Behavioral Study of Precast Concrete Structure with Fixity at Different Levels - Part I

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Rapid construction system is the need of the hour to meet the growing needs of space requirement for offices buildings/ shopping malls/ Industry and residential sector. One of the construction systems, viz., precast concrete structures is fast catching up in the country. It is greatly influenced by the behavior of beam-to-column/wall connections. Precast hollow core slabs are predominantly considered as floor slab elements, and they are one-way slabs and can span larger length like 12m to 15m. Being one-way slabs, load distribution on beam is also on the supported frames which are also one way. By utilizing precast hollow core slabs, form work is eliminated and thus saving in time. Unlike the conventional structure, where rigidity is considered in all the floors,it is proposed to give releases in alternate floors and two successive floors at a time and keep rigidity in rest of the floors in precast structures. By doing so, speed of construction can still be made faster, and construction is easire is the idea. A 7x7 bay structure of 10 story high is considered for analysis subjected to seismic and gravity loading. ETABS software is used for analysis and design,and then observe the structural stability in terms of strength, deflection and story drift etc.This paper presents the summary of releases at different floors and the results thereon.

1. Precast elements used in constructions

Basic precast concrete systems

Precast concrete building structures are composed of different types of precast elements. These elements can be combined in different ways to obtain an appropriate and effective structural concept that fulfils the needs of specific buildings. The most common types of elements used are:

- beam and column elements and their connections.
- floor and roof elements and its connections.
- bearing wall elements and its connections with flooring elements.
- façadewall elements and its connections to main structures.

The above list is not unique as there are many variations possible to achieve the same objectives that architects and engineers are now successfully exploring, such as the use of arches and rigid portal frames. Façades are sometimes load-bearing, providing also the lateral stability, but they can also be used without a load-bearing function. Other common precast systems are:

- frame systems (frame elements, connections)
- cell systems (cell elements, connections)

Floor and roof systems

The main purpose of floor and roof systems is to transfer the load to the vertical load resisting structural elements such as walls and columns. Besides, precast floors and roofs are often used as essential parts of the stabilizing system to transfer

horizontal loads by diaphragm action to the stabilizing units. The most common floor systems are hollow-core floors and double-tee floors. The connections of these systems are:

- slab to slab at longitudinal interior joints
- slab to edge element at longitudinal edge
- slab to slab at interior support
- slab to end support

A hollow core slab is a precast, prestressed concrete member with continuous voids provided to reduce weight and, still stronger element to transfer the loads, because of the prestressing. As a side benefit, voids can be used to conceal electrical or mechanical runs. Primarily used as floor or roof deck systems, hollow core slabs also have applications as both vertical and horizontal

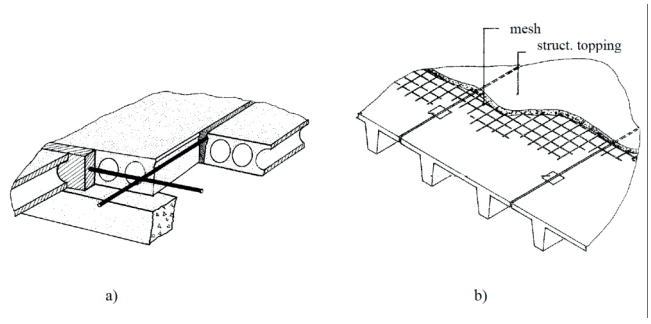


Figure 1: Typical floor systems, a) hollow core floor system, b) Double-T floor system

Precast

wall panels, spandrel members, and bridge deck slabs

- A Hollow core slab is a precast, prestressed concrete member with continuous voids provided to reduce weight, and therefore cost, and as a side benefit to use for concealed electrical or mechanical runs.
- Primarily used as floor or roof deck systems,
- Other applications include for wall panels, Spandrel members and bridge Deck units.
- Strand used in hollow core is low relaxation strand of 12.7mm(1/2 inch) dia.,
- keyway grout is normally a sand and Portland cement mixture in proportions of about 3:1

