

# Evaluating Ceramic Waste Powder for Fine Aggregate Substitution in High-Performance SCC

Addanki Sri Venkata Durga Prasad<sup>1</sup>

<sup>1</sup>*P.G. Student (21A91D8701), Aditya University, Surampalem*

**Abstract**— With the rising global population, the generation of solid waste has surged, requiring large landfill sites for its disposal. Transforming this waste into alternative resources can help alleviate the pressure on non-renewable materials and contribute to addressing landfill issues. Various studies have highlighted the potential of using solid waste in concrete production, particularly as a substitute for fine aggregates like sand. With many regions now restricting the extraction of river sand, there is a growing need for suitable alternative materials that can deliver comparable performance. One such material is ceramic waste powder (CWP), which is generated during the final shaping process of ceramic products such as cups, plates, and tiles. Specifically, this study focuses on bone china cup and plate ceramic waste powder. The disposal of CWP contributes to environmental degradation, and its use in concrete as a replacement for natural sand could have a beneficial environmental impact.

This research aims to investigate the use of CWP (Ceramic Waste Powder) as a substitute for natural sand in concrete production, examining its viability and impact on the properties of concrete in both its fresh and hardened states. CWP was utilized to replace sand in different proportions by weight: 0%, 10%, 20%, 30%, 40%, and 50%. Various tests were performed on fresh concrete containing CWP to evaluate the characteristics of self-compacting concrete (SCC), including the slump flow, V-funnel, J-ring, and L-box tests. For hardened concrete, the study assessed compressive strength, ultrasonic pulse velocity, flexural strength, water absorption, and resistance to chemical attacks such as acid, sulphate, chloride, and carbonation.

**Index Terms**—Self Compacting concrete, Ceramic waste powder, compressive strength, ultrasonic pulse velocity, flexural strength, water absorption, resistance to chemical attacks

## I. INTRODUCTION

Self-compacting concrete (SCC) is an advanced type of concrete that can be placed and compacted without the use of vibration. SCC is a type of concrete that could be compacted through each corner of the formwork using only its own weight,

rather than the use of external vibrators. That's a newly designed concrete that's a lot more fluid. In 1983, when researching the durability for concrete constructions in Japan, a major problem occurred.

The issue is that professional labour is required for appropriate compaction in order to produce a durable concrete. As a result, Okamura developed "SCC" in 1986 as a remedy to the above difficulty. As a result, Okamura is regarded as the inventor of "SCC" [1].

The production of industrial by-products and waste continues to escalate, creating significant challenges in managing and disposing of this waste in a sustainable manner. Researchers face increasing difficulties in finding environmentally responsible ways to repurpose such waste. Additionally, the concrete industry contributes to a substantial carbon footprint due to its extensive use of traditional materials like cement and natural sand. This reliance on conventional resources further exacerbates environmental concerns, emphasizing the need for sustainable alternatives [2]. The ongoing use of cement has turned into a serious environmental issue. To address this, industrial waste is being reused as an alternative to traditional materials in the concrete industry. This helps manage waste and reduce the reliance on conventional products like cement [3]. Many researchers have already utilized different waste materials, such as granite waste [2],[4], glass cutting waste [5], rubber fiber waste [6], etc. in the manufacturing of concrete. Ceramic powder is a leftover material from making tiles and dishes.

A significant amount of ceramic waste is generated during the manufacturing process of ceramic tiles and plates [7]. India ranks as the third-largest producer and consumer of ceramic materials globally, with an annual output of around 600 million square meters of ceramic waste, accounting for 6.2% of global production. This high volume of tile production is largely driven by rapid expansion

in the housing sector and favorable government policies (Indian Tile Industry Article, August 6, 2020). Currently, much of the waste generated by the ceramic industry remains unrecycled, with approximately 30% of daily production ending up as waste [8]. While many researchers have explored the use of ceramic waste in self-compacting concrete (SCC) as a partial substitute for cement, fewer studies have focused on ceramic waste powder (CWP) as a replacement for fine aggregate in SCC.

## II. LITERATURE REVIEW

Subasi et al. [3] studied the influence of ceramic waste powder on the fresh properties of SCC was examined by substituting up to 20% of the cement by weight. A beneficial impact on the fresh state properties was noted when ceramic waste was used as a filler, particularly at replacement levels up to 15%. Also, find the increase in WCP ratio increased the flowability of fresh concrete. Furthermore, fresh concrete mix's passing capacity was improved. The compressive strength of the SCC mix with WCP substitution rapidly reduced. Bond strength value of specimens, such as density and compressive strength test values, have decreased (when ceramic use as a substituted).

