[SCRICE-2018] ISSN 2348 – 8034
Impact Factor- 5.070

GLOBAL JOURNAL OF ENGINEERING SCIENCE AND RESEARCHES

BEHAVIOUR OF INTERLOCK BLOCK MASONRY UNDER COMPRESSIVE AND LATERAL LOADING

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ABSTRACT

Interlock block constructions have been initiated and developed across the world with research studies within limitations. Masonry is the most executable and adaptable building material in worldwide, but the lateral and seismic performance of masonry structures has always been a big concern. Interlock is a technique that is making objects to hold each other without any connections and by means of connecting objects with their complicate dimensions. Interlocking systems are generally used in all industries including construction fields. Generally cement is used as a binding material in buildings. It could be replaced with interlocking mechanism. The major part of the building structure is wall, if walls are casted with interlock mechanism, 50% of use of cement material will be reduced. Interlock system is more suitable for this rapid growth of 21st century.This discussion is based on the salient features of interlocking-block masonry with different materials keeping in view the requirements of shape simplicity and ease of manufacture. Testing of specimens will be carried out under compressive and lateral loading. Validation of results with material based Interlock-block masonry. Failure pattern of interlock block system under loading condition and Comparison of analytical approach with experimental test is being discussed

I. INTRODUCTION

The main and important demand for a growing construction industry is by implementing speedy and efficient structural practices has led to the development of certain ideas and techniques. Upon which development of wall structure remains to be an important aspect, thus in this paper detailing a pair of blocks were developed having projections and grooves for creating structural wall through the courtesy of bond created in an interlocking arrangement.The construction field is required to accelerate the masonry construction process for a rapid growth of civil industry. The traditionalmethod was mainly based on number of labor for rapid work due to thepresence of a large number of mortar joints. Thus the potential for developing concrete or earthen blocks in an interlocking pattern are creating the required provision of speedy and efficient construction. Process of building walls were made easier and requirement of skilled labors decreases compared to building with conventional bricks.

In this proposal however concrete blocks were developed using conventionalconcrete mix adhering to M25 grade and 25% of Ground Granulated Blast furnace Slag was replaced with cement in concrete mix. After whichwall were formed in a interlocking pattern by utilizing projecting parts present in the block design, where each projecting part fit exactly into grooves present over another block placed below. In this paper detailing two types of blocks are designed and arranged with alternative layers. Then the performance of wall were studied under evenlydistributed arrangement. Corresponding stress and deformation observed for theultimate load (under compression) and lateral pressure were analyzed using a finite element modeling (FEM) software.

II. MATERIALS AND MIX DESIGN

Cement used for this study is Portland pozzolana cement of Grade 43 and M sand sievedunder 4.75mm sieve is used as fine aggregate along with Coarse aggregate of 10mm grade conforming to the IS codal provisions. For conventional concrete mix providing M25 grade, aggregates conforming to zone-2 has been chosen and mix design is carried out under IS 10262:2009 guidelines, yielding a mix ratio of [Cement: Fine aggregate: Coarse aggregate][1:2.26:1.72] for 0.5 w/c ratio and mass of materials for 1m^3 are found to have Cement: 440.6 kg/m^3, fine

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aggregate: 996 kg/m^3, Coarse aggregate: 757.55 kg/m^{3}and water: 220.48 liters. The replacement with GGBS conforming [Cement: GGBS: Fine aggregate: Coarse aggregate] [0.75:0.25:2.26:1.72] for 0.5 w/c ratio and mass of materials for 1m^3 are found to have Cement: 330.45 kg/m^3,Ground Granulated Blast furnace Slag 110.15 kg/m^3,fine aggregate : 996 kg/m^3, Coarse aggregate : 757.55 kg/m^3 and water : 220.48 liters.Both conventional and GGBS replaced concrete mix were verified by casting cubes andtesting them under Compression testing machine by application of load over its surface area todetermine the Compressive strength of concrete for 7,14 and 28 days curing period which are presented in the **Table: 1.**

