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Seismic Behavior of Precast Building

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Abstract: **Precast Structures are widely used for construction in India. Due to construction and design faults, the behavior of these structures, when subjected to seismic events have been weak. The failure have mostly found at the connection of members of the structures. So the behavior of the connection have been critical in Precast Structure especially beam-column connection. Most designers assume the beam-column connection as an ideally hinged connection that leads to inaccurate values. In this paper an attempt is made to resolve this problem by considering the connection as semi-rigid i.e. the actual behavior of connection having some rotation at the joint. The beam-column connection is allowed with an amount of rotation as per experimental work presented in research papers. The 3-storey building with this release is modeled in SAP2000 and compared with the monolithic building for linear dynamic analysis. The model is applied to various earthquakes i.e. Northridge, El-Centro and Koyna so as to cover all the parameters. The results of Top Displacement, Base Shear and Storey Drift are compared for the two models. It concludes that the Top displacement and Storey Drift increases whereas Base Shear decreases for precast building as compared to monolithic RCC building.**

Keywords: ***Precast Structure, seismic behaviour of connections, beam-column connection.***

1. INTRODUCTION

Precast construction consists, in essence, in transferring most of the work from the construction site to the prefabrication plant, as a result of which, thanks to the superior working conditions, both labor productivity and product quality are improved. For this purpose the structural system of a building must be broken down into elements capable of off-site prefabrication, and of subsequent assembly with appropriate joints. A precast building may consist exclusively of prefabricated elements, or some of its parts may be cast-in-situ. Precast structures are suitable for construction, and are superior in terms of homogeneity of the concrete, dimensional precision and quality of the surfaces; they may also, in principle, be lighter in terms of dead load. [1]

A Precast Structure consists of large units jointed by connections whose function is to transmit compressive, shear or tensile forces or bending moment (possibly combination from one unit to another). The force distribution in the system and the deformation of its structural elements and joints under different actions depend, in large measure, on joint deformability and on the mode of assembly of the system. Its overall bearing capacity depends mainly on its strength of joint components. It is liable to possible progressive collapse as a consequence of accidental failure of the one of the bearing element.

Precast concrete systems for building are cost efficient, structural systems that provide speed and ease of erection. They allow for improved quality control in the precast plants, and freedom in the architectural form of the members. Despite many advantages of precast concrete, it is not widely used, especially in the regions of high seismic risk. The reason behind this is a lack of confidence and knowledge base about their performance in seismic region.

Connections between the structural elements in Precast Structure make an important part in its design. Research has shown that the critical area of failure in precast structure is near connection or in connection especially at beam-column joints, footing-column joints and beam-slab joint. Special emphasize has been given on beam-column joint in this paper.

Beam to Column connection can be done in several ways. The most common type of connections are a) Cast-in-Situ Connections b) connections with dowels c) connections with mechanical couplers d) hybrid connections. Typically connections with dowels are preferred considering its ease to assembling. In this case one or two dowels protrude from the top of the column and enter into the sleeves inserted in the beam. The sleeves are filled with no-shrinkage mortar of adequate strength to ensure bond anchorage of the dowels. The anchorage can also be ensured providing the dowels with a cap fixed at the top with a screwed nut. In any case the sleeve shall be filled in with mortar to avoid hammering under earthquake conditions. The below figure shows typical beam to column dowel connection

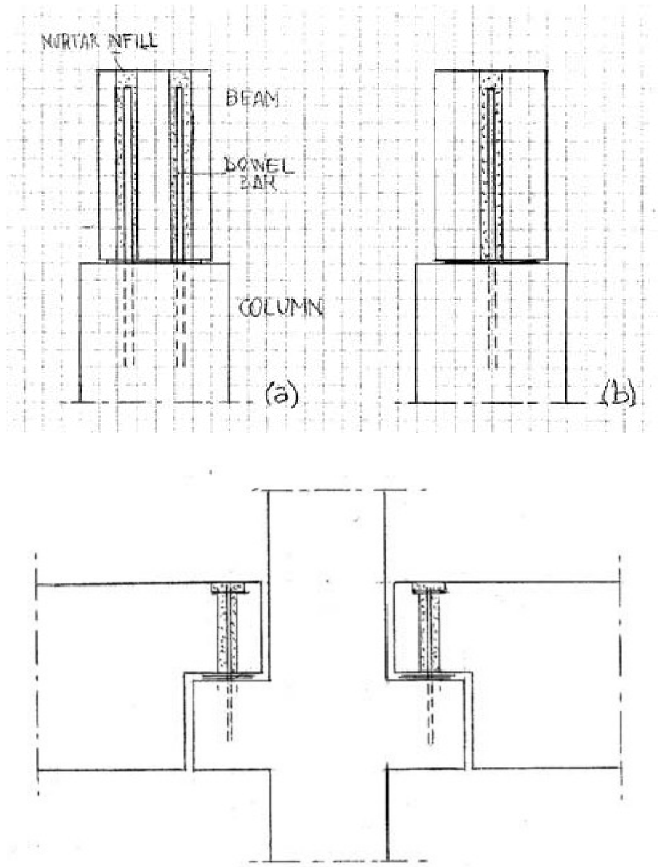

Fig.1. Dowel Connections for Beam to Column [2]

