# Study on Flexural Strength of Beam Added with Slag Aggregate

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**Abstract**
The current paper discusses the outcomes of investigational study on High-performance concrete (HPC) made with slag aggregate (SA) which obtained from steel manufacturing industries. The Beam Flexural strength (σ) test is performed to evaluate the tensile strength of the concrete in an indirect way. The test measures the capacity of beam to withstand failure in bending in MPa or psi. The Peak load, transverse strength, maximum deformation, stiffness and ductility index are analyzed from the UTM (Universal Testing Machine). And EDAX (Energy Dispersive X-Ray Analysis) Test is performed to observe elemental composition of test specimen. Using ANSYS workbench module an analytical model of beam is designed, to check the computer simulate model outputs such us stress, deformation and strain with the experimental work. This study leaves a positive way of slag aggregate use in concrete and certainly there is a room for improvement in flexural characteristics.
**Key words**: Flexural strength, ductility index, crack failure pattern and ANSYS model

## INTRODUCTION

As there is an increase in rapid urbanization and industrialization, thereby increase in usage of natural resources leads to depletion, it has forced civil engineers to find out suitable alternatives to it. The use of Slag aggregate SA (artificial aggregate) in concrete production presents a great environmental benefit through savings from the natural aggregates. It also solves the problem related with storage, transportation and dumping of slag aggregate. The High-performance concrete (HPC) provides a significantly increases in resistance to ecological influences or structural capacity while maintaining sufficient stability and it has few more qualities such as high strength, high workability, low permeability and higher resistance to chemical attack. From the research studies, it is observed that the steel slag is used as fine and coarse aggregate in concrete mixtures but it cannot be used as a both fine and coarse aggregate. Result shows that the steel slag usage in concrete as coarse aggregate replacement is more convenient than replacement of fine aggregate. The most common of all tests of hardened concrete is flexure test in concrete because of the intrinsic importance in construction. It represents the highest stress experienced within the material at its moment of yield. The EDAX test is performed to observe the orientation of the sample and qualitative information of the sample. This paper presents the experimental investigation with testing procedure of flexure test and ANSYS model of beam is designed to check the effectiveness and act regarding Stress, strain, deformation and collapse pattern are analyzed.

## 1. Materials Used

In this study High performance concrete (HPC) is designed for M30 grade of mix design, the slag used in this study is supplied by the Agni steel industry (steel manufacturing unit), India. As per the guidelines of IS: 12269-1987, the M30 mix design is calculated as Mix ratio of 1: 2.68: 1.54 with water/cement ratio 0.4. The OPC53 grade of cement is used as the material binder, as fine aggregate the M-sand with Specific gravity ($S_g$) = 2.35, the silica fume (mineral admixture) with $S_g$ = 2.59 and sieve size less than 90 micron is taken as mineral admixture addition to that the super plasticizer (chemical admixture) is also taken. The previous research studies show the size of coarse aggregate plays a vital role concrete strength, the substitute material slag has low crushing and impact values hence it is necessary to ensure the lower spread in concrete. Therefore, the SA with size range of 16-20 mm is taken as nominal size for the incorporation.

## 2. Experimental Investigation

### 3.1 Casting of specimens

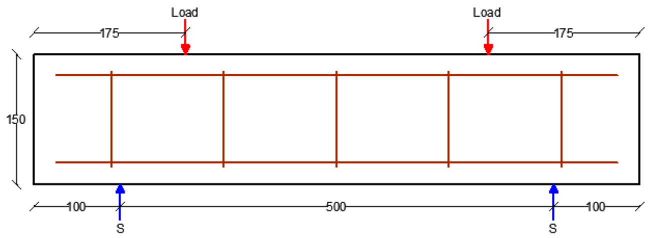
The concrete beam of mould size 700*150*150 is taken for casting. The beam is manually designed for the load carrying capacity of 50 kN to calculate the reinforcement bars. The Fig 1 shows the reinforcement diagram for the beam.

