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Performance Evaluation of Composite Wall with Boundary Column Having Triangular Corrugation

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Abstract: Composite wall is an innovation in the field of Civil Engineering that enhances the constructability by eliminating reinforcing bars and formwork. Double skin composite wall consist of a concrete core is placed between outer steel plates. By providing corrugation in the steel plate improves the seismic behavior and also stability against buckling. This paper aims to the performance evaluation of corrugation on composite wall with boundary column. For this study, four FE models of composite wall with boundary column having triangular corrugation were analyzed using Ansys 2022 R1. Composite wall with different height of corrugation ie., 25 mm, 30 mm, 40 mm and 45 mm is evaluated under monotonic loading to understand the total deformation and equivalent stress. Also perform buckling analysis on the better model obtained from different geometry of corrugation. Study shows that model with 45 mm height of corrugation shows maximum load carrying capacity.
Keywords: Corrugation, Finite Element, Total Deformation, Equivalent Stress, Double Skin Composite Wall.

I. INTRODUCTION

The Double-Skin Composite Wall (DSCW) is composed of steel plates on both sides and concrete on the inner layer, which can ensure composite action between the outer steel plate and the inner concrete through certain structural measures, such as through bolts, fastener screws and studs [1]. And an increase in the extent of the Concrete Filled Steel Tube (CFST) boundary element increases the wall's deformation and energy dissipation capacities and decelerates the degradation of the rigidity and strength of the wall [1]. For DSCW, the outer steel plate can not only bear the external load directly, but also restrain the internal concrete, so as to improve the bearing capacity and deformation performance of the wall. Moreover, the internal concrete provides support for the outer steel plate to avoid local buckling, thus improving the stability of the steel plate. Composite action is typically achieved between steel faceplates and concrete using these steel headed shear studs. The shear studs and concrete core enhance the stability of steel plates, while the steel plates serve as permanent formwork for concrete casting. SC structures have gained popularity during recent decades especially in the third generation of nuclear power facilities due to their structural efficiency, economy, safety, and construction speed[2].

For DSCW, the outer steel plate can not only bear the external load directly, but also restrain the internal concrete, so as to improve the bearing capacity and deformation performance of the wall. Moreover, the internal concrete provides support for the outer steel plate to avoid local buckling, thus improving the stability of the steel plate [1]. Compared with flat steel plate, corrugated steel plate has greater out of plane stiffness due to its special cross-section structure, so it can bear greater axial force, shear or bending moment in the strong axial direction without buckling. It is worth mentioning that the outer steel plate can be used as the formwork for concrete construction, which speeds up the construction progress and reduces the cost of formwork measures [1]. Therefore, the DSCW not only has the advantages of high bearing capacity and good seismic behavior, but also meets the requirements of fast and convenient construction of modern building structure. Once the design standards of DSCW in buildings including strength, stiffness, fire resistance and durability, etc. are developed, the DSCW will have broad application prospects.

II. FINITE ELEMENT MODELLING

Finite Element Modelling consist of four models having composite wall with boundary column having triangular corrugation is modelled. The wall may be named as CW1, CW2, CW3, CW4. CW1 refers to the composite wall with triangular corrugation of height 25 mm, CW2 refers for the wall with 30 mm height, CW3 refers to the wall with 40 mm and CW4 wall with 45 mm height. The height is limited within 25 and 45 mm because of the difficulty to manufacture the steel plate. Different corrugation geometry is used to evaluate the performance of composite wall. ie, the height of corrugation of triangular corrugation includes., 25 mm, 30 mm, 40 mm and 45 mm is changing and evaluated under monotonic loading. The model consist of a concrete is placed in between two steel plates. The thickness of steel plate provided on wall is 2.74mm. An extent to the wall, CFST member having triangular corrugation is provided as boundary column with 120 mm x 120 mm square tube of 2.89mm thickness. Different geometry of triangular corrugation is modelled and analyzed.

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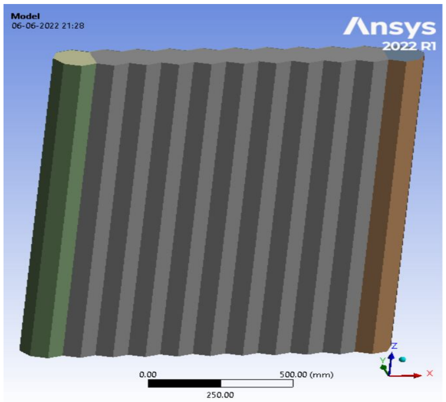

