FINITE ELEMENT ANALYSIS ON PRECAST CONCRETE CONNECTIONS SUBJECTED TO SEISMIC LOADS

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ABSTRACT
Precast Structure are an economical alternative for buildings in high seismic region, there is still a lack of design provisions for seismic resistant beam-to-column connections for suitable construction of precast concrete frame. Which limits the use of precast elements in any type of civil engineering structures?
Lateral strength of precast frame gains full lateral strength after connection of all precast elements. While stages of installation precast frame special care to be taken for lateral forces as all elements are not connected and may have not achieved full lateral strength, and in case if any lateral forces come, there is chances of complete failure of the structure, hence proper tie after installation of column is necessary. It is studied from Finite element modeling that precast frame requires proper supporting mechanism while its initial stage of installation, as cast in place concrete grout placed in connection is not strong enough to keep the frame intact during lateral forces.
Keyword: Connections, Precast elements, Installation, Finite Element Modeling

INTRODUCTION
Precast Skeletal Structures; these are most commonly used structures, it is the combination of columns - beams along with shear walls. Columns and Beams are designed to resist vertical loads and horizontal loads. Shear walls are designed to sustain horizontal loads. These precast concrete frames are connected each other by various types of connections. Precast elements are of a finite size and are connected with other elements, forming a complete structure. Therefore, when two elements are connected, several problems such as shrinkage, thermal or load will induced strains and cause volumetric changes. This volumetric changes cause movements between the two elements. Internal friction between the two elements surface is provided by using various methods such as inserting dowel between beams to column connection. Also, local crushing at the top of column occurs due to the flexural rotation of the beam. Bearing pads (such as Elastomeric pads) are provided to overcome this problem. Consideration of narrow bearing to be done for the suspended element on the vertical element. Overall stability of the structure has to be considered, as the combination of precast concrete elements and the structure is able to sustain vertical and horizontal loads or even dynamic loads. So the design and construction of the joints / connections is important. There are two important stabilizing systems, horizontal system and vertical system. The horizontal system is a floor diaphragm and the vertical system is the bracing system. Moment resisting frame system comprises of beams and columns, where connections are either equivalent monolithic / jointed. Dual system is a combination of shear walls and moment resisting frames to resist the lateral loads. The stability for the structure is provided by shear walls.

Precast Wall System; this system is also known as Panel system. Precast walls are designed as load bearing walls, which will resist vertical and horizontal loads. The structure is mainly composed of structural walls which transfer the vertical and horizontal forces to the foundation.

General considerations for precast concrete connections:
Connections must be structurally adequate to perform under service load and ultimate load.

1. Erection stress, effect of camber and rotation to be consider.
2. In case any failure, the adjacent member should fail first and then the connection, hence the safety factor for connection should be consider 10% higher than the safety factor of adjacent precast members.
3. Connections must be designed in such a way that the precast elements can rest, without any bracings, etc., to release the crane for other use, it saves a huge cost.
4. Connections must be compatible with the architecture of the structure.
5. Connections should be non-rusting, non-staining and watertight.
6. Tolerances must be accommodated by production as well as installation tolerance.
7. Connections must be more economical and easy to construct.

Cummins Technical Centre India (CTCI), Kothrud, Pune CTCI is an industrial building, located at Kothrud.The building is designed and constructed by using various types of precast concrete elements, such as gutters, bands, three floor height precast columns, beams, stringer beams, stair steps, mid-landing, single T slabs, double T slabs, Hollow core slabs, etc. Concrete grade is M50. The precast columns are three floor heights and the size varies, typical one is 900mm x 900mm with height of 10m. Precast Beams are sitting on the corbel introduced in the precast column. There are pockets of 1m kept in the column at each floor level in order to pass the continuous reinforcements of precast beams. For internal column, after installation of all four side beams and reinforcement passing in between the column pockets, then the junction is done as cast-in-place. Elastomeric pads are used underneath of precast beams for rotation, lateral forces or vertical movement in the columns due to seismic.

Photograph 1 Shows the Internal Column Beam joint, Photograph 2 shows the Peripheral Column Beam joint, In Photograph 3 shows the how the precast beam Install on site via crane machine,and In Photograph 4 shows the Site View of Column-Beam Continuing reinforcement.

Photograph 1 Internal Column-Beam joint.