a. Main Rods – 2 # 12mm Dia

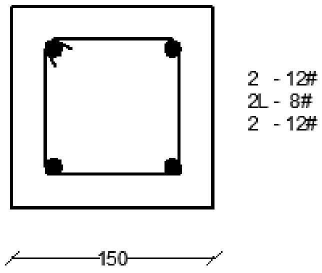
b. Hanger Bars – 2 # 12mm Dia

c. Stirrups – 5 # 8mm Dia

d. Cover – 25mm




(a)




(b)

Fig 1 – Reinforcement Diagram for the beam

### 3.2 Flexural strength (σ) test on beam

The beam σ (flexural strength) is calculated on the 4 set of test ratio of 3 each for the average calculation. The specimens are load on a testing machine and gradually load is applied as shows in Fig 2. The result such as first crack load, crack failure pattern, peak load and deformation are observed. Using the results, the stiffness and ductility index are calculated. Table 1 shows the test results observed. The following formula is used to calculate the flexural strength of concrete, where F = Load, b = width of the specimen, L = Length and d = thickness.

(Two-point loading @1/3 L) $\sigma = FL/bd^2$

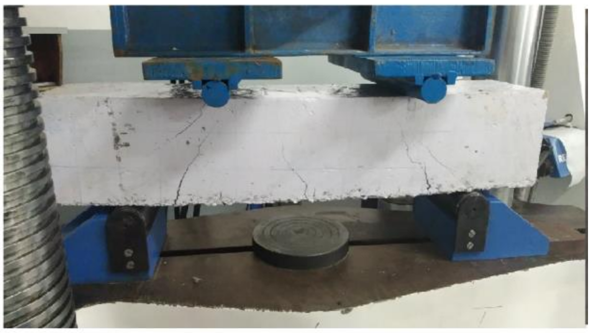


Fig 2 – Flexural test

Table 1 – Flexural strength test on beam

| Type of concrete | HPC | HPC – SA25 | HPC – SS50 | HPC – SA75 | HPC – SA100 |
|---|---|---|---|---|---|
| Load at peak (kN) | 66.32 | 60.71 | 57.39 | 53.35 | 51.12 |

| | | | | | |
|---|---|---|---|---|---|
| C.H. travel at peak (mm) | 4.86 | 4.52 | 4.38 | 4.19 | 4.04 |
| transverse strength (N/mm2) | 9.82 | 8.99 | 8.05 | 7.903 | 7.57 |

### 3.2.1 Ductility Index

The inelastic deformation of concrete without significant loss in resistance is described as the ductility ability of concrete element. If the structure possesses ductile behavior, it will be able to experience large deflections while still holding near ultimate loads and providing sample warning to the imminence of failure. In this study, the displacement ductility was investigated. Table 2 shows the ductility index (D.I.) value of beam element and Fig 3 represents the bar graph for the beam D.I value.

Table 2 – Ductility Index (D.I.) value

| Beam Designation | First crack mid span deflection δy (mm) | Ultimate mid span deflection δu (mm) | Ductility index D.I = δu/ δy |
|---|---|---|---|
| HPC | 1.29 | 4.96 | 3.84 |
| HPC- SA25 | 1.17 | 4.52 | 3.86 |
| HPC- SA50 | 1.12 | 4.38 | 3.91 |
| HPC- SA75 | 1.05 | 4.19 | 3.99 |
| HPC- SA100 | 1.01 | 4.04 | 4.1 |

