IN PLANE SHEAR BEHAVIOUR OF FERRO-CEMENT PANELS USING FINITE ELEMENT METHOD

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***ABSTRACT**: Ferrocement is a non-traditional type of construction system using mortar applied over a single or series of metal mesh. It is used to construct surfaces and structures consisting of small thicknesses for different shapes. An advantage of ferrocement concrete structures is that they are stronger and more durable than some traditional building methods. Ferrocement structures can be built quickly, which can provide a commercial advantage. Ferrocement is used often in India nowadays because the constructions made from it are more resistant to earthquakes. In this research, modelling of ferrocement panels for different thicknesses i.e. 18mm and 25mm were done in a finite element software named ANSYS mechanical APDL. These 2 types of panels were subjected to in-plane shear loads of 5000N, 8000N & 10000N each. The model was programmed by using different elements and material models with different load variations for solving in-plane shear stresses.*

***Key words**: **Ferrocement, in-plane shear stress, finite element, ANSYS mechanical APDL**.*

1. INTRODUCTION

Traditionally RCC structures are preferred for construction due to popularity, straight forward process and accessibility of materials but there are some failings observed when they are subjected to dynamic loads. Ferrocement is a system of thin wall reinforced mortar made of hydraulic cement mortar strengthened with closely spaced layers of continuous and comparatively tiny size wire mesh. Mesh could be made of metallic or different appropriate materials. The matrix might contain discontinuous fibers. This definition ignores as vital form of reinforcement presently in use in ferrocement i.e. the mixture of steel rods and wire mesh. India has been known as a developing economy that tends to provide rise to a loads of infrastructure developments particularly the building projects. RCC is most generally employed in everywhere all over world because of its high load carrying capability however the price of cement and steel is increasing day-by-day. So, we tend to need a substitute to concrete which provides the strength as that of RCC with low price. In ferrocement, hydraulic cement mortar with closely spaced tiny diameter wire meshes is employed. To enhance certain characteristics of ferrocement varied materials like admixtures, silicon dioxide fumes, fly ash and fibers are used. Generally, the thickness of ferrocement ranges from 20 up to 50 mm. Ferrocement is a wire mesh reinforcement inseminated with mortar to provide components of tiny thickness, high sturdiness and resilience and, once properly formed, high strength and rigidity. To bypass these issues and directly confirm the response of ferrocement in unconventional applications, numerical imitations via the Finite Element Method (FEM) have generated necessary ideas in recent years. To provide realistic outcomes that accurately replicate real-world situations, the constitutive model of ferrocement should be improved to reproduce even the foremost elementary phenomena. Developments in FEM like enhancements in material constitutive models and enormous increases in computer calculation speed have led to the likelihood of reproducing advanced real-world scenarios with sensible accuracy.

Generally, ferrocement slabs range from 10 to 25 mm in thickness and the reinforcement consists of layers of Steel mesh usually with steel reinforcing bars sandwich midway between. The resulting slab for panel of mash is impregnated with very rich Portland cement mortar. Other type of cements may also be used.

ANSYS simulation software gives designers the ability to access the influence of this range of variable in virtual environment. We can advance through the design and materials selection process quickly and efficiently. ANSYS still gives the user through coupled Rock and soil mechanics analysis; material specific maximum load assumptions; linear, nonlinear, static and dynamic analyses; sensitivity and parametric studies; and other related work which together provide significant insight into design behavior that would be difficult with single analysis runs.

1.1 OBJECTIVES OF THE RESEARCH

1. To study the different types of configurations of thicknesses for possible use in ferrocement panels analytically.
2. To study the stress and displacement variations due to variation of loads acting on ferrocement panels with varying thicknesses analytically.
3. To prepare analytical models of ferrocement panels for different thicknesses and applying different loadings.
4. To calculate in-plane shear stresses, reviewing Von Mises stresses & principal stresses analytically.

2.0 LITERATURE REVIEW

The unique properties of ferrocement have been investigated extensively by many researchers. The following literature survey includes summary of research papers presented in popular journals on topics similar to current field of study.

