Precast Concrete for Building Systems

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Abstract -The application of precast concrete structural systems has been attaining vast progress worldwide in the last few decades. This is due to the fact that the precast structural systems possess several advantages compared to monolithic systems, such as quality control, speedy construction, and suitable application to regularly modular systems.

The paper deals with the use and the application of precast concrete for various types of buildings. The paper also describes the earthquake performances of precast buildings, seismic-strengthening techniques and Benefits of Using Precast elements in Building Construction.

Keywords: Precast concrete, Building Structures

I. INTRODUCTION

The concept of precast (also known as “prefabricated”) construction includes those buildings where the majority of structural components are standardized and produced in plants in a location away from the building, and then transported to the site for assembly. These components are manufactured by industrial methods based on mass production in order to build a large number of buildings in a short time at low cost.

The main features of this construction process are as follows:

- The division and specialization of the human workforce
- The use of tools, machinery, and other equipment, usually automated, in the production of standard, interchangeable parts and products

Figure 1: A typical precast slab-column building.

This type of construction requires a restructuring of the entire conventional construction process to enable interaction between the design phase and production planning in order to improve and speed up the construction. One of the key premises for achieving that objective is to design buildings with a regular configuration in plan and elevation. Urban residential buildings of this type are usually five to ten stories high (see Figure 1). Many countries used various precast building systems during the second half of the 20th century to provide low-income housing for the growing urban population. They were very popular after the Second World War, especially in Eastern European countries and former Soviet Union republics.

In general, precast building systems are more economical when compared to conventional multifamily residential construction (apartment buildings) in many countries. The reader is referred to the UNIDO report for detailed coverage on precast systems and their earthquake resistance.

Categories of Precast Building Systems

Depending on the load-bearing structure, precast systems described in the WHE can be divided into the following categories:

- Large-panel systems
- Frame systems
- Slab-column systems with walls
- Mixed systems

II. LARGE-PANEL SYSTEMS

The designation “large-panel system” refers to multi-storey structures composed of large wall and floor concrete panels connected in the vertical and horizontal directions so that the wall panels enclose appropriate spaces for the rooms within a building. These panels form a box-like structure (see Figure 2a, 2b). Both vertical and horizontal panels resist gravity load. Wall panels are usually one story high. Horizontal floor and roof panels span either as one-way or two-way slabs. When properly joined together, these horizontal elements act as diaphragms that transfer the lateral loads to the walls.

Depending on the wall layout, there are three basic configurations of large-panel buildings

- Cross-wall system. The main walls that resist gravity and lateral loads are placed in the short direction of the building.
- Longitudinal-wall system. The walls resisting gravity and lateral loads are placed in the longitudinal direction; usually, there is only one longitudinal wall.

- Two-way system. The walls are placed in both directions.

Thickness of wall panels ranges from 120 mm for interior walls to 300 mm for exterior walls. Floor panel thickness is 60 mm. Wall panel length is equal to the room length, typically on the order of 2.7 m to 3.6 m. In some cases, there are no exterior wall panels and the façade walls are made of lightweight concrete.

