BEAM COLUMN JOINT ANALYSIS FOR VARIOUS LOADING USING FINITE ELEMENT METHOD FOR STEEL STRUCTURE

Dr. Pradeep P. Tapkire[1], Vinayak A. Hanchate[2], Atul S. Chandanshive[3]

[1]H.O.D. Civil Dept., N.B. Navale Sinhgad College of Engineering, Solapur, Maharashtra, India-413255
[2]Research Scholar at N.B. Navale Sinhgad College of Engineering, Solapur, Maharashtra, India-413255
[3]Lecturer Civil Dept., Solapur Education Society's Polytechnic Solapur, Maharashtra, India-413002

---***---

Abstract - *This paper presents a comprehensive finite element analysis (FEA) study on the behaviour of beam-column joints in steel structures subjected to two types of load combinations. The load combinations considered include dead load, live load, wind load, and dead load, live load, earthquake load. Furthermore, three types of column configurations and two types of beam sections are analyzed to investigate their influence on the structural response*

***Key Words*: Beam column joint, FEM.**

1. INTRODUCTION

The ideal beam-to-column couplings are pinned or completely stiff, and this assumption has long been made when designing steel portal frames.

The performance of a framed structure depends on the integrity of the joints as well as each individual structural component. The joints are the most important component of the framed structure because they ensure structural continuity. The joints are strong enough to transfer the load from a structural member to the end of the member in order to prevent structural failure.

When using the ideally pinned connection, the beam and column cannot transmit moments; as a consequence, the connections lack rotational stiffness and cannot transmit movements, while transmitting axial and shear forces. Full rigid joints transmit all forms of loads between beam and column because they have rotational compatibility. Their behaviour is decoupled from the structure during analysis of these joints. Although this simplifies the analysis and structural design processes.

In order to study and design the joint, these joint behavior models must be included into structural analysis software.

1.1 AIM & Objective

This paper aims to investigate beam to column joint in steel structures using finite element modelling.

The following points are considered to carry out finite element analysis of the beam to column junction in steel structures:

1. Study of beam to column joint under different loading.
2. The various cross section is considered for analysis by using finite element method.
3. Finite element analysis is considered for various column configuration.

Non-dimensional details will be prepared based on the results obtained by different combination of parameter.

2. Literature review

Hassan A. Saab [1] presented work was done on creating a finite element technique and using it to conduct behavioral research on steel frames during fire circumstances.

Elsayed Mashaly, Mohamed El-Heweity, Hamdy Abou-Elfath, Mohamed Osman [2] researcher developed an intuitive and accurate three-dimensional (3D) finite element model (FE) in order to properly predict the behaviour of beam-to-column connections in steel frames when subjected to lateral stresses. The bolted extended-end-plate connection was shown to be a crucial component of beam-column junctions. The extended-end-plate connection is chosen for its complexity in the analysis and behavior due to the number of connection components and their inheritable non-linear behavior. Two experimental tests from the literature were utilized to verify the finite element model. Researchers compared the results of the experimental model with the proposed finite element model.

R.A. Hawileh, A. Rahman, H. Tabatabai [3] developed a detailed three-dimensional (3D) nonlinear finite element model for the purpose of analyzing the reaction and forecasting the behavior of a precast hybrid beam-column connection subjected to cyclic stresses. Using 3D solid components and surface-to-surface contact elements between the beam and column faces, the precast junction was modeled. The model accounts for the nonlinear material behavior of concrete as well as the pre-tension effect in the post-tensioning strand. At all loading stages, a good agreement between the model response and the experimental test findings was found. The connection failed as a result of the mild steel bars breaking. Stress and strain fields in the mild-steel bars at the beam-column contact were derived using the examined model to forecast this failure scenario.

M. R. Mohamadi-Shoore, H. Ghafari and M. Amankhani [4] describes a Finite Element Modeling (FEM) of RHS-based splice beam connectors that were just bent. SUT-DAM software was used to create a THREE-DIMENSIONAL (3D) finite element model consisting of an end-plate, four bolts, a weld, and the web of a beam.