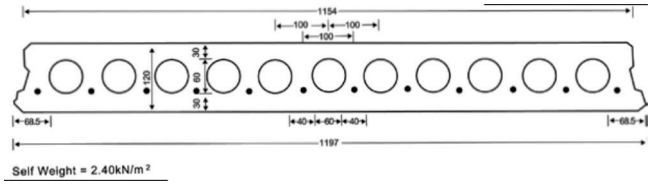


Figure 2: Hollow core slab cross-section

T-Slabs

A double tee or Double-T slab is a load-bearing floor element that resembles two single T-units connected to each other side by side. The strong bond of the flange (horizontal section) and the two webs (vertical members, also known as stems) creates a structure that is capable of withstanding high loads while having a longer span. The typical sizes of double tees are up to 15 feet (4.6 m) for flange width, up to 5 feet (1.5 m) for web depth, and up to 80 feet (24 m) or more for span length. Double tees are pre-manufactured duly providing strands in the web and it spans larger lengths like 20 to 30m. They are used for shopping malls and parking structures, where large column free spaces are required.

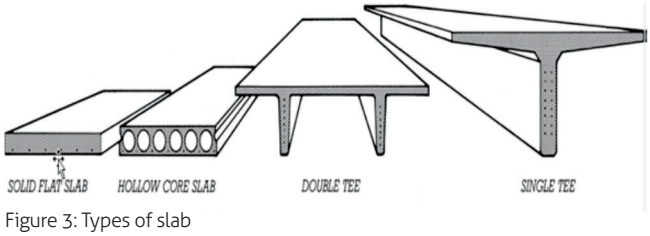
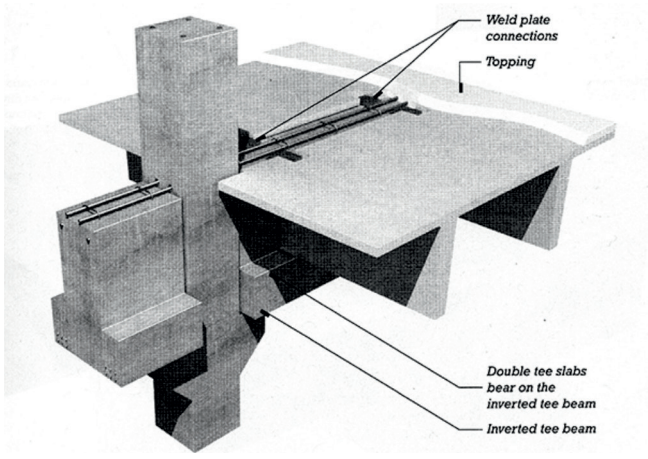


Figure 3: Types of slab



2. Precast Concrete Structure with Fixity at Different Levels.

Number of precast constructions are ongoing in India.In order to facilitate for further ease in construction and derive much more speed, the precast constructions are already adopting simply supported connections in alternate floors.

The details presented here involves reviewing and analyzing a structure by considering the simply supported connections at various levels and observe the stability and design aspects. Being a seismic plateau, the various seismic zones are also considered, and building is analyzed and designed accordingly. The building is basically 10 floor structure with 7 bays in each direction and is detailed as follows:

