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# Experimental Study on Strength and Durability of Concrete with Partial Replacement of Blast Furnace Slag

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***Abstract:*** **Blast furnace slag (BFS), a by-product of the steel manufacturing industry, being used as an effective partial cement replacement material, has already been proven to improve several performance characteristics of concrete. The reactivity of BFS has been found to depend on the properties of BFS, which varies with the source of BFS, type of raw material used, method and the rate of cooling. In this paper cement replacement level were selected to study the effects of BFS on compressive strength, hydrochloric acid and sulfate resistance in concretes. The number of tests was used to determine the resistance of BFS concrete to sulfate attack. These tests involved immersion in 10% of hydrochloric acid and 15% sodium sulfate solutions.**

**Furthermore, compressive strength of concrete mixtures that keep in water, hydrochloric acid and sodium sulfate were determined at ages up to 56 and 90 days respectively. The experimental results show that at later ages BFS concrete that keeps in water got closer compressive strength to control concrete.**

***Keywords:*** **Blast furnace slag; flexural strength; compressive strength; concrete.**

## 1. INTRODUCTION

The blast furnace slag is a by-product of the iron manufacturing industry. Iron ore, coke and limestone are fed into the furnace and the resulting molten slag floats above the molten iron at a temperature of about 1500oC to 1600oC. The molten slag has a composition of about 30% to 40% SiO2 and about 40% CaO, which is close to the chemical composition of Portland cement. After the molten iron is tapped off, the remaining molten slag, which consists of mainly siliceous and aluminous residue is then water-quenched rapidly, resulting in the formation of a glassy granulate. This glassy granulate is dried and ground to the required size, which is known as blast furnace slag (BFS).

The production of BFS requires little additional energy as compared with the energy needed for the production of Portland cement. The replacement of Portland cement with BFS will lead to significant reduction of carbon dioxide gas emission. BFS is therefore an environmentally friendly construction material. It can be used to replace as much as 80% of the Portland cement used in concrete. BFS concrete has better water impermeability characteristics as well as improved resistance to corrosion and sulphate attack. As a result, the service life of a structure is enhanced and the maintenance cost reduced. In view of the potential advantages of using BFS, the Standing Committee on Concrete Technology (SCCT) endorsed in 2008 the proposal by the Public Works Central Laboratory (PWCL) to conduct a research study to investigate the strength development and durability of BFS concrete. The main aim of the study is to compare the performance of concrete containing various proportions of BFS.

**History of the Use of BFS:**

BFS is not a new product. It has already proven itself reliably in its use all over the world since the mid1800s. Thirty-eight years after the patent for Portland cement was first lodged by John Aspdin in 1824, Emil Langin discovered BFS cement. By 1865, commercial production of lime activated BFS had commenced in Germany and by 1880 BFS was being used with Portland cement as the activator. In 1889 it was used for construction of the Paris Metro. The United States commenced production of slag cements in 1896. Since then Europe, with its many blast furnaces and steel industries has used BFS extensively in all types of structures. By 1914, BFS was being manufactured in Scotland. BS 146 was published in 1923 followed by BS 6699 in 1986 for BFS. In Britain, over 2 million tonnes of BFS is used every year. BFS is also widely used by the cement and concrete industries in continental Europe, with some 17.7 million tones now being used annually. BFS is specified for its many technical advantages and as a means of reducing the environmental impact of the production of Portland cement.

The blast furnace slag is a by-product of the iron manufacturing industry. Silicate and aluminate impurities from the ore and coke are combined in the blast furnace with a flux which lowers the viscosity of the slag. In the case of pig iron production the flux consists mostly of a mixture of limestone and forsterite or in some cases dolomite. In the blast furnace the slag floats on top of the iron and is decanted for separation. Slow cooling of slag melts results in an un reactive crystalline material consisting of an assemblage of Ca-Al-Mg silicates. To obtain a good slag reactivity or hydraulicity, the slag melt needs to be rapidly cooled or quenched below 800 °C in order to prevent the crystallization of merwinite and melilite. To cool and fragment the slag a granulation process can be applied in which molten slag is subjected to jet streams of water or air under pressure. Alternatively, in the pelletization process the liquid slag is partially cooled with water and subsequently projected into the air by a rotating drum. In order to obtain a suitable reactivity, the obtained fragments are ground to reach the same fineness as Portland cement.

