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Experimental investigation on granite waste and alccofine in concrete

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ABSTRACT

Population growth and rapid pace of globalization have increased the demand for construction materials. River sand is one of the main materials used to make the fine aggregate for concrete. As a result, finding an alternative to sand has become crucial. Granite debris and M sand are employed in place of river sand in this experiment. In this experiment, granite debris as well as M sand are used in place for river sand. Concrete constructed using granite waste and alccofine was compared to ordinary concrete that had a 0.50 w/c ratio using the M25 mix design. 10% of alum is added to cement, and 0% to 30% of fine aggregate is replaced with granite waste enrich the physical properties by 23%, 9% and 41% in compressive, split tensile and flexural strength. The mechanical and microstructural characteristics are looked at in this investigation. According to the test results, concrete made with 10% alccofine, 15% granite waste, with 85% M sand performs satisfactorily. In addition, super plasticizers are acceptable in the M5 mix compared to the other mixes. The microscopic images show a densely packed cement matrix and the aggregate transition area, which points to strong bonding.

Keywords: Granite waste; alccofine; M-sand; EDX test; SEM analysis.

1. INTRODUCTION

The main moto of this research is to make suitable replacement for M-sand in concrete with enriched mechanical properties and durability properties of the concrete. Concrete is a common building material used all over the world. Traditional concrete's primary components are cement, which is a type of M-sand, coarse gravel, and water. Because of the expansion of construction of infrastructure and the resulting rise in consumption, accessible natural resources are being rapidly depleted all over the world [1, 2]. In relation to how concrete behaves both when it is still wet and after it has hardened, aggregates account for roughly 75–80% of the total volume of concrete, which makes them more important than all other components. Between twenty-five and thirty percent of the concrete's total volume was made up of fine gravel. Concrete's mechanical properties give it enduring capabilities [3]. A 45 percent of the granite reserves in the world are in the Indian state of Tamil Nadu. Granite blocks are cut in the quarries using a variety of cutting methods before being transferred to nearby stone processing plants [4–6]. When stone sludge is thrown in landfills, its water content is drastically reduced, resulting in a dry muck that is composed of an extremely fine powder that can be easily taken in by both people and animals. Additionally, it is a non-biodegradable waste product that pollutes and damages the environment. Waste removal from granite cutting and polishing in Sathya Mangalam, Tamil Nadu, India [7]. According to previous studies, marble powder by-product has been investigated as a replacement material in the manufacturing of concrete, but research on the use of granite powder a byproduct as an additive for concrete has not received as much attention [3, 4]. Additionally, the substitution rate for including GP waste in the manufacturing of concrete had not yet been suggested. The primary goals of this study are to improve the mechanical characteristics of the concrete and experimentally explore the appropriateness of GP a byproduct as a fine aggregate replacement material. The percentage of powdered granite substitution served as the experimental parameter. The GP substituted 0%, 5%, 10%, 15%, 20%, and 25% of natural sand in the concrete specimens. [8, 9] The viability of using leftover marble and granite as a greener alternative to cement. According to both the chemical evaluation and distribution of particle sizes in this investigation, both waste products were found to be inert materials that may be used as fillers. The slump tends to gradually reduce as cement replacement ratios with granite and marble waste increase. In concrete, granite powder can be used as a filler and cement substitute at 5%, 8%, 10%, and 15%. In this study, the impact of granite powder

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on mechanical properties, corrosion resistance, and hydration products was examined. Concrete corrosion cracking as well as mechanical properties improved for 5.0% replacement, but there were no appreciable changes in the microstructure, degree of hydration, or hydration products [10, 11].

Stone debris can be used to create the coloured, high-strength mortar. In accordance with this study, reddish pigments can be produced by calcining waste granite at 700–900 °C for a brief period of time. These pigments can be utilized to create coloured concrete since Fe_2O_3 crystallises during the subsequent heating treatment and has a suitable compressive strength (fcm). Numerous studies have demonstrated that adding different forms of stone waste to the manufacturing of concrete causes the new concrete to sag less than standard concrete, and that adding more trash further reduces the slump. The stone aggregates' particle size is cited as the cause of this decreased slump [12, 13]. Granite waste powder was effectively examined and shown compatible for creating ceramic tiles and bricks in Brazil, with the results recognised by Brazil standardisation for ceramic tiles and bricks. Granite sludge waste has been discovered to be an excellent filler for pozzolanic the motors, wherein a reddish pigment is formed by calcining under lower temperatures (700-900 °C) for a short period of time, and so granite sludge can be an efficient addition in the creation of coloured motor. The sludge produced by the granite cutting and polishing businesses has also been proven to be effective for up to 10% mixing in the production of roof tiles with improved characteristics [14, 15]. This comprehensive study seeks to provide a holistic understanding of the potential advantages and limitations associated with the inclusion of granite waste and alccofine in concrete. We emphasize sustainability, workability, long-term durability and micro analysis as focal points. The knowledge derived from this research is expected to furnish the construction industry with valuable insights, ultimately fostering the adoption of more sustainable and eco-friendly concrete production practices, while simultaneously reducing waste and conserving our finite natural resources.

