Executive Summary

The Quantum II office building was built as a part of The Southside Works commercial development in Pittsburgh Pennsylvania. The 6 story 186,000 square foot office suite was later purchased, and is currently being fitted-out by the American Eagle Outfitters Corporation. Being that the structure was built without a contracted tenant the designers took steps to make it versatile and attractive to business. The building is conveniently located just outside the confusion of the city where there is more space and parking. Moreover, the engineers strived to keep as many options for fit-out as open as possible. To achieve this they utilized composite slab floor decks, large bays, and moment frame connections. The use of moment connections avoided blocking bays and obstructing the floor plan, as is par with alternate methods of lateral support, mainly cross bracing or shear walls.

The objective of this report is to design an alternative lateral system of cross bracing. Utilizing the new interior plans of the fit-out frames can be located in a manner that minimized conflict with the final architectural floor plan.

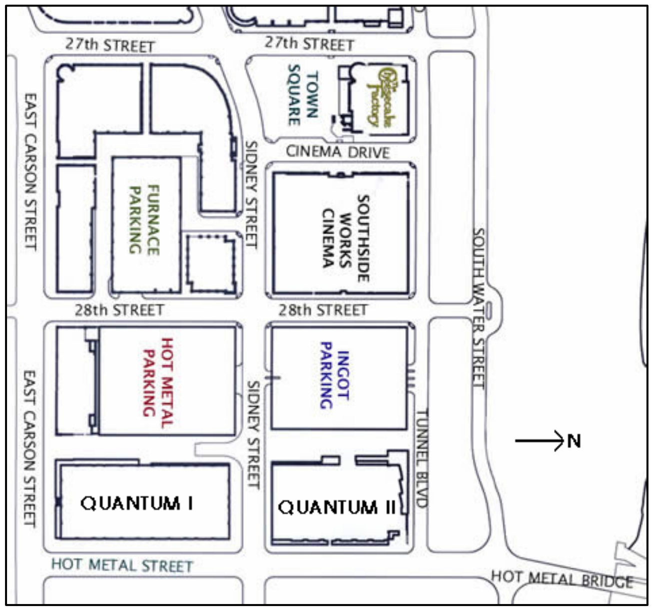
Any major structural change will have some impact on the building cost. For this reason a cost analysis and comparison of the existing and redesigned structures was performed as a breadth study. In the same spirit construction schedule of the redesigned system was also assembled.

Also, an extensive investigation into an alternative floor system, hollow core concrete planks, was performed.

Building Description & Project Background

Location & History

The Quantum II office building sits on the shore of the Monongahela River just outside the city of Pittsburgh at the site of the old Southside Works steel plant, one of many manufacturing facilities in south western Pennsylvania that made the religion and the nation an industrial power during the Second World War. The appearance of cheaper foreign steel in the 1970's and the economic decline of the 1980's closed the plants, and severely hurt the region. After over a decade of inactivity a city/county task force was assembled to utilize the prime riverfront real-estate and revitalize the area. Opening in 2002 the new Southside Works is a 34 acre milti-million dollar commercial develpoment that includes retal, dining, class A office space, parking and apartments.



The first office developments were the Quantum I and Quantum II office buildings. These structures were both designed and constructed as shells that would be fitted out once a tenant was found. Quantum II caught the eye of the American Eagle Outfitters clothing company, and is now in the tenant fit-out phase of construction.

Architecture

Quantum II makes an impression the first building seen when traveling to Pittsburgh's Southside via the historic Hot Metal Bridge. Travelers are met by its jagged glass façade and smooth vertical lines created by decorative exterior columns. All together the facility provides 6 stories and 186,000 square feet of versatile space. Large

bays and an open floor plan were utilized to maximize this versatility. The majority of space will be used as offices and conference rooms with the exception of a cafeteria on the sixth floor and lobbies and human resources on the first. A series of balconies climb up the North West corner of the building. The structure has a contemporary shape and look utilizing a brick and glass curtain wall, and fits in well with its other modern neighbors in the new district.

Project Team

Developer: The Soffer Organization
Owner: American Eagle Outfitters
Base Building Architect: Davis Gardner Gannon Pope
Base Building Engineer: Watson Engineers
Fit-out Architect: The Design Alliance
Fit-out Engineer: Atlantic Engineering Services
Fit-out MEP: Tower Engineering

The South Side Works Town Square at night.

Building Systems

Mechanical

Hating and cooling of Quantum II is handled by a CAV system. The structure has two roof top units; an 18000 CMF and a 7200 CMF.

Lighting / Electrical

Quantum II's primary electrical system is a 480/277V – 3 phase – 4 wire configuration. It also has a 208/120V – 3 phase – 4 wire secondary system. Lighting in large open office spaces is provided by fluorescent luminaries. Conference rooms, corridors, lobbies and other public spaces are illuminated by incandescent bulbs. An arrangement of halogen lamps illuminates the front façade at night.

Fire Protection

The floors plans are blanketed in an extensive sprinkler system. Upright sprinkler heads cover open office spaces, where as enclosed spaces such as conference rooms have recessed pendant sprinklers.

Transportation

The structure has three main portals on the first floor; the main entrance in the front, a side entrance on the west length, and a service loading dock in the rear. There are two adjacent elevators that lay just off center on the plan and service all six floors, as well as two fire stair wells located toward the front and rear of the building.

Structural System

Gravity

The structure is comprised of conventional steel framing. Most of the elements are made of A572-50 grade steel with a yield strength of 50 ksi. Other miscellaneous components are of A36 grade steel which has a lower yield of 36 ksi. The plan is dominated by three rows of bays measuring 30’ x 30’and one row of 30’ x 38’ bays. All bays contain two beams spaced 10’ apart spanning parallel to the 38’ long side of the larger bays. Each 31,000 square foot story of the structure consists of a composite floor deck of concrete poured over metal decking. 3” 20 gauge metal deck sits under 3” of 4ksi concrete. Steel studs ¾” in diameter and 4 ½” long are used to create composite action between the beams and the deck. Figure 1. shows beam layout for a typical floor.

