

ANALYSIS OF RC-ECC BEAM COLUMN JOINT SUBJECTED TO CYCLIC LOADING

SPANDANA .B

Assistant Professor, Department of Civil Engineering, SJB Institute of Technology, Bengaluru, Visvesvaraya Technological University, Belagavi.

Dr.T.M.PRAKASH

Professor, Department of Civil Engineering, P.E.S. College of Engineering, Mandya, Visvesvaraya Technological University, Belagavi.

Abstract

The impact of Engineered Cementitious Composite (ECC) on the performance of RC beam column joints under cyclic load has been examined in the current study. Using the programme Ansys 18.1 to model T-shape and plus (+) shape beam column joints, analysis was performed both with and without PVA (polyvinyl alcohol) fibres. PVA fibres were added at the junction of the beam column with percentage increases of 0%, 0.375%, 1.75%, 1.125%, and 1.5%. With these different PVA fibre addition percentages, the behaviour of the beam column was observed. The load deflection relationship, load bearing capability, stress-strain curves, and SN curve are among the primary factors taken into account. The analytical findings demonstrated a significant improvement in load carrying capacity and a decrease in deformation as the percentage of PVA was increased. The beam column joints with PVA fibres demonstrated incremental load resistance when compared to beam column joints without PVA, and an increase in stress was noted with the application of PVA in beam column joints. The analytical findings indicate that replacing PVA fibres in beam column joints by up to 1.5% can significantly improve structural behaviour.

Keywords: ECC, PVA Fibre, Beam-Column Joint, Ansys Software.

1. INTRODUCTION

Reinforced concrete (RC) buildings are the most often built types nowadays. Every day, new techniques are proposed to enhance the functionality of RC structures and get rid of their defects. One of the key issues that still confronts these buildings is the inherent brittleness of concrete. Connections are the most vulnerable and most susceptible portions of concrete buildings against seismic loads, according to prior earthquake experience.

Due to the concrete's brittleness in tension and shear under seismic pressures, the connecting core experiences a brittle shear failure, which causes building structures to lose their lateral stability. Engineered Cementitious Composites, or ECC for short, exhibit pseudostrain hardening behaviour with a variety of tensile strain and are categorised as one of the fibre reinforced cementitious composites. Steel reinforced cementitious composites, such as ECC, can be used as structural components. Several scientific institutions have experimented with members.

Because they are used as energy-absorbing components for structural control, improved materials for flexural members, and other factors, the majority of those specimens are of the flexural yielding type. For the purpose of designing structural performance, shear

behaviour must be understood just as flexural behaviour is. Furthermore, it is crucial that the tensile behaviour of ECC be accurately assessed and that structural performance of ECC components may be foreseen and developed from the assessment of tensile behaviour.



Fig 1: Polyvinyl alcohol fibre (PVA)

It was discovered that polyvinyl alcohol can be used as a modifier, aggregate surface pre-treatment agent, and fibre reinforcement in cement-based composite materials, which is one of the important uses of PVA. PVA fibres are monofilament fibres that propagate all through the concrete matrix, producing a multi-directional fibre network, offering shrinkage supervision, resistance to abrasion, and shielding from thermal expansion and contraction. It was discovered that polyvinyl alcohol can be used as a modifier, aggregate surface pre-treatment agent, and fibre reinforcement in cement-based composite materials, which is one of the important uses of PVA. PVA fibres are monofilament fibres that propagate all through the concrete matrix, producing a multi-directional fibre network, offering shrinkage supervision, resistance to abrasion, and shielding from thermal expansion and contraction. PVA used as a fibre reinforcer PVA fibre, which has higher strength and elastic modulus than other fibre types (such as polypropylene fibre, nylon fibre, polyethylene fibre, and others) that are typically used for cement reinforcement, has the qualities that make it an effective reinforcement for cement-based composite structures. PVA fibre has several benefits over other fibres, including improved bonding capabilities with cementitious materials, a strong tensile strength, high elastic modulus, good dispersibility, great hydrophilicity, and nontoxicity.

2. ANALYTICAL STUDY

Properties of PVA fibres are:

- Density is 1.3 g/cm³.
- Diameter: 0.039 mm

- length: 6, 8, and 12 millimetres
- Materials with specific gravities between 1.2 and 1.3 (1200–1300 kg/m³)
- The modulus of elasticity is greater than that of natural fibre, ranging from 25 to 40 Gpa.
- PVA fibre elongation ranges from 6 to 10%.

PVA fibre has a tensile strength range of 880 to 1600 Mpa

The process employed by the Ansys programme is depicted in the flow chart, which starts with the modelling of beam-column joints, characteristics specification and assignment, connections meshing, loads and support conditions, and analysis is then carried out to generate the required results. The T-shape beam-column junction is shown in Fig. 4.1 Auto cad 2D plan. The beam-column measures 400 mm by 400 mm. Four 16 mm dia bars are used for major reinforcement, and stirrups with two 8 mm dia legs are positioned 300 mm apart. ANSYS 18.1 software is used to model and analyse the beam column joints with appropriate loads and boundary conditions. There are 2 options for creating the geometry of the model, the first one is by creating geometry in ANSYS design modeler and the second one by importing from other design software in particular format like igs, step, etc. In this present study beam column joints were simulated using ANSYS design modeler and later analysis has been carried out. Meshing one among the most important steps in performing an accurate simulation using FEA. The ability of Ansys to mesh helps to cut down on the time and effort required to btain precise results. Ansys contributes by creating more effective and automated meshing tools since meshing often takes up a large percentage of the time needed to obtain simulation results.

