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Schaumburg, Illinois

Pro-Con Structural Study of Alternate Floor Systems
Due: October 31st, 2005

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Executive Summary

This technical assignment will explore the current and proposed alternate floor framing systems for the Renaissance Schaumburg Hotel. The area of focus for this assignment will be a typical bay located on floors 8 through 14 that is currently comprised of post-tensioned concrete slab.

The four alternate floor systems are as follows:
1. One-way Pan Joists
2. Steel Joists
3. Steel Composite
4. Hollow Core Slab

The existing system has been found to perform with the most efficiency; it has the least floor depth of any of the other systems considered and is considerably light for its load capacity. Both steel systems are significantly deeper, but the steel joist system would have a much easier erection procedure and design process. The one-way slab system would be a good candidate for substitution since it has a competitively low floor depth and would not greatly affect the current column or foundation designs. Hollow core pre-cast slab also shares the advantages of the one-way pan joist system, and also decreases the amount of time spend with on-site construction.

After the analysis of all these systems, it appears that the post-tension system used for the Renaissance Schaumburg Hotel is the best solution in terms of final performance. Some of the other alternative systems do have some advantages, but do not appear to be a better replacement.

This report is limited to analysis based on the most current design documents made available for the Renaissance Schaumburg Hotel and Convention Center. Simplified sketches have been included to further explain system layouts and details. Please see the appendix for other figures. This report will further detail alternate floor framing systems and the current system used in the design of the Renaissance Schaumburg Hotel and Convention Center.

Introduction – Existing Design and Load Calculations

The Renaissance Schaumburg Hotel and Convention Center (RSHCC) is composed of 17 stories. This paper will examine a typical bay, which is reproduced below, that can be found repeated from floor 8 through 14.

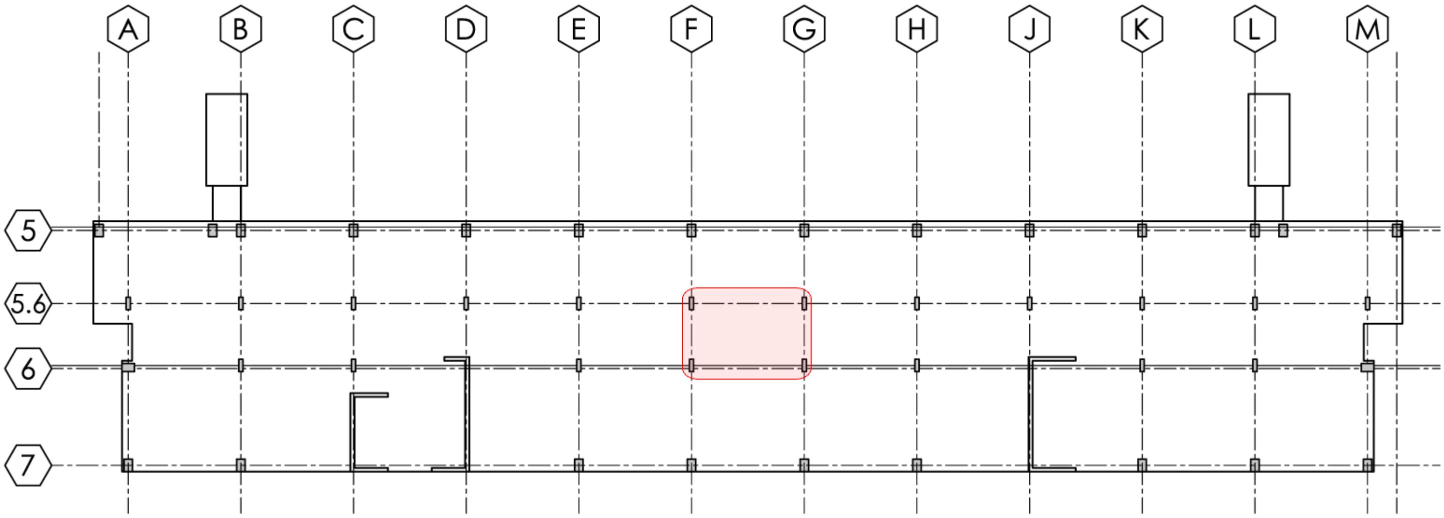


Figure 1 - Typical Floor Plan

These floors are used as guest suites, with an area approximately equal to 18,000 square feet. The typical floor is post-tensioned concrete slab, with concrete columns which range from 18" to 36" deep all of which utilize 6,000 psi strength concrete. This study will consider the bay between column lines F-5.6 and G-6 (highlighted above). The typical span considered in this study is 27' by 14'-10.5", and includes the 7.5" thick post-tensioned slab (normal weight concrete 145pcf). The typical bay will also consider the loading conditions listed in the next section.

After a preliminary look at the building layout most two-way concrete systems were ruled out as alternatives since the bay under inspection is not close to square. Although the current system uses two-way post-tensioned slab it can be controlled to behave differently based on post-tensioning forces, for a more detailed examination of the current system please see the current floor system discussion below.

Loads

Loading Conditions

Introductions to the loads that will be used through the rest of this study are as follows, though the design of each system will have some deviation (as noted in the appendix).

Live Loads (psf):

o Typical Floors (Hotels refer to residential)	40 psf
o Public rooms and Corridors	100 psf
	Design Total = 100 psf

Dead Loads (psf):

o Mechanical/Ceiling	7 psf
o Partitions	20 psf
o Carpet/Miscellaneous	5 psf
	Total = 32 psf

Load Discussion

Since the design will be governed by the largest load expected, the typical bay discusses here will be treated as a corridor (live load equals 100psf). The dead load and live load figures are similar to those used in the actual design process and are referenced from ASCE 7-02.

Current System — Post-Tension Slab

System Description

The current floor framing system used on most of the higher floors in the RSH is a two-way post-tensioned slab system. Effective pre-stressing forces range from 85 to 365 kips or average around 17.2 kips per foot. The post-tensioning system must also consist of un-bonded, low-relaxation, mono-strand tendons which must guarantee a minimum ultimate strength of 270,000 psi. These tendons are also not to be overstressed above 0.85 of the ultimate tensile strength and locked off after jacking to a value equal to or lower than 0.70 of the 270ksi.

The concrete used throughout the entire building is normal weight (145 pcf) and the 28-day compressive strength for post-tensioned slabs is 6,000 psi.

Discussion

This system will be the most shallow floor design due to its efficient use of concrete and the extra capacity of the concrete due to the pre-stressing force. This system is excellent for keeping shallow floor depths but does have a couple disadvantages.

