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AE 481W
Structural Option

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URS Office Building
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SENIOR THESIS PROPOSAL

Lateral System Redesign

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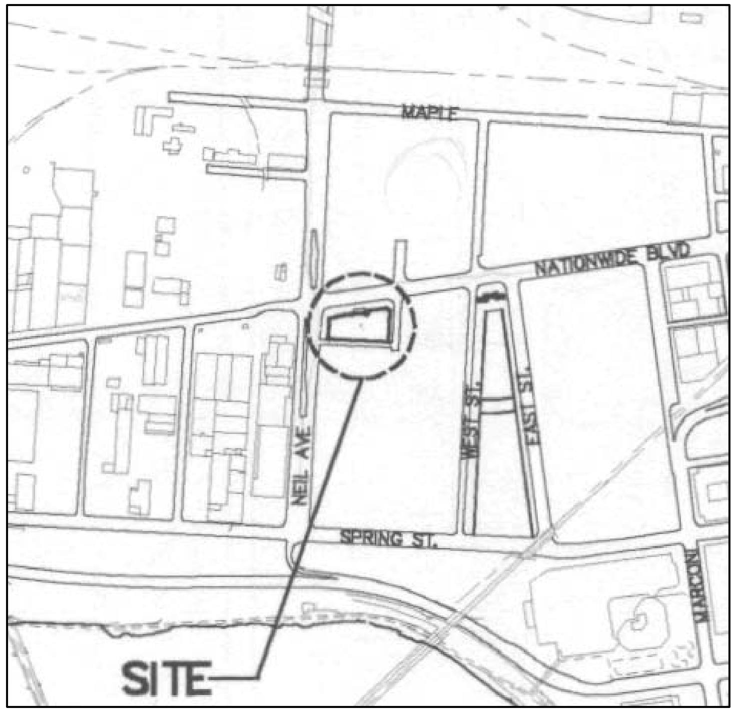
BACKGROUND

Building Introduction



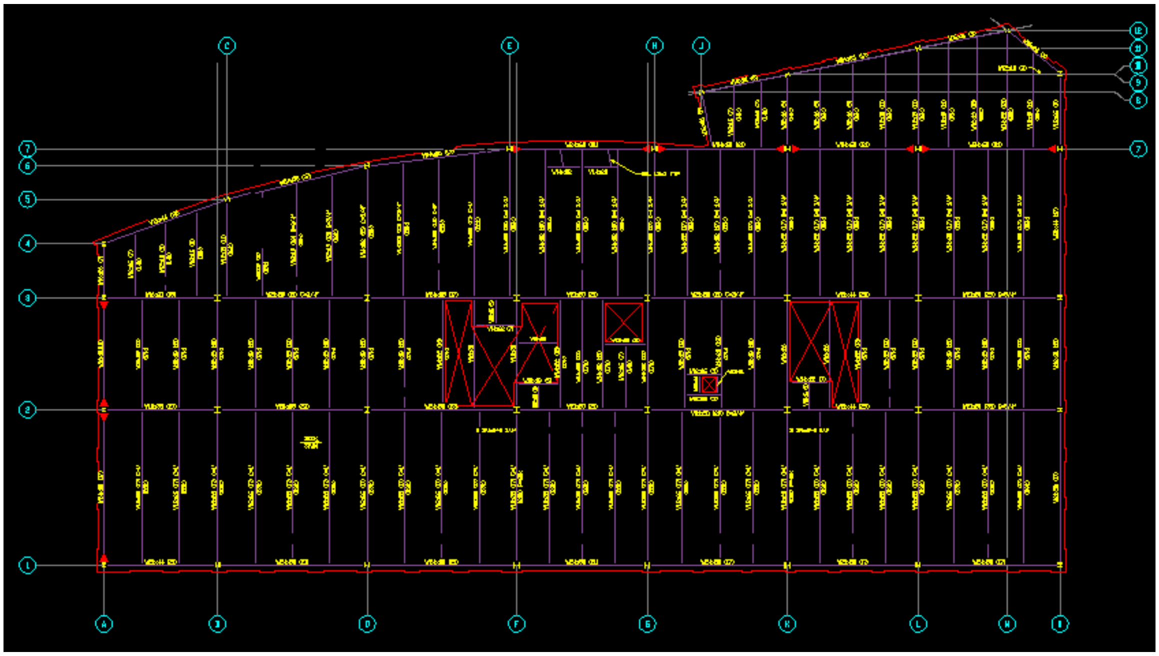
Nationwide Realty Investors hired the A/E firm URS Greiner Woodward Clyde as the design team to construct the prototype of office buildings to come in the developing Arena District. URS – Arena District Office Building located in Columbus, Ohio is 5 floor multiuse building. Ground floor serves as mercantile space and floors 2 through 5 are office space. Each floor is approximately 20,000 square feet with 16 feet floor to floor height on the ground floor and 14 feet floor to floor height on floors 2 through 5. Performed by the general contractor Continental Building Systems construction began March of 2000. Completion date was January of 2001 with the total project cost of 7 million dollars. Careful to detail, the building footprint follows the shape of the site which gives distinction to the otherwise rectangular building. The clean masonry façade with large industrial glass covering the window openings complement the adjacent Blue Jacket Arena as well as reflecting the essence of the surrounding areas.