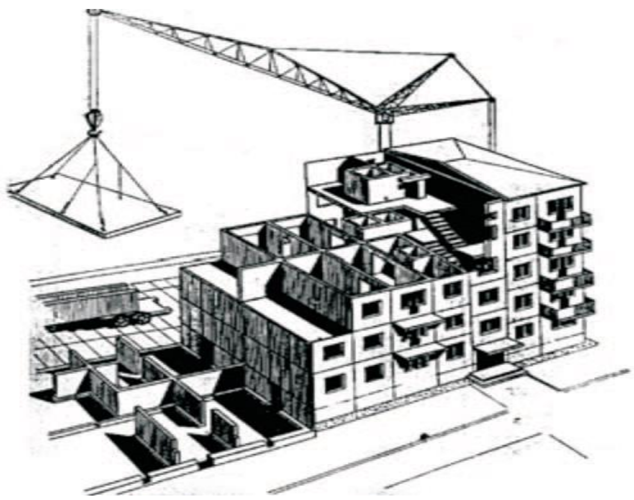


Figure 2a: A large-panel concrete building under construction

Figure 2b: Cross Wall construction

Lateral stability of a large-panel building system is provided by the columns tied to the wall panels. Boundary elements are used instead of the columns as "stiffening" elements at the exterior. The unity of wall panels is achieved by means of splice bars welded to the transverse reinforcement of adjacent panels in the vertical joints. Longitudinal dowel bars placed in vertical and horizontal joints provide an increase in bearing area for the transfer of tension across the connections. Wall-to-floor connection is similar to that shown in Figure 3.

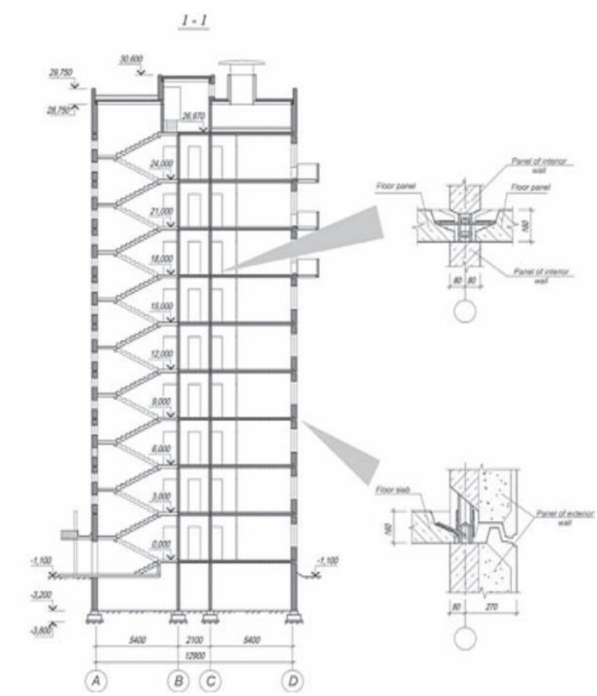


Figure 3: Plan of a large-panel building showing vertical connection details

III. FRAME SYSTEMS

Precast frames can be constructed using either linear elements or spatial beam-column sub assemblages. Precast beam-column sub assemblages have the advantage that the connecting faces between the sub assemblages can be placed away from the critical frame regions; however, linear elements are generally preferred because of the difficulties associated with forming, handling, and erecting spatial elements. The use of linear elements generally means placing the connecting faces at the beam-column junctions. The beams can be seated on corbels at the columns, for ease of construction and to aid the shear transfer from the beam to the column. The beam-column joints accomplished in this way are hinged. However, rigid beam-column connections are used in some cases, when the continuity of longitudinal reinforcement through the beam-column joint needs to be ensured. The components of a precast reinforced concrete frame are shown in Figure 4.