Ceramic waste powder (CWP) was used to replace natural fine aggregate in self-compacting concrete (SCC) by up to 50% by weight. The study revealed that when CWP replaced more than 25% of the natural fine aggregate, the compressive strength of the concrete decreased [18]. The addition of CWP to concrete mixtures of 25 Mpa and 50 Mpa improved workability retention. The development of compressive strength was inhibited by CWP, primarily at early in life. At 90 days of age, all CWP combinations shows high strength development. In comparison to control mixtures, the addition of CWP to concrete mixes reduced the evaluated 120-day drying shrinkage strain. The decrease is nearly proportional of CWP replacement. The addition of CWP to concrete mixes resulted in a significant increase in resistance chloride ion penetration (RCPT) as well as increased bulk electrical resistivity value, identifying superior durability. The enhancement is proportional of CWP replacement. For achieving suitable concrete, the inclusion of such CWP with the other supplementary cementing materials (SCM) in concrete mixes to generate binary or tertiary mixes needs investigating.

Ali et al. [19] in their research indicated that replacing 20-30% of cement with ceramic waste powder (CWP) significantly reduces the porosity of cement paste and self-compacting concrete (SCC). This decrease in porosity enhances both the mechanical properties and durability of SCC, offering a promising solution for improving the overall performance of concrete structures.. Because CWP has a lower specific gravity than cement, mixtures containing CWP have a higher paste quantity, which reduces friction between both the aggregates and also the paste surface, working to improve coherence and plasticity, and hence improving SCC flowability properties. The CWP partial replacement had a minor effect on the unconfined flowability the Mixes in both groups. Despite this disadvantage, all mixes deformed well according to their self weight. The results of the J-ring or L-box tests showed that SCC mixes CWP had sufficient passing ability. The passing ability enhanced even as quantity of CWP in the mixtures increased. This indicates that CWP mixtures are appropriate for applications requiring flow through high strength. The formation of high CWP improved segregation resistance significantly. It is necessary to investigate the durability with SCC designed with high CWP as a replacement of cement, as well as carbonation. CWP has the ability to improve upto 40 % of cement in the production of SCC that meets international standards for fresh properties or compressive strength.

Ogawa et al. [27] found that when fine aggregate was replaced with 40% porous ceramic waste aggregate (PCWA), internal curing significantly enhanced the compressive strength of steam-cured fine aggregate concrete. Using 40% FA, PCWA increased the concrete's compressive strength by 10-25%, benefiting both early-age and long-term strength. Additionally, no negative effects were observed for up to 20% replacement with PCWA over a period of 364 days, due to the porous structure of the material. In heat FA concrete, PCWA substantially reduced autogenous shrinkage or increased drying shrinkage. With addition of PCWA, its accelerated carbonation resistance for steam-cured concrete having 40% FA dramatically improved, as well as the impacts of PCWA at percentage replacement between 10% to 20% on carbonation resistance was nearly identical. The accelerated corrosion coefficient for 40% FA concrete was lowered by roughly 35% with PCWA replacements at 10% to 20%. Regardless on PCWA

substitution, an inverse linear association between compressive strength or accelerated carbonation factor was detected. This finding demonstrated that CO<sub>2</sub> primarily reaches its mortar matrices, not its PCWA, and because porous structure if PCWA has no negative impact on concrete's carbonation resistance. Internal curing with PCWA could significantly boost its FA reaction or cement hydration when considering its pore size distribution. PCWA increased compressive strength as improved carbonation resistance by reducing macropore volume and in mortar matrix. As a result, even though PCWA is created from waste, this can be used as an interior curing agent for enhance the quality both of steam cured cement and steam cured Fine aggregate concrete. The increased quality of PCWA can help to promote the use of PCWA trash and FA byproducts within building area. To elucidate the rationale of PCWA's internal curing action, more research into the morphology and internal humidity levels variation of concrete over time is required. This might be handy for the PCWA substitute ratio design as well.

### III. METHODOLOGY

Portland pozzolana cement (PPC) is the most popular form of cement used as primary ingredients in concrete, mortar or no specialty grout all over the world.

In this study, Portland Pozzolana Cement (PPC) served as the binder. Basalt stone, an igneous rock with a 10 mm size, was used as the coarse aggregate.

Krishna river sand, conforming to Zone II as specified in IS 383 [29] and passing through a 4.75 mm sieve, was used as the fine aggregate.

Ceramic waste powder, sourced from Veda Ceramics, Bandhan Exclusive in Telangana, India, was used to replace sand (fine aggregate) at varying percentages in the mix.

The physical properties of coarse aggregate, fine aggregate, and ceramic waste powder are presented in Table 1.

