SILVER SPRING GATEWAY
Pro-Con Structural Study of Alternate Floor Systems

1133 East-West Highway
Silver Spring, Maryland

The Pennsylvania State University
Department of Architectural Engineering

Senior Thesis 2007-2008

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EXECUTIVE SUMMARY:

Purpose

This Pro-Con Structural Study of Alternate Floor Systems Report contains the description of the physical existing conditions of the structure of the Silver Spring Gateway including information relative to architecture design concepts and required loading per code. This report discusses the strength and practicality of four different alternative floor framing systems resisting only gravity loads; as well as, addressing such items as fire protection, overall weight, acoustic and vibration attenuation, cost, least depth, and other serviceability factors.

Building Description

The Silver Spring Gateway is a mixed-use high rise development including 14,080 square feet of retail space, 100,215 square feet of parking, 395,439 square feet of residential space, and a 1,000 square feet roof top swimming pool. The building envelop consists of brick cavity walls and aluminum Centria storefront curtain walls. The main structural system consists of two-way flat plate post-tensioned slabs supported by 176 reinforced concrete columns without a typical bay grid. Every column transfers its load into transfer beams or directly into caissons carrying the load to the bedrock below. The lateral loads are resisted by three twelve inches thick reinforced concrete shear walls. The Silver Spring Gateway also contains a steel truss bridge spanning thirty-six feet over the garage entrance to connect the two portions of the residential space.

Alternative Floor System Study Results

This study analyzed four floor systems including: composite steel frame, girder-slab system, post tensioned concrete flat plate lift slabs on steel columns, and two-way reinforced concrete flat plate slab. The existing primary structural frame consists of reinforced concrete columns and two-way post tensioned concrete flat plate slabs. The alternative floor system study revealed the existing system as the best choice. The two-way reinforced concrete flat plate slab shows promise for this mixed-use high rise development, but other nuances in the structure bring post-tensioning as the forerunner. While the steel systems can be utilized in regard to strength and serviceability, architectural functionality and height restrictions diminish the practicality of these systems for the Silver Spring Gateway.

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INTRODUCTION

This Pro-Con Structural Study of Alternate Floor Systems Report contains the description of the physical existing conditions of the structure of the Silver Spring Gateway including information relative to architecture design concepts and required loading per code. This report discusses the strength and practicality of four different alternative floor framing systems resisting only gravity loads; as well as, address such items as fire protection and fire ratings, overall weight, acoustic and vibration attenuation, cost, least depth, and other serviceability factors.

BACKGROUND

The Silver Spring Gateway (Cover and Figure 1) is located at 1133 East-West Highway in Silver Spring, Maryland. The existing tight, flat urban brownfield site, surrounded by Blair Mill Road to the Northwest, East-West Highway to the South, and CSX Transportation, Inc. Railway to the Northeast was used primarily as a parking lot (Figure 2). The Silver Spring Gateway site currently abandons a section of Blair Mill Road, transforming the original trapezoidal shaped site to a more useable, rectangular shaped site (Figure 3). Construction of the fifteen-story, 766,459 square feet building was started in July 2006 and is scheduled to be completed in July 2008 with an estimated bid cost of $89 million. The mixed-use, primarily residential, building owned by The JBG Companies was designed by Weihe Design Group (WDG) of Washington, D.C., and is being constructed under a gross mean price, design-build contract by multiple prime contractors, including general contractor and construction manager Turner Construction Company (Turner) of Washington, D.C. Tadjer, Cohen, Edelson Associates, Inc. (TCE) of Silver Spring, Maryland served as the structural engineering firm (See Appendix A for Project Team Directory).

According to the Urban Land Institute, a development containing “three or more significant revenue producing uses, significant functional and physical integration of the different uses, and conforms to a coherent plan” is defined as a mixed use development. The Silver Spring Gateway certainly exudes this quality as it contains 14,080 square feet of retail space located on the Ground Floor, 100,215 square feet of parking extending from the Basement Level (B1) to the Seventh Floor, and 395,439 square feet of residential space (condominiums and apartments) dispersed among the Second Floor through the Fifteenth Floor (Figure 9). The Basement Level is a rectangular space below grade completely dedicated to parking. The parking garage is sited in the rear of the building or northeast section and continues with the same shape and overall size for eight floors. The Ground Floor is “L” shaped with the long leg parallel to and the short leg pointing toward the East-West Highway and accommodates the lobby, fitness center, and common spaces for the residents; as well as, the retail portion of the building (Figure 5). The retail space is located in the front of the building or south and southwest section along the East-West Highway and is divided by an internal street located at the southeast corner leading to the parking garage entrance. The service corridor and loading dock for the retail space acts as a buffer between the residential public and retail spaces and the parking garage. The service corridor, loading dock, and portions of the internal street utilize a heated ceiling system.

The second floor contains a portion of the residential space located toward the front of the building and a section of the parking garage located in the rear of the building. With a shape similar to the Ground Floor, the second floor also helps reconnect the portion of the building separated by the internal street with an enclosed pedestrian bridge spanning approximately 36 feet. Floors three through six follow the same layout and shape as the second floor except for the bridge area, which contains residential space. The Seventh Floor also maintains the same layout and shape as floors three through six; however, the floor initiates a shape and layout change through the parking garage section. The center portion of the last parking garage level will be open from above and will be surrounded on three sides by the remaining floors (Photo 2). The end portions of the parking garage will utilize a heated ceiling system similar to the Ground Floor.

The remaining eight floors are strictly for residential use and organized in a "figure four". The corridor running through the center of the layout is doubly loaded. Starting on the Twelfth Floor, the southern tip of the building shortens and creates a restricted access roof for the remaining four floors. The penthouse roof maintains the "figure four" layout from below and contains several mechanical and electrical rooms, picnic areas, and a 1,000 square foot residential swimming pool with related functional amenities to complete the fifteen story mixed use development (Figure 6).

The exterior façade of the Silver Spring Gateway is comprised of several different systems. The primary system is a Norwegian and Engineer brick masonry cavity wall with cold formed light gauge steel back-up framing. The Ground Floor utilizes a similar system, however, is expressed differently with prairie stone along with an aluminum storefront curtain wall system for retail areas. Small portions of the building also exhibit Centria aluminum faced composite panels and metal screen walls near the penthouse level and on the parking garage elevation for acoustical concerns. The owner has also opted to incorporate a moisture control initiative with extensive flashing details and unorthodox elevation construction.

DOCUMENT AND CODE REVIEW

The IBC 2003 was adopted and amended by Montgomery County, MD on 1 April 2005. Montgomery County amended several commercial construction design parameters; such as, ground snow load, wind speed, spectral response acceleration, weathering, and frost line depth. The most recently published sub-codes and standards will be used for the purposes of this report instead of those referenced by the IBC 2003. The following documents were either furnished for review or otherwise considered:

<u>*Codes and Standards*</u>

- PCI *Manual for the Design of Hollow Core Slabs* 2nd Edition published in 1998 by the Precast/Prestressed Concrete Institute
- *International Building Code 2003* (IBC 2003) published 16 February 2003 by the International Code Council
- ACI 318-05 *Building Code Requirements for Structural Concrete* published August 2005 by the American Concrete Institute (ACI 318)
- AISC *Steel Construction Manual* 13th Edition published December 2005 by the American Institute of Steel Construction, Inc. (AISC 13^{th} ed.)
- ASCE/SEI 7-05 *Minimum Design Loads for Buildings and Other Structures* published in 2006 by the American Society of Civil Engineers (ASCE 7)
- *Post-Tensioning Manual*, 6^{th} Edition published in 2006 by the Post-Tensioning Institute
- *Girder-Slab Design Guide v1.3* published in 2006 by Girder-Slab Technologies, LLC

References

- *Design of Prestressed Concrete* authored by Arthur H. Nilson published in 1987 by John Wiley & Sons, Inc.
- *Architectural Graphic Standards* Student Edition published in 2000 by the American Institute of Architects (AIA)

Construction Documents

- Geotechnical Report dated 13 May 2005 by GeoConcepts Engineering, Inc. (GCE)
- Construction Documents S1.01-S4.05 dated 31 August 2006 by TCE and WDG
- Construction Documents C1-C32 and S1 dated 3 November 2006 by Loiederman Soltesz Associates, Inc.
- Construction Documents and A1.01-A12.41 dated 17 November 2006 by WDG
- Shop Drawings F1.01-F15.02, B1.01-B1.03, C.01-C.39, L1.01-L1.08, PH.01-PH.07,W.01-W.05 dated 17 March 2006 by Harris Rebar
- Shop Drawings PT-0.00-PT-1.61 dated 12 August 2006 by Suncoast Post-Tension L.P.
- Specifications Sections 00001-14560 dated 6 April 2007 by WDG
- Site Photos taken 20 July 2007 (See Appendix B for Photos)

EXISTING STRUCTURAL SYSTEM DISCUSSION

With the Silver Spring Gateway located approximately seven miles from Washington, D.C., it comes as no surprise that the primary structural material is concrete. Per the geotechnical report published by GCE, the foundation system utilizes caissons ranging from 30 inches to 66 inches in diameter with a minimum depth of 10’-0” below grade. Exterior grade and transfer girder beams ranging in size from 12 inches by 30 inches to 54 inches by 66 inches were needed to avoid the 72 inches in diameter storm line that travels through the site. A four inches thick slab on grade and spread footings were also employed where appropriate.

