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Structural Option

Pennsylvania Judicial Center

Harrisburg, PA

Thesis Proposal

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Executive Summary

The Pennsylvania Judicial Center is a nine-story, 425,000 square foot building project currently under construction in Harrisburg, PA. This $95 million building will house the Pennsylvania Unified Judicial System, and features courtrooms, conference rooms, and offices.

The building's primary structural system is comprised of a steel frame with composite floor slabs. The building resists lateral loads using concentrically braced frames between the floor slabs, which act as rigid diaphragms. The frames use stiffness in the plane of the lateral load and act similarly to a truss to transfer the loads to the columns, which then transfer the loads to the foundation below.

The function of this building creates an increased security concern over other buildings of a similar size and location. In order for the judicial officials to be able to perform their jobs adequately, the building should provide them with physical security. Therefore, the main focus of this thesis will be a study of blast resistance and progressive collapse. National interest in blast protection was reinvigorated after the attacks on September 11, 2001, and the United States Department of Defense responded by publishing guidelines on how to accomplish this for a building.

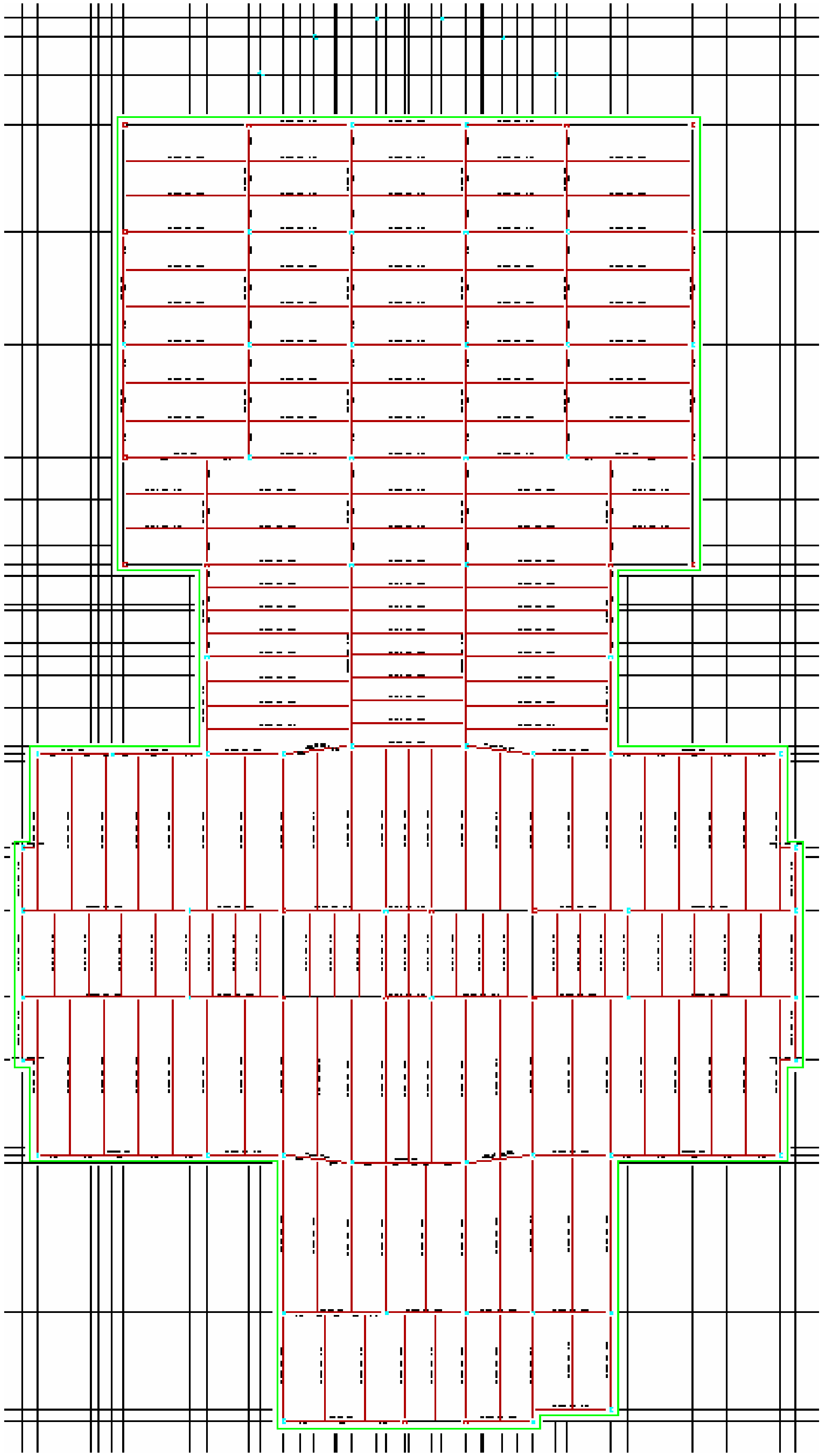
Two primary areas in which an attack is most likely to occur have been identified: the parking area below the building and the exterior at the front face of the building. For an interior explosive blast, building damage is basically inevitable no matter how well designed the structural system may be. Therefore, for interior blasts, the design goal will be to simply prevent catastrophic failure. For the exterior of the building, the facade elements, especially the glazing, should be designed for blast resistance according to ASTM standards. Glass shards falling inwards from the primary atrium to the main lobby of the building could present a serious life safety risk.

