Effectiveness of Precast Beam Column Connection Over Conventional Beam Junction

Mr. Rohan Dnyanoba Solunke[1], Prof. Dr. Pujari. A. B[2]
[1]Dept of Civil Engineering
[2]Associate Professor, Dept of Civil Engineering
[1, 2] K.J College of Engineering and Management Research, Kondwa, Tal-Haveli, Dist-Pune – 411048

Abstract- *Ancient Romans used concrete and poured it into moulds to construct their intricate network of aqueducts, culverts, and tunnels. There are several architectural and structural applications for precast technology today, including individual components and even full building systems. In 1905, precast panelled structures were introduced to the contemporary world in Liverpool, England. John Alexander Brod, a municipal engineer who also devised the concept of the football goal net, invented the method. The concept was not widely adopted in Britain. Nonetheless, it was accepted globally, especially in Eastern Europe and Scandinavia. To do analysis of RCC building for Dead load, living load, and Earthquake load in order to find Critical joint and joints. To do an ANSYS study of a key joint's axial forces, shear forces, and bending moment. The research will compare beam column joint precast beam column connection with RCC beam column connection in terms of bending loads, shear stresses, main stresses, and deflection. In this project, a comparison is done between RCC and PRECAST beam column connections, and the following observations are made.The result for Maximum Deformation for all models concludes that the Deformation for precast model no. 1 is less than the other precast patterns and RCC model by approximately 5-10% for precast models and 30-40% for RCC model. • The result for Normal Stress for all models concludes that the Normal Stress for precast model no. 3 is less than the other precast patterns and RCC model by approximately 15-20% for precast models and 40-50% for RCC model.*

Keywords- Precast, beam-column junction, ANSYS.

I. INTRODUCTION

1.1 History:

Ancient Romans made use of concrete and they poured that material into moulds to build their complex network of aqueducts, culverts, and tunnels. Modern uses for pre-cast technology include a variety of architectural and structural applications — including individual parts, or even entire building systems.

In the modern world, precast paneled buildings were pioneered in Liverpool, England, in 1905. The process was invented by city engineer John Alexander Brod who also invented the idea of the football goal net. The idea was not taken up extensively in Britain. However, it was adopted all over the world, particularly in Eastern Europe and Scandinavia.

1.2 Introduction:

Precast concrete systems have many advantages like speed in construction, good quality due to factory production, economy in mass production. Despite these advantages of precast concrete, it is not widely used throughout the world, especially in regions of high seismic risk. The reason behind this is lack of confidence and knowledge base about their performance in seismic regions as well as the absence of rational seismic design provisions in major model building codes (Priestley, 1991). High storey precast frame panel buildings performed poorly in the 1988 Spitak, Armenia earthquake due the lack of adequate seismic design considerations such as ductility in precast joints (Hadjian, 1993). A significant number of parking structures suffered extensive damage and a number of precast concrete parking structures collapsed in the 1994, Northridge earthquake. One of the reasons for the collapse was lack of proper diaphragm connections (Mitchell et al., 1995). In the 1995 Kobe earthquake, most of the precast prestressed concrete structures performed well, only three sustained severe structural damage. The structural damage was due to insufficient connection detailing (Muguruma et al., 1995). The lessons learnt from the past earthquakes are that the connections are the weakest link. Hence more research is required in the study of connections.
For Purpose of Rehabilitation and protection against seismic actions concerns a large number of buildings made of precast and prestressed concrete elements, basically for industrial-manufacturing purposes. These buildings are very common in many countries and especially in Italy, where a large number of constructions were built in the ‘50s, ‘60s and ‘70s, during the reconstruction after World War II and the consequent economic and social development. At that time the buildings were characterized by innovative and even high performance

materials and by complex structural solutions exploiting new material and design approaches. The latter however were not comparable with modern regulations and technical knowledge, so that assessment of present conditions needs specific studies on local and global behavior. This circumstance is more relevant if seismic risk is analyzed; in fact, many constructions are located in areas recognized to be exposed to seismic risk after erection, so that the original design takes into account only gravity loads, without any consideration of lateral loads due to earthquake

