I. J. Engineering and Manufacturing, **2023, 5, 38-47**
Published Online on October 8, 2023 by MECS Press (http://www.mecs-press.org/)
DOI: 10.5815/ijem.2023.05.05

Study of PET Fiber Concrete in Beam-Column Joint under Cyclic Loading Using Finite Element Analysis

Nirav M. Patel*
Department of Civil Engineering, Parul Institute of Engineering and Technology, Parul University, Vadodara, Gujarat, 391760, India
E-mail: nirav.patel20968@paruluniversity.ac.in
ORCID ID: https://0000-0002-1789-4886
*Corresponding Author

M. N. Patel
Department of Civil Engineering, Parul Institute of Engineering and Technology, Parul University, Vadodara, Gujarat, 391760, India
E-mail: nmp1290@gmail.com
ORCID ID: https://0000-0001-5676-8287

Tapsi D. Sata
Department of Civil Engineering, Parul Institute of Engineering and Technology, Parul University, Vadodara, Gujarat, 391760, India
E-mail: tdsata1999@gmail.com
ORCID ID: https://0000-0003-4120-722X

Received: 20 June, 2023; Revised: 01 August, 2023; Accepted: 03 September, 2023; Published: 08 October, 2023

Abstract: The failure behavior of beam-to-column connections can be minimized or avoided to some extent by using PET waste fibers. With the change of composition, different seismic performances of concrete joints can be adjusted. FEM analysis was performed in ABAQUS software to compare the performance of concrete beam-to-column connections reinforced with conventional concrete fibers and waste PET under cyclic loading. The concrete mix is designed to achieve a concrete grade of M25. Seven figures of the external beam-to-column connections were modeled as a quarter of the architectural prototype. The first joint is conventional concrete and designed according to IS 1893 (Part 1):2022 and the reinforcement in the joint part are specified according to the ductility requirements of IS 13920:2016. Six other samples were designed to contain different PET waste fibers (0.25% to 1.50%) in the seam area. Beam-to-column connections have 0.75% to 1.25% PET fiber inclusions that have better performance in terms of strength, load-carrying capacity, energy dissipation capacity, joint shear strength, and ductility in the joint area. Incorporating PET waste fibers into concrete can provide the best solution for waste management, and also has the potential to reduce the cost of reinforced concrete by 15%-20% holds economic significance, and concrete with PET waste fibers indeed demonstrates better seismic performance, and could lead to increased safety and longevity of structures in seismic-prone areas. This suggests that experimental work or studies might have explored how these fibers affect the concrete's properties, strength, durability, and other characteristics.

Index Terms: Strength performance, PET waste fiber, Failure behavior, Exterior beam-column, Waste management.

1. Introduction

The long-term performance of structures is essential for the economies of all countries. Since the beginning of ancient communities, concrete has been the most important material for providing reliable and stable infrastructure. So much research has been done in the 20th century [1]. As a result, new materials and compositions have been developed and cement types improved. Today, concrete structures with a compressive strength greater than 140 MPa are built all over the world [2].

In research laboratories, concrete has a compressive strength of up to 800 MPa. Damage to reinforced concrete structures is mainly attributed to insufficient reinforcement details and lack of transverse steel and concrete shear forces in the structural members [3]. High-strength concrete is brittle and has insufficient ability to dissipate and absorb inelastic energy. Beam-to-column connections subject to reverse cyclic loading require great attention to detail. The acceptable interpretation of beam-to-column connections, especially under seismic loading, largely depends on the lateral stresses of the connections.

The behavior of beam-to-column connections using various fiber-reinforced concretes under vibration conditions has been an important area of research for many years [4]. This study discusses conventional steel details in beam-to-column connections and the provision of waste plastic fiber-reinforced concrete. This fiber-reinforced concrete at the joints has better compressive, flexural, and tensile strength compared to conventional concrete [5].

Plastic production is one of the fastest production units in the world. Plastic packaging materials are discarded as waste once they have served their purpose. For many years, plastics remained non-biodegradable and posed a significant threat to the environment [6]. Although recycling plastic waste is a possible option to reduce the threat, it requires more energy and a lot of labor. Because recycling plastic waste requires various technologies and a lot of resources.

The use of plastic waste directly in the needs of the concrete industry can be considered a new approach. Since the concrete industry uses conventional resources [7]. Different fibers such as steel, glass, carbon, nylon, etc. Has good tensile strength and higher pre-treatment cost. In contrast, plastic fibers require much less tension than their fiber counterparts [8-10].

