Understating the Structural Behavior of Precast Concrete Structures

An Online Continuing Education Course for Engineers

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Understating the Structural Behavior of Precast Concrete Structures

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1. COURSE CONTENT

1.1 General

The main structural difference between cast-in-situ buildings and precast buildings lies in their structural continuity. The structural continuity of conventional cast-in-situ buildings is inherent and will automatically follow as the construction proceeds. For precast structures, there must be a conscious effort to ensure that structural continuity is created when precast components, such as slabs and walls, are connected. The connections act as bridging links between the components.

As the structural elements in precast buildings will only form a stable structural system after the joints are connected, structural considerations for stability and safety are necessary at all stages.

A load-bearing structure with stabilizing elements that can sustain both vertical and horizontal loads and transmit these to the foundation and the soil is required. The structure must be robust and adequately designed against structural failure, cracking, and deleterious deformations.

The overall behavior of a precast structure is dependent on the behavior of the connections, which must respond to:
• resistance to all design forces
• ductility to deformations
• volume changes
• durability
• fire resistance
• production considerations
• construction considerations

1.2 Loadings and Load Tables

1.2.1 Design procedures in general

A logical design procedure for the structural engineer must include these four phases (Figure 1.1):

1. Load Assessment: Setting up load estimates and load tables.
2. Calculation Model: Defining the structural system, describing a possible load path, evaluating of stiffness of components and joints, the execution methods, and load combinations.
3. Structural Analysis: Starting with the determination of loads on components and joints, calculation of the strength or carrying capacity of materials, cross-sections and joints; thereafter, the loads and the resistance are to be compared.
4. Documentation: Preparation of specifications, sketches, shop drawings, and assembly drawings.

PROCEDURES	ACTIONS
1. LOAD ASSESSMENTS	Load Tables Load Estimates
2. CALCULATION MODEL	Structural System Load Path Stiffness of Components and Joints Execution Methods Load Combinations **Calculations:** Internal Forces Reactions
3. STRUCTURAL ANALYSIS (CODES OF PRACTICE)	**Design:** Stresses Deformations Deflections
4. DOCUMENTATION	Specifications Calculations Sketches Drawings

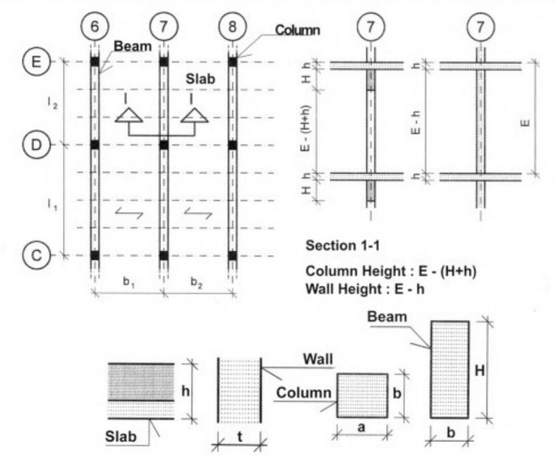
Figure 1.1 Procedure for Structural Design

1.2.2 Vertical and horizontal loads

The building design loads can usually be extracted from the load specifications in codes of practice or building bylaws. If a load type, such as the wind load, cannot be established because it is a specially shaped-building, tests must be conducted.

The vertical loads comprise the dead weight of the structure, superimposed dead loads, and live loads. Load from lightweight partition walls is normally treated as a line load. It can be equated to a uniform load if the floor slabs distribute the load evenly.

For precast buildings with simply supported main structural members, it is easy to organize and accumulate the loads acting from top to bottom of the building in load tables. An example of how it deals with accumulating vertical loads in general is shown in Figure 1.2.



ACCUMULATION OF VERTICAL LOADS	1		2	3	4 (1×2)+3		5	6 (1×2)+5		7		8	9	10 (4×8)+9		11	
CHARACTERISTIC VALUES	SLAB LOADS		SLAB SPAN	BEAM SW	BEAM LOADINGS		WALL SW	WALL LOADINGS		$\Sigma 6$		BEAM SPAN	COLUMN SW	COLUMN LOADINGS		$\Sigma 10$	
	kN/m²		m	kN/m	kN/m		kN/m	kN/m		kN/m		m	kN	kN		kN	
	DL	IL	$\frac{1}{2}(b_1+b_2)$	DL	DL	IL	DL	DL	IL	DL	IL	$\frac{1}{2}(l_1+l_2)$	DL	DL	IL	DL	IL
TOP FLOOR (ROOF)																	
NORMAL FLOOR																	
↓ × N																	
GROUND FLOOR																	
BASEMENT																	
FOUNDATION																	

DL is for superimposed dead load, IL for live load, and SW for self weight of structures.

