IJITECH International Journal of Innovative Technologies
WWW.IJITECH.ORG
ISSN 2321-8665
Volume.07, Issue.01,
January-June, 2019,
Pages:01-12

A Parametric Study on the Performance of Steel Angle Member with Perporations under Axial Compression

T. SURESH BABU[1], M. JAYAKUMAR BHASKAR[2], R. VISHNU VARDHAN REDDY[3]
[1]Professor, Dept of Civil Engineering, Visvodaya Engineering College, Kavali, SPSR Nellore (Dt), AP, India.
[2]Assistant Professor, Dept of Civil Engineering, Visvodaya Engineering College, Kavali, SPSR Nellore (Dt), AP, India.
[3]PG Scholar, Dept of Civil Engineering, Visvodaya Engineering College, Kavali, SPSR Nellore (Dt), AP, India.

Abstract: This paper is concerned with the ultimate load capacity of non-perforated and perforated channel hot rolled steel column. An analytical study has been undertaken to investigate the behaviour of such members under compression FEM models are used in order to carry out buckling and non linear analyses with the aim of detecting the capacity of the channel members in case of one or more perforations. The software used for finite element analysis in this project is ABAQUS.

Keywords: FEM, FEA.

I. INTRODUCTION

A steel structure is an assemblage of a group of members expected to sustain their share of applied forces and to transfer them safely to the ground. Depending on the orientation of the member in the structure and its structural use, the member is subjected to the forces, either axial, bending, or torsion, or combination thereof. Axial load can be either tensile or compressive members. A compression member is a structural member which is straight and subjected to two equal and opposite compressive forces applied at its ends. Different terms are used to designate a compression member depending upon its position in structures. Columns, stanchion or post is a vertical compression member supporting floors or girders in a building.

A. Hot Rolled Sections

Like concrete, steel section of any shape and size cannot be cast on site, since steel needs very high temperature to melt it and roll into required shape. Steel sections of standard shapes, sizes and length are rolled in steel mills and marketed. Many steel sections are readily available in the market and are in frequent demand such steel sections are known as regular steel sections. Some steel sections are not in use commonly, but the steel mills can roll them if orders are placed. Such steel sections are known as special sections.Various types of rolled steel sections manufactured are listed below:

- Rolled steel I sections
- Rolled steel Channel sections
- Rolled steel Angle sections
- Rolled steel Tee Sections
- Rolled steel bars
- Rolled steel tubes
- Rolled steel plates
- Rolled steel flats.

The scope of this project lies in understanding the behavior of the perforated steel angle members in consideration by performing experiment and analysis on the members. They are mentioned below

- Study is limited to Single, Double, Triple perforations in Loaded Leg and Single, Double, Triple perforations in Unloaded Leg of steel members.
- Only axial behaviour will be studied under static loading
- Study is limited to angle sections.

Design of the compression members is carried according to IS 800: 2007.

II. PROPOSED SYSTEM

A. Finite Element Modeling And Analysis

Analytical and finite element analysis is always carried out to predict its behavior and capacity before carrying out the experiments to scrutinize number of tests so that large number of expensive experiments can be avoided. In the present investigation, a parametric study has been carried out using ABAQUS. Two types of analysis is performed, namely

- Buckling analysis to incorporate the initial imperfections
- Nonlinear post buckling analysis to predict the capacity, load deformation behavior and also for finding out the different buckling modes.

The details of finite element modeling and analysis (FEA) are discussed in the following sections.

B. Fem Modeling Procedures

Finite Element Model: The buckling behavior of the perforated compression angle members is simulated by a finite element model.

Types of Elements: Generally there are four different base features in ABAQUS. They're Solid; Shell, Wire and Point. For hot-rolled steel members are thicker compared to its different dimensions. If the section thickness is a smaller amount than 1/10 of an elemental dimension; the section is to be shapely with shell components. ABAQUS shell component library provides various kinds of shell elements that enable curved modeling, shells intersection and nonlinear material response. These shell elements are divided into 3 categories consisting of all-purpose, thin, and thick. Finite element model for axial loading compression members with axial direction released is developed using ABAQUS. The member is loaded through one leg. The loading compression member has been modeled as shell element as shown in Fig.1.

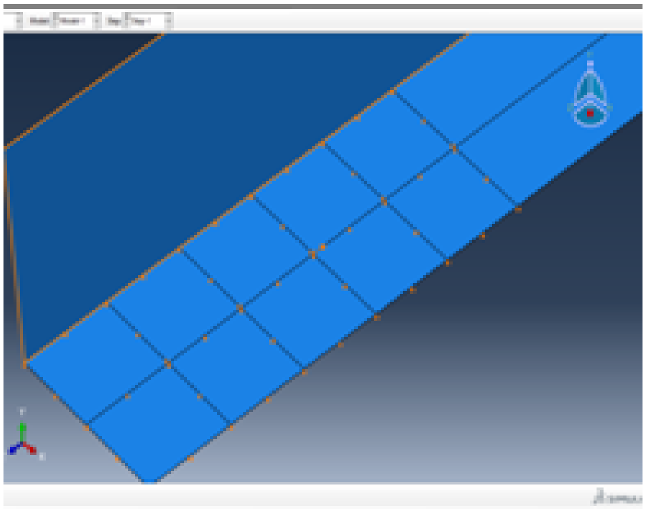


Fig.1. Load Applied as Displacement.

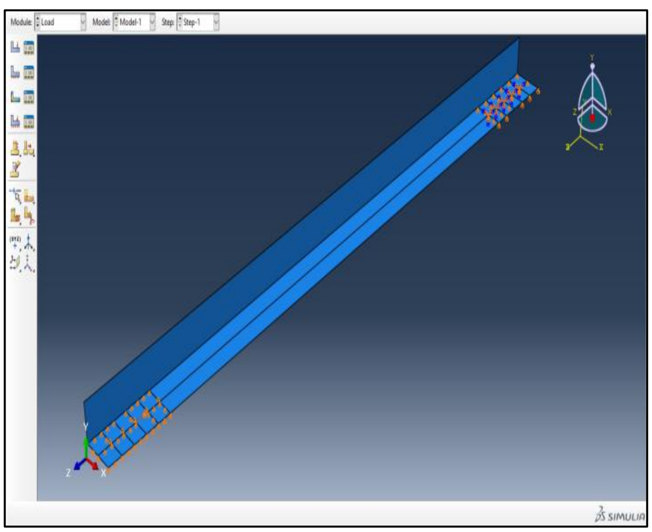


Fig.2. Boundary Condition.

Boundary Conditions: The boundary conditions are applied in such a way to simulate the important test setup. The experiments were conducted in loading frame, during which the each ends of the specimens is connected to gusset plate with bolts and is assigned with fixed boundary condition at the bolted region at one end and free at the opposite end as shown in Fig.2. The highest end of the specimen is assigned with fixed boundary condition, however free to move axially. The “load” within the non-linear finite component analysis was applied because the displacement at the third bolt at one end, negative 40mm displacement mimicking the loading method of the testing. Automatic load increment method is most popular as a result of ABAQUS tool selects increment size based on process efficiency.

Imperfection Modeling: The load carrying capacity is especially suffering from geometric imperfections. Imperfections are developed from manufacturing, transportation and also from fabrication. This imperfectness is simulated using buckling analysis of the specimen. Precise knowledge of the distribution of geometric imperfectness isn't accessible for all experimental specimens; Scaled price of linear buckling mode shape is used to form an initial geometric imperfectness for the non-linear post-36 buckling analysis. The degree of imperfectness is assumed because the most amplitude of the buckling mode shape and thought of as percentage of the structure thickness. Type 1(local), type 2(distortional) and type 3(overall buckling). Most native imperfectness (Fig.3) happens in an un stiffened component. In present study, type 3 buckling mode is only considered.

