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Comparative Study of Precast and Monolithic Structures

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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.

1. Introduction

Precast concrete methods outperform traditional cast-in-place concrete constructions in terms of product quality, cost-effectiveness, and construction speed [7]. Precast concrete structures are also called ecological and ecological buildings in order to conserve natural resources and prevent pollution [7]. The rising use of precast is linked to contractors and engineers greater desire in discovering cost-effective alternatives to cast-in-place concrete elements [3]. 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 [3]. 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 [15]. Prefabs are useful for industrial operations since large buildings can be built beneath them without the need for columns [15].

Prefabricated components, such as culverts, abutments, retaining walls, and drainage channels, can also be advantageous in the field of infrastructure.[15]

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.

2. Literature Review

Ehsan NoroozinejadFarsangi et.al.[1]The finite element analysis was performed on four types of prefabricated connectors: pin, rigid, semi-rigid, and newly designed components. The stiffness of the new relationship was calculated using the slope of the graph of total load versus deflection in the elastic spectrum. The complete system was then subjected to seismic loads adapted from the El Centro earthquake of 0.15 g and 0.5 g. According to the study's findings, the new connection has appropriate stiffness, strength, and even better ductility. Meanwhile, the whole structural review results suggest that the new relationship functions as a semi-rigid connection. LUSAS and SAP2000 were employed in the study.

Patrick Tiong Liq Yee, et.al.[2]Despite demonstrating significant advantages over traditional cast-in-situ construction in Malaysia, the approval level of precast concrete structures is still estimated to be low. The repercussions of tougher seismic construction regulations will exacerbate the situation. The primary goal of this research was to identify the best type of beam-column connection for the precast concrete industry to use, particularly in places with low to moderate seismicity. As a result, this study provided a thorough analysis of the findings of experiments done to assess and explore the performance of precast concrete structures put under simulated earthquake loads using conventional joints or joints. The ductility of the fasteners joining each precast segment, particularly important connections such as beam-column joints, was critical to the seismic performance of the precast concrete system. The hybrid post-tensioned beam-column joint and the Dywidag Ductile Connector were found to be among the most often utilized prefabricated structural connectors in seismically vulnerable areas, according to the study.

R.A. HawilehLankeetal[3]A precast hybrid beam-column joint subjected to cyclic loading was evaluated using nonlinear finite element analysis and modelling. A thorough three-dimensional (3D) nonlinear finite element model was built to investigate and predict the behaviour of a precast hybrid beam-column connection subjected to cyclic loads tested at the National Institute of Standards and Technology (NIST) laboratory. The model accounted for the effect of prestress on prestress as well as the nonlinear material behaviour of concrete. When the model response was compared to the experimental test results, there was good agreement at all load stages. The breakdown of the link caused the mild steel bars to shatter. In addition, the magnitude of the force exerted during post-tensioning of the steel prestressing reinforcement was monitored, and it was discovered that it did not yield throughout the whole loading history. They came to the conclusion that successful finite element modelling would give a realistic and cost-effective method for investigating the behaviour of such bonds.

3. Problem Statement

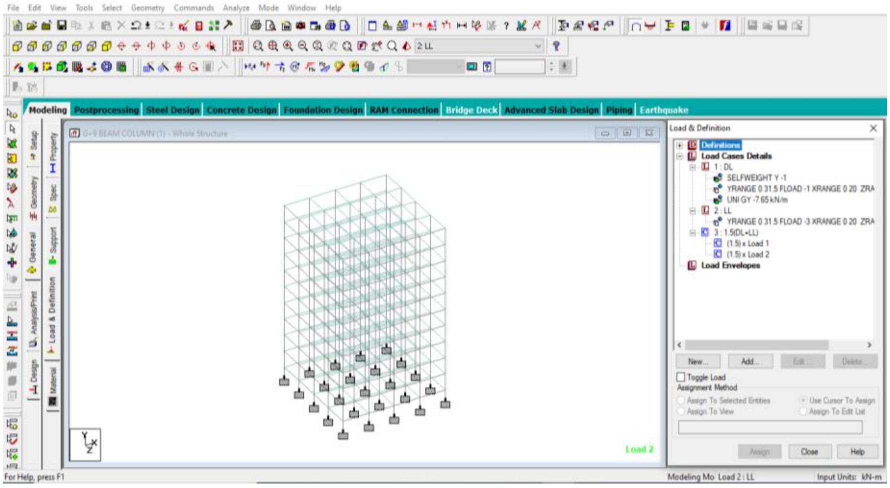
In this study, a G+9 RCC commercial construction was analyzed with Staad Pro. Following the examination, the junction or node with the greatest force on the column and the accompanying beam with the greatest force was chosen for further investigation. ANSYS was used to do the joint analysis. To conduct 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. The following are the model's specifications:

Plan dimensions: 20 m x 20 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: 3 kN/m^2
- Roof finish: 1.0 kN/m^2
- Floor finish: 1.0 kN/m^2
- Brick wall in longitudinal direction: 150 mm thick
- Brick wall in transverse direction: 150 mm thick
- Beam in longitudinal direction: 230x450 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.

4. Analysis Of Model in Staad Pro

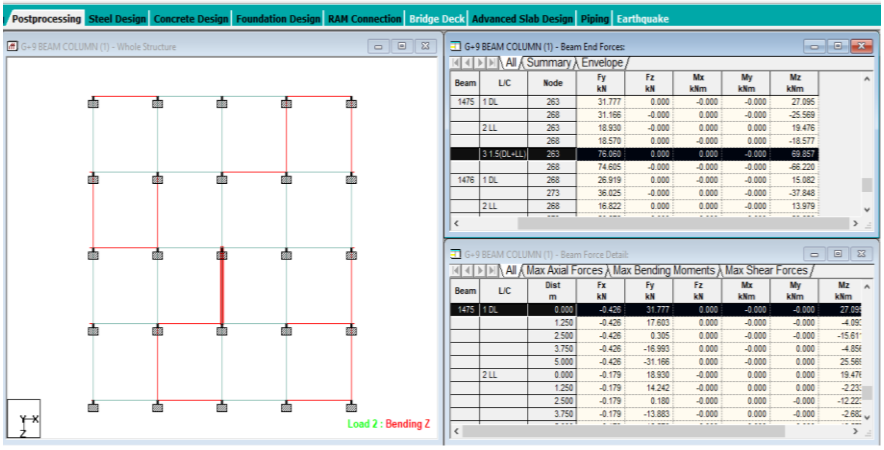
Fig 1 depicts a G+9 storey structure that was modelled in this section. Following the examination, the column and beam with the greatest forces were chosen for further investigation.



