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Research Article

Investigations on Study of Precast Concrete connections under Seismic Conditions

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Abstract

This paper presents a FEA model of column to beam joint, considering the column and beam as precast elements. The contour readings are taken at 10 location for precast beam bottom and in corbel incorporated in precast column, where the precast beam rest. RCC frame of G+12 is modeled, static and dynamic (response spectrum) analysis is done. FEA modeling of two connections CB1 and CB2 is modeled as precast elements, considering moment resisting connections. The loadings to be applied on connections are calculated and applied. Three construction stages are considered. From the results of contour readings of 10 locations, the reading at location 9 shows more readings than the tensile strength of concrete (referring IS 456 : 2000, 6.2.2, page 16), which is due to applying lateral force on upper column surface. This will be addressed by additional reinforcement. SAP2000 have been used for analysis. To validate SAP2000, modeling of RCC frame (G+3) along with Static analysis and Pushover is done by using SAP2000 and the calculated base shear is matching with the same G+3 RCC frame modeled by using ETABS (referring to published paper at Int. Journal of Engineering Research and Applications , Vol. 3, Issue 5, Sep-Oct 2013, pp.540-546, by Mr. Mohommed Anwaruddin Md. Akberuddin, Mohd. Zameeruddin Mohd. Saleemuddin)

Keywords: *Contour, construction stages, FEA model, lateral force, moment resisting connections, precast.*

1. Introduction

Connections are the crucial element to boundary any building damage. Precast concrete structures are ever-increasing in India. The particular interest in consideration of developing any joints / connections are done by using most commonly used construction materials, as cast-in-place concrete, reinforcement steel, etc.

Many researches have been done on moment resistant connection for column-beam joints. The connections are designed as cast-in-place / monolithic connections, still the fabrication of the connection is complex, which slow down the construction speed. Precast structures are cost effective but are not so favorite in the highly seismic areas. Therefore, it is very essential to understand and study the actual behaviour of the column-beam joints / connections, as earthquake may damage the whole structure.

2. Validating Software's

Mohommed Anwaruddin Md. Akberuddin, Mohd. Zameeruddin Mohd. Saleemuddin, published paper on Pushover Analysis of Medium Rise Multi-Story RCC Frame With and Without Vertical Irregularity in year 2013. The modeling of G+3 RCC frame, Base shear and Pushover are done by using ETABS. Base shear is calculated as 3572.85 kN.

The same G+3 RCC frame have been modeled by using SAP2000. Calculations of Static analysis done and gives base shear as 3559.30 kN, which is near about equal to base shear of 3572.85kN as calculated by ETABS.

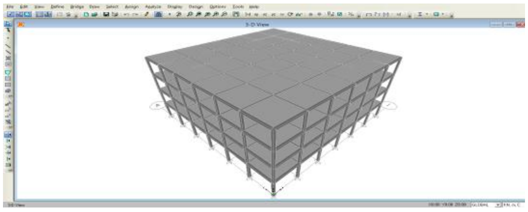

Fig.1 G+3 Modeling in SAP2000

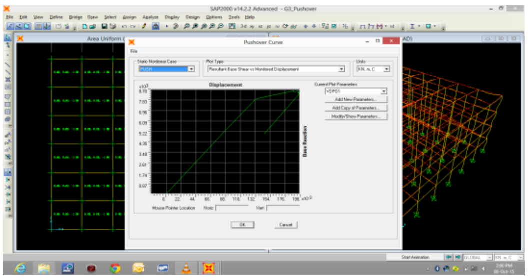

Fig.2 G+3 Pushover in SAP2000

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4. Design basis for G+12 building

