Structural Comparison between Pan Joist Concrete and Steel Frame Systems for UMCP Student Housing – Building B

Executive Summary

The proposed thesis will include an investigation of two different alternative structural systems for the UMCP Student Housing – Building B at the University of Maryland. These two structural systems are a pan joist concrete system and a steel frame system. This proposed thesis will include the design of both of these systems for the whole building.

One of the systems that will be investigated is the pan joist concrete system. For this system, sizes will be determined, and the loads on the floor will be determined. The frame will then be analyzed using STAAD Pro, a frame analysis program, to determine its adequacy. The output will be analyzed and a decision will be made if any change in size needs to be done to make the system work. All of the design of the concrete frame will meet ACI 318-02 (Building Code Requirements for Structural Concrete).

Another system that will be investigated is the steel frame system. For this system, the sizes of all the beams and columns will be designed to meet all of the gravity loads. All of the structural member sizes and loads will then be entered into STAAD Pro, a frame analysis software program, to determine the adequacy of the system. From there, changes in the members will occur if problems arise. All of the design will meet the Manual of Steel Construction (Load and Resistance Factor Design) Second Edition.

Along with the changes in the structural system, some additional construction management issues will arise. Some of these issues include: site layout, crane location, and formwork design. For example, site layout will be very important for the crane location and where the material will be positioned. Formwork will be designed for the pan joist concrete system. These issues will be investigated for both of the proposed structural systems and will aid in the comparison of the systems.

Finally, since the whole structure is going to change throughout the whole building, why not look at some possible architectural alternatives. One of the alternatives is to look at the facade. This could be done by expressing the structural elements in the facade. Another alternative is to expose the structural system in the interior spaces. This could be done in the lobby areas and other public spaces. One last alternative is to look at the roof. This could be done by expressing the mechanical system is the roof or by a different roof system.

Background

The UMCP Student Housing – Building B, which is located at the campus of the University of Maryland at College Park, Maryland, is used as a dormitory building. These dorms are fully furnished apartments that provide all the students with their living necessities, while being conveniently located on campus. The building also has lounges and study areas that the students can meet and study in a quiet environment.

The building is a 77,445 square foot building that is five stories tall. Each floor occupies a floor space of 62 feet by 300 feet, which is not an exact rectangle. The floor plan is attached on page 8 shows the general lay out of the building. The reason is that multiple sized rectangles make up the building lay out. The total project building cost is approximately $52 million; this figure includes four other buildings of the same size and geometry. The project took from November 2000 to August 2002 to complete.

Before construction of the building could commence, an existing structure needed to be demolished. The demolition was done in a fashion to minimize the damage to the surrounding structures. In addition, the utilities that supply the surrounding buildings run underneath the site. During construction, disruption of the utility service was not recommended because the surrounding buildings were in use during the construction of the project. Finally, transportation around the construction site was not to be disrupted. This was done by keeping the pedestrian sidewalks open and the roads open by taking deliveries in non-traffic hours.

The structural system of the building is load-bearing light gauge metal stud walls and masonry shear walls. The structure also consists of tube steel columns, but they only extend up to the second floor. The floor system is a composite system of Hambro open web steel joists that bear on the load-bearing walls, see illustration in Figure 1. On the fifth floor, the light gauge metal studs convert to wood framed walls. This can be done because the building is of Construction Type R-2 as per BOCA 1999 building code, Section 310.4.1 (Dormitories) and Table 602 (Fire resistance Ratings of Structural Elements). This means that as long as the wood members are fire retardant, they can be used in the building. The roof consists of pre-fabricated wood trusses that are of multiple sizes and shapes to fit the architectural situations. The foundation system consists of strip footings and retaining walls, which adequately transfer the load from the building to the earth below. See building section attached on page 9, for a section view of the structural system.

Figure 1 Typical Hambro Joist Layout

The mechanical system of the building is a multi-zone system, which allows for temperature control in each individual apartment. This is why a multi-zone system was used. Two rooftop chillers supply the cold air to the building. Then various sized electric heating units were placed around the building to supply the desired comfort level in each individual apartment. The lighting system is a fluorescent lighting system that provides enough illumination to keep the space comfortable. The electrical system that supplies the power to the lighting system consists of multiple panel boards that distribute the 244/120 V power throughout the building. These panel boards not only supply power to the lighting system, but they also supply power to the mechanical system, outlets, and elevator systems.

