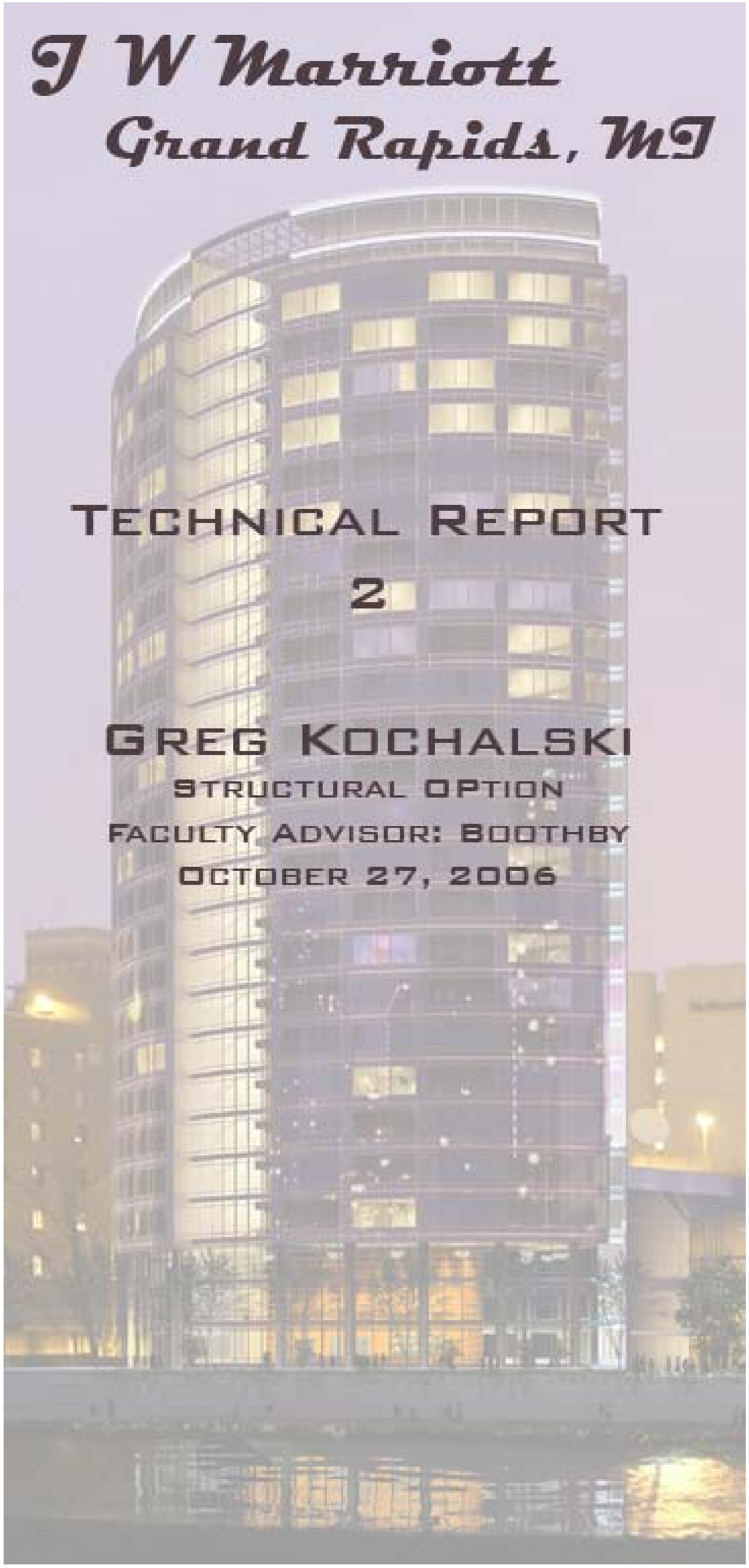

J W Marriott
Grand Rapids, MI

Technical Report
2

Greg Kochalski
Structural Option
Faculty Advisor: Boothby
October 27, 2006

Executive Summary

JW Marriott, Grand Rapids, MI

October 27, 2006

Greg Kochalski

Structural

Advisor: Boothby

Purpose:

The goal of this report is to investigate alternative floor systems for the flat plate system used in the JW Marriott. Once the alternatives have been analyzed, I will determine which systems are and are not viable based on numerous economic, construction, structural, and architectural criteria.

Alternative Systems:

Five alternate systems were investigated as alternatives for the JW.

1. Two Way Flat Slab with Drop Panels
2. Two Way Flat Plate
3. One Way Flat Plate with Beams*
4. Hollow Core Plank
5. Composite Steel

Figure A. JW Marriott and Flat Plate system

Conclusion:

The current one way flat plate system performs best to meet the vision of the architect. This includes unobstructed views from the guest rooms, greater license with interior partitions, freedom with ceiling finishes, and mechanical/electrical system routing ease. The high aspect ratio, >2, lends itself best to the system used. With a few of the alternate systems it is possible to limit interior partition width to the current10 inches. However the material and construction savings do not outweigh the uniformity of construction and architectural sacrifices. In addition the bay size and floor loads are not large enough to take full advantage of the two way systems' benefits. The most viable alternatives are two way flat plate and composite steel, due to reduction in slab thickness and improved seismic response, respectively. Simple construction techniques and formwork drive project costs down. Smaller vertical runs increase economic gains with other building systems. Given the unique shape of the JW Marriott I believe that the existing floor system is the best choice.

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Introduction

Description:

The JW Marriottis a 24 story hotel currently under construction in Grand Rapids, Michigan and is being constructed under the 2003 Michigan Building Code. The 2003 MBC references the IBC 2003 design loads for buildings. In this report I will study the typical floors from level 5 through 22. On these levels the code specifies 40 psf live load. This live load matches the designer's choice. The designer also specified 20 psf dead load for the partitions, flooring, MEP, etc. This is a generous allowance in part because the interior spaces had yet to be designed once erection began. The code calls for 12 psf for the partitions used. This allows the designer 8 psf remaining for the flooring and MEP, which usually is 3 psf and 5 psf. These loads will be used in the determination of alternate floor systems throughout this report.

Structural Codes:

- *Building Code*
  Michigan Building Code 2003. The 2003 Michigan Building Code is an adoption of the IBC 2003 with state amendments.
- *Structural Concrete*
  ACI 318-2002. Building Code Requirements for Structural Concrete.
- *Concrete Masonry*
  ACI 530-1999. Building Code Requirements for Masonry Structures.
- *Structural Steel*
  LRFD Specification for Structural Steel Buildings, 2nd Edition. AISC.

Existing Structural Description

Existing System:

The existing floor system of the JW is a one-way reinforced concrete flat plate from floors 5 through 22. The slab is 7.5 inches thick and uses 5000 psi strength concrete (unless otherwise noted). Normal weight concrete was used. 14 openings in the slab, located in the main corridor, allow for mechanical duct access. The overall shallow depth of the system permits greater flexibility for the architect’s interior design. The size of the typical bay is a trapezoid with vertical lengths 10’-7” and increasing to 17’-9” and a horizontal length of 35’-3”. The typical bay studied in this report has been highlighted in Figure 1.

Advantages:

The flat plate system in the JW allows for maximum freedom of design of partitions and ceiling finishes. A shallow floor system has significant savings in MEP runs from floor to floor. Simple formwork reduces construction costs by increasing uniformity. Guest views are not obstructed by edge beams and create larger glass windows to view the skyline.

Disadvantages:

The higher aspect ratio of the bay gives way to larger flexure and shear forces in the slab. The thickness is governed by the longer span and can result in economy loss.

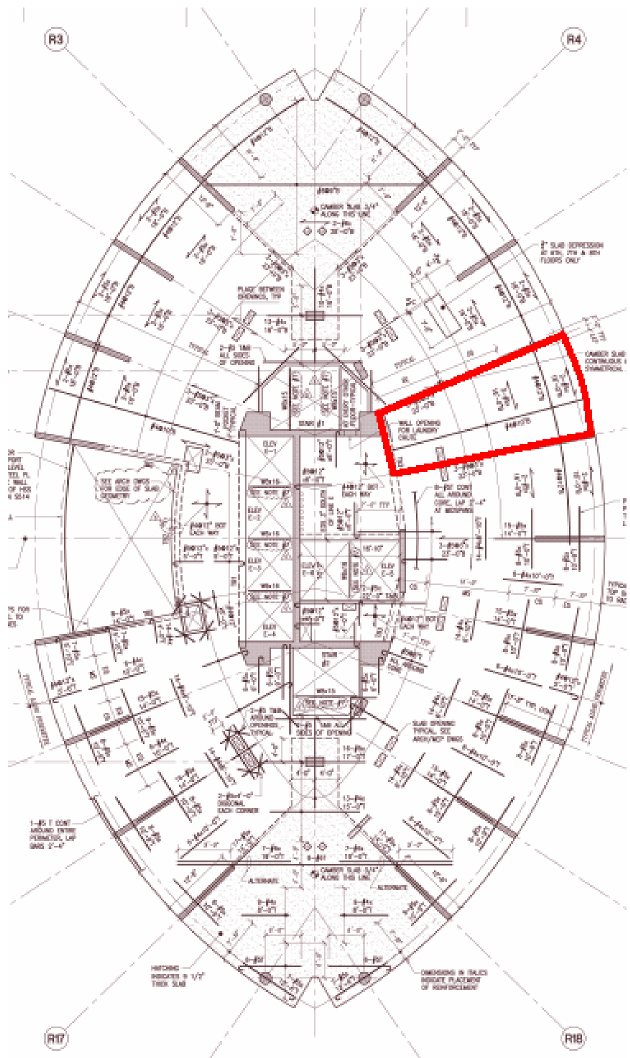

Figure 1. Typical Bay.

Alternate Structural Systems

Five alternate systems were investigated throughout this report for the JW. For those marked with an asterisk, additional columns were added (Fig. 2 shown in green) to achieve a suitable aspect ratio or overall system depth and subsequently making one bay into two.

- Two Way Flat Slab with Drop Panels*
- Two Way Flat Plate*
- One Way Flat Plate with Beams*
- Hollow Core Plank
- Composite Steel

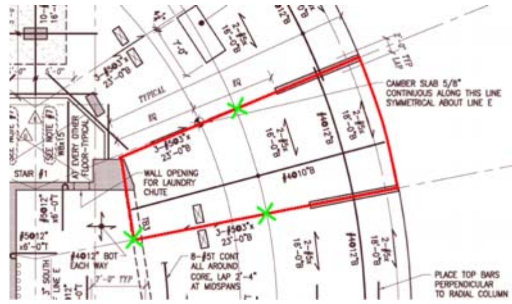

Figure 2. Bay with Added columns.

