Journal of Chemical Health Risks

www.jchr.org

JCHR (2024) 14(3), 2693-2699 | ISSN:2251-6727

Investigating the Properties of Blended Concrete with Silica Fume and Marble Dust Experimentally

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(Received: 04 February 2024 Revised: 11 March 2024 Accepted: 08 April 2024)

KEYWORDS

Silica fume; marble dust; compressive strength; pozzolanic materials; blended concrete; etc.

ABSTRACT:

In this research, silica fume functions as a pozzolanic component in concrete and marble dust is used as the fine aggregate. The performance of marble dust and silica fume separately and in combination with blended concrete is evaluated in this study using metrics including slump value, 28-day compressive strength, and 7-day compressive strength. Cement, marble dust, silica fume, coarse aggregate, water, and fine aggregate make up the concrete mixture. Ten distinct proportional combinations, or "mix designations," are subjected to laboratory testing in order to ascertain the compressive strength at 7 days, 28 days, and the slump value. In this concrete mix design, 10%, 15%, and 20% of the fine aggregate are replaced with marble dust, while 3%, 5%, and 7% of the cement is substituted with silica fume. C (control), SF3%, SF5%, SF7%, SF3%MD10%, SF3%MD15%, SF3%MD20%, MD10%, MD15%, and MD20% are the mix combinations that are indicated by these letters. This entails mixing 10%, 15%, and 20% marble dust with 3% silica fume in different proportions. The compressive strength of the concrete after seven and twenty-eight days of curing, as well as the slump value of the fresh concrete, are assessed in the laboratory trials.

1. Introduction

Concrete is an essential building material that is now made of more than just cement, water, and coarse and fine particles. Cement, water, pozzolanic materials, fine and coarse aggregates, and a variety of chemical and mineral admixtures are the ingredients of contemporary concrete. These pozzolanic materials are frequently byproducts of other industries, such thermal power plants and metallurgical businesses. It's crucial to remember that improper management of these by-products' disposal might provide serious environmental risks. But according to study, these by-products may be used to efficiently replace extra pozzolanic or cementitious components, increasing the strength and longevity of the concrete and lowering the requirement for more cement.Portland cement binds concrete efficiently, however there are several environmental issues facing the cement business today. These problems include the depletion of natural resources, air pollution, hazardous pollutant emissions from fuel burning, and waste product management. Fossil fuels must be used in the manufacturing of cement, which results in the emission of carbon dioxide, one of the greenhouse gases that causes global warming. The production of cement is responsible for around 5% of global carbon dioxide emissions, with each tonne of cement produced producing a tonne of CO2. India is the country that produces the second most cement globally, after China, accounting for around 7% of India's CO2 emissions. Graph Shown in figure :1

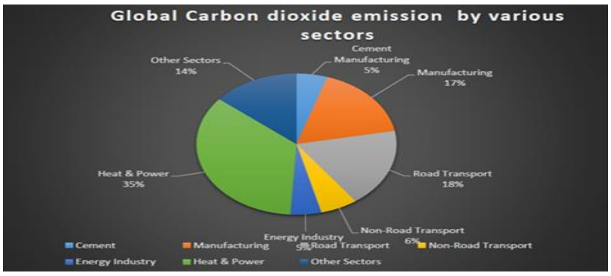

Figure 1. Various industries' contributions to global CO2 emissions

1.1. Pozzolanic Substances

The process of determining how external loads impact physical structures and their component pieces is called

Journal of Chemical Health Risks
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JCHR (2024) 14(3), 2693-2699 | ISSN:2251-6727

as structural analysis. This kind of analysis is applicable to a various range of constructs that have loads to support, including as buildings, bridges, cars, furniture, clothes, geological strata, prosthesis, and biological tissues. All construction eventually collapses under the weight placed on it by the Earth, creating internal strains on different structural components.

$$\boldsymbol{silica + Ca(OH)_2 + Water \rightarrow C - S - H\ gel\ (Cementing\ Material)}$$

One well-known reaction in structural materials is the pozzolanic reaction, which is defined as the interaction of pozzolanic chemicals with calcium hydroxide. Pozzolanic qualities are exhibited by a number of industrial byproducts, including as materials from metallurgical and thermal power plant operations. Among these byproducts are ground granulated blast furnace slag, fly ash and silica fume. Another name for these industrial leftovers is "synthetic pozzolans." On the other hand, volcanic ash and tuff make up naturally occurring pozzolans.