Vishawadeep Shivaji Ghodajkar, Dr. R.M. Sawant [5] researcher observed that top and seat angle connections cause smaller strains than double web angle connections and extended end plate connections when various loads and accelerations are applied to the three separate connections in one of those connections.

Kuldeep Kaushik, Avadesh Kumar Sharma, Rishi Kumar[6] researchers states that the flush end-plate connection is more goal-oriented than the extended end-plate connection, in order to join members in bridge and shade structures efficiently and effectively,

Chintamani N. Khadake, Prashant M.Pawar [7] conducted RCC structural analysis and design. Following that, FEA software was used to examine one of the outside beam column joints.

Kathirvelmurugan K R V, Satheshkumar K [8] describes Finite Element Model (FEM) for the efficient analysis of structural connections in order to decrease the complexity in connection design. For the examination of connections, a novel method known as Component Based Finite Element Model (CBFEM) was introduced in this article. This technique enhances the connection by decreasing structural flaws and raising moment bearing capability.

Balamuralikrishnan R., Saravanan J. [9] researchers used ABAQUS software to quantitatively analyze the behaviour of an external beam-column connection that included internal GFRP reinforcements under various material, loading, and support circumstances. The mechanical properties of these reinforcements are well documented and are utilized for modelling analysis.

3. PROBLEM FORMULATION

The various finite elements were considered in this project are as follows: -

C1 - Single "I" section.
C2 – Back to back channel section
C3 – Toe to Toe channel section
B1 – Single "I" section
B2 – "I" section with top plate.

Three alternative column geometries and two different beam geometries were taken into consideration for the study of the beam column junction.

Each floor height is 4 meters, and a G+4 building* with a span of 3, 4, 5, and 6 meters was examined.

To determine the maximum bending moment on the beam and the axial force on the column, the Staad Pro ver. 8 program was utilized..

Load combination: -

In this case two load combinations were considered are as follows:

1. DL+LL+WL
2. DL+WL+EQ

3.3 Analytical Work: -

Geometry Specifications of finite elements are as follows:

B1 - ISMB 250 @ 37.3 kg/m

B2 - ISMB 250 @ 37.3 kg/m, width of plate 150 mm & thickness of plate 10 mm

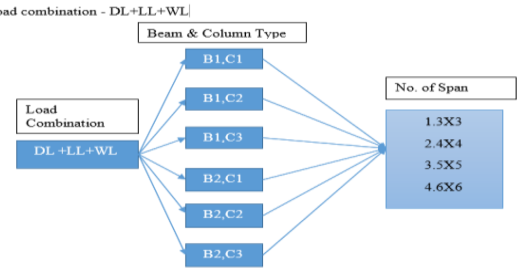
C1 - ISHB 300 @ 58.8 kg/m

C2 - ISMC 250 @ 30.4 kg/m, spacing 10 mm back to back

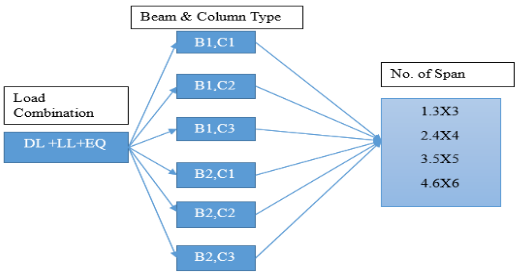
C3 - ISMC 250 @ 30.4 kg/m spacing 10 mm toe to toe

After the consideration of specification two types of load combinations were taken into account, and 48 models in Staad Pro were created according to the above-mentioned span.

1. Load combination - DL+LL+WL



2.Load combination – DL+LL+EQ



Methodology

Calculations of Load combinations: -

1. DL

1.1 Self Weight

1.2 Member load (Wall load)

Height of Wall = 3.75m, Width of wall = 0.169m

Member load = 20 x 0.169 x 3.75 = 12.65 KN/m

1.3 Floor Load = 1.5 N/m

2. Live Load = 2 KN/m

Auto Load Combination in Staad pro ver 8 as follows:

