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Recycling of bone china ceramic waste as cement replacement to produce sustainable self-compacting concrete

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ABSTRACT

Ceramic waste (CW) is produced during the cutting and polishing stage in the ceramic industry, which is hazardous to the environment and requires a large area for its disposal. This study aims to see the incorporation of bone china ceramic waste (BCCW) in self-compacting concrete (SCC) as a partial substitution for cement. BCCW was used at a percentage of 0 to 40% with an improved step level of 10% through mass of cement. Different properties of SCC were examined for the fresh and hardened state. Various fresh properties of SCC as slump flow, V-funnel, L-box height, J-ring, and T_{500} were examined, and results are found acceptable within the EFNARC limitation. To assess the hardened property of concrete, compressive strength, flexural strength, water absorption and ultrasonic pulse velocity experiments were performed. The experimental results exhibited that incorporating up to 10% BCCW in SCC enhanced the compressive and flexural strength. However, on further inclusion of BCCW (beyond 10%), decrease in the strength of modified SCC was observed. Moreover, superior ultrasonic pulse velocity and better resistance to water absorption were found on the inclusion of up to 20% BCCW in SCC. The experimental results of scanning electron microscopic and X-ray diffraction also showed the dense concrete matrix and higher hydration products on the inclusion of up to 10% BCCW in SCC. Study concluded that the inclusion of up to 10% BCCW in SCC increases the fresh and hardened characteristics of concrete and can be effectively used in the concrete industry as a substitute material for natural sources.

1. Introduction

Concrete is the most diversely used construction material that consumes massive amount of non-renewable natural materials as its ingredient. Due to rapidly increasing population worldwide, the usage of natural raw materials in infrastructural development has grown at a fast rate. This advancement in the infrastructural industry has resulted in the depletion of natural raw materials [1–7]. At the same time, the growth in industrialization results in the generation of large amounts of hazardous and toxic solid waste, which requires a large area of land for disposal. Various researchers are hence researching different abandoned materials to overcome this problem. The utilization of such waste materials as alternative resources in the concrete industry will reduce the load over the non-renewable sources used conventionally in concrete manufacturing. This will also reduce the load on the disposal sites and will decline the adverse effect on the environment [6,8,9].

Self-compacting concrete (SCC) is a progressed form of conventional concrete that provides effortless flow and spreads in thinner and denser reinforcement sections without extra vibration. The SCC has been one of the great achievements in the construction sector since it evolved in the year 1983. SCC is now an advanced construction technique with several other advantages like reduced labor cost, construction time, passing ability, flow ability, filling ability, and segregation resistance [2,10,11]. The homogenous concrete mixture can be designed with SCC, which will be free from honeycombing. SCC participation in the construction sector is also growing because of the aforementioned beneficial characteristics [12].

However, SCC requires a large amount of cement to maintain its powder content and flowability. During the production of 1 ton of Portland cement, the same amount of CO_2 is generated in the atmosphere and it is also the main reason for greenhouse gas emission [13,14]. As a researcher, our primary aim is to make environment-friendly and eco-friendly concrete. Minimizing the utilization of cement by using supplementary cementitious materials like ceramic powder, kota stone slurry waste, silica fume, fly ash, metakaolin etc. will have greater impact on cost of construction as well as reduction in

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