The beam-to-column joint zone is a very important zone in the seismic resistance of a frame, especially for external T-joints because they transmit greater shear forces than internal joints. During an earthquake, the side of the building is subjected to a large lateral force, and the shear force generated by the reinforcement of the longitudinal beam enters the core of the node [11]. Shear forces can occur in corner-to-corner to diagonal tensile failures. Joint shear failure can occur in joints that are not designed to withstand high shear forces, such as beam-to-column joints before the 1970s. Well, stressed joints have superior properties, but the stirrups and hoops in the joint area can cause the binding of the steel [12, 13].

Considering the previously described advantages of plastic fiber reinforced concrete waste, such as high energy absorption capacity, improved tensile strength, and damage tolerance of concrete, the use of PET fibers in beam-to-column joints can be used as a construction method to minimize stirrups. Piles and shear resistance of seismic joints of frames [14].

The major research objectives are;

- Optimal Inclusion Levels
- Strength Enhancement
- Structural Performance
- Resilience Improvement
- Sustainability Impact

2. Analytical Program Using ABAQUS

ABAQUS was likely selected for this research case due to its advanced capabilities in simulating complex structural behavior and analyzing materials under various loading conditions. Some reasons for choosing ABAQUS could include:

- Advanced Simulation
- Nonlinear Analysis
- Material Modeling
- Customization
- Seismic Analysis
- Validation Potential
- Research Compatibility

ABAQUS's advanced simulation capabilities, nonlinear analysis features, material modeling options, and customization potential make it a suitable choice for investigating the effects of incorporating PET waste fibers into concrete, especially when considering complex structural behavior and seismic performance.

The test specimen joint design includes a beam and column with 90 mm X 110 mm and 90 mm X 90 mm respectively. At the joint, beam longitudinal reinforcement at the top was 1.52 %, and at the bottom was 1.00 % of gross area. The vertical longitudinal reinforcement of the joint is 2.40 %. The amount of reinforcement of hoops and shear at the joint portion was 2.25 % for the seismic region and another portion i.e., for the nominal zone was 1.10 % considered. Figure 1 shows seismic joints and ordinary & fibrous joints. For a seismic joint, this hoop spacing is 20 mm for a distance of 180 mm ($2*d_b$) (d_b = effective depth of beam) from the face of the column in the beam and at a distance of 90 mm (d_b) from the bottom and top of the beam in the column. The fibrous joints were cast by using fiber-reinforced concrete in the joint region for a distance of two times the effective depth from the face of the column on the beam and one time the effective depth from the face of the beam on either side of the column. The effective cover for the main reinforcement is 20 mm.

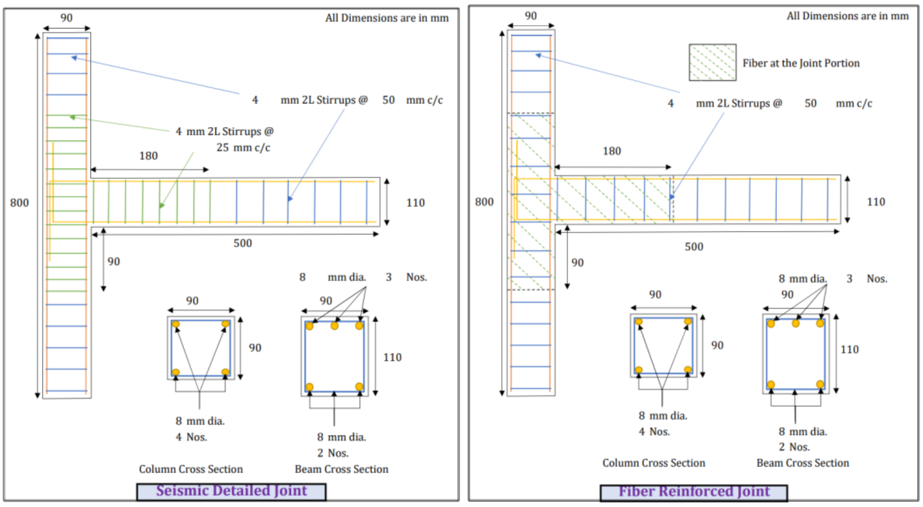

Fig. 1. Seismic and Fiber Reinforcement Detailed Joint.

3. Material Properties

3.1. Concrete

Concrete is defined as an isotropic material before yielding. But after yielding cracking model is defined for nonlinear analysis. In the isotropic elasticity option modulus of elasticity, poison's ratio and density of concrete are defined. Poisson's ratio is considered 0.2 for the concrete. The modulus of elasticity is defined according to IS 456 as shown in the below equation [15, 16].

$$E = 5000 \times \sqrt{f_{ck}}$$

To predict the nonlinear damage behavior of concrete, plasticity models are used. The concrete damage plasticity model uses stress/strain curves to correlate relevant parameters of concrete damage in tension and compression. In addition to these basic parameters for determining the stress-strain relationship, parameters based on the concrete microstructure must also be determined. These parameters are presented in Table 1 [17].