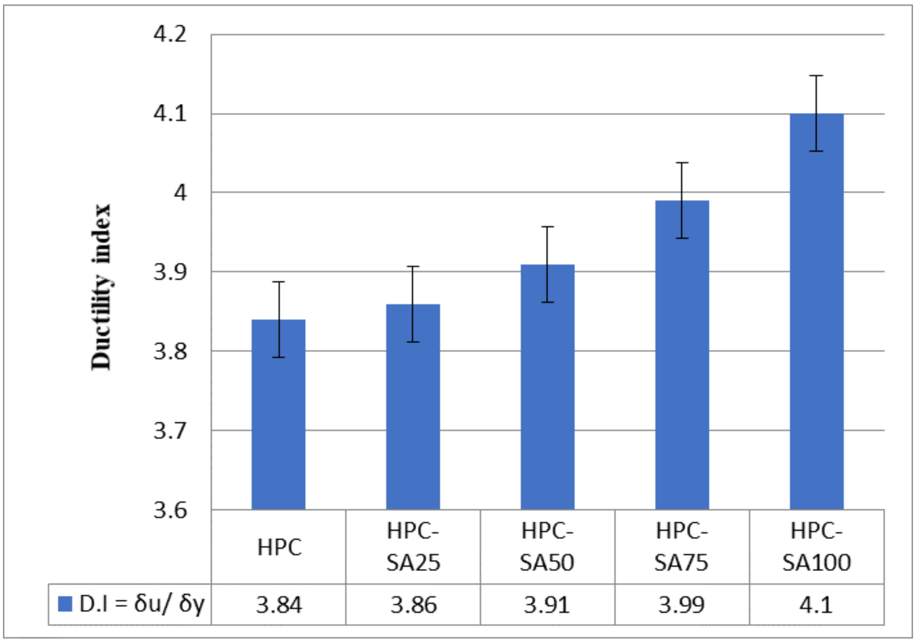



Fig 3 - Ductility Index (D.I.) value graph

### 3.2.2 Stiffness

The load required to cause the unit deflection is described as stiffness, the stiffness value of test specimens at first crack load and ultimate load are presented in table 3 and table 4. The bar graph of stiffness value is shown in Fig 4.

Table 3 – Stiffness at First crack load

| Beam Designation | First crack Load (kN) | First crack mid span deflection (mm) | Stiffness kN/mm |
|---|---|---|---|
| HPC | 18.42 | 1.29 | 14.27 |
| HPC- SA25 | 15.19 | 1.17 | 12.98 |
| HPC- SA50 | 13.76 | 1.12 | 12.28 |
| HPC- SA75 | 11.5 | 1.05 | 10.95 |
| HPC- SA100 | 10.83 | 1.01 | 10.72 |

Table 4 – Stiffness at ultimate load

| Beam Designation | Ultimate Load (kN) | Mid span deflection at Ultimate load | Stiffness kN/mm |
|---|---|---|---|

| | | (mm) | |
|---|---|---|---|
| HPC | 66.32 | 3.84 | 17.27 |
| HPC- SA25 | 60.71 | 3.86 | 15.74 |
| HPC- SA50 | 57.39 | 3.91 | 14.6 |
| HPC- SA75 | 53.35 | 3.99 | 13.37 |
| HPC- SA100 | 51.12 | 4.1 | 12.4 |

