An Analytical and Experimental Investigation of Ultimate Load Carrying capacity of Self Compacting Concrete Columns Containing Furnace Slag

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Abstract: *Self-compacting concrete (SCC) is one of the most revolutionary development in concrete because of its several advantages in technical, economic and environmental terms. Especially on the environmental aspects moves the research towards recycling industrial by-products, as fly ash and furnace slag. This paper presents the results of an investigation to study the performance of Self Compacting concrete prepared with utilizing furnace slag in SCC mix proportions ranging M40grade of concrete as a partial replacement material for fine aggregates. The overuse of river sand for construction has various undesirable social and ecological consequences. GBFS (Granulated Blast Furnace Slag) is a slag obtained from the manufacture of iron in steel industries. This research aims to investigate the possibility of replacing Granulated Blast Furnace Slag as a sand substitute in concrete. Use of steel slag, as by-product from the steel industries in concrete may help to conserve natural resources and at the same time be an economically positive option. Experimental study is carried out and the behaviour of SCC with Ground Furnace Slag & Fly Ash is investigated. A suitable & appropriate chemical admixture i.e. super plasticizer is used. Mechanical properties of the Self Compacting concrete with steel slag aggregates were found and the experimental results obtained show that the strength of concrete attain an optimum value at a particular replacement percentage of fine aggregate by steel slag and further replacement affect negatively the strength of concrete. The overuse of river sand for construction has various undesirable social and ecological consequences. This research aims to investigate the possibility of replacing Granulated Blast Furnace Slag (GBFS) as a sand substitute in concrete.*

Keywords: *Blast Furnace Slag, self compacting concrete, chemical properties of furnace slag, fresh and hardened properties of cube, cylinder and prism.*

1. INTRODUCTION

SCC has occupied a unique position among modern construction materials. It gives considerable freedom to the architect to mould structural elements to any shape. Self-compacting concrete (SCC) is considered as a concrete which can be compacted under its self-weight with no vibration effort, and which is at the same time, cohesive enough to be handled without segregation or bleeding. Almost all concretes rely critically on being fully compacted. Self-compacting concrete is an innovative concrete that does not requires vibration for placing and compaction. It is able to flow under its own weight, completely filling formwork and achieving full compaction, even in the presence of congested reinforcement. The hardened concrete is dense, homogeneous and has the same mechanical properties and durability as traditional vibrated concrete. Popularity of using self-compacting concrete in concrete construction is increased in many countries, since SCC is effectively applied for improving durability of structures while reducing the need of skilled workers at the construction site.

1.1 History of Self-Compacting Concrete

For several years beginning in 1983, the problem of the durability of concrete structures was a major topic of interest in Japan. To make durable concrete structures, sufficient compaction by skilled workers is required. However, the gradual reduction in the number of skilled workers in Japan's construction industry has led to a similar reduction in the quality of construction work. One solution for the achievement of durable concrete structures independent of the quality of construction work is the employment of self-compacting concrete, which can be compacted into every corner of a formwork, purely by means of its own weight and without the need for vibrating compaction. The necessity of this type of concrete was proposed by Okamura in 1986. Studies to develop self-compacting concrete, including a fundamental study on the workability of concrete, were carried out by Ozawa and Maekawa at the University of Tokyo [**1**].

1.2 Need For SCC:

For several years, the problem of the durability of concrete structures has been a major problem posed to engineers. To make durable concrete structures, sufficient compaction is required. Compaction for conventional concrete is done by vibrating. Over vibration can easily cause segregation. In conventional concrete, it is difficult to ensure uniform material quality and good density in heavily reinforced locations. If steel is not properly surrounded by concrete it leads to durability problems. This is the problem mainly with heavily reinforced sections where a very high congestion of reinforcement is seen. In this case, it becomes extremely difficult to compact the concrete. The SCC concept can be stated as the concrete that meets special performance and uniformity requirements that cannot always be obtained by using conventional ingredients, normal mixing procedure and curing practices. The SCC is an engineered material consisting of cement, aggregates, water and admixtures with several new constituents like colloidal silica, pozzolanic materials, chemical admixtures to take care of specific requirements, such as, high-flowability, compressive strength, high workability, enhanced resistances to chemical or mechanical stresses, lower permeability, durability, resistance against segregation, and possibility under dense reinforcement conditions.

