mpa	14 days in Mpa	28 days in Mpa
0% CCA + 0% GGBS	3.22	3.69	3.92
3% CCA + 15% GGBS	3.65	3.87	4.27
6% CCA + 15% GGBS	3.87	4.14	4.48
9% CCA + 15% GGBS	4.21	4.38	4.91
12% CCA + 15% GGBS	3.56	3.34	3.58
15% CCA + 15% GGBS	2.93	2.81	3.06

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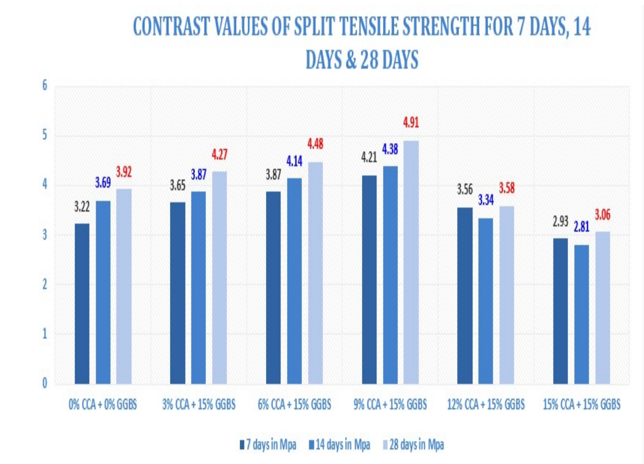
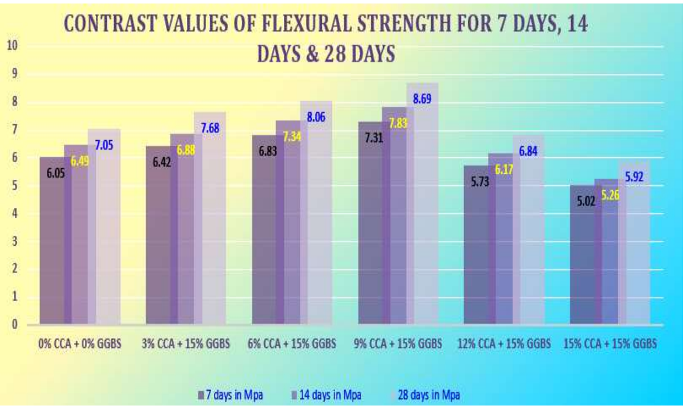


Graph no 3 Split Tensile Strength at 7,14 & 28 days

Table no 5 Test results of Flexural Strength at 7 days, 14 days & 28 days:

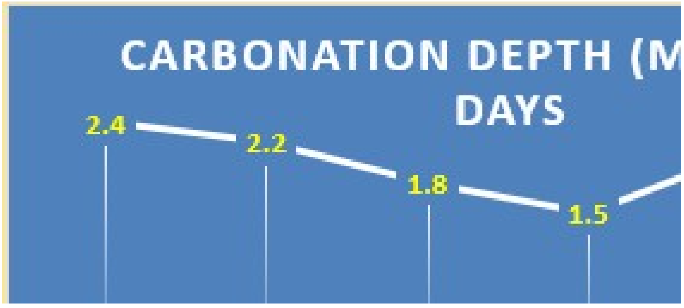
Mix % Replacement	7 days in Mpa	14 days in Mpa	28 days in Mpa
0% CCA + 0% GGBS	6.05	6.49	7.05
3% CCA + 15% GGBS	6.42	6.88	7.68
6% CCA + 15% GGBS	6.83	7.34	8.06
9% CCA + 15% GGBS	7.31	7.83	8.69
12% CCA + 15% GGBS	5.73	6.17	6.84
15% CCA + 15% GGBS	5.02	5.26	5.92



