SILVER SPRING GATEWAY
Structural Concepts and Existing Conditions Report

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 structural concepts and existing conditions report contains the description of the physical existing conditions of the structure of the Silver Spring Gateway including information relative to design concepts and required loading per code. This report also discusses the relevant design codes and confirmation through structural analysis of the Silver Spring Gateway's structural strength and serviceability.

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.

Structural Analysis Results

The scope of this report includes the analysis of the floor system and one lateral resisting component utilizing IBC 2003, ASCE 7-05, and the PTI *Post-Tensioning Manual* 6th Edition. The floor system was analyzed in the parking garage area since it maintained a regular grid layout. The floor system design resulted in a 7 ½ inches thick concrete slab with sixteen tendons uniformly distributed in the East-West direction and banded over the column lines in the North-South direction. The slab thickness is the only discrepancy in the designs. The accuracy of the designs indicates the validity of the assumptions, since the discrepancy between the designs is most likely related to the use of updated codes and standards and the use of different loads and load cases.

A column within this frame was analyzed as well. The live load was reduced as permitted by ASCE 7-05 and the total moment and axial load subjected on the column fell well within the interaction diagram for the column proving its structural adequacy in strength.

Three shear walls resist the lateral loads for the mixed-use high rise building. After determining the loads, the base shear and overturning moment related to wind pressure was the governing lateral load. This load was assumed to distribute equally among the shear walls for the analysis. The design resulted in a twelve inches thick concrete shear wall reinforced with two curtains of #4 horizontal and vertical bars spaced at eight inches on center and uses the boundary columns for extra stiffness. The existing system differs only in reinforcement by using #5 bars instead. The accuracy between the two designs indicates valid assumptions as the discrepancy can be indicted on the use of the most recent ASCE 7 instead of the referenced version and/or different loads and assumed weights.

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INTRODUCTION

This structural concepts and existing conditions report contains the description of the physical existing conditions of the structure of the Silver Spring Gateway including information relative to design concepts and required loading per code. It provides an overview of all the structural components of the high-rise including, but not limited to, the general floor framing, structural slabs, lateral resisting system, foundation system, bracing elements, and the support of the exterior envelope system of the building. This report also discusses the relevant design codes and confirmation through structural analysis of the Silver Spring Gateway's structural strength and serviceability.

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 4). 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 following documents, listed in ascending chronological order, were either furnished for review or otherwise considered:

- *Design of Prestressed Concrete* authored by Arthur H. Nilson published in 1987 by John Wiley & Sons, Inc.
- *Recommendations for Concrete Members Prestressed with Unbonded Tendons* published in the ACI Structural Journal May-June 1989 issue by ACI-ASCE Joint Committee 423
- *International Building Code 2003* (IBC 2003) published 16 February 2003 by the International Code Council
- Geotechnical Report dated 13 May 2005 by GeoConcepts Engineering, Inc. (GCE)
- 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 13th 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*, 6th Edition published in 2006 by the Post-Tensioning Institute
- 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)

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.

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. 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 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:

Gravity Loads

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
	Cold-formed, light gauge steel stud wall with insulation and 5/8" gypsum wall board	5 psf	WDG
	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.
	Miscellaneous	10 psf	
Live Load	Assembly and Pool Space	100 psf	ASCE 7
	Roof	20 psf	ASCE 7
Snow Load	Ground Snow Load	30 psf	Montgomery County
	Terrain Category	B	ASCE 7
	C_e Exposure Factor	1.0	ASCE 7
	C_t Thermal Factor	1.0	ASCE 7
	Importance Factor	1.0	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

The Silver Spring Gateway has fifteen stories that must resist lateral loads created by wind and earthquakes. ASCE 7 contains design parameters to determine the magnitude of these loads. Wind loading is equated to varying pressures on the windward side of the structure and a constant pressure on the leeward side. The Silver Spring Gateway is 143 feet tall; therefore, the Analytical Method is required to determine the pressures. The following lists the parameters for the Analytical Method:

- Basic Wind Speed, V — 90 mph (Appendix D)
- Wind Directionality Factor, K_d — 0.85
- Importance Factor, *I* — 1.0
- Exposure Category — B
- Velocity Pressure Coefficient, K_z — Case 2
- Topographic Factor, K_{zt} — 1.0
- Gust Effect Factor, G — 0.81
- Enclosure Classification — Enclosed
- Internal Pressure Coefficient, GC_{pi} — ±0.18
- External Pressure Coefficient, GC_{pf} — 0.8 (Windward); -0.5 N-S and -0.48 E-W (Leeward)

Using these parameters and the equations provided by ASCE 7 for a flexible structure, the wind pressure in pounds per square inch (psf) at various heights are recorded in the table below:

Wind Pressures (North-South)			
Height (ft)	Windward (psf)	Leeward (psf)	Total (psf)
0-15	7.93	-10.75	18.68
20	8.62	-10.75	19.38
25	9.18	-10.75	19.93
30	9.74	-10.75	20.49
40	10.57	-10.75	21.32
50	11.26	-10.75	22.02
60	11.82	-10.75	22.58
70	12.38	-10.75	23.13
80	12.93	-10.75	23.69
90	13.35	-10.75	24.11
100	13.77	-10.75	24.52
120	14.46	-10.75	25.22
140	15.16	-10.75	25.91
143	15.22	-10.75	25.98

Wind Pressures (East-West)			
Height (ft)	Windward (psf)	Leeward (psf)	Total (psf)
0-15	7.93	-10.46	18.74
20	8.62	-10.46	19.43
25	9.18	-10.46	19.99
30	9.74	-10.46	20.55
40	10.57	-10.46	21.38
50	11.26	-10.46	22.07
60	11.82	-10.46	22.63
70	12.38	-10.46	23.19
80	12.93	-10.46	23.74
90	13.35	-10.46	24.16
100	13.77	-10.46	24.58
120	14.46	-10.46	25.27
140	15.16	-10.46	25.97
143	15.22	-10.46	26.03

These pressures along with the information presented in Appendix E result in a total base shear of 932 kips in the North-South direction and 850 kips in the East-West direction and a total overturning moment of 65,225 foot-kips in the North-South direction and 59,500 foot-kips in the East-West direction.

