International Journal of Research in Advent Technology (E-ISSN: 2321-9637) Special Issue
International Conference on Technological Advancements in Structures and Construction
"TASC- 15", 10-11 June 2015

Study of Hybrid Precast Beam Column Connection

Fasil V P[1], Dr. P R. Sreemahadevan Pillai[2]
Department of Civil Engineering, NSS College of Engineering[1, 2],
MTech student[1], *Professor* [2]
Email: fasilvp018@gmail.com[1]

Abstract- Connections are the vital element in the precast construction. A new type of connection which is having the aesthetics of hidden corbel is investigated in this study. This type of connection can be used as simply supported as well as moment resisting type in precast skeletal frames. Both the cases are evaluated in this study. In simply supported case confinement has a major role and hence it is investigated. STRAND7 software is used for the confinement study. In moment resisting type of this connection, a mathematical model of failure by using elementary solid mechanics is used to calculate stiffness of connection. By incorporating this stiffness performance is evaluated. ETABS software is used for this study. In the performance evaluation the behaviour of precast building with different types of precast connections are compared. From the confinement study, stress distribution at the support region is studied and the importance of the stiffener in the connection is identified. From the performance evaluation it is identified that the semi rigid connection with shear wall is performing better than ordinary monolithic connection model.

Index Terms- Precast frame; moment-curvature; hidden corbel connection; confinement; hybrid connection

1. INTRODUCTION

Precast construction is the new trend in the modern construction scenario. It consists in building a complex structure by connecting prefabricated concrete elements such as precast columns, precast beams, stairs etc… which aids in the fast construction and the good quality products since the precast elements are produced in the factory following stringent quality criteria. Moreover, prefabrication allows the use of elements of complicated shape without construction difficulties or expensive formwork elements. Connections are the vital parts in pre-cast structures. So numerous studies are involving in the research field with regards to the connections.This also have a role in aesthetics also. So the development of new connection should take into consideration of this factor also. This study focusses on a connection having the above advantages.

2. PROBLEM IDENTIFICATION

A new type of connection which is having the advantage of using as simply supported as well as moment resisting type is evaluated in this study. The moment resisting connection is achieved by welding the reinforcement of the beams to the back plate of the hidden corbel. In the simply support case the concrete filled hidden corbel area acts as a composite concrete construction. The major factors affecting in the simply supported case are anchorage length and the composite action and hence confinement of the concrete inside the connection is studied by using STRAND7 Software. When we use this connection as moment resisting then a semi rigid type connection is obtained. Connections of precast construction play an important role in affecting the behaviour of the complete structure because the amount of moment-transfer is controlled by the joint characteristics. Hence performance evaluation of this type of connection is done for a G+4 building by using ETABS Software.

3. CONFINEMENT STUDY

3.1. *Specimen details and methodology of FEA*

For this study a precast beam of span 5 m is designed. The beam dimension used is 300x500 mm. Large beam dimension was chosen in order to develop high shear force at the supports because study focusses on the support region. By incorporating the dead load, live load and partition load the total load is 18.875 kN/m. Corbel bottom length is designed as 50 mm by considering the bearing stress as 45 f_{ck}.

Considering the methodology of FEA, STRAND7 software is used for the study. Initially a 2D Model is prepared as per the specimen details without steel shoe. 3D Model is developed by modelling only steel shoe region. After that by collecting the stresses from the elements of the 2D model passing through the interior face of the steel shoe is found out and by converting it into normal and shear stresses it is applied to the 3D model.

