TECHNICAL ASSIGNMENT 2

STRUCTURAL STUDY OF ALTERNATIVE FLOOR SYSTEMS

Duquesne University Multipurpose/ Athletic Facility

Michael Szott
Structural Option
Advisor: M. Kevin Parfitt

October 25, 2006
Technical Report 2

Executive Summary

The intention of this report is to explore alternative floor framing systems for the Duquesne University Multipurpose Athletic Facility. Four alternative systems were chosen and evaluated.

- Modified composite steel framing
- Concrete pan joist construction
- Composite open web steel joists
- One way concrete slab

To begin, a single representative bay was chosen from the existing framing system layout. The geometry of this bay was used in the design of all four alternatives. For ease of design, several design aids and engineering software programs were consulted during the compilation of the enclosed calculations. For the existing steel framing, a RAM model was created, and used to model the modified steel construction. For the concrete alternatives, the CRSI Handbook was consulted. The gravity loading for this exercise is the same as was used in Technical Report 1.

Here is an overview of the alternative systems designed in this report.

Floor System	Slab Used	Beams	Girders
Modified Composite Steel	4.5" NWC slab on 2" composite metal deck	W12x14 (8)	W24x62 (24)
Concrete Pan Joists	3" NWC slab	30" forms, 6"x20" ribs	17x26
Composite Steel Joists	2.5" NWC slab on 2" composite metal deck	12VC	existing
One Way Concrete Slab	6" NWC slab	16x22	18x22

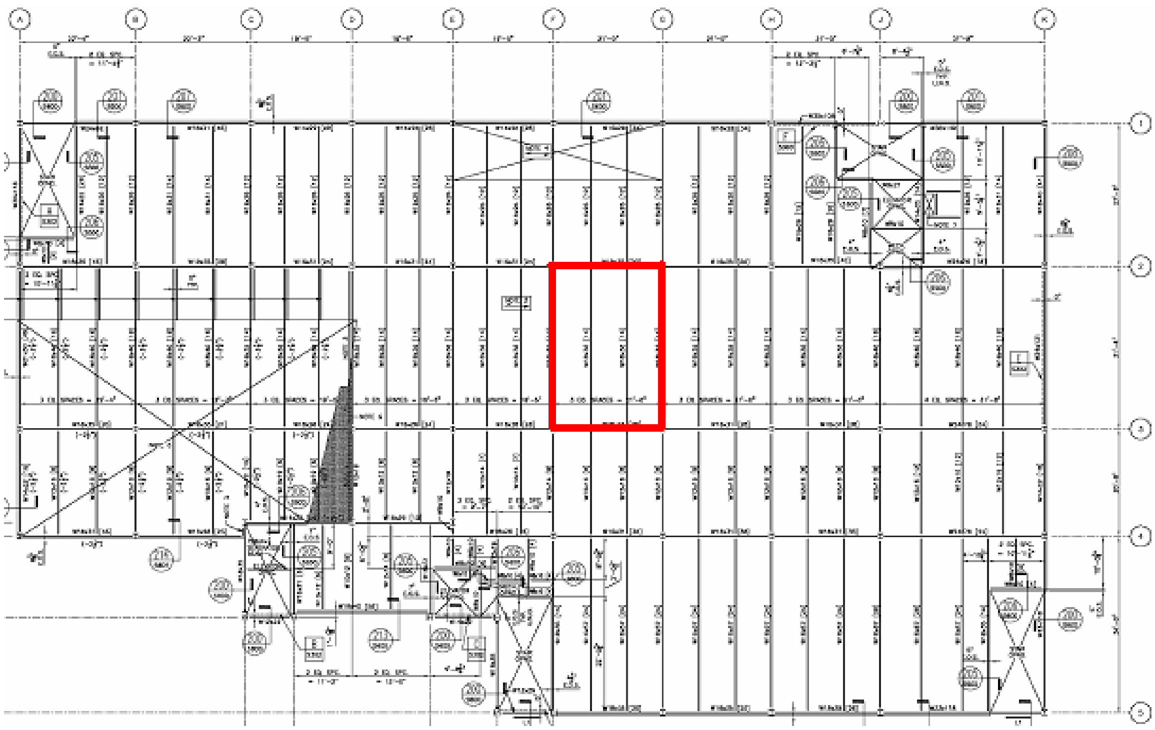
A comparison chart summarizing all of the systems is listed on page 9 of this report, detailing the positive and negative attributes of each evaluated system. The chart outlines constructability, cost, effects on lateral and foundation systems, and floor depth. After the evaluation of each floor system, I have concluded that the only other feasible floor system that should be evaluated further is the composite steel joist construction. Each other system negatively impacts the building in ways that warrant no further inspection.

Table of Contents

Introduction

Duquesne University's Multipurpose Athletic Facility is currently under construction on Pittsburgh's Forbes Avenue. The building is supported by a steel superstructure, including a composite steel floor system. Each of the first three floors are framed in rectangular bays, ranging in size from 20'x20' to 21'x34'. The upper athletic and ballroom floors are also composite steel, but are framed with longer spans (79'6") due to the open plan of the gymnasiums below.

Currently, the typical floor depth does not exceed 30.5" (W24, 4.5" concrete, 2" metal deck). While a W24 is the largest member within the interior floor bays, most members fall in the range of W12's through W18's. When looking at the gymnasium and ballroom levels, the floor depth is at most 42.5" (W36, 4.5" concrete, 2" metal deck). Since the upper gymnasium floors differ from the typical floor bays, I will concentrate the comparisons on a typical floor bay as shown below.



- Highlighted Section shown with description of existing floor system

Gravity Loading

Live Loads (ASCE 7-02, Table 4.1)

Lobbies and Public Spaces…………............100 PSF
Corridors (above first floor)………………...80 PSF
Mechanical…………………………………75 PSF (assumed)
Athletic Floors………………………………100 PSF
Stairs and Exits…………………………….. 40 PSF
Offices………………………………………50 PSF

Dead Loads

Partition Allowance……………………….. 20 PSF
Reinforced Concrete Slab………………….. 150 PCF
MEP……………………………………... 5 PSF
Metal Decking……………………………... 2-3 PSF (deck catalog)
Joist/Beam Weight…………………………Specific to each member

Alternative Systems

In this report, I will be evaluating four alternative floor systems against the existing composite construction, including:

- **Modifying the existing bays** will be evaluated in the hopes that the smaller beam spans will yield a lighter overall floor system.
- **A one way concrete slab with beams and girders** will be assessed to determine if a concrete system will be structurally and economically comparable to steel.
- **Concrete pan joists** will be checked to compare another fully concrete system's performance against the existing steel.
- **Composite Steel Joists** is another option for the typical bays and the long span areas of the floor framing.

