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Flexural Behavior of Reinforced Steel Slag Concrete Beams using Finite Element Analysis

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Abstract : Now a day's concrete plays a major role in construction industry. Availability of construction material is less day by day. So we can introduce a new kind of material in construction industry to reduce the cost as well as user friendly material. The main objectives of the project, by using the available waste material to introduced in concrete industry. Fully replacement of concrete is not possible, so we can made an attempt to develop partial replacement of concrete material. While making steel there is about 20% slags for every ton of steel. Slag metal content can be 10-25%. Apart from these productions of cement with emission of CO_2 is more. So we can control the emission of CO_2 by partial replacement of steel slag instead of cement. The replacement of cement by steel slag is 5%, 10%, 15%, 20%. Normally, the property testing of concrete takes more time to identified accurately. At the same time, material, human effect, is also waste. So we can concerned with it major aspects, to introduce the analysis system by using ANSYS software. In this software, it takes only 3 to 4 hours for analyzing the results. It is a better way to analysis the results in fast growing industry. So we do not waste the materials for testing purpose and time consumptions with high degree of accuracy.
Keywords: Reinforced concrete beams, finite elements analysis, ANSYS, Reinforcement modeling.

1.0 Introduction

Portland cement (or simply "cement") is the single most commonly used building material in the world today. The manufacture of cement in the United States was in 2002 a 103.8 million metric ton, $8.6 billion industry. Worldwide production is at present in excess of 2.2 billion metric tons per year[1]. The origins of cement date back to well over 5000 years ago when the Egyptians developed mortars composed of lime (CaO) and gypsum (CaSO4.2H2O) to hold together the enormous stone blocks of the pyramids. Three thousand years later, between 300 BC and 476 AD, the Romans developed the first durable concrete, with a cementitious matrix of lime and volcanic ash (chiefly SiO2) from Mount Vesuvius, and used it to build the Coliseum and the huge Basilica of Constantine. The Romans also employed chemical admixtures in their cements, such as animal fat, milk, and blood, perhaps to improve the workability of their pastes[2].

Chemicals found in these fluids are still used today to modify the setting of cement. The use of natural cement, consisting of mixtures of lime and clay (aluminum silicates), emerged in England in the late 18th century[3]. Joseph Aspdin obtained the first patent on cement manufacture in 1824. Aspdin carefully proportioned amounts of lime and clay, then pulverized the mixture and burned it in a furnace. Technological developments such as the rotary kiln enhanced production capabilities and allowed cement to become one of the most widely used construction materials. Cement production may be classified by application into two primary groups: construction and energy services[4].

The construction applications for cementing consume the lion's share of cement manufactured world-wide, but the cement produced for energy services applications is an integral part of meeting the world's energy needs and requires tighter quality control standards to meet that industry's

Higher demands on control of the rheological properties of the fluid slurry state, the solid state, and especially the transition from the former state to the latter, or the setting process.

While making steel there is about 20% slags for every ton of steel. Slag metal content can be 10-25%.

Here in this work an attempt is made to utilize steel slag, a waste material obtained from AGNI steel industry-ingur, in concrete as a partial replacement material for cement. Slag fines may be used as a substitute for cement without any deleterious effect. Volume stability, good sulphate resistance, and corrosion resistance to chloride solutions make reinforced slag concrete suitable for many applications.

1.1 Finite Element Analysis:

Finite element analysis (FEA) is a fairly recent discipline crossing the boundaries of mathematics, physics, and engineering and computer science. The method has wide application and enjoys extensive utilization in the structural, thermal and fluid analysis areas.

The finite element method is comprised of three major phases:

1. Pre-processing
2. Solution,
3. Post-processing,

Pre-processing: In which the analyst develops a finite element mesh to divide the subject geometry into sub domains for mathematical analysis, and applies material properties and boundary conditions.

Solution: During which the program derives the governing matrix equations from the model and solves for the primary quantities.

Post-processing: in which the analyst checks the validity of the solution, examines the values of primary quantities (such as displacements and stresses), and derives and examines additional quantities (such as specialized stresses and error indicators).

1.2 FE Modeling of Steel Reinforcement

Tavarez discusses three techniques that exist to model steel reinforcement in finite element models for reinforced concrete (Figure 2.8): the discrete model, the embedded model, and the smeared model.

