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Granite powder concrete

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Abstract

This paper 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°C and 38°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. The test results obtained indicate 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. Furthermore, the test results 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.

Keywords: Granite powder, fly ash, silica fume, superplasticiser, concrete, mechanical properties, shrinkage.

Introduction

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. 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, prevents the sustainable development. The waste disposal problem is becoming serious. 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.

Table 1. Sieve analysis results of coarse aggregates

Sieve Size (mm)	% Passing
25	100
20	98
16	87
12.5	64
10	26
6.3	03
4.75	00

Table 2. Sieve analysis results of fine aggregates

Sieve Size	Sand % Passing	Granite Powder % Passing
4.75mm	98	100
2.36mm	96	98
1.18mm	78	93
600µm	51	62
300µm	26	47
150µm	7	26

Research objectives

The present study involves addition of fly ash, silica fume, slag, superplasticizer and granite powder for conventional concrete. Therefore, the study had several typical objectives.

- The first aim was to estimate an optimal composition of concrete mixtures with respect to all operating conditions.
- The other objective of this work was to determine under what conditions the granite powder in conjunction with silica fume, fly-ash and ground granulated blast-furnace slag and superplasticiser increasing the strength of concrete when these are used as partial replacement materials.
- Further, to determine the degree of strength improvement in concrete obtained with the addition of granite powder with admixtures.
- The last objective of this study was to estimate the plastic and drying shrinkage characteristics.

Materials and methods

Materials used

The most commonly available Portland cement of 43-grade was selected for the investigations. It was dry, powdery and free of lumps. While storing cement, all possible contact with moisture was avoided. Condensed silica fume is considered (7.5% as a replacement of cement) as the most efficient micro filler for high performance 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 and 40% Fe_2O_3. Fly ash (Type F) from the thermal power plant Chennai, India was used. 10% fly ash was considered in the present study as a replacement of cement. 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. In the present study, 10% ground granulated blast furnace slag was used along with other admixtures as a replacement of cement. Superplasticiser was added 1% of cement mass according to supplier prescription. With higher dosage, some delay in hydration and hardening may occur together with apparent early setting of the fresh mix. Ordinary blue metal was used as a coarse aggregate in concrete. Stones are generally coarse to medium grained, holocrystalline and equigranular rocks. Optimum size of the coarse aggregate in most situations was about 1.9 cm. They generally posses all the essential qualities of a good building stone showing very high crushing strength, low absorption value and least porosity. Sieve analysis of the course aggregates was done and percentages passing at different sieves are furnished in Table 1. In the present study, the concrete mixes were prepared using river sand and granite powder. The percentage of granite powder by weight ranging from 0 to 100% as a replacement of sand was used in concrete. Granite powder is obtained from the crusher units are the finer fraction collected from the crushing and sieving equipment and its properties were tested. Fineness modulus and specific gravity of the granite powder are 2.43 and 2.58 respectively. 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. Fineness modulus and specific gravity of the sand are 2.33 and 2.63 respectively. Sieve analysis was carried out for the sand and granite powder at different sieve sizes and the results are presented in Table 2. It is shown that the amount of fine particles present in granite powder is considerably higher when compared to the river sand.

Table 3. Details of concrete mix

Mix Designation	Weight in kg per m^3 of concrete							Fine Aggregate	
	Cement	Fly ash (10%)	Silica fume (7.5%)	Slag (10%)	Super plasticizer (1%)	Water	Coarse Aggregate	Granite Powder	Sand
GP0	343	48	36	48	5	192	1086	0	533
GP25	343	48	36	48	5	192	1086	133	340
GP50	343	48	36	48	5	192	1086	266.5	266.5
GP75	343	48	36	48	5	192	1086	340	133
GP100	343	48	36	48	5	192	1086	533	0
NA100	480	-	-	-	-	192	1086	533	0
CC	480	-	-	-	-	192	1086	-	533

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.