Use of SCC overcomes the problem of concrete placement in heavily reinforced sections and it helps to shorten construction period.

Self-compacting concrete is growing rapidly, especially in the precast market where its advantages are rapidly understood and utilized.

Super plasticizer enhances deformability and with the reduction of water/powder segregation resistance is increased.

High deformability and high segregation resistance is obtained by limiting the amount of coarse aggregate.

1.3 Furnace Slag:

Slag making has always been a vital part of steel and iron making. After all, at least 10% of the slag was produced in the steel and iron making process. Granular slag from the local steel making plant; Blast Furnace Slag is a by product of the steel industry. It is defined as "the non-metallic product consisting essentially of calcium silicates and other bases that is developed in a molten condition simultaneously with iron in a blast furnace". Ground Granulated Blast-Furnace Slag powder is a fine white dust. It is made from Blast -Furnace Slag - a co product of iron and steel. For this work GGBFS was obtained from Quality Polytech, Manglore - Karnataka.

1.4 Requirements of Furnace Slag:

The slag volume should be kept as low as possible.

It should have the properties of alkali removal and fulfil the desulphurization requirements.

The composition of the primary slag must be uniform.

Slag formation should be confined to a limited height of blast furnace and the slag should be stable.

The slag should provide good permeability in the zone of slag formation.

The melting point of the slag should be neither too high nor too low.

1.5 Properties of Furnace Slag:

Table No1.1

PROPERTIES	RESULTS
Specific Gravity	2.24
Fineness Modulus(m^2/kg)	33
Magnesia content (%)	8.34
Sulphide sulphur (%)	0.50
Sulphite content (%)	0.52
Loss on ignition (%)	0.16
Manganese content (%)	0.09
Chloride content (%)	0.010
Glass content (%)	93

2. FINITE ELEMENT ANALYSIS

Finite element analysis is the most common tool used for stress and structural analysis of the complicated structures. Finite element procedures are at present very widely used in engineering analysis, and we can expect this use to increase significantly in the years to come. The procedures are employed extensively in the analysis of solids and structures and of heat transfer and fluids, and indeed, finite element methods are useful in virtually every field of engineering analysis. The main advantages are that it can be applied to arbitrary shapes in any number of dimensions. The material properties can be non-homogeneous or isotropic. Finite element analysis is used for the discretization of complex object to simple analysis.

2.1 MODELING OF COLUMN

In the present study, reinforced concrete column of size 150mmx 150 mm and length of the column is 0.5m taken and simply supported boundary conditions is analyzed using finite element method. In this approach solid plate and link elements are used to model the concrete slab and steel reinforcement. Solid element is defined by eight nodes having three degrees of freedom at each node X, Y and Z, while link element is a tri axial tension compression element with three degrees of freedom at each node. Slabs are modelled using 8 nodded solid 65 elements and link 8 elements are modelled as reinforcements. Steel behaviour is modelled using bilinear stress strain curve and multi linear curve is used to characterize the behaviour of concrete. Displacement boundary conditions are needed to constrain the model to get a unique solution. To ensure that the model acts the same way as the experimental slabs, boundary conditions need to be applied at where the supports and loading exist. Loading was applies at loading point. Since the whole model was analyzed by the support conditions whereas experimental was restrained to ensure roller support conditions at all its ends.