2. MATERIALS AND METHODS

In this study project, cement, fine aggregate M-sand, coarse gravel, alccofine, granite waste, and Glenium Stream will be used to prepare concrete. For each material, the specific attributes were tabulated below.

2.1. Cement

Cement is a material that serves as a binder in concrete. Ordinary Portland cement (OPC 53) was utilized for this experiment. Tables 1 and 2 below list its physical and chemical characteristics.

Table 1: Physical composition of cement.

PHYSICAL COMPOSITION OF CEMENT	VALUE
Grade	OPC 53
Colour	Grey
Specific gravity	3.13
Surface area(cm^2/gm)	2245
Physical state	Solid
Size microns mean	<90
Volume Expansion	3 mm
Physical state	powder

Table 2: Chemical properties of cement.

CHEMICAL COMPOSITIONOF CEMENT	VALUE
SiO_2	20.15
Al_2O_3	4.55
Fe_2O_3	2.25
CaO	61.14
MgO	1.08
Loss on ignition	2.48

2.2. Alccofine

ALCCOFINE 1203 is a substance created using the controlled granulation method from high-glass, high-reactivity material. Low-calcium silicates make up the majority of the raw materials [14,15]. Tables 3 and 4 list the chemical and physical characteristics of the processed mixture after it has been combined with other carefully chosen materials.

2.3. Fine aggregate

M-Sand that was readily available locally was used for the inquiry, and parameters such density and particular gravity were measured in accordance with IS: 383- 1970. Utilizing sieves analysis, the M-Sand Grading result per IS: 383-1970 has been determined. The characteristics of M- Sand are given in Table 5 as follows.

2.4. Coarse aggregate

For effective use the coarse aggregate the 20 mm, locally accessible coarse aggregate has the certification of IS 383 codes. The choice of size is crucial for creating self-consolidating concrete since the size of the larger aggregate particles affects the flow behavior. The physical attribute is listed below in a Table 6. The natural

Table 3: Physical properties of alccofine.

PHYSICAL PROPERTIES	ALCCOFINE
Appearance	Powder form
Colour	White
Size	5µ
Bulk Density	689 kg/m^3
Specific Gravity	2.75
Surface Area	12100 cm^2/g

Table 4: Chemical composition of alccofine.

CHEMICAL COMPOSITION	ALCCOFINE (%)
SiO_2	34
CaO	32
Al_2O_3	22
Fe_2O_3	0.9
MgO	6.5
SO_3	0.06

Table 5: Physical properties of M sand.

PHYSICAL PROPERTIES	M-SAND
Appearance	Grainy
Specific Gravity	2.63
Bulk Density	15.6 g/cc
Water Absorption	6.14%
Moisture Content	1.56%
Zone	II
Colour	Grey
Fineness Modulus	4.67
Maximum Grain Size	1.18

Table 6: Physical properties of coarse aggregate.

PHYSICAL PROPERTIES	COARSE AGGREGATE
Specific Gravity	2.75
Bulk Density	2.5 g/cc
Water Absorption	1.3%
Surface Moisture	Nil
Aggregate Impact Value	13.7%
Finness Modulus	6
Size	20 mm
Shape	Angular

coarse aggregate employed for the experiment consists of crushed blue metal granite aggregate with a maximum particle size of 20 mm. In terms of volume, concrete is 70–75% coarse aggregate. Numerous experiments were carried out to determine the physical characteristics, including testing on the aggregate impact strength, crushing strength, water absorption, specific gravity, sieve analysis, size, and shape [16].

2.5. Glenium stream 2

All cements can be modified for viscosity using Glenium Stream 2, which is free of chloride. It cannot be used with admixtures that contain superplasticizers made from naphthalene sulphonate.In fact, Glenium Stream 2, a well-known liquid, organic, viscosity-modifying chemical that is ready to use, was created especially for the creation of concrete that has higher viscosity and controlled mechanical strength [17]. This combination demonstrated excellent stability as well as controlled bleeding characteristics, boosting segregation resistance and making placement easier. Table 7 shows the properties of Glenium Stream 2

2.6. Granite Waste

The granite cutting industry in the area at Sangeeth Granites in Sathya Mangalam, India, provided the waste material in a wet state. It was utilized in this investigation as a dry substitute for fine aggregate. Tables 8 and 9 reveal its physical and chemical characteristics of granite debris. The size of the GW particles was less than that of the naturally occurring fine aggregate while exceeding the upper border limit of the Zone IV fine aggregate category.