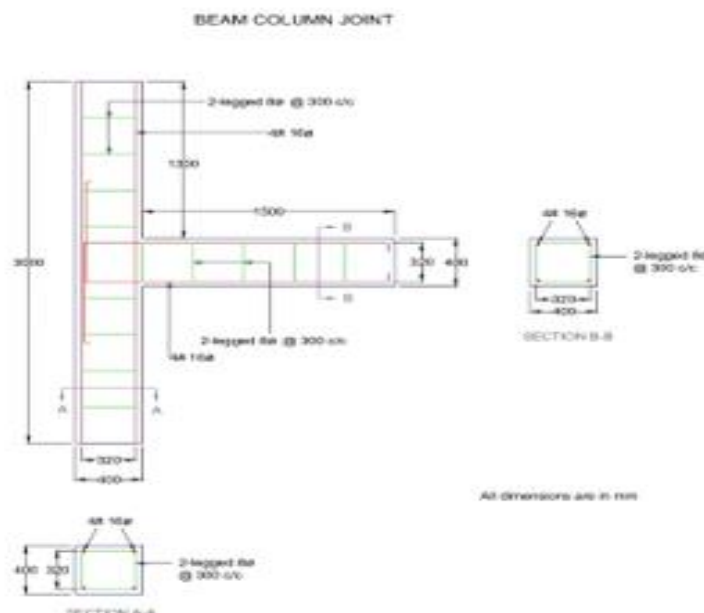


Fig 2: AUTOCAD 2D plan of T shape beam column joint

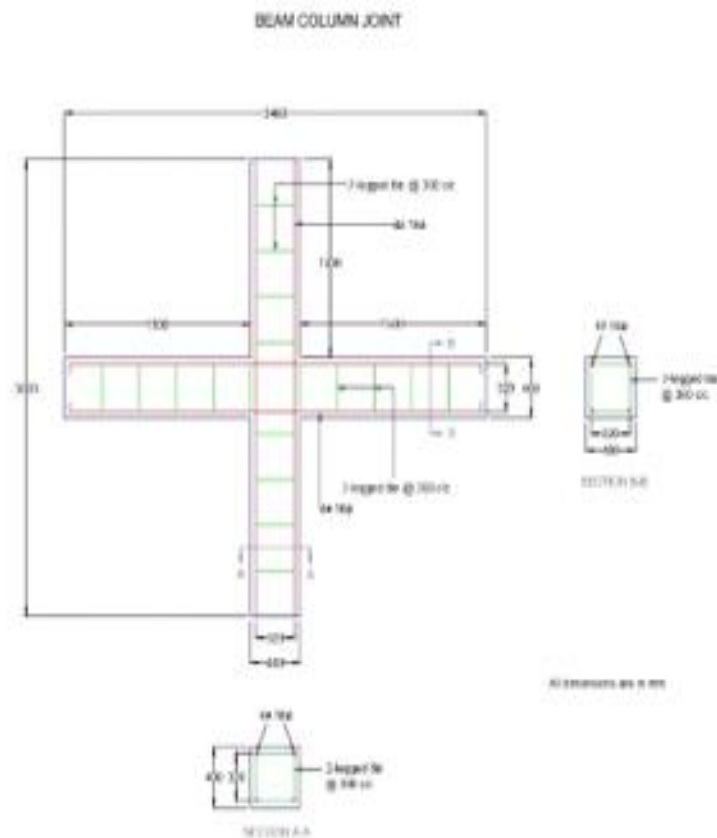


Fig 3: AUTOCAD 2D plan of Plus (+) shape beam column joint

The crucial processes in performing an effective simulation using FEA is meshing. A mesh is composed of components that have nodes in them that represent the geometry's form.

Uneven forms are difficult for a FEA solver to deal with, but typical shapes like cubes make it much happy. The action of meshing is the transformation of amorphous forms into more recognisable volumes, or “elements.”

There two primary categories of meshing in ANSYS workbench:

- Tetrahedral element meshing (tet)
- Hexahedral element meshing (hex)

In comparison to tetrahedral elements, hexahedral elements frequently yield more accurate outcomes at lower element counts. Tetrahedral components could be the best option if the geometry is complicated.

These automated or default meshing techniques could be sufficient to get the outcomes we need. There are other approaches, though, that might give you greater mesh control.