Table: 1 Target Compressive strength results

curing period	7days	14 days	28days
Specimen	Compressive strength N/mm^2		
Conventional mix	20.3	25.7	30.13
GGBS mix	23.6	27.7	32.6

III. DESIGN OF CONCRETE BLOCKS

Two forms of blocks are used in the development of interlocking wall system, they are arranged at alternative rows. Where one block having projections and groovesat vertical and horizontal directions and other having projections and grooves at vertical direction.As per the IS2185 (Part 1): 2005 code of practice of concrete masonry units, the original size of blocks are 520mm x 300mm x 240mm (horizontal and vertical grooves and projections), 440mm x 300mm x 240mm (including vertical projections and grooves). In this proposal the prototype of a blocks are designed and analyzed.The scale of a model is reduced to 1 in 0.5 for prototype analysis. One block is designed tohave a width of about 120 mm, whose length is usually more than its width which is about260 mm and overall depth constituting to 150mm(including projections). The other block is designed with 220mm length and 150mm width and 120mm thick (including projections).Projections and grooves are provided with half of thickness. Vertical projections and grooves are sized 30mm x 30mm x 60mm, horizontal projection and groove sized 40mm x 40mm x60mm.The figures below mentioned dimensions are all in cm.

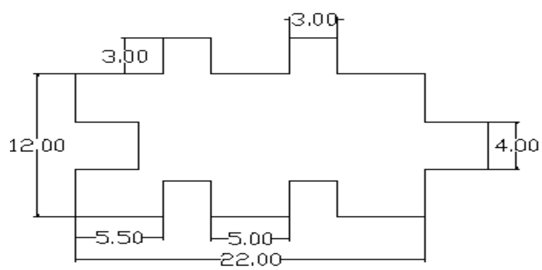

Figure:1block 1

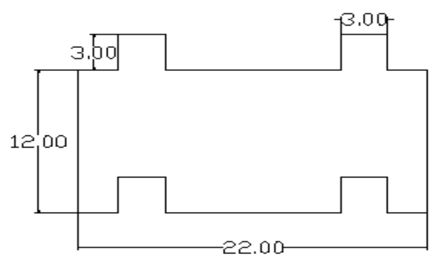

Figure:2block 2

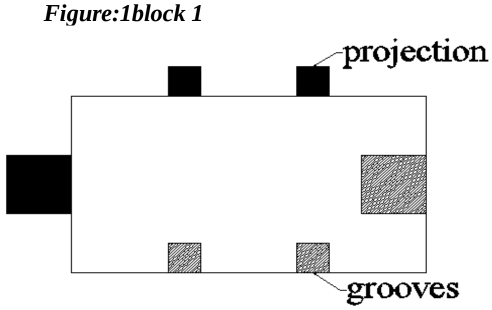

Figure:3, projections and grooves of block 1,

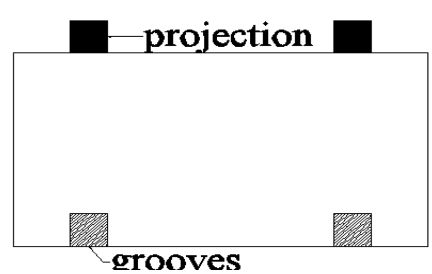

figure: 4 projections and grooves of block 2

IV. SERVICEABILITY CHECKS

4.1 Density of block

Blocks designed for the purpose of acting as a load bearing building unit shall satisfy the IS 2185 (Part1): 2005 codal provision in which blocks are grouped under different gradesbased on its function, thus in this study density of block is found out from thestandard procedure specified. The volume of specimen are found out bymeasuring their dimensions after which their density are found out from the formula givenbelow. Calculated values of density are then presented in **Table: 2**

$$\textbf{Density} = \frac{\text{mass of con crete in kg}}{\text{Volume of specimen ,in cm 3}} \times 10^6 \text{ kg/m}^3$$

Table: 2 Density of blocks (kg/m3)

Specimen	1	2	3	Average (kg/m^3)
Conventional block	2323.2	2325.6	2323.7	2324.2
GGBS replaced block	2455.8	2455.4	2456.0	2455.7