Design References/Software

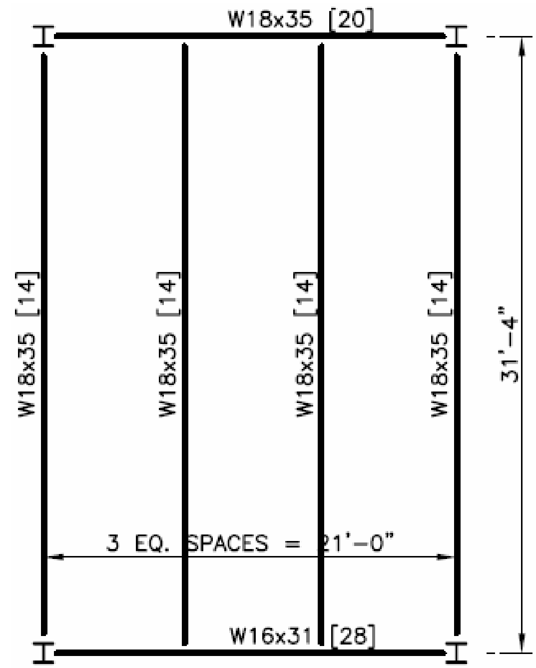
This report will be completed with the use of several structural design aides and other resources. They include:

- AISC Manual of Steel Construction, 13th edition
- Vulcraft Steel Roof and Floor Deck catalog
- Vulcraft Composite Steel Joist and Joist Girder catalog
- CRSI Handbook
- R.S. Means 2006, Assemblies Cost Data

Software:

- RAM Structural System
- Enercalc Structural Engineering Library

Existing Floor System



The existing floor framing is composed of 20'x20' to 21'x31'-34' bays, topped with 4.5" of normal weight concrete on 2" composite metal decking. In this system, beams span in the long direction and the girders span in the short direction. The girders short span allows the designer to carry the large beam forces with relatively small members, reducing the overall weight and depth of the floor system.

Comparison of the existing framing to the alternative choices can be found in the appendices of this report.

Advantages

Weight: The overall weight for this typical floor bay is approximately 54,500#. The use of steel framing greatly reduces the weight as compared to concrete. This lighter structure will impact the foundation design and, if seismic forces should control over wind forces, the lateral system as well.

Floor Depth: In this particular bay, the floor depth is measured at 24.2". This relatively small floor depth is favorable for the coordination of MEP equipment, architectural aspects of the structure, and maintaining required floor to ceiling heights.

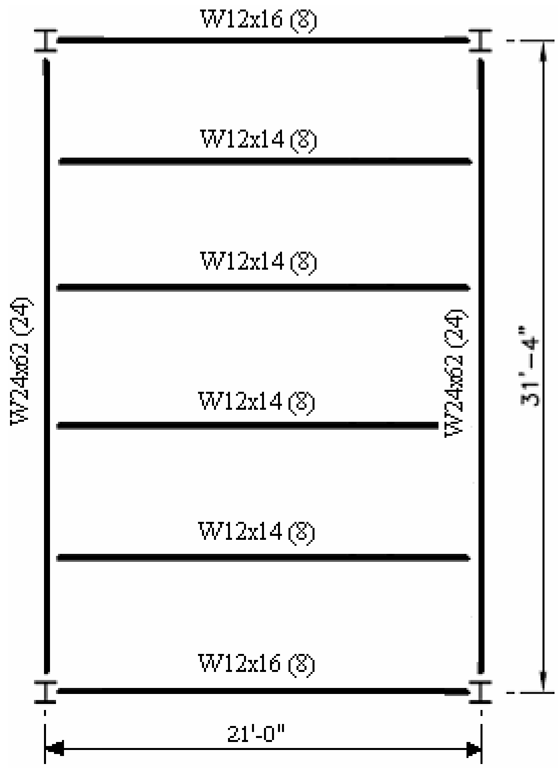
Constructability: The use of steel framing allows the buildings skeleton to be erected quickly and efficiently. Once the decking is in place a working platform is immediately available for use by all involved.

Disadvantages

Cost: *See comparison chart*

Modified Composite System

The modified composite system is modeled in the same typical 21'x31'-4" bay as shown in the existing system. The slab remains as specified, 4.5" of concrete on a 2" composite deck. The beams are now spaced in equal intervals (6.25') and span in the short, 21' direction. In this new system, the beams are a considerably smaller depth, but the girders have become deeper, and almost two times heavier.



Comparison of the existing framing to the alternative choices can be found in the appendices of this report.

Advantages

Weight: The overall weight for this typical floor bay virtually the same as the existing system, weighing in at 54,400#. The amount of shear studs is less, but only by 8 studs.

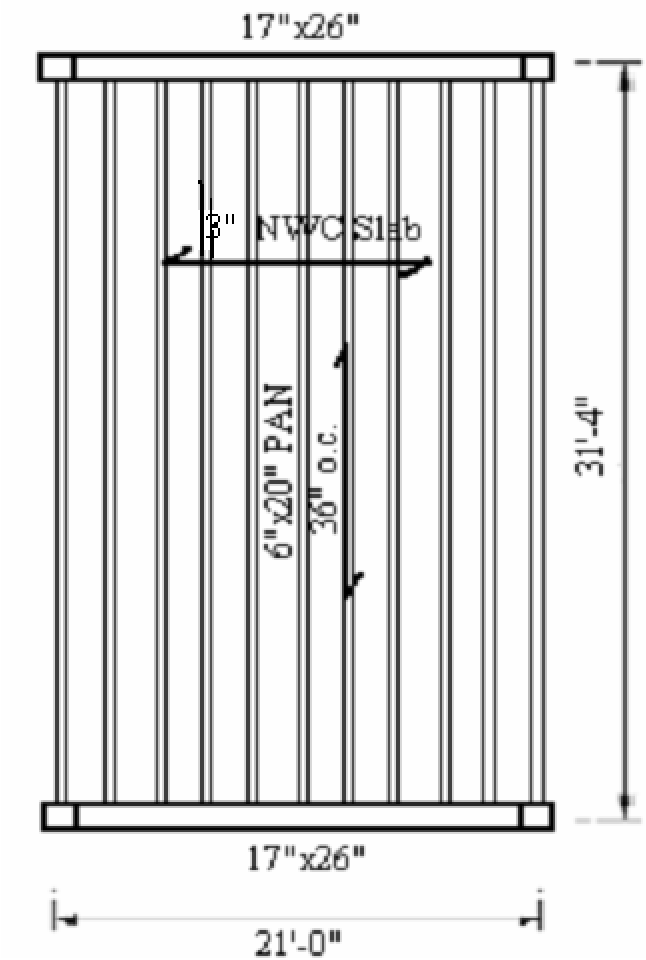
Disadvantages

Floor Depth: Although the beam depth has decreased by 6 inches, the girder depth has increased from a W18 to a W24 sized member. The new floor depth is 30.2", decreasing possible floor to ceiling height and crowding/restricting MEP space availability.