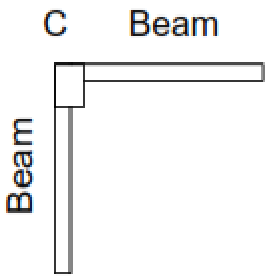
1. 1.5 DL + 1.5 LL
2. 1.2 DL +1.2 LL + 1.2 WL
3. 1.2 DL+1.2 LL -1.2 WL
4. 1.2 DL + 1.2 LL
5. 1.5 DL + 1.5 WL
6. 1.5 DL -1.5 WL
7. 1.5 DL
8. 0.9 DL

4.3 Cases Considered

As per design deformation were calculated at different three types of Joints of beam & column considered as follows:

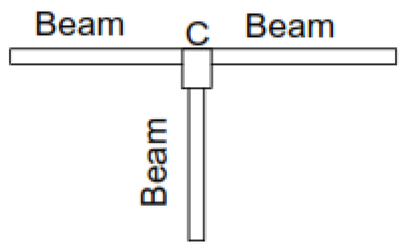
1. Joint 1 – End Column
2. Joint 2 – At Middle ('T')
3. Joint 3 – At Centre

1.Joint 1 – End column were two beams are connected at that joint.



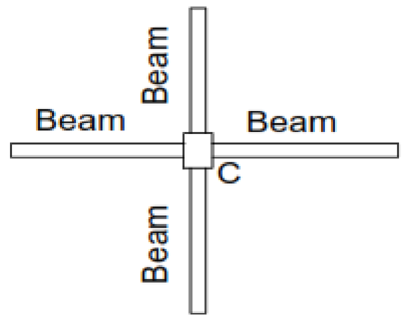
Joint 1

2.Joint 2 - At middle (T) were three beams are connected at that joint



Joint 2

3.Joint 3 -At Centre were four beams are connected at joint



Joint 3

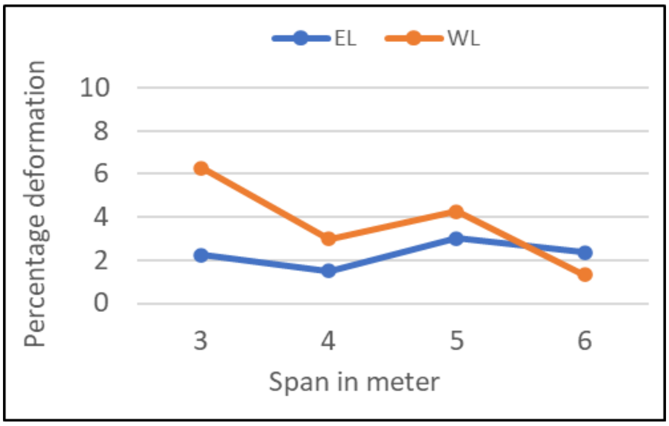
4. RESULTS

In order to analyze the beam-column junction, two forms of loading—DL, LL, WL and DL, LL, EL—and six distinct types of geometry were taken into account. Using a spreadsheet, the dimensions of the beam and column are determined for various spans and heights. The ANSYS finite element program is used to resolve the various spans with fixed heights for varied geometries. For the scenarios under consideration, the maximum deformation, maximum principal stresses, and minimum principal stresses are determined, and the results show the % variation for deformation and stresses,

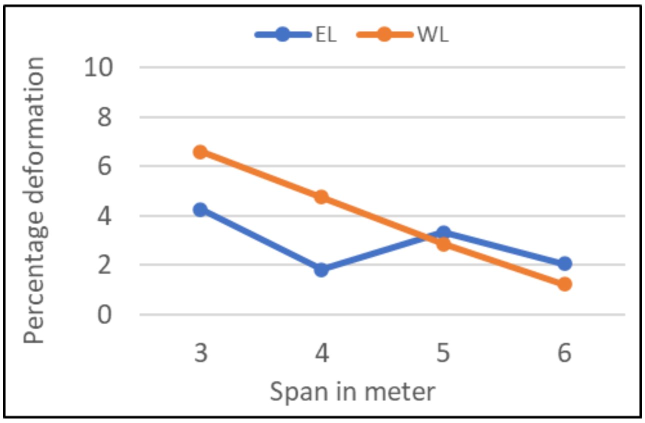
Effect of different loading on deformation and stress for various beam column combination.