4.2Water absorption test

IS codal provision of 2185 (part 1):2005 specify a limit of 10 percent by mass. Percentage of water absorption are found out from the formula given below. Calculatedpercentage of water absorption are presented in **Table: 3.**

Percentage of water absorption $= \frac{W2-W1}{W1} \times 100$

Where, w_1 - weight of wet block observed in kg

w_2 - weight of dry block observed in kg

Table: 3 Percentage of water absorption

S.no	Specimen	W1(kg)	W2(kg)	% of water absorption	Average %
1	conventional concrete	7.36 7.32 7.35	7.77 7.79 7.61	5.57 6.40 3.50	5.15
2	GGBS replaced concrete	7.78 7.8 7.73	8.17 8.23 8.20	6.04 5.50 6.08	5.87

V. EXPERIMENTAL INVESTIGATION

5.1Pattern of wall formed

Wall developed by using the concrete blocks must provide the required homogeneity tothe structure, thus key to cohesion-less (interlocking) pattern is the arrangement carried outusing blocks. Blocks are arranged at alternative layers to create wall system. In this proposal three blocks are arranged in a row and three blocks are arranged in a column for experimental testing.For testing, 660mm x 360mm x 120mm size of wall is taken. Locking pattern of three blocks are presented in Figure 3and the arrangement of fully developed wall are presented in **Figure: 4.**

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Figure: 3interlocks of 3 blocks

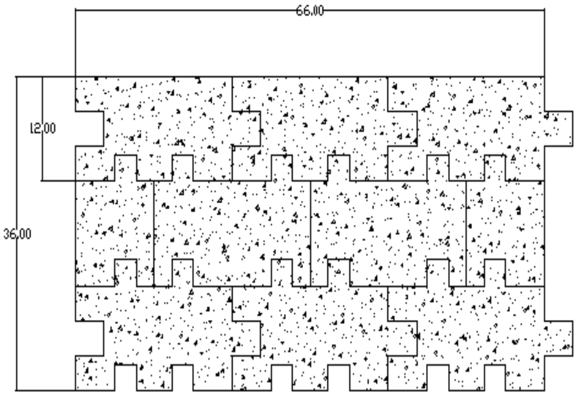

Figure: 4Plan showing fully developed wall in cm

5.2Testing of wall

Wall developed using the cohesion-less (interlocking) pattern is experimentallyinvestigated for determining the maximum load carrying capacity by applying axial load in theform of evenly distributed pattern covering the entire surface area of wall by the virtue ofchannel section over the loading frame in Universal Testing Machine (UTM). In this study concrete blocks made of both conventional concrete mix corresponding toM25 grade and 0.25 percentage of GGBS replaced with cement into concrete mix. Thus forming two cohesion-lesswalls, each having a dimension of 660 x 360 x 120 mm comprising 9 blocks with each row contains 3 blocks and 3 columns presented in **Figure: 5**.

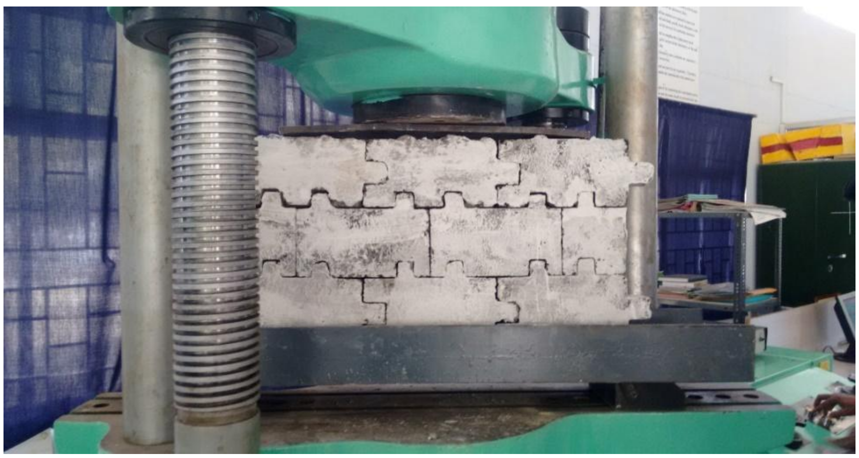

Figure :5 setup for testing of wall

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Figure:6 failure of conventional mix

