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AN ANALYTICAL APPROACH FOR DETERMINATION OF JOINT SHEAR DEMAND IN EXTERIOR BEAM-COLUMN JOINT USING STAAD.PRO

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ABSTRACT

History has seen much destruction of structures due to joint failures during earthquakes. Beam-column joint failure is the major cause for such destructions. Therefore major concern is given in refurnishing their behaviour. While considering the core behaviour, there is need to calculate joint shear demand also. In earlier days scientists have considered that beam-column joints 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. Here through this analytical approach an attempt is made to understand the behaviour of joint core and joint shear demand. For this purpose 2d mid to low rise building models with some predefined parameters are considered and modelled in STAAD Pro V8i software. These models were designed by using Limit State Design Method as per IS 456:2000. The joint shear demand is then calculated as per ACI 352-02. The results of analytical approach with considered parameters are then discussed briefly and conclusions are drawn.

KEYWORDS: Exterior Beam-column Joint, Joint shear demand, Joint core behaviour and STAAD Pro.

INTRODUCTION

The portion of the column where beam is use to join it is called beam-column joint. Beam column joints are classified into three types based on the number of beams ending into the column

i) Interior Beam-Column joints
ii) Exterior Beam-Column joints
iii) Corner Beam-Column joints

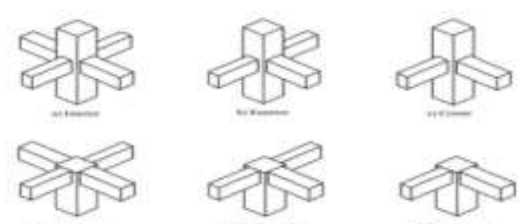

Fig: 1 Types of Beam-Column Joints (ref: ACI 352-02)

Beam-column joint is subjected to very high shear forces due to pulling of top rebar and pushing of bottom rebar's or vice versa in the concrete structure especially during the earthquake loading. Such high shear forces leads to the brittle damage, those are not permissible and leads to failure of structure. Earlier in 1970's no codes has provided the joint confinement which leads to the major devastation like Kacholi earthquake Turkey, 1999 and many more which had change the thought of researcher about joints To prevent the damage due to joint shear failure they come up with idea of joint confining with the rebar. Confining the Beam-column joints isn't so easy because there are already rebar coming from three directions. With the extra provision as per the present codes confining stirrups leads to the problem of the congestion as shown in the Fig. 2.

Fig. 2 Congestion at the Beam-Column Joints (ref.: www.concreteconstruction.net)

SPECIFICATION OF MODELS

The buildings considered for this purpose are mid to low rise buildings as number of such buildings are more than high rise buildings in India. Many parameters which may influence joint shear demand are considered and buildings are modelled accordingly in STAAD-Pro software V8i. The Limit State Method is followed for the designing as per IS 456:2000. Joint shear demand is calculated as per ACI 352-02. Joints having maximum shear demand values are identified and are considered for the final conclusions.

Following are the range of parameters which has been taken for the parametric studies.

1. Story heights: It varied from 3m 3.5m and 4m in the reference buildings.
2. Number of story or height of the building: It is varied from 2nd story to 10th story with each as 3m of height.
3. Width of the bays: Bays width has chosen as 3m 4m and 5m
4. Number of the bays: number of bays has also be chosen as 3 4 and 5
5. Grade of the concrete: Grade of the concrete is taken as 30MPa, 35MPa, 40MPa, 45MPa, 50MPa, 55MPa and 60MPa.

