FEM analysis of RCC Beam-Column Joint retrofitted with Ferrocement Jacketing

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***ABSTRACT**: - Beam column joints in concrete framed structure have been identified as critical member for transferring forces and bending moments between beams and columns. The change of moments in beam and columns across the joint region, under loadings, induces high shear force and stresses as compared with other adjacent members. The shear failure caused is often brittle in nature which is not an acceptable structural performance. Retrofitting enhances the moment carrying capacity of joint. Often beam column joints need to be strengthened. Author proposes use of ferrocement for retrofitting as wrapping technique, cost effective alternative to costly FRP wrapping technique. In this present research study, modelling & comparison of Beam-Column joint with and without ferrocement jacket is carried out by finite element method using software ANSYS APDL. The comparison shows enhanced performance of the jacketed model over Non jacketed in terms of stresses, ultimate load carrying capacity.*

***KEYWORDS**: - Ferrocement Jacketing, Beam-column joint, FEM, Moment capacity, Retrofitting*

1. INTRODUCTION

India has already been illustrious to be associate earthquake prone space. Here, most residential buildings are reinforced concrete (RC) structures. In reinforced concrete structures, parts of columns that area unit common to beams at their intersections area unit referred to as beam-column joints. Since, their constituent materials have restricted strengths; the joints have restricted force carrying capability. Once forces larger than these area unit applied throughout earthquakes, joints area unit severely broken. The bulk of the structures, that are still being constructed using indigenous techniques don't follow the codal provisions because of lack of data and steering. Such non - designed constructions area unit principally rife in earthquake prone areas of the developing world, that embrace countries like India, Pakistan, turkey and Iran etc. In Indian structural style practise, the beam-column joint is usually neglected for specific style. As per the present codes the concentration is proscribed solely to providing comfortable anchorage for the longitudinal reinforcement of the beam reinforcement within the columns. Because of this negligence there is so much requirement of jacketing and retrofitting at the junction and joints

Until early nineteen nineties, concrete jacketing and steel jacketing were the 2 common strategies adopted for strengthening the deficient RC beam-column joints. Concrete jacketing leads to substantial increase within the cross-sectional space and self-weight of the structure. Steel jackets are poor in resisting weather attacks. Each strategies area unit, however, labour-intensive and generally tough to implement at the positioning. A mint technique has emerged recently that uses fibre-reinforced polymer (FRP) and CFRP (carbon fibre-reinforced polymer) sheets to strengthen the beam-column joints. FRP materials have variety of favourable characteristics like ease to put in immunity to corrosion, high strength; convenience in sheets etc. However, FRP and CFRP are costly and low availability material and so might not be economically engaging in developing countries. Different ought to be asked for.

Ferrocement emerged as a verified material for general purpose repair of RC structures. Over the past 3 decades, the employment of ferrocement has gained tremendous quality in numerous areas of technology (e.g. masonry structures, water tanks, fluid holding structures etc.). Ferrocement or ferro-cement is system of reinforced mortar or plaster (lime or cement, sand associated water) applied over associate frame work of metal mesh, woven expanded-metal or metal-fibres and closely spaced steel rods like rebar. In the upcoming decades this material will take place of all other material available. These ferrocement jacketing is much reliable for the strengthening and the retrofitting purpose due to its effectiveness and its cost-efficiency as compared to other methods. This type of jacketing can be effective in improving strength of existing sub-standard beam-column joint and improving its load carrying capacity.

The FEM (finite element method) is a particular numerical method for solving partial differential equations in two or three space variables. The FEM subdivides a large system into smaller, simpler parts that are called finite elements. Finite element method (FEM) is the most widely used method for solving problems of engineering and mathematical models. Hence, in this study, ANSYS, a FEA (Finite element analysis) software used here to provide comparison between jacketed and non-jacketed beam column joint.