Table 1. Concrete Parameters

Dilation Angle	Eccentricity	f_{bo}/f_{co}	K	Viscosity Parameter
36	0.1	1.16	0.667	0

The stress-strain relationship proposed by Kent and Park model was used for the uniaxial compressive stress-strain curve as:

$$\sigma_c = (1 - d_c)\, E_0\, (\varepsilon_c - \varepsilon_c^{pl,h})$$

$$\varepsilon_c^{in,h} = \varepsilon_c - \frac{\sigma_c}{E_0}$$

$$\varepsilon_c^{pl,h} = \varepsilon_c - \frac{\sigma_c}{E_0}\left(\frac{1}{1 - d_c}\right)$$

$$\varepsilon_c^{pl,h} = \varepsilon_c^{in,h} - \frac{d_c}{(1 - d_c)}\frac{\sigma_c}{E_0}$$

$$\sigma_c = \sigma_{cu}\left[2\left(\frac{\varepsilon_c}{\varepsilon'_c}\right) - \left(\frac{\varepsilon_c}{\varepsilon'_c}\right)^2\right]$$

$$d_c = 1 - \frac{\sigma_c}{\sigma_{cu}}$$

Where,
σ_c = Yield Stress
σ_{cu} = Ultimate Yield Stress

ε_c = Strain
$\varepsilon_c^{in,h}$ = Inelastic Strain
$\varepsilon_c^{pl,h}$ = Plastic Strain
d_c = Damage Parameter

Linear behavior is defined up to the cracking of concrete and after that tension stiffening part is defined linearly decreasing and becoming zero at strain value 0.01.

$$\sigma_t = (1 - d_t)\, E_0\, (\varepsilon_t - \varepsilon_t^{pl,h})$$
$$\varepsilon_t^{ck,h} = \varepsilon_t - \frac{\sigma_t}{E_0}$$
$$\varepsilon_t^{pl,h} = \varepsilon_t - \frac{\sigma_t}{E_0}\left(\frac{1}{1 - d_t}\right)$$
$$\varepsilon_t^{pl,h} = \varepsilon_t^{ck,h} - \frac{d_t}{(1 - d_t)}\frac{\sigma_t}{E_0}$$
$$d_t = 1 - \frac{\sigma_t}{\sigma_{t0}}$$

No softening effect is considered for numerical simulation. Figure 2 shows the stress-strain graph of concrete under compression & tension. Tables 2 & 3 show values of stress, strain, and compression damage parameters data for M25 grade concrete under compression & tension respectively.

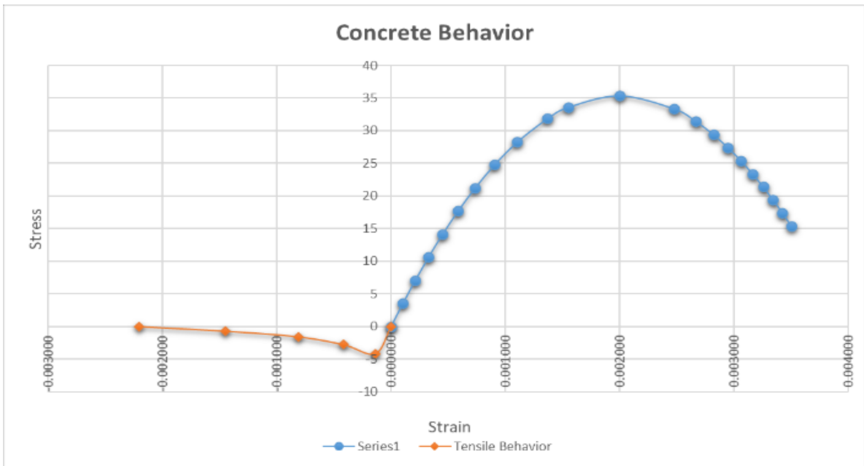

Fig. 2. Concrete compressive & tension stress v/s strain curve

Table 2. Stress-strain for M25 grade concrete under compression

Yield Stress	Strain	Inelastic Strain	Damage Parameter	Inelastic Strain
σ_c	ε_c	ε_c^{in}	d_c	ε_c^{in}
17.7	0.000586	0.000000	0	0.000000
21	0.000735	0.000032	0	0.000032
24.78	0.000905	0.000084	0	0.000084
28.32	0.001106	0.000168	0	0.000168
31.86	0.001368	0.000313	0	0.000313
33.63	0.001553	0.000440	0	0.000440
35.4	0.002000	0.000828	0	0.000828
33.4	0.002475	0.001370	0.06	0.001370
31.4	0.002672	0.001633	0.11	0.001633
29.4	0.002823	0.001850	0.17	0.001850
27.4	0.002951	0.002044	0.23	0.002044
25.4	0.003063	0.002222	0.28	0.002222
23.4	0.003164	0.002390	0.34	0.002390
21.4	0.003258	0.002550	0.40	0.002550
19.4	0.003345	0.002703	0.45	0.002703
17.4	0.003426	0.002850	0.51	0.002850
15.4	0.003503	0.002994	0.56	0.002994