Load & Definition

- Definitions
- Load Cases Details
  - 1 : DL
    - SELFWEIGHT Y -1
    - YRANGE 0 31.5 FLOAD -1 XRANGE 0 20 ZRA
    - UNI GY -7.65 kN/m
  - 2 : LL
    - YRANGE 0 31.5 FLOAD -3 XRANGE 0 20 ZRA
  - 3 : 1.5(DL+LL)
    - (1.5) x Load 1
    - (1.5) x Load 2
- Load Envelopes

Fig. 1 Modeling in Staad Pro



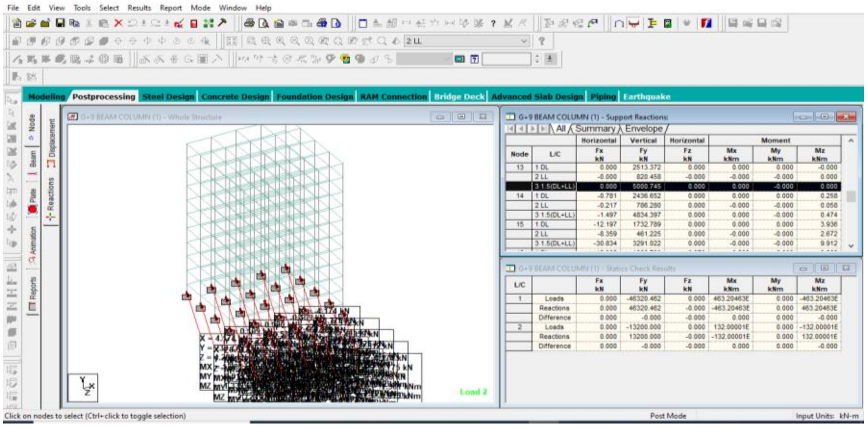
G+9 BEAM COLUMN (1) - Beam End Forces:

Beam	L/C	Node	Fy kN	Fz kN	Mx kNm	My kNm	Mz kNm
1475	1 DL	263	31.777	0.000	-0.000	-0.000	27.095
		268	31.166	-0.000	0.000	-0.000	-25.569
	2 LL	263	18.930	-0.000	0.000	0.000	19.476
		268	18.570	0.000	-0.000	0.000	-18.577
	3 1.5(DL+LL)	263	76.060	0.000	0.000	-0.000	69.857
		268	74.605	-0.000	-0.000	-0.000	-66.220
1476	1 DL	268	26.919	0.000	-0.000	-0.000	15.082
		273	36.025	-0.000	0.000	-0.000	-37.848
	2 LL	268	16.822	0.000	0.000	-0.000	13.979

G+9 BEAM COLUMN (1) - Beam Force Detail:

Beam	L/C	Dist m	Fx kN	Fy kN	Fz kN	Mx kNm	My kNm	Mz kNm
1475	1 DL	0.000	-0.426	31.777	0.000	-0.000	-0.000	27.09
		1.250	-0.426	17.603	0.000	-0.000	-0.000	-4.09
		2.500	-0.426	0.305	0.000	-0.000	-0.000	-15.61
		3.750	-0.426	-16.993	0.000	-0.000	0.000	-4.85
		5.000	-0.426	-31.166	0.000	-0.000	0.000	25.56
	2 LL	0.000	-0.179	18.930	-0.000	0.000	0.000	19.47
		1.250	-0.179	14.242	-0.000	0.000	0.000	-2.23
		2.500	-0.179	0.180	-0.000	0.000	-0.000	-12.22
		3.750	-0.179	-13.883	-0.000	0.000	-0.000	-2.68

Fig. 2 Max Force on Beam



G+9 BEAM COLUMN (1) - Support Reactions:

		Horizontal	Vertical	Horizontal	Moment		
Node	L/C	Fx kN	Fy kN	Fz kN	Mx kNm	My kNm	Mz kNm
13	1 DL	0.000	2513.372	0.000	0.000	0.000	-0.000
	2 LL	-0.000	820.458	-0.000	-0.000	-0.000	0.000
	3 1.5(DL+LL)	0.000	5000.745	0.000	0.000	-0.000	0.000
14	1 DL	-0.781	2436.652	0.000	0.000	0.000	0.258
	2 LL	-0.217	786.280	0.000	-0.000	-0.000	0.058
	3 1.5(DL+LL)	-1.497	4834.397	0.000	0.000	-0.000	0.474
15	1 DL	-12.197	1732.789	0.000	0.000	0.000	3.936
	2 LL	-8.359	461.225	0.000	-0.000	-0.000	2.672
	3 1.5(DL+LL)	-30.834	3291.022	0.000	-0.000	-0.000	9.912

G+9 BEAM COLUMN (1) - Statics Check Results

L/C		Fx kN	Fy kN	Fz kN	Mx kNm	My kNm	Mz kNm
1	Loads	0.000	-46320.462	0.000	463.20463E	0.000	-463.20463E
	Reactions	0.000	46320.462	-0.000	-463.20463E	0.000	463.20463E
	Difference	0.000	-0.000	-0.000	0.000	0.000	-0.000
2	Loads	0.000	-13200.000	0.000	132.00001E	0.000	-132.00001E
	Reactions	0.000	13200.000	-0.000	-132.00001E	0.000	132.00001E
	Difference	0.000	-0.000	-0.000	0.000	0.000	-0.000

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.

