MECHANICAL PROPERTIES OF HIGH PERFORMANCE CONCRETE INCORPORATING GRANITE POWDER AS FINE AGGREGATE

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Abstract

This paper reports 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% superplasticiser. The effects of curing temperature at 32°C and 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. Experimental results indicate 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.

Key words: High-performance concrete, fine aggregate, granite powder, silica fume, fly ash, slag, superplasticiser, strength.

I. INTRODUCTION

The recent development in the field of concrete technology represents a giant step toward making concrete a high tech material with enhanced characteristics. A number of different rock types have been used to make high performance concrete; these include limestone, dolomite, granite, andesite, diabase, and so on. For high strength concrete, the coarse and fine aggregate particles themselves must be strong, which are the important constituents in concrete.

They give body to the concrete, reduce shrinkage and effect economy. Indian granite stone industry currently produces around 17.8 million tones of solid granite waste, out of which 12.2 million tones as rejects at the industrial sites, 5.2 million tones in the form of cuttings/trimmings or undersize materials and 0.4 million tones 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. With the enormous increase in the quantity of waste needing disposal acute shortage of dumping sites, sharp increase in the transportation and dumping costs, affecting the environment, preventing the sustainable development. The waste disposal problem is assuming serious.

On the other hand, the non availability of the sufficient quantity of ordinary river sand for the making of cement concrete is affecting the growth of construction industry in many parts of the country. Recently Tamil Nadu government (in India) has imposed restrictions on sand removal from the riverbeds due to unsafe impacts threatening many parts of the state. Hence this research is aimed at developing a new building material from the granite scrap, an industrial waste as a replace material of course and fine aggregates in high-performance concrete. Substitutions of alternate materials can result in changes in the performance characteristics that may be acceptable for high-performance concrete. In recent years, the terminology "High-Performance Concrete" has been introduced into the construction industry worldwide with the benefits of improved characteristics such as workability, durability, ease of placement, compactness, early age strength, long-term mechanical properties, permeability, heat of hydration, toughness, volume stability and long life in severe environments.

The American Concrete Institute (ACI) defines high-performance concrete as concrete meeting special combinations of performance and uniformity requirements that cannot always be achieved routinely when using conventional constituents and normal mixing, placing and curing practices. The main difference between conventional concrete and High-Performance Concrete is essentially the use of chemical and mineral admixtures. Use of chemical admixtures, usually superplasticiser reduces the water content, thereby reducing the porosity within the hydrated cement paste (Bharatkumar etal, 2001). Silica fume, fly ash and blast furnace slag are generally called as mineral admixtures, also 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). Since silica fume concrete was introduced on a large scale, it has been known that strength is rapidly improved. During the pozzolanic interaction between silica fume and Portland cement, some calcium hydroxide was transformed into silicate hydrates, which increased the strength (Bertil, 1998).

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. Ground granulated blast furnace slag has been used as a partial replacement for cement for a number of years in many different countries. The researcher, Kefeng and Xincheng, 1998, reported in his paper 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. More over, (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. It is well established that the incorporation of micro silica could contribute the high strength concrete. Based on the above observation, to check the possibilities of improving the performance of concrete by varying the granite powder along with admixtures such as silica fume, Fly-ash, ground granulated blast-furnace slag were considered in this study as a partial replacement of cement. The preliminary study (Felix kala et al, 2007) indicated that compressive strength of concrete with 50 % granite powder and river sand as fine aggregate is similar to that of usual concrete (only river sand as fine aggregate).

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, 25, 50, 75 and 100% as a replacement of sand (fine aggregates) used in concrete. Mixes incorporating 0% granite powder, or 25% granite powder, or 50% granite powder, or 75%, or 100% granite powder, were designated as GP0, GP25, GP50, GP75, and GP100 respectively. Cement was replaced with 7.5% Silica fume, 10% fly ash, 10% slag and 1% superplasticiser for each concrete mixes. The effects of curing temperature at 32°C and 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.

II. EXPERIMENTAL INVESTIGATIONS

A. Materials Used

Cement

The most common available Portland cement of 43-grade was selected for the investigations. It was dry, powdery and free of lumps. While storing cement, avoided all possible contact with moisture. Stored the cement away from exterior walls, off damp floors, and stacked close together to reduce air circulation.

