Case Study CS002

A Case Study in FEMA Design and Construction Requirements for Prestressed Concrete Structures

Garden City High School

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Garden City High School:

FEMA 361 Safe Room Design and Construction Criteria

Project Name: Garden City High School

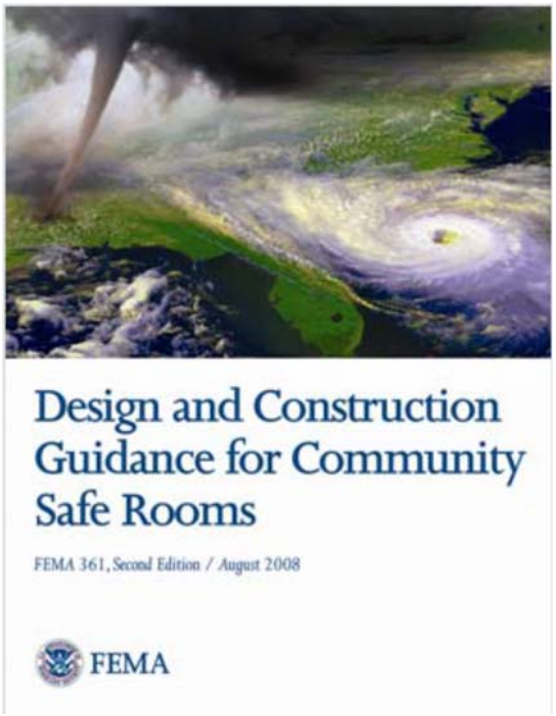
Project Location: Garden City, Kansas

Project Overview

The new Garden City High School features a community safe room system designed to specific FEMA 361 standards. The school consists of three separate safe rooms, ranging in size from 5300 to 7600 ft². Lateral stability is obtained with shear wall panels ranging from 17 to 35 feet tall, and from 5 to 12 feet wide. In addition to the primary wind resistance they provide, the safe room walls also act as exterior walls in some locations. Because of the location of the high school in a highly tornadic area, FEMA requires all designs to meet occupancy density, debris missile impact, suction, and direct wind speeds of up to 250 mph, for an EF5 rating. The safe rooms are all built as individual units to exist without structural support from the surrounding school building. Because of this, there are double interior walls that provide extra durability and required redundancy.

FEMA 361 Code Requirements for Safe Rooms

FEMA 361, Design and Construction Guidance for Community Safe Rooms, sets standard requirements for any safe room project in order to minimize probability of death and injury during an extreme weather event. The goal of a safe room system is to provide absolute protection for the occupants during extreme storms. Safe room system requirements include a 100-pound-per-square foot roof live load, in addition to modified load factors for load combinations that include wind effects. The project must also include design wind speeds ranging from 130 mph to 250 mph, meet criteria for flying debris, and meet code requirements for occupancy of five square feet of floor area per person, and be designed to hold collapse loads of all non-FEMA 361 buildings in the vicinity.



FEMA reviews all safe room system plans receiving federal grant funding to ensure plans and specifications for the systems are in accordance with current requirements. A special inspection for quality assurance is also required during construction. Because precast concrete is produced at a manufacturing plant meeting PCI certification requirements, the precast process assures a high degree of excellence in plant facilities, production, design, and quality control operations. This certification by PCI eliminates the need for special inspections during the wall panel fabrication process, reducing the project budget.

Fujita Tornado Damage Scale

EF0 Light: Chimneys are damaged, tree branches are broken, shallow rooted trees are toppled.

EF1 Moderate: Roof surfaces are peeled off, windows are broken, some tree trunks are snapped, unanchored mobile homes are overturned, and attached garages may be destroyed.

EF2 Considerable: Roof structures are damaged, mobile homes are destroyed, debris becomes airborne (missiles are generated), and large trees are snapped or uprooted.

EF3 Severe: Roofs and some walls are torn from structures, some small buildings are destroyed, non-reinforced masonry buildings are destroyed, and most trees in forest are uprooted.

EF4 Devastating: Well-constructed houses are destroyed, some structures are lifted from foundations and blown some distance, cars are blown some distance, and large debris becomes airborne.

EF5 Incredible: Strong frame houses are lifted from foundations, reinforced concrete structures are damaged, automobile-sized missiles become airborne, and trees are completely debarked.

