T.C. WILLIAMS HIGH SCHOOL

ALEXANDRIA, VA

CHRISTOPHER B. DEKER

STRUCTURAL OPTION

TECHNICAL REPORT #2

29 OCTOBER 2007

FACULTY CONSULTANT: PROF PARFITT

Table Of Contents

EXECUTIVE SUMMARY

The purpose of technical report 2 is to analyze possible alternative structural systems in the T.C. Williams High School. Originally, the school was built using a steel composite system. There are 4 alternative systems being analyzed in this report are non-composite steel beams, k-series steel joists, waffle slab, and a two way flat slab with drop panels.

All of the systems where analyzed under the same basic criteria. This criterion includes 70 PSF live loads for rooms, 80 PSF live loads for corridors, and 14 PSF superimposed dead loads. Deflection was assumed to be governed by beams and slabs themselves as opposed to masonry walls they support. This was done because the masonry walls are located in some bays but not others, and they are placed at differently locations in each bay. Therefore they will be ignored for this preliminary analysis and be accounted for in future reports. The steel members are set to a live load deflection of l / 360, and a total load deflection of l / 240, while the concrete was set to a total load deflection of l / 420.

All the structural systems where designed with LRFD. Steel beams were chosen on the basis of w = 1.2D + 1.6L, while the masonry was designed from tables which used w = 1.4D + 1.7L. K-series steel joists were taken out of a table which already accounted for factors of safety, so no factoring of loads was necessary.

In conclusion, it was determined that non-composite steel beams and the two-way flat slab can be ruled out as possible designs. They are both inferior to other alternatives, as they offer no advantages over the steel composite system and the waffle slab system respectively. Even though fireproofing is an issue, the k-series steel joists are a definite possibility given their extremely cheap cost compared to the other systems. However, the main issue with the steel joists would be vibration, and with a 3” slab this is expected to be a major issue. The original composite system seems to still be one of the best systems available. It easily accounts for fireproofing, long spans, heavy loads, and vibration, all while being a relatively light system. Waffle slabs on the other hand are a heavier system, which after a quick estimate seem to be a costly solution.

STRUCTURAL SYSTEM OVERVIEW

ROOF SYSTEM

Typical flat roof systems on T.C. Williams High School consists primarily of a Thermoplastic Polyolefin (TPO) Membrane system with rigid insulation on 1½” 22 gauge steel roof deck, supported by K-Series Steel Joists which are typically spaced 5’ O.C. Typical sloped roofing systems are similar to the flat roofing systems except instead of the TPO Membrane system there is a standing seam metal roof.

Typical roofing systems over larger span areas such as the gymnasium and the auditorium consist of 3” 20 gauge steel roof deck, supported by DLH Steel Joists typically spaced 12’ O.C.

FLOOR SYSTEM

Typical floor systems consist of a steel composite deck and beam system with a 3” concrete slab on 1½” 18 gauge steel composite deck, supported by Steel Beams typically spaced 8’ O.C. The concrete slab is made of Normal Weight Concrete (145 PCF) and has a minimum 28 day compressive strength (F’c) of 4000 PSI. Most typical Steel Beams are W18x35 spanning a maximum of 34’ with steel studs spaced at 12” O.C. The range of steel beams varies greatly depending on specific room requirements; generally ranging anywhere from a W16x26 to a W21x44. Steel studs creating the composite action are ¾” in diameter and 3½” long.

FOUNDATION

All main building foundations are constructed on subgrade soils improved by the installation of a ‘Geopier Rammed Aggregate Pier Soil Reinforcement’ system and are designed to bear on strata capable of sustaining a minimum bearing pressure of 6,000 PSF. The slab on grade consists of Normal Weight Concrete (145 PCF) and has a minimum 28 day compressive strength (F’c) of 3,500 PSI. Typical slabs are 4” thick and are reinforced with 6x6-W1.4xW1.4 WWF at mid depth. All spread and strip footings consist of Normal Weight Concrete (145 PCF) and have a minimum 28 day compressive strength (F’c) of 3,000 PSI.

Lateral System

T.C. Williams is separated into 6 different “buildings” through the use of ‘Fire Walls’. Both classroom towers are laterally supported with ordinary steel concentrically braced frames in both the N-S and E-W directions. The 3 story area connecting the 2 three story classroom towers is laterally supported with ordinary steel moment frames in both the N-S and E-W directions. Gymnasium and auditorium areas are supported by intermediate reinforced masonry shear walls, in all directions. The rest of the building, which includes the area between the gymnasium and auditorium sections, is laterally supported by ordinary reinforced masonry shear walls, in all directions.

Columns

Steel columns are the primary gravity load resisting members of the building. They consist of Grade 50 ASTM A992 wide flange shapes, grade 46 ASTM A500 rectangular HSS shapes, and grade 42 ASTM A500 round HSS shapes. The wide flange shapes generally range from a W10x49 to a W10x68, and are the primary support for most of the building. The Round HSS shapes found connecting the two classroom wings and under the green roof, and generally range from HSS12.750x.375 to HSS16x.500.

Codes

Original Design Codes:

Virginia State Building Code (VUSBC), 2000 Edition

International Building Code (IBC), 2000 Edition

American Society of Civil Engineers (ASCE-7), 1999 Edition

Building Code Requirements for Structural Concrete (ACI 318-95)

Standard Specifications for Structural Concrete (ACI 301-96)

AISC Code of Standard Practice for Steel Buildings, 2000 Edition

AISC Specification for Structural Steel Buildings, Allowable Stress Design and Plastic Design, 1989 Edition

Thesis Design Codes:

International Building Code (IBC), 2006 Edition

American Society of Civil Engineers (ASCE-7), 2005 Edition

AISC Steel Construction Manual, LRFD, 13th Edition

Thesis Deflection Criteria:

Total = L / 240

Live = L / 360

Construction = L / 360

Structural Member Supporting Masonry Walls = L / 600

LOADS

SUPERIMPOSED ROOF DEAD LOAD	THESIS DESIGN
TPO Membrane / S.S. metal Roof	3 psf
4"-6" Rigid Insulation	2.5 psf
Ceiling Finishes	5 psf
Mechanical / Electrical	6.5 psf
Sprinklers	2.5 psf
TOTAL	19.5 psf

SUPERIMPOSED FLOOR DEAD LOAD	THESIS DESIGN
Ceiling Finishes	5 psf
Mechanical / Electrical	6.5 psf
Sprinklers	2.5 psf
TOTAL	14 psf

TYPICAL ROOF LIVE LOAD	THESIS DESIGN	CODE REFERENCE
Minimum Roof LL	20 psf	ASCE 7-05 Section 4.9.1
Ground Snow Load (Pg)	25 psf	IBC Figure 1608.2
Importance Category III	Is = 1.10	IBC Section 1604.5
Exposure Factor	Ce = 1.0	IBC Table 1608.3.1
Thermal Factor	Ct = 1.0	IBC Table 1608.3.2
Flat Roof Snow Load	19.25 psf + Drift	IBC Section 1608.3
Drift	Varies	ASCE 7-05 Section 7.7

FLOOR LIVE LOADS	THESIS DESIGN	ORIGINAL DESIGN	ASCE 7-05 MIN VALUE
Classroom	50 psf	50 psf	40 psf
First Floor Corridor	100 psf	100 psf	100 psf
Above First Floor Corridor	80 psf	80 psf	80 psf
Offices	50 psf	50 psf	50 psf
Light' Storage	125 psf	125 psf	125 psf
Mechanical	150 psf	150 psf	n/a
Green Roof	100 psf	100 psf	n/a
Library Stacks	150 psf	150 psf	150 psf

System Analysis Overview

Analyzed Structural Systems

- Steel Composite System (Original)
- Steel Non-Composite System
- K-Series Steel Joist System
- Waffle Slab System
- Two Way Flat Slab System

All Structural Systems are going to be designed using the basic criteria:

- Live Load
    - Classrooms and Offices = 50 PSF + 20 PSF Partition Allowance
    - Corridors = 80 PSF
- Dead Load
    - Superimposed = 14 PSF
    - Self Weight = Varies
- Deflection
    - Steel
        - Total = L / 240
        - Live = L / 360
    - Concrete
        - Total = L / 420
- Fire Rating = 2 Hours
- Analyzing a strip of bays through the building to gain a more accurate price between the different systems.

Steel Composite System

This system is the original system chosen for the building. In order to simplify the procedure of comparing the different structural systems, it is necessary to redesign the original system with the basic design criteria explained above. In addition to redesigning with these new criteria I have chosen to maintain equal spacing between beams.