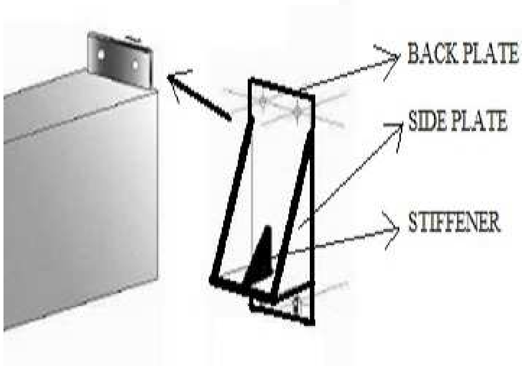

Fig. 1.Precast Connection with stiffener

3.1.1. *Modelling and meshing of 2D model*

Model is made up of Q8 Plate elements. Meshing is done manually for result verification. Meshing is done by classifying the model into zones. Zones are meshed such that elements having almost square shape

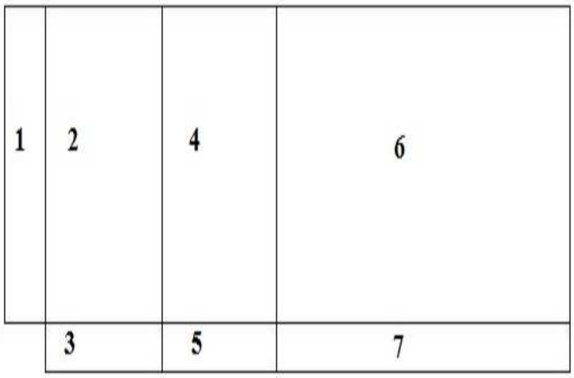

Fig. 2.Zones for 2D Modelling

3.1.2. *Methodology of stress strain curves employed*

Stress in the concrete in compression is defined as negative and tension as positive. For zone 1 in which there is no reinforcement stress strain curve of concrete is provided. For all other zones a modified stress strain curve which incorporates the tension resistance by reinforcement and compression resistance by concrete is given. The usage of modified stress strain curve for all other zones except zone 1 is justified because the investigation focusses on the stress distribution at support region and moreover the advantage of allowing tensile field in modified stress strain curve is that stress distribution can get directly from modelling.

3.1.3. *Simulating stress distribution due to stiffness of support*

Truss elements are used to simulate the support and are then connected to the Q8 plate element at the support region. The truss element length is 55mm. There are total 8 nodes to attach these truss elements at the support region. That is 4 plates (155, 156, 157, 1).Standard uniaxial truss deformation equations are used to simulate the stiffness at the support. The spring stiffness of plate 155 is assumed and the stiffness of the other plates are calculated by similar triangles.

Table1: Plate stiffness

Plate q8 element	**Distance between node 1 to each Q8 element**	**Spring stiffness**
155	12.5	12000
156	25	6000
157	37.5	4000
1	50	3000

After the calculation of spring stiffness each is to be distributed to the nodes. Each Q8 plate distributes the

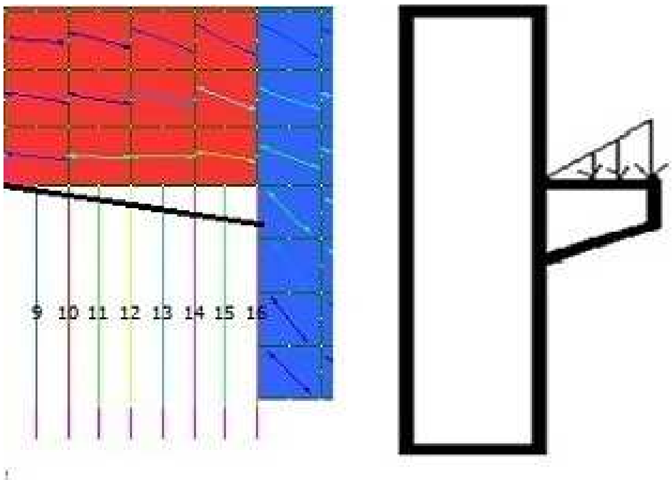

Fig. 3.Truss elements attached to plate and required stress distribution

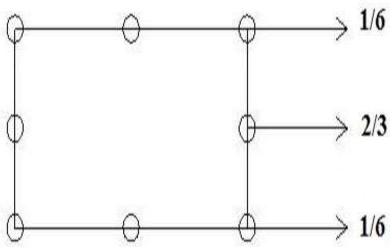

Fig. 4.Stress distribution to nodes in a Q8Plate element

stiffness through its nodes in the proportion given in the fig4.