Mahmoud R. Maheri & M. A. Najafgholipour [1], in this study, the results of a series of tests with different levels of simultaneous in-plane shear and out-of-plane bending loadings on brick walls were presented. The tests results indicated noticeable interaction between the in-plane shear and out-of-plane bending strengths of brick walls. A simple analytical approach was presented for evaluating the in-plane shear and out-of-plane bending interaction curve for unreinforced brick walls. D.G. Gaidhankar, M. S. Kulkarni, Abhay R. Jaiswal[2], in this paper, analytical and experimental comparisons of welded square mesh and wovens square mesh subjected to flexural strength were studied under different loading conditions. They concluded that, such models can be used as quick, simple, and inexpensive methods to calculate the optimal deflection of ferrocement channels for various spans and sizes of tensile reinforcement. Darshan G. Gaidhankar, Mrudula S. Kulkarni, Abhizer Akhtar [3], in this research, experimental study on effects of panel thickness, types of mesh, types of grade of mortar, types of fibers on deformation, equivalent stress and normal stress of panel under low velocity and high velocity impact loading were studied. Their study concluded that when fibers were added in the mortar, deformation due to impact loading was reduced and stress resistance of ferrocement panel was increased, also when welded square mesh was used instead of woven mesh penetration, depth reduced. S. Rohini, R. Thenmozhi, S. Deepa Shri [4], in this research, analytical study of self-compacting concrete (SCC) ferrocement slabs with weld mesh as reinforcement were modelled for 2 different thicknesses as 25mm and 30mm, they were subjected to 2-point load. The study was performed on ANSYS software. The results obtained from their analysis gave good experimental result when compared to the loads at failure. Their results showed that with increasing number of layers of weld mesh, the ultimate load carrying capacity of slabs is increased. Valerio Alecci, Mario Fagone, Tommaso Rotunno, Mario De Stefano [5], in this study, results of an experimental investigation, carried out on triplets using standard shear test and diagonal compression tests on brick masonry walls assembled with different kinds of mortar are reported. A comparison between the values of the masonry shear strength, calculated applying the three formulas available in literature for the diagonal compression test data, and those obtained by laboratory tests on shear triplets, is presented in this study. Daniel Bedoya-Ruiz, Bryan Chalarca, Felipe Uribe, Diego A. Alvarez and Jorge E. Hurtado [6], this research proposed two different configurations of precast ferrocement walls tested under cyclic load conditions, to evaluate their seismic performance and potential application to the mass production of dwelling houses. A total of four full-scale walls were tested under cyclic loading conditions; from those results, the sufficiency of the system was evaluated in terms of shear strength, ductility, energy dissipation, damping and crack patterns. The study showed that these novel configurations of ferrocement walls can be applied in susceptible earthquake regions because of their high energy dissipation, stiffness and low strength degradation properties.

3.0 MATERIAL PROPERTIES

Finite element model

ANSYS software is capable of handling dedicated models for the non-linear response of concrete under static and dynamic loading. In this study, Ferrocement panel consists of small thickness merely 18mm and 25mm. therefore SHELL-181 element was used to model the panel. Internal meshing was determined by adding a shell element and providing spacing between internal meshes and overall spacing. Same element type was used for defining mortar, just different material models were added for mortar and mesh.

Analysis using Ansys

The following steps are involved in analyzing the trough element using the finite element software package ANSYS

1. Element selection
2. Defining material properties
3. Model creation
4. Meshing
5. Applying boundary conditions and loading
6. Analysis
7. Viewing results

The accuracy of the results depends upon the type of element used and the way in which the model is meshed. Among these steps the element selection and meshing are very important.

Element type

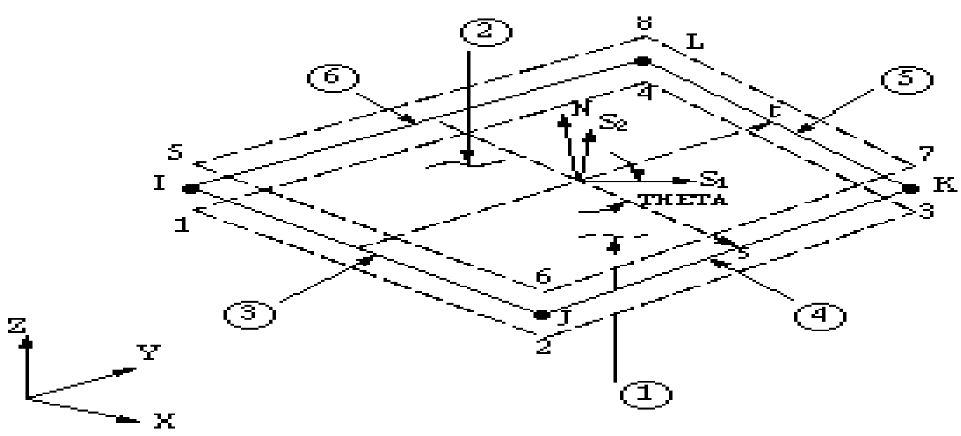
The following element type was used for simulation:

- SHELL 181

Shell 181

SHELL181 is suitable for analyzing thin to moderately-thick shell structures. It is a four- noded element with six degrees of freedom at each node: translations in the x, y, and z directions, and rotations about the x, y, and z axes. The degenerate triangular option should only be used as filler elements in mesh generation.

SHELL181 is well-suited for linear, large rotation, and/or large strain nonlinear applications. Change in shell thickness is accounted for in nonlinear analyses. In the element domain, both full and reduced integration schemes are supported. SHELL181 accounts for follower effects of distributed pressures. SHELL181 can be used instead of SHELL43 for many problems that have convergence difficulty with SHELL43[7].



Input data

Following is the input data required to create a material model for mortar and steel mesh in ANSYS:

	MORTAR	STEEL MESH
Modulus of Elasticity (Ec)	$2x10^5$ Nmm^2	27385 Nmm^2
Poisson's ratio (v)	0.29	0.22

4.0 MODELLING

In this study analytical work is done totally in ANSYS Mechanical APDL. In which Ferro cement panel was modeled. The size of Ferrocement panel is 600 x 900mm. The thickness of the panel is taken as 18mm and 25mm. In 18mm and 25mm panel, number of wired meshes are two which are placed at a cover of 3mm from top and bottom.

In the modelling option, a shell element was created and then parameters were defined accordingly. The squared wire mesh was modelled such, that the c/c spacing of the wire is 15mm in both directions. The outer wire of the mesh is placed at a cover of 15mm on both sides. The diameter of the wire is taken as 2mm. A body interaction is defined while modelling, which is used to define that the wire mesh which is placed inside the Ferro cement panel is reinforcement of it. After defining the parameters, ANSYS considers wire mesh as reinforcement inside the panel and does analysis accordingly.