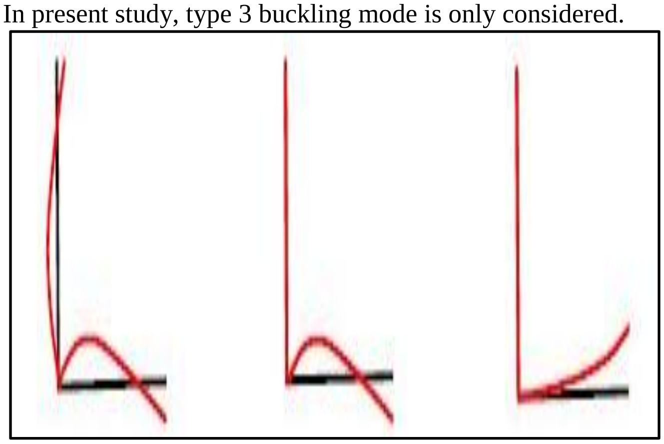


Fig.3. In-plane Deformation of Cross Section in Case of Local Buckling.

Overall imperfection amplitude of L/1000 was used for validating the experimental specimens. The same magnitude of imperfections was used for parametric study also.

Meshing: Abaqus/CAE will use a variety of meshing techniques to mesh models of various topologies. In some cases you'll select the technique used to mesh a model or model region. In alternative cases only one technique is valid. The various meshing techniques provide varying levels of automation and user management. There square measure two meshing methodologies available in Abaqus/CAE: top-down and bottom-up. Top-down meshing generates a mesh by operating down from the geometry of an area or region to the individual mesh nodes and elements. You'll be able to use top-down meshing techniques to mesh one-, two-, or three-dimensional geometry using any offered element type. The ensuing mesh specifically conforms to the first geometry. The rigid conformity to geometry creates top-down meshing preponderantly an automatic method however might make it difficult to provide a high-quality mesh on regions with advanced shapes.

Bottom-up meshing generates a mesh by working up from two-dimensional entities (geometric faces, element faces, or two-dimensional elements) to make a three-dimensional mesh. You'll use bottom-up meshing techniques to mesh only solid three-dimensional geometry using all or nearly all hexahedral elements. Generating a mesh using a manual method, and also the ensuing mesh could vary considerably from the initial geometry. However, allowing the mesh to vary from geometry could enable you to provide a top quality hexahedral mesh on regions with advanced shapes.

C. FEM Analysis Procedure

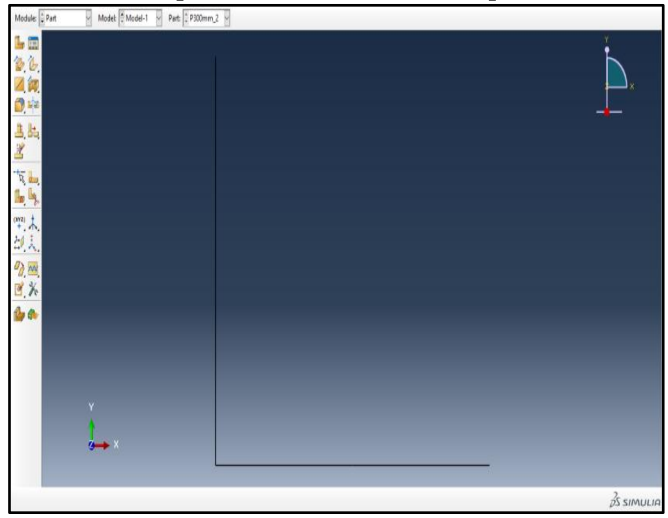
Buckling Analysis: The buckling analysis is carried to predict the buckling masses and the corresponding buckling shapes. These are used as a parameter in determinant the post buckling strength and have further application for incorporating the input values of the geometric imperfectness using first buckling mode shape values. Procedure for Buckling Analysis in ABAQUS

- Initially angles are assigned material and cross sectional member properties and meshed.
- An additional step is created in ABAQUS. For buckling analysis; all boundary condition from initial step is propagated to this newly created step.
- For buckling analysis to take place an initial displacement of 1mm is applied at the required location on the section.
- The above created model is analyzed using Lanczos Eigen Solver requesting an Eigen value of fifty (50) to obtain overall mode of buckling.
- Form the obtained results of buckling analysis; over-all buckling is selected for incorporating the imperfection modeling.

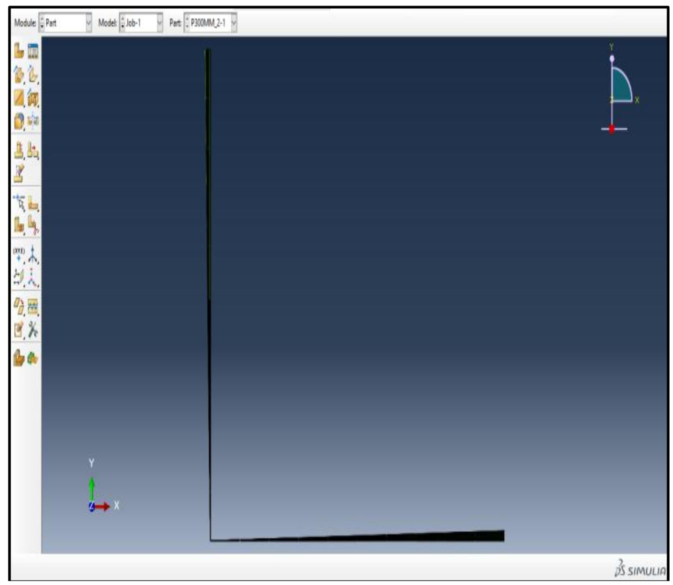
Procedure for Incorporating Overall Buckling Displacement into ABAQUS

- Input file from ABAQUS (.inp) is extracted from temp folder.
- Displacement corresponding to over-all buckling is added to get total displacement.
- Total displacement is added to the input co-ordinates of ABAQUS input (.inp) file.
- After incorporating the displacement, the file is opened and saved with other name to avoid overwriting of the previous buckling analysis file.
- The newly opened file now has the imperfection incorporated in it, over-all buckling.
- Imperfection incorporated file is analyzed for “Static General Analysis” to obtain maximum ultimate load.

The following Fig.4. shows clearly the model before incorporating imperfection and after incorporating imperfection. The Fig.4.(a) and (b) shows the front view of the model without and with incorporating imperfection in ABAQUS respectively into the software from MS-Excel.. The buckling solution can be obtained by Finite Element Method.



(a) Without Imperfection



(b) With Imperfection

Fig.4. (a) Without Imperfection (b) Incorporating Imperfection in ABAQUS.

III. RESULTS AND DISCUSSIONS

The results obtained after conducting experiment and performing FEM analysis for variable number of perforations and non-perforated angle members are listed in detail.

A. Analytical Results

The angle members with varying in number of perforations and without perforations are modeled for length of 1500 mm, and 6mm thickness.

ISA 100 x 100 x 6 mm of Length 1500 mm: Buckling analysis of the member after imperfection is implemented into the Abaqus file. Below Figs.5 to 18 shows the deflection mode of the perforated member after implementing the imperfection in ABAQUS.

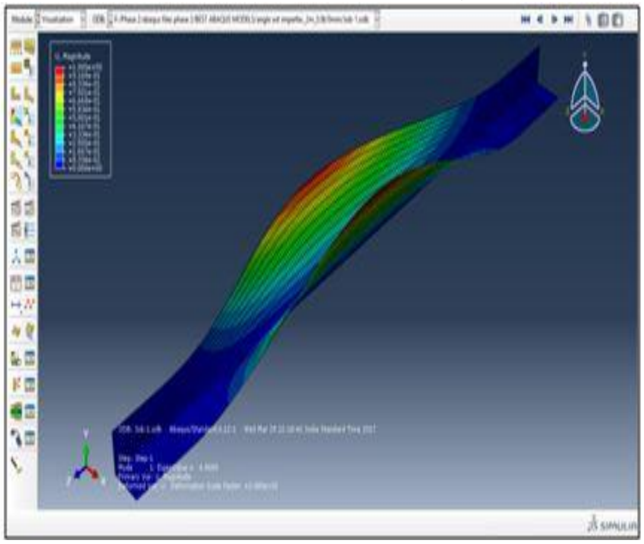


Fig.5. Buckling of the Angle Member without Perforations before implementing imperfections.