Advantages:

- Good with Vibration
- Quick and Easy Construction
- Cost Effective
- Allows for Long Spans
- Lighter Weight Shapes

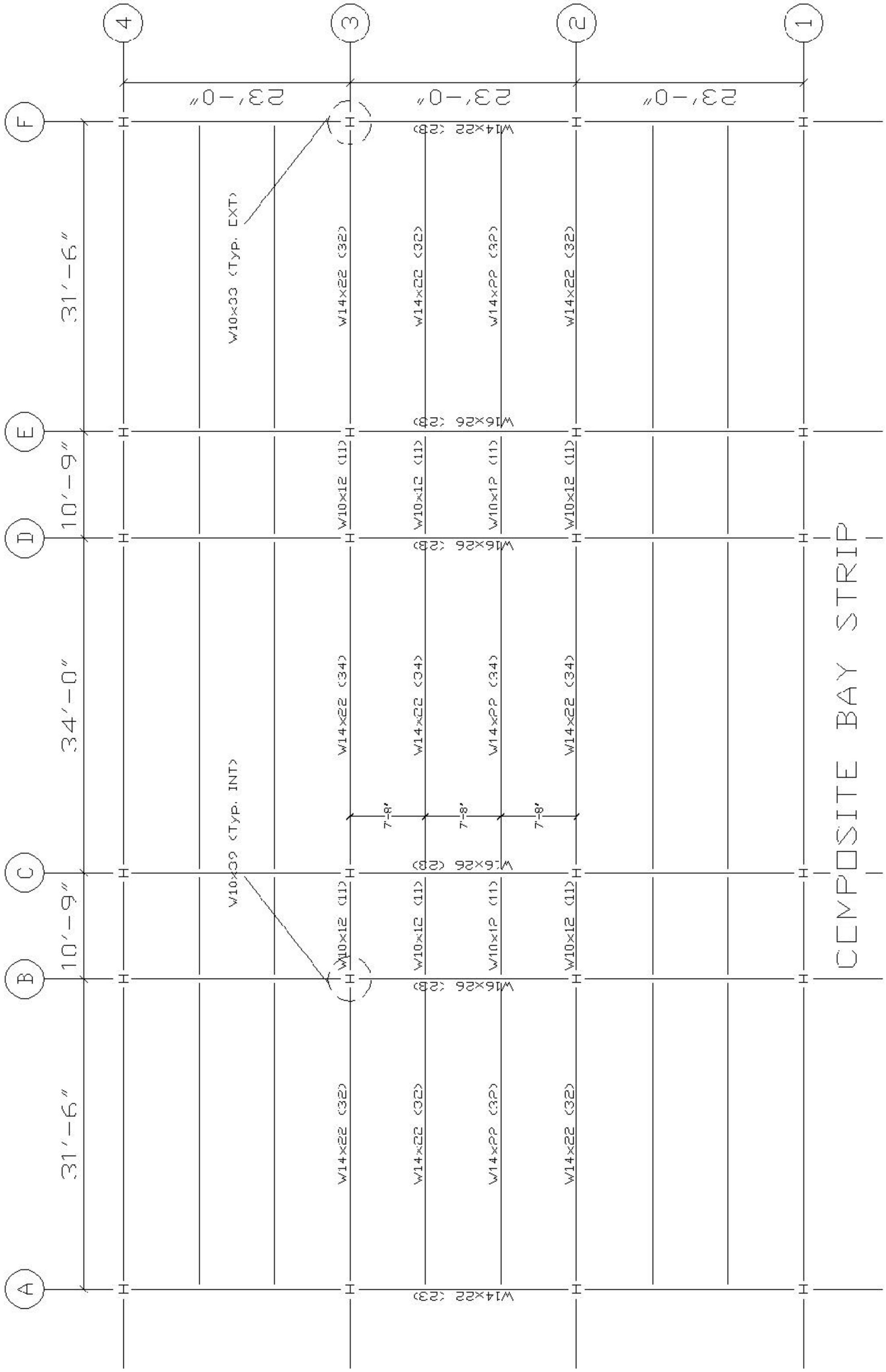
Disadvantages:

- Requires Shear Studs

Using RAM Structural Systems, the system was redesigned. Equal beam spacing of 7 feet 8 inches where used. The 1½" 18 gauge composite decking and the 3" NWC thickness above the decking remained the same. Shear studs where 3½" x ¾", also the same as before. One notable change made was the assumption of a required deflection of L / 360 live load deflections instead of L / 600 used with masonry walls. This assumption was made due to limited knowledge of deflections with the waffle and two way slabs.

Summary:

The composite steel system is defiantly still worth considering, due to its light weight and moderately cheap cost. The total cost of the system came out to $21.32 / SF, while the total system depth was 18.5". The constructability if relatively easy but the hardest part would be installing all the shear studs required. Spray on fireproofing will be used, and a 2 hour fire rating will be obtained. Another main advantage of the composite design is its ability to resist vibration. Changing of beam spacing should be a consideration used in a possible future redesign.


COMPOSITE BAY STRIP
A
B
C
D
E
F
1
2
3
4
23'-0"
23'-0"
23'-0"
31'-6"
10'-9"
34'-0"
10'-9"
31'-6"
W10x33 (Typ. EXT)
W10x39 (Typ. INT)
W14x22 (23)
W16x26 (23)
W16x26 (23)
W16x26 (23)
W16x26 (23)
W14x22 (23)
W14x22 (32)
W10x12 (11)
W14x22 (34)
7'-8"
7'-8"
7'-8"

Steel Non-Composite System

Non Composite is very similar to the composite system except composite action is not permitted. There will be savings on not having shear studs, but the beams will be required to be spaced closer together, and also end up being deeper.

Advantages:

- Good with Vibration
- Quick and Easy Construction
- Cost effective
- Allows for Long Spans
- Savings on no shear studs

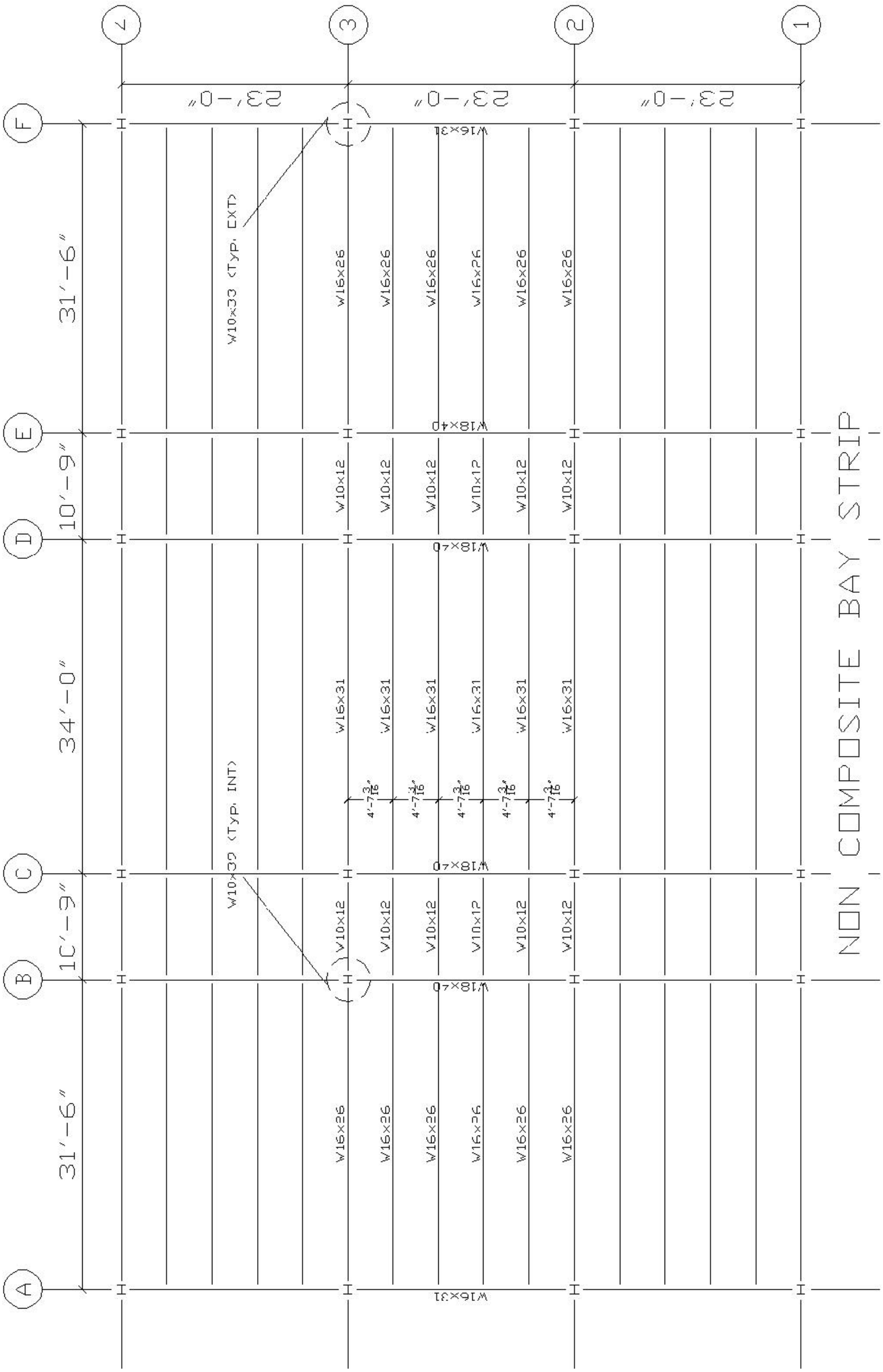
Disadvantages:

- Heavier Steel Shapes
- Deeper Steel Shapes

Using RAM Structural System a typical bay strip was designed. An equal beam spacing of 4.6 feet was used. A 24 gauge 1" form deck, with 3" NWC above the deck was used, for a total slab thickness of 4".