Photograph 2 Peripheral Column-Beam joint.

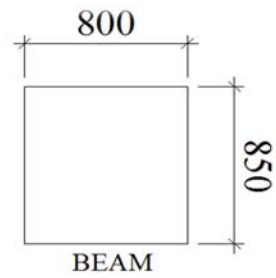
Photograph3 Installationof Beam

Photograph 4 Site view, Pockets in Column for continuing Beam reinforcement

Multilevel car park, Infosys, Hinjwadi, Pune, MLCP, is a multilevel car park building, located at IT sector, Hinjwadi. The building is designed and constructed by using various types of precast concrete elements, such as architectural facades, three floor height precast columns,spandrel beams, stringer beams, stair steps, mid-landing, single T slabs, double T slabs, Hollow core slabs, etc. Concrete grade is M50. The precast columns are three floor height and the size is 900mm x 900mm and height is 9.6m.

Dowel-pins are industrial fasteners that are used to join two or more items together. They are short, cylindrical rods, made of various materials including wood, metals and plastic. Dowel pins can be tapered, slotted, grooved or otherwise altered to change its mechanical properties.

Calculation of UDL from SF and BM



Beam Size 0.8m x 0.85m

Surface area of beam for applying UDL = 7.6 x 0.8 = 6.08 m^2

Calculations for SF, BM and AL (As per SAP 2000 Output and calculations)

BM For Beams from Node 273 to 266 and 273 to 280

Moment for Beam Node from 273 to 266 = 1665.38 KN.m

Moment for Beam Node from 273 to 280 = 1645.11 KN.m

SF For Beams, From Node 273 to 266 and 273 to 280

Shear for Beam Node from273 to 266 = 288.65 KN

Shear for Beam Node from 273 to 280 = 273.43 KN

BM For Column Node from 273 to 274 and 273 to 272

Moment for Column Node 273 to 274 = 1664.84 KN.m

Moment for Column Node 273 to 272 = 3160.65 KN.m

SF For Column Node from 273 to 274 and 273 to 272

Shear for Column Node 273 to 274 = 919.19 KN.m

Shear for Column Node 273 to 272 = 1587.6 KN

Permissible Bending Stress (Beam)

$$\frac{M}{Z} = \frac{M}{I/_{Y}}$$

$$\frac{I}{Y} = \frac{bd^3/12}{d/2} = \frac{bd^2}{6}$$

Hence, $\frac{M}{bd^2/6} = \frac{1665.38}{0.8\ x\ 0.85\ x\ 0.85/6}$

= 17287.7 KN/m^2

Permissible Bending Stress (Columns)

Calculation for BM and SF for Applying as an UDL On Beams
Considering continuous beams,

W = P x A

Whereas,

P = Uniformly distributed load in KN/m^2

hence, Moment = $\frac{P\ x\ A\ x\ L^2}{12}$

1665.4 = $\frac{P_{1}\ x\ 7.6\ x\ 0.8\ x\ 8.4\ x\ 8.4}{12}$

P_1 = $\frac{1665.4\ x\ 12}{7.6\ x\ 0.8\ x\ 8.4\ x\ 8.4}$

P_1 =46.6 KN/m^2

UDL (BM) On Beam above Corbel

= 1665.38 – 46.6 = 1618.80 KN/m^2

P_2 = $\frac{1618.80}{0.2}$ = 8093.98 KN/m^2 (On beam. above Corbel)

UDL (SF) On Beam

Shear Force = Pressure Load x Area

= 46.6 x 7.6 x 0.8

(P_3) = 283.2 KN

As maximum SF on Beam is 273.43 KN

UDL (SF) On Beam above Corbel

Remaining Force (difference) = 283.2 – 273.4

= 9.8 KN

SF on beam, above corbel location = Remaining Force (difference) / Surface area of beam, above corbel for applying UDL

$$P_4 = \frac{9.8}{0.2}$$

(SF to be loaded on beam, above corbel)

= 48.99 KN/m^2 (UDL per running m on Beam)