Silica fume

Condensed silica fume is considered as the most efficient microfiller 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_2, 0.39% CaO, 0.21% MgO, 0.11%

K_2O, 0.15% Na_2O, 0.13% Al_2O_3,).40% Fe_2O_3. The properties of silica fume result in more efficient gel

Table 1. 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%

development. Silica fume improves considerably the performance of binder phase and increase the bonding action with aggregate and reinforcement. The properties of silica fume used in this study are given in Table I.

Fly ash

Fly ash is a fine, glass powder recovered from the gases of burning coal during the production of electricity. These micron-sized earth elements consist primarily of silica, alumina and iron. Fly ash particles are almost totally spherical in shape, allowing them to flow and blend freely in mixtures. 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. Nearly naturally occurring elements can be found in fly ash in trace quantities. Certain trace elements, including As, Mo, Se, Cd, and Zn, are primarily associated with particle surfaces. The most abundant species in fly ash extracts are inorganic ions derived from Ca, Na, Mg, K, Fe, S, and C. The Chemical and physical properties of Fly ash and Slag are given in Table 2.

Slag

Table 2. Chemical and Physical Properties of Fly Ash and Slag (%)

Properties	Fly ash	Slag
Specific gravity	2.43	2.79
Compressive strength, 28 day, MPa	-	-
Pozzolanic activity index, 28 day, %	85.4	106.3
Specific surface, Blaine, m^2/kg	565	599
S_iO_2	63.5	34.4
Al_2O_3	11.1	9.0
Fe_2O_3	5.2	2.58
CaO	14.7	44.8
MgO	1.98	4.43
SO_3	0.35	2.26
Na_2O	0.48	0.62
K_2O	0.4	0.5
LOI	2.1	1.32

Slag works very well as a loose aggregate and can be ground to produce a more even grain. It is produced during the smelting process in several ways. Common components of slag include the oxides of silicon, aluminum, and magnesium as well as sulfur, which is always present. Slag also contains phosphorous, calcium ash, remnants of flux materials such as limestone, and remainders of chemical reactions between the metal and the furnace lining. Other compounds found in slag depend on the type of smelting. Non-ferrous smelting, used to refine copper, lead, and similar metals, produces highly ferrous slag, as iron is an undesired element.

Superplasticiser

A Sulphonated naphthalene formaldehyde condensates based superplasticiser was in the investigation. Superplasticiser were added 1% of cement mass according to procedures prescription. With higher dosage some delay in hydration and hardening may occur together with apparent early setting of the fresh mix. The compatibility of superplasticiser with cement as well as their efficiency, duration of fresh mix fluidity, sensitivity to ambient temperatur and other factors should be verified by experiments executed in local conditions [IS: 10262]. The technical details of superplasticiser as per the manufacturer's literature are given in Table 3.

Coarse aggregate

Table 3. 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 temperature	10 – 40°C

Granite was used as a coarse aggregate in concrete. Granites are plutonic light colored igneous rocks. The word granite is derived from Latin word granum meaning a grain and obviously refers to the equigranular texture of the rock.

Granites are generally coarse to medium grained, holocrystalline and equigranular rocks. Optimum size of the coarse aggregate in most situations was about 1.9 cm. Granitic, graphic, porphyritic and inter growth textures are the most common types met with in granites. They show, on a large scale, massive structures. Many types of granites are distinguished on the basis of relative abundance of some accessory minerals and special textural features. Other common types of granites named on the same pattern are: hornblende-granite, augite-granite, tourmaline-granite and so on. Sometimes a type is also named on the basis of its texture, such as graphic granite, porphyritic granite. They generally posses all the essential qualities of a good building stone showing very high crushing strength, low absorption value, least porosity, interlocking textures variety of appealing colors and susceptibility to perfect polish. General properties of commonly available granite are given in Table 4. Sieve analysis of the course aggregates was done and passed through the 19 mm size sieve and percentage of passing was 99.

Table 4. 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	2500-2650 Kg/m^3
5.	Crushing strength	1000-2500 Kg/m^2
6.	Frost resistance	Good
7.	Fire resistance	Low
8.	Color	Mostly light colored

Water

In general, water fit for drinking is suitable for mixing concrete. Impurities in the water may affect concrete, setting time, strength, shrinkage or promote corrosion of reinforcement. Hence locally available purified drinking water was used in the present work.