Summary:

A non composite system is still a viable solution, and there isn't anything wrong with it, but it doesn't excel in anything. The total cost of the system is $21.80 / SF. Compared to the composite system savings are made through the elimination of shear studs, but the overall system is much heavier than the composite, while deeper beams are also needed. The overall system depth equates to 20". Much like the composite system the non-composite system gains a two hour fire rating through spray on fireproofing. It also has a good resistance to vibration. However, overall this system is far inferior to the composite and shouldn't be a viable solution.


NON COMPOSITE BAY STRIP
A
B
C
D
E
F
1
2
3
4
31'-6"
10'-9"
34'-0"
10'-9"
31'-6"
23'-0"
23'-0"
23'-0"
W10x33 (Typ. EXT)
W10x33 (Typ. INT)
W16x31
W18x40
W18x40
W18x40
W18x40
W16x31
W16x26
W10x12
W16x31
4'-7 3/16"
W10x12
W16x26

K-Series Steel Joist System

Steel Joist systems tend to be very cheap and light weight, and should always be in consideration when cost is an issue. The maximum spacing of floor joists is 2.5 feet, and fireproofing along with vibration issues will be a challenge.

Advantages:

- Quick and Easy Construction
- Extremely Cost Effective
- May Allow for Long Spans
- Very Light System

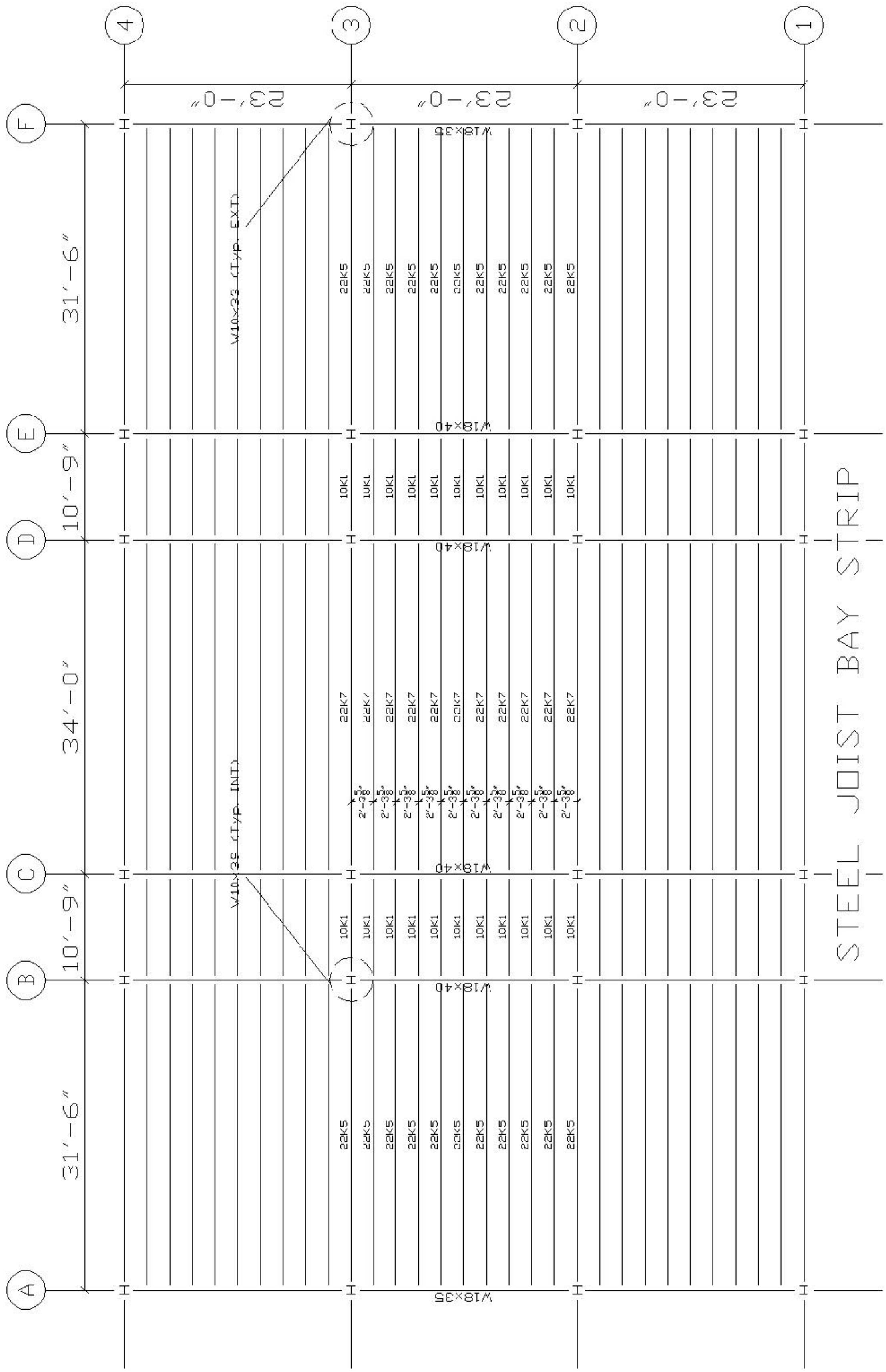
Disadvantages:

- Very Deep System
- Poor with Vibration
- Issues with Fireproofing

Using RAM Structural System along with the original column grid a typical bay strip was designed. Max spacing was set to 2.5‘, which allowed a uniform spacing of 2.3’. A $^{9}/_{16}$” form deck with a 3” slab was used.

Summary:

Steel joists are an excellent way to cut costs a great amount. The total system cost equates to $16.96 / SF, and the total depth of the system is about 25.6”. The depth may be an issue, and slightly more expensive joists may be used to reduce depth. The major problem to consider is the effect of vibration on the school. However, in this case the vibration allowed by the joists can be controlled. Most all of the heavy traversing in a school is caused in the corridors. In this case all the corridors are their own separate bays, and shouldn’t affect the classrooms. As for the classrooms themselves, it may be assumed that students will not be running around the classroom, instead they will be sitting in their chairs and vibration won’t be an issue at all. More on vibration analysis calculations will come in future reports. Fireproofing is also a major issue in joist design as they will require a chicken wire be wrapped around them before being sprayed with fireproofing. Even with the increase of cost to achieve a two hour fire rating, it is still the cheapest system available.


STEEL JOIST BAY STRIP
1
2
3
4
A
B
C
D
E
F
23'-0"
31'-6"
10'-9"
34'-0"
W18x35
W18x40
W10x33 (Typ. EXT)
W10x35 (Typ. INT)
22K5
10K1
22K7

WAFFLE SLAB SYSTEM

Waffle slab systems are ideal for spanning long distances, and supporting heavy loads. They also excel in fire protection, vibration, and durability. Square bays are optimal when using a waffle slab, so the current column grid would need to be changed.

Advantages:

- Efficient Over Long Spans
- Great Vibration Resistance
- No Extra Fireproofing Needed
- Easily Support Heavy Loads
- Very Durable