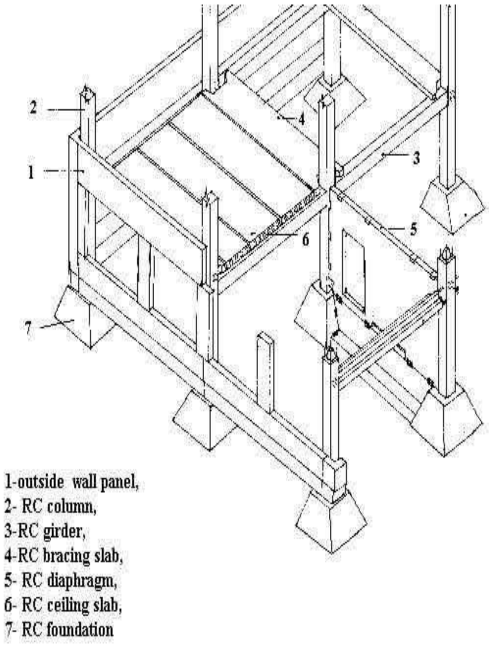


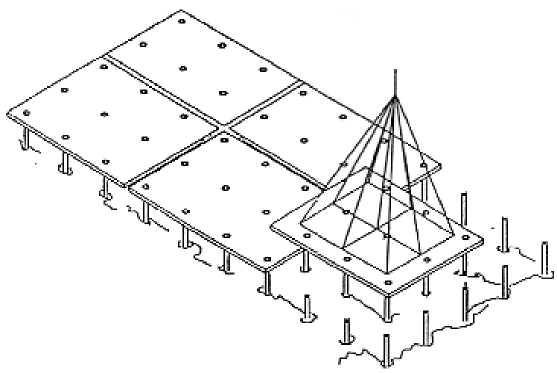
Figure 4: Components of a precast reinforced concrete frame system

IV. SLAB-COLUMN SYSTEMS WITH SHEAR WALLS

These systems rely on shear walls to sustain lateral load effects, whereas the slab-column structure resists mainly gravity loads. There are two main systems in this category:

- Lift-slab system with walls
- Pre-stressed slab-column system

The load-bearing structure consists of precast reinforced concrete columns and slabs, as shown in Figure 6. Precast columns are usually two stories high. All precast structural elements are assembled by means of special joints. Reinforced concrete slabs are poured on the ground in forms, one on top of the other, as shown in Figure 5. Precast concrete floor slabs are lifted from the ground up to the final height by lifting cranes. The slab panels are lifted to the top of the column and then moved downwards to the final position. Temporary supports are used to keep the slabs in the position until the connection with the columns has been achieved.



The Large Precast Flat Slab System

Figure 5: A lift-slab building under construction

V. Earthquake Performance

There is a general concern among the earthquake engineering community regarding the seismic performance of precast construction. Based on experience in past earthquakes in Eastern European and in Central Asian countries where these systems have been widely used, it can be concluded that their seismic performance has been fairly satisfactory. However, when it comes to earthquake performance, the fact is that “bad news” is more widely publicized than “good news.” For example, the poor performance of precast frame systems of Seria 111 in the 1988 Spitak (Armenia) (M7.5) earthquake is well known. However, few engineers are aware of the good seismic performance (no damage) of several large-panel buildings under construction at the same site, remained undamaged.

Due to their large wall density and box-like structure, large panel buildings are very stiff and are characterized with a rather small fundamental period. For example, a 9-story building in Kazakhstan has a fundamental period of 0.35 to 0.4 sec (WHE Report 32). In general, large-panel buildings performed very well in the past earthquakes in the former Soviet Union, including the 1988 Armenia earthquake and the 1976 Gazly earthquakes (Uzbekistan). It should be noted, however, that large-panel buildings in the area affected by the 1976 Gazly earthquakes were not designed with seismic provisions. Most such buildings performed well in the first earthquake (M 7.0), but more damage was observed in the second earthquake that occurred the same year (M 7.3), as some buildings had been already weakened by the first earthquake

VI. SEISMIC-STRENGTHENING TECHNOLOGIES

According to WHE reports, no major efforts have been reported regarding seismic strengthening of precast concrete buildings. However, seismic strengthening of precast frame buildings was done in Uzbekistan . The techniques used include the installation of steel straps at the column locations (see Figure 6) and reinforcing the joints with steel plates to provide additional lateral confinement of the columns.

