Experimental Study on Structural Beams Using Waste Foundry Sand and Phosphogypsum

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Abstract— This experimental research was conducted to study the effect of waste foundry sand and phosphogypsum on structural beams. Phopshogypsum is a byproduct of phosphate based fertilizers. Foundry sand (FS) is a by-product from the metal alloys casting industry with high silica content. This project is relevant as cost of the building material is increasing and availability of the material is decreasing, which leads to many environmental issues. M25 mix concrete was used in the study. The fine aggregate was replaced by foundry sand and cement with phosphogypsum in different proportions. Quarry sand was replaced at 10, 20, 30, 40 and 50% by foundry sand while cement replaced at 4, 6, 8, 10 and 12% with phosphogypsum. The strength properties of the mixes were compared with that of conventional concrete mix. Strength tests such as compressive strength, split tensile strength and flexural strength tests were conducted. The results say that the maximum strength was obtained at an optimum replacement of 30% foundry sand and 10% Phosphogypsum. The beam test results showed good characteristics with respect to the load deflection curves. The replaced material mixes are strong enough as well as economical.

Keywords— Phosphogypsum, Foundry sand, Quarry sand, optimum replacement, silica content, load deflection characterestics.

INTRODUCTION

Construction is a continuous process involved in rising new structures, demolishing old ones and fulfillment of the needs of mankind providing shelter, developing industrial areas and providing a basic foundation for all advancements. For construction there are a wide variety of materials being used especially due to the fast advancing techniques and inventions in this field. Yet the material that meets the standards and which is being termed a "conventional material" is concrete. The reason behind such a terminology must be due to the easy availability of materials, low cost, ease of use, strength characteristics and durability to withstand adverse conditions. In this era of advancement in almost every field, countries worldwide are developing at a steady and speedy rate to secure titles of being a "developed country". A few problems occurring due to construction is pollution as a result of cement manufacture and lack of resources.

Foundry sand is high-quality silica sand that is used to form molds for ferrous and nonferrous metal castings. They can stand close to the concept of green concrete as it is compatible with the environment. Foundry sand is reused routinely and as the process goes on the particles eventually become too fine for the molding process and finally is discarded as spent foundry sand (SFS) or used foundry sand (UFS). In the long run, this disposal results in millions of tonnes of UFS as landfill. Based on researches done in the past few decades, FS has been utilized in highway applications, but the amount re-utilized was still negligible. For this reason, there is a need to utilize FS in other ways become very imperative. Recently, research has been carried out on the utilization of FS in concrete and concrete related products.

Phopshogypsum contributes in replacing cement partially in order to reduce the problems caused due to cement manufacture. Phosphogypsum is the gypsum formed as a byproduct of phosphate based fertilizer industries. It is produced as solid chemical hazardous waste or byproduct in industries, by wet or dry processes by action of sulphuric acid on phosphate rocks. It is slightly radioactive and hence the disposal of it in form of landfills is a threat to the surroundings and hence effective ways of disposal should be found out in order to make sure that it is safely disposed off without causing any threat to the environment

SIGNIFICANCE OF THE WORK

A. Scope of the Work

Based on the research works already done, it is seen that replacement of constituents of concrete is effective keeping in view the strength aspects as well as economy. Different replacement materials have been studied so far in order to reduce the use of cement and fine aggregate. The increasing pollution as well as lack of resources has lead researchers to find alternate materials to replace the constituents in conventional concrete. To reduce the consumption of river sand, used foundry sand is being used and cement is being replaced with phosphogypsum.

B. Objective of the Work

The objective is replace cement with phosphogypsum and fine aggregate with foundry sand respectively in order to reduce their consumption as well as keep it economical.

C.Methodology

The methodology of the work consists of: (1) Selection of concrete grade; M25

(2) Mix design for M25 grade concrete

(3) Casting specimens to find the optimum replacement- 0, 4, 6, 8, 10 and 12% for phosphogypsum and 0, 10, 20, 30, 40 and 50% for foundry sand

(4)Workability, compressive strength, splitting tensile strength and flexural strength tests of concrete were conducted. (5) Optimum percentage of both phosphogypsum and foundry sand was determined.

(6) based on the optimum percentage obtained, RC beams were cast to test strength aspects of the material and study load deflection characteristics.