1. Effect of different loading on deformation.

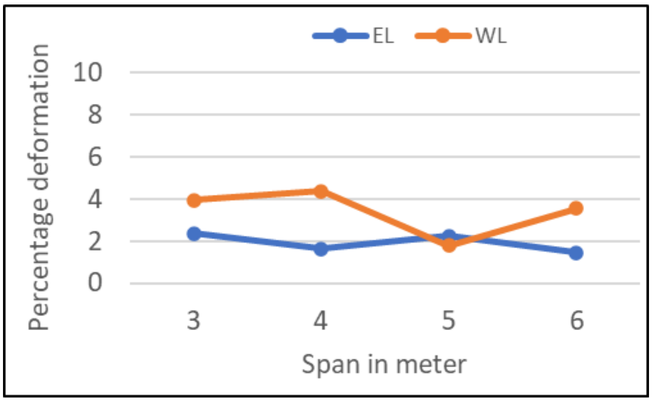
From Graph G1 through G6, the relationship between varied loads and deformation for various beam column ccombinations is displayed.



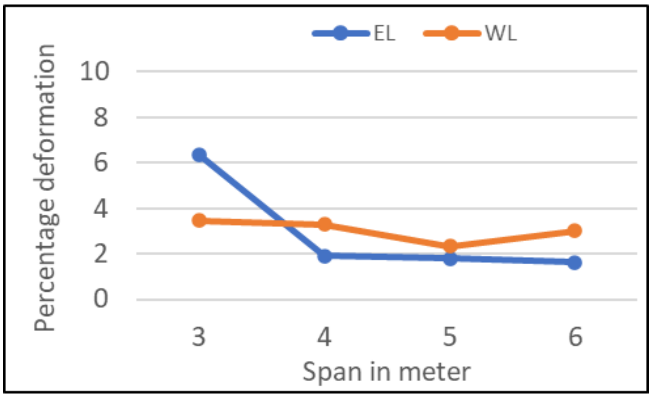
Graph G1: Variation of percentage deformation of B1C1 beam-column joint.



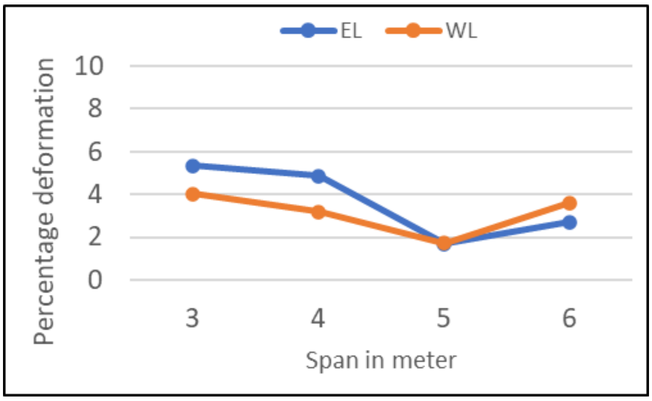
Graph G2: Variation of percentage deformation of B2C1 beam-column joint.



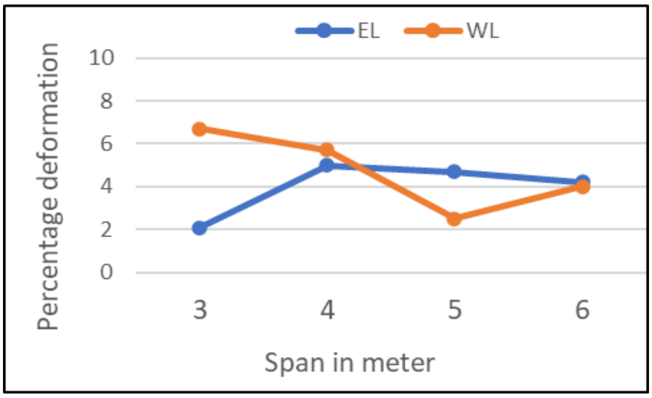
Graph G3: Variation of percentage deformation of B1C2 beam-column joint.



Graph G4: Variation of percentage deformation of B2C2 beam-column joint.