First, post-tensioned systems are typically much more expensive then reinforced concrete slabs with respect to the installation cost. Specialization of post-tension erection will not only incur costs due to construction, but will also require more steps from the post-tensioning contractor during the design stage. The structural notes state that the post-tensioning contractors are responsible for tendon layout, tendon size, and determining amount of tendons to use. This system must also be reviewed and have records kept for all theoretical and actual elongation. All of this leads to a really efficient design, but also results in a price premium. The rest of this study will examine other systems that would be suitable for post-tensioned slab alternates.

Alternate System 1 —One Way Pan Joists

System Description

Using the *Concrete Reinforcing Steel Institute* Design Handbook (2002) and following the load procedure described below, a 30" pan joist one-way slab system was designed to be an alternate floor framing system to the current post-tensioned slab system. A sketch of the system is shown in figure 2, and a floor plan in figure 3. The system uses 30" pans with 6" ribs, this creates a perfect modular unit of 3 feet on center, and since the perpendicular span direction is 27' an even 9 joists will span the short (~15') direction. The system totals to 11" deep including a 3" slab (meets required 1.5 hour fire rating) with top reinforcing using #4 bars at 12" and 2-#4 bars in the bottom layer of steel reinforcing. This design guide considers factored loads differently than every other analysis procedure detailed in this report. The CRSI uses a factored load of 1.4(Dead Load) + 1.7(Live Load). See Appendix A for the design procedure used to arrive at this floor system.

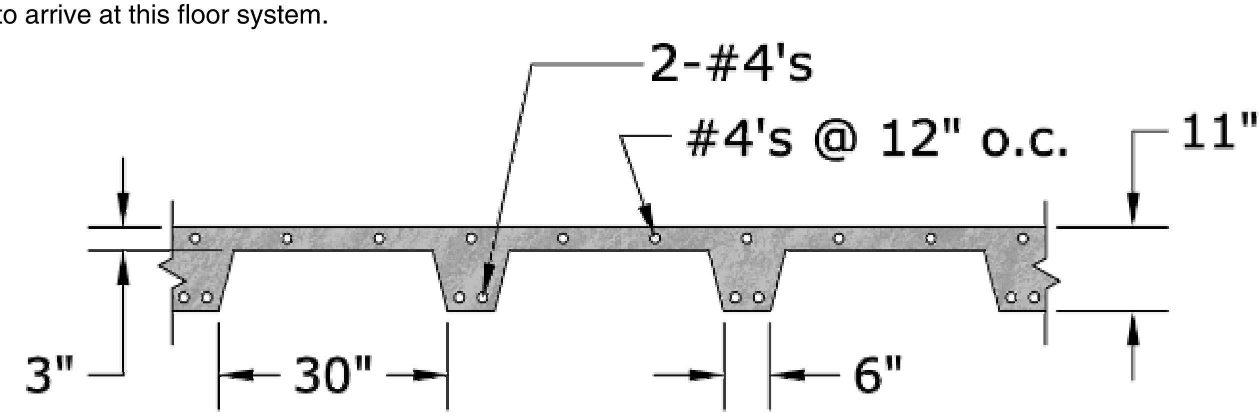


Figure 2 - Pan Joist

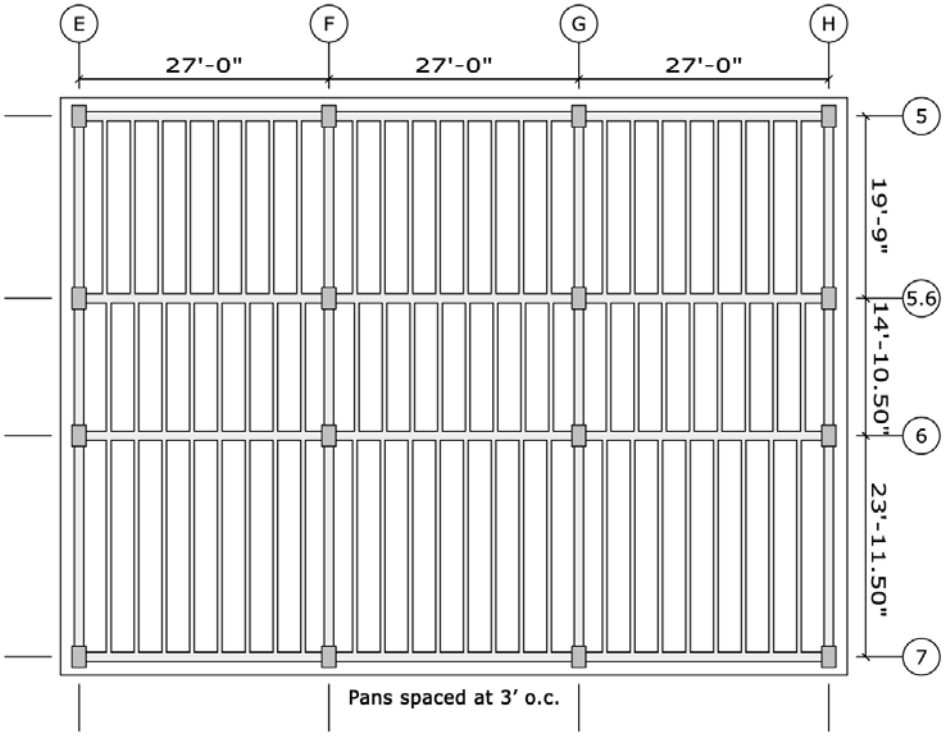


Figure 3 - Pan Joist System

Discussion

This system takes up slightly more space vertically than the post-tensioned system, but would not require the same degree of difficulty in erection. Due to this system being slightly easier to construct it would also keep building costs lower and require a less specialized installation. Contractors will be able to become more efficient in erecting this system if it can be used over and over through the entire floor. However, there are a few disadvantages to using this system.

The one-way pan joist system is much more expensive in formwork than flat-plate systems. This increases cost due to formwork construction, and may lengthen the initial time needed to place the floor slab system. This system is slightly deeper than the post-tensioned system so due to the increased depth, the girders would be designed to match the 11" depth, but this increase could impose on many other building systems (such as mechanical, electrical and plumbing systems). This system is only slightly heavier than the pos-tensioned system, however, such an increase could increase the load on columns and eventually impact the size of the foundation pile caps.