1) Concrete Grade : M50, Steel Grade : Fe500
2) Building size 67.2mx42m, one bay size is 8.4mx8.4m.
3) Column size, GL to 5th floor (800mm x 800mm), 6th to 9th floor (700mm x 700mm), 10th to 12th floor (600mm x 600mm).
4) Beam size, GL to 5th floor (800mm x 850mm), 6th to 9th floor (700mm x 750mm), 10th to 12th floor (600mm x 650mm).
5) Load combinations are Bending moment + Shear force + Axial load.
6) Load cases : 301 = 1.5 DL + 1.5 LL, 302 = 1.5 DL + 1.5 SEQX & 306 = 1.2 DL + 1.2 LL + 1.2 SEQX

   Floor levels :
7) Imposed load / Live load, udl = 10 kN/ m2 (reference, IS : 875 (Part 2) - 1987, Table 1, V. j., page no. 10)
8) Brick masonry wall density = 1800 kg/cum, (reference, IS : 875 (Part 1) - 1987, Table 1, 13., page no. 6), UDL, Wall = 1 rmt x 0.23 thk. x 3.9 height x 1800 kg/cum / 1000 for ton x10 for kN = 16.15 kN per running metre
9) Floor finish = 220 kg/ m2 (ref. IS : 875 (Part 1) - 1987, Sec.3.1. pt. 7, page no. 29)

   Roof level :
10) Imposed load / Live load, udl = 7.5 kN/ m2 (reference, IS : 875 (Part 2) - 1987, Table 2, 1.i.a, page no. 14), Dead load = 4.5 kN/ m2
11) Parapet, Brick masonry wall density = 1800 kg/cum (reference, IS : 875 (Part 1) - 1987, Table 1, 13., page no. 6) UDL, Wall = 1 rmt x 0.23 thk. x 1.5 height x 1800 kg/cum / 1000 for ton x10 for kN = 6.21 kN per running metre

5. Modeling

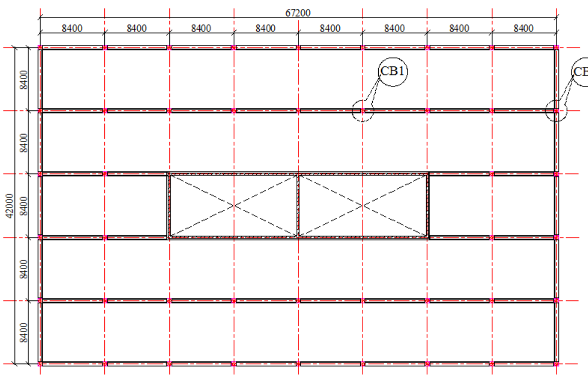


Fig.3 Typical Floor Plan (showing beams and columns)

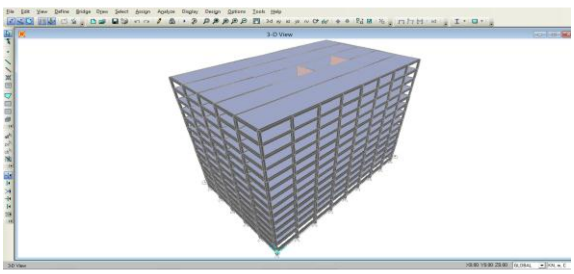


Fig.4 G+12 Modeling in SAP2000

5. Static analysis & Dynamic analysis (response spectrum

1) Response Factor, R = 5.0 (As per IS 1893 (Part 1) : 2002, Table 7, page 23)
2) Zone Factor, Seismic zone = V, Seismic intensity = Very severe, Zone factor, Z = 0.36 (As per IS 1893 (Part 1) : 2002, Table 2, Sec 6.4.2, page no. 16)
3) Natural period of vibration in seconds, T x = 0.589 seconds (X-direction), Ty = 0.745 (Y-direction), (As per IS 1893 (Part 1) : 2002, Sec. 7.6.2, page 24)
4) Soil Condition, Type II, medium soil sites, Sa/g = 2.31 (X-direction), Sa/g = 1.83 (Y-direction), (As per IS 1893 (Part 1) : 2002, Sec. 6.4.5, page 16)
5) Importance Factor, I=1.5 (As per IS 1893 (Part 1):2002,Table 6, Sec.6.4.2,page 18)
6) Design horizontal seismic coefficient, (As per IS 1893 (Part 1) : 2002, Sec. 6.4.2, page 18), Ah = Z/2 x I/R x Sa/g, Ah = 0.12 (X-direction), Ah = 0.13 (Y-direction)
7) Design seismic base shear, Vb (As per IS 1893 (Part 1) : 2002, Sec. 7.5.3, page 18), DL = 545306.84 kN, LL = 323870.40 kN, W = DL+0.5LL, W = 707242.04 kN, Vb = AhW, hence, Vb = 88183.12 kN (X-direction), Vb = 92957.24 kN (Y-direction)
8) Static earthquake in X-direction, SEQX = 88183.2 kN (as per SAP2000 output) which matches with calculated Base Shear.
9) Response Spectrum, Dynamic earthquake in X-direction, U_QX = 23425.161 kN (as per SAP2000 output)
10) Scale Factor, SEQX / U_QX = 3.765

