Chemical Resistance of High-Performance Concrete containing chemical admixtures using Granite Sand as fine aggregate

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ABSTRACT

Concrete is a versatile material of construction used globally. River sand and cement are essential materials in concrete. River sand being used as fine aggregate constantly in concrete leads to its depletion which causes strain in environment simultaneously affecting the sustainability in construction. This problem could be solved by replacing the river sand with industrial waste such as granite powder. With the objective of developing concrete for sustainable concrete, it was therefore decided to Sand replaced with granite powder at the rate of 0%, 25%, 50%, 75% and 100%, and silica fume replaced by cement at 7.5%, Fly Ash at 10%, and slag at 10%. To reduce consumption of water, superplasticizer was used at a dosage of 1%. In this research to evaluate the resistances of this concrete to chemical attack such as acid, chloride and sulphate attack for M60 grade of concrete. Control cubes of size 150 mm were immersed in 4% HCl, 4% NaCl and 4% MgSO4 solutions for 28 days, 56 days, 90 days, 180 days and 365 days to check their durability and their resistance to acid regarding extra strength was assessed. In the case of M60 concrete without granite powder were 2.19%, 0.73% and 1.9% and in the case of 25% granite powder concrete were 2.11%, 3.52% and 1.41% for HCl, NaCl and MgSO4 solutions respectively.

KEYWORDS: High – Performance Concrete, Granite sand; Acid, Chloride, Sulphate test.

Introduction

Concrete is a popular construction material next to water prepared from locally available crushed stone and river sand mixed well with a binder called cement with potable water, cast in the desired shape and well cured for 28 days after which subjected to loading. Construction industry accounts for about 11% of India's Gross Domestic Product and has large significance towards economy and employment. The drawback in this system of preparation of concrete is that in the production of cement, CO2 released at the rate 1 ton for every ton of it produced. Therefore, it is imperative to reduce its consumption with the substitution of supplementary cementitious materials available from industries as wastes. Another issue involved in it is that excessive use of river sand depletes the natural resources thus causing strain in the environment. Recently, National Green Tribunal, India (Urmi Goswami, 2013) has imposed restrictions. Overcome this problem, it is advisable to explore the possibility of using alternative materials as fine aggregate. One such material that dumped in a landfill is granite powder. With the beautiful nature of the construction of buildings for residential and official purposes, granite used on a large scale. Studies on properties of new materials like high-performance concrete are of supreme importance for instilling confidence in engineers and builders. The literature indicates that some studies are available on high performance using admixtures and other materials as a replacement of cement and aggregate. However, little information is reported about the usage of granite powder, which is generally considered as a waste material, causes an environmental load due to disposal problem. The use of granite powder as a fine aggregate in the concrete mixture will reduce the demand for natural sand. Thus, this research was conducted to evaluate the durability of granite powder as a sand replacement in the production of high-performance concrete. Granite powder is one of the materials used in high-performance concrete that could be considered as a waste material which could have a promising future in the construction industry as a partial or full substitute of natural river sand. At the same time, some of the admixtures also could be considered as waste materials such as silica fume, slag, fly ash which is used in the construction industry as a partial replacement of cement. For a predominant execution of mixture proportions, it is required to think about logically the properties of concrete. Eventually, the study results will be a foundation to commercialize the concrete mixture and will be a boon to the concrete manufacturing sector. This was the main motivation of the present research study.

1. Materials

1.1 Concrete

Concrete is made usually from a properly proportioned mix of Air, Portland cement, Gravel or crushed stone, Sand and water. In this study Ordinary Portland Cement (OPC) of 53 grades was used. For fine aggregate the river sand, locally available sand was used as per IS code specifications. Granite powder was found that the percentage of passing was 99. Granite was igneous rock family. Granite powder got from the cutting and polishing units. Crushed blue metal was used as a coarse aggregate in the preparation of concrete. The size of the coarse aggregate used in the study was 20 mm and water used in mixing the concrete.

1.2 Admixtures

The admixtures could be considered as waste materials such as silica fume, slag, fly ash which is used in the construction industry as a partial replacement of cement. For a predominant execution of mixture proportions, it is required to think about logically the properties of proposed concrete.