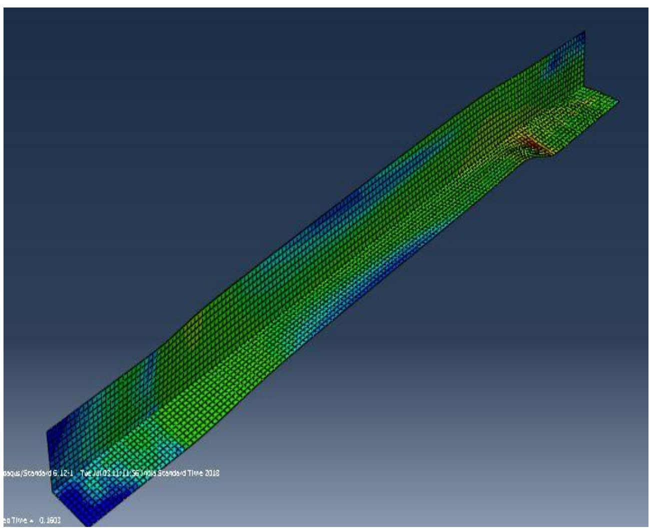


Fig.6. Deflection of the Angle Member without Perforations after implementing the imperfections.

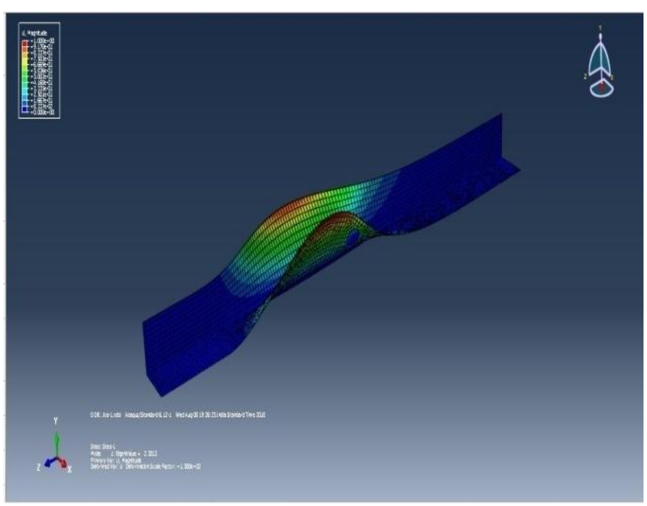


Fig.7. Buckling of the loaded leg single perforation angle member before implementing imperfections.

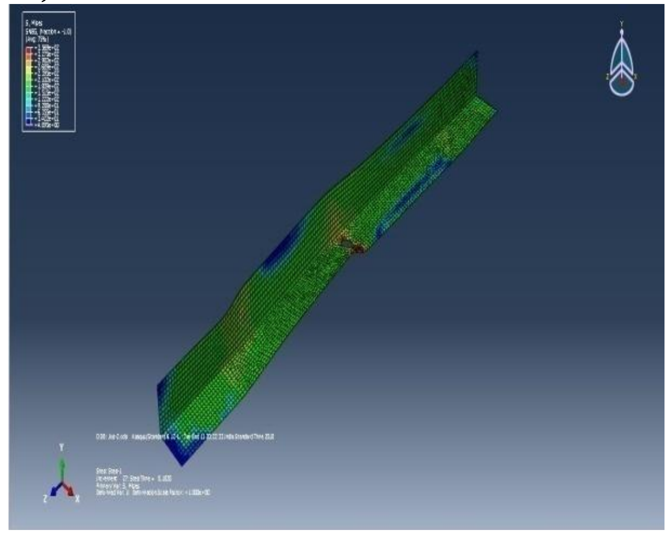


Fig.8. Deflection of the Angle Member loaded leg with single perforations after implementing the imperfections.

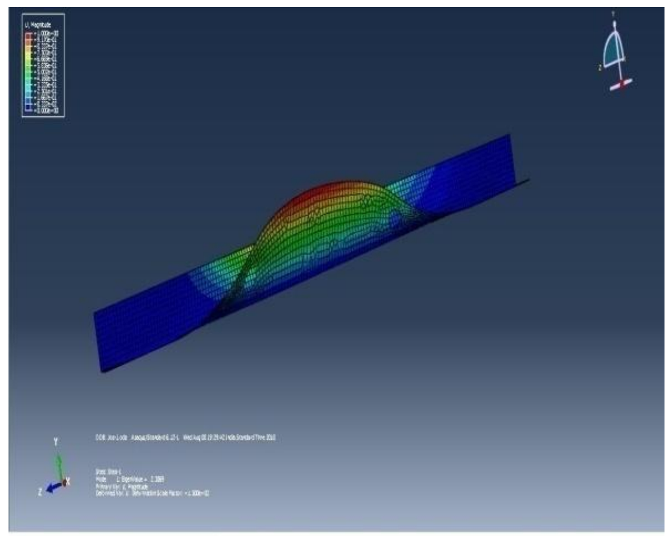


Fig.9. Buckling of the Angle Member loaded leg with two Perforations before implementing the imperfections.

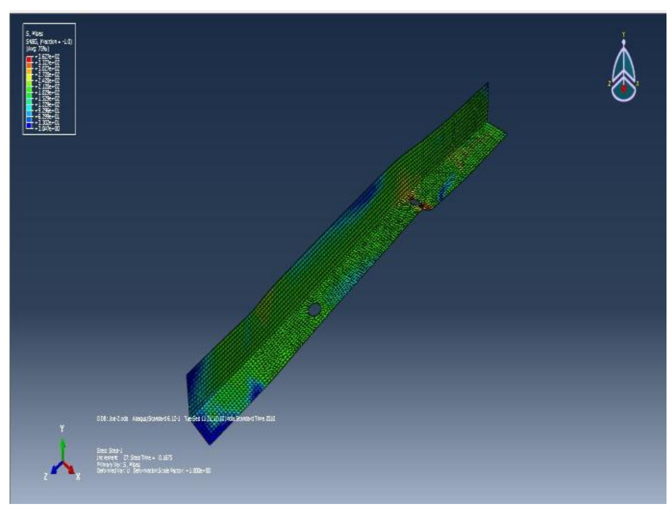


Fig.10. Deflection of the Angle Member loaded leg with two Perforations after implementing the imperfections.

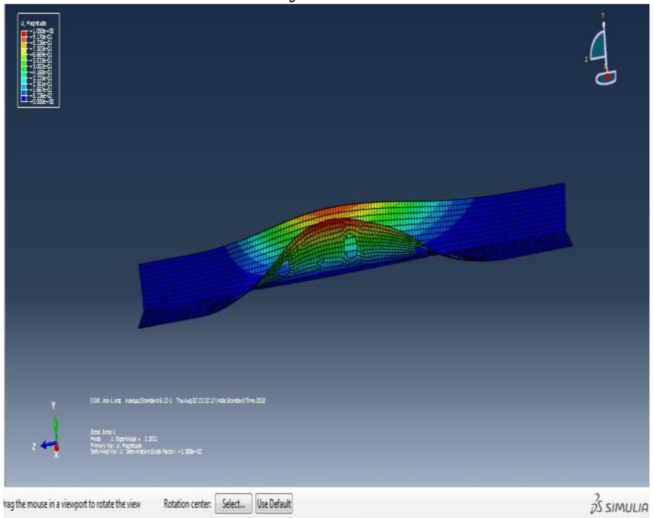


Fig.11. Buckling of the Angle Member loaded leg with three Perforations before implementing the imperfections.