Graph G5: Variation of percentage deformation of B1C3 beam-column joint.



Graph G6: Variation of percentage deformation of B2C3 beam-column joint.

From various graph G1 to G6, the deformation of various beam column combination according to span and different loading are observed.

From the above graph it is noted that wind load is predominant in some cases specially beam column joint combination with C1 type column.

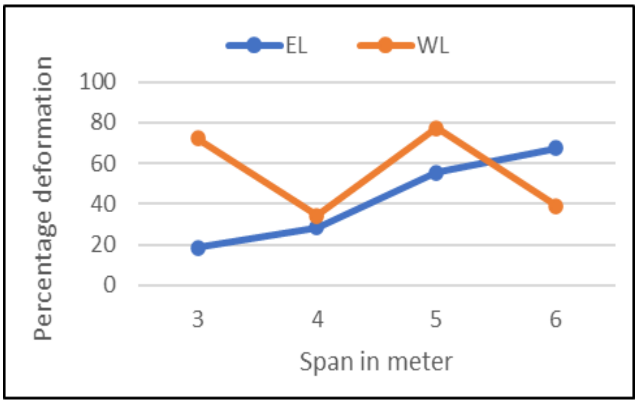
Beam column joint with C2 type variation shows more deformation for wind load cases.

Earthquake forces are slightly effective for a beam column joints with column C3 variation.

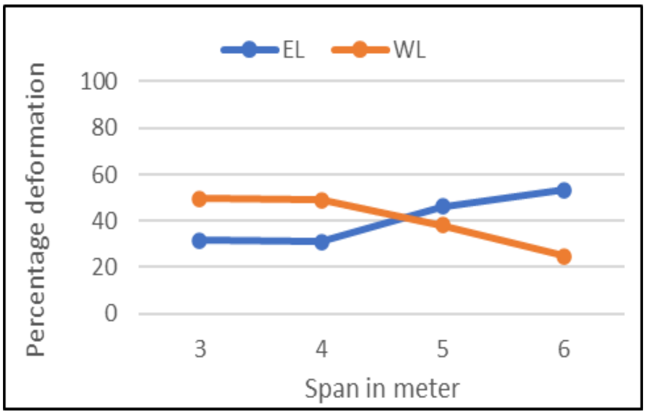
Span of beam is also affecting the deformation for different loading. Especially span lower than 8m showing higher deformations for various beam column joints.

Beam column joints with 5m span shows comparatively lower deformation for all combinations also effect of loading is not much differ for 5m span.

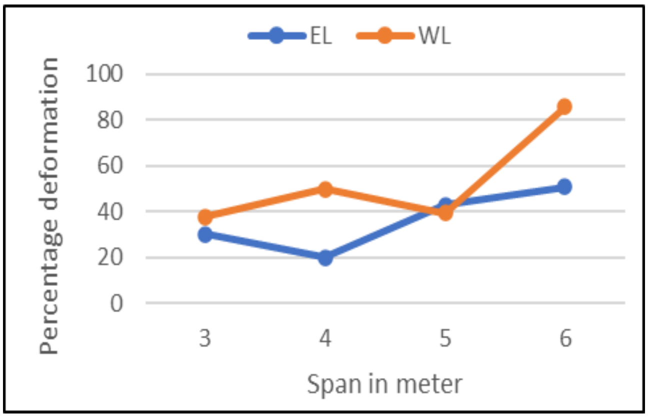
2. Effect of different loading on maximum stress (tensile)



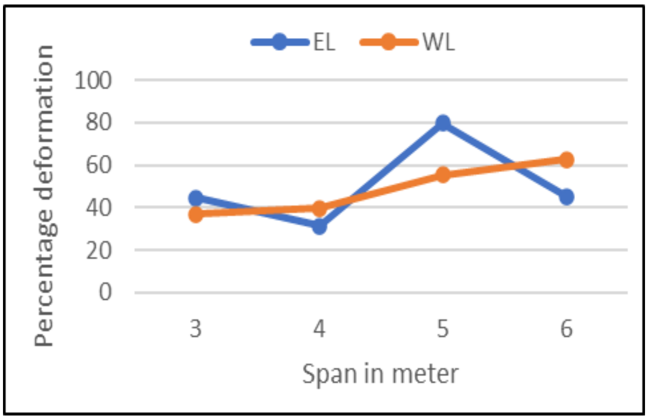
Graph G7: Variation of percentage maximum stress (tensile) of B1C1 beam-column joint.