5. 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.

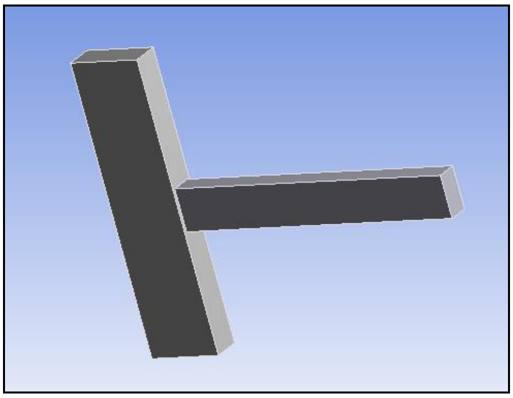
Details of ANSYS Models for Precast and RCC connection

- 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

Table 1 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 modelswere modelled in Ansys as shown in Fig.4 to 7.



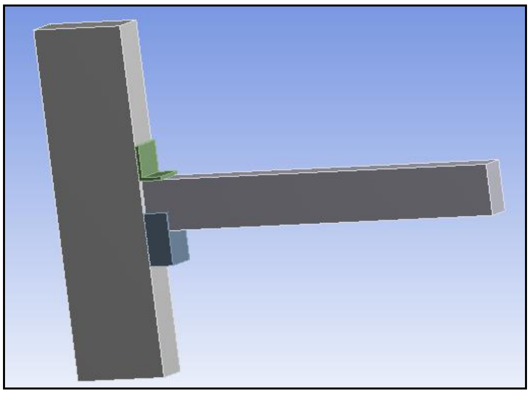
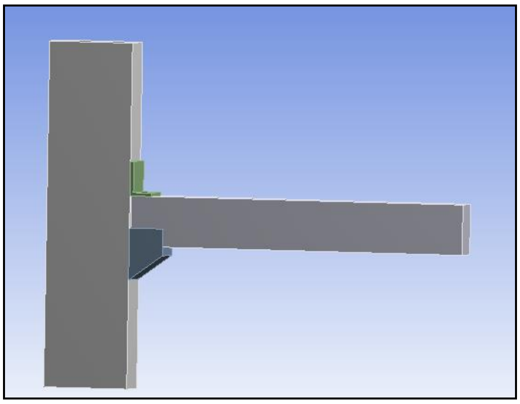


Fig.4 Model of RCCFig.5 Precast Model Type 1



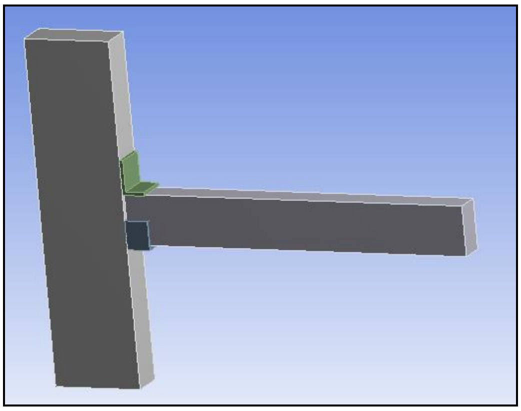
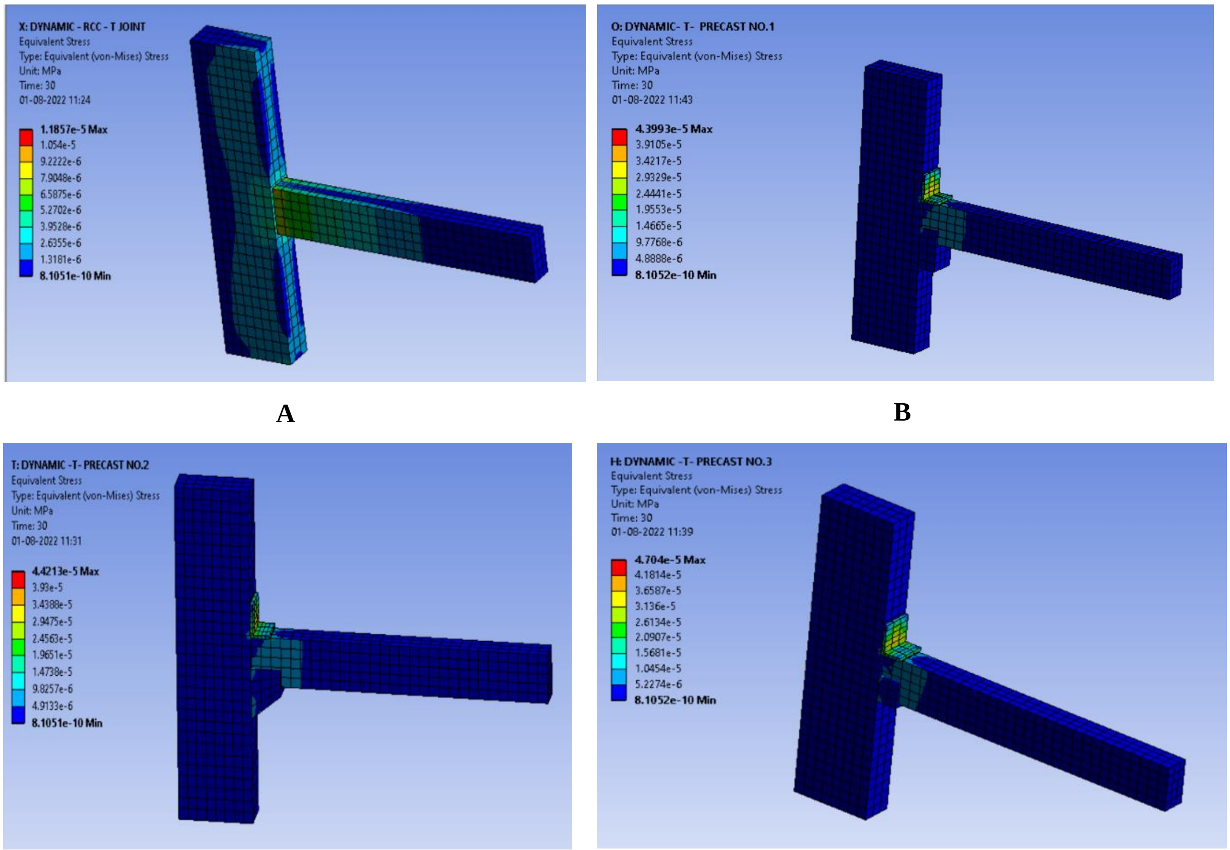