2. OBJECTIVES OF STUDY

The article represents analytical study to evaluate additional moment resisting capacity of the joint. Progression from rigid joint to pin joint/plastic hinge. Performance of RC beam-column joints retrofitted with ferrocement jacket under flexural loading. The article comments on Comparative study of the bare RC beam-column joints with and without ferrocement jacket for its structural behaviour.

3. 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.

B. Venkatesan and R. Ilangovan performed [1], study using four specimens. Specimens were tested under cyclic loading in cantilever portion using hydraulic push and pull jack in which two as reference specimen and remaining two used for strengthen specimen with the Ferrocement laminate is a composite material collective with weld mesh and woven mesh and they found that capacity of the retrofitted specimen is 66% more than that of the ductile control specimen.

P. Kannan, S. Sivakumar, and K. R. Bindhu [2], in their study, six scaled down models of the beam-column joint of a non-seismically designed structure were prepared. Retrofitting were done in two form conventional and advanced. In advanced technique the corner joint were rounded. In the result it was found that both technique were 33.33% more efficient in carrying ultimate load capacity compared to non-retrofitted model.

Nassif H. H. and Najm H [3], the adding of a thin layer of ferrocement to a concrete beam also enhances its ductility and cracking strength. An increase in the number of layers leads to enhancement in the cracking stiffness of the composite beams.

K. R. Bindhu, P. M. Sukumar, and K. P. Jaya [4], tested their specimen under two different axial loads to evaluate the effect of axial load on the behaviour of joints. According to them an increase in the column axial load improves the load carrying capacity and stiffens the joints but reduces the load carrying capacity and ductility.

C. V. R. Murty, D. C. Rai, K. K. Bajpai, and S. K. Jain [5], Have tested the exterior beam column joint subject to static cyclic loading by changing the anchorage detailing of beam reinforcement and shear reinforcement. It was reported that the practical joint detailing using hairpin-type reinforcement is a competitive alternative to closer ties in the joint region.

D. G. Gaidhankar, M. S. Kulkarni, and A. R. Jaiswal[6], they tested Flexural strength and load carrying capacity of the beam. They found that strength of the beam increases when the number of mesh layers increases from 2 to 4 numbers also there was 60% percent increase in load carrying capacity for that of the woven mesh.

C. G. Karayannis, C. E. Chalioris, and G. M. Sirkelis[7], the effect of retrofitting of RC exterior beam-column joints with reinforced concrete jackets. The joints were initially loaded to cyclic loading and then retrofitted using thin RC jackets and they retested under the same load sequence. Test results indicated that the seismic performance of the retrofitted specimens was fully restored and, in some cases, substantially improved with respect to the performance of the same specimens in the initial loading, since they exhibited higher values of load capacity and hysteretic energy dissipation.

G. S. Dhanoa, J. Singh, and R. Singh[8], they studied the retrofitting effect on the beam casted. The Retrofitting of the beams by ferro cement technique using two different welded mesh wires increased the load carrying capacity by 35% and 45% for stressed beams and 55% and 70% for overloading beams.

N. Karthika and N. M. Azhar[9], they studied the strengthening of reinforced concrete columns using ferrocement laminates. In The study test they results showed that the confined concrete specimens can enhance the ultimate concrete compressive strengths and failure strains. They column retrofitted performed better in reducing the deflection and increasing the moment carrying capacity.

4. ANALYTICAL SIMULATION PROGRAM

The nonlinear response of joint with ferrocement jacketing can be computed using the finite element method (FEM). The graphical user interface in ANSYS provides an efficient and powerful environment for solving many anchoring problems. ANSYS enables virtual testing of structures using computers, which is the present trend in the research and development world. This study uses static analysis model which support RCC element in ANSYS Apdl.

4.1 Finite element model

All the information and requirement planning are done in the appropriate method. The planning phases have namely data gathering like parameters and finding the objective function and constrains. Literature studies are done to get more information. All the materials are collected by the journal and research paper. The Beam Column joint has been modelled using a FEM software. The modelling consists of two type, one with the ferrocement jacket and other is Non jacketed. The dimension of the beam is 1000 x 150 x150 mm and column dimension is 550 x 150 x 150 mm. In beam 12 mm diameter bar is used for every design and 12 mm diameter is used in column. This model is fixed at both faces of the column.

