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Comparative analytical study of seismic performance of beam column joint strengthened with different materials

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Abstract - *The beam column joint is the most affected area in a reinforced concrete moment resisting frame. It is unprotected to large forces during severe ground shaking and its behavior has a significant influence on the retort of the structure. Joints are crucial part for the transfer of force reactions and moments effectively between the connecting elements like beams and columns. As a result, joints often become the weakest links in the structural system. The main objective of this paper is to analytically check different types of strengthened beam column (B-C) joint with different and compare the final results. A cyclic load is applied to beam column joint model to check the reactions, ultimate load, total deformation and ductility. The retrofitting techniques for strengthening a weak structure are researched in many ways during the past and contemporary. Here we use some cost-effective techniques to strengthen, they are TRM, SRP layer coating, Kevlar-149 lamination over the structure based on the ultimate load and lateral deflection, a comparative study is done with different strengthened models. The project also explains about the shear stress, normal stress, deflection, reactions and moment acting on the model. Analysis of the structure is done with computational aided software "ANSYS Workbench 16.2".*

Key Words: **External Beam Column Joint, seismic strengthening, CTRM, BTRM, SRP, Kevlar-149, Ansys Workbench 16.2**

1. INTRODUCTION

The analysis of reinforced concrete moment resisting structures the joints are assumed to be rigid. In the case reinforced concrete structures the most vulnerable area subjected to seismic loading is the beam column joints, where the proper design and detailing is absent in the case of Indian codes. But the formation of plastic hinges inside the column may leads to the entire disintegration of the respective element. So, the study is aimed to occur the formation of plastic hinges in the beams at the first stage. So that an initial sign can be given by the structure indicate the initial cracking. So necessary precautions can be taken at this stage. Generally, the exterior joint is more affected than when compared to that of the internal joints. So that the exterior joint is subjected for the study. In the codes since they have not provided the special joint designs, so that strengthening of the beam column joints can be done by the application of the additional layer or panel at the joints whose dimensions can be fixed based on the affected flexural span of the beam during the seismic loading. The paper is aimed at the strengthening of beam column joint by adding u-wraps with different materials and improve the seismic function of joints.

It is very clear that many global and local studies have done in the of analysis of beam column joint and also retrofitting of the joint and has helped in the current study and helps in the fixation of the material properties. The studies also proved analytical studies are showing almost similar results from the experimental study.

2. LITERATURE REVIEW

Mohammad S. Alhaddad et. al. performed an analytical study for comparing the lateral displacement of exterior beam column joint strengthened with CFRP, GFRP, CTRM and also compared with the experimental values[1]. Another study is conducted to analyze the strength and behavior of SRP, which is done experimentally to find out the energy dissipation ability and also the ductility characteristics of SRP when applied to a beam column joint [2]. A study is conducted experimentally to compare the IS Codes to assess the strength of beam column joint provided with ductile detailing for which a critical column of six storey building is selected [7]. Study regarding the tensile strength of aramid and Kevlar-149 fibres which is done experimentally [5]. Another experimental study is conducted for the strengthened RC beam column joints using CFRP composites and to compare with the control specimen [8].

Detailed literature review shows that poor performance of non-seismically designed joints can be dazed using different strengthening techniques**.** It also accomplishes efficiency of panel as a strengthening material since it owns high strength to weight ratio, high strength to weight ratio, high flexural strength, shear capacity, and low cost etc. No analytical studies are conducted on the performance joints strengthened with Kevlar 149, SRP, BTRM. This study reveals performance of a typical non-ductile RC beam column joint strengthened with four different materials when seismic loads are applied at the selected exterior beam column joint.

3. ANALYTCAL STUDY

3.1 General

In the current study, researchers were done to assess performance of strengthened beam column joint compared to an un strengthened control specimen. The analytical program consists of modelling and analysis of joint strengthened with four different materials with same thickness. A typical exterior beam- column joint is designed with detailing as per IS 456:2000 (IS 2000) and is scaled down. No shear reinforcement is provided at joint portion. Dimensions reinforcement details are shown in Table 1 and Table 2. Reinforcement detailing are shown in figure 1.

