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RESEARCH ARTICLE OPEN ACCESS

Linear or nonlinear analysis of RCC and precast beam column connections

Priya Gholap*, R. P. Amale**, Dr. P. K. Kolase***
**(PG student, Department of Civil, Pravara Rural Engineering College, Ahmednagar)*
*** (Assistant Professor, Department of Civil, Pravara Rural Engineering College,Ahmednagar)*
**** (Associate Professor, Department of Civil, Pravara Rural Engineering College,Ahmednagar)*

ABSTRACT
The rapid increase of construction operations for homes and other buildings is boosting demand for construction materials such as bricks, wood, concrete, and steel. The weight of a standard concrete construction constitutes a fairly substantial fraction of the total load of the structure. Today, prefabricated structures are widely used in a wide range of residential and commercial projects. RCC beam-column connections are compared to precast beam-column connections for "T," "L," and "X" connections for applied loads in this article. Dynamic analysis is performed on beam and column connections. Equivalent Stress, Normal Stress, Total Strain, and Maximum Principal Elastic Strain are the parameters employed in the analysis. The analysis was carried out with the help of the FEM tool ANSYS workbench. The dynamic analysis of the "T" joint for four parameters revealed that the performance of precast model types 1 and 2 is nearly identical. As a result, the type 1 precast model was employed in conjunction with the RCC model for joint "L" and joint "X" analysis. For dynamic study on "L" and "X" joints, the "X" joint performed better than the "L" and "T" types..
Keywords-ANSYS,Beam-column junction, Dynamic analysis, Precast, RCC.

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I. INTRODUCTION

Precast concrete methods outperform traditional cast-in-place concrete constructions in terms of product quality, cost-effectiveness, and construction speed . Precast concrete structures are also called ecological and ecological buildings in order to conserve natural resources and prevent pollution . The rising use of precast is linked to contractors' and engineers' greater desire in discovering cost-effective alternatives to cast-in-place concrete elements. Despite its numerous advantages, precast concrete is not frequently employed, particularly in seismically prone areas. This is attributable to a lack of trust and information regarding their seismic performance, as well as the absence of reasonable seismic design provisions in the major model building codes. In the factory, structural sections are better constructed, which decreases frequent design issues such as insufficient cover depth, stirrup spacing, stirrup shape, water-cement ratio, and so on. Prefabs are useful for industrial operations since large buildings can be built beneath them without the need for columns. Prefabricated components, such as culverts, abutments, retaining walls, and drainage channels, can also be advantageous in the field of infrastructure.

1.1. Precast Structure

Architecturally, precast concrete building parts and construction site equipment are employed as mantels, cladding, decorative items, accessories, and perimeter walls. Precast concrete structural applications include foundations, beams, floors, walls, and other structural elements. Each structural element must be designed and tested to withstand both tensile and compressive loads that will be applied to the element during its lifetime.

1.2. Monolithic Structure (Mivan Structure)

These are the most advanced formwork methods available. It's quick, easy, and adjustable. It produces absolutely high-quality work that requires no maintenance and is designed with longevity in mind. It is a completely established system ahead of time, with the entire technique planned down to the smallest elements. The walls, columns, and slab are all formed in one continuous cast onto the concrete in this procedure. Air curing/curing substances can be used to remove formwork prematurely. These moulds are solid and durable, well-made, and simple to use. Because the components are composed of aluminium, they are very light. They permit a high number of repetitions (around 250). Because re-attachment is simple, a short cycle time can be attained.

1.3 Research objective

2. To analyze and compare the precast element with the RCC structure.
3. Analyze precast and RCC structural models for the ground motion.
4. To verify and evaluate parameters for linear or non-linear such as displacement, shear stress and principal stress.

II. FRAME STRUCTURE DETAILS AND PROBLEM STATEMENT

In this study, we began by analyzing a G+9 RCC commercial construction with Staad Pro. Following the examination, the junction or node with the greatest force on the column and the accompanying beam with the greatest force was chosen for further investigation. ANSYS was used to do the joint analysis. To conduct comparison research, the RCC and precast joints were investigated. The joints under consideration for analysis were the 'T' Joint, the 'L' Joint, and the 'X' Joint.

Table 1 model's specifications:

1	Seismic zone	Zone-III
2	Grade of concrete:	M 25
3	Grade of steel	Fe 500
4	Live load on roof	2 kN/m^2
5	Live load on floors	3 kN/m^2
6	Roof finish	1.0 kN/m^2
7	Floor finish	1.0 kN/m^2
8	Column size	300x750 mm
9	Beam size	230x350 mm.

2.1 Analysis Of Model in Staad Pro

Fig 1 depicts a G+9 storey structure that was modelled in this section. Following the examination, the column and beam with the greatest forces were chosen for further investigation.