Spring stiffness corresponding to the consistent nodal load from each Q8 plate element to its nodes is calculated and area of each truss element is determined. This area used for truss modelling.

Table 2:Truss stiffness

Node	Stiffness	Belonging to q8 element		Belonging to truss element	Area(mm^2)	Corresponding dia(mm)
581	8000	155		9	2200	52.92
582	3000		156	10	825	32.41
583	4000			11	1100	37.42
28	1666.6	157		12	458.33	24.15
584	2666.6			13	733.31	30.55
585	1166.6		1	14	320.83	20.21
586	2000			15	550	26.46
3	500			16	137.5	13.23

3.1.4. *Verification of FE 2D Model*

The 2D model is verified by using shear force calculation. Shear force at a particular section is calculated from the FE model and it is compared with the shear force calculation at the same section by using basic mechanics.

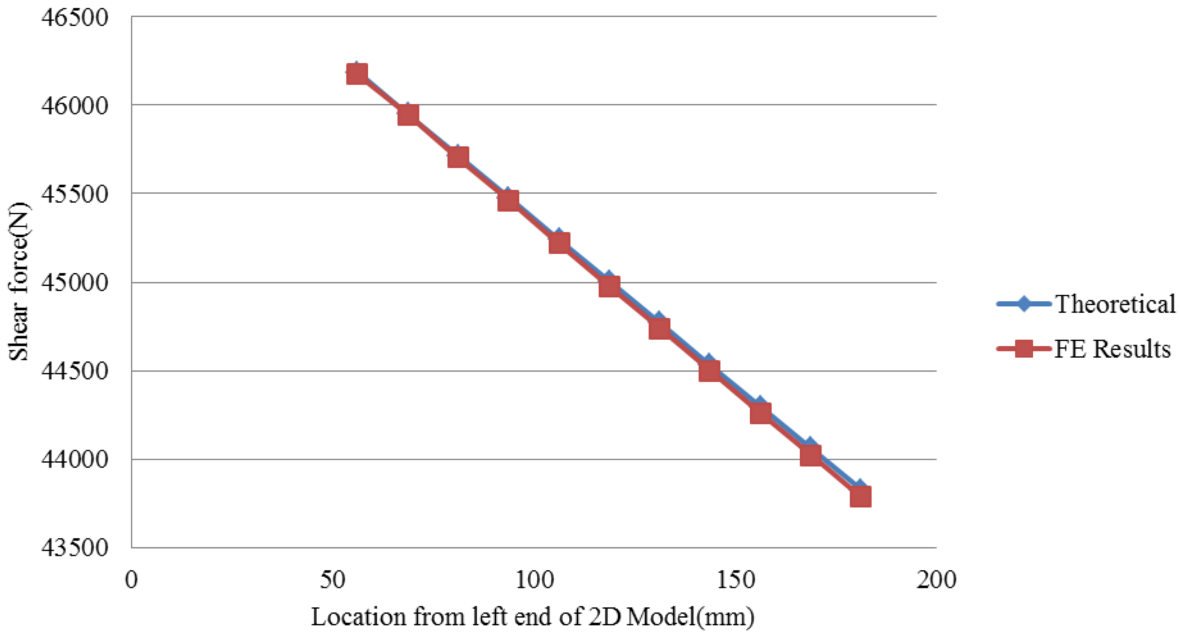

Fig. 5.Verification of FE model(shear force calculation)

3.1.5. *Modelling and loading of 3d model*

Elements used are shell elements for plates and 20 noded hexahedron brick elements for modelling concrete.The stresses of plates of the 2D Model passing through sloping line of side plate in steel shoe region is collected from the STRAND7 Database and converted into normal stress and shear stress and applied to the surface of the 3D Model brick element as shear stress and normal stress.

