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Design and Concrete of Precast Concrete Jail Cells in USA

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General

Precast concrete jail cells are very efficient in construction of prison housing facilities. The precast jail cells offer much higher security comparing to concrete masonry units (CMU) cells. All amenities in the cells are tamper-proof. There is no loose element in the cells for inmates to cause harm to others or themselves or to make an escape. The quality of the product can be closely controlled since all the modules are produced in manufacturing plant as opposed to site construction of CMU cells. Precast concrete jail cells require less construction time so they can save equipment and labor cost. These advantages lead to popularity of precast concrete jail cells in USA.

There are several levels of security for prison housing units that will reflect in functional design of the facilities. For instance, the shower unit is included in the maximum security cell as shown in Fig. 1. In lower security levels, shower area is provided within the building to make the housing facility self-contained.

The distinct components for precast concrete prison housing facilities are cell modules, balcony slabs and plenums. The general configuration of the housing facility is shown in Fig. 2. This facility is located in Florida State. In this project, the cell modules are placed stacking up to two levels with balcony slabs in between. The roofs of the lower cell modules serve as floor slabs for the upper cell modules. The balcony slabs are cantilevered from the cell modules. There are plenums on top of the upper modules for attic spaces to provide MEP (Mechanical, Electrical and Plumbing) feed ducts to each individual cell. The plenums are optional. They can be replaced with simple concrete wall panels. However, the plenums have some advantages to wall panels in resisting lateral wind load from the roofs.

Components

Cell Modules

The cell modules may contain two or four cell units, called double and quad modules respectively. A quad module is shown in Fig.3. The module consists of external walls on all sides and a roof slab cast monolithically. Openings for cell doors, embeds and amenities are set at the time of casting. The exterior walls exposed to the weather are insulated. Electrical ducts, Plumbing and other mechanical ducts are embedded in the concrete and placed through the triangular chases shared between two adjacent cells. Bunks, toilets and other amenities are fixed to the cells with tamper-proof bolts.

The quad module is typically 15’-0” wide x 30’-0” long x 8’-8” high with 1’-0” lifting devices on the top of the module. Total weight is about 85 kips. The double module is typically 15’-0” wide x 15’-2” long x 8’-8” high with 1’-0” lifting devices and weighs 46 kips.

The cell module width is a determining factor for transportation. Modules wider than allowed in local regulation may need police escort, which increases the construction cost.

Balcony Slabs

Placed between upper and lower cell modules are the balcony slabs. These slabs serve as corridors and places for lighting fixtures for the lower level. The slabs are furnished with railings to prevent inmates from falling. They are normally tapered to reduce the structural weight as shown in Fig.4. Electrical conduits for lighting and security camera are embedded in the slabs.

Plenums

Plenums are C-shaped structures placed upon the upper cell modules to form the attics as in Fig.5. Aside from their function as walls for attic ducts, they also help resisting the lateral wind load and the roof weight from the steel roof structures. Walls of the plenums can be tapered to reduce the structural weight. The top of the plenums is notched to support the roof trusses.

Other components such as wall panels, flat slabs and columns are used at other locations than jail cells such as the corner spaces or middle walls supporting steel trusses. They are not jail cell specific and therefore not elaborated in this article.

Connection Details

In precast concrete construction, good connection details are very vital to the overall structural stability. Insufficient connections can greatly reduce the strength and durability of the structures.

Key connections for prison housing facilities are cell module to cell module connections, balcony slab and cell module connections, plenum and cell module connections and cell module to foundation connections. Most connections are compression-controlled so dowels and corrugated sleeves are sufficient. Some specific connections need detailed design such as connections for cantilevered balcony slabs to cells. Sample connection details are shown in Fig.6.

Connection hardware must be protected from element by means of grouting or caulking. The exposed hardware must be hot dip galvanized to prevent rust. In correctional institute, security issue must be taken into account. The exposed connections must be kept at minimum and the exposed ones must be tamper-free.