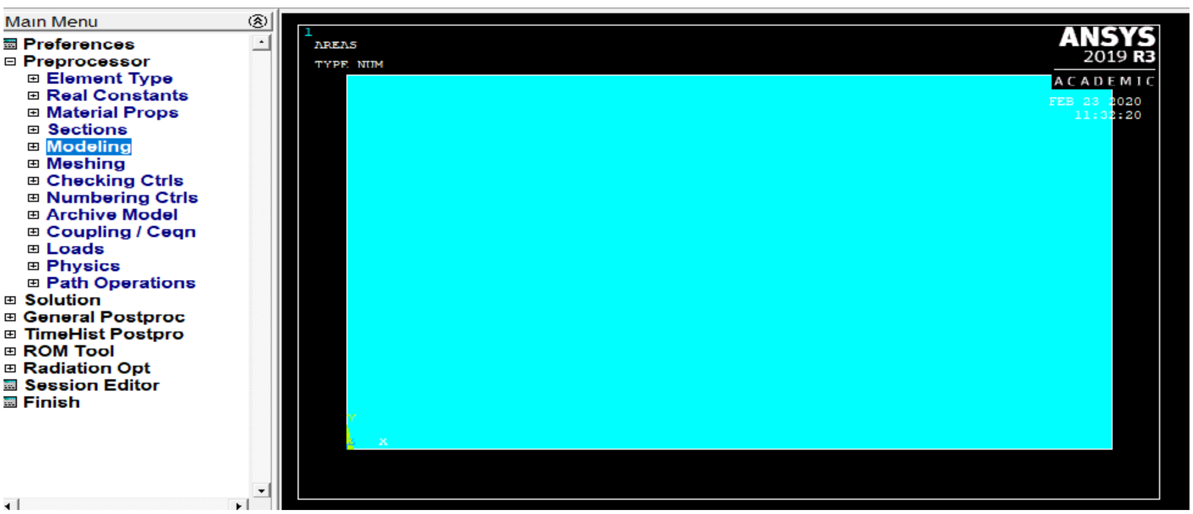


Figure 1: Modelling of panel

LOADING CONDITIONS

After the panel was modelled, the next important step is applying loading conditions. In this case, initially the bottom of the panel was fully restrained in all directions. This will restrict the panel to initiate movement when the loading is applied and help in resisting the load it can yield. Then the loading was applied on the left top corner for respective loads i.e. 5000n, 8000N and 10000N. the purpose of applying the load on the left top corner of the panel is, because during earthquake condition, the shear forces acts between the middle of two storeys.

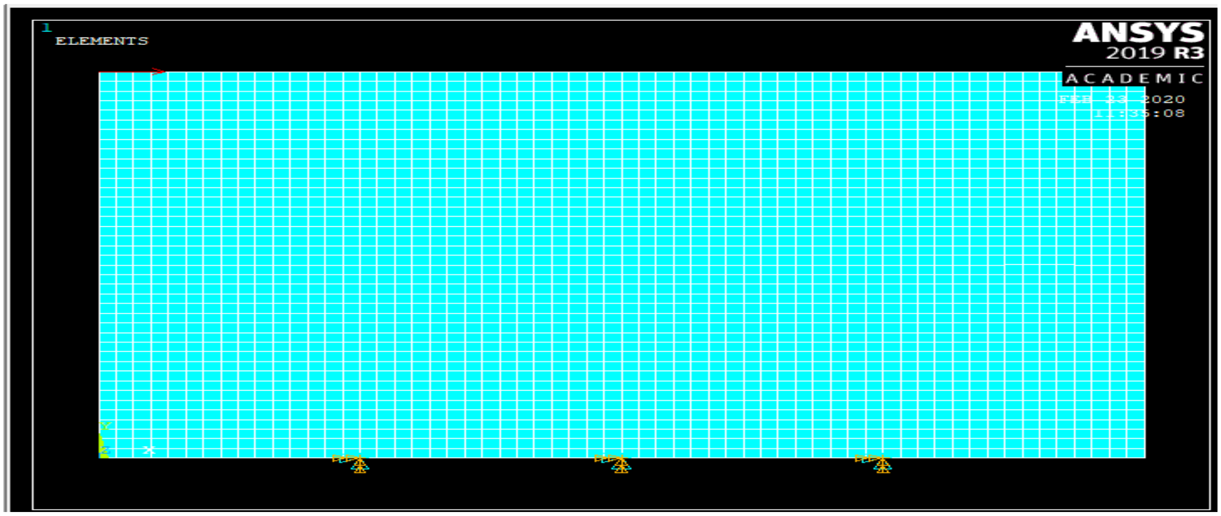


Figure 2: Meshing of panel and Applying Loading conditions

5.0 OBSERVATIONS & RESULTS

Table 1: FEM results for von mises and panel displacement

Horizontal loading on panel (N)	Panel thickness (mm)	Von Mises stresses σ (N/mm²)	Panel displacement δ (mm)
5000	18	12.2355	0.073
8000	18	19.5768	0.12
10000	18	24.471	0.145
5000	25	9.35655	0.056
8000	25	14.9705	0.089
10000	25	18.7131	0.11

The analysis results of ferrocement panels under In-plane shear loads acting as seismic loads using ANSYS software are presented in the above table. The load is applied in on each panel for various load variations such as 5000N, 8000N and 10000N, and stresses and the corresponding displacements were noted down. The values obtained from FE analysis using ANSYS analysis software were then plotted in the graphical format (refer figure 3 and figure 4) to give us better understanding of the stress and displacement variations with respect to applied load.