   Size of the beams: Size of the beam are varied from 350, 400, 450 and 500mm
7. Size of the columns: The sizes of the columns have been change from 400mm, 450mm, 500mm, 550mm and 600mm.
8. Material: M25 and Fe415
9. Earthquake Zone: V
10. Soil type: II
11. Response Reduction Factor: 5
12. Importance Factor: 1

One designed model with all these parameters is shown in figure below:

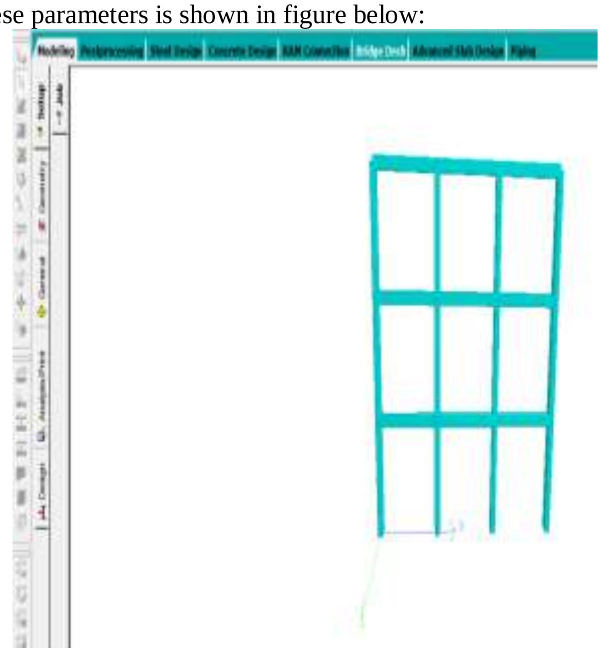

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Fig. 3 3D rendered view of model in STAAD-Pro

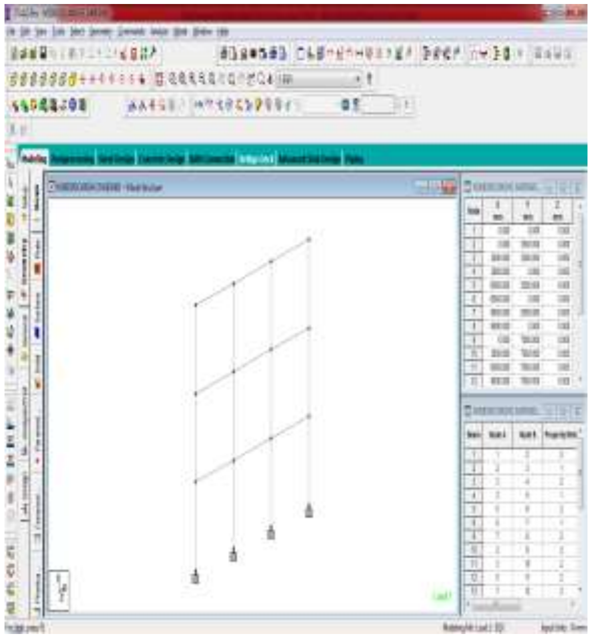

Fig. 4 Structure of model in STAAD-Pro

ANALYSIS OF MODELS

The joint shear demand is calculated as per ACI 352-02 by formula of Column shear in the joint as,

$$V_c = 1.4 \text{ X } \frac{Mh+Ms}{h}$$

Where,
M_h = Hogging moment of the beam connecting to the joint.
M_s = Sagging moment of the beam connecting to the joint.
h = Height of the story.
From the equilibrium of the force in the joint, joint shear demand,
$V_j = T_1 + C_s + C_c - V_c$
$C_s + C_c = T_2$
$V_j = T_1 + T_2 - V_c$
Where, T_1 = tensile force in the bar = 1.25 x f_y xA_{st1}
T_2 = tensile force in the bar = 1.25 x f_y xA_{st2}
C_s = compressive force in steel
C_c = compressive force in the concrete

RESULTS

The study of joint core behaviour and joint shear demand is done considering various parameters. Followings are the parameter which has been checked to understand their influence on the joint shear demand. And following that the graph has been shown to discuss how they are affecting the shear force demand of the joints.