Figure:7 failure of GGBS mix

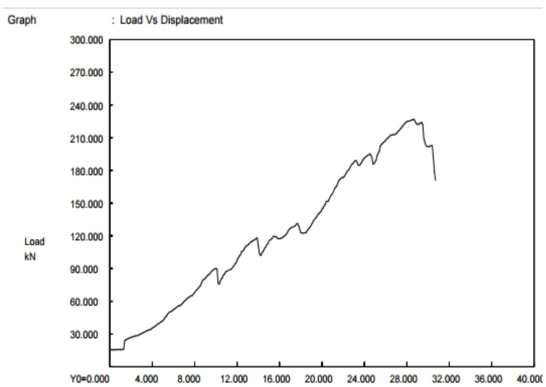

Figure:8conventional mix

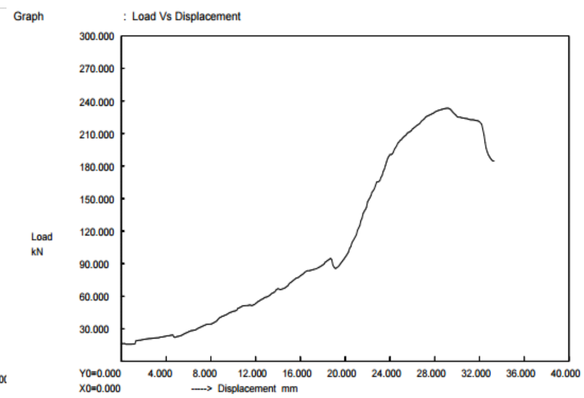

Figure:9 GGBS mix

Conventional concrete mix wall carried a maximum load of 227.1kN and hada maximum displacement of 28.7mmwhereas the GGBS replaced (25%) wall carried a maximum load of 233.2 kN and it had a displacement of29.1mm for the corresponding load.

VI. ANALYTICAL BEHAVIOR UNDER COMPRESSIONLOADING

Finite element modeling software used for studying the analytical behavior of interlocking wall made of both conventional and GGBS inducedconcrete mix. "Static structural" is the pane used for performing the analysis in the software,where parameters such as density of blocks, modulus of elasticity is obtained by utilizing theIS-456:2000 codal provision and ultimate compressive strength are inherited by using theEngineering data interface as shown In **Table: 4**. Then Model for analysis is developed using thegeometry interface where the use of "Boolean" command created the provision for developingblocks of our desired shape are presented in Figure 10 and after which key stage of modelinterface is reached where mesh for performing FEM analysis is provided in a refined size inorder to obtain accuracy are presented in Figure 11along with it friction type of connection arechosen between bodies.

Table: 4 Input parameters of model

Material	Density of blocks (Kg/m3)	Ultimate compressive strength (N/mm²)	Young's Modulus (N/mm²)
Conventional concrete mix	2324.2	30.13	25000
GGBS mix	2455.7	32.6	26275