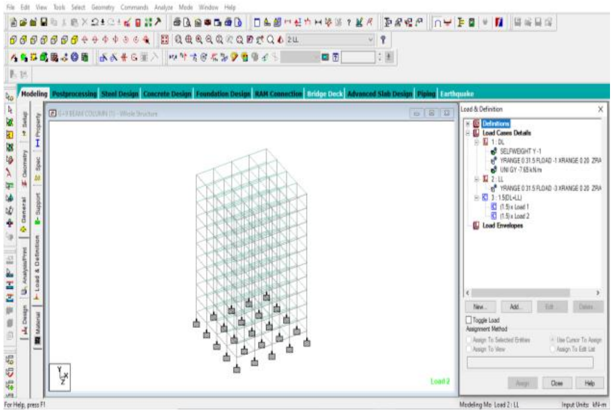


Fig. 1 Modeling in Staad Pro

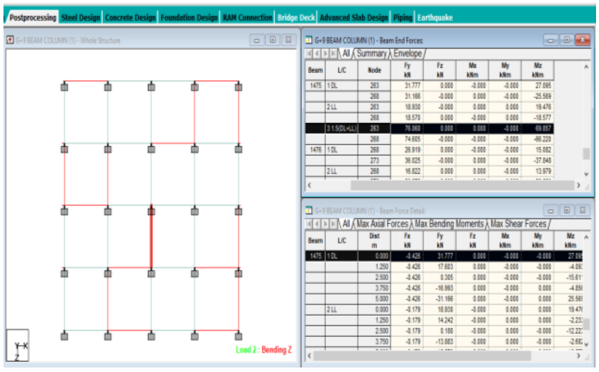


Fig. 2 Max Force on Beam

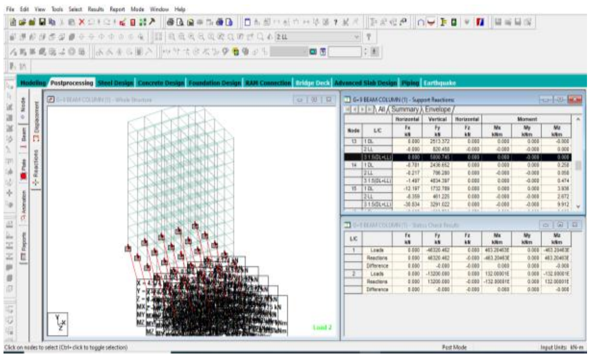


Fig. 3 Max Force on Column

The model's highlighted lines depict the columns and beams with the highest beam end forces. According to Figs. 2 and 3, the greatest column force was 5000 kN at node 13, and the maximum force on the beam adjacent to this node was 76.06 kN.

2.2 Modelling In ANSYS

For the FEM, ANSYS was used to perform dynamic analysis on RCC and three distinct types of precast models. The joints studied were the 'T' Joint, the 'L' Joint, and the 'X' Joint. The 'T' Joint was investigated for RCC and Precast Models

1,2,3. The best performing precast model was then assessed using the RCC model for the 'L' and 'X' joints. It was discovered that Precast model types 1 and 2 outperform type 3. As a result, RCC and Precast model 1 were studied further for 'L' and 'X' Joint analysis. The specifications for ANSYS models are listed below.

Details of ANSYS Models for Precast and RCC connection

- Column Size – 300 x 750 mm
- Reinforcement for Column –12mm ø – 16No
- Beam Size –230 x 450 mm
- Reinforcement for Beam – Top –12mm ø -2, Bottom- 12mm ø -2, Shear – 10mm ø@120 C/C
- Total Maximum Load on column and beam –5000 kN and 76.06 kN

Table2: Description of RCC and Precast models in ANSYS.

Sr. No	Model No.	Description
1	RCC	Monolithic beam column joint
2	Precast Model 1 (PC 1)	Precast beam column with rectangular haunch size 200 x 450 mm with
		2 bolts of 20mm diameter
		Gusset plate of 30mm thickness
3	Precast Model 2 (PC 2)	Precast beam column with trapezoidal haunch size 300 x 450 mm
		2 bolts of 20mm diameter
		Gusset plate of 30mm thickness
4	Precast Model 3 (PC 3)	Precast beam column with haunch size 200 x 250 mm
		2 bolts of 20mm diameter
		Gusset plate of 30mm thickness

According to the details of the models mentioned above in Table 1, the models were modelled in Ansys as shown in Fig. 4 to 7.

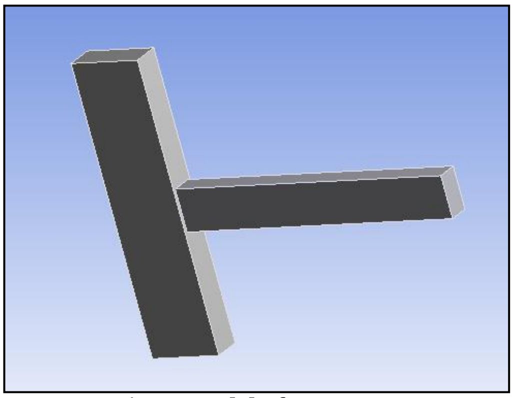


Fig. 4 Model of RCC

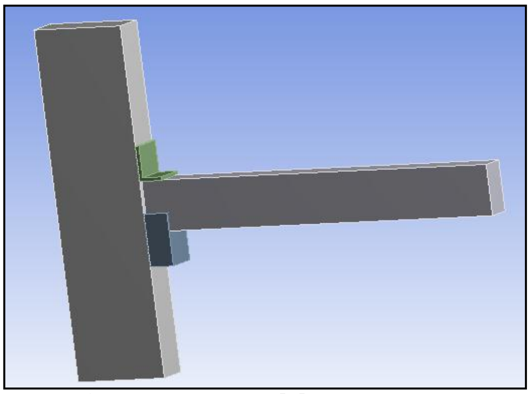


Fig. 5 Precast Model Type 1

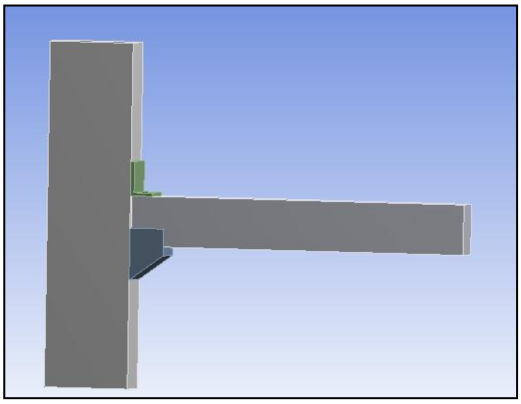


Fig. 6 Precast Model Type 2

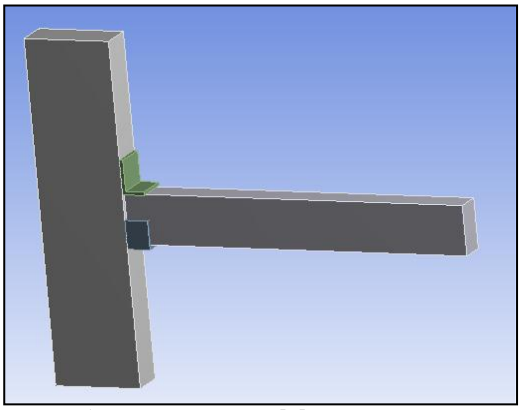
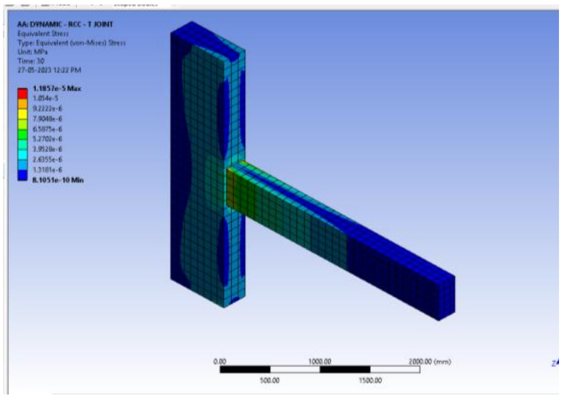


