STRUCTURAL EXISTING CONDITIONS REPORT

THE HEALTH CENTRE

LOCATION | SOUTHEASTERN US

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STRUCTURAL OPTION | ADVISOR: DR. HANAGAN

1 | Executive Summary

The Health Centre is a 450,000 square foot university hospital expansion project located in the southeastern United States. Located adjacent to existing hospital facility 'Clinic B,' this nine story L-shaped building is connected by two bridges to the surrounding campus. Demand for new, state-of-the-art medical technology, additional research space, and extra hospital beds prompted the design and construction the Health Centre. At a height of 163 feet, the Health Centre will be by far the tallest building in the surrounding area when its construction is complete in 2016.

As a nod to the heritage and character of the surrounding university campus, The Health Centre takes its architectural cues from classical Italian and contemporary sources. Façade materials used on the building include stucco, metal panels, and a glass curtain wall. A green roof and four story underground parking garage contribute towards its goal of LEED silver certification. This building was designed as a "core-and shell," necessitating a structural consideration for flexibility of spaces and future expansion.

The structure of the Health Centre is mainly cast-in-place concrete on drilled piers and spread footings. Its floor system in the hospital bed tower consists of cast-in-place one-way concrete slabs and beams. Concrete moment frames spread throughout the structure resist the building's lateral loads. Below grade, parking garage floor slabs consist of two-way post-tensioned concrete slabs. The parking garage has its own lateral system of concrete shear walls. Some structural steel components exist in the building, including roofing and bridges connecting to other buildings on campus.

Governing codes for the design of the Health Centre required the use of IBC 2012. However, an exemption was obtained to allow the structural design to use IBC 2006 requirements. ASCE 7-05 provides the minimum design loads for live, snow, wind, and seismic considerations. Due to the life safety importance associated with hospital structures, a conservative approach was used to determine building loads.

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2 | Introduction

2.1 Purpose

The primary objective of this investigation is to determine the existing structural and building conditions of The Health Centre located in the southeastern United States. Documentation of the existing structural systems, including lateral and gravity systems, will provide the foundation for future technical reports. This report will also establish relevant building codes and standards, as well as identify any unique structural conditions that exist in this building.

2.2 General Building Overview

The Health Centre is a university hospital expansion project consisting of a nine-story hospital bed tower with a mechanical penthouse and four-story underground parking garage. Located in the southeastern United States in the middle of a university campus, this L-shaped concrete building is built alongside existing hospital facilities referred to as 'Clinic B.' It features a lower green roof and new state-of-the-art technical facilities – including an ICU, emergency department, clinical facilities, and med-surg patient rooms (Figure 2). Upon completion in 2016, the building will become certified LEED Silver.

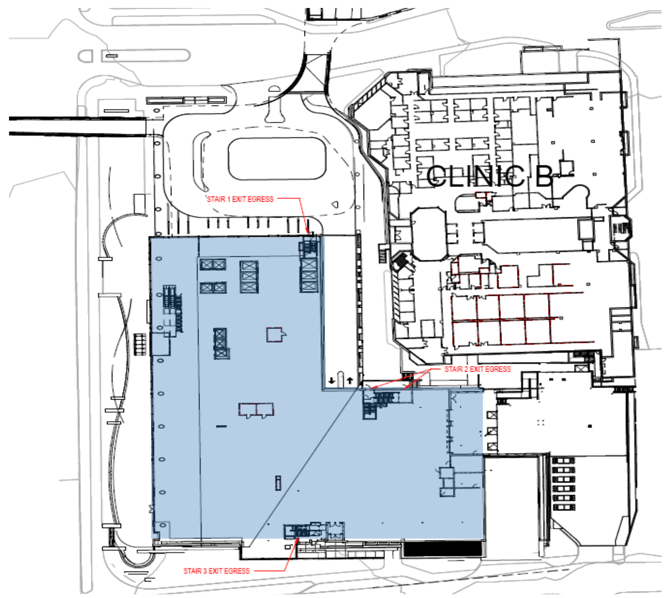


Figure 1 | Site Plan (Courtesy of SmithGroupJJR)

With an estimated cost of $203 million dollars, the new building will add approximately 450,000 square feet and 210 new hospital beds to the existing hospital complex. The building is designed to be a "core-and-shell" building with adaptable spaces and the possibility for future expansion. SmithGroupJJR was responsible for the architectural design of the building, while Walter P. Moore was responsible for the building's structural design.

The tallest building in the immediate area, the building stands out architecturally with a glass and metal façade system as shown on the following page in Figure 3. In addition to the new technical facilities, the building site features a new entry drive for easier patient access and sustainable initiatives such as bioswales.

Figure 2 | East Elevation (Courtesy of SmithGroupJJR)

Figure 3 | South Façade (Courtesy of SmithGroupJJR)

2.3 Structural System Overview

Above ground, The Health Centre is mainly a cast-in-place concrete frame structure (Figure 4). The structural material used for the building was a choice driven by the contractors from McCarthy Building Construction, who noted the availability of concrete over steel in the building's southeastern location. Cast-in-place floors are one-way flat slabs that connect the building's diaphragm, and the building uses regular square bays wherever possible.

The below-grade parking garage consists of two-way post-tensioned flat slabs. Foundations are typically cast-in-place spread footings, with some deep drilled piers on competent rock. CMU walls in the building are non-load bearing. A steel bridge connects the structure to other campus buildings. Further details regarding the building's structural system will be explored throughout this report.

Due to the life-safety concerns for hospital structures, The Health Centre is Building Category IV under ASCE 7-05. The building was designed for basic wind speeds of 90 MPH and Seismic Design Category C.

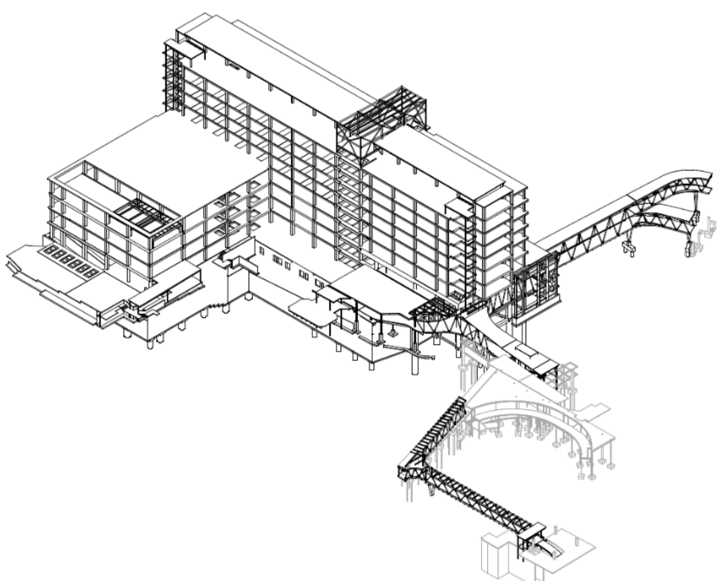


Figure 4 | Overall Building Structure (Courtesy of Walter P. Moore)

3 | Structural Systems

3.1 Foundations

The two primary foundation types used in this building are drilled piers and spread footings. All foundations were designed to be 4,000 psi normal weight concrete and are spaced the width of a typical 30'x30' bay in most locations. A partial foundation layout is provided in Figure 7.

Drilled piers are used mainly underneath the parking structure and the western side of the building. They were designed for 80 ksf net end bearing pressure on competent rock. There are 14 types of drilled piers with pier diameters ranging from 36" to 96". The piers use both #3 and #4 ties spaced at 12" and typically have #11 bars for vertical reinforcement. Typical details for drilled piers are provided in Figure 5. In some locations, drilled piers are embedded into the rock a depth of 5'-0".