Seismic loading is equated to lateral forces on each story based on the total base shear due to building weight and other parameters and provisions listed in ASCE 7. Since the Silver Spring Gateway falls in Seismic Design Category A, the Equivalent Lateral Force Procedure is valid. The provisions to determine the total base shear, V, are listed below:

- Short Period MCE Spectral Response Acceleration, S_S — 18.7% (Appendix D)
- One Second Period MCE Spectral Response Acceleration, S_1 — 6.3% (Appendix D)
- Site Class — B
- Site Coefficients, F_a and F_v — 1.0
- Short Period Design Spectral Response Acceleration, S_{DS} — 12.47%
- One Second Period Design Spectral Response Acceleration, S_{D1} — 4.2%
- Seismic Use Group — I
- Importance Factor, *I* — 1.0
- Response Modification Factor, R — 5.0
- Fundamental Period, T — 1.32 seconds
- Seismic Response Coefficient, C_S — 0.00635

These parameters along with the information presented in Appendix E result in a total base shear of 549 kips and a total overturning moment of 54,664 foot-kips. Since these lateral load values are less than those developed from wind loading, the wind load will govern the design of the lateral load resisting system.

STRUCTURAL DESIGN DISCUSSION:

Typical Floor Frame

The Silver Spring Gateway was designed with an irregular column layout. This presents a challenge in the design of a two way flat plate post tensioned slab; however, one location in the parking garage has a regular grid of columns. This location will be used in order to complete a simplified analysis (Figure 8). The slab and column frame span the length of building, but for simplicity, the frame will encompass only four columns (Figure 9). With these stipulations and the procedure presented in the *Post Tensioning Manual* as well as other references listed, the calculations resulted in a 7 ½ inches thick flat plate slab with sixteen post tensioned tendons uniformly distributed in the East-West direction and banded over the column lines in the North-South direction. The existing structure consists of a 9 inches thick flat plate slab with seventeen tendons uniformly distributed in the East-West direction and sixteen tendons banded over the column lines in the North-South direction. The accuracy of the designs indicates the validity of the assumptions, since the discrepancy between the designs is related to the use of updated codes and standards and the use of different loads and load cases. The drawings indicate a live load of 50 pounds per square foot used in the parking garage; whereas, ASCE 7 requires only 40 pounds per square foot. It should be noted that the live load used in the calculations is equivalent to the live load used in the rest of the Silver Spring Gateway which utilizes a 7 inches thick slab with similar tendon quantities and layout. Overall, the analysis proves valid and the existing structural system is adequately designed. See Appendix F to review the design calculations for the structural frame analysis.

Column

This mixed-use high rise building is supported by 176 reinforced concrete columns. With the transferred moments known from the analyzed frame, one column from the parking garage area will be analyzed. The column supports four levels of parking above which allows for a 20% reduction in the 40 pounds per square foot live load. Since the moment and axial load determined falls within the interaction diagram created for the column, the capacity of the column is adequate for the calculated service loads. See Appendix F to review the design calculations for the structural column analysis.

Shear Wall

The Silver Spring Gateway has three shear walls to resist lateral load (Figure 10). In order to complete the analysis of the shear walls, a few assumptions were made. First, the shear walls in the Silver Spring Gateway vary in compressive strength similar to the columns. B1 to the Seventh Floor has a compressive strength of 8,000 pounds per square inch. The Seventh Floor to the Thirteenth Floor has a compressive strength of 6,000 pounds per square inch. A compressive strength of 4,000 pounds per square inch is specified for the remaining floors. In order to simplify the analysis, the compressive strength of the shear walls was taken as 6,000 pounds per square inch. Another simplifying assumption was to distribute the lateral load due to wind equally among the three shear walls. The assumptions and analysis produced a twelve-inch thick concrete shear wall reinforced with two curtains of #4 horizontal and vertical bars spaced at eight inches on center and uses the boundary columns for extra stiffness. The existing system differs only in reinforcement by using #5 bars instead. The accuracy between the two designs indicates valid assumptions as the discrepancy can be indicted on the use of the most recent ASCE 7 instead of the referenced version and/or different loads and assumed weights. See Appendix F to review the design calculations for the lateral resisting system.

Other Structural Elements

Several structural components have not been analyzed within the scope of this report; however, further attention may be warranted at a later time. The roof uplift for the Silver Spring Gateway was not determined, but the overall roof weight from green areas, ballast, and the swimming pool decreases the significance of this issue. Further detail and analysis should be done regarding the strength of the structural components of the sunscreens, canopies, and building envelop supports and proper load transfer into the structural slab. The high rise also includes a structural steel truss system containing wide flange chords and web members. Analysis of these members for structural strength and serviceability should be done in the future; as well as, its impact on the overall structural scheme.

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 slab also supports the building envelop and the roof top pool. The other structural system, located at the pedestrian bridge, is comprised of structural steel trusses with wide flange chords and web members. Three reinforced concrete shear walls resists the lateral loads subjected on the building. A simplified analysis through general assumptions and limiting focus confirmed the adequacy of the existing structural design based on the most recent codes and standards.

APPENDIX A – 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 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 – 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.

