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Strength and durability properties of concrete made with granite industry waste

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ABSTRACT

Granite polishing and cutting industries in Tamilnadu, and its surrounding areas are dumping their powder waste on vacant lands causing pollution and affecting the health of the people. Although the reutilization of granite wastes has been practiced, the amount of wastes reused in that way is still negligible. Therefore, the need for its application in other industries is becoming absolutely vital. The main objective of this study is to experimentally investigate the suitability of granite powder (GP) waste as a substitute material for fine/natural aggregate in concrete production. The physical and chemical characterization of the granite powder was tested at National Testing House at Chennai, Tamilnadu. The GP waste showed a very high specific surface value of about 340kg/m2 and the results of chemical analysis showed that the GP by-product contains about 72.14% of soluble silica. Several tests such as slum0p cone, split tensile strength, flexural strength; and compressive strength tests were performed on cubes and cylinders were prepared by 0%, 5%, 10%, 15%, 20%and 25% of fine/natural aggregate substituted by GP waste. Experimental results revealed that, rough texture and high specific area of the GP waste significantly decreased the workability of the concrete and the substitution of GP waste up to 15% does not affect the mechanical and fresh concrete properties.

Index Terms: Granite powder, Waste, Concrete, Compressive strength, Workability.

INTRODUCTION

Among the 32 states in India, Tamilnadu state has the 45% of total granite reserve. Using different type of cutting methods, granite stones are machined from the quarries and that blocks are transported to the nearby processing plants. Then the stones are industrially processed such as sawing and polishing, finally processed stones are used for decorative purposes. During this industrial process, the fine granite particle and the water mixed together and become a granite colloidal waste. When stone slurry is disposed in landfills, its water content is drastically reduced and the waste becomes a dry mud consisting of very fine powder that can be easily inhaled by human being and animals. In addition to that, it is a non-biodegradable waste that causes pollution and environmental damage. Fig. 1 shows the dumping of granite waste on vacant land by granite polishing and cutting industries in Hosur, Shoolagiri. The data available from the literature, the amount of wastes in the different production stages of the granite industry reaches some 20 to 25% of its global production, meaning millions of tons of colloidal waste per year and disposal of those fine wastes is one of the environmental problems worldwide today.

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Fig1: Granite waste dumped near SIPCOT Industrial estate, Hosoor

With increasing restrictions on landfills in nearby area, the cost of deposition also will increase and the industries will have to find ways for reusing their wastes. Although the reutilization of granite wastes has been practiced, the amount of wastes reused in that way is still negligible. Therefore, the need for its application in other industries is becoming absolutely vital. Past few decades, the construction industry especially the concrete industry has utilized almost all stone industrial waste to solve the environmental problem. One of the first known study in this topic involved that utilization of granite dust for making aerated concrete and ceramic production conducted by Beretka et al., (1991). Test results of Moreira et al. (2005) illustrated that the ceramic bodies containing granite powder waste are adequate for manufacture of structural ceramic and the employed methodology is environmentally correct. Saboya et al. (2007) investigate the utilization of powder marble by-product to enhance the brick ceramic properties. The samples were prepared by mixing clayey soil with different waste contents of marble powder of 0%, 5%, 10%, 15% and 20% in weight. Test results shown that the use of 15% of waste content fired at 8500C considered as a best proportion and might be used in industrial scale for commercial use of the ceramic body.

Ilker Bekir Topcu et al. (2009) experimentally investigated the utilization of the waste marble dust as a filler material in self-compacting concrete (SCC) and the marble dust (MD) directly used without attempting any additional process. MD used as a binder material instead of cement with the substitution rate of 0, 50, 100, 150, 200, 250 and 300 kg/m^3. Test results showed workability of fresh SCC has not been affected up to 200 kg/m3 However mechanical properties of the concrete were decreased with the increases in the MD substitution rate. Binici et al. (2008) studied the suitability of the marble and granite rock waste as a coarse aggregate in concrete production through durability and fresh concrete properties. Test results showed that the durability of the specimen containing marble and granite found to be superior to the control mixture. The increased durability can be attributed to the improved bonding among the additives, cement and aggregate, which contributed in a more condensed matrix. Finally it was suggested that the marble and granite waste aggregates can be used to improve the mechanical properties, workability and chemical resistance of the conventional concrete mixtures. Valeria Corinaldesi et al. (2010) characterized the waste marble powder from a chemical and physical point of view in order to use it as mineral addition for mortars and concretes, especially for self-compacting concrete and also proved that these materials can be potentially used as a substitution for fine aggregates in concrete production. The test results of Thomas and Partheeban (2010) showed that the partial replacement of sand by granite powder has beneficial effect on the mechanical properties of concrete and considerable advantages in plastic and drying shrinkage.