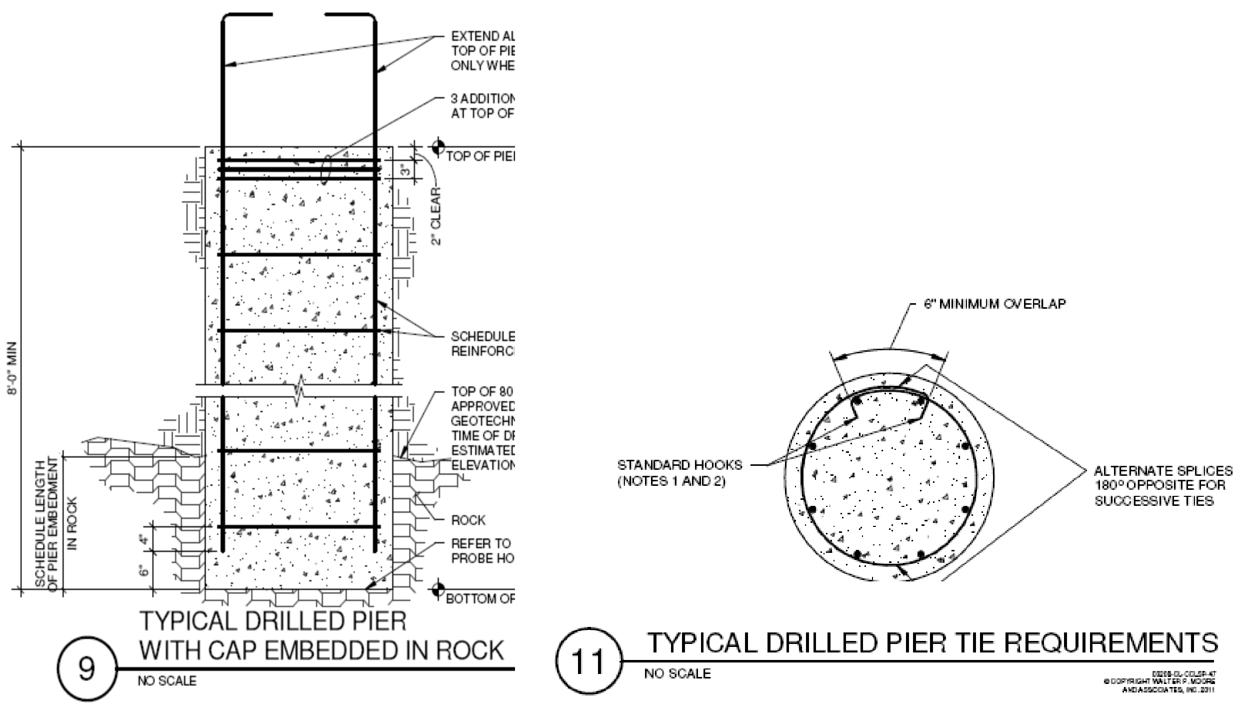


Figure 5 | Typical Drilled Pier Details (Courtesy of Walter P. Moore)

Rectangular spread footings range in size from 4'x6'x18" with #6 rebar to 12'x12'x82" with #9 rebar. They were designed for 30 ksf net pressure on competent rock or 2 ksf net pressure on compacted soil depending on their location in the building. Some spread footings have an equivalent drilled pier that the contractor may choose to use instead. Typical details for spread footings are shown in Figure 6.

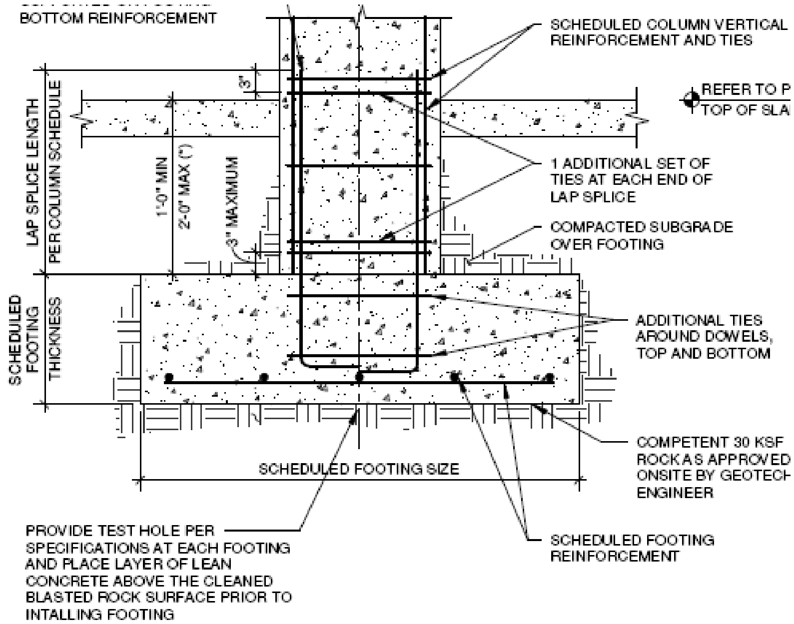


Figure 6 | Typical Foundation Detail (Courtesy of Walter P. Moore)