Table 7: Properties of glenium stream.

PHYSICAL PROPERTIES	GLENIUM STREAM
Colour	Colourless
Appearance	Liquid Form
Specific Gravity	1.01
PH	>6
Chloride Iron Content	<0.18%

Table 8: Physical properties of granite waste.

PHYSICAL PROPERTIES	GRANITE WASTE
Appearance	Grain
Colour	Black
Fineness Modulus	1.4
Bulk Density	1250 kg/m^3
Specific Gravity	2.71
Water Absorption	4.49

Table 9: Chemical composition of granite waste.

CHEMICAL COMPOSITION	GRANITE WASTE (%)
SiO_2	69.77
CaO	0.89
Al_2O_3	10.74
Fe_2O_3	1.80
MgO	0.54
Na_2O	3.12

Table 10: Mix design designation.

MIX NO	MIX REPRESENTATION
M1	CC – CONVENTIONAL CONCRETE
M2	10% AF + 100% OPC+ 0% GD +100% CA + 100% M Sand+ 1% SP
M3	10% AF + 100% OPC + 5% GD + 100% CA + 95% M Sand + 1% SP
M4	10% AF +100% OPC + 10% GD + 100% CA + 90% M Sand + 1% SP
M5	10% AF + 100% OPC +15% GD + 100% CA + 85% M Sand + 1% SP
M6	10% AF + 100% OPC + 20% GD + 100% CA + 80% M Sand + 1% SP
M7	10% AF + 100% OPC + 25% GD + 100% CA + 75% M Sand + 1% SP
M8	10% AF + 100% OPC + 30% GD + 100% CA + 70% M Sand + 1% SP
M9	10% AF + 100% OPC + 35% GD + 100% CA + 65% M Sand + 1% SP
M10	10% AF + 100% OPC + 40% GD + 100% CA + 60% M Sand + 1% SP
M11	10% AF + 100% OPC + 45% GD + 100% CA + 55% M Sand + 1% SP
M12	10% AF + 100% OPC + 50% GD + 100% CA + 50% M Sand + 1% SP

2.7. Water

Water is actually the second-most important component in the creation of concrete, behind cement. It is also the most affordable. Poor water management could lead to concrete. Three functions of water in concrete. Additionally, it reacts chemically with the cement to form calcium silicate hydrate, or C-S-H gel, lubricating the mixture to make it more manageable. This ingredient evenly distributes the cement. Use of potable water was used to cast concrete samples. The water, which exhibited a chloride concentration of about 160 mg/lit and was soluble in water, was devoid of oils, acids, and alkalis.

3. MIX DESIGN

To satisfy the M25 concrete grade requirements, mix design was conducted in compliance with the requirements and a directive established by Indian Standards (IS) rules IS 10262: 2009. The properties of cement 53 grade, fine gravel (M Sand, Granite Waste, alccofine), coarse aggregate, and super plasticizers were used to calculate the ratio of 1: 2.05: 4.015 with 0.50 water cement. Table 10 shows the details of mix design designation of various mix from M1 to M12. The features of the mix are comprised of cement 53 grade, fine aggregate, coarse gravel, M Sand, Granite Waste, which is alccofine, coarse aggregate, and super plasticizers [18, 19].

4. EXPERIMENTAL INVESTIGATION

In the Slump cone test, which complies with ASTM C 143, the flow ability of fresh concrete is examined using a mould made of 1.18 mm thick metal in the shape of the lateral surface of a frustum cone, with a base dia of two hundred millimeters, a top surface dia of hundred millimeters, and a height of three hundred millimeters. The mix design proportions are then tested in both their new and hardened stages. This experiment examined the compressive property of 36 cube samples measuring approximately 150 × 150 × 150 mm [20, 21]. This examination used an Axial Testing Machines with a capacity of 2000 KN to ensure conformity with IS: 516-1959. The load is dispersed in accordance with the specifications of the IS codal. Figures 1 represent

