Analysis of Steel Fiber Reinforced Concrete Beam-Column Joint Subjected to Blast Loading by Finite Element Method

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Abstract - *The increased number of terrorist attacks mainly in the last couple of years has shown that the impact of blast loads on buildings is a serious matter that we should consider during the building design process. The research has shown that the two joints (i.e. corner joint and exterior joint) are tested for blast loading of 6kgTNT charge effect with varying scaled distances (0.5m, 0.75m, 1m). Both joints are tested for both conditions that are in presence of steel fibers and in absence of steel fibers. Every steel designer should design Beam-Column joint for blast resistant as the beam-column joint become weak during blast. While these terrorist attacks are rare events, dynamic loads, i.e. blast loads, always need to be measured carefully much like earthquake loads and wind loads. The investigation of behavior of Beam-Column joint with and without Steel Fiber Reinforced Concrete under blast loading is presented in this paper using finite element method. Individual behavior of Beam-Column joint under blast loading before and after adding Steel Fibers is studied in this paper.*

***Key Words*: Blast load, Steel Fibres, TNT, Beam-Column joint, finite element method.**

1. INTRODUCTION

Explosions due to civilian accidents, from high explosives or due to weapons effects result in extreme loading conditions on structures such as building and some important structures. Such Explosions at or near the ground and in air surface mainly generate blast pressures and fragments generated by the explosion. Terrorist attacks and incidents are increased in last three decades so to protect such structures from such incidents the beam-column joint design is considered important. In the design of moment-resistant frames the reinforced concrete joints are considered as rigid. In Indian usage, the joint is normally ignored for particular nature and focus is restricted to supplying adequate anchorage for longitudinal beam strengthening, which could be suitable if the frame is not prone to earthquake loads.

A beam-column joint is structurally weak when subjected to large lateral loads, which include wind loads, earthquake loads and blast loads. Beam-column joint is the critical zone in a reinforced concrete frame structure. During its service life, it is exposed to considerable pressures and its action has a direct impact on the structural stability. While the designing of reinforced concrete structures, more attention is given to increase the compressive strength of basic structural elements like columns, beams, slabs. Comparatively, a beam-column joint becomes structurally less efficient when subjected to large lateral loads. Keeping this in view, paper presents the results of analytical study of reinforced concrete structure subjected to blast loading in presence and absence of steel fibres. Regular concrete is characterised by a comparatively low tensile strength and brittle tensile failure. However, the ductility of the concrete can be improved considerably by adding steel fibres to the matrix. As steel fibre reinforced concrete (SFRC) is subjected to an increasing load in e.g. bending, cracks developed in the concrete are the first step towards fracture of the material. If the structures are properly designed for these abnormal loads damage can be contained. Additionally, in order to ensure safety of existing structures against such events, an evaluation procedure for their inspection and eventual retrofit is needed.

The second phase of the study includes the comparison of analytical results with and without steel fibres calculated from finite element analysis software ANSYS 16 Workbench. Finite Element analysis method introduced by Zeinkiewicz analyses the structure fairly well and near accurate. The deformation, equivalent stress and equivalent strain have been evaluated at outer faces of the beam-column joint.

2. AIM

The aim of this research is to calculate blast loading effect on SFRC column-beam joint using Finite Element Method.

3. OBJECTIVES

3.1 To compare study of the Beam-Column joint for blast loading in ANSYS Workbench with and without Steel Fibres.

3.2 Calculate Total Deformation, Equivalent Stress and Equivalent Strain for TNT charge of 6kg and for varying scaled distances.

4. MATERIAL PROPERTIES

Table -1: Model & Reinforcement Properties (adopted for Column-Beam joint Modeling)

Model	Dimensions (mm)	Reinforcement
Beam 1	150×150×550	#4 – 12mm bars
		8mmΦ@150mm c/c
Beam 2	150×150×550	#4 – 12mm bars
		8mmΦ@150mm c/c
Column	150×150×1000	#4 – 12mm bars
		8mmΦ@150mm c/c

Table -2: Material Properties (adopted for Column-Beam joint Modeling)

Property	Concrete	Reinforcement
Compressive strength [N/mm^2] (experimental data)	M_{40}	
Young's modulus (E) [N/mm^2] (theoretical data)	20000	1.3×10^5 N/mm^2
Poisson's ratio μ (theoretical data)	0.11	0.3
Density [kg/m^3] (theoretical data)	2500	7850

Table -3: Properties of fibers (adopted for Column-Beam joint Modeling)

Type of Fiber	Hooked End Steel Fiber
Aspect Ratio	80
Density [kg/m^3]	7850
Percentage	1.5%
Orientation	Random

5. MODELLING IN ANSYS

ANSYS 16 WORKBENCH (WB)

ANSYS WB 16 is used for simulation and study of the finite elements. It is used line body approach in the construction of the Beam-Column Joint to build reinforcing bar and fabric. ANSYS Workbench meshing aims to include reliable, easy-to-use meshing software that will improve the mesh generation phase. Drag the Engineering Data element method from the Toolbox to the Project Data sheet or double-click the device in the Toolbox to attach an Engineering Data feature method to the Design Scheme.