Table 3. Stress-strain for M25 grade concrete under tension

Tensile Stress	Strain	Cracking Strain	Damage Parameter	Cracking Strain
f_{ct}	ε_{ct}	ε_t^{ck}	d_t	ε_t^{ck}
4.1649	0.000138	0	0	0
2.7766	0.000414	0.000322	0.333333	0.000322
1.5618	0.000810	0.000758	0.625000	0.000758
0.6941	0.001447	0.001424	0.833333	0.001424
0.0000	0.002205	0.002205	1.000000	0.002205

3.2. *Reinforcement*

Parameters for material modeling up to the elastic limit include young's modulus of elasticity which is equal to 200000 N/mm2 and poison's ratio for steel equal to 0.3. Plastic behavior is defined as the stress v/s plastic strain relationship. The Stress-Strain curve for Reinforcement bars embedded in reinforcement is proposed by Belarbi and Hsu was used [18]. Figure 3 shows the stress-strain relationship of FE–500 reinforcement.

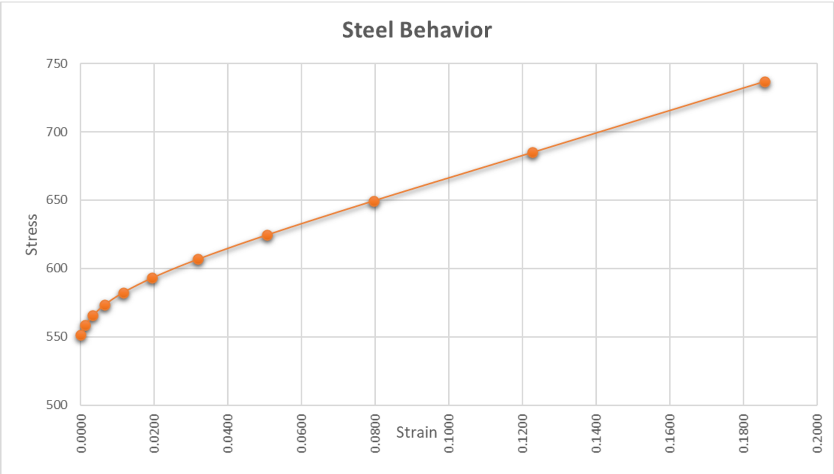

Fig. 3. Stress-strain relationship of FE-500 steel reinforcement

3.3. *PET Plastic Waste Fiber*

As shown in Figure 4, the PET contained in wastewater bottles and soft drink bottles was shredded into fibers using a shredder. The studies were carried out using fibers of constant length and width of 20 mm and 2.5 mm, respectively. Table 4 lists the general and tested characteristics of PET. The fibers are added to the concrete in varying proportions, ranging from 0% to 1.5%, fixed interval of 0.25 depending on the mix volume.

Fig. 4. Shredded PET waste fibers

Table 4. Properties of PET Fiber

Sr. No	Properties	Unit	Value
1	Length	mm	25
2	Width	mm	2 – 3
3	Thickness	mm	0.0625
4	Aspect Ratio	-	400
5	Specific Gravity	-	1.39
6	Tensile Strength	N/mm^2	137.30
7	Elongation	%	64.00

4. Results and Discussion

4.1. Load-Carrying Capacity

The results show that the upward and download load-carrying capacity of the PET fiber concrete increase up to 1.00 % of the increment of the fiber dosage after that again it indicates the downfall in the load-carrying capacity. By keeping the deflection amount constant, loading values are identified. The load-carrying capacity of all the variations is shown in Table 5. 1.00 % inclusion of waste PET fiber in the M25 grade of concrete gives up to 25 % higher load-carrying capacity compared to conventional concrete at constant deflection. Figure 5 indicates the load-carrying capacity and its % variation for all the analyses.