Table 1: Physical properties of natural river sand, aggregate and ceramic

Properties	Fine aggregate	Coarse aggregate	Ceramic powder
Water absorption (%)	1	0.2	2.78

Specific gravity	2.62	2.73	2.43
Fineness modulus	2.66	5.78	2.91

Fig. 1 and Fig. 2 illustrates that ceramic waste particles possess a rough and angular texture, while fine aggregate particles have a smooth and granular surface. This distinction is clearly depicted in the microscopic images, which reveal the contrasting characteristics of both materials. The roughness and angularity of the ceramic waste particles may influence their behavior and performance in concrete, setting them apart from the more uniform and rounded fine aggregate particles

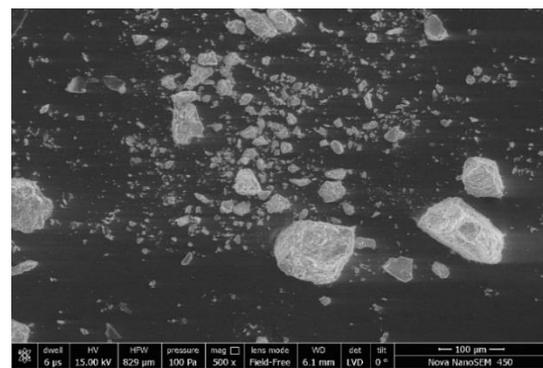


Fig. 1 Ceramic waste particle

A polycarboxylate ether (PCE) superplasticizer was utilized to achieve the desired flowability of the concrete mix. For both the mix design process and the curing of the test specimens, regular tap water was employed.

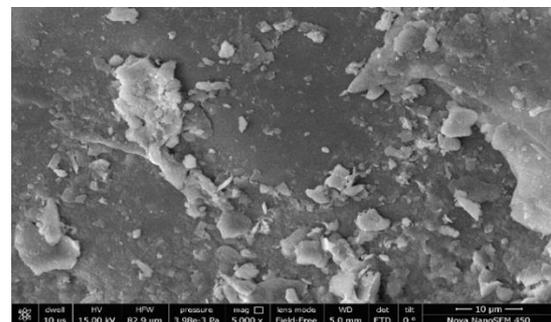


Fig. 2 Natural Sand

### IV. MIX PROPORTIONS

Table 4 presents the mix proportions for the self-compacting concrete (SCC) mixtures used in this study. The proportioning was carried out in accordance with the EFNARC-2005 [30] standard. Six different replacement levels of ceramic waste powder (CWP) were utilized, specifically 0%, 10%, 20%, 30%, 40%, and 50% by weight. Each mix

maintained a consistent binder content of 565 kg/m<sup>3</sup>. In this context, the control mix, which contains no ceramic waste powder, is designated as CWP0. Conversely, the mix where 10% of the fine aggregate is replaced with ceramic waste powder is labeled CWP10. This systematic approach allows for a comprehensive evaluation of how varying proportions of CWP affect the properties of SCC. Other replacement mix ID shown in table 2. The numerical digits of mix ID shows the percentage replacement of ceramic powder.

Table 2: Details of SCC mix proportions (Kg/m<sup>3</sup>)

Mix ID	Cement (kg)	FA (Kg/m <sup>3</sup> )	CWP (Kg/m <sup>3</sup> )	CA (Kg/m <sup>3</sup> )	Water (Kg/m <sup>3</sup> )	SP dosage (%)
CWP0	567	981	0	696.75	191	1.2
CWP10	567	881	97	696.75	191	1.1
CWP20	567	785	195	696.75	191	1.08
CWP30	567	685	295	696.75	191	1.29
CWP40	567	589	393	696.75	191	1.41
CWP50	567	491	491	696.75	191	1.49

This study includes tests for fresh state properties such as slump flow, V-funnel time, T500 time, L-box passing ratio, and J-ring step height, all conducted according to the EFNARC 2005 [30] guidelines.

V. RESULTS AND DISCUSSIONS

Figure 3 demonstrates the correlation between slump values and superplasticizer (SP) dosage in self-compacting concrete (SCC) mixtures. The recorded slump values range from 700 ± 30 mm, classifying them within the SF2 slump flow category, as per EFNARC 2005 guidelines. The superplasticizer dosage ranges between 1% and 1.5%. As the amount of ceramic waste powder (CWP) increases, there is a noticeable reduction in slump flow values, which is consistent with expectations.

Scanning electron microscopy (SEM) images of CWP, as shown in Figure 1, reveal that CWP possesses a larger specific surface area, irregular particle shapes, and a rough texture, which likely affect its behavior in the mix. The reduced or comparable dosage of superplasticizer required for CWP contents up to 20% is likely attributed to the lubrication effect of smaller CWP particles filling the gaps between the larger cement and aggregate particles.

Figure 4 presents the slump flow values for all mixtures, while Figures 5 and 6 display the changes in T500 and V-funnel times. These tests are crucial

for assessing the filling capacity of SCC mixes; lower values for both parameters signify enhanced flowability.