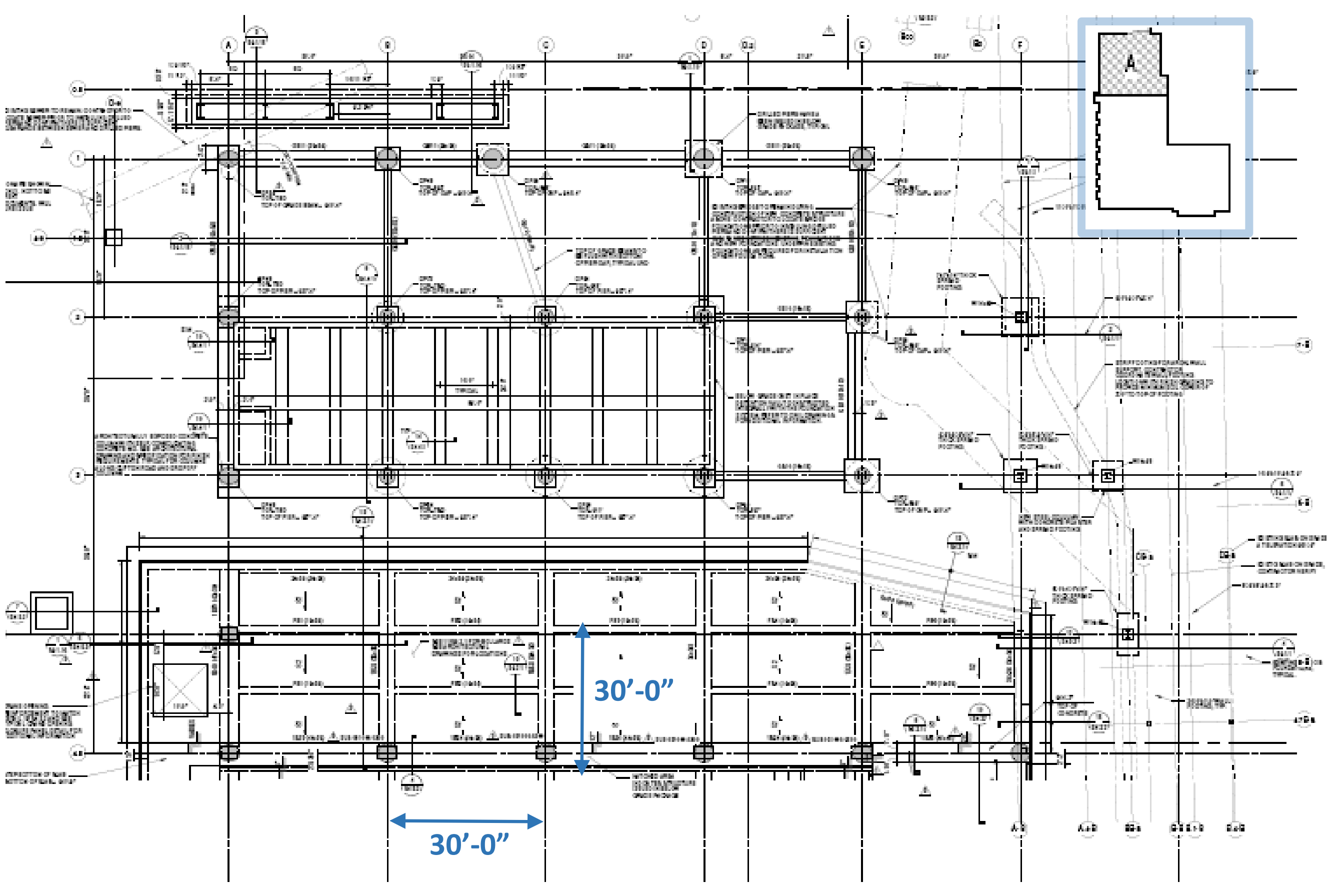


Figure 7 | Partial Foundation Plan (Courtesy of Walter P. Moore)

3.2 Gravity System

3.2.1 Typical Bay

A typical bay size of 30’x30’ is used throughout the building for floors above ground. Overall, the floor system consists of a cast-in-place one-way concrete slab and beam system (Figure 8). Typical girders are 36”x25” and typical purlins are 9”x25” with #8 top and bottom bars. In some locations – usually near floor openings or slab depressions – there is variation in beam width and depth. The flat floor slab depth ranges from 5” to 14” thick. Top and bottom bars vary in size and spacing depending on the slab location, but are typically #3 or #4 spaced at 12”. Some depressions in the slab occur for medical equipment and other hospital technology. All floor system components for the hospital bed tower and parking garage are 5,000 psi normal weight concrete.

Figure 9 on the following page shows a typical bay from the third level of the building. The main exceptions to the typical bay are the ground floor, where lobby and other entrance spaces require different bay conditions, and large transfer girders.

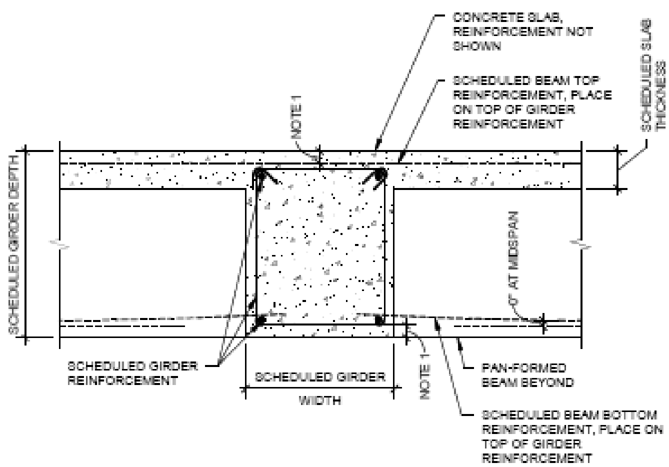


Figure 8 | Typical Floor Section (Courtesy of Walter P. Moore)

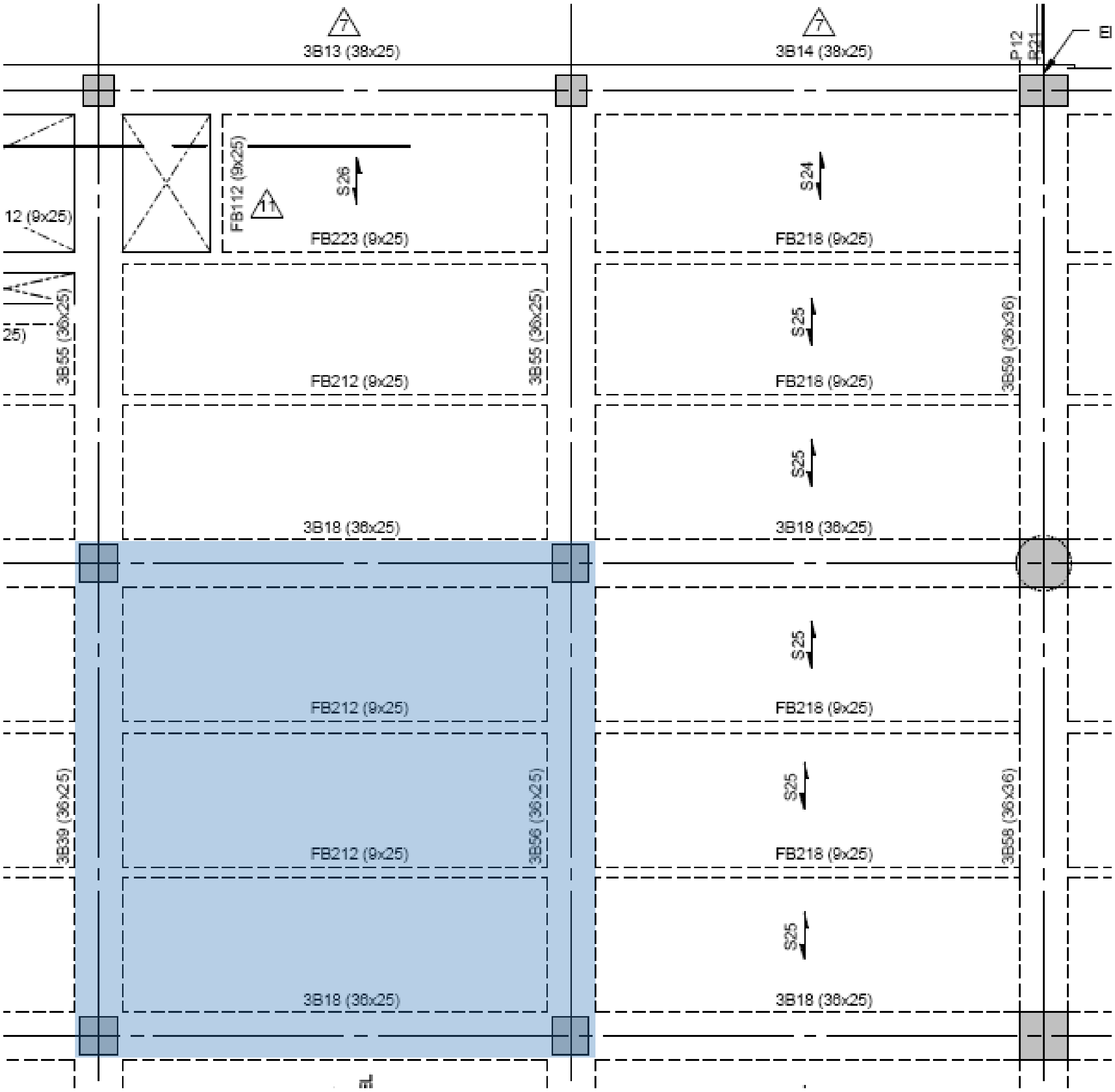


Figure 9 | Typical Bay from Third Floor Area D Floor Plan (Courtesy of Walter P. Moore)

3.2.2 Columns

For the bed tower, as floor level increases the column size decreases. Parking garage columns are typically 28”x44” with 22 #9 rebar for vertical reinforcement. From the ground floor of the bed tower to the bottom of the fourth level, most columns are 28”x32” with vertical reinforcement consisting of 12 #8 rebar. Floors above the fourth floor, including the penthouse, typically have 24”x24” square columns with 8 #8 vertical reinforcement. A column splice is used when these size changes occur (Figure 10). Some columns have also been sized for future steel expansion. 7000 psi normal weight concrete is used for all cast-in-place columns.