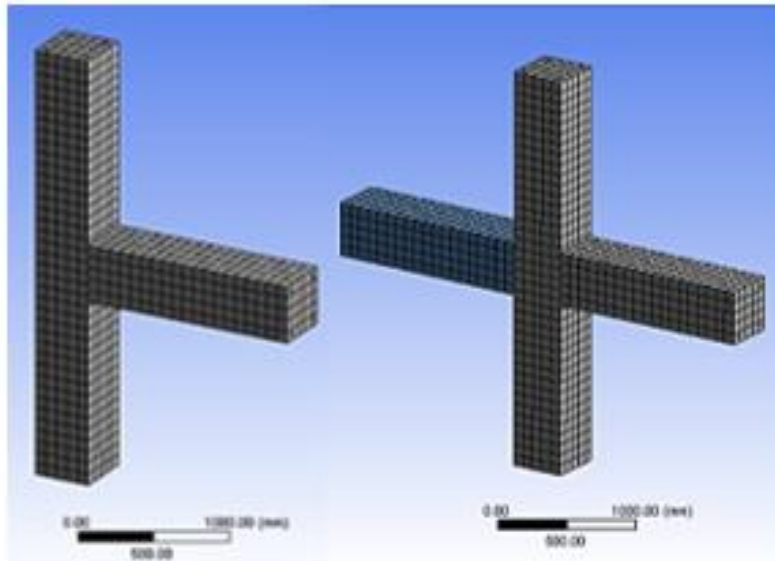


Fig 4: Hexahedral meshing of T shape and plus (+) shape beam column joint

The boundary condition for the beam column joints were taken as fixed supports at the two ends of the column, and far end of the beam kept as free. In the static analysis the loads are applied on the free end of the beam and in dynamic analysis cyclic load has been applied. The provision for use of PVA fibres in concrete mix ranges from 0.1% to 1.5%, the increase in percentage of PVA fibre used for different shapes and specimens are 0%, 0.375%, 0.75%, 1.125% and 1.5%.

Table 1: Alternating stress values details

SL NO.	CYCLES	ALTERNATING STRESS (MPa)
1	10	3999
2	20	2827
3	50	1896
4	100	1413
5	200	1069
6	2000	441
7	10000	262
8	20000	214
9	1E+05	138
10	2E+05	114
11	1E+06	86.2

3. VALIDATION

The below Fig shows the auto cad 2d plan of beam column joint which is used in the experimental work in journal. Validation has been made to verify the beam column joint

analytical results extracted from the Ansys 18.1 software with the experimental results of beam column joints of selected journal paper.

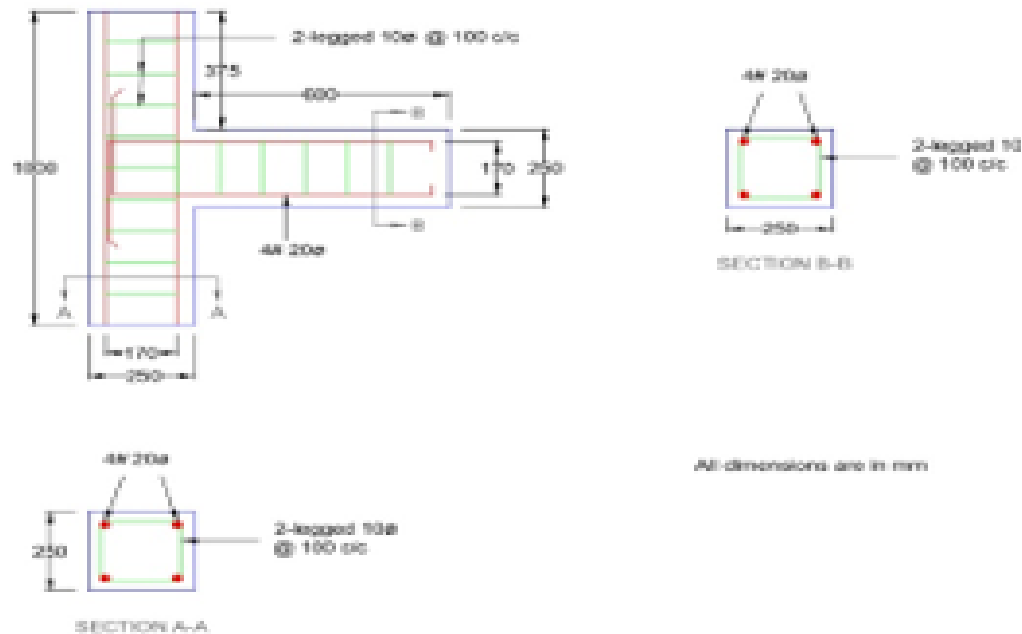


Fig 5: AUTOCAD 2D plan of T shape beam column joint

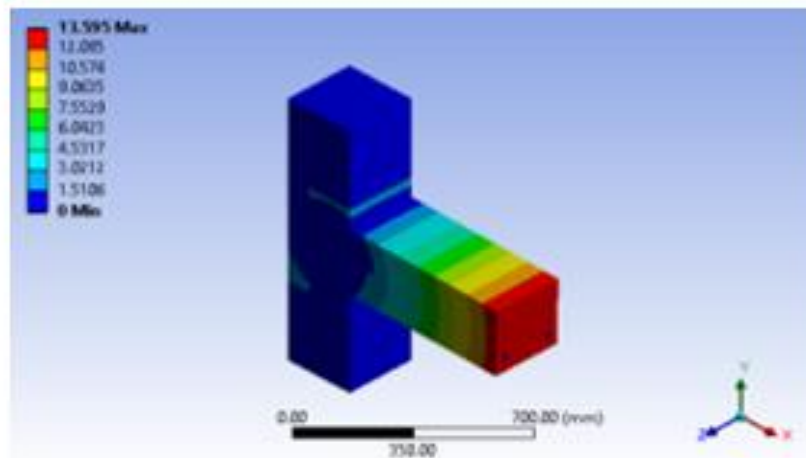


Fig 6: Deformation of T-beam

SI No.	PVA %	Experimental results		Analytical results	
		Load (kN)	Displacement (mm)	Load (kN)	Displacement (mm)
1	2%	30	15.08	30.125	13.595