3.2. *Results of confinement study*

From the 2D Analysis the stress distribution near to the connection is identified and from the analysis of the 3D Model confinement of concrete inside the shoe of connection with and without stiffener is studied and it

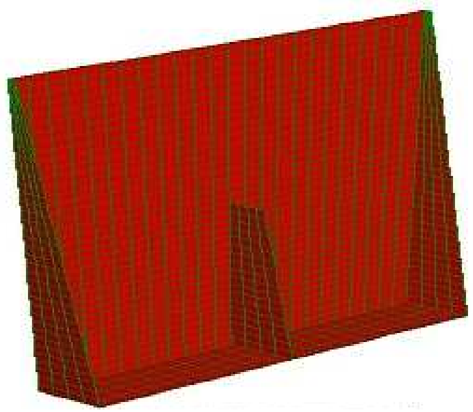

Fig. 6.Precast connection shoe with stiffener

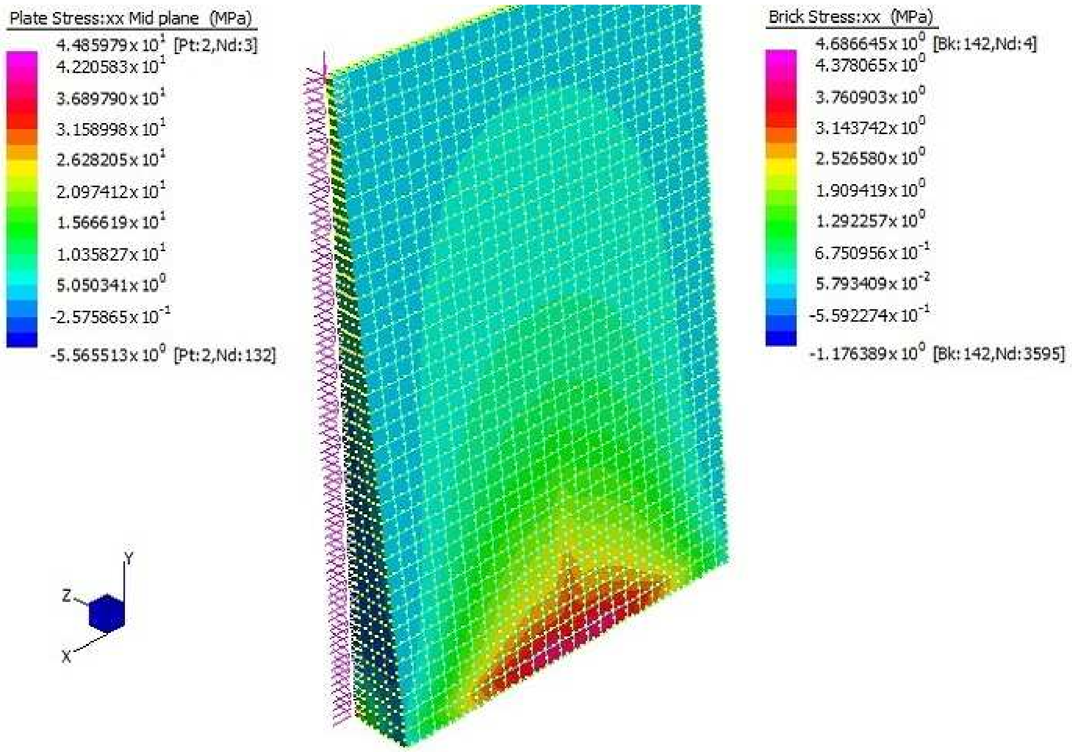

Fig. 7.Confinement results of precast connection shoe with stiffener

is identified that with stiffener the confinement is highly increased which is a direct factor for proper composite action of the connection shoe and moreover which prevents the pullout of reinforcement to a great extent.

The fig7 and fig8 illustrates the stress distribution in the 3D Corbel for comparison of confinement in the 3D Model.