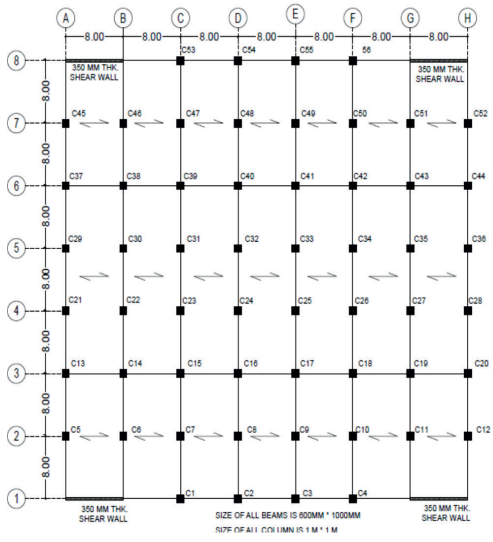


Figure 4: Plan of building in Zone-II &III

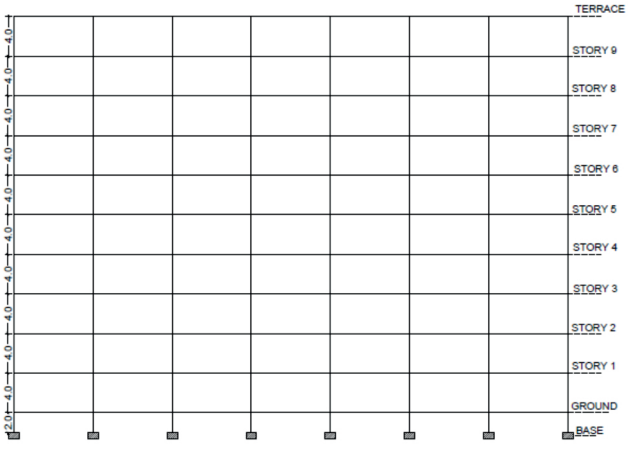


Figure5: Elevation of building inZone-II &III

- The structure is so chosen that each bay is 8m in both the directions.
- In zone -II and III area, the structure is provided with four shear walls, two on each periphery corners in X- direction in addition to columns.
- The floor plate is proposed as consisting of prestressed pre-cast hollow core slabs, which are predominantly one-way slab.
- In x- direction,two frames are provided on the periphery.Each of these frames have two shear wallseach and interconnected by columns and beams. In addition, the structure is also provided with two internal frames connecting the columns in the x-direction, thereby total four moment resisting frames are provided in the x-direction
- In Y- direction, the structure has moment resistant frames consisting of columns and beams with hollow core slabs resting on them.
- The intention is to provide less internal beams,such that it will not affect the air condition duct positioning system also.

Flooring System

- Hollow core slab is provided with structural topping on top duly provided with reinforcement and it is interlinked with shear links in between the hollow core slab joints.
- Hollow core slab is also provided with internal ties, peripheral ties for effective diaphragm action and composite action of HCS+ topping is derived thus to acts as one element. The structural topping reinforcement will also be linked with the precast column and beams such that rigidity develops, and effective transfer of forces happens.

Structural Configuration

- Dimension of building 56M*56M
- Bay spacing 8M*8M
- No. of bays 7 on each side
- Column Size 1M*1M
- Beam Size 0.6M*1M
- Shear Wall 0.35M*8M
- Story height 4 M
- No. of Stories 10 Stories (G+9)
- Importance factor 1.2
- Seismic Zone II(0.10), III (0.16)
- Response reduction factor 3
- Floor Slab System: Precast slab 200 mm thick + Structural Topping of 75 mm thick.
- Equivalent Slab thickness modeled = 200mm one-way slab
- Materials
  - Concrete M40 for frame
    M60 for shear wall
  - Steel HYSD500
- Unit weight of RCC 25 KN/m^3
- Unit weight of Masonry 20 KN/m^3
- Loads considered
  - Live load 4 KN/m^2
  - Floor Finish 1.5 KN/m^2
  - Partition load 1 KN/m^2
  - Services and utilities 0.5 KN/m^2

Load combinations

Building is analyzed for above loading and designed in the ETABS. Load combinations for seismic design are considered as per IS 1893: 2002 as:

1. 1.5 (DL+LL)
2. 1.2 (DL + LL ± EQX) And 1.2 (DL + LL ± EQY)
3. 1.5 (DL ± EQX) and 1.5 (DL ± EQY)
4. 0.9DL ± 1.5EQX and 0.9DL ±1.5EQ

Structural framing

- Moment resistance frame + shear wall will resist the Gravity and lateral forces and gives stability to the structure.
- Precast HCS are one-way slabs. The beam supporting HCS are interconnected with columns and thus forming moment resistance frames in one direction (Y- direction)
- Peripheral and internal two frames of beams connecting columns and shear walls will resist lateral forces in other direction (X- direction)
- HCS's are provided with 75 mm thick topping thus achieving composite as well as required diaphragm action in effective transfer of forces.
- 4 No. of shear walls are provided in X- direction at periphery to effectively resist the lateral forces, in addition to the columns in that direction.
- The HCS's are running parallel to these shear walls, but structural topping reinforcement is connected to the shear wall for effective transfer of forces.