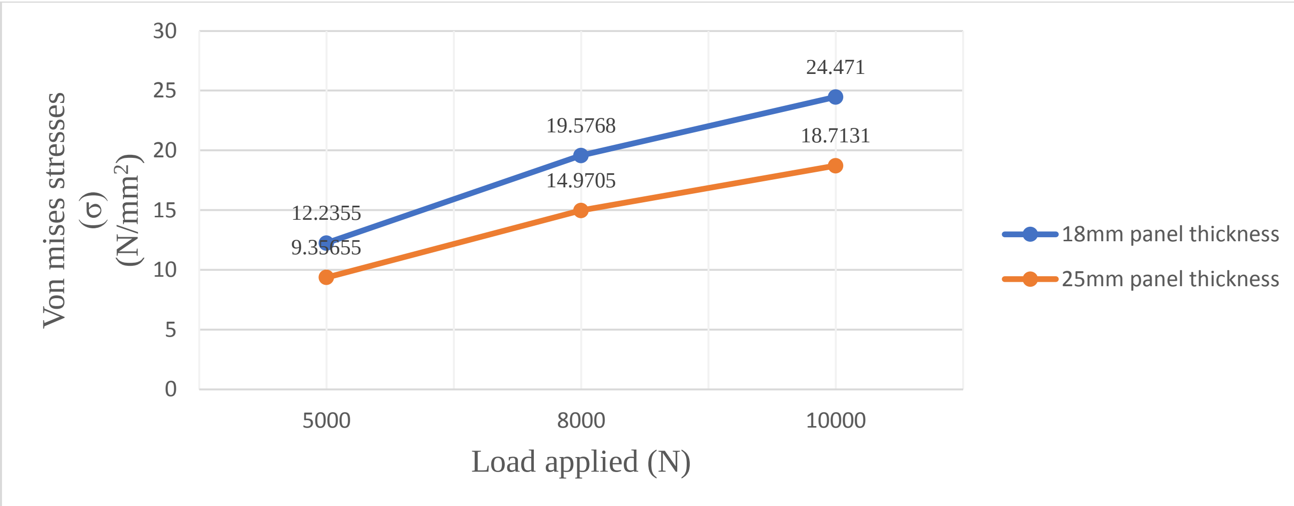


Figure 3: Von mises vs Loading applied for 18mm and 25mm panel thickness

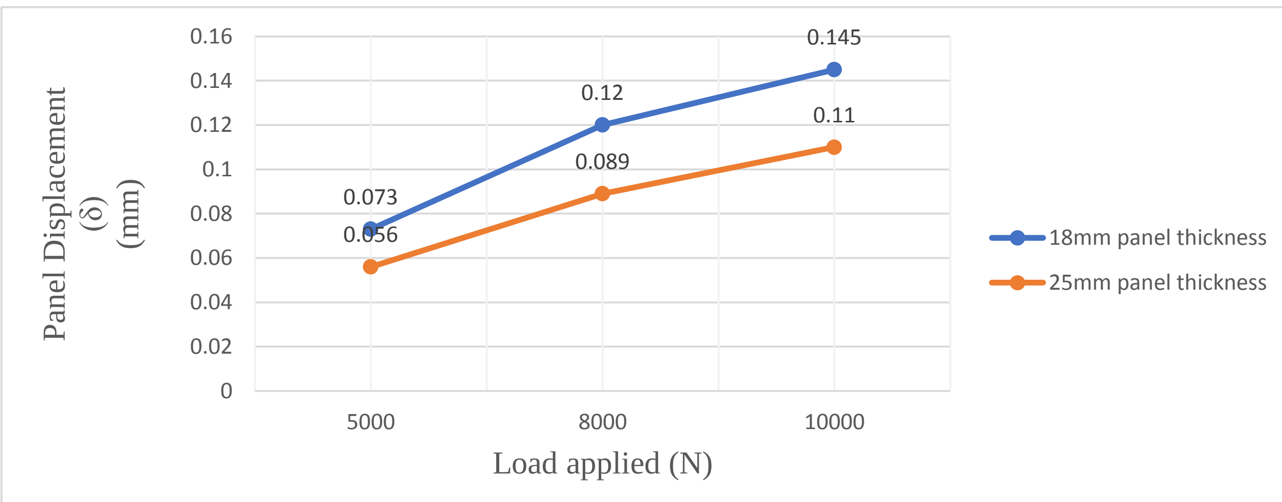
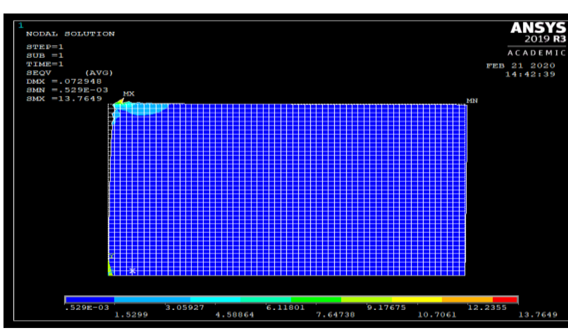


