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Effect on Replacement of Conventional Sand with Used Foundry Sand in Flyash Bricks

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Abstract: *The fast growing continuous technological development has led to enormous amount of waste, the accumulation of which is an environmental concern. The demand of natural sand in the construction industry has increased a lot, resulting in the reduction of availability of natural sand resources. Natural sand deposits are being depleted and causing serious threat to environment as well as the society. In this situation research began for inexpensive and easily available alternative material to natural sand, a sincere attempt has been made in choosing waste/used foundry sand as an alternative and as a partial and full replacement of conventional sand in the Fly ash bricks and the strength property are assessed and is compared with the conventional Fly ash bricks. When compared with CF bricks 28 days Compressive strength of NCF50 Bricks is 5% more and NCF100 is less by 35%. Water absorption capacity of NCF50 is less by 0.8% and NCF100 Bricks is more or less equal, Efflorescence for both NCF50 & NCF100 Bricks is Nil.*

Keywords: *Waste Foundry Sand (WFS), Spent Foundry Sand, Used Foundry Sand (UFS), Fly ash bricks, Fly ash*

I. INTRODUCTION

A. Foundry sand

Foundry sand is high quality silica sand that is a by-product from the production of both ferrous and nonferrous metal castings. Foundry sand used for the centuries as a moulding casting material because it's high thermal conductivity. When sand can no longer be reused in the foundry, it is removed from the foundry and is termed "Used Foundry Sand."(USD)(Fig.1). Foundry sand production is nearly 6 to 10 million tons annually. The raw sand is normally of a higher quality than the typical bank run or natural sands used in fill construction sites. The sands form the outer shape of the mould cavity. These sands normally rely upon a small amount of betonies clay to act as the binder material. There are two basic types of foundry sand available, green sand (often referred to as molding sand) that uses clay as the binder material, and chemically bonded sand that uses polymers to bind the sand grains together. Green sand consists of 85-95% silica, 0-12% clay, 2-10% carbonaceous additives, such as sea coal, and 2-5% water. Green sand is the most commonly used molding media by foundries. Green sands also contain trace chemicals such as MgO, K₂O, and TiO₂. Chemically bonded sand consists of 93-99% silica and 1-3% chemical binder. Silica sand is thoroughly mixed with the chemicals; a catalyst initiates the reaction that cures and hardens the mass. There is various chemical binder systems used in the foundry industry. The most common chemical binder systems used are phenol-urethanes, epoxy-resins, fury alcohol, and sodium silicates.



Fig1: Used Foundry Sand

B. Fly Ash

Fly ash (Fig.2) is the finely divided mineral residue resulting from the combustion of powdered coal in thermal power generating plants. The products formed during the combustion of coal are bottom ash, fly ash and vapor. Fly ash which tries to escapes with the combustion gas from the boiler is collected by either mechanical or electro static precipitator. Fly Ash is an excellent resource

material for construction industry. Bureau of Indian standard BIS-1489 suggested that fly ash up to 35% by mass of cement conforming to BIS-3812 can be used in the manufacture of Portland pozzolanic cement (PPC). Also, IS 456-2000 suggested that up to 35% by mass of cement can be replaced with fly ash in RCC works. The Central Public Works Department, in its circular dated 13.05.2004, permitted to use fly ash in Ready Mixed Concrete (RMC). Fly ash is currently utilized in variety of applications such as Cement manufacture, concrete mixes, fly ash bricks/blocks, light weight aggregates, cellular light weight concrete blocks, autoclaved aerated concrete blocks, roads/embankments etc.



Fig2: Fly Ash

C. Fly Ash Brick

Fly Ash Bricks (Fig.3) are machine made bricks manufactured by hydraulic or vibratory press. Raw materials required for manufacturing Fly Ash Brick are Fly Ash (by-product of thermal power station), hydrated lime, Gypsum, locally available sand/stone dust and water. Ordinary Portland cement can also be used in place of hydrated lime and gypsum. Raw materials in the required proportion are mixed in the pan mixer to have a semi dry uniform mix. Semi dry mix is placed in the moulds of hydraulic/vibro-press. Molded bricks are air dries for one or two days in a shed depending upon the weather conditions and then water cured for 28 days. The brick thus produced are sound compact and uniform in shape. These are produced with or without fog and are uniform in shape and size and therefore requires less mortar in brick work. These bricks are environmental friendly also.

