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ISSN 0974-5904, Volume 08, No. 02

International Journal of Earth Sciences and Engineering

April 2015, P.P.301-306

Fire Resistance Test on Granite Powder Concrete

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Abstract: Concrete is probably the most comprehensively used construction material in the world. The most commonly used fine aggregate is river sand. River sand is expensive due to excessive cost of transportation from natural sources. Also large scale depletion of the source creates environmental hazards. These environmental, transportation and other constraints make the availability and use of river sand less attractive. An alternative fine aggregate for concrete industry needs to be found. The main parameter investigated in this study is M30 grade concrete with replacement of sand by granite powder of 0, 25 and 100 percent and cement as partial replacement with silica fume, fly ash, slag and super plasticiser. This paper presents a detailed experimental study on compressive strength of concrete when exposed to fire. Fire resistance on concrete was also studied and percentage of weight loss is compared with different mixtures. Test results indicated that use of granite powder and admixtures in concrete has improved the performance of concrete in strength as well as in fire resistant characteristics.

Keywords: *Granite powder, compressive strength, fire resistance, fine aggregate, admixtures, etc.*

1. Introduction

In all construction industries across the world, the most commonly used fine aggregate is river sand. River sand is expensive due to excessive cost of transportation from natural sources. The global consumption of natural river sand is very high due to the extensive use in concrete. (The demand for natural river sand in developed countries is particularly high for its infrastructural development purposes).

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 are rejected at the industrial sites, 5.2 million tonnes as the form of cuttings/trimmings or undersize materials and 0.4 million tonnes granite slurry are at processing and polishing units. The granite waste that has been dumped unscrupulously results in environment issues.

The present work 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 cost reduction in 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 hydrated cement paste (Bharatkumar et al., 2001). Silica fume, fly ash and blast furnace slag are generally called as mineral admixtures and used as cement replacement materials. These are pozzolanic in character 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 substitutes. These substitutes are pozzolanic in nature and possess cementing properties when mixed with free lime which is similar to that of ordinary Portland cement. The strength and durability properties of the concrete products made from these substitutes are enhanced when either of them are used individually or combined in proper combination with cement and super-plasticizers. In order to obtain high performance to cement concrete, admixtures are added as partial replacement of cement along with super-plasticizer as a water reducer.

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 inclusion of silica fume to cement paste has been observed to provide high early strengths (Mitchell et al., 1998). Silica fume used in concrete displays increased strength development and reduced permeability along with providing a better 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 of 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 a good engineering practice (Adam and 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 and Pierre-Claude, 1998). The concrete with 10% fly ash exhibited higher early strength followed by an excellent development of strength over time (Haque and 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 of 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 units along with admixtures such as silica fume, fly ash, ground granulated blast-furnace slag and superplasticiser as a partial replacement of cement.

C. Selin Ravikumar. et. al. [2013] has indicated the fire resistant test results show that there is a reduction in the compressive strength, after heating the concrete at 300°C for 2 hours. Without the addition of fibre, the decrease in the compressive strength is 32 per cent over its original strength. For 0.5% addition of fibre, the decrease in the compressive strength is 25 per cent over its original strength. Similarly, with 1 percent addition of fibre, the decrease in the compressive strength 10 percent over its original strength. This investigation shows a higher resistance of fibre reinforced concrete to fire when compared to normal concrete. So, glass fibre concrete has better fire resistant characteristics.

Aka Adefemi et. al. (2013) The Carbide Waste (CW) performs satisfactorily as concrete fire resistance if the proportion of the CW is kept at 10 % replacement. The compressive strength of CW concrete compares favourably with that of control in ordinary water at 28 days. Soundness of cement increase as CW content increase. CW has increase influence on both initial and final setting time of OPC concrete; the setting times increase with increase in % of CW. Replacing OPC with 10% of CW would increase the fire resistance of concrete by 14% to that of OPC concrete at 500 °C.

Gai-Fei Pen et.al. [2012] RPC at a low W/B ratio from 0.16 to 0.20 is highly prone to explosive spalling under high temperature. PP fiber has a slightly positive effect on inhibiting explosive spalling RPC, which is not as efficient as in high-strength or high-performance concrete. As a whole, RPC had much higher fracture energy than that of plain concrete. Moreover, fracture energy of RPC after exposure to 600◦C was still quite high. The reason may be that the bonding force of hardened cement paste in RPC is so high that a more pronounced fiber pull out process can take place during fracture of RPC after heating.