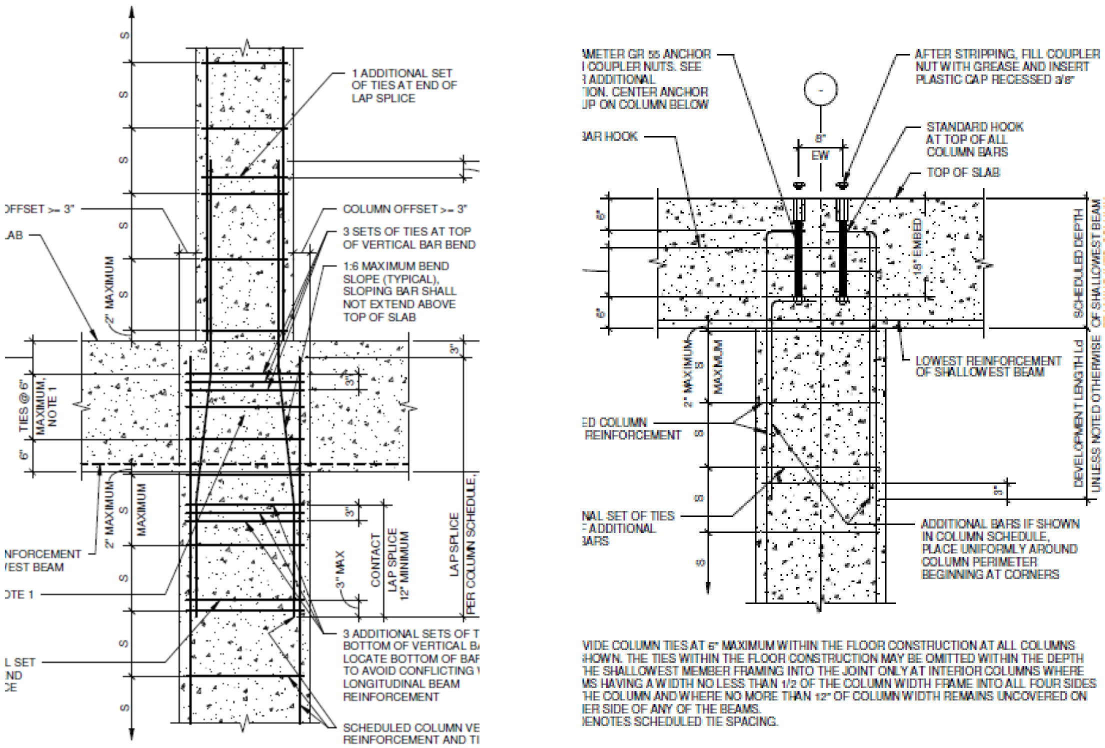


Figure 10 | Typical Column Splice and Steel Expansion Details

Ellipse concrete columns are used in some locations, including underneath the bridge structure (Figure 11). Additionally, W14 structural steel encased in concrete is used in some locations between the ground and fourth levels when columns do not continue below grade to the underground parking garage.

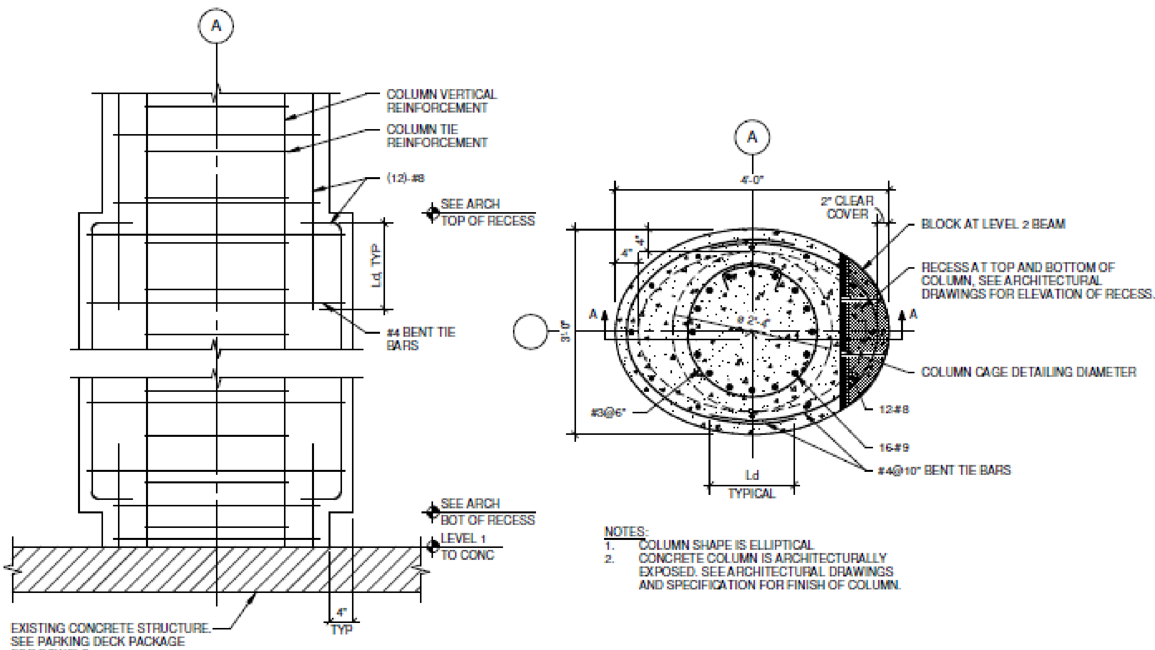


Figure 11 | Ellipse Column Detail

3.3 Lateral System

A dual lateral system consisting of concrete moment frames and shear walls is used for the parking garage and bed tower complex. Concrete moment frames are found mainly in the bed tower, while concrete shear walls are found in the parking garage and are located on the exterior. 7000 psi normal weight concrete is used for all lateral system elements. Lateral load is transferred into the moment frames and shear walls through the floor diaphragm

Basement shear walls in the parking garage begin at the bottommost level and end at grade (Figure 12). Typically 2' thick and approximately 50' high, they extend around the exterior of the parking structure. A 1.5"x3" continuous shear key and standard hooks connect the walls to the post-tensioned floor diaphragm.

Lateral load resistance in the bed tower structure takes advantage of the fact that all concrete framing provides a certain level of moment resistance. Structural drawings do not indicate different details, sections, or notation for special concrete moment frames. Instead, all frames appear to be reinforced to contribute to lateral resistance. Large girder sizes on the exterior, typically 50"x48", indicate that particular attention was paid to lateral resistance on the exterior of the structure (Figure 13), assuming this was not to account for heavy exterior cladding. Pending verification from Walter P. Moore engineers, this will be confirmed in a future version of the report.

A concrete floor diaphragm consisting of a 5" one-way flat slab and 25" deep beams (in most locations) transfers the lateral load throughout the building (Figure 14). Due to the nature of this lateral system, concrete moment frames extend the full height of the building with some stopping at the fourth floor green roof.

Service requirements take into consideration lateral deflection of both wind and seismic loading. Wind loads with a 10-year mean recurrence interval were considered for a lateral deflection of typical floor height/400. Seismic concerns considered a lateral deflection of typical floor height/67. For further wind and seismic loading details, see *Section 4: Codes and Loading*.