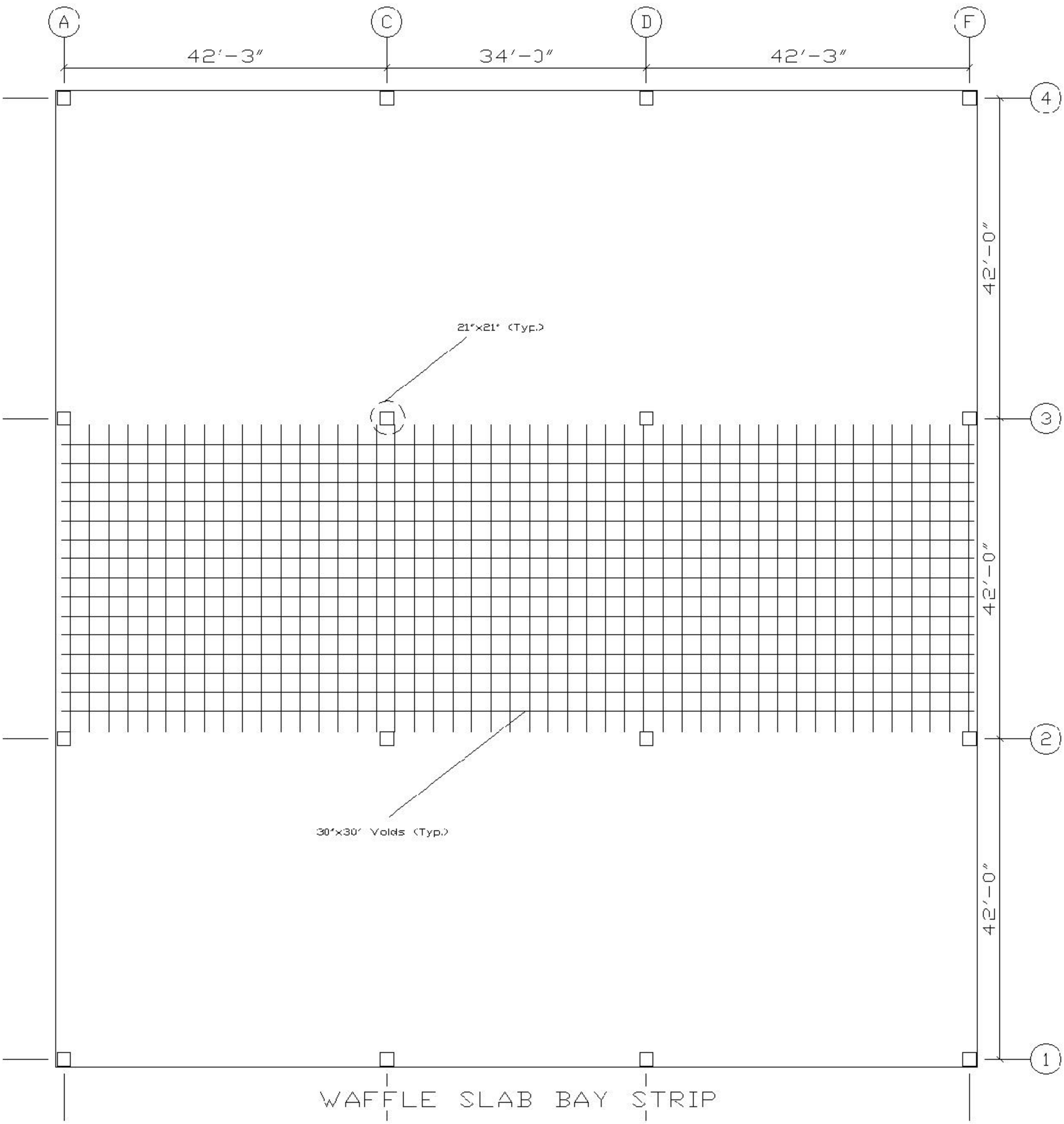
Disadvantages:

- Very Heavy System
- Very Complicated Construction
- Not Cost Efficient
- Very Large Columns

Using the CRSI handbook, along with a new column grid, a typical bay strip was designed. Spans were made as square as possible, ranging from 42'x42' to 34'x42'. This was the best option available to keep the columns from landing in the center of the classroom or corridor. The slab itself is 3" deep.

Summary:

Waffle slab systems are an excellent choice for large spans, and are a very viable option. However the total cost of the system came out to $32.46 / SF, and the depth equated to 23". The major problem with waffle slabs is the difficulty of construction. Complicated forms must be used, which takes a lot of time and money. One of the major advantages is that to achieve a two hour fire rating, no extra fireproofing is required. Also there will be absolutely no problem with vibration, as this is one of the best systems to resist it.



A
C
D
F
42'-3"
34'-0"
42'-3"
4
3
2
1
42'-0"
42'-0"
42'-0"
21"x21" (Typ.)
30"x30" Voids (Typ.)
WAFFLE SLAB BAY STRIP

TWO WAY FLAT PLATE SYSTEM

Two Way Flat Plate Systems are usually economically ideal for spanning smaller spans. They are also very durable, have excellent vibration control, and do not require any additional fireproofing. Square bays are ideal when designing for the two way flat plate system so the column grid will need to be altered.

Advantages:

- Very Efficient Over Short Spans
- Great Vibration Resistance
- No Extra Fireproofing Needed
- Easy Construction
- Very Durable

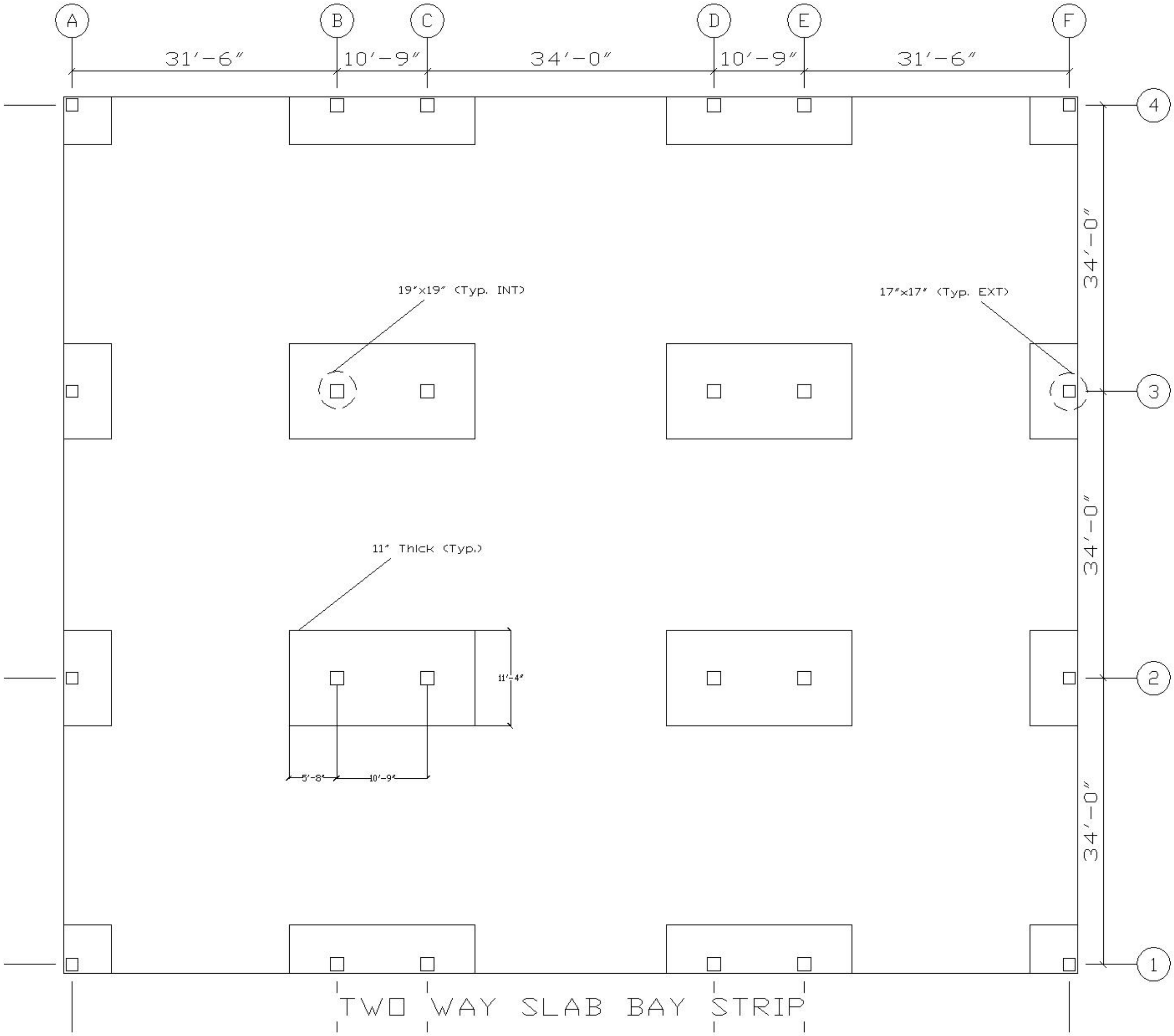
Disadvantages:

- Very Heavy System
- Not Cost Efficient
- Large Columns

Using the CRSI handbook, along with a new column grid, a typical bay strip was designed. The new bay spans ranged from 32'-32' to 11'-32' to 32'-34'. This was the only possible solution for bay sizes. The slab itself is 12" thick.

Summary:

The two way flat plate system is not the best choice for longer spans. The total cost of the system equated to $32.50 / SF, while the total depth of the system was found to be 23" when accounting for drop panels. One advantage of this system is that additional fireproofing is not needed to gain a two hour fire rating. Vibration will also not be a factor at all. However, due to the heavy weight, high cost, and inefficiency with long spans, the two way flat plate system is outperformed by the waffle slab system. The two way flat plate system is not a viable solution.


