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Study on the Behaviour of Exterior Beam-Column Joint Using Crossed-Rebar with Prestress

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Abstract: ***Beam-column joint is the gap in the modern ductile design of building. Especially under the Earthquake loading this is more susceptible to damage. Due to brittle nature of failure this type of failure cannot be afford. Due to cross pre stressing there is increase in the shear strength of the concrete in the joint core. A model can be formulated to calculate the increase in shear strength of the joint core using ANSYS. The increase in the performance of the joint due to cross-pre stressing which may leads to the decrease in the joint confinement reinforcement. Further a formulation can be generated to calculate that how much reinforcement can be reduced due to this cross-pre stressing. Here it is combine the benefits of the crossed rebar and pre stressing in the joints together. The present work is divided into two phase. First phase for modeling a frame using STAAD and find out the critical exterior joint. The ANSYS model is created with pre stressing force through rebar is being applied at the joint with the help of the steel plates acting as the bearing.***

Keywords: Beam-column joint, Crossed-Pre stress rebar, STAAD PRO, ANSYS

1. Introduction

Beam-column joint has not been area of research for many decades because Scientist believes that beam column joint behave as rigid joint with no deformation Contributed by it. Beam-column joint has no problem in itself until the dead and live loads are concern. As soon as lateral loads, *i.e.* seismic force, comes into picture it will become a critical problem. This problem has not been solved completely till date. As we know that, practically we can't construct the structure earthquake-proof, so there must be way out to earthquake problem. And we are fortunate enough that the solution come in only one term and that is ductility. Make the structure enough ductile and forget about the force which is going to come on it. So in short the solution to the problem of earthquake is ductility. So whatever going to come in the way of ductility and your structure you have to kill that, simple enough to understand? So in this process of removing our enemy through the research of 70 years in the seismic design, only beam-column joint shear failure is left behind. The portion of the column where beam is use to join it is called beam-column joint.Beamcolumn joints are classified into three types based on the number of beams ending into the column.

- Interior Beam-Column joints
- Exterior Beam-Column joints
- Corner Beam-Column joints

2. Mechanics of Beam Column Joint Core, Shear Force

Shear force is very critical in the earthquake resistance design of the structure because of it induce brittle failures. But if the structure is subjected to lateral force due to wind or earthquakes most of the shear force is being concentrated in the joint cores, which leads to the brittle failure of the many structure in the past earthquakes. Even though the mechanic of the calculation of the shear force in the joint core is very simple it had been ignore for many decades with the wrong assumption of the rigid joint behaviour.

3. Mechanics of beam column joint core, shear Deformation

Deformation of the joints contributes significant lateral drift of the story and the global story displacement. But due incapability to calculate the shear deformation most of the code till present assume the rigid joint behaviour of the joint. Which may sometime leads to significant error in the calculation of the max story displacement. Estimation or calculation of lateral story drift due to shear deformation of the joint is very challenging. From the past many scientist has tried to solve this riddle. They proposed many different type of models starting with the rigid joint assumption, matrix method based on the central line analysis, implementation of the panel zone concept to add the shear deformation, adding rotational hinge and the use of full scale finite element analysis etc. with every advancement they are moving forward to the accurate estimate of the shear deformation.

4. Objective of the study

- Due to cross pre stressing, shear strength of the concrete in the joint core will be increases. So a model can be formulated to calculate the increase in shear strength of the joint core.
- How much reinforcement can be reduced due to this cross pre stressing in the joint.

5. Methodology

5.1 General

My present work is divided into two phases. In the first one I have design the multistorey building to find the location of maximum shear force in the beam to column joints. Once we got the joint with maximum shear force we can implement the pre stressing in the beam to column joints to prevent the damage and avoiding the congestion at the same time.

5.2 Phase 1: Joint with maximum shear force

The first phase of the work is dedicated to find out the beam to column joint which may goes under maximum shear force demand under all the possible parameter variation. So I have arbitrary chosen a multi-storied building with 3m as the height of the story. For easy reference, this building is named as "Reference Building". Many parameters have been selected from lot of literature review which is supposed to affect the shear demand of the beam to column joints. Taking these parameters studies has been done to find the influence of these parameters. All the different buildings with different parameters have been design with STAAD.Pro according to IS 456:2000 "Limit State Method" and shear force is calculated according to the ACI 352-02. Joints with the maximum shear force are shorted out where probable congestion is being expected.