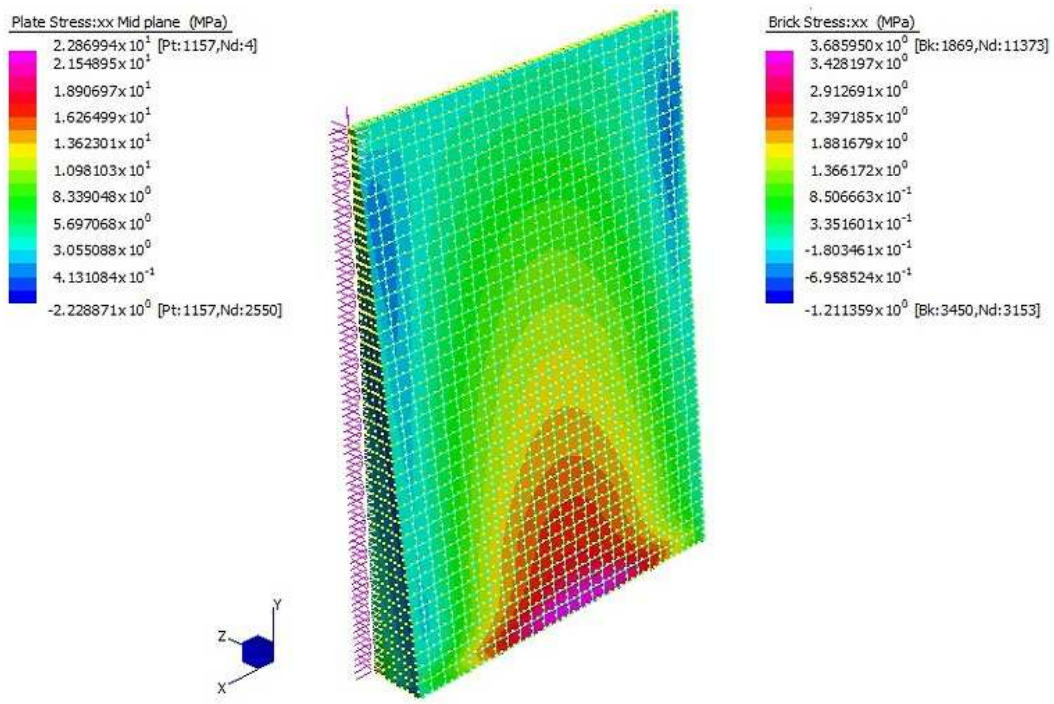

Fig. 8.Precast connection shoe without stiffener

4. MOMENT RESISTING HYBRID CONNECTION

The hybrid connection involved in this study can also be utilized as moment resisting connection by welding the beam reinforcement to the bottom and back plates of the hidden corbel. Hence we get a partially rigid connection.

b=width of the plate

d=effective depth of the beam

θ2=Rotation due to bending of plate

θ=Total rotation

t=Thickness of plate

t_w=Thickness of washer

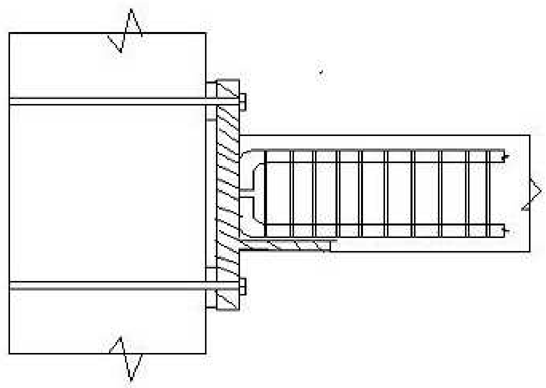

Fig. 9.Conceptual model of semi rigid hybrid connection

4.1. *Mathematical Model*

The mathematical model is made up of basic mechanics equations.

$$\Delta=(M\div h)/((t+t_w)/(N_bA_bE_s)) \quad (1)$$
$$\theta_1=\Delta/h=(4M(t+t_w)/(\pi N_bh^2d_b^2E_s)) \quad (2)$$

$$E_sI_{plate}\theta_2=M[\{(h-d)^3/12h^2)\}+\{d(h-d)(3h-2d)/(24h^2)\} \quad (3)$$

Hence we can obtain θ_1 and θ_2

$$\theta= \theta 1+ \theta 2 \quad (4)$$

Nb=No. of bolts

Iplate=Moment of inertia of plate

The slope of M- θ Curve gives the stiffness of the joint.