Fine Aggregate

The percentage of granite powder by weight ranging from 0 to 100% as a replacement of sand was used in concrete. Sand from seashores, dunes or riverbanks are usually too fine for normal mixes. In the present study locally available river sand was adopted. Its range is size from less than 0.25 mm to 6.3 mm. Finesse modulus and specific gravity of the sand are 2.33 and 2.63 respectively. The sand was before used to avoid

problem of bulking. Granite powder is obtained from the crusher units are the finer fraction collected from the crushing and sieving equipment and its properties were tested. Finesse modulus and specific gravity of the granite powder are 2.43 and 2.58 respectively. In the present study, the concrete mixes were prepared using river sand and granite powder. Sieve analysis was carried out for the sand and granite powder, was passed through a No. 4 (4.75 – mm) sieve. Percentage of passing for sand was 99 and for granite powder was 100.

B. Concrete and Mix Proportions

The mixes were designated with the grade of concrete and the fine aggregate type used. ACI mix design method (M.S. Shetty 1986, SP23-BIS and IS: 10262) was used to achieve a mix with a compressive strength of 30 MPa. Based on the preliminary studies, the mix proportions of the control mix M30 was considered. The details of mix proportions are given in Table 5.

Table 5. Mix Proportions

Weight in kg per m^3 of concrete									
Mix Designation	Cement	Fly ash	Silica fume	Slag	Superplasticiser	Water	Coarse Aggregate	Fine Aggregate: Granite Powder	Fine Aggregate: Sand
GP0								0	806
GP25								202	604
GP50	437	61	46	61	6	244	1833	403	403
GP75								604	202
GP100								806	0

C. Best Specimens and Procedure

The granite scrap are initially broken into pieces with sledge hammer and then fed into a jaw crusher which in turns break them into the required size of 19mm. The granite aggregates are sharp and angular in shape, which resembles that of the natural coarse aggregates. The granite powder was collected from different crusher units and its properties were tested. The aggregates were soaked in part of the mix water for about 5 minutes, prior to the start of the mixing operations.

A tilting type rotary drum was used to mix properly all the ingredients. Coarse aggregate was placed in the drum first and batch water was increased to account for the adsorption of the aggregates during rotation. After mixing for 10 to 15 seconds the fine aggregates with correct proportions was introduced and mixed in for the period of 15 to 20 seconds. This was followed by the final 20% of the water and all the superplasticiser were added with cement, Fly ash, Silica fume and Slag, which mixed in until a total mixing time of 60 seconds was achieved. Cube and cylinder specimens were cast and tested for studying the variation in strength properties due to replacement of Cement, Admixtures and Fine aggregates. The superplasticiser was added 30 s after all the other materials during the mixing. The entire test specimen were cast in removable cast iron moulds and compacted on a vibrating table. After 1 day the demoulded specimens were cured at water temperature of 32°C (±2°C). Different batches were adopted for 1 day, 7 days, 14 days, 28 days 56 days and 90 days ages.

The various strength properties studied were compressive strength, Split Tensile strength, Modulus of elasticity, Water Penetration test, Drying shrinkage and hydration. The dimensions and the number of specimens used for the present study are listed in Table 6. The various specimens cast were tested after curing for required period. Compressive strength and Split Tensile Strength were determined using Compression Testing Machine (CTM) of 3000kN capacity and Universal Testing Machine (UTM) of capacity 600kN. Modulus of Elasticity was determined at initial stages of loading.

Table 6. Details of Test Specimens

Material Properties	Shape and Dimensions of the Specimens	No of Specimens
Compressive Strength (1,7,14,28,56 and 90 days)	Cube : 150mm X 150mm X 150mm	90
Split Tensile Strength (1,28 and 90 days)	Cylinder : 100mm X 200mm	45
Modulus of Elasticity (7 and 90 days)	Cylinder : 100mm X 300mm	30
Water Penetration test (7 and 90 days)	Slab : 100mm X 500mm X 500mm	30
Drying Shrinkage (1,7,14,28,56 and 90 days)	Prism : 100mm X 100mm X 300	60

III. TEST RESULTS AND DISCUSSION

Mechanical properties

The laboratory test is conducted for finding the characteristic Mechanical properties such as compressive strength, split tensile strength, modulus of elasticity, water penetration and drying shrinkage of concrete mixtures at 32°C (±2°C) for 1, 7, 14, 28, 56 and 90 days of curing for 0.40 water-cement ratio and are summarized in Fig. 1 through 6. Each value represents average of three test specimens.

