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AN EXPERIMENTAL AND NUMERICAL STUDY ON CONCRETE BY PARTIAL REPLACEMENT OF FINE AGGREGATE USING STAINLESS STEEL SLAG

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ABSTRACT

These days concrete plays a major role in construction industry. Availabilityof construction material is less day by day. So we can introduce a new kind ofmaterial in construction industry to reduce the cost as well as user friendly material.Stainless steel slag is one of the materials that is considered as a by-product(waste material) obtained during the matte smelting and refining of steel. It has thephysical properties similar to the fine aggregate, so it can be used as a replacement forfine aggregate in concrete. By the replacement of 1%, 2% and 3% of steel slag (byweight) as a replacement for fine aggregate will produce a concrete with durabilityrequirements. This work shows the results of an experimental study on various strengthparameters of concrete containing Stainless steel slag as a replacement of fine aggregate such compressive test. Numerical analysis is performed in Ansys 14.5 for split tensile test and flexural strength. For this research work M30 grade is used and the tests are conducted for various proportions of Stainless steel slag with fine aggregate 1%, 2% and 3%.The obtained results were compared with those ofconventional concrete.

KEY WORDS :*ANSYS, STAINLESS STEEL*

INTRODUCTION

Concrete is probably the most extensively used construction material in the world.However long-term performance of structures has become vital to the economies of allnations. Concrete has been the major instrument for providing stable and reliableInfrastructure.The main objective of this work

1.To study the compression and flexural of the concrete by using Stainless steel fiber,replacing the fine aggregate with very less percentage.
2. Validate the compression test results in ANSYS
3. To check the numerical analysis in ANSYS for flexural and tension test for the samereplacement mixes.

METHODOLOGY

Methodology of the present work is shown in Fig 1

EXPERIMENTAL WORK

1. Standard cubes (Id: S) with M30 MPa was casted (no replacement is made in this). Therefore this stands as the Bench mark for all other cubes for itsproperty.
2. Six number of cubes were casted (3 for 7th day test and 3 for 28th day test).
3. For replacement concretes, the IDs were used as “A” for 1% replacement in theweight of the sand, “B” for 2% replacement and “C” for 3% replacement.
4. For these replacements mixes A, B, C mixes 6cubes for each mix , 3 for 7th dayand 3 for 28th day were casted and tested.
5. Cylinder and beam were casted for the standard concrete only, since the nonavailability of stainless steel slag.
6. While testing the movement of plates in the compression testing machine wasnoted through a strain gauge.

NUMERICAL WORK

1. The model for standard cubes were made and the strain observed wasvalidated.
2. With this validation, the models of beam and cylinder for the mix A, B and Cwere modeled and checked for their stresses.
3. These beam and cylinder were not casted for experimental work.
4. The validation of the cube test results were taken as the reference for beam andcylinder tests.
5. Results of the cube cylinder and beams were reviewed and the optimum valueof the percentage to be mixed is studied

