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Pozzolanic reaction and strength activity index of dolomite powder incorporated cement mortar

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Abstract

Assessment of pozzolanic activity of an alternative material is a key parameter for its application as a cementitious material. This study has been conducted to check the scope of dolomite powder in its native and calcined state as a substitute for cement for sustainable construction practices. Dolomite is a variety of limestone consisting of calcium carbonate and magnesium carbonate in predominant compositions. The chemical composition of dolomite powder is determined using X-ray florescence (XRF) technique. XRF test results showed the presence of 31.08 % of Calcium Oxide and 21.3 % of Magnesium Oxide as major compounds in dolomite powder. Frattini and Strength Activity Index (SAI) tests have been conducted to analyze the pozzolanic activity of dolomite powder. Frattini test determines the consumptions of hydroxyl ion (OH^-) and calcium ion (Ca^{+2}), which are plotted in the solubility curve to decide the pozzolanic behavior of a material. The test on dolomite powder in its native state resulted in no pozzolanic activity, while in the calcined form, pozzolanic activity was observed. This behaviour was due to the activation of quick lime after the calcination process. The strength Activity Index (SAI) test is conducted to compare the compressive strength of nominal and

modified mixes at 7 and 28 days. The dolomite powder in its native state satisfied the Strength Activity Index (SAI) criteria at 7 and 28 days owing to its ultra-fine particle size. The SAI test observations were on the higher side in the calcined state as both – ultra-fine particle size and quick lime contributed to the strength of the mix.

Introduction

India is a developing country, and the government of India is infusing very high funds into the infrastructure development of the country. The government is focusing on projects like the development of mass transit facilities, roadways, and railway infrastructure, resulting in expansion of construction sector. Since concrete is the primary construction material for the majority of the projects, the cement industry has taken notice of the significant growth in the infrastructure sector. Cement manufacturing affects the environment in two different ways. One problem with the use of cement is its high carbon footprint cement production contributes 7 % of global CO_2 emissions. This is due to the high energy consumptions and emissions from the production process, including the burning of fossil fuels and the release of carbon dioxide from the limestone used in the production process. It also consumes 12 – 15 % of total industry energy use [1]. It puts a massive burden on sustainable construction practices. Another problem is production of cement releases large amount of dust and particulate material into the air which can cause respiratory problems and another health issues The extraction of raw materials and transportation of cement can also have negative impacts on the environment including deforestation and air pollution. Therefore, the impact on the environment due to cement production can be minimized by reducing the usage of conventional raw materials and finding alternative pozzolanic materials.

India is the biggest producer of natural stones, accounting for 27 % of total natural stone production worldwide. Bihar is the biggest mineral-rich state in India that comes along with Rajasthan on the second number. Rajasthan is a dominant producer of marble, sandstone, limestone, dolomite, granite, etc. [2].

India produces 7 – 8 million tonnes of dolomite every year. Predominant dolomite producers in India are Andhra Pradesh, Madhya Pradesh, Chhattisgarh, Karnataka, Odisha, Rajasthan, and Telangana [3]. As per data available on the Ministry of Mines, Govt. of Rajasthan website, there are 599.4 million tons of dolomite reserves in the state of Rajasthan. Significant dolomite sources are in Rajasthan's Ajmer, Bhilwara, Chittorgarh, Jaipur, Jodhpur, and Udaipur districts [4]. Dolomite powder is commercially available and widely used in many industries. Steel industries utilize its primary component along with cement, agriculture, glass, ceramic, and rubber industries [5].

Studies show that dolomite has been successfully utilized in various civil engineering applications. In combination with dolomite powder (3:1), fly ash has been successfully used in self-compacting concrete [6]. A reduction in slump value was observed when dolomite powder was used as filler material in self-compacting concrete [7]. Dolomite stone can be used as the base material in road construction [8], [9]. Dolomite fines up to 20 – 30 % can replace fine and coarse aggregates in concrete and mortar [10]. Lime is conventionally used as a stabilizing agent in clayey soils [11], [12]. Dolomite is a variety of limestone with a very comprehensive proportion of calcium and magnesium carbonate. Thus dolomite alone or in combination with other materials is also used to stabilize problematic soils [13], [14], [15].

The stone industry material with a cement-like composition can be utilized as a partial substitute for cement without compromising the properties of the cementitious mixes. It will reduce the construction cost as well as save the environment and natural resources. This will be a step towards sustainable construction practices. The utilization of alternative materials and industrial by-products will help in achieving the goal of social and economic sustainability [16], [17].

To check the pozzolanic behaviour of any material, Frattini test and Strength Activity Index (SAI) test can be adopted. In Frattini test, the test sample of cement and test pozzolan material is prepared as per guidelines specified in EN 196–5 [19]. The test sample has to undergo through a titration process to check the concentration of dissolved Ca^{2+} and OH^- in the solution. In SAI test, the strength of a standard cement mould is compared to that of a mould containing cement and pozzolanic material [18].

The major objective of this research is to check the presence of pozzolanic activity in dolomite powder. The dolomite powder is tested in native as well as calcined state. Frattini test and Strength Activity Index have been chosen to check the pozzolanic activity in dolomite powder. These tests are selected as they have been widely reported in many studies, and the standard procedures (EN 196–5 for Frattini test and ASTM C311 for Strength Activity Index [19], [20]) exist for these methods.

Section snippets

Materials

The major materials used in this study were cement, sand and dolomite powder. The dolomite powder was used in native state and after calcination in laboratory. The details of procurement, physical characteristics of raw materials and calcination process of dolomite powder is shown below: …

Frattini test

In this test, the concentration of CaO and OH^- obtained by the titration process was plotted against the lime activity curve. As shown in Fig. 2, the average repeatability values of OH^- and CaO for dolomite powder are 8.8 and 57 mmol/l, respectively. This point falls above the lime activity curve, which shows no pozzolanic activity. The standard deviation for OH^- and CaO are 0.45 and 0.15 mmol/l which are within the limits of 0.5 and 0.2 mmol/l specified in BS EN 196–5. While in the case of …

Results and discussions

Listed are the conclusions obtained from the above test results:

- XRF test results confirmed the presence of Calcium Carbonate (55.5 %) and Magnesium Carbonate (43.04 %) as predominant compounds in dolomite powder. The calcination process leads to removal of carbon dioxide from dolomite powder resulting in activated Calcium Oxide and Magnesium Oxide. …

- Frattini test (as per BS EN 196–3) test results showed non pozzolanic behavior of dolomite powder in its native state. Pozzolanic behavior was …

…

CRediT authorship contribution statement

Nishant Sachdeva: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Resources, Validation, Writing – original draft, Writing – review & editing. **Neha Shrivastava:** Methodology, Supervision, Writing – review & editing. **Sandeep Shrivastava:** Methodology, Supervision. …

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. …

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