In order to make these investigations possible several reference handbooks and software programs were used.

- References
  - CRSI Handbook 2002
  - PCI Design Handbook 6th Edition
  - AISC Specification for Structural Steel Buildings 13th Edition
  - RS Means Assemblies Cost Data, 2006 Edition
  - Underwriters Laboratories Fire Resistance – Volume 1. 2001

- Software
  - RAM Structural System
  - Enercalc

The alternate systems were designed with the hopes that the added columns would not disrupt the current floor plan and be small enough to fit within existing partitions. A few systems met this goal, others did not. The wall columns for this report were assumed to be replaced by a square shape and located at the perimeter. The existing wall columns are 10 inches wide and made this goal difficult to reach. Alternate system overall depths were designed attempting to match the 7.5 inch flat plate depth of the JW. Due to the reduction in spans, most systems were able to accomplish this.

Alternate 1: Two Way Flat Slab with Drop Panels

This system uses two-way reinforced slab with drop panels only. In order to achieve an aspect ratio necessary to utilize this system two columns were added at the mid-span of the existing system (Fig. 2) and one column in the South West corner. Column capitals were not used due to higher costs. The design given in the CRSI handbook gives the minimum drop panel size per ACI 13.4.7.

The larger, exterior bay governs the sizing of the slab, columns, and reinforcing. The interior bay shall be built to the specifications of the larger bay to increase constructability and form efficiency.

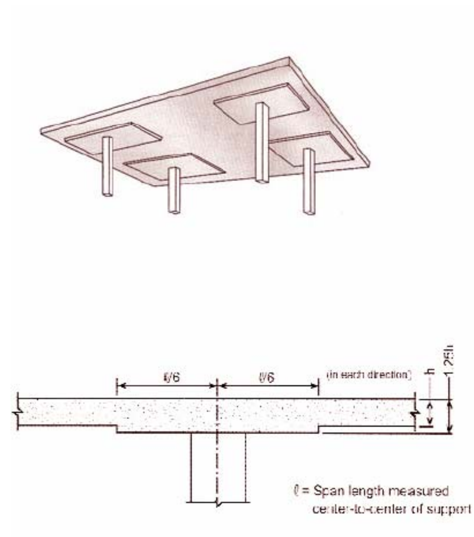

Figure 3. Drop Panel Detail.

Calculations may be found in *Appendix A*. Chapter 10 of the CRSI Handbook was used to determine the appropriate size, details, reinforcing, drop panels, etc.

Advantages:

For heavier loads and longer spans, the flat slab will require less reinforcing and concrete. The slight added cost of forming drop panels has savings over a flat plate in the amount of rebar and concrete needed. In addition smaller columns can be utilized. These designs are most efficient for bays that are square. Drop panels help to provide shear strength around the column and guard against “punching shear.”

Disadvantages:

Unsightly drop panels around columns have potential to disrupt interior designs and possibly even floor plans. In a bay with span of roughly 18 ft. there is not enough span to take full advantage of the cost savings when compared to a flat plate. For a live load of 50 psf or less a flat plate is only economically viable with spans between 25 and 30 ft. Formwork costs are approximately 47% of the total system cost.

The addition of columns will limit partition placement and has potential to alter floor plans.

Alternate 2: Two Way Flat Plate

This system was chosen in order to study the effects of added columns and decreased spans on the overall flat plate depth. Significant savings in depth should occur now that two-way action can occur. In addition the span has been cut in half.

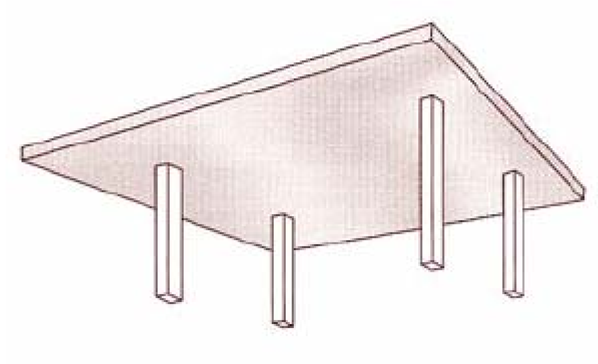

Figure 4. Flat Plate System.

Similar to the drop panel design, the larger exterior bay governs the sizing of the slab, columns, and reinforcing. The interior bay shall be built to the specifications of the larger bay to increase constructability and form efficiency.

Calculations may be found in *Appendix B*. Chapter 9 of the CRSI Handbook was used to determine the appropriate thickness, details, reinforcing schedule, etc.

Advantages:

Primarily found in hotels and residential medium to high rise structures, this system has advantages in both construction and architecture. The simple construction and formwork reduces finishing costs since the finish may be applied directly to the underside of the slab. This also allows greater freedom with partition and aesthetic design. Significant cost savings are also gained in the low story heights made possible by the shallow floor system. Smaller vertical runs of cladding, partitions, mechanical ducts, and plumbing all translate into greater savings.

Disadvantages:

The flat plate system is only economical for shorter spans. With a live load of 50 psf the economical span is a mere 20 to 25 ft. With larger spans deflection criteria ceases to govern and punching shear or bending moments begin to control the design. Floor panels with an aspect ratio of 2 tend to have a 30% greater cost than those with an aspect ratio of 1. The thickness of a rectangular span would be governed by the longer span and results in economy loss.

Additional columns will limit the placement of partitions and other building systems.

Alternate 3: One Way Flat Slab with Beams

The addition of beams to the flat slab system was done in order to remove the unsightly drop panels from view of the guests. The beams shown in Figure 5 are wider than the column, but in this design it was attempted to keep the base of the beam to a maximum of 10 inches, the same width of the JW's existing wall-columns. Savings in thickness should occur in this system due to the addition of flexural members and shorter spans.

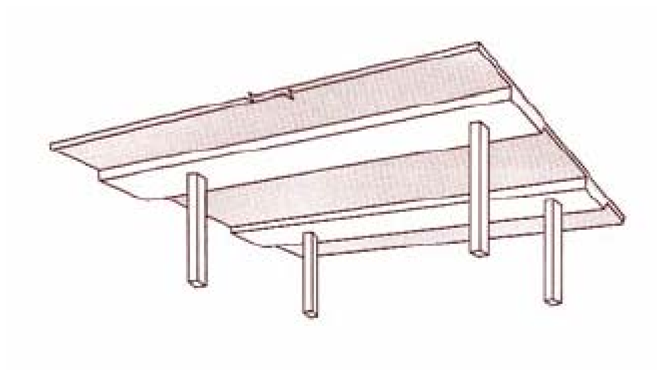

Figure 5. Flat Slab with Beams.

The larger span will control the overall design of the beams and the slab in the two bays. Formwork efficiency can only be achieved if this is the case.

Calculations may be found in *Appendix C*. Chapter 7 of the CRSI Handbook was used to determine the appropriate thickness, details, reinforcing schedule, etc. of the slab. The provisions set forth in Chapter 10 of the ACI code were used to design the beams.

Advantages:

The added flexural stiffness of the beams will have savings of slab depth when compared to a flat plate. Limiting the beam width to 10 inches, although not always possible, will allow the architect to hide the beams in the interior partitions of the JW.

Disadvantages:

The presence of beams complicates the routing mechanical ducts, plumbing systems, and limits the placing of interior partitions. The necessary formwork for the beams will slow the production schedule and add formwork, labor, and schedule costs to the project. The additional columns with further restrict the freedom of partition placement.

ALTERNATE 4: HOLLOW CORE PLANK

This system utilizes the same beam layout as floors 1 through 4. The addition of a column in the Southwest corner of the bay (Fig. 2) was necessary to carry out the design. Although the planks are capable of longer runs, spanning two bays for roughly 35 ft. was not reasonable due the unique shape of the JW Marriott.

The larger exterior span will control the overall size of the the plank. Formwork efficiency can only be achieved if this is the case.

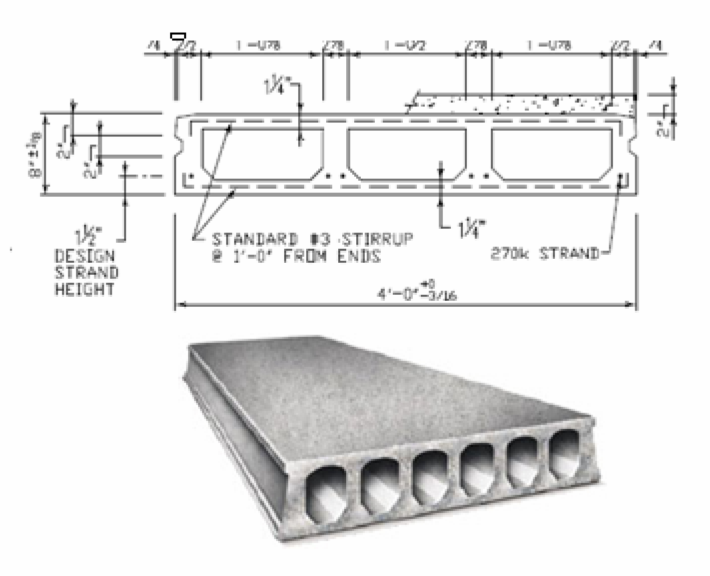

Figure 6. Hollow Core Plank.

Calculations may be found in *Appendix D*. Chapter 2 of the PCI Design Handbook was used to determine the appropriate thickness, details, reinforcing schedule, etc. of the slab. The provisions set forth in Chapter 10 of the ACI code were used to design the beams.

Advantages:

Hollow core plank provides a finished ceiling surface that can be used as installed or easily painted or sprayed to match the specifications of the architect. The plank may be drilled to install dropped ceilings, lighting, electrical, and mechanical fixtures. The hollow cores give the plank superior acoustic properties.

Higher strengths, longer spans, desirable fire ratings, and increased durability may be reached due to precision casting done in a controlled environment. With no curing time, construction may continue in any weather or season.

Disadvantages:

The beams supporting the plank may influence partitions and building system designs. Additional formwork can be expensive and inhibit the construction schedule. This system may not be economical given the shorter spans of the JW's typical size bay. Design changes may be hazardous with lead-in times that accompany hollow core construction.

The addition of one column in the Southwest corner may disrupt partition placement.

