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Structural Option

Advisor: Dr. Linda Hanagan
The 400: Bremerton, WA
October 5, 2005
AE 481W

Structural Technical Report 2
Alternate Framing Analysis

Executive Summary:

The 400 is a condominium complex located in Bremerton, Washington, right across the bay from Seattle. The building consists of two levels of concrete parking below four stories of residential non-composite metal frame construction. Ground has recently been broken for construction of The 400, and updated plans are in the process of being developed.

This technical assignment consists of an analysis of the existing structural system. Then, four possible alternate systems are evaluated, with advantages and disadvantages for each.

- Engineered Lumber
- Hollow Core Planks
- Two-way Flat Slab
- Waffle Slab

The most important considerations are site limitations for construction and soil properties which do not accommodate very well to large loads. In addition, height requirements are also a concern because The 400 is already designed to the maximum possible height.

All four alternate systems are then compared and contrasted to determine which systems should be considered for re-design (NOTE: All calculations and tables used for design are located in the Appendix). Many aspects, including vibration, foundation and column load implications and depth of system, were compared and contrasted. The Engineered Lumber system was chosen to be the best candidate for re-design, for many reasons including lighter and cheaper overall system.

Typical Bay Information:

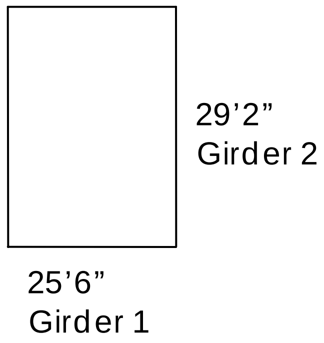


Figure 1

The typical bay analyzed throughout this technical assignment was a 25'6" x 29'2" bay. While this is the most typical bay in the building, it is also the largest, making it a good representation while comparing systems. The loads used were that of a typical residential level, 40psf live load and 20psf dead load. The self-weight of the members are also included, as necessary, in each re-design.

NOTE: For worst loading, assume adjoining bays are the same size as the typical bay described in Figure 1.

The soil is very critical in the structural design because of the proximity of the building to the Port Washington Narrows. In addition, the soil located in the southwest corner of the building design is extremely critical and required additional support. The foundation is built in accordance with the load that is required, so any design which decreases the load which is transferred to the foundation or the foundation design in general would dramatically decrease the cost of the building. Additionally, maximum use of the site is already being used, so the least amount of space required for construction, the better.

Existing Structural System – Non-composite Structural Steel:

The 400 is built according to the 2003 International Building Code and locally to the Bremerton Municipal Code. ASCE 7-02, ACI 318-05, and LRFD design were used for analysis of the building, as necessary.

To accurately compare systems, the floorplan shown in Figure 2 was used for all designs and re-designs. This floorplan was simplified as a rectangle for analysis. The shear walls for the seismic considerations are not considered in design or re-design for simplicity. The most typical bay in the floorplan is the 25'6" x 19'2" bay shown in Figure 1. As mentioned above, this bay is also the largest bay in the floorplan, providing a very good representation.

NOTE: The members being compared are not identical to the members used in building design. To accurately compare designs, an LRFD RAM model was created and members were re-designed according to the new floor layout.

Bay layouts for typical floor:

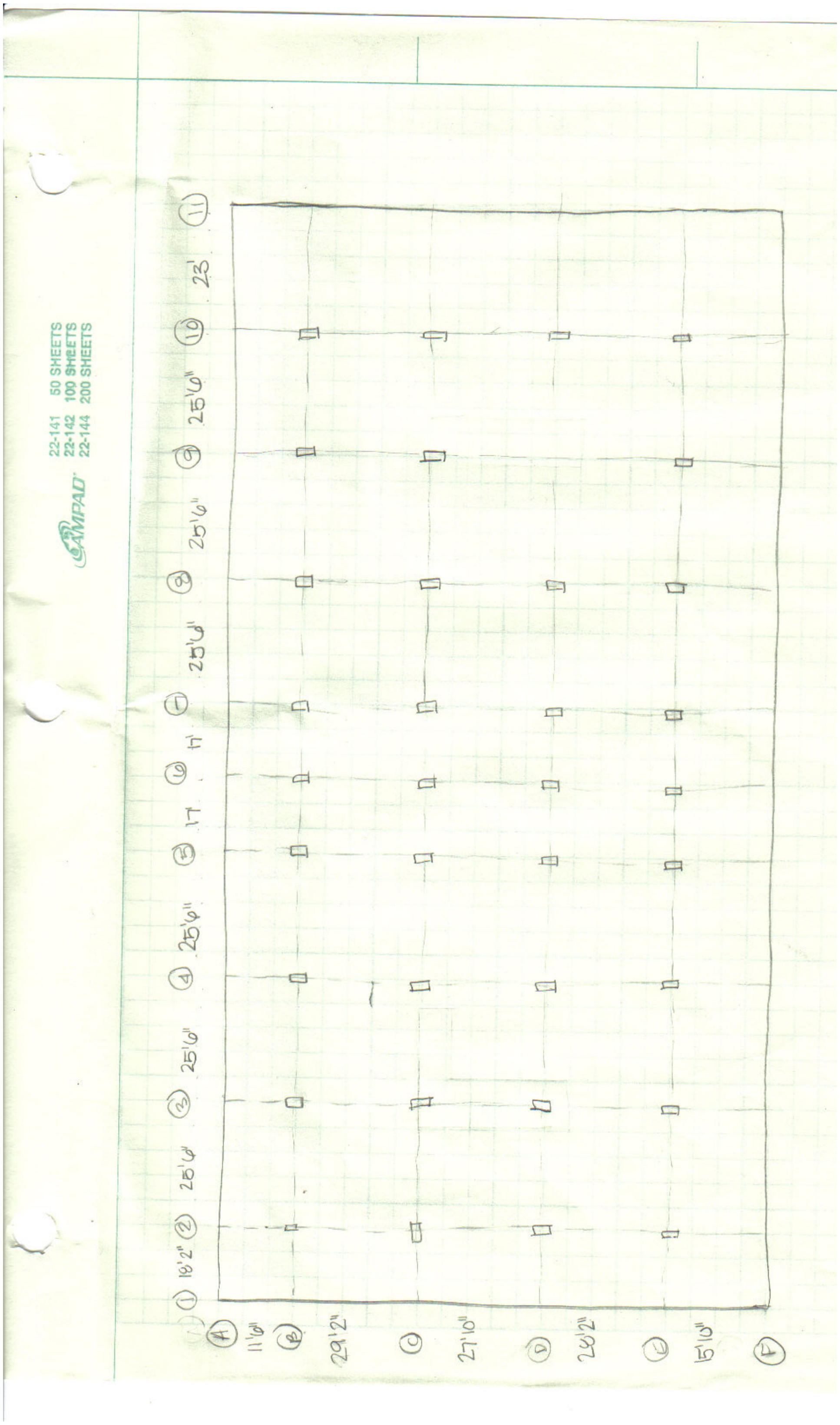


Figure 2

The typical framing used:

- Girder 1: W16 x 31
- Girder 2: W8 x 10
- Joists: 16K2 24” o.c.

ADVANTAGES	DISADVANTAGES
• Fairly easy to run mechanical systems and utilities through existing systems • Fairly typical system for the geographical location for condominium application when compared to concrete systems, so labor may be less expensive, while experience would be greater • More durable system when compared to wood	• Relatively expensive system • Relatively heavy weight when compared to wood system, increasing load transferred to columns and foundations • Steel not very good for exterior applications; not applicable for this application, but considered for possible future renovations to the project

Summary:

- Depth of system: 18 ½” (including 2 ½” metal deck)
- Dead Load of System: 20psf
- Total Dead Load: 40psf
- Spacing: 2’
- Spans: 29’2”
- Design: Girder 1 – W16 x 26
  Girder 2 – W8 x 10
  Joists –16K2 @ 24” o.c.

NOTE: All calculations and tables used for design are located in the Appendix

Major advantages of the existing structural system include the ease of running utilities and mechanical systems through the floor system, a fairly durable system, and subcontractor expertise because of repetitive design on similar projects, while major disadvantages include and expensive and heavy system transferred to the columns and foundation.

Alternate System 1 – Engineered Lumber:

Possible Designs:

Girder 1 (from Figure 1):

- 3 ½” x 34” Parallam (PSL) Commercial Beam
- 5 ¼” x 30” Parallam (PSL) Commercial Beam
- 7” x 26” Parallam (PSL) Commercial Beam

Girder 2 (from Figure 1):

- 3 ½" x 36" Parallam (PSL) Commercial Beam
- 5 ¼" x 30" Parallam (PSL) Commercial Beam
- 7" x 26" Parallam (PSL) Commercial Beam

Joists (spanning the 29'2" length):

- 18" L65 Joists 16" o.c.
- 24" L65 Joists 19.2" o.c.
- 16" L90 Joists 16" o.c.
- 20" L90 Joists 19.2" o.c.

All design was in accordance with the most recent Trus Joist Literature, Specifier's Guide's 1062 and 1048. The loading was too high to use residential beams and joists, so commercial materials were required for this application.

Recommended Design:

Girder 1: 7" x 26" Parallam (PSL) Commercial Beam
Girder 2: 7" x 26" Parallam (PSL) Commercial Beam
Joists: 24" L65 Joists 19.2" o.c.

NOTE: Generally, deeper joists or beams are cheaper. Because the height of the building is a concern, the shallowest girders were chosen, but the deepest joist was still less shallow than the girders, so the deepest joist would be most cost effective. In addition, using the wider spacing of 19.2" o.c. reduces the joists necessary to span the required distance, reducing costs of the joists.

NOTE: Tables in Literature are based on L/360 deflection criteria and simple spans.

ADVANTAGES	DISADVANTAGES
• Wood design popular in geographical location; expertise easy to locate and labor most likely relatively cheap • Wood cost generally cheaper than other material cost (especially steel) • Rigid floor diaphragm to transfer loads • Lighter system overall – this would allow a lighter load to be	• All materials are commercial and special order materials, so they can be more expensive than other wood options • Current story height is 10'6"; depth of girders at least 26", so to maintain inside ceiling height, the entrance to the garage can be lowered • Wood not as durable as steel • Wood floors can sometimes be "squeaky" when compared to

transferred to the columns and foundation system • Engineered lumber as compared to standard board lumber less defects/less squeaky floors • Pieces can be cut to desired length on site • Engineered lumber spans much farther than solid sawn lumber	steel floors; other possible vibration issues can develop as well • Weathering can be a problem with wood; The engineered lumber cannot be exposed to outside elements, although sealants and treated material can be used in areas which are exposed to outside elements • Area must be altered for mechanical systems and utilities (Trus Joist does provide services and literature for allowable hole sizes) • The spacing of joists is changed from 24” o.c. for steel joists • If the location of bearing walls change, the lateral system may require further evaluation

Summary:

- Depth of system: 26” (not including panels)
- Dead Load of System: 10psf
- Total Dead Load: 30psf
- Spacing: 19.2”
- Spans: 25’6”
- Design: Girder 1 – 7” x 26” Parallam (PSL) Commercial Beam
  Girder 2 – 7” x 26” Parallam (PSL) Commercial Beam
  Joists –26” TJI L65 Commercial Joists

NOTE: All calculations and tables used for design are located in the Appendix

Major advantages to an Engineered Lumber design include decreased building weight to be transferred to the columns and foundation, increased expertise of subcontractors due to relatively common design for condominiums, and relatively cheap cost. Major disadvantages include decreased joist spacing, increased vibration in and “squeaky” floors, low durability of wood material (especially in exterior applications), and increased structural system height required.

Alternate System 2 – Hollow Core Planks:

The hollow core planks are to span the 25'6" direction, parallel to girder 1 in Figure 1. The same load of 40psf live load and 20psf dead load are used. Using the PCI Handbook, a 4HC6-96-S (9 strands of 6/16ths thickness) topped was designed for this application.

Using the dead load of hollow core planks, an LRFD RAM model was created with a non-composite metal deck. This RAM model is shown in the Appendix.

ADVANTAGES	**DISADVANTAGES**
• Relatively fast construction • Reduced labor • Do not need to attach subflooring to joists as in other possible systems • Vibration and "squeaking" reduced • Pre-cast, so do not need much extra space on the site, which is a problem to begin with • Ready-made holes for conduit • Flexibility to penetration • Weathering less of a problem when compared to wood or steel system	• Heavier load, which increases load transferred to the columns and foundation, which is critical • Cannot easily vary in length • Relatively expensive • Problems accommodating utilities (possible suspended ceiling) • Walls can become poured concrete or masonry, which is harder to altar the structural system, if desired • Lateral resistance system changes

NOTE: To decrease floor height, hollow core planks will be connected on the inside of the steel I-beams using angles. This will allow the height of the system to be solely the required I-beam sizes.

Summary:

- Depth of system: 24" (height of largest steel I-beam)
- Dead Load of System: 74psf
- Total Dead Load: 94psf
- Spacing: 4' wide planks
- Spans: 25'6"
- Design: Planks - 4HC6+2-96-S
  Girder 1 – W24 x 55
  Girder 2 – W 8 x 10

NOTE: All calculations and tables used for design are located in the Appendix

Major advantages include increased construction time, decreased labor costs, and pre-cast materials, so not much on-site space is necessary. Major disadvantages to Hollow Concrete Plank Design are increased dead load, expensive system, and inability to vary in length.

Alternate System 3 – Two-way Flat Slab System:

The loads used were 40psf live load and 20psf dead load, but the 1992 CRSI Manual was used, so the 1.4DL + 1.7LL factors were used instead of 1.2DL + 1.6LL. The load to be used in the tables, then, was 96psf total load.

A 10 ½" slab with 10' x 10' drop panels 7 ½" deep was sized for this application.

Edge Panel Design:

Reinforcing Bars:
Column Strip
- Top exterior – (14) #5
- Bottom – (15) #7
- Top interior – (23) #5

Middle Strip
- Bottom – (10) #7
- Top interior – (10) #6

Total steel: 3.35psf (NOTE: this does not need to be included in dead load values because 150pcf was used for reinforced steel)

Interior Panel:

Reinforcing Bars:
Column Strip
- Top – (20) #5
- Bottom – (16) #5

Middle Strip
- Top – (12) #5
- Bottom – (11) #5

Total steel: 2.64psf (NOTE: this does not need to be included in dead load values because 150pcf was used for reinforced steel)

ADVANTAGES	DISADVANTAGES
• Two-way system generally more economical than one-way	• Concrete system in general more expensive than wood

system - Depth of 18”, so more shallow than wood system - “Squeaky” floors and vibrations less of an issue with concrete system - Spans relatively far	- Dead Load of structural system of 144psf negatively affects columns and foundation, which is critical - Fairly thick concrete system to be altered if holes are necessary for utilities

Summary:
- Depth of system: 18” (including 7.5” drop panel)
- Dead Load of System: 144psf
- Total Dead Load: 164psf
- Spacing: N/A
- Spans: 30’
- Design: 10 ½” slab with 10’ x 10’ drop panels 7 ½” deep

NOTE: All calculations and tables used for design are located in the Appendix

Major advantages of Two-way Flat Slab Design include long spans, more shallow system height than for Engineered Lumber system, and decreased vibration issues. Disadvantages include increased weight transferred to columns and foundation, thick concrete system to make alterations for MEP equipment, and relatively expensive system when compared to wood.