$$Vc = 1.4 \times \frac{(Mh + Ms)}{h} \quad (1)$$

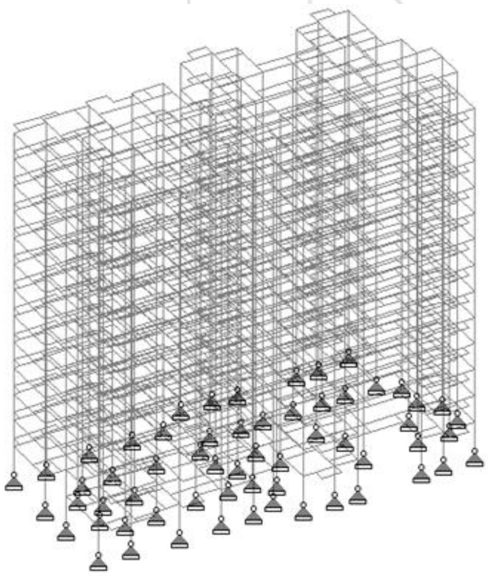

Figure 1: Multistorey building modelled in STAAD

First Phase Methodology:
1) Consider a multi storey building as reference building.
2) The building is designed as per IS 456:2000(LSD) and analysis done with STAAD .
3) Shear force has been calculated as per ACI: 352-02.
4) Ten number of exterior joints selected from the reference building.
4. Critical joints have been shorted out from the Equation (1).

Table 1: Joint with max shear force calculation

Exterior joint	*Hogging Moment*	*Sagging moment*	*Column joint shear, V_c(Kn)*	*Remarks*
EJ-1	168.03	209.45	176.15	Critical joint
EJ-2	125.85	154.57	130.86	Approx: equal
EJ-3	95.68	178.08	127.75	
EJ-4	97.14	177.3	128.07	
EJ-5	178.77	208.98	180.95	Critical joint
EJ-6	85.23	116.56	94.18	Mini:
EJ-7	43.53	95.96	65.09	Mini:
EJ-8	107.71	144.47	117.68	Mini:
EJ-9	150.77	185.57	156.96	Approx: equal
EJ-10	139.34	185.53	151.6	

5.3 Phase 2: Modelling in ANSYS

ANSYS is general FE software which could model the concrete and reinforced concrete with high level of accuracy. For the present study ANSYS v16.2 is being used. It is very accurate in predicting the cracks and crushing behaviour of the reinforced concrete. Modelling in ANSYS is providing appropriate elements, defining geometry and assigning the suitable material models. Modelling is the most time consuming part of the FEM analysis. So it should be done with very care and patience. Few of the basic theory must be followed before going for the modelling in ANSYS specially of the concrete modelling. One major problem which has been encountered by the engineer/scientists working in the FEM of concrete in the convergence problem associated with it. First of all the exterior joint is being modelled in ANSYS as the experimental program to act as the control specimen .And the second ANSYS model is created with pre stressing force through rebar is being applied at the joint with the help of the steel plates acting as the bearing. The column size is 200X800mm and the beam size of the model is 200X600 mm.To model the real world problem into any of the FE software we have to make few assumptions to simplify the problem. Below is the assumption which has been taken during modelling of the present work.

- Concrete is assumed to be behaving as isotropic and homogeneous.
- Steel rebar and steel plate are also assumed as isotropic and homogeneous.
- Steel rebar is model as bilinear material model with kinematic hardening model.
- No slip of rebar is assumed. Where ever the concrete element nodes and rebar nodes is coinciding it is taken as same. Leading to the perfect bonding between the concrete and rebar, and also between plate and concrete.

5.3.1 Element types used in ANSYS

When you are working in ANSYS concrete can be better model through the element named as SOLID65. According to the ANSYS literature, this element has eight nodes with three degrees of freedom at each node – translations in the nodal x, y, and z directions. This element is capable of plastic deformation, cracking and crushing in three orthogonal directions.
A Link8 or BEAM188 element is used to model steel reinforcement. LINK180 element is a 3D spar element and it has two nodes with three degrees of freedom at each node –

translations in the nodal x, y and z directions. This element is also capable of plastic deformation. This element can take either tension or compression only or both. This element can only take the square cross-section with only user can give the area of the element. But on other hand in BEAM188 you can give the desire shape from the dropdown table and can also add desire meshing to it. According to ANSYS v16.2, this element is based on Timoshenko beam theory. Shear deformation effects are included. BEAM188 is a linear (2-node) beam element in 3-D with six degrees of freedom at each node. The degrees of freedom at each node include translations in x, y, and z directions, and rotations about the x, y, and z directions. Warping of cross sections is assumed to be unrestrained. As this element is design for the beam behaviour but can also be used as rebar with better accuracy as compared to LINK8. The beam elements are well-suited for linear, large rotation, and/or large strain nonlinear applications.

