A review on the effects of ceramic waste into concrete composition

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ABSTRACT: Population growth, economic growth and rapid development have contributed to increase consumption of natural resources and waste generation. Ceramic wastes are long-lasting, and they will remain in landfills for a long time and taking up space. Increasing population and development also increases the demand of concrete and cement in construction industry. Many efforts have been made to use ceramic waste in concrete production for green buildings. The effect of ceramic waste on the compressive strength properties of several types of concrete is the focus of this review paper. The ceramic waste powder has excellent pozzolanic reactivity. Concrete utilising ceramic waste as a replacement for cement and aggregate was found to have better mechanical characteristic of compressive strength and flowability. Most research found that 20% replacement for cement and 100% replacement for coarse and fine aggregate produced improved compressive strength.

Keywords: *Ceramic; Waste; Concrete; Construction; Economic*

1. INTRODUCTION

Increasing population, economic growth, and rapid development have all contributed to the consumption of a large amount of natural resources and then generated waste which increases annually. Ceramic waste is currently collected worldwide with more than 274,300 tonnes referring to data for 2020, and are durable and extremely resistant to biological, chemical, and physical degradation forces [1]. Due to the increase in population and development, the demand of concrete and cement in construction industry also increases. The Global Construction 2030 report expects the average global construction growth to be 3.9% per annum till 2030 [2]. A majority of the research focuses solely on ways to enhance concrete and its physical performance, such as crack control and improved strength, toughness and fire resistance, by removing or adding waste materials to the concrete itself. This type of concrete is called the green concrete. According to the World Green Building Council the demand for green buildings is expected to increase in the next three years [3].

2. EFFECT OF CERAMIC WASTE ON CONRETE

Ceramics are non-metallic, inorganic solids (ones that are not metal or based on carbon compounds) that are (generally) made up of compounds formed from metallic and non-metallic elements that are heat resistant [4]. Usually they are metal oxides (compounds of metallic elements and oxygen), but many ceramics (especially advanced ceramics) are compounds of metallic elements and carbon, nitrogen, or sulphur. The final product may be crystalline, semi-crystalline, or vitreous in nature. Owing to the presence of silica and alumina, which provide pozzolanic reactivity, ceramic waste can be recycled in Self Compacting Concrete (SCC), concrete, and mortar as a cement and aggregate substitute. El-Dieb et al. (2018) was tested the compressive strength of concrete cubes containing up to 40% ceramic waste in place of cement. Compressive strength was raised by up to 20% with the inclusion of ceramic waste. Compressive strength was reduced by more than 20% of the replacement. This could be due to the substitution of non-hydraulic binding materials for hydraulic binding materials. With the lengthening of the curing period, the compressive strength increased. The presence of the pozzolanic feature in Ceramic Waste Powder (CWP) material could explain the increased strength [5].

Jeronimo et al. (2018) was assessed the compressive strength of SCC by substituting Ground Clay Brick Waste (GCBW) for cement up to 40%. The results showed that the 20% replacement mix had a 7-day improvement in strength over the control mix, while the remaining mixes had a 6–10% drop in compressive strength. After 28 days of curing, the pickup of the compressive strength of the other SCC mixtures is between 0 and 4% compared to the control mixture. Similarly, after a 90-day curing period, the strength of the 20% and 30% GCBW replacement mixtures increased by 6% and 11%, respectively, as compared to the control SCC combination [6]. Awoyera et al. (2018) was studied the compressive strength of concrete with ceramic as a fine and coarse aggregate substitution (0 %, 25 %, 50 %, 75 %, and 100 %). When compared to the control mix, the result revealed a 36.1 % increase in concrete strength with 100 % coarse aggregate replacement. It is possible that the irregular form and rough surface of ceramic coarse aggregate is what allows aggregates and cured cement paste to connect properly. When 100 % ceramic fine aggregate was replaced, the compressive strength rose by 22.1 %. The improved outcome could be attributed to ceramics' increased water absorption capacity as well as the pozzolanic activity of ceramic particles [7].

Subasi et al. (2017) was evaluated the compressive strength of SCC mixtures employing ceramic waste as filler in the amounts of 0%, 5%, 10%, 15%, and 20% with cement replacement after a 7-day and 28-day curing period. At 7 and 28 days, decreased compressive strength values of Waste Ceramic Powder (WCP) replacement increased. In comparison to the control mixture, the lowest compressive strength value was found with 20% WCP substitution. Although the compressive strength of waste ceramic is lower, it is possible that the decrease in compressive strength is attributable to a little change in clinker mineralogical composition (WCP-13.24% lower, WCP-20% higher) [8]. Nayana et al. (2018) was studied the compressive strength of mortar mixtures created with ceramic waste as a fine aggregate substitute at 0%, 15%, 30%, and 50% by weight, as well as silica fume addition at 0%, 5%, and 10% by weight of cement. The inclusion of silica fume increased the strength of the mixture. The results was revealed 15% of the ceramic waste is replaced with sand, the strength increases, but as the amount of sand is increased, the strength decreases. The filling effect and the pozzolanic impact of ceramic waste could account for this improvement in strength. The addition of silica fume, which is substituted by cement, was also shown to result in a substantial increase in compressive strength [9].