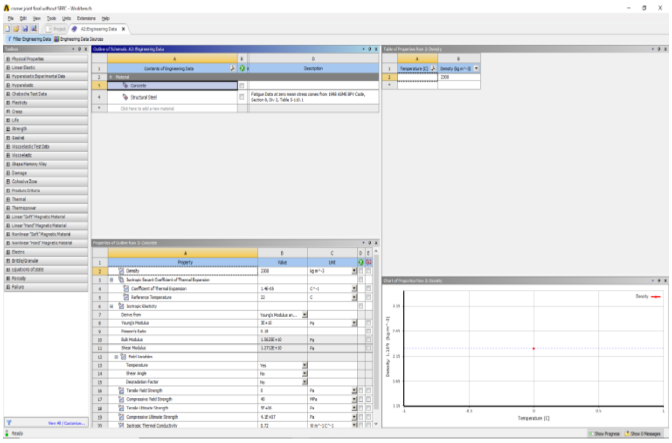

Fig -1: Selecting Engineering Data Source for Beam-Column Joint

5.1 MODELLING OF CORNER BEAM-COLUMN JOINT WITH AND WITHOUT SFRC

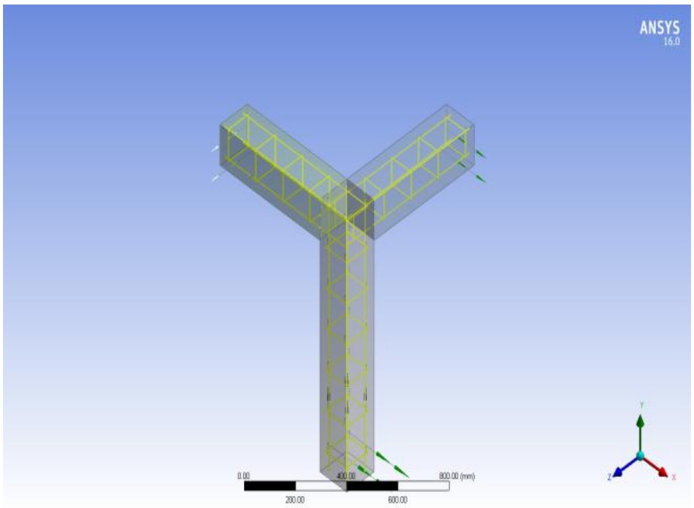

Fig -2: Modeling Corner Beam-Column joint without SFRC

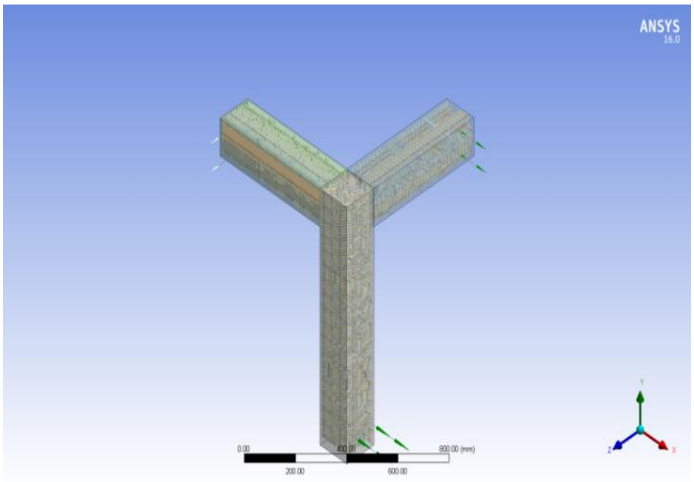

Fig -3: Modeling Corner Beam-Column joint with SFRC

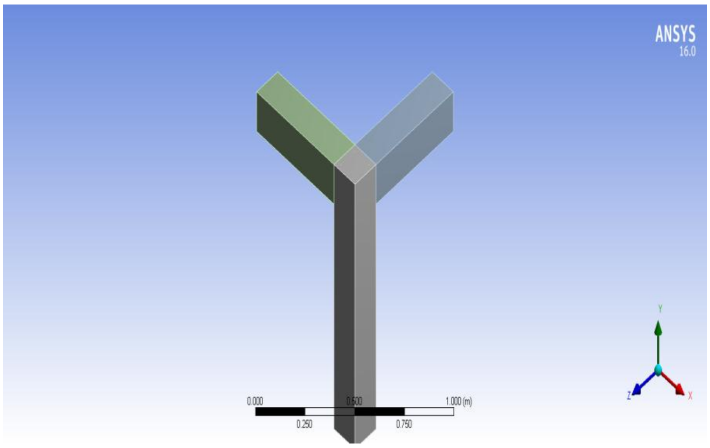

Fig -4: Adding material Properties to Corner Beam-Column Joint

5.2 MODELLING OF EXTERIOR BEAM-COLUMN JOINT WITH AND WITHOUT SFRC

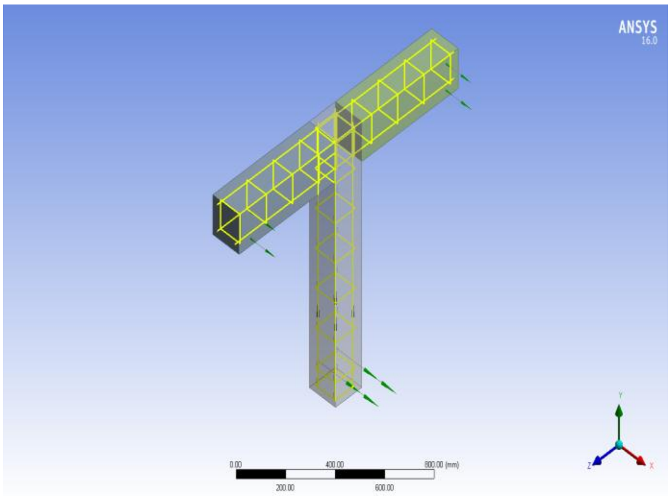

Fig -5: Modeling Exterior Beam-Column joint without SFRC

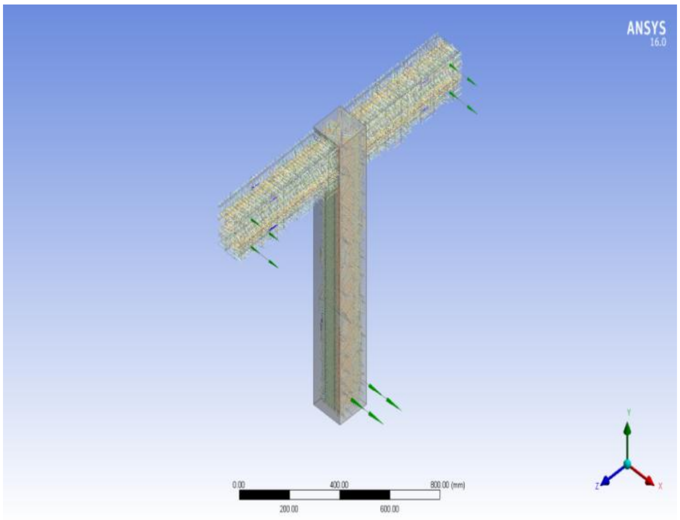

Fig -6: Modeling Exterior Beam-Column joint with SFRC

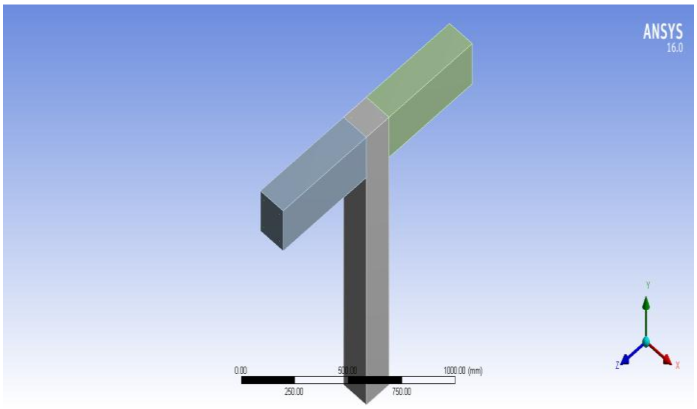

Fig -7: Adding material Properties to Exterior Beam-Column Joint

5.3 MODELING IN ANSYS OF BEAM-COLUMN JOINT UNDER BLAST LOADING

DEFINITION OF BLAST LOAD

As per the IS 4991:1968, A blast is a rapidly moving shock wave which may release pressure many times greater than those experienced under the greatest of the hurricanes. However, in blast phenomenon, the peak intensity lasts for very small amount of time.

5.3.1 CALCULATION OF BLAST LOAD

Equivalent weight of TNT- W (Kg.)

Scaled Distance (Z)- $Z = R/\sqrt[3]{W}$

Where, R = distance from the point of interest (m) to the detonation source

W = the weight (more absolutely: the mass) of the explosive (Kg).

Table -3: Blast Pressure for 6Kg TNT charge

Sr. No.	Stand-off Distances (m)	Scaled Distance (Z)(m)	Pressure (N/mm^2)
1	0.5	0.27	111.845
2	0.75	0.41	56.155
3	1	0.55	32.773