Fig.1 CW1

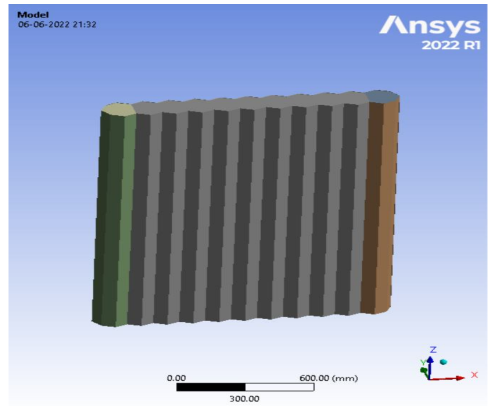

Fig.2 CW2

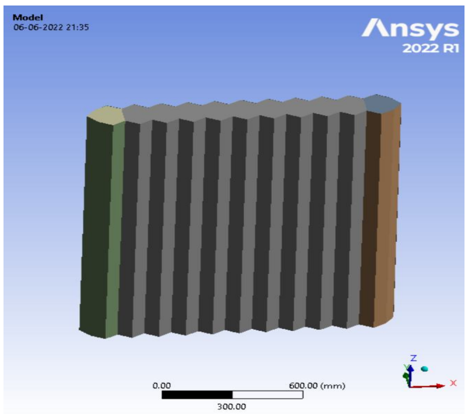

Fig.3 CW3

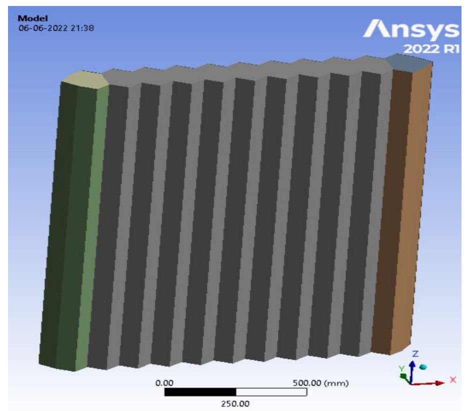

Fig.4 CW4

III.FINITE ELEMENT ANALYSIS

For FE analysis, Ansys 2022 R1 is used. Four models were considered for the finite element analysis. The FEM is a general numerical method for solving partial differential equations in two or three space variables (i.e., some boundary value problems). To solve a problem, the FEM subdivides a large system into smaller, simpler parts that are called finite elements. This is achieved by a particular space discretization in the space dimensions, which is implemented by the construction of a mesh of the object: the numerical domain for the solution, which has a finite number of points.

A. Material Properties

The material properties assigned for steel and concrete is listed in the table. The Poisson's ratio for steel and concrete is taken as 0.3 and 0.2 respectively. The yield strength provided for steel as 310 MPa. The Young's Modulus for steel and concrete are 200000 MPa and 31600 MPa respectively.

TABLE I
MATERIAL PROPERTIES

Properties	Steel	Concrete
Poisson's Ratio	0.3	0.2
Young's Modulus	200000 MPa	31600 MPa
Density	7850 kg/m^3	2300 kg/m^3

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B. Boundary Conditions

For analysis, using Ansys software various models of triangular corrugation are evaluated under monotonic loading. Here Displacement controlled loading is provided. So, the composite wall is treated like one end is fixed and other is free. Fig.5 shows the composite wall having boundary condition. The bottom portion of the wall is taken as fixed that is shown in the figure and denoted as 'B. The loading is provided in the top of the wall in X direction as remote displacement. In Ansys Remote displacement is a useful tool for evaluating the deformation, stress etc. With the remote displacement boundary condition, the guided displacement of the face with a remote point can be specified. Remote displacement point is denoted as 'A' that is in the direction of X axis.

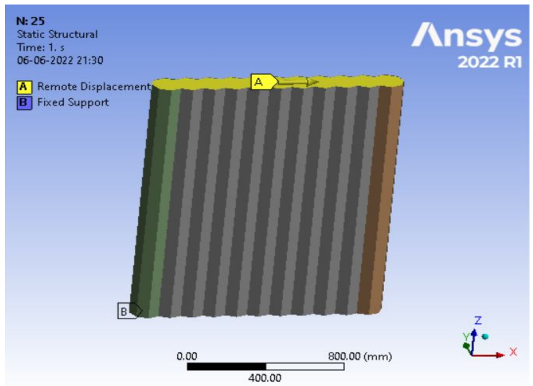

Fig. 5 Boundary condition of CW1

C. Total deformation of composite wall

The total deformation of composite wall having triangular corrugation under monotonic loading is given below.