Table 2: Element types for the control specimen

Material Type	*ANSYS Element*
Concrete	Solid 65
Steel Reinforcement	Link8&Beam188
Steel Plate	Solid185

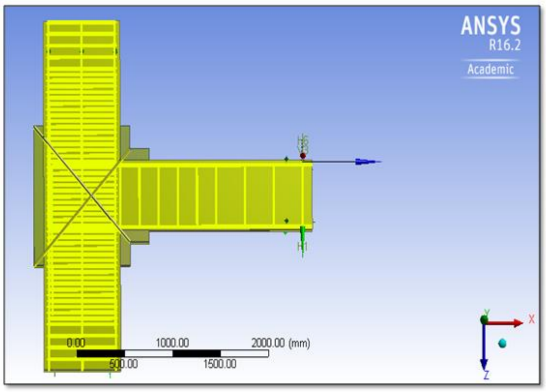

Figure 2: Pre stressed beam column joint ANSYS model

5.3.2 Meshing

For the better results of Solid65 element, it is always meshed as rectangular mesh, so, all the concrete Solid65 elements are meshed as rectangular element with small size. As there is no requirement of the meshing of the rebar element, it is joined as element between the spacing of the nodes created by the meshing of the concrete.

5.3.3 Load and Boundary Condition

Both the top and the bottom of the column are fixed. Column axial load (D) 40Kn acting at the top of the column face. For the result, a displacement 0.2m (I) applied at the end of the beam and pre stress applied in bar through bolt pretension (B&C) as 1026N/mm2 .A nodal force 25Kn(E) 300mm from the free end. Steel plate bonding kept as fixed (A, F&G). H is the effective lateral load as 0.24Kn from STAAD. Beam is kept as cantilever and point loads up to failure. These loading and boundary conditions are kept same for both type of Exterior Beam-Column Joint i.e. pre stressed and non pre stressed.

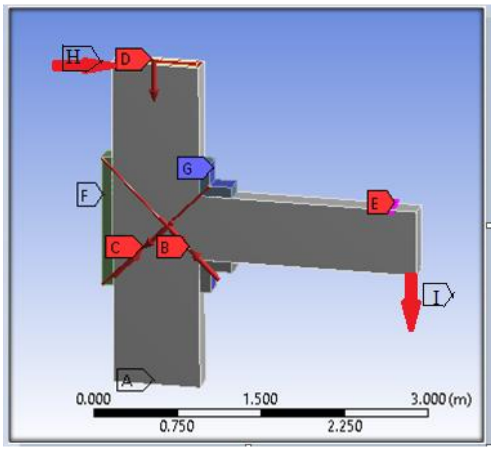

Figure 3: Loading and Boundary condition of joint

6. Results and Discussion

6.1Nonlinear ANSYS Results

Comparison of results between "The Pre stressed Beam-Column Joints" and "The Non Pre stressed Beam-Column Joints": Exterior Beam-Column Joint with pre stressed core as proposed by the present work. There extra two rebar are crossed running through the joint with the pretension. Plates are used just as the bearing to avoid the crushing of the concrete at the corner.

6.1.1 Comparison between crack of the both joints fixed condition

Two different convergence criteria are being used in the whole non-linear analysis of the exterior beam-column joints. In the first phase of analysis before the first crack in the concrete there is being no problem of the convergence so both force and displacement criteria. But after the first crack in the concrete, convergence was impossible. So after the convergence failure after the first crack, forced convergence criteria was dropped. And at the same time load steps are increased to consider the loss of stiffness due to increase in the crack of concrete.