Structural System

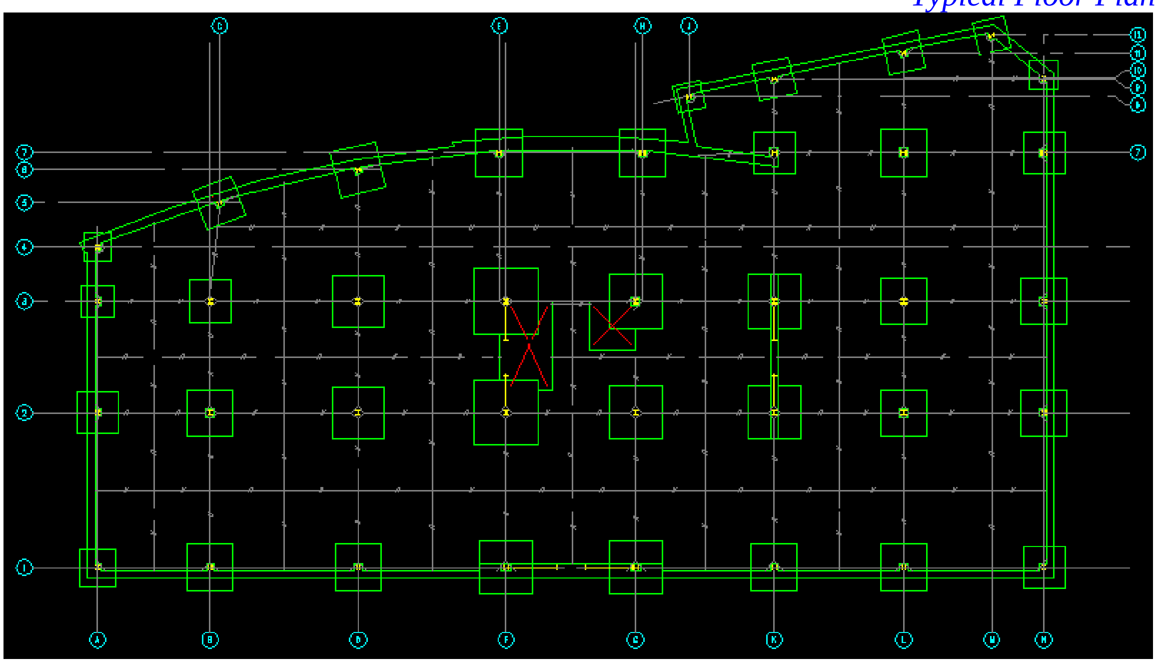
Open floor plan with minimum interruptions such as columns and load bearing walls was required by the owner. To meet this requirement, steel framing was employed. Structural steel used for beams, columns, and girders was ASTM A572 grade 50 wide-flange with yield strength of 50,000psi. Longest beam spans 33’4” and longest girder spans 32’. Typical bays are 30’x 30’ with most bays being approximately a square. Brace members to resist lateral loads were ASTM A500, Grade B tube steel with yield strength of 46,000psi.