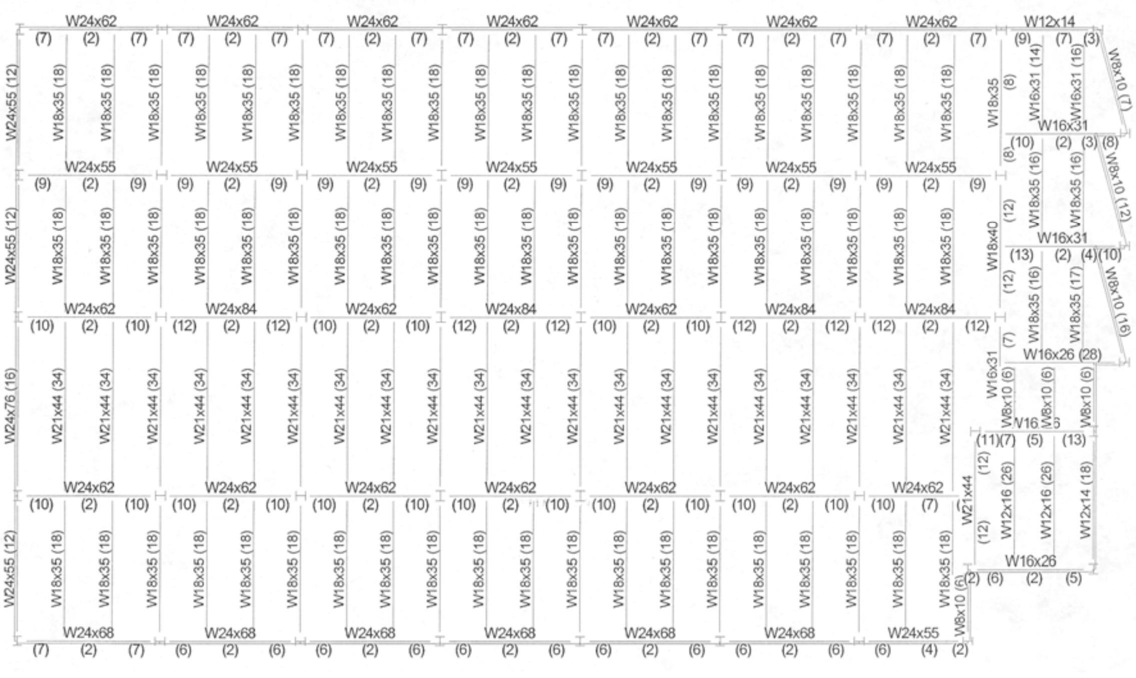


Figure 1. Existing Typical Floor

Lateral

Moment frames have been used to resist wind and seismic loads. This utilization avoided blocking bays with alternate methods of lateral support, mainly cross bracing or shear walls. This was to keep floor plan as open as possible for tenant fit-out. The system is extensive and nearly every connection in the steel frame is a moment connection and contributes in lateral force resistance.

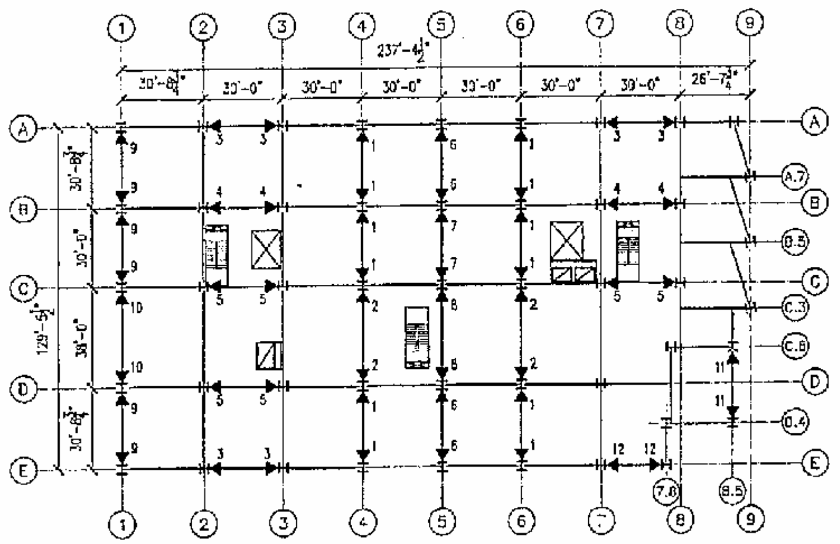


Figure 2.A. Moment Framing Plan

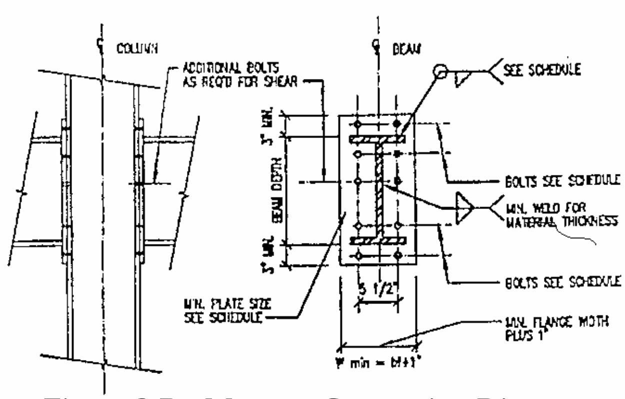


Figure 2.B. Moment Connection Diagram

Foundation

The main foundation element is a system of 45' concrete/auger piles. Columns sit on pile caps covering varying numbers of piles. Concrete grade beams run along the perimeter. All foundational elements are made of 3ksi concrete and reinforced with 60 ksi steel.

