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FEM Analysis of Connections to Resist Progressive Collapse in Steel Structures

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***Abstract*- This paper deals with the importance of connections to resist progressive collapse. Progressive collapse event can be defined as "The spread of an initial local failure from element to element, eventually resulting in the collapse of the entire structure or a disproportionately large part of it". During sudden column removal, plastic hinges will be formed at the center and at the two ends of the beam. The beam which was resisting loads by flexural action will suddenly change its behavior to tensile catenary action in order to resist the progressive collapse. But the connections are not designed for such axial loads and the structure fails due to failure of the connections. Hence, to resist progressive collapse, it is necessary to design connections for such high moments and axial forces.**

This paper discusses the behavior of connections during progressive collapse and their failure conditions using FEM analysis. A web cleat connection was modeled in ANSYS and its behavior was studied during progressive collapse. The FEM Models were validated by experimental data.

Keywords—Progressive Collapse, Connections, FEM Analysis, Catenary Action

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I. INTRODUCTION

The study of steel connections subjected to dynamic loading started since 1960's but after 11th September, 2001 there is a rising concern over behavior of connections when affected by sudden column removal or blast loads. The beam column connection plays an important role in the structural response. However, present design guidelines do not impose any strict detailing requirements to design against blast loads. The Army Technical manual TM5-1300 gives guidelines to design blast resistant structures but it does not give any specific guideline to design the connections of the steel structures. Sabuwala et al [1] have studied different steel connection systems and showed that welded flange plates showed better performance under blast loads and low stresses at the connection regions. G.S. Urgessa et al. [2] developed innovative types of connections and also showed that a SidePlate connection provides better performance against blast loading. Kang Hai Tan et al [3] also studied different connections and showed that web cleat connection has an improved performance than other types of connections. A guideline by the Department of Defense (DOD) "Design of buildings to resist progressive collapse"[4] has significant improvements with regard to direct and indirect design approaches.

This paper shows the preliminary results of a FEM analysis of steel frame connection subjected to blast. Understanding the behavior of connections is important in keeping the structural continuity of steel frames during blast scenarios

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II. MODEL VALIDATION

A. Geometry of the model

A beam column joint that was considered for experimental tests is shown in fig 1. The load was applied on the extreme end of the beam. The specimen consisted of a steel beam and a steel column connected with each other using two angles of size 50 x 50 x 5. This model was prepared to validate FEM model in ANSYS. The steel beam and column both are made up of ISMB 100.

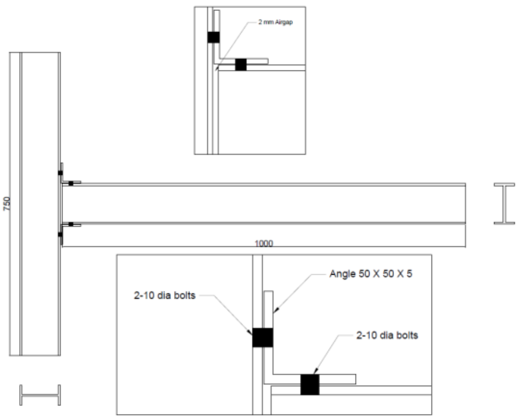

Figure 1

B. Discretisation of the model

The mesh is chosen in such a way that, accurate results would be available in a reasonable analysis time. As shown in Figure 2, finer mesh has been used in areas of high stresses i.e. at the contact zones of the joint.

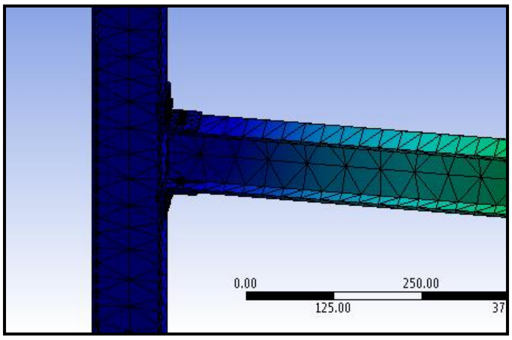

Figure 2

In order to achieve simplicity, the bolts are not modeled with a hexagonal head but are assumed to have a circular head and the nut is bonded with the bolt in such a way that the nut is assumed to have a permanent connection with the bolt. Slipping of the nut from the bolt is also not considered. All the contact surfaces in the connection were assumed to be frictional with a frictional co-efficient of 0.15. The tangential contact between the bolt hole and bolt shank was considered frictionless.

For the experimental set-up, the steel material of columns, angles and beams was of grade Fe 250. 10 mm diameter bolts were used.