4.2 Modelling using Ansys

Three basic steps involved in simulation using ANSYS include:

1. Pre-processing: Inserting of the Properties, Geometry modelling, Mesh Generation Setting of Boundary and load conditions.

2. Solving: Submitting the model to ANSYS solver.

3. Post processing: Evaluating and interpreting solution. Presentation of Results in the form of list of results and contour plot or animation.

4.3 Element Types

The FEA (ANSYS) for analytical study of the beam column joint is subjected to loading at the cantilever portion of the beam and has been carried out. The concrete has been modelled using eight node solid element (SOLID 65) specially designed for concrete, capable of handling plasticity, creep, cracking in tension and crushing in compression. The reinforcing steel has been modelled using a series of two node beam element (Beam 188). Beam 188 element is suitable for analysing slender to thick structures. This element is also well-suited for linear, large rotation and large strain nonlinear applications. The ferrocement jacketing layer has been modelled using3Disotropic element (SHELL181). SHELL181 is four node elements with six degree of freedom. SHELL181 may be used for layered application for modelling composite shells and sandwich construction. The various parameters required in modelling is shown in table 4.3.1.

Material no.	**Element type**	**Material type**	**Material properties**	
1			Modulus of Elasticity	Poisons ratio
	SOLID 65 (Concrete)	Linear isotropic	20000 MPa	0.20
2	BEAM 188 (Reinforcement)	Linear Isotropic	200000 MPa	0.30
3	SHELL 181 (Mortar)	Linear Isotropic	27385 MPa	0.22
4	For steel mesh (Jaali)		130000MPa	0.29

Table 4.3.1: Material Properties and Element types for ANSYS

4.4 Modelling and Meshing

The beam column joint is first modelled as 2D area then it was extruded to make it a 3D volume. To obtain good results from the Solid65 element, the use of a rectangular mesh is recommended with sweep method. The meshing divided it into a number of small brick elements with required (25 x 25 x 25) mm dimensions. No mesh of the reinforcement is needed because individual elements are created in the modelling through the nodes created by the mesh of the concrete volumes.

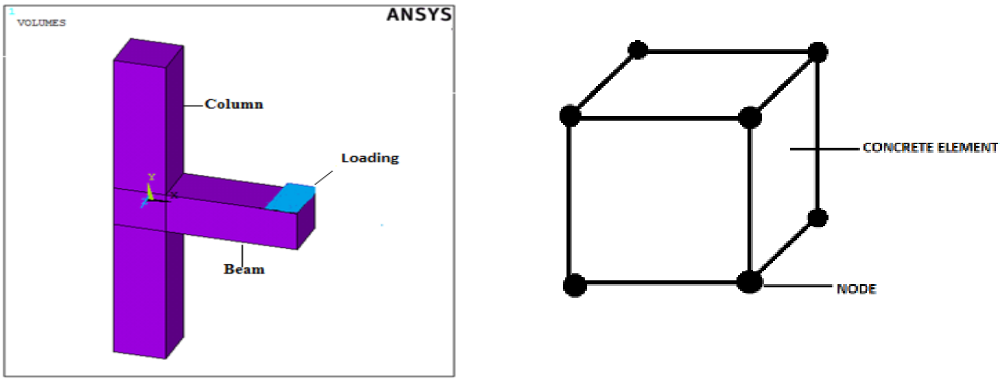


Fig-1. Volume and mesh parts in ANSYS for Specimen

4.5 Loads, Boundary Conditions and Analysis

Displacement boundary conditions are needed to constrain the model to get a unique solution. To achieve this, the translations at the nodes (UX, UY and UZ) are given constant values of 0. The applied load was performed as a static load at the free end of the cantilever beam as a small force divided by the number of nodes at that location. For the purpose of this model, the Static analysis type is utilized. The FE analysis of the model is set up to examine different behaviours: deflection, ultimate load carrying capacity and formation of hinge of the beam-column joint. Load increment is done with 5000 N at each step.