2. Method

2.1 Details of Mix Design

Mix proportion corresponding to M60 grade concrete was designed as per ACI mix design method (Shetty, 1986) and the specimens were cast with such designed concrete. In the developed concrete mix, granite powder (G) was substituted in place of river sand as fine aggregate and the percentages of granite powder added were 0, 25, 50, 75, and 100. Mixes incorporating 0% granite powder and 100% river sand; 25% granite powder and 75% river sand; 50% granite powder and 50% river sand; 75% granite powder and 25% river sand; 100% granite powder and 0% river sand; 100% granite powder and 0% river sand without admixtures were developed. However, all of them contained admixtures like, silica fume, fly ash and slag as cementitious materials. These mixes were designated as G0, G25, G50, G75, G100, and NA100 respectively. Two mixes were prepared separately without admixtures; one with 100% granite powder only and the same was designated as NA100, and another one was conventional concrete with 100% sand and without granite powder and designated as CC. Cement was replaced with silica fume (7.5%). Similarly, fly ash was also added at 10%. Along with these materials GGBFS at the rate of 10% was also incorporated in concrete.

Table 1(below heading 3.1): Details of Concrete Mix for M60 grade (w/c = 0.35)

<table>
<tr><th rowspan="3">Concrete mix</th><th colspan="9">Weight in kg per m^3 concrete</th></tr>
<tr><th rowspan="2">Cement</th><th rowspan="2">Fly Ash (10%)</th><th rowspan="2">Silica Fume (7.5%)</th><th rowspan="2">Slag (10%)</th><th rowspan="2">Super-plasticiser (1%)</th><th rowspan="2">Water</th><th rowspan="2">Coarse Aggregate</th><th colspan="2">Fine Aggregate</th></tr>
<tr><th>Granite Powder</th><th>Sand</th></tr>
<tr><td>G0</td><td rowspan="5">339</td><td>47.4</td><td>35.55</td><td>47.4</td><td>4.74</td><td rowspan="7">166</td><td rowspan="7">1113</td><td>0</td><td>636</td></tr>
<tr><td>G25</td><td>47.4</td><td>35.55</td><td>47.4</td><td>4.74</td><td>159</td><td>477</td></tr>
<tr><td>G50</td><td>47.4</td><td>35.55</td><td>47.4</td><td>4.74</td><td>318</td><td>318</td></tr>
<tr><td>G75</td><td>47.4</td><td>35.55</td><td>47.4</td><td>4.74</td><td>477</td><td>159</td></tr>
<tr><td>G100</td><td>47.4</td><td>35.55</td><td>47.4</td><td>4.74</td><td>636</td><td>0</td></tr>
<tr><td>NA100</td><td rowspan="2">474</td><td colspan="4" rowspan="2">—</td><td>636</td><td>0</td></tr>
<tr><td>CC</td><td>0</td><td>636</td></tr>
</table>

2.2 Mixing, Casting and Curing

Thorough mixing and sufficient curing are most important for obtaining a good concrete. Generally, demoulding was done 24 hours after casting. Locally available water was used for curing concretes. Sample specimens of cylinder and cubes are casted. Immediately after casting and after initial setting, the concrete was water cured by immersing cubes in water. The dimension of various specimens used is shown in Table 2. Specimens were prepared based on the following conditions:

(1) Mixes: G0, G25, G50, G75, G100, NA100 and CC

(2) Curing days: 28, 56, 90,180 and 365 days

Table 2 (below heading 3.2): Details of test specimen

Material properties	**Shape**	**Dimensions of the specimen (mm)**
Compressive strength (28,56,90,180,365 days)	Cubes	150x150x150
Acid resistance test (28,56,90,180,365 days)	Cubes	150x150x150
Chloride resistance test (28,56,90,180,365 days)	Cubes	150x150x150
Sulphate resistance test (28,56,90,180,365 days)	Cubes	150x150x150

Table 3(below heading 3.2): Compressive strength of M60 Concrete

Replacement level	**Total no of specimens**	**28 days**	**56 days**	**90 days**	**180 days**	**365 days**
G0	15	68.5	72	73	74.5	77
G25	15	71	73.2	74.25	76.7	79
G50	15	68	69.5	71.25	72.2	74.7
G75	15	66.5	69	70.5	73	74

G100	15	66	68.8	71	72.2	74
NA 100	15	64	65.8	66.5	67	71
CC	15	67	72	72	73.5	75

3.3 Acid Resistance Test

The weight of the specimen was taken initially. The measuring of acid solution and preparation of acid shown in Figure 1. The acid resistance of the concrete was studied by immersing concrete specimens in 5% HCl solution (Figure 1). To maintain the concentration of solution throughout the test period continuously, the solution was changed at regular intervals immersion period was 28, 56, 90, 180 and 365 days, and after that, the specimens were removed from the curing tank, loose materials from the specimens were removed, and the specimens were wiped dry.