While the basement level and ground floor systems are 8 inches or 12 inches thick normal weight cast in place reinforced concrete, the remaining floors utilize a 7 to 9 inches thick two way flat plate post tensioned concrete system with one-way banded tendon distribution over column lines opposite of uniformly distributed tendons (Figure 7). One hundred and seventy-six reinforced concrete columns, ranging in compressive strength from 4,000 pounds per square inch to 8,000 pounds per square inch, support the selected floor systems. In addition, only the lower level columns have 10 feet by 10 feet by 5 ½ inches thick drop panels. Several columns are sloped to realign the upper floor grid with the lower floor grid. While the bay dimensions are not consistent throughout the building with rotated columns and radial column lines, the longest span of the two way flat plate post tensioned floor slab is approximately 27 to 30 feet. The building envelop is supported by continuous 3/8 inches thick bent plates with ¾-inch diameter wedges at two feet on center. The lateral load resisting system located in the north, east, and south corners of the building (Figure 4) consists of three 12 inches thick concrete shear walls reinforced with #6 bars at six inches on center below the Second Floor and #5 bars at eight inches on center above the Second Floor.

Although most of the Silver Spring Gateway structure is cast in place reinforced or post tensioned concrete, the enclosed pedestrian bridge and canopy structures are exposed structural steel. The bridge system in particular is constructed of a 6 ½ inches thick composite concrete slab on six steel trusses composed of W14x114 chords and W12x210s, W12x190s, and W10x45 web members spanning approximately 36 feet (Photo 7). Several W16, W14, and W12 composite infill beams, along with the steel trusses, are moment connected utilizing full penetration welds (Photo 8). Composite W14x257 steel columns encased in a two feet by two feet concrete column supports the entire bridge structure. The canopy members and wall panel supports are typically tube shaped steel members.

BUILDING DESIGN LOAD DISCUSSION:

In order to analyze the Silver Spring Gateway, the static and dynamic loads acting on the building must be determined. The construction documents, including drawings and specifications, AISC 13th ed., and ASCE 7 provide insight to code compliant loadings and material specifications and weights. The following table lists the appropriate gravity loads classified by type and system:

Floor System Loads			
Load Type	Material / Occupancy	Load	Reference
Dead Load	Normal Weight Concrete	150 pcf	ACI 318
	Steel	Per shape	AISC 13th ed.
	Steel Deck	2 psf	USD
	Partition Wall	15 psf	ASCE 7
	Brick Masonry	40 psf	AISC 13th ed.
	Miscellaneous	10 psf	
Live Load	Lobby and Common Spaces	100 psf	ASCE 7
	Corridors	100 psf	ASCE 7
	Apartments and Condominiums	40 psf	ASCE 7
	Corridors servicing Residential Spaces	40 psf	ASCE 7
	Balconies	60 psf	ASCE 7
	Parking Garage	40 psf	ASCE 7
	Retail Spaces	100 psf	ASCE 7

Roof and Terrace System Loads			
Load Type	Material / Occupancy	Load	Reference
Dead Load	Normal Weight Concrete	150 pcf	ACI 318
	Water (Swimming Pool)	62.4 pcf	AISC 13th ed.
	Green Roof	70 pcf	AISC 13th ed.
	Ballast, insulation, and waterproofing membrane	8 psf	AISC 13th ed.
	Brick Masonry	40 psf	AISC 13th ed.
Live Load	Assembly and Pool Space	100 psf	ASCE 7
	Roof	20 psf	ASCE 7
Snow Load	Ground Snow Load	30 psf	Montgomery Co.
	Terrain Category	B	ASCE 7
	C_e Exposure Factor	1	ASCE 7
	C_t Thermal Factor	1	ASCE 7
	Importance Factor	1	ASCE 7
	Flat Roof Load	21 psf	ASCE 7

The miscellaneous gravity load will include building components such as ductwork, lighting, telecommunications, drop ceilings, etc. Snow drift loads will accumulate around the penthouses increasing the dead load on the roof; however, the magnitude of this loading was not determined for this report. The Montgomery County Department of Permitting Services has published *Building Codes & Standards*, which displays all major model codes and industry standards adopted and the subsequent amendments. For the Silver Spring Gateway, several parameters, as previously mentioned, are dictated by the county (See Appendix D). Lateral loads, such as wind and seismic forces, due act on the high rise building; however, these loads are not analyzed within the scope of this report.

ALTERNATIVE FLOOR SYSTEM DISCUSSION

With the Silver Spring Gateway located in Washington D.C. area, a concrete floor system usually produces the most economical and efficient structural system due to building height restrictions and local labor expertise. However, this report will assay four different systems based on criteria of strength, depth, cost, and serviceability that may result in a more efficient system for the mixed use high rise development. The four systems are: composite steel frame, two way reinforced concrete flat plate, girder-slab, and a hybrid system of steel columns supporting a post tensioned lift slab. The Silver Spring Gateway was designed with an irregular column layout. This presents a challenge in the design of any floor system; however, one location displays the largest span in both directions. This location will be used and will be shifted to form a thirty foot square bay in order to complete a simplified analysis (Figure 8). The main design criterion is floor to floor height. Currently, the Silver Spring Gateway utilizes a seven inches thick slab with soffits located above cabinets and insignificant rooms to direct mechanical, plumbing, and other engineered systems. With a typical floor to floor height of 9’- 1” and a seven inches thick slab, the target floor system depth is thirteen inches thick. The calculations and decisions herein are based on this premise. See Appendix E to review the design calculations for all of the schematic floor system designs and Appendix F for the Alternative Floor System Comparison Table.

Composite Steel Frame

The schematic design began with the composite deck and concrete slab. The thinnest result was a 4 ½ inches thick slab and composite deck assembly. In order to maintain a shallow system, the girder and beams chosen ended up being non-composite (Figure 10). A composite section would certainly reduce the wide flange section depth normally; however, the members chosen to develop a shallow system did not contain the appropriate serviceability capacity for the pre-composite deflections. While shoring could be utilized, the cost of temporary shoring would decrease the feasibility of this system all the more. The column size for the live loads accrued resulted in W14 sections.

The overall depth of this system resides slightly deeper than sixteen inches thick. While this is more than the target, the roof and first floor have enough extra height to shift the additional three inches per floor to remain under the 143 feet building height restriction. The main issue resulting from this system requires altering the column layout. With the existing sporadic layout of columns, a steel system is not ideal; therefore, the columns would need adjusted to form a more regular grid potentially disrupting architectural layout and functionality.

Unlike the existing structural system, the steel floor framing requires a finished ceiling surface for aesthetics and fire protection purposes. The finished ceiling will need to have a two hour fire rating. The service plenum can be located anywhere under the floor system instead of isolated within a soffit. The ceiling finish or fireproofing and column relocation adds to the total cost of this system which is relatively higher than the existing system. The column relocation will have a design and cost impact on the foundation design, since the existing caissons are strategically placed to avoid impeding the storm drainage line located in the middle of the footprint.

Girder-Slab System

The Girder-Slab design initiated with the precast plank sizing from the *PCA Hollow Core Design Manual 2nd Edition*. Using the load tables, an eight inches thick plank can span thirty feet with the live load determined. Using this plank size and subsequent weight, the girder-slab system required a DB9x41 with a two inches thick normal weight concrete topping (Figure 11). The columns necessary for this system are similar to the composite steel floor system.

The overall depth of this system is about ten inches thick. This system is favorable for the depth criterion; however, similar to the composite steel frame the column layout will needed adjusted. Even more problematic, the altered beam sections used in this system will require an extra column to halve the span. Shoring could be utilized during the pre-composite curing; however, the additional cost could decease the practicality of this system. If a section could be engineered outside of the standard members available, this system could span the desired length, but this would incur additional manufacturing costs.

This steel and precast floor framing does not require a finished ceiling surface for fire protection purposes, but for aesthetics it would be beneficial. The finished ceiling will need to have a two hour fire rating. The service plenum will be located under the floor system within isolated soffits similar to the existing condition. The column relocation adds to the total cost of this system which is approximately the same cost as the composite system and relatively more expensive than the existing system.

Two-way Reinforced Concrete Flat Plate System

The two-way reinforced concrete flat plate trial floor slab was nine inches thick with #5 bars, since the existing post-tensioned slab is seven inches thick. Using the Direct Design Method, the slab would require a maximum of thirty-six to minimum of ten #5 bars. The system would require 1.4 square inches of shear reinforcement near the columns or the slab would need increased to 11 ½ inches thick. The columns based on previous loads need to be at least sixteen inches square with variable concrete compressive strength similar to the existing design.

This system has an overall depth of nine inches or eleven and a half inches depending on shear reinforcing. This system complies with the set target depth and can utilize the current column layout. This system has the most promise out of the four with depth and column layout; however, other features of the building, like the rooftop swimming pool and parking garage, may diminish the feasibility of this system.

