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Performance of granite cutting waste concrete under adverse exposure conditions

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ABSTRACT

Granite cutting waste is becoming a serious concern as the amount of waste produced is reaching monstrous proportions, thus making it virtually impossible to ensure proper disposal. The large volume of waste generated is dumped on to the dumping grounds nearby factory location. This unattended waste poses serious environmental and health threats and is an alarming call to seek out methods of production which may utilize this waste and thus lead to a cleaner environment. The research study aims at assessing the durability characteristics of the concrete incorporating this waste as a partial replacement for fine aggregate. The aim of the paper is to present a comprehensive, detailed and systematic picture of performance of the concrete thus obtained under adverse exposure conditions in terms of response to carbonation attack, sulphate attack, chloride ion penetration, acid attack and elevated temperature with variable w/c ratios. The test results clearly showed that modified granite cutting waste substituted concrete exhibits enhanced resistance to carbonation, chloride ion penetration, acid attack and exposure to elevated temperature at optimum granite cutting waste replacement of 25%. No loss in weight was observed at all durations of exposure to $MgSO_4$ solution. The specimen with 25% granite cutting waste replacement exhibited greater intensity and peak area for hydration products namely C–S–H and ettringite as compared to the control specimen.

1. Introduction

With only a few states in India privileged to have valuable granite reserves, the state of Rajasthan is the proud owner of about 20% of the total available granite reserves. A wide variety of machining processes (sawing, polishing, finishing and cutting methods) are deployed before the granite stone reaches to its finished usable form. The fine granite dust particles generated as a by-product of these industrial processes form a colloidal waste on contact with water. When this slurry loses its water content, it generates dry mud with extremely fine particles which are blown away with wind and eventually get suspended in the atmosphere. Fine granite particles reduce the permeability and porosity of top layer of soil and ultimately lead to water logging problem. This prevents the percolation of water from catchment from reaching the ground water table and thus adversely affects the ground water level. The fine granite dust particles are blown by wind and ultimately settle down on vegetation and crops which severely threatens the ecology around granite processing industries. Granite slurry pollutes the surface water reservoirs when washed away with drainage water. Fine granite dust particles cause severe respiratory ailments like Asthma, Bronchitis etc. Moreover, huge mounds of unattended granite cutting waste degrade the aesthetic beauty of the landscape. Since quarrying, machining, finishing of granite result in the release of a huge amount of powdered granite as a byproduct which is a severe environmental pollutant and a potential threat to the human health, there has been a significant concern over the proper disposal of this waste. One such humongous peak of granite cutting waste is shown in Fig. 1. Construction industry in recent years has emerged as one of the most promising sink for this undesirable waste. The studies on the inclusion of marble powder as a substitute in the concrete manufacturing process in the past have established the potential of marble as a suitable

Abbreviations: GCW, granite cutting waste; w/c, water–cement ratio; d, days; Ref., reference; TGA, thermo gravimetric analysis.

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Fig. 1. One of the heaps of granite cutting waste in Shahpura industrial area.

replacement for fine aggregates and cement up to certain optimum percentage level. However only a few studies have been carried out to study the effect of substitution of fine aggregate with granite cutting waste in concrete.

