International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES)
Impact Factor: 5.22 (SJIF-2017), e-ISSN: 2455-2585
Volume 4, Issue 09, September-2018

EXPERIMENTAL INVESTIGATION ON PERFORATED HOT-ROLLED STEEL EQUAL ANGLE MEMBERS

SK.Rahaman[1] ,M.Jayakumar Bhaskar[2]

[1]*M.Tech Schlor,Civil engineering department,Visvodaya engineering college,kavali,india.*
[2]*Assistant Professor,Civil engineering department,Visvodaya engineering college,kavali,india.*

Abstract*— This paper is concerned with the ultimate load capacity of non-perforated and perforated equal-angle hot rolled steel columns.The experiment conducted like single perforation,double perforations and triple perforations in both legs of a steel member.An experimental study has been undertaken to investigate the behaviour of such members and column specimens were tested to failure under axial loading. The software used for finite element analysis in this project is ABAQUS. In this software we are getting the analysis values and we are compare the analysis values and experimental values.The analytical and experimental research has been developed to the performance assessment of angle members subjected to compression.

***Keywords*— Angle member with perforations,single,double,triple,imperfections**

I. INTRODUCTION

A steel structure is a ingathering of a group of members expected to have their role of applied power and to transfer them risk less to the state. Depending on the emplacement of the component part of the construction and its constructive use, the part is affected by the power, either axial, crooked, or torsion, or combination thereof. Axial loading can be either ductile or compact members.
A compression member is a structural member which is straight and subjected to two equal and opposite compressive forces applied at its terminals. Different conditions are applied to indicate a compression member, depending upon its position in structures. Columns, stanchion or post is a vertical compression member supporting floors or girders in a construction.

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. User has to cut them into required length and use required sections for the steel framework. 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.

II. METHODOLOGY

The software used for analyzing the compression members is 'ABAQUS'.

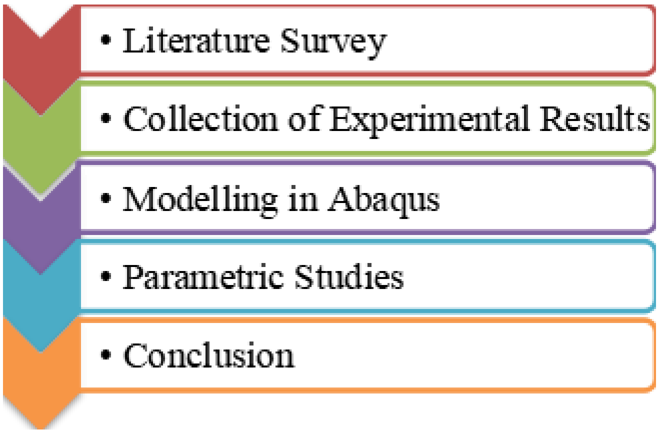

Fig. 1: Objectives Flow Chart

The flow chart representing the various steps followed in this project is summarized as shown in the figure. 1
The aim is to calculate and compare the capacity and deflection values for both experimentally and analytically. A steel framed structure is modeled using a Finite Element Analysis (FEA) Software i.e. ABAQUS software. The compressive

load is considered in this project by calculating as per IS: 800-2007. The calculated loads are applied to the angle members using ABAQUS and the deflection values obtained are noted and tabulated.

The needed steps after the modeling until the loading step in Abaqus software is carried out. The load is given to the angle members having perforations as displacement instead of loads such as point load or uniformly distributed load or uniformly varying load. The main objective is to study the case of behavior perforated angle members under axial load condition.

In order to carry out the experiment, specimens with perforations & specimen without perforation are considered. First, angle members with perforations subjected to axial compression are considered. The obtained capacity of members and deflection values are tabulated and compared with the non-perforated angle specimen. Further non-perforated and perforated angle members carried out for the analytically in ABAQUS and capacity of the members and deflection values are tabulated and compared.