Alternate System 4 – Waffle Slab:

The loads used were 40psf live load and 20psf dead load, but the 1992 CRSI Manual was used, so the 1.4DL + 1.7LL factors were used instead of 1.2DL + 1.6LL. The load to be used in the tables, then, was 96psf total load.

Edge Panels:

Reinforcing bars (each direction):

Column Strip
- Top Edge – (29) #4
- Bottom
    - Long Bars - #6
    - Short Bars - #6
- Top Interior – (25) #5

Middle Strip
- Bottom
    - Long Bars - #5

    - Short Bars - #5
- Top Interior – (15) #4

Total steel: 2.44psf (NOTE: this does not need to be included in dead load values because 150pcf was used for reinforced steel)

Interior Panel:

Reinforcing Bars (each direction):

Column Strip

- Bottom
    - Long Bars – #5
    - Short Bars - #6
- Top Interior – (24) #5

Middle Strip

- Bottom
    - Long Bars – #4
    - Short Bars - #5
- Top Interior– (15) #4

Total steel: 2.33psf (NOTE: this does not need to be included in dead load values because 150pcf was used for reinforced steel)

ADVANTAGES	**DISADVANTAGES**
• Increased surface area when compared to wood systems because relatively easy to span long directions • Sound barrier between floors • Light fixtures can be recessed in the slab • Concrete over wood or steel can be used for passive solar heating (thermal storage) and save on HVAC costs • Vibration benefits with concrete as compared to other systems • Relatively cheap system for concrete and as compared to steel • Decreased story height	• Additional thermal mass will alter structural and seismic loads • Additional dead weight of 68psf will negatively affect the supporting columns and foundation, which is critical • Aesthetically, waffle slabs are usually not as appealing as other systems, so additional features may need to be added to ceiling • Relatively expensive system when compared to wood

Summary:

- Depth of system: 11” (including 7.5” drop panel)
- Dead Load of System: 68psf
- Total Dead Load: 88psf
- Spacing: N/A
- Spans: 30’
- Design: 30” x 30” voids; 6” ribs @ 36” o.c.

NOTE: All calculations and tables used for design are located in the Appendix

Major advantages for a Waffle Slab include an increased sound barrier, spaces for recessed lighting, and possibilities for passive solar heating. Major disadvantages include additional dead load to be transferred to columns and foundation, aesthetically displeasing design, and relatively expensive system when compared to wood.

Special Considerations:

Typical condominiums in specifically the Bremerton, WA area and more generally in the whole state of Washington and most of the west coast in general are:

- Entirely wood (less than 5 stories)
- Concrete parking with wood above
- Concrete parking with steel above

Generally, concrete condominiums are not that popular, due to price and increased weight. Also, as previously discussed, concrete buildings (especially masonry walls) do not generally allow for building expansion. This is very important in areas which are experimenting with condominiums, such as Bremerton and condominiums in general. If, at some point in time, the owner would like to expand on the existing building or purchase the adjoining condominiums, the structural systems can more easily and less expensively be combined in a wood or metal frame as compared to a masonry façade.

Because these are the typical building styles, more experienced subcontractors would be available for construction of buildings which conform to one of these three most popular designs. While this should not prevent other systems from being used, cost of labor and expertise should and would contribute heavily to design.

Other system considerations:

While only the residential structural floors were evaluated, other systems were evaluated. The current structural system consists of concrete parking with steel above. To simplify construction (costs and labor, because only one trained crew could be hired for the entire building), an entire steel system or an entire concrete system was considered.

Entirely Steel System:

The main change to the existing system for this system is changing the parking to steel framed. The extreme drawback of steel parking garages is deflection and deterioration due to outside elements. While the majority of the parking is not exactly exteriorly exposed, the entrance would most likely be influenced by the outside elements and would require extra maintenance that other designs would not.

As far as deflection is concerned, even though structurally it might not be failing, the more deflection in a building, the more generally uneasy the users of the structure feel. Considering the prices of some of the condominiums, the tenants should feel safe in their building, so a steel parking garage with excessive deflection might not be the best solution.

Entirely Concrete System:

As displayed in the Hollow Core System in Alternate System 2, concrete systems increase the dead loading (when compared to wood systems), and an increased dead loading makes the foundation design requirements more critical. When foundation requirements are already critical, increasing dead weight throughout each floor of the building is probably not a good idea.

Two-way Flat Plate System:

Because the typical bays were rectangular, a two-way flat plate system was analyzed, but the system could not span the required 30’. The bays could be decreased, but that would cut back on the size of the condominiums, which would decrease the value they could be rented for.

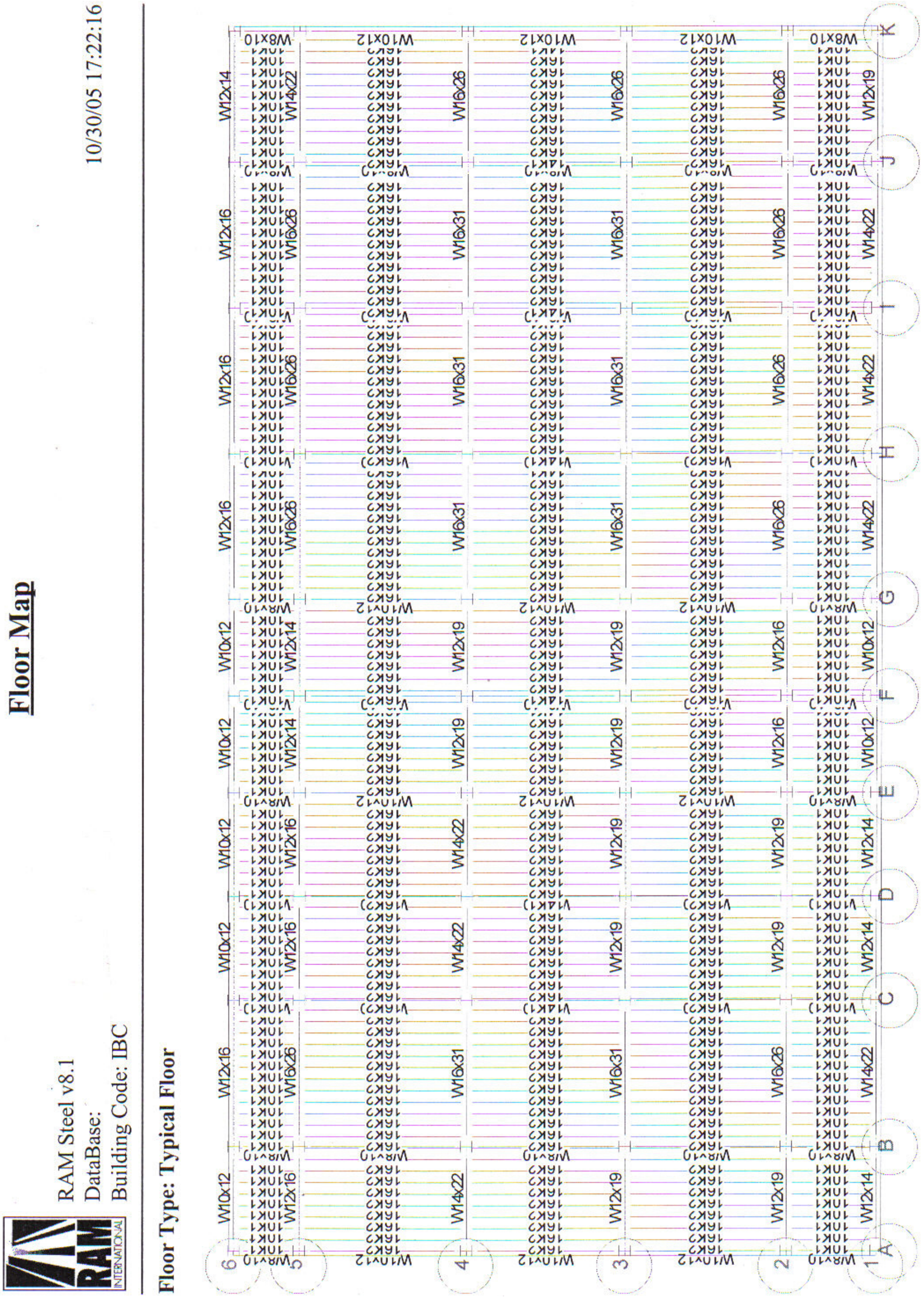
Summary of Alternate Systems:

SYSTEM	SYSTEM RECOMMENDED FOR REDESIGN?	REASONS
Engineered Lumber	Yes	• Lighter weight • Increased expertise • Cheaper system
Hollow Core Planks	No	• Increased weight • Relatively expensive • Lengths cannot easily be altered
Two Way Flat Slab	No	• Increased weight • Relatively expensive • Difficult to accommodate mechanical systems and utilities
Waffle Slab	No	• Increased weight • Relatively expensive • Not aesthetically pleasing

Overall, the only system to be considered while weighing all of the factors is the engineered lumber system. This corresponds with what the industry views as typical for the four story condominium.

APPENDIX

Existing Design:



Floor Map

RAM Steel v8.1
DataBase:
Building Code: IBC

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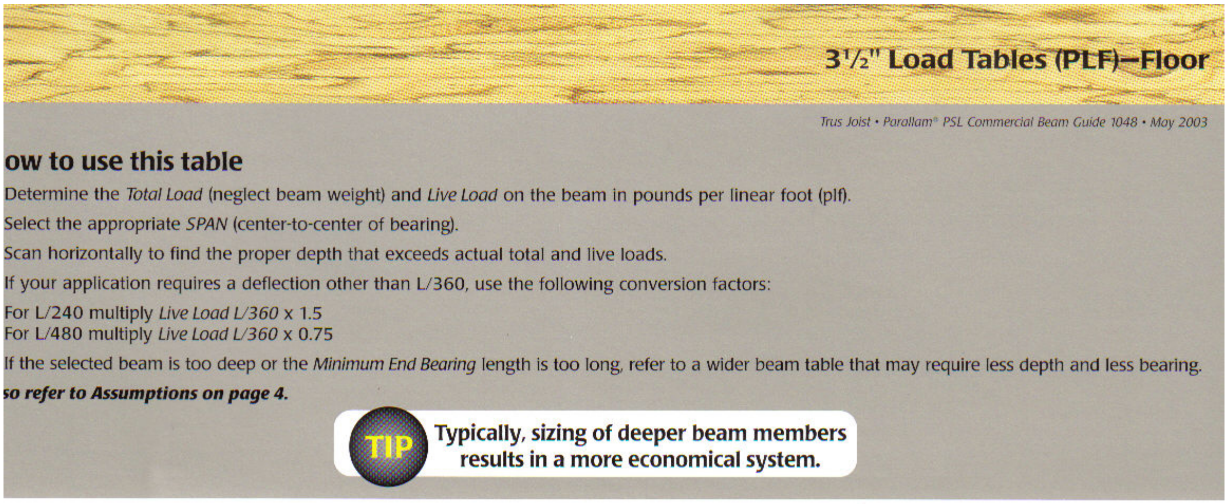
Floor Type: Typical Floor

Figure 3

Alternate System 1: Engineered Lumber:

3 ½” PSL (Parallam) Beam:



3½" Load Tables (PLF)—Floor

Trus Joist • Parallam® PSL Commercial Beam Guide 1048 • May 2003

ow to use this table

Determine the *Total Load* (neglect beam weight) and *Live Load* on the beam in pounds per linear foot (plf).

Select the appropriate *SPAN* (center-to-center of bearing).

Scan horizontally to find the proper depth that exceeds actual total and live loads.

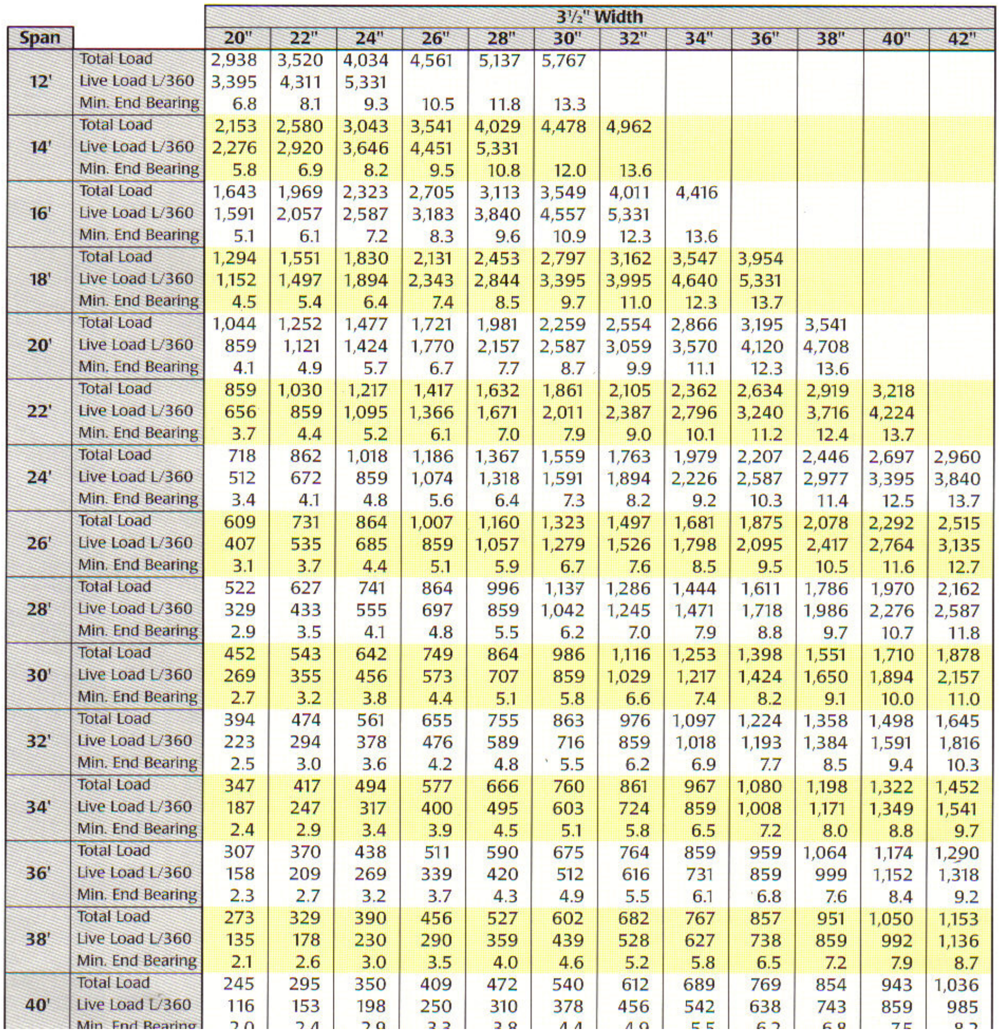
If your application requires a deflection other than L/360, use the following conversion factors:

For L/240 multiply *Live Load L/360* x 1.5
For L/480 multiply *Live Load L/360* x 0.75

If the selected beam is too deep or the *Minimum End Bearing* length is too long, refer to a wider beam table that may require less depth and less bearing.

so refer to Assumptions on page 4.