The building will be redesigned using the same type of structural system as the existing one: steel frame with composite slabs. The system will be designed to withstand a single large, rapidly applied pressure force in several different locations in the lower parking deck. The building will be analyzed as a whole using a model developed in RAM Structural System, and the effect of a blast on an individual frame or bay will be modeled using RAM Advanse. The frame will be designed based on provisions of the 13th Edition of the AISC Manual of Steel Construction.

The breadth study of the mechanical system will also focus on mitigation of the effects of a terrorist attack. Airborne contaminants can cause sickness or death within minutes of exposure. The mechanical system will be designed to depressurize automatically upon sensing a dangerous level of contaminants and exhausting the space while bringing in 100% outdoor air. This system will be designed for a courtroom, which is likely to have the greatest occupant load.

The other breadth study involves the architectural aspect of the building. Designing the exterior facade for blast resistance and adding large exhaust towers to the roof of the structure will obviously impact its appearance. The architectural goal is to make the changes to the exterior and the floor plan while maintaining the original architect's vision for the edifice and maintaining the conservative appearance appropriate for a judicial building.

Framing Plan – 2nd Floor



Building Background

Floor system:
The typical floor is supported by a composite steel and concrete system. The concrete is lightweight (110 pcf dry unit weight) and has a minimum 28-day strength of 4000 psi. There are 3½" of concrete above a 3" 18-gage galvanized composite cellular metal deck, for a total slab depth of 6½". Typical reinforcement is welded wire fabric, 6x6-W2.9xW2.9. The slab is supported by steel beams with typical sizes ranging from W16x36 to W24x68. Typical spans are as long as 42 feet, and the widest spacing between beams is ten feet. The typical spacing between beams is also approximately ten feet. Composite action is enforced by ¾" diameter shear studs with 5½" length.

Roof system:
The flat roof system is identical to the typical 6½" concrete slab floor system. The sloped monitor roof on the ninth-floor tower has a 3" 20-gage galvanized metal deck. The roof is supported by sloped beams ranging from W8x10 to W12x19, with spans no longer than 25 feet and a 9' maximum spacing. The monitor above the main atrium features the same deck, but it is supported by bent W30x90 beams spanning 56' and spaced at ten feet o.c.

Lateral system:
The structure is laterally supported by concentrically braced steel frames in both the N-S and E-W directions. These frames consist of the wide flange columns, wide flange beams at each story and two HSS (hollow structural section) diagonal braces between each story. The geometry of the diagonal members varies, and this has an impact on their relative stiffnesses. This lateral system features no moment connections, and relies on concrete floor and roof slabs to act as rigid diaphragms and to distribute the lateral loads accordingly.