The 11 columns on the load table are:
1. Load assessment based on a preliminary design
2. Geometrical determination of slab spans
3. Based on a preliminary design
4. Column (1x2)+3
5. Similar to 1 and 3, based on a preliminary design
6. Column (1x2)+5
7. Sum of 6, $\Sigma 6$
8. Geometrical determination of beam spans
9. Based on a preliminary design
10. Column (4x8)+9
11. Sum of 10, $\Sigma 10$

Figure 1.2 Accumulation of Vertical Loads

The horizontal loads are derived from either the wind forces or from the so-called notional force, which is determined as a certain percentage of the total vertical load on the building. In CP65, the notional horizontal load is taken to be 1.5% of the characteristic dead weight of the structure and is treated as an ultimate load for which the stability of the building has to be checked. It occurs due to eccentricities of the structure, tremors, or subsoil settlements. In countries where earthquakes are frequent, a considerably higher value is used, or dynamic calculations have to be made.

The wind forces act on the facades and gables of the building. The notional force, on the other hand, is located at the points of application of the vertical forces, normally accumulated at the centers of gravity of the structural walls and of the floor slabs.

The wind forces and the notional force are assumed to act in an arbitrary direction. The designer only needs to consider the greater of the two forces.

Accidental action is an action applied to the structure as the result of accidents and not due to specified imposed loads. Accidental action could occur from collisions, explosions, or vertical loads on air raid shelters.

For structures that must be assumed to be exposed to the risk of accidental action, specifications in the Code* (*:CP65 (1999) shall hereafter be referred to as the "Code") normally give the designer a choice between:

- Designing the structure in such a way that the parts of the structure subjected to the accidental action can withstand this or
- designing the structure in such a way that failure of a given magnitude will not result in the progressive collapse or toppling of the entire structure, as detailed in Figure 1.3

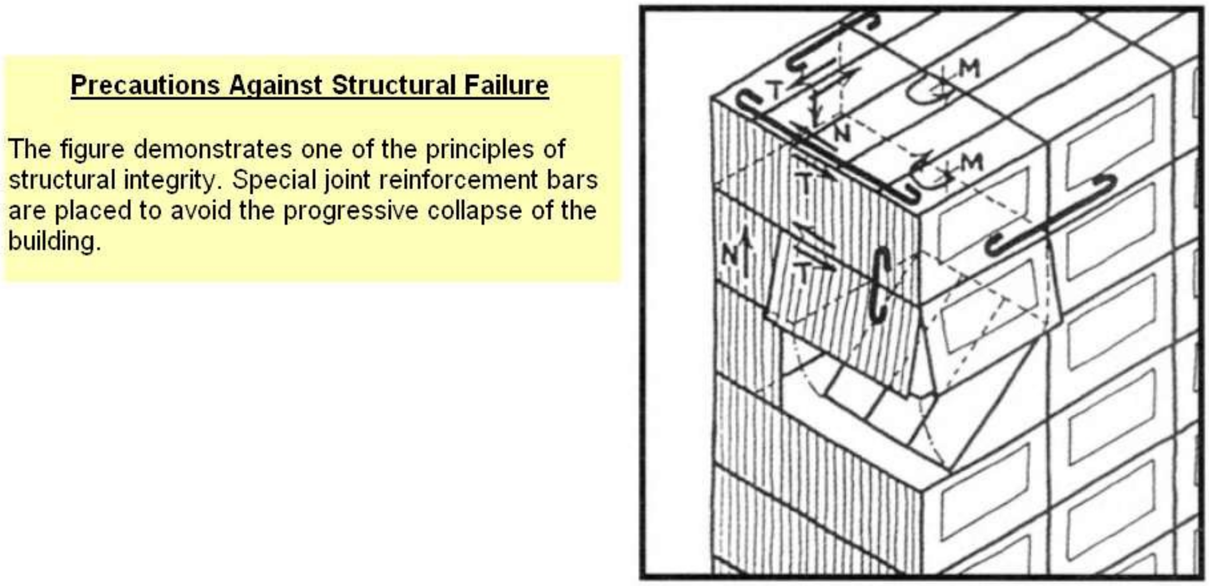


Figure 1.3 Structural Integrity Ties Against Failure

1.2.3 load path description

A building constructed from precast components becomes a so-called "house of cards." It requires rather simple structural calculations as most of the load-bearing structural members are considered simply supported.

Using precast floor slabs, walls, beams, and columns, it is seldom possible to achieve restraint in the joints, mainly due to the small dimensions of the components. This calls for special attention when evaluating the stability of the entire structure.

After having made the load assessment and the choice of calculation model, the next and very important step is the load path description. It should explain in detail a possible load path for a specific load from the point of application to where the load is transmitted to the foundation and the soil.