The intention is to see how the releases could be given to structures at various floors and observe the structure stability, serviceability limits of horizontal deflection, story drifts, modal mass participations, story shears and how column size and reinforcements are changing because of releases given at floor levels.

Analysis

Various types of releases adopted and analyzed, are as follows.

Alternate story released

- All story rigid
- 9th story released (last but one from terrace level)
- 9th&7th story released
- 9th, 7th& 5th story released
- 9th, 7th, 5th& 3th story released

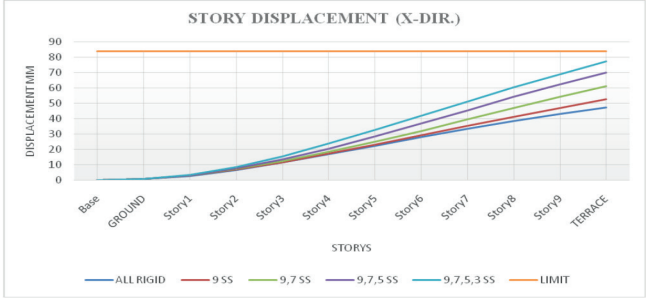
Two successive story releases at a time

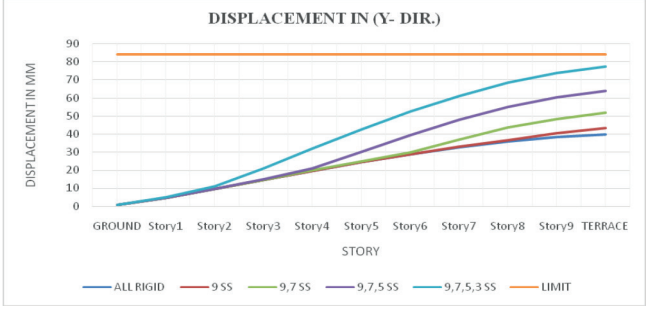
- 9th& 8th story released
- 9th& 8th, 6th& 5th story released
- 9th& 8th, 6th& 5th, 3rd&2nd story released

Considering the loads mentioned above, and the structural configuration, the structure is analyzed using ETABS software and response spectrum is considered for dynamic analysis. Considering the four different zones, i.e. zone-II to zone -V four models areconsidered, and they areanalyzed and results presented.

3. Alternate Story Released (ZONE-II)

The analysis results for alternate story released structure in zone-II are presented in the following tables;





STORY DISPLACEMENT

All Story Rigid B-600X1000 C-1000X1000 Sw-350 Mm Thk					
STORY	DISP. IN X DIR.	DISP. IN Y DIR.	DISP. LIMIT(H/500)	CONDITION OF FIXITY (R/SS)	REMARKS
TERRACE	47.192	39.623	84	R	Displacements are well within the limits
Story9	42.959	38.166	84	R	
Story8	38.291	35.813	84	R	
Story7	33.232	32.622	84	R	
Story6	27.848	28.749	84	R	
Story5	22.278	24.358	84	R	
Story4	16.718	19.603	84	R	
Story3	11.418	14.625	84	R	
Story2	6.681	9.571	84	R	
Story1	2.847	4.683	84	R	
GROUND	0.614	0.723	84	R	
Base	0	0	84	R	
STORY 9,7,5,3 IS SS					
TERRACE	77.454	77.358	84	R	
Story9	69.158	73.653	84	SS	
Story8	60.371	68.531	84	R	
Story7	51.232	61.114	84	SS	
Story6	41.906	52.529	84	R	
Story5	32.632	42.47	84	SS	
Story4	23.708	31.864	84	R	
Story3	15.578	21.047	84	SS	
Story2	8.585	10.962	84	R	
Story1	3.507	4.954	84	R	
GROUND	0.715	0.743	84	R	
Base	0	0	84	R	

R-Rigid SS- Simply Supported
Table 1: Story Displacement in x and y-direction

Column Reinforcement

The reinforcement in column increases, as the number of story's are being released that is floor levels are made simply supported at different floors and the increased percentage in columns are presented below with reference to various conditions.

