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EXPERIMENTAL RESEARCH ON THE BEHAVIOR OF CONCRETE WITH THE INCORPORATION OF GRANITE AGGREGATE IN PARTIAL SUBSTITUTION TO FINE AGGREGATE

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ABSTRACT

The river banks are the main sources of natural sand. Owing to over-exploitation and contamination from additives and contaminants from nearby industries, these natural resources are being exhausted very rapidly. In order to conserve the natural resources, manufactured sand is used widely in concrete. Manufactured sand (M-Sand) is the manufacturing by-product of quarries that are suited to fine aggregate properties. An innovative concrete called the Self Compacting Concrete (SCC) is widely used in congested reinforcement and in formworks that cannot be externally compacted. As the name suggests SCC compacts itself by its own self weight. In order to maintain a green environment, utilization of hazardous waste is necessary. Many industries are producing a huge amount of hazardous wastes. This paper mainly deals with the utilization of a hazardous waste i.e.granite powder, which is obtained in the granite industry by cutting and polishing granite. As a partial replacement for manufactured sand, granite powder is used. 0 percent, 10 percent, 20 percent, 30 percent, 40 percent and 50 percent of manufactured sand substituted by the granite powder were prepared for concrete mixtures. Various parameters like the strength properties and durability were evaluated. The findings obtained suggested that up to 10 percent substitution of fine aggregate with granite powder demonstrated strong strength and durability parameters.

Keywords*: Manufactured sand (M-Sand), Granite powder, Durability, Strength parameters.*

1. INTRODUCTION

Concrete is a highly demanded and consumed material in construction due to its versatility and low cost [12]. In the past decades various experimental studies have been carried out to find new ways to improve the quality in regards to durability and strength [17]. In Japan, an advanced concrete was created in 1988 that fills any nook and corner of a building through its own weight with no external compaction, called Self Compacting Concrete. [16, 17]. Okamura, the developer of SCC proposed various recommendations to achieve compatibility in concrete like the content of aggregate should be low, water-powder ratio is reduced, and super plasticizer is used [20]. Sand mining is a major threat to the biodiversity. Due to this heavy usage of sand in construction, the river beds natural properties are getting depleted [19]. In order to maintain a proper ecosystem, manufactured sand is used in accordance with natural sand as permitted in IS 383:1970 [18]. The manufactured sand is angular and cubical shaped. This leads in better interlocking of particles and improved strength [19]. Industrial waste is increasing day by day causing great problem in disposal. Many researches are being carried out to dispose them in a sustainable manner [21]. Many researches has been carried out in different waste materials such as glass fiber [1], brick dust [22], saw dust [23], spend garnet [24], etc in concrete. Granite is an igneous tock and has better durability, good resistance to heat and cold [21]. They are used in construction industry in various forms. The waste ie. the slurry obtained causes great environmental impacts [27]. When granite dust was added as an addition to cement, An rise in power parameters was shown. [25]. The addition of granite dust in normal concrete has showed improved mechanical properties [26]. Millions of tons of waste are being generated from the granite industry causing various landfill problems to the environment [26]. If it can be used as a partial substitute in the building industry, the volume of its landform occupancy is limited.

In this study granite powder, a byproduct produced while cutting and polishing of granite in the granite industry is used as a partial substitution for fine aggregate.

2. MATERIAL PROPERTIES

2.1 Cement:

The choice of cement is OPC-43 grade which mainly depends upon the specific requirements of the concrete. The cement utilized in the proportioning of SCC is tested as per IS: 4031 - 1988 and IS 4032 – 1988 and the results obtained are shown in the table below.

