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Analysis of Finite Element on Precast Concrete Diaphragms and Their Connections under Seismic Loading

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ABSTRACT

The precast concrete buildings structures are high superiority and speedy construction with the assurance of durability. In addition there would be a reduction in site labor, formwork and possible damage during earthquake. Probably due to lack of understanding of the basic 'nature of precast concrete during earthquake these could not get a place in India till recent past. In fact with available tools and design philosophies designer of precast concrete structures can create a structure which will not only survive an earthquake but will be subjected to a very little, if any, damage. Desirable for this is the expertise and limit of tolerance in construction practice.the performance of precast concrete systems depends on the behaviour of connections. In low seismic region where gravity loads govern the design of structures, precast construction have been extensively used because it is assumed that minor discontinuities in the structures do not cause any problems hence less attention is paid to the connection details. But, in high seismic region, the connections between precast elements require special attention..this research is focus on the role of diaphragm and their connections for precast concrete structures within the lateral force resisting system. The main objectives of this study work are the connections for different options of precast concrete floor unit in building situated in seismic zone for different aspect ratio and determine, if precast concrete structures were more susceptible to earthquake damages, due to poor floor connections, to make the recommendations to codal provision to improve the performance of these structural systems in future seismic events with the help of software.

Indian standards of construction do not provide significant importance to seismic design of precast construction. Some of the issues which need immediate attention in the Indian construction standards have been identified as mentioned in this study. the precast concrete buildings structures are now worldwide accepted as an economic, structurally sound and architecturally versatile form of construction. From literature it is concluded that precast construction is continuously increasing and have become popular even in Seismic sensitive country.

INTRODUCTION

This technology has many advantages over the conventional cast in situ construction. For example: better quality control, durability, lesser need of formwork, flexibility, control of creep and shrinkage, better finish, low maintenance, long spans/heavy loads, social and environmental benefits, easy to erect and dismantle, mould ability into desire shapes, all weather construction, And massive reconstruction works after the earthquakes in a short duration are some benefits.

Role of connections in precast concrete building

The performance of precast concrete systems depends on the behaviour of connections. In low seismic region where gravity loads govern the design of structures, precast construction have been extensively used because it is assumed that minor discontinuities in the structures do not cause any problems hence less attention is paid to the connection details. But, in high seismic region, the connections between precast elements require special attention. Structural continuity is essential at the joints to provide adequate load path in the structure. Connections also play a key role in the dissipation of energy and redistribution of loads. The configuration of connectionsaffects the constructability, stability, strength, flexibility and residual forces in the structure. Thestrength and rigidity of precast concrete diaphragms will depend to a great extent on the type andspacing of connections.

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Figure 1 Construction of Typical Precast Building.

Objective of Study

This study is focus on the role of diaphragm and their connections for precast concrete structures within the lateral force resisting system. The main objectives of this dissertation work are:

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1. To study the connections for different options of precast concrete floor unit in building situated in seismic zone for different aspect ratio.

2. To determine, if precast concrete structures were more susceptible to earthquake damages, due to poor floor connections, to make the recommendations to codal provision to improve the performance of these structural systems in future seismic events.

3. To model the precast structure with the help of software.

Modeling & Design

In the present work a symmetrical 6-storied, building subjected to live load of 5 KN/m^2. These buildings are assumed to be situated in seismic zone V as defined in Indian Seismic Code IS 1893 (Part I): 2002. Building diaphragm are analyzed and designed, considering as topped diaphragm for the RCC solid slab as:

Design of Solid Pre-stressed units and RCC units are as per IS-1343:1983 and IS-456:2000. Designs of diaphragms are as per Uniform Building Code (UBC) 1994.

The grade of concrete used is M20 and steel for main and transverse reinforcement is Fe 415, for pre-stressed precast slab M30 grade of concrete is used, pre-stressing R/F strength is taken as 1800Mpa. Structure analysis (Linear structural analysis) and design are carried out as per PCIdesign manual: 1995.