UDL, SF P3 = 283.2 KN/m^2 on entire beam length

UDL, SF P4 = 48.99 KN/m^2 on beam, above corbel

Calculation of Axial Loads for Column

Maximum Pressure on Column as per SAP2000

TABLE: Element Forces - Frames

Frame	Station	OutputCase	CaseType	P	V2	V3	T	M2	M3	FrameElem	ElemStation
Text	m	Text	Text	KN	KN	KN	KN-m	KN-m	KN-m	Text	m
178	0	306_1.2DL+1.2LL+1.2SEQX	Combination	-55085.31	8366.727	-43.15	-8.6656	-138.454	8022.242	178-1	0
178	1	306_1.2DL+1.2LL+1.2SEQX	Combination	-55065.34	8366.727	-43.15	-8.6656	-95.3044	-344.4853	178-1	1
377	0	306_1.2DL+1.2LL+1.2SEQX	Combination	-55074.6	8398.526	34.091	9.4462	108.9802	8061.6933	377-1	0

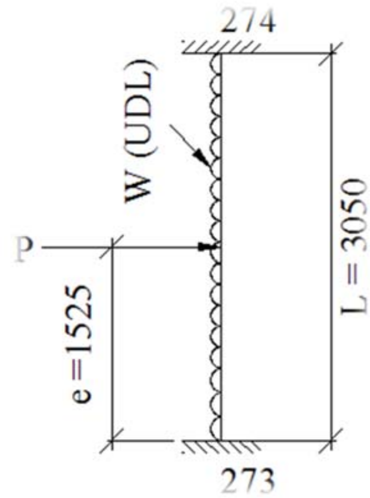
Maximum Pressure = 55085.3 KN

Column C/S Area = 0.64 m^2

$$\text{Axial Load} = \frac{\text{Maximum Pressure}}{\text{Column C/S Area}} = \frac{55085.3}{0.64} \quad 86070.8 \ \text{KN/m}^2$$

UDL, Axial load P_5 = 86070.8 KN/m^2 On C/S top of column in joint.

For column node 273 to 274



M = P x e

W = a x b x pressure load

$$e = \frac{L}{2} = \frac{3.05}{2}$$

e = 1.525 m

Hence,

M = P x e

1664.84 = P x 1.525

P = 1091.70 KN

Calculate, BM acting on column surface as an UDL, P_6

P = P_6 x surface area

1091.70 = P_6 x 2.44

P_6 = 447.42 KN/m^2

Hence, P_6 BM acting on Column Surface as an UDL = 447.42 KN/m^2

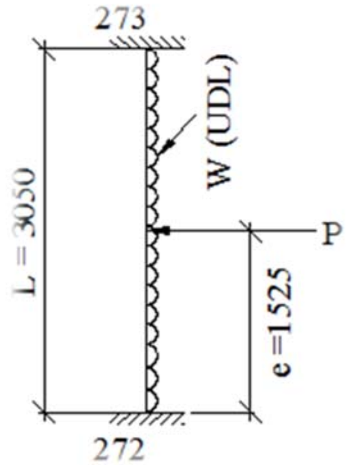
Calculate acting On Column Surface as an UDL

$$SF = \frac{P}{2} = \frac{1091.70}{2}$$

P_6 = 545.85 KN

As per SAP model = 919.75 KN

For column node 273 to 272



P = W x L

W = a x b x pressure load

$e = \frac{L}{2} = \frac{3.05}{2}$

Hence,

M = P x e

3160.65 = P x 1.525

P = 2072.56 KN

Calculate, BM acting on column surface as an UDL, P_7

P = P_7 x surface area

P = P7 x 2.44

P_7 = 849.41 KN/m^2

Hence, P_7 BM acting on column surface as an UDL = 849.41 KN/m^2

Calculate, SF acting on column surface as an UDL

$SF = \frac{P}{2} = \frac{2072.56}{2}$

Actual P_9 = 1036.28 KN

SF, permissible as per SAP model = 1587.6 KN

Hence,
For bending moment:
Beam, UDL, BM, P_1 = 46.6 KN/m^2 on entire beam length
Beam, UDL, BM, P_2 = 8094 KN/m^2 on beam, above corbel
Column node 273 to 274, UDL, BM, P_6 = 447.42 KN/m^2 on column surface,
Column node 273 to 272, UDL, BM, P_7 = 849.41 KN/m^2 on column surface
For shear force:
UDL, SF, P_3 = 283.2 KN/m^2 on entire beam length
UDL, SF, P_4 = 48.99 KN/m^2 on beam, above corbel
Column node 273 to 274, UDL, SF, P_8 = 919.19 KN/m^2 on column surface,
Column node 273 to 272, UDL, SF, P_9 = 1587.6 KN/m^2 on column surface
For axial load:
P_5 = 86071 KN/m^2 on C/S top of column in joint.