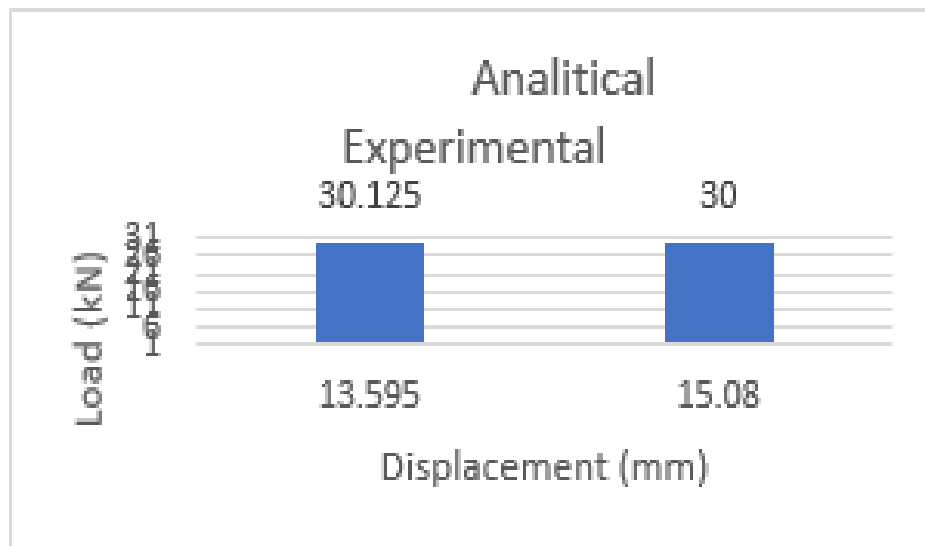


Fig 7: Comparison graph of experimental and analytical results

In the experimental findings, the breaking point of the specimen was at 30 kN for 15.08 mm of displacement for replacement of 2% PVA fibres in the concrete joints. Table 6.2 above illustrates the experimental and analytical results of maximum load and maximum displacement of beam column joint. Using Ansys 18.1 software, analysis was performed for identical dimensions and material properties, and the breaking point was found to be at 30.125 kN, which is nearly identical to the experimental load, and 13.595 mm of displacement was observed at 2% replacement of PVA fibre. Fig 7 shows a comparison graph of the experimental and analytical results of load vs. displacement. The difference between experimental and analytical work can be observed to be within 10%.