Table -1: Dimensions of specimen

Member	Dimensions (mm)
Beam size	100 x 150 x 550
Column size	100 x 150 x 1000
Joint size	100 x 150 x 150

Table -2: Details of Reinforcement for Beam-Column Joint Specimens

Beam	
Beam main bars	Beam stirrups
2 nos of 8mm Ø & 2 nos of 6mm Ø at top and bottom	3mm Ø bars @ 35mm c/c (270 mm from column face) remain @ 50 mm c/c
Column	
Column main bars	Column ties
4 nos of 8mm Ø and 4 nos of 6mm Ø	3mm Ø bars @ 100mm c/c

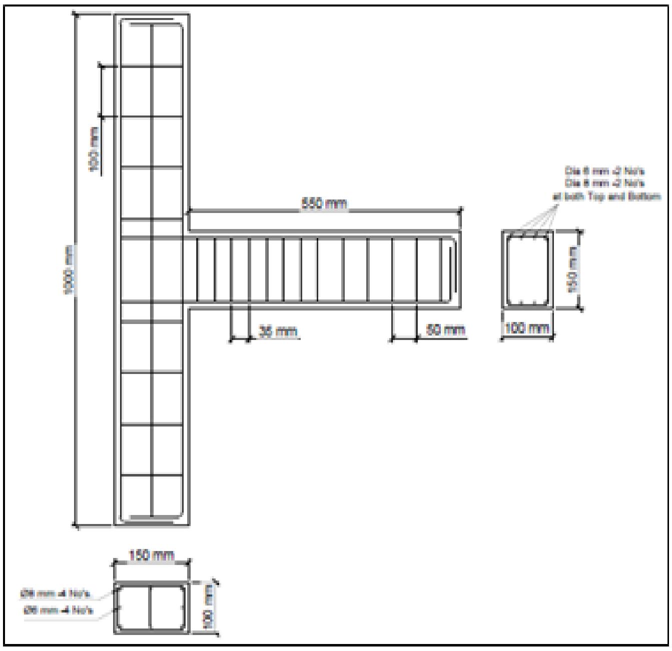

Figure 1: Dimension and reinforcement details of control specimens

The configuration selected for strengthening the joint is shown in figure 2. Material is fully wrapped in column region and U wrapping in beam portion

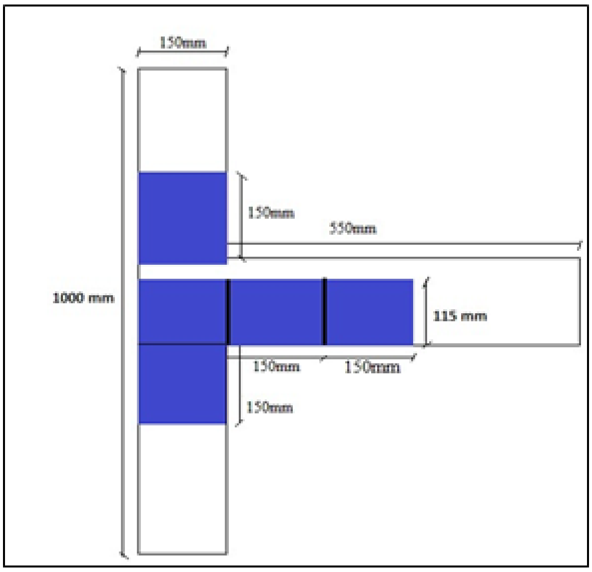

Figure 2: Configuration of panel wrapping

3.2 Material properties

Following table 3 & 4 shows the material properties used for analysis.