The reinforcement in the discrete model (Figure 2.8a) uses bar or beam elements that are connected to concrete mesh nodes[5,6]. Therefore, the concrete and the reinforcement mesh share the same nodes and concrete occupies the same regions occupied by the reinforcement.

A drawback to this model is that the concrete mesh is restricted by the location of the reinforcement and the volume of the mild-steel reinforcement is not deducted from the concrete value.

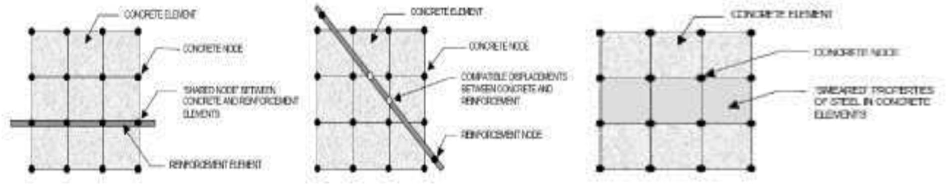
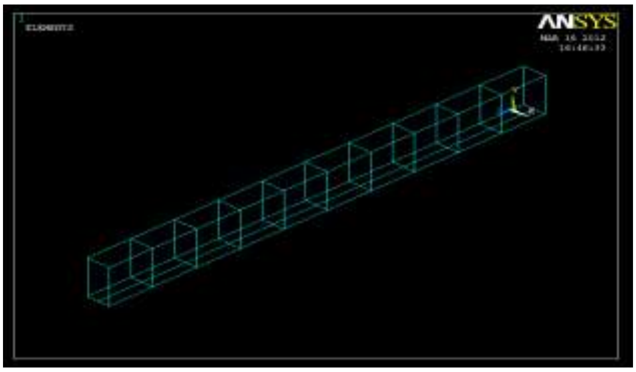


Figure 2.8 - Models for Reinforcement in Reinforced Concrete (Tavarez 2001): (a) discrete; (b) embedded; and (c) smeared.

The embedded model (Figure 2.8b) overcomes the concrete mesh restriction(s) because the stiffness of the reinforcing steel is evaluated separately from the concrete elements. The model is built in a way that keeps reinforcing steel displacements compatible with the surrounding concrete elements. When reinforcement is complex, this model is very advantageous. However, this model increases the number of nodes and degrees of freedom in the model, therefore, increasing the run time and computational cost. The smeared model (Figure 2.8c) assumes that reinforcement is uniformly spread throughout the concrete elements in a defined region of the FE mesh. This approach is used for large-scale models where the reinforcement does not significantly contribute to the overall response of the structure.

Fanning (2001) modeled the response of the reinforcement using the discrete model and the smeared model for reinforced concrete beams. It was found that the best modeling strategy was to use the discrete model when modeling reinforcement[7,8].



Reinforcement model in Beams

2.0 Materials Properties:

2.1 Steel Slag:

Steel slag, a by-product of steel making, is produced during the separation of the molten steel from impurities in steel-making furnaces. The slag occurs as a molten liquid melt and is a complex solution of silicates and oxides that solidifies upon cooling. Virtually all steel is now made in integrated steel plants using a version of the basic oxygen process or in specialty steel plants (mini-mills) use an electric arc furnace process. The open hearth furnace process is no longer used.

In the basic oxygen process, hot liquid blast furnace metal, scrap, and fluxes, which consist of lime (CaO) and dolomitic lime (CaO.MgO or "dolime"), are charged to a converter (furnace). A lance is lowered into the converter and high-pressure oxygen is injected. The oxygen combines with and removes the impurities in the charge. These impurities consist of carbon as gaseous carbon monoxide, and silicon, manganese, phosphorus and some iron as liquid oxides, which combine with lime and dolime to form the steel slag. At the end of the refining operation, the liquid steel is tapped (poured) into a ladle while the steel slag is retained in the vessel and subsequently tapped into a separate slag pot.

There are many grades of steel that can be produced, and the properties of the steel slag can change significantly with each grade. Grades of steel can be classified as high, medium, and low, depending on the carbon content of the steel. High-grade steels have high carbon content. To reduce the amount of carbon in the steel, greater oxygen levels are required in the steel-making process. This also requires the addition of increased levels of lime and dolime (flux) for the removal of impurities from the steel and increased slag formation[9].