MATERIAL TESTS

TABLE I

MATERIAL TEST RESULTS

Test	Material	Equipment	Values
Specific Gravity	Ordinary Portland	Le-Chatelier	3.15
Specific Gravity	Fine Aggregates	Pycnometer	2.7
Specific Gravity	Coarse Aggregates	Vessel	2.94
Workability	M25 Concrete	Slump Cone	100mm

TABLE II

PHOSPHOGYPSUM PROPERTIES

Property	Results
Fineness	16%
Specific gravity	2.72

Table III

FOUNDRY SAND PROPERTIES

Property	Results
Specific gravity	2.7

MIX DESIGN

TABLE IV

MIX PROPORTIONS

Cement (Kg/m^3)	374.30
Fine aggregate (kg/m^3)	751.03
Coarse aggregate (Kg/m^3)	1280.31
Water (l/m3)	149.72
Water cement ratio	0.40
Mix ratio	1:2.006:3.420

TABLE V

VARIOUS MIXES

Mix	Phosphogypsum (%)	WFS (%)
CM	0	0
P4	4	0
P6	6	0
P8	8	0
P10	10	0
P12	12	0
F10	0	10
F20	0	20
F30	0	30
F40	0	40
F50	0	50
P10F30	10	30

Fig.1 Cast specimens

EXPERIMENTAL INVESTIGATION

A. Experimental Procedure

A total of 188 specimens were cast and tested. Details of specimens cast are shown in Table VI. Five ratios each were selected to replace cement and fine aggregate. CM denotes the control specimen. P denotes Phoshphogypsum mix ratios. For example F10 denotes a mix with 10% foundry sand. Based on the optimum percentages, 8 RCC beams were cast.

B. Compressive strength

For compressive strength test, cube specimens of dimensions 150 x 150 x 150 mm were cast for M25 grade of concrete. These were then covered using plastic and later on after 24 hours they were unmoulded and kept for curing in curing tanks

C. Split tensile strength

For Split tensile strength test, cylinder specimens of dimension 150 mm diameter and 300 mm length were cast. The specimens were demoulded after 24 hours of casting and were transferred to curing tank wherein they were allowed to cure for 28 days.

D. Flexural strength

For flexural strength test beam specimens of dimension 100x100x500 mm were cast. Flexural strength specimens were tested under two point loading as per I.S. 516-1959, over an effective span of 400 mm on Flexural testing machine. Load and corresponding deflections were noted up to failure.

TABLE
VI

DETAILS OF
SPECIMENS CAST

Sl. No.	Specimen	Size (mm)	Nos36.
1	Cubes	150 x 150 x 150	72
2	Cylinders	300 x 150 ϕ	36
3	Cubes	100 x 100 x 100	36
4	Prisms	100 x 100 x 500	36
5	RC beams	150 x 200 x 1250	8

Dimension of all the specimens are 150mm x 200mm x 1250mm, with an effective span of 990mm.Main reinforcement provided is 3# 12mm diameter bars, 2# 8mm diameter bars are provided as anchor bars and stirrups are provided as 8 mm diameter bars @ 130mm c/c. Two point loading using 50t loading frame was used for testing the specimens. Thus a total of 12 mixes including control mix were cast, cured and tested for.

E. Beam Test Procedure

Beams were tested using a 50t loading frame. Dial gauge was used to determine the deflection at the center of the beam. The behaviour of the beams was keenly observed from beginning to failure. The strength of the beam was tested as a two point loading system using a hydraulic jack attached to the loading frame.

The appearance of the first crack, and the development and the propagation of cracks due to increase in the load were also recorded. The loading was continued after the initial crack formation and was stopped when the beam was just on the verge of collapse. The values of load applied and deflection are noted directly and further the plot of load vs deflection is performed which is taken as the output. The load in kN is applied with uniformly increasing the value of the load and the deflection under the different applied loads is noted down. The applied load increased up to the breaking point and the ultimate cracking load was noted. The reinforcement details are provided below

Fig.2 Experimental setup of beam specimen

TABLE VII

REINFORCEMENT DETAILS

Specimen	Longitudinal Reinforcement	Stirrups	FS (%)	PG (%)
RB	3# 12 mm ϕ bars	8 mm dia @ 130mm c/c	0	0
FSB30	3# 12 mm ϕ bars	8 mm dia @ 130mm c/c	30	0
PFB10	3# 12 mm ϕ bars	8 mm dia @ 130mm c/c	0	10
P10F30	3# 12 mm ϕ bars	8 mm dia @ 130mm c/c	30	10

EXPERIMENTAL RESULTS

A. Workability

Workability of all mixes were found out. The workability of the mix reduced on adding the materials. The harshness of foundry added mixture must be due to presence of very fine particles in it. The mix was seen to have a compaction factor of 0.89.