Architectural Design Success

The safe room system is composed of 8 inch thick gray structural precast interior concrete walls, and 13 inch insulated architectural precast exterior concrete walls. The walls require additional connections and reinforcement to meet the loads required. The wall panels are designed for high lateral loads, with a lateral load system consisting of floor and roof diaphragms transferring lateral forces to precast concrete shear walls, and down to the foundations.

Engineering Design Accomplishments

Special consideration was given to the connection requirement for the primary roof members, metal decking, and structural topping. The resultant embed plate was designed for gravity and uplift, with specific size to accommodate field tolerances (See Detail 3), wall panel base connections transfer uplift, overturning, and shear requirements into the foundation (See Detail 2).

Specific considerations for topping and uplift of roof members are implemented into the design of the precast panels for this project. In addition, these requirements plus shear loads are transferred into the foundation. Per FEMA 361, the safe room foundation must be designed for five times the load of a traditional structure. The use of interior double walls ensures that the safe room is a completely separate system that can stand on its own if the surrounding structure is demolished.

Manufacturing images are provided on page 9.

Construction Solutions

Precast concrete has become a common option for meeting FEMA building requirements. Precast wall panels and roof members are ideal for meeting the load force requirements. The use of precast also provides a quality control process and a cost-effective solution for project construction. The wall panels included in this project are one and two stories high, in a single wall unit. The reinforcing is in two mats of mild steel in the 8" thickness. The principal reinforcing runs vertical, with shrinkage and temperature running steel horizontally.

Roof System

For the Garden City High School project, steel beams supporting a metal deck with cast in place topping are used for the safe room roof system. Concrete is poured on top of this metal deck to distribute wind and seismic load forces to the shear walls, and to ensure that uplift force resistance is met. The typical detail for connecting this metal decking and CIP topping to the precast shear walls is shown in Sketch 3. The shear walls are connected to the foundation with multiple welded connections, per Detail 2.

Quality and Consistency Levels

The precast panels were fabricated in accordance to PCI MNL-116, and their installation followed PCI MNL-127.

Value Options

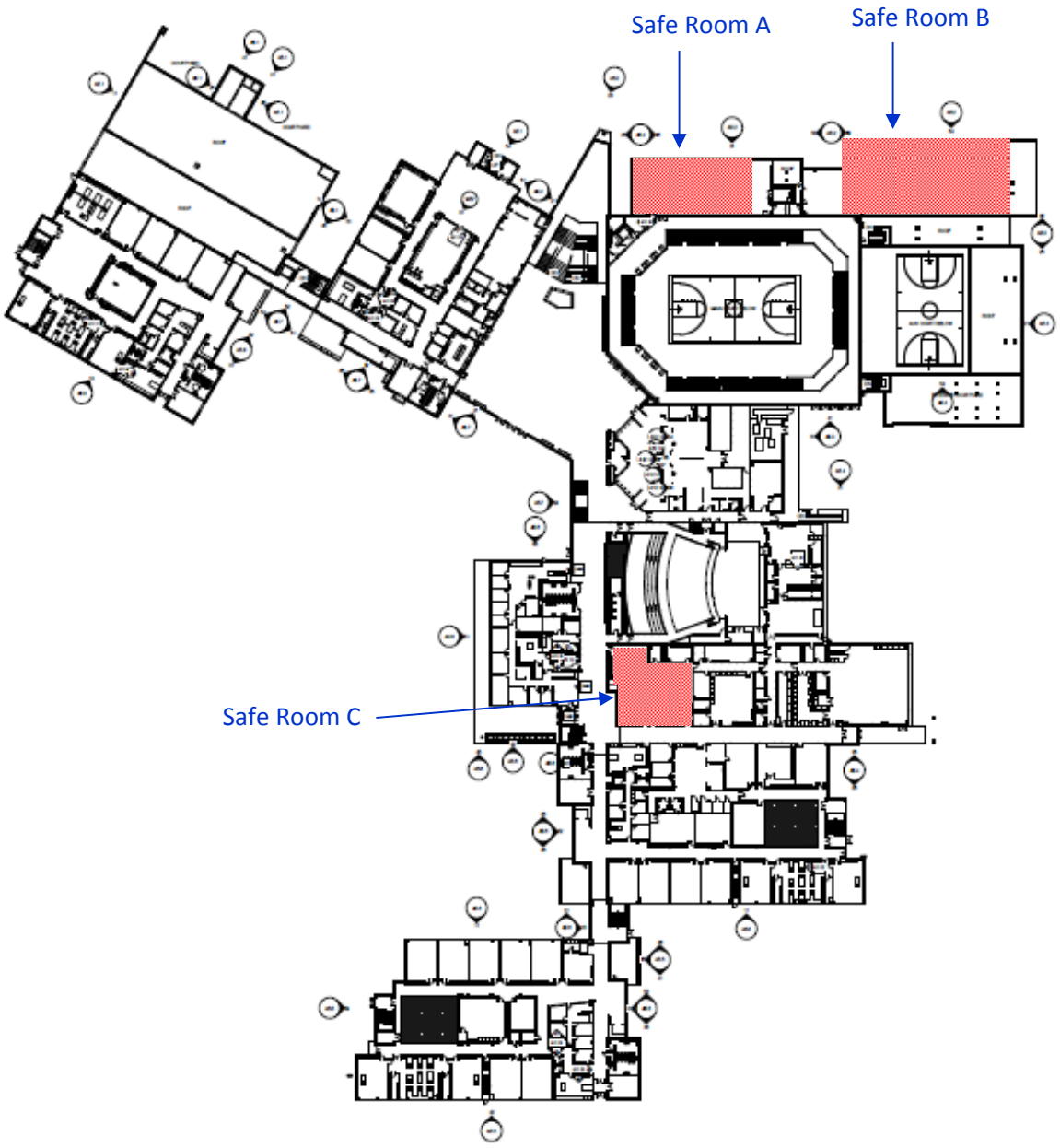
Value options can enhance safe room performance and provide alternatives that may alter project price and build time. Common options for safe room projects not used in the Garden City High School safe rooms are precast roof components and insulated precast wall panels.