This system relates to the existing system in column layout and floor plate thickness. Since it closely matches the existing system the underside of the concrete slab does not require a finished ceiling and the service plenum will reside in isolated soffits within the kitchens, closets, and bathrooms. The cost of this system is slightly cheaper than the post-tension slab and overall, relatively low in cost comparatively.

Post-tensioned lift slab on steel columns

This system acts primarily as a hybrid of two other systems. The post-tensioned slab is the thinnest floor system, while steel columns maintain the smallest dimensions. The post-tension slab is 7 ½ inches thick with 16 tendons uniformly distributed in one direction and banded over the columns in the opposite direction. The steel columns are similar W14 sections as in the steel composite floor system.

As with any steel column system, the column layout will pose an issue. However, a post tension slab allows for greater spans and more complex floor plans, so further design development and communication with the architecture concept could bring a regular column grid with a thin slab to the Silver Spring Gateway.

This hybrid system brings the advantages with sound attenuation, ceiling surface, fire protection, and depth of the post-tension slab. However, the steel columns force a regular grid layout which may add to the cost. The lift-slab construction methods and column connections will certainly add to the cost as well. Overall this system has a moderate cost in comparison; however, this system exudes the best chance for column relocation.

CONCLUSION

The Silver Spring Gateway contains a complex and collective structural system. The primary structural frame consists of reinforced concrete columns and two-way post tensioned concrete flat plate slabs. The alternative floor system study revealed the existing system as the best choice. The two-way reinforced concrete flat plate slab shows promise for this mixed-use high rise development, but other nuances in the structure bring post-tensioning as the forerunner. While the steel systems can be utilized in regard to strength and serviceability, architectural functionality and height restrictions diminish the practicality of these systems for the Silver Spring Gateway.

APPENDIX A – FIGURES

Figure 1: Architectural Rendering of Silver Spring Gateway from the corner of East-West Highway and Blair Mill Road.

Figure 2: Original site (red hatch) and surrounding streets, railway, and buildings.

Figure 3: Current site (red hatch) abandons a portion of Blair Mill Road.

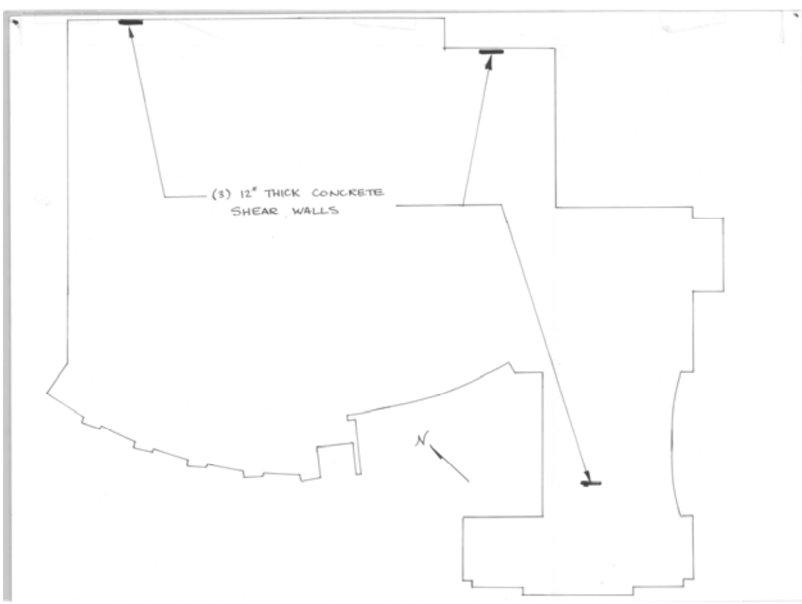


Figure 4: Location of the three shear walls designed to resist the lateral loads.

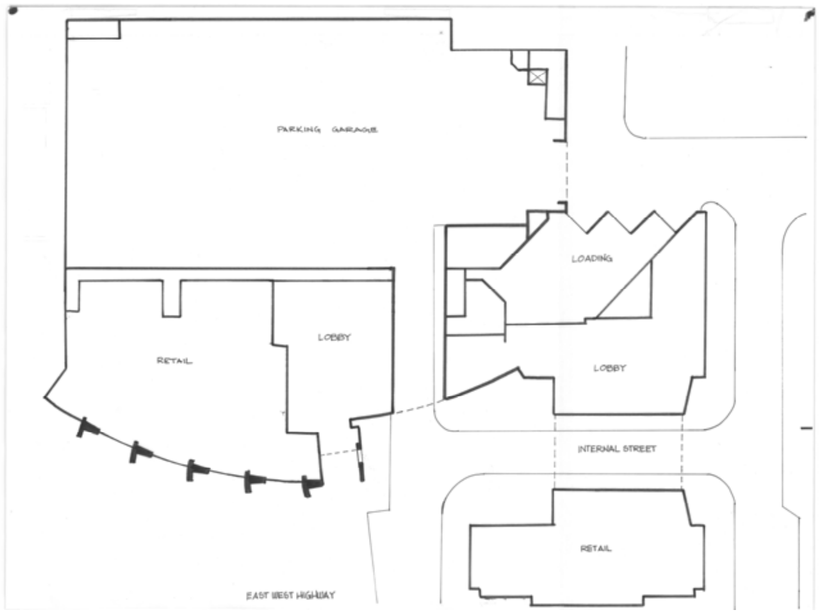


Figure 5: First Floor and Overall Site Plan showing overall shape for lower floors.

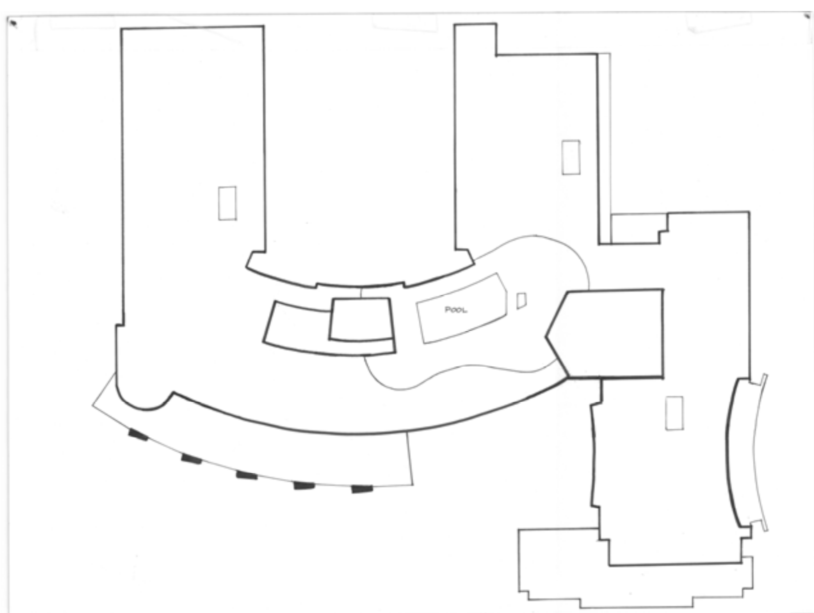


Figure 6: Penthouse Roof Plan showing overall shape of the upper floors and location of penthouse amenities.

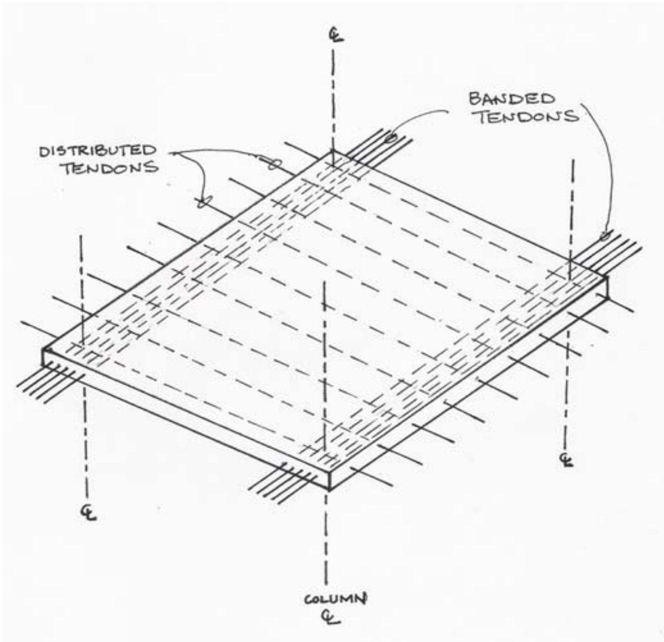


Figure 7: Typical post-tensioning tendon layout.

Figure 8: Column layout for the Silver Spring Gateway with the red hatch indicating the area of schematic design.