## 2. MATERIALS

The materials used in the experiment are:

a. Cement

b. Fine aggregate

c. Coarse aggregate

d. Water

**MINERAL ADMIXTURES:**

The admixtures used in these experiments are:

a. Blast furnace slag

**CHEMICAL ADMIXTURES:**

The chemical admixtures used in this experiment:

a. Super plasticizer-Fosroc (For workability)

## 3. METHOD OF NEXT INVESTIGATION STEP

A) Collection of blast furnace slag

B) Physical Tests to be conducted on blast furnace slag

C) Preparation of mix design for M40 grade

D) Adding of BFS from 40, 45, 50, 55, 60% in cement

E) Making number of samples of concrete cubs

F) Testing of cubes is to be done for 7, 28 & 56 days

The following testes are to be conducted on specimens

- Compressive strength
- Flexural strength

- Durability test
- Thermal test

**Specific gravity of BFS**

Specific gravity of BFS = 2.80

## 4. MIX PROPORTIONS FOR M40 GRADE

Cement = 400 kg/$m^3$

Water = 160 litre

Fine aggregate = 813.38 kg/$m^3$

Coarse aggregate = 1099 kg/$m^3$

Chemical admixture = 0.5 kg/$m^3$

Water – Cement ratio = 0.40

## 5. COMPRESSION TEST

Compression test is the most common test conducted on hardened concrete, partly because it is an easy to perform, and partly because most of the desirable characteristic properties of concrete is related to its compressive strength. The compressive strength of concrete is one of the most important and useful properties of concrete. In most structural applications concrete is employed primarily to resist compressive stresses. In those cases where strength in tension or in shear is of primary importance, the compressive strength is frequently used as a measure of these properties.

Compression test is carried on specimens of cubical in shape. The cube specimen is of the size 150mmX150mmX150mm. The cube moulds were coated with mould oil on their inner surfaces and were placed on Plate. Concrete was poured in to the moulds in three layers each layer being compacted using mechanical vibrator. The top surface was finished using trowel. After 24 hours concrete cubes were de-moulded and the specimens were kept for curing under water.

## 6. CASTING AND CURING

The Cubes and beam moulds are assembled on the concrete leveled flooring with a paper between the mould and the floor. The inner side of the mould is lubricated properly. Cover blocks of sufficient thickness are placed below the bottom of the case so that the required effective depth is maintained. The materials are mixed in the electronically operated mixer thoroughly to get the uniformity. The concrete is placed in the moulds in two layers and compacted with tamping rod. The moulds are de moulded after 24 hours of casting. After the required period of curing, the specimens are taken out of the curing tank, wiped off the moisture and the surface is made dry.

The physical properties of concrete depend to a large extent on the degree of hydration of the cement and the resultant microstructure of hydrated cement. It is necessary to create conditions of temperature and humidity during a relatively short period immediately after placing and compaction of concrete, favorable to the setting and hardening of concrete. The process of creation of a favorable environment is termed as curing. The cube specimen was kept in water for 28 days and column specimens are kept in water for 28 days of curing before conducting the tests.