Small concrete section in jail cells limits choice of connection hardware to only small embed that does not interfere with reinforcement or protrude from the concrete surfaces.

Design Concept

Loading

The structures are designed to resist both gravity and lateral loads. Gravity load computation is quite straightforward. However, lateral loads can play significant role in

determining the design. Structural stability of precast structures can sometimes govern the design of members and connections. Major lateral loads are wind load and earthquake load. Example project is located in Florida so the wind load is the governing lateral force.

The housing facilities are designed to resist lateral loads by the whole buildings as shown in Fig.7. The surrounding cell modules act as counterweight for lateral moment. With large moment arms, there can hardly be any tension in the base connections. Top steel roofs are used as the lateral link between both sides of cell modules to keep them moving together as a whole. This whole-building approach can greatly reduce lateral loads on the wall panels in the middle of the buildings, which make the wall panel design more economical.

Stacked cell modules have to be checked for structural stability from lateral loads. The connections must be able to resist base tension if there is any. Lateral bracing has to be sufficient to prevent hinge mechanism, which can occur on stacked wall panels.

Design

Precast concrete jail cells are normal reinforced concrete. Wire meshes are used due to their limited wall thickness. Door openings are usually steel framed so there is no cracking problem at corners. Other openings are surrounded with usual corner and edge reinforcing steel. The insulated walls on the exterior face of the cell are usually design using only the inner wythe to resist the load instead of using both wythes by composite action. The reason behind this is to reduce the area of solid part required for composite walls. The solid concrete part can reduce much of the insulation effect and can cause sweat outside the building when the temperatures between inside and outside of the building are much different.

If the attic level walls are not made of plenums, the attic walls must be supported by steel bracings. The steel bracings must be able to withstand the lateral load acting on the attic walls. The C-shape of the plenums, on the other hand, can inherently resist the lateral loads.

Precast concrete members must also be designed for loading during transportation and handling. These handling loads can sometimes exceed the service loads especially for thin long wall panels or flat slabs with support on the short direction. Impact from handling and transportation must be taken into account. In some case where the concrete panels are thin and having large openings, special casting bed that can be tilted up are used to prevent stress from stripping process.

There are other non-structural limitations imposed on the design such as maximum size and weight of the member that can be transported, local regulation and functional requirement. The designer must get with the local authority and survey local condition of transportation and precast manufacturer when doing the design.

Manufacturing

Distance between casting yard and jobsite is the criterion for decision between casting at job site and casting at yard. When the jobsite is very far from the casting yard such as out-of-state location, it may be more economical to set up casting yard at jobsite. Since a separated casting yard requires separated work force and equipment such as lifting crane, QC lab, concrete mixing plant and concrete placing equipment, only remote large project jobsites are eligible.

Cell modules are cast with collapsible core formwork for each cell and moveable side forms for the exterior faces of the module. All reinforcement and insulation are prefabricated from suppliers and are ready to be placed into the form. Embedded materials such as connection hardware, windows, doors, toilets, electrical outlets and conduits are shipped to casting yard for placing into the form prior to concrete pouring. Fig. 8 shows the fabrication of insulation, reinforcement and embeds prior to concrete placing.

Each cell module takes 24 hours from fabrication to form removal. High strength concrete is used in order to achieve sufficient early strength for form removal. The patching and finishing of the cell module is done outside the form to save construction time.

Transportation

Specially designed trucks are used to transport cell modules as shown in Fig. 9 to reduce the total height of the laden trucks. Out-to-out dimension of the cell modules is critical since wider load requires escort and may limit transportation time to daytime only. Total load height also limits transportation route because low pedestrian bridges, flyovers and tunnels are to be avoided when transporting high modules.

Erection

At jobsite, construction cranes will move the cell modules from the trucks and place them on designated locations (Fig. 10). The mat foundation is also used as ground floor slab of the prison housing facility. Dowels inserted into pre-bored holes on mat foundation fix cell modules in desired places. Fig. 11 shows drilling of a dowel hole on mat foundation.