Table 1 Cement Properties

PROPERTY	OBTAINED VALUE	CODE RECOMMENDATIONS
Specific Gravity	3.15	3.10-3.15
Consistency	29 %	25-35
Initial setting time	45 minutes	Not less than 30 minutes
Final setting time	6 hours and 30 minutes	Not greater than10hours
Fineness	3 %	Not greater than10%
Soundness	1	Maximum 10

2.2 Coarse Aggregate

The strongest and least porous part of concrete is the coarse aggregate. When choosing the aggregate for SCC, some important coarse aggregate characteristics such as crushing strength, toughness modulus of elasticity, gradation, shape and surface texture characteristics and flakiness and elongation indices are taken into account. Proper grading improves particle which reduces the voids. Lowering the voids would require lower paste and lesser water to produce good workability. In compliance with IS: 2386 - 1963, the coarse aggregates are tested and the results are given in Table 2 and 3.

Table 2 Coarse Aggregate Properties

SL.NO.	PROPERTIES	RESULTS	IS RECOMMENDED LIMIT
1	Specific gravity	2.68	2.5-2.8
2	Bulk density (kg/m^3)	1590	1650
3	Aggregate impact value	12.52%	30
4	Aggregate crushing value	26.68%	30
5	Fineness modulus	6.69	6 – 7 for 20mm Aggregate 4 – 4.2 for mixed aggregate
6	Water absorption (%)	0.20	<0.5%
7	Flakiness index	24.20	25%

Table 3 Coarse Aggregate Sieve Analysis

IS Sieve size	% of Passing	IS Recommended limit
12.50 mm	100	85-100
10.00 mm	35	0-45
4.75 mm	. 0	0-10

2.3 Fine Aggregate

2.3.1 Manufactured Sand

Manufactured sand, such as Crushed sand, Rock sand, Green sand, UltraMod Sand, Robo sand, Poabs sand, Barmac sand, Pozzolan sand, etc. are widely known by many names. M Sand is formed by a Vertical Shaft Impactor (VSI) rock-on-rock or rock-on-metal in which the mechanism of creating alluvial deposits is closely simulated. M-sand is used as a fine aggregate, comparable to that of Zone II. Table 4 includes the physical M-Sand validation for IS 2386 (Part III) 1963.

2.3.2 Granite Powder

Granite powder is a residue that is collected from the granite industry when granite is being cut and polished. There are many granite industries in India; they produce tons of waste every year in the form of slurry. This slurry consists of lime, residues and granite powder [27]. The disposing of slurry in land destroys the soil fertility also causes pollution to the groundwater. The particle size distribution of granite powder is shown in the table 4.

Table 4 Fine Aggregates Sieve Analysis

IS SIEVE DESIGNATION	IS 383:1970 SPECIFICATION FOR ZONE II	% OF PASSING IS RECOMMENDED LIMIT FOR MANUFACTURED SAND	% OF PASSING IS RECOMMENDED LIMIT FOR GRANITE POWDER
4.75 mm	90 – 100	99	100
2.36 mm	75 – 100	91	100
1.18 mm	55 – 90	72	9
600 µm	35 – 59	46	56
300 µm	8 – 30	21	44
150 µm	0 – 10	5	20

2.4 Super plasticizer

For the selected portion of the ingredient, it is used to optimize the workability of fresh concrete. It is a chemical based on sulphonated naphthalene polymers. This super plasticizer confirms to the requirement of IS: 9103–1999, BS: 5073 Part 3 and ASTMC–494. Table 5 displays the physical properties of the super plasticizer supplied by the manufacturer.

Table 5 Super plasticizer - Properties

PROPERTIES	RESULTS
Type	Sulphonated naphthalene formaldehyde condensate
Specific gravity	1.220 to 1.225 at 30o C
Chloride content	Nil as per IS: 456 and BS: 5075
Recommended dosage	0.60 – 1.50 Litres per 100 kg of cement
Approximate additional air Entrainment	1% at normal dosages
Solids content	40%

Compatibility	All types of cement except high alumina cement
Workability	Produce a highly usable flowing concrete mix without segregation and does not require compaction
Cohesion	Minimized segregation and improved surface finish
Compressive strength	Early strength up to 40 to 50 %
Durability	Increase in density and impermeability

2.6 Water

For the fine aggregate and coarse aggregate the major lubricant used is water. For cement, it acts to form a paste with the aggregate. Water is also used for concrete application. Therefore the water used should be free from impurities [27]. The presence of impurities will have a negative effect on the concrete. The tap water accessible in the research lab with a pH value of 7 that satisfies the criteria of IS 456:2000 is the water used in this current research. This impurity-free water was used in the grinding and curing of concrete specimens.