Foundation:
The slab on grade concrete is normal-weight (145 pcf dry unit weight) and has a minimum 28-day strength of 5000 psi. The slab on grade is fiber-reinforced at not less than 1.5 lb/yd^3 in some areas and is reinforced with #3 bars @ 18" c/c in the rest of the slab. Typical slab thicknesses are 5" with 6" drainage fill and 8" with 8" drainage fill. Column loads of up to 1,000 kips are supported using concrete piers with diameter of up to eight feet end bearing on rock. Larger column loads are supported by socketed caissons with diameters up to 4.5 feet with up to 18' depth. The piers will bear on grey limey shale bedrock with an allowable bearing stress of 30 ksf. The median core depth to reach bedrock was 9.5 feet, and bedrock depth is relatively uniform throughout the site. The concrete basement foundation walls are supported by continuous wall footings.

Columns:
The columns are ASTM A992 Grade 50 wide flange steel shapes laid out in a rectangular grid. In this system, the columns are acting as the primary gravity resistance members. The columns that are attached as braced frames are also the main lateral force resisting members. The braces between columns are ASTM A500 Grade B HSS shapes ranging in size from 8×8×1/2" to 12×12×5/8". The largest column is a W14x550, though most of the columns are on the order of 300 lb/ft at the ground floor.

Mechanical System:

The HVAC system is a hot and chilled water variable volume air-handling unit system with fan-powered VAV boxes and the capability of future humidity control. Ventilation air is supplied to indoor air-handling units from rooftop make-up air units with heat recovery wheels. The system includes variable volume hot and chilled water pumping: chilled water is generated through a heat exchanger from a central plant; hot water is generated through a heat exchanger from high pressure city steam. This pressure is reduced inside the building system. The system also includes a multiple-evaporator variable volume refrigerant system to cool security and data rooms throughout building.

Architectural Program:

This structure is a modern yet conservative building suitable for its judicial purpose. The exterior of the building is primarily clad in Indiana limestone to match the other buildings in the Capitol Complex. The walls have parapets on all sides of a primarily flat roof. There are gable roofs on monitors that contain clerestory windows centered on the larger roof masses. The building consists of three primarily rectangular forms. A centralized five-story atrium topped with a skylight for major circulation and shared conference spaces is the main interior architectural feature. There is also a six-story mass that houses the Commonwealth Courts (courtrooms, judge's chambers, related support spaces) and a nine-story office tower. Only one floor will be built of the back section in the current phase, but it is designed to enable expansion up to six stories.

Problem Statement

Based on all analyses performed on the Pennsylvania Judicial Center in this project, the structural system is sufficient to resist all design gravity, wind, and seismic loads. However, the ability of the building to withstand a blast force is undetermined. Based on conversations with the structural engineering firm that designed the building, blast resistance was considered but was only implemented in a very limited sense due to budget constraints. The blast capacity of the building enclosure system is also unknown. To provide a higher level of physical security to the building occupants, it is desirable to redesign the building so that damage is minimized in the event of a blast force.

Proposed Solution

The proposed enhancement to the Pennsylvania Judicial Center is to enable the building to withstand a blast force originating in the parking area below the building or a blast on the exterior building at the front. These areas have been identified as the most likely areas that an explosive large enough to threaten the integrity of the structure could be placed.

This thesis will explore different possibilities for structural redesign to withstand blast resistance. These methods may be employed independently or in combination; the method(s) chosen will be dependent on effectiveness and economic analysis. One method is to protect the columns from the blast using concrete (creating composite columns), steel plates as “armor”, or another rigid material. This method will likely be calculable by hand only, using provisions of the 13th Edition of the AISC Steel Construction Manual and the ACI 2005 code.

Another method is to design for the prevention of progressive collapse. In this method, it is assumed that a column or group of columns is obliterated in a blast, and the building is designed to redistribute the loads. This will be performed based on Progressive Collapse Analysis and Design Guidelines, published by the Government Services Administration. Since analysis will include several different locations for the origin of the explosion, use of RAM Structural System to assist in design will be essential.