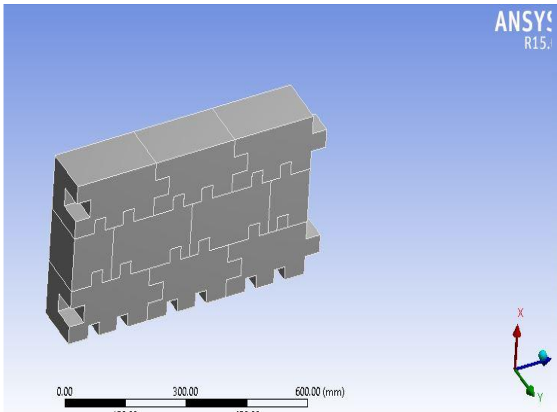

Figure: 10(3D)-geometry of the wall

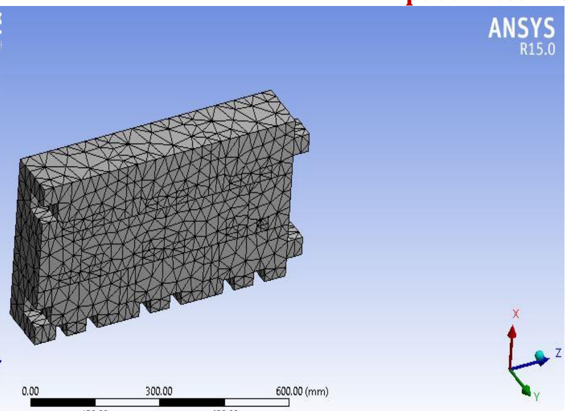

Figure: 11mesh for FEM analysis

To predict its behavior pattern under equivalent stress and deflection alongY-axis of cohesion-less wall made of both conventional concrete mix and GGBS replacedconcrete mix.Von-misses stress pattern observed for the both mixes represented in Figure 12(a) & 12(b)respectively.

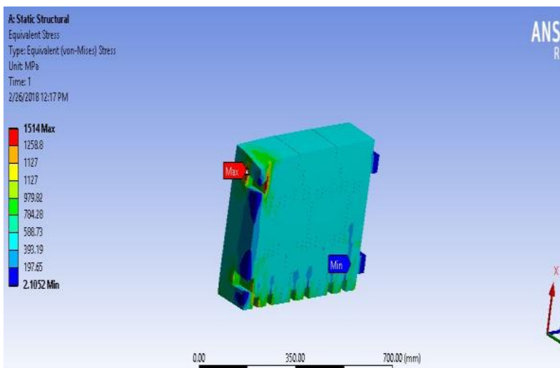
Figure: 12(a)Von-mises stress pattern of conventional mix

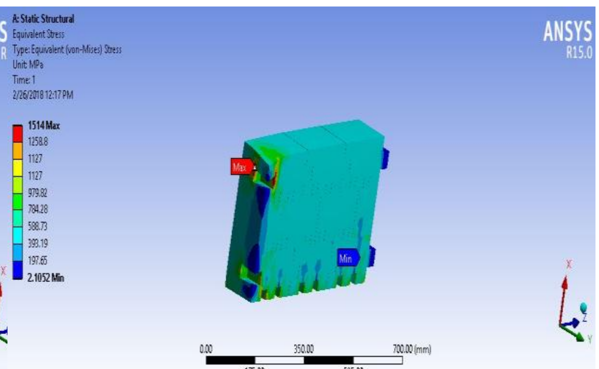

Figure: 12(b)Von-mises stress pattern of GGBS induced interlocking wall

Deflection observed under the y-axis of the wall. Deformation pattern observed for the conventional and GGBS replaced walls are presented in Figure 13(a) & 13(b)respectively.