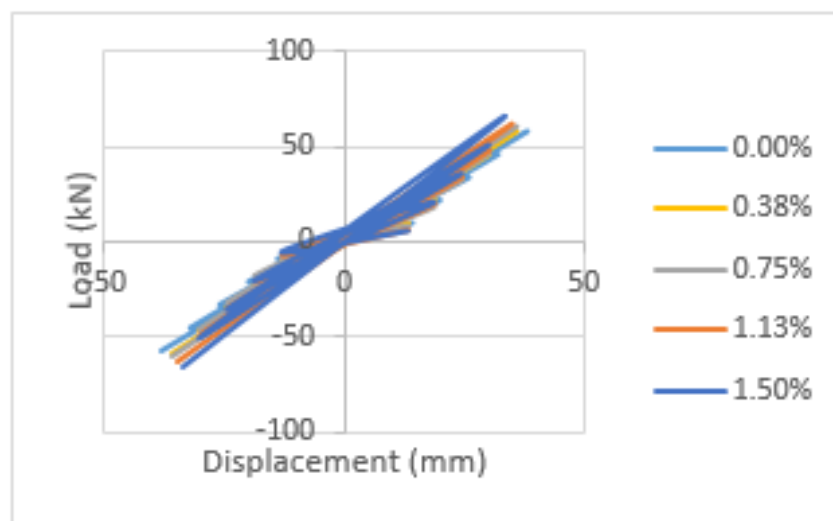


Fig 8: Stress diagram

4. RESULTS AND DISCUSSION

a. T- Shape Beam Column Joints

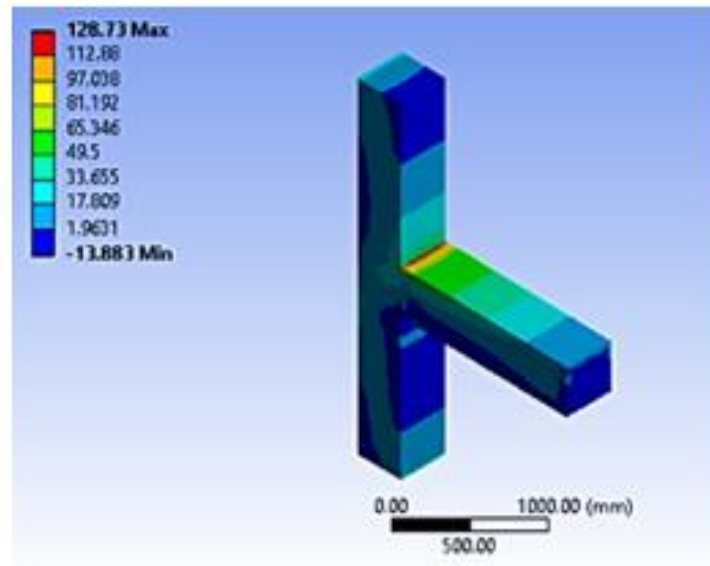


Fig 9: Deformation of T-beam

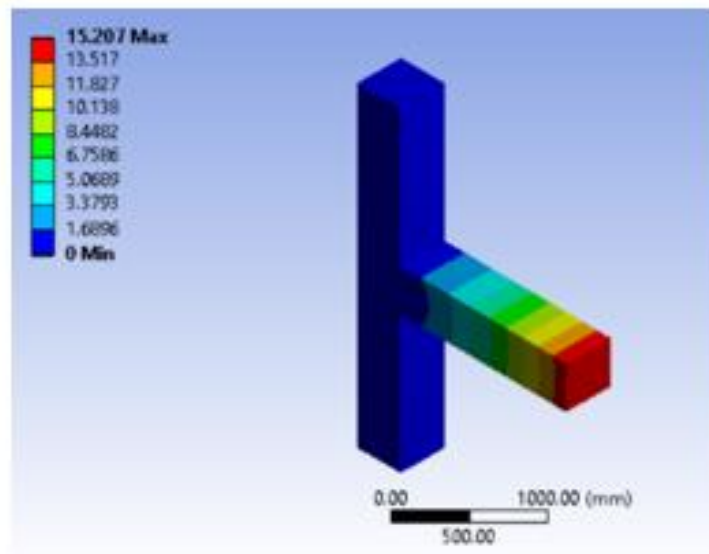


Fig 10: Comparison of load vs displacement

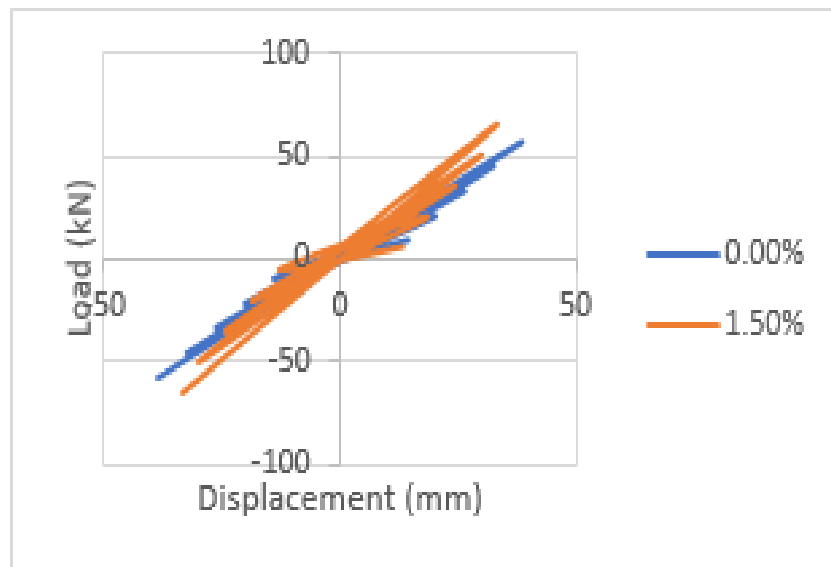


Fig 11: Comparison of max and min Load vs Displacement

The comparison of maximum and minimum loads versus displacement of T shape beam-column joint is shown in the Fig 11. For the 0% PVA specimen, the breaking load was discovered to be 57.32 kN for a displacement of 38.359 mm, and the specimen with 1.5% PVA fibre is the specimen with excellent results when compared to other percentages of PVA fibre and obtained 65.48 kN load at 33.60 mm displacement. These analytical findings lead to the conclusion that specimens with PVA fibres perform better than specimens without PVA fibres.