4.1.1. *Proposed design procedure for back plate and bolts*

1. Draw the shear force and bending moment diagram of the beam

2. As per the shear force calculated find the number of bolts required and the diameter of the bolts.

3. As per the applied moment find the diameter and

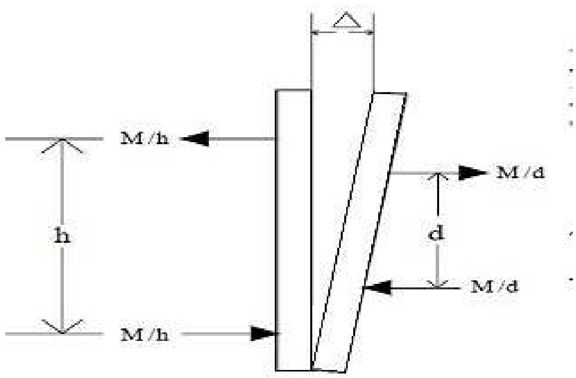

Fig. 10.Assumed failure mode

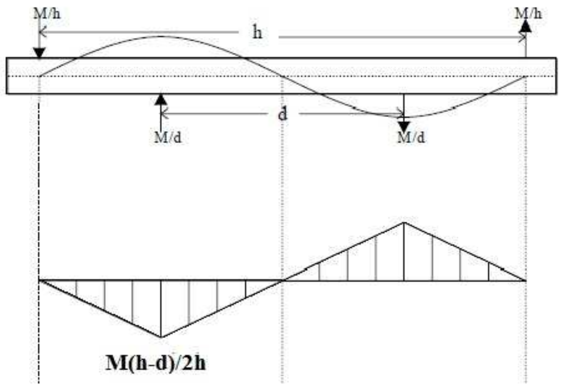

Fig. 11. Assumed failure mode

number of bolts from the equation below.

$A_b = (M/h)/(N_b f_b)$ (5)

$d_b = \sqrt{(4M/(\pi N_b h^2 d_b^2 E_s)}$ (6)

4. Use the largest diameter obtained from the step 3 and 4.

5. Calculate the stiffness of the joint from the proposed method for stiffness calculation.

6. Model in SAP2000 or ETABS by using the feature of partial fixity factor.

Table3:Connection details

t	t_w	Nb	H	dia	d	b
20mm	2.7mm	4	480mm	20 mm	410 mm	300mm

M=8.65E-11XΘ

Hence stiffness=11557.02 KNm/radian

This stiffness is incorporated into the model by using partial fixity factor.Thickness of shear wall employed in the model is 150 mm.

4.2. *Performance Evaluation*

4.2.1. *Model Details*

A 5story 3bay building with a story height of 3m is used for the study. All beams having the dimension of 300x450 mm and columns having the dimensions of 400x400 mm.A live load 2.5 Kn/m^2 is used for the study. Lateral loads are applied as per IS875 and IS1893.Earthquake load is applied by equivalent static method. The parameters of the connection are given in the table below

4.2.2. *Modelling Cases*

Six models are prepared for performance evaluation in which three connections are compared and studied with and without shear wall.The three connections used for comparison are pinned,fixed,semirigid hybrid connection. The connections are notified as PNS(Pinned with no shear wall),PWS(pinned with shearwall),SNS(semi rigid with shear wall),SWS(Semi rigid with shear wall),FNS(fixed with no shear wall),FWS(fixed with shear wall)

4.2.3. *Load Combinations*

Load combinations as per IS1893:2002 is used for this study. Loads considered are dead load (DL), live load (LL), wind load (WL), Earthquake load (EL)