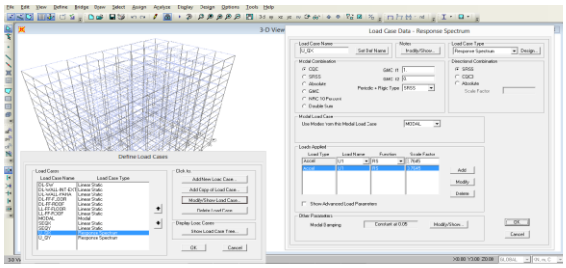


Fig.4 Scale Factor

6. CB1 column to beam connection

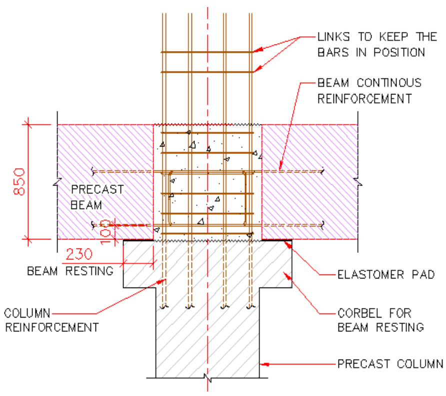


Fig.6 Section (CB1)

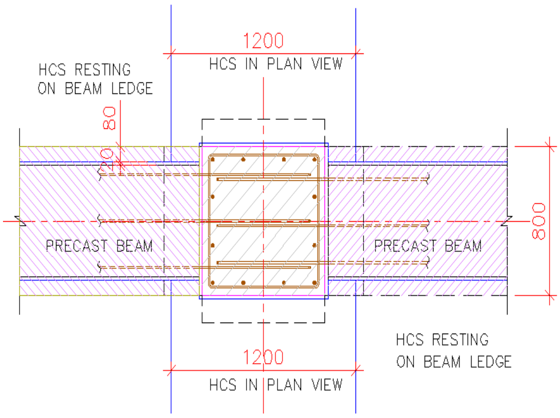
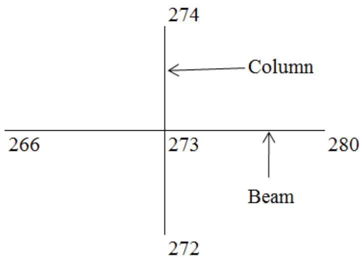


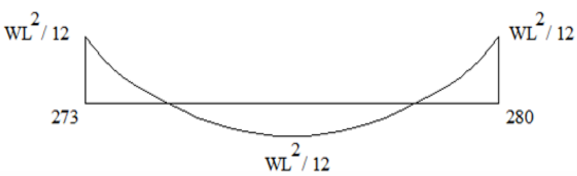
Fig.7 Plan (CB1)

Calculation for SF, BM and AL, (as per Sap2000 output and calculations)

1) Load case no. 306, (1.2 DL + 1.2 LL + 1.2 SEQX)