METHODOLOGY

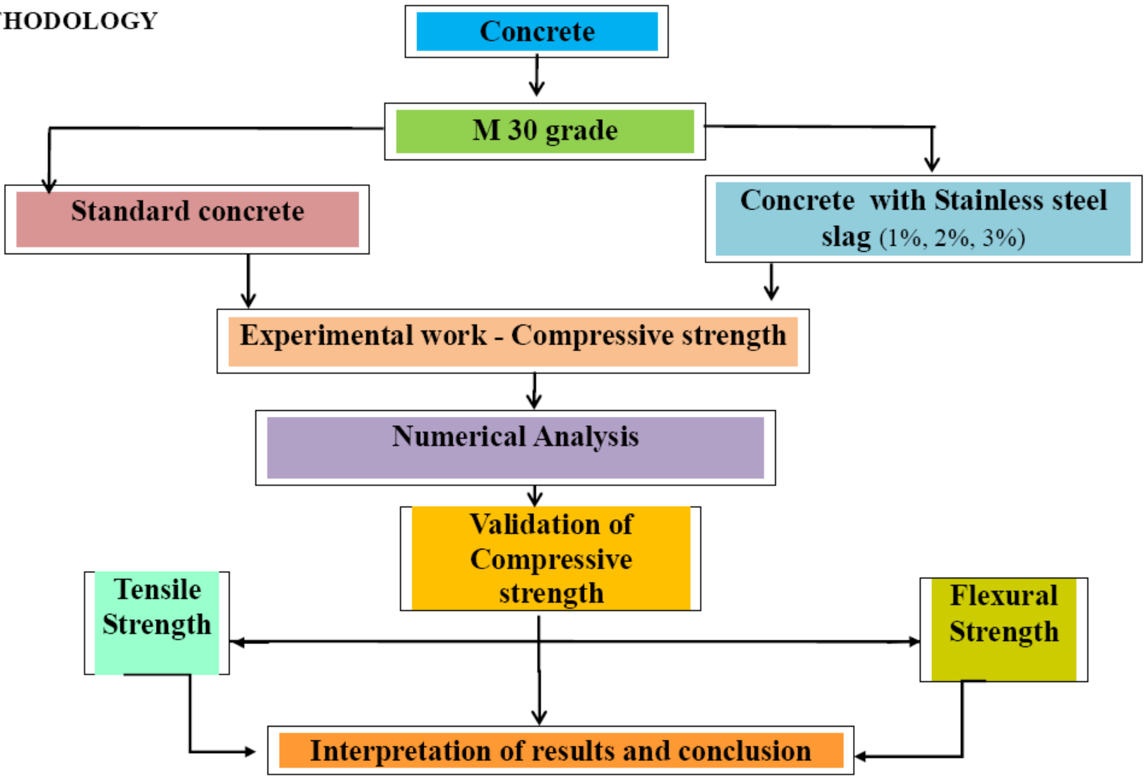

Figure 1 shows the methodology

MIX PROPORTION

Mix design was done as per IS: 10262 – 2009 for M30 Grade of concrete and mix ratio was found to be 1:1.53:3.67 and water cement ratio 0.38. slump was found to be 100 mm

CUBE COMPRESSIVE STRENGTH

For cube compression testing of concrete, 150mmx150mmx150mm size cubes were used. And kept in curing for 7 and 28 days Removing the specimen from water after specified curing time and wipe out excess water from the surface. Compressive strength test performed as per IS 516:1959

FLEXURE STRENGTH TEST

The flexural strength would be the same as the tensile strength if the materialwere homogeneous. In fact, most materials have small or large defects in them which actto concentrate the stresses locally, effectively causing a localized weakness.Beam is the element which is normally tested for flexure.

TENSILE STRENGTH TEST

Strength of the concrete can be broadly classified as direct and indirect methods. Thedirect methods suffer from a number of difficulties related to holding the specimenproperly in the testing machine without introducing stress concentration and to theapplication of uniaxial tensile load which is free from eccentricity to the specimen.Even a very small eccentricity of load will induce bending and axial force conditionsand the concrete fails at apparent tensile stress other than the tensile strength. Because ofthe difficulties involved in conducting the direct tensile test, numbers of indirectmethods have been developed to determine the tensile strength.

NUMERICAL WORK

Numerical analysis was performed in Ansys 14.5 (V).The following steps are followed

1. Geometry and Elements
2. Assemblies and Contact Types
3. Analysis Settings
4. Run analysis
5. Obtaining results

For a linear static structural analysis, the displacements {x} are solved for in the matrixequation below:

[K] is constant

• Linear elastic material behavior is assumed
• Small deflection theory is used
• Some nonlinear boundary conditions may be included

{F} is statically applied

• No time-varying forces are considered
• No inertial effects (mass, damping) are included

It is important to remember these assumptions related to linear static analysis. Since the load is added in the “y” axes, deformation to be measured in the axes, thereforethe above formula will be modified accordingly.

Geometry and Elements

In structural analyses, all types of bodies supported by Simulation may be used.For surface bodies, thickness must be supplied in the “Details” view of the “Geometry”branch.The cross-section and orientation of line bodies are defined within Design Modeler andare imported into Simulation automatically.

MATERIAL PROPERTIES

Young’s Modulus and Poisson’s Ratio are required for linear static structural analyses:Material input is handled in the “Engineering Data” application.

– Mass density is required if any inertial loads are present.

– Thermal expansion coefficient is required if a uniform temperature load is applied. Inthis work thermal expansion is not considered.

– Thermal conductivity is NOT required for uniform temperature conditions.

