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A Critical Review on the Use of Ceramic Waste Fines and Recycled Fine Aggregates in Green Concrete

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ABSTRACT

the research investigates the use of CTWP as a replacement material for cement in various proportions, ranging from 10% to 40%. The study confirms that the interaction between alumina and silica in CTWP with calcium in cement results in the formation of C-S-H gel, which enhances concrete's compressive strength by up to 30% at a replacement level of 30.14 N/mm^2. This strength is slightly higher than the characteristic compressive strength of M30 grade concrete (30 N/mm^2) at 28 days. Additionally, microscopic examination using SEM validates CTWP effectiveness as a replacement material, as it closely resembles cement particles. The examination of CTWP chemical properties using EDX and XRD shows the presence of silica (62.61%) and alumina (15.15%) content, indicating its potential as a pozzolanic material. The study also includes correlation analysis, demonstrating a strong correlation (R^2 = 0.9 - 1.0) between different combinations of mechanical performance of CTWP mix. Secondly, the research explores the utilization of RCFA as a replacement for fine aggregates in proportions of 25%, 50%, 75%, and 100%. At a 25% replacement level, it achieves a compressive strength of 31.09 N/mm^2 at 28 days. However, higher replacement levels negatively impact workability and durability properties due to porosity and interconnected voids. SEM analysis clearly shows the formation of hydrated compounds in the old cement mortar of recycled aggregate, and EDX and XRD confirm the presence of silica, alumina, sodium, and calcium in RCFA

1. SCOPE AND OBJECTIVES

The central objective is to evaluate the ecological impact of CW and investigate the viability as substitute materials for cement and FA in concrete. The research objectives aim to focus on the following:

- Evaluate the socio-economic and environmental impact of CW and determine its suitability as a sustainable material for incorporation in concrete production.
- To investigate the CTWP performance as a substitute for cement and determine the ceramic waste impact on concrete properties.
- To evaluate the feasibility of utilizing RCFA as a substitute for FA in concrete and effects on the properties and characteristics of the concrete.
- To compare the properties of concrete containing CTWP and RCFA with those of conventional concrete.
- To examine the effects of incorporating CTWP and RCFA on the carbon footprint and cost analysis of concrete.
- To provide recommendations and insights for the utilization of CTWP and RCFA in eco-efficient concrete production.

2. MATERIALS AND RESEARCH METHODOLOGY

The mix selection process for Eco-efficient concrete entailed establishing the ratios of each constituent material, showcased in Table 3.4. This table provides a comprehensive overview of replacement percentages of CTWP with cement, ranging from 0% to 40%. It also denotes the inclusion of RCFA in different experimentation phases, with substitution ratios for natural fine aggregate set at 25%, 50%, 75%, and 100%.The mix design presented serves as a foundation for conducting the subsequent experimental tests and evaluating the properties of the eco- efficient concrete mixtures. It enables a systematic investigation into the effects of varying CTWP and RCFA contents on the performance and sustainability aspects of the concrete. Further analysis and interpretation of the data obtained from the experimental tests will provide insights to the optimal proportions of CTWP and RCFA in eco-efficient concrete.

Table 1. Design Mix for M30 Grade of Concrete with Partial Replacement for Cement (1kg/m^3)

Mix No	Mix code	Description	Cement	CTWP	CA	FA	W/C
1	M 1	0% CTWP (Normal Conventional Mix)	360	0	1160	545	0.45
2	M 2	10% CTWP	324	36	1160	545	0.45
3	M 3	20% CTWP	288	72	1160	545	0.45
4	M 4	30% CTWP	252	108	1160	545	0.45
5	M 5	40% CTWP	144	216	1160	545	0.45