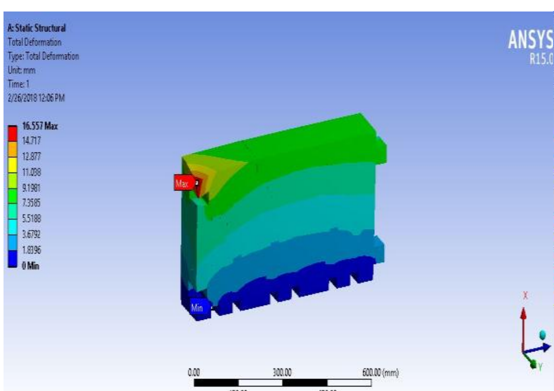

Figure: 13(a)Deflection along y-axis of conventional mix

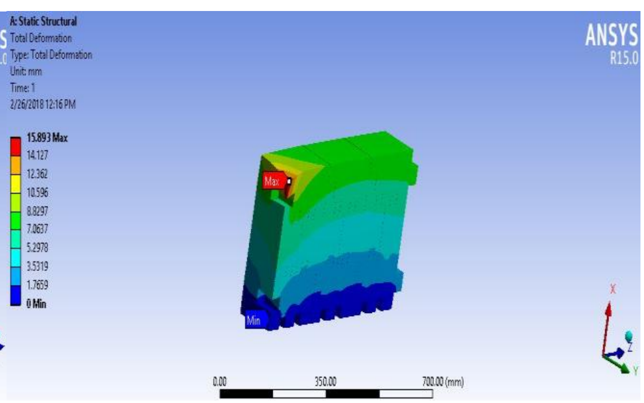

Figure: 13(b)Deflection along y-axis of GGBS replaced wall

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VII. ANALYTICAL BEHAVIOR UNDER LATERAL LOADING

To determine the behavior of interlock block system under lateral loading 1000mm x 1000mm wall size carried out.For lateral loading, end conditions are assumed to be fixed.