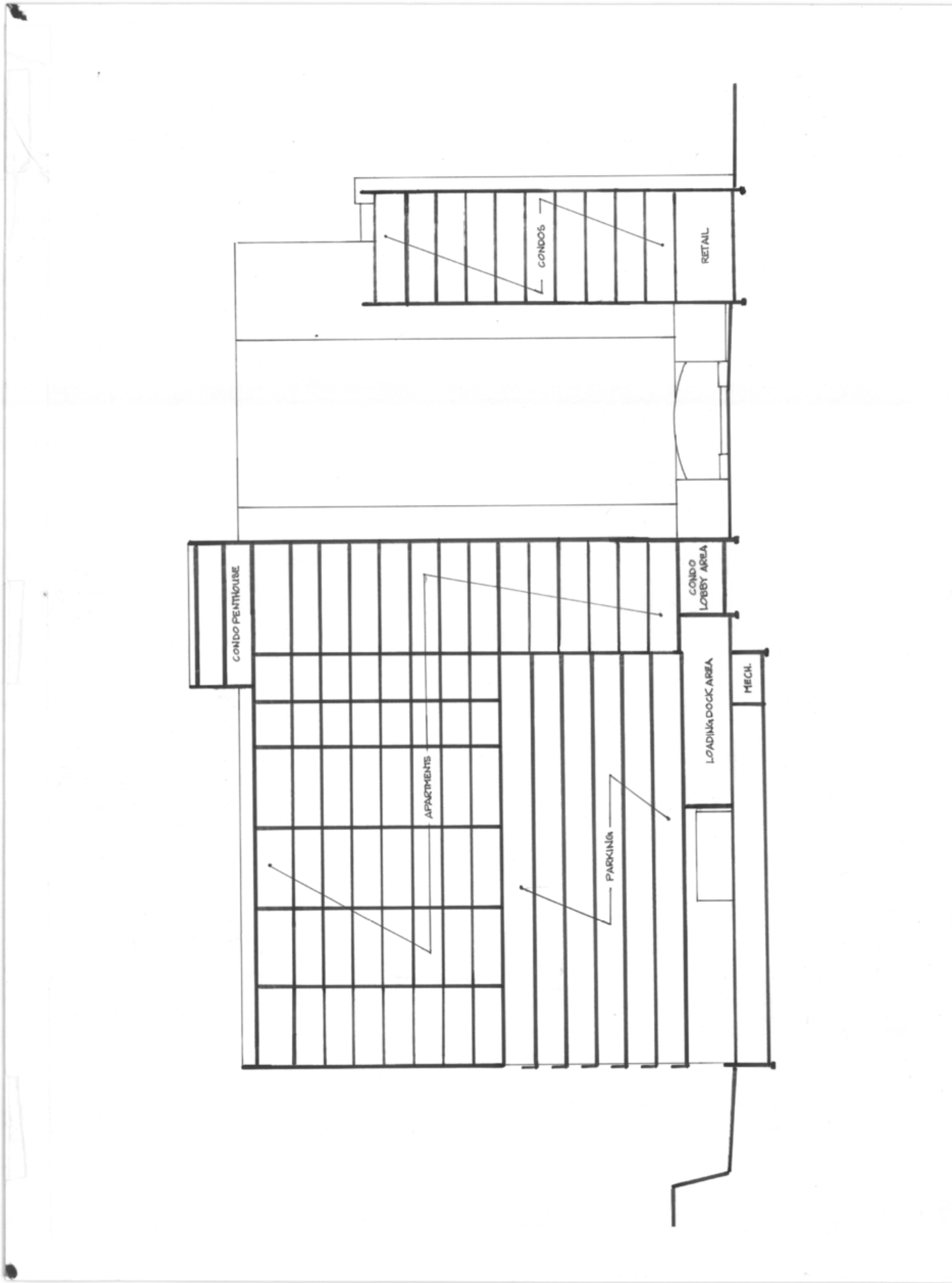


Figure 9: Building Section showing occupancies per floor.

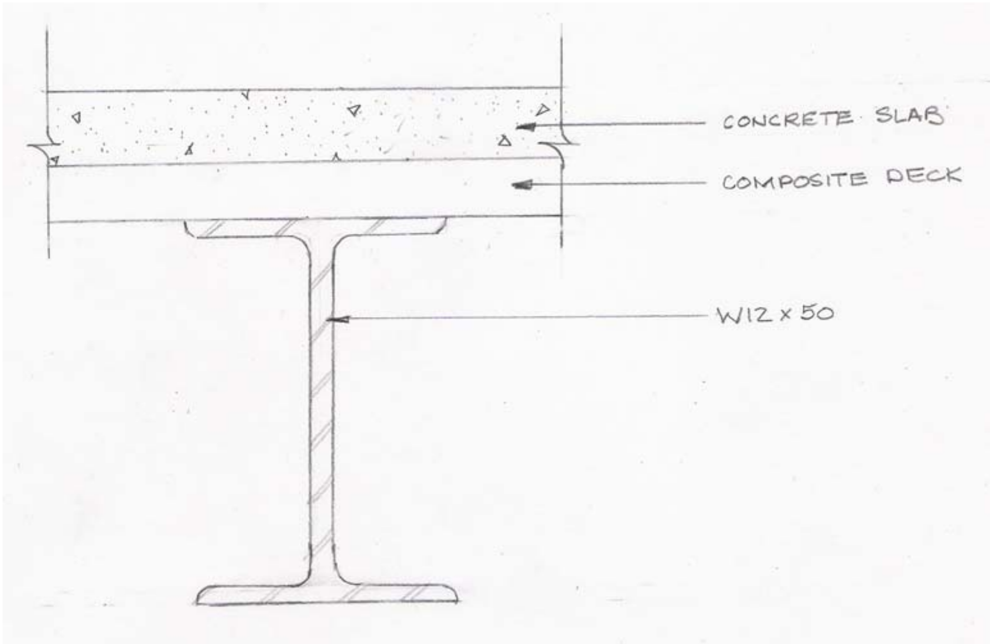


Figure 10: Typical section through steel wide flange and composite deck.

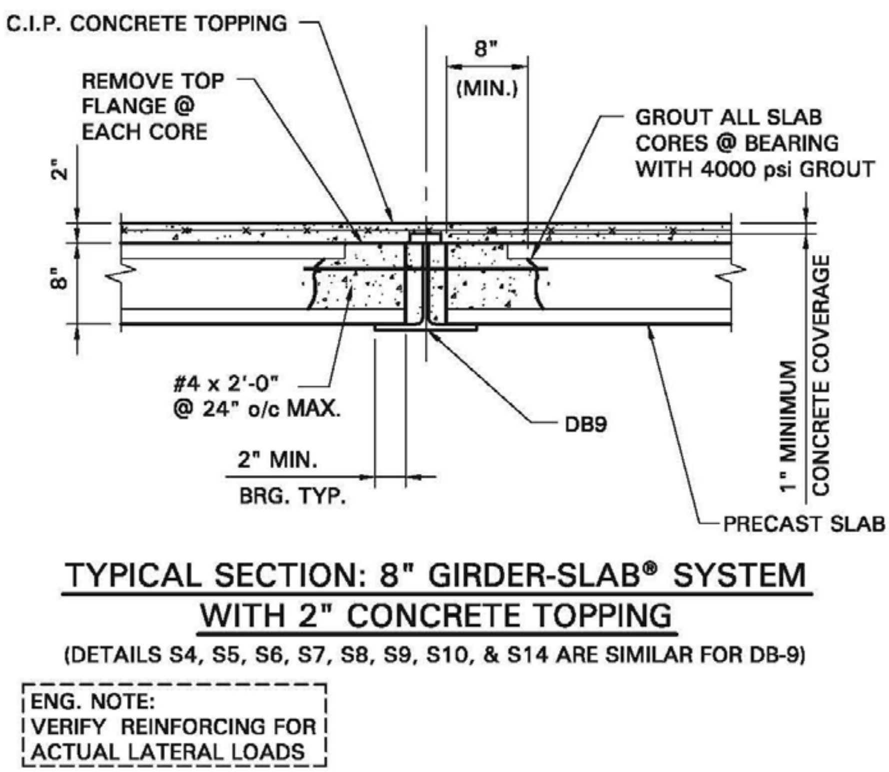


Figure 11: Typical section through Girder-Slab floor system from www.girder-slab.com.

APPENDIX B – PHOTOS

Photo 1: Overall view of Southeast elevation of Silver Spring Gateway.

Photo 2: Partial view of courtyard from the top level of the parking garage.

Photo 3: Partial view of the Southwest elevation.

Photo 4: Partial view of the inside corner between the Southwest elevation and a small portion of the West elevation.

Photo 5: Partial view of lower floor construction on East-West Highway elevation (Southwest).

Photo 6: Interior View of the parking garage.

Photo 7: Interior view of pedestrian bridge steel structure.

Photo 8: Typical full penetration welded connection of the bridge truss structure.

Photo 9: Interior view of a typical residential corridor.

Photo 10: View of post-tensioning cables prior to jacking force application.

