The Study of Failure in Beam - Column Joints

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Abstract - **The present work is divided into two phase. In first phase few sample of normal low and medium high building has been chosen and designed according to the IS 456:2000(LSD) and shear force are calculated as per ACI 352-02. From this phase we come to conclusion that first two stories have higher shear force demand and these are the joints more susceptible to congestion and prestessing of joint core should be implemented to these joints only. In the second phase two exterior beam-column joint from previous experimental programme. They were model and analyse using ANSYS v13. Improvement in the ultimate load and failure pattern has been detailed in the thesis. From this phase we come to conclusion that this new technique is more effective than the previous prestressing technique of joints.**

Keywords: **Beam-column joint, RCC, Crossed-rebar, Prestress, ANSYS, Shear force.**

INTRODUCTION 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. Detailed version will be discussed in the literature review section. Here we will over view the status of estimation and contribution of shear deformation in the global deformation of the building. Following are the deformation model propose in the timeline orders

1. Conventional rigid joint model
2. ASCE/SEI 41-06 joint model
3. Modelling inelastic joint action within the beam-column element
4. Rotational hinge models
5. Continuum models and FEM

1.5 OBJECTIVE

- With introduction presented in this chapter and literature review in the next chapter the salient objective of the present study is presented below:
- To find the joint height which is more critical from the point of view of reinforcement congestion and maximum joint shear demand.
- To find the effectiveness of the direct joint prestressing to divert the failure from the joint to the beam by reducing the shear demand at the joint by combine effect of crossed rebar and prestressing.

1.6 SCOPE OF THE STUDY

Following are the scope of the present study

- As most of the congestion problem came in the high rise building but only low-rise and midrise building as it can be justified because most of the building in India fall under these range.
- Bond slip has not been considered but it is very obvious that due to confining the band capacity will also increase preventing the damage due to slip of the rebar.
- As the dynamic nature of any earthquake is most critical for the damage of the joint but for study static loads has been applied to study the effect of the prestressing of beam-column joint.

1.7 METHODOLOGY

The present work is divided in two phases. The first phase is to find the critical joints with respect to the reinforcement congestion and shear force demand. And second phase deals with the effectiveness of the direct prestessing of the beam-column joint in mitigating the brittle failure at the joint to the ductile failure in the beam. An introduction to methodology of both phase are presented here. More detailed one is presented in the chapter 3.

First Phase Methodology:

1.Few samples of the low and midrise 2D building are selected with standard dimensions and standard loading.

2. All building is being designed as per IS 456:2000(LSD).

3. Shear force has been calculated as per ACI:352-02

4. Critical joints have been shorted out on which the prestressing is being applied as going to be proposed in the phase 2.

The Following outcome from the phase I

- That joint name E1 shear demand is more for only up to two- story building(fixed support) and thereafter E2 shear demand is leading. From this figure it is clear that joint shear demand of the 2nd story level is critical but the gap of difference goes on decreasing as the number of story goes on increasing.
- It is also plotted on the same data but with respect to floor level (fixed support). As you can see that first story joint shear demand is less as compare to the above few joint but again the shear demand decrease very fast. This trend is same for all type of story.
- This figure shows the shear demand of the joint at the various levels with increasing number of story for the hinge support. As you can see that due to hinge support there is drastic increase in the first level of joints.
- This figure is showing the variation of shear demand due to increase in the story height of the building with the fixed support. Form the figure we can simply interpret that increasing the height of story increase the shear demand of the building.
- This is same as plotted but this is for the hinge support. And you can directly see that hinge support increase the shear demand of the first story. We can simply say that increasing the height of the story increase the shear demand of the joints.
- This figure shows the effect of width of bay on the joint shear demand for the fixed support. This figure is clearly showing the positive effect of the width of the bay on the shear demand. As you can see the increase in the bay width from 3m to 4m the shear demand got double for both E1 and E2 joint.
- This figure is showing the same effect of bay width on the shear demand of joint but for the hinge support. And you can see the jump in the shear demand from 500kN to 900kN. This conclude that the making the support hinge increase the demand of the joint.
- This figure is showing the effect of number of bay on the shear demand of the joints. From the figure it is clear that the increasing the number of bay has not significant effect on the joint shear demand of the joint.
- This figure is showing the effect of depth of beam on the shear demand of the joints. Clearly from the graph it can be proved that the increasing the depth of beam decrease the shear demand of the joint. So, if we want less shear demand at the joint we can increase the depth of beam.
- This figure shows the effect of grade of concrete on the shear demand of the joint. As you can see that there is no significant effect on the shear demand on the joint due to change in the grade of concrete

Second Phase Methodology:

1.Two exterior beam-column joints which were going to fail at joints due to shear failure have been selected from the literature.

2.Both the joint has been modelled in ANSYS v13 as per the experiment performed in the literature to verify the result.