1.2. Silica fume

Another important pozzolanic substance is silica fume. It is a byproduct of the reduction process that uses coal and quality quartz to generate silicon alloy in an electric arc furnace. If we compare SFto other pozzolans such as fly ash or GGBS, it has the highest pozzolanic activity. Calcium hydroxide is created when Portland cement and water combine. Calcium silicate hydrate (C-S-H gel) is formed when SFand calcium hydroxide are mixed. A replacement level of 10% to 15% of the cement's weight is usually advised for silica fume.

1.2.1 Silica fume reactions in concrete

The Advantages of adding SF to concrete are directly related to changes in the concrete's microstructure, which are a result of the fume's chemical and physical contributions.

1) **Physical Contribution**: Because of its existence, SF acts as fine aggregate by packing the spaces in concrete with a myriad of little particles. The concrete's qualities are greatly improved by this very small particle micro filling of the voids.

2) **Chemical Input:** Amorphous silicon dioxide, which is present in SF at high concentrations, makes it a very reactive pozzolan. When Portland cement and water react, calcium hydroxide and calcium silicate hydrate are the end products. Concrete voids are created when the water-soluble component, calcium hydroxide, dissolves in water. Conversely, the combination of calcium hydroxide with SF produces calcium silicate hydrate, which makes concrete harder.

1.3. Marble Dust

Marble is a typical building material that is used to create and decorate small temples and other religious buildings. The procedure is removing marble from quarries, treating it, and then chopping it into pieces that may be used. About thirty percent of the marble is produced during this process as marble dust, a fine powder. One consequence of the extraction and processing is this marble powder. However, because marble powder may contribute to soil, water, and air pollution, disposing of it properly carries a substantial ecological risk. The possible pollution of groundwater is one of the urgent issues. Calcium carbonate is a common chemical component of marble powder. Marble powder may be efficiently repurposed for building purposes by using it as a fine aggregate and filler in concrete as a workable solution to this problem.

1.4 Importance of the Study

Selecting the optimal combinations becomes increasingly challenging as the number of components in concrete grows. This study investigates the effects of adding marble dust and silica fume as extra ingredients in a particular method. For this inquiry, the control concrete in the experimental setup is only M20 concrete.

2. Literature Review

A Research by Sidhu D.S. looked at SF in concrete and its early-age behavior in 2001. The purpose of the study was to evaluate how adding SF would affect concrete density, elastic modulus, and compressive strength. Two concrete grades, M30 and M50, were used in this experiment. 0% to 25% of the weight of the cement was replaced with SF in different proportions. The concrete samples were tested at intervals of 1, 3, 7, 14, 21, and 28 days, and measurements were made of their density and elastic modulus. The results showed that the density of the silica fume-containing concrete was somewhat lower than that of the silica fume-free concrete—about

Journal of Chemical Health Risks
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2.3 percent less. Additionally, the study showed that the silica fume-blended concrete's strength rose dramatically after 14 days, but the control specimen originally showed greater strength after 7 days compared to the silica fume-blended specimen. It became clear after 28 days that the concrete mixed with SF had a far higher compressive strength than the control concrete. In summary, the study found that before compressive strength decreases, a 15% replacement level of SF for cement is ideal. It was also found that adding SF to concrete had obvious results in as little as seven days.

Dotto et al. looked into the effects of SF on the characteristics of concrete and the corrosion of reinforcing bars in 2004. They evaluated electrical resistance in concrete at several water-to-binder ratios and with SF replacing 6% and 12% of the cement. According to their research, adding 6% Sf increased electrical resistance by 2.5 times, while adding 12% SF increased electrical resistance by 5 times. Additionally, SF in concrete improved resistance to corrosion caused by chlorides.