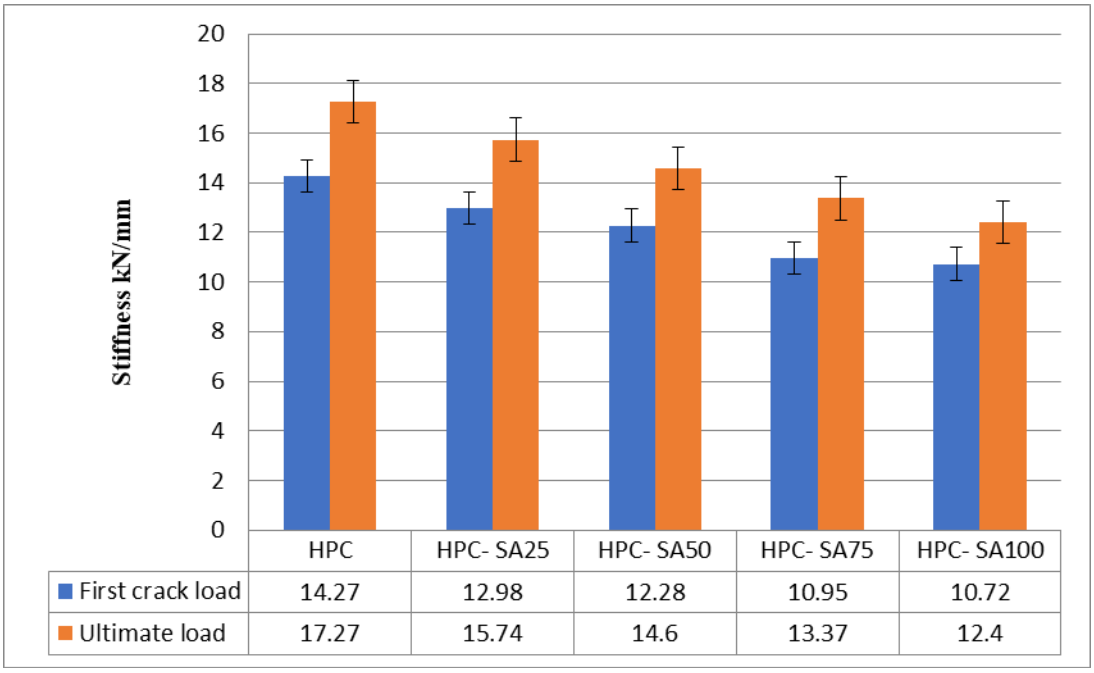


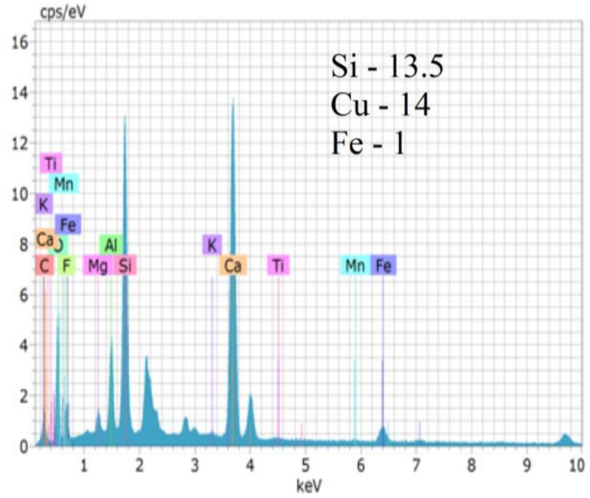

Fig 4 – Stiffness value of beam

### 3.2.3 Crack failure pattern

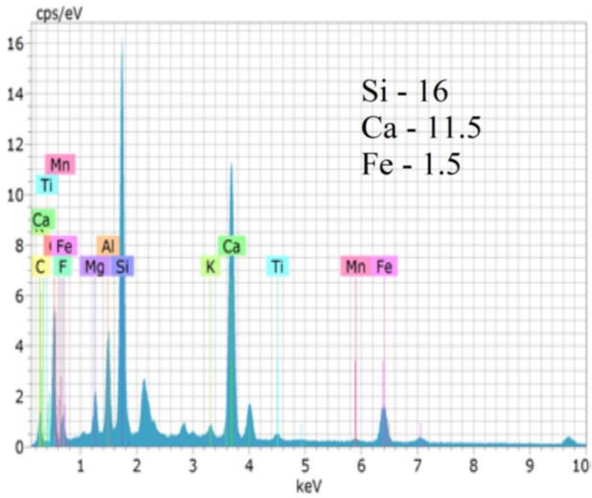
The failure pattern of the beam is observed while testing, in the HPC specimens due to application of loading at initially flexural cracks are been developed later further application of loading shear cracks are appreared near the both end supports and load acting point. The same phenomen of cracks are seen in HPC-25 and HPC-50, but in other two test specimens flexural alone observed.