An entirely precast roof system solution is available for implementation into safe room projects and ensures a reinforced roofing system while fulfilling FEMA 361 project requirements. Precast deck bulb tees, hollow core panels, and double tee panels can be incorporated in place of steel beams. Hollow core can be used for roof spans up to 40 feet; double tees can be used for longer spans of 80 feet. (See Details ALT 1 and ALT 2.) For the

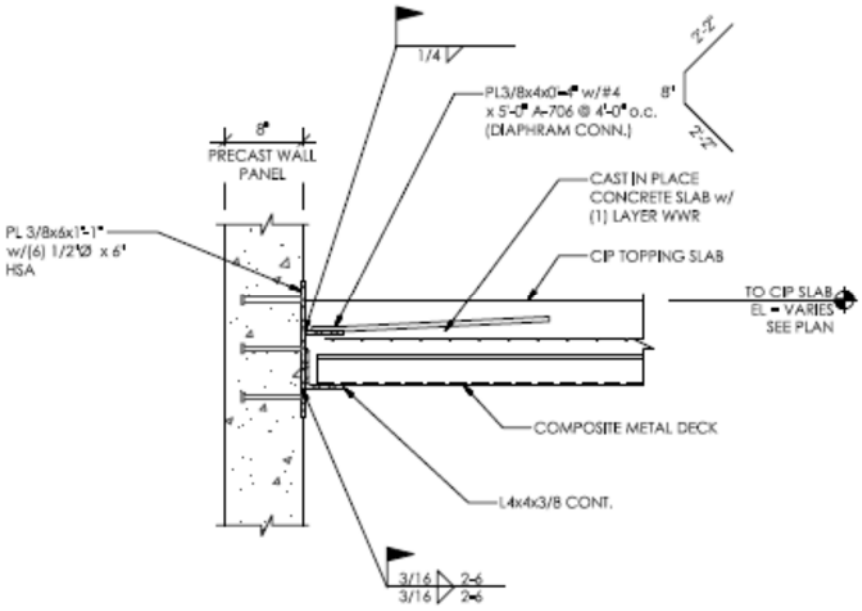
largest span needs, deck bulb tees can be incorporated into the roofing system. Because of the increase in weight of the structural components thinner topping slabs may be achieved.

Key benefits of insulated precast wall panels are thermal efficiency and thermal mass. Insulated precast wall panels with continuous insulation and a non-conductive connector system create thermal efficiency in safe room systems. Thermal mass performance of the wall panel system is derived from an interior layer of concrete, which creates a mechanism for the storage of heat, reducing energy demands. Natural thermal efficiency in insulated precast wall panels increases savings in energy costs of up to 50%, while also meeting stringent IgCC and ASHRAE requirements that designate performance requirements for exterior wall components. The thermal insulating property, or R-Value, is based on insulation thickness, and concrete materials of the wall panel. Actual performance R-Value may be much greater than the calculated material R-value due to the mass effect of the insulated precast wall. Alternate details 1 and 2 are shown with this layer of rigid insulation and Alternate detail 3 is shown with the existing steel roof members and an insulated wall panel.