The quality of Fly Ash bricks depends on following factors

- 1) Quality of Raw materials
- 2) Proportioning of Raw materials
- 3) Handling and mixing of Raw materials
- 4) Handling and Pressing of mix
- 5) Curing Period

Proportioning of Raw materials is an important aspect for making desired quality of Fly Ash brick

For Fly Ash, Sand, Sludge lime and Gypsum Bricks

TABLE I: MATERIALS IN FLY ASH, SAND, SLUDGE LIME AND GYPSUM BRICKS

S.no	Material	% by weight
1	Fly Ash	55-60
2	Sand	20-25
3	Sludge Lime	15-20
4	Gypsum	5

For Fly Ash, Sand and Cement Bricks (Considered Brick)

TABLE II: MATERIALS IN FLY ASH, SAND AND CEMENT BRICKS

S.no	Material	% by Weight
1	Fly Ash	50-60
2	Sand	32-40
3	Cement	8-10

D. Objectives

- 1) The main objective is to compensate the scarcity of natural sand.
- 2) Used foundry sand as an alternative for conventional sand?
- 3) To economise the cost of construction works.
- 4) Strength comparison of CF and NCF Bricks.
- 5) Deciding suitable percentage of Used Foundry sand as an alternate for conventional sand.

II. METHODOLOGY

Flow chart showing Methodology for the study is shown below

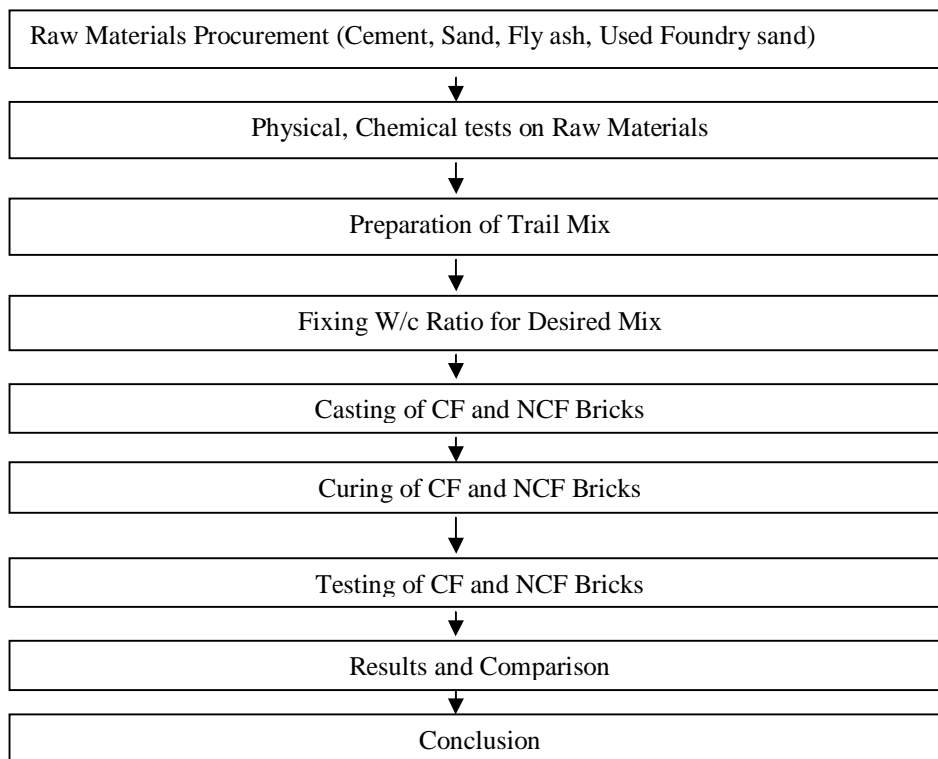


Fig3: Methodology for the study

A. Tests on Conventional and Used Foundry Sand

Tests conducted on the Conventional and Used foundry sand are as follows:-

- 1) Silica Content
- 2) Fineness Modulus
- 3) Specific gravity
- 4) Bulking
- 5) Bulk Density