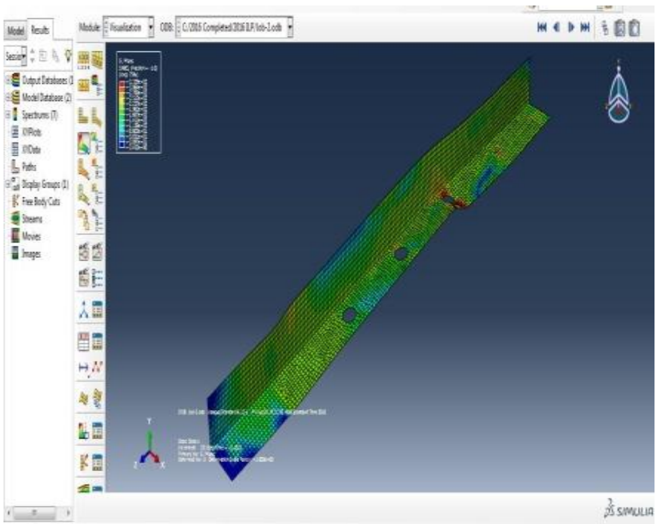


Fig.12. Deflection of the Angle Member loaded leg with three Perforations after implementing the imperfections.

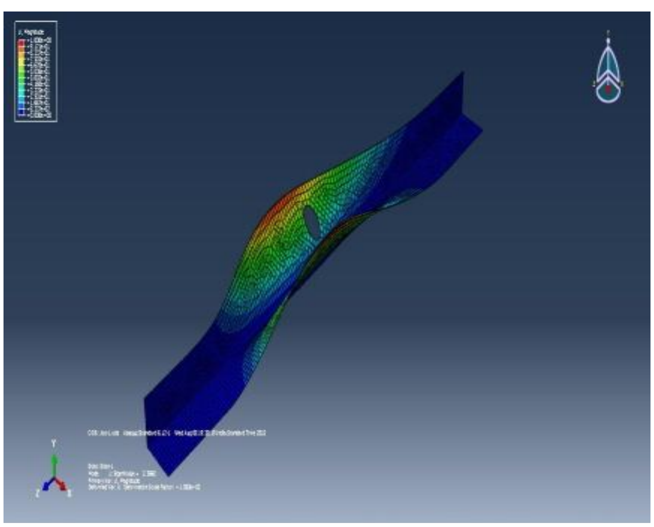


Fig.13. Buckling of the unloaded leg single perforation angle member before implementing imperfections.

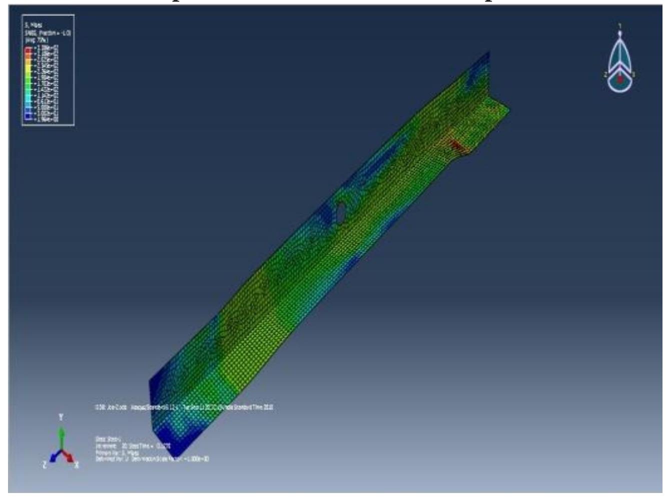


Fig.14. Deflection of the Angle Member unloaded leg with single perforations after implementing the imperfections.

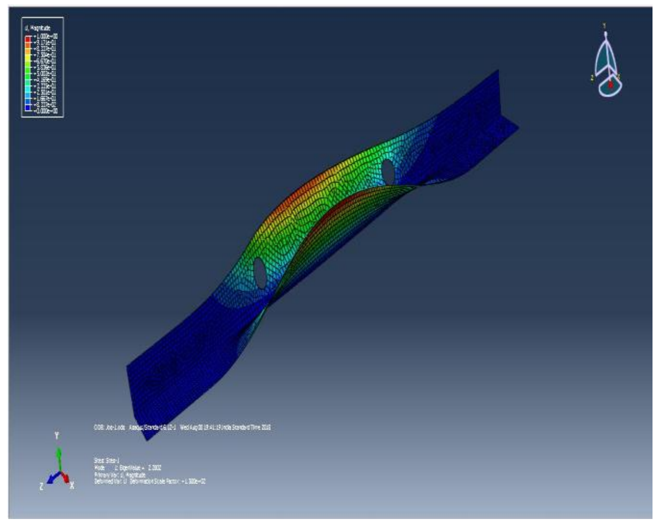


Fig.15. Buckling of the Angle Member unloaded leg with two Perforations before implementing the imperfections.

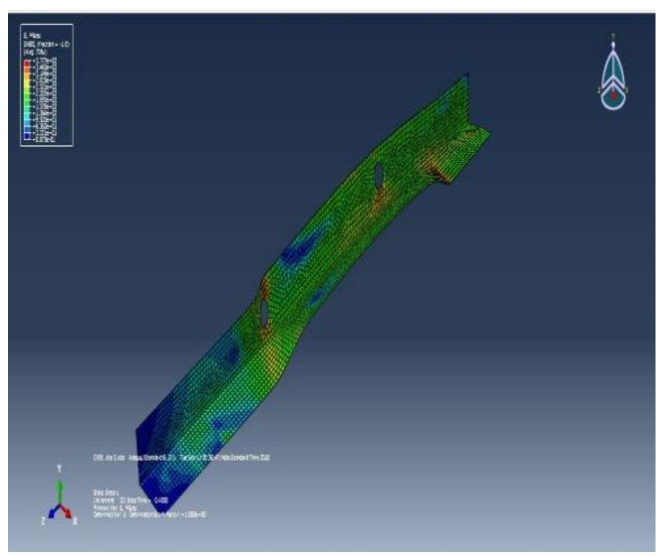


Fig.16. Deflection of the Angle Member unloaded leg with two Perforations after implementing the imperfections.

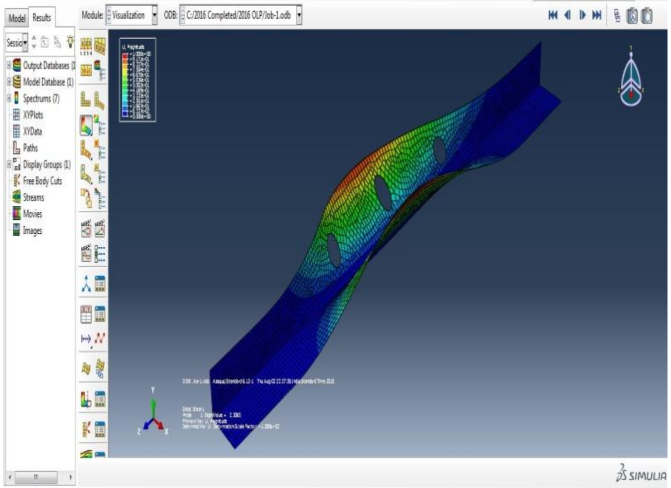


Fig.17. Buckling of the Angle Member unloaded leg with three Perforations before implementing the imperfections.

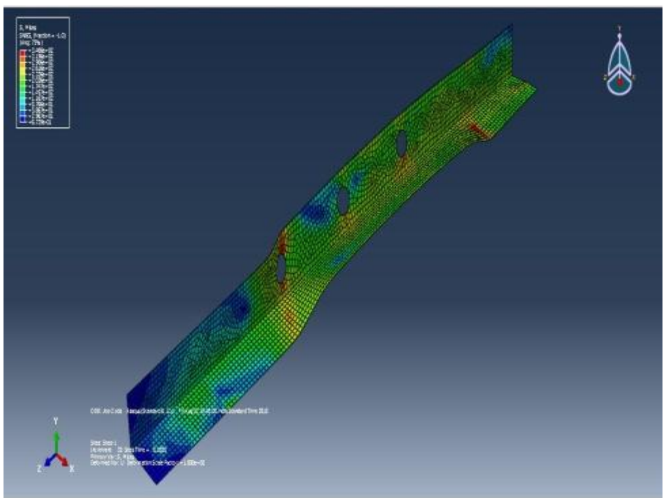


Fig.18. Deflection of the Angle Member unloaded leg with three Perforations after implementing the imperfections.

The following Fig.19 to 25 show Load vs. deflection graph for Angle Member.