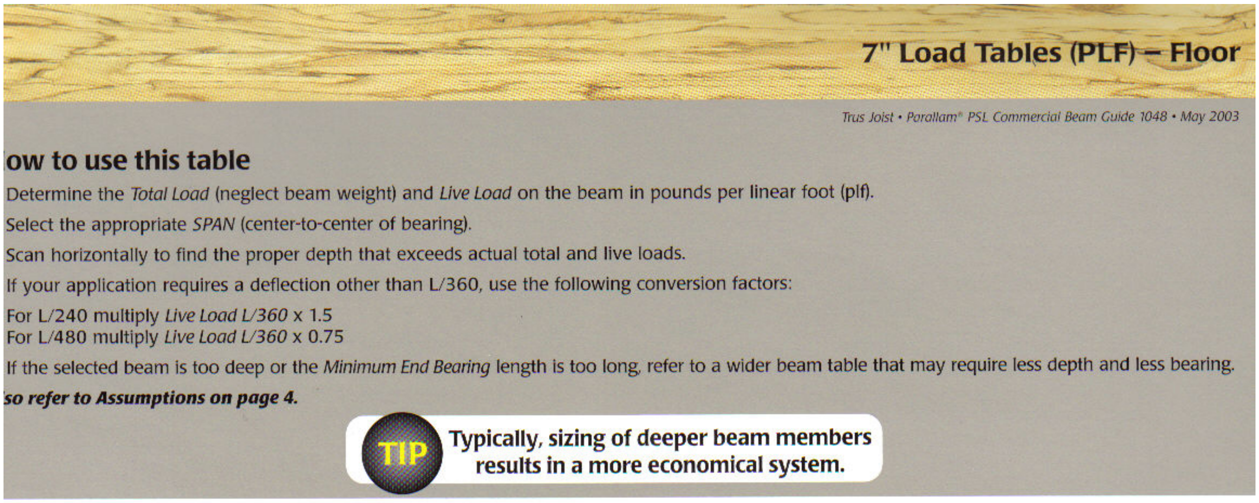
TIP **Typically, sizing of deeper beam members results in a more economical system.**



		3½" Width											
Span		**20"**	**22"**	**24"**	**26"**	**28"**	**30"**	**32"**	**34"**	**36"**	**38"**	**40"**	**42"**
12'	Total Load	2,938	3,520	4,034	4,561	5,137	5,767						
	Live Load L/360	3,395	4,311	5,331									
	Min. End Bearing	6.8	8.1	9.3	10.5	11.8	13.3						
14'	Total Load	2,153	2,580	3,043	3,541	4,029	4,478	4,962					
	Live Load L/360	2,276	2,920	3,646	4,451	5,331							
	Min. End Bearing	5.8	6.9	8.2	9.5	10.8	12.0	13.6					
16'	Total Load	1,643	1,969	2,323	2,705	3,113	3,549	4,011	4,416				
	Live Load L/360	1,591	2,057	2,587	3,183	3,840	4,557	5,331					
	Min. End Bearing	5.1	6.1	7.2	8.3	9.6	10.9	12.3	13.6				
18'	Total Load	1,294	1,551	1,830	2,131	2,453	2,797	3,162	3,547	3,954			
	Live Load L/360	1,152	1,497	1,894	2,343	2,844	3,395	3,995	4,640	5,331			
	Min. End Bearing	4.5	5.4	6.4	7.4	8.5	9.7	11.0	12.3	13.7			
20'	Total Load	1,044	1,252	1,477	1,721	1,981	2,259	2,554	2,866	3,195	3,541		
	Live Load L/360	859	1,121	1,424	1,770	2,157	2,587	3,059	3,570	4,120	4,708		
	Min. End Bearing	4.1	4.9	5.7	6.7	7.7	8.7	9.9	11.1	12.3	13.6		
22'	Total Load	859	1,030	1,217	1,417	1,632	1,861	2,105	2,362	2,634	2,919	3,218	
	Live Load L/360	656	859	1,095	1,366	1,671	2,011	2,387	2,796	3,240	3,716	4,224	
	Min. End Bearing	3.7	4.4	5.2	6.1	7.0	7.9	9.0	10.1	11.2	12.4	13.7	
24'	Total Load	718	862	1,018	1,186	1,367	1,559	1,763	1,979	2,207	2,446	2,697	2,960
	Live Load L/360	512	672	859	1,074	1,318	1,591	1,894	2,226	2,587	2,977	3,395	3,840
	Min. End Bearing	3.4	4.1	4.8	5.6	6.4	7.3	8.2	9.2	10.3	11.4	12.5	13.7
26'	Total Load	609	731	864	1,007	1,160	1,323	1,497	1,681	1,875	2,078	2,292	2,515
	Live Load L/360	407	535	685	859	1,057	1,279	1,526	1,798	2,095	2,417	2,764	3,135
	Min. End Bearing	3.1	3.7	4.4	5.1	5.9	6.7	7.6	8.5	9.5	10.5	11.6	12.7
28'	Total Load	522	627	741	864	996	1,137	1,286	1,444	1,611	1,786	1,970	2,162
	Live Load L/360	329	433	555	697	859	1,042	1,245	1,471	1,718	1,986	2,276	2,587
	Min. End Bearing	2.9	3.5	4.1	4.8	5.5	6.2	7.0	7.9	8.8	9.7	10.7	11.8
30'	Total Load	452	543	642	749	864	986	1,116	1,253	1,398	1,551	1,710	1,878
	Live Load L/360	269	355	456	573	707	859	1,029	1,217	1,424	1,650	1,894	2,157
	Min. End Bearing	2.7	3.2	3.8	4.4	5.1	5.8	6.6	7.4	8.2	9.1	10.0	11.0
32'	Total Load	394	474	561	655	755	863	976	1,097	1,224	1,358	1,498	1,645
	Live Load L/360	223	294	378	476	589	716	859	1,018	1,193	1,384	1,591	1,816
	Min. End Bearing	2.5	3.0	3.6	4.2	4.8	5.5	6.2	6.9	7.7	8.5	9.4	10.3
34'	Total Load	347	417	494	577	666	760	861	967	1,080	1,198	1,322	1,452
	Live Load L/360	187	247	317	400	495	603	724	859	1,008	1,171	1,349	1,541
	Min. End Bearing	2.4	2.9	3.4	3.9	4.5	5.1	5.8	6.5	7.2	8.0	8.8	9.7
36'	Total Load	307	370	438	511	590	675	764	859	959	1,064	1,174	1,290
	Live Load L/360	158	209	269	339	420	512	616	731	859	999	1,152	1,318
	Min. End Bearing	2.3	2.7	3.2	3.7	4.3	4.9	5.5	6.1	6.8	7.6	8.4	9.2
38'	Total Load	273	329	390	456	527	602	682	767	857	951	1,050	1,153
	Live Load L/360	135	178	230	290	359	439	528	627	738	859	992	1,136
	Min. End Bearing	2.1	2.6	3.0	3.5	4.0	4.6	5.2	5.8	6.5	7.2	7.9	8.7
40'	Total Load	245	295	350	409	472	540	612	689	769	854	943	1,036
	Live Load L/360	116	153	198	250	310	378	456	542	638	743	859	985
	Min. End Bearing	2.0	2.4	2.9	3.3	3.8	4.4	4.9	5.5	6.2	6.8	7.5	8.2

Figure 4

7” PSL (Parallam) Beam:



7" Load Tables (PLF) – Floor

Trus Joist • Parallam® PSL Commercial Beam Guide 1048 • May 2003

ow to use this table

Determine the *Total Load* (neglect beam weight) and *Live Load* on the beam in pounds per linear foot (plf).

Select the appropriate *SPAN* (center-to-center of bearing).

Scan horizontally to find the proper depth that exceeds actual total and live loads.

If your application requires a deflection other than L/360, use the following conversion factors:

For L/240 multiply *Live Load L/360* x 1.5
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If the selected beam is too deep or the *Minimum End Bearing* length is too long, refer to a wider beam table that may require less depth and less bearing.

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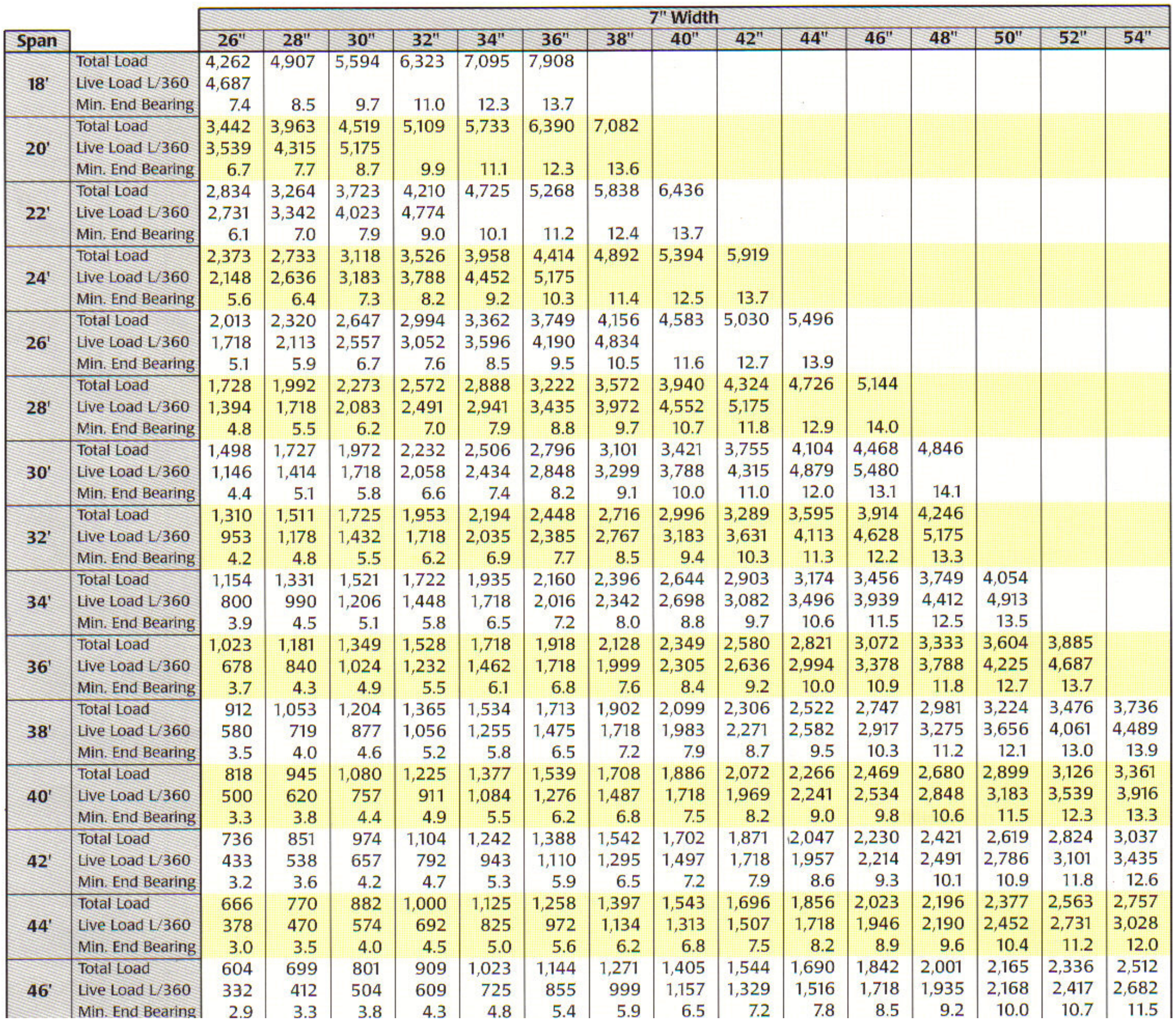
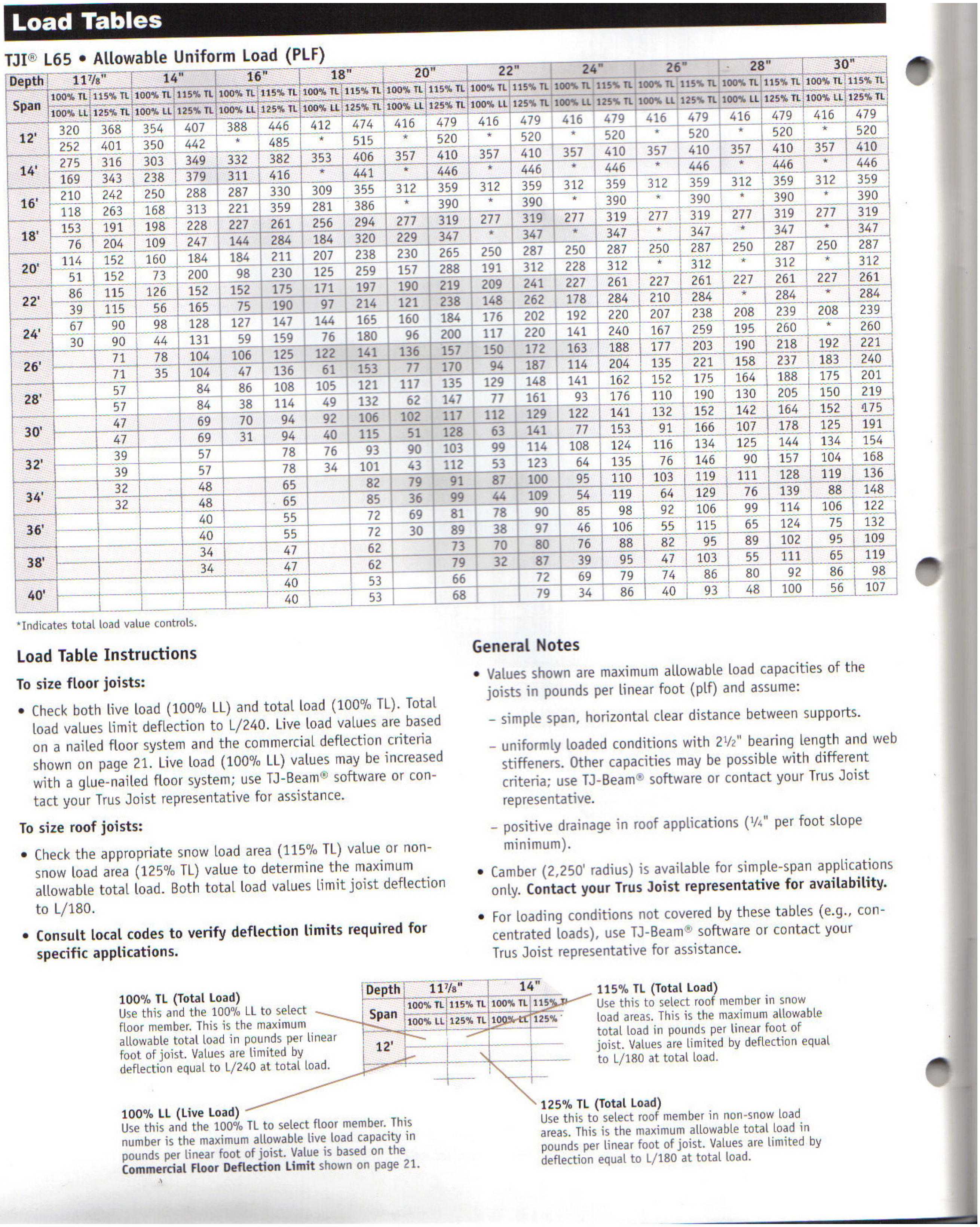