1.2.1 Beam-Column Connections

The beam-column connection is one of the few vital regions determining the seismic resistance efficiency of a framed or partially-framed structure. The present need is to develop a rational analytical model capable of predicting the ultimate capacity of a variety of embedded steel member precast connections. The development of this analytical model is based on the results of a series of experiments in which the different variables like effect of column axial load, effect of additional welded reinforcement, effect of shape of embedded member were studied. The analytical model has been used to construct a series of non-dimensional design curves for connections with or without additional welded reinforcement. The connection between the beam and column must be strong enough as it serves as part of the vertical load resisting system in order to comply with one of the failure modes in which the beams must fail before columns. Under earthquake loading, the joint will be the most critical area to resist the lateral seismic reaction forces. Its characteristics affect the global behavior of the whole structure, particularly when subjected to seismic loading. Therefore, the strength of the joint has to be higher than the strength of the member it joins. This makes the proper reinforcement of this zone difficult to construct and not fully established. The designed joint failed in shear and the beam bars slipped only after the first cycle of inelastic loading.

Precast concrete has been recognized as a feasible means of building structural structures that are secure, robust, efficient, quality, and cost-effective. However, its application in high seismic regions has been restricted, mostly because of the lack of availability of construction standards relative to those required for concrete frameworks cast in place. Over the years, the introduction of precast concrete has demonstrated benefits of concrete production, such as better quality protection, smoother construction schedule management, effective usage of resources and cost savings.

1.3 OBJECTIVE:

- To perform analysis of RCC building for Dead load, live load and Earthquake load to identify Critical joint.
- To Perform analysis of critical joint for axial forces, shear forces and Bending moment in ANSYS
- To study the comparative analysis of beam column joint precast beam column connection with RCC beam column connection for bending stresses, shear stresses, principal stresses and Deflection

II. LITERATURE REVIEW

Ehsan Noroozinejad Farsangi et. al. [1] studied finite element analysis on 4 types of precast connections which are pinned, rigid, semi rigid and a new proposed connection. The stiffness of the new connection was obtained from the slope of the total load versus deflection graph in the elastic range. Then the seismic loading from El Centro earthquake modified with 0.15g and 0.5g were applied to the whole structure. He concluded from the analysis results that new connection has sufficient stiffness, strength and also higher ductility. Meanwhile, the whole structure analysis results showed that the new connection behaves as semi rigid connection. LUSAS and SAP2000 were used for analysis.

R.A. HawilehLanke et al [2] Studied nonlinear finite element analysis and modeling of a precast hybrid beam–column connection subjected to cyclic loads. A detailed three-dimensional (3D) nonlinear finite element model was developed to study the response and predict the behavior of precast hybrid beam–column connection subjected to cyclic loads that was tested at the National Institute of Standards and Technology (NIST) laboratory. The model had taken into account the pre-tension effect in the post-tensioning strand and the nonlinear material behavior of concrete. The model response was compared with experimental test results and yielded good agreement at all stages of loading. Fracture of the mild-steel bars resulted in the failure of the connection. In addition, the magnitude of the force developed in the post-tensioning steel tendon was also monitored and it was observed that it did not yield during the entire loading history. He concluded that successful finite element modeling will provide a practical and economical tool to investigate the behavior of such connections.

Vidjeapriya. R et al [3] Developed a 3-D nonlinear FE model to study the response of an exterior precast beam to column connection subjected to reverse cyclic loading. Tests of a one-third scale exterior beam column precast concrete connections was conducted. Two types of connections were compared. The connections included a monolithic connection and two precast beam - column connections (i) using J-bolt (ii) using Cleat Angle. ANSYS finite element software was used for the nonlinear analysis of the precast beam column connection. For the nonlinear analysis, one-third scale model was developed. Two types of elements were used including solid elements and contact elements. The finite element analysis results compared well with the experimental data. It is concluded that if the material constitutive relation and failure criterion can be selected suitably, the finite element model can accurately predict the overall seismic behavior and the inelastic performance of these two kinds of joints.