The primary work in the study of granite powder as a replacement for fine aggregate in the manufacturing of aerated concrete and ceramics was carried out by Beretka and Taylor (1991). Inoue et al. (2000) examined the properties of concrete with granite dust obtained from Togou dam site as fine aggregate. They recommended the use of retarder type air-entraining agent in the granite dust concrete. The viability of granite powder as a substitute satisfying mechanical strength requirements in accordance with the relevant standards and codes have been established by Saboya et al. (2007), Topcu et al. (2009), Binici et al. (2008), Corinaldesi et al. (2010), Hebhoub et al. (2011) and Felixkala and Partheeban (2010). Balaji Rao et al. (2012) made a probabilistic analysis of mode II fracture of concrete having crushed granite stone as replacement for sand. Rania et al. (2011) examined the properties of the concrete bricks incorporating marble and granite waste respectively up to 40% (of the coarse and fine aggregates) replacement. They observed that all the samples prepared showed compliance with the Egyptian code and qualified as a structural brick for use in the building sector. The optimum percentage replacement with granite waste was found out to be 10%. Alzboon and Mahasneh (2009) studied the feasibility of utilizing stone sludge as a source of water in concrete. It was found that stone sludge can be used as a source of water upto 25% of the total volume of water required. Dhanapandian et al. (2009) assessed the feasibility of utilizing granite and marble waste as raw material in the manufacturing of bricks. They found that the optimum percentage replacement with granite and marble waste as a raw material was 50%. A noticeable enhancement in the flexural and compressive strength was observed at this percentage replacement. Ribeiro and Holanda (2014) examined the properties of soil-cement bricks incorporating granite cutting sludge from ornamental industry as partial replacement for soil. It was observed that the soil can be replaced with granite cutting sludge upto 30% by weight. Enhancement in physical and mechanical properties was observed at this optimum percentage replacement. An attempt to study the strength & durability of concrete with granite powder as partial replacement for sand was made by Vijayalakshmi et al. (2013) for a fixed w/c ratio. They found that replacement of natural sand with granite waste up to 15% was favourable for making concrete without significantly compromising mechanical strength and durability parameters. Lakhani et al. (2014) reviewed the utilization of stone waste in the manufacturing of various value added products. It can be readily observed that the detailed studies on assessing the feasibility of granite waste on durability grounds are very limited. Singh et al. (2015) observed enhanced compressive and flexural strength and reduced permeability at an optimum percentage replacement of 25% of natural sand with granite cutting waste. However, a slight decrement in workability was observed. In an another study Singh et al. (2016a) recommended 30% of granite cutting waste as the optimum replacement for fine aggregate in concrete based on enhanced strength and durability parameters coupled with economical savings. Singh et al. (2016b) observed improved microstructure besides enhanced compressive strength, flexural strength and corrosion and carbonation resistance at the optimum percentage replacement of 25%. However, a detailed study on the inclusion of granite powder as partial replacement for sand in concrete under adverse exposure conditions with variable water cement ratio was still missing. The present detailed study aims at systematically assessing the performance of granite substituted concrete under adverse exposure conditions for the w/c ratios of 0.3 and 0.40. The percentage of granite cutting waste was varied in steps of 0%, 10%, 25%, 40%, 55% and 70% of the total weight of fine aggregate for each of the w/c ratio. Various tests which have not been attempted earlier including acid attack, sulphate attack, carbonation and chloride penetration test were carried out to assess the long term performance of the granite cutting waste concrete. Moreover, Thermo-gravimetric Analysis test was also carried out for the specimens to gain better insight into the behaviour of concrete in adverse exposure conditions.

2. Experimental programme

2.1. Ingredient attributes

2.1.1. Cement

The Ordinary Portland Cement of grade 43 in compliance with BIS: 8112-1989 was used (BIS, 1989). The specific gravity, normal consistency, initial setting time and final setting time were 3.14, 35%, 120 min and 380 min respectively.

2.1.2. Fine aggregate

The sand aggregate used in the experimental study was obtained from the Banas river bed. The sand confirmed to Zone III as per BIS 383:1970 (BIS, 1970). Physical properties of sand such as specific gravity, water absorption and fineness modulus are mentioned in Table 1. The chemical properties of sand are given in Table 2.

2.1.3. Coarse aggregate

The coarse aggregates of maximum nominal size 20 mm were used. The mean specific gravity and the fineness modulus of coarse aggregates used were 2.63 and 6.78 respectively.

Table 1
Physical properties of granite cutting waste and river sand.

Property	GCW	River sand
Specific gravity	2.624	2.70
Water absorption (%)	4.36	2.90
Fineness modulus	2.573	3.36