Graph no 4 Flexural Strengths at 7,14 & 28 days

Table no 6 Test results of Carbonation Depth at 7 days

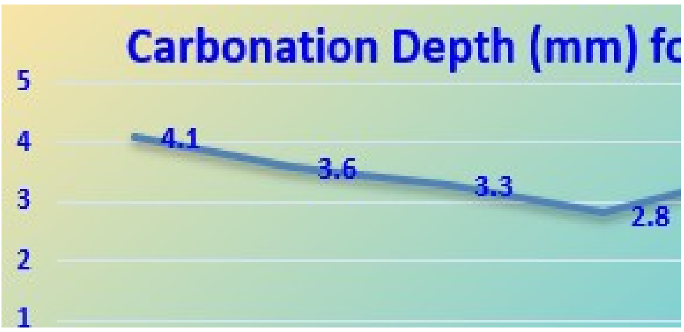
Mix % Replacement	Carbonation Depth (mm) for 7 days
0% CCA + 0% GGBS	2.4
3% CCA + 15% GGBS	2.2
6% CCA + 15% GGBS	1.8
9% CCA + 15% GGBS	1.5
12% CCA + 15% GGBS	2.1
15% CCA + 15% GGBS	2.8



Graph no 5 Carbonation Depth at 7 days

Table no 7 Test results of Carbonation Depth at 14 days

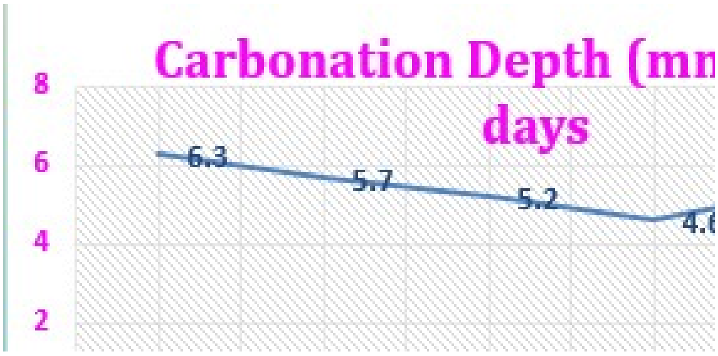
Mix % Replacement	Carbonation Depth (mm) for 14 days
0% CCA + 0% GGBS	4.1
3% CCA + 15% GGBS	3.6
6% CCA + 15% GGBS	3.3
9% CCA + 15% GGBS	2.8
12% CCA + 15% GGBS	3.5
15% CCA + 15% GGBS	4.7



Graph no 6 Carbonation Depth at 14 days

Table no 8 Test results of Carbonation Depth at 28 days

Mix % Replacement	Carbonation Depth (mm) for 28 days
0% CCA + 0% GGBS	6.3
3% CCA + 15% GGBS	5.7
6% CCA + 15% GGBS	5.2
9% CCA + 15% GGBS	4.6
12% CCA + 15% GGBS	5.4
15% CCA + 15% GGBS	7.4



Graph no 7 Carbonation Depth at 28 days

V. CONCLUSION

At the end of the paper, the key points drawn from earlier discussions and findings are highlighted:

- ✓ Using GGBS at a constant 15% and Corn Cob Ash (CCA) in increments of 0%, 3%, 6%, 9%, 12%, and 15% in M40 Solid, the results demonstrate that CCA and GGBS may successfully substitute cement.
- ✓ The optimal strength is obtained by replacing 9% CCA with 10% GGBS, as shown by the compressive, ductile, and flexural characteristics analysis.
- ✓ The highest compressive strength measured is 48.97 MPa following 28 days.
- ✓ After 28 days, the maximum tensile strength achieved is 4.91 MPa.
- ✓ The highest observed flexural strength after 28 days is 8.69 MPa.
- ✓ The results of the durability test on concrete with a mix replacement of 9% CCA + 10% GGBS reveal that the carbonation depth is 1.5 mm, 2.8 mm, and 4.6 mm after 7 days, 14 days, and 28 days, respectively.
- ✓ This concrete is considered green since it includes recycled waste CCA.

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