– Stress Limits are needed if a Stress Tool result is present shall be used, which is notcovered in this work. ANSYS Analysis running model is shown in fig 2

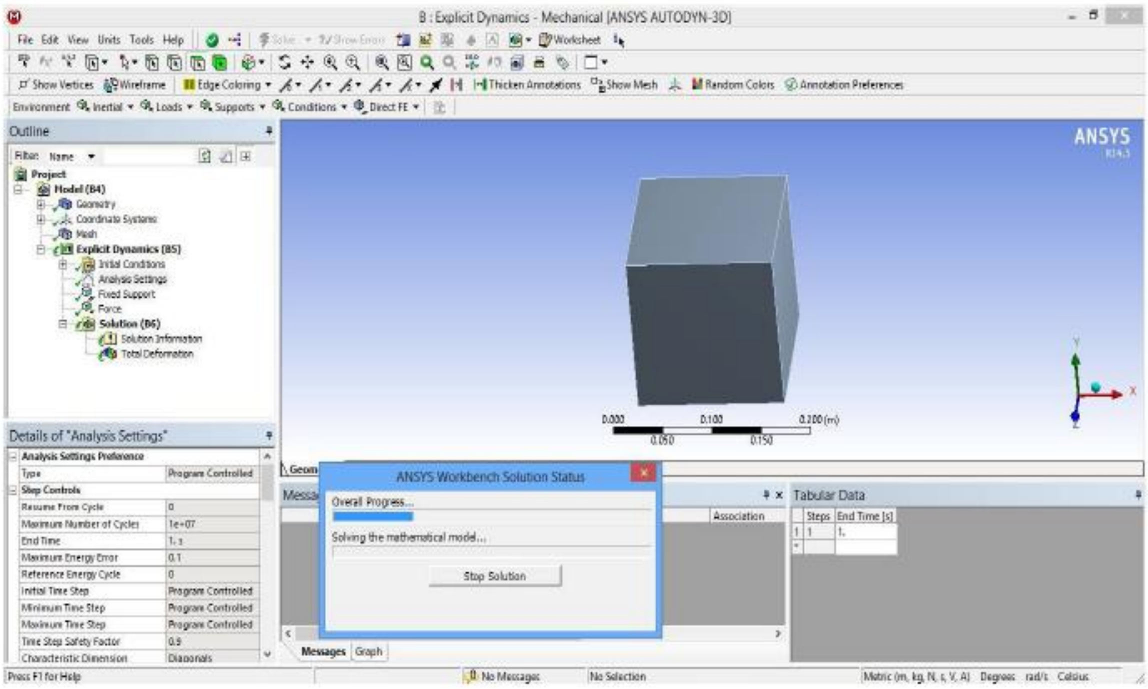

Figure 2 ANSYS ANALYSIS RUNNING MODEL

LOADS AND SUPPORTS

Loads and supports are thought of in terms of the degrees of freedom (DOF) available for the elements used. Supports, regardless of actual names, are always defined in terms of DOF.

Load is given in the top face i.e., "y" positive whereas "y" negative face was kept fixed.

RESULTS AND POSTPROCESSING

Numerous structural results are available:

1. Directional and total deformation.

a. Components, principal, or invariants of stresses and strains. – Contactoutput. – Reaction forces.

2. The deformation of the model can be plotted:a. Total deformation is a scalar quantity:

The x, y, and z components of deformation can be requested under "Directional", in
global or local coordinates.The total deformation is taken in our case and studies were made. The snap shorts took aswhileperforming analysis shown in fig 3,4,5. FIG 6 ANSYS analysis for cylinder