2. LITERATURE REVIEW

Dionysios A. Bournas, Paolo Negro, Francisco J. Molina [3] carried a full-scale three-storey precast building was tested under seismic conditions at the European Laboratory for Structural Assessment in the framework of the SAFECAST project. The unique research opportunity of testing a complete structural system was exploited to the maximum extent by subjecting the structure to a series of pseudodynamic (PsD) tests and by using four different structural layouts of the same mock-up, while 160 sensors were used to monitor the global and local response of each layout. Dry mechanical connections were adopted to realize the joints between: floor-to-floor, floor-to-beam, wall-to-structure; column (and wall)-to-foundation and beam-to-column. Particular emphasis was given to the seismic behavior of mechanical beam–column connections, as well as to the response of floor diaphragms.

Paolo Negro, Dionysios A. Bournas, Francisco J. Molina [4] in the framework of the SAFECAST Project, a full-scale three-storey precast building was subjected to a series of pseudodynamic (PsD) tests in the European Laboratory for Structural Assessment (ELSA). The mock-up was constructed in such a way that four different structural configurations could be investigated experimentally. Therefore, the behavior of various parameters like the types of mechanical connections (traditional as well as innovative) and the presence or absence of shear walls along with the framed structure were investigated. The first PsD tests were conducted on a dual frame-wall precast system, where two precast shear wall units were connected to the mock up. The first test structure sustained the maximum earthquake for which it had been designed with small horizontal deformations. In the second layout, the shear walls were disconnected from the structure, to test the building in its most typical configuration, namely with hinged beam–column connections by means of dowel bars (shear connectors). This configuration was quite flexible and suffered large deformations under the design level earthquake. An innovative connection system, embedded in the precast elements, was then activated to create emulative beam–column connections in the last two structural configurations. In particular, in the third layout the connectors were restrained only at the top floor, whereas in the fourth layout the connection system was activated in all beam–column joints

A. Bellari, M. Torquati, P. Riva [5] In this paper Displacement Based Assessment – DBA is used to consider the moment-curvature and force-displacement relationship of typical precast connections, beam to column and column to foundation, to estimate the system equi-viscous damping as a function of rotational and translational ductility of the structural elements and connections. The DBA procedure is applied to a three storey precast concrete frame and validated by means of nonlinear incremental dynamic analysis.

3. MODELING

Typical Floor Plan of 3-Storey building used for actual Precast Building construction is used for modeling, the properties of building are similar and the plan of building is shown in figure. The X-direction is along longer direction and Y-direction is along shorter direction. The Material and element properties considered for the modeling in SAP2000 is given below

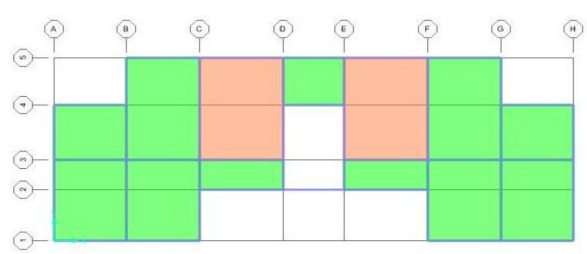

Fig. 2. Typical Plan for Modeling

Column Size = 350x350mm
Beam Size = 350x465mm
Slab = 125mm and 150mm (for w/c and bath)
Wall = 150mm
Height from footing top to Plinth beam bottom = 2.5m
Floor Height above Plinth Beam for all storey = 3.2m
Head Room above Roof Level = 2.5m
Height of Parapet Wall = 1.4m
Concrete Strength (fck) = 30N/mm^2
Ec = 5000√fck
Unit Weight = 25kN/m^3
Masonry Wall
Compressive Strength (fm) = 900psi
Em = 550fm
Unit Weight = 18kN/m^3
Loading:
Dead Load = Unit Weight x Volume
Floor Live Load = 2kN/m^2
Roof Live Load = 1.5kN/m^2
Staircase Live Load = 3kN/m^2
Floor Finish = 0.75kN/m^2
Water Tank Point Load = 20kN

Precast Building is modeled for rotation at Beam-Column joint. The rotation was measured to an equivalent moment by using Moment-Rotation Diagram [5]. The moment was released as per the values obtained at the column end point and beam start and end point as shown in figure. The ground floor was kept as parking floor as per now-a-days architectural needs, so no walls were modeled at the ground floor.