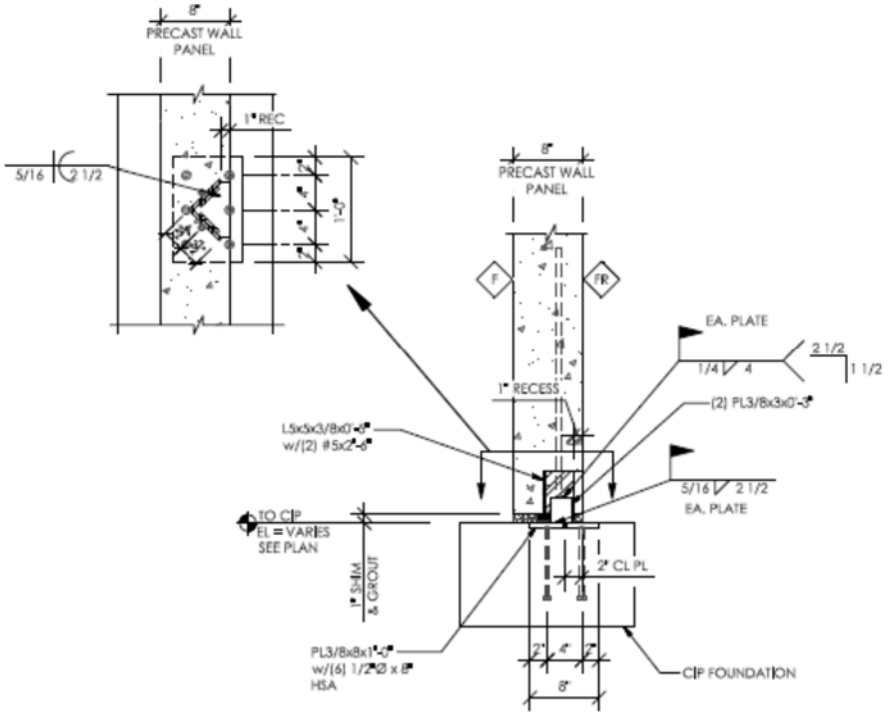
Variations in project design and material preferences allow for these different safe room system options. All options presented meet FEMA 361 requirements and ensure maximum safety for safe room occupants.



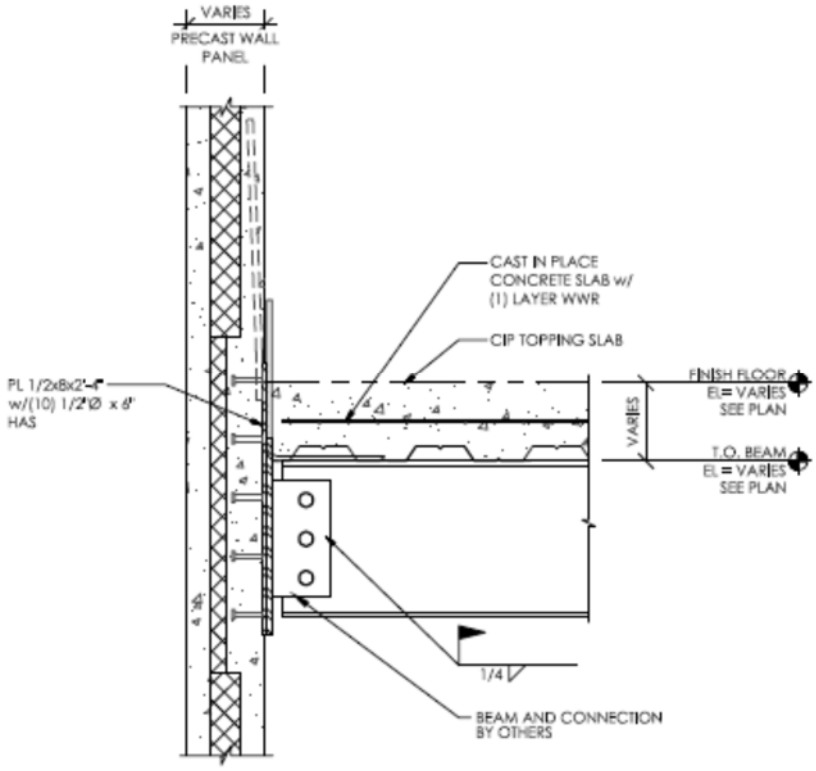
Safe Room	Stories	Safe Room Use	Size	Occupancy
A	2	Athletic room top floor/Locker room bottom floor	5600 ft²	1120 people
B	2	Athletic room top floor/Locker room bottom floor	7600 ft²	1520 people
C	1	Speech and Debate	5312 ft²	1062 people