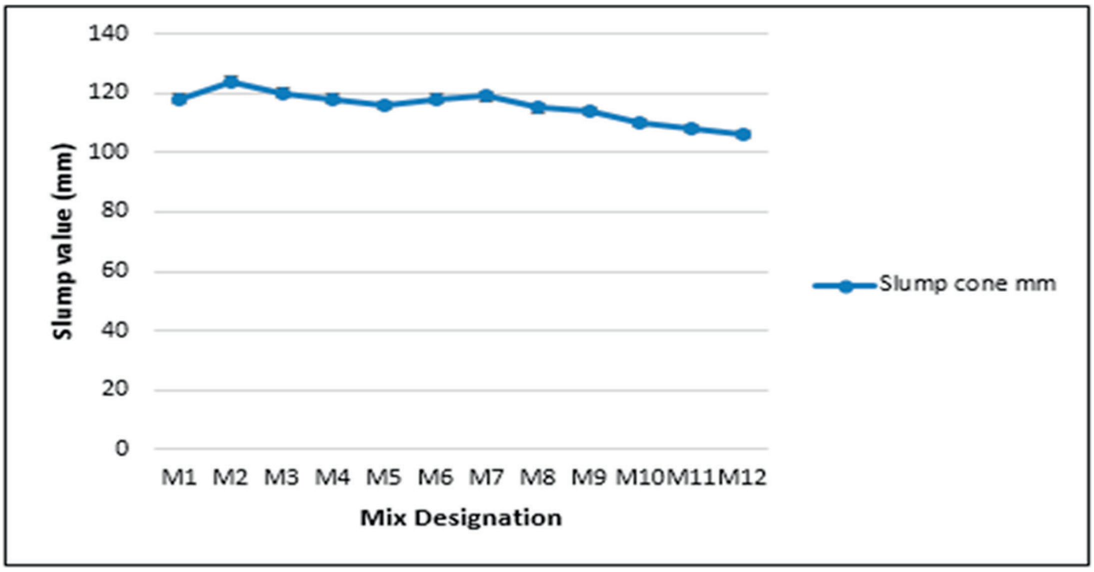

Figure 1: Slump value variations.

the compressive strength experimental results, and Table 1 summarises the results of the axial strength. To ensure adherence to IS 5816:1998 a split tension test was conducted. At 7, 14, and 28 days, the split tensile strength of concrete 36-cylinder samples with diameters and heights ranging from 150 mm to 300 mm was tested (CTM). In the compression testing equipment with a 20 tonnes capacity, the cylinders are tested by applying a load along their whole length. Notables included the maximum load, the concrete's look, and the kind of collapse [22, 23]. The samples are produced according to the directions, and a table showing the mean findings for the initial three examinations is provided. The axial strength is calculated using the formula 2P/(dl), where fck is the tensile strength in MPa, P is the load that breaks in N, d is the size of a cylinder specimen in mm, and l is the measurement of the sample in mm [24]. A set of 36 prismatic specimens, each measuring 100 × 100 × 500 mm, underwent flexural strength testing at different ages (3, 7, 14, and 28 days) following IS: 516-1959 guidelines. These tests were conducted using an Universal Testing Machine (UTM) under a central point loading configuration, capable of exerting loads up to 40 tonnes. During the testing, critical data was recorded, including the maximum load applied, the fracture position within the specimen, and the visual appearance of the concrete. The flexural strength, expressed as a modulus of rupture, was determined using the formula PL/bd^2. Here, L represents the height of the sample in millimeters, b its width in millimeters, and d the depth at the point of failure in millimeters. Meanwhile, P corresponds to the maximum load borne by the specimen in Newtons, where L = L/2. A scanning electron microscope (SEM), SEM analysis, or an X-ray diffraction test were used to investigate the microstructure [25, 26]. Through research, the ideal replacement proportion was established to be 10% AF+ 100% OPC+15% GD + 85% M Sand + 1% SP. The VEGA3 TESCAN SEM instrument of 20 kV was used to analysis for the microstructure features of the concrete samples. The silicate phase affects how strongly concrete gets stronger. Because nanoparticles fill the gaps in the C–S–H gel, concrete becomes denser. SEM examination can be used to investigate the production of CH in a C–S–H gel. The measurement of the intensity of X-ray diffraction lines serves as the foundation for quantitative phase analysis. X-ray diffraction techniques are commonly used to identify and characterise crystalline materials. The concrete specimens' powdered samples were taken, and the Rigaku Mini Flex II-C X-Ray Diffractometer was used to analyse the results.

5. RESULT AND DISCUSSION

5.1. Slump cone test

In the Slump cone test, which complies with ASTM C 143, the flow ability of fresh concrete is examined using a mould made of 1.18 mm metal in the shape of the lateral surface of a frustum cone, with a base dia of two hundred millimeters, a top surface dia of hundred millimeters, and a height of three millimeters. The M25 mix proportion of 10% AF+ 100%OPC+ 0% GD +100%CA + 100% M Sand + 1% SP, SP provides the highest slump value. Figure 1 shows the results of slump cone test. The increase in granite waste above 15% reduce the flow-ability of the fresh concrete.