**Experimental work:**

The specimens required for compressive strength test (both number of specimens and its size) are cast with established Concrete mix proportion, as per the relevant codal requirement, the details of which are as given below. To study the compressive strength behavior of M40 grade incinerator ash concrete in which cement is partially replaced. The cube specimens of size 150mmx150mmx150mm are prepared. The cubes each tested for 7, 28 & 56 days. Compressive strength of modified concrete is compared with normal concrete**.**

## 7. RESULTS AND DISCUSSION

➢ **Compressive Strength**

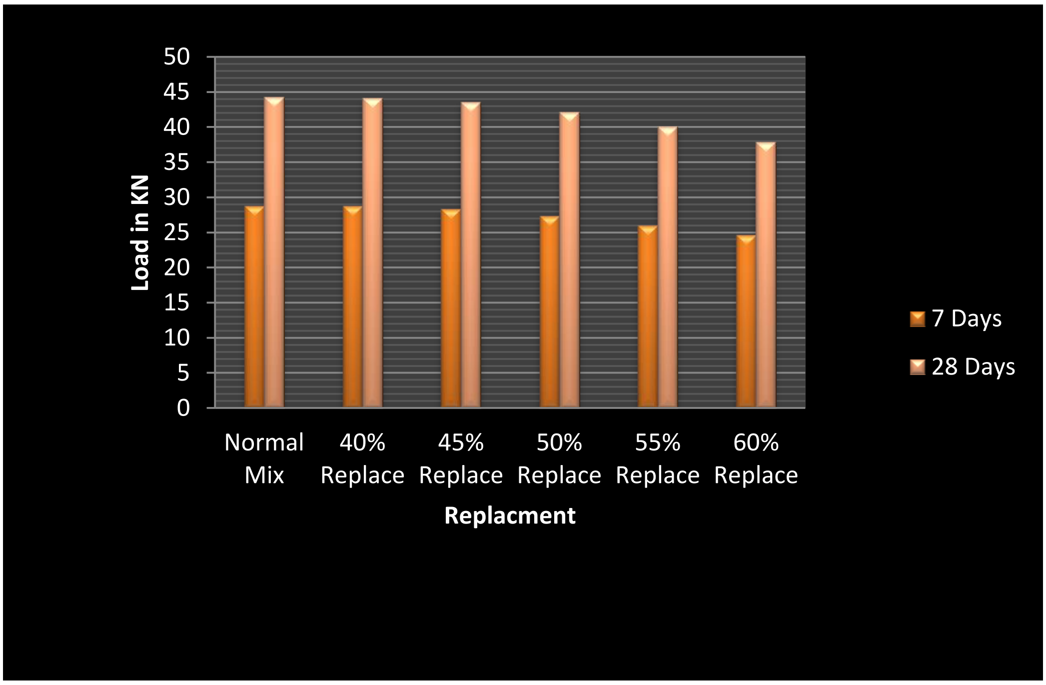


**Fig.1 The strength variation is to be shown in graph**

After the curing period the test results are carried out for all the specimens and found the optimization where the strength is reducing. The strength is varying in the range of 40 to 60%. The value of M40 is nearer to the 53% to 56% replace so that the further value to be fixed to find in between 53, 54, 55 & 56% replacement.