Summary

The seismic performance of the design of precast concrete depends very much on the ductility of the joints framed by beams and columns that are precast. The purpose of this analysis was to decide the most appropriate type of beam-column connections. The dimensionless hysteresis models of two types of joints were proposed and found the rationality of the monolithic precast joint model was confirmed. The models will serve as an important method for the seismic performance review and investigation of design parameters of pre-cast links, claim the researchers**.**

III. METHODOLOGY

Methodology steps:

1. Collection of Data
   a. Study of Time History
2. Study of Connections
   a. RCC Beam Column Connection
   b. Precast Beam Column Connection
3. Software Modeling
   a. Building modeling and analysis in STAAD Pro.
   b. Modeling of Beam column connection in ANSYS.
4. Result and Conclusion.

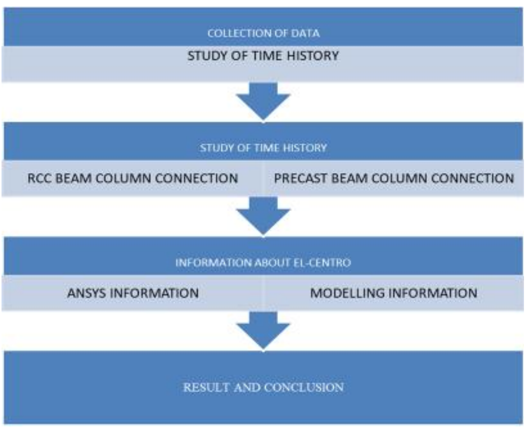


Fig 1: Flow Chart

IV. PROBLEM STATEMENT

4.1 Problem statement: -

A G+7 RCC Commercial building is considered for analysis and design purpose in staad pro the details of the building considered are as follows:

Plan dimensions: 12 m x 12 m
Location considered: Zone-III
Soil Type considered: Hard Strata.

General Data of Building:

• Grade of concrete: M 25
• Grade of steel considered: Fe 500
• Live load on roof: 2 KN/m^2
• Live load on floors: 4 KN/m^2
• Roof finish: 1.0 KN/m^2
• Floor finish: 1.0 KN/m^2
• Brick wall in longitudinal direction: 200 mm thick
• Brick wall in transverse direction: 140 mm thick
• Beam in longitudinal direction: 230X350 mm
• Column size: 300X750 mm
• Density of concrete: 25 KN/m^3
• Density of brick wall including plaster: 20 KN/m^3
• Plinth beam: 230X350 mm

Total of 4 models are analyzed in ANSYS:
Figure 4.4.1 is conventional RCC model,
Figure 4.4.2 is precast model no. 1,
Figure 4.4.3 is precast model no. 2, and
Figure 4.4.4 is precast model no. 3.

4.3Analysis of model: -

The analysis results of the G+7 RCC Commercial Building in STAAD.Pro is shown in the figure 4.3.1. The highlighted lines in the model shows the columns and beams with highest beam end forces. The beams with highest beam end forces are shown in Table 4.3.1.