		7" Width														
Span		**26"**	**28"**	**30"**	**32"**	**34"**	**36"**	**38"**	**40"**	**42"**	**44"**	**46"**	**48"**	**50"**	**52"**	**54"**
18'	Total Load	4,262	4,907	5,594	6,323	7,095	7,908									
	Live Load L/360	4,687														
	Min. End Bearing	7.4	8.5	9.7	11.0	12.3	13.7									
20'	Total Load	3,442	3,963	4,519	5,109	5,733	6,390	7,082								
	Live Load L/360	3,539	4,315	5,175												
	Min. End Bearing	6.7	7.7	8.7	9.9	11.1	12.3	13.6								
22'	Total Load	2,834	3,264	3,723	4,210	4,725	5,268	5,838	6,436							
	Live Load L/360	2,731	3,342	4,023	4,774											
	Min. End Bearing	6.1	7.0	7.9	9.0	10.1	11.2	12.4	13.7							
24'	Total Load	2,373	2,733	3,118	3,526	3,958	4,414	4,892	5,394	5,919						
	Live Load L/360	2,148	2,636	3,183	3,788	4,452	5,175									
	Min. End Bearing	5.6	6.4	7.3	8.2	9.2	10.3	11.4	12.5	13.7						
26'	Total Load	2,013	2,320	2,647	2,994	3,362	3,749	4,156	4,583	5,030	5,496					
	Live Load L/360	1,718	2,113	2,557	3,052	3,596	4,190	4,834								
	Min. End Bearing	5.1	5.9	6.7	7.6	8.5	9.5	10.5	11.6	12.7	13.9					
28'	Total Load	1,728	1,992	2,273	2,572	2,888	3,222	3,572	3,940	4,324	4,726	5,144				
	Live Load L/360	1,394	1,718	2,083	2,491	2,941	3,435	3,972	4,552	5,175						
	Min. End Bearing	4.8	5.5	6.2	7.0	7.9	8.8	9.7	10.7	11.8	12.9	14.0				
30'	Total Load	1,498	1,727	1,972	2,232	2,506	2,796	3,101	3,421	3,755	4,104	4,468	4,846			
	Live Load L/360	1,146	1,414	1,718	2,058	2,434	2,848	3,299	3,788	4,315	4,879	5,480				
	Min. End Bearing	4.4	5.1	5.8	6.6	7.4	8.2	9.1	10.0	11.0	12.0	13.1	14.1			
32'	Total Load	1,310	1,511	1,725	1,953	2,194	2,448	2,716	2,996	3,289	3,595	3,914	4,246			
	Live Load L/360	953	1,178	1,432	1,718	2,035	2,385	2,767	3,183	3,631	4,113	4,628	5,175			
	Min. End Bearing	4.2	4.8	5.5	6.2	6.9	7.7	8.5	9.4	10.3	11.3	12.2	13.3			
34'	Total Load	1,154	1,331	1,521	1,722	1,935	2,160	2,396	2,644	2,903	3,174	3,456	3,749	4,054		
	Live Load L/360	800	990	1,206	1,448	1,718	2,016	2,342	2,698	3,082	3,496	3,939	4,412	4,913		
	Min. End Bearing	3.9	4.5	5.1	5.8	6.5	7.2	8.0	8.8	9.7	10.6	11.5	12.5	13.5		
36'	Total Load	1,023	1,181	1,349	1,528	1,718	1,918	2,128	2,349	2,580	2,821	3,072	3,333	3,604	3,885	
	Live Load L/360	678	840	1,024	1,232	1,462	1,718	1,999	2,305	2,636	2,994	3,378	3,788	4,225	4,687	
	Min. End Bearing	3.7	4.3	4.9	5.5	6.1	6.8	7.6	8.4	9.2	10.0	10.9	11.8	12.7	13.7	
38'	Total Load	912	1,053	1,204	1,365	1,534	1,713	1,902	2,099	2,306	2,522	2,747	2,981	3,224	3,476	3,736
	Live Load L/360	580	719	877	1,056	1,255	1,475	1,718	1,983	2,271	2,582	2,917	3,275	3,656	4,061	4,489
	Min. End Bearing	3.5	4.0	4.6	5.2	5.8	6.5	7.2	7.9	8.7	9.5	10.3	11.2	12.1	13.0	13.9
40'	Total Load	818	945	1,080	1,225	1,377	1,539	1,708	1,886	2,072	2,266	2,469	2,680	2,899	3,126	3,361
	Live Load L/360	500	620	757	911	1,084	1,276	1,487	1,718	1,969	2,241	2,534	2,848	3,183	3,539	3,916
	Min. End Bearing	3.3	3.8	4.4	4.9	5.5	6.2	6.8	7.5	8.2	9.0	9.8	10.6	11.5	12.3	13.3
42'	Total Load	736	851	974	1,104	1,242	1,388	1,542	1,702	1,871	2,047	2,230	2,421	2,619	2,824	3,037
	Live Load L/360	433	538	657	792	943	1,110	1,295	1,497	1,718	1,957	2,214	2,491	2,786	3,101	3,435
	Min. End Bearing	3.2	3.6	4.2	4.7	5.3	5.9	6.5	7.2	7.9	8.6	9.3	10.1	10.9	11.8	12.6
44'	Total Load	666	770	882	1,000	1,125	1,258	1,397	1,543	1,696	1,856	2,023	2,196	2,377	2,563	2,757
	Live Load L/360	378	470	574	692	825	972	1,134	1,313	1,507	1,718	1,946	2,190	2,452	2,731	3,028
	Min. End Bearing	3.0	3.5	4.0	4.5	5.0	5.6	6.2	6.8	7.5	8.2	8.9	9.6	10.4	11.2	12.0
46'	Total Load	604	699	801	909	1,023	1,144	1,271	1,405	1,544	1,690	1,842	2,001	2,165	2,336	2,512
	Live Load L/360	332	412	504	609	725	855	999	1,157	1,329	1,516	1,718	1,935	2,168	2,417	2,682
	Min. End Bearing	2.9	3.3	3.8	4.3	4.8	5.4	5.9	6.5	7.2	7.8	8.5	9.2	10.0	10.7	11.5

Figure 5

TJI L65 Load Tables:



Load Tables

TJI® L65 • Allowable Uniform Load (PLF)

Depth	11⅞"		14"		16"		18"		20"		22"		24"		26"		28"		30"	
Span	100% TL 100% LL	115% TL 125% TL	100% TL 100% LL	115% TL 125% TL	100% TL 100% LL	115% TL 125% TL	100% TL 100% LL	115% TL 125% TL	100% TL 100% LL	115% TL 125% TL	100% TL 100% LL	115% TL 125% TL	100% TL 100% LL	115% TL 125% TL	100% TL 100% LL	115% TL 125% TL	100% TL 100% LL	115% TL 125% TL	100% TL 100% LL	115% TL 125% TL
12'	320	368	354	407	388	446	412	474	416	479	416	479	416	479	416	479	416	479	416	479
	252	401	350	442	*	485	*	515	*	520	*	520	*	520	*	520	*	520	*	520
14'	275	316	303	349	332	382	353	406	357	410	357	410	357	410	357	410	357	410	357	410
	169	343	238	379	311	416	*	441	*	446	*	446	*	446	*	446	*	446	*	446
16'	210	242	250	288	287	330	309	355	312	359	312	359	312	359	312	359	312	359	312	359
	118	263	168	313	221	359	281	386	*	390	*	390	*	390	*	390	*	390	*	390
18'	153	191	198	228	227	261	256	294	277	319	277	319	277	319	277	319	277	319	277	319
	76	204	109	247	144	284	184	320	229	347	*	347	*	347	*	347	*	347	*	347
20'	114	152	160	184	184	211	207	238	230	265	250	287	250	287	250	287	250	287	250	287
	51	152	73	200	98	230	125	259	157	288	191	312	228	312	*	312	*	312	*	312
22'	86	115	126	152	152	175	171	197	190	219	209	241	227	261	227	261	227	261	227	261
	39	115	56	165	75	190	97	214	121	238	148	262	178	284	210	284	*	284	*	284
24'	67	90	98	128	127	147	144	165	160	184	176	202	192	220	207	238	208	239	208	239
	30	90	44	131	59	159	76	180	96	200	117	220	141	240	167	259	195	260	*	260
26'		71	78	104	106	125	122	141	136	157	150	172	163	188	177	203	190	218	192	221
		71	35	104	47	136	61	153	77	170	94	187	114	204	135	221	158	237	183	240
28'		57		84	86	108	105	121	117	135	129	148	141	162	152	175	164	188	175	201
		57		84	38	114	49	132	62	147	77	161	93	176	110	190	130	205	150	219
30'		47		69	70	94	92	106	102	117	112	129	122	141	132	152	142	164	152	175
		47		69	31	94	40	115	51	128	63	141	77	153	91	166	107	178	125	191
32'		39		57		78	76	93	90	103	99	114	108	124	116	134	125	144	134	154
		39		57		78	34	101	43	112	53	123	64	135	76	146	90	157	104	168
34'		32		48		65		82	79	91	87	100	95	110	103	119	111	128	119	136
		32		48		65		85	36	99	44	109	54	119	64	129	76	139	88	148
36'				40		55		72	69	81	78	90	85	98	92	106	99	114	106	122
				40		55		72	30	89	38	97	46	106	55	115	65	124	75	132
38'				34		47		62		73	70	80	76	88	82	95	89	102	95	109
				34		47		62		79	32	87	39	95	47	103	55	111	65	119
40'						40		53		66		72	69	79	74	86	80	92	86	98
						40		53		68		79	34	86	40	93	48	100	56	107

*Indicates total load value controls.

Load Table Instructions

To size floor joists:

- Check both live load (100% LL) and total load (100% TL). Total load values limit deflection to L/240. Live load values are based on a nailed floor system and the commercial deflection criteria shown on page 21. Live load (100% LL) values may be increased with a glue-nailed floor system; use TJ-Beam® software or contact your Trus Joist representative for assistance.

To size roof joists:

- Check the appropriate snow load area (115% TL) value or non-snow load area (125% TL) value to determine the maximum allowable total load. Both total load values limit joist deflection to L/180.
- **Consult local codes to verify deflection limits required for specific applications.**

General Notes

- Values shown are maximum allowable load capacities of the joists in pounds per linear foot (plf) and assume:
  - simple span, horizontal clear distance between supports.
  - uniformly loaded conditions with 2½" bearing length and web stiffeners. Other capacities may be possible with different criteria; use TJ-Beam® software or contact your Trus Joist representative.
  - positive drainage in roof applications (¼" per foot slope minimum).
- Camber (2,250' radius) is available for simple-span applications only. **Contact your Trus Joist representative for availability.**
- For loading conditions not covered by these tables (e.g., concentrated loads), use TJ-Beam® software or contact your Trus Joist representative for assistance.

100% TL (Total Load)
Use this and the 100% LL to select floor member. This is the maximum allowable total load in pounds per linear foot of joist. Values are limited by deflection equal to L/240 at total load.

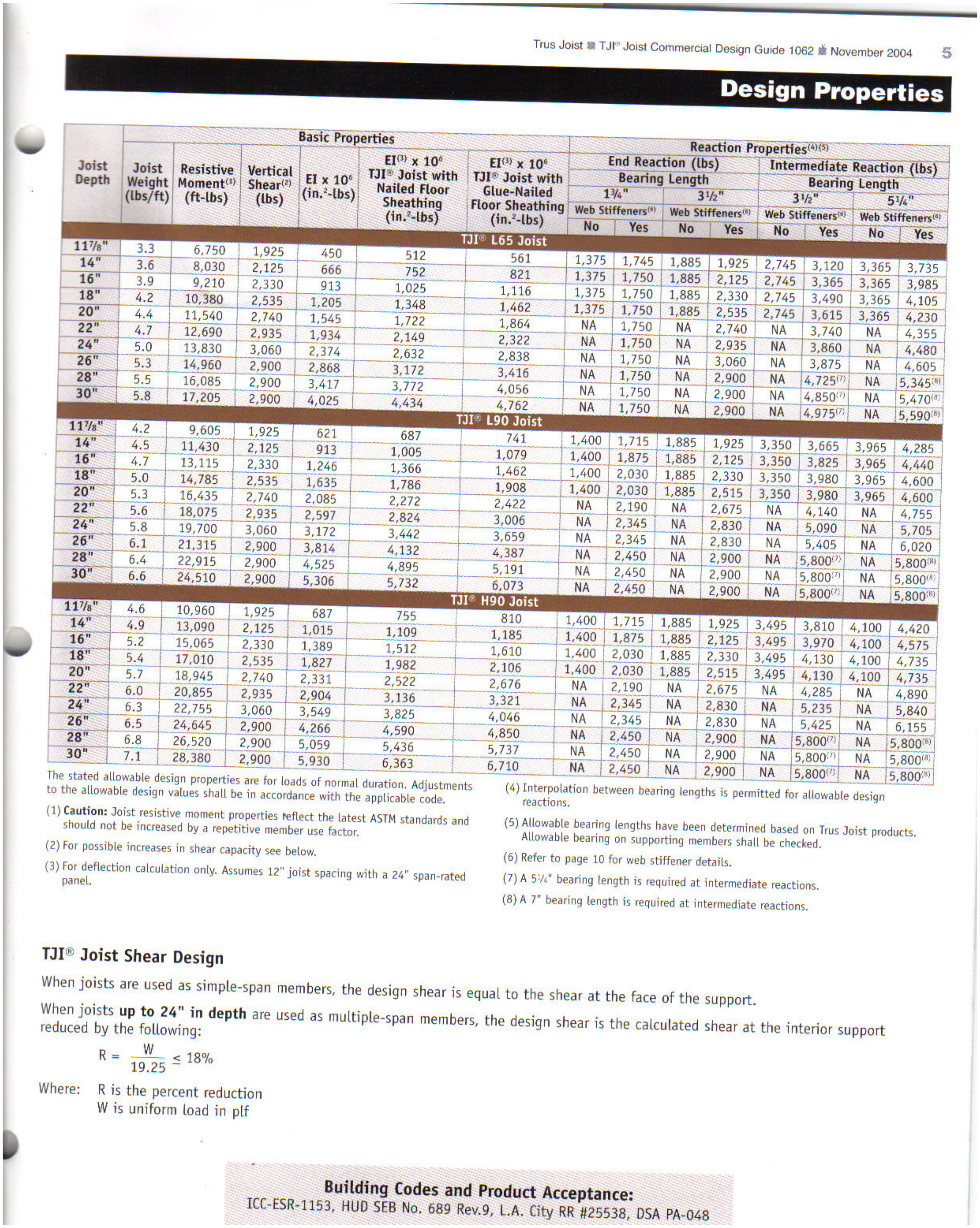
115% TL (Total Load)
Use this to select roof member in snow load areas. This is the maximum allowable total load in pounds per linear foot of joist. Values are limited by deflection equal to L/180 at total load.

