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An investigation on effect of partial replacement of cement by waste marble slurry

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HIGHLIGHTS

- This paper presents an experimental study on use of marble slurry as partial replacement of cement.
- Indigenous fabrication of equipment for percentage air content, Figg's air and water permeability and surface resistivity.
- Marble slurry replacement percentages kept as 10%, 15%, 20%, 25%.
- Experimental trials on under reinforced beams for flexure and bending.
- Compressive strength prediction model using Artificial Neural Networks.

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ABSTRACT

In this study, waste marble slurry from Makrana region of Rajasthan in India is characterized for various physiochemical properties and used to replace cement partially by weight in concrete. Effects of marble slurry on hydration process, fresh and hardened concrete properties and durability properties using indigenously fabricated equipment are investigated. Effect of particle size of marble slurry on compressive strength and experimental trials on reinforced concrete with dried marble slurry are also conducted. No significant effect on characteristics of cement pastes is noted. Drying shrinkage is found to decrease and strength of mortar improves for a certain percentage replacement. Marble slurry is found to show filler effect by giving the concrete a denser and even structure. It is observed that the mechanical properties of concrete enhanced with incorporation of dried marble slurry for up to 15% replacement. The quality of concrete improves as per ultrasonic pulse velocity and durability tests. Reinforced concrete with marble slurry also shows promising results with increased bond strength. Finally, a compressive strength prediction model is developed using artificial neural network (ANN). The results for ANN are plotted as experimentally evaluated 28 days' compressive strength versus predicted compressive strength.

1. Background

Rajasthan, a state in North-West India is home to more than 50 types of minerals and rocks. It has a large variety of natural rock deposits, a few essentials are granite, marble, sandstone, limestone, slate and quartzite. Perhaps, nowhere in the world, any other society is found to be so engraved with stone and stone based products as it is in Rajasthan. The state has around 4000 marble mines and 1100 marble processing units which are spread over in 16 districts. The main areas known for marble mining are Kishangarh, Rajasmand, Makrana, Banswara, Jaipur and Udaipur. With the increase in demand for these stones throughout the country, number of marble processing units and quarries in Rajasthan have significantly gone up in the past decade As the marble processing industry continues to expand, large amounts of waste in the form of marble slurry is generated and released into the environment. A significant growth in marble slurry has been seen, but the increase in extent has not been documented. It is estimated that almost five to six million tons of marble slurry is generated per anum. This waste slurry is dumped along road sides and near processing units, thus causing environmental degradation and escalating health problems in the surrounding areas. The very fine particulate matter in this waste slurry causes air and water pollution. Also, the waste slurry clogs agricultural lands causing long-term damage to the soil and crops. Hence, there is a dire need to utilize this waste material in one or the other way to minimize its harmful impact on the environment. Additionally, with advancement in technology

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finding viable options to reuse or treat this waste is not only possible, but also important. Due to the ever-increasing demand of cement for infrastructure projects it is essential to find a material which could help replace cement in concrete up to and acceptable percentage. Cement contributes to almost 70% of the total embodied energy in raw materials used for production of concrete and it accounts for 5% of the man made production of carbon dioxide. If the alternative material for cement is a waste, it would aid in mitigating the indiscriminate dumping of wastes and also simultaneously help reduce the amount of carbon dioxide produced up to a certain extent. Waste marble slurry is one such material which has found use in partially replacing cement in concrete thus promoting the utilization of this waste material and reduce the use of cement.