Figure 4: Panel Displacement vs Loading applied for 18mm and 25mm panel

5.1 Von-mises stress contours for 18mm, 25mm panel thickness when applied to 5000N, 8000N & 10000N



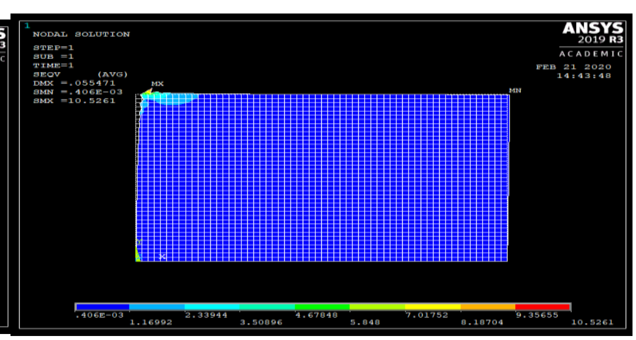
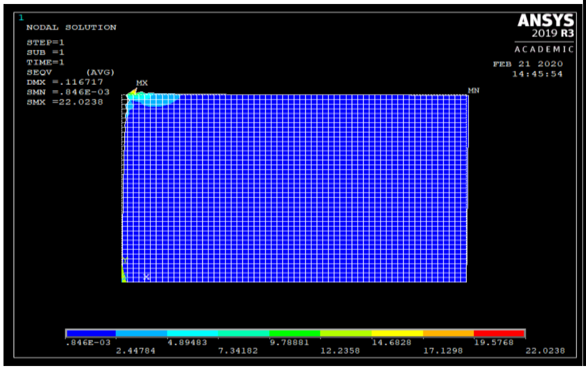


Fig 5.1.1: Von mises stress contour for 18mm panel thickness and 5000N Load

Fig 5.1.2: Von mises stress contour for 25mm panel thickness and 5000N Load



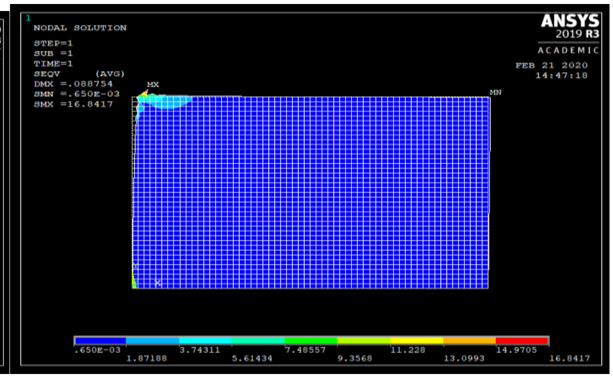
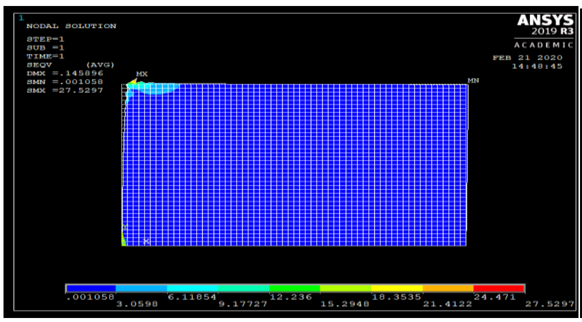


Fig 5.1.3: Von mises stress contour for 18mm panel thickness and 8000N Load

Fig 5.1.4: Von mises stress contour for 25mm panel thickness and 8000N Load



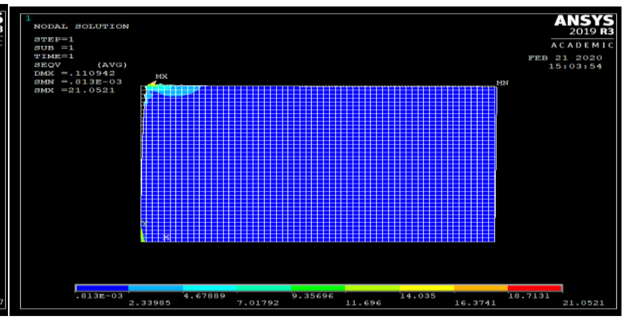
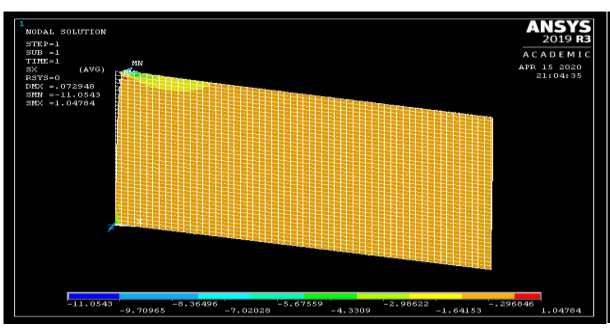


Fig 5.1.5: Von mises stress contour for 18mm panel thickness and 10000N Load

Fig 5.1.6: Von mises stress contour for 25mm panel thickness and 10000N Load

5.2 Shear stress contours in X, Y & X-Y directions of 18mm & 25mm thickness panel under 5000N, 8000N &10000N

Also shear stress in X, Y and X-Y direction were observed for each panel thicknesses under different loads shown in the form of contours.