A
B
C
D
E
F
31'-6"
10'-9"
34'-0"
10'-9"
31'-6"
4
3
2
1
34'-0"
34'-0"
34'-0"
19"x19" (Typ. INT)
17"x17" (Typ. EXT)
11" Thick (Typ.)
11'-4"
5'-8"
10'-9"
TWO WAY SLAB BAY STRIP

COMPARISON SPREADSHEET

CRITERIA	COMPOSITE	NON-COMPOSITE	JOISTS	WAFFLE SLAB	TWO WAY FLAT PLATE
COST / SF	$21.12	$21.64	$15.59	$32.45	$32.11
SLAB DEPTH	3"	3"	3"	3"	12"
SYSTEM DEPTH	18.5"*	20"	25.6"	23"	23"
CONSTRUCTABILITY	MEDIUM	EASY	EASY	HARD	EASY
FIREPROOFING	SPRAY ON	SPRAY ON	SPRAY ON / SPECIAL DETAIL	NO EXTRA REQD	NO EXTRA REQD
VIBRATION RESISTANCE	GOOD	GOOD	POOR	GREAT	GREAT
DEFLECTION ISSUES	NONE	NONE	NONE	NONE	NONE
WEIGHT OF SYSTEM	MEDIUM	MEDIUM / HEAVY	LIGHT	HEAVY	VERY HEAVY
DURABILITY ISSUES	STEEL FATIGUE	STEEL FATIGUE	STEEL FATIGUE	CONCRETE SPALLING	CONCRETE SPALLING
COLUMN GRID CHANGES	NONE	NONE	NONE	YES	YES
LATERAL SYSTEM EFFECTS	NONE	NONE	NONE	YES	YES
VIABLE SOLUTION	**YES**	NO	**YES**	**YES**	NO

*The original system was designed for a depth of 22.5”

APPENDENCES

- Calculations of Cost / SF ***(RS MEANS 2008 Building Cost Data)***
  - Composite
  - Non-Composite
  - Joists
  - Waffle
  - Flat Plate
- Beam Summaries
  - Composite
  - Non-Composite
  - Joists
- CRSI Tables
  - Waffle
  - Flat Plate

STEEL COMPOSITE COST DATA

STEEL COST DATA

Size	Length (ft)	Units	Quantity	Total (LF)	Cost / Unit ($ / LF)	Total Cost ($)	Square Feet	Cost / SF
W14x22 (BM)	34	LF	4	136	$36.00	$4,896	2,725.50	$1.80
W14x22 (BM)	31.5	LF	8	252	$36.00	$9,072	2,725.50	$3.33
W10x12 (BM)	10.75	LF	8	86	$25.50	$2,193	2,725.50	$0.80
W16x26 (BM)	23	LF	4	92	$40.50	$3,726	2,725.50	$1.37
W14x22 (BM)	23	LF	2	46	$36.00	$1,656	2,725.50	$0.61
Shear Studs	-	-	618	-	$15 / Stud	$9,270	2,725.50	$3.40
W10x33 (COL)	15	LF	4	60	$49.65	$2,979	2,725.50	$1.09
W10x39 (COL)	15	LF	8	120	$57.57	$6,908	2,725.50	$2.53
				TOTAL				$14.93

CONCRETE COST DATA

Name	Qty (CF)	Qty (CY)	Cost / Unit ($ / CY)	Total Cost ($)	Square Feet	Cost / SF
Concrete Slab	681.375	25.23611	$291	$7,344	2,725.50	$2.69
			TOTAL			$2.69

STEEL DECK COST DATA

Name	Qty (SF)	Cost / Unit ($ / SF)	Total Cost ($)	Square Feet	Cost / SF
Form Deck	2725.5	$3.70	$10,084	2725.50	$3.70
		TOTAL			$3.70

TOTAL COST / SF = $21.32

STEEL NON-COMPOSITE COST DATA

STEEL COST DATA								
Size	Length (ft)	Units	Quantity	Total (LF)	Cost / Unit ($ / LF)	Total Cost ($)	Square Feet	Cost / SF
W16x31 (BM)	34	LF	6	204	$48.00	$9,792	2,725.50	$3.59
W16x26 (BM)	31.5	LF	12	378	$40.50	$15,309	2,725.50	$5.62
W10x12 (BM)	10.75	LF	12	129	$25.50	$3,290	2,725.50	$1.21
W18x40 (BM)	23	LF	4	92	$61.00	$5,612	2,725.50	$2.06
W16x31 (BM)	23	LF	2	46	$48.00	$2,208	2,725.50	$0.81
W10x33 (COL)	15	LF	4	60	$49.65	$2,979	2,725.50	$1.09
W10x39 (COL)	15	LF	8	120	$57.57	$6,908	2,725.50	$2.53
TOTAL								$16.91

CONCRETE COST DATA						
Name	**Qty (CF)**	**Qty (CY)**	**Cost / Unit ($ / CY)**	**Total Cost ($)**	**Square Feet**	**Cost / SF**
Concrete Slab	681.375	25.23611	$291	$7,344	2,725.50	$2.69
TOTAL						$2.69

STEEL DECK COST DATA					
Name	**Qty (SF)**	**Cost / Unit ($ / SF)**	**Total Cost ($)**	**Square Feet**	**Cost / SF**
Form Deck	2725.5	$2.20	$5,996	2725.50	$2.20
TOTAL					$2.20

TOTAL COST / SF = $21.80

STEEL JOIST COST DATA

STEEL COST DATA								
Size	Length (ft)	Units	Quantity	Total (LF)	Cost / Unit ($ / LF)	Total Cost ($)	Square Feet	Cost / SF
22K7 (jst)	34	LF	11	374	$12.20	$4,563	2,725.50	$1.67
22K5 (jst)	31.5	LF	22	693	$11.20	$7,762	2,725.50	$2.85
10K1 (jst)	10.75	LF	22	236.5	$10.80	$2,554	2,725.50	$0.94
W18x40 (BM)	23	LF	4	92	$61.00	$5,612	2,725.50	$2.06
W18x35 (BM)	23	LF	2	46	$54.50	$2,507	2,725.50	$0.92
W10x33 (COL)	15	LF	4	60	$49.65	$2,979	2,725.50	$1.09
W10x39 (COL)	15	LF	8	120	$57.57	$6,908	2,725.50	$2.53
TOTAL								$12.07

CONCRETE COST DATA						
Name	**Qty (CF)**	**Qty (CY)**	**Cost / Unit ($ / CY)**	**Total Cost ($)**	**Square Feet**	**Cost / SF**
Concrete Slab	681.375	25.23611	$291	$7,344	2,725.50	$2.69
TOTAL						$2.69

STEEL DECK COST DATA					
Name	**Qty (SF)**	**Cost / Unit ($ / SF)**	**Total Cost ($)**	**Square Feet**	**Cost / SF**
Form Deck	2725.5	$2.20	$5,996	2725.50	$2.20
TOTAL					$2.20

TOTAL COST / SF = $16.96

WAFFLE SLAB COST DATA

WAFFLE SLAB COST DATA							
Name	**Qty (CF)**	**Qty**	**Qty (CY)**	**Cost / Unit ($ / CY)***	**Total Cost ($)**	**Square Feet**	**Cost / SF**
Waffle Slab	5030.34	1	186.31	$665	$123,895	4,596	$26.96
				TOTAL			$26.96

COLUMN COST DATA							
Size	**Height**	**Qty**	**Qty (CY)**	**Cost / Unit ($ / CY)**	**Total Cost ($)**	**Square Feet**	**Cost / SF**
21"x21"	15'	8	13.61	$1,306	$17,775	4,596	$3.87
				TOTAL			$3.87

COLUMN FORMWORK COST DATA							
Size	**Height**	**Qty**	**Qty (SFCA)**	**Cost / Unit ($ / SFCA)**	**Total Cost ($)**	**Square Feet**	**Cost / SF**
21"x21"	15'	8	840	$8.91	$7,484	4,596	$1.63
				TOTAL			$1.63

TOTAL COST / SF = $32.46

TWO WAY FLAT SLAB COST DATA

TWO WAY FLAT PLATE COST DATA						
Name	Qty (CF)	Qty (CY)	Cost / Unit ($ / CY)*	Total Cost ($)	Square Feet	Cost / SF
Large Bays	3332	123.41	$560	$69,108	4,064	$17.00
Small Bays	731	27.07	$635	$17,192	4,064	$4.23
Drop Panels	588.35	21.79	$635	$13,837	4,064	$3.40
			TOTAL			$24.64

COLUMN COST DATA							
Size	Height	Qty	Qty (CY)	Cost / Unit ($ / CY)	Total Cost ($)	Square Feet	Cost / SF
17"x17"	15'	4	4.46	$1,481	$6,605	4,064	$1.63
19"x19"	15'	8	11.14	$1,394	$15,529	4,064	$3.82
				TOTAL			$5.45

COLUMN FORMWORK COST DATA							
Size	Height	Qty	Qty (SFCA)	Cost / Unit ($ / SFCA)	Total Cost ($)	Square Feet	Cost / SF
17"x17"	15'	4	340	$8.91	$3,029	4,064	$0.75
19"x19"	15'	8	760	$8.91	$6,772	4,064	$1.67
				TOTAL			$2.41

TOTAL COST / SF = $32.50

Gravity Beam Design

RAM Steel v11.0
Typical Strip Bay
DataBase: TypBayStripComp — 10/24/07 10:47:29
Building Code: IBC — Steel Code: AISC LRFD

Floor Type: Typ Floor **Beam Number = 460**

SPAN INFORMATION (ft): I-End (0.00,15.33) J-End (31.50,15.33)

Minimum Depth specified = 9.85 in
Beam Size (User Selected) = W14X22 Fy = 50.0 ksi
Total Beam Length (ft) = 31.50

COMPOSITE PROPERTIES (Not Shored):