Details of concrete mix

The mixes were designated with the grade of concrete and the fine aggregate type used. ACI mix design method (Shetty, 1986) was used to achieve a mix with cube strength of 30 MPa. Based on the literature survey, the mix proportions of the control mix M30 was considered in the initial stage. The details of mix proportions are given in Table 3. In this study, the percentage of granite powder added by weight was 0, 25, 50, 75 and 100% as a replacement of sand (fine aggregates) used in concrete. Mixes incorporating 0% granite powder (100% river sand), 25% granite powder (75% river sand), 50% granite powder (50% river sand), 75% granite powder (25% river sand), 100% granite powder (0% river sand), no admixtures but with 100% granite powder and conventional concrete were designated as GP0, GP25, GP50, GP75, GP100, NA100 and CC respectively. Water curing is the most effective method of curing. It produced the highest level of compressive strength and modulus of elasticity. If a concrete is not well cured, it cannot gain the properties and durability for its long service life. A proper curing greatly contributes to reduce the porosity and drying shrinkage of concrete and thus to achieve higher strength and greater resistance to physical or chemical attacks in aggressive environments. Therefore, a suitable curing regime is essential in order to produce strong and durable concrete (Zain & Matsufuji, 1997). This study presents the effect of 2 curing temperatures at different climates of 26°C (±2°C) and 38°C (±2°C) with 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 and shrinkage strains of concrete.

Table 4. Details of test specimens

Material Properties	Shape and Dimensions of the Specimens	No: of Specimens Tested
Compressive Strength	Cube : 150 mm X 150 mm X 150 mm	72
Split Tensile Strength	Cylinder : 100 mm X 200 mm	36
Modulus of Elasticity	Cylinder : 100 mm X 300 mm	24
Plastic Shrinkage	Slab : 1000 mm X 1000 mm X 100 mm	06
Drying Shrinkage	Slab : 1000 mm X 1000 mm X 100 mm	12

Preparation of test specimens

The granite powder was collected from different crusher units and its properties were tested. The aggregates were soaked in part of the mixing water for about 5 min, prior to the start of the mixing operations. 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 sec, the fine aggregates with correct proportions was introduced and mixed in for the period of 15 to 20 sec. This was followed by the final 20% of the water and all the cement were added with fly ash, silica fume and slag which were mixed in until a total mixing time of 60 sec 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 addition of all the other materials during the mixing. After 1 day the demoulded specimens were cured at water temperature of 26°C (±2°C) and 38°C (±2°C). Different batches were adopted for 1 day, 7 days, 14 days, 28 days, 56 days and 90 days of ages. The various strength properties studied were compressive strength, split tensile strength, modulus of elasticity, plastic and drying shrinkage strains. The dimensions and the number of specimens used for the present study are listed in Table 4. The various specimens such as cube, cylinder and slab were cast and tested for studying the variation in strength properties due to the replacement of sand with granite powder after curing for required period.

Experimental procedures

Detailed study was carried out on concrete as per the specifications prescribed in ASTM C 596-89 and IS: 516 (1959) to ascertain the properties. Compressive strength and split tensile strength were determined using compression testing machine (CTM) of 3000 kN capacity and universal testing machine (UTM) of capacity 600 kN. Modulus of elasticity was determined at initial stages of loading. The study of shrinkage is of great importance to concrete engineers, especially when dealing with admixtures. Plastic shrinkage and drying shrinkage are of great value owing to the application of high performance concrete (HPC) in construction. Hence, plastic and drying shrinkage strain characteristics were also studied and the test procedures adopted are described here. Plastic shrinkage measurements were conducted for 24 hrs after casting while drying shrinkage measurements were conducted after the completion of the curing period. Immediately after casting, the slab specimens were kept in open atmospheres at different stages of 26°C (±2°C) and 38°C (±2°C) with the mould. Plastic shrinkage strain was measured by embedding aluminium strips (measuring 25x150x6 mm) to a depth of 100 mm in the slab concrete specimens. The strips were placed at the mid-section of each of the 4 sides of the specimen. The movement of the strips was monitored using liner variable differential transducers (LVDTs) that were connected to a data acquisition system for a period of 24 hrs. Shrinkage readings were recorded every 10 mins during the first 400 mins and every 30 mins thereafter. The drying shrinkage strain was measured after the completion of the curing and readings were taken at 1, 7, 14, 28, 56 and 90 days of drying for 26°C (±2°C) and 38°C (±2°C) curing temperatures. This was done by embedding demec gauges on the surface of the specimens. 2 pairs of demec gauges were fixed on each specimen. Drying shrinkage was measured by measuring the length between the demec gauges with the help of an extensometer.