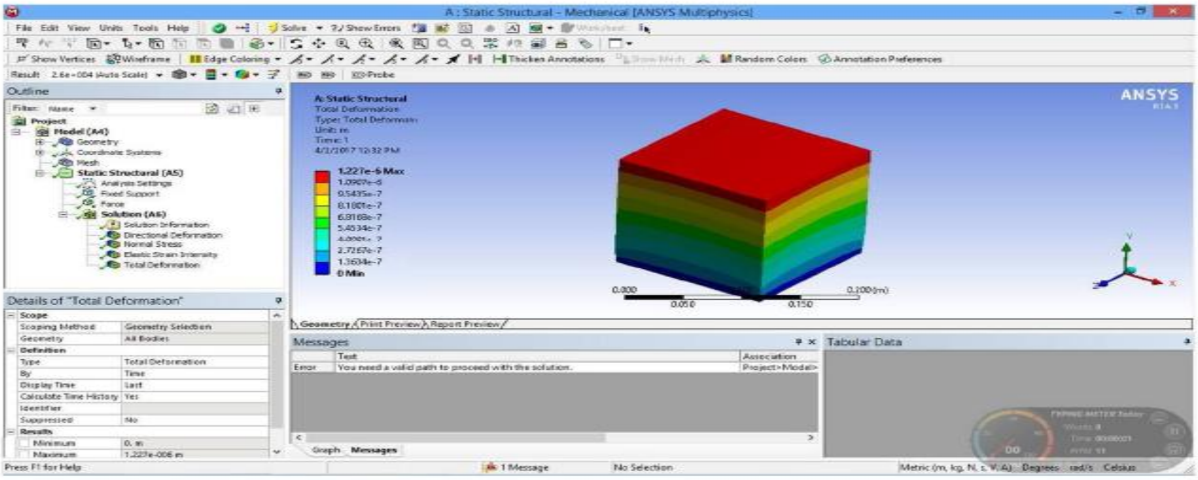

Figure 3 ANSYS SOLOUTION FOR MIX S

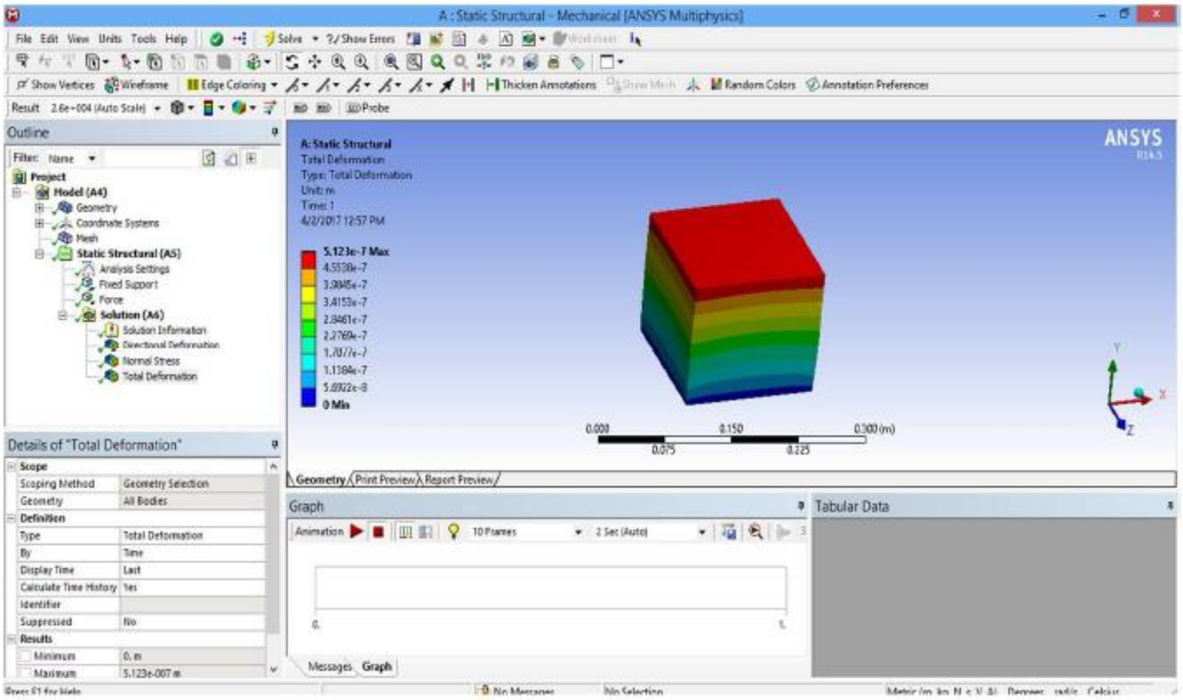

Figure 4 shows ANSYS SOLUTION FOR MIX A

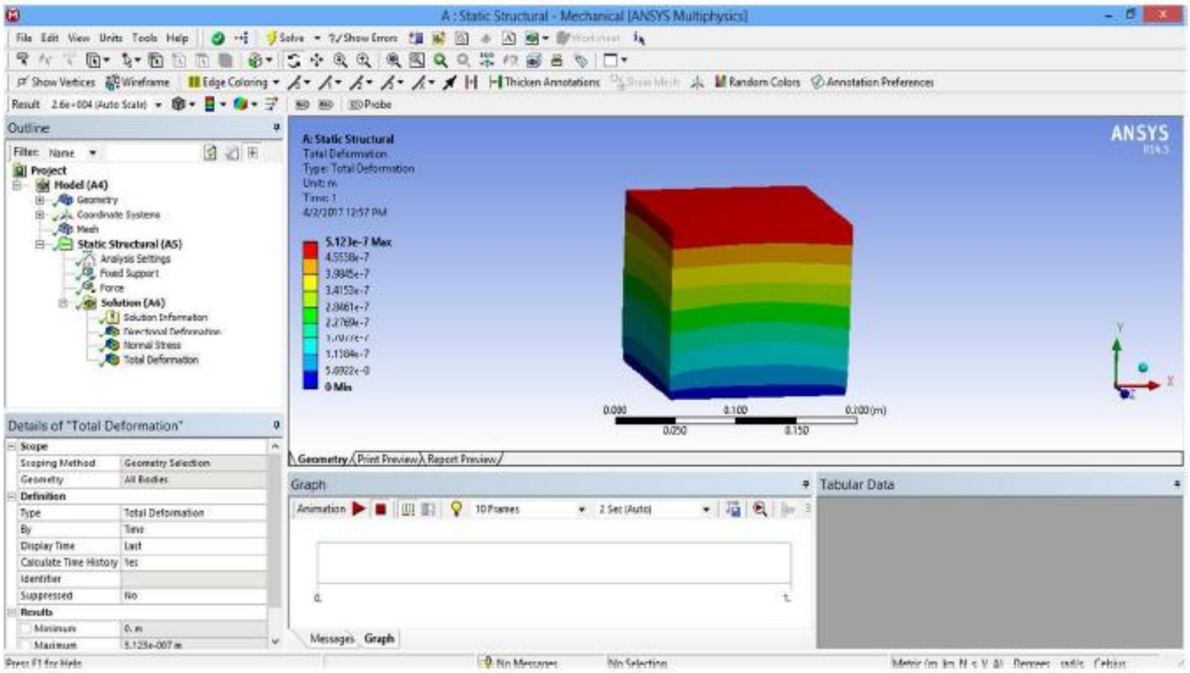

Figure 5 shows ANSYS SOLUTION FOR MIX B

