Durability Studies on Granite Powder Concrete

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Abstract
All construction industries in world, the most commonly used fine aggregate is river sand. The river sand is expensive due to excessive cost of transportation from natural sources. Also, large scale depletion of the source creates environmental problems. As environmental, transportation and other constraints make the availability and use of river sand less attractive a substitute or replacement product for concrete industry needs to be found. The granite powder can be utilized as a partial replacement of natural sand in high performance concrete. Durability of the concrete is also essential for obvious reasons. This paper compares the durability properties of high-performance granite powder concrete with traditional concrete made using Natural River sand through chloride attack and sulphate attack tests as well as compressive strength test. The percentage of granite powder added by weight was 0, 10 and 20 as a replacement of sand used in concrete and cement was replaced with silica fume, fly ash, slag and super plasticiser. The results has to be indicated that the chloride and sulphate attack of concrete in the granite powder concrete specimens between the ordinary concrete specimens.

Keywords: Granite powder, durability properties, chloride attack, sulphate attack, High-performance concrete, fine aggregate, granite powder

Introduction

High Performance Concrete (HPC) is the recent development in concrete. It has become more popular these days and is being used in many prestigious projects. Mineral admixtures such as fly ash, rice husk ash, metakaolin, silica fume etc are more commonly used in the development of HPC mixes. Fine aggregate is an essential component of concrete. The most commonly used fine aggregate is natural river sand. The global consumption of natural river sand is very high due to the extensive use of concrete. In particular, the demand of natural river sand is quite high in developed countries owing to infrastructural growth.

The non-availability of sufficient quantity of ordinary river sand for making cement concrete is affecting the growth of construction industry in many parts of the country. Recently, Tamil Nadu government (India) has imposed restrictions on sand removal from the river beds due to unsafe impacts threatening many parts of the state. On the other hand, the granite waste generated by the industry has accumulated over years. Indian granite stone industry currently produces around 17.8 million tonnes of solid granite waste, out of which 12.2 million tonnes as rejects at the industrial sites, 5.2 million tonnes in the form of cuttings/trimmings or undersize materials and 0.4 million tonnes granite slurry at processing and polishing units. The granite waste generated by the industry has accumulated over years. Only insignificant quantities have been utilized and the rest has been dumped unscrupulously resulting in environment problem.

In the present work, it is aimed at developing a new building material from the granite scrap, an industrial waste as a replacement material of fine aggregate in concrete. By doing so, the objective of reduction of cost of construction can be met and it will help to overcome the problem associated with its disposal including the environmental problems of the region. Substitutions of alternate materials can result in changes in the performance characteristics that may be acceptable for high performance concrete. Use of chemical admixtures usually superplasticiser reduces the water content, thereby reducing the porosity within the hydrated cement paste (Bharatkumar et al., 2001). Silica fume, fly ash and blast furnace slag are generally called as mineral admixtures and called as cement replacement materials. These are pozzolanic in character and develop cementing properties in a similar way as normal Portland cement when they come in contact with free lime. Use of these materials individually or in combination with cement and proper dosage of superplasticiser improves the strength and durability of products. The admixtures can be added to cement concrete as a partial replacement of cement along with superplasticiser as a water reducer to get the high performance.

It is well recognized that the use of silica fume as a partial replacement for cement provides a significant increase in strength of concrete (Xiaofeng et al., 1992). The addition of silica fume to cement paste has been shown to give rise to high early strengths (Mitchell et al., 1998). Silica fume is used in concrete for increased strength development, reduced permeability and economy (Francis, 1994). Mineral admixtures such as fly ash and slag have the inherent ability to contribute to continued strength development and very high durability, the latter through pore refinement and reduced sorptivity. Kefeng and Xincheng (1998) have reported that the compressive strength of concrete incorporating the combination of fly ash and finely ground granulated blast furnace slag is higher than that of individual concrete. Moreover, Swamy (1991) showed that of all the mineral admixtures, silica fume is a class apart from fly ash and slag because its mineralogical composition and particle size distribution.

The mass of silica fume, when used, represents 5 to 15% of the total mass of the cementitious material, the value of 10% being typical. Moreover, silica fume is very expensive. Wasting a very expensive material is not good engineering practice (Adam & Pierre-Claude, 1998). While considering the inclusion of fly ash and slag in the mix, these materials are generally cheaper than Portland cement. Secondly, they do not contribute to the slump loss. On the other hand, mixes that have more fly ash or more slag develop a lower strength, but this can be compensated by lowering the ratio of the mass of water to the total mass of cementitious material (Adam & Pierre-Claude, 1998). The concrete with 10% fly ash exhibited higher early strength followed by an excellent development of strength over time (Haque & Kayali, 1998). Hence, it is expected that the incorporation of silica fume in concrete with fly ash and slag as a partial replacement of cement could contribute the high strength concrete. Accordingly, this paper will examine the properties of concrete by varying the granite powder as a replacement of sand in the concrete that have originated from granite crushed unites along with admixtures such as silica fume, fly ash, ground granulated blast-furnace slag and superplasticiser as a partial replacement of cement.