Table -3: Material properties

Properties	values
concrete	
compressive strength	30 N/mm^2
Young's modulus	27386 N/mm^2
Poisson's ratio	0.18
rebar	
Young's modulus	200000 N/mm^2
Poisson's ratio	0.3
yield tensile strength	415 N/mm^2

3.3 Analytical modeling

Modeling and analysis performed using the software ANSYS16.2 WORKBENCH. Element type opted for modeling concrete member is SOLID186 and for rebar element lBeam188 is adopted. The panels are modelled using the element SOLID186. Mesh size of 25 mm is selected and this size gives finer result in analysis. Figures 3-5 illustrates the Ansys model of joint, rebars and panels

Table -4: Material properties

Properties	CTRM
Density (kg/m^3)	1700
Young's modulus in long. Dir. (N/mm^2)	82500
Poisson's ratio	0.3
Young's modulus in transverse. Dir. (N/mm^2)	4600
Poisson's ratio	0.22
Bilinear Isotropic Hardening	
Yield strength (N/mm^2)	777
	BTRM
Density (kg/m^3)	2330
Young's modulus in long. Dir. (N/mm^2)	65000
Poisson's ratio	0.3
Young's modulus in transverse. Dir. (N/mm^2)	3700
Poisson's ratio	0.22
Bilinear Isotropic Hardening	
Yield strength (N/mm2)	2100
	KEVLAR-149
Density (kg/m^3)	1470
Young's modulus in long. Dir. (N/mm2)	186000
Poisson's ratio	0.35
Young's modulus in transverse. Dir. (N/mm^2)	8900
Poisson's ratio	0.3
Bilinear Isotropic Hardening	
Yield strength (N/mm2)	2558
	SRP
Density (kg/m^3)	1700
Young's modulus in long. Dir. (N/mm^2)	191000
Poisson's ratio	0.3
Young's modulus in transverse. Dir. (N/mm^2)	42500
Poisson's ratio	0.25
Bilinear Isotropic Hardening	
Yield strength (N/mm^2)	3800

3.4 Loading pattern and boundary conditions

For stimulating seismic loading in the specimen, a displacement controlled quasi static cyclic loading were applied laterally on top of column. Displacement is applied from zero to 35 mm and the applied cyclic displacements were divided into a series of increments called load steps and load sub steps. A constant axial load of 120 KN is applied at top column in downward direction. This force is induced for adding dead weight and live load on joint. At the bottom of column, a hinge support and at the free end of beam, a roller support are provided. Load pattern and boundary conditions are illustrated in Fig 6