Alternate 5: Composite Steel

Composite steel allows for spans similar to actual spans in the JW. The composite action of the concrete helps to reduce the size of the steel member needed to carry the loads. This helps to reduce the overall depth, a common problem with steel systems.

A RAM model was built for three typical bays (shown in Figure 7) in order to determine the sizes of the steel members and required shear studs. The Vulcraft 2.0VL deck with a 3 inch topping spans 7 ft and although larger spans are available, the goal of this investigation was to determine only the applicability of the system itself.

Calculations may be found in *Appendix E*. RAM Structural System software was used to determine the appropriate member size and shear stud schedule. The provisions set forth in the AISC Specification for Structural Steel Buildings, 13th Edition was used to RAM model and Composite Beam. design the beams.

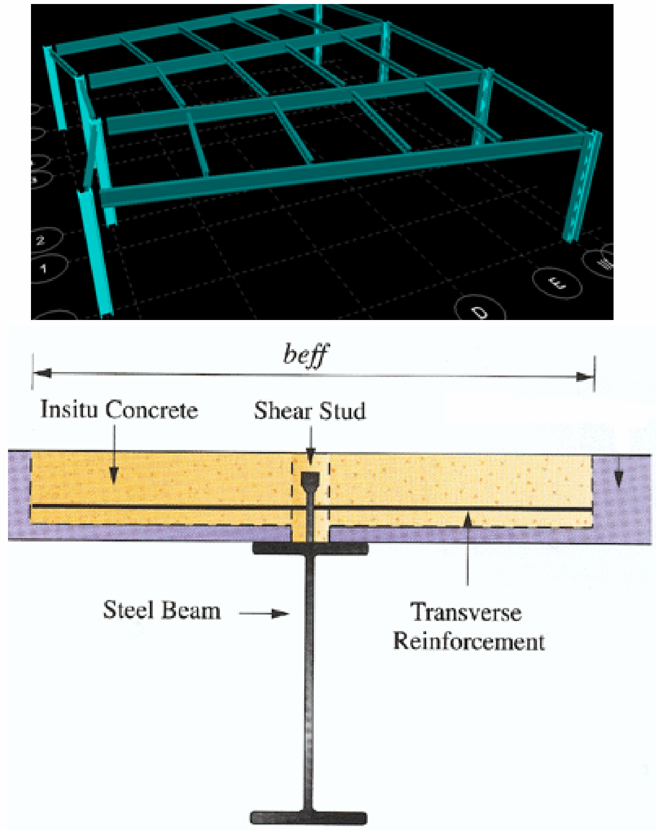

Figure 7.

Advantages:

Added flexural resistance of the concrete reduces member sizes, floor system depths, and steel tonnage. Construction is simple and fast. Time consuming activities such as shoring and preparing formwork are eliminated. A 2 hour fire resistance rating will be supplied by the slab, depending on thickness. With less concrete and a lower building mass, better seismic response periods can be reached.

Disadvantages:

Long lead-in times are needed in order to accommodate the fabricator. This also makes change orders difficult. As spans grow it becomes difficult to ensure the absence of camber needed to make this system work. Cost of steel construction is high and not generally economical for mid rise structures such as the JW Marriott.

Comparison and Conclusion

System	Existing	Flat Slab w Drop Panels	2 Way Flat Plate	Flat Slab w Beams	Hollow Core	Comp. Steel
Weight (psf)	93.75	75	93.75	68.75	74	62.5
Slab Depth (in.)	7.5	6	7.5	5.5	4	5
Largest Depth (in.)	7.5	8.5	7.5	18	24	W16x26 d = 16.7
Column Size (in.)	10x140	12x12	10x10	10x10	24Φ	W14
Construction Difficulty	Medium	Medium-Hard	Medium	Medium-Hard	Easy	Medium
Long Lead	No	No	No	No	Yes	Yes
Formwork	Yes	Yes	Yes	Yes	No	No
Fire Rating (hrs.)	>2	>2	>2	>2	1-2	1.5-2
Cost per ft^2 (USD)						
Materials	5.45	5.75	5.45	5.30	15.60	12..25
Labor	7.20	7.55	7.20	10.00	5.55	6.45
Total	12.65	13.30	12.65	15.35	21.15	18.70
Foundation Impact	-	Little-None	None	Little	Little-None	Yes*
Viable Alternative	-	No	Yes	Yes	No	Yes
Further Study	-	No	Yes	No	No	Yes

*Less building mass from the change to a steel system will reduce soil stresses and allow for foundation designs.

Conclusion:

The flat plate performs its purpose best to meet the vision of the architect. This includes unobstructed views from the guest rooms, greater license with partitions, freedom with ceiling finishes, and mechanical/electrical system routing. The high aspect ratio, >2, lends itself best to the system used. With a few of the alternate systems it is possible to limit interior partition width to the current10 inches. However the material and construction savings may not outweigh uniformity of construction and architectural costs. In addition the bay size and floor loads are not large enough to take full advantage of the two way systems investigated. The most viable alternatives are two way flat plate and composite steel, due to reduction in slab thickness and improved seismic response, respectively. Simple construction techniques and formwork drive project costs further downward with the current system. Smaller vertical runs increase economic gains with other building systems. Given the unique shape of the JW Marriott I believe that the existing floor system is the best choice.

Appendices

Appendix A

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TWO WAY FLAT SLAB (DROP PANELS)

SPAN ≤ 18'

THICKNESS B/W DROP PANELS	6"
CAPACITY	100 PSF

EXT SQ PANEL

C.S. BARS	
TOP EXT	12#4
BOT	11#4
TOP INT	12#4
M S BARS	
BOT	12#3
TOP INT	9#4
SQ DROP PANEL	
DEPTH	2.5"
WIDTH	6'
COL SIZE	12"

INT SQ PANEL

COL STRIP BARS	
TOP	12#4
BOT	13#3
MS BARS	
TOP	9#4
BOT	11#3

SQ D.P.* SAME AS EXT PANEL

COL SIZE	12"

f'_c = 3,000 psi
Grade 60 Bars

FLAT SLAB SYSTEM

SQUARE EDGE PANEL With Drop Panels No Beams — **SQUARE INTERIOR PANEL With Drop Panels (2) No Bea**

SPAN c.-c. $\ell_1 = \ell_2$ (ft)	Factored Superimposed Load (psf)	Square Drop Panel Depth (in.)	Square Drop Panel Width (ft)	Square Column ℓ_c = 12'-0" (3) Size (in.)	α_{ec}	Reinforcing Bars (E. W.) Column Strip (1) Top Ext.	Column Strip Bot.	Column Strip Top Int.	Middle Strip Bot.	Middle Strip Top Int.	Total Steel (psf)	Moments Edge (−) (ft-k)	Moments Bot. (+) (ft-k)	Moments Int. (−) (ft-k)	Factored Superimposed Load (psf)	Square Column ℓ_c = 12'-0" (3) Size (in.)	α_{ec}	Reinforcing Bars (E. W.) Col. Strip Top	Col. Strip Bot.	Mid. Strip Top	Mid. Strip Bot.	Total Steel (psf)	Concr (cu. ft / sq. ft)
h = 6 in. = TOTAL SLAB DEPTH BETWEEN DROP PANELS															h = 6 in. = TOTAL SLAB DEPTH BETWEEN DROP PANELS								
15	100	1.50	5.00	12	0.760	10-#4	10-#3	10-#4	9-#3	8-#4	1.60	21.2	38.4	53.4	100	12	0.380	10-#4	9-#3	8-#4	9-#3	1.60	0.513
15	200	2.50	5.00	12	0.734	10-#4	15-#3	10-#4	10-#3	8-#4	1.76	30.4	56.5	78.1	200	15	0.708	10-#4	10-#3	8-#4	9-#3	1.65	0.523
15	300	3.50	5.00	14	1.122	10-#4	12-#4	11-#4	8-#4	8-#4	2.13	49.8	75.7	101.0	300	15	0.686	10-#4	15-#3	8-#4	10-#3	1.88	0.532
15	400	4.50	5.00	15	1.322	10-#4	16-#4	12-#4	10-#4	8-#4	2.60	66.5	99.0	124.5	400	15	0.661	12-#4	20-#3	8-#4	13-#3	2.33	0.541
16	100	1.50	5.33	12	0.731	11-#4	13-#3	11-#4	10-#3	8-#4	1.67	25.4	47.3	65.5	100	12	0.365	11-#4	10-#3	8-#4	10-#3	1.62	0.513
16	200	2.50	5.33	12	0.709	11-#4	11-#4	12-#4	13-#3	8-#4	1.95	36.5	69.6	95.9	200	15	0.677	11-#4	13-#3	8-#4	10-#3	1.74	0.523
16	300	4.50	5.33	14	1.038	11-#4	14-#4	12-#4	9-#4	8-#4	2.24	58.6	89.2	123.8	300	16	0.763	11-#4	10-#4	8-#4	11-#3	1.97	0.541
16	400	5.50	5.33	15	1.230	11-#4	19-#4	14-#4	8-#5	10-#4	2.90	78.7	117.5	152.5	400	16	0.740	13-#4	9-#5	9-#4	15-#3	2.57	0.550
17	100	1.50	5.66	12	0.704	12-#4	15-#3	12-#4	10-#3	9-#4	1.70	30.0	57.5	79.3	100	12	0.352	12-#4	11-#3	9-#4	11-#3	1.67	0.513
17	200	3.50	5 66	13	0 838	12-#4	13-#4	13-#4	15-#3	9-#4	2.04	48.4	82.0	115.0	200	15	0.632	12-#4	15-#3	9-#4	10-#3	1.77	0.532
17	300	4.50	5.66	14	1.002	12-#4	11-#5	15-#4	11-#4	10-#4	2.49	69.4	104.5	149.3	300	17	0.861	13-#4	11-#4	9-#4	13-#3	2.11	0.541
17	400	5.50	6.80	17	1.594	12-#4	14-#5	16-#4	9-#5	12-#4	3.08	105.0	133.0	181.0	400	17	0.797	15-#4	16-#4	11-#4	18-#3	2.73	0.573
18	100	2.50	6.00	12	0.665	12-#4	11-#4	12-#4	12-#3	9-#4	1.76	34.8	69.4	95.2	100	12	0.332	12-#4	13-#3	9-#4	11-#3	1.63	0.523
[illegible]	[illegible]	[illegible]	[illegible]	13	0.779	12-#4	16-#4	14-#4	10-#4	9-#4	2.16	55.7	99.3	138.3	200	15	0.591	12-#4	18-#3	9-#4	12-#3	1.83	0.541
[illegible]	[illegible]	[illegible]	[illegible]	15	1.146	12-#4	13-#5	16-#4	22-#3	11-#4	2.72	88.4	122.3	177.4	300	17	0.807	14-#4	9-#5	11-#4	9-#4	2.41	0.550
[illegible]n. = TOTAL SLAB DEPTH BETWEEN DROP PANELS															h = 6½ in. = TOTAL SLAB DEPTH BETWEEN DROP PANELS								
15	100	2.00	5.00	12	0.648	10-#4	10-#3	10-#4	10-#3	8-#4	1.66	20.1	41.0	56.0	100	12	0.324	10-#4	10-#3	8-#4	10-#3	1.67	0.560
15	200	2.00	5.00	13	0.828	10-#4	8-#4	10-#4	10-#3	8-#4	1.76	33.2	56.7	79.5	200	15	0.631	10-#4	10-#3	8-#4	10-#3	1.68	0.560
15	300	3.00	5.00	14	1.003	10-#4	11-#4	12-#4	13-#3	8-#4	2.09	48.1	79.9	103.6	300	15	0.616	11-#4	8-#4	8-#4	10-#3	1.91	0.569
15	400	4.00	5.00	15	1.187	10-#4	15-#4	13-#4	10-#4	8-#4	2.56	64.4	104.1	127.1	400	15	0.593	12-#4	7-#5	8-#4	12-#3	2.28	0.578
15	500	5.00	6.00	15	1.056	10-#4	9-#6	14-#4	8-#5	9-#4	3.09	73.1	132.9	153.0	500	15	0.528	13-#4	9-#5	8-#4	9-#4	2.68	0.608
16	100	2.00	5.33	12	0.626	10-#4	12-#3	10-#4	11-#3	8-#4	1.65	24.1	50.4	68.7	100	12	0.313	10-#4	11-#3	8-#4	11-#3	1.64	0.560
16	200	2.00	5.33	12	0.625	10-#4	10-#4	13-#4	12-#3	8-#4	1.89	34.8	72.7	99.0	200	15	0.604	11-#4	12-#3	8-#4	11-#3	1.75	0.560
16	300	4.00	5.33	15	1.143	10-#4	13-#4	12-#4	15-#3	8-#4	2.13	62.3	91.4	125.2	300	16	0.689	11-#4	9-#4	8-#4	11-#3	1.90	0.578
16	400	5.00	5.33	16	1.334	10-#4	17-#4	14-#4	11-#4	9-#4	2.65	82.4	120.4	153.7	400	16	0.667	13-#4	13-#4	8-#4	8-#4	2.39	0.587
16	500	6.00	6.40	16	1.197	10-#4	15-#5	10-#5	10-#5	11-#4	3.33	94.3	154.8	185.1	500	16	0.598	14-#4	16-#4	10-#4	11-#4	2.88	0.621
17	100	2.00	5.66	12	0.606	11-#4	15-#3	11-#4	11-#3	9-#4	1.69	28.6	61.2	83.2	100	12	0.303	11-#4	11-#3	9-#4	11-#3	1.63	0.560
17	200	3.00	5.66	13	0.747	11-#4	12-#4	13-#4	8-#4	9-#4	1.98	46.6	85.6	118.7	200	15	0.569	12-#4	8-#4	9-#4	11-#3	1.79	0.569
17	300	4.00	5.66	15	1.102	11-#4	15-#4	15-#4	10-#4	9-#4	2.31	73.8	104.7	151.1	300	17	0.784	14-#4	18-#3	9-#4	12-#3	2.05	0.578
17	400	5.00	5.66	16	1.285	12-#4	13-#5	11-#5	13-#4	11-#4	2.92	97.8	138.1	185.6	400	17	0.762	15-#4	14-#4	10-#4	16-#3	2.53	0.587
17	500	6.00	6.80	17	1.392	13-#4	17-#5	12-#5	16-#4	13-#4	3.60	120.8	174.1	220.8	500	17	0.696	11-#5	19-#4	8-#5	8-#5	3.22	0.621