(a)



(b)



(c)



(d)

Fig. 3 Slump for various SCC mixes

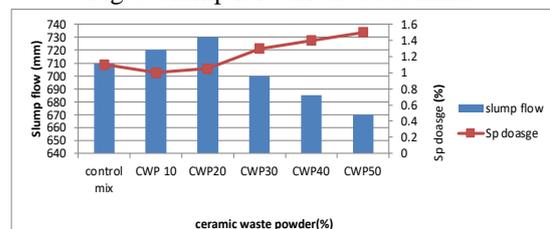


Fig. 4 Slump flow and SP dosage

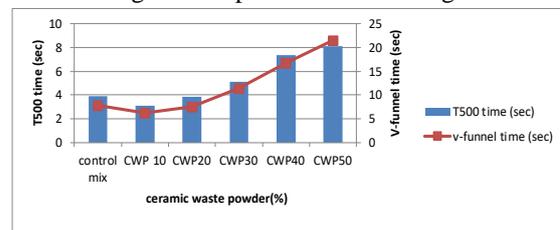


Fig. 5 T500 and V-funnel

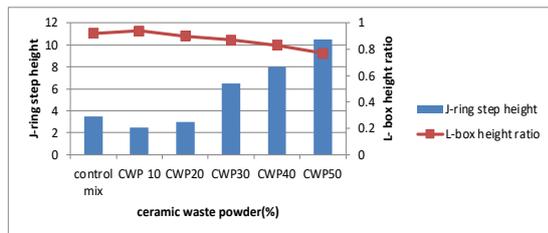


Fig. 6 J-Ring and L-Box

## V. CONCLUSIONS

The objective of this investigation was to evaluate the fresh and mechanical properties of self-compacting concrete (SCC) incorporating ceramic waste powder (CWP) as a partial replacement for fine aggregates. Based on the findings, the following conclusions can be drawn:

- i. Increased Superplasticizer Demand: SCC mixes with ceramic waste powder (CWP) required a higher superplasticizer dosage than the control SCC due to the ceramic particles' higher surface area and angular shape, which needed more lubrication to achieve desired flow.
- ii. Impact on Fresh Properties: The addition of CWP notably affected the SCC's workability, flowability, and viscosity, requiring superplasticizer adjustments to maintain fresh properties within a workable range.
- iii. Compliance with EFNARC Standards: Despite adjustments, all SCC mixes with CWP adhered to EFNARC guidelines for fresh properties like slump flow and viscosity, ensuring they met consistency and performance standards.
- iv. Need for Mix Optimization: To effectively incorporate CWP, optimizing the mix design—particularly the superplasticizer dosage—was essential to achieving proper flow and stability without sacrificing fresh properties.
- v. Sustainable Use of Ceramic Waste: Successfully integrating CWP into SCC not only meets EFNARC standards but also promotes sustainability, offering a viable reuse of industrial waste in construction.

## REFERENCES

[1] Sivakumar, A., Srividhya, S., Sathiyamoorthy, V., Seenivasan, M., & Subbarayan, M. R. (2022). Impact of waste ceramic tiles as partial replacement of fine and coarse aggregate in concrete. *Materials Today: Proceedings*, 61, 224-231.

[2] A. Jain, R. Gupta, and S. Chaudhary, "Performance of self-compacting concrete comprising granite cutting waste as fine aggregate," *Constr. Build. Mater.*, vol. 221, pp. 539–552, 2019, doi: 10.1016/j.conbuildmat.2019.06.104.

[3] Awoyera, P. O., Ndambuki, J. M., Akinmusuru, J. O., & Omole, D. O. (2018). Characterization of ceramic waste aggregate concrete. *HBRC journal*, 14(3), 282-287.

[4] L. Gautam, J. K. Jain, P. Kalla, and M. Danish, "Materials Today: Proceedings Sustainable utilization of granite waste in the production of green construction products : A review," *Mater. Today Proc.*, no. xxxx, 2020, doi: 10.1016/j.matpr.2020.10.532.

[5] Torkittikul, P., & Chaipanich, A. (2010). Utilization of ceramic waste as fine aggregate within Portland cement and fly ash concretes. *cement and concrete composites*, 32(6), 440-449.

[6] A. M. Rashad, "Gulf Organisation for Research and Development A comprehensive overview about recycling rubber as fine aggregate replacement in traditional cementitious materials," *Int. J. Sustain. Built Environ.*, vol. 5, no. 1, pp. 46–82, 2016, doi: 10.1016/j.ijse.2015.11.003.

[7] Elemam, W. E., Agwa, I. S., & Tahwia, A. M. (2023). Reusing ceramic waste as a fine aggregate and supplemental cementitious material in the manufacture of sustainable concrete. *Buildings*, 13(11), 2726.