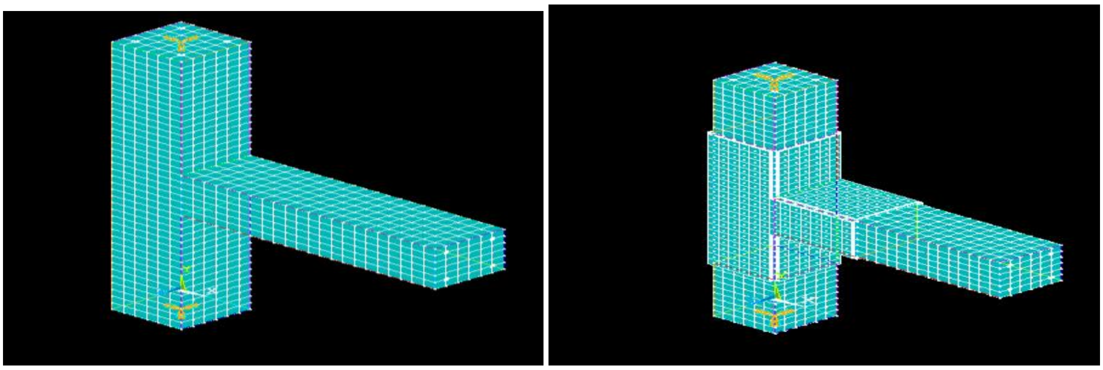


Fig 2. Boundary Conditions in ANSYS for the non-jacketed and jacketed model

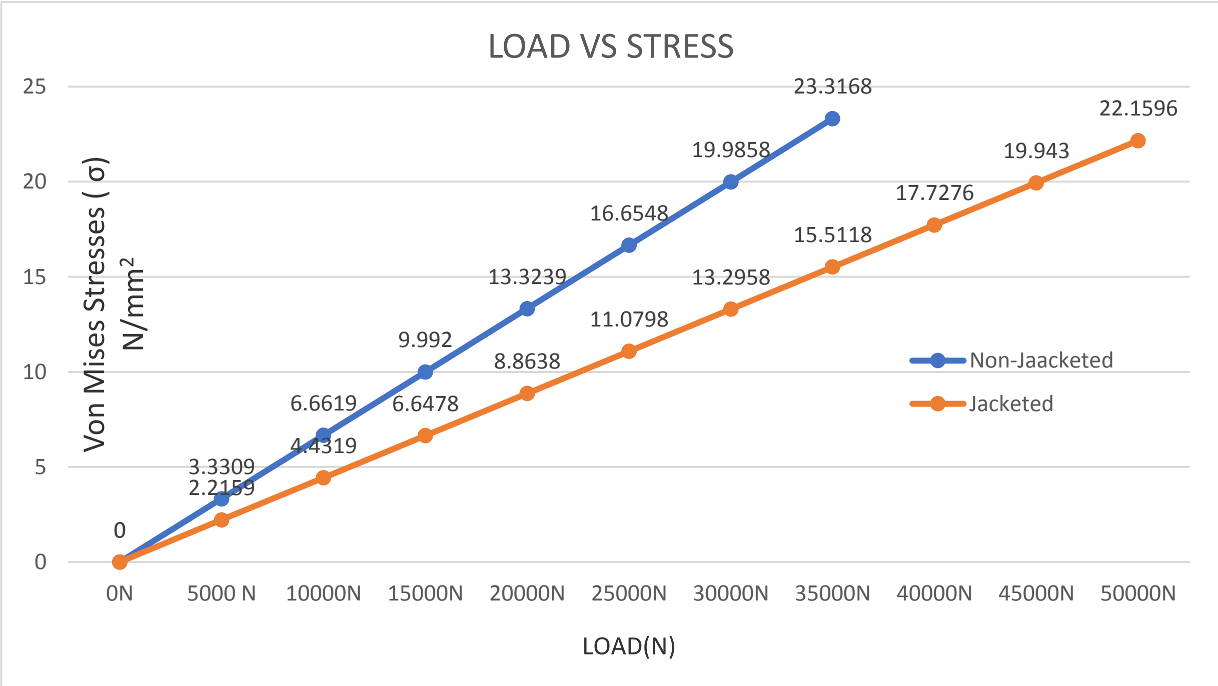
5. RESULT AND OBSERVATIONS

The results and observation from the above Analytical study of the controlled specimen are compared with the results of the Ferrocement jacketed specimen. The displacement and von misses stress are plotted in the form of the tabular form (ref Table 2) which gives a brief idea of the enhancement which is overserved after comparing the von mises stress also the displacement of the Non- Jacketed specimen with the Ferrocement jacketed specimen.

LOAD	VON MISSES STRESS (MPa)		DISPLACEMENT (mm)	