Problem

The overall design of the building has proved to be a good design, but there are some issues that could be addressed further. One of the issues is that the plenum space could be more open to the mechanical and electrical systems. The floor-to-floor height is already low, 9'-10.5" high, so the only alternative is to open up the plenum more. This can be done by designing a different floor system then the composite Hambro open web steel joist system that exists currently. The floor system would then need to be designed to resist all of the loads that apartments and corridors will supply. The floor system will resist all the dead loads, equipment loads based on the equipment schedule, and live load of 40 psf for the apartments and 100 psf for the corridors, as per the 1999 BOCA building code, Table 1606 (Minimum Uniformly Distributed Live Loads).

Problem Solution

Alternative #1 (Pan Joist Concrete System)

Alternative #1 will be a pan joist concrete system, as illustrated in Figure 2. The floor system will have a five (5) inch slab to meet a 2-hour fire rating. The system will also be designed using 40 inch pans to fit a four (4) foot module. The depth of the joists will be determined using ACI 318-02, Table 9.5a (Minimum Thickness of Non-prestressed Beams or One-way Slabs unless Deflections are Computed). After the depth of the joists is determined, the joists will be designed for both shear and flexure using ACI 318-02 code requirements for reinforcing bar ductility. The girders will be assumed to be 24 inch wide and designed for shear and flexure based on ACI 318-02. The columns will be assumed to be 18 inches by 18 inches. The floor-to-floor height will remain the existing 9'-10.5" in height. The live loads on the floor system will be determined as per 1999 BOCA building code with a 40 psf in the apartments and 100 psf in the corridors. All the concrete structural elements will be designed to the ACI 318-02 (Building Code Requirements for Structural Concrete).
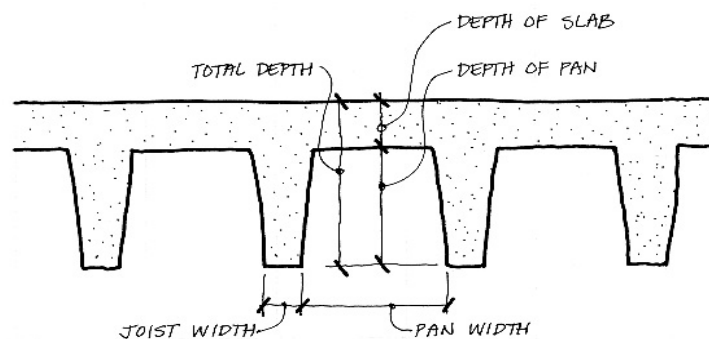

Figure 2 Section of Typical Pan Joist Concrete System

Alternative #2 (Steel Frame System)

Alternative #2 will be a steel frame system is made up of structural steel elements, as illustrated in Figure 3. The floor system will be a composite beam system where the metal deck and the beam are joined together by shear studs. The slab will be 4" thick with a ribbed metal deck designed by United Steel Deck design manual. The live loads on the floor system will be determined as per 1999 BOCA building code with a 40 psf in the apartments and 100 psf in the corridors. All of the composite beams and columns will be designed using the Manual of Steel Construction (Load & Resistance Factor Design) Second Edition.

Figure 3 Typical View of a Steel Frame System

Problem Method

Alternative #1 (Pan Joist Concrete System)

The pan joist concrete system will be designed using ACI 318-02 (Building Code Requirements for Structural Concrete). The frame will then be entered into STAAD Pro to determine its adequacy. From there changes in member sizes will made if necessary. In addition, the live loads will be calculated using pattern loadings. One case will be full live load on all spans. Another case will be live load on alternate spans. Finally, the live load on adjacent spans. From these pattern loadings, the worst-case moments and shears will be used in the design of the floor system.

Alternative #2 (Steel Frame System)

The steel frame system will be designed in accordance to the Manual of Steel Construction (Load & Resistance Factor Design) Second Edition. The composite beams will be designed to Part 4 (Beams) Beam Design Moment Charts. The live loads will be determined by pattern loading. The following pattern loadings will be implemented: full live on all spans, alternate loaded spans, and adjacent loaded spans. All of the columns will be designed to Part 3 (Column Design) Design Strength of Column Tables. All of the gravity loads will be factored

using the load factors in the the Manual of Steel Construction Second Edition. The slab and ribbed metal deck will be designed to the United Steel Deck design manual.