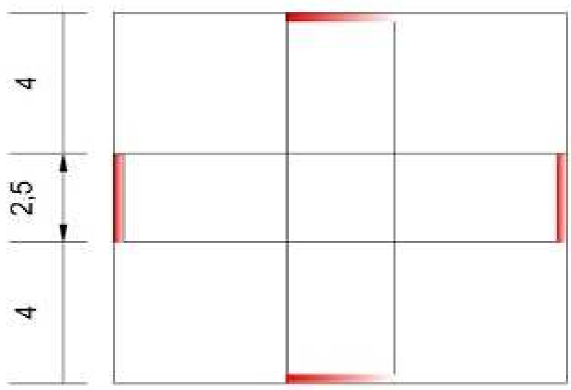

Fig. 12.Plan of building model with shear wall

1.5(DL+LL)

1.2(DL+LL±EL±WL)

1.5(DL±EL±WL)

0.9DL±1.5EL±WL

4.2.4. *Results of performance evaluation*

Lateral displacement in each story of every model is plotted for comparison since which describes a direct measure of lateral load resistance. In performance evaluation it is identified that by employing semi rigid connection with shear wall the precast construction can be safely used in the construction industry since in this case semi rigid connection with shear wall (SWS) is performing better than the ordinary monolithic connection model (FNS).