There are several different types of steel slag produced during the steel-making process. These different types are referred to as furnace or tap slag, raker slag, synthetic or ladle slags, and pit or cleanout slag. Figure 18-1 presents a diagram of the general flow and production of different slags in a modern steel plant.

The steel slag produced during the primary stage of steel production is referred to as furnace slag or tap slag. This is the major source of steel slag aggregate. After being tapped from the furnace, the molten steel is transferred in a ladle for further refining to remove additional impurities still contained within the steel. This operation is called ladle refining because it is completed within the transfer ladle. During ladle refining, additional steel slags are generated by again adding fluxes to the ladle to melt. These slags are combined with any carryover of furnace slag and assist in absorbing deoxidation products (inclusions), heat insulation, and protection of ladle refractories. The steel slags produced at this stage of steel making are generally referred to as raker and ladle slags.

3.0 Scope:

1. To minimize the construction materials used.
2. To have a comparison of the results between experimental results and analytical results.

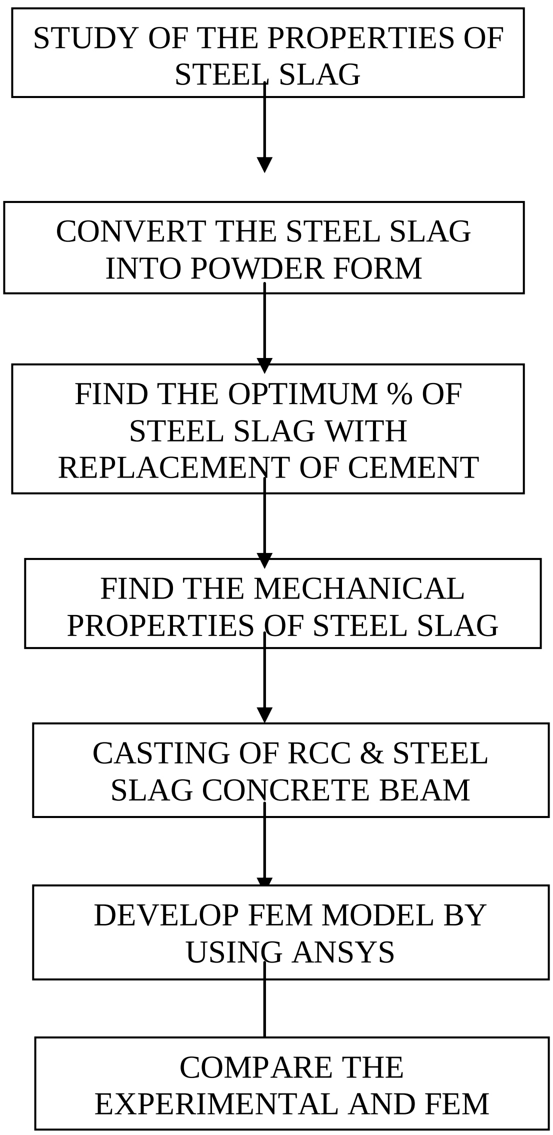
4.0 Objective:

The objective of this investigation is

1. To find out an effect on strength of the RC beam by the partial replacement of cement by steel slag.
2. To compare the Flexural Behavior of Reinforced Steel Slag Concrete Beams using Finite Element Analysis
3. To study about the crack pattern and the crack width.
4. To compare the load vs deflection curve

For the experimental and analytical results.