The erection starts from ground level up to roof, i.e., the cell modules of the first floor, the balcony slabs, the second level cell modules and the plenums. The ring of the cell modules and the middle walls are connected with the roofing system on top of the plenums. Steel components such as stairs, balcony railings are installed after the precast construction is done (Figs. 12, 13). Fig. 14 shows prison housing facilities after all pieces were erected.

Conclusion

Precast concrete cells are gaining more popularity due to their security, structural durability, short construction period, concrete quality and better workmanship. The structural design is not much complicated and can be mastered in a short period. However, other non-structural criteria would require in-depth study of the construction condition and local condition. Transportation and handling of the members such as cell modules are as critical as the service stage design.

With some modification, this fabrication and construction technique can be applied for low-cost residential housing units. The advantages of precast construction are more noticeable with more precast units. Construction times and cost can be greatly reduced with additional forms and equipment. This modular construction is a viable option when material and labor costs keep increasing nowadays.

Fig. 1 In-Cell Shower Booth for Maximum Security Unit

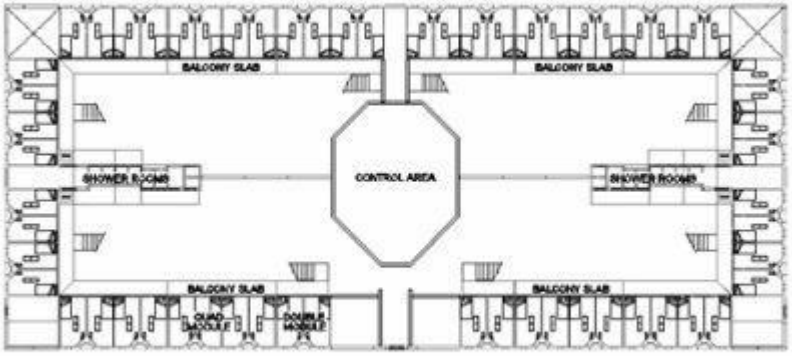


Fig. 2 Prison Housing Facility Configuration

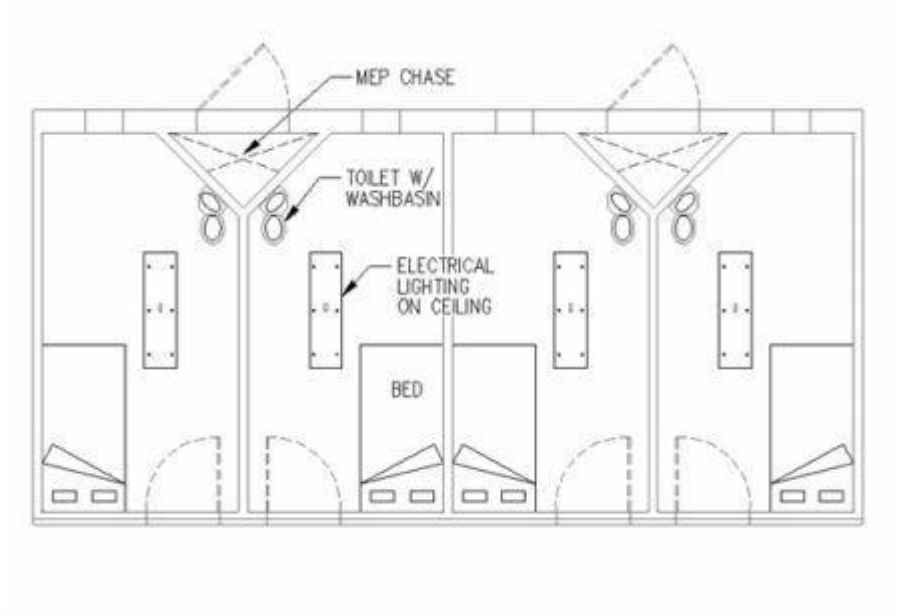
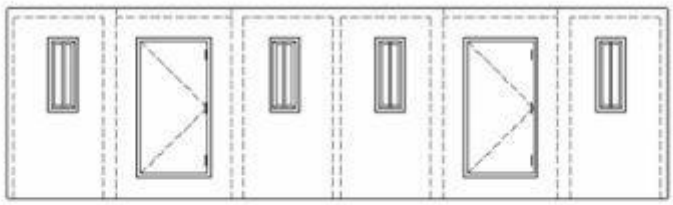
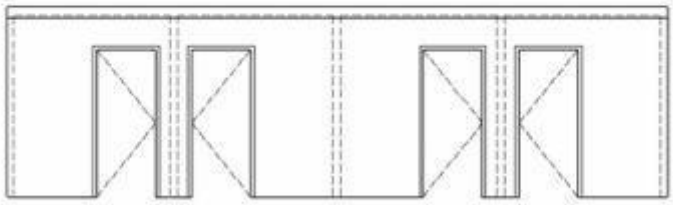