B. Silica estimation in Conventional and Used Foundry Sand

Weigh accurately 0.5 g of the finely ground test sample in a crucible. Add 3 to 4 g of anhydrous fusion mixture and mix thoroughly. Heat the crucible gently at first and finally at 950° C to 1000°C for at least half an hour with occasional swirling of the melt with

platinum tipped tongs the lid into a platinum dish containing 75 to 100 ml of dilute hydrochloric acid (1: 2) and 2 drops of dilute sulphuric acid (1: 1). Cover the dish with the watch glass. When the reaction ceases, wash the crucible and the lid thoroughly with water. Evaporate the solution over a steam bath until the smell of hydrochloric acid is no longer detected. Finally cover the dish with the watch glass and bake the mass for an hour in an air oven at 105° to 110°C. Cool and digest the contents of platinum dish with about 50 ml of dilute hydrochloric acid (1:2). Filter through fine textured filter paper. Transfer quantitatively all the residue by hot water to the filter paper. Wash the residue five times with hot dilute hydrochloric acid and then with hot water until free from chloride. Preserve the filtrate and washings in a 500 ml beaker for the subsequent determination to get a clear melt. Cool and observe that a transparent mass is obtained. Place the crucible and residual silica. Ignite the paper with the residue in a weighed platinum crucible raising the temperature gradually and finally at 950° to 1000°C for 30 minutes. Cool in desiccators and weigh. Moisten the residue with a few ml of water; add 1 drop of dilute sulphuric acid and 10 ml of hydrofluoric acid. Keep the crucible covered at room temperature for 10 minutes. Then remove the lid and place the crucible on a sand bath for evaporation and continue up to copious fuming. Cool the crucible, add further 5 ml of hydrofluoric acid and repeat the process. Lastly, drive out all the acid to obtain a dry residue. Finally, ignite the residue at 1000°C for 30 minutes. Repeat heating, cooling and weighing until constant mass is obtained.

$$\text{Major silica, \% by mass} = \frac{\text{mass of impure silica} - \text{mass after adding HF}}{\text{mass of sample taken}}$$



Fig4: Conventional and Used Foundry Sand Sample Fig5: Addition of Hydrochloric and nitric acid Fig6: Heating of sample after adding HF

C. Fineness modulus

Fineness modulus is an empirical factor obtained by adding the cumulative percentage of aggregate retained on each of the standard sieves ranging from 4.75 mm to 150 micron and dividing this sum by 100. The sieve analysis is conducted to determine the particle size distribution in a sample of aggregate, which we call gradation. The fine aggregates generally used normally ranges from size of 4.75 mm to 150 micron and the fraction of particle between those sizes is usually termed as Fine Aggregate. The size 4.75 mm is a common fraction appearing both in coarse aggregate and fine aggregate.

TABLEIII: RANGES OF F.M OF DIFFERENT SANDS

S.NO	Type of sand	Fineness Modulus Range
1	Fine Sand	2.2-2.6
2	Medium Sand	2.6-2.9
3	Coarse Sand	2.9-3.2



Fig7: Sieve analysis Test

D. Specific Gravity

Specific gravity is normally defined as the ratio between the weight of a given volume of material and weight of an equal volume of water. The Pycnometer method is used for the determination of specific gravity of fine aggregate. Apparatus required for the experiment are Pycnometer with closed cap and a measuring jar and a weigh balance of 0.1gm accuracy. Clean and dry the Pycnometer. Tightly screw its cap. Take its Weight (W₁) to the nearest 0.1gm. Mark the cap and Pycnometer with vertical line parallel to axis of Pycnometer to ensure the cap is screwed to the same mark each time. After that fill the total pycnometer with water up to the mark and then take the weight of pycnometer full of water. That weight is reported as W₄. Then remove the water and then find out the volume of the pycnometer. After finding out the volume of Pycnometer fill the pycnometer with the fine aggregate sample up to two-third of its total volume and then weigh it. That weight is reported as W₂. Then fill the remaining one third volume of the pycnometer with water and then weigh it. That weight is reported as W₃.