5.3.2 APPLYING PRESSURE & END TIME FACTOR ON CORNER & EXTERIOR BEAM-COLUMN JOINT

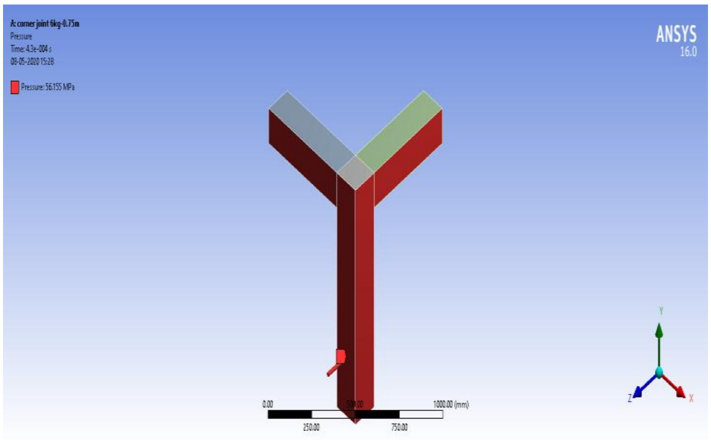

Fig -8: Applying Pressure & End Time Factor on Corner Beam-Column Joint

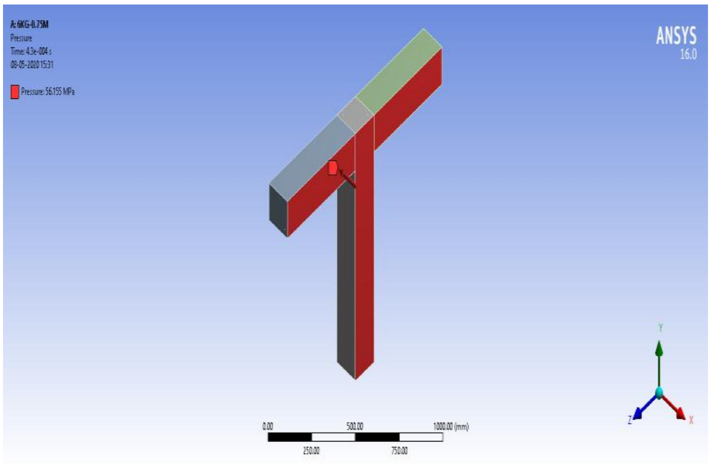

Fig -9: Applying Pressure & End Time Factor on Exterior Beam-Column Joint

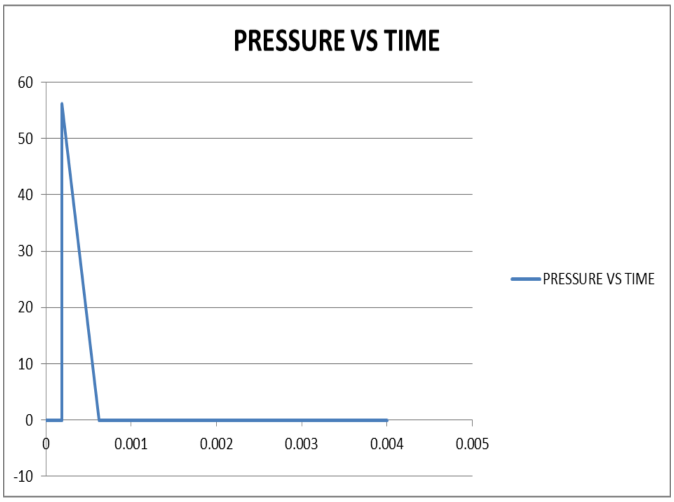

Chart -1: Pressure vs. Time for 6Kg of TNT equivalent for 0.75m Standoff Distance