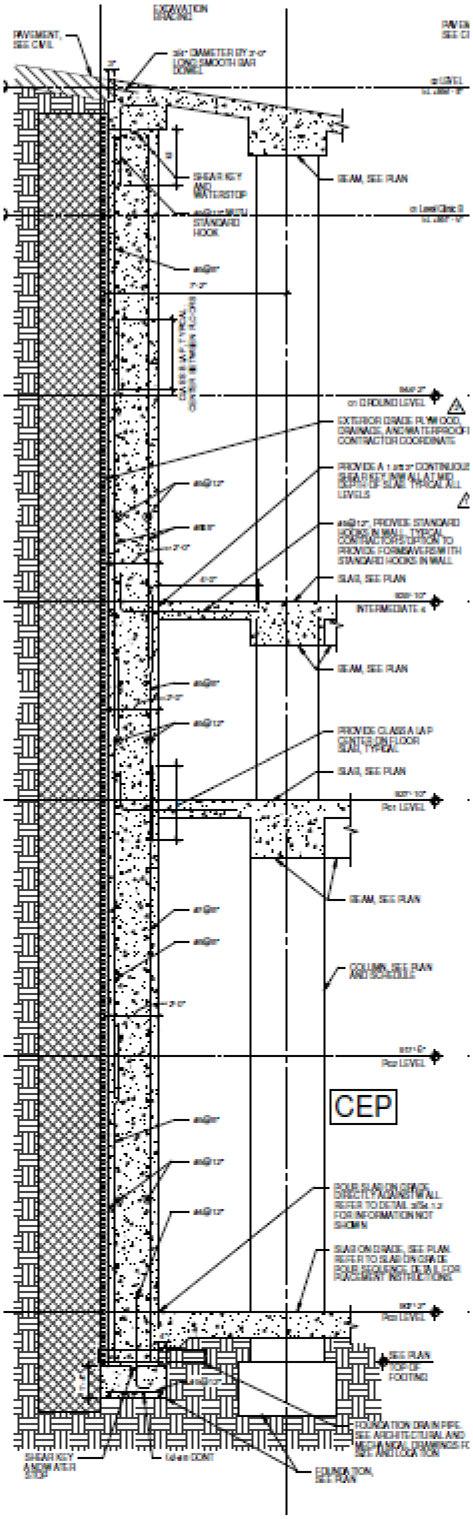


FIGURE 12 | Exterior Concrete Shear Wall Detail

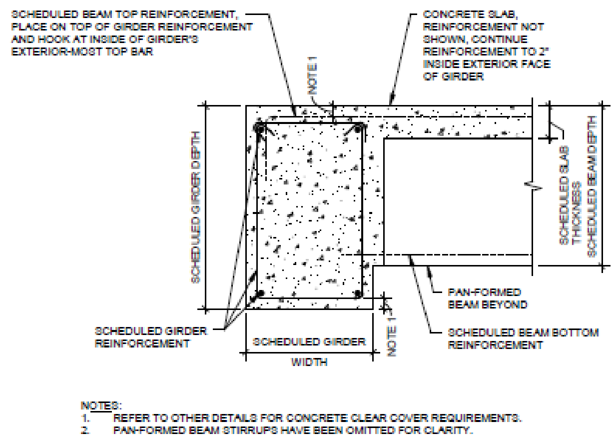


Figure 13 | Deep Exterior Beam (All Images Courtesy of WPM)

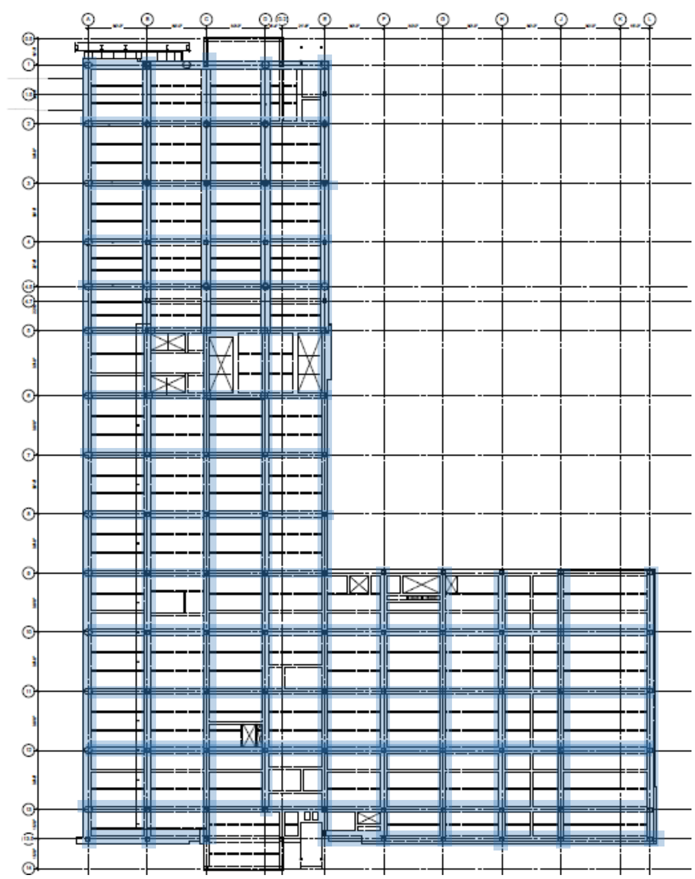


Figure 14 | Fourth Floor Diaphragm with Concrete Moment Framing Highlighted

3.4 Structural Details

3.4.1 Secondary Structural Elements

An architecturally exposed structural steel (AESS) canopy is a major architectural feature on the western side of the building. The canopy consists of double steel plate fins welded to AESS 4”x2”x ½” HSS. The canopy is connected to and supported by a 2x3 steel plates and 4x4x5/16 double angle kicker. These steel supports are welded to embed plates to connect the canopy to the concrete framing (Figure 15).

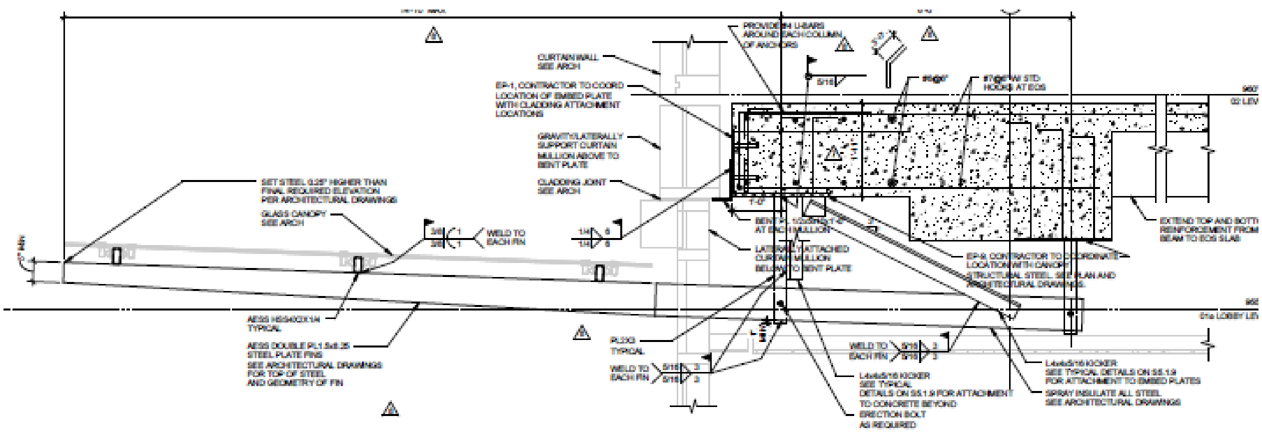


Figure 15 | West HSS Canopy Connection to Concrete Framing (Courtesy of Walter P. Moore)

An 8” non-load bearing CMU wall surrounds all elevator and stair shafts on the parking garage level. For these 8” interior CMU walls, vertical reinforcing is typically #5 or #6 rebar depending on wall height. The concrete strength of these masonry units at minimum 1,900 psi. Typical details for masonry connection to structural framing are shown in Figure 14.