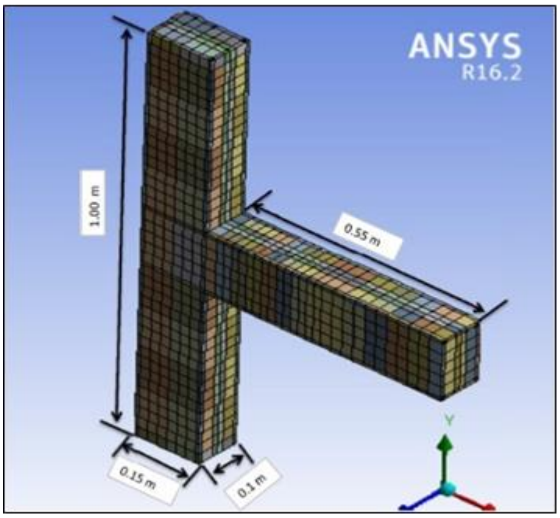

Figure 3: ANSYS model

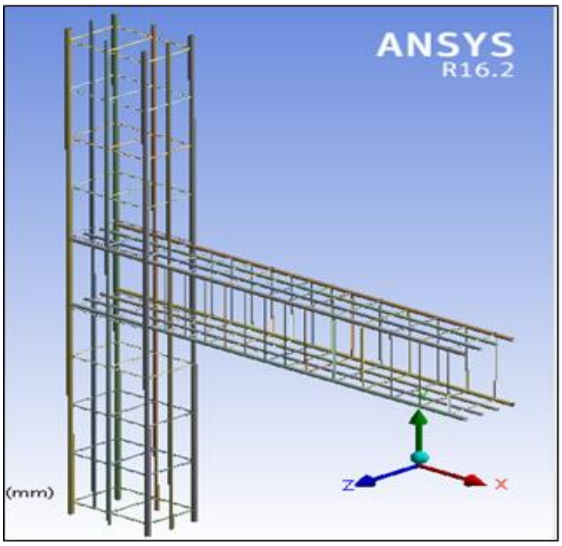

Figure 4: Reinforcement model

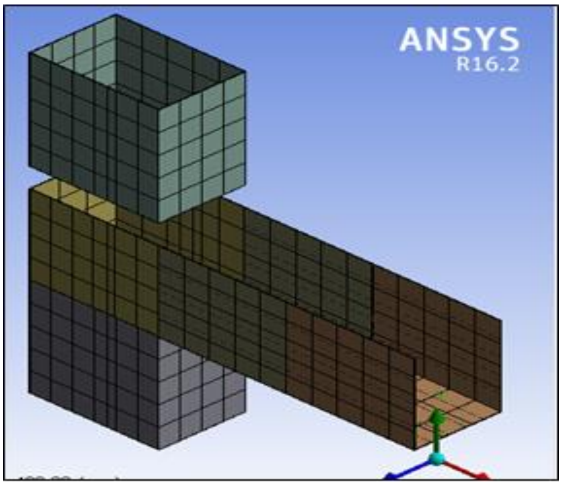

Figure 5: Panel wrapping

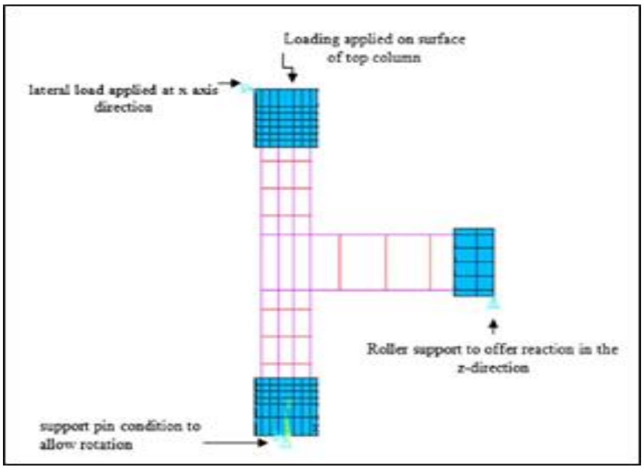

Figure 6: Loading Pattern & Boundary Conditions

4. RESULTS AND DISCUSSIONS

Performance of beam column joint, strengthened with different type of materials are compared with load-displacement behavior and ductility ratio. Designations of the specimens are given in the table below.

Table 5: Designation of Specimens

Specimen	Designation
Control Specimen	BJ - CS
Strengthened with Carbon textile reinforced mortar	BJ - CTRM
Strengthened with Basalt textile reinforced mortar	BJ - BTRM
Strengthened with Kevlar 140	BJ – K 140
Strengthened with Steel reinforced polymer	BJ – SRP

4.1 Load-Displacement behavior

The tests were conducted under displacement controlled cyclic lateral loading as discussed previously. The lateral load displacement envelope of the tested beam-column joint specimens and are presented in Figs. 8-13