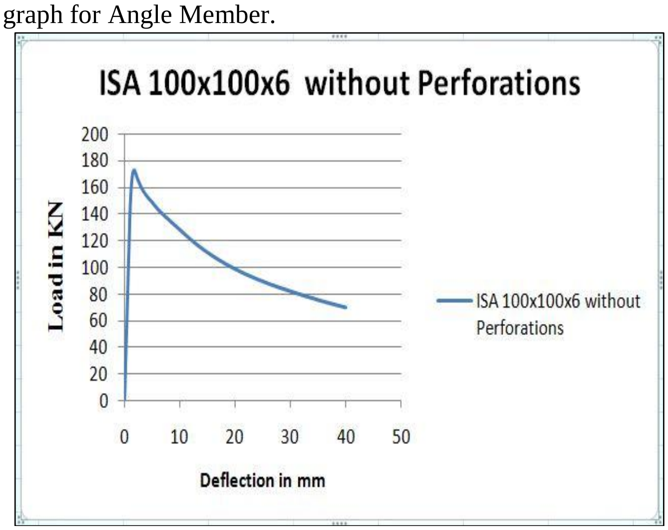


Fig.19. Load vs. Deflection graph for angle member without perforations.

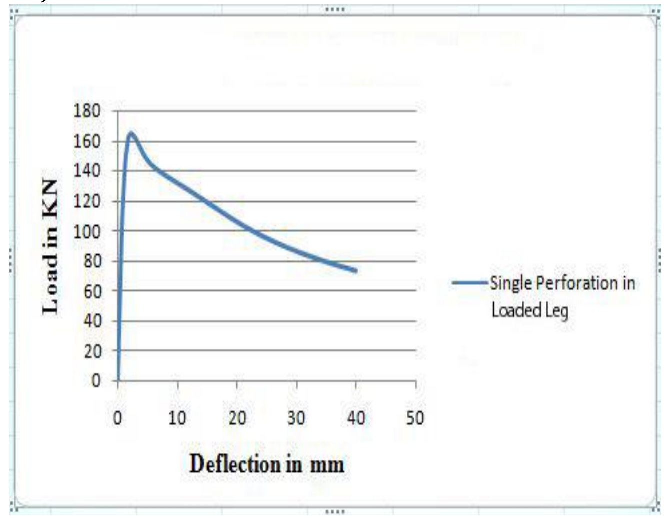


Fig.20. Load vs. Deflection graph for single perforation in loaded leg.

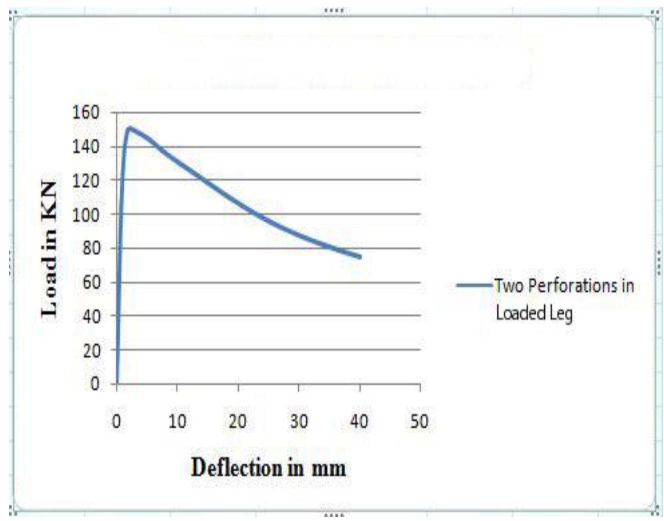


Fig.21. Load vs. Deflection graph for two perforations in loaded leg.

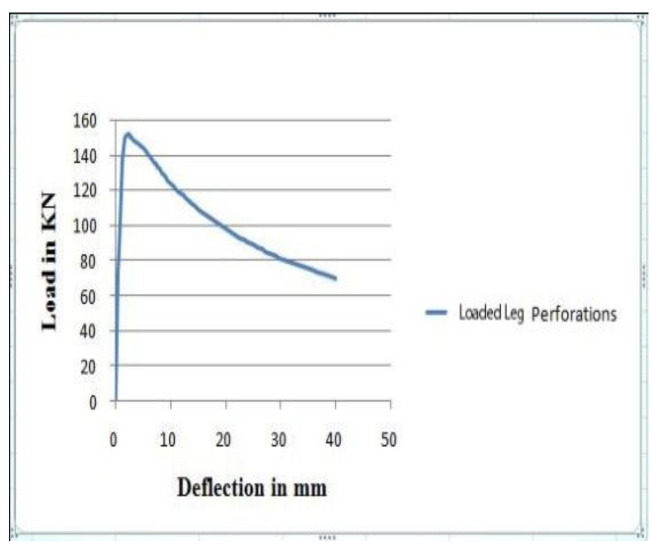


Fig.22. Load vs. Deflection graph for three perforations in loaded leg.

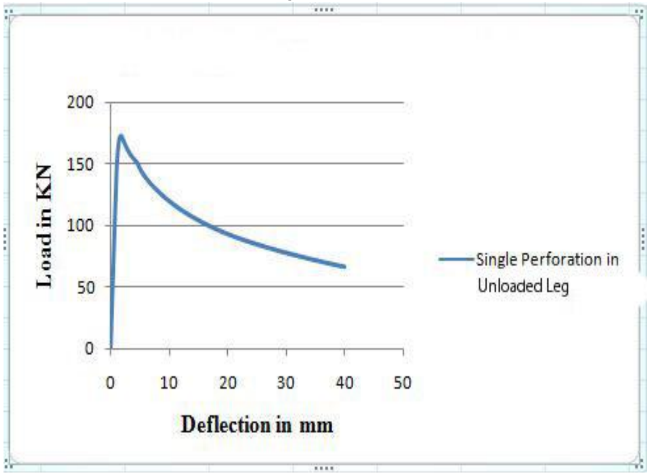


Fig.23. Load vs. Deflection graph for single perforation in unloaded leg.

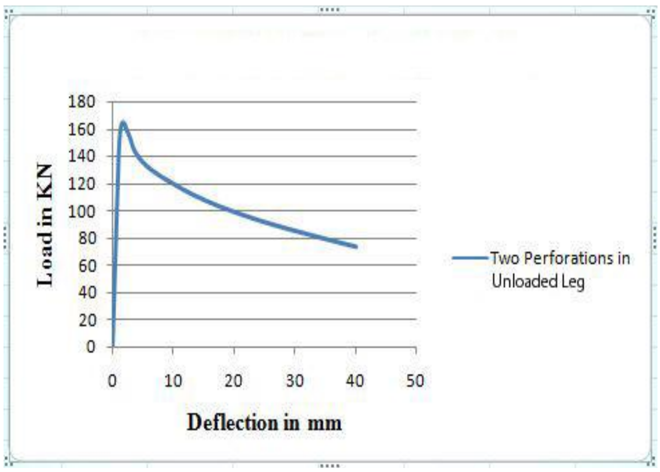


Fig.24. Load vs. Deflection graph for two perforations in unloaded leg.

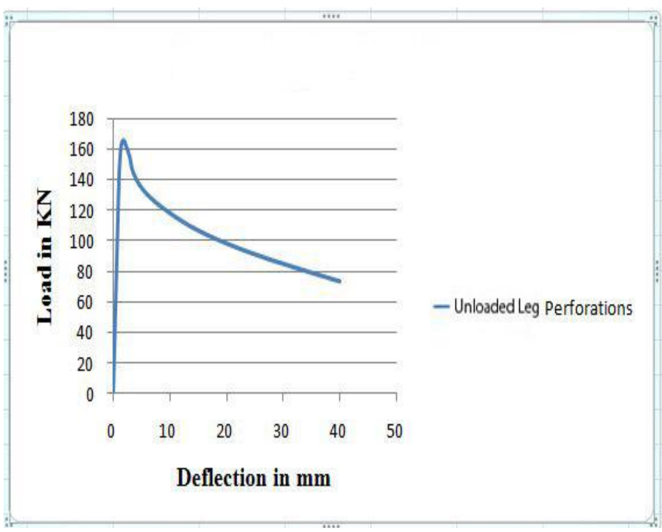


Fig.25. Load vs. Deflection graph for three perforations in unloaded leg.