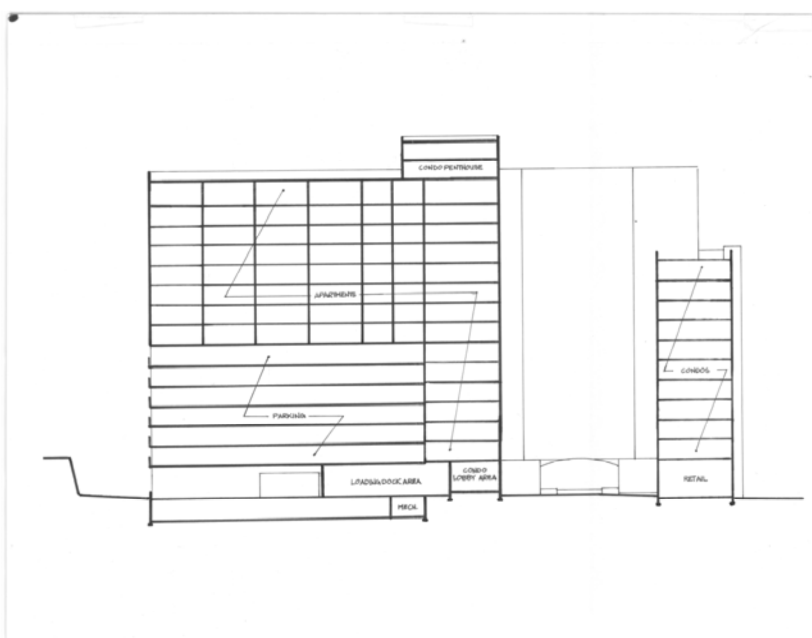


Figure 4: Building section showing occupancies per floor.

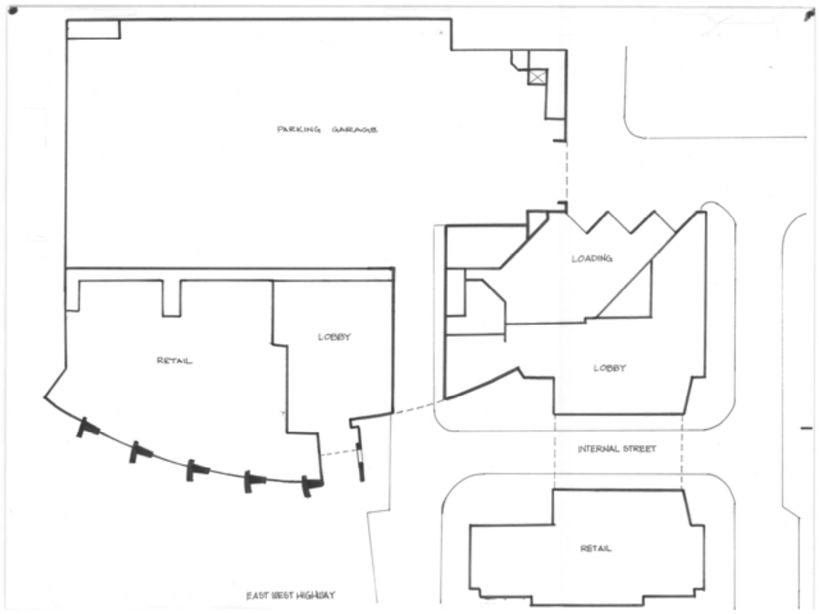


Figure 5: First Floor and Overall Site Plan showing overall shape for lower floors.

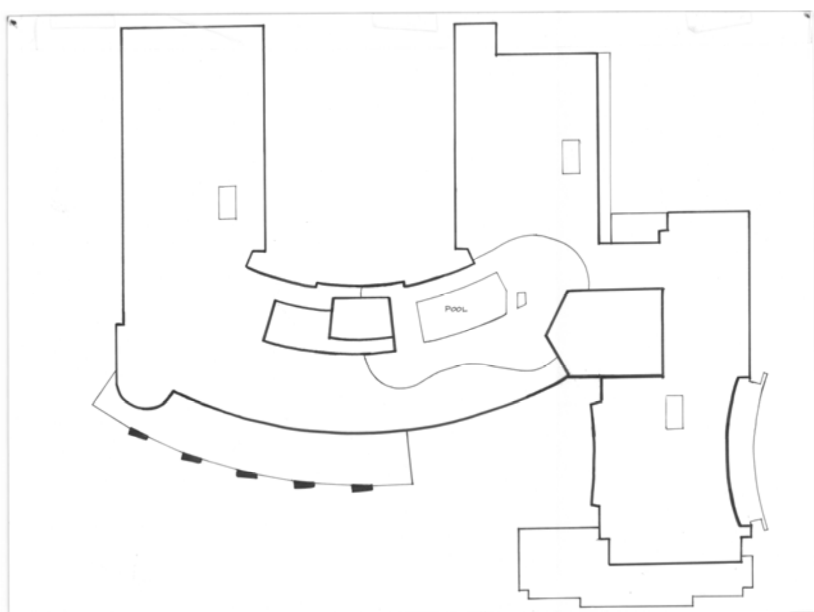


Figure 11: Penthouse Roof Plan showing overall shape of the upper floors and location of penthouse amenities.