2) Moment for Beam node. 273 to 266 = 1665.38 kN-m
3) Moment for Beam node. 273 to 280 = 1645.11 kN-m
4) Shear for Beam node. 273 to 266 = 288.65 kN
5) Shear for Beam node. 273 to 280 = 273.43 kN
6) Surface area of column for applying UDL = 3.05x0.8 = 2.44 m2
7) Surface area of beam, above corbel for applying UDL = 0.25x0.8 = 0.2 m2
8) Moment for Column node. 273 to 274 = 1664.84 kN-m
9) Moment for Column node. 273 to 272 = 3160.65 kN-m
10) Shear for Column node. 273 to 274 = 919.19 kN
11) Shear for Column node. 273 to 272 = 1587.6 kN
12) Permissible bending stress (Beams) = M/Z, (Z = I/Y = (bd3 / 12) / (d / 2) = bd2 / 6), M / (bd2 / 6) = 1665.38 / (0.8x0.85x0.85 / 6) = 17288 kN/m2
13) Permissible bending stress (Columns) = SF / A = 288.65 / 2.44 = 118.30 kN/m2
14) Considering continuous beams,



W = P x A, P = Uniformly distributed load in kN/m2 , Moment = P x A x L2 / 12

For, Node 273 to 274

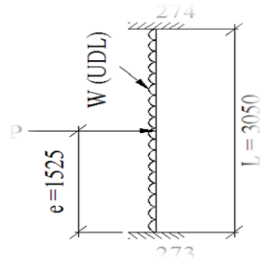
UDL, BM, on entire beam length, P1 = 46.6 KN/m2

UDL, BM, on beam, above corbel, P2 = 8094 KN/m2

15) UDL, SF, on entire beam length, Shear Force = Pressure Load x Area = P3 = 46.6x7.6x0.8 = 283.2 kN
16) 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), P4 = 9.8 / 0.2 = 48.99 KN/m2
17) for P5, Axial Load = (Maximum Pressure / Column C/S Area) = 55085 / (0.8x0.8) = P5 (on C/S top of column in joint) = 86071 KN/m2



18) For column node 273 to 274

    M = P x e, P = W x L, W = a x b x pressure load

    e = L/2 = 3.05/2 = 1.525m

    M = P x e, 1664.8 = P x 1.525, hence P = 1091.70 kN

    P6 (BM acting on column surface as an UDL) = 1091.70 = P6 x 2.44, P6 = 447.42 KN/m2

    P7 (BM acting on column surface as an UDL) = 2072.56 = 76 x 2.44, P7 = 849.41 KN/m2

    P8 (SF acting on column surface as an UDL) = P8 = P/2 = 1091.7 / 2 = 545.85 kN

    SF for P8, permissible as per SAP model = 919.19 kN

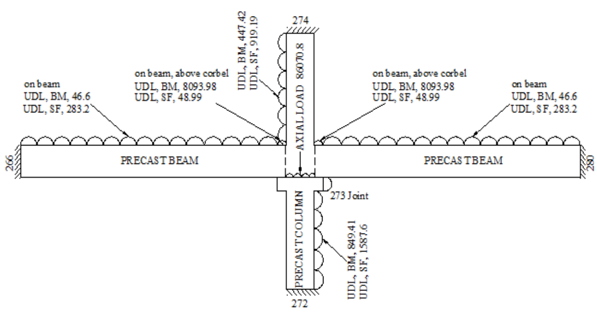


Fig.8 Loading details for CB1 Model (load case 306)

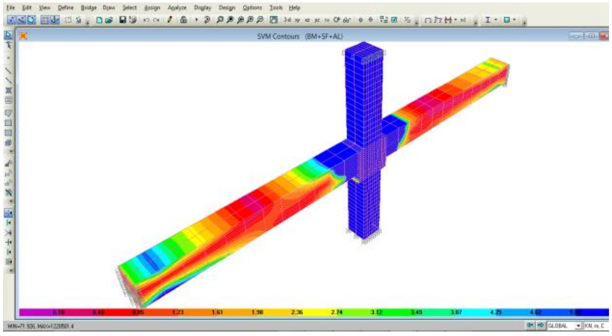


Fig.9 Connection CB1, Finite Element Model (load case 306)