The capacity and deflection values obtained in ABAQUS from both the non-perforated and perforated members will be compared with the values obtained in the experiment and the variation will be studied.

As seen from the above methodology flow chart, the first step involves collection of various literature's related to the current study. The next step is to collect experimental results from the collected literature's and studying their results. This can be achieved by using Limit State Design in accordance with IS: 800-2007. ISA 100 x 100 x 6 sections shall be considered for the analysis.

III. FEM ANALYSIS PROCEDURE

A.Buckling Analysis

The buckling analysis is carried to predict the buckling loads and the corresponding buckling shapes. These are used as a parameter in determining the post buckling strength and have additional application for incorporating the input values of the geometric imperfection using first buckling mode shape values.

B.Procedure for Buckling Analysis in ABAQUS

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

The following figure. 2 shows clearly the model before incorporating imperfection and after incorporating imperfection. The figure 2 (a) and 2(b) shows the front view of the model without and with incorporating imperfection in ABAQUS respectively into the software from MS-Excel. These are used as a parameter in determining the post buckling strength and have additional application for incorporating the input values of the geometric imperfection using first buckling mode shape values. The buckling solution can be obtained by Finite Element Method.

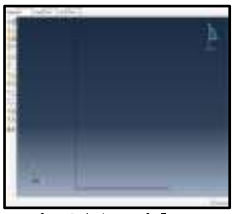

Fig 2(a) Without Imperfection

Fig 2(b) Without Imperfection

fig.2: Incorporating Imperfection in ABAQUS

IV.MANUAL DESIGN

IV. DESIGN OF COMPRESSION MEMBERS

A. General

A structural member loaded axially in compression is generally called a compression member. Vertical compression members in buildings are called columns, posts or stanchions. A compression member in roof trusses is called struts and in a crane is called a boom. Columns which are short are subjected to crushing and behave like members under pure compression. Columns which are long tend to buckle out of the plane of the load axis.

B. Design of Compression Member Loaded Through One Leg

When angle are loaded in compression through their centroid, they can be designed as per the procedure described below. However angles loaded eccentrically by connecting one of its legs either to a gusset plate or to an adjacent member. Such angles will buckle in flexural torsion in which there will be significant twisting of the member. Such twisting may be facilitated by the flexibility of the gusset plate and the other members connected to it. To simplify the code considers only two cases one gusset fixed and other is gusset is hinged. The other parameter which will influence the strength of the angle strut is its width to thickness ratio of either leg.

Thus, to account for reduction in strength due to flexural torsion mode, the code gives an equivalent slenderness ratio as a function of the overall slenderness ratio and the width thickness ratio. In general, the equivalent slenderness ratio is less or equal to the slenderness ratio for the flexural buckling $\lambda_{vv.}$

The flexural torsional buckling strength of single angle loaded in compression through one of its legs may be evaluated using equivalent slenderness ratio as given below

$\lambda_e = \sqrt{(k_1+k_2 \times \lambda_{vv}^2+k_3 \times \lambda_Ø^2)}$

Where K_1, K_2, K_3 are constants depends on the end conditions

$\lambda_{vv} = (l/r_{vv})/(\varepsilon \times \sqrt{((\pi^2E)/250)})$ and $\lambda_Ø = ((A+B)/2t)/(\varepsilon \times \sqrt{((\pi^2E)/250)})$

Where

l = center to center length of the supporting member

r_{vv} = radius of gyration about minor axis

A & B = width of two legs of the angle member

t = thickness of the leg

ε= yield stress ratio $\sqrt{(250/fy)}$

Constants K_1, K_2, K_3

Sl.no	No. of bolts at each end connection	Gusset / connecting member fixity	k_1	k_2	k_3
1	>= 2	Fixed	0.20	0.35	20
		Hinged	0.70	0.60	5
2	1	Fixed	0.75	0.35	20
		Hinged	1.25	0.50	60