5.2. Compressive strength test

The samples are prepared in accordance with the instructions, and the axial strength is calculated using the equation fck = P/A. Where P represents the rupture force in N, fck is the amount of force applied during axial in MPa, while A is the cube specimen's cross-sectional area in mm^2. The M25 mix proportion of 10% AF + 100% OPC + 15% GD + 85% M Sand + 1% SP provides the highest axial strength. Figure 2 shows the results of axial strength test. The maximum axial strength is archived at M5 mix of 33.57 MPa and the least at M12 mix 21.09 MPa. The increase in granite waste above 15% reduce the axial strength of the hardened concrete.

5.3. Split tensile strength test

The tensile strength split by crack patterns variation is shown in Figure 3 and the test results. The M4 mix (10% AF + 100% OPC + 10% GD + 90% M Sand + 1% SP mix proportion is shown to be less similar, whereas the M5 mix (10% AF + 100% OPC + 15% GD + 85% M Sand + 1% SP) is found to have the highest Split Tensile strength. The peak split tensile strength is archived at M5 mix of 4.02 MPa and the least at M12 mix 2.89 MPa. The increase in granite waste above 15% reduce the split tensile strength of the hardened concrete [27].

5.4. Flexural strength test

The flexural strength by crack patterns variation is shown in Figure 4 and the test results. The M4 mix (10% AF + 100% OPC + 10% GD + 90% M Sand + 1% SP mix proportion is shown to be less similar, whereas the M5 mix (10% AF + 100% OPC+ 15% GD + 85% M Sand + 1% SP) is found to have the highest flexural strength [28, 29].

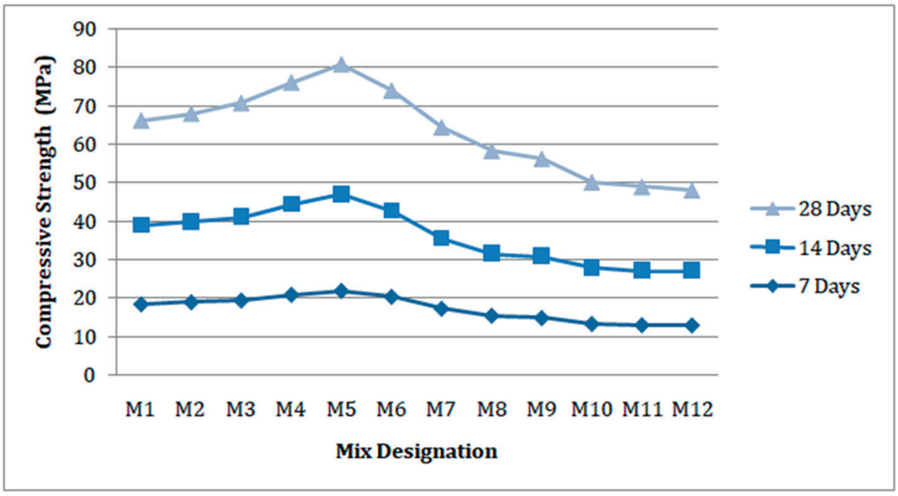

Figure 2: Compressive strength variations.

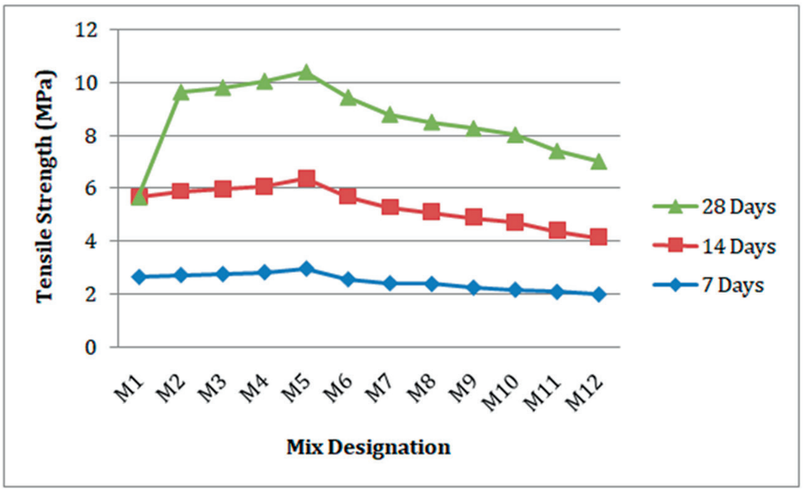

Figure 3: Split tensile strength variations.