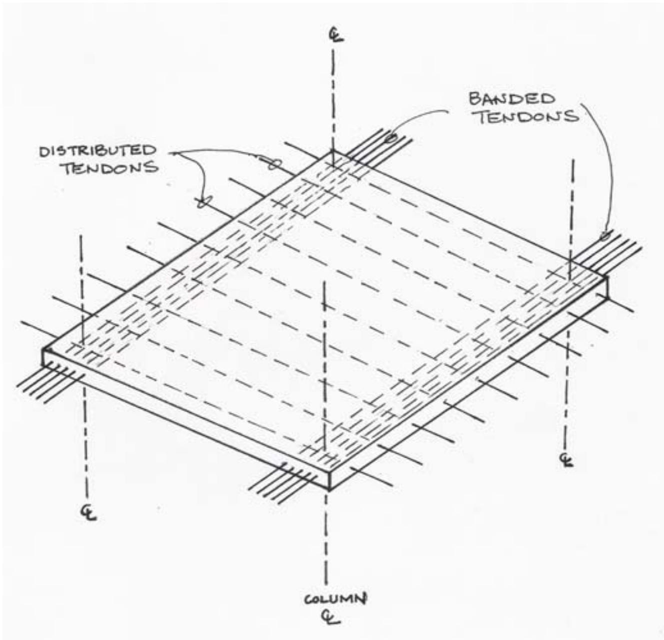


Figure 7: Typical post-tensioning tendon layout.

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

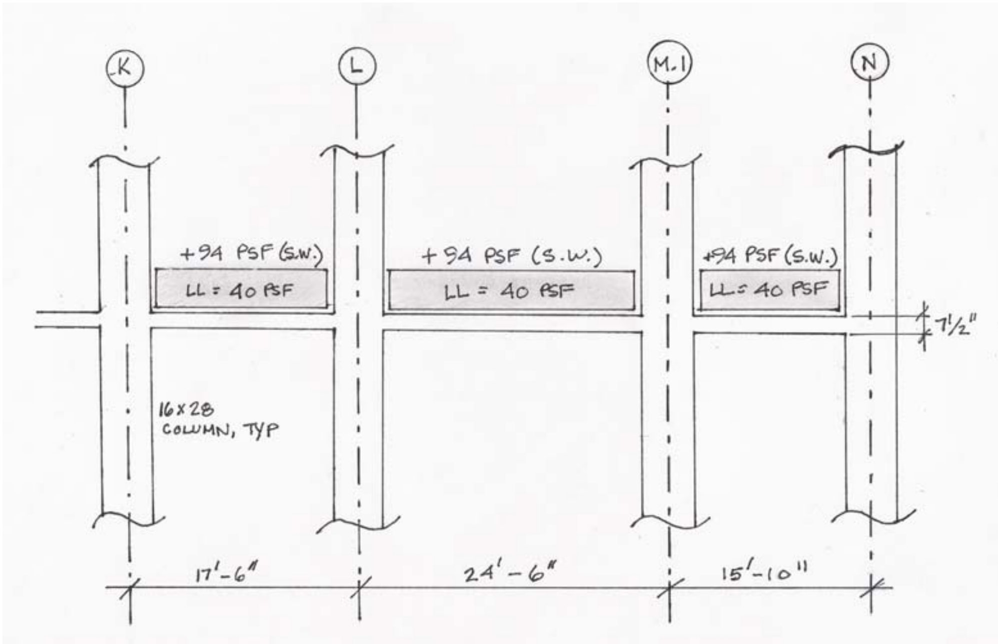


Figure 9: Sketch of analyzed frame with dimensions and loads.

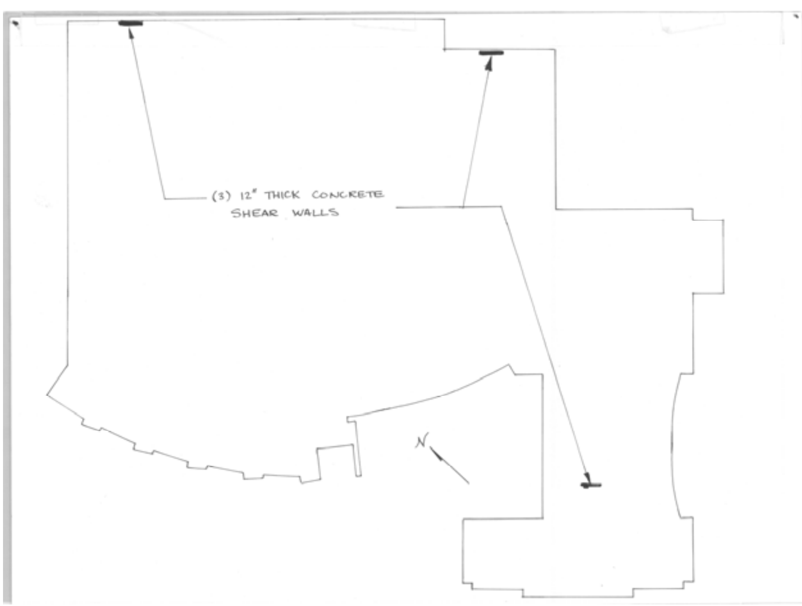


Figure 10: Location of the three shear walls designed to resist the lateral loads.

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 – LATERAL LOAD TABLES

WIND LOADING:

Gust Factor Variables for Silver Spring Gateway						
I_z	c	ž (ft)	g_Q	g_v	h	L_z
0.26	0.3	85.8	3.4	3.4	143	440.022
v	l	g_r	n_1	R	V_z (ft/s)	b
0.33	320	4.26	1.32	0.006262	69.31494	0.45
α	V (mph)	N_1	R_n	R_b	R_h	β
0.25	90	8.379566	0.036428	0.03769	0.07823	1.5