Fig.6 Precast Model Type 2Fig.7 Precast Model Type 3

6. Results

6.1 Results For Dynamic Analysis of 'T' Joint

- **Equivalent Stress MPa**



A B

C D

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

Table 2 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

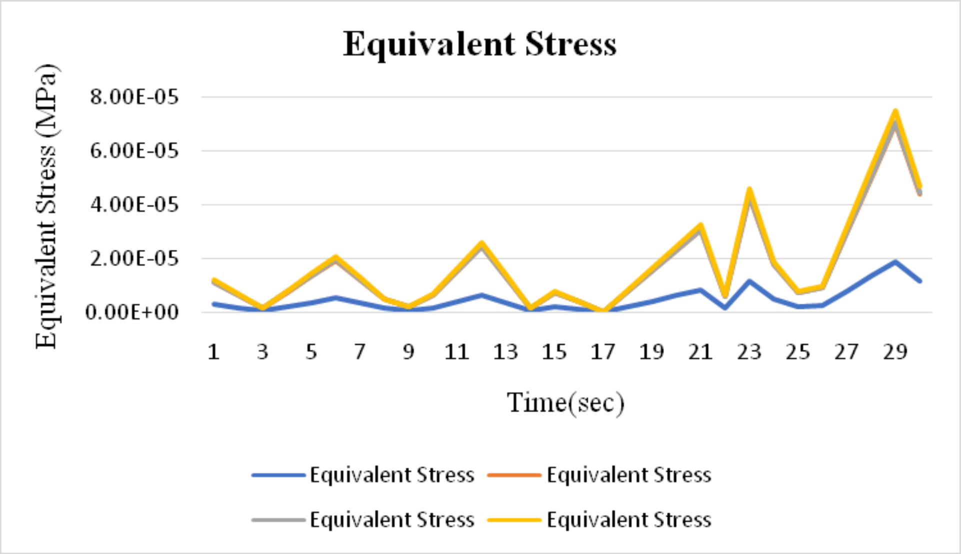


Fig.9 Equivalent Stress of 'T' Joint

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

6.2 Results ForDynamic Analysis of 'T' Joint for Normal Stress

Table 3NormalStress (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

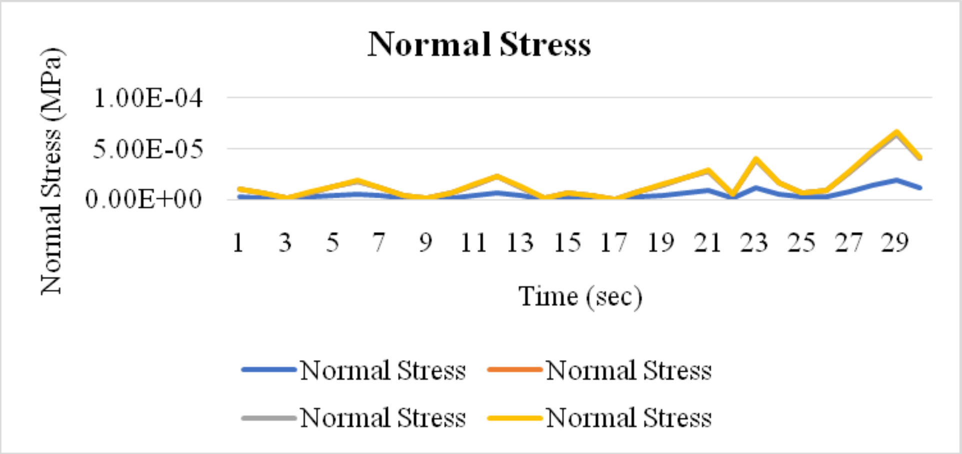


Fig.10 Normal Stress of 'T' Joint

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 3by 4-10%.