Labor: The increased number of beams means there are more connections to make. The labor costs associated with increased man hours may drive up costs.

Cost: *See comparison chart.*

Concrete Pan Joists



This system uses the same 21'x31'4" bay as the existing system. The joists are able to span the existing dimension and take up less floor space. The slab is now 23" thick as compared to the 30.2" modified bay and the 24.2" existing bay. The system is composed of 30" forms and 6"x20" ribs spaced at 36" c.c. The girders, however, are deeper that the slab, potentially causing room height problems.

Comparison of the existing framing to the alternative choices can be found in the appendices of this report.

Advantages

Floor Depth: The pan joists are 1.2" more shallow than the existing system. The girders are 3 inches deeper, but should not effect the placement of MEP equipment.

Constructability: Reusable, pre-fabricated formwork is not only an advantage in cost of construction but a savings in storage space on site.

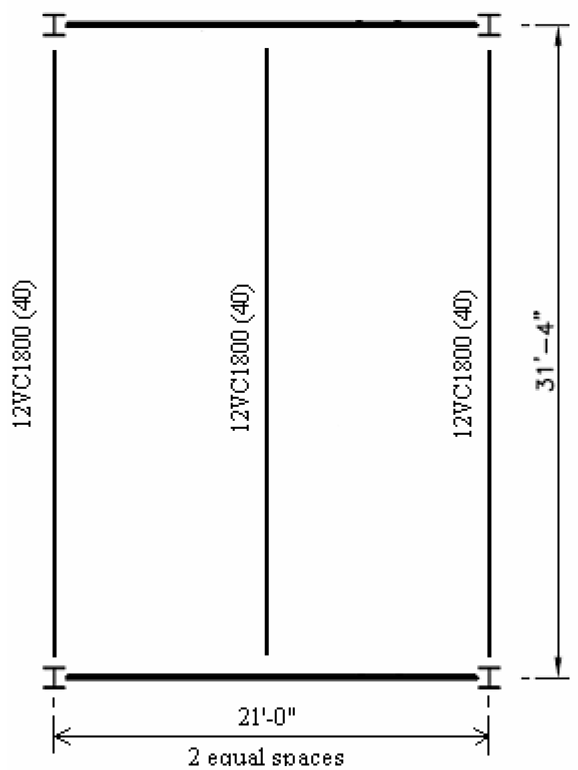
Disadvantages

Weight: The addition of a concrete floor system adds a significant amount of weight to the structure. This added weight will have a great impact on the size of the foundation system.

Lateral System: Because of the added weight, wind forces may no longer control the design of the lateral force resisting system. Consequently, the system may need to be more stringently designed, possibly as shear walls, or another concrete system.

Composite Steel Joists

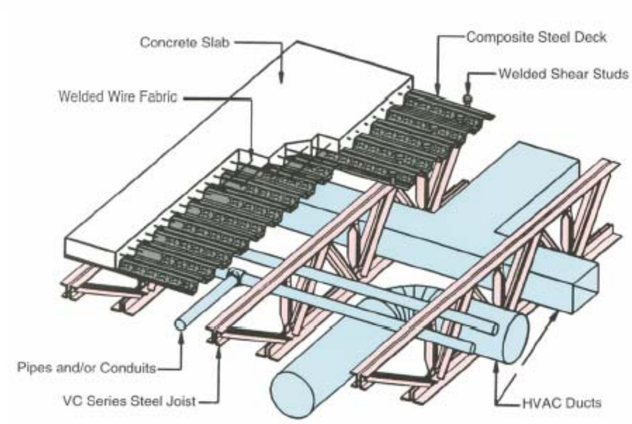
The composite steel joists are laid out at 10' intervals and have a reduced slab for the typical bay: 2.5" NWC slab on 2" composite deck. The open web joist span 31'4", sized at 12VC1800/850/300 joists with (40) ¾" shear studs.



Comparison of the existing framing to the alternative choices can be found in the appendices of this report.

Advantages

Weight: These composite joists weigh 37 pounds per foot, very comparable to the existing W-shape weights. The big savings comes in the reduction of the floor slab from 6.5" to 4.5". This reduction saves 19,000# typical bay.



Floor Depth: The depth of this system is 16.5". This reduction in depth, coupled with the open web spaces as possible paths for MEP make this system favorable.

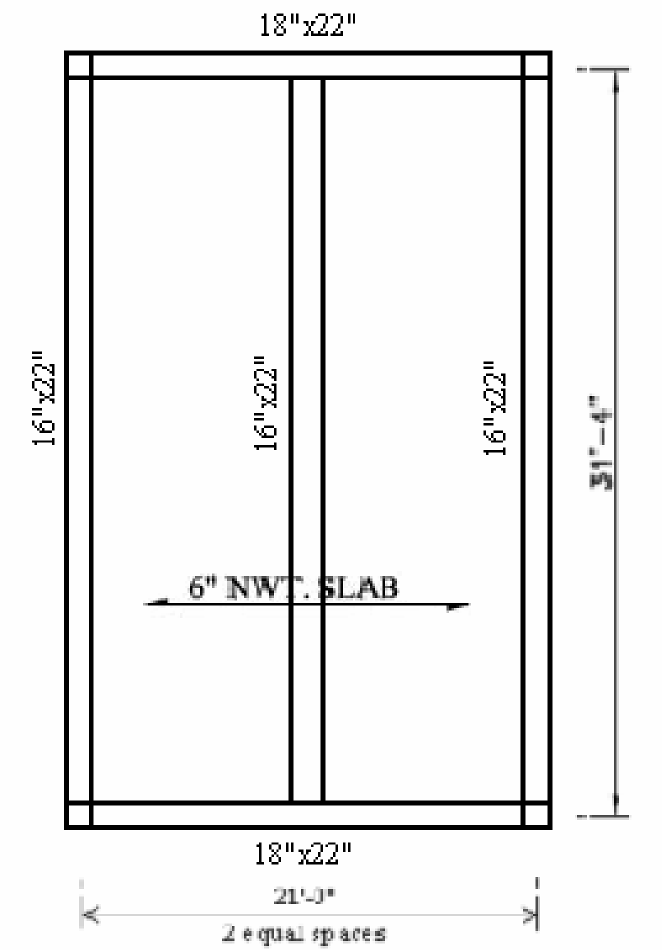
Long Span Capabilities: These joist have the ability to span up to 100' thus giving the designers this option for all spans throughout the building.