APPENDIX C – PROJECT TEAM DIRECTORY

Role	Firm	Website
Owner	The JBG Companies 4445 Willard Ave., Suite 400 Chevy Chase, MD 20815	www.jbg.com
Architect	WDG Architecture 1025 Connecticut Ave., Suite 300 Washington, DC 20036	www.wdgarch.com
Civil Engineer	Loiederman Soltesz Associates, Inc. 1390 Piccard Drive, Suite 100 Rockville, MD 20850	www.LSAssociates.net
Structural Engineer	Tajder-Cohen-Edelson Associates, Inc. 1109 Spring Street Silver Spring, MD 20910	www.tadjerco.com
Landscape Architect	Hord Coplan Macht 750 E. Pratt Street, Suite 1100 Baltimore, MD 21202	www.hcm2.com
Interior Designer	Carlyn and Company 746 Walker Road, Suite 22 Great Falls, VA 22066	www.carlynco.com
Environmental Consultant	Environmental Resolutions, Inc. 14609 Jaystone Drive, Suite 100 Silver Spring, MD 20905	
Geotechnical Consultant	GeoConcepts Engineering, Inc. 19955 Highland Vista Drive, Suite 170 Ashburn, VA 20147	www.geoconcepts-eng.com
Acoustics Engineer	Cerami & Associates, Inc. 1250 Connecticut Ave., N.W. Washington, DC 20036	www.ceramiassociates.com
Mechanical Engineer	Atlas Air Conditioning Company 10693 Wakeman Ct. Manassas, VA 20110	www.atlascsusa.com
Electrical Engineer	Power Design, Inc. 11207 S. Danka Blvd., Suite A St. Petersburg, FL 33716	www.powerdesigninc.us
Construction Manager	Turner Construction Company 10400 Little Patuxent Pkwy., Suite 200 Columbia, MD 21044	www.tcco.com
Seismic Monitoring	Seismic Surveys P.O. Box 1185 Frederick, MD 21702	www.seismicsurveys.net

APPENDIX D – MONTGOMERY COUNTY ADOPTED CODES AND AMENDMENTS

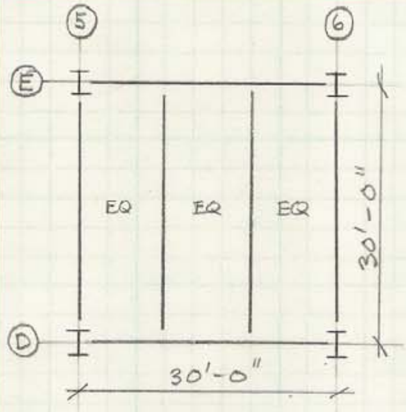
http://permittingservices.montgomerycountymd.gov/dpstmpl.asp?url=/permitting/bc/nfbldc.asp

TYPE	CODE/EDITION	LOCAL AMENDMENTS		EFFECTIVE DATE
		Yes	No	
Commercial Building Code	ICC International Building Code/2003	X		04-01-2005
	MBRC Maryland Building Rehabilitation Code		X	06-01-2001
Residential Building, Energy & Mechanical Code	ICC International Residential Code/2003	X		04-01-2005
	MBRC Maryland Building Rehabilitation Code		X	06-01-2001
Electrical Code	NFPA National Electrical Code/2002	X		04-01-2005
Commercial Mechanical Code	ICC International Mechanical Code/2003 ICC International Fuel Gas Code/2003	X		04-01-2005
Plumbing & Gas Code	WSSC Plumbing Code		X	1988
Life-Safety Code	NFPA-101/2003	X		11-28-2006
Fire Alarm Code	NFPA-72/2002	X		11-28-2006
Sprinkler Code	NFPA-13/2002	X		11-28-2006
Residential Sprinkler	NFPA-13D & 13R/2002	X		11-28-2006
Accessibility	COMAR 05.02.02, ADAAG & FFHAG		X	02-01-1995
Energy Conservation (Commercial Buildings)	ICC International Energy Conservation Code/2003	X		04-01-2005

Commercial Construction Design Parameters					
Ground Snow Load	Wind Speed	Spectral Response Acceleration		Wea-thering	Frost Line Depth
		Ss %g	S1 %g		
30 PSF (1.4 kN/m²)	90 mph (145 km/hr)	18.7	6.3	Severe	24 in (610 mm)

APPENDIX E - CALCULATIONS

SILVER SPRING GATEWAY | SILVER SPRING, MD | COMPOSITE STEEL | 1



$f'_c = 3000$ PSI
$f_y = 50$ KSI

$w_{LL} = 1.6(55) = 88$ PSF

$w_{DL} = 1.2(10) = 12$ PSF

$w_u = 100$ PSF

SLAB DESIGN

TRY 4.5" SLAB W/ 19 GA. 2" LOK FLOOR DECK

ALLOWABLE LOAD: 135 PSF > 100 PSF ✓
MAX UNSHORED SPAN = 10.08' > 10' ✓

REINFORCING REQ'D: 0.023 IN^2/FT

$A_{6 \times 6 W1.4 \times 1.4 WWF} = 0.028\ IN^2/FT > 0.023\ IN^2/FT$ ✓

USE 4½" SLAB W/ 19 GA. 2" LOK FLOOR DECK AND 6x6 W1.4 x 1.4 WWF

BEAM DESIGN

$M_u = \frac{100(10)(30)^2}{8000} = 113^{1k}$ W10 x 26 $\phi M_n = 117^{1k}$

ASSUME $a = 1.0$ $Y2 = 4''$ $b_{eff} = 90''$ $\Sigma Q_n < 230$

SHAPE	PNA	ΣQ_n	ϕM_n	# STUDS	WT	I (IN^4)
W10x12	1	177^k	118^{1k}	22	580#	53.8
W10x15	5	113^k	115^{1k}	14	590#	68.9
W10x17	6	89.8^k	118^{1k}	12	630#	81.9
W10x19	7	70.2^k	122^{1k}	10	670#	96.3
W10x22	7	81.1^k	143^{1k}	10	760#	118
W10x26	—	—	117^{1k}	—	780#	144

SILVER SPRING GATEWAY | SILVER SPRING, MD | COMPOSITE STEEL 2

WT OF CONC: $\frac{3.5}{12}(145) = 42.3$ PSF

$\delta_{DL} = \frac{5(.423)(30)^4(1728)}{384(29\,10^3)\,I} \leq 1''$ $\quad I \geq 266$ IN^4

SINCE NONE OF MEMBERS IN THE TABLE MEET THIS REQUIREMENT THE DECK WILL WORK COMPOSITELY WHILE THE STEEL SECTION WILL WORK ALONE

$\delta_{LL} = \frac{5(.55)(30)^4(1728)}{384(29\,10^3)\,I} = \frac{30(12)}{360}$ $\quad I \geq 346$ IN^2

TRY W12 x 45 FOR HEIGHT REQ'TS

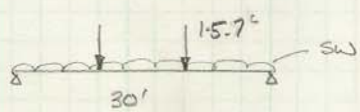
$\delta_{TL} = \frac{5(.645)(30)^4(1728)}{384(29\,10^3)(348)} = 1.16'' < \frac{30(12)}{240}$ ✓

$M_u = \frac{1.045(30)^2}{8} = 117.5^{'k} < 241^{'k}$ ✓

$V_u = \frac{1.045(30)}{2} = 15.7^k < 121^k$ ✓

| USE W12 x 50 A992 NON COMPOSITE |

GIRDER DESIGN



$\delta_T = \frac{(15.7)(30)^3(1728)}{28(29\,10^3)\,I} + \frac{5(.08)(30)^4(1728)}{384(29\,10^3)\,I}$

$I \geq 635$ IN^4

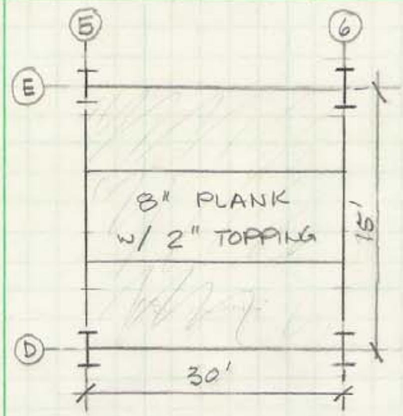
SINCE A W10 x 100 IS 11" MAINTAINING A $14\frac{1}{2}$" STRUCTURE DEPTH IS NOT VALID SO FOR ECONOMY USE A W12 x 79

$M_u = 15.7(10) + \frac{.079(30)^2}{8} = 165.9^{'k} < 446^{'k}$ ✓

$V_u = 15.7 + .079(15) = 16.9^k < 175^k$ ✓

| USE W12 x 79 A992 NON COMPOSITE |

SILVER SPRING GATEWAY | SILVER SPRING, MD | GIRDER - SLAB | . 1



PLANK DL = 60 PSF
LIVE LOAD = 40 PSF
PARTITION = 15 PSF
PLANK f'_c = 5000 PSI
GROUT f'_c = 4000 PSI

DB SPAN = 15'-0"

PLANK SPAN = 30'-0"

NWC : 150 PCF

INITIAL LOAD - PRECOMPOSITE

$$M_{DL} = \frac{(30)(0.06)(15)^2}{8} = 51^{'k} \le 61^{'k} \quad (DB\ 9\times41) \checkmark$$

$$\Delta_{DL} = \frac{5(30)(0.06)(15)^4(1728)}{384(29000)(159)} = 0.44'' < 0.5'' \checkmark$$

TOTAL LOAD - COMPOSITE

$$M_{SUP} = \frac{(30)(.015 + .04 + 0.025)(15)^2}{8} = 67.5^{'k}$$

$$M_{TL} = 51 + 68 = 119^{'k}$$

$$S_{REQ} = \frac{119(12)}{.6(50)} = 47.6\ IN^3 < 68.6\ IN^3 \checkmark$$

$$\Delta_{SUP} = \frac{5(30)(0.08)(15)^4(1728)}{384(29000)(356)} = 0.26'' < 0.5'' \checkmark$$