B. Compressive strength on concrete cubes

Fig. 4 shows the 7 day and 28 day compressive strength. It is observed from the graph that there was a gradual increase in compressive strength of concrete on the addition of foundry sand. This increase was seen till 30% beyond which it dropped. Fig 5 shows the variation of compressive strength with increase in phosphogypsum replacements by 0, 4, 6, 8, 10 and 12%. The plot shows a gradual increase in compressive strength values of concrete. The increase is till 10% beyond which it decreases.

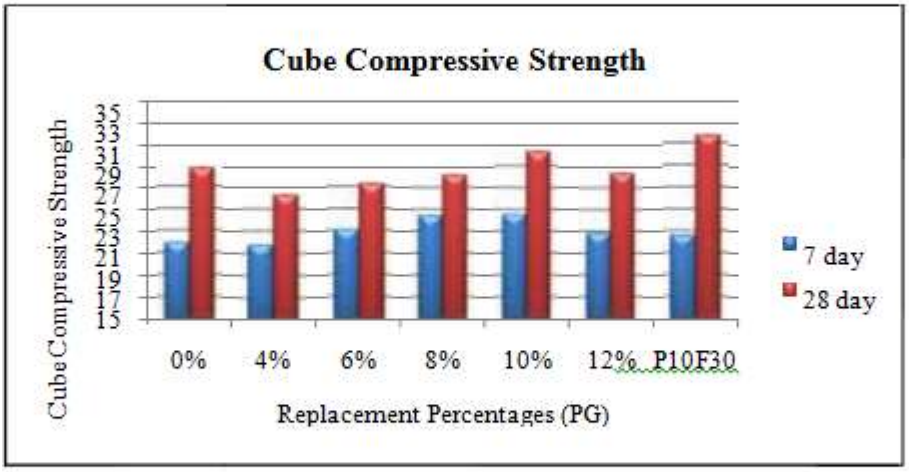

Fig 3. Variation in compressive strength for various mixes of Phosphogypsum

Fig 4. Variation in compressive strength for various mixes of foundry sand

C. Split tensile strength

Split tensile strength for Phosphogypsum incorporated concrete showed a similar trend of increase till 10%. Same is the case for foundry sand where it is seen to be increasing up to 30% replacement. Further replacement shows a decreasing trend. Fig 5 and 6 shows the variation of split tensile strength in case of Phosphogypsum and foundry sand respectively.

D. Flexural strength

Flexural strength increased in both mixes of phosphogypsum and foundry sand. The trend is similar to that of split tensile strength. The plots are given in figures 7 and 8