Compressive Strength

Compressive strength is one of the most important and discusses properties of concrete. Particularly related to HPC, the possible retrogression of the strength in admixtures concretes is of supreme importance. The compressive strength, average of three cubes, of various concrete mixtures at 32°C is shown in Fig. 1 and Fig. 2. The data presented show that the compressive strength of all the granite powder concrete was higher closer to that of reference mix (GP0). In the present study, significant increment was observed in the concrete mixture with 25% granite powder (GP25). The compressive strength of GP25 is 2 to 7 % higher than that of GP0 for all the days of curing. The mixes with (higher than 25%) granite powder showed lesser compressive strength than the mix with river sand (GP0). This can be the effect of higher the amount of fine granite powder present in the mixes. It is also shown that the compressive strength increases with the increase in days of curing for all the mixtures. It is to be noted from the figures that for all the mixtures at the ages of 1 and 7 days the difference in compressive strength is higher than that of all other ages (7 to 90 days). This can be attributed that the lower age is not enough to resist the influence.

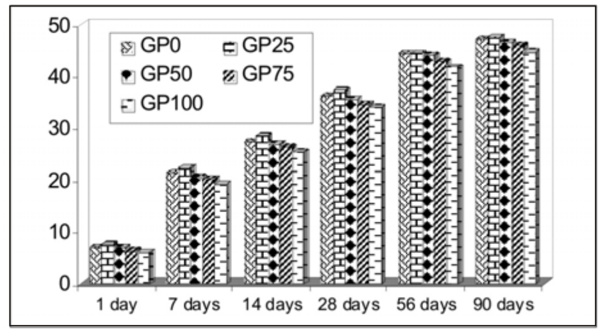

Fig. 1. Variation of Compressive Strength (Mpa) with Days of Curing

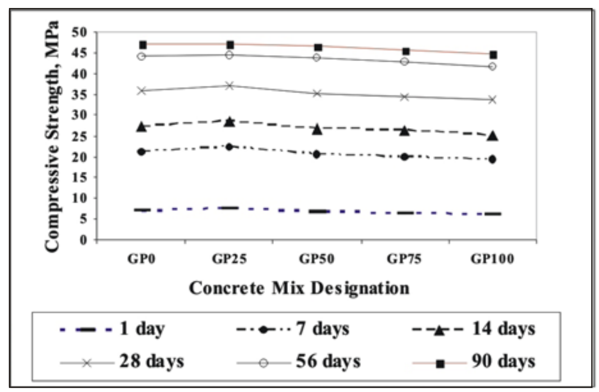

Fig. 2. Variation of Compressive Strength (Mpa) with Concrete Mix

Split Tensile Strength

Specimens of 100 mm diameter cylinder have been tested at the age of 1, 28 and 90 days. The variation of split tensile strength with age of curing is shown in Fig. 3. It is observed that the concrete mixes with granite powder produced almost same strength as produced by concrete mix with river sand (GP0) expect GP25. This may be due to the reason that higher amount of fine granite powder present in the concrete mixes. However the mix with 25% granite powder (GP25) enhances the strength.

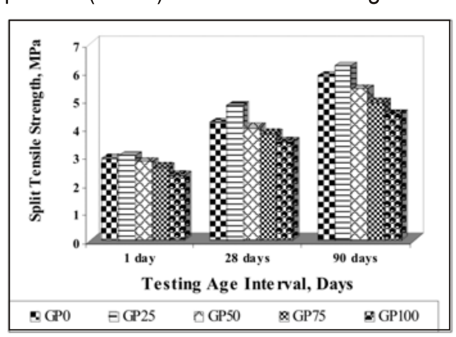

Fig. 3. Variation of Split Tensile Strength (Mpa) with Days of Curing

Modulus of Elasticity

The Modulus of Elasticity data are plotted in Fig. 4. The measurements were performed at the age of 7 and 90 days. The tests show that the modulus of elasticity of all the concrete mixtures was almost similar or higher than that of GP0 both for 7 and 90 days. It is also shown that the modulus of elasticity of concrete mixture with a 25 % granite powder (GP25) is 2 % higher than that of GP0 at 90 days of curing. This may be the reason that the age of curing enhances the strength.