Review of Literature

T. Felixkala (et al. 2010)[1] had obtained the test results that granite powder of marginal quantity as partial sand replacement has beneficial effect on the mechanical properties such as compressive strength, split tensile strength, modulus of elasticity. They also indicated that the values of both plastic and drying shrinkage of concrete in the granite powder concrete specimens were nominal than those of ordinary concrete specimens. They examines the possibility of using granite powder as replacement of sand and partial replacement of cement with fly ash, silica fume, slag and superplasticiser in concrete. The percentage of granite powder added by weight was 0, 25, 50, 75 and 100 as a replacement of sand used in concrete and cement was replaced with 7.5% silica fume, 10% fly ash, 10% slag and 1% superplasticiser. The effects of water ponding temperatures at 26^{o}C and 38^{o}C with 0.4 water-to-binder (w/b) ratios on mechanical properties, plastic and drying shrinkage strain of the concrete were studied and compared with natural fine aggregate concrete.

Kanmalai Williams. (et al 2008 [2]) reported the results of an experimental study on the high performance concrete made with granite powder as fine aggregate. The percentage of granite powder added by weight a range viz. 0, 25, 50, 75 and 100% as a replacement of sand used in concrete and cement was replaced with 7.5%Silica fume, 10% fly ash, 10% slag and 1% super plastiziser. The effects of curing temperature at 32 Sand 0.40 water-to-binder (w/b) ratio for 1, 7, 14, 28, 56 and 90 days on compressive strength, split tensile strength, modulus of elasticity, drying shrinkage and water penetration of concrete were studied. Their results indicated that the increase in the proportions of granite powder resulted in a decrease in the compressive strength of concrete.

The highest compressive strength was achieved in samples containing 25% granite powder concrete, which was 47.35 kPa after 90 days. The overall test performance revealed that granite powder can be utilized as a partial replacement of natural sand in high performance concrete.

Research Objective

Consequently, the main objective of this research is to:

1. Investigate the potential use of granite powder in concrete as replacement for natural sand.
2. Determining under what conditions the granite powder, in conjunction with silica fume, Fly-ash, and ground granulated blast furnace slag, increases the strength of concrete when these are used as partial replacement materials.
3. Determining the degree of strength improvement in concrete obtained with the addition of granite powder and admixtures such as silica fume, Fly-ash, and ground granulated blast-furnace slag.

In general high performance concrete will be made with cement, admixtures, aggregates and water. The percentage of granite powder added by weight a range viz. 0, 10 and 20% as a replacement of sand (fine aggregates) used in concrete. Mixes incorporating 0% granite powder, or 10% granite powder, or 20% granite powder were designated as GP0, GP10 and GP20 respectively. Cement was replaced with Silica fume, fly ash, slag and superplasticiser for each concrete mixes. The effects of curing temperature, water-to-binder (w/b) ratio for 1, 7, 14, 28, 56 and 90 days on compressive strength of concrete were studied.

M. G. Shaikh (et al 2011) [3] has found that the mixes with the artificial sand with dust as fine aggregate gives consistently higher strength than the mixes with natural sand. The sharp edges of the particles in artificial sand provide better bond with the cement than the rounded part of the natural sand. It was found that the weight loss of artificial sand block is considerably same with respect to natural sand blocks at 20, 40, and 60 and 90 days, immersed in sulphuric acid solution during the experimental period and maintain pH 4 across it. Both concrete made using artificial sand and natural sand are moderate to chloride permeability. In water absorption test we observed after 24 hours curing, the increase in weight of both natural sand and artificial sand blocks are less than 3% that means both concrete are low absorber hence concretes are good quality. The test result obtained from well planned and carefully performed experimental program encourage the full replacement of natural sand by artificial sand with dust considering the technical, environmental and commercial factor.

R. Ilangovana (et al 2008) [4] The Durability of Quarry Rock Dust concrete under sulphate and acid action is higher inferior to the Conventional Concrete. Permeability Test results clearly demonstrates that the permeability of Quarry Rock Dust concrete is less compared to that of conventional concrete. The water absorption of Quarry Rock Dust concrete is slightly higher than Conventional Concrete Therefore, the results of this study provide a strong support for the use of Quarry Rock Dust as fine aggregate in Concrete Manufacturing. Thus, it can be concluded that the replacement of natural sand with Quarry Rock Dust, as full replacement in concrete is possible.