North - South Wind Direction			
B	Q	R_l	G_f
300	0.782617	0.037328	0.81

East- West Wind Direction			
B	Q	R_l	G_f
280	0.787003	0.039939	0.81

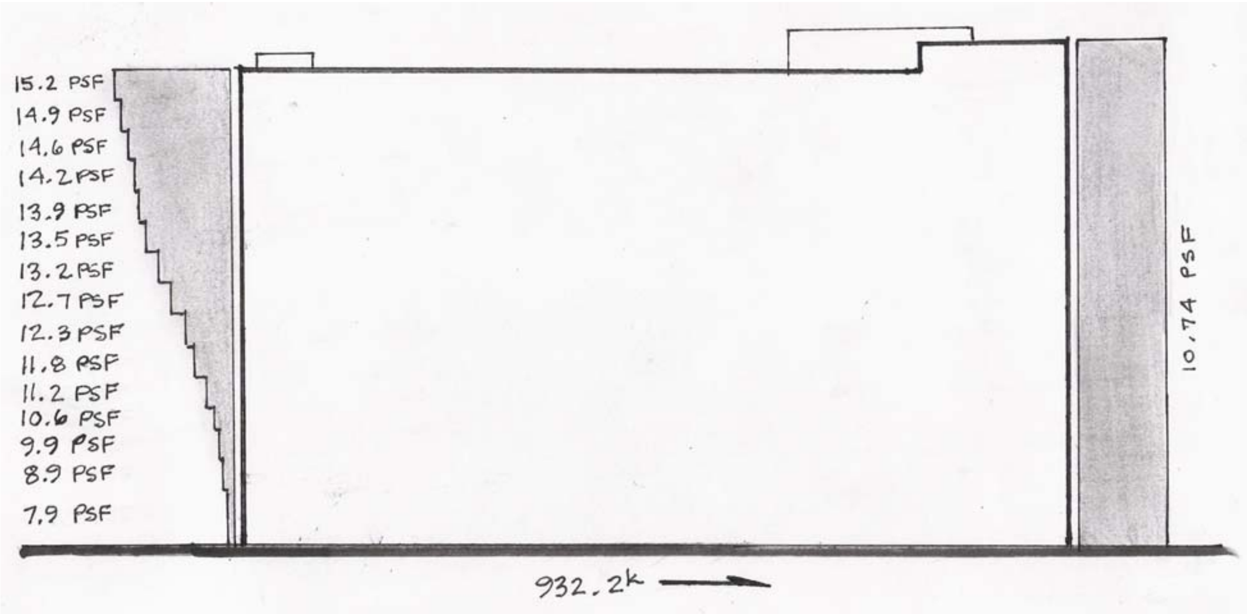
Wind Load Distributed per Floor with resulting Base Shear and Overturning Moment

Wind (North-South)										
Floor	Height (ft)	Tributary Height (Ft)	K_z	q_z (psf)	Windward (psf)	Leeward (psf)	Total (psf)	Story Force (kips)	Story Shear (kips)	Overturning Moment (ft-kips)
Ground	0.00	0.00	0.57	0.00	0.00	0.00	0	0.00	932.20	65224.7
2	13.00	11.04	0.57	9.57	7.93	-10.74	18.67	61.62	932.20	65224.7
3	22.08	9.08	0.64	10.78	8.93	-10.74	19.67	53.41	870.58	56883.0
4	31.17	9.08	0.71	11.90	9.85	-10.74	20.59	55.91	817.17	49217.8
5	40.25	9.08	0.76	12.80	10.60	-10.74	21.34	57.94	761.26	42049.0
6	49.33	9.08	0.81	13.56	11.23	-10.74	21.97	59.66	703.32	35397.4
7	58.42	9.08	0.85	14.24	11.79	-10.74	22.53	61.17	643.66	29279.9
8	67.50	9.08	0.88	14.84	12.28	-10.74	23.03	62.52	582.48	23711.2
9	76.58	9.08	0.92	15.38	12.73	-10.74	23.48	63.75	519.96	18704.3
10	85.67	9.08	0.95	15.88	13.15	-10.74	23.89	64.87	456.21	14270.8
11	94.75	9.08	0.97	16.34	13.53	-10.74	24.28	65.91	391.34	10421.5
12	103.83	9.08	1.00	16.78	13.89	-10.74	24.63	66.89	325.43	7166.1
13	112.92	9.08	1.02	17.18	14.23	-10.74	24.97	67.80	258.54	4513.9
14	122.00	9.08	1.05	17.57	14.55	-10.74	25.29	68.67	190.74	2473.5
15	131.08	10.21	1.07	17.93	14.85	-10.74	25.59	78.09	122.07	1052.8
Roof	142.42	5.67	1.09	18.36	15.20	-10.74	25.95	43.98	43.98	249.4

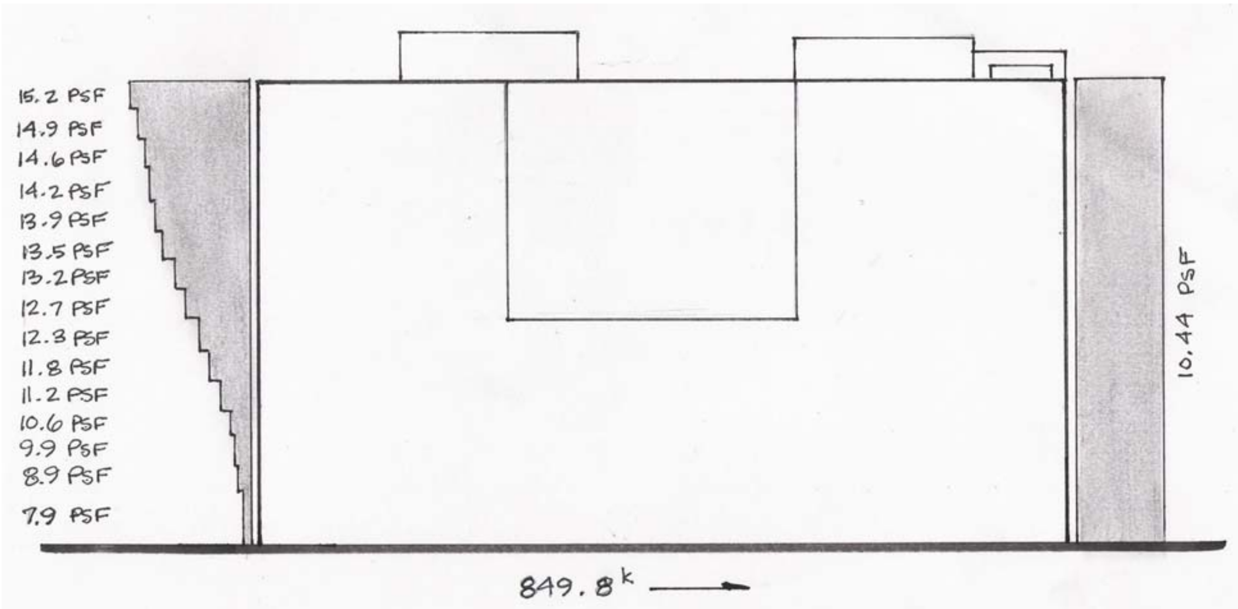
Wind Load Distributed per Floor with resulting Base Shear and Overturning Moment