6.3 Results For DynamicAnalysisof 'T' Joint for Total Deformation

Table 4Total 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

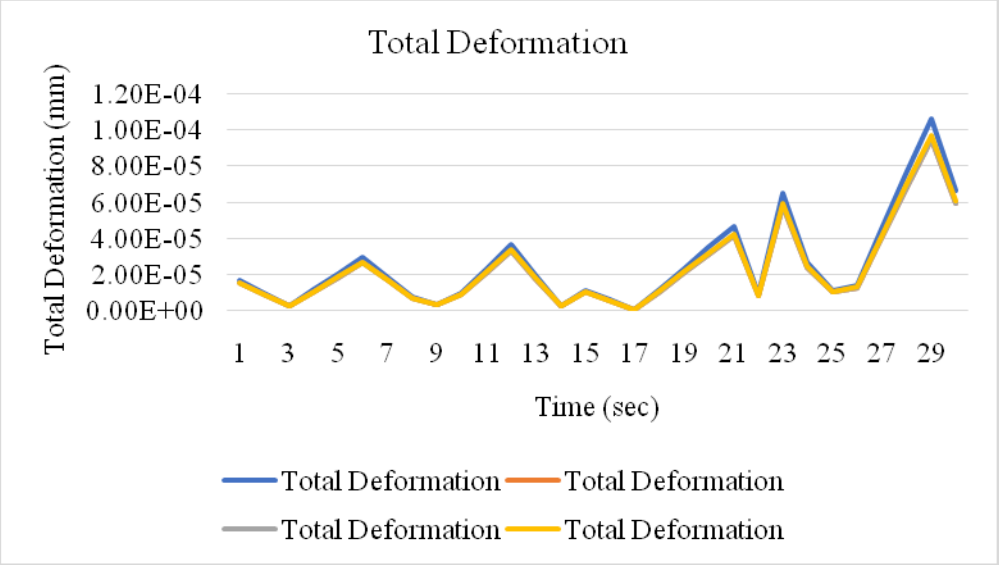


Fig. 11 Total Deformationof 'T' Joint

From (Table 4 and Fig. 11),for dynamic analysis,Total Deformation for RCC ismore than precast modelPC1, PC2 and PC3 by 10-15%.

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

Table 5 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

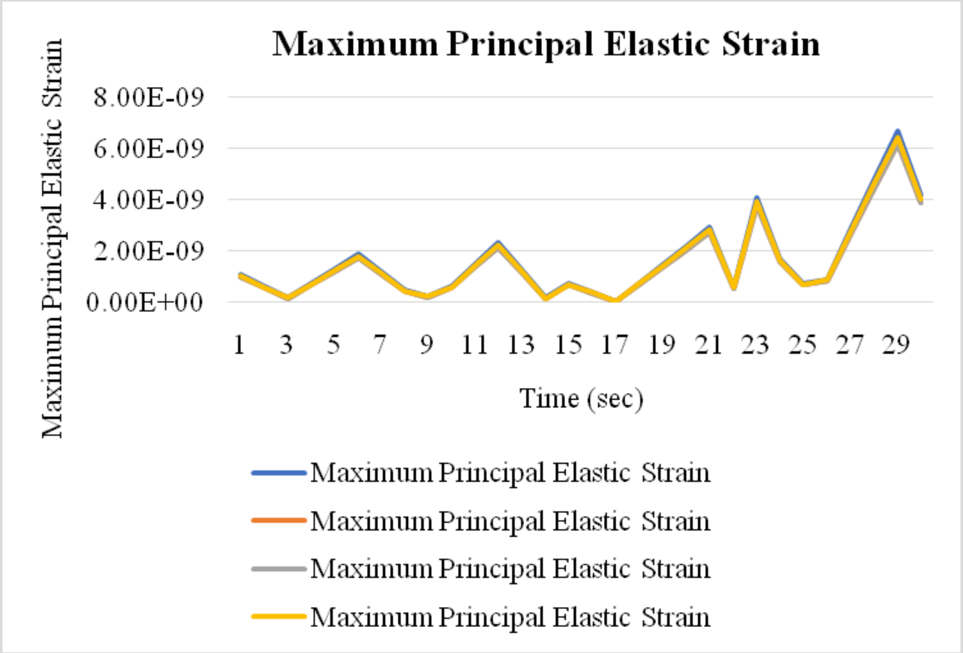
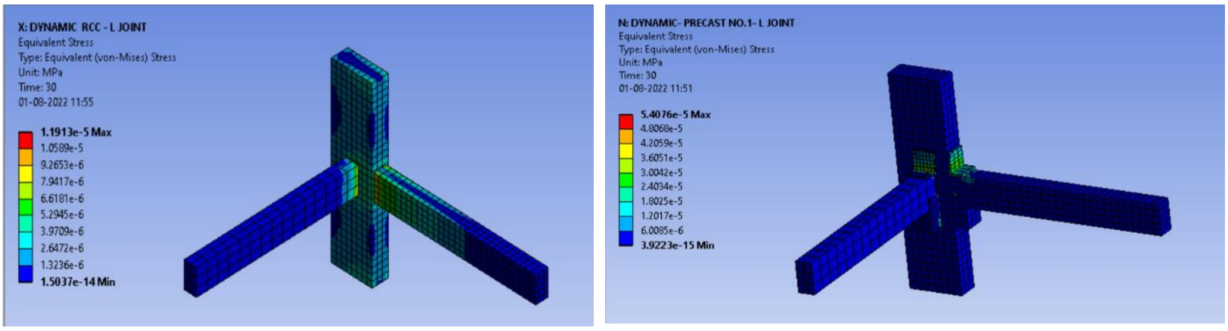


Fig. 12 Maximum Principal Elastic Strainof ‘T’ Joint

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 modelPC 1 and PC 2 are nearly same. Hence, for further analysis of ‘L’ Joint and ‘X’ Joints, only precast modelPC 1 was compared with RCC model.