The design bearing capacity was determined to be 4000 PSF by the sub-surface investigation. Minimum of 7 feet of lean concrete was to be placed under all foundations. Spread footings with minimum compressive strength at 28 days of 3000psi together with grade beams are employed as the foundation system. The size of footing varies from 4’x 4’ to 14’x 14’. The grade beams also vary in width as well as depth. Both the spread footings and grade beams utilize bars #6, #7, #8, or #9 with #4 stirrups. The slab on grade is required minimum compressive strength at 28 days of 4000psi and the composite slabs are to be lightweight concrete with minimum strength of 3000psi. First floor slab on grade is 5” concrete slab. The composite slabs on floors 2 through 5 are composed of 2” steel deck and 3-1/4” light weight concrete.

Steel roof decks are galvanized 20 gage ASTM A653 grade 33 G90 zinc coated steel. The composite steel floor decks are galvanized 20 gage ASTM A653 grade 33 G60 steel. Headed studs ¾”ϕ x 4” spaced evenly across the steel members are used to achieve composite action.



Typical Floor Plan



Foundation Plan

Concentric braced frames are used to resist most of the lateral loads in the URS Office Building. Three K-bracing and along with 2 moment frames compose the complete lateral system *(see Figure 1)*. The bracing members are rectangular hollow structural sections and moment frame elements are W-shapes. Brace frame 1 resists the east-west lateral loads. Brace frames 2 and 3 provide lateral resistance in the north-south direction.

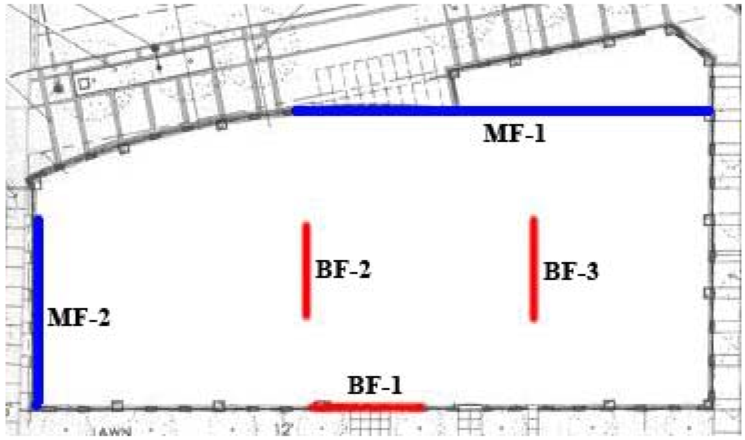
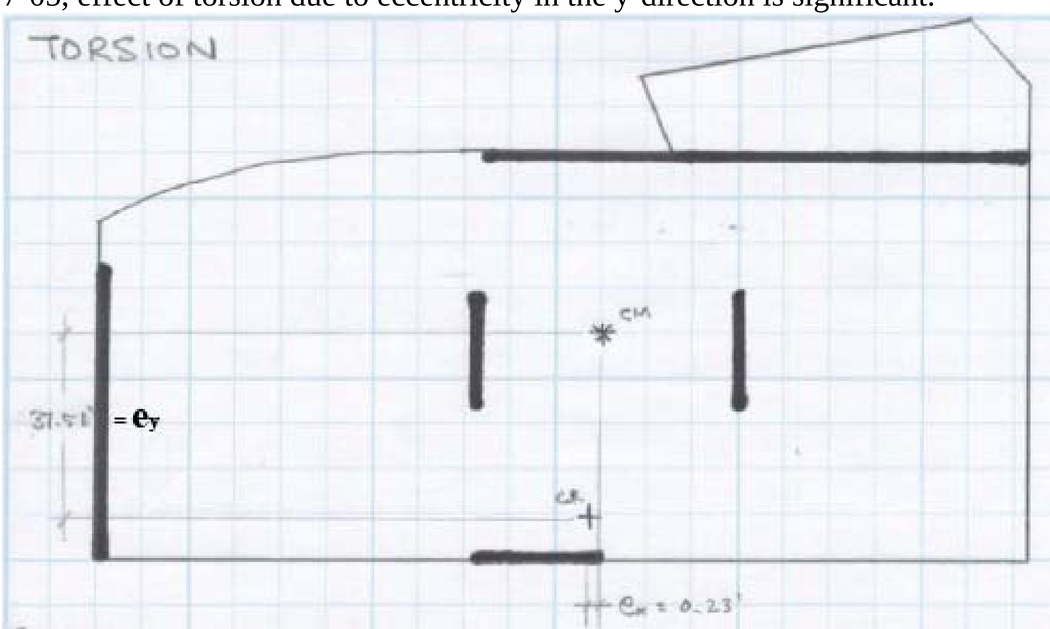


Figure 1

Moment frames 1 and 2 exist to provide stability against torsion. Moment frames were employed due to architectural constraint. North face of the building being the street façade prevented the use of braced frame. The composite floor system provides a rigid diaphragm to distribute the lateral loads to the frames.