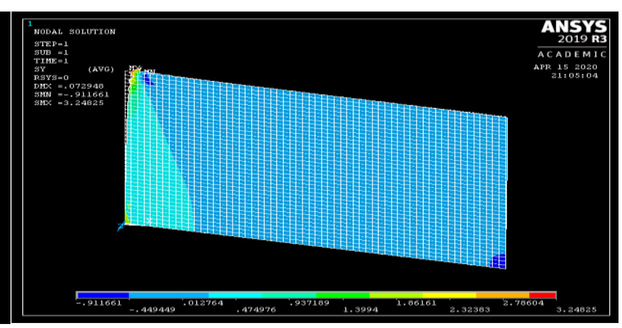


Fig 5.2.1: X direction shear stress contour for 18mm panel thickness and 5000N Load

Fig 5.2.2: Y direction shear stress contour for 18mm panel thickness and 5000N Load

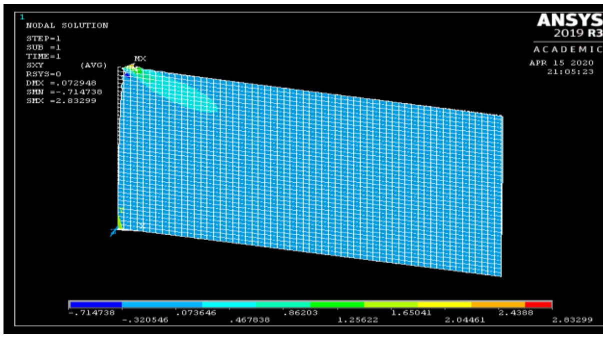
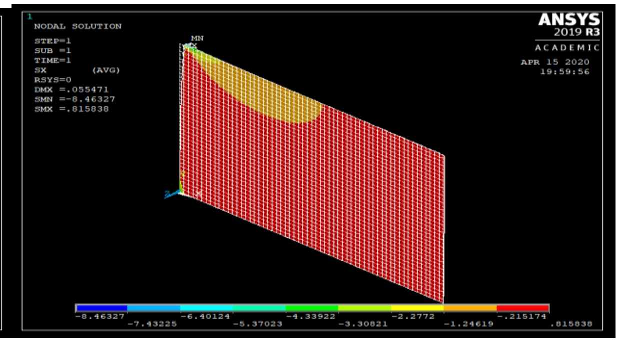



Fig 5.2.3: X-Y direction shear stress contour for 18mm panel thickness and 5000N Load

Fig 5.2.4: X direction shear stress contour for 25mm panel thickness and 5000N Load

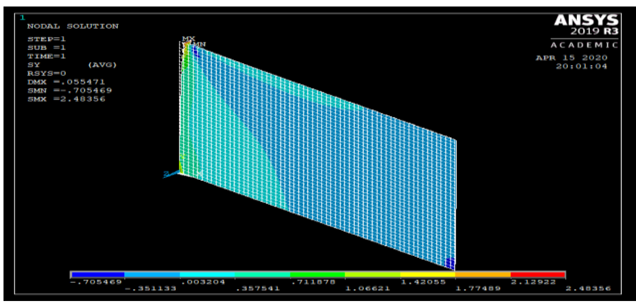
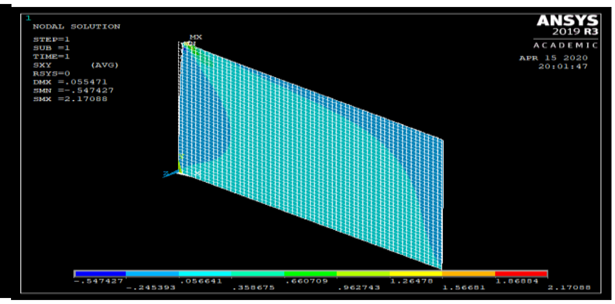



Fig 5.2.5: Y direction shear stress contour for 25mm panel thickness and 5000N Load

Fig 5.2.6: X-Y direction shear stress contour for 25mm panel thickness and 5000N Load

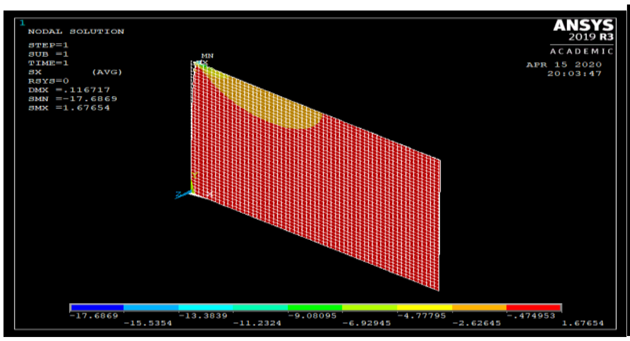
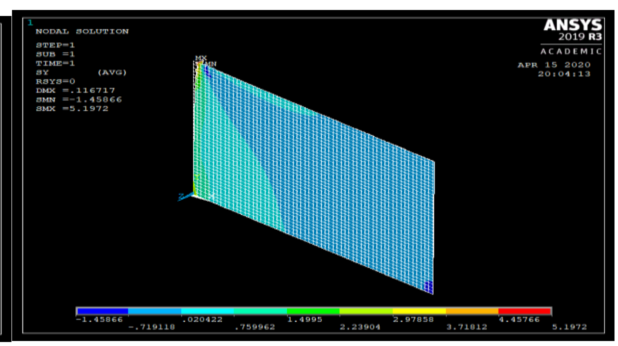
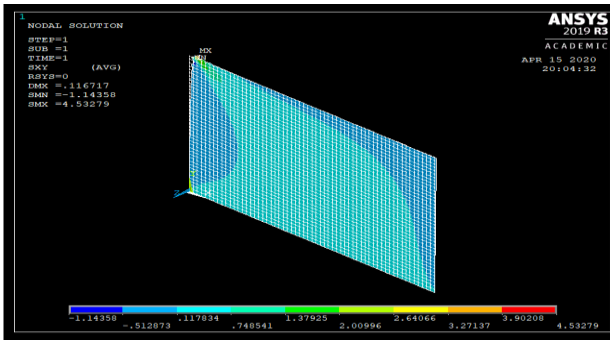