100% LL (Live Load)
Use this and the 100% TL to select floor member. This number is the maximum allowable live load capacity in pounds per linear foot of joist. Value is based on the **Commercial Floor Deflection Limit** shown on page 21.

125% TL (Total Load)
Use this to select roof member in non-snow load areas. This is the maximum allowable total load in pounds per linear foot of joist. Values are limited by deflection equal to L/180 at total load.

Figure 6

Design Properties Commercial Joists:



Design Properties

Joist Depth	Basic Properties						Reaction Properties(4)(5)							
	Joist Weight (lbs/ft)	Resistive Moment(1) (ft-lbs)	Vertical Shear(2) (lbs)	EI x 10^6 (in.^{2}-lbs)	EI(3) x 10^6 TJI® Joist with Nailed Floor Sheathing (in.^{2}-lbs)	EI(3) x 10^6 TJI® Joist with Glue-Nailed Floor Sheathing (in.^{2}-lbs)	End Reaction (lbs) Bearing Length				Intermediate Reaction (lbs) Bearing Length			
							1¾"		3½"		3½"		5¼"	
							Web Stiffeners(6)		Web Stiffeners(6)		Web Stiffeners(6)		Web Stiffeners(6)	
							No	Yes	No	Yes	No	Yes	No	Yes
TJI® L65 Joist														
11⅞"	3.3	6,750	1,925	450	512	561	1,375	1,745	1,885	1,925	2,745	3,120	3,365	3,735
14"	3.6	8,030	2,125	666	752	821	1,375	1,750	1,885	2,125	2,745	3,365	3,365	3,985
16"	3.9	9,210	2,330	913	1,025	1,116	1,375	1,750	1,885	2,330	2,745	3,490	3,365	4,105
18"	4.2	10,380	2,535	1,205	1,348	1,462	1,375	1,750	1,885	2,535	2,745	3,615	3,365	4,230
20"	4.4	11,540	2,740	1,545	1,722	1,864	NA	1,750	NA	2,740	NA	3,740	NA	4,355
22"	4.7	12,690	2,935	1,934	2,149	2,322	NA	1,750	NA	2,935	NA	3,860	NA	4,480
24"	5.0	13,830	3,060	2,374	2,632	2,838	NA	1,750	NA	3,060	NA	3,875	NA	4,605
26"	5.3	14,960	2,900	2,868	3,172	3,416	NA	1,750	NA	2,900	NA	4,725(7)	NA	5,345(8)
28"	5.5	16,085	2,900	3,417	3,772	4,056	NA	1,750	NA	2,900	NA	4,850(7)	NA	5,470(8)
30"	5.8	17,205	2,900	4,025	4,434	4,762	NA	1,750	NA	2,900	NA	4,975(7)	NA	5,590(8)
TJI® L90 Joist														
11⅞"	4.2	9,605	1,925	621	687	741	1,400	1,715	1,885	1,925	3,350	3,665	3,965	4,285
14"	4.5	11,430	2,125	913	1,005	1,079	1,400	1,875	1,885	2,125	3,350	3,825	3,965	4,440
16"	4.7	13,115	2,330	1,246	1,366	1,462	1,400	2,030	1,885	2,330	3,350	3,980	3,965	4,600
18"	5.0	14,785	2,535	1,635	1,786	1,908	1,400	2,030	1,885	2,515	3,350	3,980	3,965	4,600
20"	5.3	16,435	2,740	2,085	2,272	2,422	NA	2,190	NA	2,675	NA	4,140	NA	4,755
22"	5.6	18,075	2,935	2,597	2,824	3,006	NA	2,345	NA	2,830	NA	5,090	NA	5,705
24"	5.8	19,700	3,060	3,172	3,442	3,659	NA	2,345	NA	2,830	NA	5,405	NA	6,020
26"	6.1	21,315	2,900	3,814	4,132	4,387	NA	2,450	NA	2,900	NA	5,800(7)	NA	5,800(8)
28"	6.4	22,915	2,900	4,525	4,895	5,191	NA	2,450	NA	2,900	NA	5,800(7)	NA	5,800(8)
30"	6.6	24,510	2,900	5,306	5,732	6,073	NA	2,450	NA	2,900	NA	5,800(7)	NA	5,800(8)
TJI® H90 Joist														
11⅞"	4.6	10,960	1,925	687	755	810	1,400	1,715	1,885	1,925	3,495	3,810	4,100	4,420
14"	4.9	13,090	2,125	1,015	1,109	1,185	1,400	1,875	1,885	2,125	3,495	3,970	4,100	4,575
16"	5.2	15,065	2,330	1,389	1,512	1,610	1,400	2,030	1,885	2,330	3,495	4,130	4,100	4,735
18"	5.4	17,010	2,535	1,827	1,982	2,106	1,400	2,030	1,885	2,515	3,495	4,130	4,100	4,735
20"	5.7	18,945	2,740	2,331	2,522	2,676	NA	2,190	NA	2,675	NA	4,285	NA	4,890
22"	6.0	20,855	2,935	2,904	3,136	3,321	NA	2,345	NA	2,830	NA	5,235	NA	5,840
24"	6.3	22,755	3,060	3,549	3,825	4,046	NA	2,345	NA	2,830	NA	5,425	NA	6,155
26"	6.5	24,645	2,900	4,266	4,590	4,850	NA	2,450	NA	2,900	NA	5,800(7)	NA	5,800(8)
28"	6.8	26,520	2,900	5,059	5,436	5,737	NA	2,450	NA	2,900	NA	5,800(7)	NA	5,800(8)
30"	7.1	28,380	2,900	5,930	6,363	6,710	NA	2,450	NA	2,900	NA	5,800(7)	NA	5,800(8)

The stated allowable design properties are for loads of normal duration. Adjustments to the allowable design values shall be in accordance with the applicable code.

(1) **Caution:** Joist resistive moment properties reflect the latest ASTM standards and should not be increased by a repetitive member use factor.

(2) For possible increases in shear capacity see below.

(3) For deflection calculation only. Assumes 12" joist spacing with a 24" span-rated panel.

(4) Interpolation between bearing lengths is permitted for allowable design reactions.

(5) Allowable bearing lengths have been determined based on Trus Joist products. Allowable bearing on supporting members shall be checked.

(6) Refer to page 10 for web stiffener details.

(7) A 5¼" bearing length is required at intermediate reactions.

(8) A 7" bearing length is required at intermediate reactions.

TJI® Joist Shear Design

When joists are used as simple-span members, the design shear is equal to the shear at the face of the support.

When joists **up to 24" in depth** are used as multiple-span members, the design shear is the calculated shear at the interior support reduced by the following:

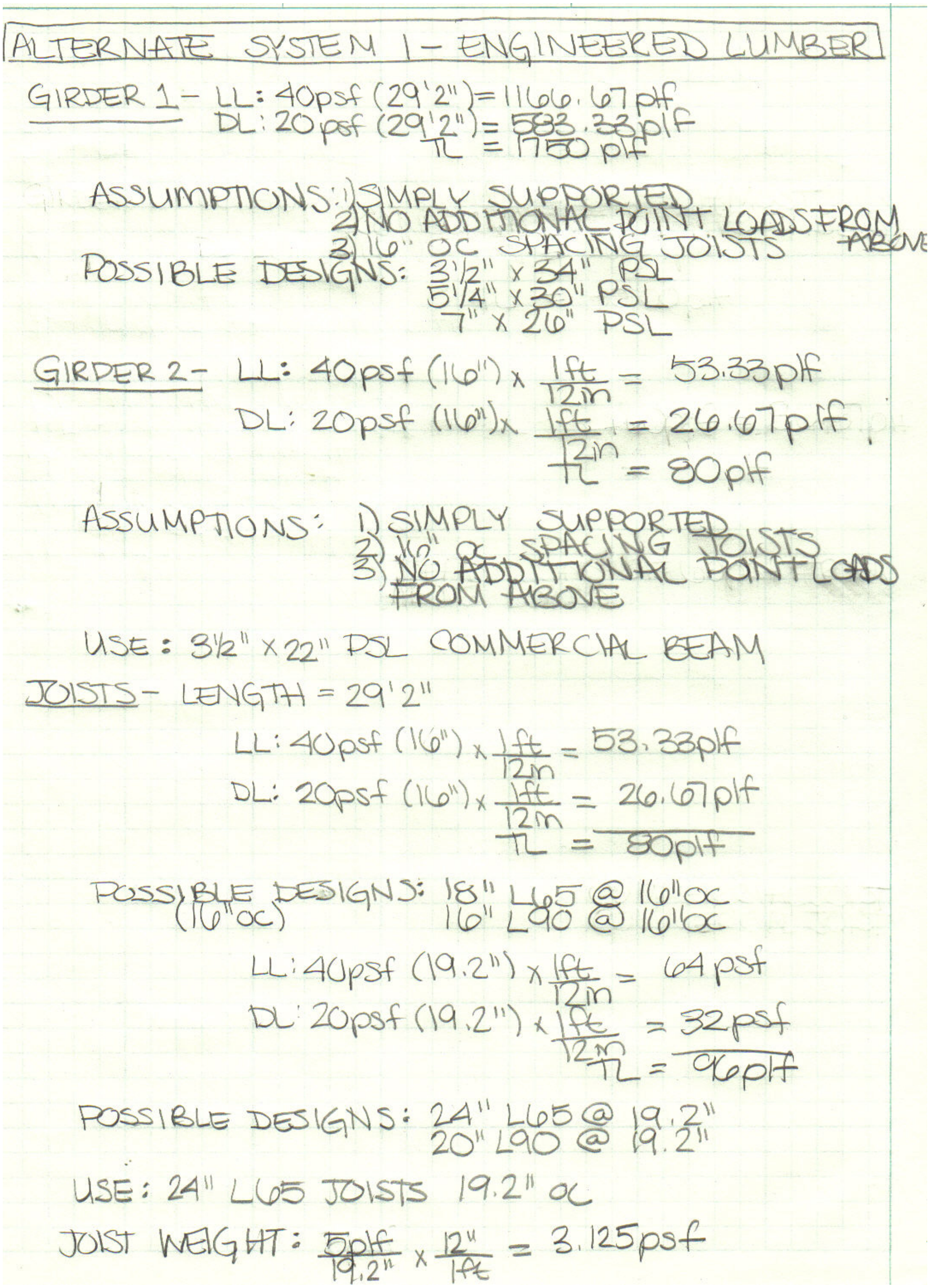
$$R = \frac{W}{19.25} \le 18\%$$

Where: R is the percent reduction
W is uniform load in plf

Building Codes and Product Acceptance:
ICC-ESR-1153, HUD SEB No. 689 Rev.9, L.A. City RR #25538, DSA PA-048

Figure 7

Engineered Lumber Calculations:



ALTERNATE SYSTEM 1 – ENGINEERED LUMBER

GIRDER 1 – LL: 40psf (29'2") = 1166.67 plf
DL: 20psf (29'2") = 583.33plf
TL = 1750 plf

ASSUMPTIONS: 1) SIMPLY SUPPORTED
2) NO ADDITIONAL POINT LOADS FROM ABOVE
3) 16" OC SPACING JOISTS

POSSIBLE DESIGNS: 3½" x 34" PSL
5¼" x 30" PSL
7" x 26" PSL

GIRDER 2 – LL: 40psf (16") x $\frac{1ft}{12in}$ = 53.33plf
DL: 20psf (16") x $\frac{1ft}{12in}$ = 26.67plf
TL = 80plf

ASSUMPTIONS: 1) SIMPLY SUPPORTED
2) 16" OC SPACING JOISTS
3) NO ADDITIONAL POINT LOADS FROM ABOVE

USE: 3½" x 22" PSL COMMERCIAL BEAM

JOISTS – LENGTH = 29'2"

LL: 40psf (16") x $\frac{1ft}{12in}$ = 53.33plf
DL: 20psf (16") x $\frac{1ft}{12in}$ = 26.67plf
TL = 80plf

POSSIBLE DESIGNS: 18" L65 @ 16" oc
(16" oc) 16" L90 @ 16" oc

LL: 40psf (19.2") x $\frac{1ft}{12in}$ = 64 psf
DL: 20psf (19.2") x $\frac{1ft}{12in}$ = 32psf
TL = 96plf