By using a detailed load path description for vertical as well as horizontal loads, the designer is able to calculate all internal forces acting on components and joints necessary for a proper design.

The description could also act very conveniently as a guide for the accumulation of loads and as a list of contents for the structural calculations.

1.2.4 load distribution

The last preparatory step before the structural analyses can begin is the distribution of all loadings from their application points to the load-bearing and bracing systems. This process is very much linked to the load path description. Based on the determinatio... ructural models an... uation of structural stiffness or rigidity, the distribution of loads ca...

With si... he load-bearing elemen... nd, are more difficult... valuations are made.

The illustr... zontal loads for a panel sys...

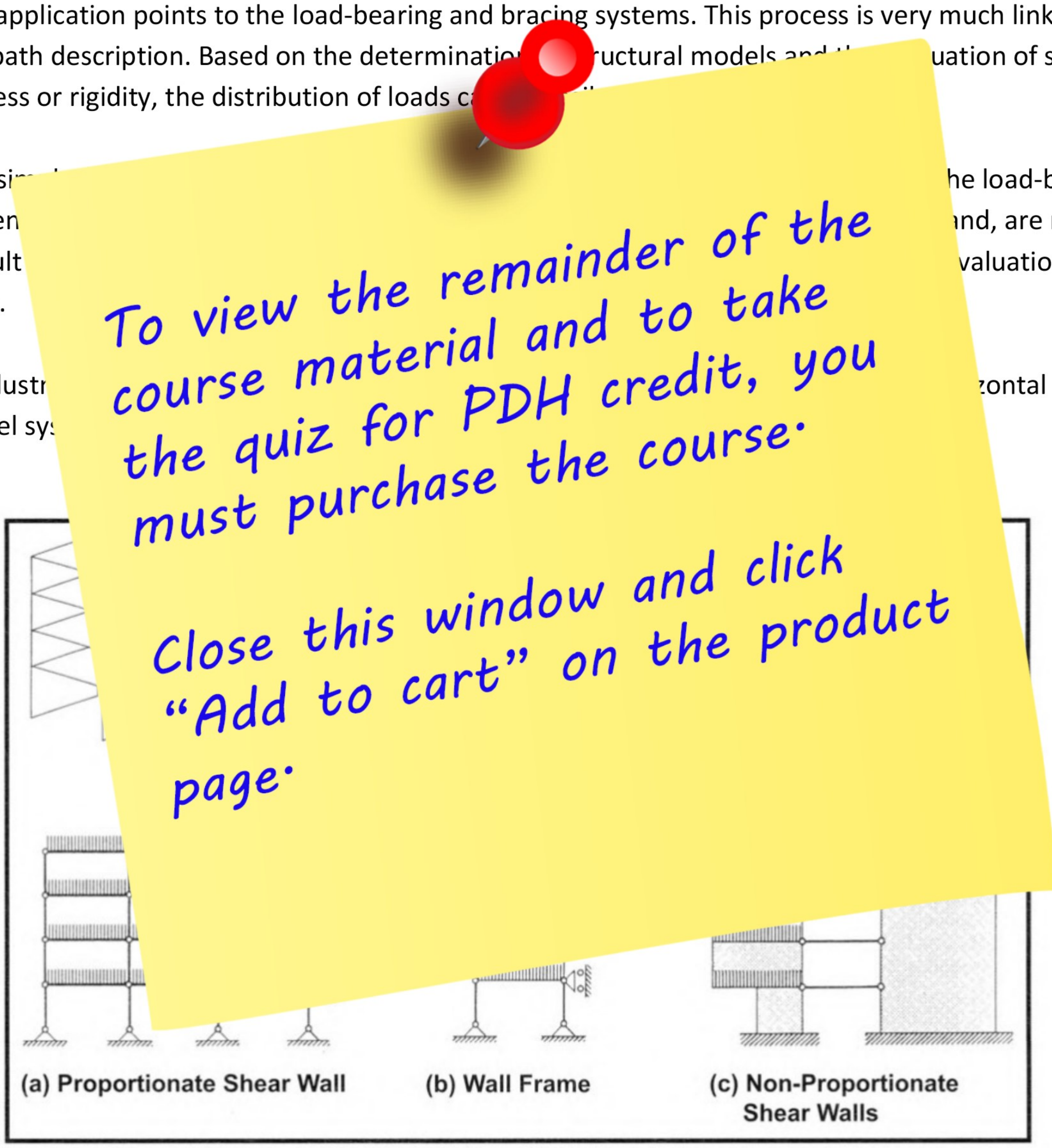


Figure 1.4 Statically Models For Vertical and Horizontal Load Distribution of Large Panel Structures