Fig 5.2.7: X direction shear stress contour for 18mm panel thickness and 8000N Load

Fig 5.2.8: Y direction shear stress contour for 18mm panel thickness and 8000N Load



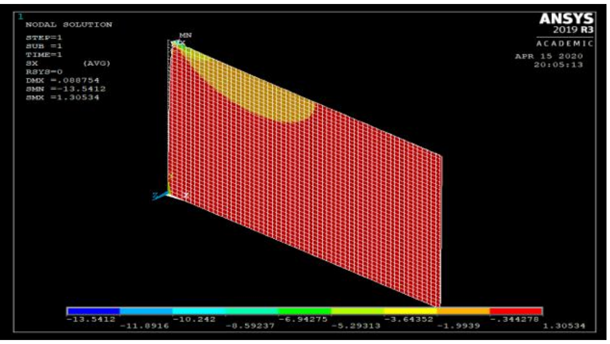
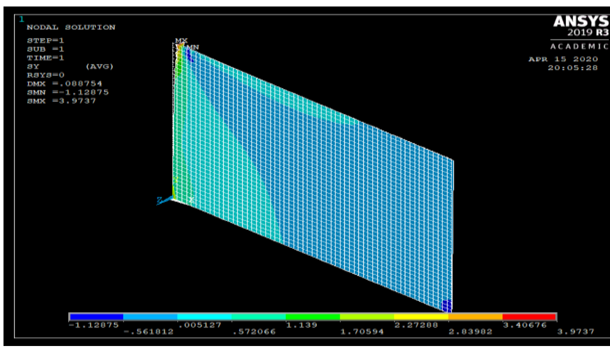


Fig 5.2.9: X-Y direction shear stress contour for 18mm panel thickness and 8000N Load

Fig 5.2.10: X direction shear stress contour for 25mm panel thickness and 8000N Load



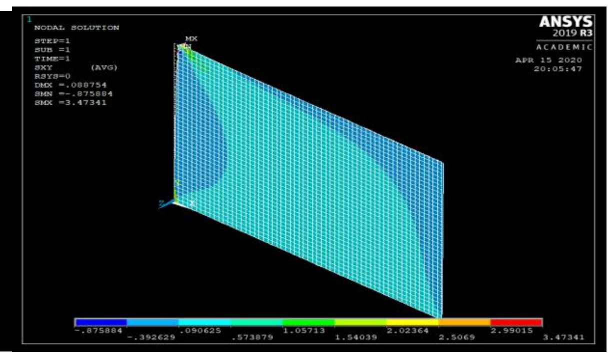
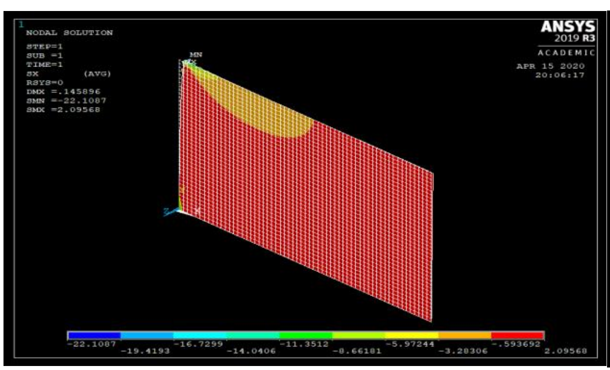


Fig 5.2.11: Y direction shear stress contour for 25mm panel thickness and 8000N Load

Fig 5.2.12 X-Y direction shear stress contour for 25mm panel thickness and 8000N Load



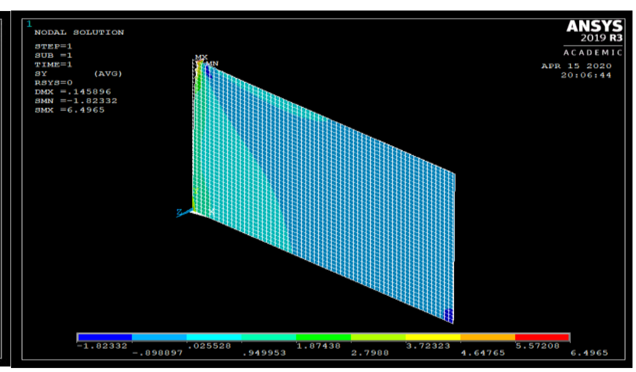
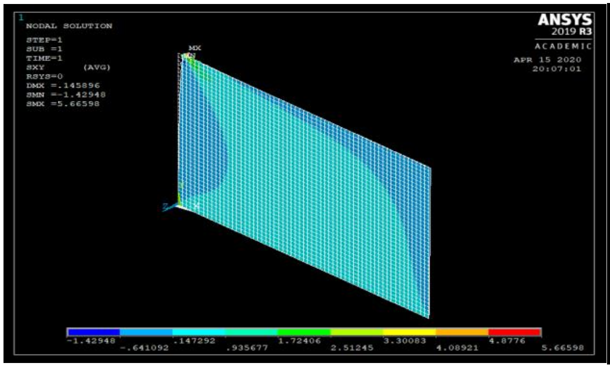