Fig 1(below heading 3.3). Acid resistance test

3.4 Chloride Resistance Test

The chloride resistance of the concretes calculated through a chemical attack by immersion of concrete cubes in 5% NaCl solution. Figure 2 shows in progress of chloride resistance test of M30 concrete. Advances in chloride resistance test on M60 grade concrete is shown in Figure 2. The size of the specimen was 100 mm × 100 mm × 100 mm cube. The NaCl solution was frequently changed to maintain consistent concentration.

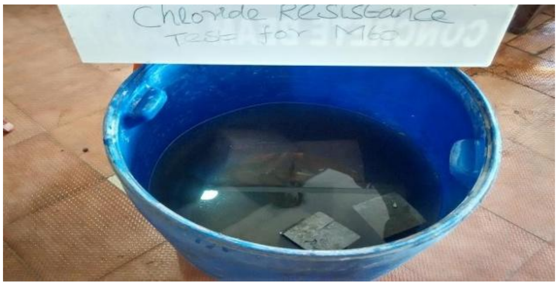

Fig 2 (below heading 3.4). Chloride resistance test

3.5 Sulphate Resistance

This test was conducted on 150 mm × 150 mm × 150 mm cubes by immersing concrete cubes in $MgSO_4$ solution (5%). Figure 3 shows sulphate resistance test on M30 grade concrete. Monitored, measured the specimen masses and determined the weight losses till the test period of 28 days at regular intervals. After sulphate attack, the residual strength was evaluated by compression test on cubes.

Fig 3 (below heading 3.5). Sulphate resistance test

3. Results and Discussion

With reference to M60 grade concrete, the CC category attained the strength of 67 MPa after 28 days of normal curing and before submersion in acid solution (Table 4). The strength of this CC concrete after of 28 days of acid attack was 65 MPa which is 2.99% lower than the strength of CC before immersion. The strength decreased for other days of immersion like 56 days, 90 days, 180 days and 365 (Table 2 and Figure 4) days till the strength reached a value of 58.5 MPa at 365 days. In the case of NA100 concrete, strength attained after 28 days of chloride attack was 62 MPa which is 7.46% lower than CC before immersion in acid. For all other days of immersion, the strength decreased continuously, however, the magnitude of strength was lower than that of CC at every age of submergence in acid solution.

For G0 concrete, the 28th day strength of acid attack was 67 MPa. This is about 3.07% greater compared to CC before submersion. There is a marginal increase in strength after prolonged curing for 56 days. For other ages of submergence in solution the strength was decreasing, however, for 180 and 365 days the strength attained was below that when matched up to the CC before immersion. The G25 concrete has registered a strength value as 69.5 MPa after being immersed in solution for 28days.

This is 3.73% higher when observed with CC before immersion. The strength values for other ages have decreased and except for 56 days the strength remained less while seeing that of the CC concrete before immersion. With the further increase in the percentage addition of granite powder the strength of concrete remained below that of the CC before submergence in acid solution.

Table 4 (below heading 4: para 2). Acid Resistance of M60 Concrete

Replacement Level	**Total No. of Specimens**	**Normal compressive Strength after 28 days**	**After Acid attack Compressive Strength (N/mm^2)**				
			28 Days	**56 Days**	**90 Days**	**180 Days**	**365 Days**
G0	15	68.5	67.0	65.8	64.0	62.5	61.0
G25	15	71.0	69.5	68.0	66.8	65.5	64.0
G50	15	68.0	66.2	65.0	64.0	62.0	60.0
G75	15	66.5	64	62.5	61	58.2	57
G100	15	66.0	62.7	61.0	58.0	57.0	55.8
NA100	15	64.0	62.0	60.0	58.5	56.0	54.0
CC	15	67.0	65.0	63.5	62.0	60.8	58.5