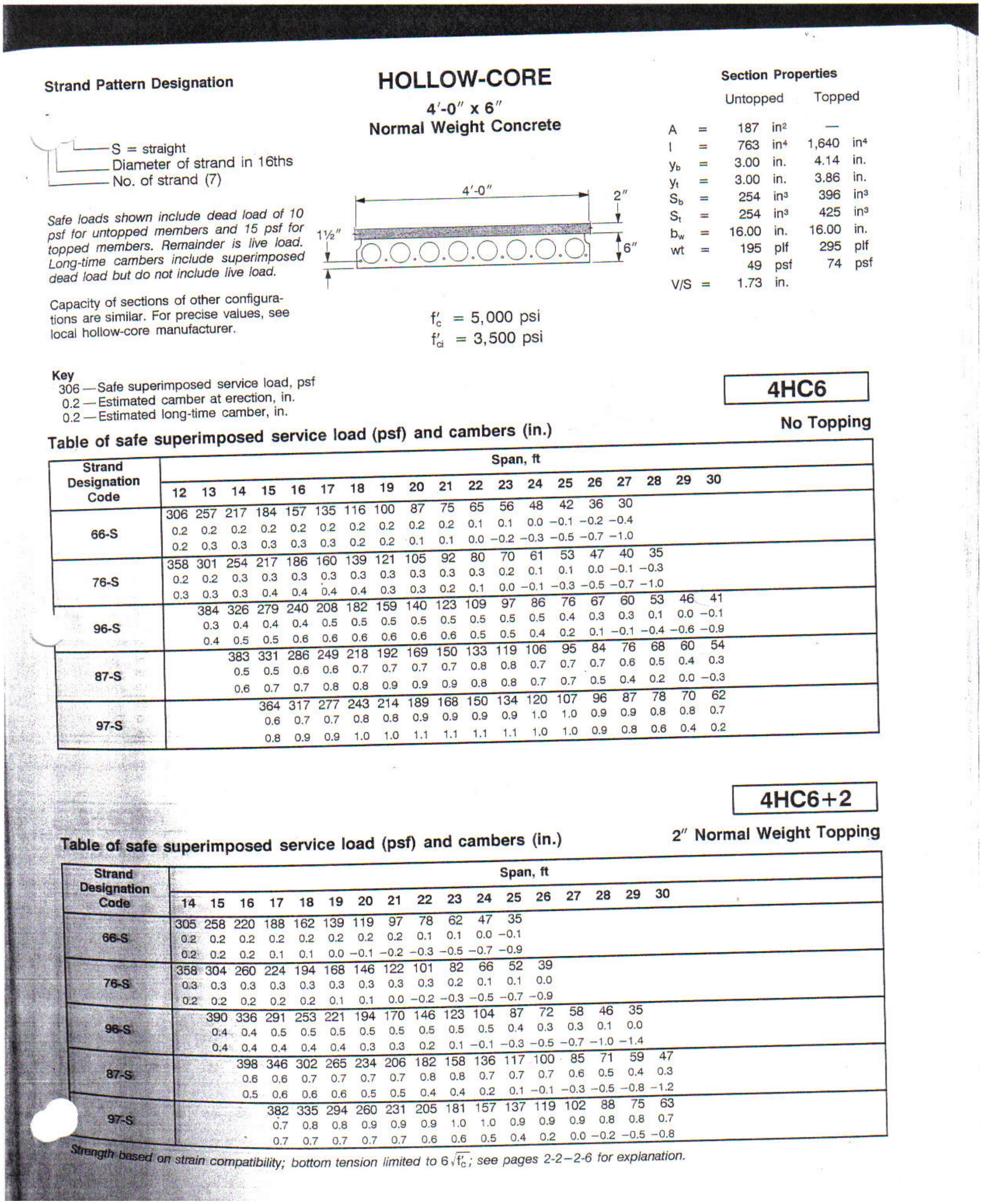
POSSIBLE DESIGNS: 24" L65 @ 19.2"
20" L90 @ 19.2"

USE: 24" L65 JOISTS 19.2" oc

JOIST WEIGHT: $\frac{5plf}{19.2"}$ x $\frac{12"}{1ft}$ = 3.125psf

Figure 8

Alternate System 2: Hollow Core Planks:



Strand Pattern Designation

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.

HOLLOW-CORE

4′-0″ x 6″
Normal Weight Concrete

$f'_c = 5{,}000$ psi
$f'_{ci} = 3{,}500$ psi

Section Properties

	Untopped	Topped
A =	187 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
b_w =	16.00 in.	16.00 in.
wt =	195 plf 49 psf	295 plf 74 psf
V/S =	1.73 in.	

Key
306 — Safe superimposed service load, psf
0.2 — Estimated camber at erection, in.
0.2 — Estimated long-time camber, in.

4HC6

No Topping

Table of safe superimposed service load (psf) and cambers (in.)

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	306	257	217	184	157	135	116	100	87	75	65	56	48	42	36	30			
	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.0	−0.1	−0.2	−0.4			
	0.2	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.1	0.1	0.0	−0.2	−0.3	−0.5	−0.7	−1.0			
76-S	358	301	254	217	186	160	139	121	105	92	80	70	61	53	47	40	35		
	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		
	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.3	0.3	0.2	0.1	0.0	−0.1	−0.3	−0.5	−0.7	−1.0		
96-S		384	326	279	240	208	182	159	140	123	109	97	86	76	67	60	53	46	41
		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
		0.4	0.5	0.5	0.6	0.6	0.6	0.6	0.6	0.6	0.5	0.5	0.4	0.2	0.1	−0.1	−0.4	−0.6	−0.9
87-S			383	331	286	249	218	192	169	150	133	119	106	95	84	76	68	60	54
			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
			0.6	0.7	0.7	0.8	0.8	0.9	0.9	0.9	0.8	0.8	0.7	0.7	0.5	0.4	0.2	0.0	−0.3
97-S				364	317	277	243	214	189	168	150	134	120	107	96	87	78	70	62
				0.6	0.7	0.7	0.8	0.8	0.9	0.9	0.9	0.9	1.0	1.0	0.9	0.9	0.8	0.8	0.7
				0.8	0.9	0.9	1.0	1.0	1.1	1.1	1.1	1.1	1.0	1.0	0.9	0.8	0.6	0.4	0.2

4HC6+2

2″ Normal Weight Topping

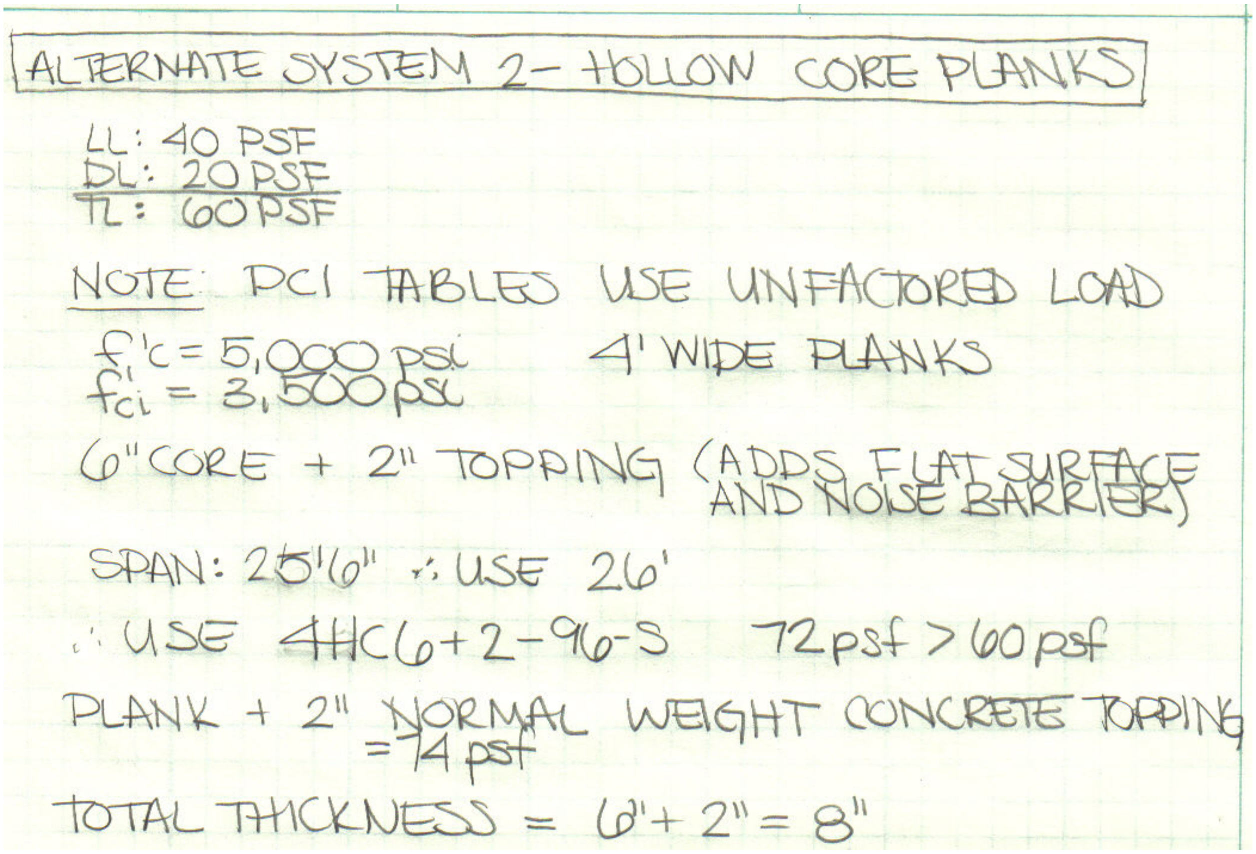
Table of safe superimposed service load (psf) and cambers (in.)

Strand Designation Code	Span, ft																
	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
66-S	305	258	220	188	162	139	119	97	78	62	47	35					
	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.0	−0.1					
	0.2	0.2	0.2	0.1	0.1	0.0	−0.1	−0.2	−0.3	−0.5	−0.7	−0.9					
76-S	358	304	260	224	194	168	146	122	101	82	66	52	39				
	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				
	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.0	−0.2	−0.3	−0.5	−0.7	−0.9				
96-S		390	336	291	253	221	194	170	146	123	104	87	72	58	46	35	
		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	
		0.4	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	
87-S			398	346	302	265	234	206	182	158	136	117	100	85	71	59	47
			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	0.6	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				382	335	294	260	231	205	181	157	137	119	102	88	75	63
				0.7	0.8	0.8	0.9	0.9	0.9	1.0	1.0	0.9	0.9	0.9	0.8	0.8	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 based on strain compatibility; bottom tension limited to $6\sqrt{f'_c}$; see pages 2-2–2-6 for explanation.

Figure 9

Hollow Core Planks Calculations:



ALTERNATE SYSTEM 2– HOLLOW CORE PLANKS

LL: 40 PSF
DL: 20 PSF
TL: 60 PSF

NOTE: PCI TABLES USE UNFACTORED LOAD

$f'_c = 5{,}000$ psi   4' WIDE PLANKS
$f'_{ci} = 3{,}500$ psi

6" CORE + 2" TOPPING (ADDS FLAT SURFACE AND NOISE BARRIER)

SPAN: 25'6" ∴ USE 26'

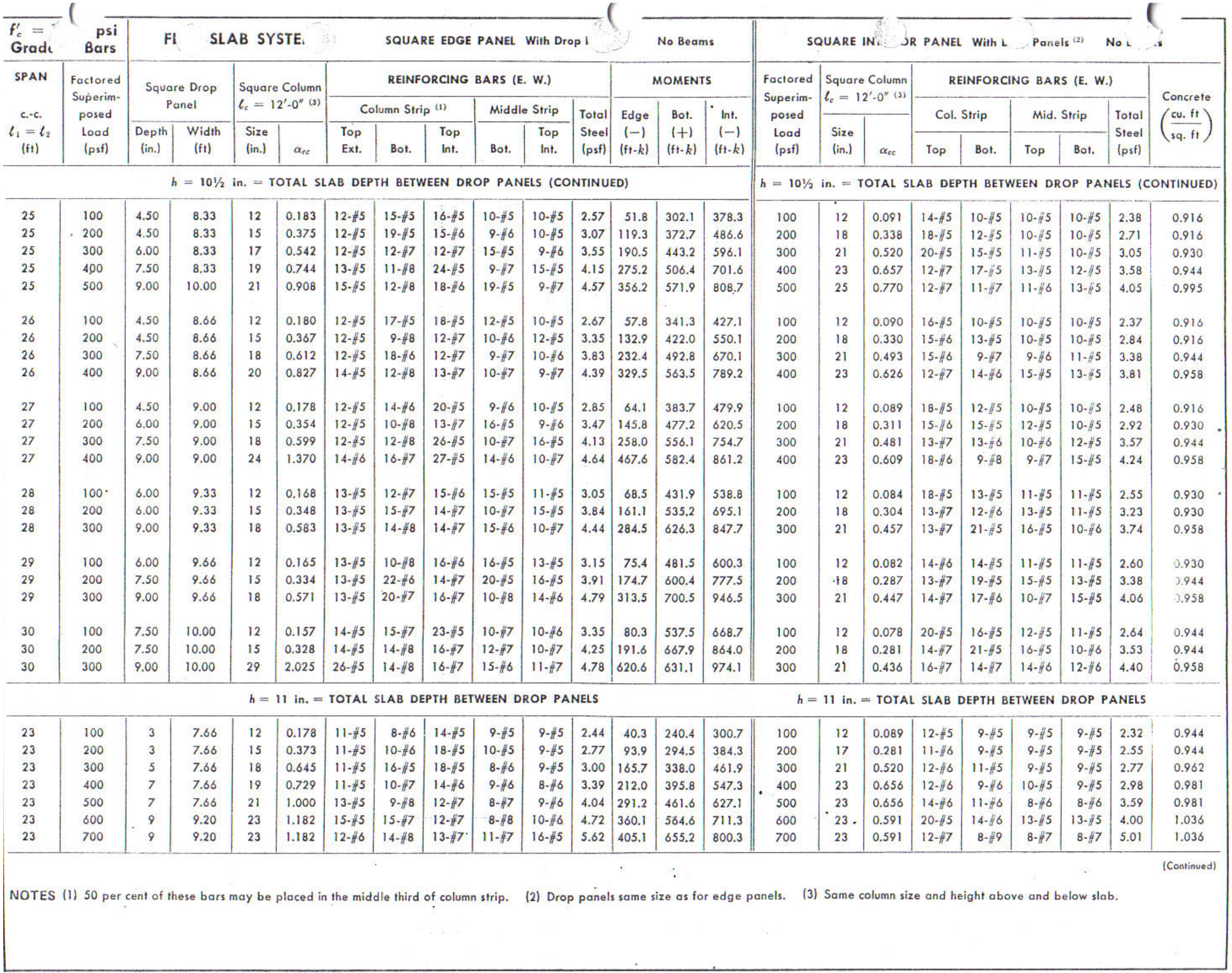
∴ USE 4HC6+2–96–S   72psf > 60psf

PLANK + 2" NORMAL WEIGHT CONCRETE TOPPING = 74 psf

TOTAL THICKNESS = 6" + 2" = 8"

Figure 10

Alternate 3 – Two Way Flat Slab System:



f'_c = psi Grad Bars | FL SLAB SYSTE | SQUARE EDGE PANEL With Drop | No Beams | SQUARE IN OR PANEL With Panels [2] No s