Wind (East-West)										
Floor	Height (ft)	Tributary Height (Ft)	K_z	q_z (psf)	Windward (psf)	Leeward (psf)	Total (psf)	Story Force (kips)	Story Shear (kips)	Overturning Moment (ft-kips)
Ground	0.00	0.00	0.57	0.00	0.00	0.00	0.00	0.00	849.83	59501.8
2	13.00	11.04	0.57	9.57	7.93	-10.44	18.37	56.01	849.83	59501.8
3	22.08	9.08	0.64	10.78	8.93	-10.44	19.37	48.58	793.83	51896.8
4	31.17	9.08	0.71	11.90	9.85	-10.44	20.29	50.90	745.24	44906.9
5	40.25	9.08	0.76	12.80	10.60	-10.44	21.04	52.77	694.35	38368.7
6	49.33	9.08	0.81	13.56	11.23	-10.44	21.68	54.36	641.58	32301.4
7	58.42	9.08	0.85	14.24	11.79	-10.44	22.23	55.75	587.22	26720.6
8	67.50	9.08	0.88	14.84	12.28	-10.44	22.73	57.00	531.46	21639.9
9	76.58	9.08	0.92	15.38	12.73	-10.44	23.18	58.13	474.46	17071.3
10	85.67	9.08	0.95	15.88	13.15	-10.44	23.59	59.17	416.33	13025.6
11	94.75	9.08	0.97	16.34	13.53	-10.44	23.98	60.13	357.16	9512.6
12	103.83	9.08	1.00	16.78	13.89	-10.44	24.34	61.03	297.03	6541.5
13	112.92	9.08	1.02	17.18	14.23	-10.44	24.67	61.88	236.00	4120.7
14	122.00	9.08	1.05	17.57	14.55	-10.44	24.99	62.68	174.12	2258.1
15	131.08	10.21	1.07	17.93	14.85	-10.44	25.29	71.29	111.44	961.2
Roof	142.42	5.67	1.09	18.36	15.20	-10.44	25.65	40.15	40.15	227.7

Wind Loading Diagram for North – South Direction:



Wind Loading Diagram for East - West Direction:



SEISMIC LOADING:

Since the calculated wind load results in a higher base shear and overturning moment, the values for the seismic load analysis will be presented without a loading diagram.

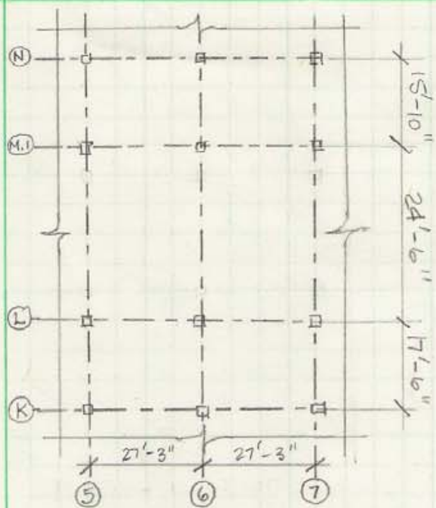
Seismic Parameters for Silver Spring Gateway												
Ss	S_1	Site Class	Fa	Fv	S_{ds}	S_{d1}	SUG	SDC	I	R	Cu	Ta
0.187	0.063	B	1	1	0.12	0.042	I	A	1	5	1.6	0.83
T	Ts	Cs	Roof Dead Load (psf)	Floor Dead Load (psf)	Snow Load (psf)	Wall Load (psf)	W_{roof} (kips)	W_{floor} (kips)	W (kips)	A (ft^2)	P (ft)	V (kips)
1.32	0.34	0.00635	88	108	6	40	4961	5818	86410	50,000	1150	549

Seismic Load Distributed per Floor with resulting Base Shear and Overturning Moment

Floor	Height (ft)	Tributary Height (Ft)	C_{vx}	F_x (kips)	Overturning Moment (ft-kips)
Ground	0.00	0.00	1.00	549	54664
2	13.00	11.04	0.001554	1	54664
3	22.08	9.08	0.004485	2	49683
4	31.17	9.08	0.008934	5	44719
5	40.25	9.08	0.014901	8	39789
6	49.33	9.08	0.022385	12	34919
7	58.42	9.08	0.031387	17	30141
8	67.50	9.08	0.041906	23	25497
9	76.58	9.08	0.053943	30	21036
10	85.67	9.08	0.067498	37	16813
11	94.75	9.08	0.082571	45	12893
12	103.83	9.08	0.099162	54	9347
13	112.92	9.08	0.11727	64	6254
14	122.00	9.08	0.136896	75	3700
15	131.08	10.21	0.158039	87	1779
Roof	142.42	5.67	0.159068	87	495