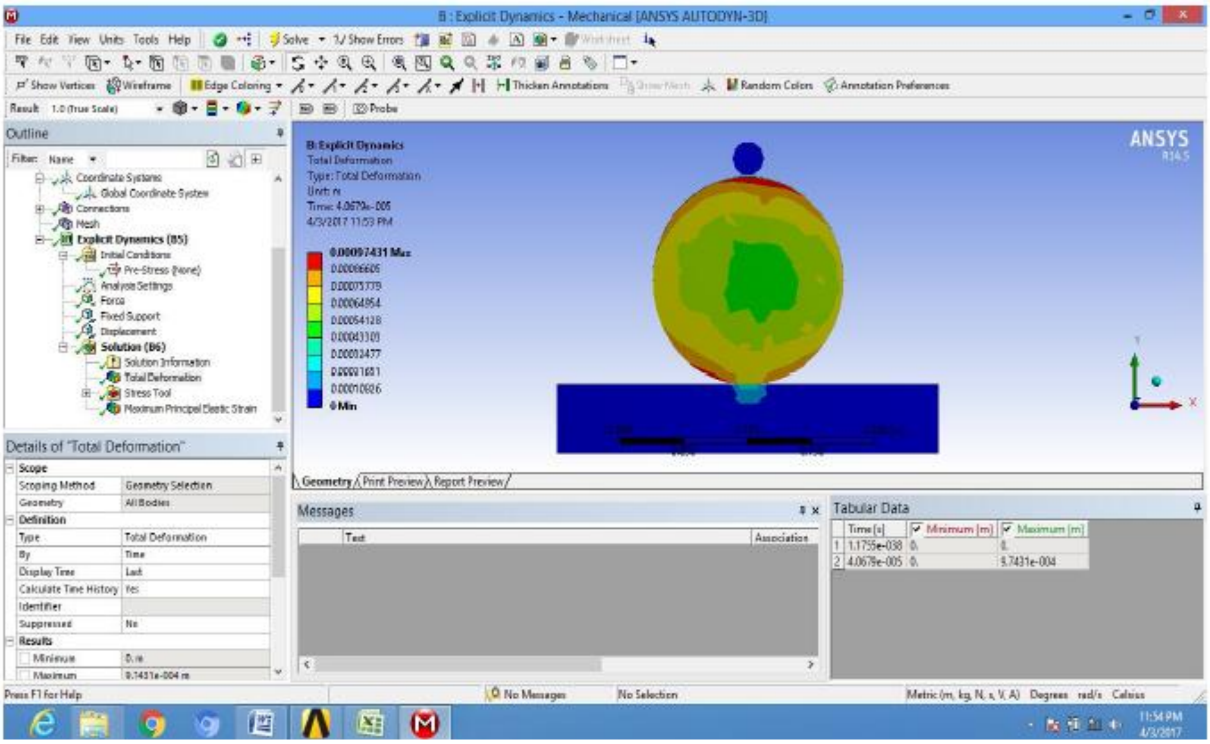

Figure 6 shows ANSYS ANALYSIS CYLINDER TESTING

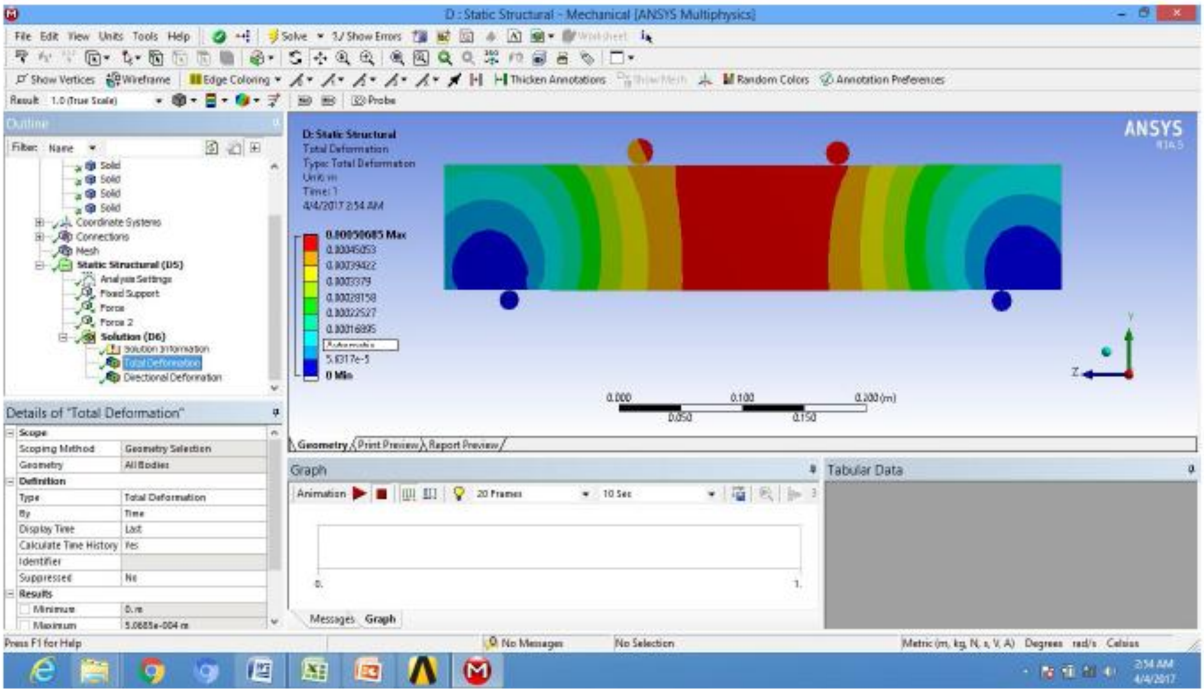

Figure 7 shows ANSYS ANALYSIS BEAM TOTAL DEFLECTION

RESULTS AND DISCUSSIONS

CONTOL CONCRETE CUBE:

Strengths at 7th day, an average value of 20.74 MPa isobtained, and for the 28th day, it is 37.04 MPa. This is slightly more than thecharacteristic compressive strength. While seeing the weights of the cubes, an averagevalue of 8.515 kg is obtained.