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 etc. 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. The plastic shrinkage strain in the conventional concrete specimens are 282 µm and 275 µm respectively for 26oC and 38oC curing temperatures. This increases plastic shrinkage strain in the granite powder 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 percentages 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 32º 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. 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 MPa after 90 days.

The overall test performance exposed that granite powder can be utilized as a partial replacement of natural sand in high performance concrete.

B.B.Patel.et. al (2012) [6] has reported 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% to due excess amount of HRM which reduces the w/b ratio and delays 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 met kaolin in cement enhances 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 by 4.88%.

2. Research Objective

Consequently the main objective of this research is to

1) Determine whether the granite powder concrete is highly resistant to fire as compared to conventional concrete.
2) Investigate the potential use of granite powder in concrete as replacement for natural sand.
3) Determining under what conditions the granite powder, in combination with silica fume, fly-ash, and ground granulated blast furnace slag increases the strength of concrete when these are used as partial replacement materials. 4) 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.

3. Experimental details

3.1. Materials

3.1.1. Cement

The most commonly available Portland cement of 53-grade was used for the investigation. Cement was bought from the same source throughout the research work. While storing cement, all possible contact with moisture was avoided.

3.1.2. Fine aggregate

In the present work, the 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*

S. 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

3.1.3. Coarse aggregate

Broken granite stones were used as a coarse aggregate in concrete. Size of the coarse aggregate used in the investigation was 10 mm – 20 mm. General properties of commonly available granite are given in Table 1. Sieve analysis of the course aggregates was done and passed through the 19 mm size sieve and percentage of passing was 99.

3.1.4. Water

Water is an important ingredient of 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.

3.1.5. Granite powder

Granite belongs to igneous rock family. 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. General properties of commonly available granite are given in Table 1.

3.2. Admixture

3.2.1. Superplasticiser

Superplasticiser 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 superplasticiser was found to be 0.5% to produce slump of 100 mm. The technical details of superplasticiser as per the manufacturer's literature are given in Table 2.

Table 2: *Chemical and Physical Properties of Superplasticiser (%)*

S. 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 ºC

3.2.2. Silica Fume

Silica fume Condensed silica fume is considered as the most efficient micro filler for high performance concrete. Its two fold effects are reduction in w/c ratio and increase in strength of hardened concrete. The silica fume used for this study was in powder form and contained 95% SiO, 0.39% CaO, 0.21% MgO, 0.11% KO, 0.15% NaO, 0.13% AlO, and 40% FeO. 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 percent SiO, 0.39 percent 0.21 percent 2CaO, 0.11 percent MgO, 0.15 percent KO, 0.13 percent NaO, 40 percent AlO and FeO.

The properties of silica fume results in more efficient gel development. Silica fume improves the performance of binder phase considerably and increases the bonding action with aggregate and reinforcement. The properties of silica fume used in this study are given in Table.3.

Table 3: *Physical Properties of silica fume*

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

3.2.3. Fly ash

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. 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.

3.2.4. Slag

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

3.3. Mixing, Demoulding and Curing

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

3.4. Compressive Strength

The compressive loading tests on concrete were carried out on a compression testing machine (CTM) of capacity 3000 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 100 mm cube. The test was performed at 28 days. The specimens were tested immediately after taking the cubes from curing tank in surface dry condition.

3.5. Fire Resistance

The concrete cubes were subjected to elevated temperature of 70ºC, 140ºC, 210ºC and 280ºC for one hour and two hours duration. Afterwards they were tested under Compression Testing Machine to determine their residual strength as generally, the compressive strength of the concrete will be reduced after it is heated.

4. Results and Discussion

4.1. Compressive Strength

The compressive strength concrete mixtures at different testing ages are presented in Table 4 and illustrated in Figure 1, 2 ,3 and 4. The data presented shows that the compressive strength of all the granite powder concretes thermally treated at 70º, 140º, 210º and 280ºC for 1 hour and 2 hours. It was observed that the compressive the 140º, 210º and 280ºC for 1 hour and 2 hours. It was observed that the compressive strength of granite powder specimen increased with temperature to 70ºC and then decrease to 280ºC. Compressive strength of control concrete is 6 per cent higher than that at 2 hours strength and that of granite powder concrete varies from 8 to 34 per cent. Therefore granite powder concrete with admixtures contributes immensely in enhancing the compressive strength of concrete and the increase is 1.23 times that of normal concrete.