Hebhoub et al. (2011) showed that the mechanical properties of concrete specimens produced using the marble wastes were found to be conforming to the concrete production standards and the substitution of natural aggregates by waste marble aggregates up to 75% of any formulation is beneficial for the concrete resistance. Mucteba uysal et al. (2012) investigated the effect of mineral admixtures on propertied of self-compacting concrete; mixtures were modified to 10%, 20% and 30% limestone, basalt and marble powder instead of Portland cement and their fresh and hardened properties were compared.

From the past research, it was observed that research carried out so far boundless in marble powder by- product as a substitute material in concrete besides investigations on granite powder (GP) by-product as a filler material in concrete is not widespread. Research results were suggested that marble powder waste up to 15% of any formulation is favorable for concrete production and it can be can be used as alternative aggregates for normal concrete and for many other purposes such as bricks manufacturing and road construction. The main objective of this study is to experimentally investigate the suitability of GP waste as a substitute material for fine/natural aggregate in concrete production. And aimed to study the Physical and chemical properties of the granite powder by- product as well. The experimental parameter was percentage of granite powder substitution. The concrete cubes and cylinder specimens were prepared with 0%, 5%, 10%, 15%, 20%and 25% of natural sand is substituted by GP by-product. Several tests such as density, slump cone test were performed to evaluate the fresh concrete properties and tests such as split tensile strength test (28 days), flexural strength test and compressive strength (7 days, 28 days and 90 days) were performed to assess the hardened concrete properties.

MATERIALS

Portland Cement

The commercial Portland cement supplied by India cements was used in this study. The specific gravity of the cement was tested according to IS 455:1980 and the obtained value was about 3.14.

Aggregates

Natural sand passing through 4.75mm sieve and having a specific gravity of 2.48 was used in this study. The maximum size and the specific gravity of the coarse aggregate were 20mm and 2.67 respectively. According to IS 2386(1), grain size distribution analysis was carried out on both fine and coarse aggregate and the results are listed in Table 1.

Granite Powder

The granite powder (GP), which is a by-product obtained from granite processing industry was used in this study. To verify the physical and chemical characterization of the granite powder, the following tests were carried out at National Testing House.

Specific Gravity

The granite powder was put in an oven to dry at a temperature of 110^{0}C (saboya) and the specific gravity of the granite powder was determined by according to IS 2386(3). The obtained specific gravity value of the granite powder was about 2.386, which is little bit less than the specific gravity value of the sand.

Specific surface area and water absorption

Fineness of the material is the very important characteristic in concrete making. According to IS 4031(2), the test was carried out in order to bear out the fineness of the GP by-product. The specific surface area value of the GP by-product was about $351m^2/kg$ which is equivalent to the finess of the cement. From this it was observed that, the GP by-product has a very high specific surface and its addition to concrete which leads more cohesiveness to concrete. The water absorption of the GP by-product is determined according to IS 1124 and the value is about 0.37%.

Table1: Grading of GP by-product, fine and coarse aggregate

Granite Powder (GP)		Fine Aggregate		Coarse Aggregate	
Sieve Size	% of Passing	Sieve Size	% of Passing	Sieve Size	% of Passing
4.75mm	100	4.75mm	100	19mm	100
2.36mm	100	2.36mm	90	12.7mm	78
1.18mm	100	1.18mm	50	9.5mm	31
600 micron	93.6	600 micron	25	4.75mm	0
300 micron	72.3	300 micron	7		
150 micron	55.2	150 micron	2		
75 micron	41.3	Pan	0		
45 micron	31.2				
Specific Gravity 2.386		Specific Gravity 2.650		Specific Gravity 2.610	

Gradation

To verify the physical characterization of the GP by- product, its grain size distribution analysis was carried out according to the IS 2386(1) and the results are listed in Table 1. From that it was observed that, 55% of granite powder is less than 150micron and the 31% of particles are less than 45micron.