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



A **B**

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

Table 6Equivalent 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

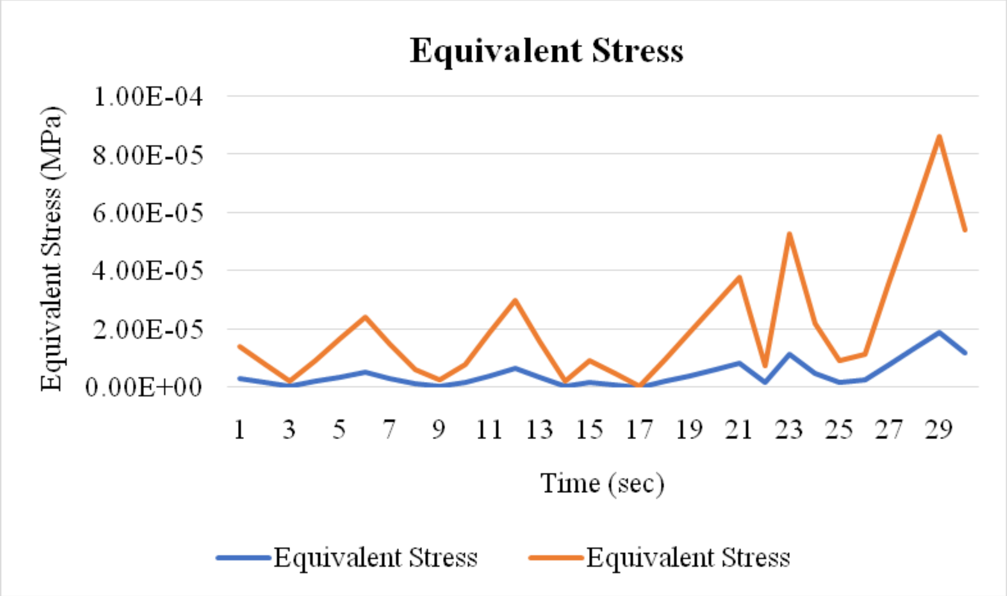


Fig.14Equivalent Stressof ‘L’ Joint

From (Table6 and Fig. 14) for dynamic analysis of‘L’ joint, Equivalent Stress for RCC is less than precast modelPC 1 by 60-70%.