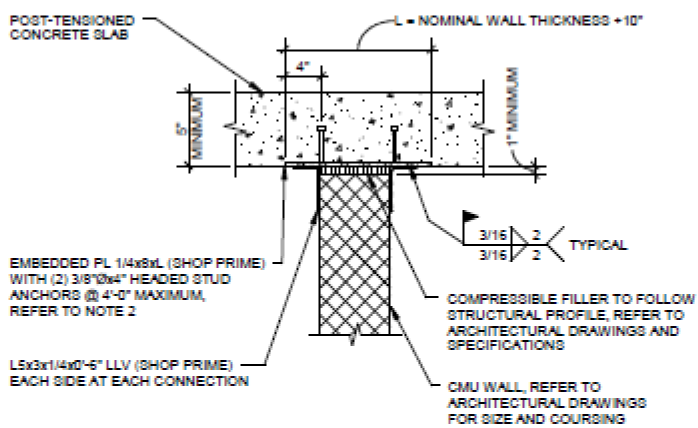
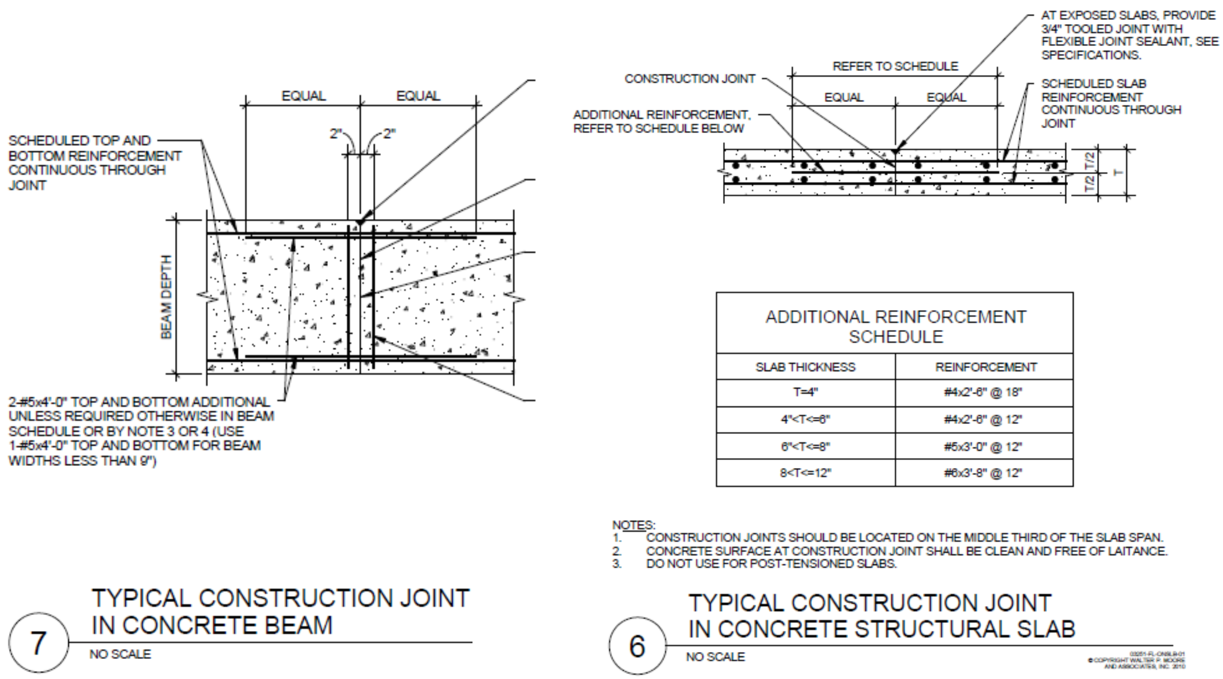


Figure 16 | Building Section Looking North (Courtesy of WPM)

3.4.2 Joint Details

With a variety of architectural and structural systems in The Health Centre, there are many different joint types to consider for construction and design. Due to this being a largely concrete structure, joints are particularly important to avoid cracking and other structural defects. On the following page, Figure 16 depicts typical details for joints in concrete connections.



ADDITIONAL REINFORCEMENT SCHEDULE

SLAB THICKNESS	REINFORCEMENT
T=4"	#4x2'-6" @ 18"
4"<T<=6"	#4x2'-6" @ 12"
6"<T<=8"	#5x3'-0" @ 12"
8<T<=12"	#6x3'-8" @ 12"

Figure 17 | Typical Construction Joints in Bed Tower Concrete Floor System (Courtesy of Walter P. Moore)

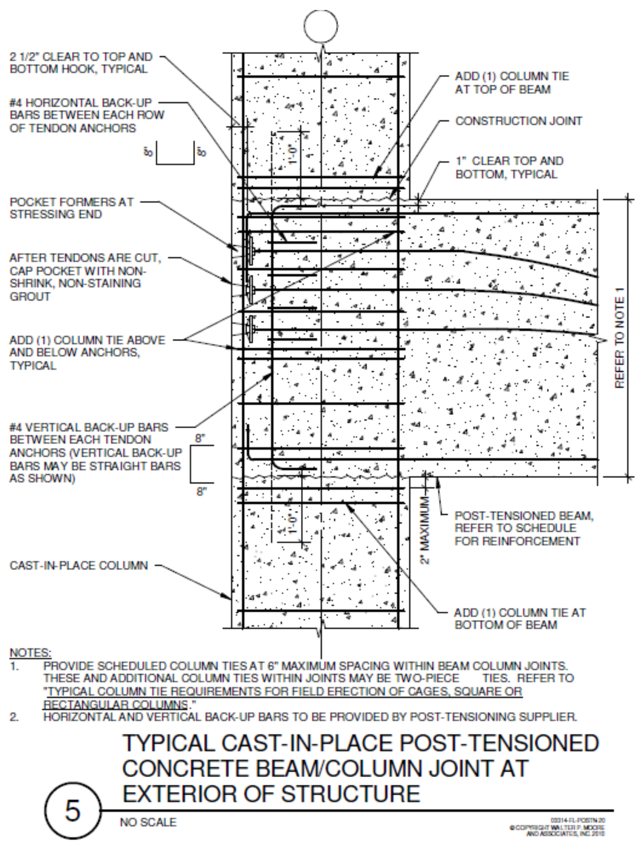


Figure 18 | Typical Cast-In-Place PT Exterior Beam/Column Joint in Parking Garage (Courtesy of WPM)

Figures 17-20 show typical joints for four story underground post-tensioned parking garage. Structures such as parking garages are often post-tensioned to prevent deflection and sagging due to car weight, and allow longer bay spans. At the exterior of the structure, the post-tension slab connects to a cast-in-place columns. 1" of clear cover for top and bottom of the slab is typical above and below anchors. #4 back-up bars are located between the tendon anchors. At the stressing end are pocket formers. Once the tendons are cut, the pocket is capped with non-shrink, non-staining grout. The reinforcing schedule for the two-way post-tensioned slab in Figure 18 shows the location of 90° and 180° hooks, as well as drop panels and reinforcing.