	NON-JACKETED	JACKETED	NON-JACKETED	JACKETED
5000 N	3.3309	2.2159	1.0329	0.5149
10000N	6.6619	4.4319	1.549	1.0298
15000N	9.9920	6.6478	2.0659	1.5447
20000N	13.3239	8.8638	2.5823	2.0596
25000N	16.6548	11.0798	3.0988	2.5745
30000N	19.9858	13.2958	3.6153	3.0894
35000N	23.3168	15.5118	4.1318	3.6043
40000N	-	17.7276	-	4.1192
45000N	-	19.943	-	4.6342
50000N	-	22.1596	-	5.1491

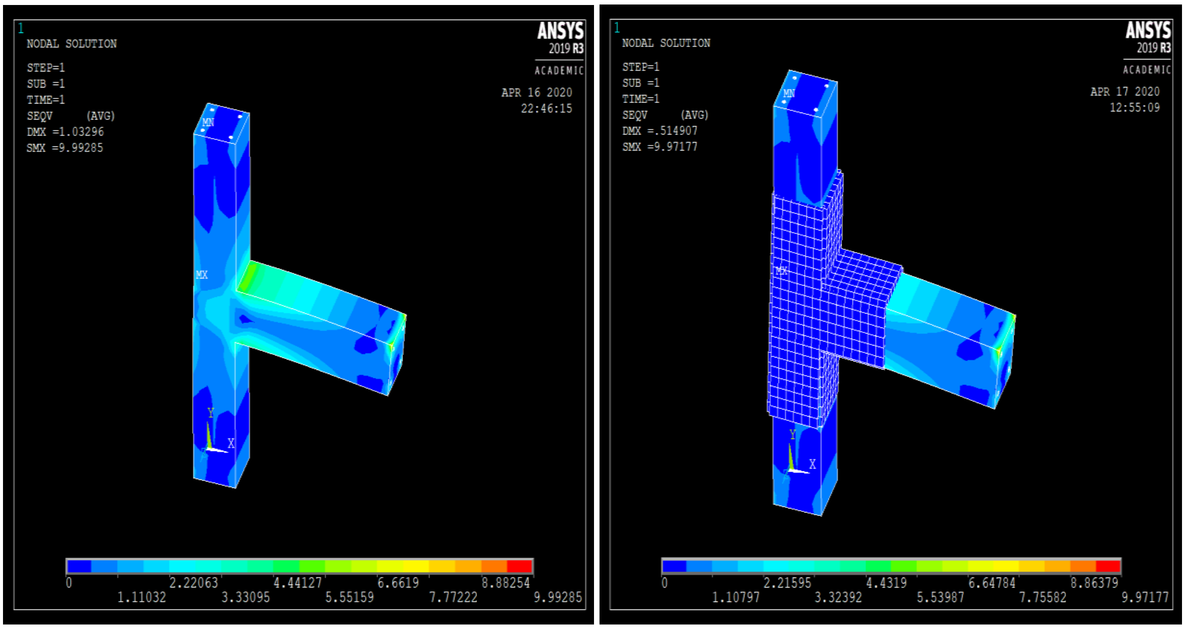
Table 5.1. Von Mises stresses and displacements in tabulated form

The values obtained from FE analysis using Ansys Analysis software are plotted in the graphical format (refer Graph No.1 and Graph no.2). It gives us better understanding of stress and displacement variation with respected to applied load.