Alternate System 2 — Steel Joists

System Description

The Steel Joist Institute's Joist design guide is an excellent tool for arriving at suitable joist selection types. The proposed system that was derived from joist selection tables includes 14K1 open web steel joists placed at 3' on center, with one row of bridging. The model created in Ram Steel produced joists sized as 12K1 (shown below in figure 4), which was close the to size required by the Steel Joist Institutes Catalog, but since the load factoring approach is different there is reason to believe that this small size difference is due to a change between ASD and LRFD methods. See Appendix B for the design procedure used to arrive at this floor system.

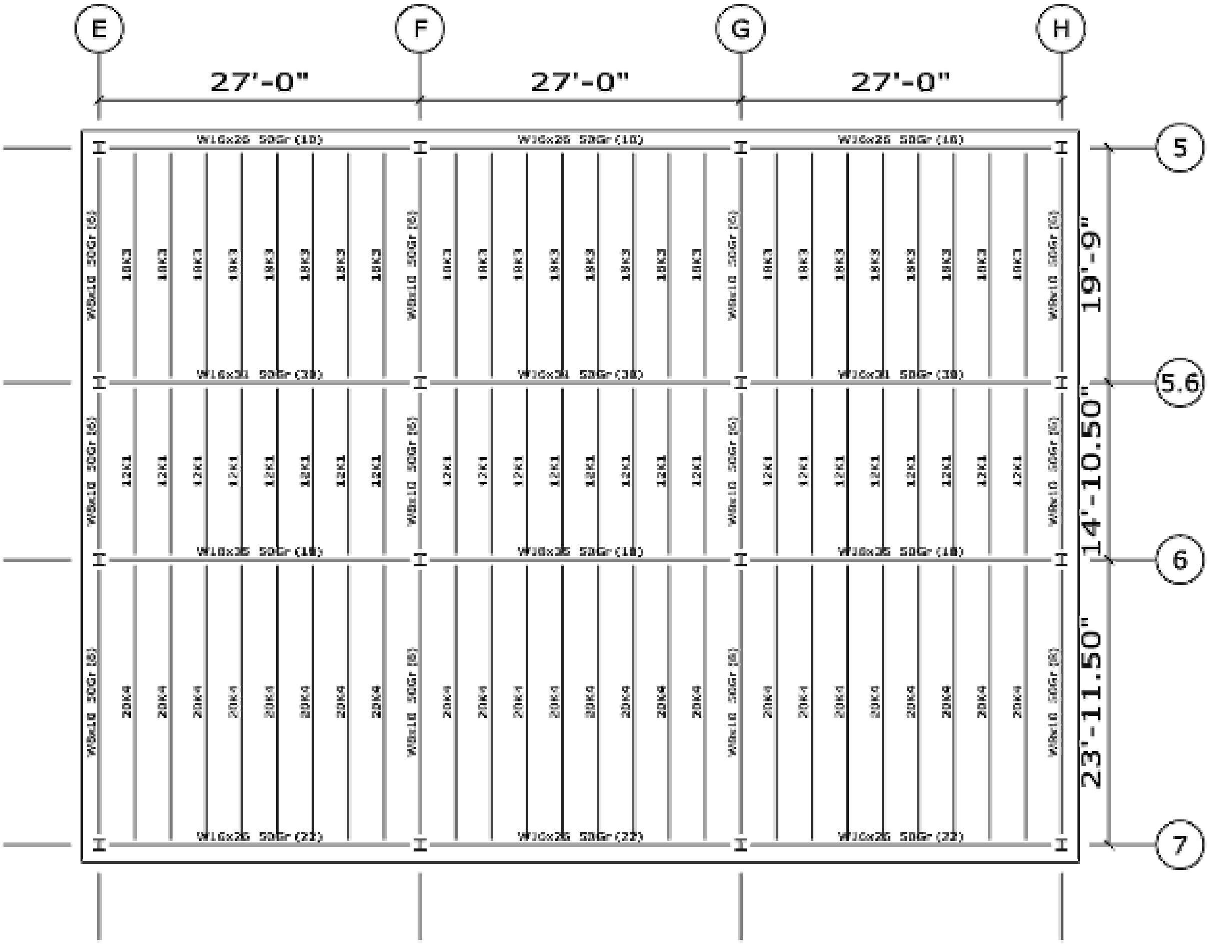


Figure 4 - Joist system

Discussion

The design guide referenced for this system optimizes Nucor Vulcraft Steel Joists. Conveniently there is a plant that produces joists and deck in St. Joe, Indiana which is close to Illinois; this is a good exercise to follow with all construction material. Keeping to resources in and around the immediate area of the construction site will help to keep transportation costs down and fuel local economies.

This system is also performs exceeding well in terms of weight. Due to the efficient use of steel, the system is the lightest of the others examined in this study. This lightweight construction transfers to a reduced impact on foundation and column systems. Mechanical and other building systems can also be integrated into the openings within the truss webs, so this means that even though the system itself is deep, it is possible to gain back some space if the design is incorporated properly. The last advantage examined as a result of using open web steel joists includes constructability. Construction and erection in systems like these are highly repetitive and relatively simple compared to those of one-way slabs, this means faster erection time and minimized construction costs.

Steel Joist do have a fair share of problems, this includes susceptibility to vibration. These systems, even though they are strong enough to carry significant loads, often have problems dealing with vibration. The lack of self-weight is actually the cause of vibration since they provide very little damping. Fireproofing is also a cause for concern. Steel joist systems will require additional fireproofing, which due to the geometric complexity of the joist, may be a difficult and time consuming process.

Alternate System 3 — Steel Composite Deck

System Description

A steel composite slab system was also examined to fit into the RSH floor framing system. Ram Steel was used to create a typical bay layout and design a suitable steel alternate system. The result of this exercise yielded the design presented below in figure 5. Typical beam sizes that were computed for the bay redesign were considerably small. This is due to the short span between columns lines 6 and 5.6. The girder members are sized to be W16x31 or W 16x26 grade 50 steel. Due to the unsymmetrical bay sizes that run vertically these members designed by the computer differ by one size. For design simplicity, and for steel fabrication and erection, it is suggested that a designer specify those members marked below as W16x26 to be changed to W16x31. Please note that members along lines E and H are not actually exterior bay members, the building repeats the 27 foot horizontal offset 3 more times. Decking was chosen as 2" USD Lok-floor and the slab thickness was specified as 3" as to provide sufficient fire protection and ¾" shear studs were used (the number in figure 3 below in parenthesis next to beam shape). See Appendix C for the design procedure used to arrive at this floor system.