The Fig. 26 represents a comparison of angle members with and non-perforated member.

- From the following figure we can see that load carrying capacity of single perforated angle member is less than that of angel member Non-perforated member.
- After the peak load we can see that for angle member Non-perforated, even for small increase in load there is more deformation.
- For single perforated angle member after the peak load, further increase in load there is less deformation when compared to the angle member without perforations.

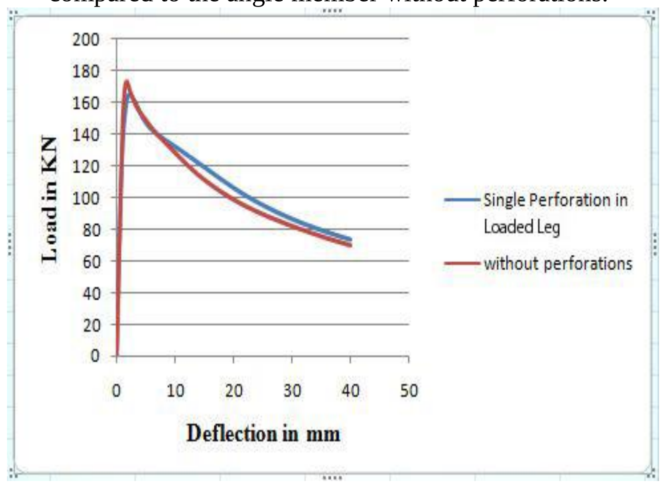


Fig.26 Load vs. Deflection graph for loaded leg with single perforations in angle member and non- perforated angle member.

The Fig. 27 represents a comparison of angle members with two perforations and non-perforated member. From the following figure we can see that load carrying capacity of two perforated angle member is less than that of angel member with non-perforated member.

- After the peak load we can see that for two perforation angle member with non-perforated member, even for small increase in load there is more deformation.
- But for two perforated angle member after the peak load, further increase in load there is less deformation when compared to the angle member with non-perforated member.

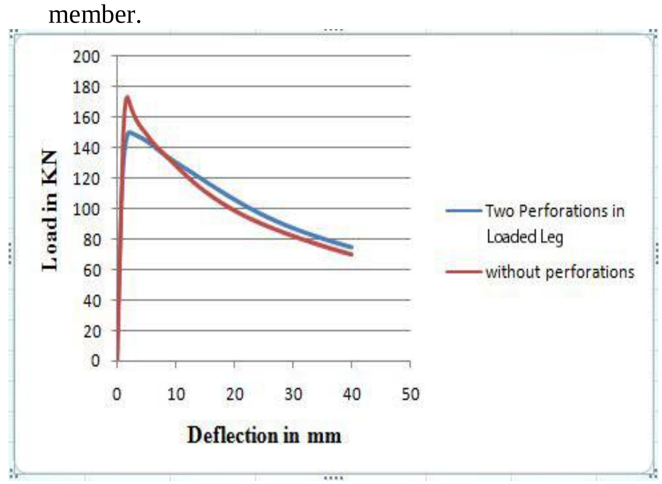


Fig.27. Load vs. Deflection graph for loaded leg with two perforations and non- perforated angle member.

The Fig.28 represents a comparison of angle members loaded leg with three perforations and non-perforated Member. From the following figure we can see that load carrying capacity of three perforated angle member is less than that of angel member with non-perforated member.

- After the peak load we can see that for angle member with non-perforated member, even for small increase in load there is more deformation.
- But for three perforated angle member after the peak load, further increase in load there is less deformation when compared to the angle member with non-perforated member.

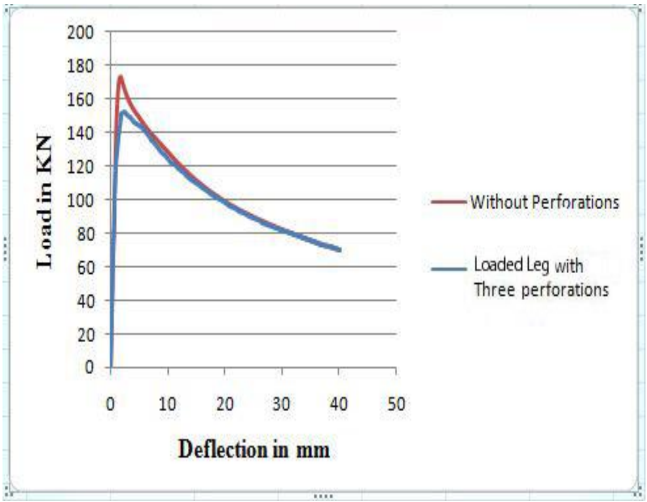


Fig.28. Load vs. Deflection graph for loaded leg with three perforated angle member and non- perforated angle member.

Load vs. deflection graph comparison of both angle members unloaded leg with single and non-perforated member. The Fig.29 represents a comparison of angle members with and non-perforated member. From the following figure we can see that load carrying capacity of single perforated angle member is less than that of angel member Non-perforated member.

- After the peak load we can see that for angle member Non-perforated, even for small increase in load there is more deformation.
- For single perforated angle member after the peak load, further increase in load there is less deformation when compared to the angle member without perforations.

The Fig.30 represents a comparison of angle members unloaded leg with two perforations and non-perforated member. From the following figure we can see that load carrying capacity of two perforated angle member is less than that of angel member with non-perforated member.

- After the peak load we can see that for angle member with non-perforated member, even for small increase in load there is more deformation.
- But for two perforated angle member after the peak load, further increase in load there is less deformation when compared to the angle member with non-perforated member.

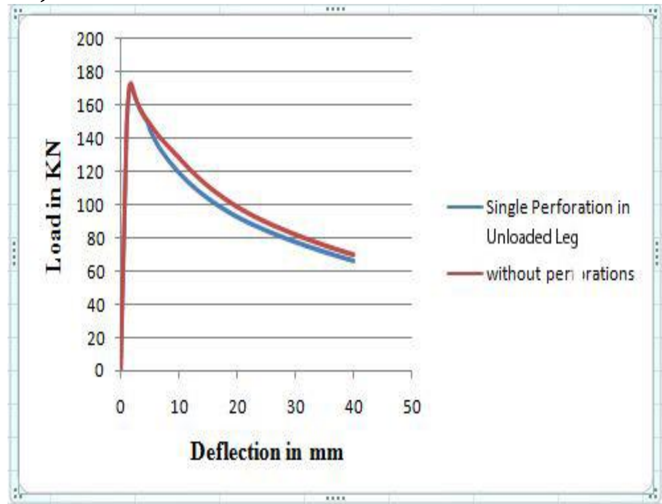


Fig.29. Load vs. Deflection graph for unloaded leg with single perforations in angle member and non- perforated angle member.

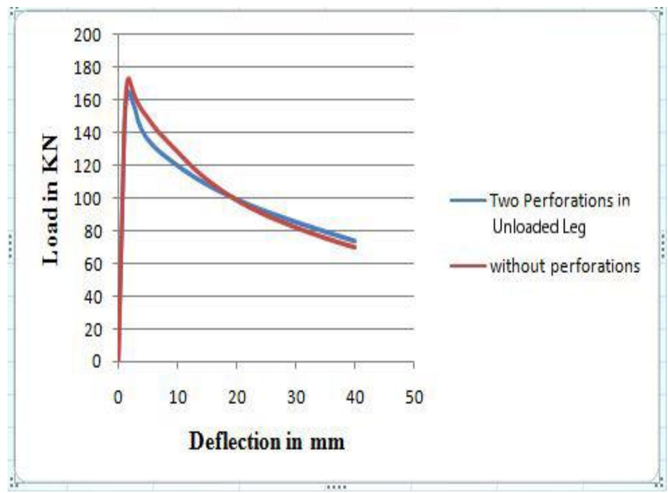


Fig.30. Load vs. Deflection graph for unloaded leg with two perforations and non- perforated angle member.