Table.4: *Compressive strength of Concrete with the Inclusion of Different Percentage of Granite powder at Different Temperature*

Temperature in °C	Replacement Level in %				Compressive Strength in N/mm^2
	GP0	GP25	NA100	CC	
70	51	52	42	39	1 hour
140	49	48	40	38	
210	46	44	39	35	
280	44	40	37	32	
70	48	49	40	37	2 hours
140	47	47	39	36	
210	46	42	36	34	
280	34	38	34	31	

4.2. Fire Resistance

The concrete cubes were subjected to elevated temperature of 70°C, 140°C, 210°C and 280°C for one hour and two hours duration. Afterwards they were tested under Compression Testing Machine to determine their residual strength as generally, the compressive strength of the concrete will be reduced after it is heated. From Figure 1, 2, 3 & 4, it is obvious that the granite powder concrete exhibits more resistance to high temperature as the percentage of granite powder increased up to 25% and after that resistance to temperature gradually decreases with the increase of percentage of granite powder. It is clear from the experimental investigation that inclusion of granite powder produces increase in strength at lower temperature.

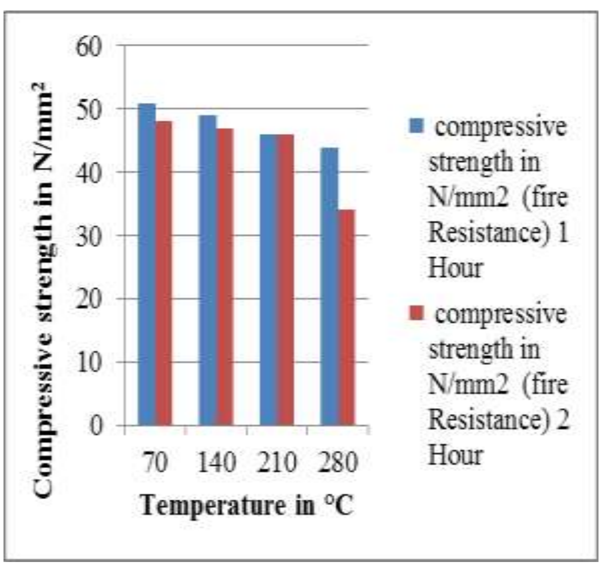

Figure 1: *Compressive strength in N/mm^2 (GP0)*

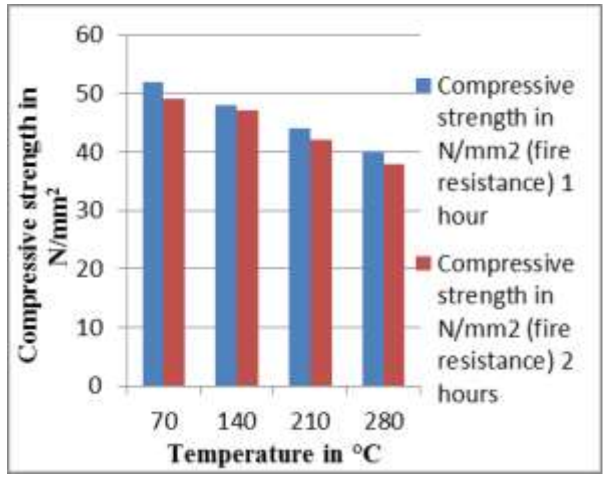

Figure 2: *Compressive strength in N/mm^2 (GP25)*

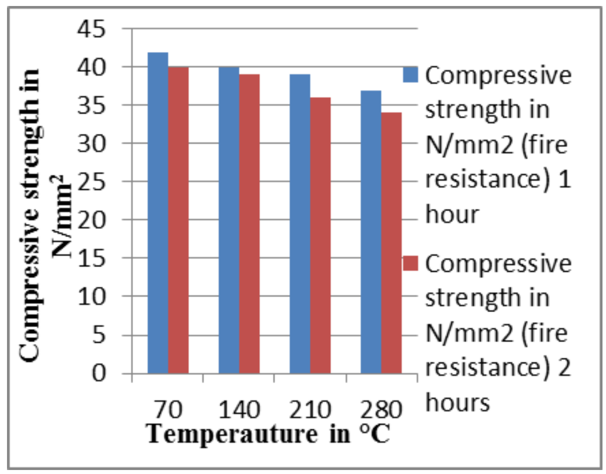

Figure 3: *Compressive strength in (N/mm^2) (NA100)*

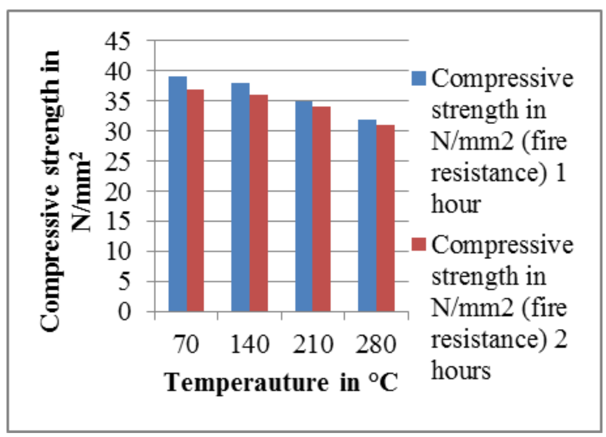

Figure 4: *Compressive strength in (N/mm^2) (CC)*

5. Conclusion

The test results show clearly that granite powder as a partial sand replacement has beneficial effects of concrete. Among the four mixtures considered, GP25 was found to be the most superior one.

Compressive strength, particularly in all the ages was higher than that of the conventional concrete mix. There was an increase in strength as the days of curing increases.

From Figure 1, 2, 3 & 4 it is concluded that the percentage loss of weight in the fire resistance depends upon the replacement of granite powder. The 25% granite powder concrete enhances the resistance and thus can improve the fire resistance of concrete.

The present experimental programme indicates that the strength and resistance of the concrete could enhance the effect of utilization of granite powder f granite powder obtained from the crusher units in the place of river sand in concrete.

References

[1] T. Felixkala and P. Partheeban, "Granite Powder Concrete" *Indian Journal of Science and Technology* vol. 3, No. 3 ISSN: 0974 – 6846, Mar 2010.