Disadvantages

Constructability: The steel joists are connected to their

One Way Concrete Slab

The one way floor slab is the second concrete floor alternative explored in this report. Although it is shallow, it is heavy like the pan joist system previously evaluated. The beams and girders are both 22” deep. The slab is consistent with the existing slab, 6”/6.5”.



Comparison of the existing framing to the alternative choices can be found in the appendices of this report.

Advantages

Floor Depth: The floor depth has been reduced to 22” from 24.2” in he existing system, and 23” in the pan joist system.

Disadvantages

See concrete pan joist system disadvantages.

Comparison

Floor Framing System	Advantages	Disadvantages	Cost ($/ft^2)	Further Investigation
Existing: Composite Steel	Light weight system 24.2" floor depth Constructability	Cost	$20.35	N/A
Modified Composite Steel	Light weight system Constructability	Cost 30.2" floor depth Increased labor	$20.35	No
Concrete Pan Joists	Reusable forms 23" floor depth	Heavy weight alternative Foundation impact Lateral system impact	$17.20	As a concrete alternative for typical bays
Composite Steel Joists	Lightest floor system 16.5" floor depth MEP routed through joists Long span capability	Shipping/availability Erection time/welding	$17.20	Yes
One Way Concrete Slab	22" floor depth	Heavy weight alternative Foundation impact Site storage of formwork	$18.75	No

Conclusion

After the preliminary design of the 4 alternative floor framing systems, only one appears to be well suited for further inspection. The composite open web steel joist system seems to be the most favorable system in terms of cost, weight, and floor depth. Also, the joist construction is able to handle long spans, making this system attractive for possible design of the gymnasium and ballroom areas. Of the other options, the composite steel construction seems to make the most sense in terms of weight, and constructability. It is the most expensive floor system per square foot, but makes up for itself in weight and overall capability.

Of the concrete systems, the pan joists are relatively shallow compared to all other systems, and are cheaper per square foot than the one way system. However, both concrete systems yield obvious weight issues, leading to lateral system impact as well.

Appendices

Modified Composite System

* Entire floor system was redesigned in RAM Steel. The following is a check of a beam in the new span and spacing.

ALTERNATIVE: MODIFIED COMPOSITE

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

$q_n = 26.1^K$
$l_n = 21'$
SPACING = 7'

DL = 69 SLAB DECK
3 MTL DECK
10 MEP/CLG
20 PARTITION
102 PSF

LL = 100 PSF

$W_u = 1.2(102) + 1.6(100)$
$= 282.4^{1K}$

$$M_u = \frac{282.4(7')(21')^2}{8(1000)} = 110^{1K}$$

ASSUME $a = 1''$
$Y2 = 6.5 - \frac{1}{2} = 6''$

TRIAL SECTIONS:

	ϕM_p	ϕM_{pc}	ΣQ_n	# STUDS	WEIGHT
W 10x12	47.3^{1K}	117^{1K}	114^K	10	350^K
W 10x15	60.0^{1K}	145^{1K}	140^K	12	435^K
W 12x14	65.3^{1K}	156^{1K}	141^K	12	414^K
W 12x16	75.4^{1K}	176^{1K}	156^K	12	456^K

TRY W12x14:

$$b_{eff} = \frac{21'(12'')}{4} = 63''$$

$$a = \frac{141^K}{0.85(4)(63')} = 0.658'' < 1''$$

$\phi M_n > M_u = 110^{1K}$

W12x14 (12) ∴ OK FOR LOADING

Concrete Pan Joists

ALTERNATIVE: CONCRETE PAN JOISTS

SUPERIMPOSED DL = 30 PSF
LIVE LOAD = 100 PSF

$W_u = 1.4(30) + 1.7(100)$
$= 212$ PSF

$l_n = 32'0"$ ∴ USE 20" DEEP RIB + 3" TOP SLAB
30" FORMS + 6" RIB @ 36" C.-C.

END SPAN

REINFORCING: TOP → #5 @ 9" o.c.
BOTTOM → (6) #7

$W_u = 229$ PSF > 212 PSF

INTERIOR SPAN

REINFORCING: TOP → #5 @ 10" o.c.
BOTTOM → (5) #6

$W_u = 249$ PSF > 212 PSF

* SEE CRSI TABLE *

GIRDER:

0.6 CF/SF (150 PCF) = 90 PSF

$W_u = 1.2(90+30) + 1.6(100)$
$= 304$ PSF

304 PSF $(31') = 9.4$ KLF

$M_u = \frac{9.4(21')^2}{8} = 518^{1K}$

ASSUME $\rho = 0.6\rho_{max} = 0.6(0.0206) = 0.0124$

$M_u = \phi M_n$
$518(12) = 0.9(0.0124)(60)bd^2\left(1 - 0.59\frac{\rho f_y}{4}\right)$
$bd^2 = 10428"$

b = 17"
d = 26"

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
20" Deep Rib + 3.0" Top Slab = 23.0" Total Depth													
TOP BARS	Size @	# 4 10	# 4 8	# 4 7	# 5 9	# 6 11	End Span Defl. Coeff. (3)	# 4 9	# 5 11	# 5 9.5	# 5 8	# 6 9	Int. Span Defl. Coeff. (3)
BOTTOM BARS	# #	# 5 # 5	# 5 # 6	# 6 # 6	# 6 # 7	# 7 # 7		# 4 # 5	# 5 # 5	# 5 # 6	# 6 # 6	# 6 # 7	
Steel (psf)		.85	1.04	1.23	1.44	1.69		.93	1.18	1.38	1.66	2.01	
CLEAR SPAN		END SPAN						INTERIOR SPAN					
30'-0"		117	167	218	278	334*	9.752	165	228	301	375	395*	6.001
		0	0	0	0	340		0	0	0	0	458*	
31'-0"		101	148	196	253	310	11.119	147	206	274	343	374*	6.842
		0	0	0	0	0		0	0	0	0	426	
32'-0"		87	131	176	229	283	12.625	130	185	249	314	355*	7.769
		0	0	0	0	0		0	0	0	0	391	
33'-0"		74	116	158	208	259	14.278	114	166	226	287	337*	8.787
		0	0	0	0	0		0	0	0	0	360	
34'-0"		63	102	141	188	236	16.089	100	149	206	263	320*	9.901
		0	0	0	0	0		0	0	0	0	332	
35'-0"		52	89	126	171	216	18.067	88	134	187	241	305*	11.118
		0	0	0	0	0		0	0	0	0	306	