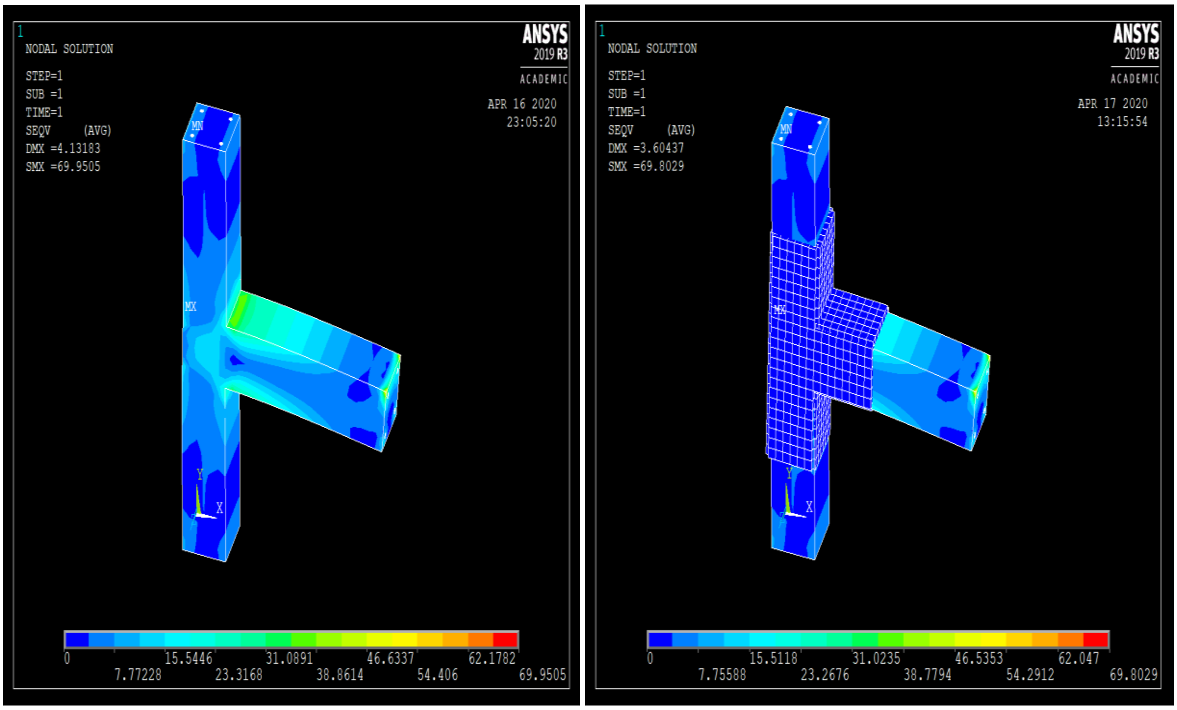
Graph 1. Represent the Load vs Stress.

The Graph 1. (Load vs Von Mises Stress) Represents the Initial, Intermediate and Peak value of the Load that the Non-Jacketed and Jacketed Specimen sustained following with their Stresses.