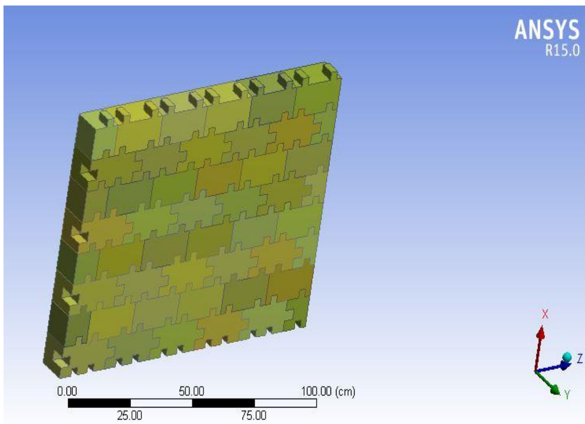

Figure: 14(a)3D wall for lateral loading

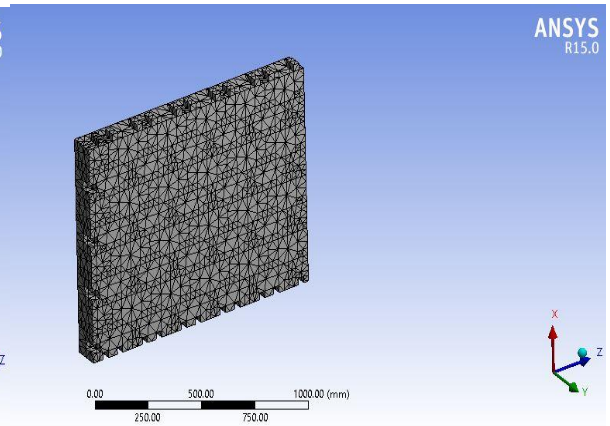

Figure:14(b)mesh for FEM analysis

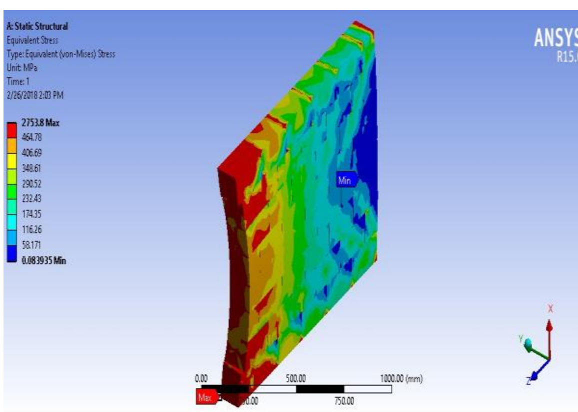

Figure:14(c)von-mises stress of wall

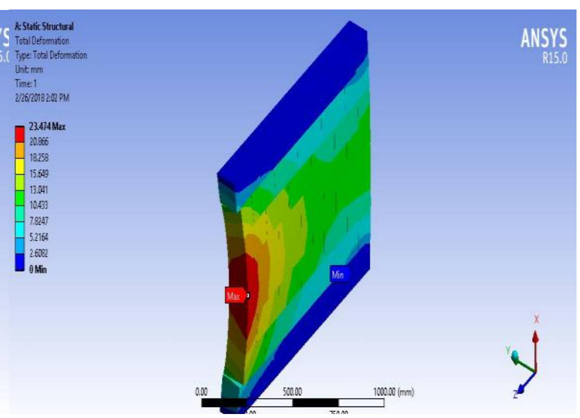

Figure: 14(d)displacement of the wall

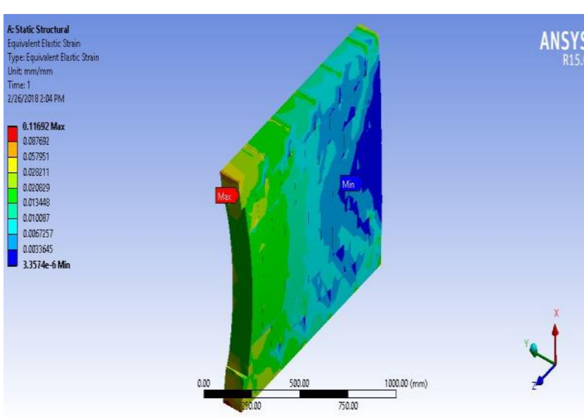

Figure: 14(e) elastic strain

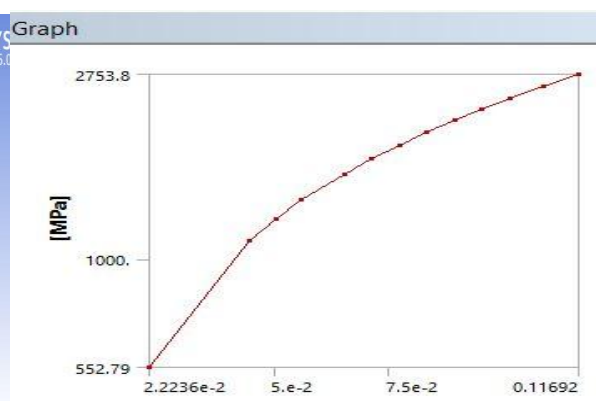

Figure: 14(f) stress vs strain graph

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VIII. CONCLUSION

- Demand for developing a speedy and efficient structural practices has been addressed inthis study by the virtue of a cohesion-less (interlocking) concrete wall which tends to act asa load carrying member.
- Concrete mix design is carried out under IS 10262:2009 guidelines, yielding a mix ratio of[Cement: Fineaggregate: Coarse aggregate] [1:2.26:1.72] for M25 grade using 0.5 w/c ratio for conventional and GGBS replacement (25% for cement content) conforming [Cement: GGBS: Fine aggregate: Coarse aggregate] [0.75:0.25:2.26:1.72].
- Density of blocks found out predicted that GGBS replaced block has 1.05 % more densitycompared to conventional mix block, whereas water absorption capacity of GGBS block was found to be 1.13 % more than conventional mix block.
- Interlocking wall developed of 660 x 360 x 120 mm using conventional concrete mixblocks found to have ultimate carrying capacity of 227.1 kN with displacement of28.7mm when subjected to evenly distributed axial load arrangement. Comparativelyperformance of cohesion-less wall improved by 2.61% withstanding ultimate load of 233.2 kN when GGBS replaced (25% for cement) concrete mix blocks were used and displacement of 29.1mm.
- The pattern were analyzed using FEM software for compressive(conventional and GGBS mix) and lateral loading(only conventional mix) to indicate the stressconcentration around the wall when withstanding the respective ultimate load(compressive), whichrevealed that conventional mix wall have more stress at top, left and rightsides compared to GGBS wall which is concentrated more at junctions ofblocks.
- Thus the interlocking wall pattern developed found to be productive on its own incarrying load under conventional concrete mix and still found to be enhanced in itsperformance by a margin, when GGBS being induced in concrete mix. Thus this wallpattern can pave way for developing easy and effective load carrying structure in a fasterrate compared to the framed structure and using interlock wall system to form temporary structures easily without skilled labors with effective time period.

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