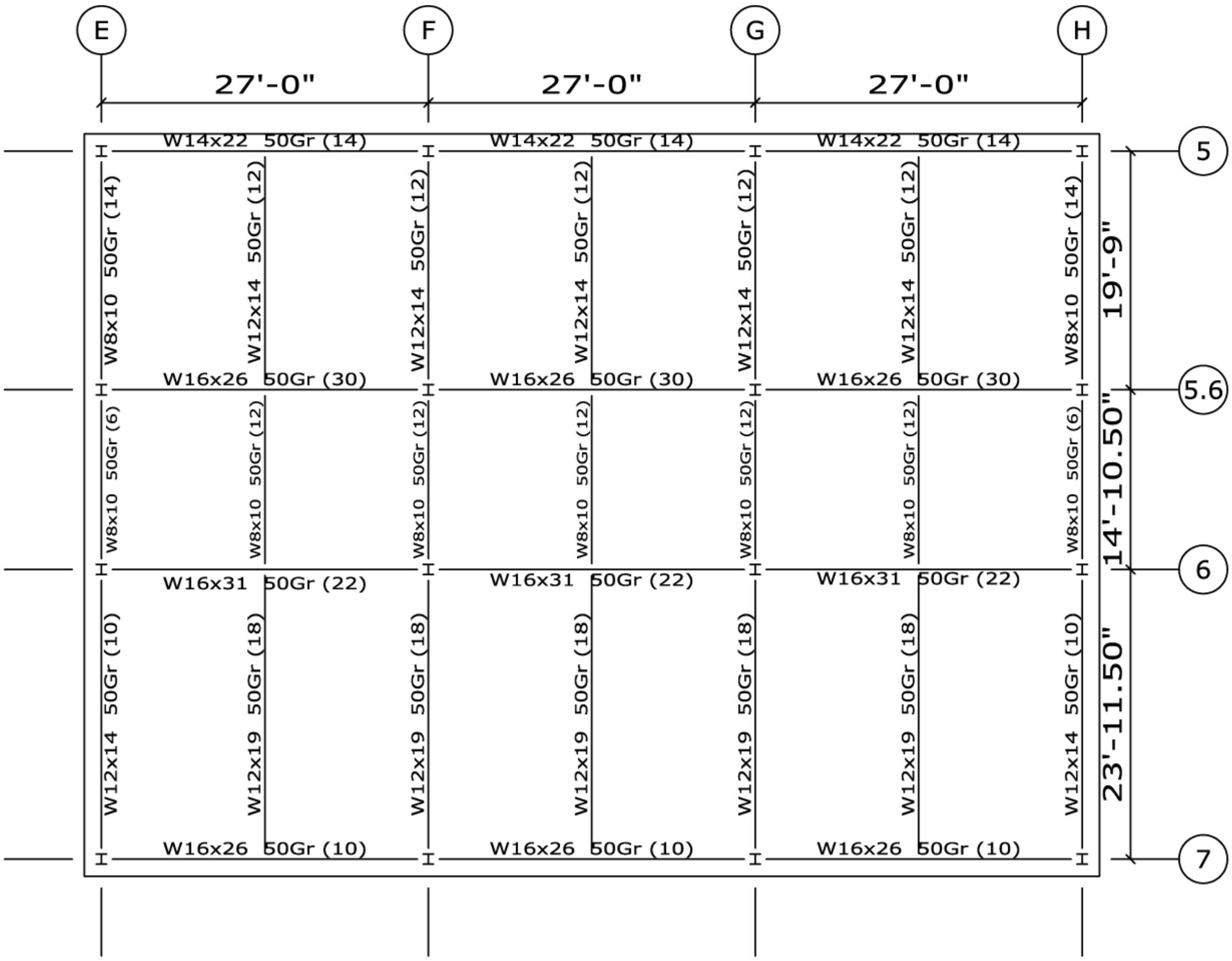


Figure 5 - Composite Steel System

Discussion

This steel system has similar impacts on the foundation and column design, just as the steel joist system. The steel column system would be lighter than the concrete one current in place, this would allow for columns that were not only smaller because of material strength, but also smaller since the dead loads would be reduced. The foundation system would also share in this impact since the connection would now be steel to the concrete pile caps, but again, less material weight would imply that the foundation system size could stand to be reduced.

This system, although light, is among the deepest at 21" and could cause a problem for mechanical and electrical installations. Steel composite systems also include labor intensive erection processes compared to other methods (like placing hollow core pre-cast slab). The other large drawback to changing this system is a reevaluation of the lateral system. Since the framing plan would now be steel based instead of concrete, a moment resisting steel frame would take the place of the shear walls. This system could be beneficial if the owner is willing to increase the height of the building due to the larger floor depth, but would also result in the benefit of a significantly lighter framing system.

Alternate System 4 — Hollow Core

System Description

Hollow core pre-cast concrete slabs as specified by Nitterhouse Concrete Products, Inc, were also considered as a floor system alternate. The SpanDeck pre-stressed concrete slab design guide used for this system was an 8” by 4’ un-topped slab. The slab is normal weight at 150 pcf and uses similar pre-stressing tendons as the post-tensioned slab system mentioned previously. After using the design table it was found that even the smallest pre-cast panel Nitterhouse had to offer had capacities much greater than those required from the load development procedure discussed in Appendix D. The slab uses 4- ½” diameter tendons and supplies a robust 74.3 ft-kips of moment capacity, while supporting 341 psf of superimposed load in flexure (or 270 psf in shear). This system also requires concrete girders which were chosen from the PCI *Pre-stressed Design Handbook* 2003 which arrived at a 28” by 32” inverted-t shaped pre-stressed girder. This system allows for a floor depth of 20”.