Table 5. Load carrying capacity

Parameters	Units	M25_S	M25_0.25%	M25_0.50%	M25_0.75%	M25_1.00%	M25_1.25%	M25_1.50%
Ultimate Upward Load	kN	13.8793	10.3315	10.7793	12.1087	17.2031	9.3515	7.0153
Ultimate Downward Load	kN	12.0668	9.0935	9.4767	11.8233	15.4029	7.5566	5.9100
Total Load	kN	25.9461	19.4250	20.2560	23.9320	32.6060	16.9081	12.9253
Ultimate Upward Deflection	mm	17.5733	17.5731	17.5714	17.5574	17.5613	17.5802	17.5710
Ultimate Downward Deflection	mm	9.9237	9.9376	9.9194	9.9369	9.9375	9.9191	9.9408
Total Deflection	mm	27.4970	27.5107	27.4908	27.4943	27.4988	27.4993	27.5118

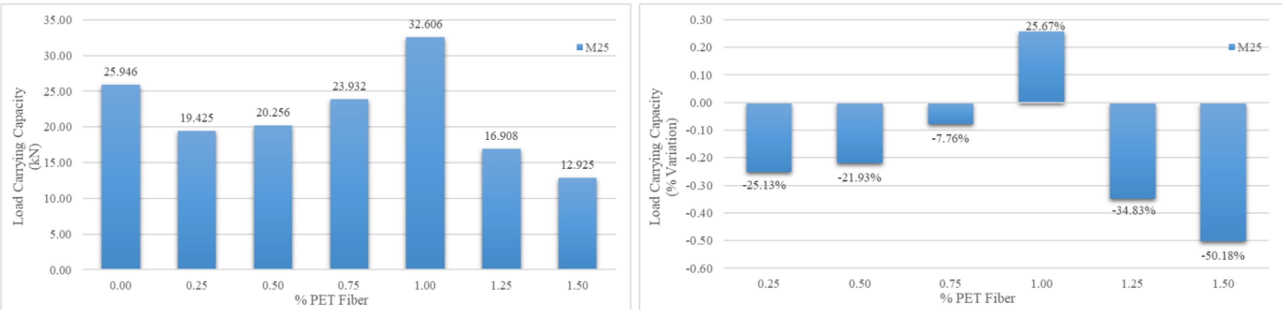

Fig. 5. Load-carrying capacity and its % variations

4.2. Energy Dissipation

The area bounded by the hysteresis loop in a given cycle represents the energy dissipated by the sample during the cycle. Figure 6 shows the energy dissipation capabilities of all samples. It can be seen from the figure that after adding 1.0% PET waste fiber, the energy dissipation capacity is increased by 57% compared to the common sample.

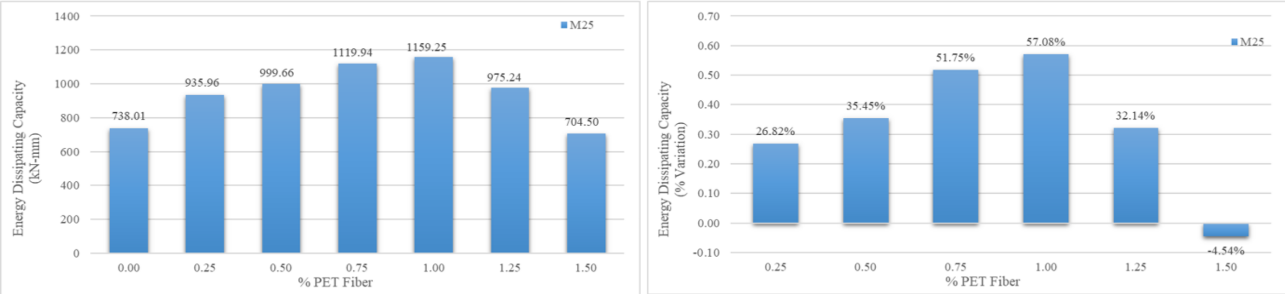

Fig. 6. Energy dissipating capacity of all the specimens

4.3. *Joint Shear Stress*

For the exterior beam-column joint the horizontal and vertical joint shear stresses (τjh, τjv) can be calculated using the following formula [19].

$$\tau_{jh} = \frac{P_u}{A^h core}\left[\frac{L_b}{d_b} - \frac{L_b + 0.5D_b}{L_c}\right]$$

$$\tau_{jv} = \frac{P_u}{A^v core}\left[1 - \left(\frac{L_b + 0.5D_c}{L_c}\right)\left(\frac{L_c - D_b}{d_c}\right)\right]$$

Where L_b and L_c are the lengths of the beam and column, respectively; D_b and D_c are the total depths of the beam and column respectively; d_b and d_c are the effective depths of the beam and column, respectively; A^h_{core} and A^v_{core} are the horizontal and vertical depth cross-sections of the joint web, respectively, resisting horizontal and vertical nodal shear forces respectively. P_u is the ultimate load. Table 6 shows the ultimate shear strength of joints using M25 concrete. Shear stress of vertical and horizontal seams with 1.00% PET waste fibers showed better results compared to all other variants.