The other data are as follows.

- Type of Structure: Multi-storied pin jointed Frame

- Lateral Force Resisting System: Shear wall

- Gravity Force Resisting System: Beams and columns

- Floor to Floor height:4 m

- Depth of Foundation below Ground: 2.50 m

- External wall: 200 mm thick (@ 20 KN/m3)

- Live load on Floors: 5.00 KN/m2

- Earthquake Load: As per IS 1893(Part–I):2002

- Diaphragm Earthquake Load distribution: As per PCI manual: 1995

Two alternative simplified modeling approaches in representing the seismic behavior ofdifferent jointed ductile precast/prestressed connections/systems.Particular emphasis is given to the modeling of hybrid connections, developed in thePRESSS Program (PRE-cast Seismic Structural System) coordinated by the University of SanDiego, for frame and wall systems. The efficiency and accuracy of the two alternativesimplified approaches and analytical methods, one based on section analysis procedure andlumped plasticity models and the other one based on the use of multi-contact spring models.Recent developments in the research of precast/prestressed concrete structures for seismicareas have resulted in the experimental validation of different innovative typologies of ductileconnections for moment resisting frames, wall systems (Priestley et al., 1999). In particular, awide range of alternative arrangements for pure precast jointed connections of precaststructural members is now available and developments are going towards a continuingimprovement of the technology of systems/connections (Pampanin et. al., 2004).

A particularly efficient and flexible solution was offered by the hybrid system (Stanton et. al. 1997), developed within the U.S.-PRESSS Program (PRE-cast Seismic Structural System),coordinated by the University of California, San Diego: unbounded post-tensioningtendons/bars with self-centering properties are adequately combined with longitudinal mildsteel or supplemental damping/dissipation devices, which can provide an appreciable energydissipation.The inelastic demand is lumped at the critical section (beam-

to-column, wall-to-foundation) through opening and closing of an existing gap at theinterface. A sort of "controlled rocking" motion of the beam or wall panel occurs.

Adding self-centering capacity, as well as providing adequate amount of energy dissipationcapacity to the connection, the seismic performance of hybrid systems has been there to beat least satisfactory as equivalent monolithic solutions in terms of maximumdisplacement/drift demand and a definitely better behavior if the residual deformations areconsidered (Pampanin et al., 2002). In the following paragraphs particular attention will begiven to critical issues related to the modeling of precast concrete hybrid connections,assuming that the same considerations can be extended to steel and LVL hybrid systems. Inparticular, attention will be given to simplified approaches, based on section analysis. procedure and lumped plasticity models and multi-contact spring models. The analyticalvalidation of the two different approaches, referred to beam-column subassemblies tested atNIST (National Institute of Standard and Technology) (Check et al, 1994) and the Universityof Canterbury (Rahman and Restrepo, 2000), and critical discussion and investigations will becarried out exclusively at global level.

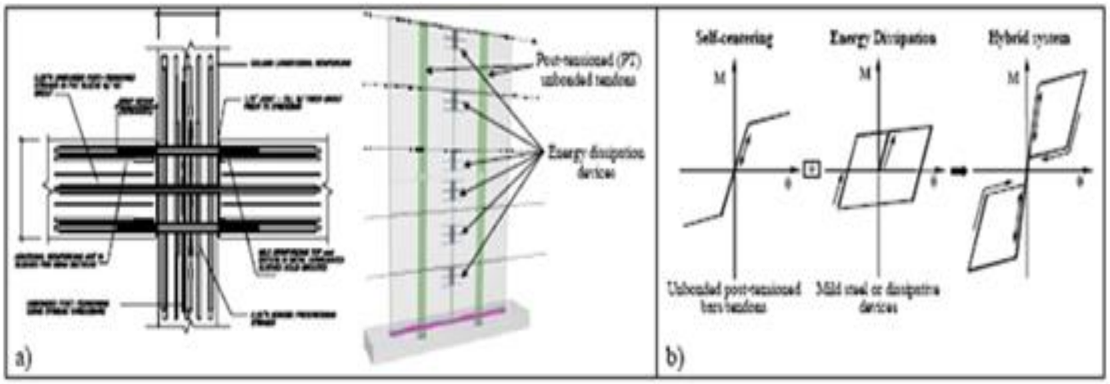

Figure 2 Hybrid solutions for precast concrete frame and wall system.