(Continued)

NOTES (1) 50 per cent of these bars may be placed in the middle third of column strip. (2) Drop panels same size as for edge panels. (3) Same column size and height above and below slab.

Appendix B

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FLAT PLATE SYSTEM
(WITHOUT SHEARHEADS)

f'_c Grade

SQUARE EDGE PANEL															SQUARE INTERIOR PANEL									
SPAN c.-c. Cols. $\ell_1 = \ell_2$	Factored Superimposed Load	Min. Sq. Floor (1) Column ℓ_c = 12'-0"		Total panel Moments			Reinforcing Bars					End Panel Steel (psf) Location of Panel			(2) Span c.-c.	(3) Load	(1) Min. Sq. Col.	Reinforcing Bars				Steel (psf) Location of Panel		
				−M Ext.	+M Int.	−M 1st. Int.	Each Column Strip			Each Middle Strip								Column Strip		Middle Strip				
							Top Ext.	Bot.	Top Int.	Bot.	Top Int.	E	EC	C				Top	Bot.	Top	Bot.	I	IE	IC
(ft)	(psf)	(in.)	α_{ec}	(ft-k)	(ft-k)	(ft-k)									(ft)	(psf)	(in.)							
6½" = TOTAL THICKNESS OF SLAB												0.541 c.f./s.f.			6½" = TOTAL THICKNESS OF SLAB							0.541 c.f./s.f.		
14	50	10	0.319	7	27	36	9-#4	9-#3	9-#4	9-#3	7-#4	1.62	1.62	1.59	14	50	10	9-#4	9-#3	7-#4	9-#3	1.64	1.64	1.64
14	100	10	0.319	10	36	46	9-#4	9-#3	9-#4	9-#3	7-#4	1.62	1.62	1.59	14	100	11	9-#4	9-#3	7-#4	9-#3	1.65	1.65	1.65
14	150	11	0.424	15	42	56	9-#4	10-#3	10-#4	9-#3	7-#4	1.66	1.67	1.67	14	150	13	9-#4	9-#3	7-#4	9-#3	1.66	1.67	1.68
14	200	13	0.674	23	46	64	9-#4	11-#3	11-#4	9-#3	7-#4	1.74	1.75	1.76	14	200	15	10-#4	9-#3	7-#4	9-#3	1.71	1.73	1.74
14	250	17	1.299	37	47	70	9-#4	7-#4	12-#4	9-#3	7-#4	1.84	1.84	1.86	14	250	16	12-#4	9-#3	7-#4	9-#3	1.82	1.82	1.82
14	300	21	2.039	49	49	76	11-#4	7-#4	13-#4	9-#3	7-#4	1.94	1.94	1.97	14	300	16	13-#4	10-#3	7-#4	9-#3	1.92	1.92	1.92
15	50	10	0.309	9	34	44	10-#4	10-#3	10-#4	10-#3	8-#4	1.66	1.66	1.63	15	50	10	10-#4	10-#3	8-#4	10-#3	1.68	1.68	1.68
15	100	10	0.309	12	45	58	10-#4	11-#3	10-#4	10-#3	8-#4	1.69	1.69	1.68	15	100	11	10-#4	10-#3	8-#4	10-#3	1.69	1.69	1.69
15	150	11	0.408	18	53	69	10-#4	7-#4	12-#4	10-#3	8-#4	1.78	1.79	1.81	15	150	13	11-#4	10-#3	8-#4	10-#3	1.75	1.76	1.77
15	200	18	1.385	41	51	75	10-#4	7-#4	13-#4	10-#3	8-#4	1.83	1.83	1.85	15	200	15	13-#4	9-#3	8-#4	10-#3	1.82	1.82	1.82
15	250	21	1.899	52	55	84	12-#4	13-#3	10-#5	10-#3	8-#4	1.98	2.00	2.00	15	250	16	14-#4	11-#3	8-#4	10-#3	1.96	1.97	1.99
16	50	10	0.299	11	42	54	10-#4	10-#3	10-#4	11-#3	8-#4	1.62	1.62	1.57	16	50	10	10-#4	11-#3	8-#4	11-#3	1.67	1.67	1.67
16	100	10	0.299	14	55	71	10-#4	13-#3	12-#4	11-#3	8-#4	1.74	1.75	1.75	16	100	11	11-#4	11-#3	8-#4	11-#3	1.73	1.74	1.74
16	150	17	1.156	40	55	79	10-#4	13-#3	14-#4	11-#3	8-#4	1.81	1.82	1.81	16	150	13	13-#4	11-#3	8-#4	11-#3	1.82	1.83	1.84
16	200	22	1.942	56	58	89	13-#4	8-#4	10-#5	11-#3	8-#4	1.99	1.98	1.99	16	200	15	10-#5	12-#3	8-#4	11-#3	1.98	1.98	1.97
17	50	10	0.289	13	51	66	11-#4	12-#3	11-#4	11-#3	9-#4	1.64	1.64	1.63	17	50	10	11-#4	11-#3	9-#4	11-#3	1.65	1.65	1.65
17	100	15	0.832	33	57	81	11-#4	8-#4	14-#4	11-#3	9-#4	1.76	1.77	1.78	17	100	11	13-#4	11-#3	9-#4	11-#3	1.74	1.75	1.76
17	150	21	1.668	55	61	93	13-#4	9-#4	16-#4	11-#3	9-#4	1.94	1.94	1.97	17	150	14	16-#4	12-#3	9-#4	11-#3	1.91	1.90	1.90
18	50	10	0.280	15	61	79	12-#4	9-#4	14-#4	12-#3	9-#4	1.73	1.75	1.81	18	50	10	12-#4	12-#3	9-#4	12-#3	1.65	1.67	1.69
18	100	19	1.299	49	63	93	12-#4	9-#4	16-#4	12-#3	9-#4	1.83	1.83	1.85	18	100	12	16-#4	12-#3	9-#4	12-#3	1.82	1.81	1.81
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	65	89	12-#4	9-#4	15-#4	13-#3	10-#4	1.77	1.78	1.79	19	50	10	14-#4	13-#3	10-#4	13-#3	1.75	1.76	1.77
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	71	107	14-#4	10-#4	12-#5	13-#3	10-#4	1.97	1.97	1.97	19	100	14	12-#5	14-#3	10-#4	13-#3	1.97	1.97	1.97
[illegible]												0.583 c.f./s.f.			7" = TOTAL THICKNESS OF SLAB							0.583 c.f./s.f.		
15	50	10	0.267	8	37	47	9-#4	11-#3	9-#4	11-#3	8-#4	1.72	1.72	1.69	15	50	10	9-#4	11-#3	8-#4	11-#3	1.75	1.75	1.75
15	100	10	0.267	11	47	60	9-#4	11-#3	10-#4	11-#3	8-#4	1.73	1.74	1.71	15	100	11	9-#4	11-#3	8-#4	11-#3	1.75	1.76	1.77
15	150	12	0.461	20	53	71	9-#4	7-#4	11-#4	11-#3	8-#4	1.81	1.83	1.82	15	150	14	10-#4	11-#3	8-#4	11-#3	1.80	1.82	1.83
15	200	13	0.576	27	61	82	9-#4	13-#3	13-#4	11-#3	8-#4	1.90	1.91	1.89	15	200	15	12-#4	11-#3	8-#4	11-#3	1.91	1.92	1.94
15	250	18	1.287	47	60	89	10-#4	13-#3	14-#4	11-#3	8-#4	1.96	1.96	1.94	15	250	16	13-#4	11-#3	8-#4	11-#3	1.97	1.98	1.99
15	300	22	1.971	61	62	96	13-#4	8-#4	10-#5	11-#3	8-#4	2.12	2.12	2.14	15	300	17	10-#5	11-#3	8-#4	11-#3	2.09	2.09	2.09
16	50	10	0.259	10	45	57	10-#4	11-#3	10-#4	11-#3	8-#4	1.64	1.64	1.62	16	50	10	10-#4	11-#3	8-#4	11-#3	1.67	1.67	1.67
16	100	10	0.259	13	58	74	10-#4	7-#4	12-#4	11-#3	8-#4	1.70	1.73	1.73	16	100	11	10-#4	11-#3	8-#4	11-#3	1.67	1.70	1.72
16	150	12	0.444	24	65	87	10-#4	8-#4	14-#4	11-#3	8-#4	1.82	1.84	1.86	16	150	14	12-#4	11-#3	8-#4	11-#3	1.78	1.80	1.82