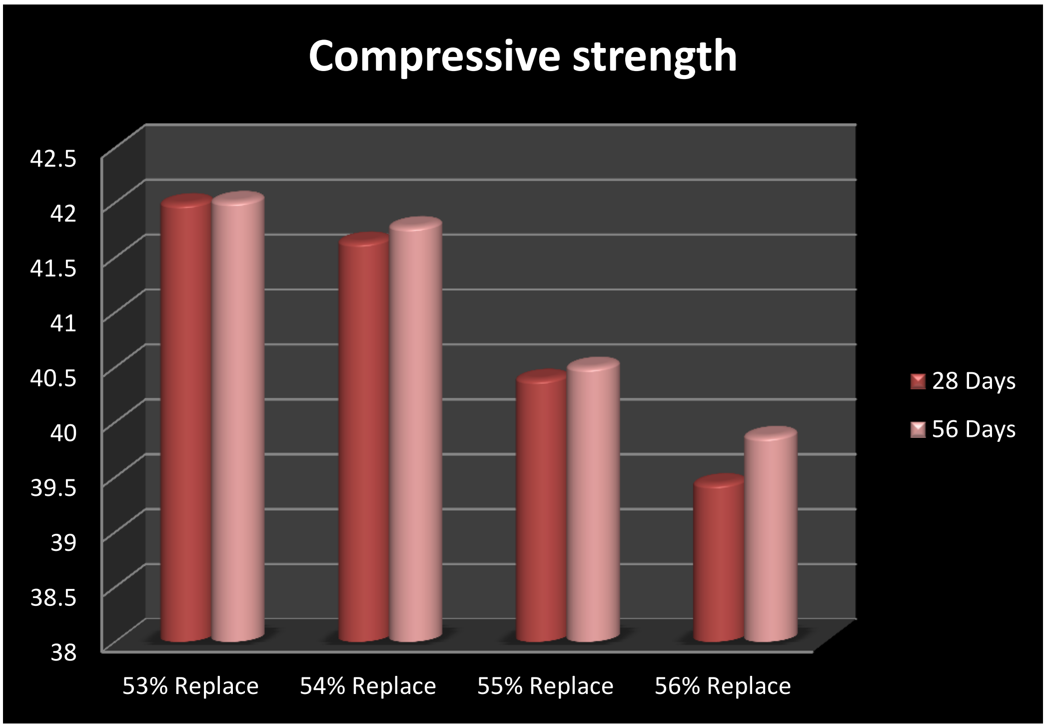


**Fig.2 the Graphical representation of compressive strength of concrete cubes after replacing with BFS in concrete**

The dependence of concrete compressive strength up to level of cement replacement is plotted in fig. 2. The replacement up to 55% does not affect the strength negatively.

**Flexural Strength**

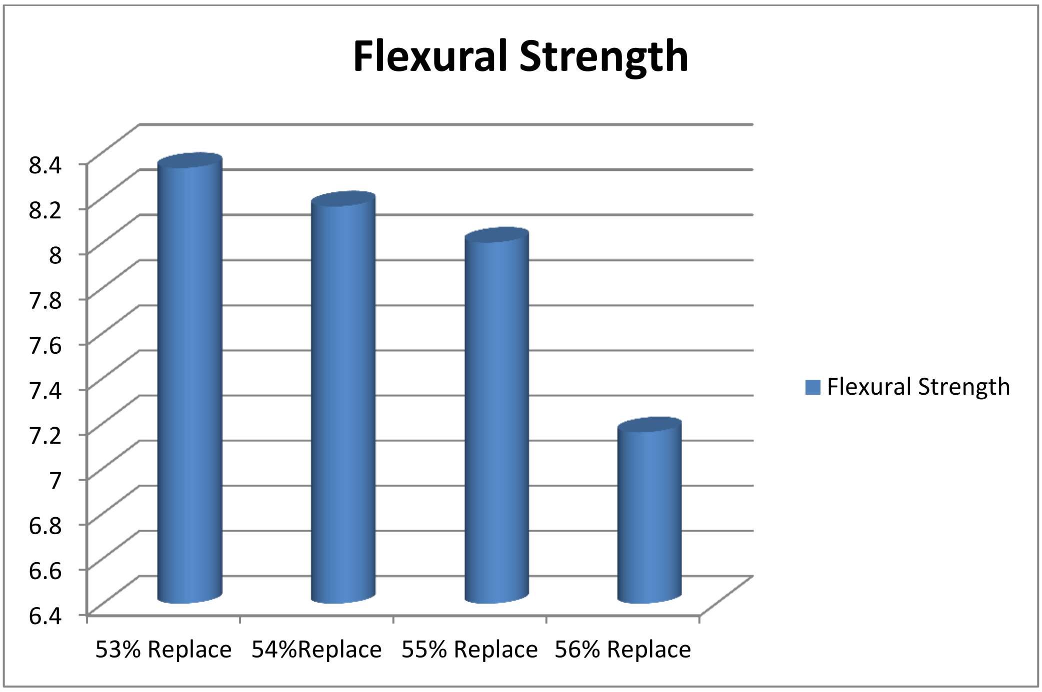


**Fig.3 the final flexural strength results of BFS**

The dependence of concrete flexural strength up to level of cement replacement in plotted in fig. 3. The replacement up to 55 % does not affect the strength negatively.