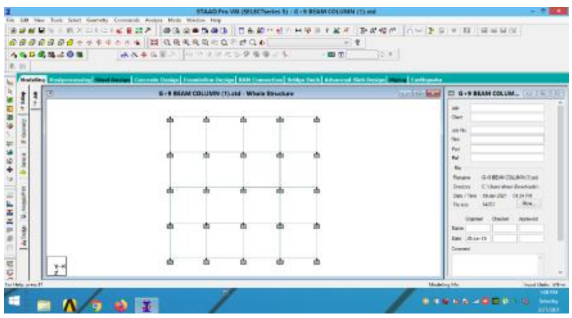


Fig 2: Plan view

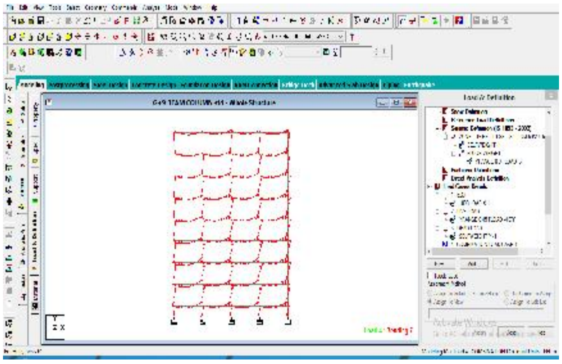


Fig 3: Bending moment of beams in staad

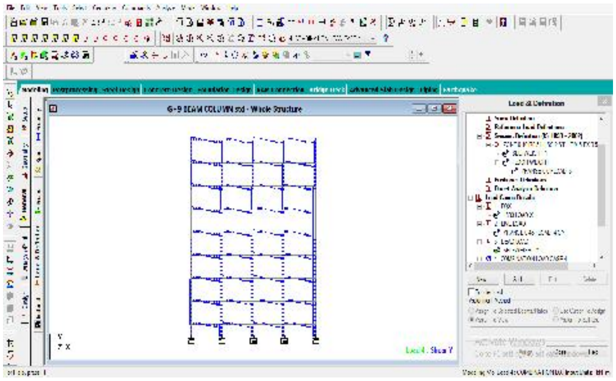


Fig 4: Shear force of beams in staad

4.4 ANSYS model: -

Details for ANSYS Models for Precast and RCC

Column Size – 300 x 750 mm

Reinforcement for Column – 12Ø – 16No
Beam Size – 230 x 450 mm

Reinforcement for Beam – Top – 12Ø -2, Bottom- 12Ø -2, Shear – 10Ø@120 C/C
Total Maximum Load – 1824 KN

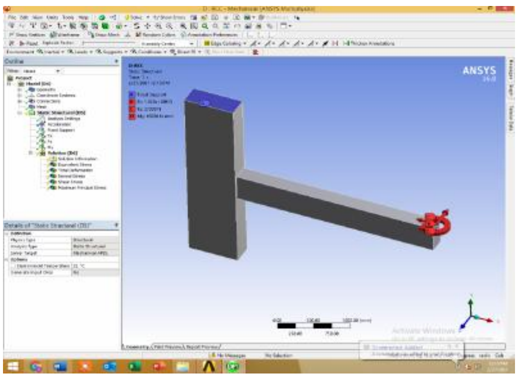


Fig 5: Modeling

The Maximum BM beam column junction is further modeled in ANSYS

DETAILS OF PRECAST MODELS

Sr.No.	Model No.	Description
1	RCC	Monolithic beam column joint
2	Precast Model 1	Precast beam column with trapezoidal haunch size 0.3 x 0.45 with 2 bolts of 20mm diameter Gusset plate of 30mm thickness
3	Precast Model 2	Precast beam column with rectangular haunch size 0.2 x 0.45 2 bolts of 20mm diameter Gusset plate of 30mm thickness
4	Precast Model 3	Precast beam column with haunch size 0.2 x 0.252 bolts of 20mm diameter Gusset plate of 30mm thickness