3.Direct prestressing is implemented in ANSYS model on both of the joints to see the improvement in shear deformation, shear strength, shear demand and failure pattern

4.2 PHASE II: Nonlinear ANSYS Results:

Comparison of results between “The Traditional Beam-Column Joints” and “The PrestressedBeam-Column Joints”: B1: Exterior Beam-Column Joint with core stirrups as experimentally tested by ***Dar (2011)*** D1: Exterior Beam-Column Joint with prestressed core as proposed by the present work. There extra three rebar are crossed running through the joint with the stain of 0.005. Plates are used just as the bearing to avoid the crushing of the concrete at the corner.

1. **Comparison between crack of the both joints:**

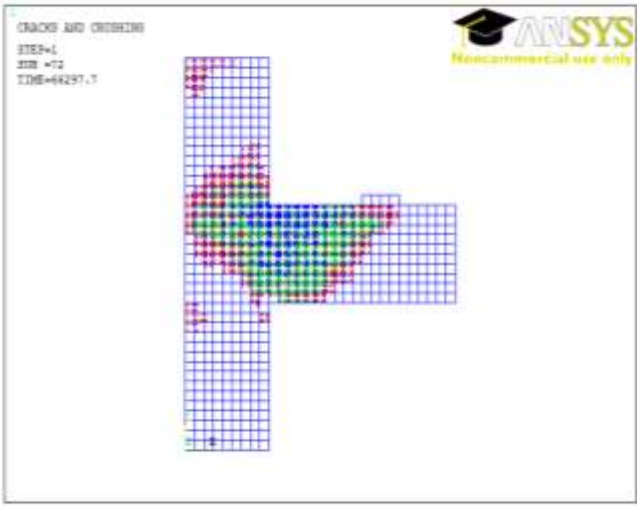

Fig. No. 1: Cracks pattern of B1 at the ultimate loads of 66.3kN

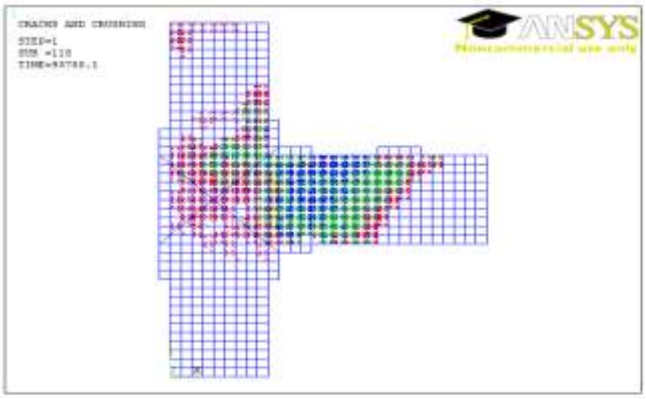

Fig. No. 2: Cracks pattern of the D1 at the ultimate load of the 93.7kN

2. **Comparison of the shear stress distribution in the joints of both type:**

Fig. No. 3: Shear stress distribution of the B1 at the ultimate load 66.3kN

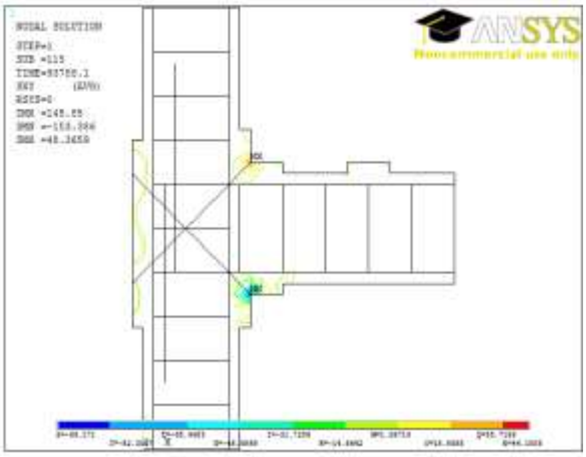

Fig. No 4: Shear stress of the D1 at the ultimate loads of 93.7kN

4. Comparison of the total mechanical shear strain:

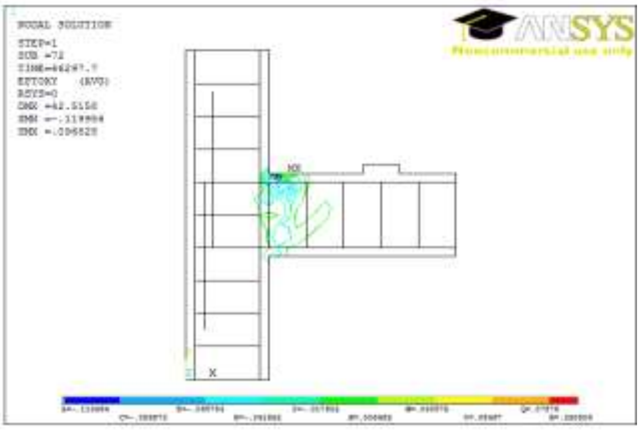

Fig. No. 5: Shear strain of the B1 at the ultimate loads of the 66.3kN

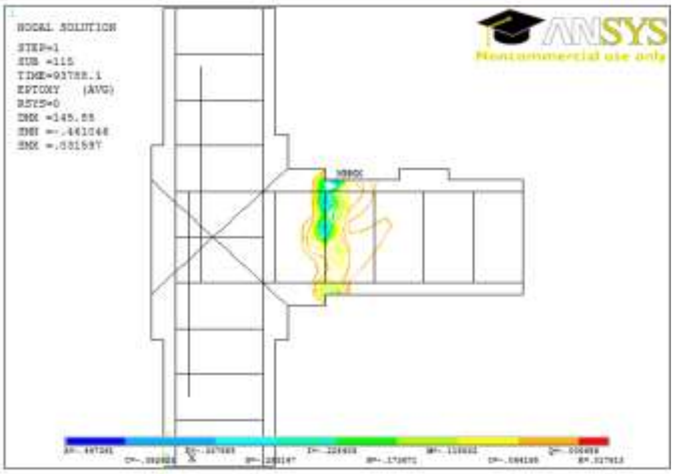

Fig. No. 6 : Shear stain of D1 at the ultimate loads of the 93.7kN

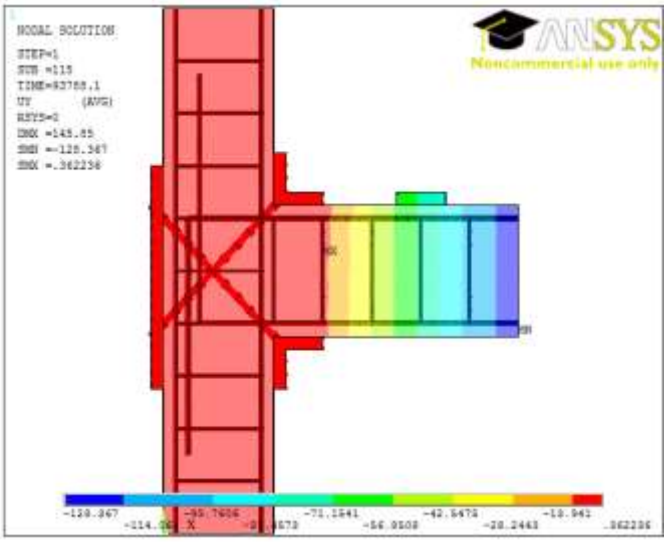

Fig. No. 7: Shear stain of D1 at the ultimate loads of the 93.7kN

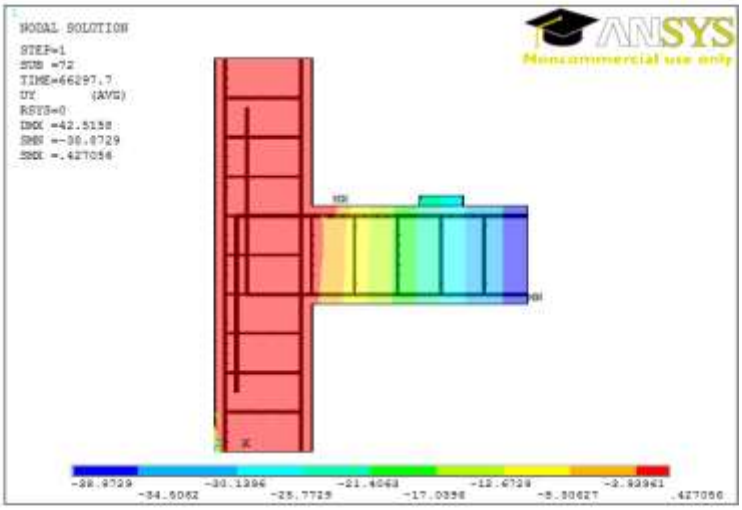

Fig. No 8: Deflection profile of B1 at the ultimate load of 66.3kN

CONCLUSION

Following are the conclusion,

Maximum joint shear demand are located at lower portion of building, starting from second story joint for both interior and exterior joints for the fixed support.

- Maximum joint shear demand is located at first story joints for the hinge support condition for the both interior and exterior joints.
- The ratio of height of maximum shear to building height is coming out as 0.4 for the fixed support.
- Shear forces demand increases with the increase of the Number of Story, Height of story, Width of Bays and Decreases with the Increase of Depth of Beams.
- Grade of Concrete, Number of Bays and Size of Columns has no effect on the demand of the shear forces in the beam-column joints.
- Due to prestressing the Exterior Beam-Column Joints there has been increase in the shear strength of the concrete in the joint core. But model for the calculation of the shear strength of concrete in the prestressed beam-column joints has not been presented in the present work.
- Due to crossed prestressing with the rebar, strut and tie model has been invoked in the joints enhancing the performance of the joints. With prestressed rebar acting as tie enhances the crack resistance in the joint and consequently enhance the strut concrete performance which will act as better than without stressed post crack condition.
- Due to presence of the steel plate at the face of the Beam-Column joint, plastic hinge shifted at the edge of the plate. This shifting of the hinge toward the centre of the beam leads to the less lateral displacement at same given rotation at plastic hinge.

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