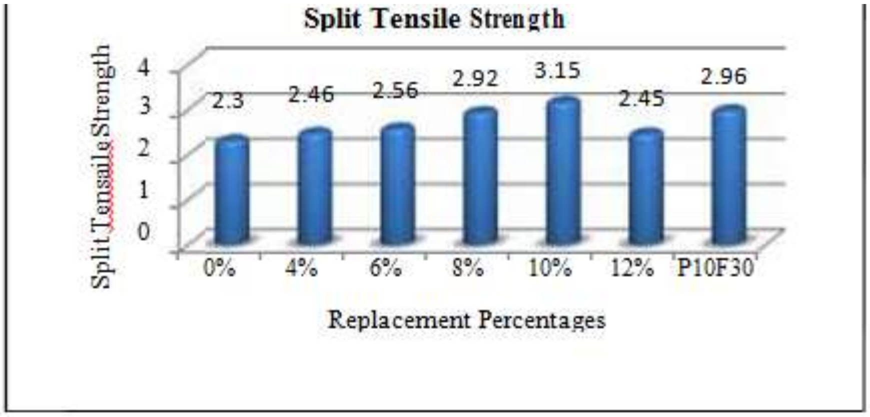

Fig 5. Variation in Split tensile strength for various mixes of Phosphogypsum

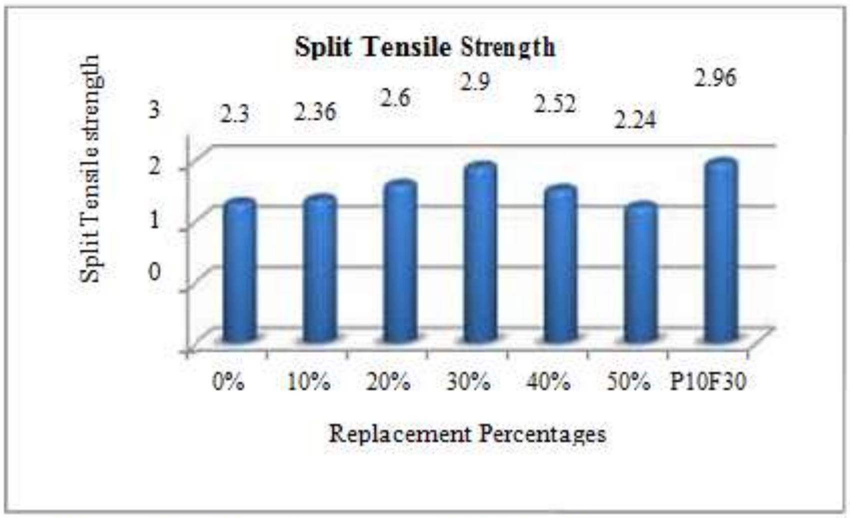

Fig 6. Variation in Split tensile strength for various mixes of Foundry sand

One important factor that leads to an increase in strength upon using waste foundry sand is the particle size. They contain very fine particles, hence making the mix less porous and denser.

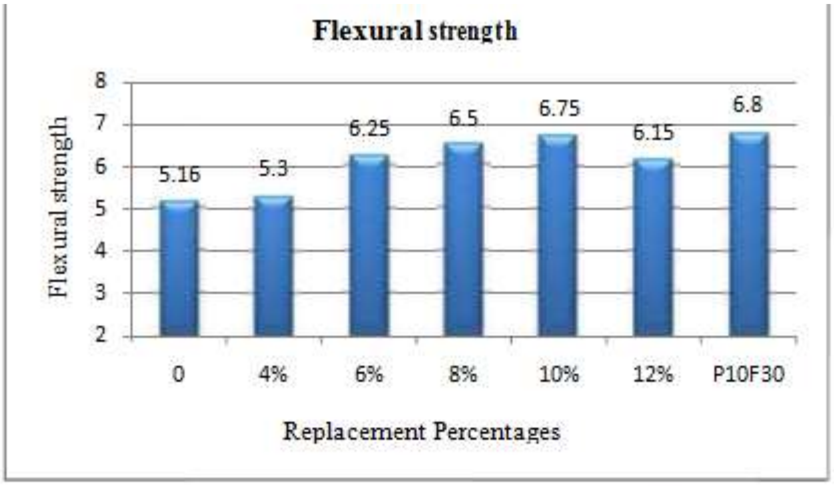

Fig.7. Variation in Flexural strength for various mixes of Phosphogypsum

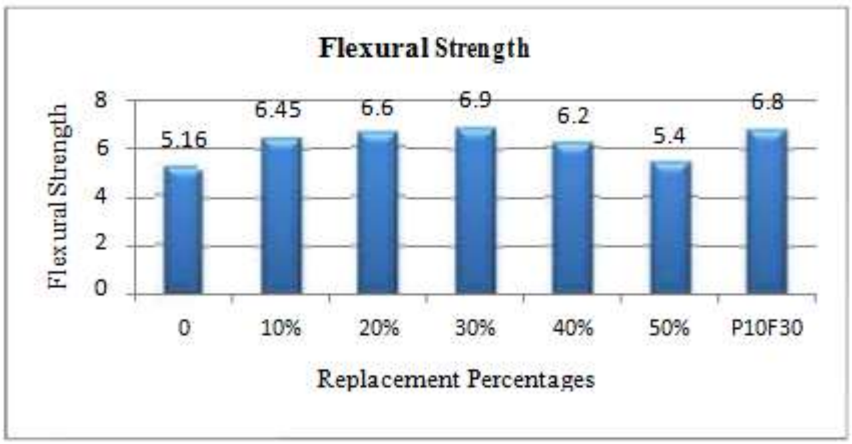

Fig.8. Variation in Flexural strength for various mixes of Foundry sand

The mixes with 10% phosphogypsum and 30% foundry sand were found to have higher strength based on the compressive strength results, flexural strength results and split tensile strength results. Thus the optimum of both materials was found. This found optimum of both obtained were then combined to obtain mixes of good strength. The compressive strength obtained for the combination of both were 31.69 MPa. The split tensile strength obtained was 3.45 MPa and flexural strength 7.25 MPa. From these results it is obvious that the combination of both proves to be successful.