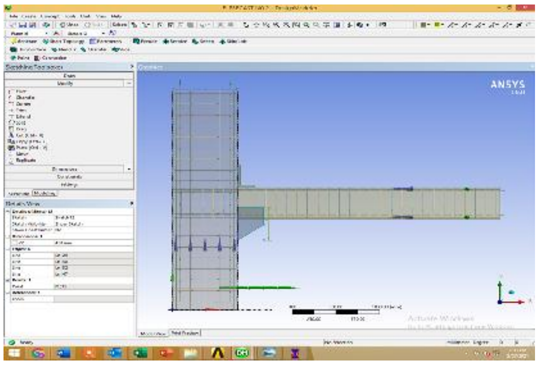


Fig 6: Precast Model 1

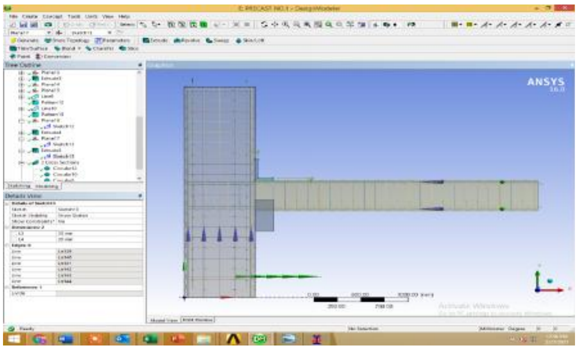


Fig 7: Precast Model 2

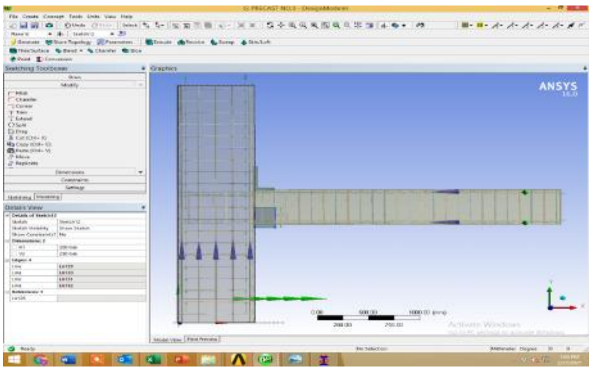


Fig 8: Precast Model 3

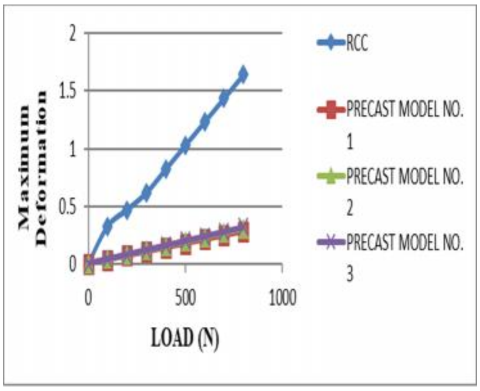
VI. RESULT AND DISCUSSION

The results obtained from the analysis of models in ANSYS are shown in tables and graphs. From Graph 5.2 it clearly shows that the total deformation in conventional RCC beam column junction is more than precast beam column junction. The normal stress, shear stresses and maximum principal stresses in precast model no. 1, 2 and 3 is more as compared to RCC beam column junction as seen in the Graphs 5.2, 5.3 and 5.4. In precast the stresses are concentrated in the connecting elements.

5.1 Maximum Deformation M25:-

Table 5.1 Maximum Deformation Of M25

LOAD (N) vs DEFORMATION (mm)				
LOAD (N)	RCC MODEL	PRECAST MODEL NO.1	PRECAST MODEL NO.2	PRECAST MODEL NO.3
100	0.32612	3.53E-02	3.84E-02	4.01E-02
200	0.46801	7.06E-02	7.68E-02	8.02E-02
300	0.61655	0.10594	0.11521	0.12036
400	0.82207	0.14125	0.15361	0.16047
500	1.0276	0.17656	0.19202	0.20059
600	1.2331	0.21187	0.23042	0.24071
700	1.4386	0.24712	0.26883	0.28083
800	1.6441	0.2825	0.30723	0.32095