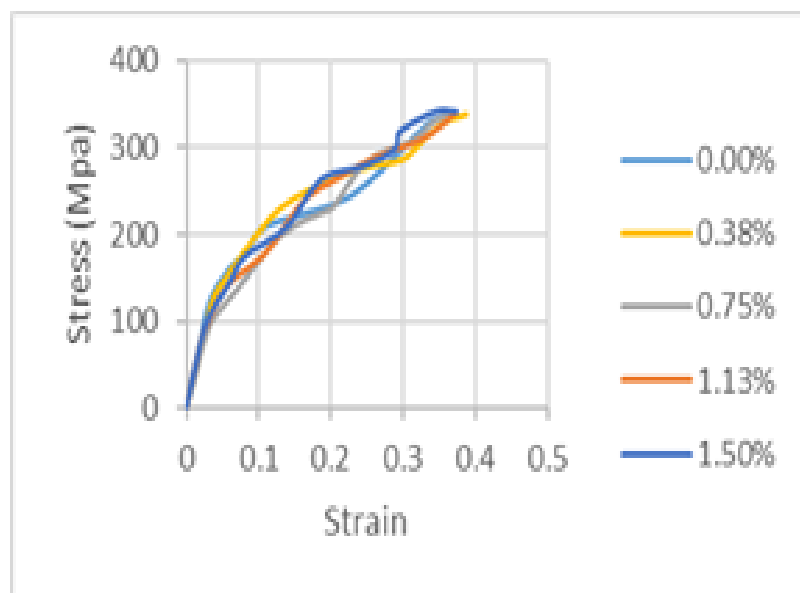


Fig 12: Comparison of Stress vs strain

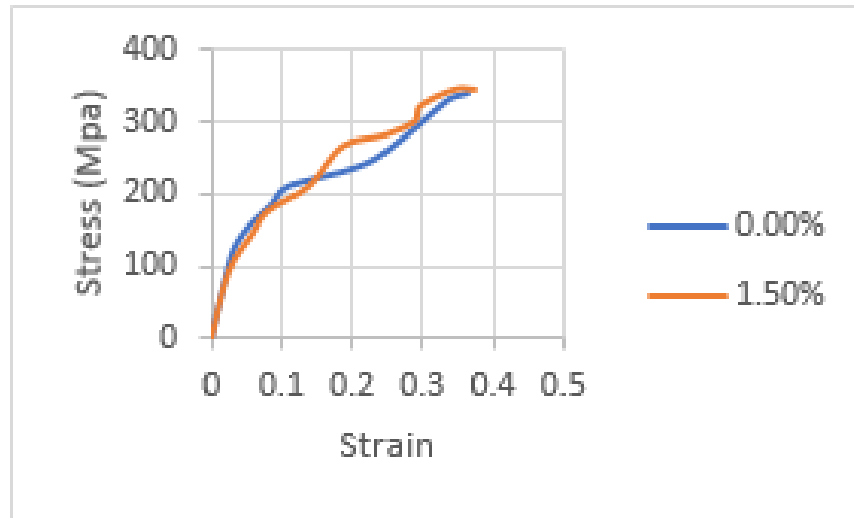


Fig 13: Comparison of max and min Stress vs strain

The comparison of the maximum and minimum stress vs strain of T-shaped beam-column joints with and without PVA fibres is shown in Fig. 13 above. In the specimens without PVA fibre, 338.79 Mpa stress was recorded at 0.3639 strain, whereas specimens with 1.5% PVA fibre content showed a higher response to stress vs strain, with 343.07 Mpa stress recorded at 0.3748 strain. These analytical results allow us to draw the conclusion that specimens containing PVA fibre with a 1.50% PVA concentration responded more favourably to stress-strain relationships.