CRSI Handbook, 2002

Composite Steel Joists

ALTERNATIVE: COMPOSITE STEEL JOISTS

[VULCRAFT COMOSITE/NON-COMP. FLOOR JOISTS]
* DESIGN EXAMPLE (PG 20) *

GIVEN: NORMAL WT. CONC.
$f'_c = 3000$ PSI
~~6.5" SLAB (4.5" CONC., 2" DECK)~~
SPACING = 7'

DESIGN LOADS:

NON-COMPOSITE DEAD LOAD:

CONCRETE →	69 PSF
JOIST (ESTIMATED) →	4.5 PSF
DECK →	3 PSF
BRIDGING →	0.1 PSF

TOTAL → 76.6 PSF (7') = **536 PLF**

CONSTRUCTION LIVE LOAD: 8 PSF

COMPOSITE DEAD LOAD:

FIXED PARTITIONS →	20 PSF
MEP →	5 PSF
CEILING/FLOOR →	5 PSF

TOTAL → 30 PSF (7') = **210 PLF**

COMPOSITE LIVE LOAD:

DESIGN LIVE LOAD → 100 PSF

REDUCTION: $L = L_o \left[0.25 + 15/\sqrt{2(31'4")(7')}\right]$
= 100 (0.966)
= 97 PSF (7') = **680 PLF**

TOTAL LOAD → 1426 PLF

FROM THE "WEIGHT TABLE + DESIGN GUIDE"

VC SERIES

NWC (145 PCF)

31'4" ≈ 32' SPAN

TOTAL LOAD = 1426 PLF

f'_c = 3000 psi

1500 PLF (10' SPACING)

TRY 10' SPACING

2.5" NWC ON 2" DECK → FROM TABLES. [VULCRAFT DECK / VULCRAFT JOIST]

f'_c = 3000 psi

CONC. = 45 PSF

JOIST = 4.5 PSF

DECK = 2.4 PSF

BRIDGING = 0.1 PSF

52 PSF (10') = 520 PLF

TOTAL LOAD = 1670 PLF

PARTITIONS = 20 PSF

MEP = 5 PSF

CLG/FLR = 5 PSF

30 PSF (10') = 300 PLF

DESIGN LIVE = 100 PSF

$$L = L_o\left(0.25 + \frac{15}{\sqrt{2(31.33)\,10'}}\right) = 84.9\,\text{PSF}(10) = 850\,\text{PLF}$$

TRIAL SIZE: JOIST DEPTH - 12"

$W_{tj} = 37$ PLF

$W_{360} = 1245$ PLF

$N\text{-}d_s = (40)\ \frac{3}{4}"\phi$

DEFLECTION:

$$I_{EST,\ NON\text{-}COMP} = 0.0488 (W_{tj}) d_j^2 = 0.0488(37)12^2 = 260\ in^4$$

$$\Delta_{EST.\ NC.DL} = \frac{1.15(5) W_{NCDL} (SPAN)^4\ 1728}{384 E_{STL} I_{ENC}}$$

$$= \frac{1.15(5)(520)(31')^4\ 1728}{384(29000\,000)(260)} = 1.64" = \left(L/230\right)$$

$$\Delta_{COMP.DL} = \frac{W_{CDL}}{W_{360}}\left[\frac{L}{360}\right] = \frac{300\ PLF}{1245\ PLF}\left[\frac{31'(12")}{360}\right] = 0.248" = \left(L/1515\right)$$

$$\Delta_{COMP.LL} = \frac{W_{CLL}}{W_{360}}\left[\frac{L}{360}\right] = \frac{850}{1245}\left[\frac{31(12)}{360}\right] = 0.705" = \left(L/530\right)$$

$$\Delta_{TL} = 1.64 + 0.25 + 0.7 = 2.60" = L/145$$

$$\text{JOIST CAMBER} = \Delta_{ENCDL} + 50\%\ \Delta_{CDL} + 20\%\ \Delta_{CLL}$$