**Split tensile strength:**

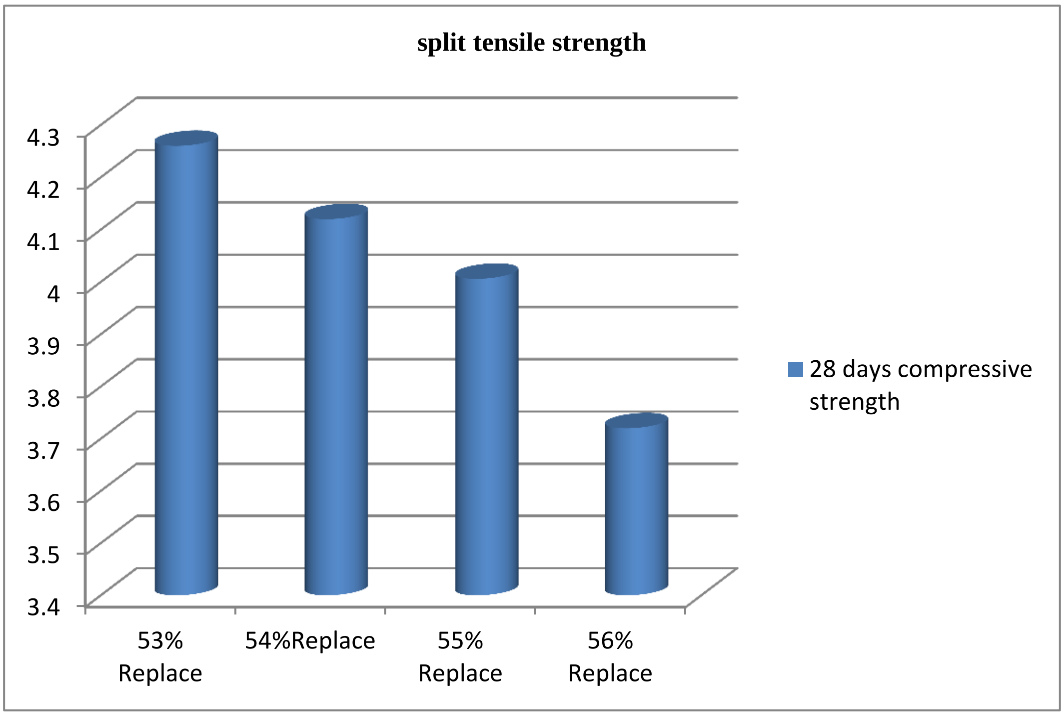


**Fig.4 the final flexural strength results of BFS**

The dependence of concrete split tensile strength up to level of cement replacement is plotted in fig. 4. The replacement up to 55% does not affect the strength negatively. It gains the strength at that level safely