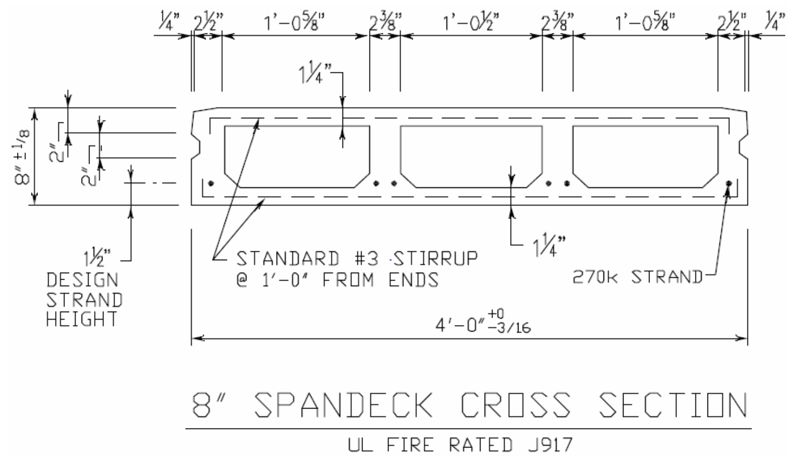


Figure 6 - Hollow Core Section

Discussion

Advantages to using hollow core pre-cast products include fast erection, and minimal surface preparation. Since the product is cast off-site, it needs only to be shipped and quickly erected into place. This system is also light due to the use of pre-stressed tendons (similar to the performance of post-tensioned slab) and does not require any on-site formwork. Hollow core is also very useful for keeping floor depths relatively shallow.

Despite the advantages, considerable drawbacks exist, such as lead time for fabrication can cause a problem. Additional fireproofing will be required and even though erection costs are low, there is a high cost associated with the production of pre-stressed concrete. There is also a need for on site adjustments to the pre-cast slab, since often times they will need to be cut to fit. This is especially true for this building floor plan that works off of 27’ span lengths, it could easily result in the need to cut the last plank on foot shorter per span. This could become expensive if it delays the expected placement time for consequent planks. Finally that last disadvantage is not one based on the performance of this system, but rather on based on material location. Nitterhouse is located in Chambersburg, PA which is very far from the Chicago site where the RSH is located. If a hollow core system were to be used it is recommended that a closer manufacturer is used for this project.

System Comparison

Table 1 - System Comparison Chart

System		Advantages	Disadvantages	Depth	Potential
-	Post-Tensioned Slab	Shallow floor depth	Specialized Design and Erection	7.5"	Existing
		Light weight	Construction Cost		
		Efficient use of material			
1	One-way Pan Joists	Moderately Shallow	Additional Formwork Cost	11"	Yes
		Repeative Construction	Increased Dead Weight		
		Convient for bay size ratio			
2	Steel Joists	Light weight	Complicated Fireproofing installation	17"	No
		Smaller Columns	Extended Lead Time for Fabrication		
		Smaller Foundations	Deep Floor Depth		
3	Steel Composite	Longer Spans Possible	Extended Lead Time for Fabrication	21"	No
		Smaller Columns	Additional Fireproofing is Necessary		
		Smaller Foundations	Deepest Floor Depth		
4	Hollow Core	Fast Construction	Additional Fireproofing is Necessary	20"	Yes
		Shallow floor depth	On-site adjustments		
		Ease of Construction	Deep Floor Depth		

Conclusion

The Renaissance Schaumburg Hotel uses post-tensioned concrete slab for the majority of the building's floor system. The four systems reviewed in this paper each had extensive advantages and disadvantages for this particular building project. Specifically hollow core planks and one-way pan joist systems appear to be the most viable alternatives based on the chart above. This investigation compares rules out the 2 steel systems based on the composite system being uncomfortably deep, and the joist system being prone to vibration problems and difficult fireproofing. Also these systems were ruled out based on the need for a redesign of the lateral resisting elements and column/foundation redesigns. If considerable cost savings could be possible with these systems a redesign is in order, but this report finds that the current post-tension system performs the best in terms of capacity and depth. [‡]

‡ End of Report – Continue with Appendices

Appendix A – One-way Pan Joists

CRSI Page 8-20 – Standard one-way joists

Live Loads (psf):

o Typical Floors (Hotels refer to residential)	40 psf
o Public rooms and Corridors	100 psf
	Design Total = 100 psf

Dead Loads (psf):

o Mechanical/Ceiling	7 psf
o Partitions	20 psf
o Carpet/Miscellaneous	5 psf
	Total = 32 psf

Load Factors: $1.4(DL)+1.7(LL)=1.4(32)+1.7(100)=214.8\,psf$

1. Since the span detailed is 14'-10.5" assume a 15' clear span (which is conservative)
2. Follow the chart across to the interior span columns until you reach a factored load >214.8psf
3. Follow the chart up to reinforcing type and steel weight (See figure below and discussion)
4. Since the design resides above the black horizontal line additional deflection calculations are not required

STANDARD ONE-WAY JOISTS (1) MULTIPLE SPANS		30" Forms + 6" Rib @ 36" c.-c. (2) FACTORED USABLE SUPERIMPOSED LOAD (PSF)											f'_c = 4,000 psi f_y = 60,000 psi
8" Deep Rib + 3.0" Top Slab = 11.0" Total Depth													
TOP BARS	Size @	# 4 12	# 4 12	# 4 11.5	# 4 9.5	# 5 11.5	End Span Defl. Coeff. (3)	# 4 12	# 4 12	# 4 11	# 4 8.5	# 5 10.5	Int. Span Defl. Coeff. (3)
BOTTOM BARS	# #	# 3 # 4	# 4 # 4	# 4 # 5	# 5 # 5	# 5 # 5		# 3 # 3	# 3 # 4	# 4 # 4	# 4 # 5	# 5 # 5	
Steel (psf)		.49	.58	.70	.86	1.06		.55	.63	.75	.95	1.20	
CLEAR SPAN		END SPAN						INTERIOR SPAN					
14'-0"		174	246	312*	321*	334*	.463	184	288	356*	366*	373*	.285
		0	0	332	419	517*		0	0	394	518	588*	
15'-0"		141	204	278*	287*	297*	.610	150	241	321*	330*	336*	.375
		0	0	279	355	440		0	0	333	441	534*	
16'-0"		114	170	235	257*	266*	.789	122	202	283	299*	303*	.486
		0	0	0	302	377		0	0	0	378	475	
17'-0"		92	142	200	233*	240*	1.006	99	170	242	272*	276*	.619
		0	0	0	259	325		0	0	0	326	412	
18'-0"		74	118	169	212*	217*	1.264	80	143	207	249*	252*	.778
		0	0	0	222	282		0	0	0	282	359	
19'-0"		58	98	144	191	198*	1.569	64	120	178	229*	231*	.966
		0	0	0	0	245		0	0	0	245	314	
20'-0"		45	80	122	165	181*	1.926	50	101	153	211*	213*	1.185
		0	0	0	0	213		0	0	0	214	276	
21'-0"			66	104	142	166*	2.342		84	131	187	197*	1.441
			0	0	0	186			0	0	0	243	
22'-0"			53	87	123	153*	2.820		70	113	163	182*	1.736
			0	0	0	162			0	0	0	214	
23'-0"			42	73	106	141*	3.369		57	96	142	169*	2.073
			0	0	0	142			0	0	0	189	
24'-0"				61	90	124	3.995		46	82	124	157*	2.458
				0	0	0			0	0	0	167	
25'-0"				50	77	108	4.703			69	108	147*	2.894
				0	0	0				0	0	148	
26'-0"				40	65	94	5.502			58	94	131	3.386
				0	0	0				0	0	0	
27'-0"					55	81	6.398			48	82	116	3.938
					0	0				0	0	0	