b. Plus (+) Shape Beam-Column Joints

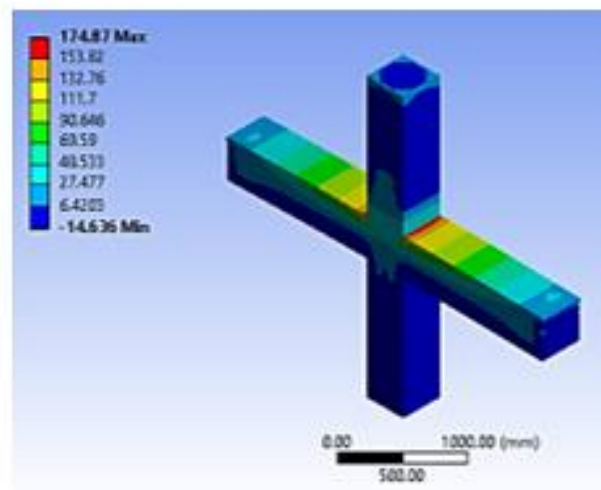


Fig 14: Stress diagram

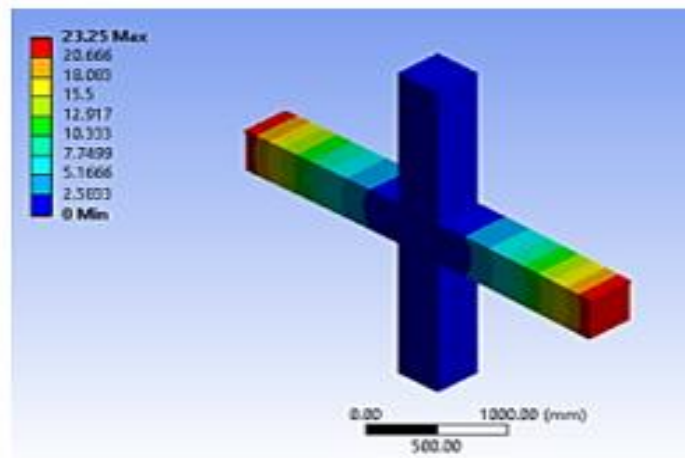


Fig 15: Deformation of plus (+) beam column

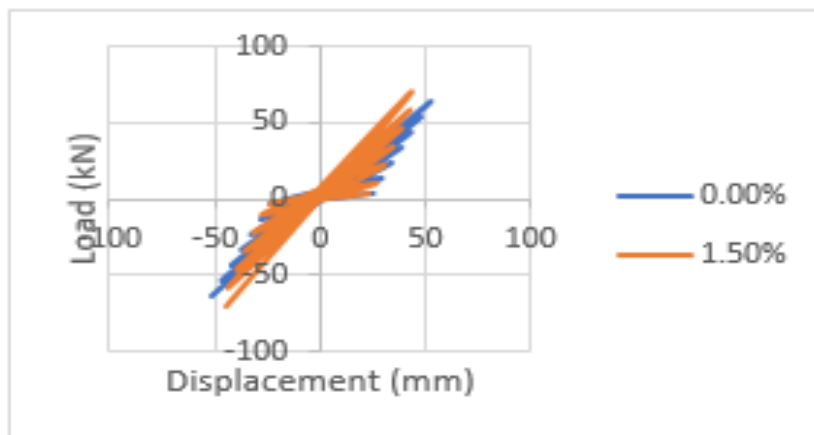


Fig 16: Comparison of Load vs Displacement

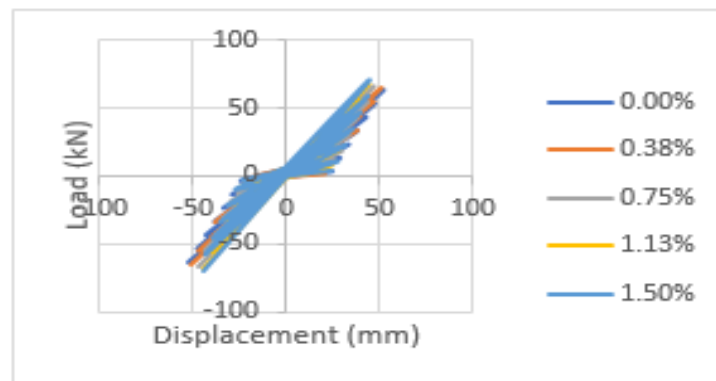


Fig 17: Comparison of max and min Load vs Displacement

The comparison of maximum and minimum loads versus displacement of Plus (+) shape beam-column joint is shown in the Fig 17. For the 0% PVA specimen, the breaking load was discovered to be 63.42 kN for a displacement of 52.15 mm, and the specimen with 1.5% PVA fibre is the specimen with excellent results when compared to other percentages of PVA fibre and obtained 70.32 kN load at 43.996 mm displacement. These analytical findings lead to the conclusion that specimens with PVA fibres perform better than specimens without PVA fibres.

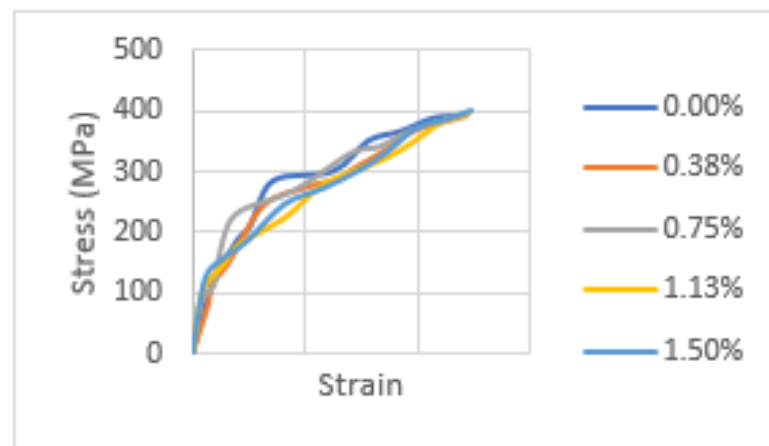


Fig 18: Comparison of Stress vs strain

The comparison of the maximum and minimum stress vs strain of T-shaped beam-column joints with and without PVA fibres is shown in Fig. 19. In the specimens without PVA fibre, 390.32 Mpa stress was recorded at 0.509 strain, whereas specimens with 1.5% PVA fibre content showed a higher response to stress vs strain, with 402.56 Mpa stress recorded at 0.4953 strain. These analytical results allow us to draw the conclusion that specimens containing PVA fibre with a 1.50% PVA concentration responded more favourably to stress-strain relationships.

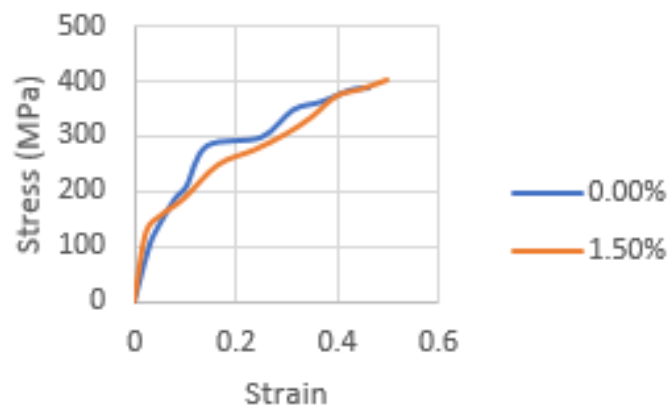


Fig 19: Comparison of max and min Stress vs strain

5. CONCLUSION

The conclusions that may be derived from the findings are as follows.