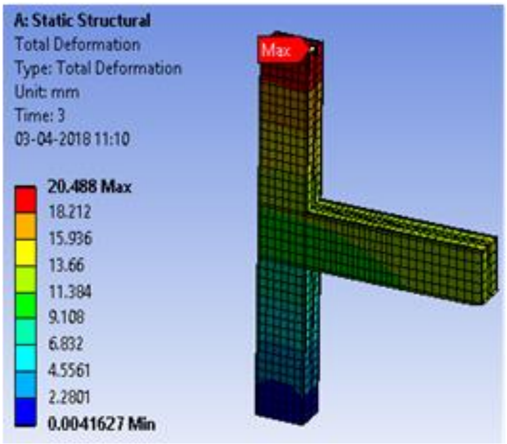

Figure 7: Total deformation BJ – CS

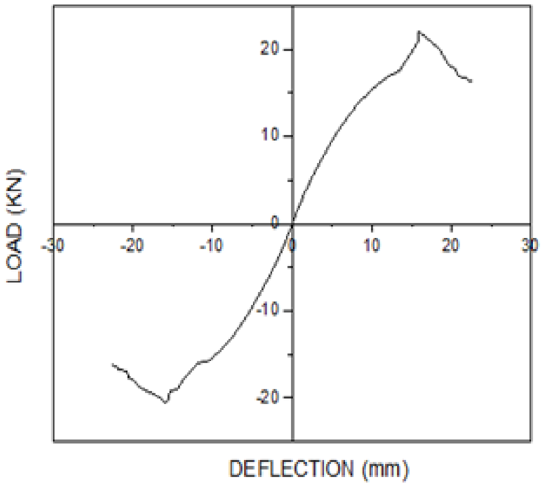

Figure 8: Load displacement response of BJ – CS

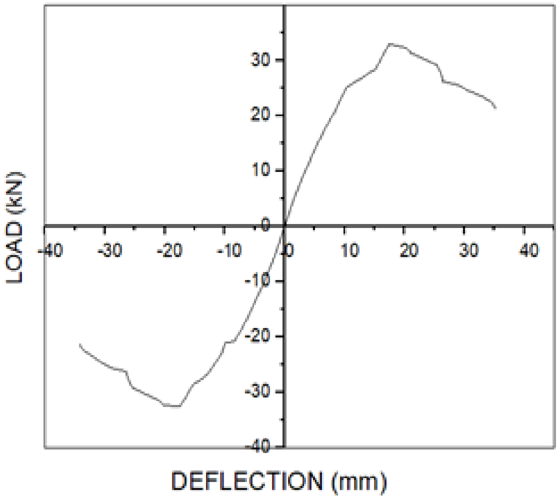

Figure 9: Load displacement response of BJ – CTRM

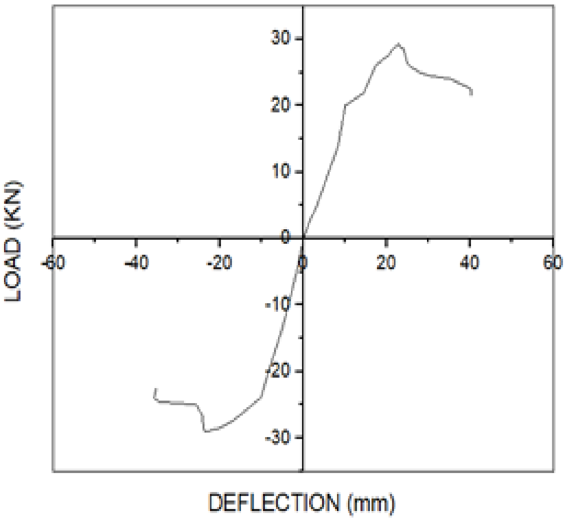

Figure 10: Load displacement response of BJ – BTRM

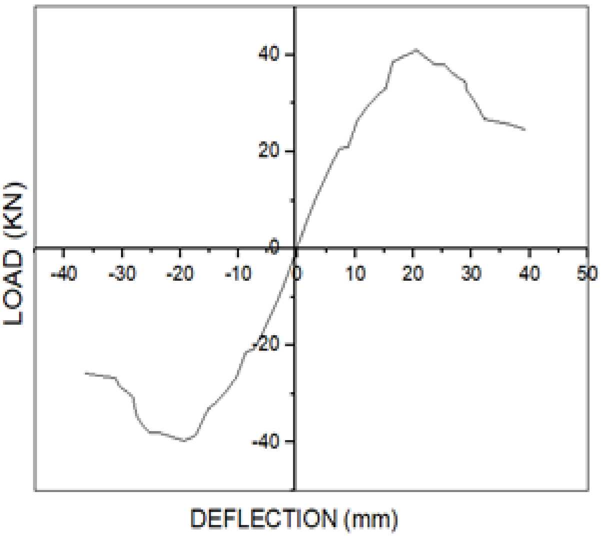

Figure 11: Load displacement response of BJ – K 149

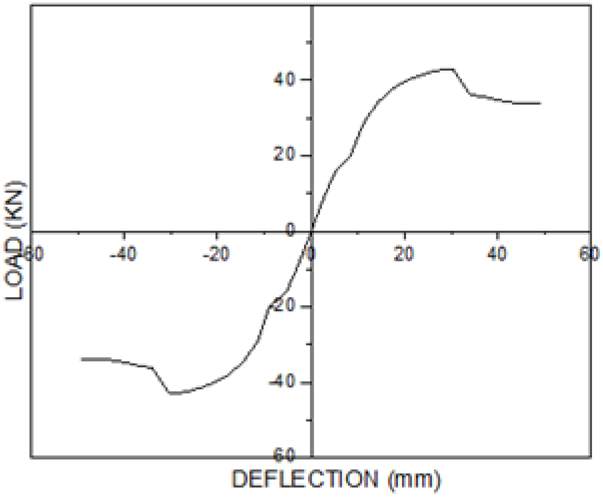

Figure 12: Load displacement response of BJ – SRP

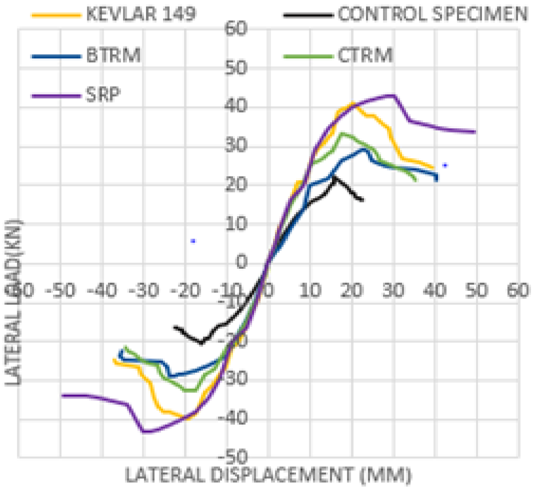

Figure 13: Load displacement response

Table 6 shows the ultimate peak load and ultimate displacement of both control and strengthened specimen. Control specimen reached an ultimate load of 21.34 kN. The specimen strengthened with CTRM is capable of reaching a peak load 1.54 times of control specimen whereas specimen strengthened with BTRM is capable of reaching a peak load of 1.36 times of control specimen. The specimen strengthened with KEVLAR-149 reached maximum peak load about 1.89 times of control specimen. And with the addition of SRP, the peak load can be raised to about 1.97 times that of the control specimen.

Table -6: Peak Test Load and displacement

Sl no	Specimen	Average peak load (kN)	Maximum displacement (mm)	% increase in load
1	BJ- CS	21.34	16.77	-
2	BJ-CTRM	32.78	26.016	54
3	BJ-BTRM	29.068	23.236	36
4	BJ – K 140	40.459	31.77	89
5	BJ – SRP	42.014	34.337	97

4.2 Ductility Ratio

The ductility ratio is an important parameter for earthquake resistant construction of structures. The ductility was computed generally as the ratio of ultimate displacement to the displacement at first yield displacement. For computation, the ultimate displacement was set at a displacement corresponding to 20% drops of peak load.