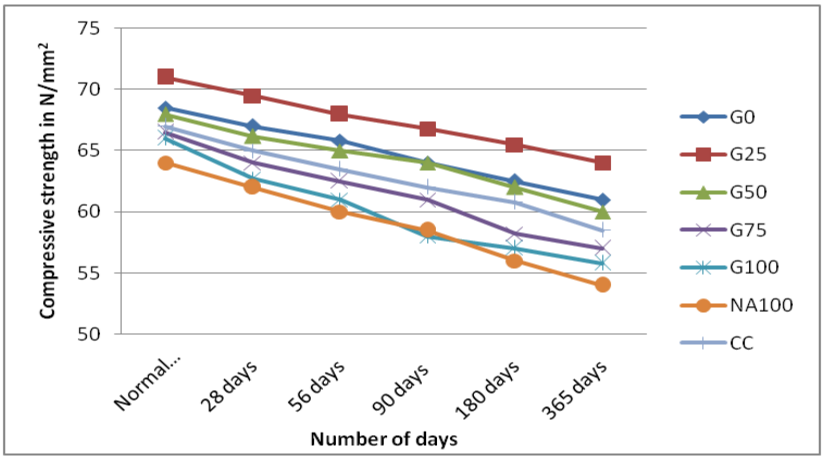

Figure 4 (below heading 4: para 2). Compressive Strength for M60 Concrete after Acid Attack

About M60 grade, the strength of CC was 67 MPa before immersion in chloride solution (Table 3). The 28th day strength after immersion came out to be 65 MPa which was lowered by 2.99% when compared with CC before immersion. The strength of CC diminished further with the increase in the period of immersion. The initial strength of NA100 before immersion in chloride solution was 64 MPa. This is 4.48% lower than that of CC of the corresponding condition. After 28 days of immersion, the NA100 concrete attained the strength of 62 MPa which was 3.125% lower than that of the early strength of the concrete used from the beginning, before immersion. In due course, for further periods of immersion, it was noticed that the concrete strength kept diminishing. In the case of G0 concrete, the strength obtained was 68.5 MPa before immersion in chloride and 28 days after immersion was 68 MPa indicating a decrease of 0.74%. For the subsequent period of immersion in chloride, there is the further decrease in strength values. As for G25, the original strength before immersion was 71 MPa. 28 days after immersion the value came down to 69.5 MPa registering a decrease of 2.11%.

The strength of this concrete diminished further for all other periods of immersion. With the increase in granite content, the strength of G50 and G100 concretes decreased further with the number of days of immersion. The results of chloride resistance of M60 concrete shown in Table 5 and Figure 5.

Table 5(below heading 4: para 4). Chloride Resistance of M60 Concrete

Replacement Level	**Total No. of Specimens**	**Normal compressive Strength at 28 days**	**After Chloride attack Compressive Strength in N/mm^2**				
			28 Days	**56 Days**	**90 Days**	**180 Days**	**365 Days**
G0	15	68.5	68	67.3	67	66.7	66
G25	15	71	69.5	68	66.8	65.5	64
G50	15	68	66.2	65	64	62	60
G75	15	66.5	64	62.5	61	58.2	57
G100	15	66	62.7	61	58	57	55.8
NA100	15	64	62	60	58.5	56	54
CC	15	67	65	63.5	62	60.8	58.5

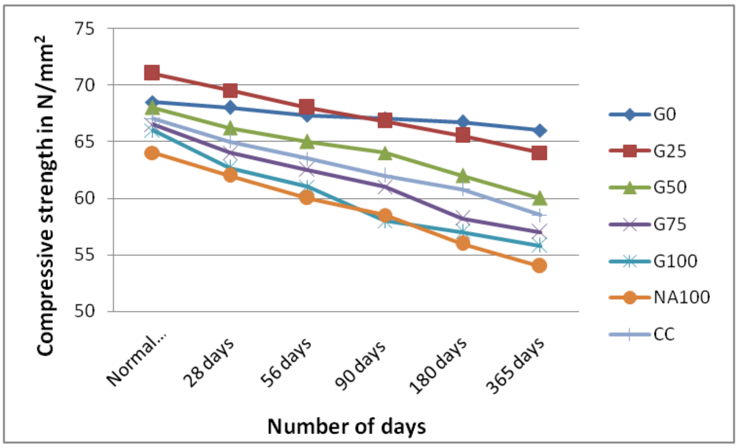

Figure 5(below heading 4: para 4). Compressive Strength of M60 Concrete after Chloride Attack