7. CB2 column to beam connection

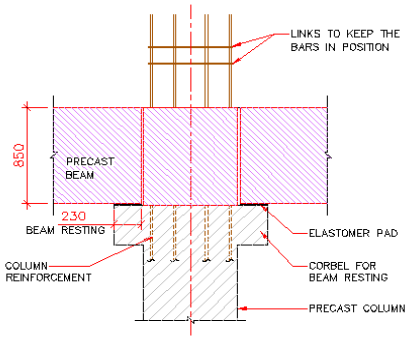


Fig.10 Section (CB2

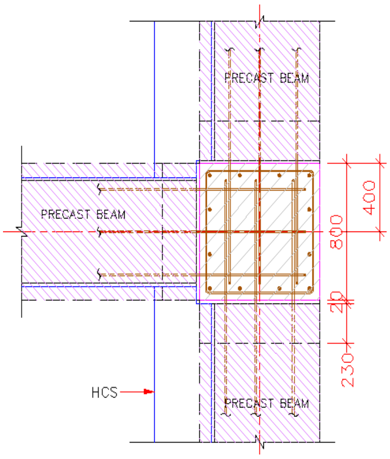
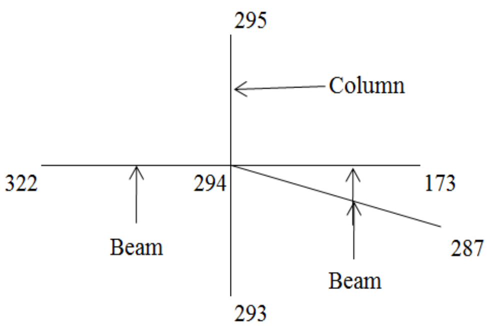


Fig.11 Plan (CB2)



Calculation for SF, BM and AL, (as per Sap2000 output and calculations), done similarly as per connection CB1

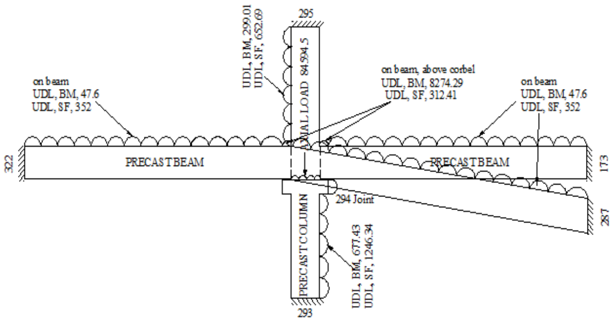


Fig.12 Loading details for CB2 Model (load case 306)

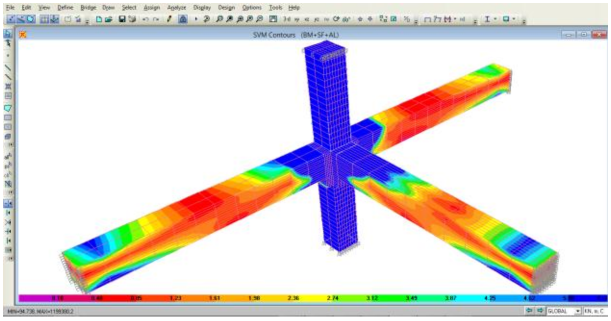


Fig.13 Connection CB2, Finite Element Model (load case 306)

8. Results and discussions

Applying the calculated loadings, considering various load cases as 301, 302 and 306 on CB1 model. The stresses are taken at 10 locations, covering the beam bottom and column corbel.