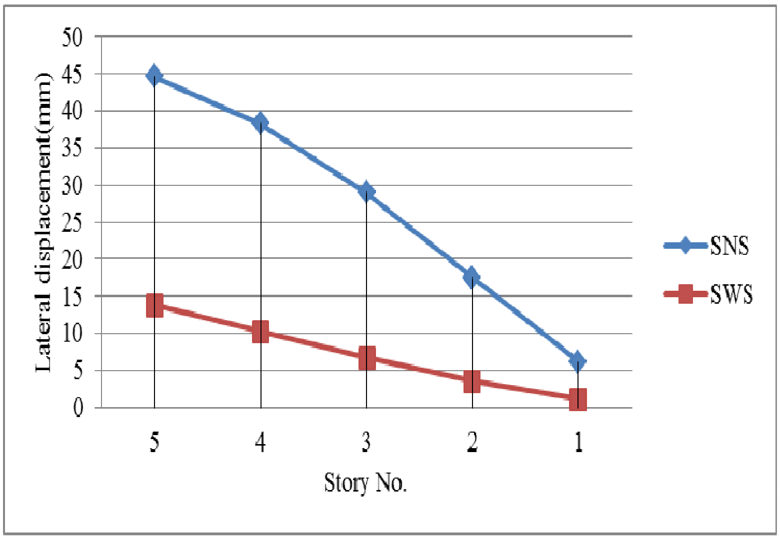

Fig. 13.Partially rigid connection

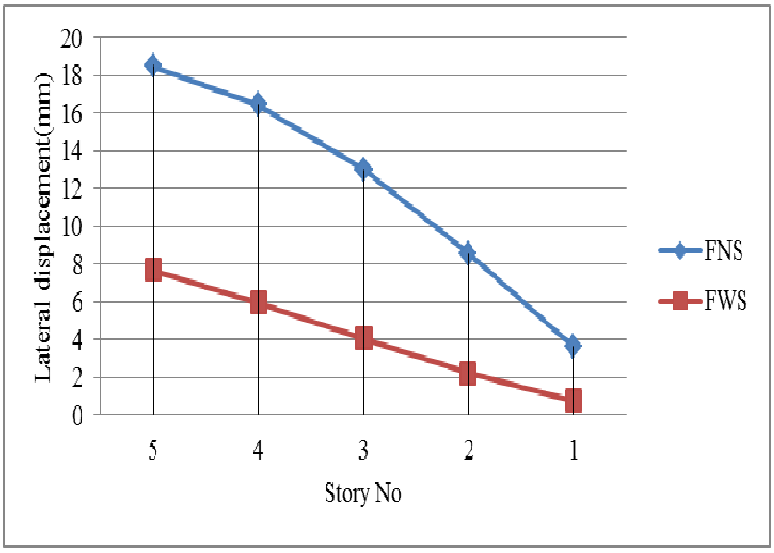

Fig. 14.Fixed connection

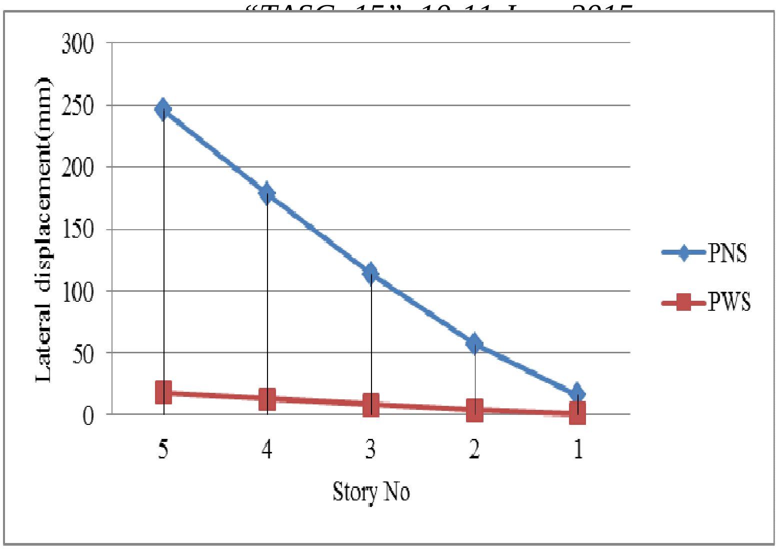

Fig. 15.Pinned connection

5. CONCLUSIONS AND FUTURE STUDY

This new type of precast connection has a great potential in the developing countries due to its simplicity in erection and construction. In the study the stress distribution at the support is investigated with and without stiffener and concluded that with the help of stiffeners high confinement is created and hence good composite action is achieved. Considering the moment resisting type of this connection, by employing shear walls new connection is performing better than pure monolithic connection model. This study can be extended to quantification of the confinement stresses by relative to plate geometry and thickness and 3D FE modelling of hybrid moment resisting beam column joint and study of parameters like ductility, energy absorbtion,ultimate load etc..

REFERENCES

[1] Aninthaneni, PK. (2014): Conceptual development: Low loss precast concrete frame building system with steel connections. NZSEE conference proceedings. 0(44), pp1-12.

[2] Tazeen Fatema, et.al. (2007): A novel approach of modeling precast concrete frame joint: modeling, numerical simulation and performance. Journal of Civil Engineering (IEB). 35 (2), pp 105-118.

[3] Sergio m alcocer, et.al. (2000): Behavior of a precast concrete beam-column connection. Proceedings of the 12th WCEE, pp 1-8.

[4] Ehsan Noroozejad Farsangi. (2010): Connections behaviour in precast structures due to seismic loading. Gazi university journal of science. 23(3), pp315-325

[5] Videjeapriya R, Jaya KP (2013): Experimental study on two simple mechanical precast beam column connections under reverse cyclic loading. ASCE Journal of performance of constructed facilities.27,pp402-414

[6] H.-K. Choi, et.al. (2013): Development and testing of precast concrete beam-to-columnconnections. Engineering Structures .56, pp1820–1835

[7] Shariatmadar, H. (2014):An investigation of seismic response of precast concrete beam to column connections:experimental study, Asian journal of civil engineering, 15(1), pp41-59

[8] Hossein, et.al (2014): A new ductile moment resisting connection for precast concrete frames. Engineering Structures. 70, pp144–157

[9] Vijaya, S (2014): Numerical modeling on behavior of reinforced concrete exterior beam-column joint retrofitted with externally bonded fiber reinforced polymer. International Journal of Research in Engineering and Technology.3,pp247-252

[10] Jin zang (2010): Investigation into a beam-column connection in pre-cast concrete. Masters theses, University of Stellenbosch.