[2] Kanmalai Williams C., Partheeban.P, Felixkala.T, "Mechanical Properties of High-Performance Concrete Incorporating Granite Powder as Fine Aggregate", *International Journal on Design and Manufacturing Technologies*, vol. 2, No. 1, Jul 2008.

[3] R.Ilangovana, N. Mahendran, Nagamani, "Strength and durability properties of concrete containing quarry dust as fine aggregate", *ARPN Journal of Engineering and Applied Sciences*, vol. 3, No. 5, ISSN 1819 – 6608, Oct 2008.

[4] H. Binici, M. Y. Durgun, T. Rizaoglu, M. Kolucolakb, "Investigation of Durability Properties of Concrete Pipes Incorporating Blast Furnace Slag and Ground Basaltic Pumice as Fine Aggregates", *Scientia Iranice*, A 19 (3), 366 – 372, 2012.

[5] J. Prabakar, P. Devadas, Manoharan and M. Neelamegam. "Effect of Fly Ash on the Durability and Performance of Concrete", *The Indian concrete journal*, Nov 2011.

[6] B. Chatveera, P. Lertwattanaruk, "Durability Of Conventional Concrete Containing Black Rice Husk Ash", *Elsevier Journal of Environmental Management*, 92, 59 – 66, 2011.

[7] P. Nath and P. Sarker, "Effect of Fly Ash on the Durability Properties of High Strength Concrete", *Elsevier Procedia Engineering* 14, 1149 – 1156, 2011.

[8] N. Bouzoubaa, M. H. Zhang and V. M. Malhotra, "Mechanical Properties and Durability of Concrete Made with High-Volume Fly Ash Blended Cements Using a Coarse Fly Ash' *Elsevier Cement and Concrete Research*, vol. 31, No. 3, pp.1393-1402, Oct 2001.

[9] Fernando Pacheco-torgal- Said Jalali, "Compressive Strength and Durability Properties of Ceramic Wastes Based Concrete", *Elsevier Materials and structures,* 44: 155 – 167 DOI 10.1617/s11527 – 010 – 9616 – 6, 2011.

[10] C. Selin Ravi Kumar and T. S. Thandavamoorthy "Glass Fibre Concrete: Investigation on Strength and Fire Resistant Properties", *IOSR Journal of Mechanical and Civil Engineering* (IOSR-JMCE) e-ISSN: 2278 – 1684, p-ISSN: 2320 – 334X, Volume 9, Issue 3, PP 21-25, Sep – Oct 2013.

[11] Gai-Fei Peng and Yi-Rong Kang "Experimental Research on Fire Resistance of Reactive Powder Concrete", *Advances in Materials Science and Engineering Volume*, Article ID 860303, 6 pages doi:10.1155/2012/860303, 2012.

[12] Aka Adefemi , Usman Muhammad "Effect of Admixture on Fire Resistance of Ordinary Portland Cement Concrete", *Civil and Environmental Research* ISSN 2222-1719 (Paper) ISSN 2222 – 2863 (Online) Vol 3, No.1, Technol., Kuala Lumpur, Malaysia. pp: 57- 66, 2013.