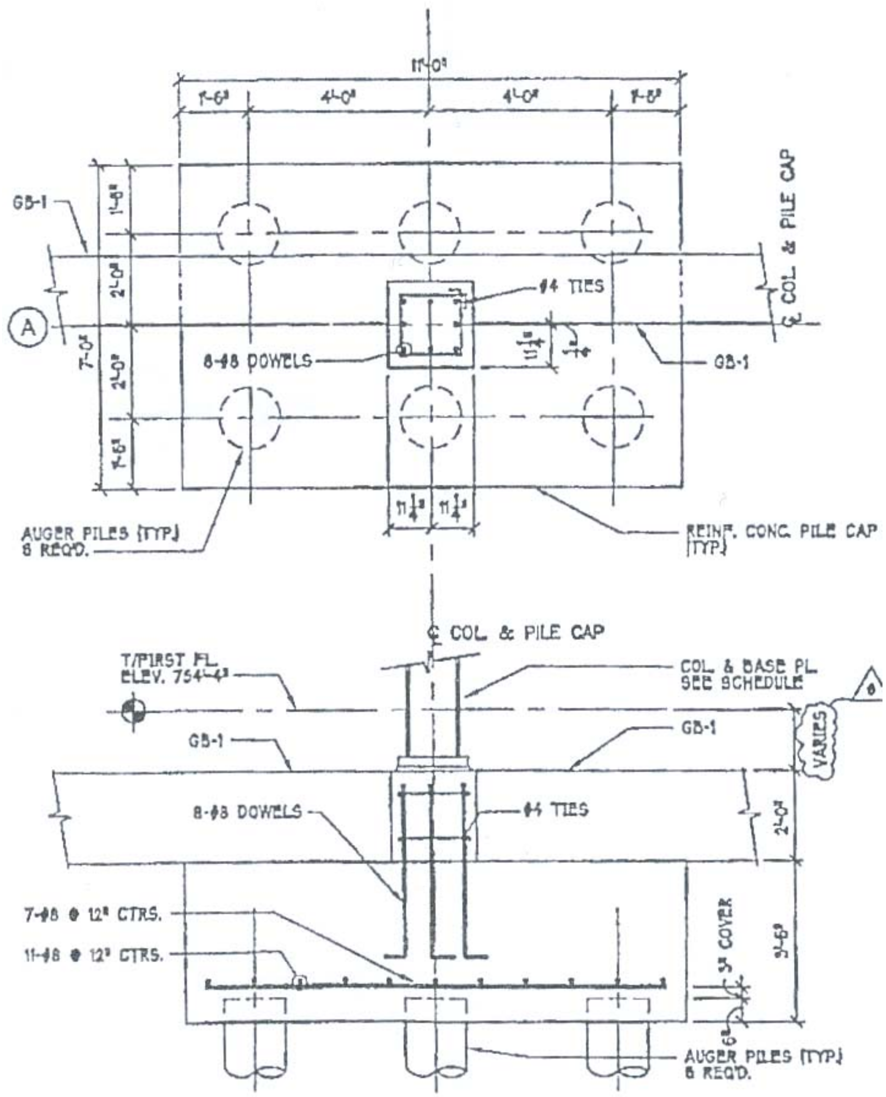


Figure 3. Pile Cap & Grade Beams

Problem Statement

As stated above Quantum II was designed for maximum adaptability during fit-out. The engineers needed a lateral system that would not obstruct the floor plan the way cross bracing and shear walls do. To achieve this fixed moment connections were utilized. Being that moment connections are less effective than their competition at resisting lateral forces, an extensive amount of the buildings connections had to be fixed. Indeed, nearly every beam column and connection is involved in the lateral system. The result of the moment frame's inefficiency is that beam and column sizes are forced to be so large that overall system cost is often greater than with other methods.

Solution Overview

An alternative to the moment connection frame would be one of lateral cross bracing, where vertical bays are filled with diagonal members to help absorb lateral load. The original designers of Quantum II avoided this method to create a completely open floor plan. However, with the advantage of the building's final architectural plans, the ability to design an alternative lateral system that does not obstruct the floor plan exists. The main objective of this thesis is to design a system of lateral cross bracing to replace the existing moment frame system.

Depth: Lateral System Redesign

Frame Layout

The challenge of retro-fitting the structure with a new lateral system lays in locating ample placement of bracing without disrupting the spaces and flow of the floor plans. Quantum II has three basic floor plans; the first floor which contains lobbies human resources and utility space, floors two through five are a typical plan of open office space surrounding a central core, and the sixth floor offering more office space and an extensive kitchen and dinning facilities. The jagged shape of the front façade made placement at the north end of the structure problematic. However, comparing the three different floor plans yielded seven suitable locations for five different frames placed throughout the floor plan in a manner that provides even support. Unfortunately, circumstances were not ideal and in two instances bracing could not be placed in one of the frame's bays. Ultimately this was overcome as the systems design proved adequate. Figure 4. outlines the frame locations in plan and 3D.