Poon C.S. et al. looked at the characteristics of high-performance concrete using mixes of metakaolin and SF in 2005. They evaluated properties such porosity, pore size distribution, chloride penetration depth, and compressive strength. The concrete demonstrated decreased chloride penetrability and increased 28-day compressive strength when SF replacements of 5% and 10% were added. With a compressive strength of 107.9 MPa, the 10% SF mix outperformed the control mix, which only managed a 96.5 MPa.

Bahar Demirel looked at the possibility of using leftover marble dust as a fine aggregate in concrete in 2010. In many concrete compositions, marble dust was used in place of fine sand in weight amounts of0%,25%, and 100%. The addition of marble dust improved the concrete's compressive strength, according to the research, which evaluated the concrete's strength at 3, 7, 28, and 90 days of curing.

2011 saw research by Baboo Rai et al. on concrete that used marble grains and powder as a partial substitute for cement and other common fines. This replacement increased the mortar's compressive strength.

Ajileye F.V. looked at the possibility of using SFin concrete in place of some of the cement in 2012. Replacement percentages of SF in cementitious materials varied from 5% to 25% by weight. The greatest compressive strength after 28 days was reached with 10% SF replacement, according to the study, which tested compressive strength at several intervals. This resulted in a 28-day compressive strength of 48.75 MPa for C30 grade concrete.

The depth of chloride penetration in concrete with high early strength Portland cement, both with and without silica fume, was investigated in 2013 by Camarini Gladis et al. When concrete is exposed to harsh chemical conditions, SF decreases the depth at which chloride ions may penetrate, greatly improving the performance of the concrete. It was discovered that the SF concrete's chloride ion penetration depth was 25 mm, which was less than that of the control concrete that did not include silica fume.

3. Experimental Study

3.1 Objectives

1) To investigate the various facets associated with including marble dust as a fine aggregate and SF as an additional cementitious component in cement concrete.

2) To assess the durability and workability of concrete that has silica fume and marble dust added to the mixture.

3.2. Methodology

The steps for conducting the experiment involving marble dust and SF in concrete can be summarized as follows:

1) **Concrete Component Selection:** In this initial phase, the suitability and compatibility of the concrete components are carefully considered, including cement, aggregates, silica fume, and marble dust.

2) **Property Selection:** Specific concrete properties of interest are selected for examination. For this particular study, the focus is on assessing properties such as the slump value, which provides insights into workability, and the compressive strength of

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www.jchr.org
JCHR (2024) 14(3), 2693-2699 | ISSN:2251-6727

concrete at two critical points in time: Seven days and Twenty-Eight days.

3) **Proportioning:** The concrete mixture is proportioned according to established standards and guidelines, specifically following the IS code 10262-2009 and IS code 456-2000. This step involves determining the precise ratios and quantities of each component to achieve the desired concrete mix.
4) **Laboratory Testing:** A comprehensive laboratory experiment is conducted to evaluate the concrete's properties. Various tests are performed to measure the selected properties, including slump tests and compressive strength tests at both the Seven days and Twenty-Eight days marks.
5) **Analysis and Conclusions:** Once the data from the laboratory experiments have been collected and analyzed, conclusions are drawn based on the observed results. These conclusions provide insights into the impact of using marble dust and SFon the workability and strength of the concrete mixture, as well as other relevant factors.

3.3. Laboratory Experiment

Concrete is primarily composed of the following main ingredients, with their proportions typically denoted by volume:

1. **Cement:** This is a key binding agent in concrete.
2. **Silica Fume:** Often used as an additional cementitious material to enhance concrete properties.
3. **Water:** Used for hydration and mixing.
4. **Aggregate:** Includes coarse and fine aggregates, providing strength and stability.
5. **Marble Dust:** An additional component that may be used in concrete mixes, potentially affecting properties like workability and strength.

The unit of volume for these concrete components is typically cubic meters (m^3), with 1 m^3 representing the total volume of the concrete mixture.