Fig 5.2.13: X direction shear stress contour for 18mm panel thickness and 10000N Load

Fig 5.2.14: Y direction shear stress contour for 18mm panel thickness and 10000N Load



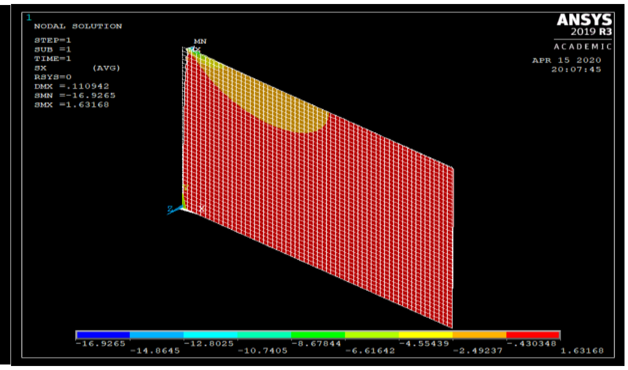
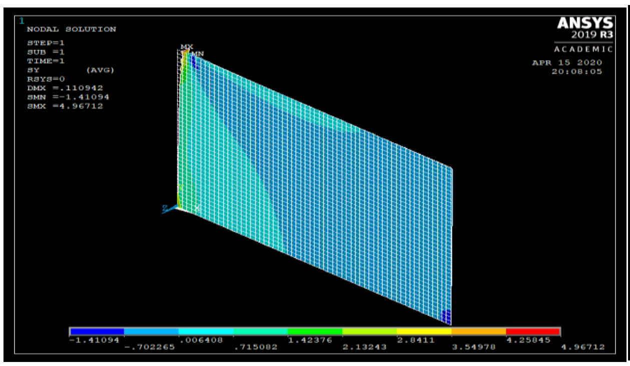


Fig 5.2.15: X-Y direction shear stress contour for 18mm panel thickness and 10000N Load

Fig 5.2.16: X direction shear stress contour for 25mm panel thickness and 10000N Load



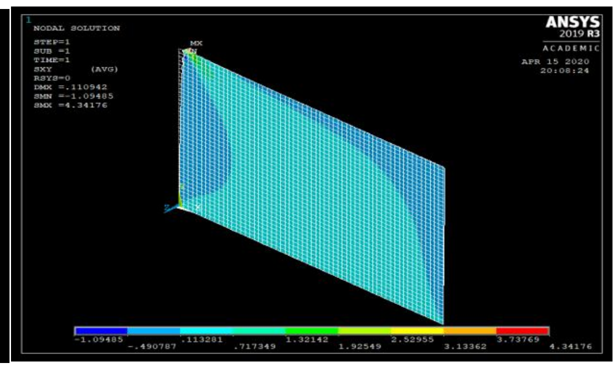


Fig 5.2.17: Y direction shear stress contour for 25mm panel thickness and 10000N Load

Fig 5.2.18: X-Y direction shear stress contour for 25mm panel thickness and 10000N Load

6.0 RESULTS & DISCUSSION

For Ferrocement panels with 18mm thickness:

- When the panel was subjected to 5000N load, the stresses were noted to be 12.2355 Nmm^2 and the panel displacement was noted to be 0.073 mm.
- When the panel was subjected to 8000N load, the stresses were noted to be 19.5768 Nmm^2 and the panel displacement was noted to be 0.12 mm.
- When the panel was subjected to 10000N load, the stresses were noted to be 24.471Nmm^2 and the panel displacement was noted to be 0.145 mm.

For Ferrocement panels with 25mm thickness:

- When the panel was subjected to 5000N load, the stresses were noted to be 9.35655Nmm^2 and the panel displacement was noted to be 0.056 mm.
- When the panel was subjected to 8000N load, the stresses were noted to be 14.9705Nmm^2 and the panel displacement was noted to be 0.089 mm.
- When the panel was subjected to 10000N load, the stresses were noted to be 18.7131Nmm^2 and the panel displacement was noted to be 0.11mm.

7.0 CONCLUSION

Based on FEM analysis following conclusions are made:

- In all Ferrocement panels i.e. 18mm & 25mm thick panels, as the load applied is increased, In-Plane shear stresses are increased
- In all Ferrocement panels i.e. 18mm & 25mm thick panels, as the load applied is increased, Displacement of panels is increased.
- The ferrocement panels with thickness 25mm are seen to resist more shear stresses than the 18mm thick panels. Also, 25mm thick ferrocement panels are seen to resist more displacement than 18mm ferrocement panels.
- As the thickness of ferrocement panel increases, the shear carrying capacity and the displacement is shown to be improved.

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