$$= 2.3" \quad \therefore\ 2\tfrac{1}{4}"$$

SUMMARY:
- 12VC 1800/850/300
- (40) 3/4"φ STUDS
- JOIST WT = 37 PLF
- 2 ROWS BRIDGING
- 5" OF BEARING

Joist Span (ft)	Joist Depth (in)	Slab Design																			
		Normal Weight Concrete (145 pcf) f 'c = 3.0 ksi																			
		tc (in)	2.00	2.00	2.00	2.00	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	3.00	3.00	3.00	3.00
		hr (in)	1.0	1.0	1.0	1.0	1.5	1.5	1.5	1.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	3.0	3.0	3.0	3.0
		Js (ft)	3.5	4.0	4.0	4.5	5.0	6.0	6.5	7.0	8.0	8.5	9.0	10.0	10.0	10.0	10.0	11.0	12.0	12.0	12.0
		Total Uniformly Distributed Joist Load in Pounds Per Linear Foot																			
		TL	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1800	2000	2200	2400	2700	3000
32	12	Wtj (plf)	10	11	13	15	16	18	20	23	25	27	28	30	33	37	41	43	46	59	71
		W360 (plf)	271	348	389	452	580	657	724	766	890	957	1022	1021	1112	1245	1365	1712	1706	1916	2202
		N-ds	20-1/2	24-1/2	26-1/2	30-1/2	32-1/2	34-1/2	38-1/2	32-5/8	24-3/4	26-3/4	30-3/4	30-3/4	34-3/4	40-3/4	48-3/4	48-3/4	50-3/4	60-3/4	60-3/4
	14	Wtj (plf)	9	11	12	13	14	17	18	19	23	24	26	27	29	34	37	39	40	46	57
		W360 (plf)	304	374	442	506	635	753	836	916	982	1037	1107	1191	1273	1406	1560	1905	1910	2094	2384
		N-ds	20-1/2	22-1/2	26-1/2	28-1/2	28-1/2	32-1/2	34-1/2	38-1/2	20-3/4	20-3/4	24-3/4	26-3/4	28-3/4	34-3/4	40-3/4	42-3/4	44-3/4	50-3/4	60-3/4
	16	Wtj (plf)	9	10	11	13	13	15	17	19	21	23	24	26	26	29	34	36	39	46	47
		W360 (plf)	338	417	496	581	717	787	924	1029	1066	1166	1232	1334	1340	1550	1699	2053	2282	2526	2518
		N-ds	18-1/2	20-1/2	22-1/2	26-1/2	24-1/2	28-1/2	32-1/2	34-1/2	18-3/4	20-3/4	22-3/4	24-3/4	24-3/4	28-3/4	34-3/4	34-3/4	42-3/4	48-3/4	50-3/4
	18	Wtj (plf)	9	9	11	12	13	13	15	17	20	22	23	23	25	28	31	32	36	41	47
		W360 (plf)	364	438	531	611	779	854	928	1010	1124	1248	1366	1379	1452	1684	1792	2115	2340	2625	2908
		N-ds	18-1/2	20-1/2	22-1/2	24-1/2	24-1/2	26-1/2	28-1/2	30-1/2	18-3/4	18-3/4	20-3/4	20-3/4	22-3/4	26-3/4	30-3/4	32-3/4	36-3/4	42-3/4	50-3/4
	20	Wtj (plf)	8	9	10	12	12	13	14	15	20	21	22	22	23	26	28	30	34	38	43
		W360 (plf)	399	467	538	685	789	932	999	1084	1180	1282	1407	1417	1562	1796	1957	2251	2435	2701	3031
		N-ds	18-1/2	20-1/2	20-1/2	22-1/2	20-1/2	24-1/2	26-1/2	26-1/2	16-3/4	18-3/4	20-3/4	20-3/4	22-3/4	24-3/4	26-3/4	28-3/4	32-3/4	38-3/4	44-3/4
	22	Wtj (plf)	8	9	10	11	12	13	14	15	19	20	21	22	22	24	27	29	30	36	40
		W360 (plf)	395	489	570	718	880	966	1049	1138	1220	1327	1441	1579	1594	1775	2039	2304	2517	2963	3013
		N-ds	18-1/2	18-1/2	20-1/2	22-1/2	20-1/2	22-1/2	24-1/2	26-1/2	16-3/4	16-3/4	18-3/4	20-3/4	22-3/4	24-3/4	26-3/4	26-3/4	28-3/4	38-3/4	38-3/4
	24	Wtj (plf)	8	9	10	11	12	12	13	14	18	19	20	21	22	24	26	28	29	33	38
		W360 (plf)	426	513	643	693	875	1000	1079	1172	1236	1349	1466	1591	1747	1930	2091	2331	2554	2919	3241
		N-ds	18-1/2	18-1/2	20-1/2	20-1/2	20-1/2	20-1/2	24-1/2	26-1/2	16-3/4	14-3/4	16-3/4	18-3/4	20-3/4	22-3/4	24-3/4	24-3/4	26-3/4	32-3/4	38-3/4
	26	Wtj (plf)	8	9	10	11	12	12	13	14	18	18	19	20	21	23	24	27	29	32	35
		W360 (plf)	428	521	647	710	890	967	1102	1197	1240	1349	1475	1594	1736	1925	2135	2373	2731	2955	3147
		N-ds	18-1/2	18-1/2	20-1/2	20-1/2	18-1/2	20-1/2	20-1/2	24-1/2	12-3/4	16-3/4	16-3/4	16-3/4	18-3/4	22-3/4	24-3/4	24-3/4	26-3/4	28-3/4	32-3/4
	28	Wtj (plf)	8	9	9	10	12	12	13	14	18	18	19	20	21	22	24	27	29	32	34
		W360 (plf)	464	537	651	780	903	1048	1176	1280	1320	1439	1563	1599	1728	1902	2113	2533	2758	2940	3169
		N-ds	18-1/2	18-1/2	18-1/2	20-1/2	18-1/2	18-1/2	20-1/2	22-1/2	12-3/4	16-3/4	16-3/4	14-3/4	16-3/4	20-3/4	22-3/4	22-3/4	24-3/4	26-3/4	30-3/4

One Way Slab

ALTERNATIVE: ONE WAY SLAB

LOADING: SDL → 30 PSF
LL → 100 PSF

SPACING: 10.5'
$l_n = 32'$

$W_u = 1.4(30) + 1.7(100)$
$= 212$ PSF

SLAB: 6" → CRSI HANDBOOK (CH.7)

BEAMS: CRSI HANDBOOK (CH.12)

$W_{SLAB} = 6/12 (150_{PCF})(10') = 750_{PLF}$

(ASSUME 18" x 24" BEAM) $W_{BEAM} = \frac{18(24)(150)}{144} = 450_{PLF}$

$W_{SDL} = 30(10.5') = 315_{PLF}$
$W_{LL} = 100(10.5') = 1050_{PLF}$

$W_u = 1.4(750 + 450 + 315) + 1.7(1050)$
$= 3.8$ KLF

TRY

	BOTTOM	TOP	TRANSVERSE REINFORCEMENT
14 x 24	(2) #11	(3) #11	(16) #4 @ 10" o.c.
14 x 22	(3) #10	(4) #10	(18) #4 @ 9" o.c.
✓✓ 16 x 22	(2) #11	(3) #11	(17) #3 @ 9" o.c.

∴ USE 16" x 22" BEAM

GIRDERS $(l_n = 21')$

$$P_u = \frac{3.8\text{KLF}(31.33')}{2} = 60^K$$

$$\text{EST. WT.} = \frac{(18'' \times 28'')}{144}(150\text{PCF}) = 525\text{PLF}(1.4) = \underline{735\text{PLF}}$$

$$M_u = P_u a = 60^K(10.5') = 630^{1K}$$

$$M_u = \frac{w_u l^2}{8} \Rightarrow 630^{1K} = \frac{w_u (21')^2}{8}$$

$$\boxed{w_u = 10.9\text{ KLF}}$$

$$\text{EQUIV. LOADING} = 10.9^{KLF} + 0.73^{KLF} = \boxed{11.6\text{ KLF}}\ ✓$$

TRY

	BOTTOM	TOP	TRANS. REINF.
18 × 22	(3) #11	(3) #14	(14) #5 @ 6"
16 × 26	(2) #14	(5) #11	(14) #5; 1 @ 2", 5 @ 8", 8 @ 11"

∴ USE 18" × 22" GIRDER

SOLID ONE-WAY SLABS—END SPAN

f'_c = 3,000 psi — Grade 60 Bars — Recommended Minimum Reinforcement $\rho \geq 0.0018bh$