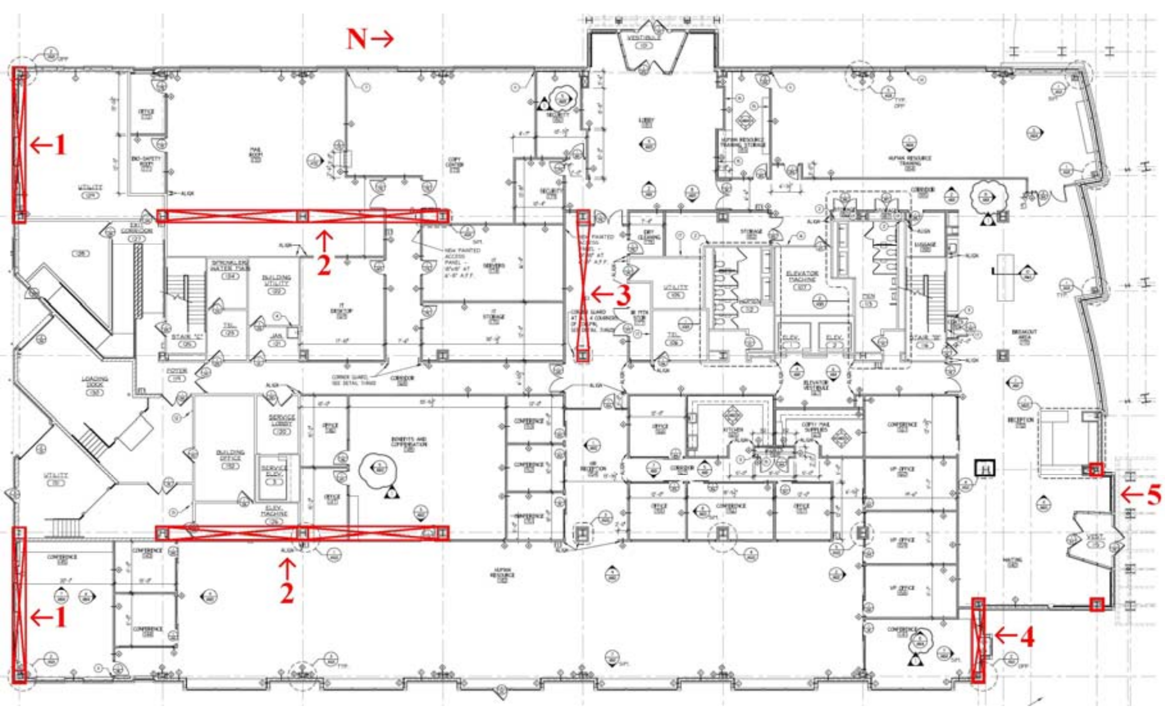


Figure 4.A. 1st Floor Frame Layout

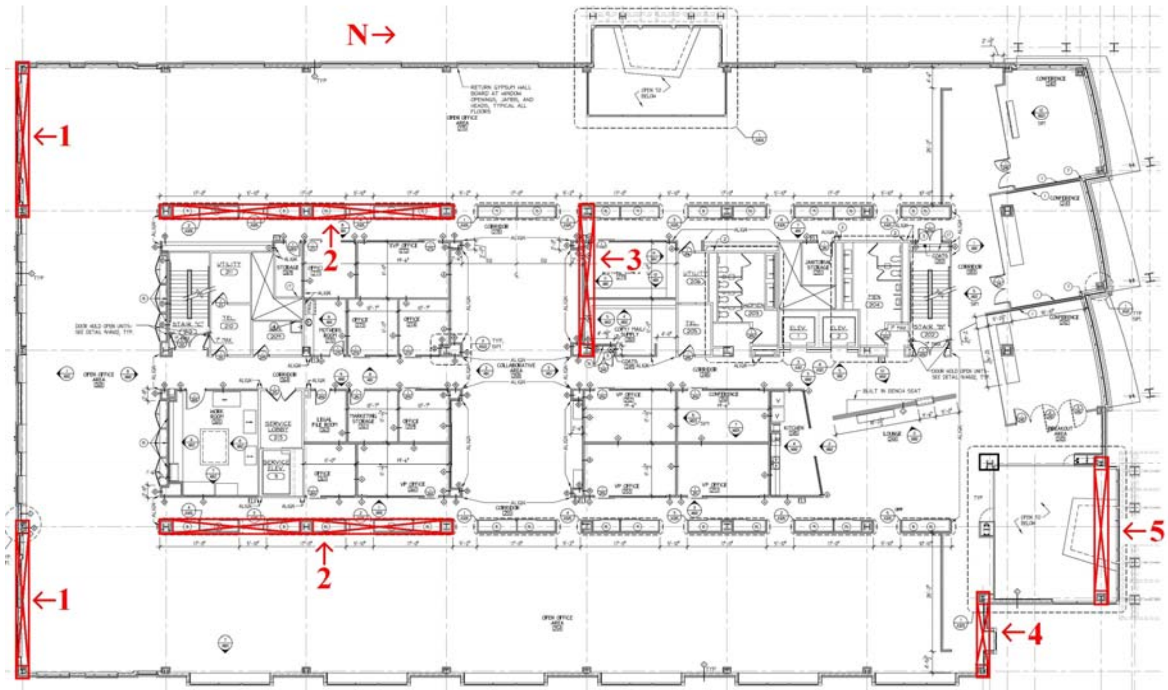


Figure 4.B. Typical Floor Frame Layout

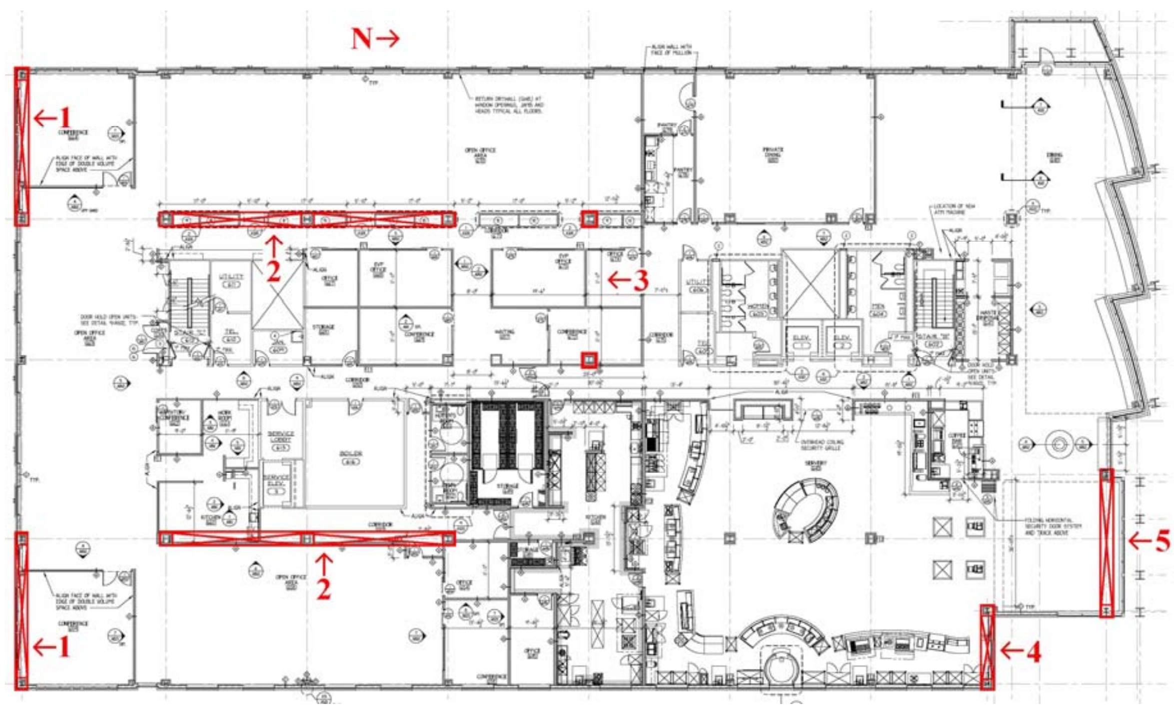


Figure 4.C. 6th Floor Frame Layout

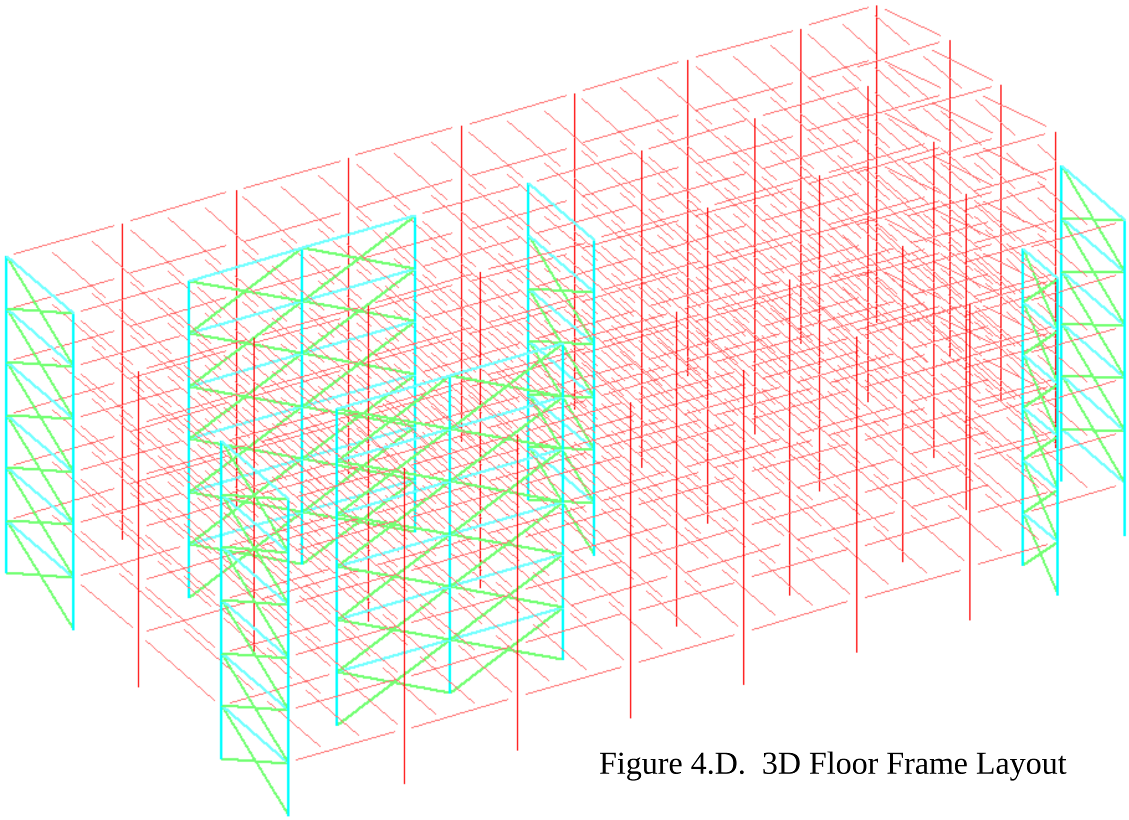


Figure 4.D. 3D Floor Frame Layout

Loads

The gravity system was designed with the following load specifications. Dead load values were derived from information in the building's structural mechanical and fit-out plans. Live loads were taken from ASCE7-02 with the exception of the floor load which has been enlarged to account for the variability of fit-out.