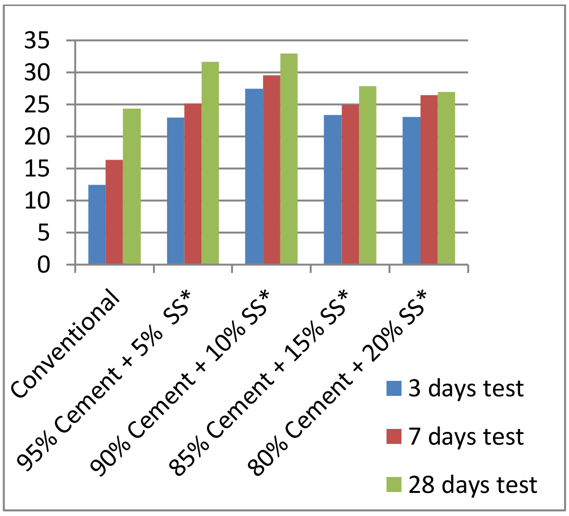
5.0 Methodology:



6.0 Results & Discussion:

Table 7.1: Compressive strength of concrete cubes

Mix proportions	Compressive strength in N/mm^2		
	3 days test	7 days test	28 days test
Conventional	12.45	16.32	24.33
95% Cement + 5% SS*	22.88	25.11	31.65
90% Cement + 10% SS*	27.37	29.48	32.94
85% Cement + 15% SS*	23.34	24.94	27.78
80% Cement + 20% SS*	23	26.44	26.88

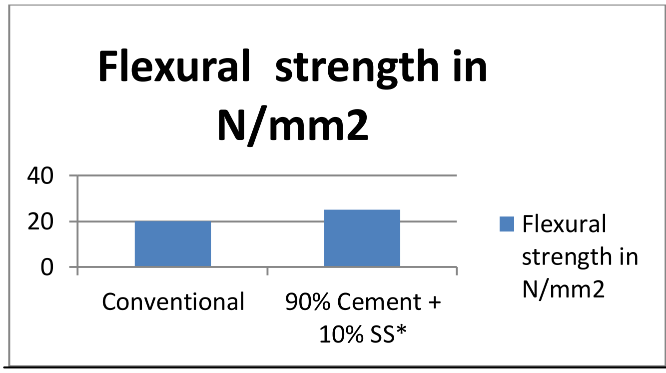


Graph 7.1: Compressive strength

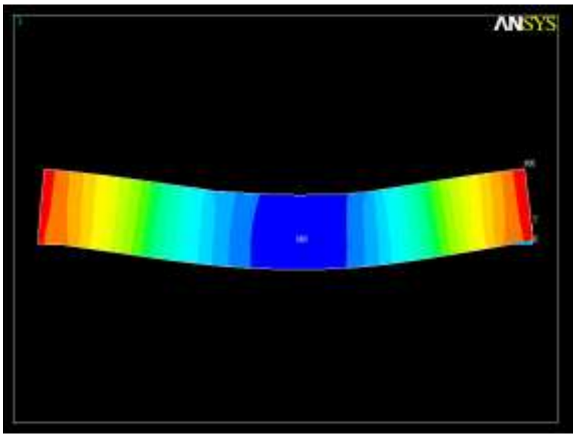
Table7.2: Flexural strength of concrete beams

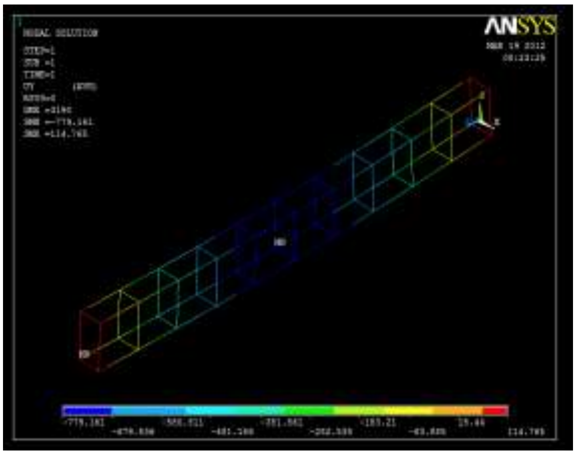
Mix proportions	Flexural strength in N/mm^2
Conventional	20.00
90% Cement + 10% SS*	25.2