Table 6. Shows the ultimate shear capacity of the joint using M25 Concrete

Test Specimen	Joint Shear Stress	
	Horizontal	Vertical
M25_S	8.328	7.356
M25_0.25%	6.199	5.476
M25_0.50%	6.468	5.713
M25_0.75%	7.265	6.418
M25_1.00%	10.322	9.118
M25_1.25%	5.611	4.956
M25_1.50%	3.546	3.132

4.4. *Curvature ductility factor*

The ability of an element to deform beyond its initial yield point with minimal loss of strength and stiffness depends on the ductility factor defined as the ratio of the ultimate strain to its yield point at the first elasticity limit. Ductility can be easily defined in the context of elastoplastic behavior [20]. Ductility coefficients for beam-to-column connections are defined based on the curvature of the axis of the critical section;

$$Curvature\ ductility\ factor = \frac{\emptyset_u}{\emptyset_y}$$

$$\emptyset_u = Curvature\ at\ peak\ load = \frac{e_t + e_b}{(d_b + a)}$$

$$\emptyset_y = Curvature\ at\ yield\ = \frac{f_y}{E_s(d_b - x)}$$

Where,

$$e_t = strain\ in\ top\ reinforcement$$
$$e_b = strain\ in\ bottom\ reinforcement$$
$$a = compressive\ reinforcement\ cover$$
$$E_s = Modulus\ of\ elasticity\ of\ steel$$
$$x = depth\ of\ neutral\ axis$$

The curvature ductility factor and its % variation for all the specimens are shown in figure 7. From the chart, it may be indicated that the PET fiber reinforced specimen shows a decrement in curvature ductility till 0.75 % inclusion and after that ductility factor increases by increasing the PET waste fiber.

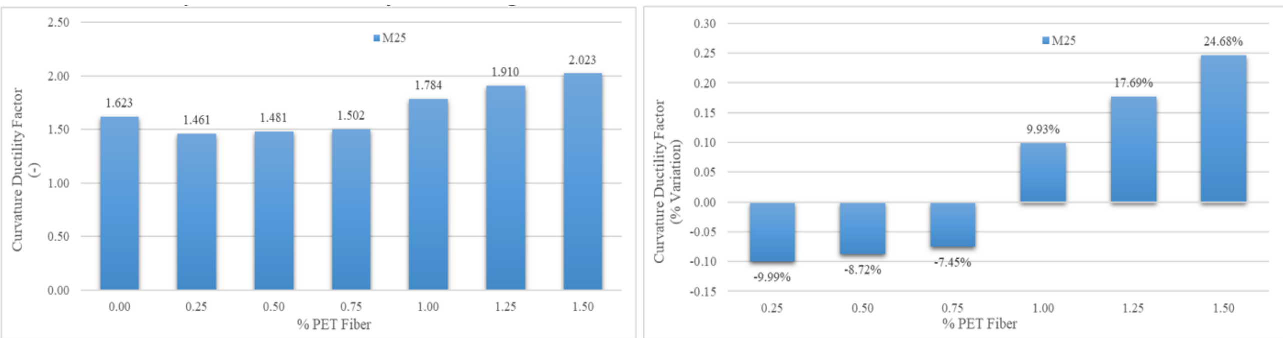

Fig. 7. Curvature Ductility Factors for all specimen

4.5. Joint Distortion Factor

The forces in the beam-to-column connections are indeed quite complex. The internal web of the node, delimited by the longitudinal members of the beam-column, is in fact subjected to a greater shearing stress and therefore presents a greater deformation than the whole of the node. Two LVDTs are installed diagonally at the back of the seal to measure the deformation of the inner core of the seal.

$$Joint\ Distorion = \left(\left(\frac{e_1 + e_2}{2}\right) \times \left(\frac{D_l}{h_j \times b_j}\right)\right)$$

Where,

$$e_{1,}e_2 = \text{Changes in length of the diagonal joint region in mm}$$
$$D_l = \text{Initial diagonal length in mm}$$
$$h_j = \text{Depth of the joint region in mm}$$
$$b_j = \text{Breadth of the joint region in mm}$$

From below figure 8, it is clearly observed that the joint distortion factor decreases quite significantly by increasing the % dosage of PET waste fiber in the concrete mix. 1.00 % inclusion indicates the best-improved results among all and the decrement of joint distortion is reduced by 20% with compare to normal concrete.