COMPRESSIVE STRENGTH OF CONCRETE

$$N = \frac{E_s}{E_c} = \frac{29000}{57000\sqrt{4000}} = 8 \qquad S_{tc} = 8(68.6) = 552\ IN^3$$

$$f_c = \frac{67.5(12)}{552} = 1.47\ ksi < F_c = (0.45)(4) = 1.8\ ksi \checkmark$$

SILVER SPRING GATEWAY | SILVER SPRING, MD | GIRDER - SLAB | 2

BOTTOM FLANGE TENSION CAPACITY

$f_b = \frac{51(12)}{50.8} + \frac{68(12)}{80.6} = 22.2 \text{ ksi}$

$F_b = (0.9)(50 \text{ ksi}) = 45 \text{ ksi} > 22.2 \text{ ksi}$ ✓

SHEAR CAPACITY

$TL = 60 + 15 + 40 + 25 = 140 \text{ PSF}$

$w = .145(30) = 4.35^{k/ft}$

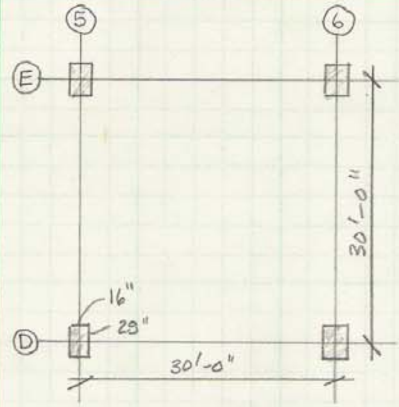
$V = \frac{4.35(15)}{2} = 32.6^{k}$

$f_v = \frac{32.6}{(.375)(5.75)} = 15.13 \text{ ksi}$

$F_v = 0.4(50) = 20 \text{ ksi} > 15.13 \text{ ksi}$ ✓

USE DB 9 x 41 w/ 8" HOLLOW CORE SLABS w/ 2" CONCRETE TOPPING

SILVER SPRING GATEWAY | SILVER SPRING, MD | RC 2-WAY FLAT PLATE | . 1



$f'_c = 4000$ PSI
$f_y = 60000$ PSI

LL = 55 PSF (1.6) = 88 PSF
DL = 10 PSF (1.2) = 12 PSF

TL = 100 PSF + S.W.

NO CAPITALS OR DROP PANELS

$t_{EXIST} = 7''$ $t_{TRIAL} = 9''$

TOTAL STATIC MOMENT

$$M_{o_E} = \frac{0.235\,(30)(30 - 16/12)^2}{8} = 724^{1k}$$

$$M_{o_5} = \frac{0.235\,(30)(30 - 28/12)^2}{8} = 675^{1k}$$

INTERIOR SPAN MOMENT DISTRIBUTION

$M_{o_E}^{+} = 0.35\,(724) = 253^{1k}$

$M_{o_E}^{-} = 0.65\,(724) = 471^{1k}$

$M_{o_5}^{+} = 0.35\,(675) = 236^{1k}$

$M_{o_5}^{-} = 0.65\,(675) = 439^{1k}$

	E		5	
COLUMN STRIP	M^-	M^+	M^-	M^+
TOTAL STATIC MOMENT, ft·k	471	253	439	236
COLUMN STRIP MOMENT, ft-k	353	152	329	142
STRIP WIDTH, b, in	180	180	180	180
EFFECTIVE DEPTH, d, in	7.625	7.625	7.625	7.625
M_n, ft·k	392	169	366	158
R, PSI	450	194	420	181
ρ	.0081	.0033	.0075	.0031
A_s, IN^2	11.12	4.53	10.29	4.25
$A_{s_{min}}$, IN^2	2.92	2.92	2.92	2.92
N	36	15	34	14
N_{min}	10	10	10	10

SILVER SPRING GATEWAY | SILVER SPRING, MD | RC 2-WAY FLAT PLATE | 2

MIDDLE STRIP	E M^-	E M^+	5 M^-	5 M^+
TOTAL STATIC MOMENT, ft·k	471	253	439	236
MIDDLE STRIP MOMENT, ft·k	118	101	110	94
STRIP WIDTH, b, IN	180	180	180	180
EFFECTIVE DEPTH, d, IN	7.625	7.625	7.625	7.625
Mn, ft·k	131	112	122	104
R, PSI	150	128	140	119
ρ	.0026	.0022	.0024	.002
A_s, IN^2	3.57	3.02	3.29	2.75
$A_{s\,min}$, IN^2	2.92	2.92	2.92	2.92
N	12	10	11	10
N min	10	10	10	10

BEAM ACTION SHEAR

$V_u = wA$
$= .235\,(30)(30/2 - 16/24 - 7.625/12) = 96.6^k$

$\phi V_c = 0.75\,(2)(\sqrt{4000})(7.625)(12)(30) = 260^k$ $V_u < \phi V_c$ ✓

PUNCHING SHEAR

$\alpha_c = 40$ $\beta_c = 28/16 = 1.75$ $b_o = 118.5''$

$V_u = wA$
$= .235\,(900 - (23.625)(35.625)/144) = 210^k$

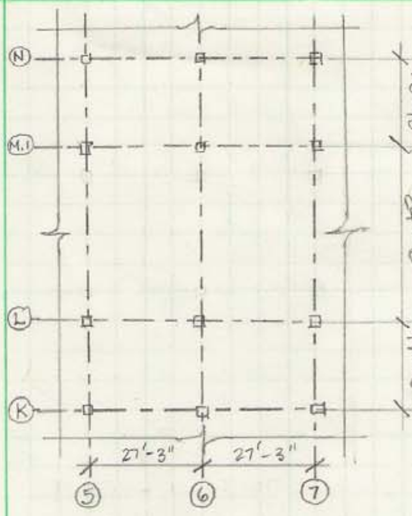
min of:
- 4 ✓
- $2 + 4/1.75 = 4.29$
- $2 + 40(7.625)/118.5 = 4.57$

$\phi V_c = .75\,(4)\sqrt{4000}\,(118.5)(7.625) = 171.^k$ $V_u > \phi V_c$ ✗

NEED 1.4 IN^2 OF SHEAR REINFORCEMENT OR INCREASE SLAB THICKNESS TO 11½"

USED EXISTING COLUMN SIZE WHICH WAS ANALYZED PRIOR.

SILVER SPRING GATEWAY | SILVER SPRING, MD | FRAME ANALYSIS | 1



COLUMNS : 16 x 28
STORY HEIGHT : 9'-1"

f'_c = 5000 PSI (SLAB) 8000 PSI (COL)
w = 150 PCF (COL/SLAB)
f_y = 60000 PSI
f_{pu} = 270,000 PSI

LL = 40 PSF (PARKING GARAGE)

SLAB THICKNESS

$\frac{SPAN}{DEPTH} = \frac{L}{45}$

LONGITUDINAL = $\frac{327}{45}$ = 7.3 IN

TRANSVERSE = $\frac{294}{45}$ = 6.5 IN

USE 7½" THICK SLAB

LOADS AND LOAD BALANCING

DEAD LOAD DUE TO SELF WT. : $\frac{7.5(150)}{12}$ = 93.75 PSF

TOTAL FACTORED LOAD : (1.2)(93.75) + (1.6)(40) = 177 PSF

a_{INT} = 7.5 − 1 − 1 = 5.5 IN (MAX. TENDON SAG)

$F_e = \frac{w_{BAL} L^2}{8a} = \frac{(0.8)(93.75)(27.25)^2}{8(5.5/12)} = 15.19$ k/ft

ASSUME 14 ksi LONG TERM LOSSES AND ½" Φ STRAND

$0.153(0.7)(270) - 14) = 26.8^k$

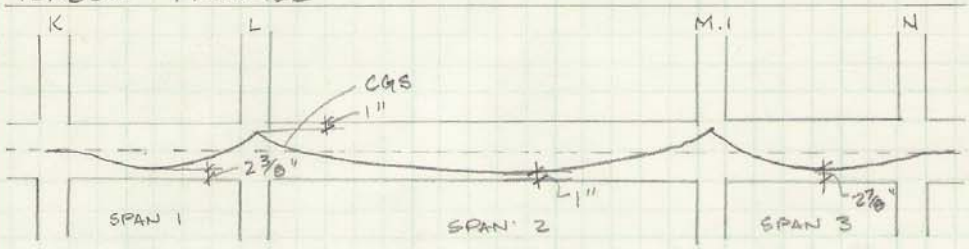
$\frac{27.25(15.19)}{26.8^k}$ = 15.4 TENDONS USE 16 TENDONS

SILVER SPRING GATEWAY | SILVER SPRING, MD | FRAME ANALYSIS | 2

$F_e = \frac{16(26.8)}{27.25} = 15.74 \text{ k/ft}$

$F/A = 15.74/(7.5 \times 12) = 0.174 \text{ ksi}$

TENDON PROFILE



$W_{BAL} = \frac{8F_e a}{L^2} = \frac{8(15.74)(5.5/12)}{(24.5)} = 0.096 \text{ ksi}$