3. MIX DESIGN

Various trial mixes were adopted by following the EFNARC guidelines trial mix proportions to get the appropriate water content, water/cement ratio and dosage of SP etc. These alterations were made to get the required properties of SCC like workability, flow ability, passing ability and filling ability. SP dosage was varied. Mix proportion which passed the fresh state tests were considered for the preparation of specimen which were then subjected to hardened state tests. The optimal combination ratio was obtained on the basis of the hardened state test data. With one mix without any substitution called the control mix. Six sample mixes were prepared and named after the control mix. The remaining mix was prepared on replacing the fine aggregate with granite powder by 10%, 20%, 30%, 40%, 50%. The binder content was maintained as 546.79 for all the mixes.

Table 6 Mix design

Mix	Cement	Fine Aggregate	Granite Powder	Coarse Aggregate	Water	Sp %
G0	546.79	845.26	0	796.54	202.31	1.35
G10	546.79	760.73	84.53	796.54	202.31	1.35
G20	546.79	676.21	169.05	796.54	202.31	1.35
G30	546.79	591.68	253.58	796.54	202.31	1.35
G40	546.79	507.16	338.1	796.54	202.31	1.35
G50	546.79	422.63	422.63	796.54	202.31	1.35

4. RESULTS AND DISCUSSIONS

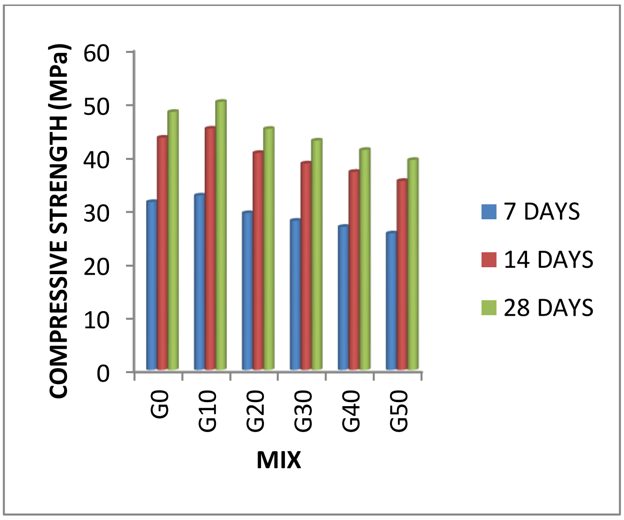
4.1 Compressive Strength

The determination of compressive strength is one of the essential material properties of hardened concrete. In concrete the load carrying capacity is based on some factors such as size of aggregates, surface texture, super plasticizer, water-powder ratio and so on. The addition of granite powder in SCC does not affect the strength up to 10%. The strength was reduced for other mix proportions compared to the control mix. Felixkala and Partheeban [30] stated that the substitution of river sand with granite powder had a higher compressive strength compared to standard concrete. Divakar[29] has shown that when granite powder is replaced by fine aggregate, there is an improvement in compressive strength. As per IS: 516-1959, the compressive strength of SCC is checked. The 150mm x 150mm x 150mm cubes have been tested for M40 grade concrete. The cubes were tested on a compression testing machine for 7 days, 14 days, and 28 days.