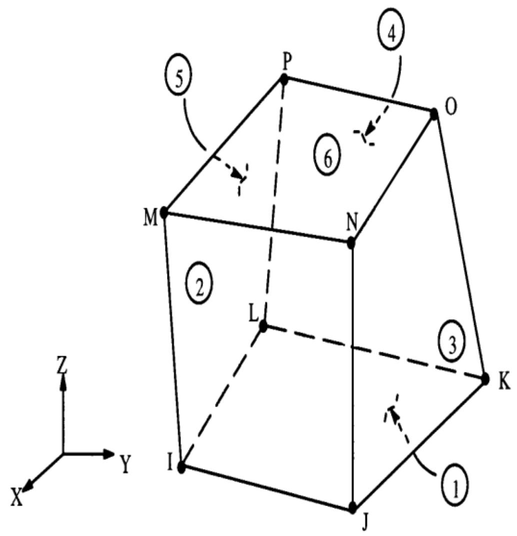

Figure 2.2.1 *Solid65 Element Detail*

2.2 DISCRIPTION OF REINFORCED CONCRETE SCC COLUMN

Reinforced self compacting concrete column of size150mmx150mm is created by using ANSYS v14.5. and simply supported boundary condition is analysed using finite element method.

Columns are modelled using 8 nodded solid 65 element and link 8 elements are modelled as reinforcements.