(1) Columns same above and below plate. (2) Center-to-center of columns; $\ell_1 = \ell_2$. (3) Superimposed factored load (factored dead load has been deducted).

TWO WAY FLAT PLATE

SPAN = 18'

THICKNESS	6.5"	7.5"
CAPACITY	100 PSF	100 PSF
EXTERIOR SQ PANEL		
COL STRIP BARS		
TOP EXT	12 #4	10 #4
BOT	9 #4	10 #4
TOP INT	16 #4	16 #4
MID STRIP BARS		
BOT	12 #3	8 #4
TOP INT	9 #4	9 #4
COL SIZE	19"	10"
SQ INT PANEL		
COL STRIP BARS		
TOP	16 #4	14 #4
BOT	12 #3	8 #4
MID STRIP BARS		
TOP	9 #4	9 #4
BOT	12 #3	8 #4
COL SIZE	12"	10"
CHOICE		✓

COL SIZE WORKS BETTER WITH EXISTING PARTITIONS

Appendix C

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ONEWAY FLAT SLAB

SPAN ≅ 18'

f'_c = 3000 psi

CRSI 2002

THICKNESS	5 ½"
CAPACITY	130 psf
TOP BAR SPACING	#5 @ 9"
BOT BAR SP.	#5 @ 10"
TOP BAR FREE END SP.	#4 @ 12"
T-S BARS SP.	#3 @ 11"
AREA STEEL in2/ft	
TOP INT	0.413
BOT	0.372
SLAB WT	69 psf

SOLID ONE-WAY SLABS—END SPAN
$f'_c = 3{,}000$ psi — Top Steel for $-M$ Grade 60 — $\rho \approx 0.0050$

Thickness (in.)	4	4½	5	5½	6	6½	7	7½	8	8½	9	9½	10
Top Bars	#4	#4	#4	#5	#5	#5	#5	#6	#6	#6	#6	#6	#6
Spacing (in.)	12	12	11	14	12	11	10	14	13	12	11	10	10
Bottom Bars	#4	#4	#4	#5	#5	#5	#5	#6	#6	#6	#6	#6	#6
Spacing (in.)	12	11	10	13	13	12	11	15	14	13	12	11	11
Top Bars Free End	#4	#4	#4	#4	#4	#4	#4	#4	#4	#4	#4	#4	#4
Spacing (in.)	12	12	12	12	12	12	12	12	12	12	12	12	12
Temperature Bar	#3	#3	#3	#3	#4	#4	#4	#4	#4	#4	#4	#5	#5
Spacing (in.)	15	13	12	11	18	17	15	14	13	13	12	18	17
Areas of Steel (in.²/ft.) Top Int.	0.200	0.200	0.218	0.266	0.310	0.338	0.372	0.377	0.406	0.440	0.480	0.528	0.528
Bot.	0.200	0.218	0.240	0.286	0.286	0.310	0.338	0.352	0.377	0.406	0.440	0.480	0.480
Slab Weight (psf)	50	56	63	69	75	81	88	94	100	106	113	119	125
CLEAR SPAN	FACTORED USABLE SUPERIMPOSED LOAD (psf)												
6'-0"	700	906											
6'-6"	586	761	967										
7'-0"	496	645	821										
7'-6"	423	552	704	949									
8'-0"	363	475	608	823	925								
8'-6"	314	412	528	718	807	976							
9'-0"	272	359	462	630	709	858							
9'-6"	237	314	405	555	625	759	916						
10'-0"	207	276	357	492	554	674	814	918					
10'-6"	158	191	248	356	481	591	722	792	933				
11'-0"	138	167	218	316	429	528	647	710	838	987			
11'-6"	120	146	192	280	383	473	582	638	754	890			
12'-0"	105	127	169	250	343	426	524	575	681	806	952		
12'-6"	91	111	149	222	308	383	473	520	617	731	865		
13'-0"	79	97	131	198	277	346	428	471	560	664	787	937	999
13'-6"	68	84	115	177	249	312	388	427	509	605	719	857	914
14'-0"	58	73	101	158	224	282	352	388	463	552	657	785	837
14'-6"	49	62	88	140	202	256	320	353	422	505	602	721	769
15'-0"	42	53	76	125	182	231	291	321	385	462	552	662	707
15'-6"		45	66	111	163	209	264	292	352	423	507	610	651
16'-0"			56	98	147	190	241	266	322	388	466	562	600
16'-6"			48	86	132	171	219	242	294	356	429	519	554
17'-0"			40	76	118	155	199	220	269	327	395	479	511
17'-6"				66	105	140	181	201	246	300	363	442	473
18'-0"				57	94	126	164	182	225	275	335	409	437
18'-6"				49	83	113	149	166	205	253	309	378	405
19'-0"				41	73	101	135	150	187	232	284	350	374
19'-6"					64	90	122	136	171	213	262	324	347
20'-0"					56	80	109	123	155	195	241	300	321

Note: See page 7-7 for reinforcing details.

SOLID ONE-WAY SLABS—END SPAN
$f'_c = 3{,}000$ psi — Top Steel for $-M$ Grade 60 — $\rho \approx 0.0075$

Thickness (in.)	4	4½	5	5½	6	6½	7	7½	8	8½	9	9½	10
Top Bars	#4	#4	#5	#5	#5	#6	#6	#7	#7	#7	#8	#8	8
Spacing (in.)	10	9	11	9	8	11	10	12	12	11	14	13	12
Bottom Bars	#4	#4	#5	#5	#5	#6	#6	#7	#7	#7	#8	#8	8
Spacing (in.)	9	8	10	10	9	12	11	13	13	12	15	14	13
Top Bars Free End	#4	#4	#4	#4	#4	#4	#4	#4	#4	#4	#4	#4	#4
Spacing (in.)	12	12	12	12	#12	12	12	12	12	12	11	10	10
Temperature Bar	#3	#3	#3	#3	#4	#4	#4	#4	#4	#4	#4	#5	#5
Spacing (in.)	15	13	12	11	18	17	15	14	13	13	12	18	17
Areas of Steel (in.²/ft.) Top Int.	0.240	0.267	0.338	0.413	0.465	0.480	0.528	0.600	0.600	0.655	0.677	0.729	0.790
Bot.	0.267	0.300	0.372	0.372	0.413	0.440	0.480	0.554	0.554	0.600	0.632	0.677	0.729
Slab Weight (psf)	50	56	63	69	75	81	88	94	100	106	113	119	125
CLEAR SPAN	FACTORED USABLE SUPERIMPOSED LOAD (psf)												
6'-0"	924												
6'-6"	777												
7'-0"	660	873											
7'-6"	566	750											
8'-0"	489	650	939										
8'-6"	425	566	822	941									
9'-0"	372	497	723	829									
9'-6"	326	438	640	734	922								
10'-0"	288	387	555*	653	822	963							
10'-6"	200	273	409	583	735	847							
11'-0"	176	242	365	523	661	761	928						
11'-6"	155	215	326	470	596	687	839						
12'-0"	137	191	292	424	538	622	760	941					
12'-6"	121	170	262	383	488	564	691	857	935				
13'-0"	106	151	236	347	443	513	629	782	854				
13'-6"	93	134	212	314	403	467	575	716	781	929			
14'-0"	82	119	191	285	368	426	526	656	717	853	943		
14'-6"	71	106	172	257*	335	390	482	603	659	785	868		
15'-0"	62	94	155	232*	301*	357	442	555	606	724	801	932	
15'-6"	54	83	140	210*	275*	327	406	511	559	669	740	862	
16'-0"	46	73	126	189*	250*	300	373	472	516	619	685	799	932
16'-6"		64	113	173*	228*	275	344	436	477	573	634	741	866
17'-0"		56	101	157*	208*	253	317	403	441	531	588	688	805
17'-6"		48	90	143*	190*	232	292	372	408	493	546	640	750
18'-0"		41	81	130*	174*	213	269	342*	378	457	508	596	699
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	159*	196	248	316*	350	425	472	555	653
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	145*	179	229	290*	325	395	439	518	610
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	134*	165	211	268*	301	368	409	483	570
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	123*	151	194	248*	280	342	381	451	533

Note: See page 7-7 for reinforcing details.
* Service loads corresponding to 1/1.7 tabulated superimposed load, result in calculated immedi[ate] deflection of 1/360 span.