Dead Loads		Live Loads	
Typical Floor Slab	57 psf	Roof	30 psf
Roof Slab	57 psf	All Floors	100 psf
Exterior Curtin Wall	20 psf	Stairs	100 psf
MEP	10 psf	Balconies	100 psf
Miscellaneous	5 psf	Flat Roof Snow	21 psf

Figure 5.
Gravity Load Summary

Lateral loads applied to the system will be based on ASCE7-02 chapters 6 for wind and 9 for seismic. Full calculations of these loads can be found in Appendix B, load diagrams are shown in Figure 6.

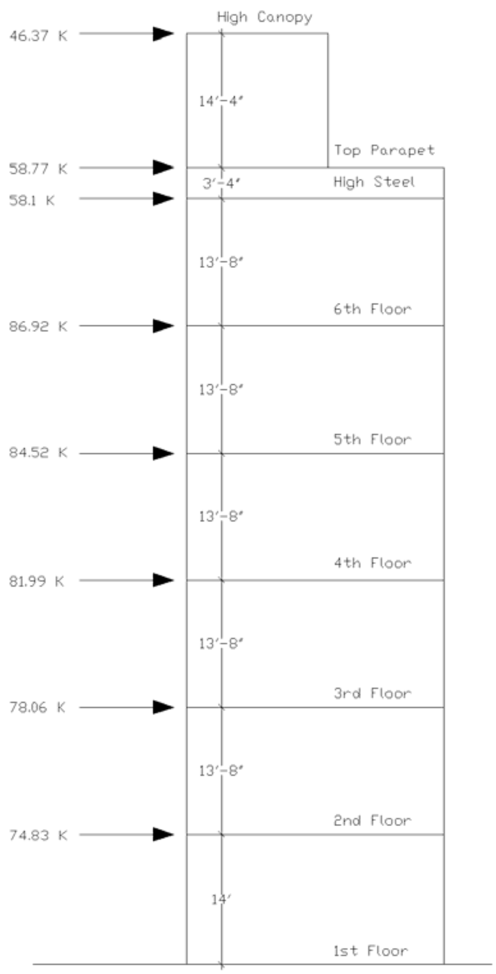


Figure 6.A. Wind Force Diagram

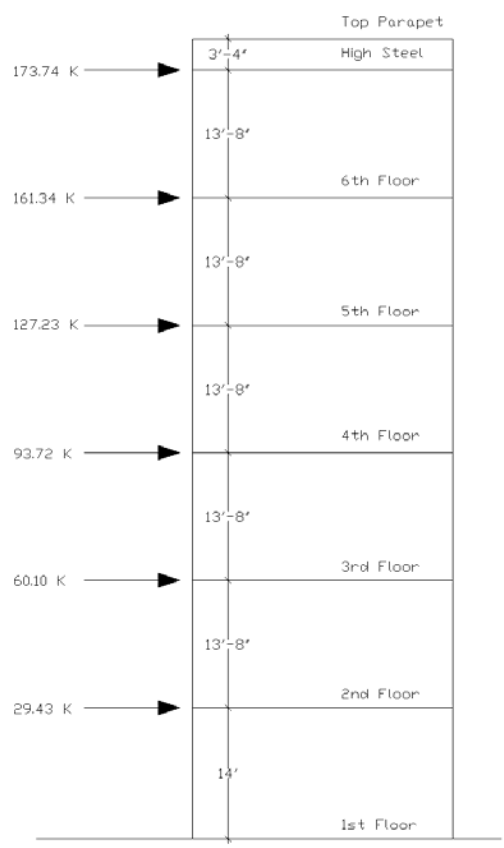


Figure 6.B. Seismic Force Diagram

Gravity System

The RAM Steel computer analysis program was an instrumental tool in the design and analysis of the new system. An assessment of the gravity system yielded the designs shown in Figure 7. The beam values here are smaller than in the existing plan. This is due to the fact that in the existing design a majority of members are active in the lateral system, and therefore must be larger to handle the additional loading. The same applies to the columns which are also smaller from only carrying gravity load. A full column schedule is located in Appendix C.