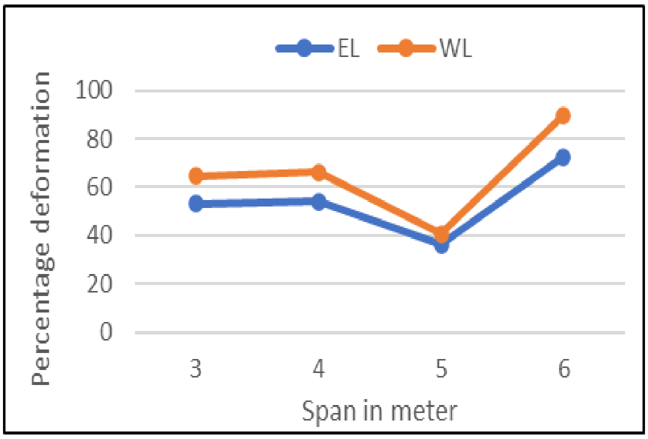
Graph G8: Variation of percentage maximum stress (tensile) of B2C1 beam-column joint.



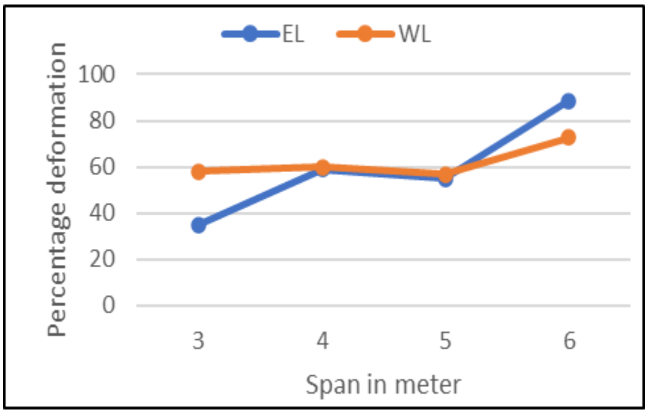
Graph G9: Variation of percentage maximum stress (tensile) of B1C2 beam-column joint.



Graph G10: Variation of percentage maximum stress (tensile) of B2C2 beam-column joint



Graph G11: Variation of percentage maximum stress (tensile) of B1C3 beam-column joint.



Graph G12: Variation of percentage maximum stress (tensile) of B2C3 beam-column joint.

Maximum tensile stresses getting affected because of various loading and span. The variation is plotted as above in graph G7 to G12.

Column type C1 shows more stress for wind load in comparison with earthquake load for lower span.

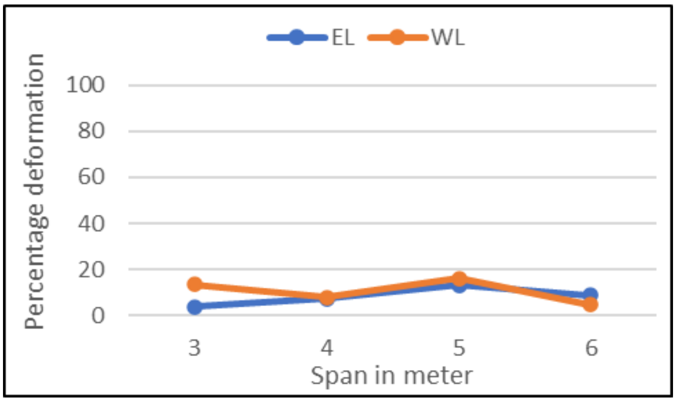
With C2 type of column variation, tensile stresses varying as per type of beam for specifically lower span.

For C3 type of column wind load induces more tensile stress as compare to earthquake load.