6.6 Results For Dynamic Analysis of ‘L’ Joint for Normal Stress

Table 7Normal 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

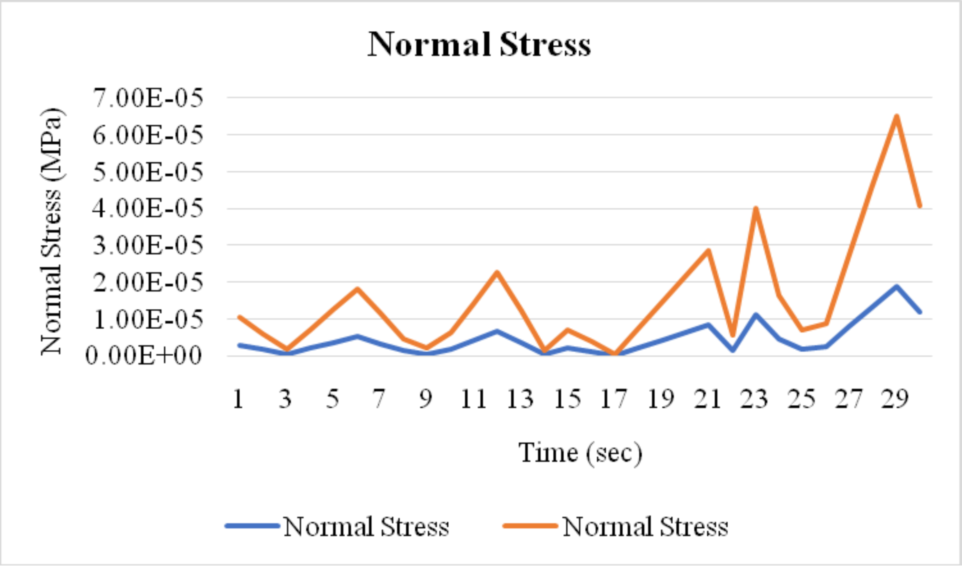


Fig. 15Normal Stressof ‘L’ Joint

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

6.7 Results For Dynamic Analysis of ‘L’ Joint for Total Deformation

Table8 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

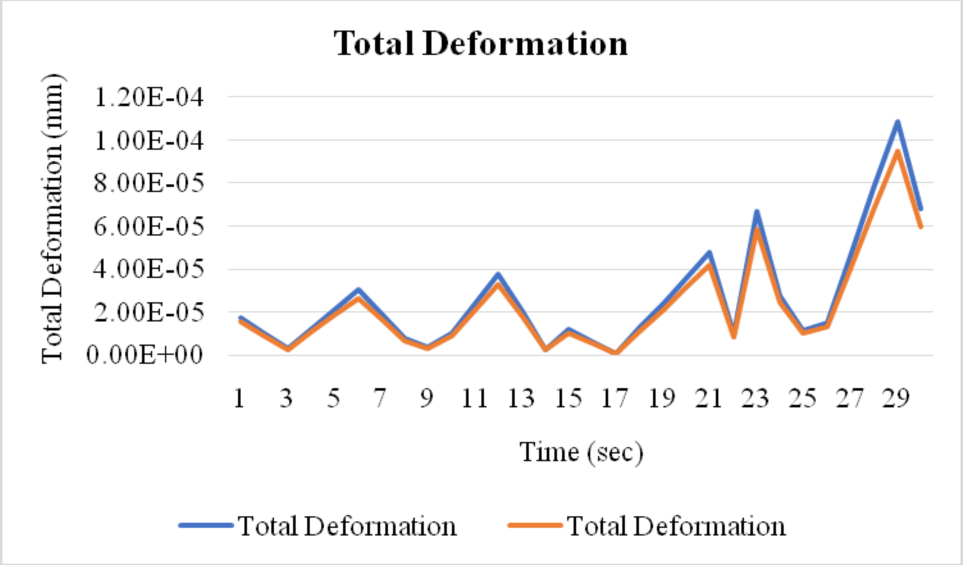


Fig. 16Total Deformationof 'L' Joint

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

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

Table 9 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

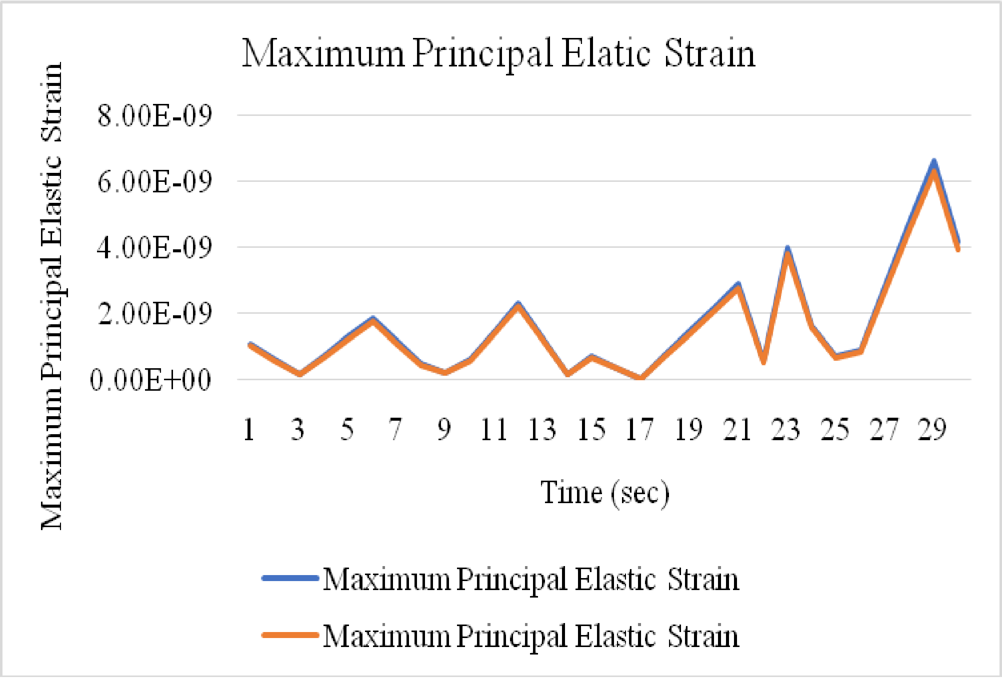
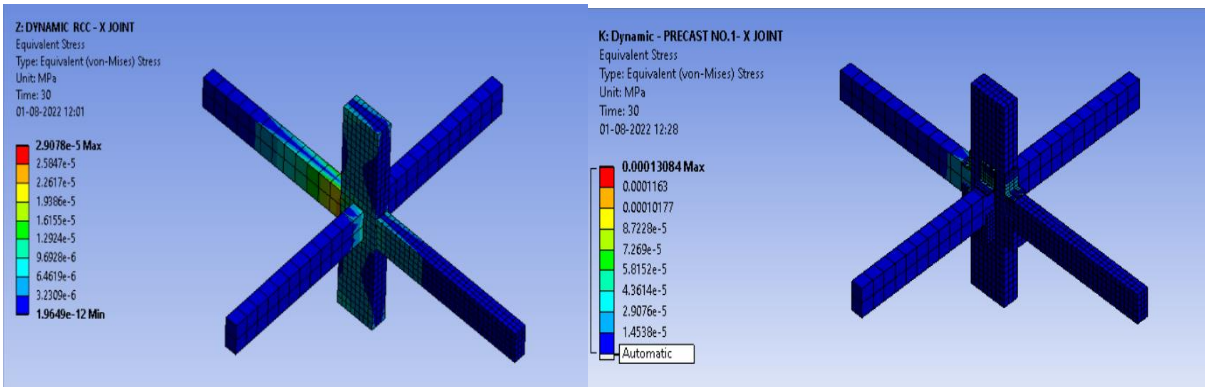


Fig.17 Maximum Principal Elastic Strain of ‘L’ Joint

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

6.9 Results For Dynamic Analysis of ‘X’ Joint for Equivalent Stress



A **B**

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

Table10 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

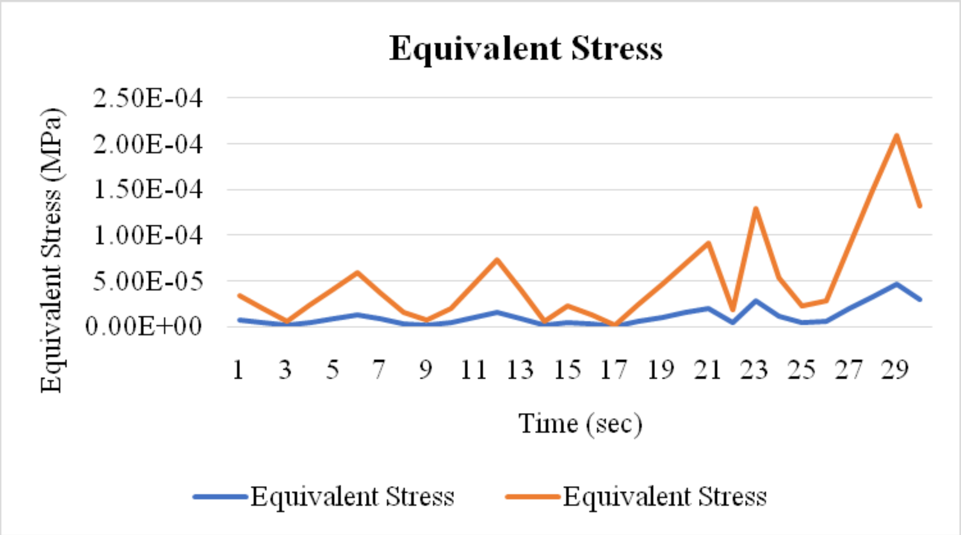


Fig.19Equivalent Stress of 'X' Joint

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%.