LONGITUDINAL R/F IN COL C-1000X1000MM SW-350 MM THK										
COL. No	ALL STORY RIGID	STORY	STORY 9 SS	STORY	STORY 9,7 SS	STORY	STORY 9,7,5 SS	STORY	STORY 9,7,5,3 SS	STORY
C1, C4	0.9%	Ninth	1.17%	Ninth	1.5%	Ninth	1.67%	Ninth	1.75%	Ninth
C2, C3	0.84%	Ninth	0.88%	Ninth	1.11%	Ninth	1.34%	Ninth	1.44%	Ninth
C5, C12	0.8%	All story	0.8%	All story	0.8%	All story	0.8%	All story	1.09%	Third
C6, C11	0.8%	All story	0.8%	All story	0.8%	All story	0.8%	All story	0.8%	All story
C7, C8, C9, C10	0.8%	All story	0.8%	All story	0.8%	All story	0.8%	All story	0.89%	Third
C13, C20	0.8%	All story	0.8%	All story	0.8%	All story	0.8%	All story	1.02%	Third
C14, C19	0.8%	All story	0.8%	All story	0.8%	All story	0.8%	All story	1.35%	Ninth
C15, C16, C17, C18	0.8%	All story	0.8%	All story	0.8%	All story	0.8%	All story	1.27%	Ninth
C21, C28	0.8%	All story	0.8%	All story	0.8%	All story	0.8%	All story	1.14%	Third
C22, C27	0.8%	All story	0.8%	All story	0.8%	All story	0.8%	All story	0.89%	Third
C23, C24, C25, C26	0.8%	All story	0.8%	All story	0.8%	All story	0.8%	All story	0.88%	Third

SS- SimplySupportedC1-Column number 1 / C29 TO C56 are likethe above configuration, correspondingly
Table 2: Column Longitudinal Reinforcement

MODAL MASS PARTICIPATION

Case	All Storyrigid			Story 9 Ss			Story 9,7 Ss			Story 9,7,5 Ss			Story 9,7,5,3 Ss		
Mode	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Ux	0.71	0	0	0.70	0	0	0.68	0	0	0	0.72	0	0	0.73	0
Uy	0	0.80	0	0	0.79	0	0	0.75	0	0.67	0	0	0.68	0	0
Rz	0	0	0.73	0	0	0.71	0	0	0.69	0	0	0.68	0	0	0.69

Table3: Modal mass participation

Observations for Alternate Storyreleasedstructure in Zone-II

a. Story displacement: - The structure is stable; deflections are within the limits (i.e. H/500) in both the directions.
b. Story drift: - Inter-story drifts are within the allowable limits of 0.004xfloor height in both the directions.
c. Column reinforcement: - Column reinforcements are nearly nominal for the story releases corresponding to 9th, 7th and 5thfloors, thereafter its demand is increasing when the 3rd floor release is also given.In addition to 9th, 7th and 5th floor, when 3rd floor is also released, increased deflections (still within allowable limits) and the reinforcement percentages are observed in the columns.
d. Modal Mass Participation: - The structure is getting the first mode in x-direction with the corresponding release of 9thand 7th floor.After the release of 5th and 3rd floor, the first mode of the structure is shifting to y-direction instead of in x-direction.The mass participation values are happening between 68% to 73%. The torsion is occurring only in the 3rd mode, and is thus meeting the standard principles of mass participations and modes.

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The Part - II will be continued in the next edition