$Ø = 0.5 \times (1+\alpha(\lambda - 0.2)+\lambda^2)$

Where α = Imperfection Factor given in the following table

Buckling Class	A	B	c	D
α	**0.21**	**0.34**	**0.49**	**0.76**

Stress Reduction Factor X = $1/(Ø+(Ø^2-\lambda^2)^{0.5})$

Design Compressive Stress f_{cd} = $(f_y/\gamma_{mo})/(Ø+(Ø^2-\lambda^2)^{0.5})$

= $X(f_y/\gamma_{mo}) \leq (f_y/\gamma_{mo})$

The design Compressive Strength P_d = $A_e x\ f_{cd}$

Where A_e = effective sectional area

f_{cd} = design compressive stress

V.RESULTS AND DISCUSSION

A.General

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

B.Analytical Results

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

B.1 ISA 100 x 100 x 6 mm of Length 1500 mm

B.1.1 ***Deflection of the member without perforations after implementing imperfections***

Buckling analysis of the member after imperfection is implemented into the Abaqus file. Figure.3 shows the buckling mode of the member after implementing the imperfection in ABAQUS.

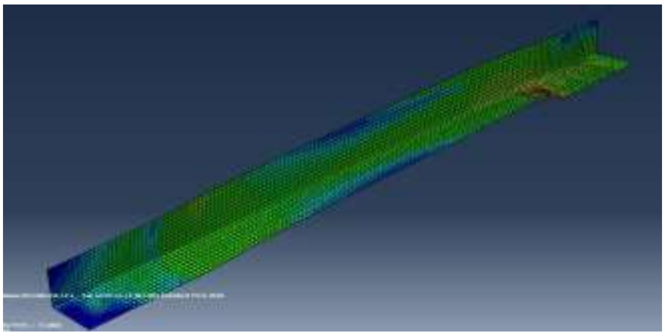

Fig 3 Buckling of the Angle Member without Perforations after implementing the imperfections

B.1.2 ***Deflection of the member with single perforations after implementing imperfections***

Buckling analysis of the member after imperfection is implemented into the Abaqus file. Figure.4 shows the buckling mode of the perforated member after implementing the imperfection in ABAQUS.

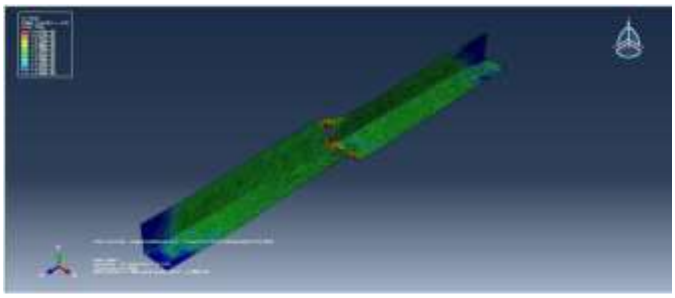

Fig 4 Buckling of the Angle Member with single perforations after implementing the imperfections

B.1.3 ***Deflection of the member with two perforations after implementing imperfections***

Buckling analysis of the member after imperfection is implemented into the Abaqus file. Figure.5 shows the buckling mode of the perforated member after implementing the imperfection in ABAQUS.

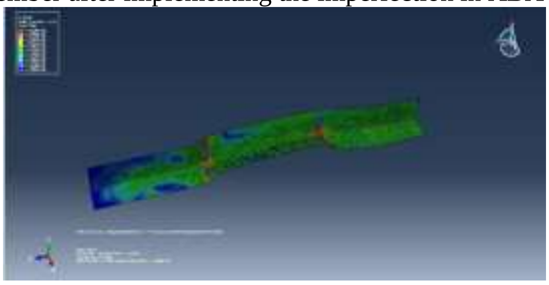

Fig 5 Buckling of the Angle Member with two Perforations after implementing the imperfections

B.1.4 ***Deflection of the member with three perforations after implementing material imperfection***

Buckling analysis of the member after imperfection is implemented into the Abaqus file. Figure 6 shows the buckling mode of the perforated member after implementing the imperfection in ABAQUS.