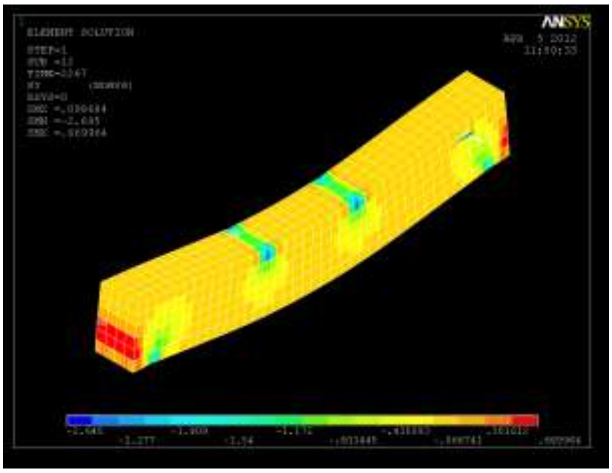
Graph 2: Flexural strength

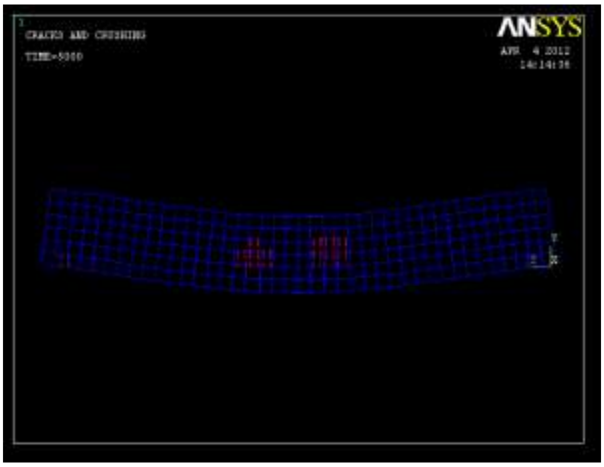


Ansys Results:

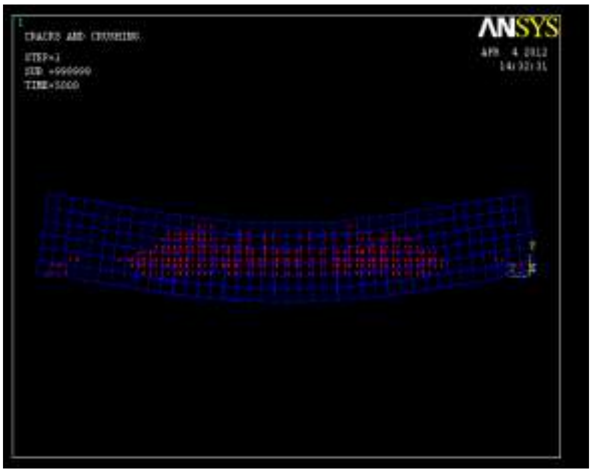


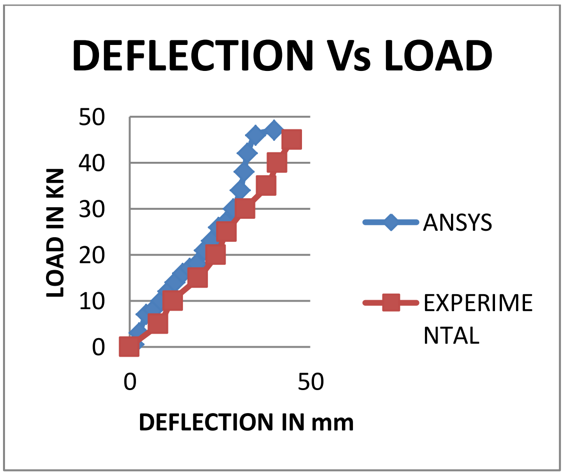






Elemental stress distribution Crack pattern (1st crack)





Crack pattern (2nd crack)Graph 3: Comparison between experimental and ANSYS results.

7.0 Conclusion:

After conducting all the tests on the specimen, it has been observed that According to the current experiments done, we achieved a maximum strength of 27N/mm^2 on 3 days and 31N/mm^2 on 7 days when cement is replaced with 10% of steel slag.10% replacement of cement with steel slag proved to be good in compression. Weight of the concrete specimen goes on increasing by increasing the slag percentage. The following conclusions can be stated based on the evaluation of the analyses of the calibration model and the steel slag concrete beam. Deflections and stresses at the center line along with initial and progressive cracking of the finite element model compare well to experimental data obtained from a reinforced concrete beam. The failure mechanism of a reinforced concrete beam is modeled quite well using FEA, and the failure load predicted is very close to the failure load measured during experimental testing.

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