Tasks and Tools

I. Revise and Post previous assignments
  - Task 1 – Revise Technical Assignment 1 (Structural Existing Conditions Report)
    - a. Recalculate the Seismic Load
    - b. Revise document writing as per Dr. Boothby's comments
  - Task 2 – Revise Technical Assignment 2 (Alternative Floor Systems)
    - a. Design the columns to support the floor systems
    - b. Revise document writing as per Dr. Boothby's comments
  - Tack 3 – Revise Technical Assignment 3 (Lateral System Confirmation Design)
    - a. Revise shear wall calculations
    - b. Revise document writing as per Dr. Boothby's comments
II. Pan Joist Concrete System
  - Task 4 – Determine the trail sizes for all the structural members
    - a. Determine the minimum thickness of the slab as per ACI 318-02 Table 9.5c
    - b. Determine the size of the joists, girders, and columns
  - Task 5 – Determine the floor loads
    - a. Determine the self weight of all the structural members
    - b. Determine superimposed dead load from the construction documents
    - c. Determine live loads based on the 1999 BOCA building code, Table 1606
    - d. Determine wind loads based on the 1999 BOCA building code, Section 1609
    - e. Determine seismic loads based on the 1999 BOCA building code, Section 1610
  - Task 6 – Do the frame analysis
    - a. Enter the geometry and loads into PCA Beam and PCA Column
    - b. Determine the reinforcement size from the program output
III. Steel Frame
  - Task 7 – Determine the floor loads
    - a. Determine the self weight of all the structural members
    - b. Determine superimposed dead load from the construction documents
    - c. Determine live loads based on the 1999 BOCA building code, Table 1606
    - d. Determine wind loads based on the 1999 BOCA building code, Section 1609
    - e. Determine seismic loads based on the 1999 BOCA building code, Section 1610
  - Tack 8 – Do the frame analysis
    - a. Determine the structural member sizes based on the loads from the Manual of Steel Construction
    - b. Enter the geometry and loads into STAAD
    - c. Check deflection of the members
    - d. Determine if members are adequate based on output

IV. Breadth Options
- Task 9 – Construction Management
  - a. Layout site to determine locations of materials and crane
  - b. Determine what formwork system to use for the Two-way concrete flat slab system
  - c. Calculate the bracing for the formwork
- Task 10 – Architecture
  - a. Take a look at the facade for a possible alternative
  - b. Take a look at exposing the structural in some of the interior spaces
  - c. Take a look at the roof for a possible alternative

V. Presentation
- Task 11 – Final Report
  - a. Gather information from both alternatives and compare
  - b. Put together the Final Report
- Task 12 – Presentation
  - a. Put together the presentation
  - b. Actually present my findings

Timetable

In the table below, a schedule shows how I am going to do this thesis project in the Spring Semester 2003. It shows when the tasks described above in a week-by-week schedule will get done.

Task	Week												
	1	2	3	4	5	6	7	8	9	10	11	12	13
1	■	■											
2		■											
3		■	■										
4			■										
5				■									
6					■								
7						■							
8							■						
9								■					
10									■	■			
11											■	■	
12													■

Table 1 Proposed Schedule for Spring Semester 2003

Concluding Remarks

The proposed thesis will include an investigation into the performance of a pan joist concrete system and a steel frame system. In this investigation, both systems will be analyzed

under gravity and lateral load situations. In addition, some construction management issues and mechanical system will be investigated. This is because when the structural system changes, these issues come up and need to be solved. Then a comparison will be made between both of the systems.

Breadth Options

Construction Management

Construction management issues are very important when changes in the structural system occur. Some of the things that need to be looked are formwork design, concrete placement issues, site layout, and crane locations for my previously mentioned structural systems. A decision on the type of formwork system and construction sequence of the formwork will all need to be looked at. The erection sequence of the steel is very important because it depends on the location of the crane and the location of the material on the site. The site layout is important because it makes an impact on the crane location and how the concrete will be delivered on the site.

Architecture

Architecture issues that will be looked into will be the following: facade, interior exposure of structure, and roof. Since the structure is changing for the whole building, why not express the structural elements to the outside world. In addition, exposing the structural system in the interior spaces could be done. This would only be done in lobby and public spaces, not in the actual residential spaces. Finally, the roof system could be expressed a bit differently. This could be done by expressing the mechanical system or by a different roof system all together.