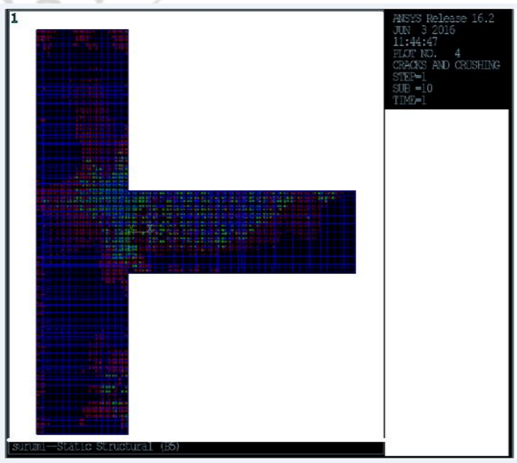

Figure 4: Crack and crushing of Non pre stressed joint

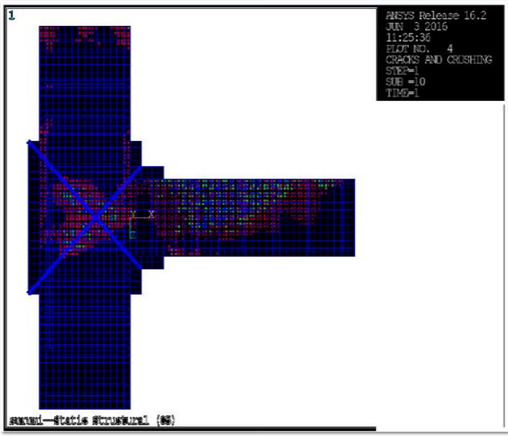

Figure 5: Crack and crushing of Pre stressed joint

6.1.2 Total nodal deformation under lateral load

As per the ANSYS result, the total deformation analyzed Pre stressed and non Pre stressed joint cases. The timely basis total deformation in non pre stressed joint has more nodal deformation than in pre stressed joint as shown in below

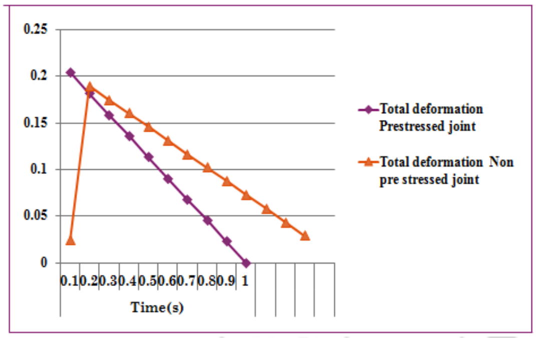

Figure 6: Graphical representation of nodal Deformation in both ends fixed joint.

6.1.3 Comparison between shear stress of joint core in both joints

From the ANSYS result, Maximum and minimum shear stress of joint core as shown in the below tables, in both cases.

Table 3: Non pre stressed joint core shear stress

Time (S)	*Minimum shear stress(Mpa)*	*Maximum shear stress(Mpa)*
0.1	-0.38	0.37
0.2	-0.56	0.56
0.3	-0.84	0.93
0.4	-2.56	2.09
0.5	-1.77	2.57
0.6	-1.87	2.64
0.7	-2.78	4.11
0.8	-5.05	4.65
0.9	-2.47	3.43
1	-2.45	5.96

Table 4: Pre stressed joint core shear stress

Time (S)	*Minimum shear stress(Mpa)*	*Maximum shear stress(Mpa)*
0.1	-0.374	0.37
0.2	-0.66	0.76
0.3	-0.91	1.55
0.4	-2.45	2.14
0.5	-1.62	2.95
0.6	-1.8	2.03
0.7	-3.12	3.1
0.8	-4.57	4.19
0.9	-2.41	5.98
1	-3.3	3.37

6.1.4 Total deformation under lateral load

From the ANSYS result, the total deformation in non pre stressed and Pre stressed joint (both ends fixed) as shown in the fig.

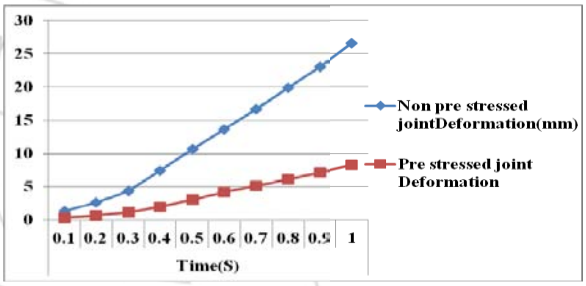

Figure 7: Graphical representation of Total deformation

7. One end fixed beam column joint condition

7.1 Comparison between shear stress of joint core in both joints:

Table 5: pre stressed joint core shear stress

Time (S)	*Minimum shear stress(Mpa)*	*Maximum shear stress(Mpa)*
0.1	-0.36	0.38
0.2	-0.62	0.56
0.3	-1.71	0.84
0.4	-2.82	2.55
0.5	-1.86	1.94
0.6	-2.69	2.95
0.7	-5.48	2.85
0.8	-5.47	3.58
0.9	-3.96	2.58
1	-3.59	4.06