Figure 3

The beam was fixed in a horizontal position as shown in Figure 3, before the test was started. A vertical load was applied at the end of the beam as shown in fig 3. The load was increased gradually until huge deformations occurred in the connections. A summary of the results containing displacement at the end corresponding to different loads has been given. Results are shown in Table 1.

Figure 4

Table 1

Force(kN)	Deflections during Experimental work in mm	Maximum Deflections in ANSYS in mm
10 kN	40	35.04
20 kN	63	68.994
25 kN	77	85.497
30 kN	91	101.85
35 kN	102	118.15

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Figure 5 shows the displacements of the free end of the beam.

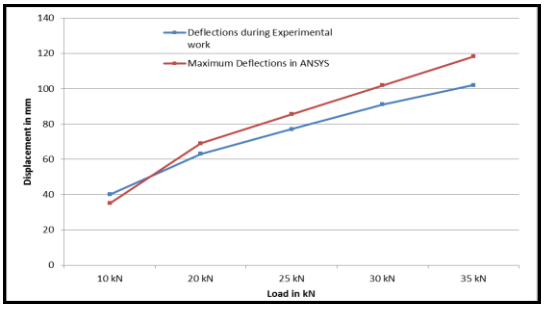
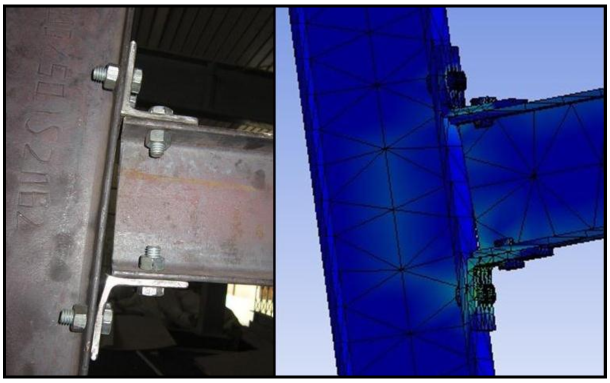


Figure 5

Figure 6 shows the co-relation of the behaviour of the actual model and the ANSYS FEM model.



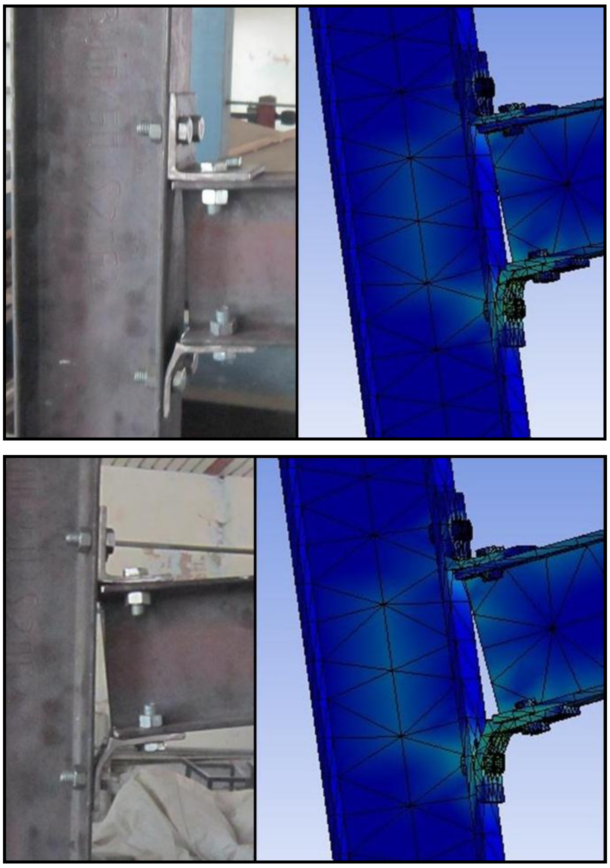


Figure 6

The figures and graph show that the method employed for FEM modeling in ANSYS is correct.

III. FEM ANALYSIS OF CONNECTION

A web cleat connection was designed to resist progressive collapse.