B. B. Patel (et al 2012) [6] The compressive strength of concrete increases with increase in HRM content up to 7.5%. Thereafter there is slight decline in strength for 10%, 12% and 15% due excess amount of HRM which reduces the w/b ratio and delay pozzolanic activity. The higher strength in case of 7.5% addition is due to sufficient amount of HRM available to react with calcium hydroxide which accelerates hydration of cement and forms C-S-H gel. The 7.5% addition of high reactivity metakaolin in cement is the optimum percentage enhancing the compressive strength at 28 days by 7.73% when compared with the control mix specimen. The 7.5% addition of high reactivity metakaolin in cement is enhanced the resistance to chloride attack. The compressive strength of concrete incorporated with 7.5% HRM is reduced only by 3.85% as compared with the reduction of strength of control mix specimen is by 4.88%. The 7.5% addition of high reactivity metkaolin in cement is also enhanced the resistance to sulphate attack. The compressive strength of concrete incorporated with 7.5% HRM is reduced only by 6.01% as compared with the reduction of strength of control mix specimen by 9.29%.

Experimental Details

Materials

Cement: The materials of cement was used in an ordinary Portland cement super grade IS: 1489 (53grade) is used. This cement is most commonly used in concrete construction

Fine aggregate: In current study, the high performance concrete mixes were prepared using locally available river sand. The sand used was confining to zone 3. Fineness modulus and specific gravity of the sand were found to be 2.33 and 2.56 respectively.

Table 1.Properties of Granite

Sl No	Properties	Values
1	Porosity	Very low
2	Absorption	0.5 to 1.5%
3	Specific Gravity	2.6 to 2.8
4	Density	2500-2650Kg/m^3
5	Crushing strength	1000-2500Kg/m^2
6	Frost resistance	Good
7	Fire resistance	Low
8	Color	Mostly light colored

Coarse aggregate: Broken granite stones were used as a coarse aggregate in concrete. Size of the coarse aggregate used in the investigation was 10 -20 mm. The specific gravity of the coarse aggregate was found to be 2.68

Table2. Chemical and Physical Properties of Fly Ash and Slag (%)

Sl No	Properties	Values
1	Specific gravity	1-220-1-225
2	Chloride content	Nil(As per BS:5075)
3	Recommended dosage	2-4% of cement
4	Approximate additional air Entrainment	1% at normal dosage
5	Solid content	40%
6	Compatibility	All types of cement except high alumina cement
7	Operating	10-40

Water: Water is an important ingredient of the concrete as it actually participates in the chemical reaction with cement. In general, water fit for drinking is suitable for mixing concrete. Impurities in the water may affect setting time, strength, shrinkage of concrete or promote corrosion of reinforcement. Locally available drinking water was used in the present work.

Granite powder: Granite belongs to igneous rock family. The density of the granite is between 2.65 to 2.75 g/cm3 and compressive strength will be greater than 200MPa. Granite powder obtained from the polishing units and the properties were found. Since the granite powder was fine, hydrometer analysis was carried out on the powder to determine the particle size distribution. From hydrometer analysis it was found that coefficient of curvature was 1.95 and coefficient of uniformity was 7.82. The specific gravity of granite powder was found to be 2.61.

Admixture

1. **Supreplasticiser** was used during investigation to improve the workability of concrete. As per Indian standards, the dosage of superplasticiser should not exceed 2% by weight of the cement. A higher

dosage of superplasticiser may delay the hardening process. After trials, the optimal dosage of the supreplasticiser was found to be 0.5% to produce slump of 100 mm.

2. **Silica fume** Condensed silica fume is considered as the most efficient micro filler for high performance concrete. Its two fold effects are reduction of w/c ratio and increase of strength of hardened concrete. The silica fume used in this study was in powder form and contained 95%SiO , 0.39% 2CaO, 0.21%MgO, 0.11%K O, 0.15% Na O, 0.13% Al O ,).40% Fe O The 2 2 23 23.properties of silica fume result in more efficient gel
3. **Fly ash** was considered in the present study as a replacement of cement in 10%. It is a fine, glass powder recovered from the gases of burning coal during the production of electricity. Fly ash improves considerably the performance of binder phase and increase the bonding action with aggregate and reinforcement. The properties of fly ash may vary considerably according to several factors
   Such as the geographical origin of the source coal, conditions during combustion and sampling position within the power plant. The major elemental constituents of fly ash are Si, Al, Fe, Ca, C, Mg, K, Na, S, Ti, P and Mn.

Slag: The ground granulated blast furnace slag was used 10% along with other admixtures as a replacement of cement `

Table 3. Units For Magnetic Properties

Sl No	PROPERTIES
1	Specific Gravity : 2.25 (Determined Using Le-Chaterlier flask)
2	Bulk density : 709 kg/m^3
3	Void content (Vv/V) : 2.25
4	Porosity(Vv/V) : 68.49 %

Mixing, demoulding and curing: Thorough mixing and adequate curing are most essential for achieving a good concrete. In the laboratory, the concrete was mixed in a hand mixing. The mixing time was kept to about 3–4 min for normal concrete. Generally, the demoulding was done 24 hr of casting. Potable water was used for curing all the concretes. All the concretes were kept in moist environment immediately after the initial set and before the demoulding.