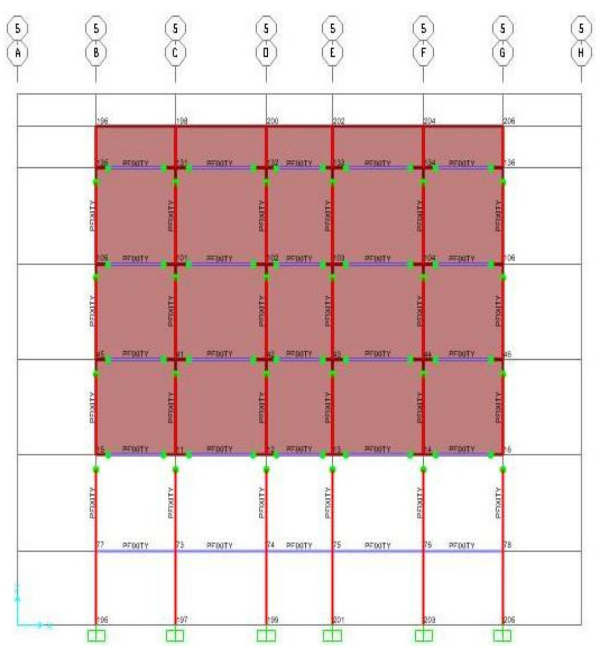

Fig. 3. Elevation with Beam-Column Joint release

4. ANALYSIS AND RESULTS

Free Vibration Analysis was carried out on the above modeled structure and Fundamental Natural time period was determined to be 0.7246sec for RCC building whereas precast building has 1.172sec. The first mode shape of RCC building is along the Y-direction, second mode shape is along X-direction and third mode shape is torsion. Time History Analysis is carried on structure to know and compare the seismic behavior of the two structures. Time History of Ground acceleration is the most accurate means of representing earthquake actions. The record of previous earthquake ground motions present is applied to the structure. Each earthquake record is unique having different peaks, duration and dominant period. For the present study, a set of three representative ground motion records have been considered i.e. El-Centro(1940), Koyna(1967) and Northridge(1994).

TABLE 1: Characteristics of the Ground Motion Records

Earthquake	Duration(sec)	Peak Ground Acceleration (m/s^2)	Dominant Period
El-Centro	53.76	3.417 (0.347g)	0.2 to 0.65
Koyna	10.72	4.80266 (0.49g)	0.05 to 0.28
Northridge	60	2.703 (0.27g)	0.05 to 0.28

The G+3 RCC and Precast building modeled were applied to the above loads and each time history subsequently in each direction. The results of analysis of Base Shear, Storey Drift and Top Displacement are compared in the following tables. It is to be noted that when earthquake is applied in X-direction the corresponding values of result of Base Shear, Storey Drift and Top Displacement is given only in X-direction and similarly it is done when earthquake is applied in Y-direction.

TABLE 2: Comparison of Results for El-Centro Earthquake

	RCC Building EQX	RCC Building EQY	Precast Building EQX	Precast Building EQY
Top Displacement (mm)	79.50	82.59	111.92	82.66
Base Shear (kN)	12500	12200	6841	12200
Storey Drift(mm) For 3rd Floor 2nd Floor 1st Floor Ground Floor	0.71 0.71 0.77 49.47	2.11 2.11 2.17 49.01	0.43 0.43 0.44 100.85	2.11 2.11 2.14 49.05

TABLE 3: Comparison of Results for Northridge Earthquake

	RCC Building EQX EQY		Precast Building EQX EQY	
Top Displacement(mm)	104.6	103.2	160.9	103.2
Base Shear (kN)	16610	14680	9338	14650
Storey Drift(mm)				
For 3rd Floor	0.94	2.69	0.57	2.69
2nd Floor	0.95	2.69	0.58	2.68
1st Floor	1.03	2.72	0.60	2.71
Ground Floor	64.98	61.64	135.57	61.62

TABLE 4: Comparison of Results for Koyna Earthquake

	RCC Building EQX EQY		**Precast Building EQX EQY**	
Top Displacement (mm)	56.02	53.01	26.71	53.03
Base Shear (kN)	8895	7523	2239	7516
Storey Drift(mm)				
For 3rd Floor	0.50	1.43	0.10	1.42
2nd Floor	0.51	1.42	0.11	1.42
1st Floor	0.55	1.44	0.11	1.44
Ground Floor	35.34	31.73	23.61	31.81

5. CONCLUSION AND DISCUSSION

In free vibration analysis it is found that the time period is increased for Precast Building compared to RCC building. The flexibility of the Precast Building is increased by considering the Beam-Column Joint as semi-rigid. The Mode Shapes are interchanged for first and second modal case, as the stiffness in X-direction is reduced by releasing moments at beam start and end points in Precast Building. In Time History Analysis it is found that due to increased flexibility of the Precast Building compared to RCC building the Top Displacement is increased whereas the Base Shear has decreased in X-direction. There is no major change in the Y-direction as it can be seen in the plan that it consists of just two bays. The Storey Drift at the Parking floor is almost doubled in Precast Building to the RCC building. This is due to no walls present at the ground floor reducing the stiffness of the story compared to the above storey. The Story Drift of Ground Floor of Precast Building is comparatively large, further studies can be carried out to find a method to reduce the drift.

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