Thickness (in.)	4	4½	5	5½	6	6½	7	7½	8	8½	9	9½	10
Top Bars Spacing (in.)	#4 12	#4 12	#4 12	#4 12	#4 12	#4 12	#4 12	#4 12	#4 12	#4 12	#4 11	#4 10	#4 9
Bottom Bars Spacing (in.)	#3 12	#3 12	#3 12	#3 11	#3 10	#3 9	#3 8	#3 7	#4 12	#4 12	#4 12	#4 11	#4 11
Top Bars Free End Spacing (in.)	#4 12	#4 12	#4 12	#4 12	#4 12	#4 12	#4 12	#4 12	#4 12	#4 12	#4 12	#4 12	#4 12
T-S Bars Spacing (in.)	#3 15	#3 13	#3 12	#3 11	#4 18	#4 17	#4 15	#4 14	#4 13	#4 13	#4 12	#5 18	#5 17
Areas of Steel (in.^{2}/ft) Top Interior Bottom	.200 .110	.200 .110	.200 .110	.200 .120	.200 .132	.200 .141	.200 .165	.200 .189	.200 .200	.200 .200	.218 .200	.240 .218	.267 .218
Slab Wt. (psf)	50	56	63	69	75	81	88	94	100	106	113	119	125
CLEAR SPAN	FACTORED USABLE SUPERIMPOSED LOAD (psf)												
6′-0″	376	443	509	636	789	926							
6′-6″	310	366	421	527	657	772							
7′-0″	258	305	350	441	552	650	859						
7′-6″	215	255	294	372	467	552	733	926					
8′-0″	181	215	247	315	398	471	629	798	911	980			
8′-6″	152	181	209	268	340	404	543	691	791	851	910		
9′-0″	128	153	177	229	292	348	471	602	691	743	795	937	995
9′-6″	108	129	150	195	251	301	410	527	605	652	697	824	875
10′-0″	90	109	126	167	217	261	358	463	533	574	614	727	773
10′-6″	75	92	106	142	187	226	313	382	415	447	534	642	685
11′-0″	62	76	89	121	161	196	274	337	365	394	473	570	608
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	419	508	542

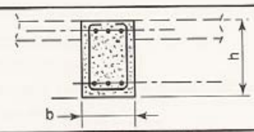
SOLID ONE-WAY SLABS—INTERIOR SPAN

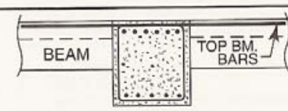
f'_c = 3,000 psi — Grade 60 Bars — Recommended Minimum Steel Top and Bottom

Thickness (in.)	4	4½	5	5½	6	6½	7	7½	8	8½	9	9½	10
Top Bars Spacing (in.)	#4 12	#4 12	#4 12	#4 12	#4 12	#4 12	#4 12	#4 12	#4 12	#4 12	#4 12	#4 11	#4 11
Bottom Bars Spacing (in.)	#3 12	#3 12	#3 12	#3 11	#3 10	#3 9	#3 8	#3 7	#4 12	#4 12	#4 12	#4 11	#4 11
T-S Bars Spacing (in.)	#3 15	#3 13	#3 12	#3 11	#4 18	#4 17	#4 15	#4 14	#4 13	#4 13	#4 12	#5 18	#5 17
Areas of Steel (in.^{2}/ft) Top Interior Bottom	.200 .110	.200 .110	.200 .110	.200 .120	.200 .132	.200 .147	.200 .165	.200 .189	.200 .200	.200 .200	.200 .200	.218 .218	.218 .218
Slab Wt. (psf)	50	56	63	69	75	81	88	94	100	106	113	119	125
CLEAR SPAN	FACTORED USABLE SUPERIMPOSED LOAD (psf)												
6′-0″	579	680	781	969									
6′-6″	483	568	652	811									
7′-0″	407	479	550	686	851								
7′-6″	345	407	468	585	727	903	990						
8′-0″	295	348	400	502	627	780	855	931					
8′-6″	253	299	344	434	543	678	743	810	876	942			
9′-0″	218	259	298	377	473	592	650	708	766	824	881	940	998
9′-6″	189	224	258	328	414	520	571	622	673	725	775	826	878
10′-0″	163	194	224	287	363	458	503	548	594	640	684	729	775
10′-6″	142	169	195	251	319	362	397	434	470	507	542	578	615

f'_c = 4,000 psi
f_y = 60,000 psi

RECTANGULAR BEAMS, INTERIOR SPANS





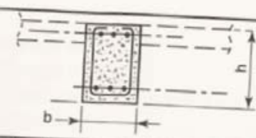
TOTAL CAPACITY $U = 1.4D + 1.7L$[3]