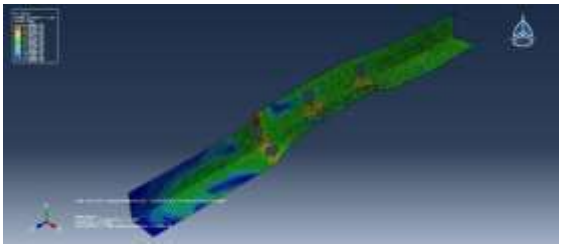

Fig 6 Buckling of the Angle Member with three Perforations after implementing the imperfections

B.1.5 Load vs. deflection graph for Angle Member without Perforations

The following figure 7shows the capacity for angle member of 1.5m length.

The maximum load carrying capacity of the angle member ISA 100 x 100 x 6 mm is approximately 175 KN after that the load carrying capacity is gradually decreasing as shown in fig 7

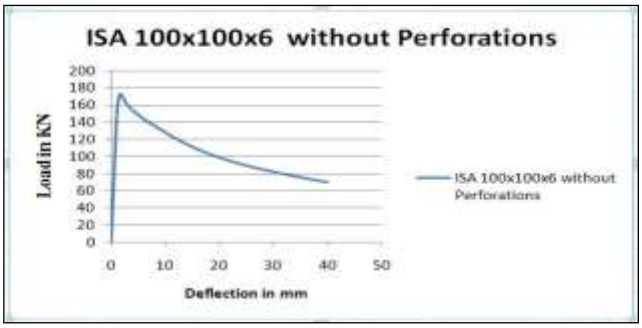

Fig 7 Load vs. Deflection graph for angle member without perforations

B.1.6 Load vs. deflection graph for Angle Member with Single Perforations

The following figure 8 shows the capacity reduction of the perforated angle member. The maximum load carrying capacity of the perforated angle member ISA 100 x 100 x 6 mm is approximately 145 KN after that the load carrying capacity is gradually decreasing as shown in fig 8

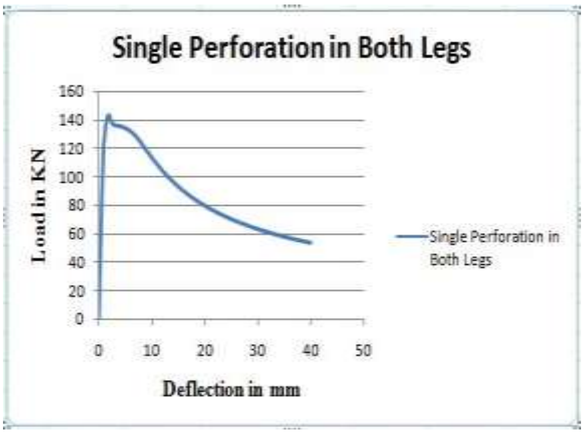

Fig 8 Load vs. Deflection graph for single perforated angle member

B.1.7 Load vs. deflection graph for Angle Member with Two Perforations

The following figure 9 shows the capacity reduction of the two perforations in angle member. The maximum load carrying capacity of the perforated angle member ISA 100 x 100 x 6 mm is approximately 130 KN after that the load carrying capacity is gradually decreasing as shown in fig 9.

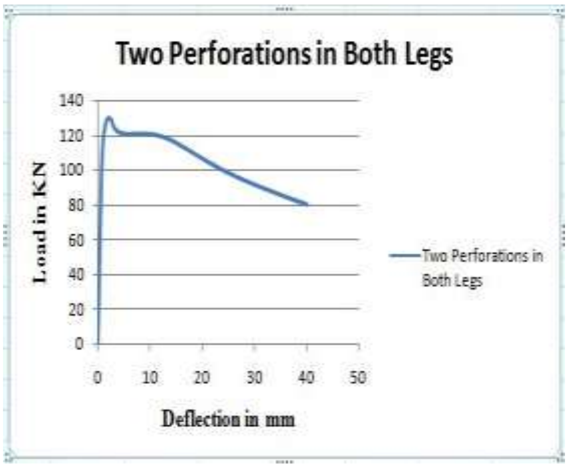

Fig 9 Load vs. Deflection graph for two perforated angle member

B.1.8 Load vs. deflection graph for Angle Member with Three Perforations

The following figure 10 shows the capacity reduction of the three perforations in angle member. The maximum load carrying capacity of the perforated angle member ISA 100 x 100 x 6 mm is approximately 130 KN after that the load carrying capacity is gradually decreasing as shown in fig 10.