Fig. 7 Precast Model Type 3

III. RESULTS

3.1 Results For Dynamic Analysis of ‘T’ Joint

- **Equivalent Stress MPa**



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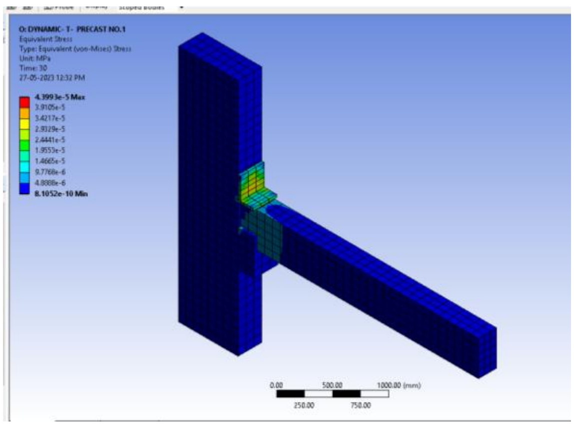

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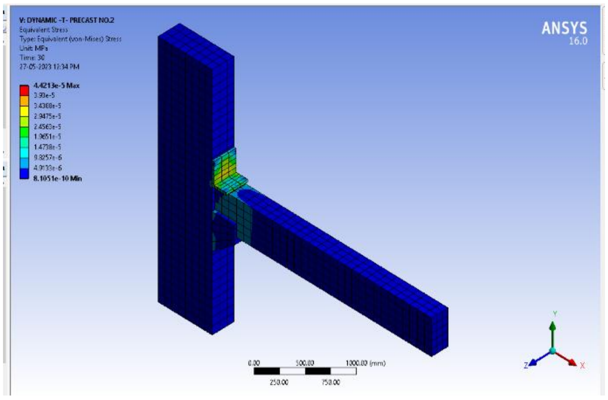

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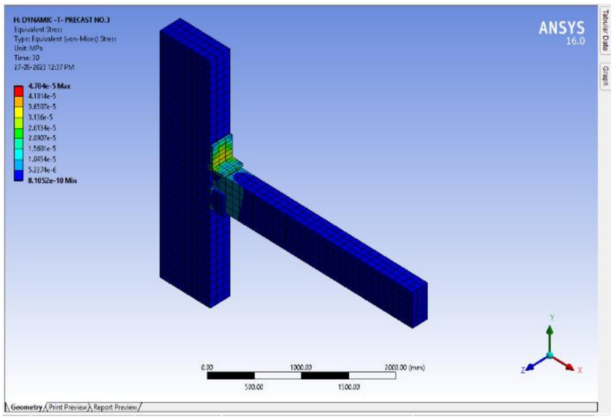


D

Fig. 8 Equivalent Stresses of A) RCC B) PC 1 C) PC2 D) PC3 models for ‘T’ Joint

Table 3 Equivalent Stress (MPa)

Equivalent Stress			
RCC	**PC 1**	**PC 2**	**PC 3**
3.05E-06	1.13E-05	1.14E-05	1.21E-05
1.76E-06	6.54E-06	6.57E-06	6.99E-06
4.79E-07	1.78E-06	1.79E-06	1.90E-06
2.07E-06	7.69E-06	7.73E-06	8.22E-06
3.67E-06	1.36E-05	1.37E-05	1.46E-05
5.26E-06	1.95E-05	1.96E-05	2.09E-05
3.30E-06	1.23E-05	1.23E-05	1.31E-05
1.34E-06	4.98E-06	5.00E-06	5.32E-06
6.20E-07	2.30E-06	2.31E-06	2.46E-06
1.78E-06	6.61E-06	6.64E-06	7.07E-06
4.18E-06	1.55E-05	1.56E-05	1.66E-05
6.58E-06	2.44E-05	2.46E-05	2.61E-05
3.52E-06	1.31E-05	1.31E-05	1.40E-05
4.55E-07	1.69E-06	1.70E-06	1.81E-06
2.03E-06	7.54E-06	7.58E-06	8.07E-06
1.07E-06	3.97E-06	3.99E-06	4.24E-06
1.02E-07	3.78E-07	3.79E-07	4.03E-07
2.15E-06	7.98E-06	8.02E-06	8.53E-06
4.20E-06	1.56E-05	1.57E-05	1.67E-05
6.25E-06	2.32E-05	2.33E-05	2.48E-05
8.29E-06	3.08E-05	3.09E-05	3.29E-05
1.66E-06	6.16E-06	6.19E-06	6.59E-06
1.16E-05	4.31E-05	4.33E-05	4.61E-05
4.80E-06	1.78E-05	1.79E-05	1.91E-05
2.01E-06	7.47E-06	7.51E-06	7.99E-06
2.56E-06	9.48E-06	9.53E-06	1.01E-05

8.00E-06	2.97E-05	2.98E-05	3.18E-05
1.35E-05	4.99E-05	5.02E-05	5.34E-05
1.89E-05	7.01E-05	7.05E-05	7.50E-05
1.19E-05	4.40E-05	4.42E-05	4.70E-05

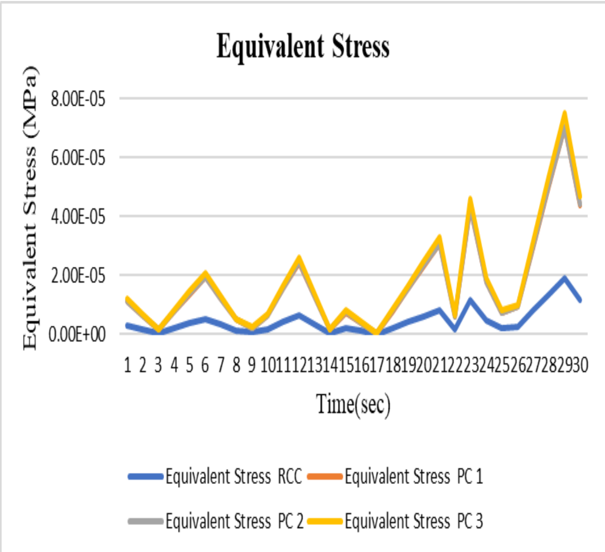


Fig. 9 Equivalent Stress of 'T' Joint

From (Table 2 and Fig.9), the Equivalent Stress for RCC was observed to be less than all precast models, this is because of fix beam column joint of RCC. As compared to PC1 and PC2, the stress in PC3 was observed to be more in the range of 5 to 10%.