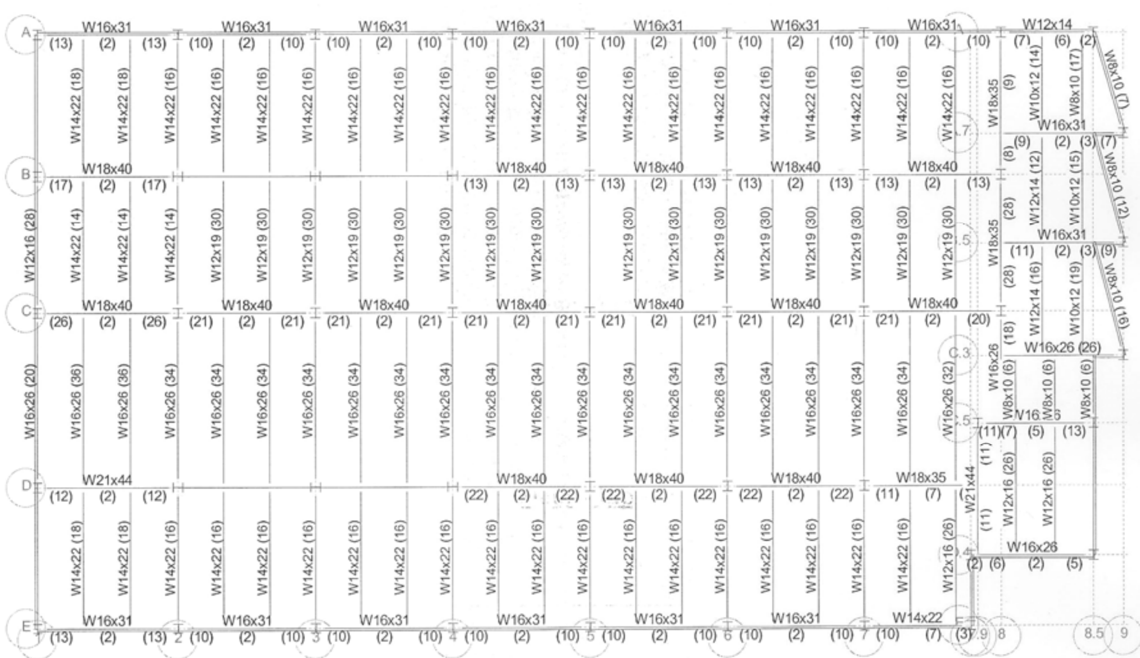


Figure 7.A. Typical Floor

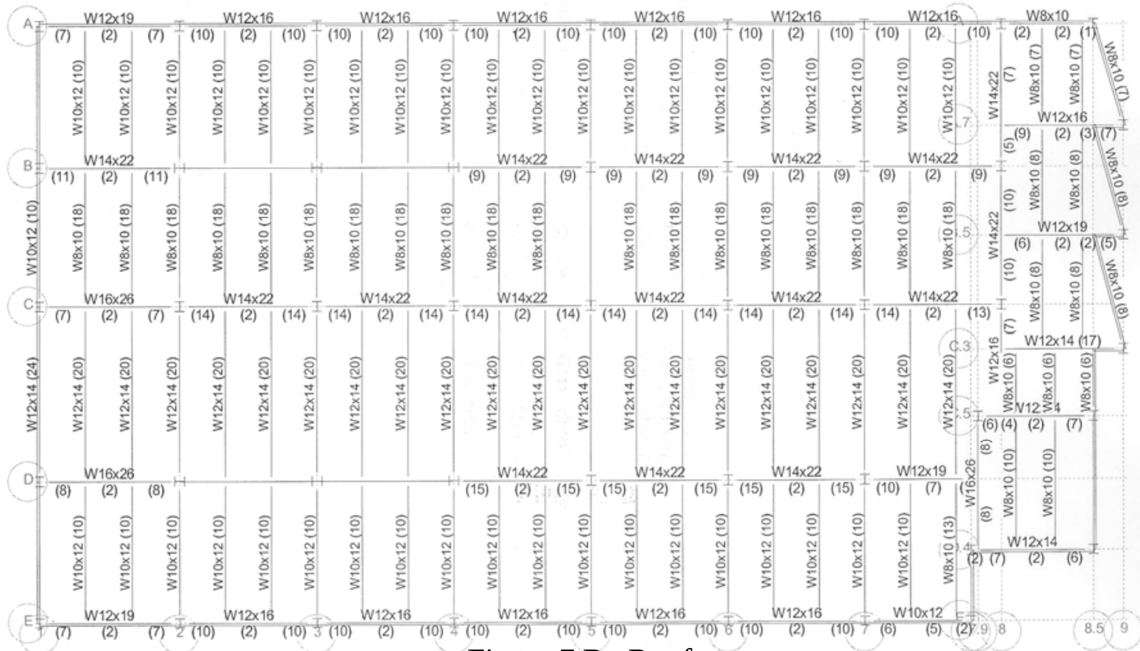


Figure 7.B. Roof

Lateral System

RAM Steel was further used in the design of the lateral system. Rectangular HSS steel members were used for diagonal bracing. Members were sized to support the load stresses and control drift to within acceptable limits. Drift limitations were taken as L/400. Results of the drift analysis are in appendix C. Results of the frame design process are shown in Figure 8. Frame numbers correspond to those on the floor plan frame layouts in Figure 4.