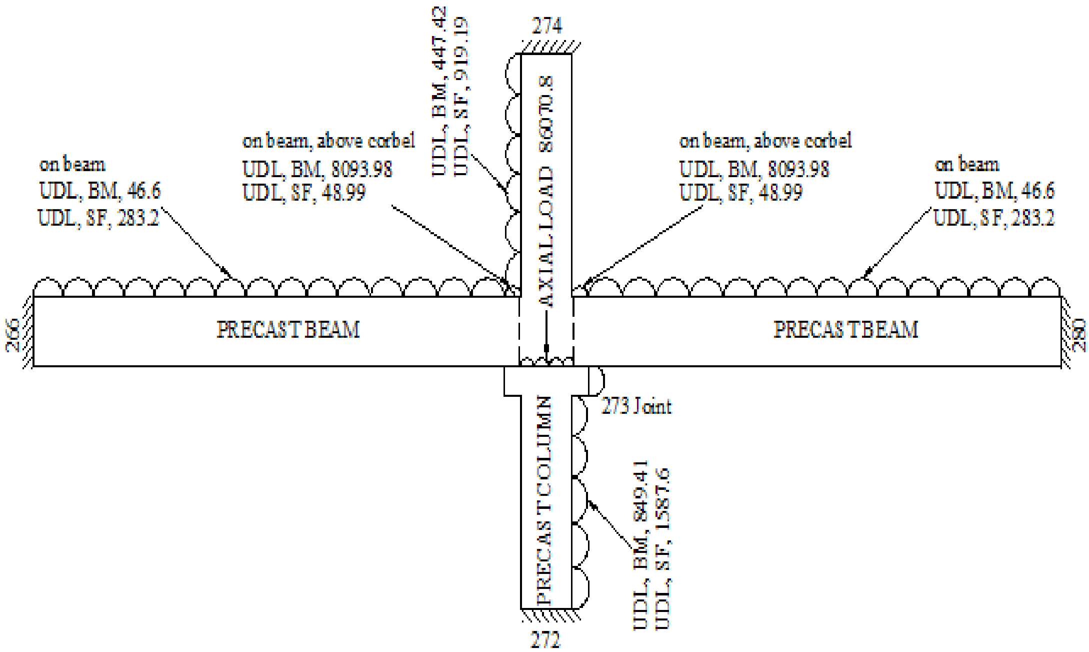


Fig.1 Loading details for CB1 Model (load case 3)

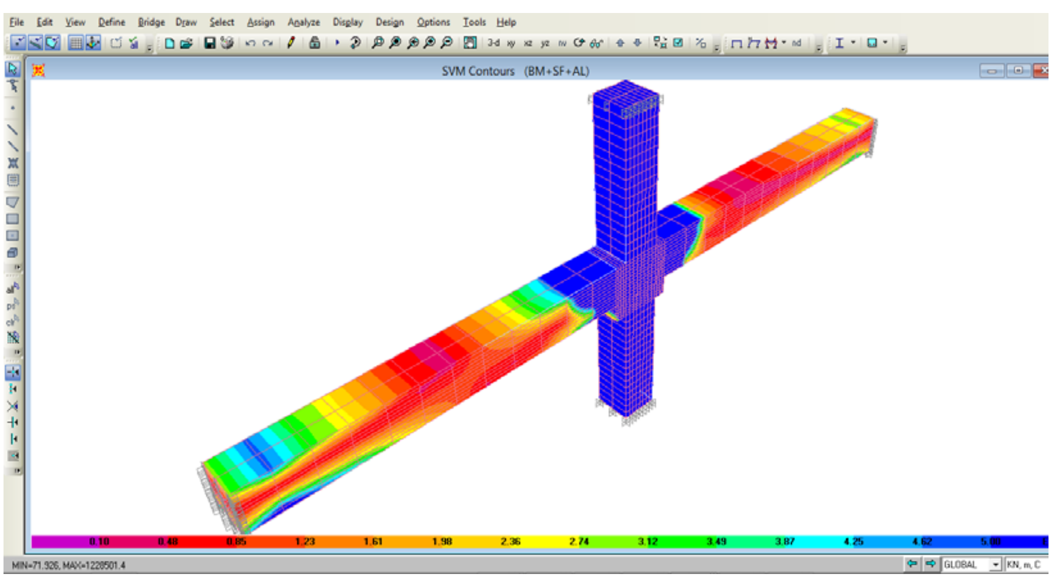


Fig 2 Connection CB1, Finite Element Model (load case 3)