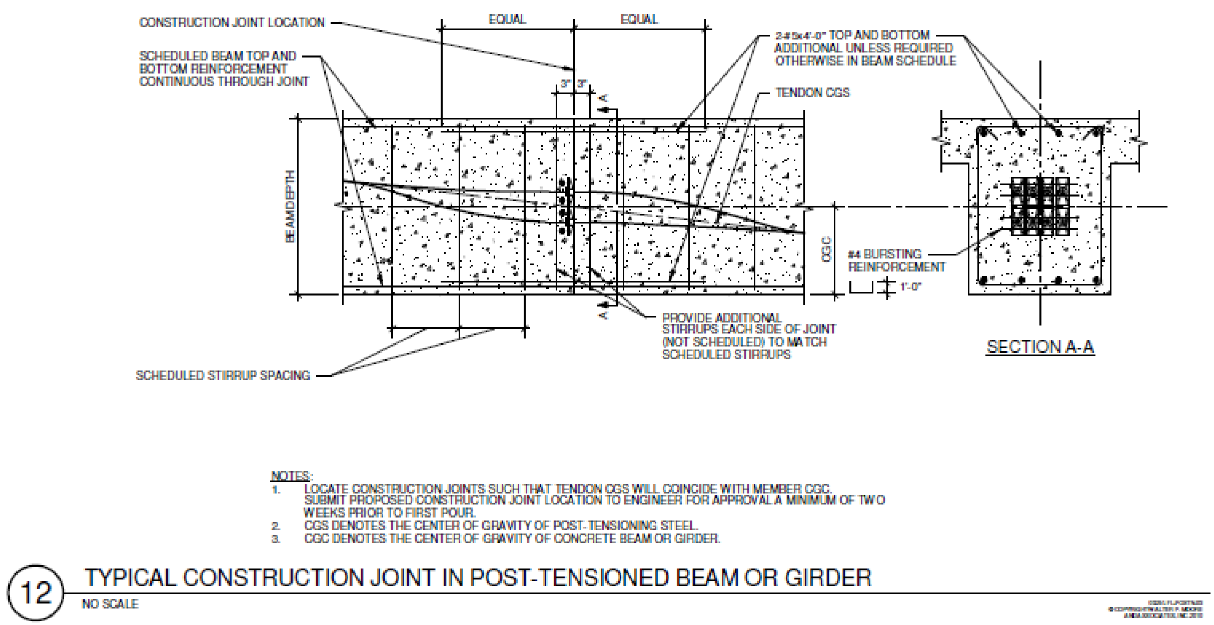


Figure 19 | Typical Cast-In-Place PT Exterior Beam/Column Joint in Parking Garage (Courtesy of WPM)

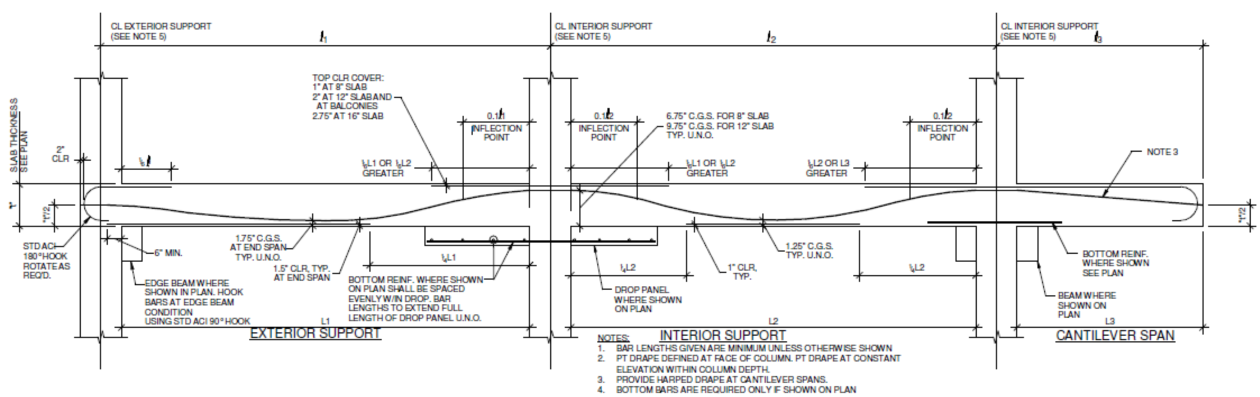


Figure 20 | Two Way PT Slab Reinforcing Diagram (Courtesy of WPM)

4 | Codes and Loading

4.1 Applicable Codes

All known building codes and standards used for The Health Centre are listed in Table 1 below. It is important to note that an exemption for the structural design permitted the use of 2006 ICC codes as amended by the state. The rest of the building components – including architecture, plumbing, and mechanical systems – use 2012 ICC codes as amended by the state. In order to build the hospital, a Special Land Use Permit was obtained from the county to build on land zoned for office-institutional use.

Category	Applicable Code
Building Code	2006 IBC | Structural Documentation Only 2012 International Building Code 2012 International Existing Building Code
Energy Code	2012 International Energy Conservation Code
Fire Code	2012 International Fire Code
Mechanical Code	2012 International Mechanical Code
Plumbing Code	2012 International Plumbing Code
Fire Protection	NFPA 10 | Standard for Portable Fire Extinguishers 2010 NFPA 13 | Installation of Sprinkler Systems 2010 NFPA 14 | Standard for the Installation of Standpipe and Hose Systems 2010 NFPA 70 | National Electrical Code 2011 NFPA 72 | National Fire Alarm and Signaling Code 2010 NFPA 101 | Life Safety Code 2000
Accessibility	ADA 2010 ICC/ANSI 117.1 Accessible and Usable Buildings and Facilities 2003
Elevators	ASME A17.1 Safety Code for Elevators and Escalators 2010
American Society of Civil Engineers	ASCE 7-05 | Minimum Design Loads for Buildings and Other Structures ASCE 7-10 | Non-Structural Requirements
American Concrete Institute	ACI 318 | Building Code Requirements for Structural Concrete
American Institute of Steel Construction	Steel Construction Manual, Edition Unknown

Table 1 | Applicable Codes

4.2 Gravity Loads

Design dead and live loads used for The Health Centre are tabulated in Table 2 below. Live loads for each occupancy/use category were taken from ASCE 7-05. Unless otherwise noted as NR, live loads are reducible. In particular, horizontal framing floor members in parking garages did not have reduced live loads. Accompanying Table 2 are key plans indicating the locations of various gravity load combinations (Figure 21).

Occupancy/Use	Superimposed Dead Load (psf)	Live Load - Uniform (psf)	Live Load – Concentrated (lbs)
Green Roof/Outdoor Area (RF2)	100	100 NR	-
Typical Hospital Areas (HOS1)	15	100	2000
Hospital Diagnostic Areas (HOS2)	75	350 NR	106,000
Mech./Elec. Rooms (MEC)	75	150 NR	2000
Penthouse Roof (RFPH)	50	20	-
Mixed Use Areas (MU1)	55	100	2000
Restroom (RR)	40	100	-
Patient Rooms (PAT)	15	80 + 15 psf (partitions)	1000
Lobbies and Corridors (PUB1)	15	100	2000
Parking Garage (PK1)	5	40 NR	3000
Storage (STO)	15	125 NR	2000
Kitchen (KIT)	95	150 NR	2000
Typical Roof (RF3)	25	20 NR	-
Insulated Roof (RF1)	50	20 NR	-