Problem Statement

Designed by experienced engineers working for the largest global engineering design firm URS Office Building was cost efficient, structurally sound, and met all of the architectural constraints. After completing the three technical assignments, decision was made to alter the current lateral system. Although adequate in resisting lateral loads determined with the aid of Ohio Building Code 2005 (adaptation of IBC 2003) and ASCE 7-05, effect of torsion due to eccentricity in the y-direction is significant.

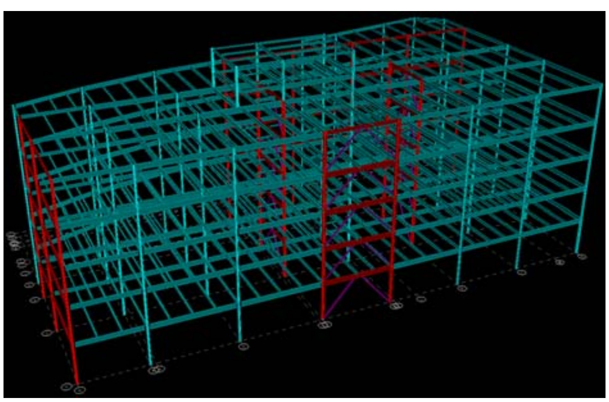


Due to lack of knowledge and inexperience, stiffness calculations for braced and moment frames were performed with simplified assumptions. With the simplified assumptions hand calculation was carried out to determine the center of rigidity. A computer program, RAM Structural Systems, was utilized in technical report 3. The center of rigidity determined by RAM was very close to the hand calculations; however RAM's method in determining the stiffness has to be investigated to give validity.

Proposed Solution

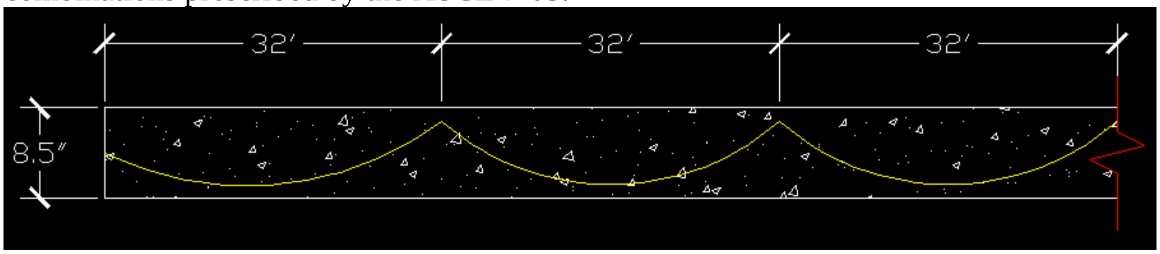
Redesign of the lateral system is proposed. Two viable solution considered are repositioning the current lateral systems, and redesign of building in concrete with shearwalls as the lateral system. In order to reduce torsion, repositioning of the braced frames is proposed. Primary goal of repositioning lateral systems is to reduce eccentricity in turn reducing the impact of torsion. Also if possible braced frames will be laid out to eliminate the moment frames. Redesign in concrete will require changes in loads applied, column sizes, and, foundation design. Shearwalls are planned to coincide with the elevator shafts and if necessary other locations to minimize eccentricity. To keep large open space without interruptions, the floor system for the concrete design will be post-tension slab. In technical report 2 the post-tension slab was the most cost efficient of the floor systems worth the further investigation. Both options mentioned need to account for the architectural constraints imposed on the original design team.