$a_1 = \frac{W_{BAL} L^2}{8F_e} = \frac{0.096(17.5)^2}{8(15.74)} = 2.81"$

MIDSPAN CGS = $(3.75 + 6.5)/2 - 2.81 = 2.315 \Rightarrow 2\frac{3}{8}"$

ACTUAL SAG = $(3.75 + 6.5)/2 - 2.375 = 2.75"$

ACTUAL BALANCED LOAD = $\frac{8(15.74)(2.75/12)}{(17.5)^2} = 0.094 \text{ ksf}$

$a_3 = \frac{0.096(15.83)^2}{8(15.74)} = 2.29"$

MID SPAN CGS = $(3.75 + 6.5)/2 - 2.29 = 2.83 \Rightarrow 2\frac{7}{8}"$

ACTUAL BALANCED LOAD = $\frac{8(15.74)(2.875/12)}{(15.83)^2} = 0.120 \text{ ksf}$

NET LOAD CAUSING BENDING:

SPAN 2:

$W_{NET} = 0.13375 - 0.096 = 0.0378 \text{ ksf}$

SPAN 1:

$W_{NET} = 0.13375 - 0.094 = 0.0398 \text{ ksf}$

SPAN 3:

$W_{NET} = 0.13375 - 0.120 = 0.0138 \text{ ksf}$

SILVER SPRING GATEWAY | SILVER SPRING, MD | FRAME ANALYSIS | 3

EQUIVALENT FRAME

COLUMN STIFFNESS:

$$I = \frac{16(28)^3}{12} = 29270 \text{ in}^4$$

$$E = \frac{57000\sqrt{8000}}{57000\sqrt{5000}} = 1.265$$

$$K_c = \frac{4(1.265)(29270)}{109 - 2(7.5)} = 1575.6 \text{ in}^3$$

TORSIONAL STIFFNESS:

$$C = \left(1 - 0.63\left(\frac{7.5}{28}\right)\right)\left(\frac{(7.5)^3(28)}{3}\right) = 3273 \text{ in}^4$$

$$K_t = \frac{9(3273)(1.265)}{(327)\left(1 - \frac{1.33}{27.25}\right)^3} = 132.5 \text{ in}^3$$

$$K_{EC}(\text{EXT}) = \left(\frac{1}{3151.2} + \frac{1}{265}\right)^{-1} = 244 \text{ in}^3 \quad K_{EC}(\text{INT}) = 244 \text{ in}^3$$

SLAB STIFFNESS:

$$K_{s_1} = \frac{4(1.265)(27.25)(7.5)^3}{(12)(17.5) - 14} = 297 \text{ in}^3$$

$$K_{s_2} = \frac{4(1.265)(27.25)(7.5)^3}{(12)(24.5) - 14} = 208 \text{ in}^3$$

$$K_{s_3} = \frac{4(1.265)(27.25)(7.5)^3}{(12)(15.83) - 14} = 331 \text{ in}^3$$

DISTRIBUTION FACTORS AND FEMs:

SPAN 1: $0.0398(17.5)^2/12 = 1.02^{\,\prime k}$

SPAN 2: $0.0378(24.5)^2/12 = 1.89^{\,\prime k}$

SPAN 3: $0.0138(15.83)^2/12 = 0.29^{\,\prime k}$

SPAN EXT_1: $297/(297+244) = 0.55$

SPAN EXT_3: $331/(331+244) = 0.58$

SPAN INT_1: 0.28 SPAN INT_2: 0.19 SPAN INT_3 = 0.31

SILVER SPRING GATEWAY | SILVER SPRING, MD | FRAME ANALYSIS | 4

	K		L		M, I		N
DF	0.55	0.28	0.19	0.19	0.31	0.58	
FEM	-1.02	+1.02	-1.89	+1.89	-0.29	+0.29	
DIST	+0.57	+0.24	+0.63	-0.30	-0.5	-0.17	
CO	+0.12	+0.29	-0.15	+0.32	-0.9	-0.025	
DIST	-0.07	-0.04	-0.03	+0.11	+0.18	+0.015	
	-0.4	1.51	-1.44	2.02	-1.51	+0.11	

NET TENSILE STRESSES

@ FACE OF COLUMN L6

$$-M_{max} = -1.44 + \frac{1}{3}\left(\frac{0.0398\,(24.5)}{2}\right)\frac{28}{12} = -1.06\ ^{'k}$$

$$S = bh^2/6 = 12\,(7.5)^2/6 = 112.5\ in^3$$

$$f_{t,b} = -f_{pc} \pm \frac{M_{net}}{S_{tb}} = -0.174 \pm \frac{12\,(1.06)}{112.5}$$

$f_{t,b} = -0.06\,;\ -0.287$ ksi (NO TENSION)

ALLOWABLE COMPRESSION

$0.6 f'_c = 3$ ksi
$0.45 f'_c = 2.25$ ksi > 0.287 ✓

@ MIDSPAN OF SPAN 2

$$+M_{max} = \frac{(0.0378)(24.5)^2}{8} - 1.89 = 0.946$$

$$f_{t,b} = -f_{pc} \pm \frac{M_{net}}{S} = -0.174 \pm \frac{12\,(0.946)}{112.5}$$

$f_{t,b} = -0.073\,;\ -0.275$ ksi (NO TENSION)

$0.275 < 2.25\,;\ 3$ ksi ✓

FLEXURAL CAPACITY

$FEM_1 = 0.096\,(17.5)^2/12 = 2.45\ ^{'k}$

$FEM_2 = 0.094\,(24.5)^2/12 = 4.70\ ^{'k}$

$FEM_3 = 0.120\,(15.83)^2/12 = 2.51\ ^{'k}$

SILVER SPRING GATEWAY | SILVER SPRING, MD | FRAME ANALYSIS | 5

	K	L		M.1		N
DF	0.55	0.28	0.19	0.19	0.31	0.53
FEM	-2.45	2.45	-4.70	4.70	-2.51	2.51
D	+1.35	+.63	+.43	-.42	-.68	-1.46
CO	.32	.675	-.21	.22	-.73	-.34
D	-.18	-.13	-.09	.097	.16	.197
	-0.96	3.63	-4.57	-4.60	-3.76	0.91

SECONDARY MOMENTS:

AT EXTERIOR COLUMN:

$M_1 = 0.96 - 15.74(0)/12 = -0.96^{1k}$ $M_3 = 0.91^{1k}$

AT INTERIOR COLUMN

$M_1 = 3.63 - (15.74)(2.75)/12 = 0.023^{1k}$

$M_3 = 3.76 - 3.61 = 0.153^{1k}$

$M_2 = 4.6 - (15.74)(2.75)/12 = 0.993^{1k}$

FACTORED LOAD

$FEM_1 = 0.177(17.5)^2/12 = 4.52^{1k}$

$FEM_2 = 0.177(24.5)^2/12 = 8.85^{1k}$

$FEM_3 = 0.177(15.83)^2/12 = 3.70^{1k}$

	K	L		M.1		N
DF	0.55	0.28	0.19	0.19	0.31	0.58
FEM	-4.52	4.52	-8.85	8.85	-3.70	3.7
D	2.49	1.21	0.82	-0.98	-1.6	-2.15
CO	0.605	1.25	-0.49	0.41	-1.08	-0.8
D	-0.33	-0.21	-0.14	0.13	0.9	0.46
	-1.66	6.77	-8.66	8.41	5.48	1.21
SM	-0.96	0.023	-0.993	-0.993	-0.153	.91
@ COL	2.62	6.79	-9.65	9.4	5.33	2.12

DESIGN MOMENTS @ MID SPAN

SPAN 1:

$V_{EXT} = \frac{0.177(17.5)}{2} - \frac{6.79 - 2.62}{17.5} = 1.31\ k/ft$

$V_{INT} = 1.79\ k/ft$

SILVER SPRING GATEWAY | SILVER SPRING, MD | FRAME ANALYSIS | 6

POINT OF ZERO SHEAR AND MAX. MOMENT:

$x = 1.31 / 0.177 = 7.40$ FT FROM COL ℄

SPAN 1: POSITIVE MOMENT

$M_{max} = 0.5(1.31)(7.4) - 2.62 = 2.23$ FT·K/FT

SPAN 2: $V = \frac{0.177(24.5)}{2} = 2.17$ k/ft

$M_{max} = -9.65 + 0.5(2.17)(12.25) = 3.64$ FT·K/FT

FLEXURAL STRENGTH

CAPACITY CHECK AT INT. SUPPORT.

$A_s = 0.00075 A_{cf}$

$= 0.00075(7.5)(27.25)(12) = 1.84\ IN^2$

TRY (6) #5 @ 6" O.C.