3.2 Results For Dynamic Analysis of 'T' Joint for Normal Stress

Table 4 Normal Stress (MPa)

Normal Stress			
RCC	**PC 1**	**PC 2**	**PC 3**
3.05E-06	1.04E-05	1.04E-05	1.09E-05
1.76E-06	5.99E-06	6.00E-06	6.30E-06
4.80E-07	1.63E-06	1.63E-06	1.71E-06
2.07E-06	7.05E-06	7.05E-06	7.40E-06
3.67E-06	1.25E-05	1.25E-05	1.31E-05
5.27E-06	1.79E-05	1.79E-05	1.88E-05
3.31E-06	1.12E-05	1.12E-05	1.18E-05
1.34E-06	4.56E-06	4.57E-06	4.79E-06
6.20E-07	2.11E-06	2.11E-06	2.21E-06
1.78E-06	6.06E-06	6.07E-06	6.37E-06
4.19E-06	1.42E-05	1.42E-05	1.49E-05
6.59E-06	2.24E-05	2.24E-05	2.35E-05
3.52E-06	1.20E-05	1.20E-05	1.26E-05
4.56E-07	1.55E-06	1.55E-06	1.63E-06
2.04E-06	6.92E-06	6.92E-06	7.27E-06
1.07E-06	3.64E-06	3.64E-06	3.82E-06
1.02E-07	3.45E-07	3.46E-07	3.63E-07
2.15E-06	7.31E-06	7.32E-06	7.68E-06
4.20E-06	1.43E-05	1.43E-05	1.50E-05
6.25E-06	2.12E-05	2.13E-05	2.23E-05
8.30E-06	2.82E-05	2.82E-05	2.96E-05
1.66E-06	5.65E-06	5.65E-06	5.93E-06
1.16E-05	3.95E-05	3.96E-05	4.15E-05
4.81E-06	1.63E-05	1.64E-05	1.72E-05
2.02E-06	6.85E-06	6.86E-06	7.20E-06
2.56E-06	8.69E-06	8.70E-06	9.13E-06
8.01E-06	2.72E-05	2.72E-05	2.86E-05
1.35E-05	4.58E-05	4.58E-05	4.81E-05
1.89E-05	6.43E-05	6.44E-05	6.75E-05
1.19E-05	4.03E-05	4.04E-05	4.24E-05

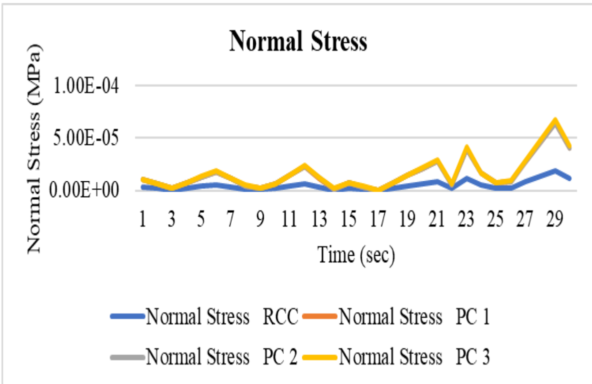


Fig. 10 Normal Stress of 'T' Joint

From (Table 3 and Fig. 10), because of the fixed beam column junction, the Normal Stress for RCC is less than that of precast models, but the Normal Stress for precast models PC1 and PC 2 is less than that of PC 3 by 4-10%.

3.3 Results For Dynamic Analysis of 'T' Joint for Total Deformation

Table 5Total Deformation (mm)

Total Deformation			
RCC	**PC 1**	**PC 2**	**PC 3**
1.72E-05	1.53E-05	1.54E-05	1.57E-05
9.93E-06	8.86E-06	8.89E-06	9.06E-06
2.70E-06	2.41E-06	2.42E-06	2.46E-06
1.17E-05	1.04E-05	1.05E-05	1.06E-05
2.07E-05	1.85E-05	1.85E-05	1.89E-05
2.97E-05	2.65E-05	2.66E-05	2.70E-05
1.86E-05	1.66E-05	1.67E-05	1.70E-05
7.56E-06	6.74E-06	6.77E-06	6.89E-06
3.49E-06	3.12E-06	3.13E-06	3.18E-06
1.00E-05	8.96E-06	8.99E-06	9.16E-06
2.36E-05	2.10E-05	2.11E-05	2.15E-05
3.71E-05	3.31E-05	3.32E-05	3.38E-05
1.98E-05	1.77E-05	1.78E-05	1.81E-05
2.56E-06	2.29E-06	2.30E-06	2.34E-06
1.15E-05	1.02E-05	1.03E-05	1.05E-05
6.03E-06	5.38E-06	5.40E-06	5.50E-06
5.73E-07	5.11E-07	5.13E-07	5.23E-07
1.21E-05	1.08E-05	1.09E-05	1.10E-05
2.37E-05	2.11E-05	2.12E-05	2.16E-05
3.52E-05	3.14E-05	3.15E-05	3.21E-05
4.67E-05	4.17E-05	4.19E-05	4.26E-05
9.36E-06	8.35E-06	8.38E-06	8.53E-06
6.55E-05	5.84E-05	5.86E-05	5.97E-05
2.71E-05	2.42E-05	2.42E-05	2.47E-05
1.14E-05	1.01E-05	1.02E-05	1.04E-05
1.44E-05	1.29E-05	1.29E-05	1.31E-05
4.51E-05	4.02E-05	4.04E-05	4.11E-05
7.58E-05	6.77E-05	6.79E-05	6.91E-05
1.07E-04	9.51E-05	9.54E-05	9.71E-05
6.68E-05	5.96E-05	5.98E-05	6.09E-05

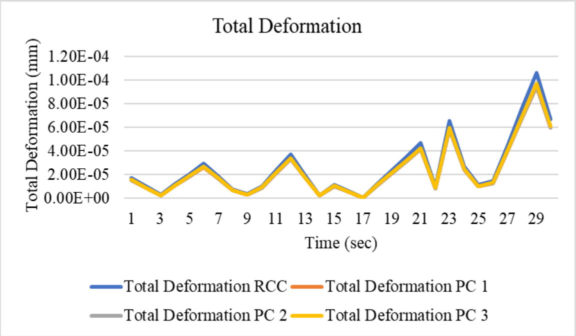


Fig. 11 Total Deformation of 'T' Joint

From (Table 4 and Fig. 11), for dynamic analysis, Total Deformation for RCC is more than precast model PC1, 2 and 3 by 10-15%.