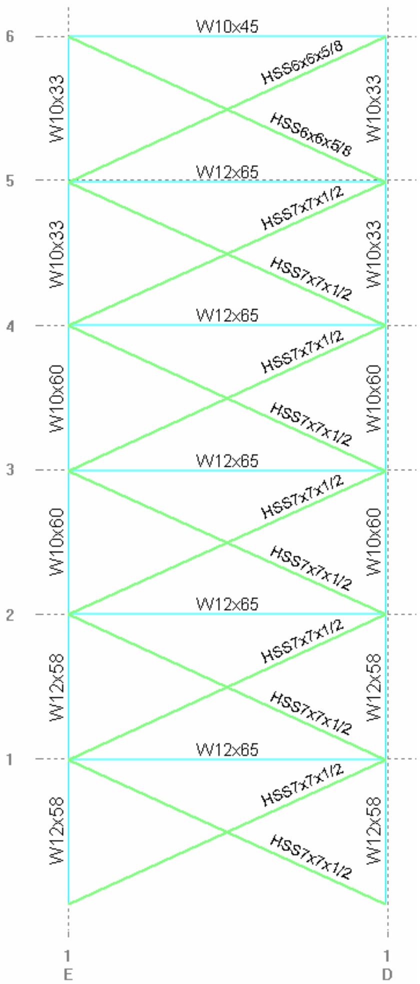


Figure 8.A. Frame 1

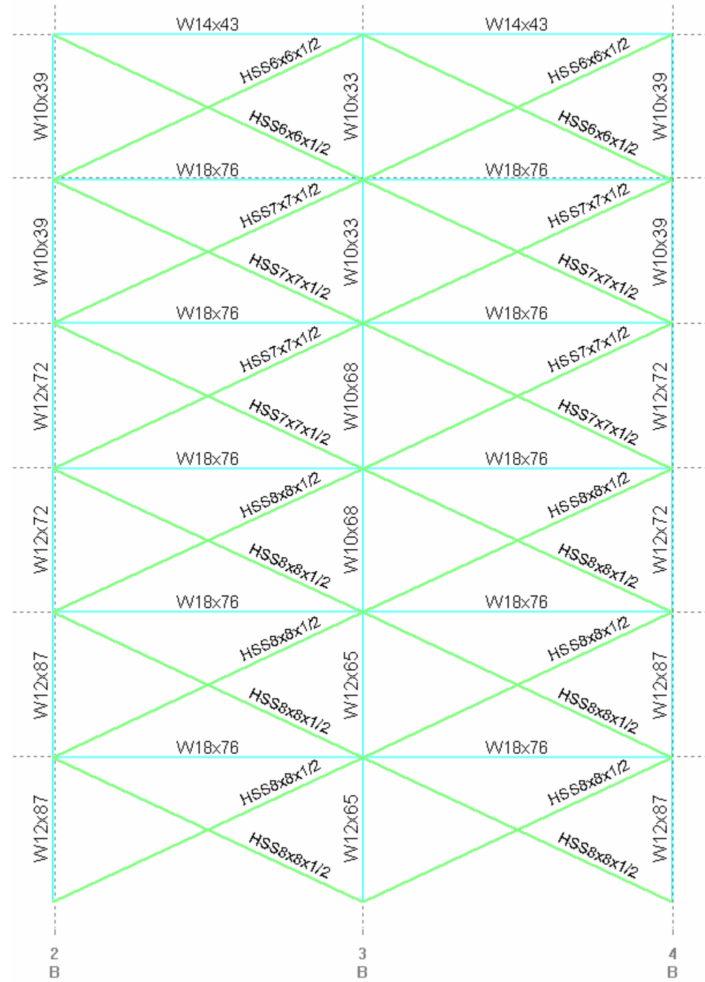


Figure 8.B. Frame 2

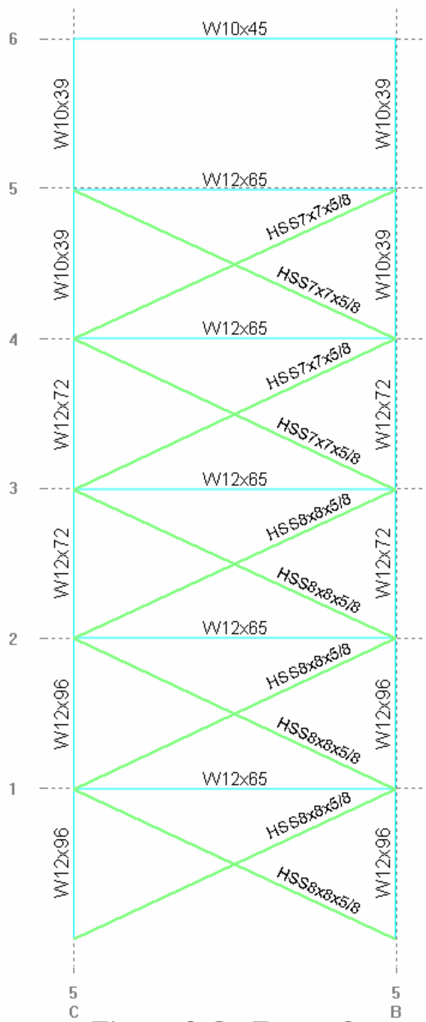


Figure 8.C. Frame 3

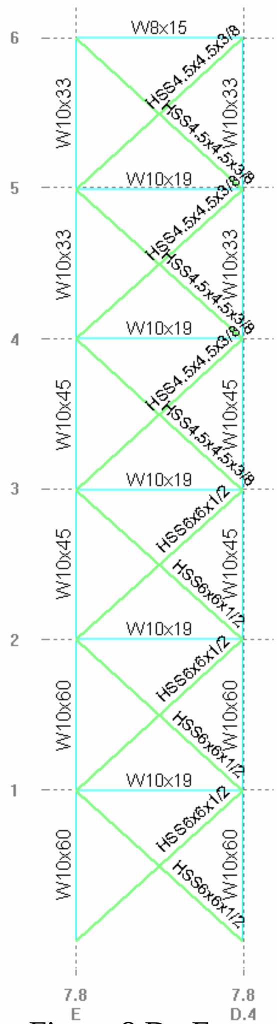


Figure 8.D. Frame 4

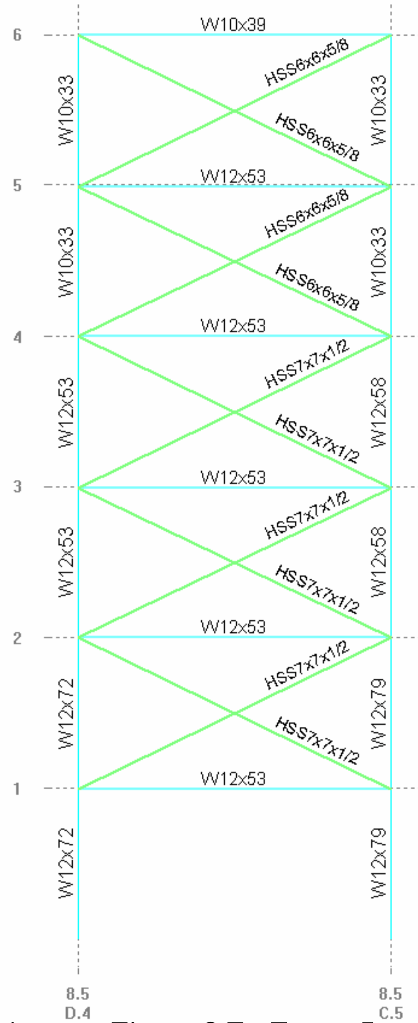


Figure 8.E. Frame 5

Architectural Impact

One of the main objectives of this project was to avoid architectural disruptions by the new lateral system. This was minimized, but unfortunately could not be totally avoided, but. Any conflict, mainly frame 2 on the first floor, can easily be settled by small movements of selected doors and walls. In some cases, frames 1 and 5, the bracing will have to be visible. However this should actually compliment the structure as a whole considering that a precedent of exposed structural elements was previously established by the decorative exterior columns of the front façade.

Breadth

Construction Management

A natural question to ask when comparing different structural designs is that of economy. Which option is cheaper? For this reason a detailed cost estimate was performed for both the existing and redesigned structure. The first step in this process was tabulating extensive take-offs of the materials. This included; beams in the roof and typical floor, the complete column schedule, composite deck including shear studs, and for the redesigned system the cross bracing members. RS Means was then used to estimate the cost of the existing system and the redesigned system. Copies of the full take-offs and calculation spread sheets can be found in appendix D. The results of the calculations are outlined in Figure 9.

Existing System		
Typical Floor (x5)	$	351,851
Roof	$	298,701
Columns	$	360,112
Total	$	2,418,068

Redesigned System		
Typical Floor (x5)	$	265,690
Roof	$	207,827
Columns	$	238,602
Bracing	$	168,848
Total	$	1,943,727

Figure 9.
Cost Comparison

It is apparent that the redesigned system holds advantage over the existing. The cost that was cut by lighter columns and beams outweighed the additional cost of the cross bracing.

Also in the spirit of construction management, a detailed construction schedule has been outlined for the redesigned structure. The data for this also stems from the spread sheets in appendix D. RS Means was again used, this time to calculate the time duration for each component based on the daily output for a typical crew. Components were then grouped and ordered to maximize efficiency of construction. Microsoft Project was then used to assemble the data on a construction schedule shown in Figure 10.