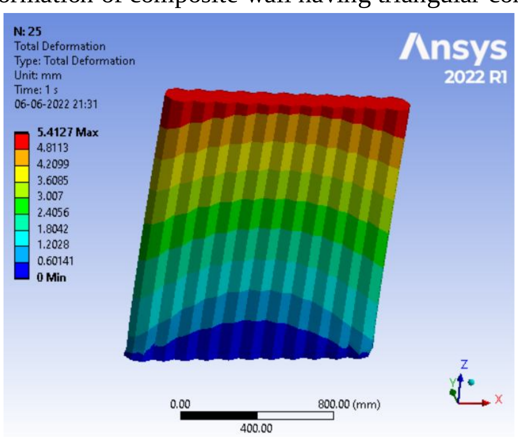

Fig.6 Total deformation of CW1

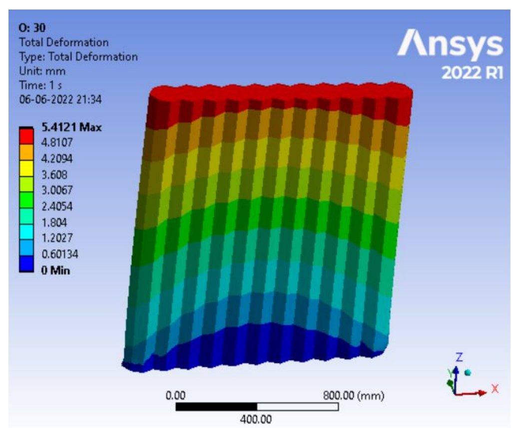

Fig.7 Total deformation of CW2

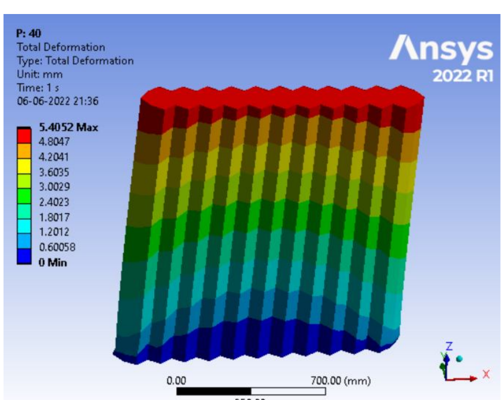

Fig. 8 Total deformation of CW3

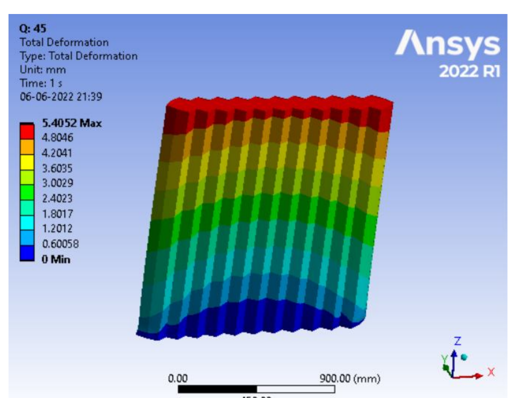

Fig.9 Total deformation of CW4

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From the total deformation, we can clearly see that as height of the corrugation increases the load carrying capacity increases. That is the composite wall with 25 mm height shows least load carrying capacity. As the corrugation height increases, it can bear more load. So, from the load deformation analysis, the composite wall with 45 mm height shows more load bearing capacity ie., CW4 has high load carrying capacity. In short, we can conclude it by comparing the load deformation graph of various composite wall models.

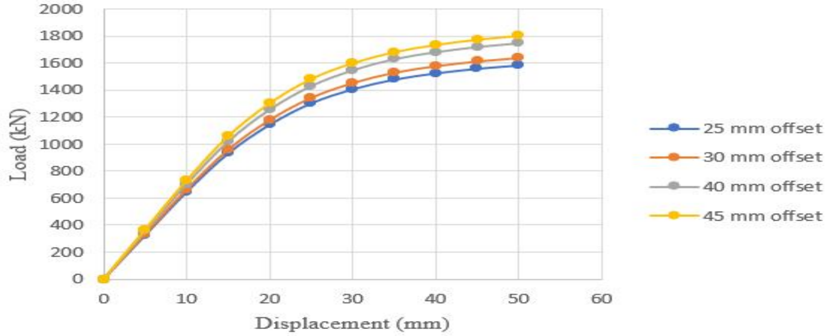

Fig. 10 Comparison of composite wall with different corrugation height

D. Equivalent Stress in Composite Wall

From equivalent stress/ von mises stress, it is a value used to determine if the material will yield or fracture. The concept of von mises is arises from the distortion energy fracture theory. According to the theory, failure occurs when the distortion energy in actual case is greater than the distortion energy in a simple tension case at the time of failure.