Fig 11 Load vs. Deflection graph for three perforations in angle member

B.1.9 Load vs. deflection graph Comparison of both Angle Members with single and non-perforated member.

The fig 11 represents a comparison of angle members with and non-perforated member.

1. 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.
2. After the peak load we can see that for angle member Non-perforated, even for small increase in load there is more deformation.
3. 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.
4.

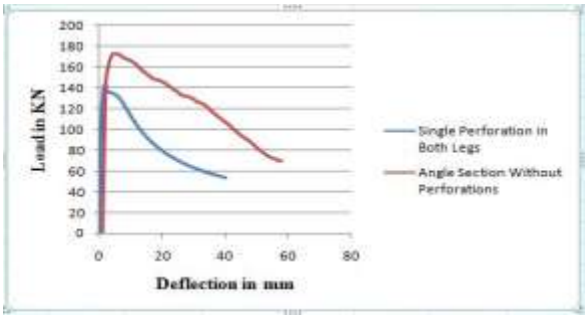

Fig 11 Load vs. Deflection graph for single perforations in angle member and non- perforated angle member

B.1.10 Load vs. deflection graph Comparison of both Angle Members with two perforations and non-perforated member.

The fig 12 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.

1. 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.
2. 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.
3.

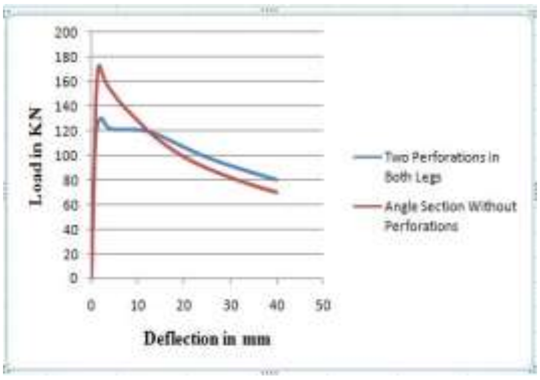

Fig 12 Load vs. Deflection graph for two perforations and non- perforated angle member

B.1.11 Load vs. deflection graph Comparison of both Angle Members with three perforations and non-perforated member.

The fig 13 represents a comparison of angle members 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.

1. 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.
2. 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.

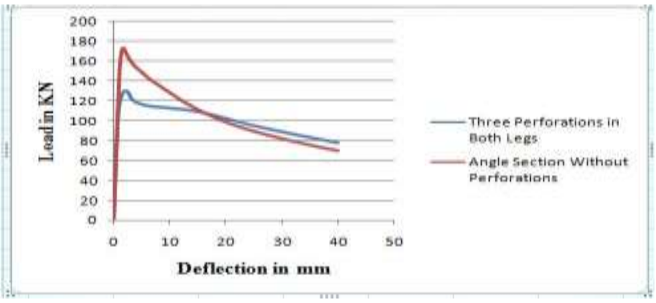

Fig 13 Load vs. Deflection graph for Three Perforated angle member and non- perforated angle member

C. Experimental Results

Both perforated and non-perforated specimens of angle sections are tested. The testing procedure has been explained in detail in the previous chapter. The deflected shapes of those specimens are shown in the following sections.

C.1 Angle Sections (ISA 100 x 100 x 6 mm) without perforations

The Non- perforated angle section has been subjected to compression load and the deflected shapes are shown in the figure 13 (a) and (b) respectively.