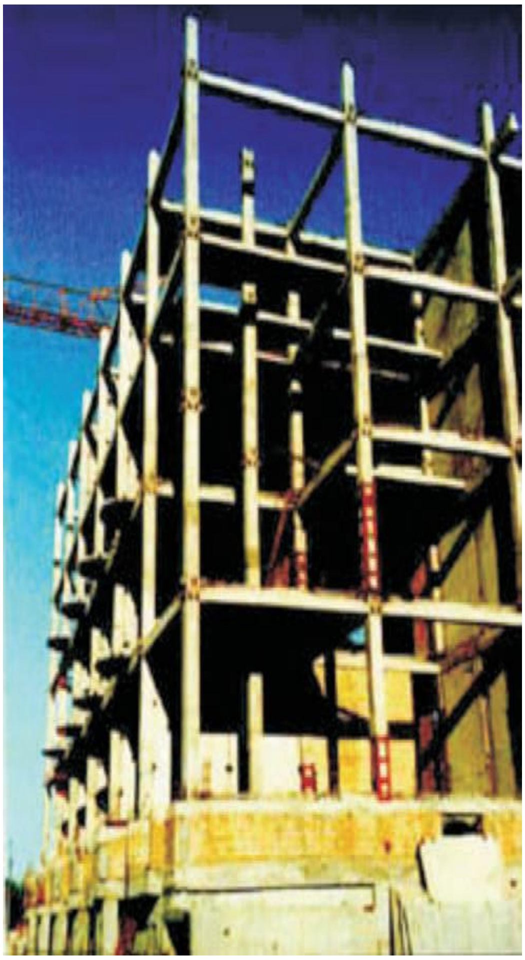


Figure 6: Seismic strengthening of precast columns with steel straps

VII. BENEFITS OF USING PRECAST ELEMENTS IN BUILDING CONSTRUCTION

A. Hotels

Precast Structures uses a system of precast elements which link together to form a cross-wall format. Panels can be formed in solid or twin wall styles to suit the design requirements of the structure. Whichever solution is selected the selections are produced in high quality finish which is suitable for direct decoration, with minimal preparatory work, obviating the need for plaster finishes, leading to cost and programme savings.

The philosophy of PCS is to produce a design which will provide the most cost effective solution, utilising the most appropriate materials for the project. This can include such items as hot rolled steel sections and cold rolled steel infill panels as appropriate.

Benefits of Using Precast Concrete Structures Include

1) High quality concrete designed for direct decoration or exposure.
2) Architectural and structural quality components.
3) Large volume supply capacity.
4) Dedicated experience project management.
5) In house Erection by trained and qualified erection personnel.
6) Solid room size slabs
7) Prefinished for direct ceiling decoration.
8) Suitable for direct carpet application.
9) Reduced structural zones free from downstands.
10) Erection of stair and lift cores as erection progresses allowing safe access for subsequent trades.
11) Pre-fitted windows option.

Figure 7: Use of precast concrete in hotel construction

Precast Concrete Structures Ltd specialise in the fast efficient delivery of the building structure, where minimal wet trades and high quality finish are essential to follow on trades. PCS strive to be market leaders in quality of finished product and offer an innovative and non-contractual approach to building structures. Some typical hotels made of precast concrete shown in Figure7.

B Student Accommodation

Cross-Wall Construction The use of cross-wall construction in student accommodation (See Figure 8) gives significant benefits for short-term build projects where a deadline for opening is critical. Precast concrete construction offers extremely durable accommodation, capable of sustaining even the toughest conditions of student living. By the use of direct finishing techniques to the walls and ceiling, together with solid room-sized slabs, and the pre-installation of bathroom pods, cross-wall construction offers speed of construction together with economy.

Key requirements for economical construction in student accommodation include:

- Repetition of room layout.
- Consistency of vertical alignment to division walls.
- Repetition of elevational treament.

By adhering to these basic principles, Precast Concrete Structures Ltd will provide advice and innovative solutions on the most economical means of manufacturing the components and sequencing the erection to the maximum benefit of the client. These benefits include:

- Fast-build programme within term-time constraints.
- Direct decoration to walls and ceilings, with only minor pre-decoration treatment.
- Pre-installation of windows.
- Early "dry-box" working for subsequent trades.
- A variety of elevational treatments using non-load bearing cladding systems (loads are transferred via the cross-walls and do not rely upon external walls for support).
- Reduced structural zone without downstands.