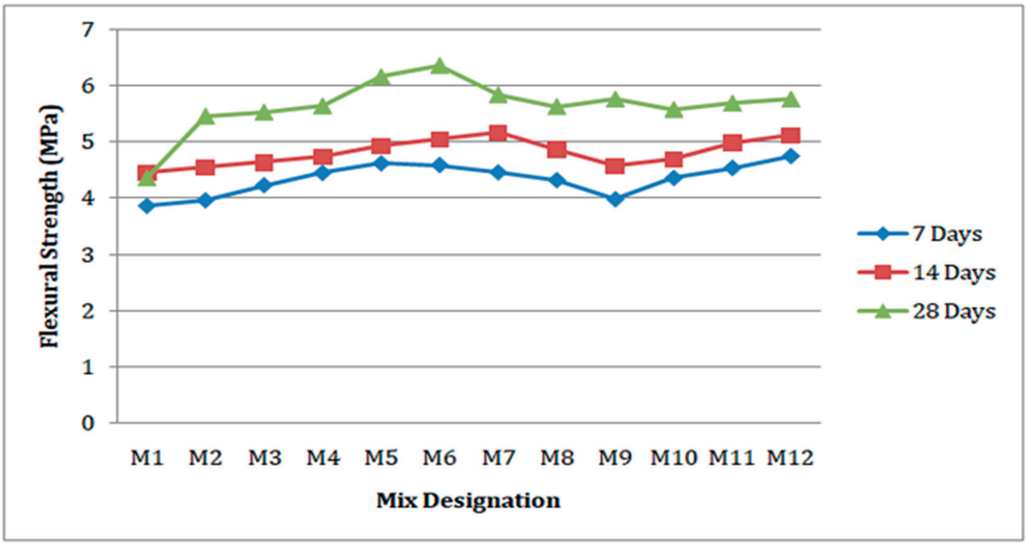

Figure 4: Flexural strength variations.

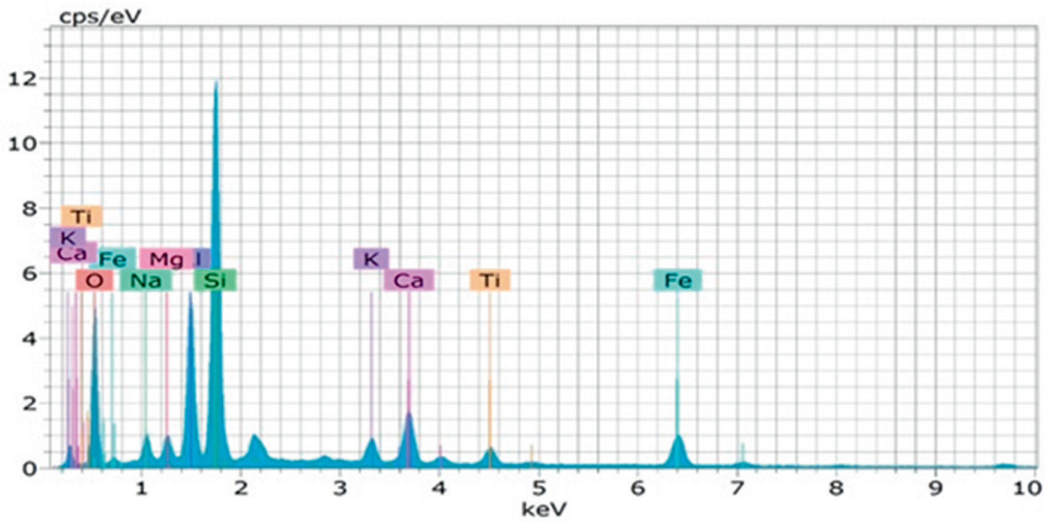

Figure 5: EDAX test results.

The peak flexural strength is archived at M5 mix of 6.16 MPa and the least at M12 mix 5.76 MPa. The increase in granite waste above 15% reduce the flexural strength of the hardened concrete.

5.5. XRD

The X-ray diffraction of powder (XRD) method aids in phase identification and mineralogy determination in concrete mixtures. The intensity of the peak and phase angles of numerous compounds are shown in Figure 6 M5 mix analysis. Figure 5 depicts compounds such as CH-Portandite, B-Alite, C-Quartz, D-CSH, E-Ettringite, F-Belite, H-Calcite, and G-Aluminum Oxide. The intensity of the peak and phase angles of numerous compounds are shown in Figure 6 M5 mix analysis. At different phase angles, CH and CSH are present. Because it is an amorphous substance, CSH has low-intensity peaks. Quartz and silica are the two main sources of SiO_2. Quartz is more prevalent and has a hexagonal crystalline structure; it is also reported to be more intense at the phase. In the M5 sample, traces of alite and belite show which replicates the absence of less unhydrated products. It is discovered that M5 has a higher SiO_2 concentration in the shape of quartz, demonstrating that leftover granite dust serves primarily as a filler ingredient. When compared to CH, the relative peaks and amorphous