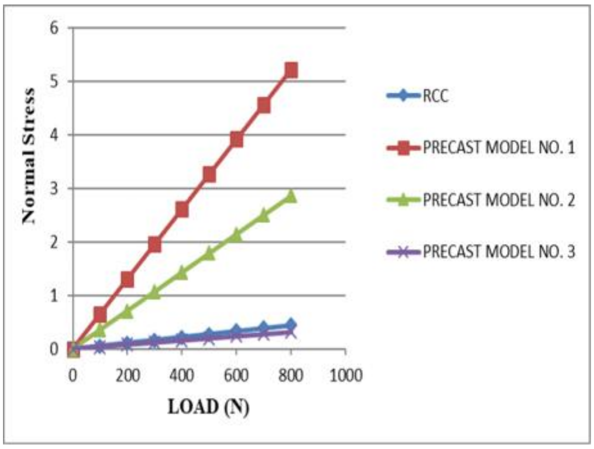
Graph 1 Maximum Deformation of M25

Above graph shows the result for Maximum Deformation for all models, the results conclude that the Deformation for precast model no 1 is less than the other precast patterns and RCC model, by around 5-10% for precast models and 30-40% for RCC model

5.2 Normal Stress M25:-

Table 5.2 Normal Stress of m25

LOAD (N) vs NORMAL STRESS (MPa)				
LOAD (N)	RCC MODEL	PRECAST MODEL NO.1	PRECAST MODEL NO.2	PRECAST MODEL NO.3
100	0.055322	6.53E-01	3.57E-01	4.01E-02
200	0.11064	1.31E+00	7.13E-01	8.02E-02
300	0.16597	1.9597	1.0689	0.12036
400	0.22129	2.6129	1.431	0.16047
500	0.27661	3.2662	1.7889	0.20059
600	0.33193	3.9194	2.1467	0.24071
700	0.38725	4.5715	2.5045	0.28083
800	0.44258	5.2259	2.8623	0.32095



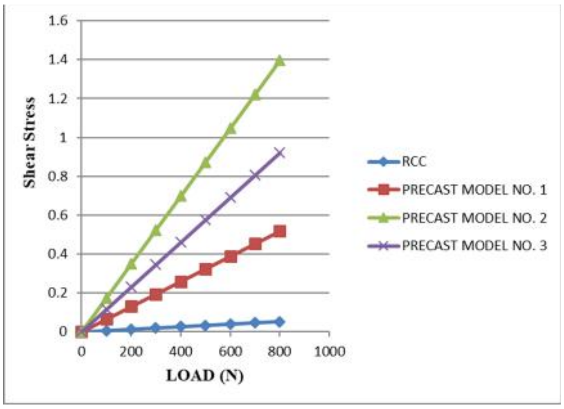
Graph 2 Normal Stress of M25

Above graph shows the result for Normal Stress for all models, the results conclude that the Normal Stress for precast model no 3 is less than the other precast patterns and RCC model, by around 15-20% for precast models and 40-50% for RCC model

5.3 Shear Stress M25:

Table 5.3 Shear Stress of M25

LOAD (N) vs SHEAR STRESS (MPa)				
LOAD (N)	RCC MODEL	PRECAST MODEL NO.1	PRECAST MODEL NO.2	PRECAST MODEL NO.3
100	0.0064701	6.48E-02	1.74E-01	1.15E-01
200	0.01294	1.30E-01	3.50E-01	2.30E-01
300	0.01941	0.1944	0.52443	0.34523
400	0.02588	0.25921	0.69812	0.4603
500	0.032351	0.32401	0.87247	0.57538
600	0.038821	0.38881	1.047	0.69045
700	0.045291	0.4535	1.2214	0.80553
800	0.051761	0.51842	1.3959	0.9206