Table 7 Compressive Strength

Mix	7 days	14 days	28 days
G0	31.33	43.38	48.2
G10	32.55	45.08	50.09
G20	29.26	40.52	45.03

G30	27.84	38.55	42.84
G40	26.70	36.98	41.09
G50	25.48	35.28	39.21

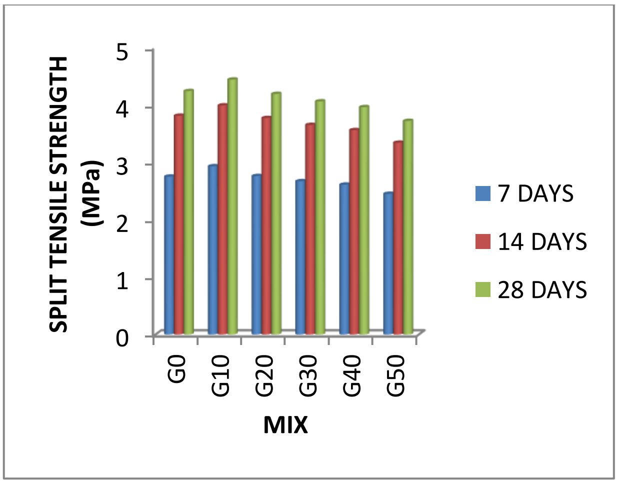


4.2 Split Tensile Strength

In accordance with IS 5816-1970, a cylindrical sample of 300 mm in length and 150 mm in diameter was used to determine the tensile strength of the SCC. The tensile strength for replacement of 10 percent by granite powder was increased. The decrease was mainly due to the voids present in the mixes when the percentage of granite powder increases. According to Vijayalakshmi et.al [26], the tensile strength of the specimen improves by up to 10 percent relative to the control mix.

Table 8 Split Tensile Strength

Mix	7 days	14 days	28 days
G0	2.75	3.81	4.24
G10	2.93	3.99	4.44
G20	2.76	3.77	4.19
G30	2.67	3.65	4.06
G40	2.61	3.56	3.96
G50	2.45	3.34	3.72

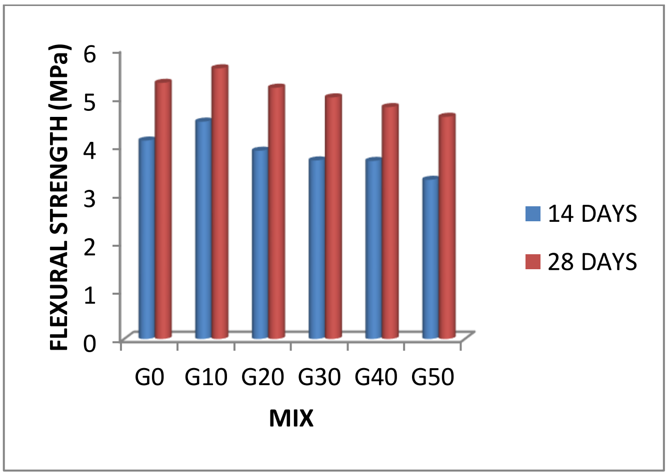


4.3 Flexural Strength

To determine the flexural strength of SCC a prism specimen of size 100mmx100mmx500mm was used. In the 10 percent rise, the substitution of fine aggregate by granite powder was checked for M40 grade concrete. When 10% of the fine aggregate has been covered by granite powder, the flexural strength increases relative to the control mix. Vijayalakshmi et.al [26] stated that there was little increase and beyond 15%the flexural strength decreases.

Table 9 Flexural strength

MIX	14 DAYS	28 DAYS
G0	4.11	5.3
G10	4.5	5.6
G20	3.9	5.2
G30	3.7	5.0
G40	3.69	4.8
G50	3.3	4.5



5. DURABILITY

Durability checks are carried out to assess the ability of the concrete to withstand chemical attack, weathering or some other process of degradation.