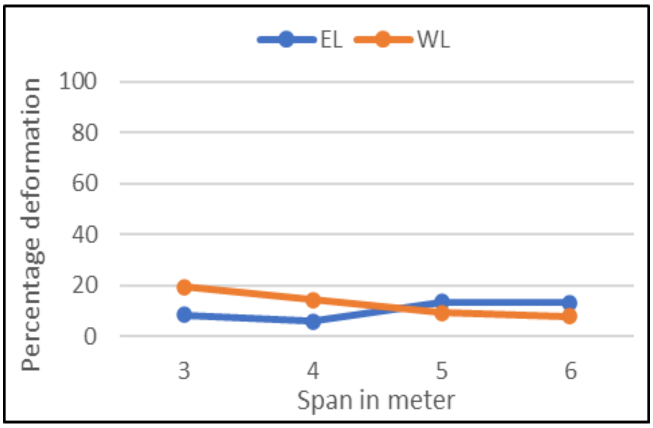
Span of beam is also affecting tensile stress induced. Similar to deformation 5m and above span shows comparatively lower stress in B1 type of combination.

For B2 type of combinations higher span shows higher stress induced.

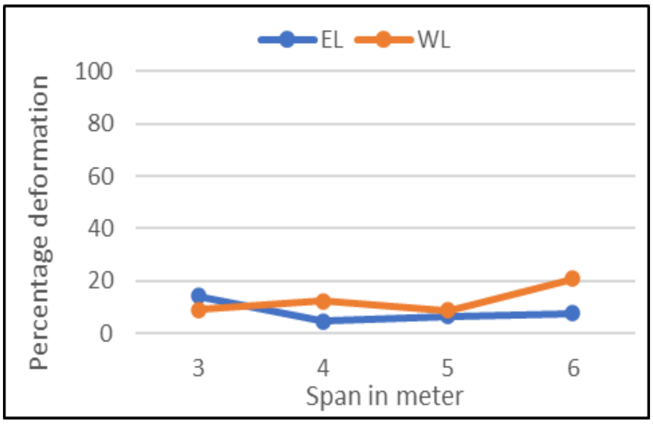
3 Effect of different loading on maximum stress (compressive)



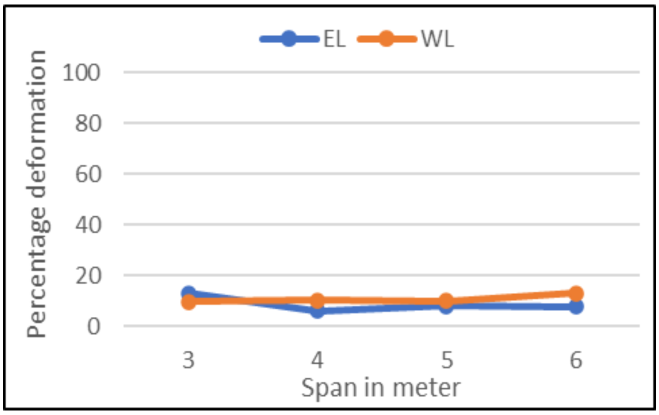
Graph G13: Variation of percentage maximum stress (compressive) of B1C1 beam-column joint.



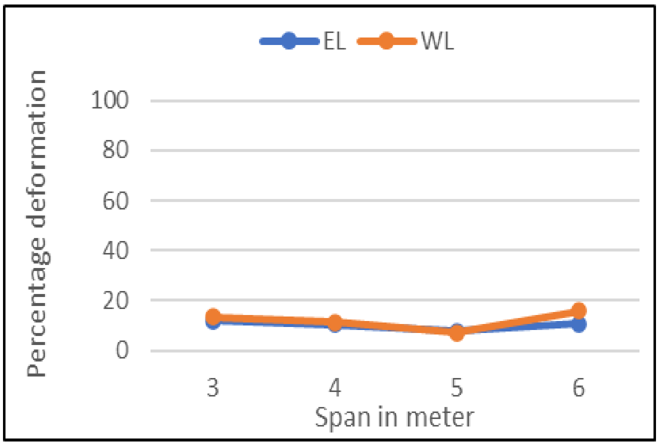
Graph G14: Variation of percentage maximum stress (compressive) of B2C1 beam-column joint