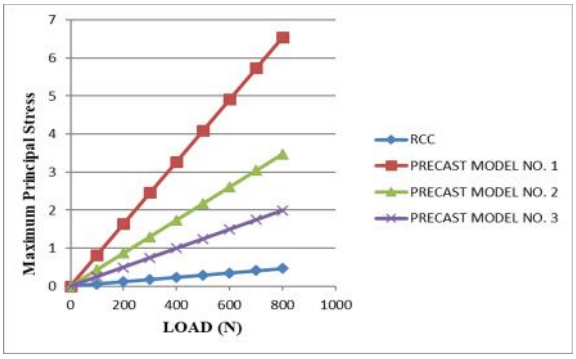
Graph 3 Shear Stress of M25

Above graph shows the result for Shear Stress for all models, the results conclude that the capacity of Shear Stress for RCC model is less than the other precast patterns, by around 30-35%

5.4 Maximum Principal Stress M25:-

Table 5.4 Maximum Principal Stress of M25

LOAD (N) vs MAXIMUM PRINCIPAL STRESS (MPa)				
LOAD (N)	RCC MODEL	PRECAST MODEL NO.1	PRECAST MODEL NO.2	PRECAST MODEL NO.3
100	0.058568	8.19E-01	4.34E-01	2.50E-01
200	0.11714	1.64E+00	8.68E-01	4.99E-01
300	0.1757	2.4575	1.3021	0.74875
400	0.23427	3.2766	1.7396	0.99834
500	0.29284	4.0958	2.1747	1.2479
600	0.35141	4.9149	2.6096	1.4975
700	0.40998	5.7327	3.0445	1.7471
800	0.46854	6.5533	3.4795	1.9967



Graph 4 Maximum Principal Stress of M25

Above graph shows the result for Maximum Principal Stress capacity for all models, the results conclude that the capacity of Maximum Principal Stress for RCC model is less than the other precast patterns, by around 40-45%

VII. CONCLUSION

In this project the comparative analysis is made for RCC and PRECAST beam column connections and following conclusions are as observed:

- The result for Maximum Deformation for all models, the results conclude that the Deformation for precast model no 1 is less than the other precast patterns and RCC model, by around 5-10% for precast models and 30-40% for RCC model
- The result for Normal Stress for all models, the results conclude that the Normal Stress for precast model no 3 is less than the other precast patterns and RCC model, by around 15-20% for precast models and 40-50% for RCC model
- The result for Shear Stress for all models, the results conclude that the capacity of Shear Stress for RCC model is less than the other precast patterns, by around 30-35%
- The result for Maximum Principal Stress capacity for all models, the results conclude that the capacity of Maximum Principal Stress for RCC model is less than the other precast patterns, by around 40-45%
- The maximum deformation are reduced by 15-20 % in to Precast beam column connections as compared to RCC beam column connections.
- From the analytical study of the different shapes of beam column connection it is found that the precast connection is more effective as compared to RCC.
- The Normal Stresses, Shear Stresses, Equivalent stresses, Principal stresses are observed more at connecting elements of precast.
- The time history analysis result for Total Deformation mm for all models, the results conclude that the Total Deformation mm for RCC model is greater than the other precast patterns, by around 10-20%, and less for model no 3
- Above graph shows the time history analysis result for Shear Stress for all models, the results conclude that the Shear Stress for RCC model is greater than the other precast patterns, by around 25-30%, and less for model no 3
- The time history analysis result for Max. Principal Stress for all models, the results conclude that the Max. Principal Stress for RCC model is greater than the other precast patterns, by around 20-25%, and less for models no 3

- The time history analysis result for Normal Stress for all models, the results conclude that the Normal Stress for RCC model is greater than the other precast patterns, by around 10-15%, and less for models no 3
- The time history analysis result for Equivalent Stress for all models, the results conclude that the Equivalent Stress for RCC model is greater than the other precast patterns, by around 10-15%, and less for models no 3

REFERENCES

[1] EhsanNoroozinejadFarsangi "Connections Behaviour in Precast Concrete StructuresDue to Seismic Loading". Gazi University Journal of Science GU J Sci 23(3):315-325 (2010).