	Left	Right
Concrete thickness (in)	3.00	3.00
Unit weight concrete (pcf)	115.00	115.00
f'c (ksi)	4.00	4.00
Decking Orientation	perpendicular	perpendicular
Decking type	VULCRAFT 1.5VL	VULCRAFT 1.5VL

beff (in)	=	92.00	Y bar(in)	=	14.64
Mnf (kip-ft)	=	292.90	Mn (kip-ft)	=	274.44
C (kips)	=	263.29	PNA (in)	=	13.58
Ieff (in4)	=	663.94	Itr (in4)	=	715.16
Stud length (in)	=	3.50	Stud diam (in)	=	0.75

Stud Capacity (kips) Qn = 16.5
\# of studs: Full = 40 Partial = 32 Actual = 32
Number of Stud Rows = 1 Percent of Full Composite Action = 81.13

LINE LOADS (k/ft):

Load	Dist	DL	CDL	LL	Red%	Type	CLL
1	0.000	0.460	0.000	0.537	---	NonR	0.000
	31.500	0.460	0.000	0.537			0.000

SHEAR (Ultimate): Max Vu (1.2DL+1.6LL) = 22.22 kips 0.90Vn = 85.08 kips

MOMENTS (Ultimate):

Span	Cond	LoadCombo	Mu kip-ft	@ ft	Lb ft	Cb	Phi	Phi*Mn kip-ft
Center	Init DL	1.4DL	0.0	0.0	---	---		
	Max +	1.2DL+1.6LL	175.0	15.8	---	---	0.85	233.27
Controlling		1.2DL+1.6LL	175.0	15.8	---	---	0.85	233.27

REACTIONS (kips):

	Left	Right
Initial reaction	0.00	0.00
DL reaction	7.24	7.24
Max +LL reaction	8.45	8.45
Max +total reaction (factored)	22.22	22.22

DEFLECTIONS:

Initial load (in)	at	15.75 ft	=	0.000			
Live load (in)	at	15.75 ft	=	-0.617	L/D	=	612
Post Comp load (in)	at	15.75 ft	=	-1.147	L/D	=	330
Net Total load (in)	at	15.75 ft	=	-1.147	L/D	=	330

Gravity Beam Design

RAM Steel v11.0
Typical Strip Bay
DataBase: TypBayStripComp — 10/24/07 10:47:29
Building Code: IBC — Steel Code: AISC LRFD

Floor Type: Typ Floor **Beam Number = 466**

SPAN INFORMATION (ft): I-End (31.50,15.33) J-End (42.25,15.33)

Minimum Depth specified = 9.85 in
Beam Size (Optimum) = W10X12 Fy = 50.0 ksi
Total Beam Length (ft) = 10.75

COMPOSITE PROPERTIES (Not Shored):

	Left	Right
Concrete thickness (in)	3.00	3.00
Unit weight concrete (pcf)	115.00	115.00
f'c (ksi)	4.00	4.00
Decking Orientation	perpendicular	perpendicular
Decking type	VULCRAFT 1.5VL	VULCRAFT 1.5VL

beff (in)	= 32.25	Y bar(in)	= 10.55
Mnf (kip-ft)	= 127.26	Mn (kip-ft)	= 100.06
C (kips)	= 82.28	PNA (in)	= 9.27
Ieff (in4)	= 165.80	Itr (in4)	= 218.07
Stud length (in)	= 3.50	Stud diam (in)	= 0.75

Stud Capacity (kips) Qn = 16.5
\# of studs: Max = 21 Partial = 11 Actual = 11
Number of Stud Rows = 1 Percent of Full Composite Action = 46.48

LINE LOADS (k/ft):

Load	Dist	DL	CDL	LL	Red%	Type	CLL
1	0.000	0.460	0.000	0.613	---	NonR	0.000
	10.750	0.460	0.000	0.613			0.000

SHEAR (Ultimate): Max Vu (1.2DL+1.6LL) = 8.24 kips 0.90Vn = 50.63 kips

MOMENTS (Ultimate):

Span	Cond	LoadCombo	Mu kip-ft	@ ft	Lb ft	Cb	Phi	Phi*Mn kip-ft
Center	Init DL	1.4DL	0.0	0.0	---	---		
	Max +	1.2DL+1.6LL	22.1	5.4	---	---	0.85	85.05
Controlling		1.2DL+1.6LL	22.1	5.4	---	---	0.85	85.05

REACTIONS (kips):

	Left	Right
Initial reaction	0.00	0.00
DL reaction	2.47	2.47
Max +LL reaction	3.30	3.30
Max +total reaction (factored)	8.24	8.24

DEFLECTIONS:

Initial load (in)	at	5.38 ft	=	0.000	
Live load (in)	at	5.38 ft	=	-0.038	L/D = 3366
Post Comp load (in)	at	5.38 ft	=	-0.067	L/D = 1923
Net Total load (in)	at	5.38 ft	=	-0.067	L/D = 1923

Gravity Beam Design

RAM Steel v11.0
Typical Strip Bay
DataBase: TypBayStripComp 10/24/07 10:47:29
Building Code: IBC Steel Code: AISC LRFD

Floor Type: Typ Floor **Beam Number = 472**

SPAN INFORMATION (ft): I-End (42.25,15.33) J-End (76.25,15.33)

Minimum Depth specified = 9.85 in
Beam Size (Optimum) = W14X22 Fy = 50.0 ksi
Total Beam Length (ft) = 34.00

COMPOSITE PROPERTIES (Not Shored):

	Left	Right
Concrete thickness (in)	3.00	3.00
Unit weight concrete (pcf)	115.00	115.00
f'c (ksi)	4.00	4.00
Decking Orientation	perpendicular	perpendicular
Decking type	VULCRAFT 1.5VL	VULCRAFT 1.5VL

beff (in)	=	92.00	Y bar(in)	=	14.64
Mnf (kip-ft)	=	292.90	Mn (kip-ft)	=	279.56
C (kips)	=	279.74	PNA (in)	=	13.61
Ieff (in4)	=	678.25	Itr (in4)	=	715.16
Stud length (in)	=	3.50	Stud diam (in)	=	0.75

Stud Capacity (kips) Qn = 16.5
# of studs: Full = 40 Partial = 34 Actual = 34
Number of Stud Rows = 1 Percent of Full Composite Action = 86.20

LINE LOADS (k/ft):

Load	Dist	DL	CDL	LL	Red%	Type	CLL
1	0.000	0.460	0.000	0.537	---	NonR	0.000
	34.000	0.460	0.000	0.537			0.000

SHEAR (Ultimate): Max Vu (1.2DL+1.6LL) = 23.98 kips 0.90Vn = 85.08 kips

MOMENTS (Ultimate):

Span	Cond	LoadCombo	Mu kip-ft	@ ft	Lb ft	Cb	Phi	Phi*Mn kip-ft
Center	Init DL	1.4DL	0.0	0.0	---	---		
	Max +	1.2DL+1.6LL	203.8	17.0	---	---	0.85	237.62
Controlling		1.2DL+1.6LL	203.8	17.0	---	---	0.85	237.62

REACTIONS (kips):

	Left	Right
Initial reaction	0.00	0.00
DL reaction	7.82	7.82
Max +LL reaction	9.12	9.12
Max +total reaction (factored)	23.98	23.98

DEFLECTIONS:

Initial load (in)	at	17.00 ft	=	0.000			
Live load (in)	at	17.00 ft	=	-0.820	L/D	=	497
Post Comp load (in)	at	17.00 ft	=	-1.524	L/D	=	268
Net Total load (in)	at	17.00 ft	=	-1.524	L/D	=	268

Steel Non-Composite Beams (1 of 3)

Gravity Beam Design

RAM Steel v11.0
DataBase: TypBayStrip
Building Code: IBC

10/24/07 10:54:20
Steel Code: AISC LRFD

Floor Type: Typ Floor **Beam Number = 35**

SPAN INFORMATION (ft): I-End (0.00,13.80) J-End (31.50,13.80)

Minimum Depth specified = 9.85 in
Beam Size (Optimum) = W16X26 Fy = 50.0 ksi
Total Beam Length (ft) = 31.50
Mp (kip-ft) = 184.17

LINE LOADS (k/ft):

Load	Dist	DL	LL	Red%	Type
1	0.000	0.276	0.322	---	NonR
	31.500	0.276	0.322		

SHEAR (Ultimate): Max Vu (1.2DL+1.6LL) = 13.33 kips 0.90Vn = 104.15 kips

MOMENTS (Ultimate):

Span	Cond	LoadCombo	Mu kip-ft	@ ft	Lb ft	Cb	Phi	Phi*Mn kip-ft
Center	Max +	1.2DL+1.6LL	105.0	15.8	0.0	1.00	0.90	165.75
Controlling		1.2DL+1.6LL	105.0	15.8	0.0	1.00	0.90	165.75

REACTIONS (kips):

	Left	**Right**
DL reaction	4.35	4.35
Max +LL reaction	5.07	5.07
Max +total reaction (factored)	13.33	13.33

DEFLECTIONS:

Dead load (in)	at	15.75 ft =	-0.700	L/D	=	540
Live load (in)	at	15.75 ft =	-0.817	L/D	=	463
Net Total load (in)	at	15.75 ft =	-1.518	L/D	=	249