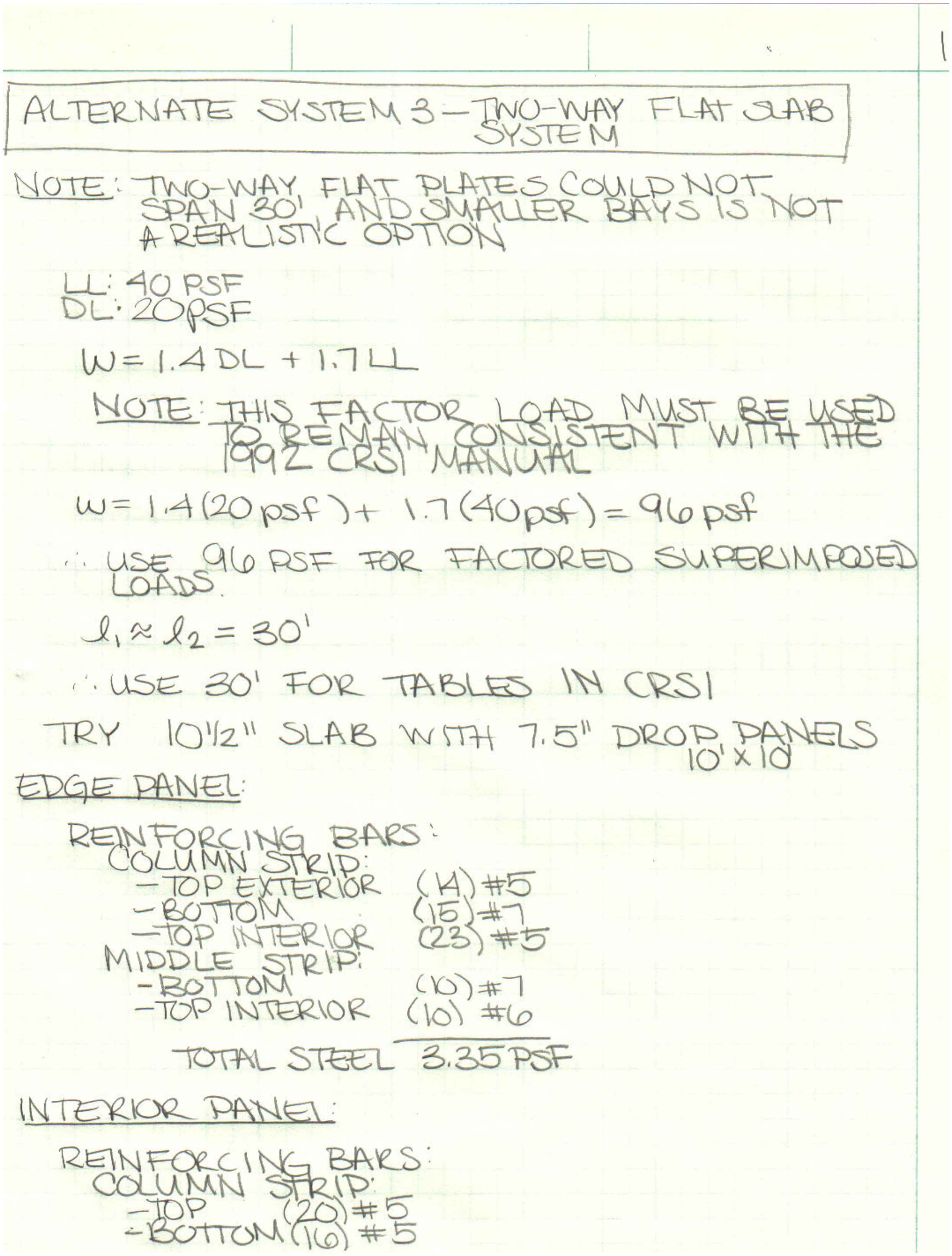
SPAN c.-c. $\ell_1 = \ell_2$ (ft)	Factored Superimposed Load (psf)	Square Drop Panel Depth (in.)	Square Drop Panel Width (ft)	Square Column $\ell_c = 12'$-0" [3] Size (in.)	Square Column α_{cc}	Column Strip [1] Top Ext.	Column Strip [1] Bot.	Column Strip [1] Top Int.	Middle Strip Bot.	Middle Strip Top Int.	Total Steel (psf)	Moments Edge (−) (ft-k)	Moments Bot. (+) (ft-k)	Moments Int. (−) (ft-k)	Factored Superimposed Load (psf)	Square Column $\ell_c = 12'$-0" [3] Size (in.)	Square Column α_{cc}	Col. Strip Top	Col. Strip Bot.	Mid. Strip Top	Mid. Strip Bot.	Total Steel (psf)	Concrete $\left(\frac{\text{cu. ft}}{\text{sq. ft}}\right)$
h = 10½ in. = TOTAL SLAB DEPTH BETWEEN DROP PANELS (CONTINUED)															h = 10½ in. = TOTAL SLAB DEPTH BETWEEN DROP PANELS (CONTINUED)								
25	100	4.50	8.33	12	0.183	12-#5	15-#5	16-#5	10-#5	10-#5	2.57	51.8	302.1	378.3	100	12	0.091	14-#5	10-#5	10-#5	10-#5	2.38	0.916
25	200	4.50	8.33	15	0.375	12-#5	19-#5	15-#6	9-#6	10-#5	3.07	119.3	372.7	486.6	200	18	0.338	18-#5	12-#5	10-#5	10-#5	2.71	0.916
25	300	6.00	8.33	17	0.542	12-#5	12-#7	12-#7	15-#5	9-#6	3.55	190.5	443.2	596.1	300	21	0.520	20-#5	15-#5	11-#5	10-#5	3.05	0.930
25	400	7.50	8.33	19	0.744	13-#5	11-#8	24-#5	9-#7	15-#5	4.15	275.2	506.4	701.6	400	23	0.657	12-#7	17-#5	13-#5	12-#5	3.58	0.944
25	500	9.00	10.00	21	0.908	15-#5	12-#8	18-#6	19-#5	9-#7	4.57	356.2	571.9	808.7	500	25	0.770	12-#7	11-#7	11-#6	13-#5	4.05	0.995
26	100	4.50	8.66	12	0.180	12-#5	17-#5	18-#5	12-#5	10-#5	2.67	57.8	341.3	427.1	100	12	0.090	16-#5	10-#5	10-#5	10-#5	2.37	0.916
26	200	4.50	8.66	15	0.367	12-#5	9-#8	12-#7	10-#6	12-#5	3.35	132.9	422.0	550.1	200	18	0.330	15-#6	13-#5	10-#5	10-#5	2.84	0.916
26	300	7.50	8.66	18	0.612	12-#5	18-#6	12-#7	9-#7	10-#6	3.83	232.4	492.8	670.1	300	21	0.493	15-#6	9-#7	9-#6	11-#5	3.38	0.944
26	400	9.00	8.66	20	0.827	14-#5	12-#8	13-#7	10-#7	9-#7	4.39	329.5	563.5	789.2	400	23	0.626	12-#7	14-#6	15-#5	13-#5	3.81	0.958
27	100	4.50	9.00	12	0.178	12-#5	14-#6	20-#5	9-#6	10-#5	2.85	64.1	383.7	479.9	100	12	0.089	18-#5	12-#5	10-#5	10-#5	2.48	0.916
27	200	6.00	9.00	15	0.354	12-#5	10-#8	13-#7	16-#5	9-#6	3.47	145.8	477.2	620.5	200	18	0.311	15-#6	15-#5	12-#5	10-#5	2.92	0.930
27	300	7.50	9.00	18	0.599	12-#5	12-#8	26-#5	10-#7	16-#5	4.13	258.0	556.1	754.7	300	21	0.481	13-#7	13-#6	10-#6	12-#5	3.57	0.944
27	400	9.00	9.00	24	1.370	14-#6	16-#7	27-#5	14-#6	10-#7	4.64	467.6	582.4	861.2	400	23	0.609	18-#6	9-#8	9-#7	15-#5	4.24	0.958
28	100	6.00	9.33	12	0.168	13-#5	12-#7	15-#6	15-#5	11-#5	3.05	68.5	431.9	538.8	100	12	0.084	18-#5	13-#5	11-#5	11-#5	2.55	0.930
28	200	6.00	9.33	15	0.348	13-#5	15-#7	14-#7	10-#7	15-#5	3.84	161.1	535.2	695.1	200	18	0.304	13-#7	12-#6	13-#5	11-#5	3.23	0.930
28	300	9.00	9.33	18	0.583	13-#5	14-#8	14-#7	15-#6	10-#7	4.44	284.5	626.3	847.7	300	21	0.457	13-#7	21-#5	16-#5	10-#6	3.74	0.958
29	100	6.00	9.66	12	0.165	13-#5	10-#8	16-#6	16-#5	13-#5	3.15	75.4	481.5	600.3	100	12	0.082	14-#6	14-#5	11-#5	11-#5	2.60	0.930
29	200	7.50	9.66	15	0.334	13-#5	22-#6	14-#7	20-#5	16-#5	3.91	174.7	600.4	777.5	200	18	0.287	13-#7	19-#5	15-#5	13-#5	3.38	0.944
29	300	9.00	9.66	18	0.571	13-#5	20-#7	16-#7	10-#8	14-#6	4.79	313.5	700.5	946.5	300	21	0.447	14-#7	17-#6	10-#7	15-#5	4.06	0.958
30	100	7.50	10.00	12	0.157	14-#5	15-#7	23-#5	10-#7	10-#6	3.35	80.3	537.5	668.7	100	12	0.078	20-#5	16-#5	12-#5	11-#5	2.64	0.944
30	200	7.50	10.00	15	0.328	14-#5	14-#8	16-#7	12-#7	10-#7	4.25	191.6	667.9	864.0	200	18	0.281	14-#7	21-#5	16-#5	10-#6	3.53	0.944
30	300	9.00	10.00	29	2.025	26-#5	14-#8	16-#7	15-#6	11-#7	4.78	620.6	631.1	974.1	300	21	0.436	16-#7	14-#7	14-#6	12-#6	4.40	0.958
h = 11 in. = TOTAL SLAB DEPTH BETWEEN DROP PANELS															h = 11 in. = TOTAL SLAB DEPTH BETWEEN DROP PANELS								
23	100	3	7.66	12	0.178	11-#5	8-#6	14-#5	9-#5	9-#5	2.44	40.3	240.4	300.7	100	12	0.089	12-#5	9-#5	9-#5	9-#5	2.32	0.944
23	200	3	7.66	15	0.373	11-#5	10-#6	18-#5	10-#5	9-#5	2.77	93.9	294.5	384.3	200	17	0.281	11-#6	9-#5	9-#5	9-#5	2.55	0.944
23	300	5	7.66	18	0.645	11-#5	16-#5	18-#5	8-#6	9-#5	3.00	165.7	338.0	461.9	300	21	0.520	12-#6	11-#5	9-#5	9-#5	2.77	0.962
23	400	7	7.66	19	0.729	11-#5	10-#7	14-#6	9-#6	8-#6	3.39	212.0	395.8	547.3	400	23	0.656	12-#6	9-#6	10-#5	9-#5	2.98	0.981
23	500	7	7.66	21	1.000	13-#5	9-#8	12-#7	8-#7	9-#6	4.04	291.2	461.6	627.1	500	23	0.656	14-#6	11-#6	8-#6	8-#6	3.59	0.981
23	600	9	9.20	23	1.182	15-#5	15-#7	12-#7	8-#8	10-#6	4.72	360.1	564.6	711.3	600	23	0.591	20-#5	14-#6	13-#5	13-#5	4.00	1.036
23	700	9	9.20	23	1.182	12-#6	14-#8	13-#7	11-#7	16-#5	5.62	405.1	655.2	800.3	700	23	0.591	12-#7	8-#9	8-#7	8-#7	5.01	1.036

(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.

Figure 11

Two Way Flat Slab Calculations:



ALTERNATE SYSTEM 3 – TWO-WAY FLAT SLAB SYSTEM

NOTE: TWO-WAY FLAT PLATES COULD NOT SPAN 30', AND SMALLER BAYS IS NOT A REALISTIC OPTION

LL: 40 PSF
DL: 20PSF

$W = 1.4\,DL + 1.7\,LL$

NOTE: THIS FACTOR LOAD MUST BE USED TO REMAIN CONSISTENT WITH THE 1992 CRSI MANUAL

$w = 1.4(20\,psf) + 1.7(40\,psf) = 96\,psf$

∴ USE 96 PSF FOR FACTORED SUPERIMPOSED LOADS.

$l_1 \approx l_2 = 30'$

∴ USE 30' FOR TABLES IN CRSI

TRY 10½" SLAB WITH 7.5" DROP PANELS 10' x 10'

EDGE PANEL:

REINFORCING BARS:
- COLUMN STRIP:
  - –TOP EXTERIOR (14) #5
  - –BOTTOM (15) #7
  - –TOP INTERIOR (23) #5
- MIDDLE STRIP:
  - –BOTTOM (10) #7
  - –TOP INTERIOR (10) #6

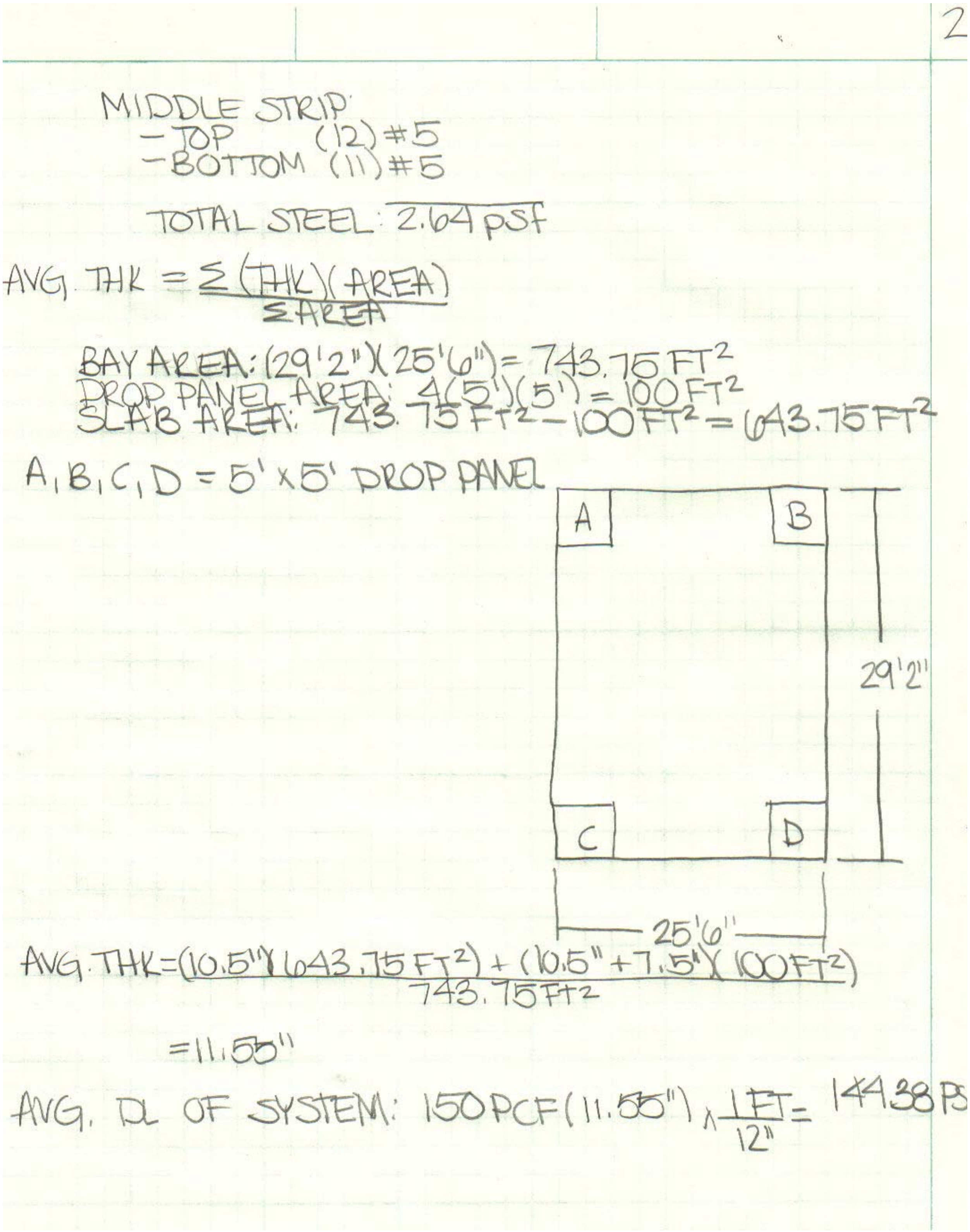
TOTAL STEEL 3.35 PSF

INTERIOR PANEL:

REINFORCING BARS:
- COLUMN STRIP:
  - –TOP (20) #5
  - –BOTTOM (16) #5

Figure 12

Two Way Flat Slab Calculations (continued):



2

MIDDLE STRIP
- TOP (12) #5
- BOTTOM (11) #5

TOTAL STEEL: $\overline{2.64 \text{ PSF}}$

$$\text{AVG. THK} = \frac{\Sigma(\text{THK})(\text{AREA})}{\Sigma \text{AREA}}$$

BAY AREA: $(29'2")(25'6") = 743.75 \text{ FT}^2$
DROP PANEL AREA: $4(5')(5') = 100 \text{ FT}^2$
SLAB AREA: $743.75 \text{ FT}^2 - 100 \text{ FT}^2 = 643.75 \text{ FT}^2$

A, B, C, D = 5' x 5' DROP PANEL

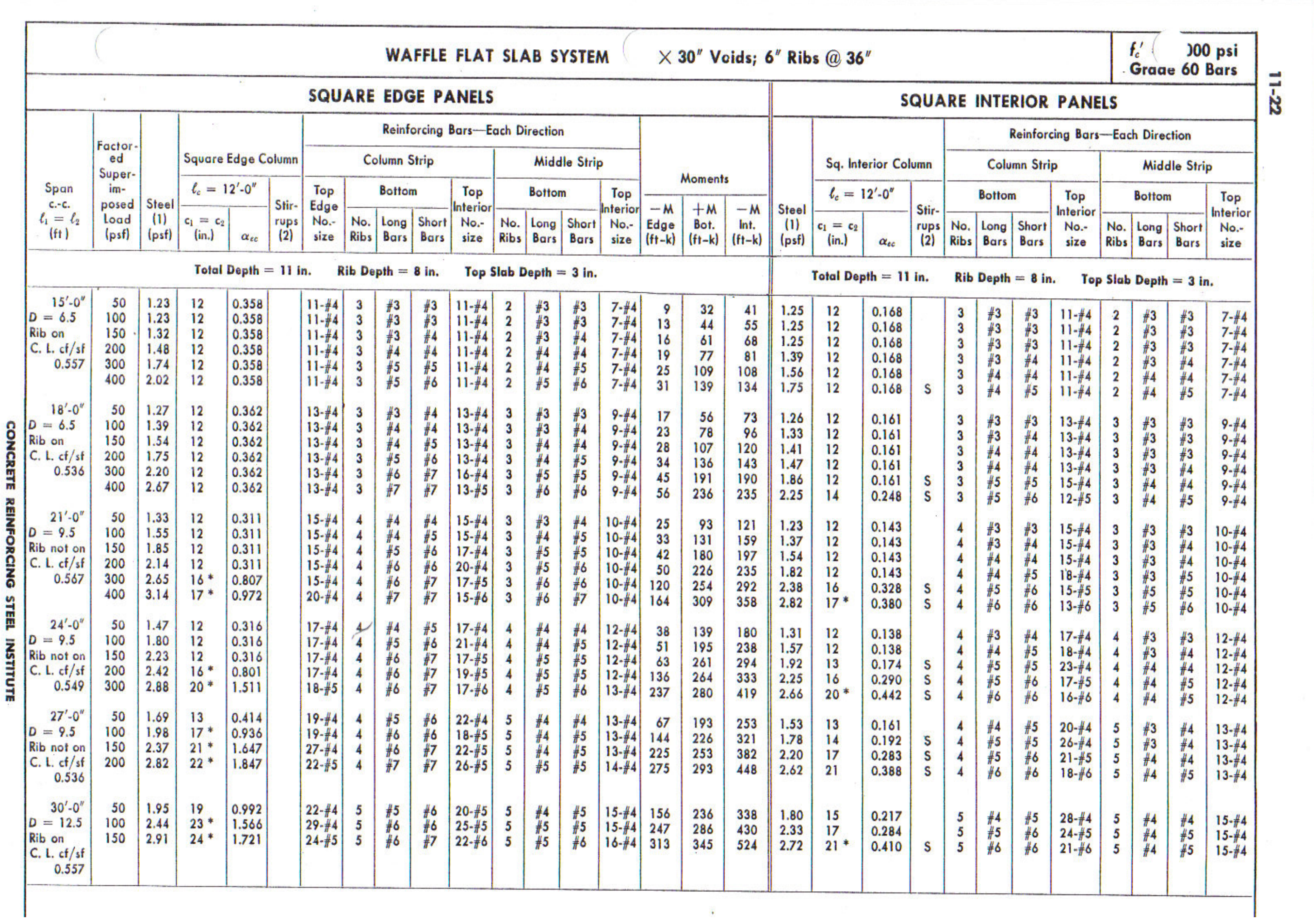
$$\text{AVG. THK} = \frac{(10.5")(643.75 \text{ FT}^2) + (10.5" + 7.5")(100 \text{ FT}^2)}{743.75 \text{ FT}^2}$$

$= 11.55"$

AVG. DL OF SYSTEM: $150 \text{ PCF}(11.55") \times \frac{1 \text{ FT}}{12"} = 144.38 \text{ PS}$

Figure 13

Alternate 4 – Waffle Slab:



11-22

WAFFLE FLAT SLAB SYSTEM [illegible] **× 30″ Voids; 6″ Ribs @ 36″**

f_c' [illegible]00 psi
Grade 60 Bars

SQUARE EDGE PANELS

Total Depth = 11 in. Rib Depth = 8 in. Top Slab Depth = 3 in.

Span c.-c. $\ell_1 = \ell_2$ (ft)	Factored Superimposed Load (psf)	Steel (1) (psf)	Square Edge Column		Stirrups (2)	Reinforcing Bars—Each Direction									Moments		
			ℓ_c = 12′-0″			Column Strip					Middle Strip						
						Top	Bottom			Top	Bottom			Top			
			$c_1 = c_2$ (in.)	α_{ec}		Edge No.-size	No. Ribs	Long Bars	Short Bars	Interior No.-size	No. Ribs	Long Bars	Short Bars	Interior No.-size	−M Edge (ft-k)	+M Bot. (ft-k)	−M Int. (ft-k)
15′-0″ *D* = 6.5 Rib on C. L. cf/sf 0.557	50	1.23	12	0.358		11-#4	3	#3	#3	11-#4	2	#3	#3	7-#4	9	32	41
	100	1.23	12	0.358		11-#4	3	#3	#3	11-#4	2	#3	#3	7-#4	13	44	55
	150	1.32	12	0.358		11-#4	3	#3	#4	11-#4	2	#3	#4	7-#4	16	61	68
	200	1.48	12	0.358		11-#4	3	#4	#4	11-#4	2	#4	#4	7-#4	19	77	81
	300	1.74	12	0.358		11-#4	3	#5	#5	11-#4	2	#4	#5	7-#4	25	109	108
	400	2.02	12	0.358		11-#4	3	#5	#6	11-#4	2	#5	#6	7-#4	31	139	134
18′-0″ *D* = 6.5 Rib on C. L. cf/sf 0.536	50	1.27	12	0.362		13-#4	3	#3	#4	13-#4	3	#3	#3	9-#4	17	56	73
	100	1.39	12	0.362		13-#4	3	#4	#4	13-#4	3	#3	#4	9-#4	23	78	96
	150	1.54	12	0.362		13-#4	3	#4	#5	13-#4	3	#4	#4	9-#4	28	107	120
	200	1.75	12	0.362		13-#4	3	#5	#6	13-#4	3	#4	#5	9-#4	34	136	143
	300	2.20	12	0.362		13-#4	3	#6	#7	16-#4	3	#5	#5	9-#4	45	191	190
	400	2.67	12	0.362		13-#4	3	#7	#7	13-#5	3	#6	#6	9-#4	56	236	235
21′-0″ *D* = 9.5 Rib not on C. L. cf/sf 0.567	50	1.33	12	0.311		15-#4	4	#4	#4	15-#4	3	#3	#4	10-#4	25	93	121
	100	1.55	12	0.311		15-#4	4	#4	#5	15-#4	3	#4	#5	10-#4	33	131	159
	150	1.85	12	0.311		15-#4	4	#5	#6	17-#4	3	#5	#5	10-#4	42	180	197
	200	2.14	12	0.311		15-#4	4	#6	#6	20-#4	3	#5	#6	10-#4	50	226	235
	300	2.65	16 *	0.807		15-#4	4	#6	#7	17-#5	3	#6	#6	10-#4	120	254	292
	400	3.14	17 *	0.972		20-#4	4	#7	#7	15-#6	3	#6	#7	10-#4	164	309	358
24′-0″ *D* = 9.5 Rib not on C. L. cf/sf 0.549	50	1.47	12	0.316		17-#4	4	#4	#5	17-#4	4	#4	#4	12-#4	38	139	180
	100	1.80	12	0.316		17-#4	4	#5	#6	21-#4	4	#4	#5	12-#4	51	195	238
	150	2.23	12	0.316		17-#4	4	#6	#7	17-#5	4	#5	#5	12-#4	63	261	294
	200	2.42	16 *	0.801		17-#4	4	#6	#7	19-#5	4	#5	#5	12-#4	136	264	333
	300	2.88	20 *	1.511		18-#5	4	#6	#7	17-#6	4	#5	#6	13-#4	237	280	419
27′-0″ *D* = 9.5 Rib not on C. L. cf/sf 0.536	50	1.69	13	0.414		19-#4	4	#5	#6	22-#4	5	#4	#4	13-#4	67	193	253
	100	1.98	17 *	0.936		19-#4	4	#6	#6	18-#5	5	#4	#5	13-#4	144	226	321
	150	2.37	21 *	1.647		27-#4	4	#6	#7	22-#5	5	#4	#5	13-#4	225	253	382
	200	2.82	22 *	1.847		22-#5	4	#7	#7	26-#5	5	#5	#5	14-#4	275	293	448
30′-0″ *D* = 12.5 Rib on C. L. cf/sf 0.557	50	1.95	19	0.992		22-#4	5	#5	#6	20-#5	5	#4	#5	15-#4	156	236	338
	100	2.44	23 *	1.566		29-#4	5	#6	#6	25-#5	5	#5	#5	15-#4	247	286	430
	150	2.91	24 *	1.721		24-#5	5	#6	#7	22-#6	5	#5	#6	16-#4	313	345	524

SQUARE INTERIOR PANELS

Total Depth = 11 in. Rib Depth = 8 in. Top Slab Depth = 3 in.

Span c.-c. $\ell_1 = \ell_2$ (ft)	Factored Superimposed Load (psf)	Steel (1) (psf)	Sq. Interior Column		Stirrups (2)	Reinforcing Bars—Each Direction							
			ℓ_c = 12′-0″			Column Strip				Middle Strip			
						Bottom			Top	Bottom			Top
			$c_1 = c_2$ (in.)	α_{ec}		No. Ribs	Long Bars	Short Bars	Interior No.-size	No. Ribs	Long Bars	Short Bars	Interior No.-size
15′-0″ *D* = 6.5 Rib on C. L. cf/sf 0.557	50	1.25	12	0.168		3	#3	#3	11-#4	2	#3	#3	7-#4
	100	1.25	12	0.168		3	#3	#3	11-#4	2	#3	#3	7-#4
	150	1.25	12	0.168		3	#3	#3	11-#4	2	#3	#3	7-#4
	200	1.39	12	0.168		3	#3	#4	11-#4	2	#3	#4	7-#4
	300	1.56	12	0.168		3	#4	#4	11-#4	2	#4	#4	7-#4
	400	1.75	12	0.168	S	3	#4	#5	11-#4	2	#4	#5	7-#4
18′-0″ *D* = 6.5 Rib on C. L. cf/sf 0.536	50	1.26	12	0.161		3	#3	#3	13-#4	3	#3	#3	9-#4
	100	1.33	12	0.161		3	#3	#4	13-#4	3	#3	#3	9-#4
	150	1.41	12	0.161		3	#4	#4	13-#4	3	#3	#3	9-#4
	200	1.47	12	0.161		3	#4	#4	13-#4	3	#3	#4	9-#4
	300	1.86	12	0.161	S	3	#5	#5	15-#4	3	#4	#4	9-#4
	400	2.25	14	0.248	S	3	#5	#6	12-#5	3	#4	#5	9-#4
21′-0″ *D* = 9.5 Rib not on C. L. cf/sf 0.567	50	1.23	12	0.143		4	#3	#3	15-#4	3	#3	#3	10-#4
	100	1.37	12	0.143		4	#3	#4	15-#4	3	#3	#4	10-#4
	150	1.54	12	0.143		4	#4	#4	15-#4	3	#3	#4	10-#4
	200	1.82	12	0.143		4	#4	#5	18-#4	3	#3	#5	10-#4
	300	2.38	16	0.328	S	4	#5	#6	15-#5	3	#5	#5	10-#4
	400	2.82	17 *	0.380	S	4	#6	#6	13-#6	3	#5	#6	10-#4
24′-0″ *D* = 9.5 Rib not on C. L. cf/sf 0.549	50	1.31	12	0.138		4	#3	#4	17-#4	4	#3	#3	12-#4
	100	1.57	12	0.138		4	#4	#5	18-#4	4	#3	#4	12-#4
	150	1.92	13	0.174	S	4	#5	#5	23-#4	4	#4	#4	12-#4
	200	2.25	16	0.290	S	4	#5	#6	17-#5	4	#4	#5	12-#4
	300	2.66	20 *	0.442	S	4	#6	#6	16-#6	4	#4	#5	12-#4
27′-0″ *D* = 9.5 Rib not on C. L. cf/sf 0.536	50	1.53	13	0.161		4	#4	#5	20-#4	5	#3	#4	13-#4
	100	1.78	14	0.192	S	4	#5	#5	26-#4	5	#3	#4	13-#4
	150	2.20	17	0.283	S	4	#5	#6	21-#5	5	#4	#4	13-#4
	200	2.62	21	0.388	S	4	#6	#6	18-#6	5	#4	#5	13-#4
30′-0″ *D* = 12.5 Rib on C. L. cf/sf 0.557	50	1.80	15	0.217		5	#4	#5	28-#4	5	#4	#4	15-#4
	100	2.33	17	0.284		5	#5	#6	24-#5	5	#4	#5	15-#4
	150	2.72	21 *	0.410	S	5	#6	#6	21-#6	5	#4	#5	15-#4

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Figure 14