### 3.3 EDAX Test

From the Flexure test tesult, the HPC-SA25 and HPC-SA50 are results fairly acceptable strength characteristics. The residues from the HPC-SA25 and HPC-SA50 specimen and analyzed for the mineral composition present in it using EDAX (Energy Dispersive X-Ray Analysis) test. The results are observed through graphical chart which shown in Fig 5.




(a)




(b)

Fig 5 – EDAX Test Result

## 3. Analytical model

The ANSYS workbench module is used to design the beam model, the Explicit dynamic which is a high speed solver is applied for the analysis. The concrete beam model is first model in CADD and imported in ANSYS software, then the concrete and steel materials are assigned next to that the load and support conditions are assigned. The mesh is formed and velocity of in m/s is feeded. Other than that thermal expansion, young's modulus, density of concrete, poisson's ratio and compressive strength are the values changed and analysis is carried out. The analysis is done for the HPC-SA25 and HPC-SA50 to observe the strain, stress and total deformation pattern. the ANSYS model is shown in Fig 6. The strain, stress and total deformation pattern of Specimen are presented in Fig 7 - HPC-SA25 and Fig 8 - HPC-SA50.

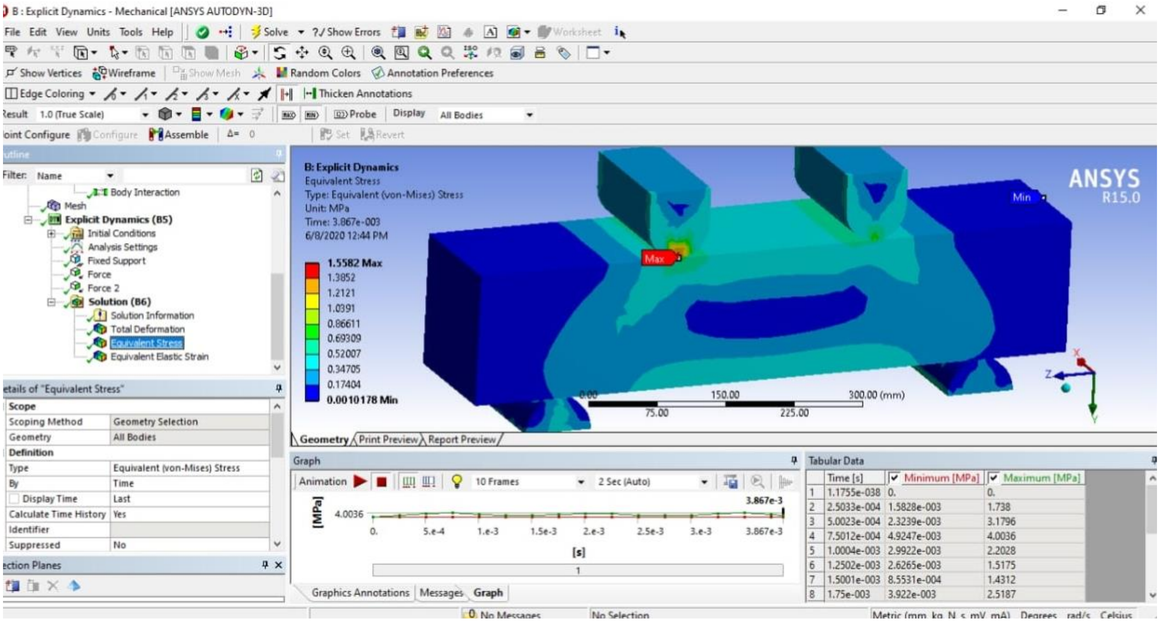
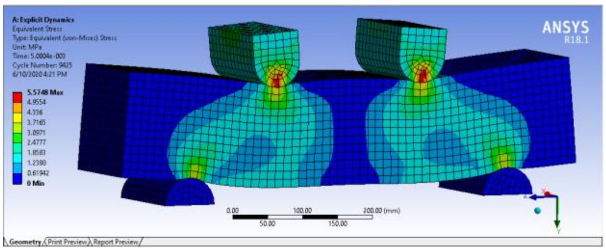
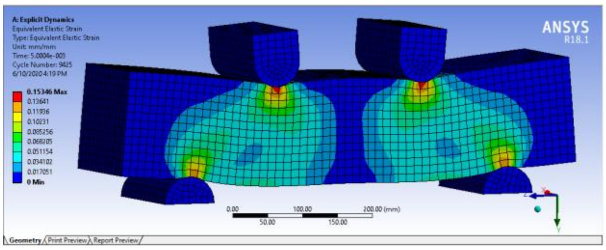