Steel Non-Composite Beams (2 of 3)

Gravity Beam Design

RAM Steel v11.0
DataBase: TypBayStrip
Building Code: IBC

10/24/07 10:54:20
Steel Code: AISC LRFD

Floor Type: Typ Floor **Beam Number = 39**

SPAN INFORMATION (ft): I-End (31.50,13.80) J-End (42.25,13.80)

Minimum Depth specified = 9.85 in
Beam Size (Optimum) = W10X12 Fy = 50.0 ksi
Total Beam Length (ft) = 10.75
Mp (kip-ft) = 52.50

LINE LOADS (k/ft):

Load	Dist	DL	LL	Red%	Type
1	0.000	0.276	0.368	---	NonR
	10.750	0.276	0.368		

SHEAR (Ultimate): Max Vu (1.2DL+1.6LL) = 4.94 kips 0.90Vn = 50.63 kips

MOMENTS (Ultimate):

Span	Cond	LoadCombo	Mu kip-ft	@ ft	Lb ft	Cb	Phi	Phi*Mn kip-ft
Center	Max +	1.2DL+1.6LL	13.3	5.4	0.0	1.00	0.90	46.94
Controlling		1.2DL+1.6LL	13.3	5.4	0.0	1.00	0.90	46.94

REACTIONS (kips):

	Left	**Right**
DL reaction	1.48	1.48
Max +LL reaction	1.98	1.98
Max +total reaction (factored)	4.94	4.94

DEFLECTIONS:

Dead load (in)	at	5.38 ft	=	-0.053	L/D = 2427
Live load (in)	at	5.38 ft	=	-0.071	L/D = 1820
Net Total load (in)	at	5.38 ft	=	-0.124	L/D = 1040

Steel Non-Composite Beams (3 of 3)

Gravity Beam Design

RAM Steel v11.0
DataBase: TypBayStrip
Building Code: IBC

10/24/07 10:54:20
Steel Code: AISC LRFD

Floor Type: Typ Floor **Beam Number = 23**

SPAN INFORMATION (ft): I-End (42.25,13.80) J-End (76.25,13.80)

Minimum Depth specified = 9.85 in
Beam Size (Optimum) = W16X31 Fy = 50.0 ksi
Total Beam Length (ft) = 34.00
Mp (kip-ft) = 225.00

LINE LOADS (k/ft):

Load	Dist	DL	LL	Red%	Type
1	0.000	0.276	0.322	---	NonR
	34.000	0.276	0.322		

SHEAR (Ultimate): Max Vu (1.2DL+1.6LL) = 14.39 kips 0.90Vn = 118.06 kips

MOMENTS (Ultimate):

Span	Cond	LoadCombo	Mu kip-ft	@ ft	Lb ft	Cb	Phi	Phi*Mn kip-ft
Center	Max +	1.2DL+1.6LL	122.3	17.0	0.0	1.00	0.90	202.50
Controlling		1.2DL+1.6LL	122.3	17.0	0.0	1.00	0.90	202.50

REACTIONS (kips):

	Left	**Right**
DL reaction	4.69	4.69
Max +LL reaction	5.47	5.47
Max +total reaction (factored)	14.39	14.39

DEFLECTIONS:

Dead load (in)	at	17.00 ft	=	-0.763	L/D	=	535
Live load (in)	at	17.00 ft	=	-0.890	L/D	=	458
Net Total load (in)	at	17.00 ft	=	-1.653	L/D	=	247

K-Series Steel Joists (1 of 3)

Standard Joist Selection

RAM Steel v11.0
Typical Strip Bay
DataBase: TypBayStripJoists 10/24/07 10:24:11
Building Code: IBC

Floor Type: Typ Floor **Beam Number = 288**

SPAN INFORMATION (ft): I-End (0.00,13.80) J-End (31.50,13.80)

Maximum Depth Limitation specified = 22.01 in
Joist Size (Optimum) = 22K5
Total Beam Length (ft) = 31.50

LINE LOADS (k/ft):

Load	Dist	DL	LL	Red%	Type
1	0.000	0.138	0.161	---	NonR
	31.500	0.138	0.161		

Maximum Total Unif. Load at any location (lbs/ft) : 299.0

Allowable Stress Ratio: 1.00

	Design Loads	Allowable Loads (lbs/ft)
Dead:	138.0	
Live:	161.0	211.5
Total:	299.0	309.0

MOMENTS:

Span	Cond	Moment kip-ft	@ ft
Center	Max +	37.1	15.8

REACTIONS (kips):

	Left	**Right**
DL reaction	2.17	2.17
Max +LL reaction	2.54	2.54
Max +total reaction	4.71	4.71

DEFLECTIONS:

Dead load (in)	=	0.685	L/D	=	552
Live load (in)	=	0.799	L/D	=	473
Total load (in)	=	1.484	L/D	=	255

Standard Joist Selection

RAM Steel v11.0
Typical Strip Bay
DataBase: TypBayStripJoists 10/24/07 10:24:11
Building Code: IBC

Floor Type: Typ Floor **Beam Number = 317**

SPAN INFORMATION (ft): I-End (31.50,11.50) J-End (42.25,11.50)

Maximum Depth Limitation specified = 22.01 in
Joist Size (Optimum) = 10K1
Total Beam Length (ft) = 10.75

LINE LOADS (k/ft):

Load	Dist	DL	LL	Red%	Type
1	0.000	0.138	0.184	---	NonR
	10.750	0.138	0.184		

Maximum Total Unif. Load at any location (lbs/ft) : 322.0

Allowable Stress Ratio: 1.00

	Design Loads	Allowable Loads (lbs/ft)
Dead:	138.0	
Live:	184.0	544.0
Total:	322.0	550.0

MOMENTS:

Span	Cond	Moment kip-ft	@ ft
Center	Max +	4.7	5.4

REACTIONS (kips):

	Left	**Right**
DL reaction	0.74	0.74
Max +LL reaction	0.99	0.99
Max +total reaction	1.73	1.73

DEFLECTIONS:

Dead load (in)	=	0.091	L/D	=	1419
Live load (in)	=	0.121	L/D	=	1064
Total load (in)	=	0.212	L/D	=	608

Standard Joist Selection

RAM Steel v11.0
Typical Strip Bay
DataBase: TypBayStripJoists 10/24/07 10:24:11
Building Code: IBC

Floor Type: Typ Floor **Beam Number = 347**

SPAN INFORMATION (ft): I-End (42.25,13.80) J-End (76.25,13.80)

Maximum Depth Limitation specified = 22.01 in
Joist Size (Optimum) = 22K7
Total Beam Length (ft) = 34.00

LINE LOADS (k/ft):

Load	Dist	DL	LL	Red%	Type
1	0.000	0.138	0.161	---	NonR
	34.000	0.138	0.161		

Maximum Total Unif. Load at any location (lbs/ft) : 299.0

Allowable Stress Ratio: 1.00

	Design Loads	Allowable Loads (lbs/ft)
Dead:	138.0	
Live:	161.0	202.0
Total:	299.0	303.0

MOMENTS:

Span	Cond	Moment kip-ft	@ ft
Center	Max +	43.2	17.0

REACTIONS (kips):

	Left	Right
DL reaction	2.35	2.35
Max +LL reaction	2.74	2.74
Max +total reaction	5.08	5.08

DEFLECTIONS:

Dead load (in)	=	0.774	L/D	=	527
Live load (in)	=	0.903	L/D	=	452
Total load (in)	=	1.678	L/D	=	243

CRSI Waffle Slab Table

WAFFLE FLAT SLAB SYSTEM 30″ X 30″ Voids: 6″ Ribs @ 36″

f'_c = 4,000 psi
Grade 60 Bars

SQUARE EDGE PANELS

Total Depth = 23 in. Rib Depth = 20 in. Total Slab Depth = 3 in.