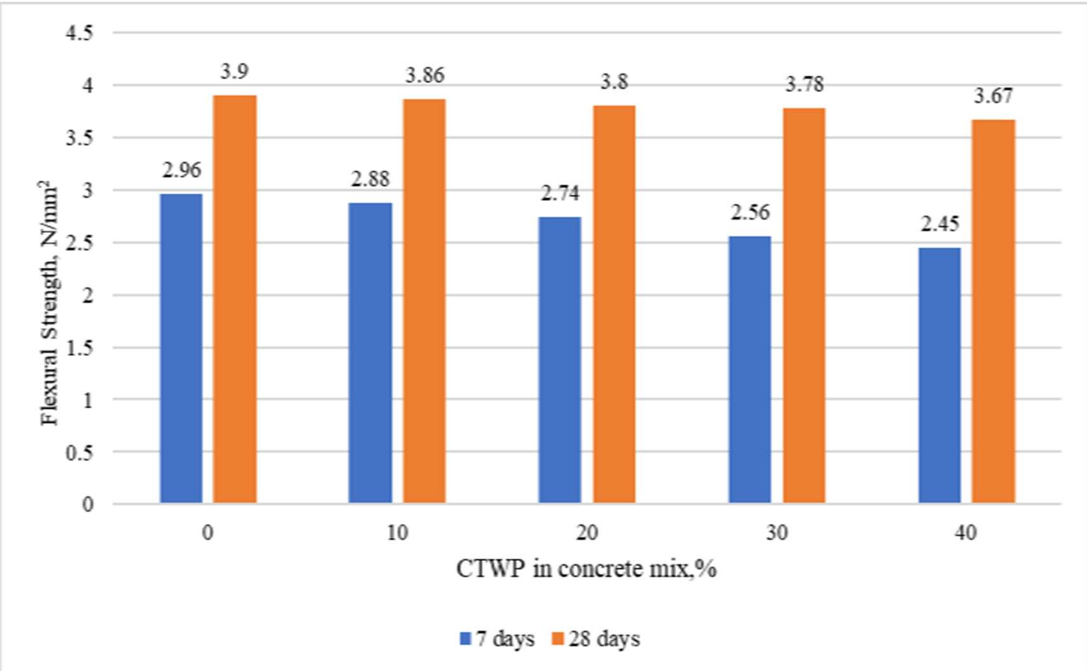

Figure 1. Effect of CTWP on Flexural Strength

3. EFFECT OF CTWP ON SPLIT TENSILE STRENGTH

When CTWP is used as a replacement for cement in concrete, improvement in strength can be seen up to 30% of the replacement (M4) compared to mix M1, which has a higher strength value (Nagdeo *et al.* 2018). The split tensile strength values for different design mixes are as follows: M1

= 3.4 N/mm^2, M2 = 3.36 N/mm^2, M3 = 3.29 N/mm^2, M4 = 3.14 N/mm^2 and

M5 = 2.98 N/mm^2. Generally, the split tensile strength of M30 grade of concrete is about 8 – 12 % of the CS of the concrete mix. As per the requirements only up to 30% of CTWP (M4) replacement strength is attained. M5 design mix fails to satisfy the condition leading to a reduced strength.

4. SUMMARY

In summary, the research findings in this chapter highlight several key points regarding the mechanical and durability performance of concrete with the combination of CTWP and RCFA, along with their carbon emission and cost implications. 1. Mechanical Performance: - Concrete with a combination of CTWP and RCFA exhibits better compressive strength up to the design mix M5 of 30% CTWP and 25% RCFA. However, beyond this mix proportion, the design mix failed to meet the characteristic compressive strength of M30 grade concrete at 28days. Ceramic powder inclusion has minimal impact on compressive strength, while recycled aggregates reduce the strength due to their porosity and water-absorbing nature. In flexural and split tensile strength, the design mix M1 to M5 shows flexural strength,

3.9 N/mm^2 (M1), 3.71 N/mm^2 (M2), 3.68 N/mm^2 (M3), 3.45 N/mm^2 (M4) and

3.32 N/mm^2 (M5) of the concrete is closer to that of 0.7√fck. Regarding split tensile strength mixes M2, M3, M4 and M5 show test values 3.1 N/mm^2, 3 N/mm^2, 2.92 N/mm^2, 2.76 N/mm^2, 2.51 N/mm^2 which is still considered good, mainly due to the lower percentage of RCFA and CTWP in the mix. Typically, the SPT of a concrete mix with M30 grade is in the range of 8% to 12% of its CS. UPV performance is better with increased ceramic content but decreases as the RCFA content increases. All mechanical performance parameters are positively correlated (> 0.7) and interdependent, as concluded from correlation analysis. 2. Durability Performance: The durability performance is optimal only for the conventional mix M1, while other mix combinations deviate from the expected results.

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