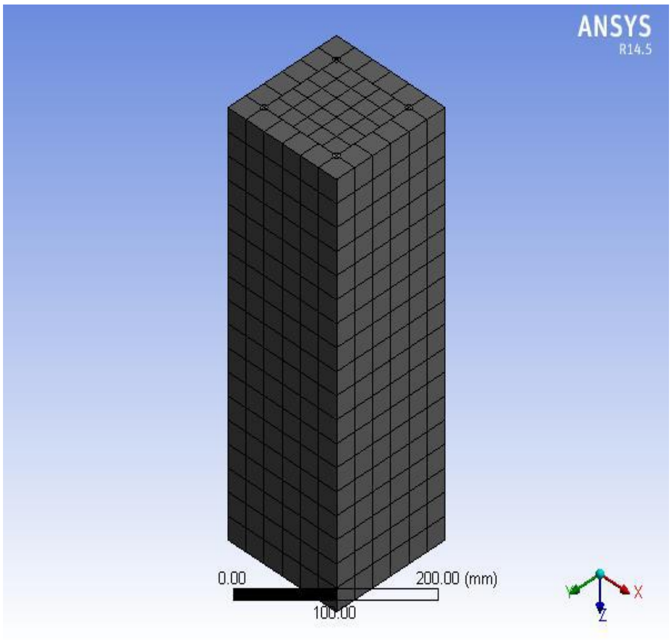

Figure 2.2.2 *Design of column using ansys*

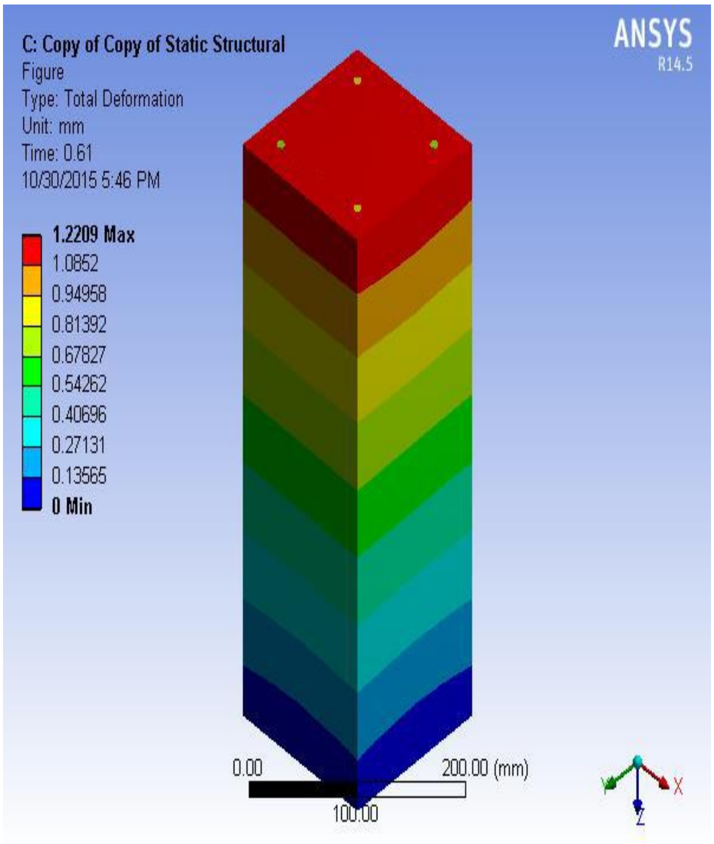

Figure 2.2.3 *Deformation of the column*

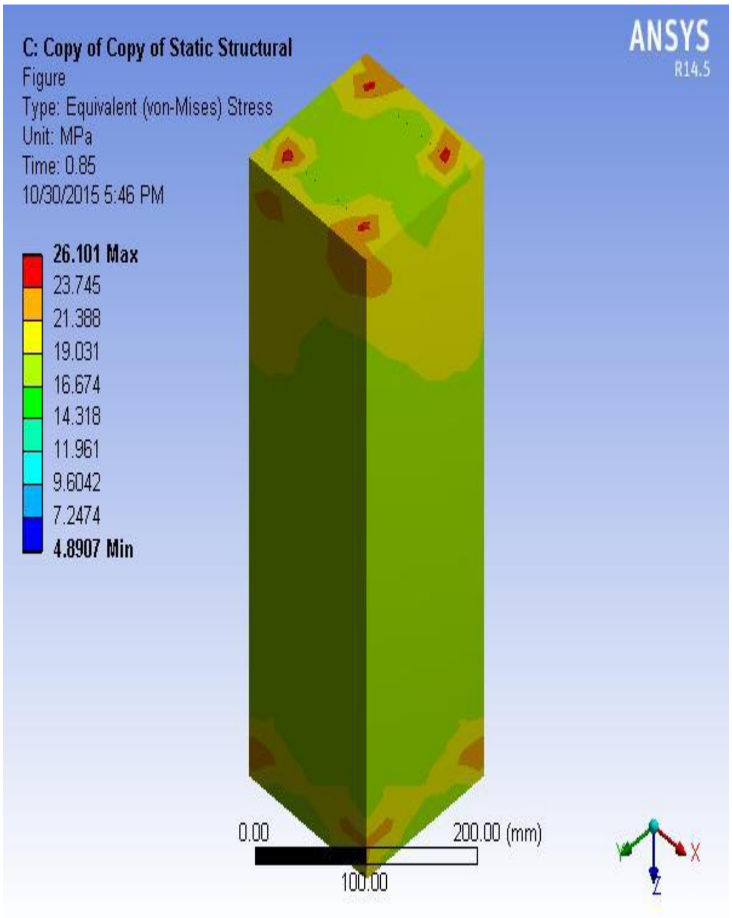

Figure 2.2.4 *Von- Mises Stress*

3. RESULTS AND DISCUSSIONS

3.1 CONCLUSION

Fresh concrete properties of SCC such as workability and flowability decreased and hardened properties such as compressive strength, flexural strength and tensile strength improved by the addition of Furnace Slag.
All the SCC mixes had a satisfactory performance in the fresh state. Among the mineral admixtures considered, the Furnace Slag 50% series had a good workability properties compared to other series.
In general the use of mineral admixtures improved the performance of SCC in fresh state and also avoided the use of VMAs.
Optimum W/P ratio was chosen as 0.35 by weight, the ratio greatly beyond or less than this may cause.

3.2 FUTURE SCOPE

This research can be further investigated in various percentage (%) replacement of furnace slag in casting of slabs to attain higher strength and to reduce the deformation of Columns.

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