	
Fig 13 (a) Deflected Shape for Non-Perforated ISA 100 x 100 x 6 mm	**Fig 13 (b) Deflected Shape for Non-Perforated ISA 100 x 100 x 6 mm**

C.2 Angle Sections (ISA 100 x 100 x 6 mm) with Single perforations

The single perforations in angle section has been subjected to compression load and the deflected shape is shown in the figure 14.

Fig 14 Deflected shape for Single Perforations Angle member

C.3 Angle Sections (ISA 100 x 100 x 6 mm) with Two pattern perforations

The Two perforations in angle section has been subjected to compression load and the deflected shape is shown in the figure 15

Fig 15 Deflected shape for Two Perforations Angle member

C.4 Angle Sections (ISA 100 x 100 x 6 mm) with Three pattern perforations

The Three perforations in angle section has been subjected to compression load and the deflected shape is shown in the figure 16.

Fig 16 Deflected shape for Three Perforations Angle member

D. Graph Plotted From Experiment

D.1 Angle Section Non-Perforations ISA 100x100x6 mm

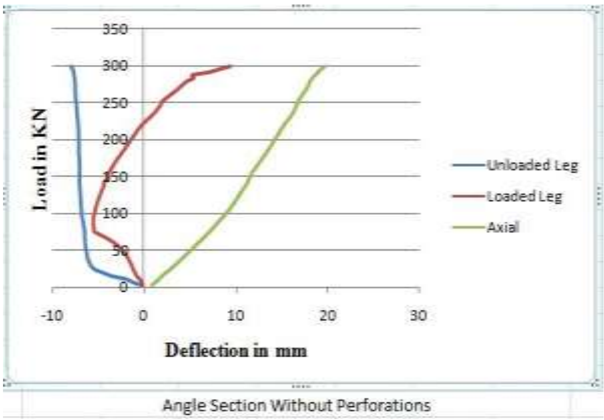

Fig 17 Load vs. Deflection graph of non-perforated angle member

From the above graph the load carrying capacity of non -perforated angle member is 300 KN and the 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.

D.2 Angle Section with Single Perforation ISA 100x100x6 mm

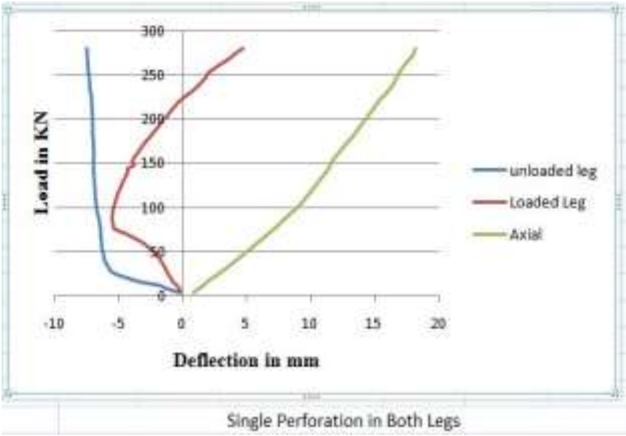

Fig 18 Load vs. Deflection graph of Single perforation angle member

From the above graph the load carrying capacity of three perforated angle member is 280 KN approximately and the deflection of the loaded leg and unloaded leg is 4 mm and 7 mm and deflection is axial direction is approximately 18 mm.