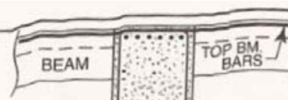
STEM h in.	STEM b in.	BARS[1] BOTTOM ℓ_n + 12 in.	BOTTOM 0.875 ℓ_n	Layers (2)	TOP	SPAN, ℓ_n = 28 ft LOAD (4) k/ft	STIR. TIES (5)	ϕT_n ft-kips	$A\ell$ sq. in.	STEEL WGT lb.	SPAN, ℓ_n = 30 ft LOAD (4) k/ft	STIR. TIES (5)	ϕT_n ft-kips	$A\ell$ sq. in.	STEEL WGT lb.	SPAN, ℓ_n = 32 ft LOAD (4) k/ft	STIR. TIES (5)	ϕT_n ft-kips	$A\ell$ sq. in.	STEEL WGT lb.	SPAN, ℓ_n = 34 ft LOAD (4) k/ft	STIR. TIES (5)	ϕT_n ft-kips	$A\ell$ sq. in.	STEEL WGT lb.	$+\phi M_n$ $-\phi M_n$ (6) ft-kip	DEFL (C) (7) ×10⁻⁹ in.
22	12	2#7		1	2#9	2.1	123G	5	-	290	1.8	123G	5	-	307	1.6	123G	5	-	324	1.4	123G	5	-	342	100	516
				1			244E	21	0.9	488		263E	21	0.9	393		273E	20	0.9	415		283E	20	0.9	438	161	
		2#8		1	2#10	2.7	143G	5	-	367	2.3	143G	5	-	389	2.0	143G	5	-	412	1.8	153G	5	-	437	130	551
				1			244E	21	0.9	558		264E	21	0.9	600		274E	20	0.9	632		284E	20	0.9	665	199	
		2#10		1	2#14	4.1	164G	5	-	651	3.6	173G	5	-	636	3.1	173G	5	-	673	2.8	183G	5	-	715	199	440
				1			244E	21	0.9	777		264E	21	0.9	835		274E	20	0.9	883		284E	20	0.9	931	320	
		2#11		1	2#14	4.5	164G	5	-	709	3.9	174G	5	-	758	3.4	184G	5	-	807	3.1	193G	5	-	789	238	418
				1			424B	21	0.9	1018		444B	21	0.9	1079		274E	20	0.9	950		284E	20	0.9	1001	320	
	14	2#8		1	3#8	2.7	133G	7	-	354	2.3	133G	7	-	375	2.1	133G	7	-	397	1.8	133G	7	-	418	131	476
				1			244E	27	1.0	558		264E	26	1.0	600		274E	26	1.0	632		293E	26	1.0	521	192	
		2#9		1	3#9	3.3	143G	7	-	441	2.9	153G	7	-	472	2.5	153G	7	-	499	2.3	153G	7	-	527	163	473
				1			244E	27	1.0	641		264E	26	1.0	689		274E	26	1.0	727		294E	26	1.0	775	236	
		2#11		1	3#11	4.8	164G	7	-	725	4.2	174G	7	-	775	3.7	174G	7	-	817	3.3	183G	7	-	802	243	386
				1			245E	27	1.0	1023		265E	26	1.0	1100		274E	26	1.0	976		294E	26	1.0	1039	344	
		2#10	1#10	1	4#10	5.2	164G	7	-	780	4.5	174G	7	-	835	4.0	184G	7	-	889	3.5	184G	7	-	935	290	351
				1			245E	27	1.0	1078		265E	26	1.0	1160		275E	26	1.0	1224		295E	26	1.0	1305	369	
	16	2#8		1	3#8	2.7	123G	8	-	352	2.4	123G	8	-	373	2.1	123G	8	-	394	1.8	123G	8	-	416	132	391
				1			214F	33	1.2	536		234F	33	1.1	579		244F	33	1.1	611		254F	32	1.1	644	194	
		2#10		1	3#10	4.2	153G	8	-	550	3.6	153G	8	-	584	3.2	163G	8	-	623	2.8	163G	8	-	657	205	402
				1			215F	33	1.1	870		234F	33	1.1	778		244F	32	1.1	824		254F	32	1.1	869	295	
		2#11		1	3#11	4.9	154G	8	-	721	4.3	164G	8	-	771	3.8	173G	8	-	758	3.3	173G	8	-	800	246	365
				1			215F	33	1.1	985		235F	33	1.1	1064		245F	32	1.1	1125		255F	32	1.1	1185	351	
		2#14		1	3#14	6.6	175G	8	-	1082	5.7	175G	8	-	1143	5.0	184G	8	-	1133	4.5	194G	8	-	1202	337	297
				1			345C	33	1.1	1487		365C	33	1.1	1584		245F	32	1.1	1428		255F	32	1.1	1508	468	

CONCRETE REINFORCING STEEL INSTITUTE

f'_c = 4,000 psi
f_y = 60,000 psi

RECTANGULAR BEAMS, INTERIOR SPANS





TOTAL CAPACITY $U = 1.4D + 1.7L$[3]

STEM h in.	STEM b in.	BARS[1] BOTTOM ℓ_n + 12 in.	BOTTOM 0.875 ℓ_n	Layers (2)	TOP	SPAN, ℓ_n = 20 ft LOAD (4) k/ft	STIR. TIES (5)	ϕT_n ft-kips	$A\ell$ sq. in.	STEEL WGT lb.	SPAN, ℓ_n = 22 ft LOAD (4) k/ft	STIR. TIES (5)	ϕT_n ft-kips	$A\ell$ sq. in.	STEEL WGT lb.	SPAN, ℓ_n = 24 ft LOAD (4) k/ft	STIR. TIES (5)	ϕT_n ft-kips	$A\ell$ sq. in.	STEEL WGT lb.	SPAN, ℓ_n = 26 ft LOAD (4) k/ft	STIR. TIES (5)	ϕT_n ft-kips	$A\ell$ sq. in.	STEEL WGT lb.	$+\phi M_n$ $-\phi M_n$ (6) ft-kip	DEFL (C) (7) ×10⁻⁹ in.
																				748							
22				1			305B	28	1.1	996		195E	28	1.0	852		215E	27	1.0	933	6.0	225E	27	1.0	997	369	
	16	2#8		1	3#8	5.3	103G	9	-	258	4.4	113G	9	-	284	3.7	113G	8	-	305	3.1	113G	8	-	326	132	
				1			154F	35	1.2	384		174F	34	1.2	427		184F	34	1.2	460		204F	33	1.2	503	194	
		2#10		1	3#10	8.1	124G	9	-	445	6.7	134G	9	-	487	5.7	134G	8	-	522	4.8	143G	8	-	511	205	
				1			155F	35	1.2	624		175F	34	1.2	695		185F	34	1.2	747		205F	33	1.2	818	295	
		2#11		1	3#11	9.7	125G	9	-	584	8.0	134G	9	-	578	6.7	144G	8	-	628	5.7	154G	8	-	678	246	
				1			245C	35	1.2	870		265C	34	1.2	948		185F	34	1.2	846		205F	33	1.2	925	351	
		2#10	1#10	1	3#14	11.8	135G	9	-	712	9.8	145G	9	-	778	8.2	155G	8	-	845	7.0	155G	8	-	899	295	
				1			245C	35	1.2	985		265C	34	1.2	1076		295C	34	1.2	1184		315C	33	1.1	1275	468	
	18	2#7	1#7	1	3#9	6.1	103G	10	-	293	5.0	113G	10	-	322	4.2	113G	10	-	347	3.6	123G	10	-	376	151	
				1			155F	42	1.3	534		174F	41	1.3	472		214E	41	1.3	543		224E	40	1.3	579	242	
		2#8	1#8	1	3#10	7.8	114G	10	-	411	6.5	123G	10	-	405	5.4	133G	10	-	441	4.6	133G	10	-	473	195	
				1			155F	42	1.3	606		175F	41	1.3	675		185F	41	1.3	726		205F	40	1.3	795	299	
		2#10	1#10	1	3#14	12.0	135G	10	-	716	9.9	135G	10	-	771	8.3	145G	10	-	837	7.1	154G	10	-	833	299	
				1			245C	42	1.3	1002		265C	41	1.3	1094		295C	41	1.3	1204		315C	40	1.3	1296	481	
		2#11	1#11	1	3#14	13.2	145DdG	10	-	786	10.9	145G	10	-	846	9.2	155G	10	-	919	7.8	155G	10	-	979	358	
				1			245C	42	1.3	1059		265C	41	1.3	1157		295C	41	1.3	1273		315C	40	1.3	1370	481	

(1) See "... ...ls" fig. 12-1. For girders. | (5) For each beam design, first line is for ...

G STEEL INSTITUTE