$$\text{Specific gravity } G = \frac{W_2 - W_1}{(W_2 - W_1) - (W_3 - W_4)}$$

W₁ = Weight of empty Pycnometer

W₂ = Weight of the Pycnometer with two-third fine aggregate

W₃ = Weight of the Pycnometer and two-third aggregate, one-third water

W₄ = Weight of Pycnometer filled with water



Fig8: Specific Gravity test on Conventional and Used Foundry Sand

E. Bulking

The volume increase of fine aggregate due to presence of moisture content is known as bulking. Fine sand bulks more as compared to coarse sand. Extremely fine sand particularly the manufactured fine aggregate bulks as much as about 40%. Fine aggregate do not show any bulking when it is absolutely dry or completely saturated. The moisture present in aggregate forms a film around each particle. These films of moisture exert a force, known as surface tension, on each particle. Due to this surface tension each particle gets away from each other. Because of this no direct contact is possible among individual particles and this causes bulking of the volume. Bulking of aggregate is dependent upon two factors they are: Percentage of moisture content and Particle size of fine aggregate. Bulking increases with increase in moisture content up to a certain limit and beyond that the further increase in moisture content results in decrease in volume. When the fine aggregate is completely saturated it does not show any bulking. Fine sand bulks more as compared to coarse sand, i.e. percentage of bulking is indirectly proportional to the size of particle. Due to bulking, fine aggregate shows completely unrealistic volume. Therefore, it is absolutely necessary that consideration must be given to the effect of bulking in proportioning the concrete by volume. The apparatus required for the Bulking experiment are 250 ml measuring cylinder, weighing balance etc. Fill a sample of moist fine aggregate (sand) into a measuring cylinder in the normal manner. Note down the level, say h₁. Pour water into a measuring cylinder and completely cover the sand with water and shake it. Since the volume of the saturated sand is the same as that of the dry sand, the saturated sand completely offsets the bulking effect. Note down the level of sand, say h₂. Subtract the initial level h₁ from final level h₂ (i.e. h₂-h₁), which shows the bulking of sand under test. Calculate percentage of bulking using formula given below.

$$\text{Bulking of sand } (\%) = \frac{H_2 - H_1}{H_2} \times 100$$



Fig9: Testing Bulking of Conventional and Used Foundry Sand

F. Bulk Density

The Bulk density or unit weight of an aggregate gives valuable information regarding the shape and grading of the aggregate. Bulk density shows how densely the aggregate is packed. The Bulk density depends on the particle size distribution and shape of the particles. The higher the bulk density, the lower is the void content. The sample which gives the minimum voids or the one which gives maximum bulk density is taken as the right sample of aggregate. The parameter of bulk density is also used for converting the proportions by weight into proportions by volume when weigh batching equipments is not available. Apparatus required for calculating bulk density are Sand pouring cylinder equipment Containers Balance. Clean and dry test sand is collected in sufficient quantity. The top cap of the sand-pouring cylinder is removed, the shutter is closed, the cylinder is filled with dry test sand up to about one mm from the top and the cap is replaced. The weight of the cylinder with the sand is determined accurate to one gram and is recorded, every time the sand is filled into the cylinder such that the initial weight of the cylinder with sand is exactly W1. The sand pouring cylinder is placed over the calibration cylinder, the shutter is opened and the sand equal to the volume of the calibration cylinder is allowed to flow out and the shutter is closed. . The sand pouring cylinder is now placed on a clean surface, the shutter is kept open till the sand fills up the cone fully and there is no visible movement of sand as seen from the top of the cylinder is removing the cap. The shutter is closed, the cylinder is removed and the sand which occupied the cone is carefully collected from the plate and weighed =W2. The sand pouring cylinder is refilled with sand such that the initial weight is again W1. Now the cylinder is placed centrally on the top of the calibration container and the shutter is opened. When the sand fills up the calibration container and the cone completely and there is no movement of sand, the shutter is closed and the pouring cylinder and the remaining sand is weighed=W3. Then the weight of sand required to fill the calibration container up to the level top can be obtained.

$$\text{Bulk density} = \frac{\text{Weight of sand in calibrating can}}{\text{Volume of calibrating can}}$$



Fig10: Bulk Density Test on Conventional and Used Foundry Sand

Table Iv:Test Results Of Conventional Sand

S.no	Test	Result	Recommendations
1	Fineness Modulus	2.47	Fine (2.2-2.6),Medium(2.6-2.9) Coarse (2.9-3.2)
2	Specific Gravity	2.6	2.5-3.0
3	Bulking (%)	8	Maximum 12
4	Density (Kg/m ³)	1430	1280-1600
5	Silica Content (%)	72.3	90%

TABLEV:TEST RESULTS OF USED FOUNDRY SAND

S.no	Test	Result	Recommendations
1	Fineness Modulus	2.69	Fine(2.2-2.6) Medium(2.6-2.9) Coarse (2.9-3.2)
2	Specific Gravity	2.42	2.5-3.0
3	Bulking (%)	4	Maximum 12
4	Density(Kg/m ³)	1325	1280-1600
5	Silica Content (%)	63	-