Tests

Compressive strength: The compressive loading tests on concrete were carried out on a compression testing machine of capacity 2000 kN. For the compressive strength test, a loading rate of 2.5 kN/s was applied as per IS: 516–1959[4]. The specimen used was 150 mm cube. The
Test was performed at 28, 90 and 180 days. The specimens were tested immediately after taking the cubes from curing tank in surface dry condition.

Acid attack : The chemical resistance of the concretes was studied through chemical attack by immersing concrete blocks in an acid solution. After 90 days period of curing, the specimens were removed from the curing tank and their surfaces were cleaned with a soft nylon brush to remove weak reaction products and loose materials from the specimen. The initial weights were measured and the specimens were identified with number .The specimens were immersed in 5% H_2SO_4 solution (Fig.1) and the pH 4 was maintained constant throughout. The solution was replaced at regular intervals to maintain constant concentration throughout the test period. The mass of specimens were measured at regular intervals up to 90 days, and the mass losses were determined.

Fig 1. Acid attack

Chloride attack: The chloride permeability test was conducted to assess the concrete quality as per ASTM C 1202 [8]. For this test 150×150 mm specimens were used. A potential difference of 60V DC was maintained across the specimen. One of the surfaces was in contact in a sodium chloride solution (NaCl) and the other with a sodium hydroxide solution (NaOH) fig.2. The total charge passing through in 6 hrs was measured, indicating the degree of resistance of the specimen to chloride ion penetration. In addition resistivity or conductivity can also be determined from the initial current reading, since the resistance of the disk can be calculated immediately from Ohm's law: R=V/I where R is resistance, V is voltage, and I is current. The resistivity is determined from: Resistivity =RA/L where A is area of the disk, and L is thickness of the disk

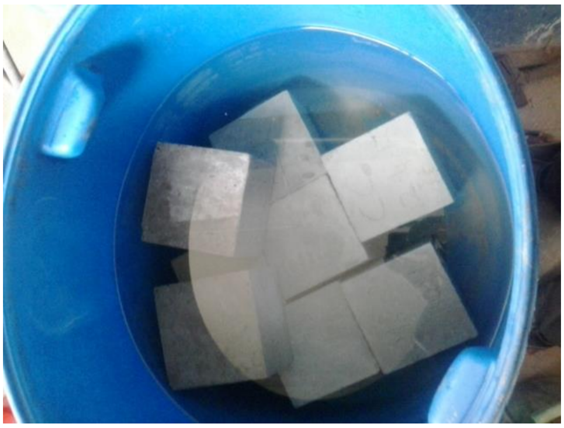

Fig 2 Chloride Attack

Results and Discussion

Compressive strength studies The results of compressive strength of cubes are obtained and are presented in Table 1. The variation of compressive strength with respect to type of concrete block made by using Conventional Concrete and granite powder concrete are observed. Result shows that the mixes with the granite powder as fine aggregate gives consistently higher strength than the mixes with natural sand. Permeable voids and water absorption the results of water absorption in 30 min (initial surface absorption) as well as the absorption after 96 h (final absorption) and the permeable voids for all the concrete are presented in Table. For the test blocks were removed from the curing tank. After that, we observed that the weight loss during that period is up to 3%. Again the samples were put into the curing tank, after regular interval up to 96 hrs the water absorption reading was taken. Water absorption is mainly influenced by the paste phase primarily; it is dependent on the extent of interconnected capillary porosity in the paste. We observed after 24 hours curing that the increase in weight of both Conventional Concrete and Granite concrete blocks are less than 3% that means both concretes are low absorber hence concretes are of good quality.

Chloride attack : Concrete is susceptible to Chloride attack because of its Chloride nature. The components of the cement paste break down during contact with Chloride. The results of Chloride attack studies in terms of the weight loss after 90 days for all the concretes are reported in Table 2. 24 cubes of Conventional

Concrete and 24 cubes of Granite concrete were kept into different containers having 5% of sodium chloride for 90 days. The weight loss during the regular interval with maintain of pH 4 was observed. A small difference between Conventional Concrete and Granite concrete blocks weight loss (in percent) during these days was witnessed.

Conclusion

Studies reported here shown that the strength of high performance granite powder concrete is comparatively 10-12 percent more than that of similar mix of Conventional Concrete. Current study also shows that drying shrinkage strains of high performance granite powder concrete are almost equal to the shrinkage strain of Conventional Concrete. The Durability of high performance granite powder concrete under sulphate and acid action are much higher inferior to the Conventional Concrete.

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