[2] AkashLanke, Dr. D. Venkateswarlu "Design, Cost & Time analysis of Precast & RCC building." International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056 Volume: 03 Issue: 06 | June-2016.

[3] R.A. Hawileh, A. Rahman , H. Tabatabai, "Nonlinear finite element analysis and modeling of a precast hybrid beam–column connection subjected to cyclic loads." Applied Mathematical Modeling 34 (2010) 2562–2583.

[4] Vidjeapriya, Bahurudeen, Jaya. K.,"Nonlinear analysis of exterior precast beam-column J-Bolt and cleat angle connections." International journal of civil and structural engineeringVolume 4, No 1, 2013 ISSN 0976 – 4399

[5] Prof. Dr. Khalid S. Mahmoud Dr. Mohannad H. Al-Sherrawi, "Nonlinear Finite Element Analysis of Composite Concrete Beams." Number 3 Volume 8 Journal of Engineering.

[6] Samir M. O. Hassan Dirar and Chris T. Morley, "Nonlinear Finite Element Analysis Of Reinforced Concrete Deep Beams." VIII International Conference on Computational Plasticity.

[7] Andrei Faur, CălinMircea, MirceaPăstrav, "A Modeling Technique for Precast Concrete Frames with Hybrid Connections." ActaTechnicaNapocensis: Civil Engineering & Architecture Vol. 55, No. 3 (2012).

[8] De-Cheng Fenga, Gang Wua, Yong Luc, "Finite Element Modeling Approach for Precast Reinforced Concrete Beam-to-Column Connections Under Cyclic Loading." Engineering Structures 174 (2018) 49–66.

[9] José F. Rave-Arango, Carlos A. Blandón, José I. Restrepob, Fabio Carmona, "Seismic Performance Of Precast Concrete Column-To-Column Lap-SpliceConnections." Engineering Structures 172 (2018) 687–699.

[10] Wenlong Han, Zuozhou Zhao, JiaruQian, Yao Cui, Shiwei Liu, "Seismic Behavior of Precast Columns with Large-Spacing and High-Strength Longitudinal Rebar's Spliced By Epoxy Mortar-Filled Threaded Couplers." Engineering Structures 176 (2018) 349–360.

[11] Saeed Bahrami, Morteza Madhkhan, Fatemeh Shirmohammadi, NimaNazemi, "Behavior of two new moment resisting precast beam to column connections subjected to lateral loading." Engineering Structures 132 (2017) 808–821.

[12] Marco Breccolotti, Santino Gentile, Mauro Tommasini, Annibale Luigi Materazzi, Massimo Federico Bonfigli, Bruno Pasqualini, Valerio Colone, Marco Gianesini, "Beam-column joints in continuous RC frames: Comparison between cast-in-situ and precast solutions." Engineering Structures 127 (2016) 129–144.

[13] Sadik Can Girgina, İbrahim SerkanMisir, SerapKahraman,"Seismic Performance Factors for Precast Buildings with Hybrid Beam-Column Connections."Procedia Engineering 199(2017) 3540–3545. X International Conference on Structural Dynamics, EURODYN 2017.

[14] Shao-Bo Kang, Kang Hai Tan, "Behaviour of precast concrete beam–column sub-assemblages subject to column removal." Engineering Structures 93 (2015) 85–96.

[15] Marcela NovischiKataoka, Marcelo Araújo Ferreira, Ana LúciaHomce de Cresce El Debs, "Nonlinear FE analysis of slab-beam-column connection in precast concrete structures." Engineering Structures 143 (2017) 306–315.

[16] Barbara Chang, Tara C. Hutchinson, Xiang Wang and Robert Englekirk, "Experimental Seismic Performance of Beam-Column Subassemblies Using Ductile Embeds." J. Struct. Eng., 2013, 139(9): 1555-1566.