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**Durability Test**

**Acid Test (HCL) of 10%**

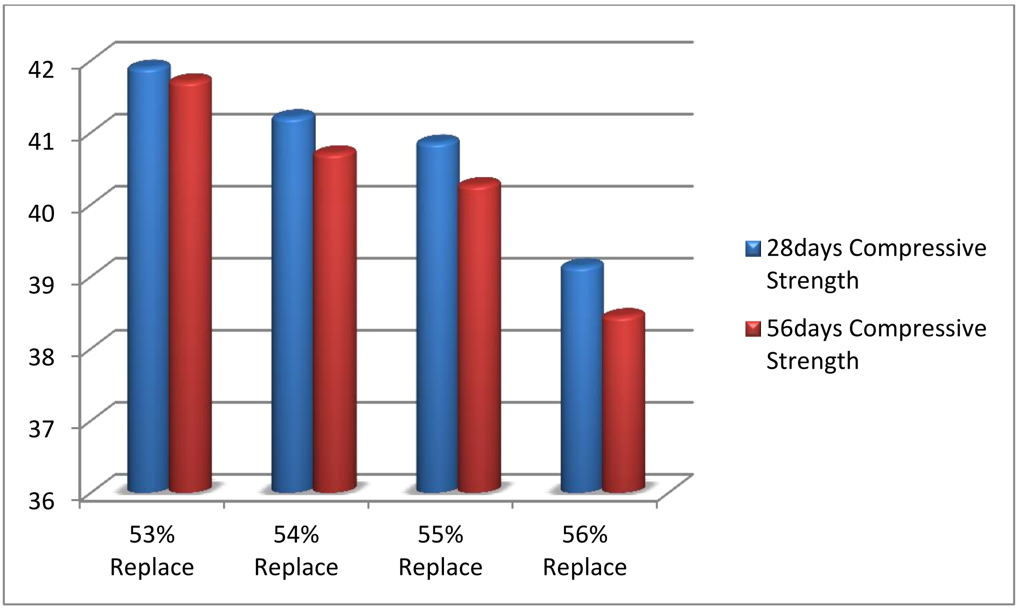


**Fig.5 the final compression strength results after acid attack on BFS concrete**

The dependence of concrete acid test can resist up to level of cement replacement in plotted in fig. 4. The replacement up to 55 % does not affect the strength negatively.