E. Beam Test Results

I. Load Carrying Capacity

Ultimate strength of beams under two point loading was confirmed through recording the maximum load indicated by the dial gauge, whereas the cracking load was specified with the development of the first crack on the beam. Table IX shows the ultimate load of all the beam specimens For both, specimens partially replaced using polyethylene balls and PVC pipes it can be clearly seen that PB3 & PP3 there is a decrease in the value. Mainly shear cracks were developed from the supporting points and widened up as the load increased. At failure, the concrete in the compression region crushed. The crack patterns for different specimens are shown in Fig 5.11 to Fig 5.14 below. At the load approaching the failure load, shear cracks were developed diagonally. The cracks continued to widen as the load increased, and failure occurred soon after depicting a typical sudden type of shear failure. The crack pattern of replaced beams is similar to that of control beam.

TABLE
IX

ULTIMATE LOAD OF ALL SPECIMENS

Beam Specimen	Ultimate Load (kN)
RB	152.44
PB10	175.39
FB30	158.64
P10F30	164.91

II. Load Vs Deflection Graph

Due to increase in the load, deflection of the beam starts, upto a certain level the load vs. deflection graph will be linear i.e. load will be directly proportional to deflection. Due to further increase in the load, the load values will not be proportional to deflection, since the deflection values goes on increasing, strength of the material also increases and material loses elasticity undergoing plastic deformation. Hence from the graph we can predict strength of the material by knowing the deflection at the corresponding load values. The load vs deflection curves is shown in Fig. 10.

III. CrackPattern

Mainly shear cracks were developed from the supporting points and widened up as the load increased. At failure, the concrete in the compression region crushed. The cracks continued to widen as the load increased, and failure occurred soon after depicting a typical sudden type of shear failure. The crack pattern of replaced beams is similar to that of control specimen.

Fig 9. Crack pattern for control specimen

VII. EVALUATION AND DISCUSSION

The experimental study based on replacement of conventional concrete materials has proven to be a successful one in terms of strength as well as economy. Waste foundry sand is being discarded in tonnes and hence its availability is in plenty. An optimum of

30% replacement of fine aggregate makes it suitable for replacing based on strength parameters.

Phosphogypsum which is being discarded in plenty as landfill is a nuisance to public and hence this has proven an effective way to keep a check on it.

The advantages regarding this concrete

are: A. Better strength

The strength properties of the concrete show better results than the conventional concrete. The replacement of both fine aggregate and cement has not reduced the strength in any way. This is the most important criteria kept in mind while conducting replacement experiments.