BEAM SPAN = 211.5" = 17.625' $f'_c = 5$ ksi $f_y = 60$ ksi

$W_R = [1.4(40) + 1.2(20) + 1.2(69)][17 + \frac{9}{12}] = 2890$ PLF

$W_L = [162.8](14' + \frac{2}{12}) = 2306$ PLF

FOR SIMPLICITY USE $w_u = 2.89$ klf

$M_u = \frac{w l^2}{8} = \frac{2.89(17.625)^2}{8} = 112.2$ ft-k

ASSUME $\rho = 0.6\rho_{max}$

$\rho = 0.6(0.0243) = 0.0146$

$M_u = \phi \rho f_y b d^2 \left(1 - 0.59 \rho \frac{f_y}{f'_c}\right)$

$(112.2)(12) = 0.9(0.0146)(60) b d^2 \left(1 - 0.59(0.0146)\left(\frac{60}{5}\right)\right)$

$bd^2 = 2421$ in^3

b	d
10	15.6 ← USE THIS

$A_{s\,reqd} = \rho b d = 0.0146(10)(15.6)$

$= 2.28$ in^2 TRY 3#9 BARS

CHECK b = 10" d = 15.5" h = 18"

$W_B = \frac{10(18)}{144}(150) = 187.5$ PLF

$M_u = 112.2 + \frac{0.1875(17.625)^2}{8}$

$= 119.5$ ftk

FIND a: $a = \frac{A_s f_y}{0.85 f'_c b} = \frac{3.0(60)}{0.85(5)(10)} = 4.24"$

$\phi M_n = \phi A_s f_y (d - \frac{a}{2}) = 0.9(3.0)(60)(15.5 - \frac{4.24}{2})$

$= 180.6$ ft-k $> M_u$ ✓ ok

Appendix D

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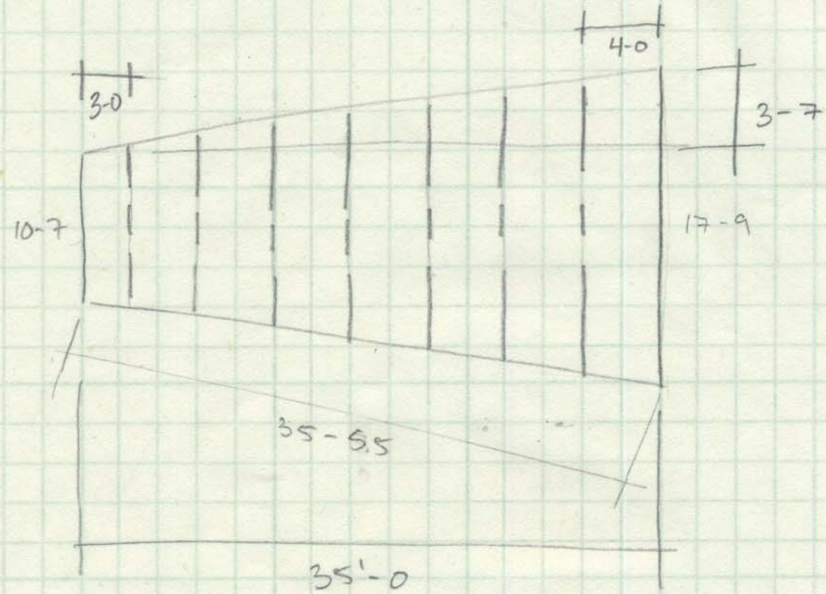


LOADS: (PSF)

LIVE	DEAD	SERVICE LOAD
20	40	60

8" SPANDECK w/o TOPPING (STRAND PATTERN 4)

SPAN	ALLOWABLE LOAD (FROM TABLE) (PSF) SHEAR	FLEXURE	SELF WT.
18	215	222	57.5
10	441	610	

USE 8" SPANDECK UL-J917

TRY 4" W/ TOPPING (2")

SAFE SERVICE LOAD AT 18' = 182 psf

∴ USE 4" HOLLOW CORE PLANK W/ 2" TOPPING

f'_c = 5000 psi; w = 74 psf < ASSUMED 75 psf
OVERALL DEPTH = 8"

USE 4HC6 + 2, 66-S

Strand Pattern Designation
76-S

- S = straight
- Diameter of strand in 16ths
- No. of Strand (7)

Safe loads shown include dead load of 10 psf for untopped members and 15 psf for topped members. Remainder is live load. Long-time cambers include superimposed dead load but do not include live load.

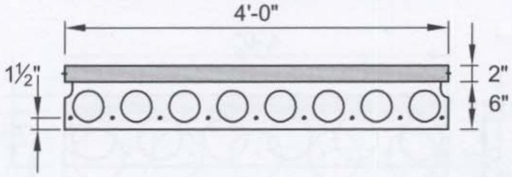
Capacity of sections of other configurations are similar. For precise values, see local hollow-core manufacturer.

Key
444 – Safe superimposed service load, psf
0.1 – Estimated camber at erection, in.
0.2 – Estimated long-time camber, in.

HOLLOW-CORE

4'-0" x 6"

Normal Weight Concrete



$f'_c = 5{,}000$ psi
$f_{pu} = 270{,}000$ psi

Section Properties

	Untopped	Topped
A =	187 in.^{2}	283 in.^{2}
I =	763 in.^{4}	1,640 in.^{4}
y_b =	3.00 in.	4.14 in.
y_t =	3.00 in.	3.86 in.
S_b =	254 in.^{3}	396 in.^{3}
S_t =	254 in.^{3}	425 in.^{3}
wt =	195 plf	295 plf
DL =	49 psf	74 psf
V/S =	1.73 in.	

4HC6

Table of safe superimposed service load (psf) and cambers (in.) — **No Topping**

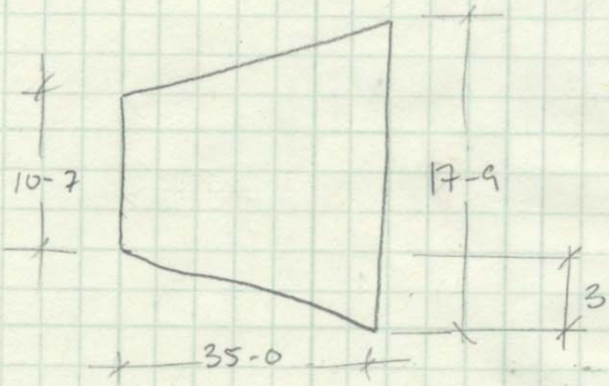
Strand Designation Code	Span, ft																				
	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
66-S	444	382	333	282	238	203	175	151	131	114	100	88	77	68	59	52	46	40	33	28	
	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.0	–0.1	–0.2	–0.4	–0.5	–0.7		
	0.2	0.2	0.2	0.2	0.3	0.3	0.2	0.2	0.2	0.1	0.1	0.0	–0.1	–0.3	–0.5	–0.7	–0.9	–1.2	–1.5	–1.9	
76-S		445	388	328	278	238	205	178	155	136	120	105	93	82	73	65	57	49	42	36	31
		0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.1	0.1	0.0	–0.1	–0.3	–0.4	–0.6
		0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.1	0.0	–0.1	–0.2	–0.4	–0.7	–0.9	–1.2	–1.6	–2.0
96-S		466	421	386	338	292	263	229	201	177	157	139	124	110	99	88	78	68	60	53	46
		0.3	0.3	0.3	0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.4	0.3	0.3	0.1	0.0	–0.1
		0.3	0.4	0.4	0.5	0.5	0.5	0.6	0.6	0.6	0.5	0.5	0.4	0.3	0.2	0.1	–0.1	–0.3	–0.6	–0.9	–1.3
87-S		478	433	398	362	322	290	264	240	212	188	167	149	134	119	107	95	85	76	68	60
		0.3	0.4	0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.7	0.7	0.8	0.8	0.7	0.7	0.7	0.6	0.5	0.4	0.3
		0.4	0.5	0.5	0.6	0.7	0.7	0.7	0.8	0.8	0.8	0.8	0.7	0.7	0.6	0.5	0.3	0.2	0.0	–0.3	–0.6
97-S		490	445	407	374	346	311	276	242	220	203	186	166	148	133	119	107	96	86	78	70
		0.4	0.4	0.5	0.5	0.6	0.7	0.7	0.8	0.8	0.9	0.9	0.9	0.9	1.0	0.9	0.9	0.9	0.8	0.7	0.6
		0.5	0.6	0.6	0.7	0.8	0.8	0.9	0.9	1.0	1.0	1.0	1.0	0.9	0.9	0.8	0.7	0.5	0.3	0.1	–0.2

4HC6 + 2

Table of safe superimposed service load (psf) and cambers (in.) — **2 in. Normal Weight Topping**

Strand Designation Code	Span, ft																		
	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
66-S	470	396	335	285	244	210	182	158	136	113	93	75	59	46	34				
	0.2	0.2	0.2	0.2	0.2	02	0.2	0.2	0.2	0.2	0.1	0.1	0.0	–0.1	–0.2				
	[illegible]	[illegible]	[illegible]	[illegible]	0.2	0.1	0.1	0.0	–0.1	–0.2	–0.3	–0.5	–0.7	–0.9	–1.2				
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	287	248	216	188	163	137	115	95	78	63	50	38	27		
	[illegible]	[illegible]	[illegible]	[illegible]	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.1	0.1	–0.0	–0.1	–0.3		
	[illegible]	[illegible]	[illegible]	[illegible]	0.2	0.2	0.2	0.1	0.1	0.0	–0.2	–0.3	–0.5	–0.7	–0.9	–1.2	–1.5		
96-S			[illegible]	[illegible]	367	319	279	245	216	186	160	137	116	98	82	68	55	43	33
			0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.4	0.3	0.3	0.1	0.0	–0.1
			0.4	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.2	0.1	–0.1	–0.3	–0.5	–0.7	–1.0	–1.4	–1.7
87-S			485	446	415	377	331	292	258	224	195	169	147	127	109	94	80	67	55
			0.5	0.5	0.6	0.6	0.7	0.7	0.7	0.7	0.8	0.8	0.7	0.7	0.7	0.6	0.5	0.4	0.3
			0.5	0.5	0.5	0.6	0.6	0.6	0.5	0.5	0.4	0.4	0.2	0.1	–0.1	–0.3	–0.5	–0.8	–1.2
97-S			494	455	421	394	357	327	288	251	219	192	168	146	127	110	95	82	70
			0.5	0.6	0.7	0.7	0.8	0.8	0.9	0.9	0.9	0.9	1.0	0.9	0.9	0.9	0.8	0.7	0.6
			0.6	0.6	0.7	0.7	0.7	0.7	0.7	0.7	0.6	0.6	0.5	0.4	0.2	0.0	–0.2	–0.5	–0.8