BAR LENGTH $= 2(24.5 - 28/12)/6 + 28/12 = 9'-9"$

$A_s = \frac{6(0.31)}{27.25} = 0.068\ IN^2/FT$

$f_{ps} = f_{pe} + 10000 + \frac{f'_c}{300\rho_p}$

$\rho_p = \frac{A_{ps}}{bd} = \frac{16(0.153)}{27.25(12)(6.5)} = 0.001152$

$f_{se} = (0.7(270) - 14) = 175$ ksi

$f_{ps} = 175 + 10 + \frac{5}{0.001152 \times 300} = 199.5$ ksi

$f_{ps} < 0.85(270) = 230$ ksi ✓

$f_{ps} < f_{se} + 30 = 175 + 30 = 205$ ksi ✓

SILVER SPRING GATEWAY | SILVER SPRING, MD | FRAME ANALYSIS | 7

$F_{SU} = \frac{199.5(0.153)(16)}{27.25} = 17.92$ k/ft

$F_U = 60 \times 0.068 = 4.08$ k/ft

$F_T = 22$ k/ft

$a = \frac{F}{0.85bf'_c} = \frac{22}{0.85(12)5} = 0.43$ IN

$\varepsilon_t = \frac{(6.5 - 0.57)(0.003)}{0.43/0.85} = 0.0352$

$d - a/2 = \left(6.5 - \frac{0.43}{2}\right)/12 = 0.524$

$\phi M_n = 0.9(0.524)(22) = 10.37$ ft-k/ft > 9.65 ft·k/ft ✓

PERMISSIBLE CHANGE IN NEG. MOMENT

$1000\varepsilon_t = 1000(0.0352) = 35\% > 20\%$ MAX

AVAILABLE INCREASE: $0.2(9.65) = 1.93$ ft·k/ft

$10.37 - 9.65 = 0.72 < 1.93$ AVAILABLE ✓

M_{MIN}^{+} IN SPAN 2:

$3.64 - 0.72 = 2.92$ ft-k/ft

CAPACITY @ MID-SPAN OF SPAN 2

$A_{ps}f_{ps} = 17.92$ k/ft

$a = \frac{17.92}{0.85(12)(5)} = 0.351$ IN

$\phi M_n = 0.9(17.92)\left(\frac{6.5 - 0.35/2}{12}\right) = 8.5$ ft·k/ft > 2.92 ft·k/ft ✓

CAPACITY @ MID SPAN OF SPAN 1

$\phi M_n = 0.9(17.92)(4.125 - 0.175)/12 = 5.31$ ft-k/ft > 2.23 'k/' ✓

CAPACITY @ MID-SPAN OF SPAN 3

$\phi M_n = 0.9(17.92)(3.625 - 0.175)/12$

$= 4.64^{1k/1} > 1.94^{1k/1}$ ✓

EXTERIOR COLUMNS:

$A_{S\,MIN} = 0.00075(27.25)(12)(7.5) = 1.84 \text{ IN}^2$

TRY (6) #5 @ 6" O.C.

$A_S = 6(.31)/27.25 = 0.068 \text{ IN}^2/\text{FT}$

$A_s f_y = 4.08 \text{ k/ft}$

$\rho_p = \frac{A_{PS}}{bd} = \frac{16(0.153)}{(27.25)(12)(3.75)} = .001996$

$f_{se} = 0.7(270) - 14 = 175 \text{ ksi}$

$f_{ps} = 175 + 10 + \frac{5}{(0.001996)(300)} = 193.35 \text{ ksi}$

$A_{ps} f_{ps} = 16(0.153)(193.35)/27.25 = 17.37 \text{ k/ft}$

$a = \frac{17.37 + 4.08}{0.85(12)(5)} = 0.421 \text{ IN}$

TENDONS:

$d - a/2 = 3.75 - 0.421/2 = \frac{3.54 \text{ IN}}{12} = 0.295$

REBAR

$d - a/2 = 6.5 - 0.421/2 = \frac{6.29 \text{ IN}}{12} = 0.524$

$\phi M_n = 0.9((17.37)(0.295) + (4.08)(0.524))$

$= 6.54^{1k/1} > 2.62^{1k/1}$ ✓

SHEAR CAPACITY AT EXTERIOR COLUMN

$V_{u_K} = 1.31(27.25) = 35.7^k$ $\quad M_{TRANS} = 27.25(2.62) = 71.4^{1k}$

$V_{u_N} = 1.2(27.25) = 32.7^k$ $\quad M_{TRANS} = 27.25(2.12) = 57.8^{1k}$

SILVER SPRING GATEWAY | SILVER SPRING, MD | FRAME ANALYSIS | 9

$d = 0.8(7.5) = 6$ IN $b_1 = 16 + 3 = 19$ IN
$C_1 = 16$ $b_2 = 28 + 6 = 34$ IN
$C_2 = 28$

$$A_c = ((2)(19) + 34)6 = 432 \text{ IN}^2$$

$$J_c/c = [2(19)(6)(19+68) + 6^3(38+34)/19]/6 = 3442 \text{ IN}^3$$

$$\gamma_V = 1 - \frac{1}{1 + \frac{2}{3}\sqrt{\frac{19}{34}}} = 0.333$$

$$V_{u_K} = \frac{V_u}{A_c} + \frac{\gamma_V M_u}{J/c}$$

$$= \frac{35700}{432} + \frac{0.33(71.4)(1000)(12)}{3442} = 165 \text{ PSI}$$

$$V_{u_N} = \frac{32700}{432} + \frac{0.33(57800)(12)}{3442} = 142 \text{ PSI}$$

$$V_c = 4\sqrt{5000} = 283 \text{ PSI} \quad \phi V_n = 0.75(283) = 212 \text{ PSI}$$

212 PSI > 165 PSI > 142 PSI ✓

SHEAR CAPACITY AT INTERIOR COLUMN

$d = 6$ IN $b_1 = 34$ IN $V_u = (1.79 + 2.17)27.25 = 108^K$
$C_1 = 28$ IN $b_2 = 22$ IN $M_u = (27.25)(2.86) = 77.9^{'K}$
$C_2 = 16$ IN

$$A_c = 2(34+22)6 = 672 \text{ IN}^2$$

$$J_c/c = [(34)(6)(34+66) + 6^3]/3 = 6872 \text{ IN}^3$$

$$\gamma_V = 1 - \frac{1}{1 + \frac{2}{3}\sqrt{\frac{34}{22}}} = 0.45$$

$$V_u = \frac{108000}{672} + \frac{0.45(77.9)(1000)(12)}{6872} = 222 \text{ PSI}$$

$$\phi V_n = 0.75(3.5\sqrt{5000} + (0.3)(174)) = 225 > 222 \text{ PSI} \checkmark$$

SILVER SPRING GATEWAY | SILVER SPRING, MD | COLUMN DESIGN | 1

COLUMN DESIGN

LEVEL	A_T	A_I	LL_{RED}
2	900 SF	3600 SF	0.5
8	6300 SF	25200 SF	0.34 (0.4)
15	12600 SF	50400 SF	0.32 (0.4)

ROOF LL : 30 (900) = 27^k
ROOF DL : 100 (900) = 90^k
FLR LL : 55 (900) = 49.5^k
FLR DL : 90 (900) = 81^k

$L = 9'-1''$
$K = 1.0$

$$P_2 = (1.2)(90+81) + 0.5(27) + 1.6(.5)(49.5) = 258^k$$
$$P_8 = (1.2)(90+(7)(81)) + 0.5(27) + 1.6(.4)(49.5)(7) = 1024^k$$
$$P_{15} = (1.2)(90+14(81)) + 0.5(27) + 1.6(.4)(49.5)(14) = 1926^k$$

COLUMN SIZES			
	W14x43	$\phi P_n = 447^k$	$> 258^k$
	W14x90	$\phi P_n = 1120^k$	$> 1024^k$
	W14x159	$\phi P_n = 1990^k$	$> 1926^k$

CONCRETE:

$K_n = 1.0 \quad R_n = 0.0$

$$1.0 = \frac{P_n}{f'_c A_g}$$

$\rho = 0.01$

LEVEL	f'_c
2	4000
8	6000
15	8000

COLUMN SIZES:	P_n	A_g / A_s	SIZE
	258^k	64.5 / 0.645	16x16 w/ (4) #4
	1024^k	170.6 / 1.71	16x16 w/ (6) #5
	1926^k	240.75 / 2.41	16x16 w/ (8) #5

APPENDIX F – ALTERNATIVE FLOOR SYSTEM COMPARISON TABLE

Floor System	Depth	Relative Cost Outlook	Architectural Intrusion	Feasibility Criteria: Fire Protection		Sound Transmission		Construction Type Classification	Finished Ceiling Required	Acceptible System for Further Investigation
				Unprotected	Maximum Protected Hours	Impact	Airbourne			
Composite Steel Frame	Approx. 17"	Moderate	Column Relocation	-	1 - 4	Poor	Fair	1, 2, and 3	Yes	No
Two-way Reinforced Concrete Flat Plate	9" - 11 1/2"	Low	None	1 - 4	3 - 4	Good	Good	1 and 2	No	Yes
Girder-Slab	8"	Moderate - High	Extra Column and Column Relocation	-	1 - 4	Fair	Fair	1, 2, and 3	No	No
Post-tensioned Lift-Slab	7" - 9"	Moderate	Column Relocation	1 - 4	3 - 4	Good	Good	1, 2, and 3	No	Yes
Two-way Post-tensioned Concrete Flat Plate	7" - 9"	Low	Existing System	1 - 4	3 - 4	Good	Good	1 and 2	No	Yes