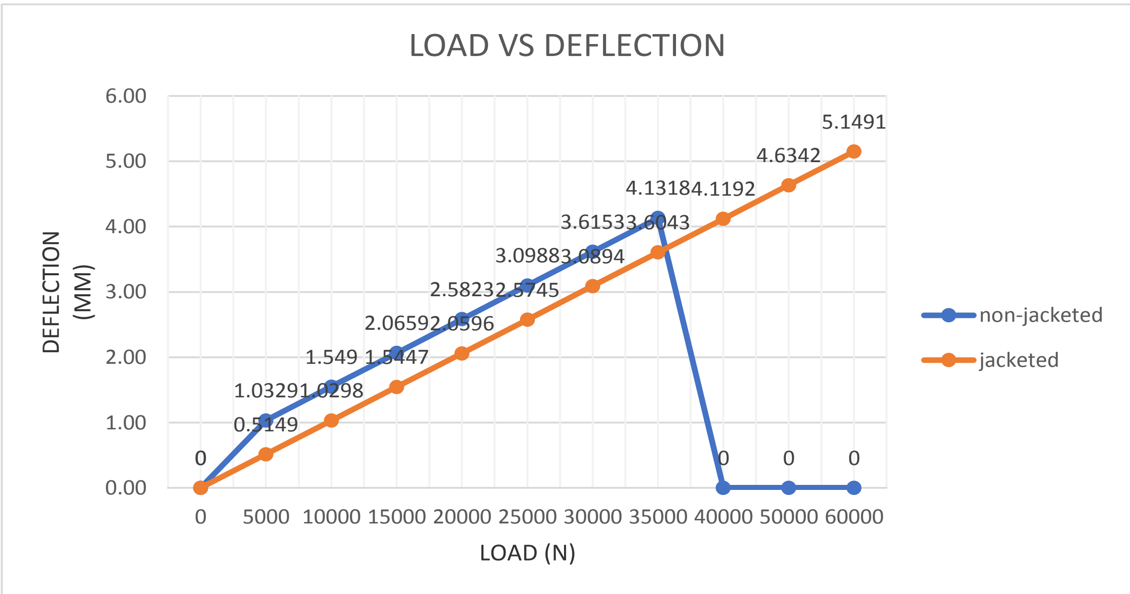
(a) (b)

Fig.3 Von mises stress at loading 5000N for the Non- Jacketed(a) and Jacketed Specimen(b)



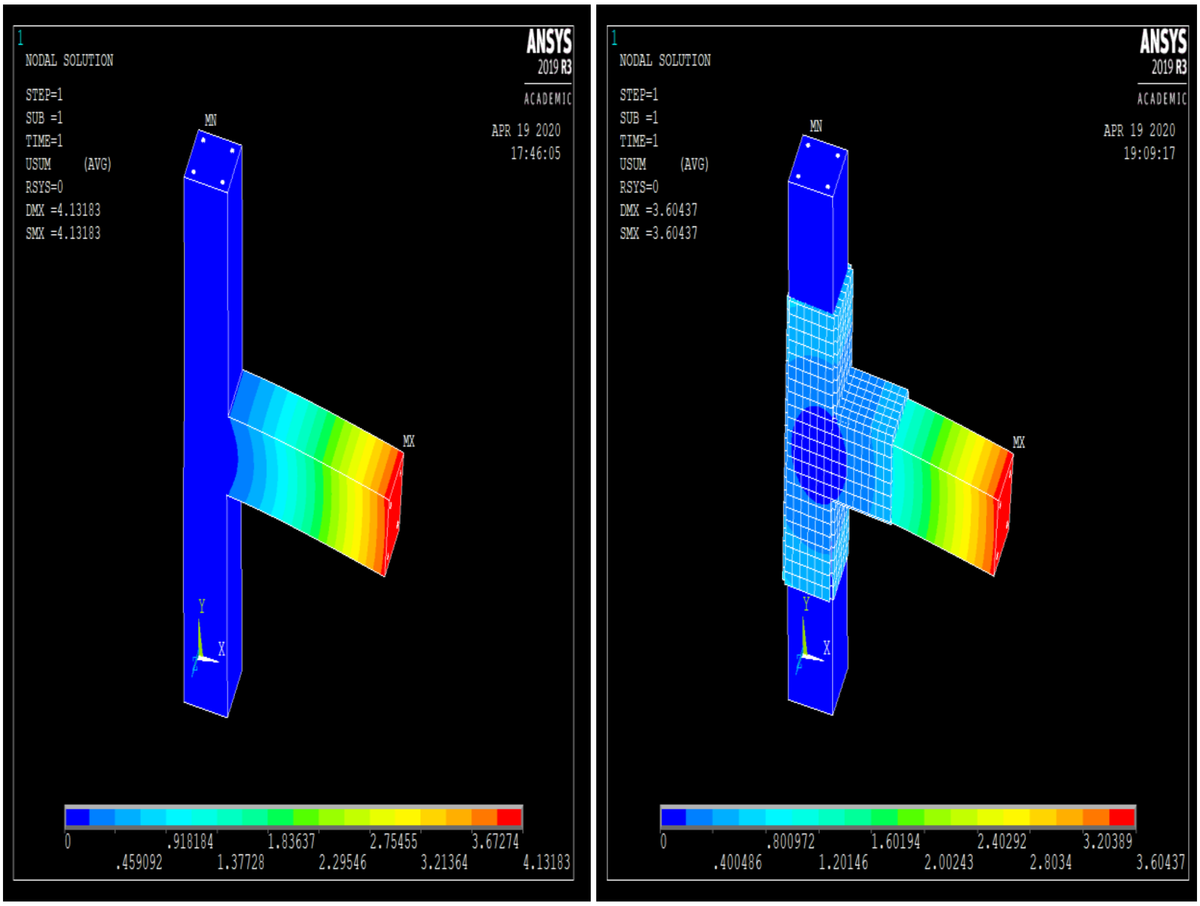
(a) (b)