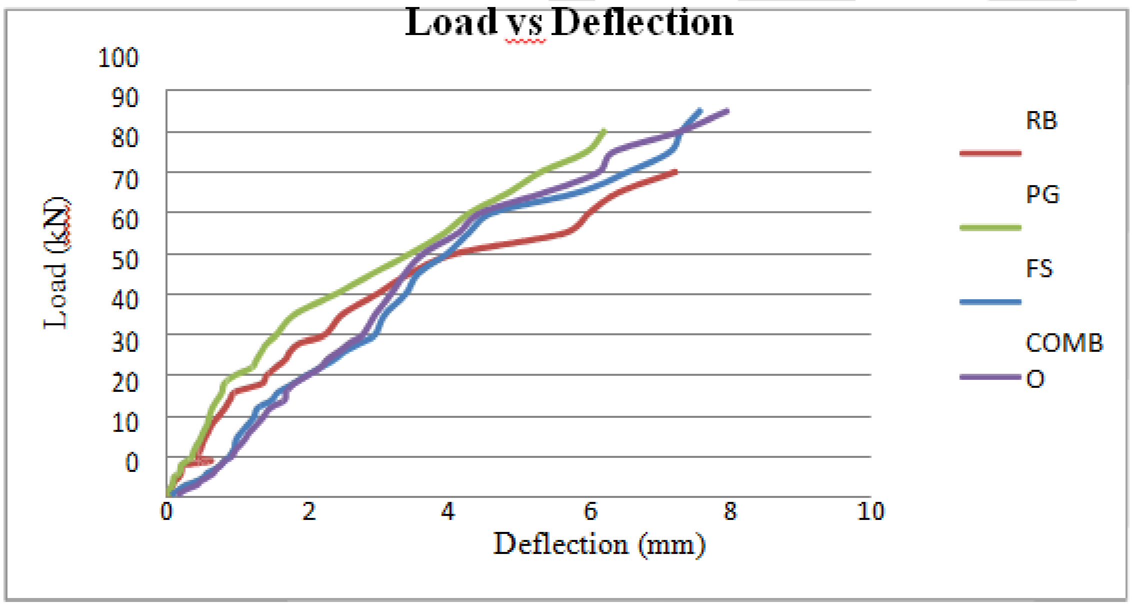

Fig.10 Load Vs Deflection Of Beams

B. Economical

The experiment has proven to be a low cost one without expenses higher than conventional concrete. This is due to the fact that both the materials used in this experiment are available as landfills and hence free of cost. Further with replacement of cement and fine aggregate, the cost further cuts down. Current days the entire field is filled with competition, and it is necessary that a business concern should have utmost efficiency and minimum possible wastages to reduce the cost of production. From the study conducted, we can conclude that usage of these two discarded materials phosphogypsum and foundry sand can be cost efficient than the conventional materials.

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CONCLUSIONS

The research work conducted on partial replacement of cement and fine aggregate with phosphogypsum and waste foundry sand respectively shows that it not only reduces the cost of construction, but also keeps the strength parameters intact. The optimum percentage of phosphogypsum to replace cement partially is 10%. The optimum percentage of waste foundry sand to replace fine aggregate partially is 30%. The workability of the mix on adding foundry sand reduces. This is due to the presence of very fine particles making the mix very harsh to work upon. The strength gain for mixes containing foundry sand is due to the very fine particles which result in a denser mix, hence stronger concrete. The experiment is very economical and materials are easily available. The RC beam load deflection gives satisfactory results in terms of strength. The load deflection curve values showed the beam with combination mix to yield under load greater than that of reference beam.

REFERENCES:

[1] Y. Aggarwal and R. Siddique, "Microstructure And Properties Of Concrete Using Bottom Ash And Waste Foundry Sand As Partial Replacement Of Fine Aggregates", Construction and Building Materials, Vol-54, 2014.

[2] D. R. Amitkumar, P. Arti and I. K. Alefiya, "Foundry Sand: Utilisation As A Partial Replacement Of Fine Aggregate For Establishing Sustainable Concrete", International Journal Of Engineering Sciences & Research Technology, Vol-4, Issue-1, 2015.

[3] S. S. Bhadauria and B. T. Rajesh, "Utilisation Of Phosphogypsum In Cement Mortar And Concrete", 31st Conference On Our World In Concrete & *Structures*, 2006.

[4] D. R Bhimani, J. Pitroda and J. J. Bhavsar, "Used Foundry Sand: Opportunities For development Of Eco-Friendly Low Cost Concrete", International Journal of Advanced Engineering Technology, Vol-4, Issue-1, 2013

[5] D. R Bhimani, J. Pitroda and J. J. Bhavsar, "Innovative Ideas for Manufacturing of the Green Concrete by Utilizing the Used Foundry Sand and Pozzocrete", *International Journal of Emerging Science and Engineering*, Volume-1, Issue-6, 2013.

[6] S. Dhinakaran, and R. S Shanthi, "Experimental Investigation on Concrete with Phosphogypsum", International Journal on Emerging Researches in Engineering Science and Technology, Volume-2, Issue-3. 2015.

[7] N. Ghafoori and W. F. Chang, "Investigation Of Phosphate Mining Waste For Construction Materials", Journal of Materials in Civil Engineering,Vol. 5, No- 2. 1993.

[8] H. K. Khater and S. R Zedane, "Geopolymerization of Industrial By-Products and Study of their Stability upon Firing Treatment", International Journal of Engineering and Technology,Vol-2, No. 2, 2012.

[9] J. M. Khatib and B. A. Herki, "Capillarity of Concrete Incorporating Waste Foundry Sand", Journal of Engineering Research and Applications, Vol. 1, 2012.

[10] R. N Kraus, T. R Naik, B. W. Ramme and R. Kumar, "Use of foundry silica-dust in manufacturing economical self-consolidating concrete", Construction and Building Materials, Vol-23, 2009.

[11] K. Lineesh, D. Sivakumar and S. J. Sundaram, "Comparative Study on Partial Replacement of Fine Aggregate by Glass Powder and Foundry Sand", International Journal of Advanced Information Science and Technology, Vol.32, No.32,2014.

[12] A. B. Mahesh, and S. A. Satone, "An Experimental Investigation Of Partial Replacement Of Cement By Various Percentage Of Phosphogypsum In Cement Concrete", International Journal of Engineering Research and Applications, Vol.2, Issue 4, 2012.