Figure 8: Use of precast concrete in hostel construction

C Apartments

Apartment construction has become increasingly popular as a modular build (Refer Figure 9) alternative to traditional steel and in-situ concrete frame methods. The system adopted uses cross-wall construction in a similar method to the hotel construction system, but differs in that the variability of room layouts and external elevations require differing techniques and innovative thinking to produce fast-build economical solutions. The options for apartments are both extensive and flexible providing key criteria in design are met. Precast Structures Ltd has broad experience in developing solutions for alternative construction, particularly suited to the Design & Build market.

Benefits include

- Direct decorative finish to walls with only minor pre-decoration treatment, negating the requirements for wet plaster.
- Optional methods of floor construction, allowing flexibility for individual client requirements, including:
  1) Traditional hollow-core.
  2) Wide slab composite flooring.
  3) Pre-finished solid slabs.
  4) Direct soffit finishing in replacement of suspended ceilings, significantly reducing construction build costs
  5) Reduced structural zone without down stands.
  6) Construction of common stairs and lift cores as the erection progresses, permitting early access for subsequent trades.
  7) Pre-fitted windows.
  8) External pre-finished cladding panels, grey concrete inner leaf only, or curtain-walling / metal stud permitting total flexibility in elevational treatment.

Figure 9: Use of Precast concrete technology in apartment construction

Apartment construction is usually designed with traditional building solutions which are subsequently modified during the design process to obtain a competitive edge in Design & Build solutions. The benefits of early consultation with Precast Structures will result in significant savings in both cost and time, resulting from economical manufacture solutions and reduced erection periods.

D Architectural Concrete

Precast Concrete Structures has extensive use in manufacture and erection of architectural and structural building components. Sections are bespoke and can be manufactured within the programme for our standard materials with a wide range of finishes and colours including:

- Brick.
- Wet cast reconstituted stone cladding and dressings.
- Composite Architectural / Structural insulated columns.
- Exposed structural elements.

Buildings are considered on an individual basis and assessed for integration of structural components to reduce programme and to ultimately drive down costs.

VII. PROGRESSIVE COLLAPSE

Concrete building structures whether, insitu or precast, is required to perform in the event of accidental damage or explosion by meeting the design criteria for progressive collapse.

Within the building structure, ties are incorporated to resist calculated forces determined by a variety of factors, including:

- Number of stories
- Centres of walls / size of spans

- Total loads carried

These are achieved by the use of the following ties incorporated into the precast cross-wall design:

- Vertical ties
- Horizontal ties
- Peripheral ties
- Internal ties

Joints between panels are tied together using pre-shuttered in-situ-fill to create a robust joint with minimal finishing required. The joints use wire ties designed to meet the specific tie-force criteria, but also to allow flexibility in assembly tolerances during erection. Peripheral and internal ties use high strength steel strand within the nominal in-situ joints at cross-wall locations and around the perimeter of the building to create a continuous tie arrangement. Building design is analysed for structural stability by Precast Structures consultants who have extensive knowledge in the design stability of cross-wall building structures.

VIII. CONCLUSION

By producing precast concrete in a controlled environment (typically referred to as a precast plant), the precast concrete is afforded the opportunity to properly cure and be closely monitored by plant employees. Utilizing a Precast Concrete system offers many potential advantages over site casting of concrete. The production process for Precast Concrete is performed on ground level, which helps with safety throughout a project. There is a greater control of the quality of materials and workmanship in a precast plant rather than on a construction site. Financially, the forms used in a precast plant may be reused hundreds to thousands of times before they have to be replaced, which allow cost of formwork per unit to be lower than for site-cast production. The use of precast concrete in Indian construction industry will definitely enhance the efficiency of the contractor in terms of quality, safety and time of project completion. In developing country like India, adoption of this technology for building construction will boost the Government's development plans, as this gives really faster way of construction and also quality of work far better than onsite casting concrete which is really value for money.

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