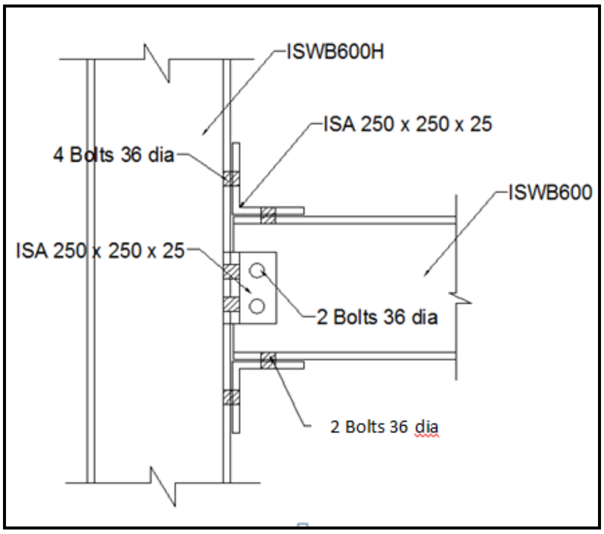


Figure 7

The yield strength of the beam and column were taken as 250 MPa and the yield strength for bolt was taken as 640 MPa while the ultimate strength of the bolt was considered as 800 MPa.

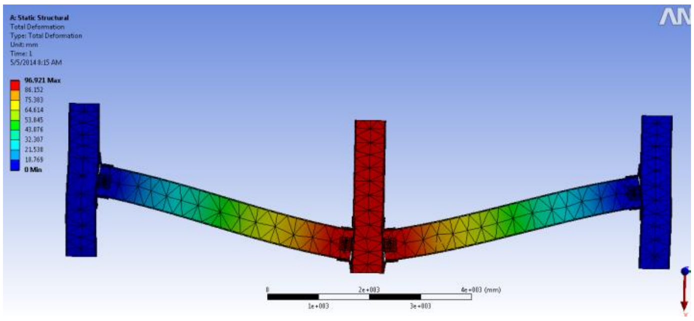


Figure 8

The bolts at the bottom were under tension while the bolts at the top of the connection were under compression. The stress distribution of the most strained bolt is shown in fig 9.

Figure 9

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The stress distribution in the cleats on both sides of the flange is shown in fig 10.

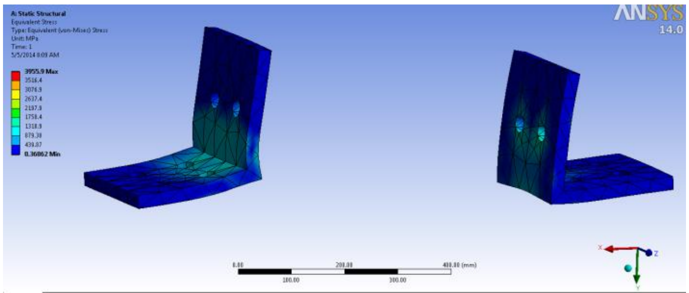

Figure 10

The moment rotation curve obtained after the FEM analysis shows that the curve is linear in the beginning and then ductility of the connection comes into play which gives a nonlinear curve.

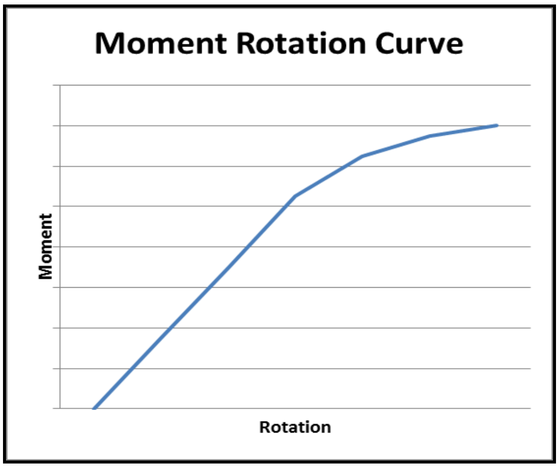

Figure 11

IV. CONCLUSION

The moment curvature curve shows that web cleat connection behaves in a ductile manner during progressive collapse.

Stiffeners can be provided at the column connection junction where there are high deformations.

Web cleat connections can resist very high axial loads and hence can easily initiate catenary action which will resist progressive collapse.

REFERENCES

[1] Tapan Sabuwala, Daniel Linzell, Theodor Krauthammer. "Finite element analysis of steel beam to column connections subjected to blast loads." International Journal of Impact Engineering 31 (2005) 861–876, 2005.

[2] T.Arciszewski, G.S.Urgessa. "Structural behavior of steel frame connections subjected to blast." - Challenges, Opportunities and Solutions in Structural Engineering, 2010.

[3] Kang Hai Tan, Bo Yang. "Behaviour of Different Types of Steel Connections in Steel Frames against Progressive Collapse." - Advanced Materials Research Vols. 374-377 (2012) pp 1330-1341, 2012.

[4] 4-023-03, UFC. Design of buildings to resist progressive collapse, UNIFIED FACILITIES CRITERIA (UFC)-DOD, June 2013.

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