Table 2 | Design Loads

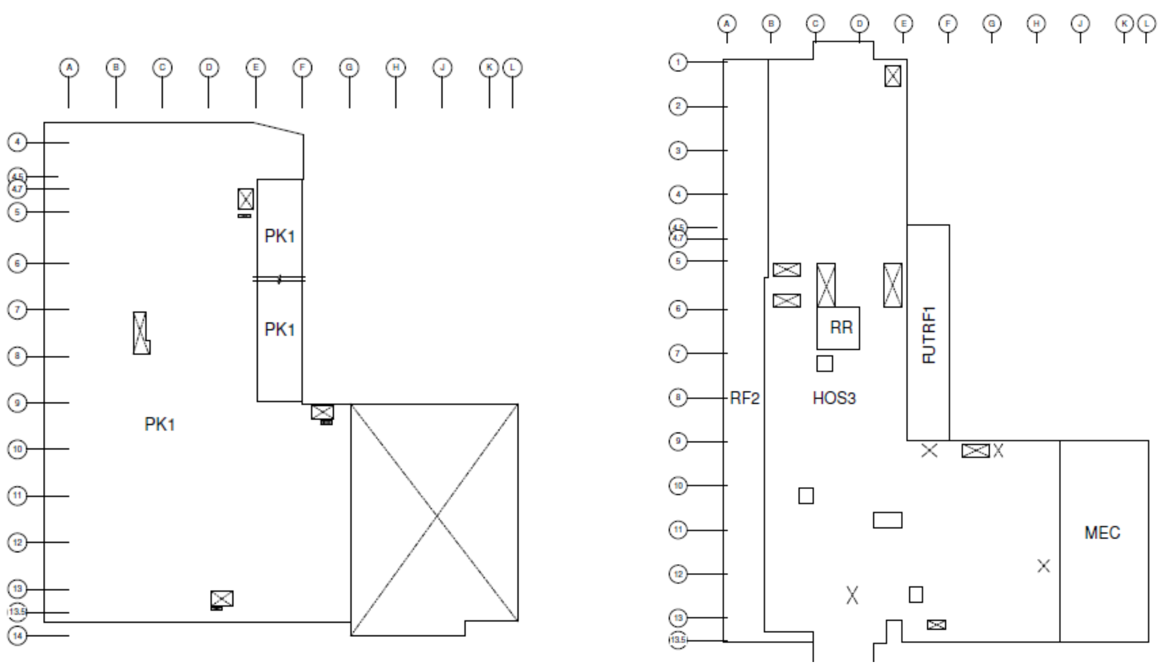


Figure 21 | Key Plan for Typical Parking Loading (left) and Fourth Level (right) | (Courtesy of Walter P. Moore)

4.3 Snow Loads

Values for snow load are based on data from ASCE 7-05. In this location, ground snow load is 5 psf and flat-roof snow load is 4 psf. Due to the importance of a hospital structure, the snow load importance factor used in determining snow loads is 1.2. The snow exposure factor for this building is 0.9. For design, these small snow loads indicate that roof live with control in building load combinations.

4.3 Lateral Loads

4.3.1 Wind Loads

Wind loads were determined using ASCE 7-05 criteria. A basic wind speed of 90 mph was used for design. The Health Centre falls into building category IV and wind exposure category B. Other factors used to determine wind loads were a wind importance factor of 1.15 and the internal pressure coefficient of +0.18/-0.18.

Components and cladding wind loads for parapets, overhangs, and façade systems were also determined using ASCE 7-05 criteria. A minimum value of 10 psf was used for components and classing design.

4.3.2 Seismic Loads

All seismic loads were calculated using the equivalent lateral force procedure from ASCE 7-05. The building is Seismic Design Category C and has an importance factor of 1.5. Soil is considered to be Site Class C. No vertical irregularities were considered for seismic loading. For this building, seismic loads control design.

4.4 Soil Loads

Soil loads were considered for design of basement retaining walls. Lateral earth trapezoidal pressure due to soil loading was modeled as 0 psf at the bottom of the basement wall x 30 psf/ft of depth at 20 percent of the retained soil height. Surcharge loads on basement walls was also considered during design.

4.5 Load Path

The two load paths under consideration for this structural are gravity and lateral load paths.

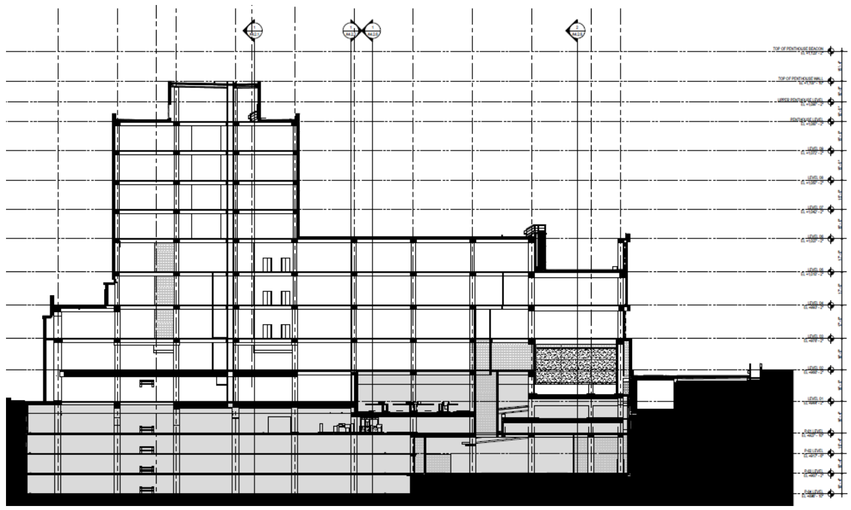


Figure 22 | Building Section Looking North (Courtesy of SmithGroupJJR)

For gravity loads, the load path begins at the penthouse roof. Roof live and dead loads are carried by columns to the floor below. On the penthouse level, mechanical equipment and cooling tower loads are carried by the concrete floor diaphragm and distributed to the columns. This process of load distribution continues throughout the remaining levels, noting the additional green roof loads on the fourth level. At grade, dead and live loads on the floor are distributed onto slab on grade and cast-in-place grade beams. Eventually, all building gravity loads are carried by the columns to the drilled pier and spread footing foundations. Depending on the foundation location, these loads are either distributed into surrounding compact soil or competent rock.

Lateral pressure on the bed tower façade creates a force on the exterior façade that is distributed along its surface. This force is distributed based on stiffness to building elements. Exterior moment frames will take some of the lateral load, and the floor diaphragm will distribute the remaining lateral force to the other concrete moment frames. The columns of the moment frames will carry the lateral force and its foundation will resist overturning moment created by the lateral force. A similar process will occur in the parking garage for lateral loads due to soil and seismic forces. Exterior shear walls will take the lateral load and transfer it to concrete foundations in the soil.

5 | Conclusion

The Health Centre consists of two main structures: a hospital bed tower and an underground parking garage. Although connected structurally, both structures have their own lateral and gravity systems. Cast-in-place concrete framing was used for the bed tower, while post-tensioned concrete was used for the underground parking structure. A regular structural grid of 30’x30’ bays allows for flexibility of spaces in this “core-and-shell” building. The regular structural gird and room layout is one of the building features identified for future exploration when considering a redesign proposal.

Laterally, concrete moment frames spaced throughout the bed tower resist wind and seismic building loads. Exterior basement shear walls resist lateral loads below grade in the parking garage. The interspersion of lateral elements throughout the structure is a choice made by designers that may point towards looking at other systems that could accomplish a similar effect, such as a steel staggered truss system.

Reviewing the existing conditions and structural documentation of the Health Centre revealed the variety of structural conditions present throughout the building. This process highlighted previously overlooked structural details, such as steel canopy connections and non-load bearing masonry walls in the parking garage. Several building elements not pertinent to the main building structure, including the connecting bridges and a detention bay, were not extensively detailed in this report due to the complexity of a health building structure. As a case study, the requirements for medical equipment and patient facilities, including vibration limits and varying slab thicknesses, provide ample opportunity for further analysis and future reports.