(1) For gross section properties, see Table 8-1.
(2) First load is for standard square joist ends; second load is for special tapered joist ends.
(3) Computation of deflection is not required above horizonal line (thickness ≥ $\ell_n/18.5$ for end spans, $\ell_n/21$ for interior spans).
(4) Exclusive of bridging joists and tapered ends.
*Controlled by shear capacity. +Capacity at elastic deflection = $\ell_n/360$.

PROPERTIES FOR DESIGN (CONCRETE .37 CF/SF) (4)											
NEGATIVE MOMENT STEEL AREA (SQ. IN.)	.60	.60	.63	.76	.97		.60	.60	.65	.85	1.06
STEEL % (UNIFORM)	.90	.90	.94	1.14	1.47		.90	.90	.99	1.28	1.61
(TAPERED)	.52	.52	.54	.66	.85		.52	.52	.57	.74	.93
EFF. DEPTH, IN.	9.8	9.8	9.8	9.8	9.7		9.8	9.8	9.8	9.8	9.7
– ICR/IGR	.195	.195	.202	.232	.273		.195	.195	.208	.252	.291
POSITIVE MOMENT STEEL AREA (SQ. IN.)	.31	.40	.51	.62	.75		.22	.31	.40	.51	.62
STEEL %	.09	.11	.15	.18	.22		.06	.09	.11	.15	.18
EFF. DEPTH, IN.	9.8	9.8	9.7	9.7	9.6		9.8	9.8	9.8	9.7	9.7
+ICR/IGR	.144	.182	.224	.267	.311		.106	.144	.182	.224	.267

This procedure considers 30" pans with 6" ribs constructed from 4ksi concrete and 60ksi steel reinforcement. Also note that this configuration will also work for the end span sections as long as one considers the necessity to use #4 bars in both the bottom and top, with the top being placed every 12". The total steel weight is 0.63 psf and the total system depth is 11" (including 3" slab).

Appendix B – Steel Joist

Vulcraft Joist Catalog – Open Web Steel Joists, K-Series

Live Loads (psf):

o Typical Floors (Hotels refer to residential)	40 psf
o Public rooms and Corridors	100 psf
	Design Total = 100 psf

Dead Loads (psf):

o Mechanical/Ceiling	7 psf
o Partitions	20 psf
o Carpet/Miscellaneous	5 psf
o Slab Dead Weight (2.5" @ 145 pcf)	30.2 psf
	Total = 62.2 psf

Load Factors: $1.2(D)+1.6(L)=1.2(62.2)+1.6(100)=234.65\,psf$

1. Since the span detailed is 14'-10.5" assume a 15' clear span (which is conservative)
2. To turn this load into a linear uniformly distributed load, multiply psf by 3' (assume joist placement every 3')

   $$(234.65\,psf)3' = 703.95\,{}^{lb}\!/_{ft}$$

3. Convert this factored weight into an un-factored load as per SJI joist catalog specification (divide by 1.65 and 0.9)

   $$\frac{703.95\,{}^{lb}\!/_{ft}}{(1.65(0.9))} = 474\,{}^{lb}\!/_{ft}$$

4. Use the standard load table (page 10) of the SJI catalog, at 15' span until you can support the required 474 lb/ft
5. This chart states a 12K3 will suffice, however we should check for joist economy on page 107 (see figure below)
6. SJI states that a 14K1 will be more efficient (although deeper), the joist is 14" deep and weighs 5.2 lb/ft
7. Page 35 of SJI states that this K-series joist will require one row of bridging

STANDARD LOAD TABLE/OPEN WEB STEEL JOISTS, K-SERIES
Based on a Maximum Allowable Tensile Stress of 30 ksi

Joist Designation	8K1	10K1	12K1	12K3	12K5	14K1	14K3	14K4	14K6
Depth (in.)	8	10	12	12	12	14	14	14	14
Approx. Wt (lbs./ft.)	5.1	5.0	5.0	5.7	7.1	5.2	6.0	6.7	7.7
Span (ft.) ↓ 8	550 550								
9	550 550								
10	550 480	550 550							
11	532 377	550 542							
12	444 288	550 455	550 550	550 550	550 550				
13	377 225	479 363	550 510	550 510	550 510				
14	324 179	412 289	500 425	550 463	550 463	550 550	550 550	550 550	550 550
15	281 145	358 234	434 344	543 428	550 434	511 475	550 507	550 507	550 507
16	246 119	313 192	380 282	476 351	550 396	448 390	550 467	550 467	550 467
17		277 159	336 234	420 291	550 366	395 324	495 404	550 443	550 443
18		246 134	299 197	374 245	507 317	352 272	441 339	530 397	550 408
19		221 113	268 167	335 207	454 269	315 230	395 287	475 336	550 383
20		199 97	241 142	302 177	409 230	284 197	356 246	428 287	525 347

The placement of joists every three feet may seem excessive; however, it does allow the use of shallower members and fits evenly into the design. Future investigations may determine a different spacing and sizing configuration, but this process appears to result in a system that is easily comparable to other systems, especially the 3 foot spacing used in the pan joist floor framing system.

Appendix C – Steel Composite

Vulcraft Joist Catalog – Open Web Steel Joists, K-Series

Live Loads (psf):

o Typical Floors (Hotels refer to residential)	40 psf
o Public rooms and Corridors	100 psf
	Design Total = 100 psf

Dead Loads (psf):

o Mechanical/Ceiling	7 psf
o Partitions	20 psf
o Carpet/Miscellaneous	5 psf
	Total = 32 psf

$$1.2(D)+1.6(L)=1.2(32)+1.6(100)=198.4\,psf$$

The loads above were placed on the floor system developed in Ram Steel, a model of which will be made available upon request.