Table 6: Non pre stressed joint core shear stress

Time (S)	*Minimum shear stress(Mpa)*	*Maximum shear stress(Mpa)*
0.1	-0.39	0.37
0.2	-0.57	0.71
0.3	-1.43	1.04
0.4	-2.49	2.64
0.5	-1.82	2.36
0.6	-2.84	2.71
0.7	-3.19	2.98
0.8	-4.5	5.4
0.9	-4.48	5.63
1	-3.23	6.67

7.2 Total deformation under lateral load

From the ANSYS result, the total deformation (one end fixed) in non pre stressed and Pre stressed joint as shown in the fig.

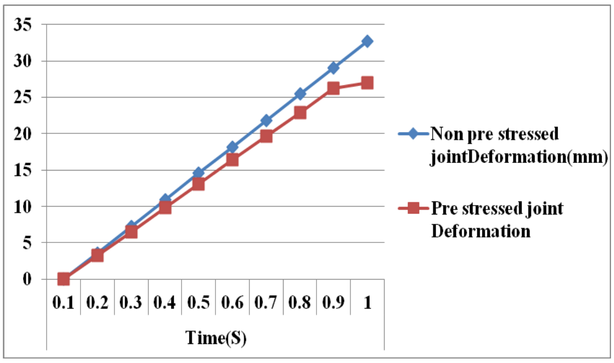

Figure 8: Graphical representation of Total deformation

Due to cross pre stressing, in joint can be reduced some percentages of reinforcement in the confined length as per IS13920:1993(lo length)

$$\frac{1026 \text{ X } 2}{415} = 6 \text{ bars}$$

Each side 3 bar with spacing @50mm = 3X50 = 150 mm

Total spacing = 800 mm

$$\%\text{ reduced spacing} = \frac{800-650}{800} = 0.1875$$

$$= (1-0.1875)$$

$$= 0.81$$

Confinement length = 0.8lo= 20% reinforcement can be reduced.

8. Conclusion

- The total deformation in non pre stressed beam column joint is 3 times more than the pre stressed beam column joint under lateral load condition.
- Crack location in joints shifted to the beam in pre stressed beam column exterior joint.
- Shear strength of joint core in pre stressed exterior beam column joint is 76.85% in terms of (stress reduction factor) improved than the non pre stressed beam column joint.
- One end fixed condition of non pre stressed and pre stressed beam column joint is also be analyzed, and the crack location in joints shifted to the beam in pre stressed beam column exterior joint and also cracks be reduced.
- In one end fixed condition Shear strength of joint core in pre stressed exterior beam column joint is 64.20% improved than the non pre stressed beam column joint.
- In confinement length 20% reinforcement can be reduced.
- Due to crossed pre stressing with the rebar, strut and tie model has been invoked in the joints enhancing &crack resistance in the joints.
- With pre stressed rebar acting as tie enhances the crack resistance in the joint.

9. Future Scope of the Study

In this case, only analysed with timely depended static load condition, it can be analysed with seismic vibration analysis too.

References

[1] Prabu N. J. and Dr. Kandasmy S. “Study on Behavior of RCC Beam Column Joint With Special Confinement Subjected To Static Loading Numerical Investigation” ISSN: 2350-0557, Volume-3, Special Issue-1, April-2015.

[2] G.Appa.Rao and V.Navya “strengthening of shear deficient RC beam-column joints in MRFS under seismic loading”. VIII International Conference on Fracture Mechanics of Concrete and Concrete Structures.2014.

[3] Thomas H.K.Kang and Mitra N. “Prediction and performance of Exterior Beam-Column Connections with the headed bars subjected to load reversal”. Engineering Structures 41(2012) 209-217, 2012.

[4] Pimanmas, P. and Chaimahawan, P. “Cyclic shear resistance of Expanded Beam-Column Joint”. Procedia Engineering 14(2011) 1292-1299.2011.

[5] Pimanmas, P. and Chaimahawan, P. “Shear Strength of Beam-Column Joint with Enlarged Joint area”. Engineering Structure. 2529-2545.2010.

[6] Ghobarah, A., and Said, A. “Shear Strengthening of Beam-Column Joints”. Engineering Structure 24, 881–888. 2002.

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