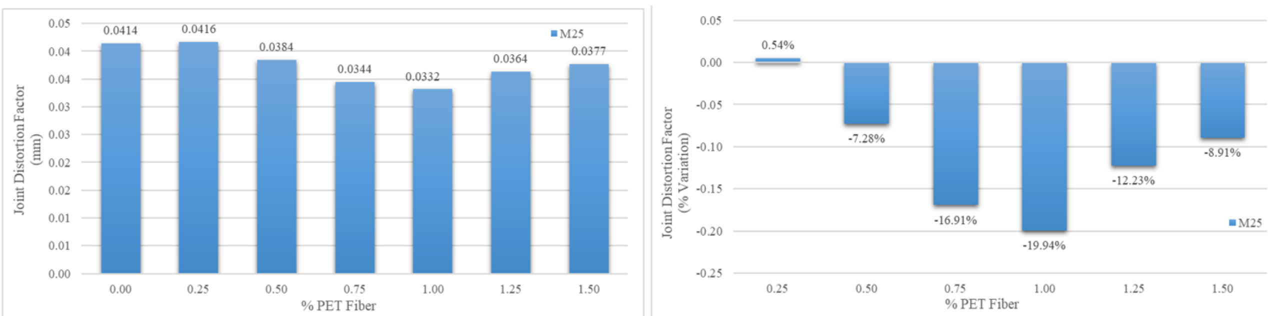

Fig. 8. Joint Distortion Factor for all the specimen

5. Conclusion

This experiment is dealing with the new concept of developing sustainable concrete by incorporating post-consumer PET waste as a concrete material, it delivers dual benefits by reducing the natural material used in concrete and major probability of utilizing waste products which improves waste management.

The following are some of the major conclusive statements based on the research study;

- The compressive strength of the PET waste fiber concrete shows better results till the 1.00 % inclusion of PET further addition of PET fiber indicates a downfall of the concrete strength. The compressive strength of PET fiber concrete increases up to 12.30% with compare to conventional concrete.

- PET fiber concrete indicates incremental graph for the flexural strength till 1.25 % dosage of the waste fiber and the optimum increment value is 19.75 % higher than the conventional concrete.
- For the splitting tensile strength, it is observed that the strength values kept increasing for all the specimens and its optimum increment reaches up to 19.65 % with compare to plain concrete.
- By adding PET waste fiber, the load-carrying capacity of the concrete is increased. The optimum increment of the load-carrying capacity touches up to 25.67 % for the 1.00 % specimen.
- For the beam-column junction, 1.00 % of PET fiber achieves 57 % additional energy dissipation compared to normal concrete.
- From the FEM analysis, it is indicated that the beam-column junction having waste fiber concrete, the ultimate stress, curvature ductility factor, and shear resisting capacity are improving by 4%, 24.5%, and 24% respectively.

All the above-mentioned results indicate that the between 0.75% to 1.25% inclusion of PET waste fiber gives optimum values for the beam-column junction under the seismic condition. And also, by adding PET waste fiber can reduce the cost around 15 % with compared to conventional concrete junction under the seismic effect.

This research advances concrete technology by establishing optimal PET waste fiber inclusion levels (up to 1.00%) for improved compressive, flexural, and splitting tensile strengths. The 12.30% compressive strength increase and 19.75% flexural strength improvement demonstrate practical benefits. Structural resilience gains, including 57% increased energy dissipation at beam-column junctions, offer significant implications for seismic performance. These findings inform sustainable construction practices and inspire further material development and design optimization.

References

[1] Pacheco-Torgal, F.: Introduction to the use of recycled plastics in eco-efficient concrete. In: Use of Recycled Plastics in Eco-Efficient Concrete, pp. 1–8. Elsevier, Amsterdam (2019).

[2] Whinfield, John Rex and Dickson, James Tennant (1941) "Improvements Relating to the Manufacture of Highly Polymeric Substances", UK Patent 578,079; "Polymeric Linear Terephthalic Esters", U.S. Patent 2,465,319 Publication date: 22 March 1949.

[3] Bhogayata, A., Arora, N.K.: Green concrete from the post-consumer plastic wastes: Indian scenario, pp. 437–440 (2011).

[4] Jain, A., et al.: Fresh, strength, durability and microstructural properties of shredded waste plastic concrete. Iran. J. Sci. Technol. Trans. Civ. Eng. 43(1), 455–465 (2019).

[5] E. Rahmani, M. Dehestani, M.H. Beygi, H. Allahyari, I.M. Nikbin, On the mechanical properties of concrete containing waste PET particles, Constr. Build. Mater. 47 (2013) 1302–1308.

[6] Nirav M. Patel, M. N. Patel: Behavioral Changes in Strength of Concrete Reinforced by Waste Plastic Fibers. Information and Communication Technology for Competitive Strategies (ICTCS 2020). Volume 191, 431 – 439. Springer, Singapore. https://doi.org/10.1007/978-981-16-0739- 4_41.