Chemical Analysis

In order to characterize the granite powder from a chemical point of view, chemical analysis was carried out according to IS 4032 and the results are given in Table 2. it can be seen from Table 2, the GP by-product contains about 72.14% of soluble silica (Sio_2) and 17.13% of alumina (Al_2O_3), indicating it is very suitable for concrete production. The X-ray diffraction analysis, Fig. 2 shows that the presence of Quartz about 3% and Microcline about 1%. The remaining GP by-product consists of amorphous silica, whose low crystallinity making them mostly undetectable by X-ray diffraction (Valeria Corinaldesi et al., 2010).

Table2: chemical Composition of Gp By-Product

Component	
Chemical composition (%)	% by mass
Lime (as Cao)	1.28
Soluble silica (as Sio_2)	72.14
Alumina (as Al_2O_3)	17.73
Iron Oxide (as Fe_2O_3)	1.58
Magnesia (as MgO)	0.41
Sulphur calculated as Sulphuric anhydride (as SO_3)	0.31
Loss on ignition	1.15
Total chloride conctent (as Cl)	0.24

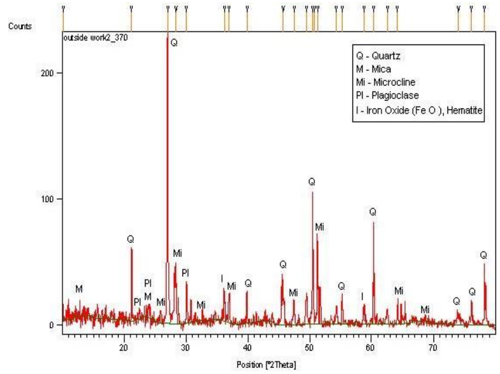

Fig 2: X-Ray diffraction of the GP by-product

Chemical Analysis

The concrete mix proportion was designed by IS method to achieve the strength of 30N/mm2 and the designed mix proportion was 1:1.39:2.77 by weight.

Table3: Concrete Mixture Proportion

Mixture	CGP 5%	CGP 10%	CGP 15%	CGP 20%	CGP 25%
W/C ratio	0.4	0.4	0.4	0.4	0.4
Water (kg/m^3)	186	186	186	186	186
Cement (kg/m^3)	465	465	465	465	465
Sand (kg/m^3)	572	542	512	482	451
Coarse Aggregate (kg/m^3)	1086	1086	1086	1086	1086
Granite Powder (GP) (kg/m^3)	31.94	63.88	95.83	127.77	159.71

The designed water cement ratio was 0.40 and the formulations of various mixtures were listed in Table 3.

EXPERIMENTAL STUDY

Preparation and Casting of Specimens

The concrete mixtures were prepared by Portland cement, natural sand, coarse aggregate (Blue metal) and GP by-product. Among the six series of mixtures, one was the control mixture and the remaining five mixtures were containing GP by-product substitution in various proportions such as 5%, 10%, 15%, 20% and 25%. For all the mixtures, aggregates were weighed in dry condition and the mixtures were mixed together for 4 to 5min in a laboratory counter current mixer. Workability of the fresh concrete was verified by slump test apparatus. Compressive and splitting tensile strength of the concrete measured using 150mmx150mmx150mm cubes and 150mmx300mm cylinders.

In addition prisms/beams were prepared to determine the flexural strength of the concrete. All the cubes, cylinders and prisms were cast in three layers and each layer was fully compacted by using a needle vibrator for prisms and a vibrating table for other specimens. After casting, specimens were kept in a room temperature for 24hrs, thereafter demoulded and transferred to the curing tank until their testing dates. Compressive strength of the cube was measured by compression testing machine (CTM) having a capacity of 2000kN at the age of 7, 28 and 90 days. The flexural and splitting tensile strength of the concrete was measured by flexure testing machine and by CTM respectively at the age of 28days. For each mixture three specimens were tested and tests were carried out according to the relevant IS standards.

Description of Mixtures

Among the 6 mixtures, five mixtures were prepared with natural sand substituted by GP by-product and the remaining one was control mixtures (CM). To identify the mixtures easily, the each mixtures was designated with the names such as CM, CGP 5%, CGP 10%, CGP 15%, CGP 20% and CGP 25%. For example CGP 10% specifies that the concrete mixture made with 10% of natural sand is substituted by GP by-product.