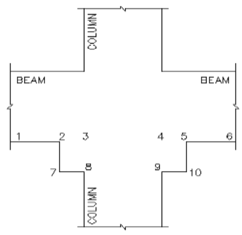
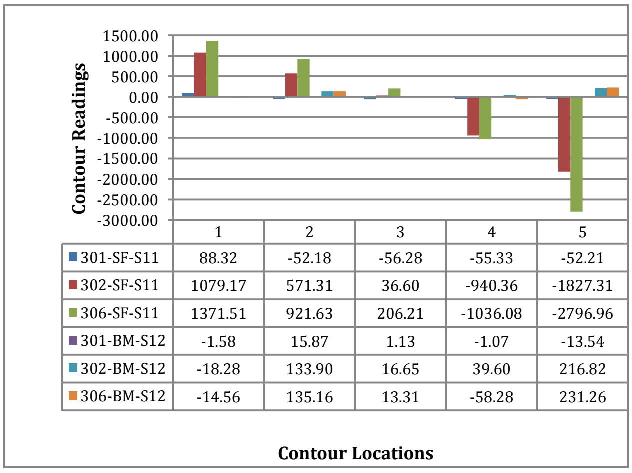


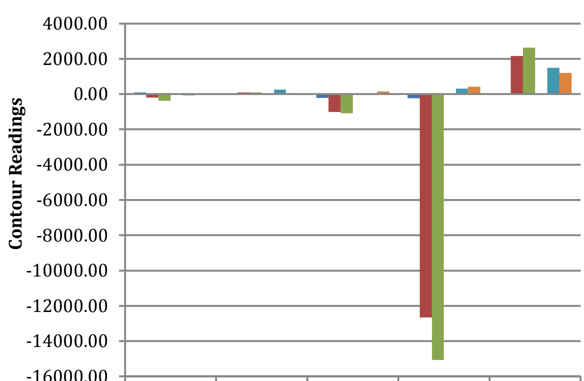
Fig.14 Locations of stresses

Table 1 Contour readings for CB1 connection



	1	2	3	4	5
301-SF-S11	88.32	-52.18	-56.28	-55.33	-52.21
302-SF-S11	1079.17	571.31	36.60	-940.36	-1827.31
306-SF-S11	1371.51	921.63	206.21	-1036.08	-2796.96
301-BM-S12	-1.58	15.87	1.13	-1.07	-13.54
302-BM-S12	-18.28	133.90	16.65	39.60	216.82
306-BM-S12	-14.56	135.16	13.31	-58.28	231.26

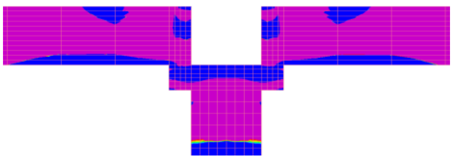
Table 2 Contour readings for CB1 connection



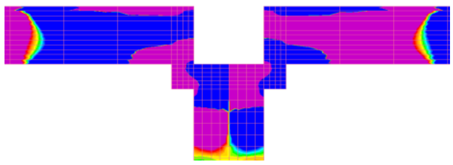
	6	7	8	9	10
301-SF-S11	86.03	18.21	-223.07	-233.19	17.21
302-SF-S11	-199.67	94.43	-1010.39	-12661.88	2166.74
306-SF-S11	-378.90	91.93	-1081.78	-15060.60	2631.11
301-BM-S12	1.14	4.58	14.87	-13.57	-6.57
302-BM-S12	-72.81	258.88	-33.55	308.00	1496.62
306-BM-S12	-43.73	31.69	147.73	416.15	1197.64

Contour Locations

Considering, construction stages, the loadings calculated are applied to the CB1 model with load case 306.

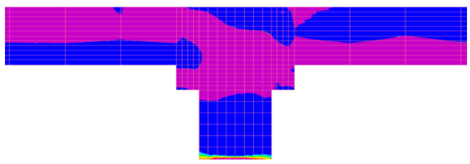


S11, SF

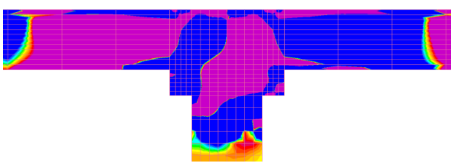


S12, BM

Fig.14 Construction Stage 1, beams are installed on the corbels incorporated in columns.