[7] S. Yang, X. Yue, X. Liu, Y. Tong, Properties of self-compacting lightweight concrete containing recycled plastic particles, Constr. Build. Mater. 84 (2015) 444–453.

[8] D. Foti, Use of recycled waste pet bottles fibers for the reinforcement of concrete, Compos. Struct. 96 (2013) 396–404.

[9] D. Foti, Preliminary analysis of concrete reinforced with waste bottles PET fibers, Constr. Build. Mater. 25 (4) (2011) 1906–1915.

[10] Nirav M. Patel, Dr. M. N. Patel. (2021). Strength Performance of Concrete by using Polyethylene-Terephthalate Waste Fibers as Concrete Constitute. Design Engineering, 141 - 156.

[11] Paul R. Gefken and Melvin, R. Rame. Increased joint hoop spacing in Type 2 seismic joints using fibre reinforced concrete, ACI Structural Journal, No. 2, 86(1989) 168-72.

[12] Filatrault A, Ladicani K, and Massicotte B. Seismic performance of code designed fibre reinforced concrete joints, ACI Structural Journal, No. 5, 91(1994) 564-71.

[13] Filiatrault A, Pineau S, and Houde J. Seismic behaviour of steel fibre reinforced concrete interior beam-column joints, ACI Structural Journal, No. 5, 92(1995) 543-51.

[14] Thanukumari B, Perumal P. Behaviour of Fibre Reinforced Exterior Beam Column Joint Subjected to Cyclic Load, Proceedings of the National Conference on Advances in Construction Materials, Methods and Management (AC3M-'09) at Chaitanya Bharathi Institute of Technology, Hydrabad, (2009) pp. 429-436.

[15] Indian Standard Plain and Reinforced Concrete Code of Practice, IS 456:2000 Bureau of Indian Standards, New Delhi, 2000.

[16] Indian Standard Criteria for Earthquake resistant Design of Structures, Part I General Provisions and Building IS 1893 (Part I) 2002 Bureau of Indian Standards, New Delhi, 2002.

[17] Ganganagoudar, A., Mondal, T. G., and Suriya Prakash, S. (2016). Analytical and finite element studies on behavior of FRP strengthened RC beams under torsion. Composite Structures, 153, 876-885. https://doi.org/10.1016/j.compstruct.2016.07.014.

[18] Belarbi A. and Hsu T.T.C. (1994). Constitutive laws of concrete in tension and reinforcing bars stiffened by concrete, ACI Struct J, 91(4), 465-74.

[19] Murty, C. V. R., Durgesh C. Rai, Bajpai, K. K. and Jain, K. 'Effectiveness of Reinforcement Details in Exterior Reinforced Concrete Beam-Column Joints for Earthquake Resistance", ACI Structural Journal, Vol. 100, No. 2, pp. 149-156, 2003.

[20] Ganesan, N. and Indira, P.V. "Latex modified SFRC beam-column joints subjected to cyclic loading", The Indian Concrete Journal, July pp. 416-420, 2000.

Authors' Profiles

Nirav M. Patel is currently working as a professor at Parul University. He did his bachelors from MS University civil engineering and he did his master's from LD College of Engineering in structural engineering. He is currently pursuing his Ph.D. in fiber-reinforced concrete and performing the analysis on FEM software named ABAQUS. During his tenure of his Ph.D., he has published several research articles in reputed journals and conferences along with two book chapters in the field of concrete technology.

His article on the effect of the construction industry postcode pandemic was recognized by the Aditya Birla group and achieved all India 3rd rank.

DR. M. N. Patel did his engineering in the Civil Branch and has been in academia since. He has served as the principal for over a decade at the Government Engineering College, Modasa, and L.D. College of Engineering, Ahmedabad before being appointed as the Ex-Vice-Chancellor of Gujarat University.

Tapsi D. Sata is a student who recently received his M.E. (First Class with Distinction) in Structure Engineering from Parul University (2023). She is highly consistent in her academic track record and is well revered amongst the faculty of the Department of Civil Engineering. From 2021 to 2023, she was a Research scholar at the R&D cell of her college, currently, she is working as a design engineer in the P. Vora Construction Pvt. Ltd.

How to cite this paper: Nirav M. Patel, M. N. Patel, Tapsi D. Sata, "Study of PET Fiber Concrete in Beam-Column Joint under Cyclic Loading Using Finite Element Analysis", International Journal of Engineering and Manufacturing (IJEM), Vol.13, No.5, pp. 38-47, 2023. DOI:10.5815/ijem.2023.05.05