**Base (Na2So4) of 15%**

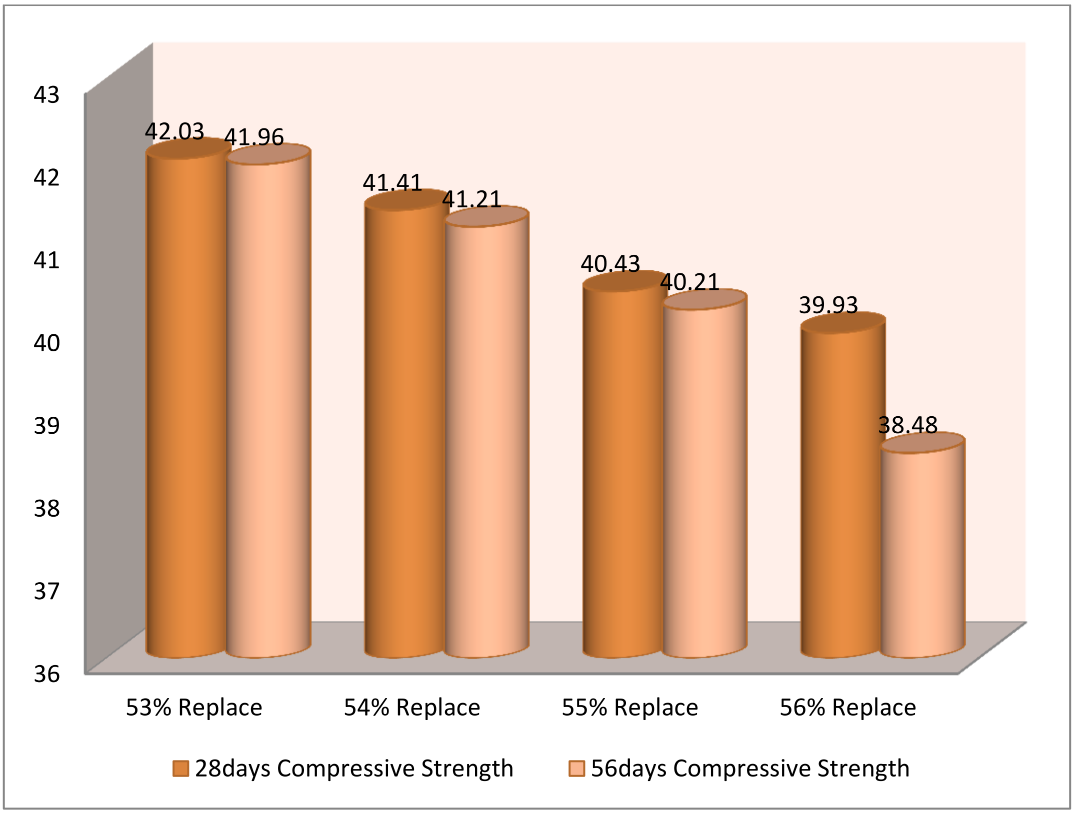


**Fig.6 the final compression strength results after base attack on BFS concrete**

The concrete compression strength after acid and base attack up to level of cement replacement is the negatively affect the strength.

**Thermal test**

**Test results of concrete cubes for 7Days, 7Cycle in Oven.**

The thermal test is carried out in oven with maintaining $80^0$C temperature at day time and at night time should be free at room temperature i.e $0^0$C

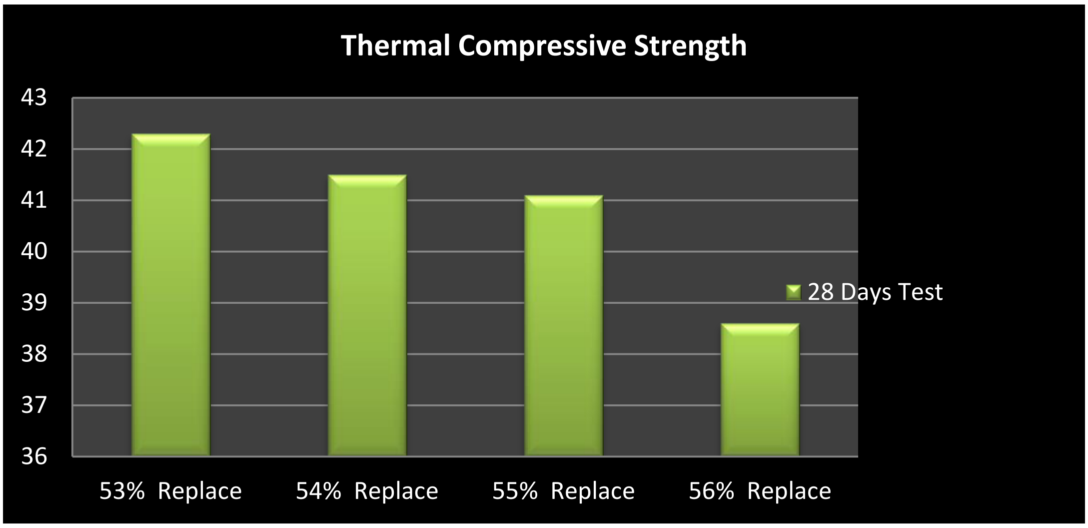


**Fig.6 the final compression strength results after thermal treatment on BFS concrete**

## 8. CONCLUSIONS

1. In all concrete samples that kept on water, as the ages goes up, the compressive resistance soars up, and in all ages studied, the lower w/c ratios indicated higher compressive resistances.

2. After 90 days the samples having 53 % BFS, didn't face a decrease in resistance, gained more compressive resistance in the solution of sodium sulfate and hydrochloric acid.

3. Compare to the normal concrete of M40 grade the 28 days strength is good and the required curing is normal. Due to the partial replacement of cement the

4. Also the amount of BFS in concrete mixtures increases, the all normal water curing, flexural strength, thermal, acid and base the BFS is capable with their standard mix design.

5. The final optimization value that is suitable for all the conditions.

6. Earlier stage strength like 7days strength is getting slower.

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