Fig. 3 Quad Cell Module



REAR ELEVATION



FRONT ELEVATION

Fig. 3 (cont.)

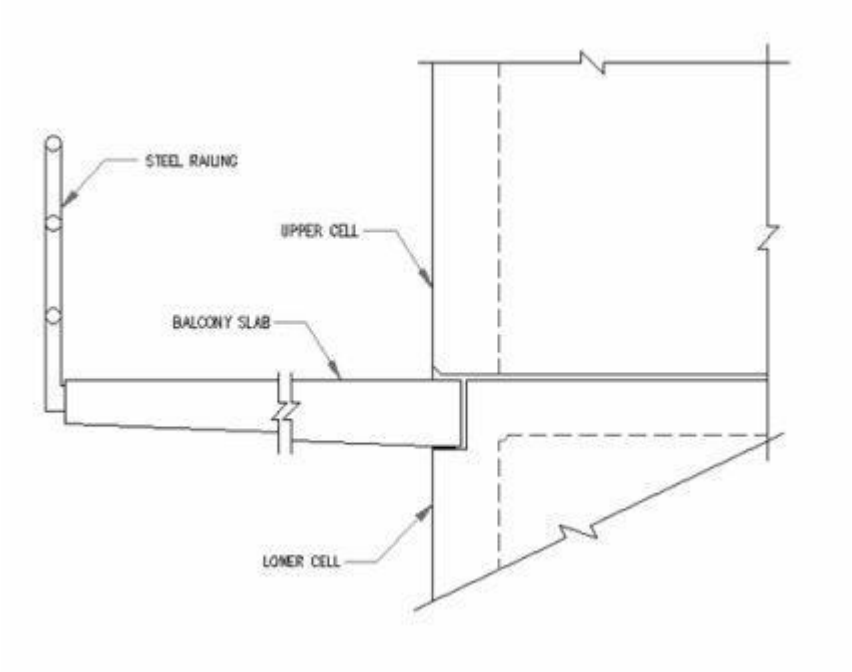


Fig. 4 Balcony Slab

Fig. 5 Plenum

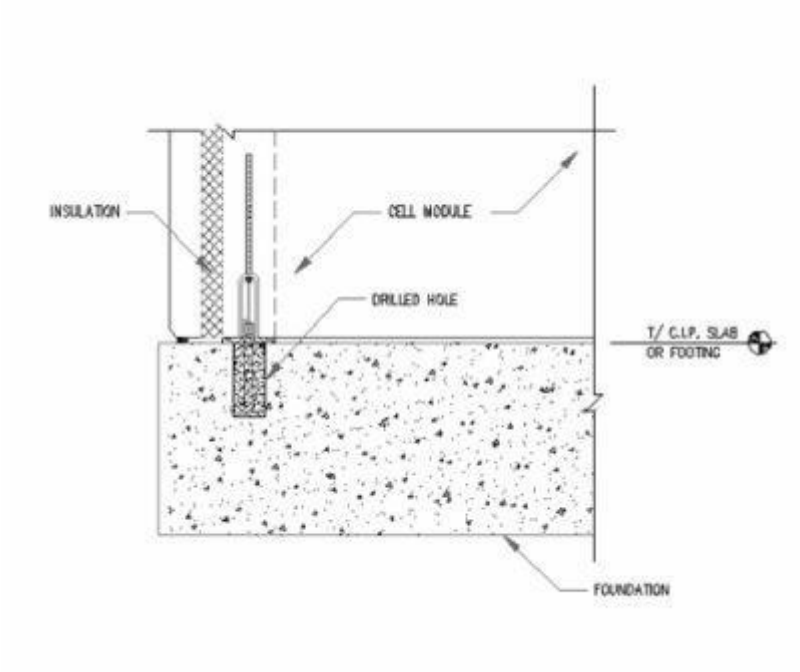


Fig. 6 Connection Details

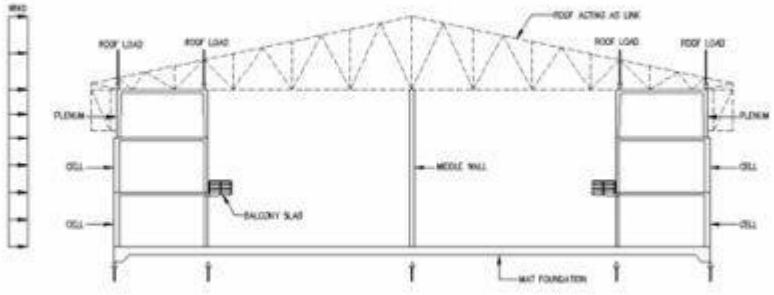


Fig. 7 Structural Model

Fig. 8 Fabrication of Embeds Prior to Concrete Placing