APPENDIX F - CALCULATIONS

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

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

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

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

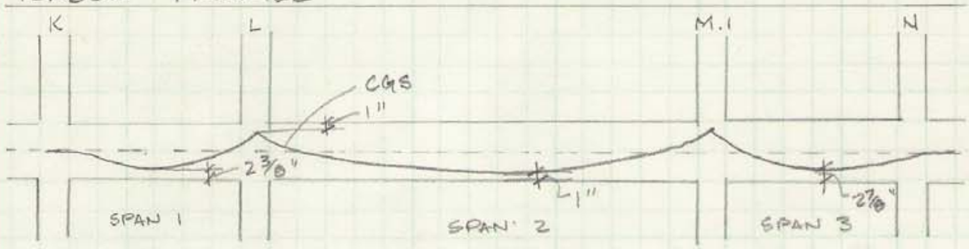
$\frac{27.25(15.19)}{26.8^k}$ = 15.4 TENDONS USE 16 TENDONS

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

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

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

TENDON PROFILE



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

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

MIDSPAN CGS = $(3.75 + 6.5)/2 - 2.81 = 2.315 \Rightarrow 2\,3/8''$

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

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

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

MID SPAN CGS = $(3.75 + 6.5)/2 - 2.29 = 2.83 \Rightarrow 2\,7/8''$

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

NET LOAD CAUSING BENDING:

SPAN 2:

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

SPAN 1:

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

SPAN 3:

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

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:

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

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

$$K_{EC}\ (\text{EXT}) = \left(\frac{1}{3157.2} + \frac{1}{265}\right)^{-1} = 244 \text{ IN}^3 \quad K_{EC}\ (\text{INT}) = 244 \text{ IN}^3$$

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, 1	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	-0.026
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

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

$S = bh^2/6 = 12\,(7.5)^2/6 = 112.5\ \text{IN}^3$

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

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

ALLOWABLE COMPRESSION

$0.6f'_c = 3$ ksi
$0.45f'_c = 2.25$ 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:

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

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

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

$FEM_2 = 0.177(24.8)^2/12 = 8.85^{1k}$

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

	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:

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

$V_{INT} = 1.79$ 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:

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

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

$A_s = 6(.31)/27.25 = 0.068\ IN^2/FT$

$A_s f_y = 4.08\ k/ft$

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

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

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

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

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

TENDONS:

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

REBAR

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

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

$= 6.54^{1k/1} > 2.62^{1k/1}$ ✓

SHEAR CAPACITY AT EXTERIOR COLUMN

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

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

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
$C_2 = 28$

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

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

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

$V_{u_K} = \dfrac{V_u}{A_c} + \dfrac{\gamma_v M_u}{J/c}$

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

$V_{u_{N}} = \dfrac{32700}{432} + \dfrac{0.33(57800)(12)}{3442} = 142$ PSI

$V_c = 4\sqrt{5000} = 283$ PSI $\phi V_n = 0.75(283) = 212$ 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 $M_u = (27.25)(2.86) = 77.9^{\prime k}$
$C_2 = 16$ IN

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

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

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

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

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

SILVER SPRING GATEWAY	SILVER SPRING, MD	FRAME ANALYSIS	10

SHEAR AND FLEXURE CAPACITY ADEQUATE.

USE 7½" FLAT PLATE SLAB W/ 16 TENDONS UNIFORMLY DISTRIBUTED ONE WAY AND BANDED OVER THE COLUMN LINE IN THE OTHER DIRECTION

COLUMN DESIGN (COLUMN L6)

$P_u = (.8)(4)(40)(27.25)(21)(1.6) + (1.2)(93.75)(4)(27.25)(21)$

$= 375^k$

$M_u = 77.9^{'k}$ (FROM PAGE 9)

$f'_c = 6000$ PSI $\quad f_y = 60000$ PSI $\quad A_s = (6)\#10 = 7.62\ \text{IN}^2$

$P_o = 0.85(6)((16)(28) - 7.62) + 7.62(60)$

$= 1954.5^k$

BALANCED POINT:

$c = \dfrac{0.003}{0.003 + \varepsilon_y} d_2 = \dfrac{0.003(26.125)}{.00507} = 15.46''$

$a = \beta_1 c = .75(15.46) = 11.6''$

$\varepsilon_{s1} = \dfrac{0.003}{15.46}(15.46 - 1.875) = 0.00264 > 0.00207$

$f_{s1} = 60$ ksi

$P_b = 0.85(6)(28)(11.6) + (3.81)(60) - (3.81)(60) = 1656.5^k$

$M_b = 1656.5\left(\dfrac{28}{2} - \dfrac{11.6}{2}\right) + 228.6\left(\dfrac{28}{2} - 1.875\right) - 228.6\left(\dfrac{28}{2} - 26.125\right)$

$= 13583.3 + 2771.8 + 2771.8 = 1594^{'k}$

PURE BENDING:

$228.6 = 331.5\,\dfrac{c - 1.875}{c} + 107c \qquad c = 1.98''$

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$\varepsilon_{s1} = \frac{0.003}{1.98}(1.98 - 1.875) = 0.000159$