1. Support conditions
2. Number of story
3. Width of the bays
4. Size of the beam
5. Grade of the concrete

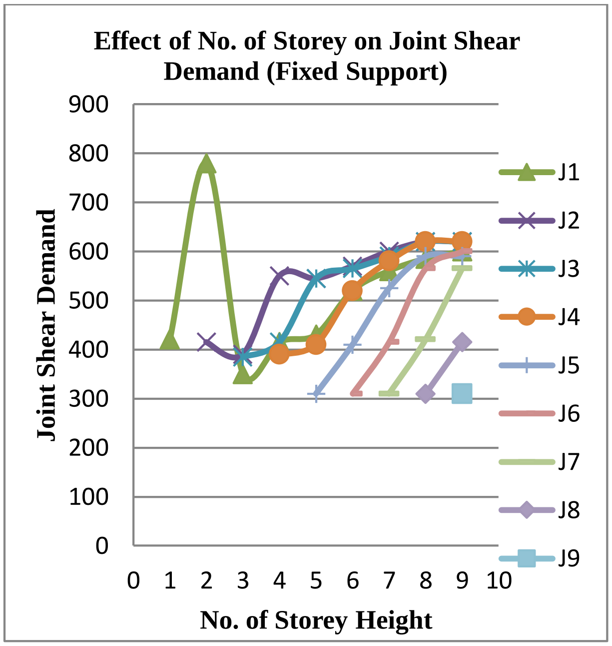

Fig. 5 Effect of No. of Storey on Joint Shear Demand (Fixed Support)

From this graph joint named as J1 shear demand is more for only up to two-story building (fixed support) and thereafter J2 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.

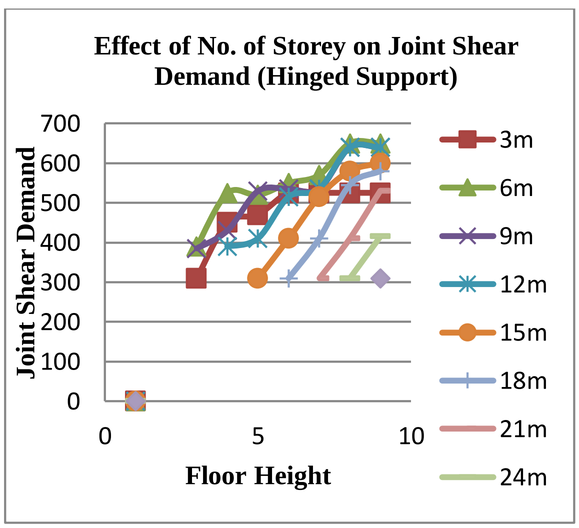

Fig. 6 Effect of No. of Storey on Joint Shear Demand (Hinged Support)

This graph is also plotted on the same data but with respect to floor level (hinged 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.

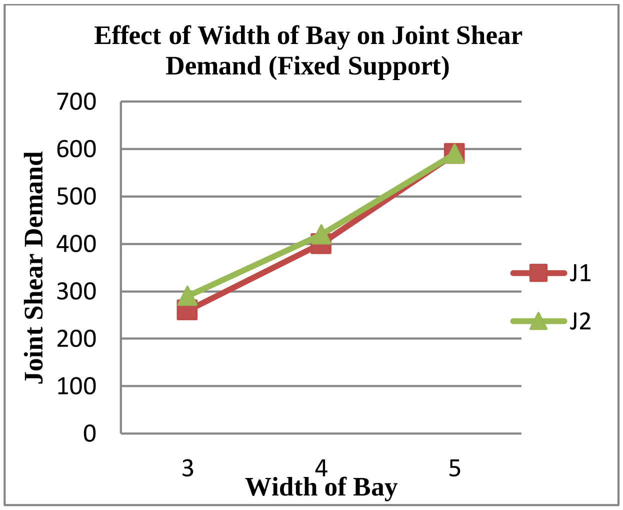

Fig. 9 Effect of Width of Bay on Joint Shear Demand (Fixed Support)

This graph shows the effect of width of bay on the joint shear demand for the fixed support. This clearly shows that there is 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 J1 and J2 joint.