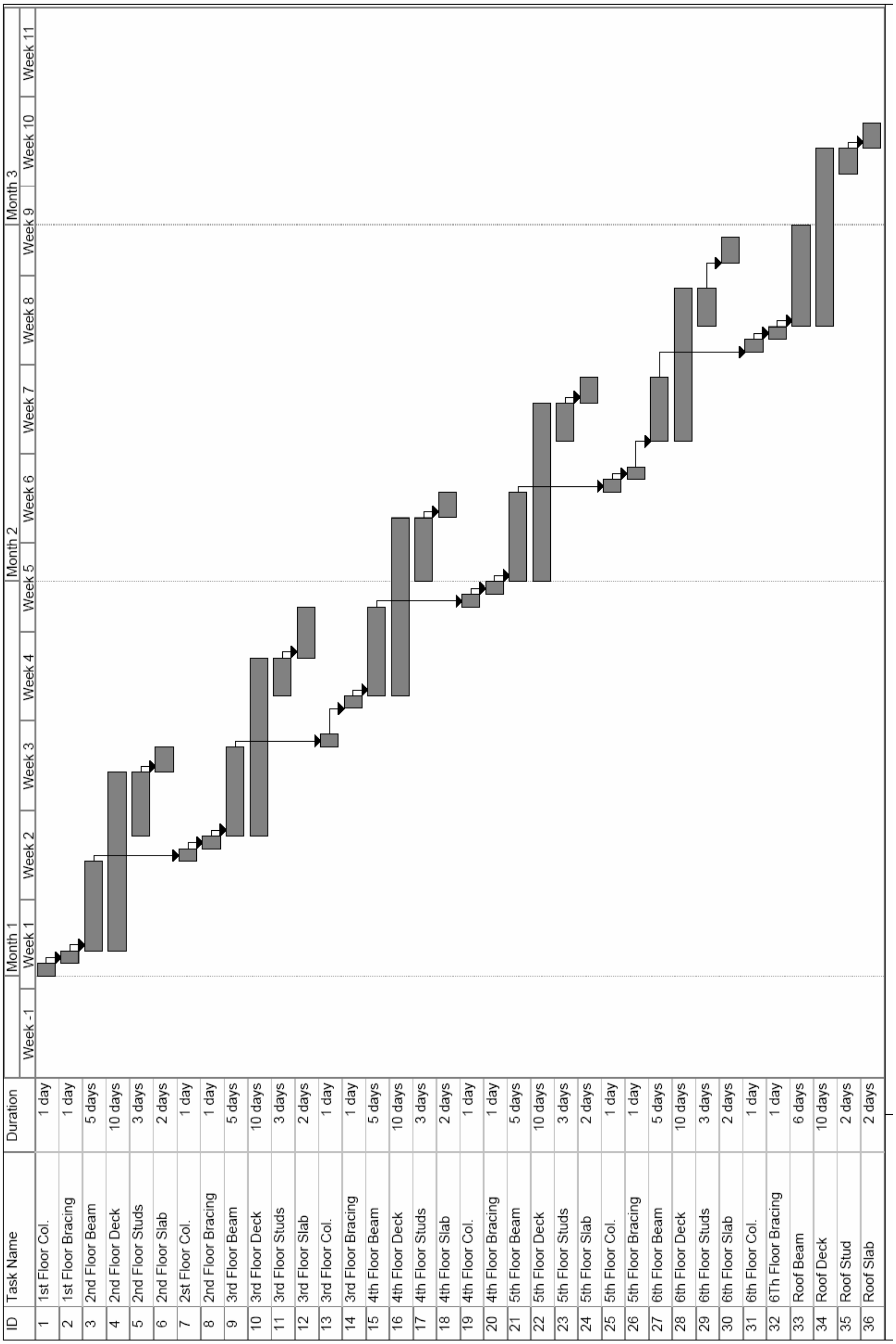


Figure 10. Construction Schedule

Alternative floor

Another intriguing area for suggested structural change is in floor systems. Steel deck and composite steel deck have claimed their place as industry standards for use with traditional steel framing. However, interesting alternatives exist. The alternative investigated in this report is hollow core concrete planks. The advantage brought by this system is that it can span relatively large distances while maintaining a relatively small thickness. Design tables obtained from Nitterhouse Concrete Products, Inc. were utilized to select the proper size. The 8" x 4' – U.L. – J952, with no topping, and strand pattern 4 – ½" was selected. This system has a concrete strength specified as 5 ksi, and a self weight of 57.5 psf. This self weight is very comparable to the composite deck used in the existing and redesigned steel systems, and would produce little effect on seismic or other lateral loads.

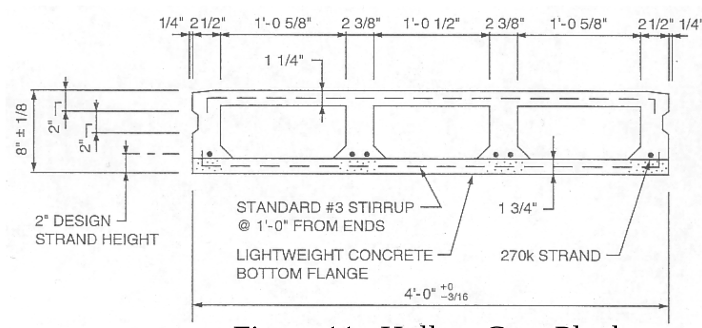


Figure 11. Hollow Core Plank

Under the required floor loads RAM steel was used to analyze a new layout for a typical floor utilizing hollow core planks. The spanning capabilities of the planks allowed the beam spacing to increase from ten feet to fifteen feet. However, this system disables the ability to utilize composite beams. To analyze the effectiveness of this system a cost analysis was performed by comparing a sample strip of the hollow core floor plan to an equal strip of the redesigned floor plan. Full spreadsheets are in Appendix E.

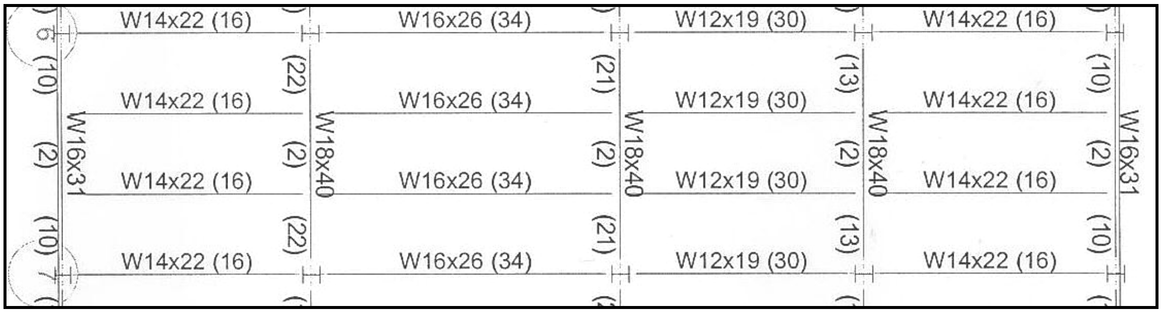


Figure 12.A. Composite Floor Strip

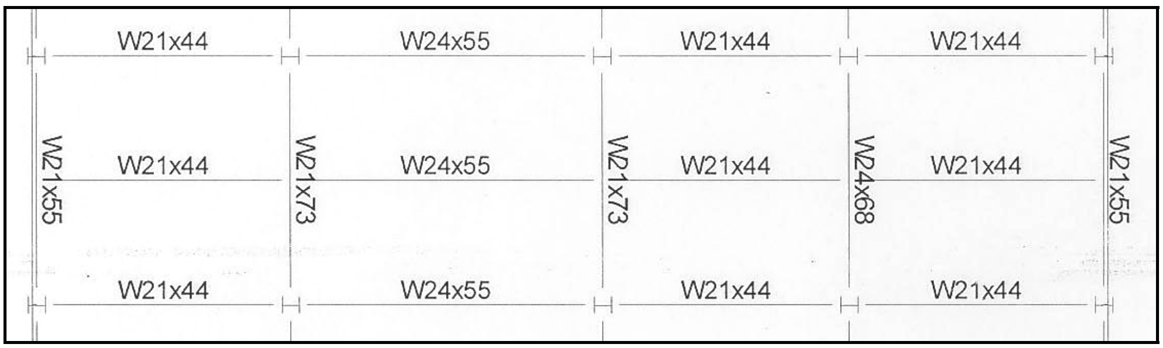


Figure 12.B. Hollow Core Floor Strip

Hollow Core Plank System		
Steel	$	33,844
Slab	$	36,826
Total	$	70,670

Redesigned System		
Steel	$	21,862
Slab	$	13,452
Total	$	35,314

Figure 13.
Floor System
Cost Comparison

The hollow core system is significantly more expensive than the composite. The spanning capabilities of the planks can be deceiving. This also highlights the efficiency and effectiveness of composite floor systems.

Summary & Conclusion

Retro-fitting the structure to accept a braced frame system was a success in all aspects. The new system provided sufficient lateral support and kept drift within acceptable limits. It also alleviated the system as a whole and allowed the sizes of gravity beams and columns to be reduced. Finally, the results of the new system are seen in a sizable cost savings. The existing system of moment connections served its purposes well under the unknown future of the building. However, the braced frame system clearly holds advantage over moment frames.

The use of alternative floor systems is something to be cautious of. Conventional composite steel deck has proven its effectiveness with steal framing.

Acknowledgements

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- American Eagle Outfitters, Inc.

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