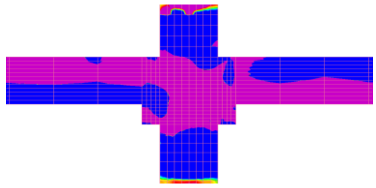


S11, SF

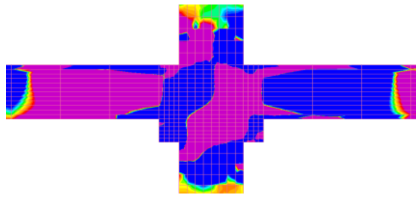


S12, BM

Fig.15 Construction Stage 2, Structural topping along with joint filling done



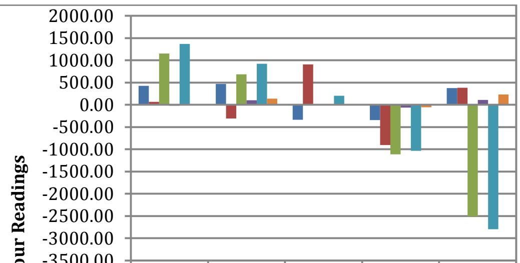
S11, SF



S12, BM

Fig.16 Construction Stage 3, with upper column

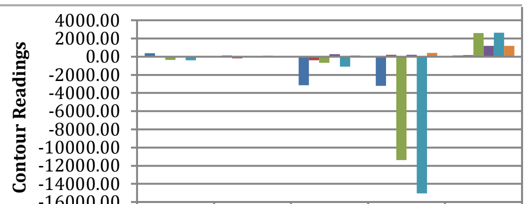
Table 3 Contour readings for CB1 at Construction Stages



	1	2	3	4	5
CB1-306-STG1-SF-S11	429.49	466.92	-336.58	-341.34	373.62
CB1-306-STG1-BM-S11	63.44	-307.19	904.73	-902.31	386.42
CB1-306-STG2-SF-S11	1151.49	683.50	9.71	-1116.46	-2510.88
CB1-306-STG2-BM-S12	-18.13	103.91	16.42	-61.70	106.30
CB1-306-STG3-SF-S12	1371.51	921.63	206.21	-1036.08	-2796.96
CB1-306-STG3-BM-S12	-14.56	135.16	13.31	-58.28	231.26

Contour Locations

Table 4 Contour readings for CB1 at Construction Stages



	6	7	8	9	10
CB1-306-STG1-SF-S11	387.93	129.02	-3129.76	-3193.70	128.93
CB1-306-STG1-BM-S11	-67.03	-172.44	-392.29	192.99	172.47
CB1-306-STG2-SF-S11	-345.89	61.38	-685.01	-11388.93	2603.50
CB1-306-STG2-BM-S12	-29.28	43.41	263.81	223.70	1177.32
CB1-306-STG3-SF-S12	-378.90	91.93	-1081.78	-15060.60	2631.11
CB1-306-STG3-BM-S12	-43.73	31.69	147.73	416.15	1197.64

Contour Locations

Tensile strength of concrete, (As per IS 456 : 2000, 6.2.2, page 16),
$0.7\sqrt{fck} = 0.7\sqrt{50} = 4.94$ N/mm2 = 4940 kN/m2

The readings observed at locations (1 to 8 and 10) are less than with reference to tensile strength of concrete as per IS code, except readings at location 9. The horizontal load is applied on the column surface of node 273 to 274 (refer Fig.8. Loading details for CB1 Model (load case 306), hence the stresses are more at location 9. The same stresses can be reduced by additional reinforcement in the corbels.

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) The cost of additional corbel in precast column is nullified as precast frame is benefited with fast and easy construction, which nullify the cost as less in precast frame.
3) The stresses observed at location 9 are more than require tensile strength of concrete, as horizontal load is applied on the column surface of node 273 to 274 (refer Fig.8), which will be reduced by additional reinforcement in the corbels.

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