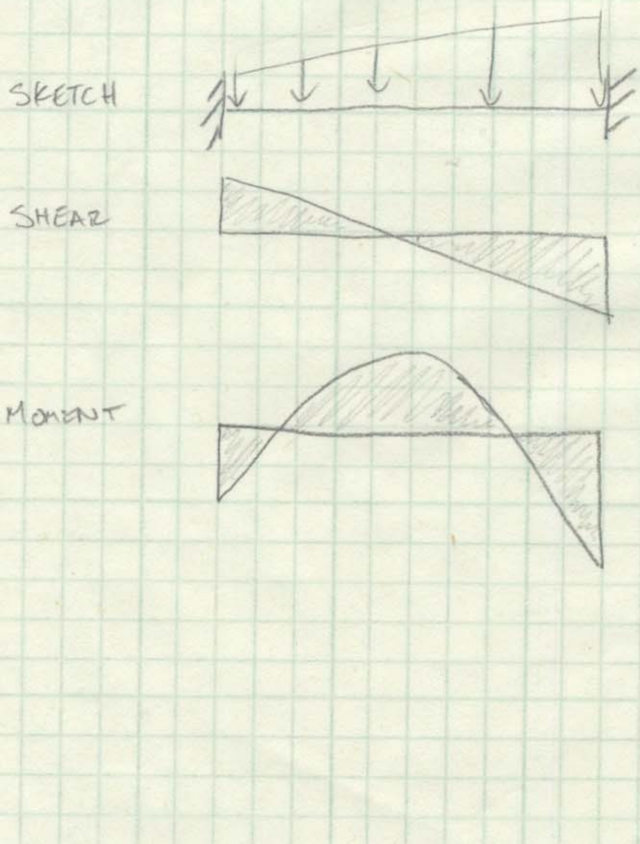
Strength is based on strain compatibility; bottom tension is limited to $7.5\sqrt{f'_c}$ *; see pages 2–7 through 2–10 for explanation.*



DEAD = 20 PSF

LIVE = 40 PSF

	END LEFT		END RIGHT
SERVICE LOADS (KLF)	0.211 D 0.425 L		0.355 D 0.710 L
	LEFT	MAX (AT 18.09 ft)	RIGHT
MOMENT (k-ft)	-33.4	17.6	-37.0
SHEAR (k)	5.38		6.59



Atlantic Engineering Services
650 Smithfield Street ▪ Suite 1200
Pittsburgh ▪ Pennsylvania 15222
AES

JOB: HOLLOW CORE PLANK
SHEET NO.: BEAM DESIGN OF
CALCULATED BY DATE
CHECKED BY DATE
SCALE

ASSUME: SELF WT = 75 PSF

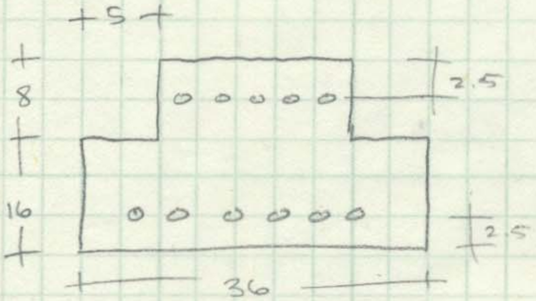
DEAD = 20 PSF + 75 PSF

LIVE = 40 PSF

SERVICE LOADS (KLF)	LEFT	RIGHT
	1.00 D	1.686 D
	0.423 L	0.710 L

	LEFT	MAX @ 18.1'	RIGHT
MOMENT (k-ft)	-158.4	83.6	-175.4
SHEAR (k)	25.5		31.3

HOLLOW CORE PLANK



A_s: 5#9 TOP
6#9 BOTTOM

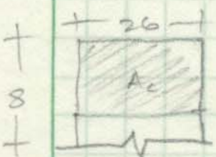
$f'_c = 5000\ psi$
$f_y = 60\ ksi$

POSITIVE MOMENT

$T = C$

$A_s f_y = 0.85 f'_c A_c$

$$A_c = \frac{6(60)}{0.85(5)} = 84.7\ in^2$$



$$\bar{y} = \frac{A_c}{w}\left(\frac{1}{2}\right) = \frac{84.7}{26}\left(\frac{1}{2}\right) = 1.63\ in$$

$$M_n = 0.85 f'_c A_c (d - \bar{y})$$

$$= 0.85(5)(84.7)(21.5 - 1.63)$$

$$= 596\ ft\ k$$

$$\varepsilon_t = \varepsilon_u\left(\frac{d_t - c}{c}\right) = 0.003\left(\frac{21.5 - 1.63/.80}{1.63/.80}\right) = 0.028 > 0.005$$

$\therefore \phi = 0.9$

$$\phi M_n = 0.9(596)$$

$$= 536\ ft\text{-}k$$

NEGATIVE MOMENT

$T = C$

$A_s f_y = 0.85 f'_c A_c$

$A_c = \frac{5(60)}{0.85(5)} = 70.6 \text{ in}^2$

$\bar{y} = \frac{A_c}{w}\left(\frac{1}{2}\right) = \frac{70.6}{36}\left(\frac{1}{2}\right) = 1.0 \text{ in}$

$M_n = 0.85 f'_c A_c (d - \bar{y})$

$= 0.85(5)(70.6)(21.5 - 1.0)$

$= 512 \text{ ft k}$

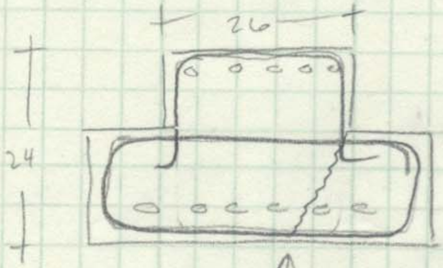
$\varepsilon_t = \varepsilon_u\left(\frac{d_t - c}{c}\right) = 0.003\left(\frac{21.5 - 1.0(.8)}{1.0(.8)}\right) = 0.048 > 0.005$

$\therefore \phi = 0.9$

$\phi M_n = 0.9(512)$

$= 461 \text{ ft} \cdot \text{k}$

HOLLOW CORE PLANK



#4 STIRRUPS AT 10" OC. (FOR CONSISTENCY WITH OTHER FLOORS)

$A_v = 2(.2) = 0.4\ in^2$

SP①

$V_c = 2\sqrt{f'_c}\, b_w d = 2\sqrt{5000}\,(26)(21.5) = 79.1\ k$

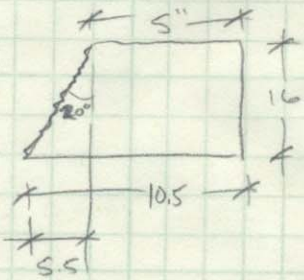
$\phi V_n = \frac{1}{2}\phi V_c = \frac{1}{2}(0.75)(79.1) = 29.7\ k$

$\phi V_s = \phi \frac{A_v f_y d}{S} = 0.75\frac{(0.4)(60)(21.5)}{10} = 38.7\ k$

$\phi V_n = \phi(V_n + V_s) = 29.7 + 38.7$

$= 68.4\ k > V_u = 31.3$ ✓ok

SP② SHEAR FRICTION METHOD (ASSUME CRACK IS 20°)



$A_{vf} = \frac{V_u \cos 20}{\phi \mu f_y} = \frac{31.3 \cos 20}{0.75(1.4)(60)} = 0.47\ in^2$

$A_{cf} = (36 \times 12)\left(\frac{5.5}{\sin 20}\right) = 6750\ in^2$

because failure is along ledge

$MAX\ V_n = \left|\begin{array}{l} 0.2 f'_c A_c = 0.2(5)(6750) = 6750\ k \leftarrow \text{use} \\ \text{Min } 800 A_c = 800(6750) \end{array}\right.$

$A_{SH} = \frac{A_{vf} f_y \cos 20}{\mu f_y} = \frac{0.47 \cos 20}{1.4} = 0.315 < A_s = 0.4\ in^2$ ✓ok

Appendix E

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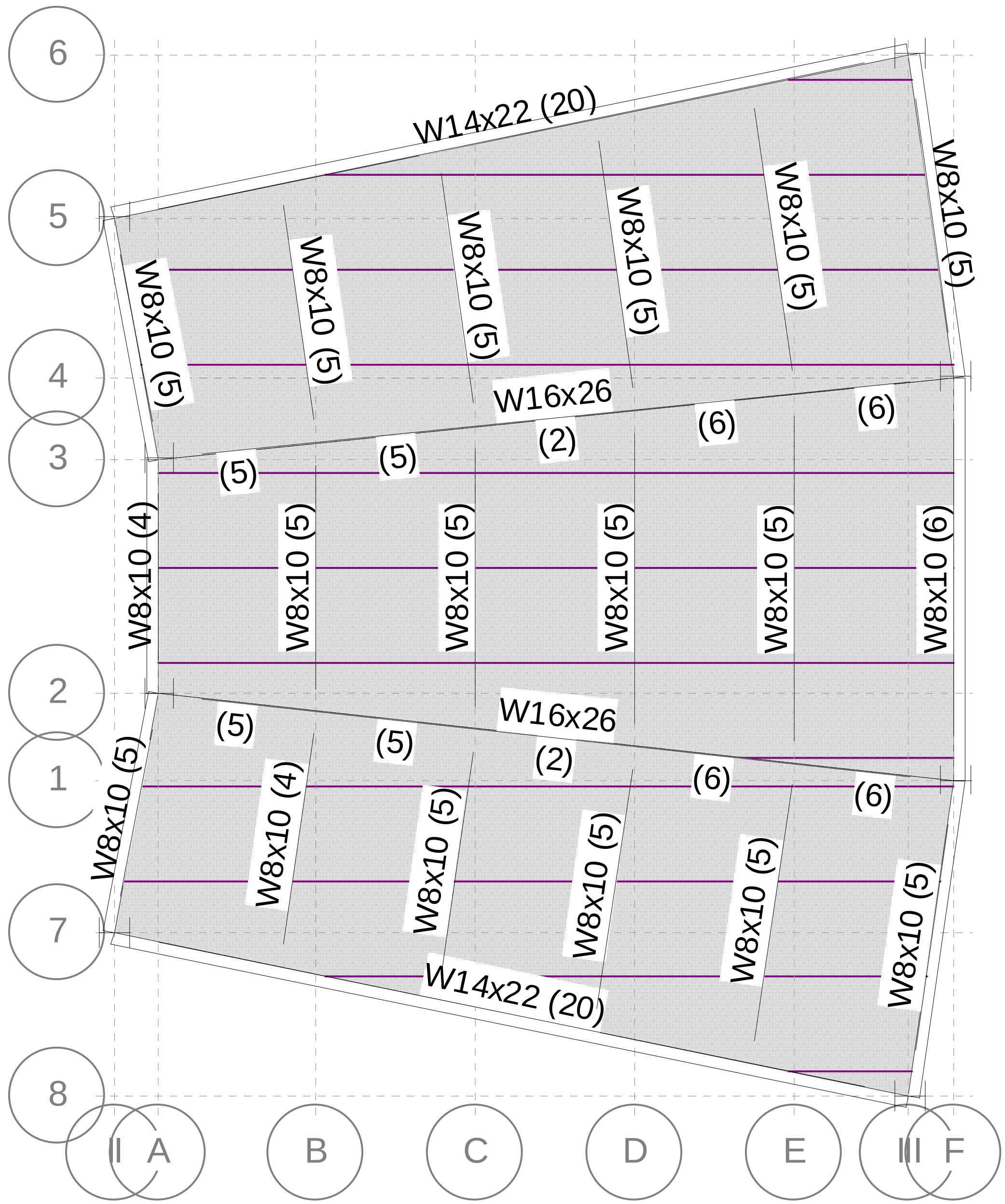
Floor Map