Fig. 9 Special Truck for Cell Module Transportation

Fig. 10 Erection by Construction Crane

Fig. 11 Mat Foundation Drilling for Precast Cell Installation

Fig. 12 Steel Component in Prison Housing Unit

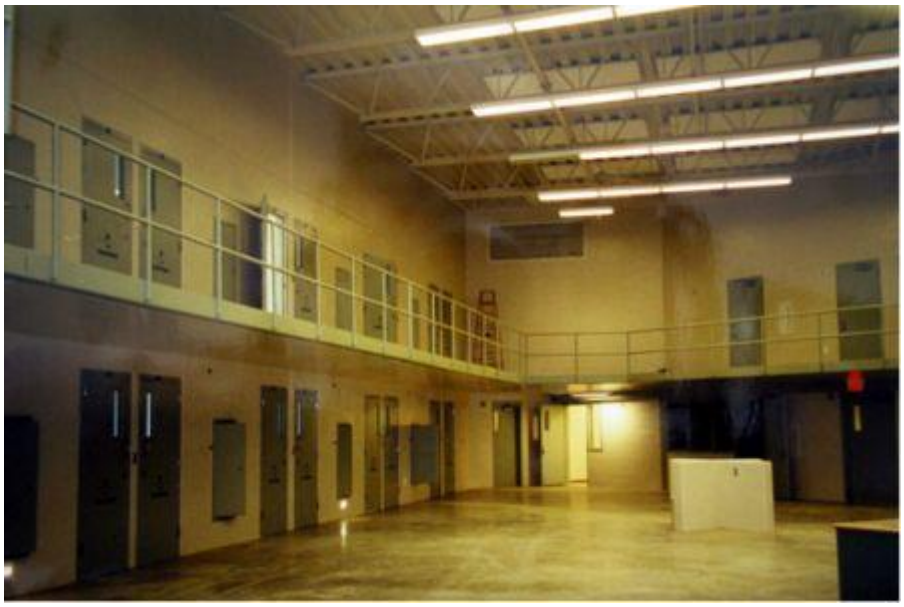


Fig. 13 Steel Trusses

Fig. 14 Prison Housing Facilities