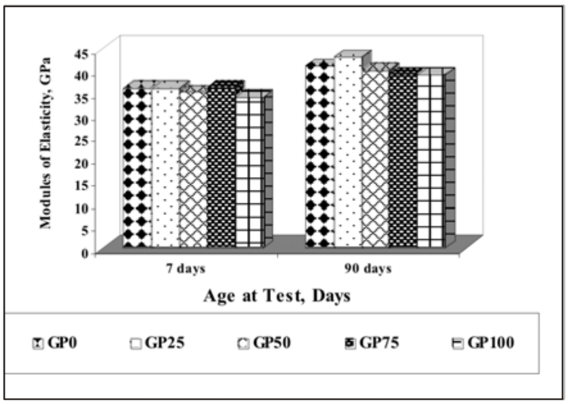

Fig. 4. Variation of Modulus of Elasticity (Mpa) with Days of Curing

Water Penetration

The Water Penetration data are plotted in Fig. 5. The measurements were performed at the age of 7 and 90 days. The water penetrability of the slabs 100mm X 500mm X 500mm containing is granite powder is almost closer to that of GP0 for the tested ages. Moreover, it is to be noted that higher the days of curing, possibility of decrement in the water penetration could be expected.

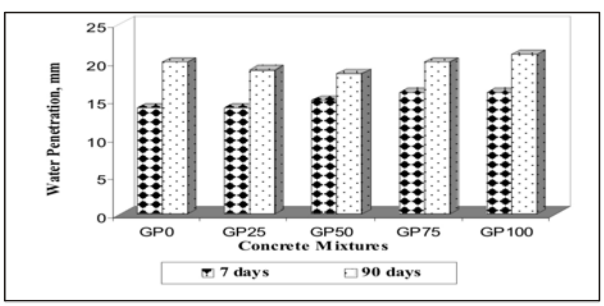

Fig. 5. Variation of Water Penetration with Days of Curing

Drying Shrinkage

The drying shrinkage from 1 day to 90 days of the concrete prisms cast at a temperature of 32°C is presented in Fig. 6. The measurements of the specimens show that increasing the granite powder in the concrete, increase the drying shrinkage. The drying shrinkage of all the five concrete mixtures is very similar with a maximum value of 425 microstrain after 90 days. In case of GP25, the drying shrinkage is very marginally increased for all the days of curing but 56 days of curing there was a nominal decrease.

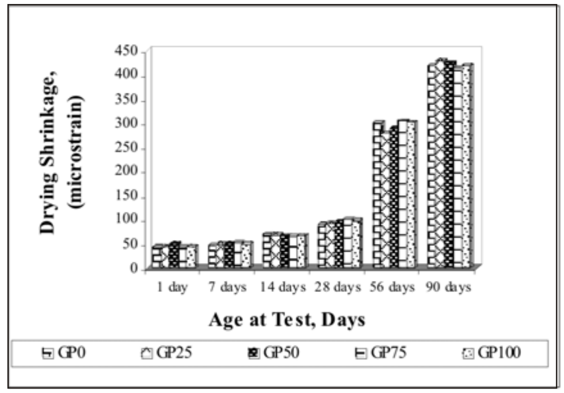

Fig. 6. Variation of Drying Shrinkage with Days of Curing

IV. SUMMARY AND CONCLUSION

The test results show clearly that granite powder as a partial sand replacement has beneficial effects of the mechanical properties of high performance concrete. Of all the five mixtures considered, GP25 was found to be superior to other mixtures as well as GP0 for all operating conditions. Hence the following conclusions are made based on a comparison of GP25 with the conventional concrete mixture, Gp0.

1. Compressive strength, Split tensile strength modulus of elasticity, particularly in all the ages higher than that of the reference mix (GP0). There was an increase in strength as the days of curing increases.
2. The water penetrability was about 5% less than the conventional concrete mixture. This result suggests that the proper use of the granite powder can produce high in concrete. In general, the behavior of granite aggregates with admixtures in concrete possesses the higher properties like concrete made by river sand. Thus granite aggregates performance concrete.
3. The drying shrinkages of all the five concretes were very similar with a maximum value of 420 microstrain after 90 days. As regards shrinkage performance, these concretes are high performance.

The present experimental programme indicates that the strength properties of the concrete could enhance the effect of utilization of granite powder obtained from the crusher units in the place of river sand both granite stone and granite powder in concrete are the best choice, where they are available. Hence the granite aggregates may be considered as equivalent or alternative coarse and fine aggregates for blue metal and river sand.

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