Silica fume, which is frequently used in concrete mixtures, is supplied by Precision Drawell Pvt. Ltd., a company based in Nagpur, Maharashtra. They report that their silica fume has a specific gravity of 2.2.

Marble dust, another component mentioned, is locally sourced. Its specific gravity is provided as 2.67. This information is essential for calculating and proportioning concrete mixes accurately.

3.4. Mix Design

The process of figuring out the perfect ratios of cement, sand, aggregates, and water to produce concrete that has the right strength for a building project is known as mix design. This process involves a comprehensive examination and calculation of the necessary components and their respective ratios to meet specific project requirements. It encompasses evaluating material properties, conducting tests, making adjustments as needed, and thoroughly documenting the mix design for reference during concrete production. A well-executed mix design is crucial to ensure that the concrete meets the project's unique needs and performs as expected in terms of strength, workability, and durability.

Table 1. Mix design ratio

Concrete	**Grade - M20 (Fck =20Kn/mm2)**
Cement Grade	OPC 43
Maximum aggregate size	20mm ±
Cement content minimum	300 Kg/meter cube
The maximum water-to-cement ratio	0.5
Workability	105 mm
Conditions of exposure	Mild conditions

3.4. Proportion of components

To ensure the production of high-quality concrete, precise component proportions play a pivotal role. These proportions are instrumental in selecting the appropriate concrete components to meet specific requirements. In this study, a systematic naming convention is employed to represent different concrete mixtures:

1. **Control (C):** This signifies the baseline or control concrete mixture.

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2. **SF3:** Refers to concrete with 3% SF is added to the cement.
3. **SF5:** Represents concrete with 5% SF is added.
4. **SF7:** Signifies concrete with 7% SF is added.
5. **MD10:** Indicates concrete with 10% marble dust, serving as a fine aggregate.
6. **MD15:** Denotes concrete with 15% marble dust in the fine aggregate.
7. **MD20:** Represents concrete with 20% marble dust as part of the fine aggregate.

The subsequent combinations incorporate both SF and marble dust in various proportions:

1. **SF3MD10:** Utilizes 3% SF and 10% marble dust in the concrete mix.
2. **SF5MD15:** Involves 5% SF and 15% marble dust.
3. **SF7MD20:** Incorporates 7% SF and 20% marble dust.

It's important to note that in the final three combinations (8th, 9th, and 10th), the proportion of silica fume (3%) remains consistent, while the proportion of marble dust varies (10%, 15%, and 20%). This implies that while the percentage of marble dust in the fine aggregate changes, the silica fume content remains constant in these mixtures.

Title	Cement quantity (kg/m3)	SF (kg/m3)	Water (kg/m3)	Coarse Aggt (Kg/m3)	Fine Aggt (Kg/m3)	MD (kg/m3)
Control	381.3	0	187	1147.08	762.79	0.00
Silica fume3	369.861	11.439	187	1147.08	762.79	0.00
Silica fume5	361.866	19.065	187	1147.08	762.79	0.00
Silica fume7	354.609	26.691	187	1147.08	762.79	0.00
Marble Dust10	381.3	0	187	1147.08	686.51	76.28
Marble Dust15	381.3	0	187	1147.08	648.37	114.63
Marble Dust20	381.3	0	187	1147.08	610.23	152.56
Silica ume3Marble Dust10	369.861	11.439	187	1147.08	686.51	76.28
Silica ume3Marble Dust15	369.861	11.439	187	1147.08	648.37	114.63
Silica ume3Marble Dust20	369.861	11.439	187	1147.08	610.23	152.56

Table 2. Proportion of Components

4. Results

4.1 Properties

Each concrete mix's test results are included in a table along with measurements of the slump value and compressive strength after seven and twenty-eight days: shown in Figure [2,3,4]