3.4 Results for Dynamic Analysis of 'T' Joint for Maximum Principal Elastic Strain

Table 6 Maximum Principal Elastic Strain

Maximum Principal Elastic Strain			
RCC	**PC 1**	**PC 2**	**PC 3**
1.08E-09	9.98E-10	9.99E-10	1.04E-09
6.22E-10	5.76E-10	5.77E-10	6.01E-10
1.69E-10	1.57E-10	1.57E-10	1.63E-10
7.31E-10	6.78E-10	6.79E-10	7.06E-10
1.30E-09	1.20E-09	1.20E-09	1.25E-09
1.86E-09	1.72E-09	1.72E-09	1.79E-09
1.17E-09	1.08E-09	1.08E-09	1.13E-09
4.73E-10	4.39E-10	4.39E-10	4.57E-10
2.19E-10	2.03E-10	2.03E-10	2.11E-10
6.29E-10	5.83E-10	5.83E-10	6.07E-10
1.48E-09	1.37E-09	1.37E-09	1.43E-09
2.32E-09	2.15E-09	2.16E-09	2.24E-09
1.24E-09	1.15E-09	1.15E-09	1.20E-09
1.61E-10	1.49E-10	1.49E-10	1.55E-10
7.18E-10	6.65E-10	6.66E-10	6.93E-10
3.78E-10	3.50E-10	3.50E-10	3.65E-10
3.59E-11	3.33E-11	3.33E-11	3.46E-11
7.59E-10	7.03E-10	7.04E-10	7.33E-10
1.48E-09	1.37E-09	1.37E-09	1.43E-09
2.20E-09	2.04E-09	2.05E-09	2.13E-09
2.93E-09	2.71E-09	2.72E-09	2.83E-09
5.86E-10	5.43E-10	5.44E-10	5.66E-10
4.10E-09	3.80E-09	3.81E-09	3.96E-09
1.70E-09	1.57E-09	1.57E-09	1.64E-09
7.11E-10	6.59E-10	6.60E-10	6.86E-10

9.02E-10	8.36E-10	8.37E-10	8.71E-10
2.83E-09	2.62E-09	2.62E-09	2.73E-09
4.75E-09	4.40E-09	4.41E-09	4.59E-09
6.67E-09	6.18E-09	6.19E-09	6.44E-09
4.19E-09	3.88E-09	3.88E-09	4.04E-09

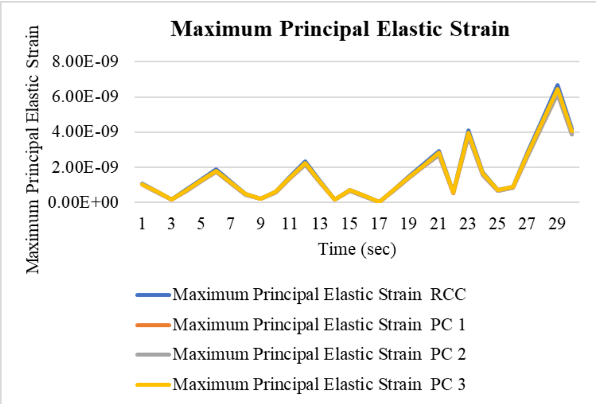
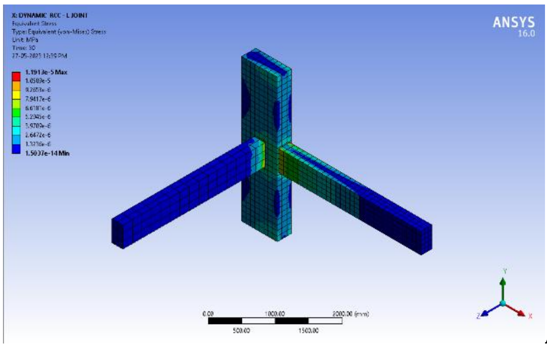


Fig. 12 Maximum Principal Elastic Strain of 'T' Joint

From (Table 5 and Fig. 12), the maximum principal elastic strain of RCC model is more than precast models by 5-10%.

From above analysis of 'T' joint for four different parameters it was observed that the performance of precast model PC 1 and PC 2 are nearly same. Hence, for further analysis of 'L' Joint and 'X' Joints, only precast model PC 1 was compared with RCC model.

3.5 Results For Dynamic Analysis of 'L' Joint for Equivalent Stress



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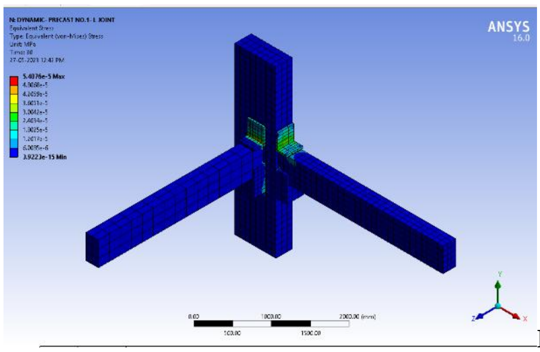


B

Fig. 13 Equivalent Stress for (A)RCC and (B) Precast Connection Type 1 for 'L' Joint

Table 7Equivalent Stress (MPa)

Equivalent Stress	
RCC	**PC 1**
3.06E-06	1.39E-05
1.77E-06	8.04E-06
4.82E-07	2.19E-06
2.08E-06	9.45E-06
3.69E-06	1.67E-05
5.29E-06	2.40E-05
3.32E-06	1.51E-05
1.35E-06	6.12E-06
6.23E-07	2.83E-06
1.79E-06	8.13E-06
4.20E-06	1.91E-05
6.62E-06	3.00E-05
3.54E-06	1.61E-05
4.57E-07	2.08E-06
2.04E-06	9.27E-06
1.08E-06	4.88E-06
1.02E-07	4.63E-07
2.16E-06	9.80E-06
4.22E-06	1.91E-05
6.27E-06	2.85E-05
8.33E-06	3.78E-05
1.67E-06	7.57E-06
1.17E-05	5.30E-05
4.83E-06	2.19E-05
2.02E-06	9.18E-06
2.57E-06	1.17E-05
8.04E-06	3.65E-05
1.35E-05	6.14E-05