- As the percentage of PVA fibre increased in beam column junction, the load carrying capacity increased up to 1.5% of fibre replacement.
- The section under goes a decrease in deformation as the fraction of PVA fibre in the beam column junction increases.
- Increase in stress was observed as the percentage of PVA fibre increased in beam column junction.
- Analytical results show that specimens of T-shape and plus (+) shape beam-columns with PVA fibres in the junctions perform better than specimens without PVA fibre in the junction.

References

- 1) Pranali Wasnik, Prof. Sanket Sanghai, Dr. P.Y. Pawade (2021) "Cyclic load Analysis of beam column joint using ANSYS", International Conference on Advances in Civil Engineering (ICACE 2021), IOP Publishing, 1197 (2021) 012056. 10.1088/1757-899X/1197/1/012056
- 2) S. Gunaselvi, M. Indumathy, S. Sivasankar (2020) "Experimental assessment of RC beam-column connections with internal and external strengthening techniques", ScienceDirect, Elsevier Ltd., Volume 27, Part 2, 2020, Pages 1210-1217. <https://doi.org/10.1016/j.matpr.2020.02.114>
- 3) Mohamed Said, T.S. Mustafa, Ali S. Shanour, Mostafa M. Khalil (2020) "Experimental and analytical investigation of highperformance concrete beams reinforced with hybrid bars and polyvinyl alcohol fibres", ScienceDirect, Elsevier Ltd., Construction and Building Materials 259 (2020) 120395. <https://doi.org/10.1016/j.conbuildmat.2020.120395>
- 4) Ayoub Dehghani, Ali Reza Mozafari, Farhad Aslani (2020) "Evaluation of the efficacy of using engineered cementitious composites in RC beam-column joints", ScienceDirect, Elsevier Ltd., Structures 27 (2020) 151–162. <https://doi.org/10.1016/j.istruc.2020.05.045>
- 5) Ahmed A. Abouhussien, Assem A.A. Hassan, Mohamed K. Ismail, Basem H. AbdelAleem (2019) "Evaluating the cracking behavior of ECC beam-column connections under cyclic loading by acoustic emission analysis", ScienceDirect, Elsevier Ltd., Construction and Building Materials 215 (2019) 958–968. <https://doi.org/10.1016/j.conbuildmat.2019.04.213>
- 6) Ali S. Shanour, Mohamed Said, Alaa Ibrahim Arafa, Amira Maher (2018) "Flexural performance of concrete beams containing engineered cementitious composites", ScienceDirect, Elsevier Ltd., Construction and Building Materials 180 (2018) 23–34. <https://doi.org/10.1016/j.conbuildmat.2018.05.238>
- 7) Lavanya P, Saranya M, Leema Rose A (2018) "Study on Exterior Beam Column Joint with Basalt Fibre Under Cyclic Loading", International Advanced Research Journal in Science, Engineering and Technology ISO 3297:2007 Certified Vol. 5, Issue 5, May. 2018. 10.17148/IARJSET.2018.5516
- 8) Mohamed K. Ismail, Basem H. Abdelaleem, Assem A.A. Hassan (2018) "Effect of fiber type on the behavior of cementitious composite beam-column joints under reversed cyclic loading" ScienceDirect, Elsevier Ltd., Construction and Building Materials 186 (2018) 969–977. <https://doi.org/10.1016/j.conbuildmat.2018.08.024>

- 9) T. Subramani, S.Poongothai, S.Priyanka (2017) "Analytical Study Of T Beam Column Joint Using FEM Software", International Journal of Emerging Trends & Technology in Computer Science (IJETTCS) Volume 6, Issue 3, May- June 2017.
- 10) B. Venkatesan, R. Ilangoan, P. Jayabalan, N. Mahendran, N. Sakthieswaran (2016) "Finite Element Analysis (FEA) for the Beam-Column Joint Subjected to Cyclic Loading Was Performed Using ANSYS", Science research publishing, Received 13 April 2016, accepted 10 May 2016, published 15 June 2016. <http://dx.doi.org/10.4236/cs.2016.78138>
- 11) Minakshi Vaghani, Dr. S.A. Vasanwala, Dr. A.K. Desai (2015) "Performance of RC Beam Column Connections Subjected to Cyclic Loading", IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE), Volume 12, Issue 2 Ver. VII (Mar - Apr. 2015). 10.9790/1684-12274853
- 12) Katsuyuki SHIMIZU, Toshiyuki KANAKUBO, Tetsushi KANDA, Satoru NAGAI (2004) "Shear behavior of steel reinforced PVA-ECC beams", 13th World Conference on Earthquake Engineering Vancouver, B.C., Canada August 1-6, 2004, Paper No. 704