Title	Compressive strength averaged over 7 days (N/mm^2)	Compressive strength averaged over 28 days (N/mm^2)	Slump value (mm)
Control	15.57	15.68	72
Silica fume3	17.36	17.49	67
Silica fume5	17.80	17.94	62
Silica fume7	18.03	18.17	57
Marble Dust10	15.34	15.46	74
Marble Dust15	15.57	15.68	70
Marble Dust20	15.42	15.54	63
Silica ume3Marble Dust10	17.63	17.76	65
Silica ume3Marble Dust15	17.61	17.74	59
Silica ume3Marble Dust20	17.42	17.55	53

Table 3. Concrete Mix's Test Compressive strength results after seven and Twenty-eight days

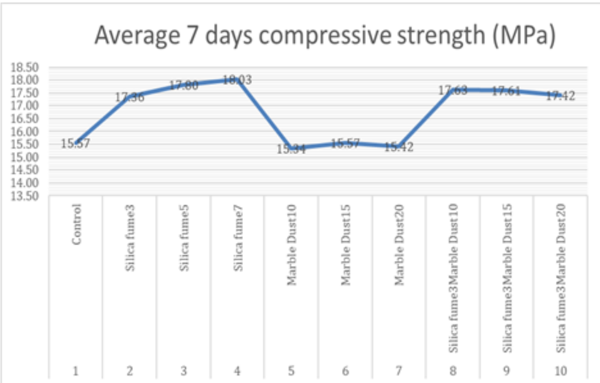

Figure 2. 7-day compressive strength represented graphically

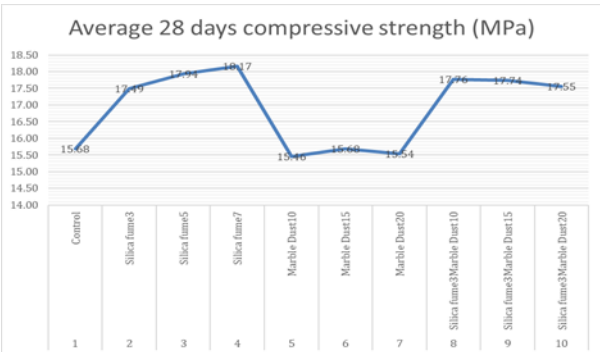

Figure 3. 28-day compressive strength represented

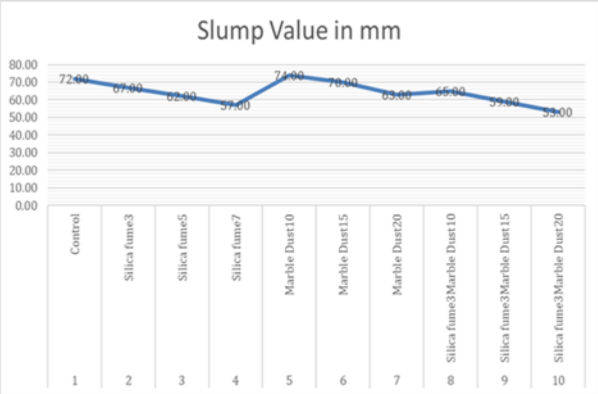

Figure 4. Slump value represented graphically

5. Conclusions

Combining silica fume and marble dust with M20 concrete can enhance its mechanical characteristics. Replacing cement with SFat levels of 3%, 5%, and 7% has been proven to enhance concrete attributes, particularly its compressive strength. Research has shown that an increase in SFcontent results in improved compressive strength, specifically at levels of 3%, 5%, and 7% substitution.

SFtends to reduce concrete workability, but the introduction of admixtures can mitigate this effect. Marble dust, when employed as a fine aggregate, does not significantly compromise concrete's compressive strength. Similar to silica fume, marble dust diminishes concrete workability, but the use of admixtures can improve workability.

Marble dust can be successfully used as a replacement for fine aggregate at a 15% substitution rate, but increasing it to 20% can have a negative impact on concrete compressive strength. Both SFand marble dust can be employed to enhance concrete properties. The combination of SFand marble dust, referred to as SF3MD20, shows the potential to enhance concrete's mechanical attributes, achieving a maximum compressive strength of 32.24 MPa.

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JCHR (2024) 14(3), 2693-2699 | ISSN:2251-6727

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