The sulphate resistance of M60 concrete was given in Table 5 for all ages of immersion in sulphate up to 365 days. The strength of CC of this grade at 28 days was 67 MPa before immersion in the sulphate solution. 28 days after immersion strength of this concrete was 66 MPa. This is 1.49% less besides the initial strength of CC before immersion. The immersion in sulphate solution for remaining days has resulted in constant decrease of the CC's strength. The concrete strength for NA100 was observed as 61 MPa after sulphate attack for 28 days. This is 8.96% lower than that of CC before immersion and has reduced from 64 MPa before immersion. The strength of NA100 for other periods of immersion decreased. In the case of G0 concrete, the strength was 67.2 MPa after 28 days of immersion in sulphate solution as against the initial strength 68.5 MPa before immersion. There a decrease in strength of 1.9%. For the left-over period of immersion, the concrete strength has decreased further mostly not increasing above the strength of CC before immersion.

In the case of G25 concrete at 28 days before sulphate attack was 71 MPa. This value decreased to 70 MPa at 28 days after sulphate attack, a percentage decrease of 1.41 when compared to its value before sulphate attack shown in Figure 6. The strength of this concrete diminished further due to sulphate attack. After 365 days the strength decreased to 66 MPa. This is 5.71% when compared to its value at 28 days. For all other periods of submersion, the decrease in value was still higher than the respective values achieved for CC concrete. It proves that G25 concrete is having better resistance against sulphate attack. With more addition of granite powder, especially in respect of G50 and G100, the strength decreased further and the values, however, were lower than the respective G25 corresponding to the period of immersion.

Table 6 (below heading 4: para 6). Residual Strength after Sulphate Attack for M60 Concrete

Replacement Level	**Total No. of Specimens**	**Normal compressive Strength at 28 days**	**After Sulphate attack Compressive Strength in N/mm^2**				
			28 Days	**56 Days**	**90 Days**	**180 Days**	**365 Days**
G0	15	68.5	67.2	66	65	64.2	63
G25	15	71	70	69	68.2	67	66
G50	15	68	66.8	66	65	64.2	62
G75	15	66.5	65	63.8	63	62.2	61
G100	15	66	63.5	63	62	61	60
NA100	15	64	61	60.25	59.8	58	57
CC	15	67	66	65.2	64	62.8	61

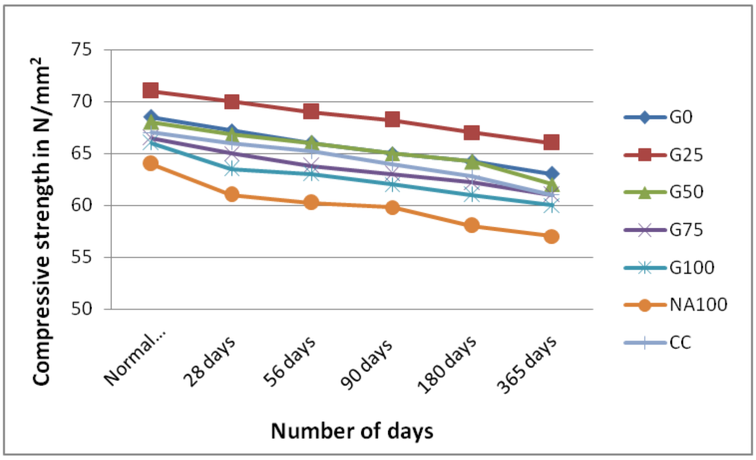

Figure 6 (below heading 4: para 6). Compressive Strength of M60 Concrete after Sulphate Attack

4. Conclusions

The optimum percentage of replacement of granite powder in concrete was found to be 25%. Strength of 25% addition of granite powder to concrete of M30 and M60 grades whose cement was partially replaced with silica fume at 7.5%, fly ash at a rate of 10% and 10% GGBFS. At the same time, sand was being replaced with granite powder at different amounts like 0%, 25%, 50%, 75% and 100%. Extensive testing of the concrete for its strength, durability, rapid chloride penetration, and fire resistance were conducted and results obtained are given below:

a) The same quantity for M60 concrete without granite powder was 2.19% and for 25% addition granite powder to concrete was 2.11%.

b) In the case of M60 concrete, the values were 0.73% for normal concrete and 3.52% for the concrete which contains 25% of granite powder.

c) For M60 grade normal concrete there was a decrease of 1.9% and for concrete made of granite powder at a rate of 25% was 1.41%.

On the whole, the behaviour of concrete containing aggregates made from granite along with admixtures hold the properties equivalent to that of the concrete having river sand.

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