Another life safety criterion to be examined in the thesis is blast-resistant glazing design. The area recognized as critical for this building is the atrium glass surrounding the main lobby. For a visual representation, refer to the rendering of the building on the cover sheet. This glass will be designed according to ASTM E 1300, "Standard practice for determining the load resistance of glass in buildings." This glazing will be designed to prevent hazard to human life only; it is assumed that in the unlikely event of a localized blast, the glass will probably need to replaced no matter how well designed.

Breadth Topics

Mechanical System:

This system will be redesigned for a typical courtroom space for the removal of excess contaminants. The purpose of this system is to design the mechanical system to protect life safety in the event of a bioterrorism attack using airborne contaminants; however, it can also be used to quickly remove smoke from the space in case of a fire. The system is reliant on building pressurization to help exhaust the unwanted air. Upon the system sensing a dangerous level of contamination, the contaminated space will become negatively pressurized, meaning that the contaminated air becomes forced into the exhaust. The main air intake for the room will need to be operating at a 100% outdoor air condition to eliminate room air mixing. The contaminated air would be exhausted out of large ducts on the roof of the building, at a safe distance from pedestrians on the ground as well as occupants of adjacent buildings.

Architecture:

Changes to the facade to help blast resistance and the large exhaust system that the changes to the mechanical system necessitate will result in a different exterior appearance from the existing building. To achieve the desired blast resistance performance, changes may be necessary to the glazing and the wall sections. Also, the size and height of the exhaust stacks necessary for the alternate mechanical system will require changes to the building shape and a redesign of the roof. The goal of this study is to make the necessary alterations to accommodate the structural and mechanical system improvements without straying far from the intended architectural program of the original architects. In addition, an effort will be made to improve the overall aesthetic of the building. Robert Holland, R.A., can assist in the architectural critique of the thesis work.

Schedule

Tasks:

Structural

1A: Research blast resistance and progressive collapse
1B: Detail 3D RAM frame model to more accurately represent slab openings and lower level parking garage
1C: Use RAM Advanse to measure blast resistance of single columns, existing and armored
1D: Modify 3D RAM model to include armored column design
1E: Modify 3D RAM model to prevent progressive collapse in a sacrificial column situation
1F: Research facade blast resistance
1G: Design glazing according to ASTM E1300 provisions
1H: Redesign front face of facade for blast resistance capability
1I: Redesign structure for new mech/arch gravity loads
1J: Redesign foundations to accommodate modified design

Mechanical

2A: Research contaminants exhaust system
2B: Size components of the contamination reduction system based on ASHRAE requirements
2C: Resize AHU to accommodate emergency 100% outdoor air system using psychrometric chart
2D: Select catalog system components

Architectural

3A: Determine new architecture that can be incorporated
3B: Redesign building shape to accommodate mech. system
3C: Redesign enclosure system architecture after blast analysis
3D: Redesign plan for 1st floor and parking garage to accommodate structural changes (if necessary)

Miscellaneous

4A: Edit and revise paper
4B: Provide faculty consultant with thesis rough draft for review
4C: Publish final version of thesis; post to CPEP site
4D: Create Powerpoint presentation
4E: Practice final presentation
4F: Final update to CPEP including ABET evaluation and reflections
4G: Modify thesis format to match requirement of Honors thesis

Week #	Dates	Tasks
1	Jan 16 – Jan 19	1A
2	Jan 22 – Jan 26	1A, 1B
3	Jan 29 – Feb 2	1A, 1B, 1C
4	Feb 5 – Feb 9	1C, 1D
5	Feb 12 – Feb 16	1D, 1E
6	Feb 19 – Feb 23	1F, 2A, 2B
7	Feb 26 – Mar 2	1G, 2C, 2D
8	Mar 5 – Mar 9	1H, 3A, 3B
SPRING BREAK		
9	Mar 19 – Mar 23	3A, 3C
10	Mar 26 – Mar 30	4A, 1I, 1J
11	Apr 2 – Apr 6	4A, 4B, 4D
12	Apr 9 – Apr 13	4C (Thesis Due Apr. 12), 4D, 4E
13	Apr 16 – Apr 20	4E (Presentation Apr. 17, 1:20pm)
14	Apr 23 – Apr 27	4F, 4G
15	Apr 30 – May 4	4G