1.90E-05	8.62E-05
1.19E-05	5.41E-05

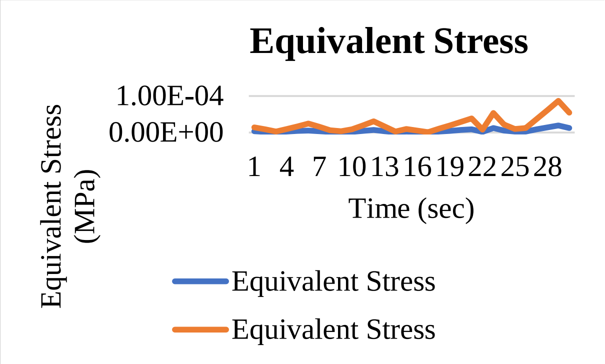


Fig. 14 Equivalent Stress of 'L' Joint

From (Table 5 and Fig. 14) for dynamic analysis of 'L' joint, Equivalent Stress for RCC is less than precast model PC 1 by 60-70%.

3.6 Results For Dynamic Analysis of 'L' Joint for Normal Stress

Table 8Normal Stress (MPa)

Normal Stress	
RCC	**PC 1**
3.04E-06	1.05E-05
1.76E-06	6.07E-06
4.78E-07	1.65E-06
2.06E-06	7.13E-06
3.66E-06	1.26E-05
5.24E-06	1.81E-05
3.29E-06	1.14E-05
1.34E-06	4.62E-06
6.02E-07	2.13E-06
1.78E-06	6.13E-06
4.17E-06	1.44E-05
6.56E-06	2.27E-05
3.51E-06	1.21E-05
4.54E-07	1.57E-06
2.03E-06	7.00E-06
1.07E-06	3.68E-06
1.01E-07	3.49E-07
2.14E-06	7.40E-06
4.18E-06	1.44E-05
6.22E-06	2.15E-05
8.26E-06	2.85E-05
1.61E-06	5.71E-06
1.13E-05	4.00E-05
4.66E-06	1.65E-05
2.01E-06	6.93E-06
2.55E-06	8.80E-06
7.98E-06	2.75E-05
1.34E-05	4.63E-05
1.88E-05	6.51E-05
1.18E-05	4.08E-05

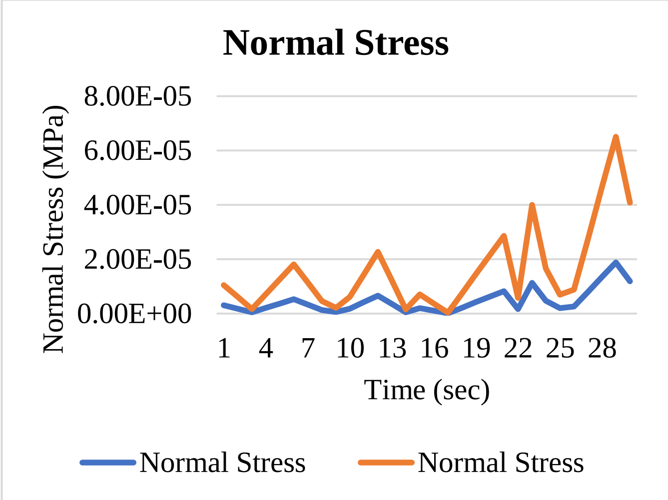


Fig. 15 Normal Stress of 'L' Joint

From (Table 7 and Fig. 15), for dynamic analysis of 'L' joint, Normal Stress for RCC is less than precast model PC 1 by 70-80%.

3.7 Results For Dynamic Analysis of 'L' Joint for Total Deformation

Table 9 Total Deformation(mm)

Total Deformation	
RCC	**PC 1**
1.76E-05	1.54E-05
1.01E-05	8.87E-06
2.76E-06	2.41E-06
1.19E-05	1.04E-05
2.11E-05	1.85E-05
3.03E-05	2.65E-05
1.90E-05	1.66E-05
7.72E-06	6.75E-06
3.57E-06	3.12E-06
1.03E-05	8.97E-06

2.41E-05	2.11E-05
3.79E-05	3.31E-05
2.03E-05	1.77E-05
2.62E-06	2.29E-06
1.17E-05	1.02E-05
6.16E-06	5.39E-06
5.85E-07	5.12E-07
1.24E-05	1.08E-05
2.42E-05	2.11E-05
3.60E-05	3.14E-05
4.77E-05	4.17E-05
9.56E-06	8.36E-06
6.69E-05	5.85E-05
2.77E-05	2.42E-05
1.16E-05	1.01E-05
1.47E-05	1.29E-05
4.61E-05	4.03E-05
7.75E-05	6.77E-05
1.09E-04	9.51E-05
6.83E-05	5.97E-05

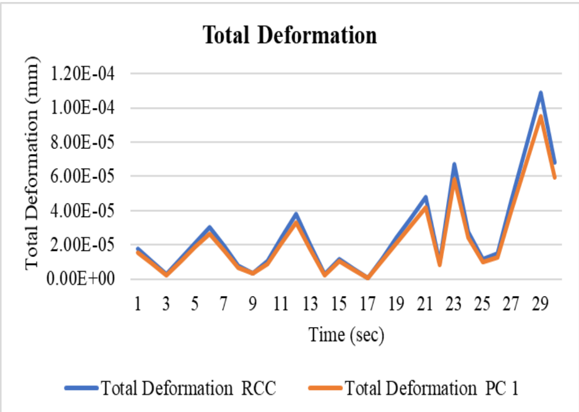


Fig. 16 Total Deformation of 'L' Joint

From (Table 8 and Fig. 16), for dynamic analysis of 'L' joint, Total Deformation for RCC is more than precast model PC 1 by 10-15%.