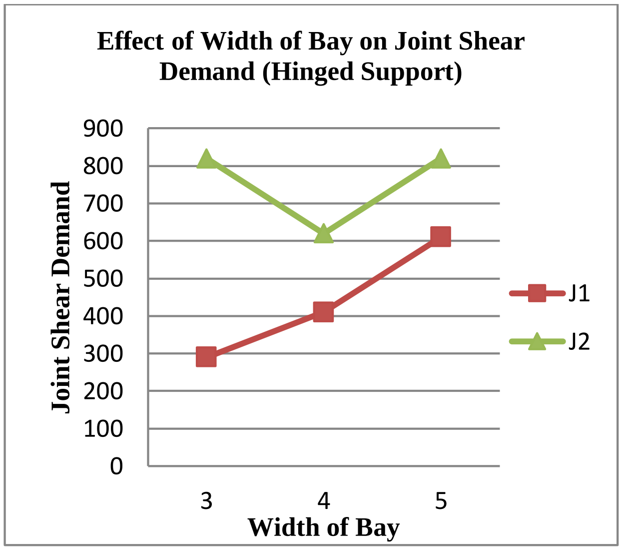

Fig. 10 Effect of Width of Bay on Joint Shear Demand (Hinged Support)

This graph is showing the same effect of bay width on the shear demand of joint but for the hinge support. It is seen that joint shear demand jumps directly for almost double value. This conclude that the making the support hinge increase the demand of the joint.

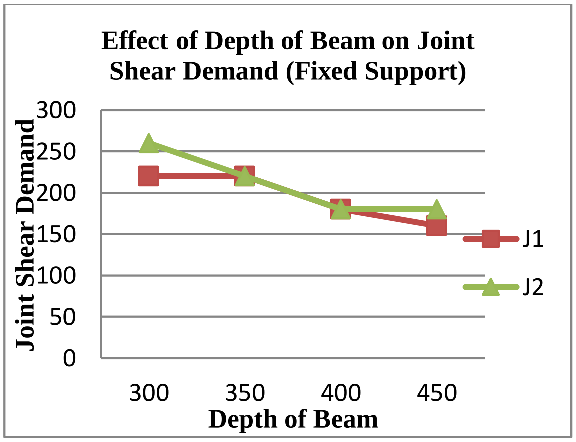

Fig. 12 Effect of Depth of Beam on Joint Shear Demand (Fixed Support)

This graph is showing the effect of depth of beam on the shear demand of the joints. It is clearly seen from the graph 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.

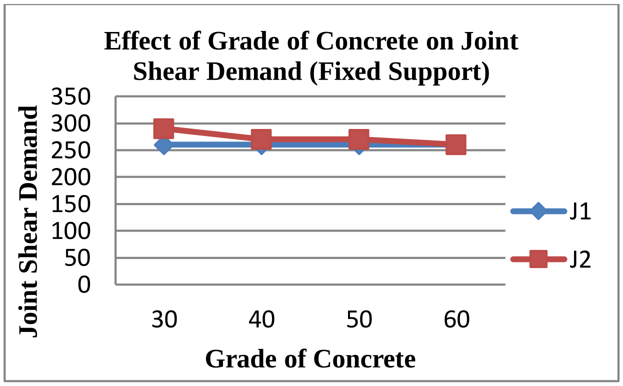

Fig. 14 Effect of Grade of Concrete on Joint Shear Demand (Fixed Support)

This graph 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.

CONCLUSIONS

The following are point-wise conclusions which are being drawn from the proposed Exterior Beam-Column Joints with:

1. 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.
2. Maximum joint shear demand is located at first story joints for the hinge support condition for the both interior and exterior joints.
3. The ratio of height of maximum shear to building height is coming out as 0.4 for the fixed support.
4. Shear forces demand increases with the increase of the Number of Story, Width of Bays and Decreases with the Increase of Depth of Beams.
5. Grade of Concrete has no effect on the demand of the shear forces in the beam-column joints.

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