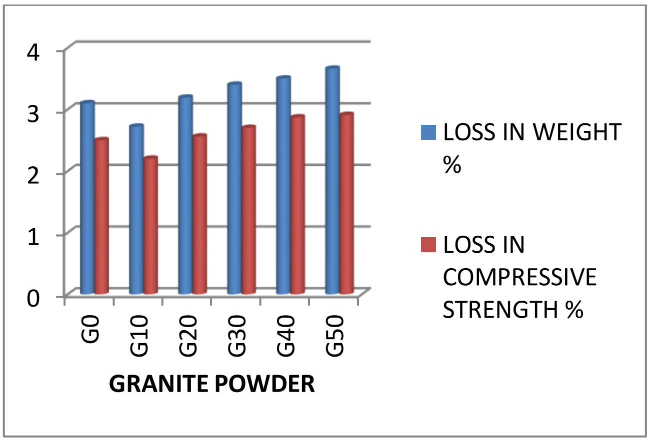
5.1 Acid Resistance Test

The 150mmx150mmx15mm cubes were cast and cured for 28 days. The initial weight was measured. Then the cubes were first soaked for 28 days in diluted hydrochloric acid (HCl). After 28 days the second weight was noted. The specimen was cleaned and the weight was noted. The findings of the test are included in the table. Compared to the control mix, the compressive strength and percentage loss of weight for the G10 mix is decreased. It is found that for the remaining mixes, the compression strength and weight loss are improved. Hence it is concluded that 10% replacement of granite powder was more durable against acid attack.

Table 10 Acid Resistance Test

Mix	Loss in weight %	Loss in compressive strength %
G0	3.10	2.5
G10	2.72	2.2
G20	3.19	2.56

G30	3.4	2.7
G40	3.5	2.87
G50	3.66	2.91

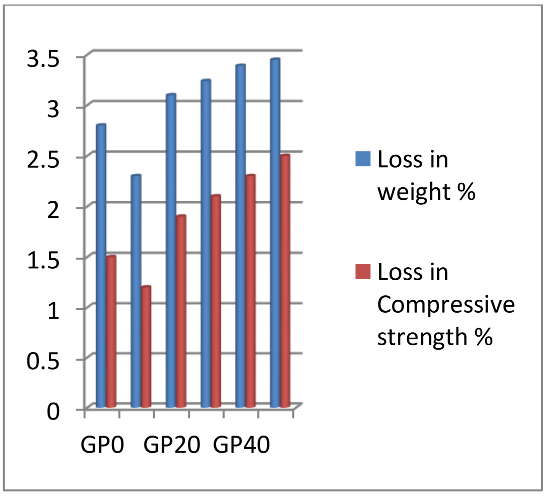


5.2 Chloride Attack Test

For 28 days, a cube specimen measuring 150mm x 150mm x 150mm was cast and cured. Then it was weighed and immersed in 3% NaCl diluted in water for 45 days. After 45 days, the sample was washed out and calculated for compressive strength and weight loss.

Table 11 Chloride Attack Test

Mix ratio	Loss in weight %	Loss in Compressive strength %
G0	2.8	1.5
G10	2.3	1.2
G20	3.1	1.9
G30	3.24	2.1
G40	3.39	2.3
G50	3.45	2.5



6. CONCLUSION

The present investigation was to examine the efficacy of granite powder in self-compacting concrete as a partial substitute for M-sand. To verify the strength and durability criteria, various laboratory tests were carried out.

The following conclusions were drawn on the basis of the experimental study undertaken.

- When M-Sand was replaced with granite powder the slump value decreased compared to the control mix. To preserve the slump value, the dosage of super plasticizer was raised and the slump value was kept as a constant of 80 mm.
- When granite powder was replaced by 10% the compressive strength, split tensile strength and flexural strength parameters of concrete was more than the control mix at all the ages.
- The strength decreased slightly due to the presence of fine particles compared to the control mix for the other mixes.
- The percentage loss of weight and compressive strength was reduced in the Acid resistance test when 10 percent granite powder was replaced compared to the control mix. In order to help improve the substitution of granite powder, there was a slight increase in compressive strength and weight loss.
- In the chloride attack measure, the percentage loss of weight and compressive strength was decreased relative to the control mixture when 10 percent granite powder was substituted. There was a small rise in compressive strength and weight loss owing to the further increase in granite powder substitution.

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