3.8 Results for Dynamic Analysis of 'L' Joint for Maximum Principal Elastic Strain

Table 10 Maximum Principal Elastic Strain

Maximum Principal Elastic Strain	
RCC	**PC 1**
1.07E-09	1.02E-09
6.18E-10	5.87E-10
1.68E-10	1.60E-10
7.26E-10	6.90E-10
1.29E-09	1.22E-09
1.84E-09	1.75E-09
1.16E-09	1.10E-09
4.70E-10	4.47E-10
2.12E-10	2.03E-10
6.24E-10	5.93E-10
1.47E-09	1.39E-09
2.31E-09	2.19E-09
1.23E-09	1.17E-09
1.59E-10	1.52E-10
7.13E-10	6.77E-10
3.75E-10	3.56E-10
3.56E-11	3.38E-11
7.53E-10	7.16E-10
1.47E-09	1.40E-09
2.19E-09	2.08E-09
2.91E-09	2.76E-09
5.68E-10	5.43E-10
3.98E-09	3.80E-09
1.64E-09	1.57E-09
7.06E-10	6.71E-10
8.96E-10	8.51E-10
2.80E-09	2.66E-09
4.71E-09	4.48E-09
6.62E-09	6.29E-09
4.15E-09	3.95E-09

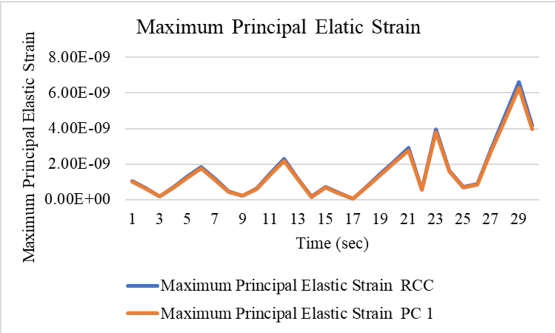
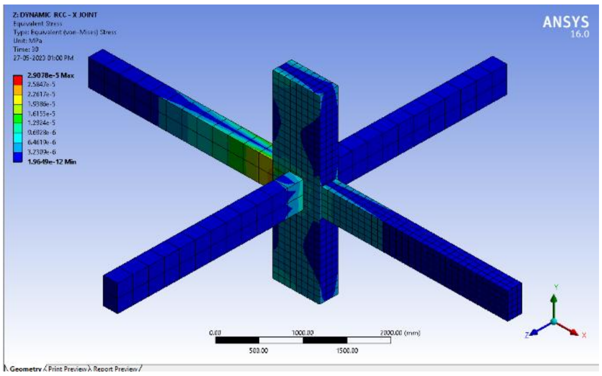


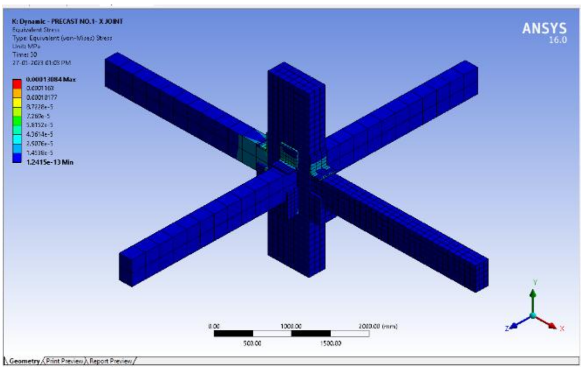
Fig. 17 Maximum Principal Elastic Strain of 'L' Joint

From (Table 9 and Fig. 17), for dynamic analysis of 'L' joint, Maximum Principal Elastic Strain for RCC is more than precast model PC 1 by 5-10%.

3.9 Results For Dynamic Analysis of 'X' Joint for Equivalent Stress



A



B

Fig. 18 Equivalent Stresses of (A) RCC and (B) Precast 1 Connection for 'X' Joint

Table 11 Equivalent Stress (MPa)

Equivalent Stress	
RCC	**PC 1**
7.48E-06	3.37E-05
4.32E-06	1.94E-05
1.18E-06	5.29E-06
5.08E-06	2.29E-05
9.00E-06	4.05E-05
1.29E-05	5.81E-05
8.10E-06	3.64E-05
3.29E-06	1.48E-05
1.52E-06	6.84E-06
4.37E-06	1.97E-05
1.03E-05	4.62E-05
1.61E-05	7.27E-05
8.63E-06	3.88E-05
1.12E-06	5.02E-06
4.99E-06	2.24E-05
2.62E-06	1.18E-05
2.49E-07	1.12E-06
5.27E-06	2.37E-05
1.03E-05	4.63E-05
1.53E-05	6.89E-05
2.03E-05	9.15E-05
4.07E-06	1.83E-05
2.85E-05	1.28E-04
1.18E-05	5.30E-05
4.94E-06	2.22E-05
6.27E-06	2.82E-05
1.96E-05	8.83E-05
3.30E-05	1.48E-04
4.64E-05	2.09E-04
2.91E-05	1.31E-04

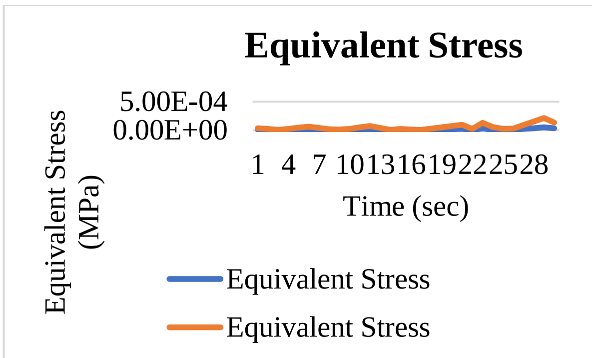


Fig. 19 Equivalent Stress of 'X' Joint

From (Table 10 and Fig.19), for dynamic analysis of 'X' joint, Equivalent Stress for RCC is less than precast model PC 1 by 50-60%.