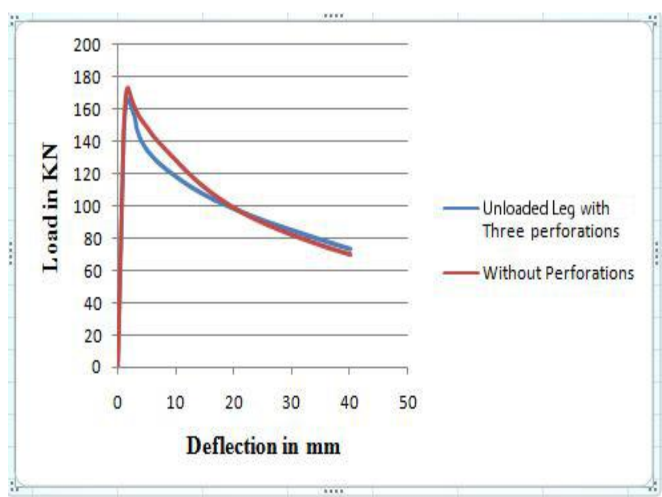


Fig.31. Load vs. Deflection graph for unloaded leg with three perforated angle member and non-perforated angle member.

The Fig.31 represents a comparison of angle members unloaded leg with three perforations and non-perforated Member. From the following figure we can see that load carrying capacity of three perforated angle member is less than that of angel member with non-perforated member.

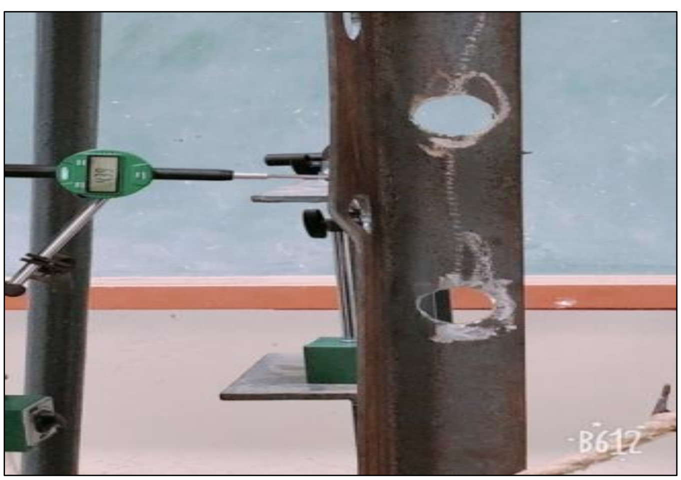
- After the peak load we can see that for angle member with non-perforated member, even for small increase in load there is more deformation.
- But for three perforated angle member after the peak load, further increase in load there is less deformation when compared to the angle member with non-perforated member.

B. Experimental Results

Both perforated and non-perforated specimens of angle sections are tested. The deflected shapes of those specimens are shown in the following sections.

Angle Sections (ISA 100 x 100 x 6 mm) with staggered pattern perforations: The perforated angle sections have been subjected to compression load and the deflected shapes are shown in the Fig.32(a) and (b) respectively.

(a)



(b)

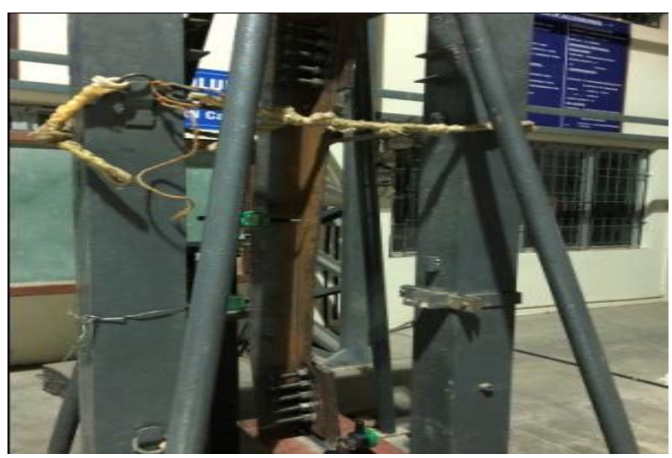
Fig.32.(a)Deflected shape for staggered pattern perforated member, (b) Deflected shape for staggered pattern perforated member.

Angle Sections (ISA 100 x 100 x 6 mm) with uniform pattern perforations: The uniform pattern perforated angle section is subjected to compression load and deflected shape is shown in the Fig.33.

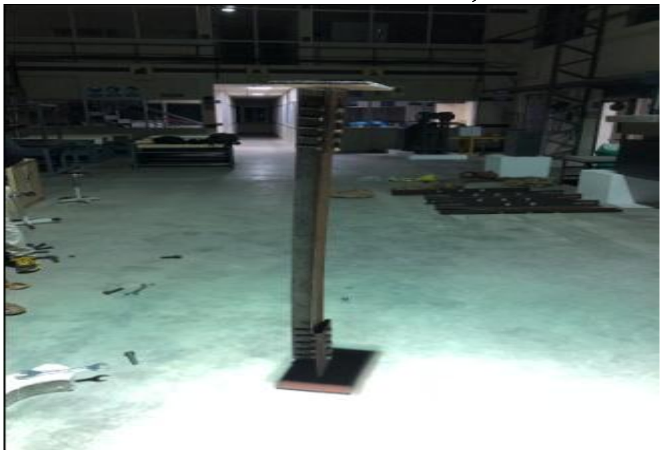
Fig.33. Deflected shape for uniform pattern perforated member.

Angle Sections (ISA 100 x 100 x 6 mm) with loaded leg perforations: The Loaded leg perforated angle section is subjected to compression load and the deflected shapes are shown in the Fig.34.

Fig.34. Deflected shape for loaded leg perforated member.



(a)



(b)

Fig.35.(a) Deflected Shape for Non-Perforated ISA 100 x 100 x 6 mm, (b) Deflected Shape for Non-Perforated ISA 100 x 100 x 6 mm.

Angle Sections (ISA 100x100x 6mm) without perforations: The Non- perforated angle section is subjected to compression load and the deflected shapes are shown in the Fig.35 (a) and (b) respectively.

C. Graph Plotted From Experiment

Angle Section without Perforations ISA 100x100x6 mm:

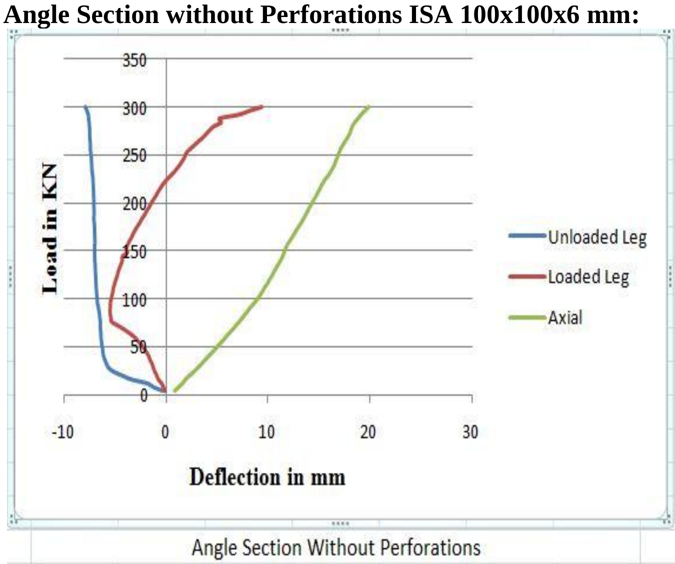


Fig.36. Load vs. Deflection graph of non-perforated angle member.

From the above graph the load carrying capacity of non - perforated angle member is 300 KN and deflection of the loaded leg and unloaded leg is 8 mm and -8 mm (- indicates other direction) and deflection is axial direction is approximately 20mm as shown in Fig.36.