Research in the area of use of marble slurry as partial replacement of cement in concrete has been a subject of interest in recent years. As per Ramezanianpour, A.A. [1] supplementary cementing materials have proven to be economical and environment friendly alternatives to typical concrete mixes Researchers have conducted studies in the recent past regarding use of marble slurry as a partial replacement of cement in concrete in spheres of durability, physical & chemical properties, strength etc. The thrust of previous research has been on efficacy and viability of marble waste as an effective replacement material. Rai et al. [2] investigated M30 grade of concrete by partially replacing cement with five different percentages by weight of marble slurry (0–20%) and found that compressive strength increases by 5–10% for up to 15% replacement. Vardhan et al. [3] reported an improved workability in their analysis of cement mortar mixture on partial replacement with marble dust from 0–50%t by weight. The results reported indicate that the maximum benefit of improved fluidity was achieved till 10% addition of marble powder. Also, the compressive strength for up to 28 day curing inspection increased slightly till 10% replacement; thereafter the strength started decreasing with increase in percentage replacement. Substitution of cement in variable ratios by marble powder and natural puzzolana to prepare self-compacting concrete was studied by Belaidi et al. [4]. The experimental investigation showed improved rheological properties of concrete mortar by addition of waste marble powder (10–40%), but showed dwindled compressive strength with addition of waste marble powder and natural puzzolana. Aliabdo, A.A., et al. [5], Arshad, A., et al. [6], Hebhoub, H., et al. [7] and Ergün, A. [8] observed a decrease in values of slump on increasing the replacement percent of cement by marble slurry which was attributed to the high percentage of fines in marble slurry. The fines increase the demand for water in concrete. However the results related to slump reported by Gupta, P. et al. [9] were contradictory. Arshad, A. et al. [6] and Hebhoub, H. et al. [7] had similar observations. Aliabdo, A.A. et al. [5] studied the effect of partially replacing cement by marble slurry for two water binder (w/b) ratios 0.40 and 0.50. Increase in compressive strength for up to 7.5% replacement for w/b ratio 0.5 and slight increase in compressive strength for up to 10% replacement for w/b ratio 0.40 was reported. Shirulea, P.A. et al. [10] reported 15% as the suitable percentage replacement which showed an increase in compressive strength as compared to the control mix. Decrease in amount of di-calcium silicate (C_2S) and tri-calcium silicate (C_3S) for the fall in strength were stated as the main contributors. Ali & Hashmi [11] reported an increase in split tensile strength on partially replacing cement by marble slurry by 10%. Ergün, A. [8] obtained similar results, but with progressively lower values for higher replacement ratios. Flexural strength was also found to improve on replacing 10% cement by marble slurry by Ali & Hashmi [11]. At 10%, there was 10.73% increase in flexure strength. However, Belaidi et al. [4] reported a decrease in the flexural strength of concrete. Soliman, N.M. [12] reported an increase in modulus of elasticity of concrete. No influence of addition of marble dust on ultrasonic pulse velocity values was observed by Aliabdo, A.A., et al. [5].

Gesoglu et al. [13] considered the effect of marble powder replacing the concrete binder. The laboratory investigation involved additions of marble in 0%, 5%, 10% and 20% proportions with parallel use of superplasticizer. The w/b ratio was reserved constant at 0.35. The authors concluded that with increase in substitution ratios, the amount of superplasticizer had to be augmented to keep the slump flow diameters at same point. Talah et al. [14] studied effect of marble powder used as partial substitute for Portland cement (PC) on durability & mechanical properties of high performance concretes and found that marble powder could be used as partial replacement of Portland cement up to 15% in composite cement. The paper also suggested reduction in oxygen permeability, chloride ion penetration and increased durability. This can be attributed to the enhanced compact microstructure of concrete formed after partial replacement with marble slurry. R. Rodrigues et al. [15] evaluated the mechanical performance of concrete (compressive strength, splitting tensile strength, ultrasonic pulse velocity, modulus of elasticity and abrasion resistance) with varying assimilation ratios of sludge from the marble extraction industry as cement replacement (0–20% of the total volume of cement), as well as with plasticizers. The experimentation reported that compressive strength decreased as the replacement ratio increased. But this decrease was not significant up to replacement ratios of 10%. Also, with use of plasticizers the compressive strength increased due to water/cement (w/c) ratio reduction. The bulk density was not significantly changed by the addition of waste marble slurry though a maximum change of 2.3% in bulk density was reported. However, on using super plasticizers bulk density was found to increase because of the increase in compactness of the mix. R. Rodrigues et al. [15] further found decrease in modulus of elasticity with the increase in replacement ratio of cement by marble dust, with maximum losses of 10.3% for 15% replacement. F. Gameiro, et al. [16] evaluated concrete containing various percentages of fine aggregates produced from marble quarrying waste on durability criteria. It was observed that at a replacement level of 20%, the inclusion of marble aggregates proved constructive in terms of water absorption by capillary action. Also, sample showed improved carbonation resistance with incorporation of marble sand. A powdered by-product of marble sawing was analyzed as an additive mineral in mortar and concrete by V Corinaldesi et al. [17]. The results suggested that fineness of marble provided sufficient cohesiveness of mortar and concrete even in low w/c ratio conditions. Also, the study suggested that in the presence of a super plasticizing admixture, 10% substitution of sand by the marble sawing waste powder provided highest compressive strength for same workability.

Comprehensive effect of partial replacement of cement with dried marble slurry and simultaneous variance in w/c ratio on characteristic properties of cement paste, mortar, mechanical & durability aspects of remains a matter of research. The present study is an attempt in the aforesaid direction.

2. Research significance

Even though a lot of studies have been conducted at the Global level, there is very little awareness in India that the waste slurry has also found use as a partial replacement of cement. The innovative part in this paper is that all aspects related to cement in mortar and concrete in terms of partial replacement of cement by marble slurry have been incorporated. Also, prediction model using ANN has been developed based on the results obtained A few equipments like air pressure meter, Figg's air and water permeability, electrical resistivity and pull out test were fabricated using locally