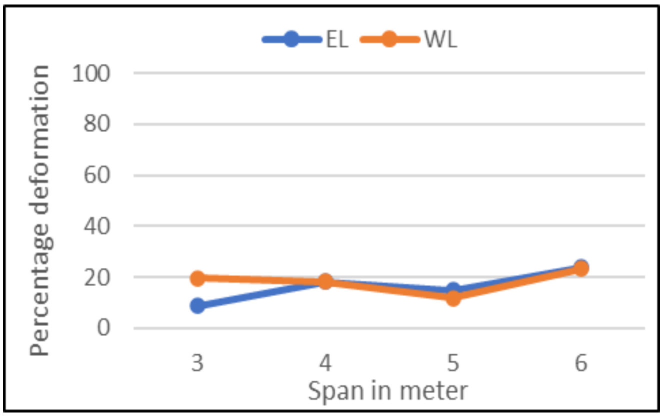
Graph G15: Variation of percentage maximum stress (compressive) of B1C2 beam-column joint



Graph G16: Variation of percentage maximum stress (compressive) of B2C2 beam-column joint.



Graph G17: Variation of percentage maximum stress (compressive) of B1C3 beam-column joint.



Graph G18: Variation of percentage maximum stress (compressive) of B1C3 beam-column joint

G13 to G18 shows variation of compressive stress along with span for various type of loading.

For all combinations of beam column joints, compressive stress is practically same for both wind load and earthquake load.

For C1 column type slight variations are observed on lower side for earthquake load.

Similar to that C2 column combinations show slightly lower stress induced for both type of loading.

C3 type of column shows practically same stress induced for both loading condition.

5. CONCLUSIONS

In C1 column configuration of beam column joint wind load induces higher tensile stress for lower span and in C2 column configuration induced stress varies with type of being connected and in C3 column configuration maximum tensile stress induced because of earthquake forces.

From the variation of different loading it is concluded that wind load is predominant for lower span (below 5m) joint with C1 column configuration

REFERENCES

[1] Hassan A. Saab (1990), "Non-linear finite element analysis of steel frames in fire conditions", University of Sheffield

[2] Elsayed Mashaly, Mohamed El-Heweity *, Hamdy Abou-Elfath, Mohamed Osman (2010), "Finite element analysis of beam-to-column joints in steel frames under cyclic loading", Alexandria Engineering Journal.

[3] R.A. Hawileh, A. Rahman, H. Tabatabai (2009), "Nonlinear finite element analysis and modeling of a precast hybrid", University of Wisconsin-Milwaukee, Applied Mathematical Modelling 34 (2010) 2562–2583.

[4] M. R. Mohamadi-Shoore, H. Ghafari, M. Amankhani (2013), "Finite Element Modeling of RHS Splice Beam Bolted Connections", Indian Journal of Science and Technology.

[5] Mr. Vishawadeep Shivaji Ghodajkar, Dr. R.M. Sawant (2018), "FEM Analysis of Steel Beam Column Joint by using Cantilever Weight and Acceleration", Journal of Ceramics and Concrete Sciences Volume 3 Issue 3.

[6] Kuldeep Kaushik, Avadesh K. Sharma, Rishi Kumar (2013), "A Review on Finite Element Analysis of Beam to Column Endplate Bolted Connection.", IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN: 2278-1684, p-ISSN: 2320-334X, Volume 8, Issue 1 (Jul. - Aug. 2013), PP 97-103.

[7] Mr. Chintamani N. Khadake, Dr. Prashant M. Pawar (2020), "Finite element analysis of beam column joint in reinforced concrete structure." International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056 Volume: 07 Issue: 07 | July 2020.

[8] Kathirvelmurugan K R V, Satheshkumar K. (2016), "ANALYTICAL & EXPERIMENTAL STUDY ON STRUCTURAL STEEL CONNECTIONS USING COMPONENT BASED FINITE ELEMENT MODEL", International Journal of Engineering Science Invention Research & Development; Vol. II Issue XI May 2016

[9] Balamuralikrishnan R., Saravanan J. (2019), "Finite element analysis of Beam – Column joints reinforced with GFRP reinforcements.", Civil Engineering Journal Vol. 5, No. 12, December, 2019.