3.10Results for Dynamic Analysis of 'X' joint for Normal Stress

Table 12 Normal Stress (MPa)

Normal Stress	
RCC	**PC 1**
6.65E-06	2.16E-05
3.84E-06	1.25E-05
1.04E-06	3.40E-06
4.52E-06	1.47E-05
8.00E-06	2.60E-05
1.15E-05	3.73E-05
7.20E-06	2.34E-05
2.92E-06	9.50E-06
1.37E-06	4.39E-06
3.88E-06	1.26E-05
9.12E-06	2.96E-05
1.43E-05	4.67E-05
7.67E-06	2.49E-05
9.92E-07	3.22E-06
4.43E-06	1.44E-05
2.33E-06	7.58E-06
2.22E-07	7.21E-07
4.68E-06	1.52E-05
9.15E-06	2.97E-05
1.36E-05	4.43E-05
1.81E-05	5.88E-05
3.67E-06	1.18E-05
2.57E-05	8.23E-05
1.06E-05	3.40E-05
4.39E-06	1.43E-05
5.57E-06	1.81E-05
1.74E-05	5.67E-05
2.93E-05	9.53E-05
4.12E-05	1.34E-04
2.58E-05	8.40E-05

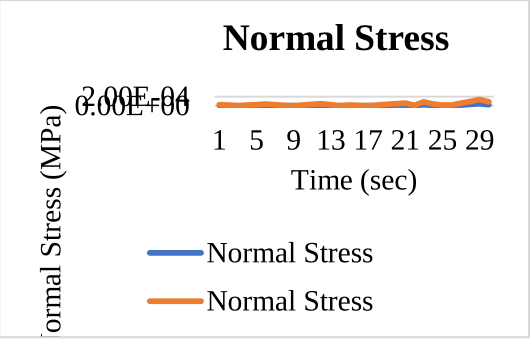


Fig. 20 Normal Stress of 'X' Joint

From (Table 11 and Fig. 20), for dynamic analysis of 'X' joint, Normal Stress for RCC is less than precast model PC 1 by 60-70%.

3.11 Results for Dynamic Analysis of 'X' Joint for Total Deformation

Table 13 Total Deformation (mm)

Total Deformation	
RCC	**PC 1**
1.65E-05	9.39E-06
9.51E-06	5.43E-06
2.59E-06	1.48E-06
1.12E-05	6.38E-06
1.98E-05	1.13E-05
2.84E-05	1.62E-05
1.78E-05	1.02E-05
7.23E-06	4.13E-06
3.34E-06	1.91E-06
9.61E-06	5.48E-06
2.26E-05	1.29E-05
3.55E-05	2.03E-05
1.90E-05	1.08E-05
2.45E-06	1.40E-06
1.10E-05	6.26E-06
5.77E-06	3.29E-06
5.48E-07	3.13E-07
1.16E-05	6.62E-06
2.26E-05	1.29E-05
3.37E-05	1.92E-05
4.47E-05	2.55E-05
8.96E-06	5.11E-06
6.27E-05	3.58E-05
2.59E-05	1.48E-05

1.09E-05	6.20E-06
1.38E-05	7.87E-06
4.32E-05	2.46E-05
7.26E-05	4.14E-05
1.02E-04	5.82E-05
6.40E-05	3.65E-05

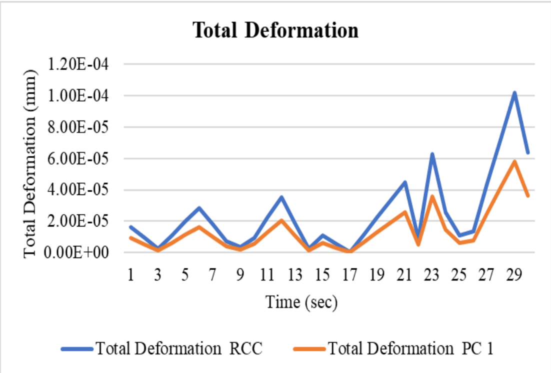


Fig. 21 Total Deformation of 'X' Joint

From (Table 12 and Fig. 21), for dynamic analysis of 'X' joint, Total Deformation for RCC is more than precast model PC 1 by 40-50%.

3.12 Results for Dynamic Analysis of 'X' Joint for Maximum Principal Elastic Strain

Table 14 Maximum Principal Elastic Strain

Maximum Principal Elastic Strain	
RCC	**PC 1**
2.17E-09	1.17E-09
1.25E-09	6.74E-10
3.41E-10	1.83E-10
1.47E-09	7.93E-10
2.61E-09	1.40E-09
3.74E-09	2.01E-09
2.35E-09	1.26E-09
9.54E-10	5.13E-10
4.43E-10	2.37E-10
1.27E-09	6.82E-10
2.97E-09	1.60E-09
4.68E-09	2.52E-09
2.50E-09	1.35E-09
3.24E-10	1.74E-10
1.45E-09	7.78E-10
7.61E-10	4.09E-10
7.23E-11	3.89E-11
1.53E-09	8.22E-10
2.98E-09	1.61E-09
4.44E-09	2.39E-09
5.90E-09	3.17E-09
1.19E-09	6.35E-10
8.30E-09	4.45E-09
3.43E-09	1.84E-09
1.43E-09	7.70E-10
1.82E-09	9.78E-10
5.69E-09	3.06E-09
9.57E-09	5.15E-09
1.34E-08	7.23E-09
8.43E-09	4.54E-09

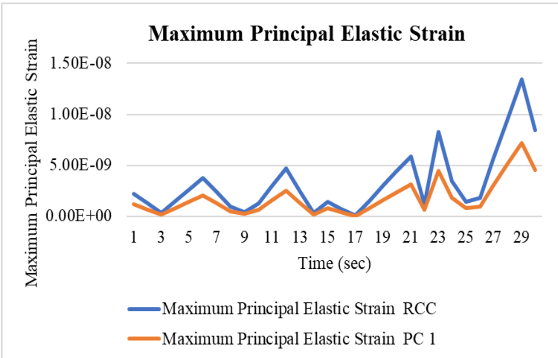


Fig. 22 Maximum Principal Elastic Strain of 'X' Joint

From (Table 13 and Fig. 22), for dynamic analysis of X joint, Maximum Principal Elastic Strain for RCC is more than precast model PC 1 by 40-50%.

CONCLUSION

The seismic performance of a precast concrete design is heavily reliant on the flexibility of the joints framed by the precast beams and columns. The goal of this investigation was to determine the best form of beam-to-column connection. The logic of the monolithic and prefabricated joint models was validated using models of three types of joints. The models will be useful for assessing seismic performance and exploring the design parameters of prefabricated joints.

- From Dynamic analysis of 'T' joint for four parameters it was observed that the performance of precast model type 1 and 2 are nearly same. Hence, precast model type 1 was taken for further analysis with RCC model for 'L', 'T' and 'X' Joint.

- For dynamic analysis on 'L', 'T' And 'X' joint, the performance of 'X' joint was better than 'L' And 'T' type of joint.

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