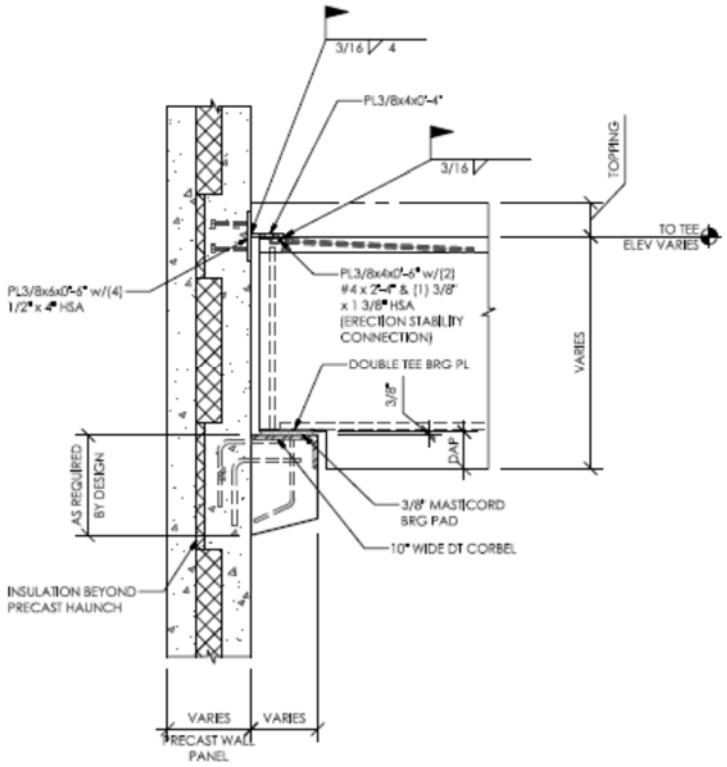
Garden City Safe Room Detail (1)



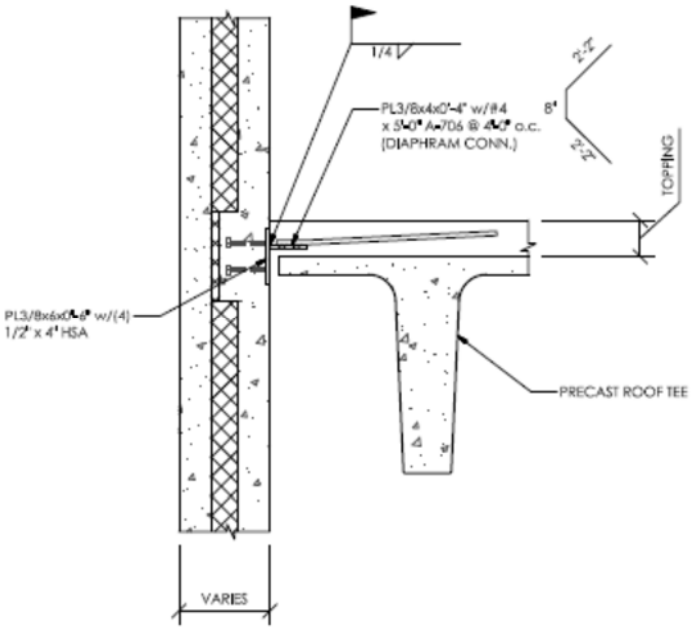
Garden City Foundation Connection at CIP Footing (2)



Typical Steel Beam Detail (3)



Alternate Typical DT BRG on Insulated Precast Wall (ALT 1)



Alternate Typical Diaphragm to Shear Wall Connection (ALT 2)

Photographs

Initial form set-up with side rails and wooden bulk heads.

100% of the forming and reinforcement is complete. Awaiting inspection and casting.

Finished exterior views of Garden City High School

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