Fig.4 Von mises stress at loading 35000N for the Non- Jacketed (a) and Jacketed Specimen (b)



Graph 2. Represent the Load vs Deflection curve.

The Graph 2, shows the peak outline of the jacketed and non-jacketed specimen in the load vs deflected curve. The Zero in Non-Jacketed reflects that it is not able to take more load and bending after its limit of ultimate load carrying capacity.



(a) (b)

Fig.5 Displacement Vector at 35000N for the Non- Jacketed (a) and Jacketed Specimen (b)

5.1. Comparative Study of Results

Loading carrying capacity of jacketed specimen is higher than the specimen without ferrocement jacketing. For control specimen 35000N is the ultimate load. For Ferrocement jacketed specimen with 22 mm thickness, the ultimate load is 50000N.

The increment of 42.857 %in the load carrying capacity of the jacketed specimen compared to the non-jacketed specimen.

The ultimate moment carrying capacity of the ferrocement jacketed specimen is 33.47% higher than the non-jacketed specimen.

Initially, Stress values in jacketed specimens are higher than control specimens. Because retrofitted specimen carries more load compared to non-jacketed specimen.

Specimen retrofitted with the ferrocement jacketing system shows a little reduction in deflection values. Ferrocement jacketed specimen with 22 mm thick shows nearabout 13% reduction in deflection values compared to non-jacketed.

6. CONCLUSIONS

1. In an Analytical study, the meshing of correct Element with Precise properties plays an important role in accurate generation of results.

2. Comparison between the load-deflection results found from ANSYS for non-jacketed and ferrocement jacketed shows that the yield load and ultimate load has significantly increased for the retrofitted specimen with ferrocement jacketed.

3. The higher value of yield load and ultimate load for the jacketed specimen is associated with lower deflections as compared to the non-jacketed.

4. The failure was along the beam and the column portion of the joint of the non-jacketed specimen which is to be avoided. In the case of ferrocement jacketed specimens, the failure was at the jacketing zone.

5. In non-jacket specimen the plastic hinge formation was exactly at the junction where as in the ferrocement jacketed specimen the plastic hinge formation from the joint shifts.

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