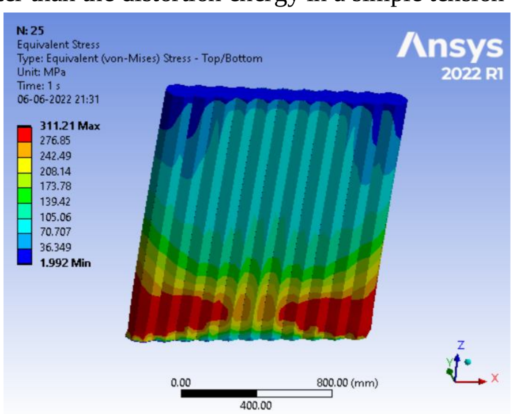

Fig. 11 Equivalent stress of CW1

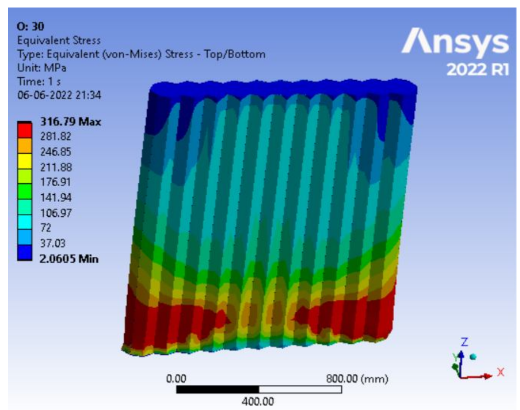

Fig. 12 Equivalent stress of CW2

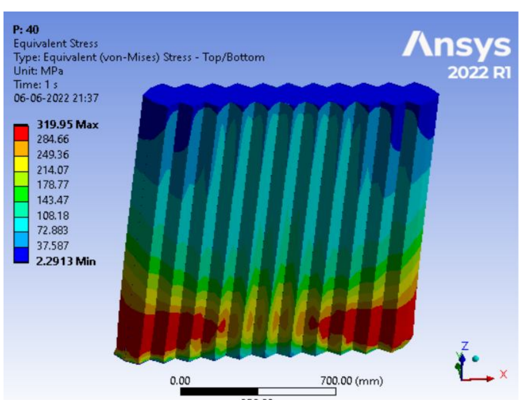

Fig. 13 Equivalent stress of CW3

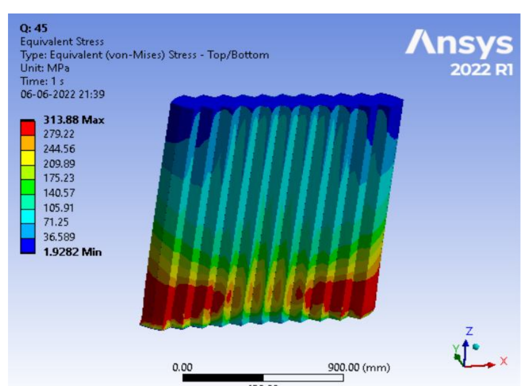

Fig. 14 Equivalent stress of CW4

The equivalent stress for 25 mm height shows 311.21 MPa and shows near to the support region. It is the minimum stress created in the composite wall. For 30 mm, the maximum of 316.88 MPa, 40 mm shows 319.95 MPa, and 45 mm shows 313.88 MPa.

E. Buckling Analysis

Eigenvalue or linear buckling analysis predicts the theoretical buckling strength of an ideal linear elastic structure. This method corresponds to the textbook approach to an elastic buckling analysis. Here the Eigenvalue Buckling is adopted for the 45 mm height corrugation model.

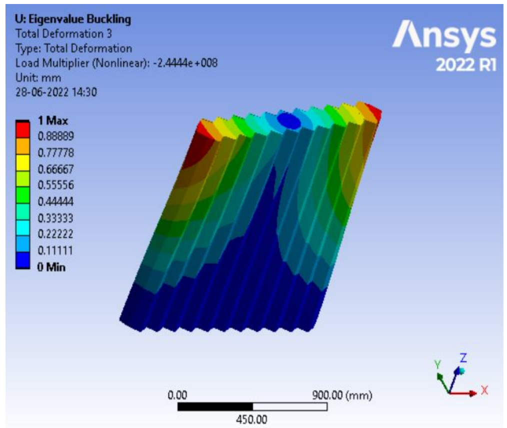

Fig. 15 Eigenvalue buckling for CW4

From the analysis, we got the load multiplier as -2.44e+008. The negative sign denotes the axis provided is reversed.

IV. CONCLUSIONS

In this paper, composite wall with boundary column having triangular corrugation of different corrugation height is evaluated under monotonic loading. The model with better performance is then subjected to Eigen value buckling. From the analysis it is clear that, the corrugation height increases, the load carrying capacity increases. ie, model having 45 mm height shows better performance. ie., load carrying capacity is more for CW4 than other models. Also, it is difficult to manufacture the composite wall with corrugation below 25 mm. From the buckling the model obtain the load multiplier as 2.44e+008.

V. ACKNOWLEDGMENT

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