D.3 Angle Section with Two Perforations ISA 100x100x6 mm

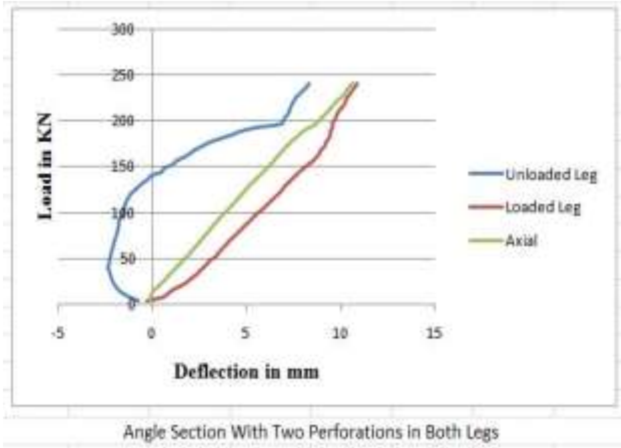

Fig 19 Load vs. Deflection graph of Two perforations angle member

From the above graph the load carrying capacity of two perforated angle member is 245 KN approximately and the deflection of the loaded leg and unloaded leg is 11 mm and 8 mm and deflection is axial direction is approximately 11 mm.

D.4 Angle Section with Three Perforations ISA 100x100x6 mm

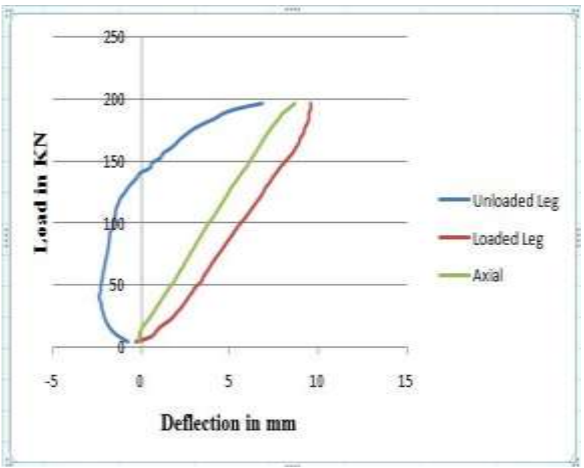

Fig 20 Load vs. Deflection graph of Three perforation angle member

From the above graph the load carrying capacity of three perforation angle member is 200 KN approximately and the deflection of the Loaded leg and unloaded leg is 9 mm and 7 mm and deflection is axial direction is approximately 8 mm.

E.Comparison Of Behavior Of Perforated And Non-Perforated Angle Members ISA 100x100x6 mm

Sl.No	Pattern of Perforations	Abaqus		Experimental	
		Capacity (KN)	Deflection (mm)	Capacity (KN)	Deflection (mm)
1.	Single Perforation in Both the Legs	145	2	280	4
2.	Two Perforations in Both the Legs	130	3	245	11
3.	Three Perforations in Both the Legs	130	2	200	9
4.	Without Perforations	175	3	300	9

VI. CONCLUSIONS

The steel angle member is crude within the finite part analysis package, ABAQUS. the strain output and displacement management square measure taken because the answer from the ABAQUS.
In the current study comprehensive analysis on angle elements varying in number of perforations and non perforated angle members are carried out.

- Strength of single perforated member is reduced by 7% when compared to non-perforated angle member.
- Strength of two perforated member is reduced by 18.4% when compared to non-perforated angle member.
- Strength of three perforated member is reduced by 33.33% 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.

Scope for Future Study

In this project the buckling resistance of punctured angle portion 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,
- ✓ Shape of perforation.

REFERENCES

1. **Wei-bin Yuan et.al (2017)** Determines the numerical and analytical investigations on the distortional buckling of perforated cold-formed steel channel-section beams with circular holes in web.
2. **Giuseppe Brando and Gianfranco De Matteis (1992)** Bckling resistance of perforated hot-rolled steel L-shaped members in compression.
3. **C Wanget.al. (2009)** An experimental and numerical study to investigate the compression behavior of lightweight structural panels using perforated sections.
4. **M. Dhanalakshmi, and N.E.Shanmugam, (2001)** The ultimate load capacity of non-perforated and perforated equal-angle cold-formed steel stub columns.
5. **Nabil Abdel-Rahman et.al. (2011) D**esign width equations for the determination of the ultimate strength of such perforated members in compression.
6. **Xingyou Yao et.al. (2013) B**uckling mode and load-carrying capacity of cold-formed thin-walled steel column with slotted web holes.