Angle Section with Staggered Perforations ISA 100x100x6 mm: From the above graph the load carrying capacity of staggered pattern perforated angle member is 180 KN approximately and the deflection of loaded leg and unloaded leg is -4 mm and 8 mm (- indicates other direction) and deflection is axial direction is approximately 20 mm as shown in Fig.37.

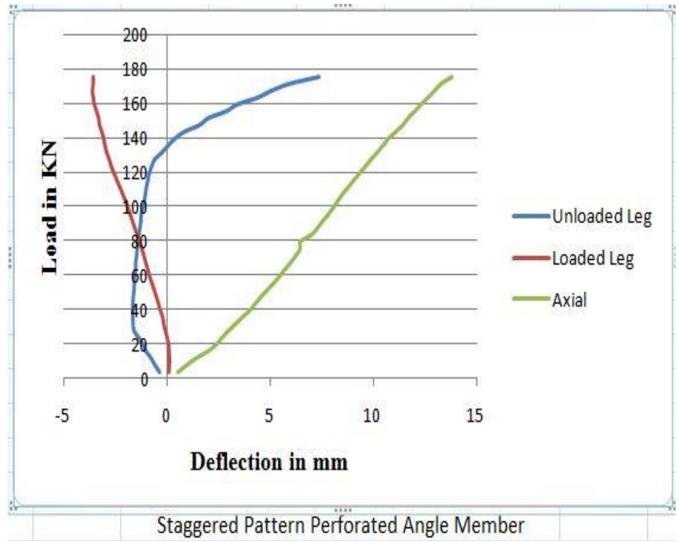


Fig.37. Load vs. Deflection graph of staggered pattern perforated angle member.

Angle Section with Uniform Perforations ISA 100x100x6 mm:

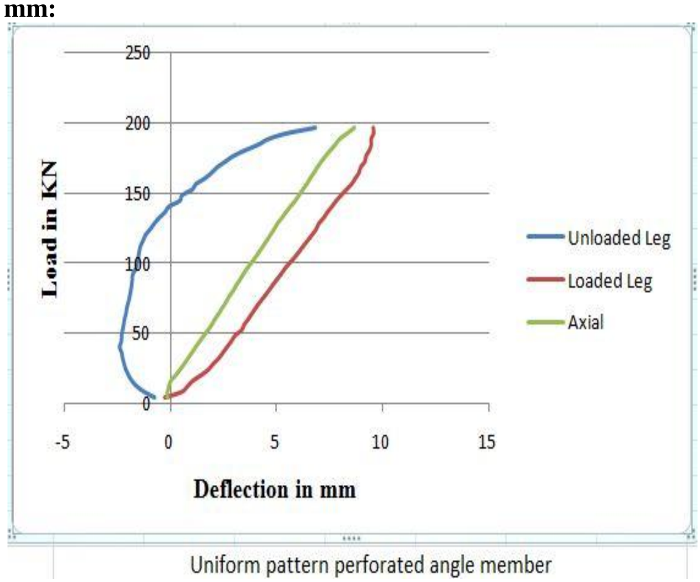


Fig.38. Load vs. Deflection graph of uniform pattern perforated angle member.

From the above graph load carrying capacity of uniform pattern perforated angle member is 200 KN approximately. The deflection of loaded leg and unloaded leg is 9 mm and 7 mm and deflection in axial direction is approximately 8 mm as shown in Fig.38.

Angle Section with Loaded leg Perforations ISA 100x100x6 mm: From the above Fig.39 the load carrying capacity of uniform pattern perforated angle member is 200 KN approximately. The deflection of loaded leg and unloaded leg is 5 mm and 8 mm and deflection in axial direction is approximately 12 mm.

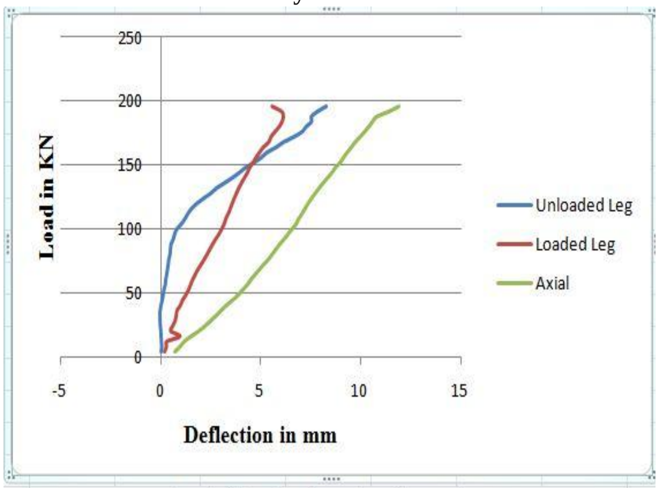


Fig.39. Load vs. Deflection graph of Loaded leg perforated angle member.

TABLE I: Comparison of Behaviour of Perforated and Non-Perforated Angle Members ISA 100 x 100 x 6 mm

Sl. no	Pattern of Perforations	Abacus		Experimental	
		Capacity (KN)	Deflection (mm)	Capacity (KN)	Deflection (mm)
1.	Staggered Pattern	145	2	180	4
2.	Uniform Pattern	130	3	200	9
3.	Loaded Leg with Perforations	150	2	200	5
4.	Without Perforations	175	3	300	9

IV. CONCLUSION

In the current study comprehensive analysis on angle elements varying in number of perforations and non perforated angle members are carried out. The influence of the perforations on the capacity of the member and effect on behavior of the buckling and resistance are investigated. The results of the analysis are evaluated in terms of the parameters. On the basis of the results the following conclusions can be done

- Geometrical non-linear buckling analysis (GNB) is carried out on the angle elements. The typical buckling modes are determined (overall buckling).
- Geometrically and material non-linear analysis (GMNI) are carried out using the first buckling mode as initial geometric imperfection. The ultimate behavior modes are determined, characterized and classified. It is observed that overall buckling occurs after the yield mechanism is developed.

Experimentally,

- Strength of Loaded Leg with Three perforated member is reduced by 36.66% when compared to non-perforated angle member.
- Strength of Unloaded Leg with three perforated member is reduced by 30% when compared to non-perforated angle member

Analytically,

- Strength of Loaded Leg with Single Perforated member is reduces by 5.71% when compared to non-perforated angle member.
- Strength of Loaded Leg with Two Perforated member is reduces by 11.42% when compared to non-perforated angle member.
- Strength of Loaded Leg with Three Perforated member is reduces by 14.28% when compared to non-perforated angle member.
- Strength of Unloaded Leg with Single Perforated member is reduces by 2.85% when compared to non-perforated angle member.
- Strength of Unloaded Leg with Two Perforated member is reduces by 4.57% when compared to non-perforated angle member.
- Strength of Unloaded Leg with Three Perforated member is reduces by 5.71% when compared to non-perforated angle member.
- Even small load applied for the specimen after they reach their capacity, deflection is more for non-perforated angle member when compared to perforated angle member.

V. SCOPE FOR FUTURE STUDY

In this project the buckling resistance of perforated angle members is determined. In future the following possibilities can be done.

- Determination of the capacity of a perforated channel member.
- Determination of the capacity of a perforated I – Section.
- Determination of the capacity of a perforated unequal angle member.
- Determination of the capacity of a perforated angle member with
    - Changing the sizes of Perforations,
    - Shapes of perforations.

VI. REFERENCES

[1]Buckling resistance of perforated steel angle members", Journal of Constructional Steel Research, Italy.

[2]"Design for openings in equal-angle cold-formed steel stub columns", Structural Steel Research Group, Singapur.

[3]"Elastic buckling analysis of thin-walled structural members with rectangular holes using generalized beam theory", Department of Civil and Environmental Engineering, Virginia Tech, USA.

[4]"A finite element analysis model for the behaviour of cold-formed steel members", Department of Civil Engineering, McMaster University, Hamilton, Ontario, Canada.

[5]"Distortional buckling of perforated cold-formed steel channel section beams with circular holes in web", International Journal of Mechanical Sciences, China.
[6]"Behaviour of cold-formed steel perforation sections in compression", Department of steel structures and structural mechanics, "Politechnica" University of Timisoara, Romania.