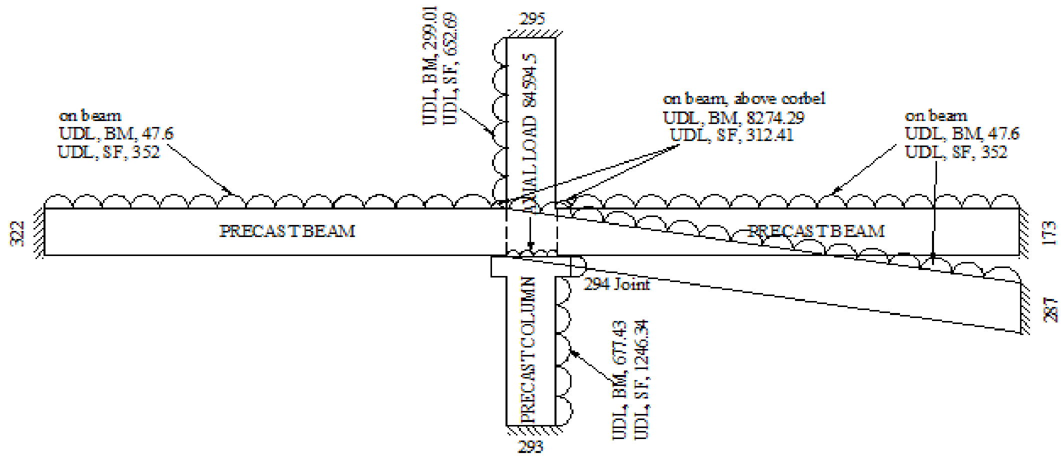


Fig. 3 Loading details for CB2 Model (load case 3)

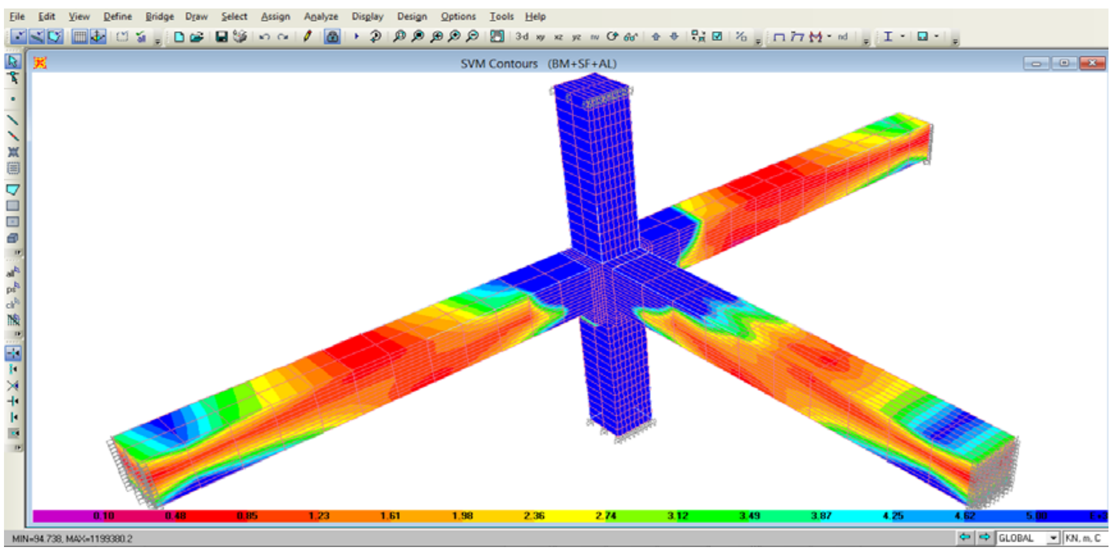


Fig 4 Connection CB2, Finite Element Model (load case 3)

Behavior in Precast Connections and RCC Connections

For G+12 RCC frame, applying the calculated loadings, considering various load cases as 1, 2 and 3 on CB1 model. The stresses are taken at 10 locations, covering the beam bottom and column corbel.