6. RESULTS

6.1 COLUMN-BEAM JOINT WITHOUT SFRC RESULTS

6.1.1 TOTAL DEFORMATION

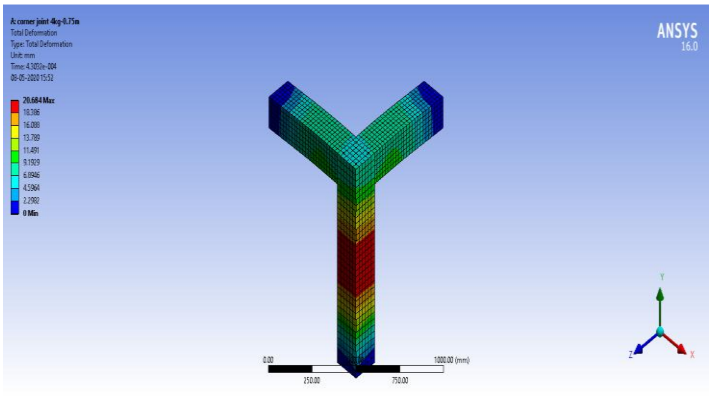

Fig -10: Total Deformation in Corner Beam-Column Joint

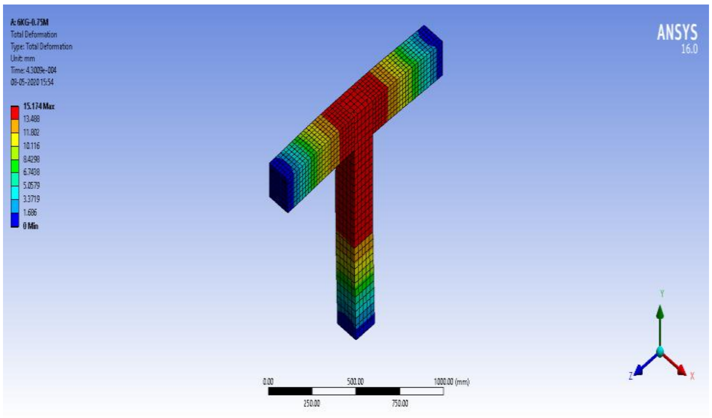

Fig -11: Total Deformation in Exterior Beam-Column Joint

6.1.2 EQUIVALENT STRESS

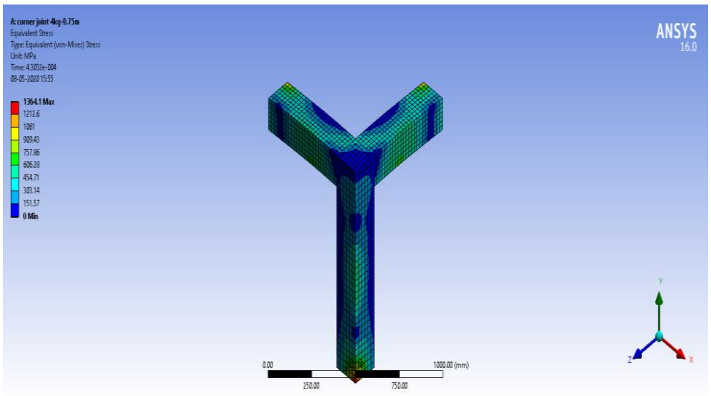

Fig -12: Equivalent Stress in Corner Beam-Column Joint

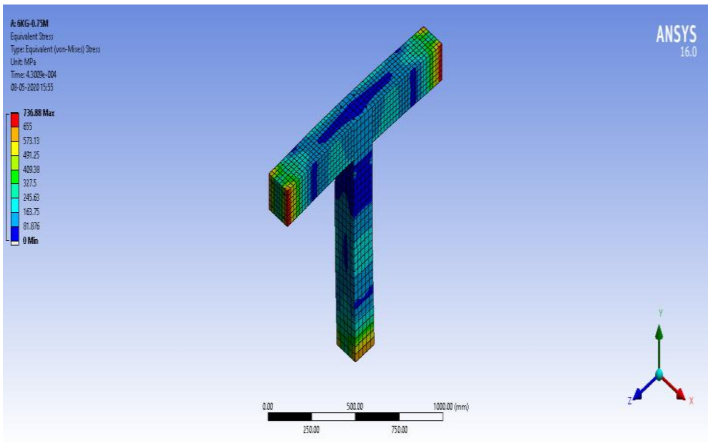

Fig -13: Equivalent Stress in Exterior Beam-Column Joint

6.1.3 EQUIVALENT ELASTIC STRAIN

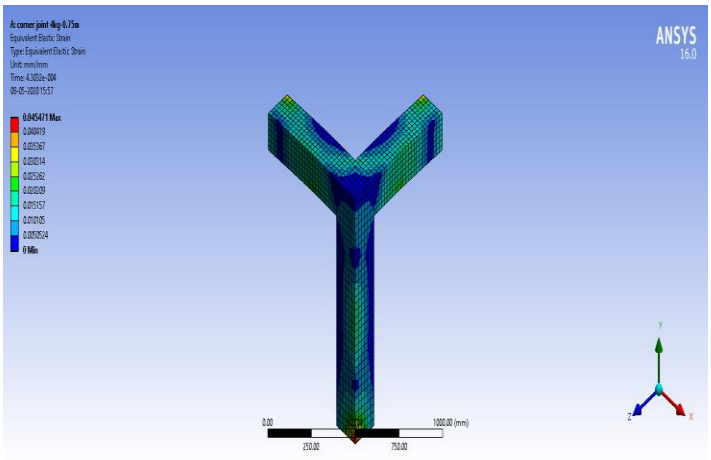

Fig -14: Equivalent Elastic Strain in Corner Beam-Column Joint

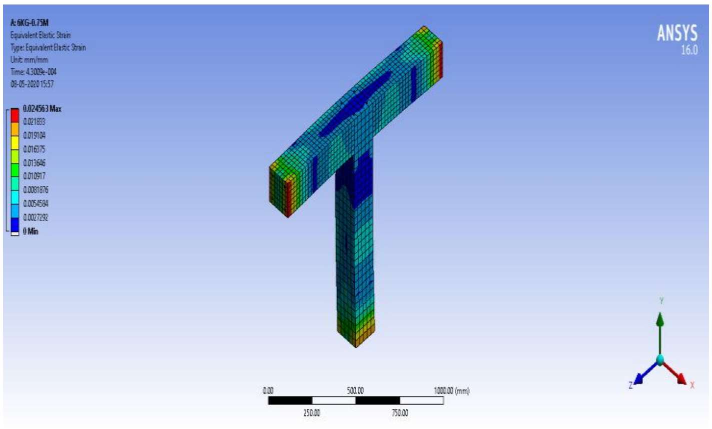

Fig -15: Equivalent Elastic Strain in Exterior Beam-Column Joint

6.2 COLUMN-BEAM JOINT WITH SFRC RESULTS

6.2.1 TOTAL DEFORMATION

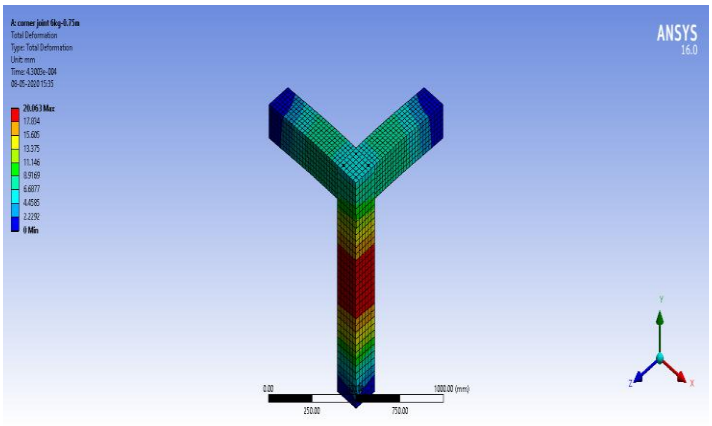