Solution Method



Modeled in technical assignment 3, frame analysis was executed in RAM. In an effort to better understand structural design and obtain reasoning behind RAM output, theory and process used by the computer program RAM will be studied. Also detailed hand calculation of frame stiffness will aid in locating the accurate center of rigidity. In addition computer program ETABS will be familiarized and used to aid design of the new lateral systems. If the proper stiffness for each lateral frames is determined, adjusting center of rigidity to coincide with center of mass would be a simple task of repositioning the existing lateral frames.

Redesign in concrete will start with the refinement from technical assignment 2. Post tensioned two-way slab thickness of 8.5" was considered a possible alternate floor system. This floor system will be designed according to the ACI 318-05 and further analysis will be performed on the adequacy of 8.5" post tension slab against the load combinations prescribed by the ASCE 7-05.



Once slab thickness is determined, columns will be sized and foundation checked. To do this PCA software will accompany hand calculations. After the gravity members are in place the shearwalls will be designed in accordance with ACI 318-05. Shearwall design will start with symmetric rectangular arrangement in the core of the building. Here ETABS will be again used to aid in the design process of the alternate lateral system.

Tasks and Tools

Research

- Learn from design documents and examples on determining stiffness
- Review post tension slab design from notes and design guides
- Read RAM manual for its method of lateral analysis
- Ask faculty and industry professionals

Understand Architectural Constraints

- Study construction document, especially the architectural drawings
- Ask the original design team members for constraints

Rearrange Current Lateral System

- Perform hand calculation based on new layout
- Adjust model created in RAM
- Use ETABS to verify results

Design Concrete Gravity Members

- Design slabs and gravity columns according to ACI 318-05
- PCA software to aid design
- Check if spread footing still works by going to CRSI Concrete Design Handbook

Design Shearwalls

- Design according to ACI 318-05 applying lateral loads obtained from ASCE 7-05
- Model building in ETABS and perform analysis

Breadth Topic Research

- Gather cost information from faculty, industry professionals, and suppliers
- Obtain original project schedule
- Organize a new schedule with the help of primavera
- Research online for ductwork with least depth and various fan sizes
- Ask peers, faculty, and industry professionals how to effectively layout ductwork

Compare Systems

- See if alternatives improve constructability, construction time, cost
- Determine downside of each system

Final Preparation

- Create presentation using power point

TIMETABLE

TASKS	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13	Week 14
Research									SPRING BREAK					
Understand Architectural Constraints														
Rearrange Current Lateral System														
Design Concrete Gravity Members														
Design Shearwalls														
Breadth Topic Research														
Compare Systems														
Final Preparation														
Present to Faculty														

Breadth Studies

Construction Management

In this breadth study, a new project schedule will be created for the concrete redesign. Complete redesign and switchover to different material are grounds for significant schedule changes. Primavera will be used to complete the new schedule. With careful planning and good coordination there is a possibility of matching construction time or reducing it. Along with the new schedule will be detailed cost analysis. Shown in technical assignment 2, rough square foot estimate determined concrete floor system to be a cheaper alternative. Goal is to prove concrete as the more cost effective solution.

Mechanical

Redesign with concrete employing post tension slab has the benefit of considerable reduction in floor depth. This reduction in volume leads to energy savings in heating and cooling. In addition less ductwork will be necessary saving cost. Focus will be to replace existing ductwork with the shallowest ductwork available to reduce floor depth even more. Also in the concrete redesign, most efficient ductwork layout will be studied. If the reduction in volume is significant enough reduce fan size, new fan will be pursued. Goal is to reduce building volume to efficiently heat, cool, and circulate the building.

Conclusion

During the course of this semester the previous four years of study came together in analyzing the URS Office Building. Completing the three technical assignments led to greater familiarity with building codes and RAM software. Also resources such as CRSI and PCI design handbooks were introduced. Technical assignment 3 provided the greatest benefit by requiring reasonable load distribution throughout the building. Valuable experience was gained and mistakes were made in the safe realm of education.

Looking forward to the next semester, great learning opportunity awaits. Better understanding of lateral force distribution along with post tension design is the primary objective planned for the second part of this senior thesis process. Repositioning of the braced frames will aid in deeper understanding of torsional behavior and its distribution. Redesign of the building to concrete will provide opportunities for complete design of a structure as well as provide experience working with post tension concrete. Furthermore, the breadth research and analysis will offer impact structural design has on construction process as a whole. Aim is to understand the structural behavior of URS Office Building and gain knowledge to apply it to different buildings.