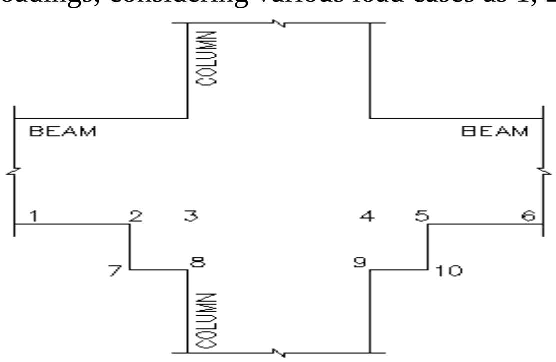


Fig 5.Beam Column Connection

Components of normal stress in the three directions are called the principal stresses and are denoted as S11, S22 and S33. These components of direct stress represent maximum magnitude of tensile and compressive stress at the particular point. Main use of principal stress is to predict failure in a structure.

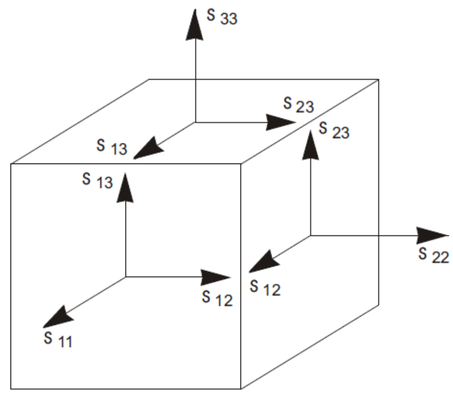


Fig 6. Principal stresses diagram

Comparison between Precast Frame and RCC Frame
Precast Frame

	1	2	3	4	5
1-SF-S11	88.32	-52.18	-56.28	-55.33	-52.21
2-SF-S11	1079.17	571.31	36.6	-940.36	-1827.31
3-SF-S11	1371.51	921.63	206.21	-1036.08	-2796.96
1-BM-S12	-1.58	15.87	1.13	-1.07	-13.54
2-BM-S12	-18.28	133.9	16.65	39.6	216.82
3-BM-S12	-14.56	135.16	13.31	-58.28	231.26

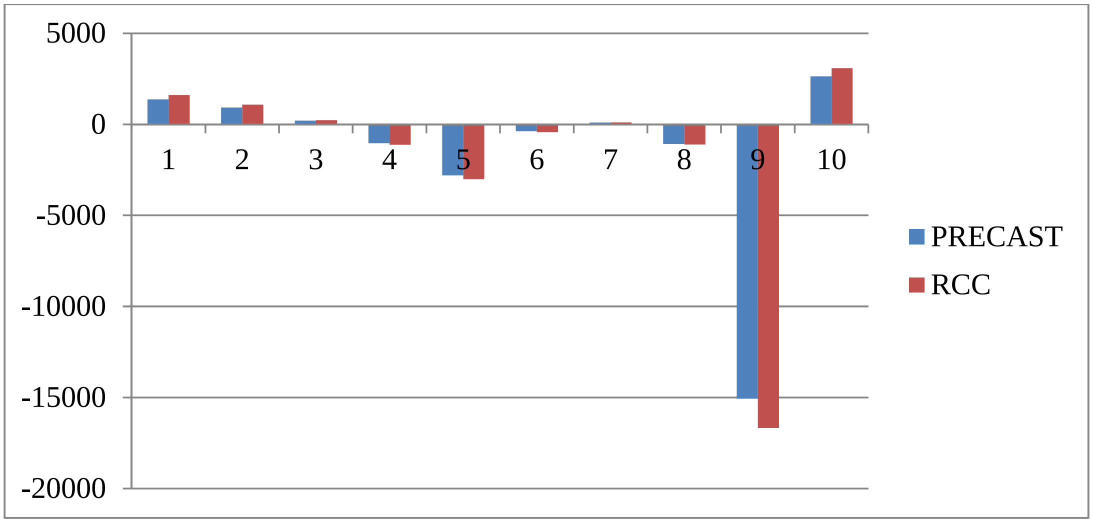
1-SF-S11	86.03	18.21	-223.07	-233.19	17.21
2-SF-S11	-199.67	94.43	-1010.39	-12661.9	2166.74
3-SF-S11	-378.9	91.93	-1081.78	**-15060.6**	2631.11
1-SF-S11	1.14	4.58	14.87	-13.57	-6.57
2-SF-S11	-72.81	258.88	-33.55	308	1496.62
3-SF-S11	-43.73	31.69	147.73	416.15	1197.64