Table -7: Ductility ratio

Specimen	Average Yield Displacement	Average Maximum Displacement	Ductility ratio (average)
BCJ – CS	11.93	17.071	1.673
BCJ-CTRM	10.484	26.22	2.514
BCJ-BTRM	10.0985	35.015	3.467
BCJ-KV149	8.784	39.706	4.117
BCJ-SRP	8.68	40.082	4.626

5. CONCLUSIONS

Based on the analytical study, it point outs to the following conclusions:

The specimen strengthened with CTRM shows 54 % increase in ultimate load compared with control specimen and can take more lateral displacement of about 26mm. The specimen strengthened with BTRM shows 36 % increase in ultimate load and can take more lateral displacement of about 23.236mm compared with control specimen. The specimen strengthened with Kevlar-149 shows 89 % increase in ultimate load and can take more lateral displacement of about 31.77mm compared with control specimen. The specimen strengthened with SRP shows 97 % increase in ultimate load and can take more lateral displacement of about 34.34mm compared with control specimen.

From the results it is very clear that SRP is the best material out of the four selected ones and is having highest load withstanding capacity and is able to take maximum lateral displacement. CTRM is having load capacity higher than BTRM but is able to take more lateral displacement than that of CTRM.

On the basis of ductility ratio the beam column joint strengthened with SRP is having highest ductility along with the load carrying capacity. But BTRM is imparting more ductility than that of CTRM while, CTRM is offering more load carrying capacity than that of BTRM. Kevlar-149 is also having moderate ductility and also having higher ultimate load than that of textile reinforced mortar.

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