Appendix D – Hollow Core

Hollow Core Load Development

Live Loads (psf):

o Typical Floors (Hotels refer to residential)	40 psf
o Public rooms and Corridors	100 psf
	Design Total = 100 psf

Dead Loads (psf):

o Mechanical/Ceiling	7 psf
o Partitions	20 psf
o Carpet/Miscellaneous	5 psf
o Slab Dead Weight (based on chart)	57.5 psf
	Total = 89.5 psf

Nitterhouse Concrete Products supplied a design guide for selecting hollow core slabs based on expected flexural and shear loads. The chart below represents allowable loading for the Nitterhouse 8"x4' SpanDeck J917 (without topping).

8" SPANDECK W/O TOPPING	ALLOWABLE SUPERIMPOSED LOAD (PSF)																						
STRAND PATTERN	SPAN (FEET)																						
	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
Flexure 4 – 1/2"ø	610	550	499	457	399	341	294	255	222	195	171	151	133	117	103	92	82	72	66	56	49	43	
Shear 4 – 1/2"ø	441	393	354	321	294	270	249	231	215	201	188	177	160	145	132	120	110	101	95	90	82	75	
Flexure 6 – 1/2"ø	885	800	726	667	586	509	437	382	334	296	263	234	208	187	168	151	136	122	111	100	90	81	73
Shear 6 – 1/2"ø	459	411	370	337	308	283	262	243	226	211	197	185	174	164	155	147	139	131	120	111	102	94	87

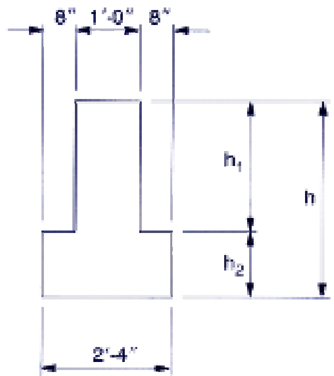
Load factors $1.2(D)+1.6(L)=1.2(89.5)+1.6(100)=267.4\,psf$

1. Since the span detailed is 14'-10.5" assume a 15' clear span (which is conservative)
2. The chart above states for a 15' clear span, the slab is to sustain 341psf in flexure and 270psf in shear (both below 267.4psf of design requirement).
3. This design requires 4-½" diameter tendons.
4. Select Girder to carry plank loads into columns using PCI design Handbook (5th Edition)
5. Load calculation of line load on girder 267.4psf x19.5'=5.2143 klf
6. Page 2-40 at 27' yields a girder member designed to be 12" wide x 32" deep, with 13 strands
7. Page 2-44 states that for a inverted-t section this design could use a 28it32, which is also 32" deep but will have the ability to "cope" around the planks talking the over all floor depth to 8"+12"=20" deep

This design is near the shear limit for the table provided with only 4 tendons, however since the load procedure was conservative, and the span is actually slightly shorter than the 15 foot clear span used, it is not uncomfortable to state this design will provide adequate support.

INVERTED TEE BEAMS

Normal Weight Concrete



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

½ in. diameter
low-relaxation strand

Key
6,929 — Safe superimposed service load, plf
0.3 — Estimated camber at erection, in.
0.1 — Estimated long-time camber, in.

Section Properties

Designation	h in.	h_1/h_2 in.	A in²	I in⁴	y_b in.	S_b in³	S_t in³	wt plf
28IT20	20	12/8	368	11,688	7.91	1,478	967	383
28IT24	24	12/12	480	20,275	9.60	2,112	1,408	500
28IT28	28	16/12	528	32,076	11.09	2,892	1,897	550
28IT32	32	20/12	576	47,872	12.67	3,778	2,477	600
28IT36	36	24/12	624	68,101	14.31	4,759	3,140	650
28IT40	40	24/16	736	93,503	15.83	5,907	3,869	767
28IT44	44	28/16	784	124,437	17.43	7,139	4,683	817
28IT48	48	32/16	832	161,424	19.08	8,460	5,582	867
28IT52	52	36/16	880	204,884	20.76	9,869	6,558	917
28IT56	56	40/16	928	255,229	22.48	11,354	7,614	967
28IT60	60	44/16	976	312,866	24.23	12,912	8,747	1,017

1. Check local area for availability of other sizes.

2. Safe loads shown include 50% superimposed dead load and 50% live load. 800 ps top tension has been allowed, therefore additional top reinforcement is required.

3. Safe loads can be significantly increased by use of structural composite topping.

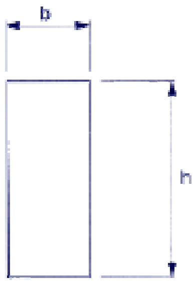
Table of safe superimposed service load (plf) and cambers

Designation	No. Strand	e	Span, ft 16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50
28IT20	9	5.82	6929	5402	4310	3502	2887	2409	2029	1723	1473	1265	1091							
			0.3	0.3	0.4	0.4	0.5	0.6	0.6	0.7	0.7	0.5	0.5							
			0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	−0.1	−0.1							
28IT24	11	6.77	9714	7580	6054	4925	4066	3398	2868	2440	2090	1799	1556	1351	1175	1024				
			0.2	0.3	0.3	0.4	0.4	0.5	0.6	0.6	0.7	0.7	0.7	0.8	0.8	0.8				
			0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	−0.1	−0.2				
28IT28	13	8.44			8505	6951	5768	4848	4118	3529	3047	2648	2313	2030	1788	1579	1399	1242	1103	981
					0.3	0.4	0.5	0.5	0.6	0.7	0.7	0.8	0.9	0.9	1.0	1.0	1.1	1.1	1.1	1.1
					0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.0	−0.1
28IT32	15	9.17				9202	7646	6435	5474	4698	4064	3538	3097	2724	2406	2132	1894	1687	1505	1345
						0.3	0.4	0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.8	0.8	0.9	0.9	0.9	0.9
						0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	−0.1
28IT36	16	10.81						8485	7236	6227	5402	4718	4145	3660	3246	2890	2581	2311	2075	1866
								0.4	0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.8	0.8	0.9	0.9	0.9
								0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	−0.1
28IT40	19	11.28							8615	7415	6433	5620	4938	4361	3868	3444	3077	2756	2475	2226
									0.4	0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.8	0.8	0.8	0.8
									0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0
28IT44	20	12.89								9308	8092	7083	6239	5624	4913	4388	3932	3535	3186	2879
										0.4	0.5	0.5	0.5	0.6	0.5	0.7	0.7	0.8	0.8	0.8
										0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0
28IT48	22	14.16									9741	8539	7532	6680	5952	5326	4783	4310	3894	3528
											0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.8	0.8	0.8
											0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
28IT52	24	15.44											8935	7934	7080	6345	5707	5151	4664	4233
													0.5	0.5	0.6	0.6	0.7	0.7	0.8	0.8
													0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
28IT56	26	16.74												9284	8294	7442	6703	6059	5493	4994
														0.5	0.6	0.6	0.7	0.7	0.8	0.8
														0.1	0.1	0.1	0.1	0.1	0.1	0.1
28IT60	28	18.04													9590	8613	7766	7027	6379	5807
															0.6	0.6	0.6	0.7	0.7	0.8
															0.1	0.2	0.2	0.2	0.2	0.2

Figure 7 - PCI Handbook (5th Edition) Page 2-44

RECTANGULAR BEAMS

Normal Weight Concrete



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

½ in. diameter
low-relaxation strand

Key
3,344 — Safe superimposed service load, plf
0.4 — Estimated camber at erection, in.
0.1 — Estimated long-time camber, in.