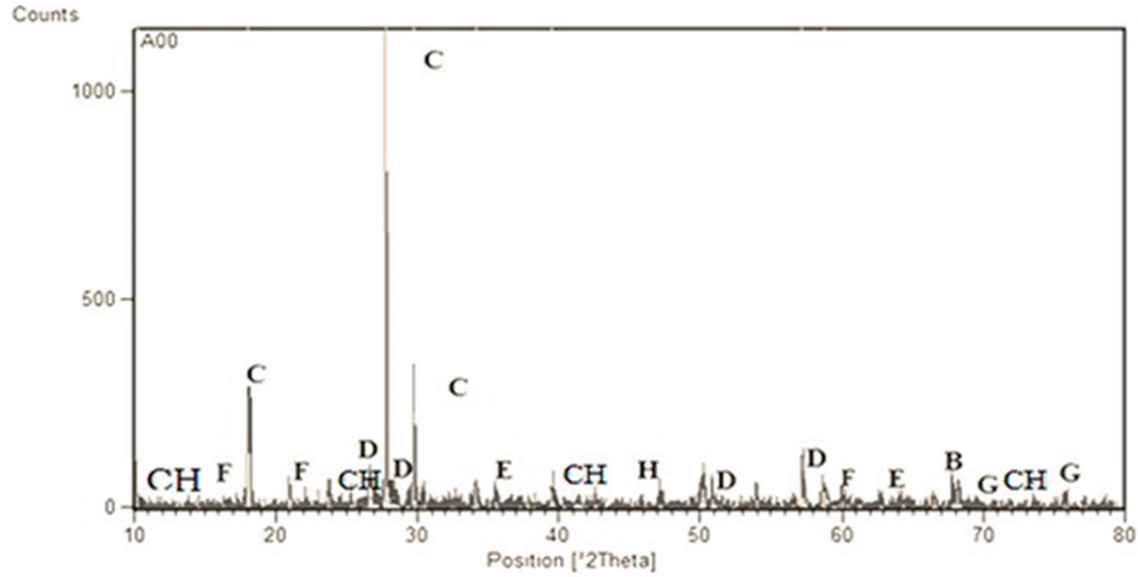

Figure 6: EDAX test results.