IV. TESTS ON 53 GRADE CEMENT

The various tests conducted on cement are tabulated as follows

Table Vi:Test Results Of 53 Grade Cement

S.no	Test	Result	Recommendations
1	Fineness (%)	99	Greater than 90
2	Normal Consistency (%)	30	Between 25-35
3	Setting time(min.)	Initial-10, Final-210	Initial<30, Final<600
4	Soundness(mm)	2	Less than 10
5	Compressive strength (N/mm ²)	54.22	Not less than 53
6	Specific gravity	3.11	3.0 - 3.25

A. Manufacturing of CF and NCF Bricks

Wooden Mould used for the preparation of both Conventional Fly Ash (CF) and Non-Conventional Fly Ash (NCF) Brick and is of Non-Modular size 230×110×75(mm) and Considered weight of one Fly Ash Brick is 3.5Kg (For both CF and NCF Bricks).

B. Composition of Fly Ash Brick

- 1) Composition of Fly Ash Brick (1:4:5) is kept as shown:-
- 2) Cement (53 grade) -10%
- 3) Sand (Conventional) /Used Foundry sand (Non conventional)- 40% Fly ash- 50%

C. Preparation of mix for casting of CF and NCF Bricks

- 1) After adopting suitable water binder ratio, casting of both CF and NCF Bricks are started
- 2) First Fly Ash and sand is mixed in pan-mixture and then cement is added into pan-mixture to have uniform dry mixture.
- 3) After getting the uniform dry mixture, then water is added to dry mix as per w/c ratio and it is mixed uniformly.
- 4) The mixing method adopted is of Hand mixing.

D. Casting of CF and NCF Bricks

- 1) The prepared mix is then transferred into the wooden Moulds and the mix is subjected to tamping with the help of rod.
- 2) Once the bricks are taken out of the mould, they are air dried for about 1-2 days.



Fig11: Preparation of Specimen

E. Curing of CF and NCF Bricks

- 1) After casting, the CF and NCF Bricks are dried for 1-2 days.
- 2) Then the bricks are kept for curing for about 3,7 and 28 days.

F. Frequency of Sampling

A total of 75 bricks are cast. In which 25 are of CF and 50 are of NCF (25 Bricks for NCF50 and other 25 for NCF100 with Used Foundry Sand).

V. TESTSON FLYASH BRICKS

Three tests are conducted on the prepared Conventional and Non-Conventional Fly Ash Bricks. They are:-

A. Compressive strength test

The dimensions of specimen shall be measured to the nearest 1 mm. The number of specimens for the test shall be selected according to IS 5454 : 1976. Apparatus required for the test are compression testing machine, the compression plate of which shall have a ball seating in the form of portion of a sphere the centre of which coincides with the centre of the plate, shall be used. Place the specimen with flat faces horizontal and between the two plywood sheets of same length and breadth and carefully centered between plates of testing machine. Apply load axially at a uniform rate of 140 kg/cm²/min till the failure occurs and note the maximum load at failure. The load at failure shall be maximum load at which the specimen fails to produce any further increase in the indicator reading on the testing machine. In place of plywood sheets plaster of Paris may be used to ensure a uniform surface for application of load.

$$\text{Compressive Strength} = \frac{\text{Ultimate load at failure}}{\text{Area of contact}}$$



Fig12: Compressive strength test on CF and NCF Bricks

B. Water Absorption Test

Water absorption test is done to determine the water absorbing capacity of Conventional and Non-Conventional Fly Ash Brick. To determine the percentage of water absorption of bricks. Apparatus used for this test are sensitive balance, oven.

Dry the specimen in a ventilated oven at a temperature of 105 to 115°C till it attains substantially constant mass. Cool the specimen to room temperature and obtain its weight (M1). Specimen warm to touch shall not be used for the purpose.

Immerse completely dried specimen in clean water at a temperature of 27 f 2°C for 24 hours. Remove the specimen and wipe out any traces of water with a damp cloth and weigh the specimen. Complete the weighing 3 minutes after the specimen has been removed from water (M2). Water absorption, percent by mass, after 24-hour immersion in cold water is given by the following formula:

$$Waterabsorption(\%) = \frac{M2 - M1}{M2} \times 100$$

C. Efflorescence test

Efflorescence is the usual terms for deposit of soluble salts, formed in or near the surface of a porous material, as a result of evaporation of water in which they have been dissolved. Usually sulphate of magnesium, calcium, sulphate and carbonate (and sometimes chloride and nitrates) of sodium and potassium are found in efflorescence. Apparatus required for the efflorescence test is a jar containing distilled water to completely saturate the specimen in water. Place the end of the bricks in the dish, the depth of immersion in water being 25 mm.. Place the whole arrangement in a warm well ventilated room until all the water in the dish is absorbed by the specimens and the surplus water evaporates. Cover the dish containing the brick with suitable glass cylinder so that excessive evaporation from the dish may not occur. When the water has been absorbed and bricks appear to be dry, place a similar quantity of water in the dish and allow it to evaporate as before. Examine the bricks for efflorescence after the second evaporation and report the results as:

- 1) When there is no perceptible deposit of efflorescence it is reported as Nil.
- 2) Not more than 10% area of the brick it is reported as Slight.
- 3) Covering up to 50% area of the brick, it is reported as Moderate.
- 4) Covering 50% or more but unaccompanied by powdering or flaking of the brick surface, then it is reported as Heavy.
- 5) When, there is a heavy deposit of salts accompanied by powdering and/or flaking of the exposed surfaces, and then it is reported as Serious.

VI. TEST RESULTS AND COMPARISION

A. Compressive Strength Test

TABLE VII:3, 7 AND 28 DAYS STRENGTH OF BRICKS

S.no	Days	CF Brick(N/mm ²)	NCF Brick(N/mm ²)	
			50% Replacement (NCF50)	100% Replacement (NCF100)
1	3	4.23	4.71	4.22
2	7	8.73	9.52	5.28
3	28	10.67	11.22	6.91

B. Water Absorption test

TABLE VIII:RESULTS OF WATER ABSORPTION TEST

S.no	Type of Brick	Water Absorption (%)	
1	CF Brick	10.4	
2	NCF Brick	50% Replacement	9.6
		100% Replacement	10.3

C. Efflorescence test

TABLE IX:RESULTS OF EFFLORESCENCE TEST

S.no	Type of Brick	Efflorescence
1	CF Brick	Nil
2	NCF Brick	50% Replacement
		100% Replacement

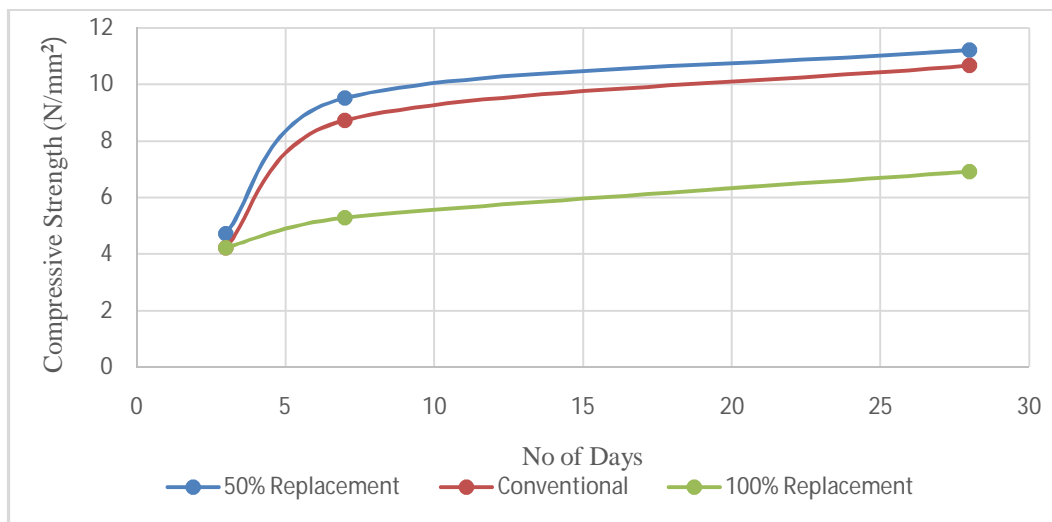


Fig13: Strength Comparison of CF and NCF Bricks

VII. CONCLUSIONS

A. Summary

1) By Comparing results of NCF Bricks (50% and 100%), It is observed that NCF 50% Replacement Brick has shown better results.

B. When compared with Conventional Fly Ash (CF) Bricks it is observed that :-

- 1) 28 days Compressive strength of NCF50 Bricks is 5% more.
- 2) 28 days Compressive strength of NCF100 Bricks is less by 35%.
- 3) Water absorption capacity of NCF50 is less by 0.8%.
- 4) Water absorption capacity of NCF100 Bricks is more or less equal.
- 5) Efflorescence for both NCF Bricks (50% and 100% replacements) is Nil.

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