Section Properties							
Designation	b in.	h in.	A in²	I in⁴	y_b in.	S in³	wt plf
12RB16	12	16	192	4,096	8.00	512	200
12RB20	12	20	240	8,000	10.00	800	250
12RB24	12	24	288	13,824	12.00	1,152	300
12RB28	12	28	336	21,952	14.00	1,568	350
12RB32	12	32	384	32,768	16.00	2,048	400
12RB36	12	36	432	46,656	18.00	2,592	450
16RB24	16	24	384	18,432	12.00	1,536	400
16RB28	16	28	448	29,269	14.00	2,091	467
16RB32	16	32	512	43,691	16.00	2,731	533
16RB36	16	36	576	62,208	18.00	3,456	600
16RB40	16	40	640	85,333	20.00	4,267	667

1. Check local area for availability of other sizes.

2. Safe loads shown include 50% superimposed dead load and 50% live load. 800 psi top tension has been allowed, therefore additional top reinforcement is required.

3. Safe loads can be significantly increased by use of structural composite topping.

f safe superimposed service load (plf) and cambers

Desig-nation	No. Strand	e	Span, ft																	
			16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50
12RB16	5	5.67	3344 0.4 0.1	2605 0.5 0.2	2075 0.6 0.2	1684 0.7 0.2	1386 0.8 0.2	1154 0.9 0.2	970 1.0 0.2											
12RB20	8	6.60	6101 0.4 0.1	4773 0.5 0.2	3823 0.6 0.2	3121 0.7 0.2	2585 0.8 0.3	2166 0.9 0.3	1833 1.0 0.3	1565 1.1 0.3	1345 1.2 0.3	1163 1.3 0.3	1010 1.4 0.3							
12RB24	10	7.76	8884 0.3 0.1	6957 0.4 0.1	5578 0.5 0.2	4558 0.6 0.2	3782 0.7 0.2	3178 0.8 0.3	2699 0.9 0.3	2312 1.0 0.3	1996 1.1 0.3	1734 1.2 0.4	1514 1.3 0.4	1328 1.4 0.4	1170 1.5 0.4	1033 1.6 0.4				
12RB28	12	8.89		9502 0.3 0.1	7630 0.4 0.2	6245 0.5 0.2	5192 0.6 0.2	4372 0.7 0.2	3721 0.8 0.3	3197 0.9 0.3	2767 1.0 0.3	2411 1.1 0.4	2113 1.2 0.4	1861 1.3 0.4	1645 1.4 0.4	1460 1.5 0.4	1299 1.5 0.4	1159 1.6 0.4	1035 1.7 0.4	
12RB32	13	10.48				8238 0.4 0.2	6859 0.5 0.2	5785 0.6 0.2	4833 0.7 0.2	4246 0.8 0.3	3683 0.9 0.3	3217 0.9 0.3	2826 1.0 0.3	2495 1.1 0.3	2213 1.2 0.3	1970 1.3 0.4	1760 1.4 0.4	1576 1.5 0.4	1415 1.5 0.3	1272 1.6 0.3
12RB36	15	11.64					8734 0.5 0.2	7376 0.5 0.2	6298 0.6 0.2	5428 0.7 0.2	4716 0.8 0.2	4126 0.9 0.3	3632 1.0 0.3	3214 1.0 0.3	2856 1.1 0.4	2549 1.2 0.4	2283 1.3 0.4	2050 1.4 0.4	1846 1.5 0.4	1666 1.5 0.4
16RB24	13	7.86		9278 0.4 0.1	7439 0.5 0.2	6079 0.6 0.2	5044 0.7 0.2	4239 0.8 0.3	3600 0.9 0.3	3084 1.0 0.3	2662 1.1 0.3	2313 1.2 0.3	2020 1.3 0.4	1772 1.4 0.4	1560 1.5 0.4	1378 1.6 0.3	1220 1.6 0.3	1082 1.7 0.3	961 1.8 0.2	
16RB28	13	8.89			9022 0.4 0.1	7383 0.4 0.1	6137 0.5 0.1	5167 0.6 0.2	4397 0.6 0.2	3776 0.7 0.2	3267 0.8 0.2	2846 0.9 0.2	2493 1.0 0.2	2194 1.0 0.2	1939 1.1 0.2	1720 1.2 0.2	1530 1.2 0.1	1364 1.3 0.1	1218 1.3 0.0	1089 1.3 0.0
16RB32	18	10.29					9145 0.5 0.2	7713 0.6 0.2	6677 0.7 0.2	5661 0.8 0.3	4911 0.9 0.3	4289 1.0 0.3	3768 1.1 0.3	3327 1.1 0.4	2951 1.2 0.4	2627 1.3 0.4	2346 1.4 0.4	2101 1.5 0.4	1886 1.6 0.4	1697 1.7 0.4
16RB36	20	11.64						9834 0.5 0.2	8397 0.6 0.2	7237 0.7 0.2	6288 0.8 0.3	5502 0.9 0.2	4843 1.0 0.3	4285 1.0 0.3	3809 1.1 0.4	3399 1.2 0.4	3043 1.3 0.4	2733 1.4 0.4	2461 1.5 0.4	2221 1.5 0.4
16RB40	22	13.00								9010 0.6 0.2	7839 0.7 0.2	6867 0.8 0.3	6054 0.9 0.3	5365 1.0 0.3	4777 1.0 0.3	4271 1.1 0.3	3832 1.2 0.4	3449 1.3 0.4	3113 1.4 0.4	2817 1.4 0.4

Figure 8 - PCI Handbook (5th Edition) Page 2-40