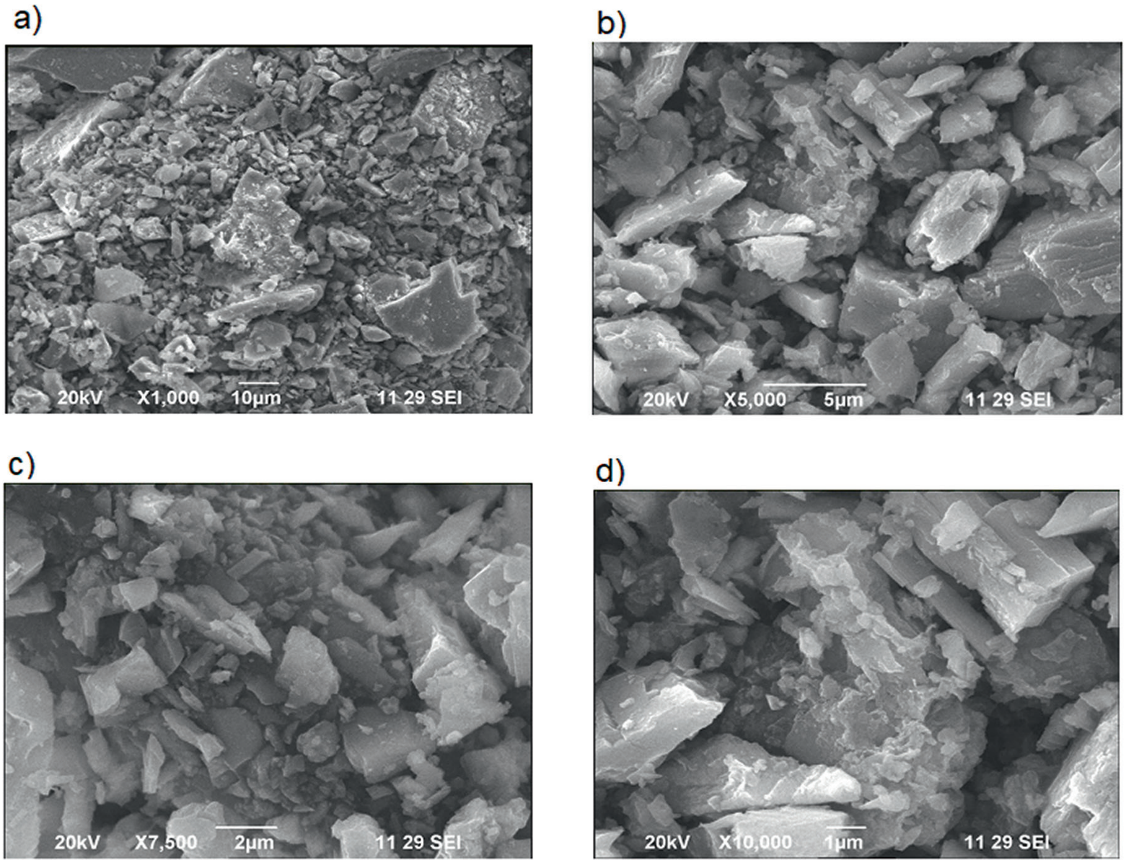

Figure 7: a) SEM analysis 20KV × 1000, 10 µm. b) SEM analysis 20KV × 5000, 5 µm. c) SEM analysis 20KV × 5000, 2 µm. d) SEM analysis 20KV × 5000, 1 µm

CSH are higher, which shows the presence of a comparatively higher CSH gel in the M5 sample and improves its strength properties. Furthermore, there is less M5 that is unhydrated. This is so that more hydrated products with poor pozzolanic activity are produced when waste granite dust combines with unhydrated lime. The EDAX data indicating a decrease in the amounts for unhydrated compounds like Alite or Belite, a significant amount of

CSH, and the mere presence of CH or Ettringite can validate the improvement in the strength properties of the M5 sample. The SEM picture is utilised to assess the M5 sample's microstructural characteristics. The outcome shows that the M5 sample has a denser matrix and that significant levels of CSH gel, CH, and ettringite are present. This suggests that the M5 specimen has a higher rate in hydration and a higher concentration of hydrated products than regular Concrete. Additionally, the M5 sample is denser because its pores are smaller than average.

Ettringite's needle-like structure and hexagon-shaped CH fill the spaces between particles and make the material more durable. Therefore, the aforementioned factors could be the cause of the waste granite dust's stronger properties when included as opposed to when it was conventional. Due to the waste granite dust's higher water absorption capacity, pores are more prevalent in waste granite-incorporated concrete. As can be seen in Figure 7 (a, b, c, d), the EDAX test outcome is derived from various places of the SEM image. Silica, oxygen, and calcium are the three main elements of standard concrete, measured in counts per second/eV. The binding strength between the mortar and the concrete's aggregate is stronger than it is in conventional concrete, according to this inference, which is compatible with a SEM result that follows this assumption. According to the microstructure, the surface was rough, thus the strength and bonding properties will be stronger compared to those of other combinations. Visual inspection reveals very few voids in the concrete specimen, which suggests great bonding quality. This bonding demonstrates the strong interfacial adhesion between the cement phase and the aggregate. The fragmented asymmetric crystal particles were easily seen. The growth of flaky crystals, which are produced by hydration, has demonstrated the presence of C-S-H. The C-S-H structure within the two-component matrix of cement and the aggregate occasionally resembled a light substantial gel. The microscopic images show a densely packed cement matrix and the aggregate transition area, which points to strong bonding. Microcracks are noticeable in M5 mix as a result of the incorporation of granite waste and alocofine.

6. CONCLUSION

The granite waste materials which have been identified and utilised as fine aggregate demonstrate that replacement methods that incorporate fine aggregate, sand addition of coarse aggregate, and super plasticizer, provide good strength. Additionally, because of alcofine's incredibly small size, this fills pores and offers strong bonding.

- The 28-day compressive strengths for concrete made with the M5 mix fraction were higher than those of all other concrete-making mixes. 10% alccofine, 100% OPC, 15% granite waste, 85% M sand, and 1% super plasticizer make up this mixture.
- The 28-day split tensile strengths were higher for concrete with the M5 mix proportion, which is 10% alccofine, 100% OPC, 15% granite waste, 85% M sand, and 1% super plasticizer. The mixture of M3, M4, and M6 contains the value that is second highest.
- The 28-day flexural strengths of concrete using the M5 mix proportion, which is composed of 10% alccofine, 100% OPC, 15% granite waste, 85% M sand, and 1% super plasticizer, were higher. The second-highest figure is accounted for by the M4 mix proportions.
- After examining the mechanical properties of concrete, it was found that the M5 mix proportion—10% alccofine, 100% OPC, 15% granite waste, 85% M sand, 1% Super plasticizers—was the most effective replacement percentage.
- Because it lowers the carbon emissions the cement creates, usingalccofine in concrete produces sustainable concrete.
- Visual inspection shows that the concrete sample has barely any voids, indicating an outstanding bonding quality. Since the surface was rough, the strength and bonding qualities will be stronger than those of other combinations, according to the microstructure.
- The M5 mix 10% AF+ 100%OPC+15% GD + 100%CA + 85% M Sand + 1% SP is the superior mix compared to all other mixes in the mechanical, durability point of view.
- The durability properties and the non-destructive test test is planned for future study.

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