Fig -16: Total Deformation in Corner Beam-Column Joint

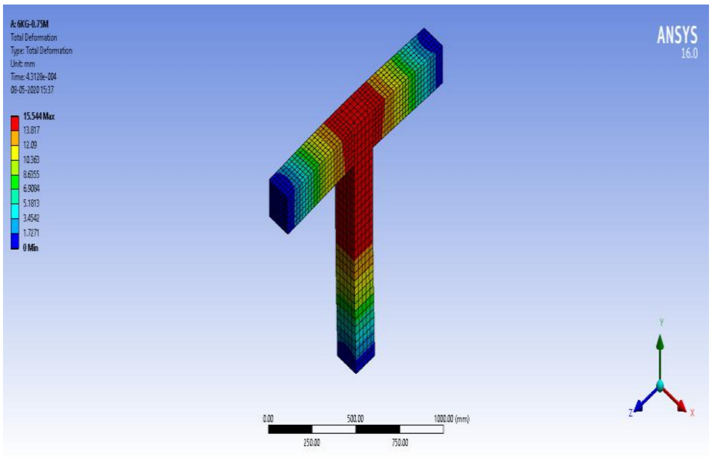

Fig -17: Total Deformation in Exterior Beam-Column Joint

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6.2.2 EQUIVALENT STRESS

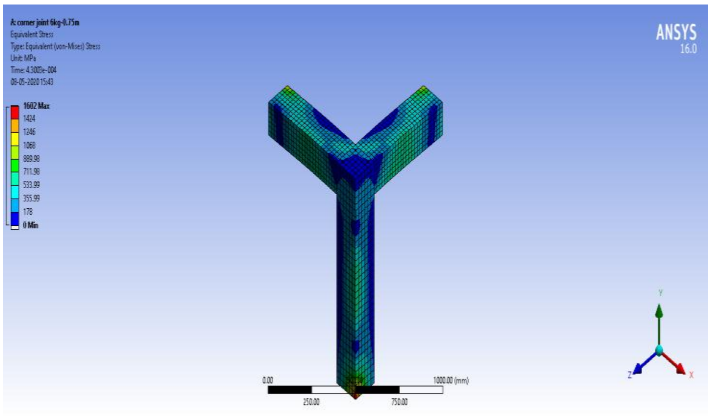

Fig -18: Equivalent Stress in Corner Beam-Column Joint

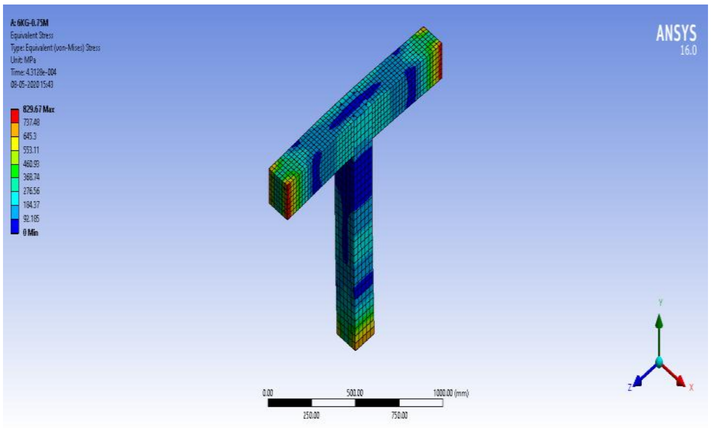

Fig -19: Equivalent Stress in Exterior Beam-Column Joint

6.2.3 EQUIVALENT ELASTIC STRAIN

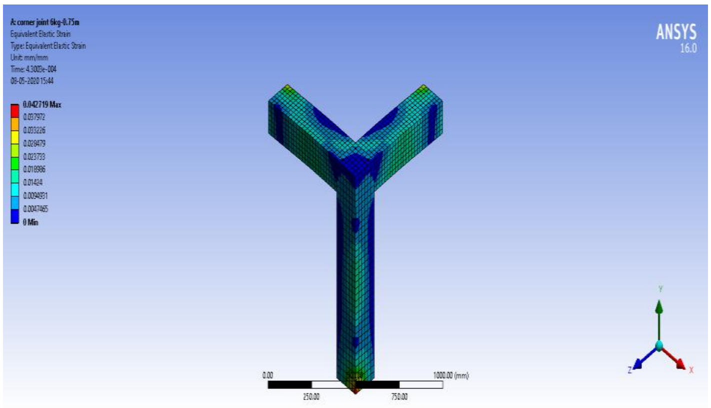

Fig -20: Equivalent Elastic Strain in Corner Beam-Column Joint

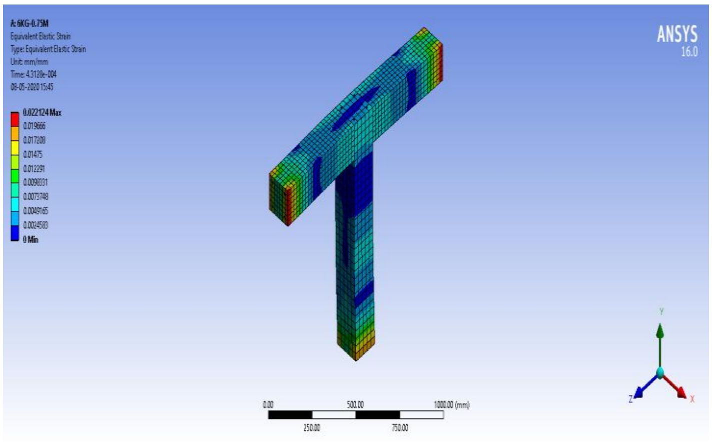

Fig -21: Equivalent Elastic Strain in Exterior Beam-Column Joint

6.3 CORNER BEAM-COLUMN JOINT WITH & WITHOUT SFRC RESULTS

Table -4: Corner joint without SFRC

Results	Corner joint without SFRC		
Standoff Distance (m)	0.5	0.75	1
Scaled distance (m)	0.27	0.41	0.55
Refracted pressure (MPa)	111.845	56.155	32.773
Total diformation (mm)	37.847	20.684	20.321
Equivalent stress (MPa)	2566.9	1364.1	1225.9
Equvalent strain	0.078853	0.042719	0.03267

Table -5: Corner joint with SFRC

Results	Corner joint with SFRC		
Standoff Distance (m)	0.5	0.75	1
Scaled distance (m)	0.27	0.41	0.55

Refracted pressure (MPa)	111.845	56.155	32.773
Total diformation (mm)	36.863	20.063	19.191
Equivalent stress (MPa)	2957	1609	1410.8
Equvalent strain	0.085563	0.045471	0.040864

6.4 EXTERIOR BEAM-COLUMN JOINT WITH & WITHOUT SFRC RESULTS

Table -6: Exterior joint without SFRC

Results	Exterior joint without SFRC		
Standoff Distance (m)	0.5	0.75	1
Scaled distance (m)	0.27	0.41	0.55
Refracted pressure (MPa)	111.845	56.155	32.773
Total diformation (mm)	30.209	17.174	18.577
Equivalent stress (MPa)	1393.7	736.88	576.7
Equvalent strain	0.042713	0.022124	0.017197