Siddique et al. (2019) investigated the compressive strength of concrete formed by replacing fine aggregate with Fine Bone China Ceramic Aggregate (FBCCA) in weight ratios of 0, 20, 40, 60, 80, and 100 percent. In comparison to the control mixture, concrete having FBCCA substitution showed an increase in strength. This may be attributed to the creation of a denser Calcium Silicate Hydrate (CSH) gel due to the presence of more water in the fresh mix, which is then released by FBCCA, resulting in an internal curing effect [10]. Kannan et al. (2017) investigated the compressive strength of concrete after 28 and 90 days of curing, using CWP to replace up to 40% of the cement. When the amount of CWP substitution increased by 10%, 20%, 30%, and 40%, the compressive strength value decreased by 15%, 17%, 18%, and 20%, respectively. At the age of 90 days, all concrete mixtures showed a minor improvement in compressive strength. CWP can be used as a filler rather than a pozzolanic material. A decrease in cement binder content could be the cause of the weakening [11].

Li et al. (2019) was investigated the effect of Ceramic Powder Waste (CPW) on the cube strength of mortar mixes with various Water-Cement (W/C) ratios. CPW was used to substitute cement up to 20% of the time. Compressive strength was said to improve as the amount of CPW replacement increased. With 20% ceramic powder replacement, cube compressive strength was improved from 37.1 to 72.4 MPa at the age of 7 days for a 0.40 W/C ratio. Similarly, with 20% ceramic powder replacement, the W/C ratio 0.55 cube compressive strength was raised from 23.9 to 48.6 MPa at the age of 7 days [12].

3. CONCLUSION

Ceramic waste powder has excellent pozzolanic reactivity. Percentage replacement limit, including ceramic waste in concrete production resulted in better compressive strength than reference concrete. As a result, ceramic waste can be used to replace cement and aggregate. Many researchers have discovered low compressive strength in concrete at an early age. However, as concrete curing age increases, they gain more strength. The researcher was substituted 10–40% and up to 100% of ceramic waste for cement and fine aggregate, respectively. Most research found that 20% replacement for cement and 100% replacement for coarse and fine aggregate produced improved compressive strength. The reduced pozzolanic activity at the beginning of the process could explain the drop in strength.

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REFERENCES

[1] A. Anwar, S. Ahmad, S. M. M. A. Husain, and S. A. Ahmad, "Replacement Of Cement By Marble Dust And Ceramic Waste in Concrete For Sustainable Development", International Journal of Innovative Science, Engineering & Technology, vol. 2, no. 6, pp. 496–503, 2015.

[2] H. Mohammadhosseini, N. H. A. S. Lim, M. M. Tahir, R. Alyousef, H. Alabduljabbar, and M. Samadi, "Enhanced performance of green mortar comprising high volume of ceramic waste in aggressive environments", Construction and Building Materials, vol. 212, pp. 607–617, 2019.

[3] S. M. A. El-Gamal, F. I. El-Hosiny, M. S. Amin, and D. G. Sayed, "Ceramic waste as an efficient material for enhancing the fire resistance and mechanical properties of hardened Portland cement pastes", Construction and Building Materials, vol. 154, pp. 1062–1078, 2017.

[4] Market Research Future, "Global Green Concrete Market Research Report: by End-Use-Forecast till 2027", *WantStats Research And Media Pvt. Ltd.*, 2021.

[5] A. S. El-Dieb and D. M. Kanaan, "Ceramic waste powder an alternative cement replacement – Characterization and evaluation", Sustainable Materials and Technologies, vol. 17, p. e00063, 2018.

[6] V. L. Jerônimo, G. R. Meira, and L. C. P. da Silva Filho, "Performance of self-compacting concretes with wastes from heavy ceramic industry against corrosion by chlorides", Construction and Building Materials, vol. 169, pp. 900–910, 2018.

[7] P. O. Awoyera, J. M. Ndambuki, J. O. Akinmusuru, and D. O. Omole, "Characterization of ceramic waste aggregate concrete", HBRC Journal, vol. 14, no. 3, pp. 282–287, 2018.

[8] S. Subaşı, H. Öztürk, and M. Emiroğlu, "Utilizing of waste ceramic powders as filler material in self-consolidating concrete", Construction and Building Materials, vol. 149, pp. 567–574, 2017.

[9] A. M. Nayana and P. Rakesh, "Strength and durability study on cement mortar with ceramic waste and micro-silica", Materials Today: Proceedings, vol. 5, no. 11, pp. 24780–24791, 2018.

[10] S. Siddique, S. Chaudhary, S. Shrivastava, and T. Gupta, "Sustainable utilisation of ceramic waste in concrete: Exposure to adverse conditions", Journal of Cleaner Production, vol. 210, pp. 246–255, 2019.

[11] D. M. Kannan, S. H. Aboubakr, A. S. EL-Dieb, and M. M. Reda Taha, "High performance concrete incorporating ceramic waste powder as large partial replacement of Portland cement", Construction and Building Materials, vol. 144, pp. 35–41, 2017.

[12] L. G. Li, Z. Y. Zhuo, J. Zhu, J. J. Chen, and A. K. H. Kwan, "Reutilizing ceramic polishing waste as powder filler in mortar to reduce cement content by 33% and increase strength by 85%", Powder Technology, vol. 355, pp. 119–126, 2019.