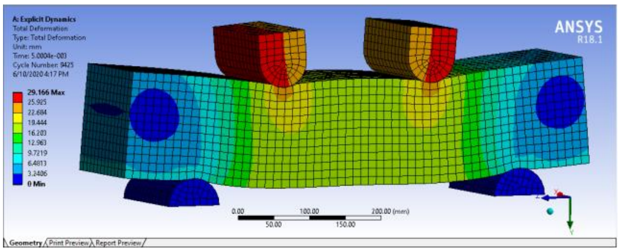

Fig 6 – ANSYS model




(a) Equivalent stress (5.5748 Max)

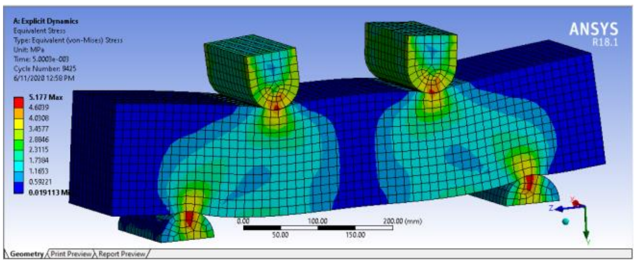



(b) Equivalent strain (0.15346 max)

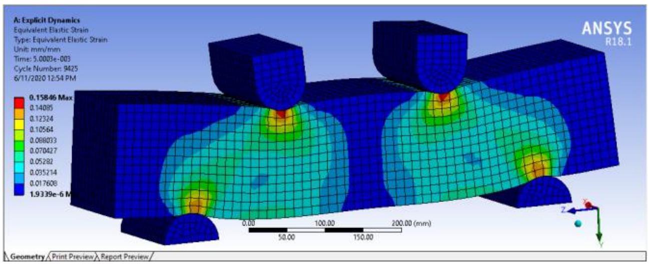



(c) Total Deformation (29.166 max)

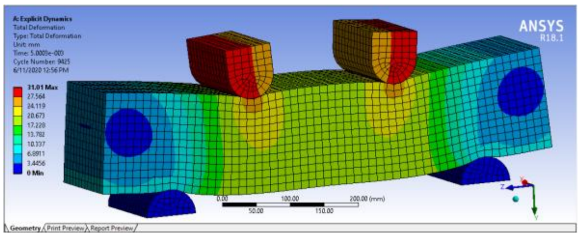
Fig 7 – HPC-SA25 ANSYS Model




(a) Equivalent stress (5.177 Max)




(b) Equivalent strain (0.15846 max)




(c) Total Deformation (31.01 max)

Fig 8 – HPC-SA50 ANSYS Model

## I. CONCLUSION

Based on the experimental work carried out, the following conclusion are made

1. For higher the percentage of replacement, the higher will be decrease in flexural strength (σ).
2. From the EDAX test, the result shows that the mineral composition of concrete is almost similar but percentage of elements are varies due to difference in the replacement percentages.
3. The Dutility index and stiffness are in accepatble rate, which offers resistance to load application.
4. The crack failure pattern shows the flexure cracks are common in all the test but the shear cracks are appears only in the lower percentage of substitution.
5. The ANSYS model elaborates the strain, stress and deformation to our perception, the point where the failure to obtain and its pattern is almost similar to the failure pattern seen in flexure test.

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