Results and discussion

Compressive strength

The compressive strength of different concrete mixtures at 26°C and 38°C curing temperatures at different testing ages is presented in Table 5 and illustrated in Fig.1 and Fig. 2. The data presented show that the compressive strength of all the granite powder concrete was closer to that of reference mix (GP0) for all the days of curing. In the present study, significant increase was observed in the concrete mixture with 25% granite powder (GP25). The compressive strength of granite powder concrete was increased when admixtures were used. The compressive strength of GP25 is 2 to 9% higher than that of GP0 for all the days of curing at 26°C and 38°C temperatures. The other mixes with higher than 25% granite powder showed lesser compressive strength than the mix with river sand (GP0). This can be explained in terms of voids present in the concrete mixes with increase of granite powder. It is also shown that the compressive strength increases with the increase in days of curing and decreases with increases in curing temperatures for all the mixtures. The reduction in strength may be due to the effect of higher evaporation rates from the concrete specimens during higher curing temperature. It is to be noted from the figs. 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 could be endorsed that the lower curing age is not sufficient to resist the power. Further it could be observed that no significant deviation in compressive strength was observed for 26°C and 38°C curing temperature, particularly at higher age of curing (28 days to 90 days).

Table 5. Compressive strength of various mixes

Mix Designation	Compressive strength in MPa											
	26°C Curing Temperature						38°C Curing Temperature					
	1 day	7 days	14 days	28 days	56 days	90 days	1 day	7 days	14 days	28 days	56 days	90 days
GP0	7	21	26	35	44	47	5.6	15	22	30	36	43
GP25	7.5	22	28	36	46	48	6.4	18	24	34	38	45
GP50	7	20.5	26	34	44	46.5	6	16	22	31	36	44.2
GP75	6.6	20	25	33	42	46	5.6	15	23	31	36	44
GP100	6.4	18	24	32.5	39	46	5.8	17	22	31	35	44
NA100	6	17	24	32.5	39	45	5.8	14	20	29	34	42

Fig.1 Variation of compressive strength (MPa)with days of curing at 26°C curing temperature

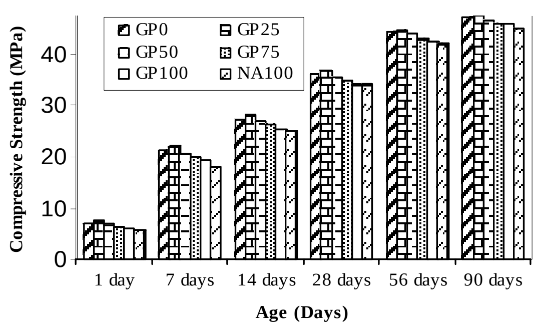


Fig.2. Variation of compressive strength (MPa) with days of curing at 38°C curing temperature

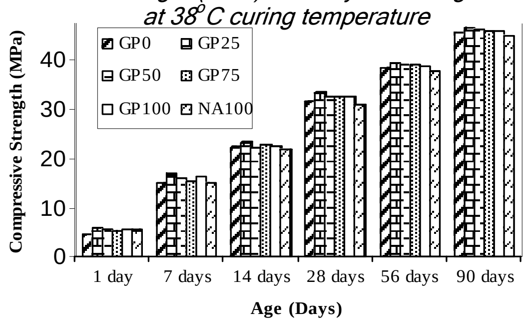
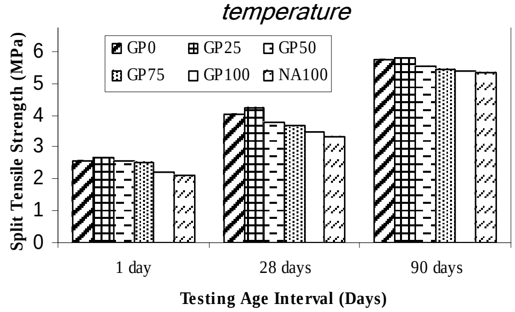


Fig.3. Variation of split tensile strength (MPa) with days of curing at 26°C curing temperature



Split tensile strength

The tensile strength characteristics of HPC are of considerable importance and the split tensile test is a simple

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and reliable method of measuring the tensile strength. The variation of split tensile strength with age of curing at 26°C and 38°C curing temperature is shown in Fig. 3-4. Specimens of 100 mm diameter cylinder have been tested at the age of 1, 28 and 90 days. It is observed from figs. that the tensile strengths decreased with increase of granite powder in the mix and the results indicate that the optimum replacement is 25%. The reduction in strength may be due to the presence of unfilled micro-voids in the concrete mixes with increase of granite powder. These micro-voids might have acted as the weak zones for the initiation and propagation of tensile cracks offering a lower ultimate tensile strength for the hardened composites (Job, 2005). The figures reveal that the split tensile strength of concerned mixes is nearly constant for the 90 days of curing at both 26°C and 38°C curing temperature. This is due to the reason that the increase of days of curing may not have significant effect for different curing temperatures. However test results demonstrate the effect of admixtures in all the concrete mixes. The experimental results of split tensile strength for different concrete mixtures are presented in Table 6.