Table -7: Exterior joint with SFRC

Results	Exterior joint with SFRC		
Standoff Distance (m)	0.5	0.75	1
Scaled distance (m)	0.27	0.41	0.55
Refracted pressure (MPa)	111.845	56.155	32.773
Total diformation (mm)	28.085	15.544	16.982
Equivalent stress (MPa)	1601.7	829.67	644.84
Equvalent strain	0.046454	0.024563	0.019223

6.5 TOTAL DEFORMATION RESULT

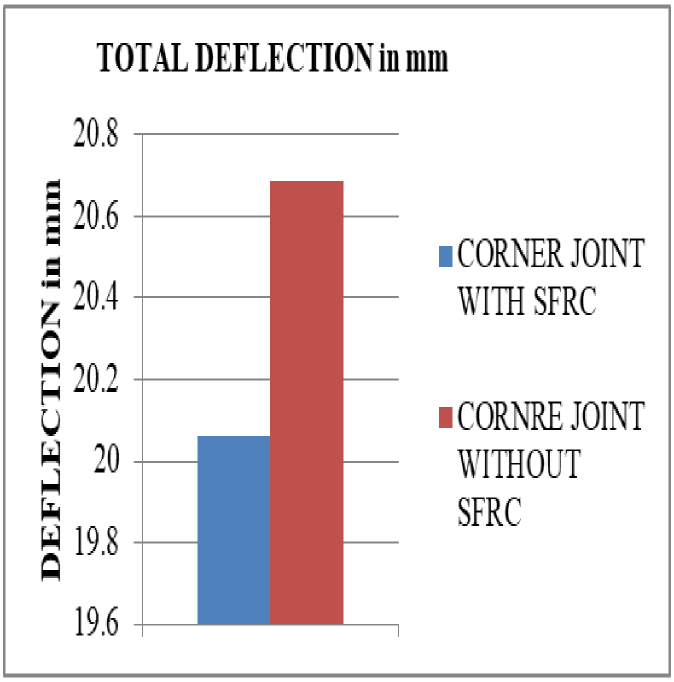

Chart -2: Corner Beam-Column Joint

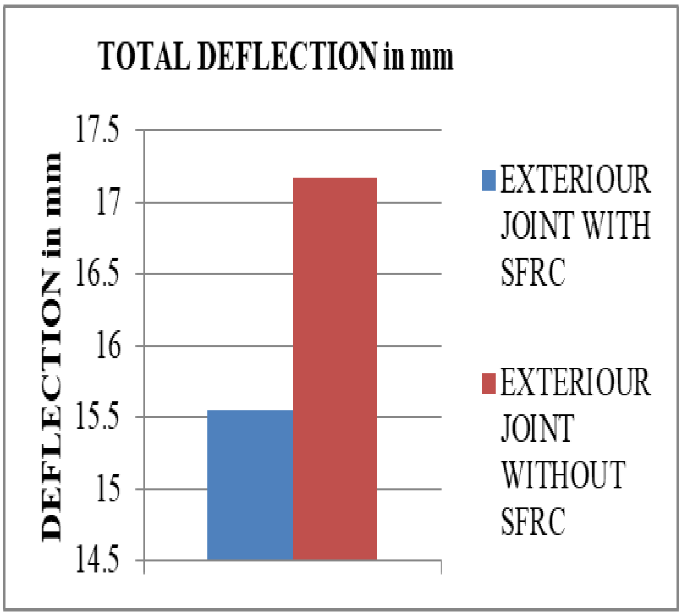

Chart -3: Exterior Beam-Column Joint

6.6 TOTAL EQUIVALENT STRESS RESULT

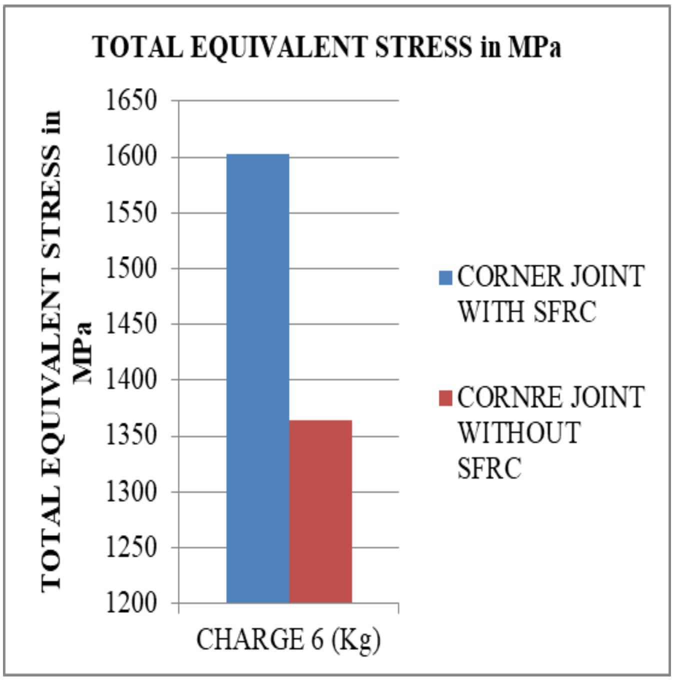

Chart -4: Corner Beam-Column Joint

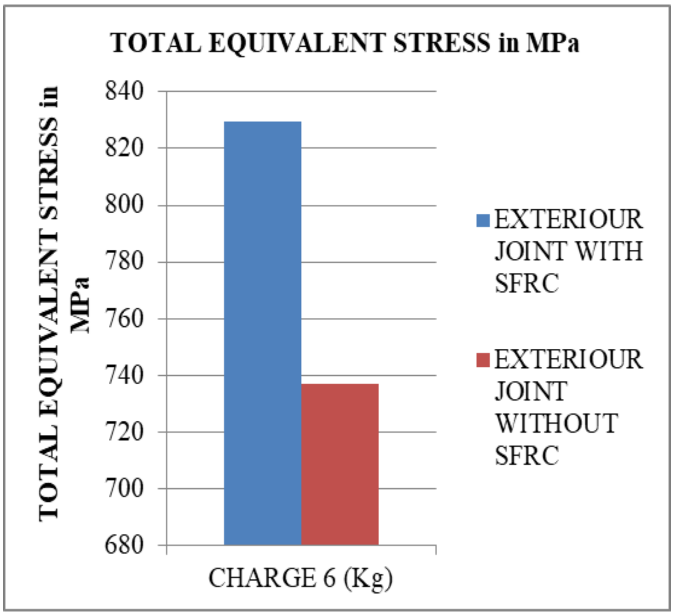

Chart -5: Exterior Beam-Column Joint

6.7 TOTAL EQUIVALENT STRAIN RESULT

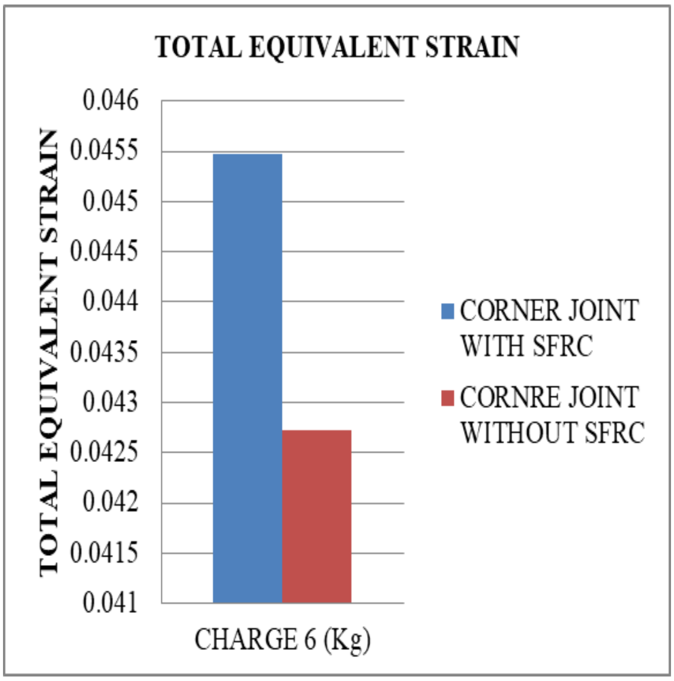

Chart -6: Corner Beam-Column Joint

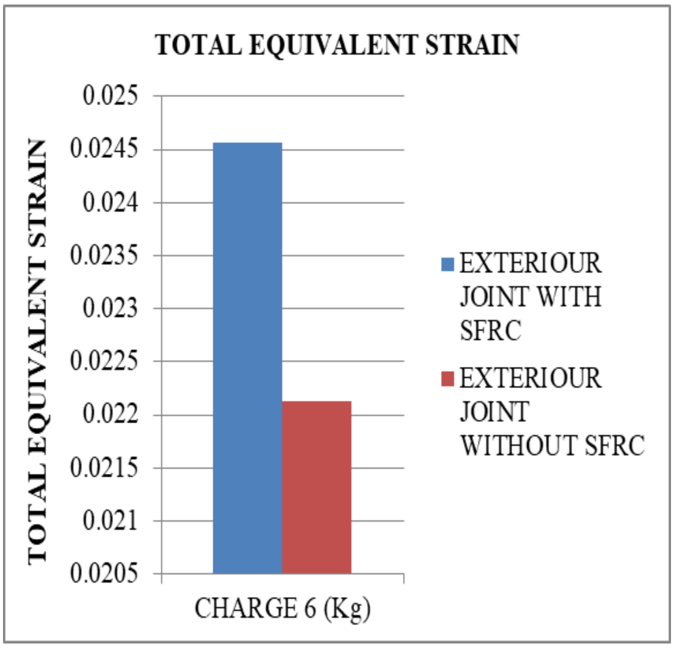

Chart -7: Exterior Beam-Column Joint

7. CONCLUSIONS

In this paper performance of corner and exterior beam-column joints with conventional reinforcement concrete and steel fiber reinforced concrete were examined analytically using ANSYS 16 modeling and compare the results.

1. It is observed that total deformation for steel fiber reinforced concrete column-beam joint is 4% less than deformation in column-beam joint without steel fibers.

2. Maximum Equivalent stresses developed in steel fiber reinforced column-beam joints are 10% more than stresses developed in column-beam joint without Steel Fibers.

3. Normal Elastic Strain developed in in steel fiber reinforced concrete is 4% more than Normal Elastic Strain developed in column-beam joint.

4. From above results and discussion it is conclude that result of adding SF in corner joint shows good results than exterior joints.

5. Hence it can conclude that, Beam-Column Joint having SF are more elastic than Beam-Column Joint without SF.

6. The beam-column joint at exterior and corner joints with SFRC shows more strength than without SFRC.

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