$f_{s1} = 0.000159(29000) = 4.61$ ksi

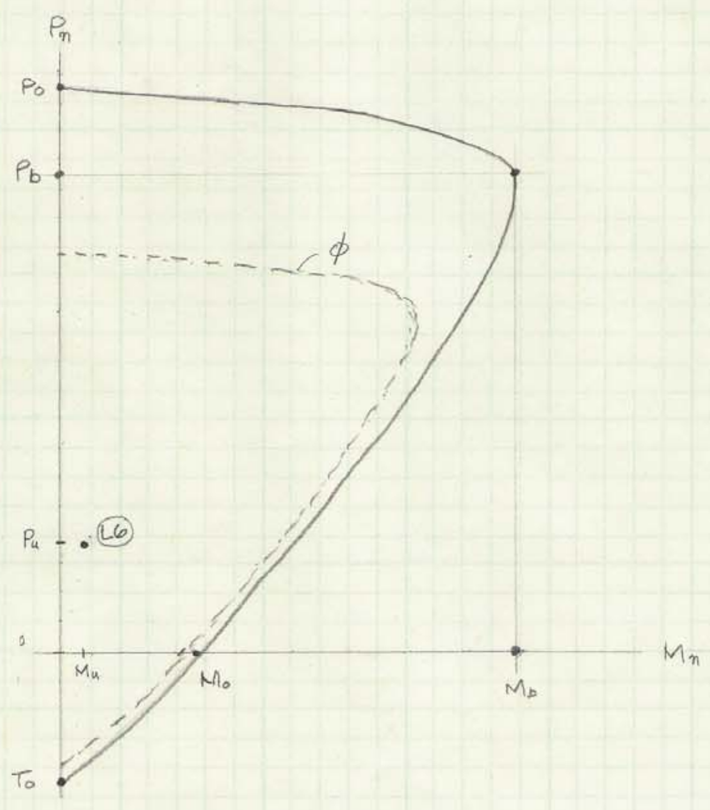
$\varepsilon_{s2} = \frac{0.003}{1.98}(1.98 - 26.125) = -0.0366$

$f_{s2} = -0.0366(29000) = -60$ ksi

$M_o = 0.85(6)(28)(0.75)(1.98)(14 - 0.7425) + 3.81(4.61)(12.125) - 228.6(14 - 26.125)$

$= 5796''^k = 483'^k$

$T_o = 7.62(60) = -457^k$



COLUMN IS ADEQUATE BASED ON INTERACTION DIAGRAM.

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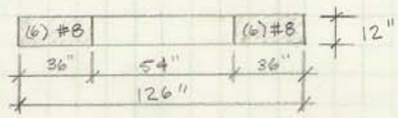

$h = 143'$
$f'_c = 6000$ PSI
$f_y = 60000$ PSI

$M_u = 65225$ 'k
$V_u = 932.2$ k

ASSUMPTIONS

FOR SIMPLICITY THE TOTAL BASE SHEAR AND OVERTURNING MOMENT WILL BE EQUALLY DISTRIBUTED TO EACH SHEAR WALL.

$M_u/3 = 21742$ 'k $V_u/3 = 311$ k

ANALYSIS

BOUNDARY ELEMENT

$$C = P_u/2 + M_u/((126-36)/12)$$

$$= \frac{(150)(10.5)(143)}{2} + \frac{21742}{7.5} = 3012^k$$

$A_g = (1.00)(10.5) = 10.5$ SF $I_g = \frac{1.0(10.5)^3}{12} = 96.47$ FT⁴

$$\frac{P_u}{A_g} + \frac{M_u(10.5/2)}{I_g} = 1470 \text{ ksf} = 10.21 \text{ ksi}$$

$10.21 \text{ ksi} > (0.2)(6) = 1.2$ ksi   ∴ BOUNDARY ELEMENT NEEDED

LONGITUDINAL / TRANSVERSE REINFORCEMENT

$$V_u \geq 2A_{cv}\sqrt{f'_c}$$

$$311^k \geq 2(126)(12)\sqrt{6000} = 234.2^k$$ ∴ 2 CURTAINS

REQUIRED ρ_ℓ AND $\rho_t \geq 0.0025$

$A_s = (0.0025)(144) = 0.36$ IN²/FT   #5 ($A_s = 0.31$ in²)

$$\frac{0.36}{12} = \frac{(2)(0.31)}{S} \qquad S_{REQ'D} = 13.3'' < 18'' \ \checkmark$$

∴ TRY 2 CURTAINS OF #4 HORIZONTAL AND VERTICAL @ 13" O.C.

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NOMINAL SHEAR CAPACITY

$$V_n = A_{cv}(\alpha_c\sqrt{f'_c} + \rho f_y)$$

$$\alpha_c = \frac{h_w}{l_w} = \frac{143}{10.5} = 13.62 > 2\ ;\ \alpha_c = 2$$

$$A_{cv} = (12)(126) = 1512\ IN^2$$

$$V_n = 1512\left(2\sqrt{6000} + \frac{(2)(0.2)}{(13)(12)}60000\right) = 467^k$$

$$\phi V_n = 0.6(467) = 280^k < 311^k \quad \times$$

TRY 8" SPACING

$$V_n = 1512\left(2\sqrt{6000} + \frac{(2)(0.2)}{(8)(12)}60000\right) = 612^k$$

$$\phi V_n = 0.6(612) = 367^k > 311^k \quad \checkmark$$

BOUNDARY ELEMENT CAPACITY

$$A_s = 6(0.79) = 4.74\ IN^2$$

$$\rho_s = \frac{4.74\ IN^2}{(12)(36)} = 0.010972$$

$$\rho_{min} = 0.01 \le 0.010972 \le \rho_{max} = 0.06 \quad \checkmark$$

$\therefore$ BOUNDARY ELEMENT CAPACITY IS ADEQUATE

SUMMARY: USE 12" CONCRETE SHEAR WALL WITH 2 CURTAINS OF #4 HORIZONTAL AND VERTICAL BARS @ 8" O.C.

NOTE: ACTUAL USES #5 @ 8" O.C. SO THE ASSUMPTIONS AND ANALYSIS ARE VALID.