Fig.4. Variation of split tensile strength (MPa) with days of curing at 38°C curing temperature

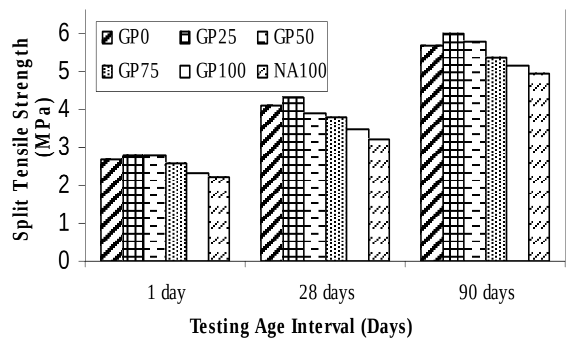

Table 6. Split tensile strength and Modulus of elasticity of various mixes

Mix Design ation	26°C Curing Temperature					38°C Curing Temperature				
	Split tensile strength in MPa			Modulus of Elasticity		Split tensile strength in MPa			Modulus of Elasticity	
	1 day	28 days	90 days	7 days	90 days	1 day	28 days	90 days	7 days	90 days
GP0	2.6	4.2	5.8	33	41	2.4	4	5.6	32	39
GP25	2.9	4.4	6.2	34	43	2.7	4.2	5.8	33	42
GP50	2.9	4	6	33	42	2.4	3.8	5.4	30	39
GP75	2.5	3.8	5.4	30	40	2.2	3.5	5.2	30	36
GP100	2.2	3.5	5.2	29	40	2	3.2	5	30	38
NA100	2	3.2	5	25	35	1.9	3	4.8	24	34

Modulus of elasticity

The Modulus of elasticity of various mixes at 26°C and 38°C curing temperatures can be seen in the Fig.5-6. The measurements were performed at the age of 7 and 90 days. The experimental results of modulus of elasticity for different concrete mixtures are also presented in Table 6.The tests results show that the modulus of elasticity of all the concrete mixtures is almost similar or higher than that of GP0 and NA100 both for 7 and 90 days at 26°C and 38°C curing temperatures. Similar to the strength properties, it is also shown that the modulus of elasticity of concrete mixture with a 25% granite powder (GP25) is about 2% higher than that of GP0 at 90 days of curing at 26°C curing temperatures. This may be the reason that the combination of higher age of curing and the lower curing temperature enhances the strength. It can also be seen from the figs. that the significant improvement in the modulus of elasticity has been observed due to the inclusion of admixtures in the concrete mixes at both 26°C and 38°C curing temperatures. It is to be noted from the numerical results that the modulus of elasticity decreases with increase in curing temperatures for all the mixtures. Hence it can be concluded that the higher curing temperature may be avoided during construction of any buildings.

Plastic shrinkage strain

Of all the 6 mixtures considered, concrete with 25% of granite powder (GP25) was found to be superior to other mixtures as well as GP0 and NA100 for all operating conditions. Hence for shrinkage measurements, 25% of granite powder (GP25) was considered and compared with GP0 and conventional concrete (CC). Figs. 7-8 are a typical presentation of the plastic shrinkage strain of different concrete mixtures GP0, GP25 and CC in the specimen (1x1 m). The data presented in the figures. indicate that the plastic shrinkage increased with the increase of period of exposure to the curing temperatures at 26°C and 38°C. It can be seen from the figs. that the plastic shrinkage strain in the admixtures concrete (GP0 & GP25) specimens was more than that in the conventional concrete. The increase in plastic shrinkage strain of GP25 up to about 900 min of casting is about 638 µm and 630 µm respectively for 32°C and 38°C curing temperatures. After about 900 min of casting, the plastic shrinkage strain in the conventional concrete specimens are 282 µm and 275 µm respectively for 26°C and 38°C curing temperatures. The increased plastic shrinkage strain in the granite powder concrete, GP25 specimens may be attributed to the low bleeding. Even though the plastic strain in the GP25 specimens was more than that in the CC and GP0 specimens, they were not high enough to cause cracking. A threshold value of plastic shrinkage strain that could result in cracking was reported to be around 1100 µm (Al-Amoudi *et al.,* 2004).