RCC frame

	1	2	3	4	5
1-SF-S11	96.23	-59.19	-61.32	-60.21	-56.21
2-SF-S11	1215.14	612.13	39.16	-1020.22	-2516.32
3-SF-S11	1612.13	1079.17	226.42	-1119.13	-3015.16
1-BM-S12	-2.56	20.96	1.2	-2.05	-17.21
2-BM-S12	-26.56	146.89	22.56	42.6	212.72
3-BM-S12	-18.85	142.32	16.32	-52.29	228.62

	6	7	8	9	10
1-SF-S11	92.02	26.12	-282.08	-271.89	18.05
2-SF-S11	-232.35	98.12	-1145.18	-13215.2	2315.17
3-SF-S11	-425.09	101.13	-1105.18	**-16679.6**	3089.11
1-BM-S12	1.2	5.02	15.03	-16.63	-8.45
2-BM-S12	-81.89	278.16	-42.15	338	1890.92
3-BM-S12	-49.51	34.69	176.51	457.15	1317.17

Graph Stress Variation for Precast and RCC Connections for Load Case 3



Graph 1 Stress Variation for Precast and RCC Connections for Load Case 3

Observations:-

1) Out of seven load cases third load case have been considered as this load case Shows Maximum Stresses.

3) From the above Results and Graph the third load case 1.2DL + 1.2 LL + 1.2EL at S11 Shows Maximum Stress at Every Location among all the Load Cases.

4) From the above Results Stresses can be observed at 10 Locations.

5) The Maximum Value of Stresses at Location 9 for Precast frame Connection is -15060.6 KN/m^2 and RCC frame Connection is -16679.6 KN/m^2

6) For Location 9 , the percentage Decrease in Stresses in Precast frame Connection is 9.70 % as Compared with RCC frame Connection.

7) Similarly the percentage Decrease in Stresses can be observed for all Locations for Load case 3 as Compared to RCC frame Connection. Table 4.6 Shows Variation in percentage in stresses

Table 1 Variation in Percentage Decrease in Stresses

Location	**Stresses in kN/m^2**		**Percentage Decrease in Stresses**
	Precast frame Connection	**RCC frame Connection**	
1	1371.51	1612.13	14.92
2	921.63	1079.17	14.59
3	206.21	226.42	8.92
4	-1036.08	-1119.13	7.42
5	-2796.96	-3015.16	7.23
6	-378.90	-425.09	10.86
7	91.93	101.13	9.09
8	-1081.78	-1105.18	2.11
9	-15060.60	-16679.6	9.70
10	2631.11	3089.11	14.82

CONCLUSION:

1. Connections in RCC frame constructions are monolithic with cast-in-situ column and beam. The same RCC frame can be constructed by using precast column and precast beam with junction in cast-in-situ which develops moment resisting connections.
2. For Location 9, the percentage Decrease in Stresses in Precast frame Connection is 9.70 % as Compared with RCC frame Connection for Load Case 3
3. Similarly the percentage Decrease in Stresses can be observed for all Locations for Load case 3 as Compared to RCC frame Connection and the average percentage Decrease in Stress found to be 9.966 %.
4. From the above Observations, as the Decrease in Stresses obtained in the Precast frame Connection, the Precast Construction can be Preferred than RCC Construction.

REFERENCES:

1. Mohommed Anwaruddin Md. Akberuddin, Mohd. Zameeruddin Mohd. Saleemuddin (2013) "Pushover Analysis of Medium Rise Multi-Story RCC Frame With and Without Vertical Irregularity", M A M Akberuddin et al. Int. Journal of Engineering Research and Applications, Vol. 3, pp.540.546.
2. Ehsan Noroozinejad Farsangi, (2010) "Connections Behaviour in Precast Concrete Structures Due to Seismic Loading" Gazi University Journal of Science, 23(3):315-325.
3. Saurav Khanna, (2012) "Finite element modeling of precast r.c.c. joints and frame under cyclic loading" Department of civil engineering, Thapar university, Patiala – 147004, (India).