RESULT AND DISCUSSION

Slump Loss

The workability of the fresh concrete was measured by slump cone test, time ranged from immediate after mixing, 30min and 60min, it is the convenient method and useful to control the quality of the concrete. Table 4 shows the slump loss of the GP substituted fresh concrete time ranged from immediate after mixing, 30min and 60min and the Fig. 3 explain the effect of GP by-product on the workability of the fresh concrete.

Split Tensile and Flexural Strength

The split tensile strength and flexural strength of the concrete measured at the age of 28days and the strength values is shown in Fig. 4 and 5. Fig. 4 and 5clearly shows that substitution of GP by-product much not affect the flexural and tensile strength.

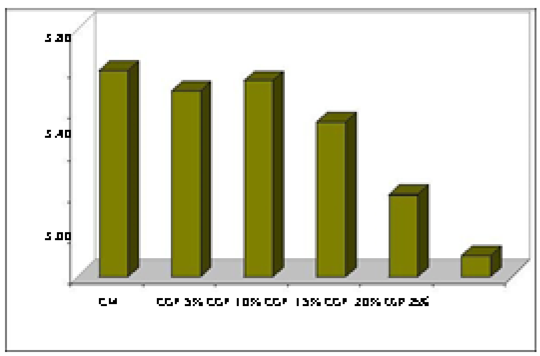

Fig4: Split tensile strength of concrete mixtures at different substitution rates

Relation between Compressive and Split Tensile Strength

The compressive strength of the concrete alone usually measured for the purpose of quality control. The tensile strength of the concrete generally determined from the compressive strength using empirical correlation. Based on the test results, the following the correlation was formulated between the compressive and flexural strength as expressed in Eq. 1.

$$f_{spt} = 0.241(f_{ck})^{0.712} \text{ MPa} \quad (1)$$

Where f_{spt} and f_{ck} are 28 days split tensile strength and compressive strength respectively.

Comprssive Strength

Compressive strength is the most important property of the hardened concrete. The concrete cubes were cast, cured and tested accordance with the IS standard and the 90 days compressive strength results of the concrete are listed in Table 5.

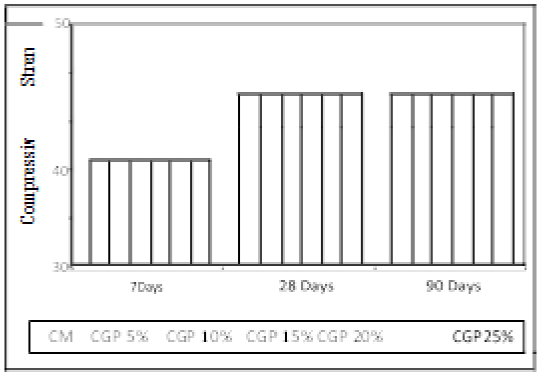

Fig6: Compressive strength of concrete mixtures at different ages-Comparison

The main objective of this research is to utilize the GP waste in concrete making with conform to the concrete production standards and not to enhance the concrete properties. As expected the addition of GP by-product does not affect the compressive strength of the concrete up to 15% of substitution rate and the compressive strength of the concrete increased upon aging. Fig. 4 clearly shows that in all ages the compressive strength values of the mixtures CGP 5%, CGP 10%, CGP 15% are neither close nor little higher than the control mixture (CM). However the lowest compressive strength obtained for CGP 20% and CGP 25% mixtures that have a poor workability. This is a result of the fact that, the increased specific surface area and specific density of the GP by-product create the increases in demand of paste volume and reduce the workability of the concrete resulting poor compactness. The compactness of the concrete is inversely proportional to the porosity of the concrete. Thus increases in porosity can led to the reduction in compressive strength.

The early age (i.e. 7 days) compressive strength of the mixtures CGP 5%, CGP 10%, CGP 15% showed better gain in strength when compared to the CM which is shown in Fig. 6. The reason may be attributed to the denser matrix of the GP by-product and the better dispersion of the cement grains. Furthermore the increased specific surface area and the siliceous property of the GP by-product will act as nucleation sites for the early reaction products (Mucteba Uysal et al., 2011). This nucleation, accelerating the hydration process and significantly increase the C_3S content as a result increasing the compressive strength of the concrete in the early stage. From the above results it was concluded that the GP substitution rate up to 15% which led to the acceptable fresh concrete properties in terms of workability and also acceptable difference in mechanical properties.

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