Drying shrinkage strain

The drying shrinkage measurements were taken after the completion of curing at the ages of 1, 7, 14, 28, 56 and 90 days of drying for 26°C (±2°C) and 32°C (±2°C) curing temperatures. Fig. 9-10 are a typical presentation

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of the drying shrinkage strain of different concrete mixes GP0, GP25 and CC in the specimen (1x1 m) cured by water ponding. The data presented in the figs. indicate that increasing the curing age, increase the drying shrinkage both at curing temperatures 26°C and 38°C. Further it can be seen from the figs. that the drying shrinkage strain in the admixtures concrete (GP0 & GP25) specimens were more than that in the conventional concrete. The drying shrinkage strain after 90 days of exposure to the curing temperatures at 26°C and 38°C was 298 µm and 282 µm respectively in the conventional concrete, while it was 397 µm and 385 µm respectively in the granite powder concrete (GP25). It is to be noted that the values for drying shrinkage of admixture concretes are very close because of the effect of combination of normal water cement ratio of 0.40 and different admixtures in the concrete mixture.

Fig.5. Variation of modulus of elasticity (GPa) with days of curing at 26°C curing temperature

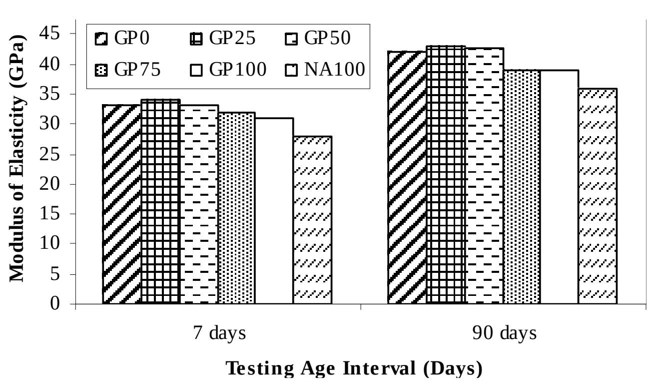
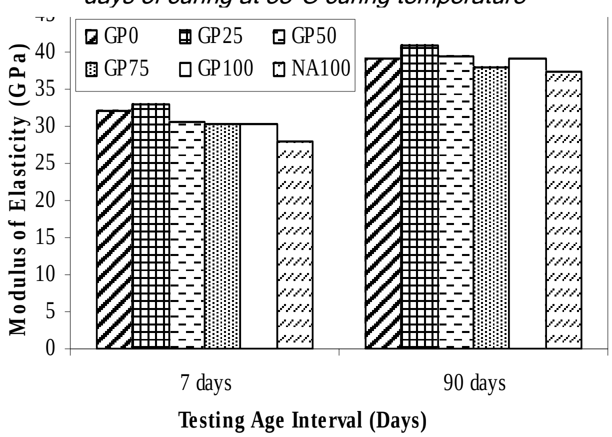


Fig.6. Variation of modulus of elasticity (gpa) with days of curing at 38°C curing temperature



Conclusion

A study on the performance concrete made with granite powder as fine aggregate and partial replacement of cement with 7.5% Silica fume, 10% fly ash, 10% slag and 1% superplasticiser subjected to water curing is conducted for finding the characteristic mechanical properties such as compressive strength, split tensile strength, modulus of elasticity, plastic and drying shrinkage strains of concrete mixtures at 26°C (±2°C) and 38°C (±2°C) for 1, 7, 14, 28, 56 and 90 days of curing for 0.40 water-cement ratio. 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 6 mixtures considered, concrete with 25% of granite powder (GP25) was found to be superior to other mixtures as well as GP0 and NA100 for all operating conditions. Therefore the conclusions are made based on a comparison of GP25 with the conventional concrete with 0% of granite powder, GP0. Mechanical properties such as compressive strength, split tensile strength and modulus of elasticity, particularly in all the ages at both curing temperature of 26°C and 38°C higher than that of the reference mix, GP0. There was an increase in strength as the days of curing increases and decreases as the curing temperature increases. The plastic shrinkage strain was primarily affected by the type of admixtures or other cementitious material used. Plastic shrinkage strain in the GP25 specimens was more than that in the CC specimens. The plastic shrinkage strain in the GP25 specimens was on an average 60% more than that in the CC specimens. The drying shrinkage strain in the granite powder concrete specimens was more than those in the CC specimens. In general, the behavior of granite aggregates with