6.10Results for Dynamic Analysis of 'X' joint for Normal Stress

Table11 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

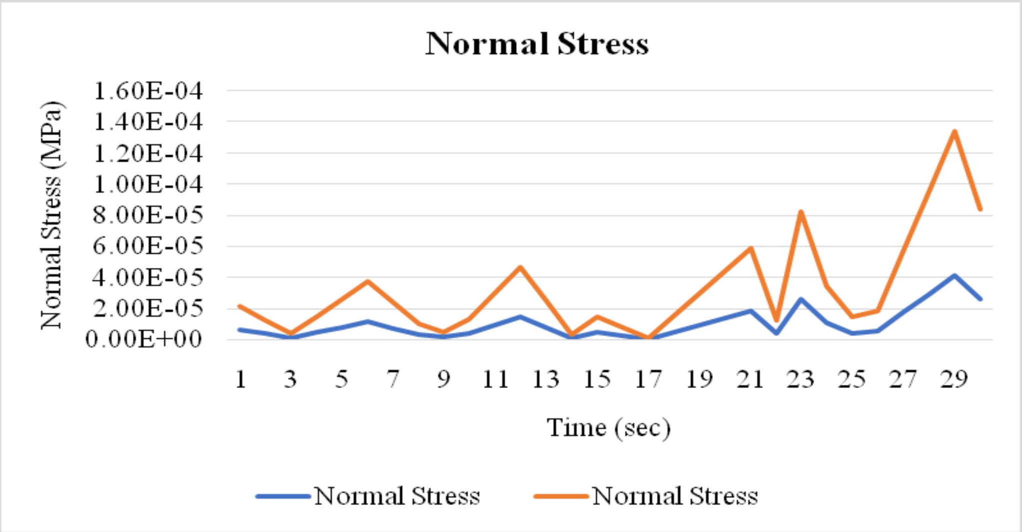


Fig. 20Normal Stress of 'X' Joint

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%.

6.11Results for Dynamic Analysis of 'X' Joint for Total Deformation

Table 12 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

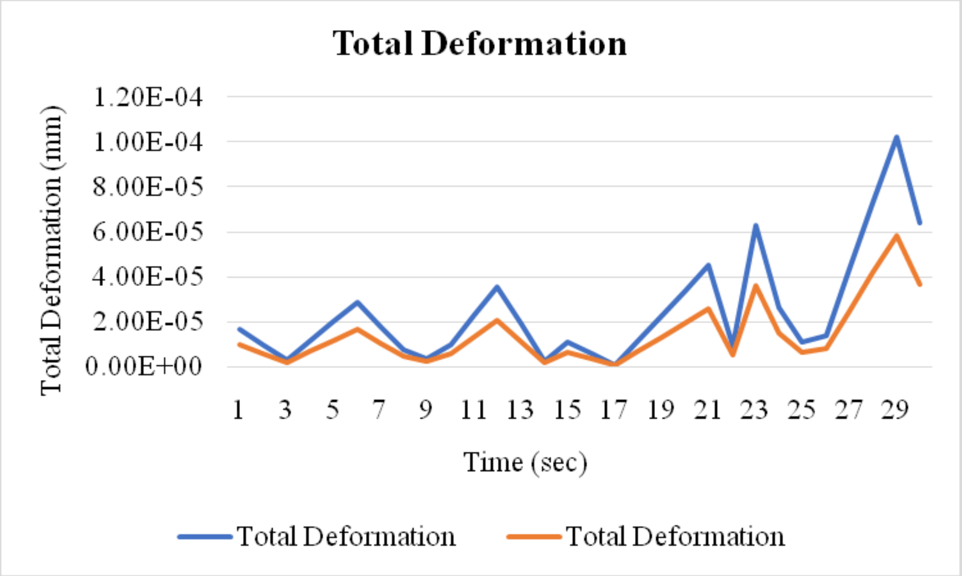


Fig.21 Total Deformation of ‘X’ Joint

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%.

6.12Results for Dynamic Analysis of ‘X’ Joint for Maximum Principal Elastic Strain

Table 13 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

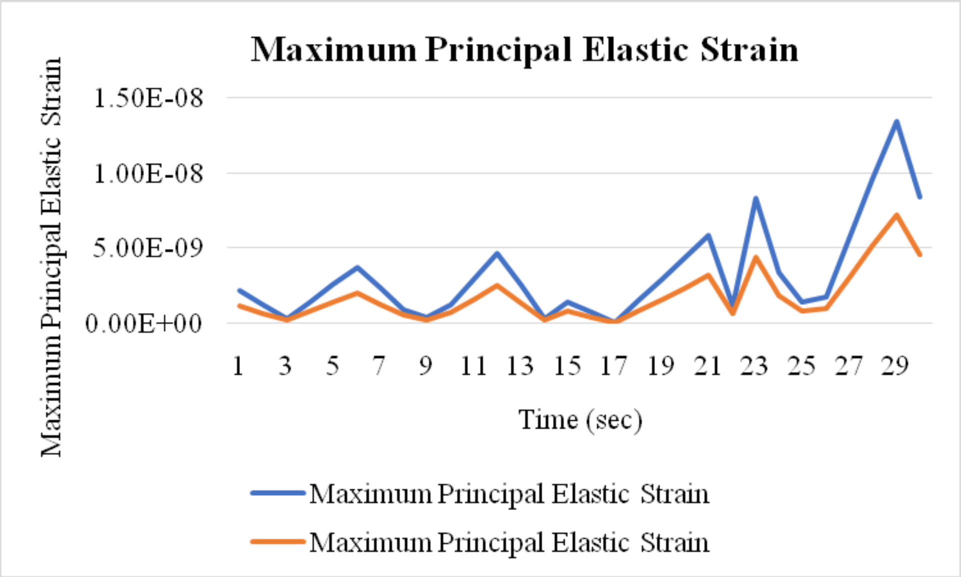


Fig. 22 Maximum Principal Elastic Strain of 'X' Joint

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

7. Conclusion

The flexibility of the joints framed by the precast beams and columns is critical to the seismic performance of a precast concrete design. The purpose of this study was to establish the best type of beam-to-column connection. Models of three types of joints were used to validate the logic of the monolithic and prefabricated joint models. The models will be useful for measuring seismic performance and investigating prefabricated joint design characteristics. Dynamic investigation of the 'T' joint for four parameters revealed that the performance of precast model types 1 and 2 are almost identical. As a result, precast model type 1 was chosen for further investigation with RCC model for 'L' and 'X' joints. The performance of the 'X' joint was superior than the 'L' and 'T' joint in dynamic analysis. Overall, RCC models outperform Precast models in terms of Equivalent Stress and Normal Stress, whereas Precast models outperform RCC models in terms of Total Deformation and Maximum Principal Elastic Strain.

8. Acknowledgment

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