MIXA-1%REPLACEMENT

Their strengths at 7th day, anaverage value of 21.33 MPa is obtained, and for the 28th day, it is 39.70 MPa. This isslightly more than the characteristic compressive strength. While seeing the weights ofthe cubes, an average value of 8.515 kg is obtained.

MIX B- 2% REPLACEMENT

Strengths at 7th day, an average value of 21.33 MPa is obtained, and for the 28th day, it is 39.70 MPa. This is slightly more than the characteristic compressive strength.

MIXC-3%REPLACEMENT

Strengths at 7th day, an average value of 21.93 MPa is obtained, and for the 28th day, it is 40.59 MPa. This is slightly more than the characteristic compressive strength.

VALIDATION OF RESULTS IN ANSYS

The strength obtained in the Experimental work is made as input in the Ansys program.As that of experimental cube test, the cube models analysis was made. To validate the results of the experimental work, the displacement of the face was checked with “deformation prob” tool. The strains measure is tabulated in the following table. As perthat table, it is founded that the percentage deviation is 0.82% for Standard model, 0.8%for Mix A, 0.79% for mix B and 1.79% for mix C. In all the above mixes, it is found that the variation of the percentage is very minimum. The reason behind this may be theleast count of the strain gauge measured the strain. In Ansys result, the deformation measured is considered upto 10-7mm . If the decimals are reduced then the percentageerror may be minimum or nil.Therefore the conclusion of the validation may be said that, the Numerical results arematching with the experimental one.

TABLE 1 COMPARISON BETWEEN DEFORMATION OF CUBE FACE

CUBE ID	Experimental Strain in mm	Numerical (ANSYS) Strain in mm	Percentage Variation
S	0.00122	0.0012272	0.82%
A	0.00126	0.0012703	0.80%
B	0.00127	0.0012796	0.79%
C	0.00126	0.0012855	1.79%

NUMERICAL ANALYSIS RESULTS

Results of the numerical analysis are tabulated as below. Flexural and tension tests wereperformed in the numerical analysis. Comparing the results it is founded that the tensionstress of the standard cube was 3.56MPa and it was 3.63MPa, 3.70MPa, 3.81MPa forMix A, B and C respectively. As the same, Flexural strength is measured as 3.59MPa,3.52 MPa, 3.83 MPa and 3.86 MPa for Standard mix (S) and mixes A, B and Crespectively.

DISCUSSION IN THE RESULTS OBTAINED

COMPRESSION TEST:

Comparing the results of compression test, it is observed the result for standard mix is 37.04MPa which is made as base for the all cubes. Further, it is observed that, the strength increases by 7.2% in Mix A, 8.8% for mix B and 9.6% in mix C. Therefore, it may be said that, the compression property of the concrete is increasing with the increase in the addition of the stainless steel material. It may reach an optimum value to minimize thecost and extract high strength, if this research work is continued further.

TENSILE STRENGTH

Results obtained in the ansys model is viewed and the observations are listed as,i) 7.16% of increase in tension for the Mix C, which is maximum that other mixesA and B.ii) Further addition of the may lead to increase in the tensile strength of theconcrete, since the fiber particles of the stainless steel gives additional tensilestrength to the concrete.

FLEXURAL STRENGTH

Ansys results for flexural results shows that, for the standard mix, flexural and tensilestrength are same. For other mixes, there is some variation between flexural and tensilestrengths. It is observed that, flexural strength has decreased in the case of mix A. this isquite surprising. This is to be studied separately, which may consume much time. Forthis purpose this dissertation work has not touched with the points dealing with thereduction of flexural strength for an addition of 1% replacement of sand in the M30 mixconcrete.

For all other concrete mixes, it is clearly viewed that, the flexural strength increases with increase in the addition of stainless steel slag. Maximum value reached is for the mix C , which is 7.67% more than the standard mix.

CONCLUSION

As a conclusion of the work executed, the following conclusions are drawn:

1.Compression test results shows strength increase by 9.6% with the normalconcrete, when 3% of replacement is made.

2. Tensile and flexural tests shows 7.16% and 7.67% increase from their respectivenormal (standard sample) strengths for the mix "C".

3. This shall be concluded that, more the replacement, more the result of increase instrength in terms of compression, tension & flexure.

4. While comparing the cost, Stainless steel (slag) costs more. Therefore it is upto tothe designer to fix the percentage replacement of sand, if this work isreferred for execution.

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