Fig.7. Variation of plastic shrinkage in 1 x 1 m with days of curing at 26°C water ponding

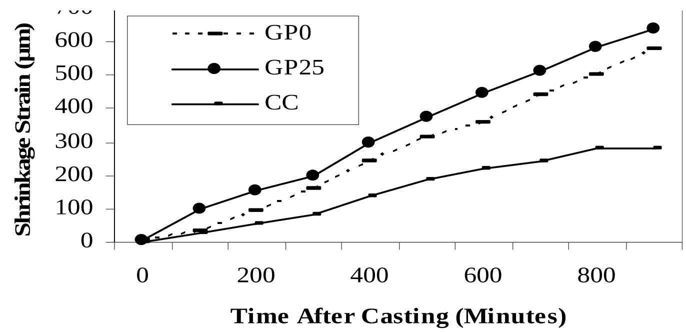
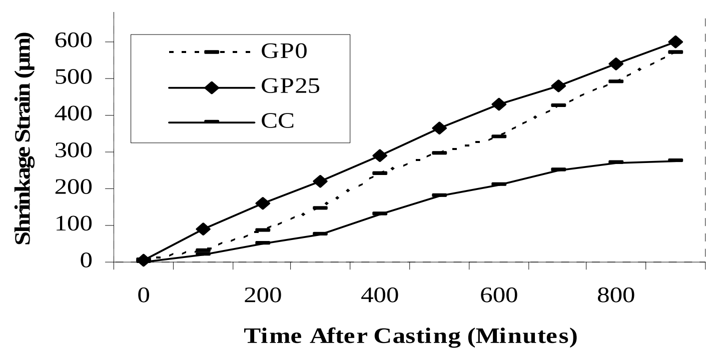


Fig.8. Variation of plastic shrinkage in 1 x 1 m with days of curing at 38°C water ponding



admixtures in concrete possesses the higher properties like concrete made by river sand. Thus granite powder aggregate in concrete is the best choice, where they are available. It is believed that the granite powder concrete will be the benefit of construction industry in the near future.

Fig.9. Variation of drying shrinkage in1 x1 m with days of curing at 26°c water ponding

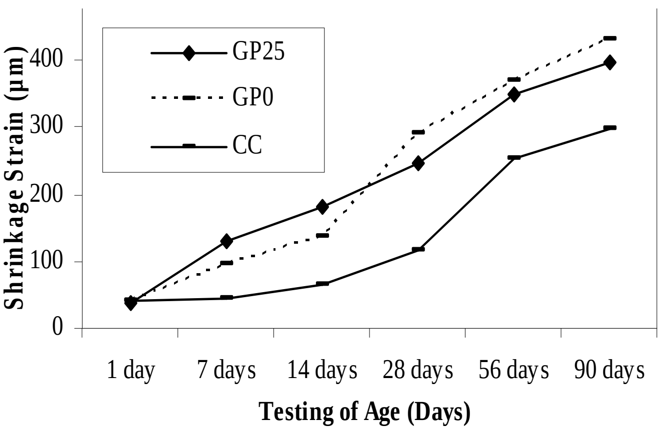
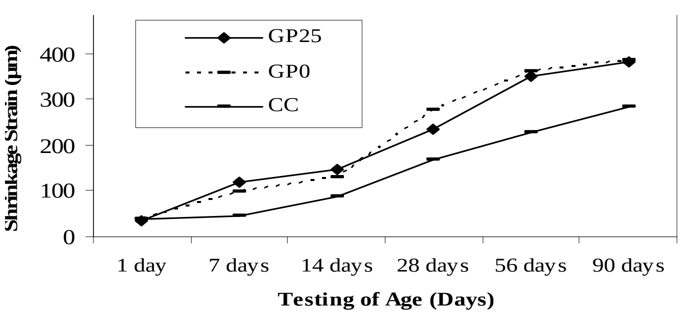


Fig.10. Variation of drying shrinkage in 1 x 1m with days of curing at 38°C water ponding



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