Results and discussions

- Indian standards provide guidelines for design and construction of precast concrete structures. No specific guidelines are provided for reinforcement and design of precast concrete floor slabs with lateral loads i.e., seismic design of precast concrete diaphragms, especially for the hollow core slabs. Precast floor diaphragms are to be classified based on their construction and behavior requirements to provide an easy and suitable selection option to the designer.

- No specific guidelines are provided for connection of precast concrete diaphragm with lateral loads. i.e. seismic design of precast concrete diaphragms connection.

- Lateral loads on floor systems due to earthquakes and wind is an untouched topic in Indian standards and there are no provisions for obtaining the diaphragm forces. The guidelines to obtain diaphragm forces from the base shear distributions need to be included in the Indian standards for precast construction. The Uniform Building Code provides these specifications as

$$F_{px} = \frac{F_t + \sum_{i=x}^{n} F_i}{\sum_{i=x}^{n} w_i} w_{px}$$

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- In G+3, manual design precast building connection provided where not appropriate due to which building where damage,in present work modifications in the connections are suggested to high seismic forces. Detail drawing as been shown in the figure above.

- Further, a floor system is designed as a one way or two way slab with similar reinforcement following Indian standards but diaphragms require dedicated chord, web and collector reinforcements. There is a need to provide guidelines for these reinforcements adhering to the other similar requirements in the Indian standards for reinforced concrete construction. These requirements must be in coherence with the reinforcement guidelines provided in reinforced concrete construction.

- In high seismic zones only solid slab concrete panels are recommended and their connection is permitted between ribs only. While the structural standards of practice across the world allow using composite or non-composite topping slab reinforced and detailed to provide for a complete transfer of forces to the lateral-force-resisting system Such flexibility must be brought in to the Indian standards to boost the use of precast concrete diaphragms in active seismic zones.

The absence of updates on precast concrete diaphragms Indian standards is partly due to the relative low magnitude of such construction being used in India. This also reflects by the relatively faster updates in the relevant construction standards in countries with high use of such construction practices. But with the infrastructure growing like never before and the demands for faster, innovative and safer construction option the doors to more numbers of such construction practices. In this regards, it is high time that Indian standards look into the seismic design provisions of precast concrete floor system.

Conclusions

The precast concrete buildings structures are now worldwide accepted as an economic, structurally sound and architecturally versatile form of construction. From literature it is concluded that precast construction is continuously increasing and have become popular even in Seismic sensitive country. An account of International practice on design and connection details of precast frame is presented. Brief description on precast concrete construction is studied and presented.

- A parametric study of G + 6 story building is attempted to understand and compare the modeling of precast concrete building with using different software's.
- Study of manual deign is also presented in which the cause of failure of joints and suggested joints in G+3 story building is calculated and shown; design of floor diaphragm is also suggested.
- It is observed that after performing such an analysis and design of diaphragms in moderate to high rise structures required detailed modeling in dedicated programs like SAP2000, ETABS 9, severaval provision related to precast concrete diaphragm analysis and design are unavailable or ambiguous in Indian structural standards.
- It is suggested to include guidelines for the procedure to be followed for the diaphragm analysis and the methodology for the diaphragm load distribution within the diaphragm. The reinforcement detailing for chord, web and collector steel need to be clarified and their distinction from regular floor panels elements has to be pointed out. It is immediately required to address the connection philosophy and research and experience shows that a combination of topping concrete and welded mechanical connectors proves effective in seismic loading.

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