RAM Steel v10.0
DataBase: tech 2 bay
Building Code: IBC

10/25/06 21:57:24
Steel Code: AISC LRFD

Floor Type: 5th floor framing



Floor Map

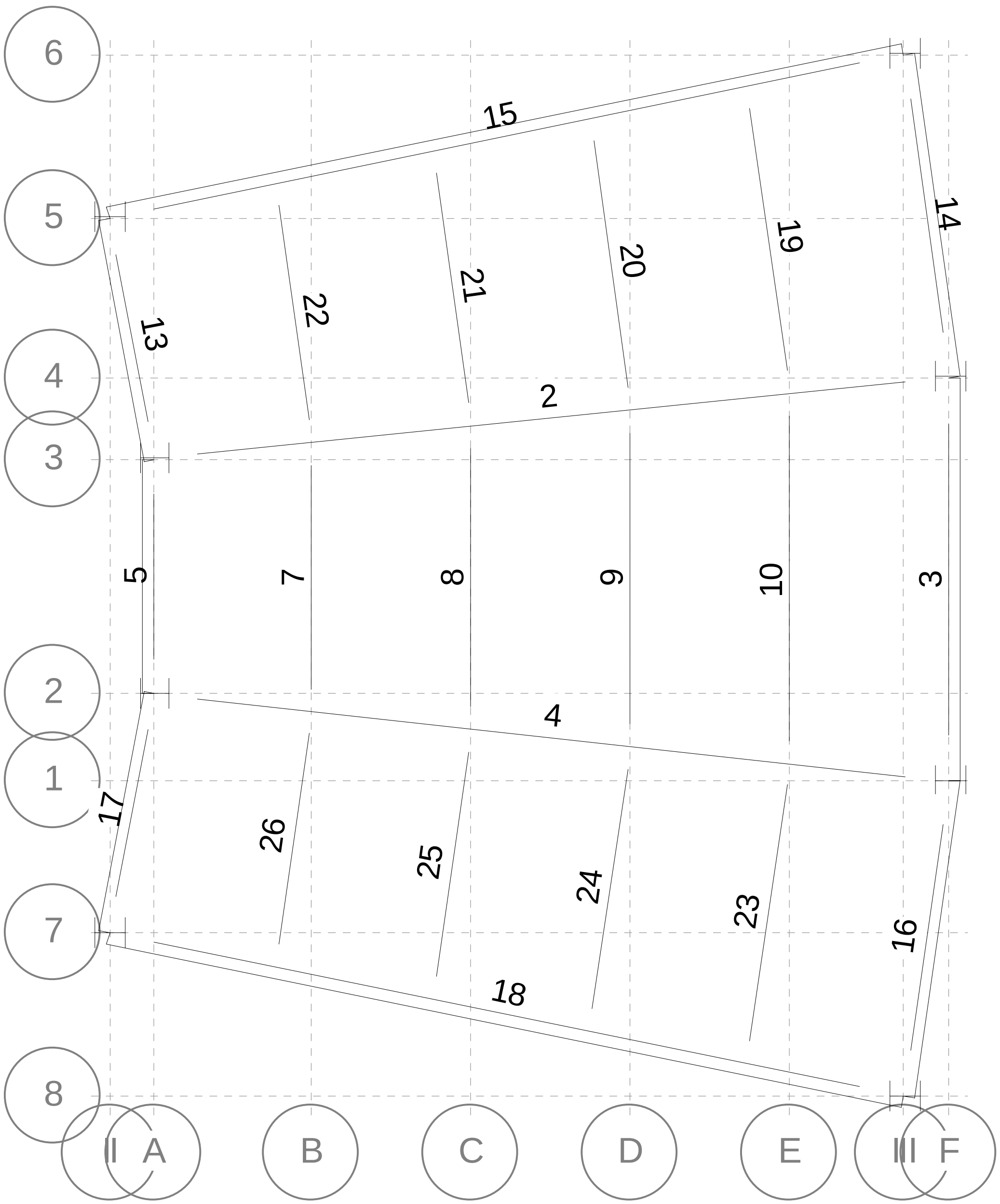
Decks:	Deck Type	Orientation
	VULCRAFT 2.0VL	0.00 degrees

Floor Map

RAM Steel v10.0
DataBase: tech 2 bay
Building Code: IBC

10/25/06 21:57:24
Steel Code: AISC LRFD

Floor Type: 5th floor framing



Beam Summary

RAM Steel v10.0
DataBase: tech 2 bay
Building Code: IBC

10/25/06 21:57:24
Steel Code: AISC LRFD

STEEL BEAM DESIGN SUMMARY:

Floor Type: 5th floor framing

Bm #	Length ft	+Mu kip-ft	-Mu kip-ft	Mn kip-ft	Fy ksi	Beam Size	Studs
17	10.77	9.9	0.0	63.4	50.0	W8X10	5
18	35.73	173.8	0.0	259.0	50.0	W14X22	20
13	10.77	9.9	0.0	63.4	50.0	W8X10	5
15	35.73	175.5	0.0	259.0	50.0	W14X22	20
5	10.31	8.8	0.0	63.3	50.0	W8X10	4
4	35.21	306.3	0.0	384.9	50.0	W16X26	5, 5, 2, 6, 6
2	35.18	307.4	0.0	384.9	50.0	W16X26	5, 5, 2, 6, 6
26	11.44	19.2	0.0	64.0	50.0	W8X10	4
22	11.49	19.4	0.0	64.0	50.0	W8X10	5
7	11.80	20.0	0.0	64.0	50.0	W8X10	5
25	12.09	21.1	0.0	64.1	50.0	W8X10	5
21	12.20	21.4	0.0	64.1	50.0	W8X10	5
8	13.29	25.4	0.0	64.1	50.0	W8X10	5
24	12.74	23.4	0.0	64.1	50.0	W8X10	5
20	12.90	24.0	0.0	64.1	50.0	W8X10	5
9	14.78	31.4	0.0	64.2	50.0	W8X10	5
23	13.39	25.9	0.0	64.1	50.0	W8X10	5
19	13.60	26.7	0.0	64.1	50.0	W8X10	5
10	16.26	38.1	0.0	64.2	50.0	W8X10	5
16	14.04	20.8	0.0	63.7	50.0	W8X10	5
14	14.31	21.6	0.0	63.7	50.0	W8X10	5
3	17.75	33.2	0.0	63.9	50.0	W8X10	6

* after Size denotes beam failed stress/capacity criteria.
# after Size denotes beam failed deflection criteria.
u after Size denotes this size has been assigned by the User.

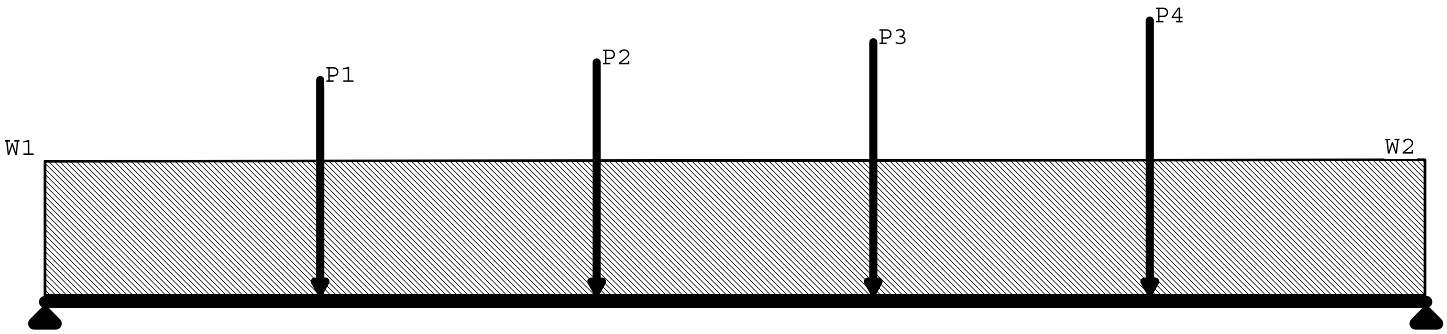
Load Diagram

RAM Steel v10.0
DataBase: tech 2 bay
Building Code: IBC

10/25/06 21:57:24

Floor Type: 5th floor framing **Beam Number = 2**

Span information (ft): I-End (0.00,14.17) J-End (35.00,17.75)



Load	Dist	DL	LL+	LL-	Max Tot
	ft	kips	kips	kips	kips
P1	7.037	6.691	2.541	0.000	9.232
P2	14.073	7.287	2.767	0.000	10.054
P3	21.110	7.932	3.012	0.000	10.944
P4	28.146	8.577	3.257	0.000	11.834
	ft	k/ft	k/ft	k/ft	k/ft
W1	0.000	0.056	0.011	0.000	0.067
W2	35.183	0.056	0.012	0.000	0.068