Span c.-c. Columns $\ell_1 = \ell_2$ (ft)	Factored Super-imposed Load (psf)	(1) Steel (psf)	Square Edge Column: $c_1 = c_2$ (in.)	Square Edge Column: γ_f	Square Edge Column: (2) Stirrups	Reinforcing Bars—Each Direction, Column Strip: Top Edge No.-size +	Column Strip Bottom: No. Ribs	Column Strip Bottom: Bars per Rib	Column Strip: Top Interior No.-size	Middle Strip Bottom: No. Ribs	Middle Strip Bottom: Long Bars	Middle Strip Bottom: Short Bars	Middle Strip: Top Interior No.-size	Moments: −M Edge (ft-k)	Moments: +M Bot. (ft-k)	Moments: −M Int. (ft-k)
30′- 0″ D=12.500 RIB ON COLUMN LINE 1.048 CF/SF	50	2.27	15	0.641		22-#5+ 0	5	2-#5	22-#5	5	#5	#5	9-#5	200	399	537
	100	2.27	15	0.641		22-#5+ 0	5	2-#5	22-#5	5	#5	#5	9-#5	240	480	646
	150	2.34	15	0.641		22-#5+ 0	5	1-#5 and 1-#6	22-#5	5	#5	#5	9-#5	280	592	754
	200	2.48	15	0.669		22-#5+ 0	5	1-#6 and 1-#7	22-#5	5	#5	#5	9-#5	320	732	863
	300	3.02	15	0.735		22-#5+ 0	5	1-#7 and 1-#8	27-#5	5	#6	#6	9-#5	401	994	1080
	400	3.79	15	0.817		22-#5+ 2	5	1-#8 and 1-#9	23-#6	5	#7	#7	11-#5	482	1248	1297
	500	4.33	15 *	0.642		22-#5+ 1	5	2-#9	27-#6	5	#7	#8	9-#6	562	1496	1514
33′- 0″ D=12.500 RIB ON COLUMN LINE 1.02 CF/SF	50	2.37	16	0.640		25-#5+ 0	5	1-#5 and 1-#6	25-#5	6	#5	#5	10-#5	263	526	708
	100	2.43	16	0.661		25-#5+ 0	5	2-#6	25-#5	6	#5	#5	10-#5	317	633	852
	150	2.56	16	0.697		25-#5+ 0	5	1-#6 and 1-#7	25-#5	6	#5	#5	10-#5	370	774	997
	200	2.90	16	0.733		25-#5+ 0	5	1-#7 and 1-#8	29-#5	6	#5	#6	10-#5	424	961	1142
	300	3.60	16 *	0.804		25-#5+ 0	5	1-#8 and 1-#9	26-#6	6	#6	#7	12-#5	532	1310	1432
	400	4.46	16 *	0.641		25-#5+ 0	5	1-#9 and 1-#10	31-#6	6	#7	#7	10-#6	639	1647	1721
36′- 0″ D=12.500 RIB ON COLUMN LINE 0.998 CF/SF	50	2.42	18	0.637		27-#5+ 0	5	2-#6	27-#5	7	#5	#5	11-#5	337	674	908
	100	2.54	18	0.676		27-#5+ 0	5	1-#6 and 1-#7	28-#5	7	#5	#5	11-#5	407	814	1095
	150	2.82	18	0.717		27-#5+ 0	5	1-#7 and 1-#8	33-#5	7	#5	#5	11-#5	476	966	1283
	200	3.18	18	0.758		27-#5+ 0	5	2-#8	27-#6	7	#5	#6	12-#5	546	1210	1470
	300	4.21	18 *	0.868		27-#5+ 6	5	1-#9 and 1-#10	34-#6	7	#6	#7	11-#6	685	1660	1845
39′- 0″ D=15.500 RIB NOT ON COLUMN LINE 1.036 CF/SF	50	2.49	19	0.670		29-#5+ 0	6	1-#6 and 1-#7	30-#5	7	#5	#5	12-#5	437	874	1176
	100	2.79	19	0.715		29-#5+ 0	6	2-#7	36-#5	7	#5	#6	12-#5	526	1051	1415
	150	3.11	19	0.789		29-#5+ 4	6	1-#7 and 1-#8	30-#6	7	#5	#6	14-#5	614	1230	1654
	200	3.80	19 *	0.848		29-#5+ 8	6	1-#8 and 1-#9	34-#6	7	#6	#7	11-#6	703	1544	1893
	300	4.91	19 *	0.637		30-#5+ 6	6	2-#10	44-#6	7	#7	#8	14-#6	880	2117	2371
42′- 0″ D=15.500 RIB NOT ON COLUMN LINE 1.015 CF/SF	50	2.72	21	0.680		31-#5+ 0	6	2-#7	37-#5	8	#5	#5	13-#5	539	1078	1452
	100	3.20	21	0.748		31-#5+ 2	6	2-#8	32-#6	8	#5	#6	15-#5	650	1300	1750
	150	3.64	21 *	0.822		31-#5+ 7	6	1-#8 and 1-#9	37-#6	8	#6	#6	12-#6	760	1521	2047
	200	4.26	21 *	0.880		31-#5+12	6	1-#9 and 1-#10	43-#6	8	#6	#7	14-#6	871	1844	2345

SQUARE INTERIOR PANELS

Total Depth = 23 in. Rib Depth = 20 in. Total Slab Depth = 3 in.

Span c.-c. Columns $\ell_1 = \ell_2$ (ft)	Factored Super-imposed Load (psf)	(1) Steel (psf)	Square Interior Column: $c_1 = c_2$ (in.)	Square Interior Column: (2) Stirrups	Reinforcing Bars—Each Direction, Column Strip Bottom: No. Ribs	Column Strip Bottom: Bars per Rib	Column Strip: Top Interior No.-size	Middle Strip Bottom: No. Ribs	Middle Strip Bottom: Long Bars	Middle Strip Bottom: Short Bars	Middle Strip: Top Interior No.-size
30′- 0″	50	2.25	15		5	2-#5	22-#5	5	#5	#5	9-#5
	100	2.25	15		5	2-#5	22-#5	5	#5	#5	9-#5
	150	2.25	15		5	2-#5	22-#5	5	#5	#5	9-#5
	200	2.25	15		5	2-#5	22-#5	5	#5	#5	9-#5
	300	2.60	15		5	2-#6	25-#5	5	#5	#5	9-#5
	400	3.26	15	†	5	2-#7	22-#6	5	#5	#6	10-#5
	500	3.81	15 *	†	5	1-#7 and 1-#8	25-#6	5	#6	#6	12-#5
33′- 0″	50	2.29	16		5	2-#5	25-#5	6	#5	#5	10-#5
	100	2.29	16		5	2-#5	25-#5	6	#5	#5	10-#5
	150	2.40	16		5	1-#5 and 1-#6	25-#5	6	#5	#5	10-#5
	200	2.57	16		5	2-#6	27-#5	6	#5	#5	10-#5
	300	3.10	16	†	5	2-#7	24-#6	6	#5	#5	11-#5
	400	3.99	16 *	†	5	2-#8	29-#6	6	#6	#6	13-#5
36′- 0″	50	2.29	18		5	2-#5	27-#5	7	#5	#5	11-#5
	100	2.39	18		5	1-#5 and 1-#6	27-#5	7	#5	#5	11-#5
	150	2.57	18	†	5	2-#6	30-#5	7	#5	#5	11-#5
	200	2.89	18	†	5	1-#6 and 1-#7	25-#6	7	#5	#5	11-#5
	300	3.77	18 *	†	5	2-#8	31-#6	7	#5	#6	10-#6
39′- 0″	50	2.28	19		6	2-#5	29-#5	7	#5	#5	12-#5
	100	2.50	19		6	1-#5 and 1-#6	33-#5	7	#5	#5	12-#5
	150	2.84	19		6	2-#6	28-#6	7	#5	#5	13-#5
	200	3.42	19	†	6	2-#7	32-#6	7	#5	#6	15-#5
	300	4.31	19 *	†	6	2-#8	40-#6	7	#6	#6	13-#6
42′- 0″	50	2.55	21		6	2-#6	34-#5	8	#5	#5	13-#5
	100	2.91	21		6	1-#6 and 1-#7	29-#6	8	#5	#5	14-#5
	150	3.31	21	†	6	2-#7	35-#6	8	#5	#5	16-#5
	200	3.82	21 *	†	6	1-#7 and 1-#8	40-#6	8	#5	#6	13-#6

(Continued on next page)

NOTES See the notes on Page 11-19 regarding the * for column size and (1) for average reinforcing steel weight.

(2) A single dagger "†" indicates stirrups, equivalent to at least #5 bars spaced at 8 inches, are required in each joist rib from the face of the solid head to the first cross rib, i.e., a length of one module. A double dagger "††" indicates stirrups, equivalent to at least #5 bars spaced at 8 inches, are required in each joist rib from the face of the solid head to the second cross rib, i.e., a length of two modules. The size, configuration, and spacing of the stirrups are to be specified by the designer.

CRSI Two Way Flat Plate Table

f'_c = 4,000 psi
Grade 60 Bars

FLAT SLAB SYSTEM

SQUARE EDGE PANEL With Drop Panels No Beams

SPAN c-c. $\ell_1 = \ell_2$ (ft)	Factored Superimposed Load (psf)	Square Drop Panel Depth (in.)	Square Drop Panel Width (ft)	(3) Square Column Size (in.)	γ_f	Reinforcing Bars (E. W.) Column Strip (1) Top Ext.	+	Column Strip Bottom	Column Strip Top Int.	Middle Strip Bottom	Middle Strip Top Int.	Total Steel (psf)	Moments Edge (−) (ft-k)	Bot. (+) (ft-k)	Int. (−) (ft-k)
h = 12 in. = TOTAL SLAB DEPTH BETWEEN DROP PANELS															
30	100	7.00	10.00	12	0.808	14-#5	3	12-#7	16-#6	15-#5	13-#5	3.10	257.4	514.8	693.0
30	200	9.00	10.00	16	0.707	14-#5	3	15-#7	18-#6	10-#7	11-#6	3.65	329.4	658.8	886.8
30	300	9.00	10.00	19	0.763	15-#5	5	12-#9	22-#6	12-#7	19-#5	4.62	401.5	803.1	1081.0
30	400	11.00	10.00	21	0.661	16-#5	3	17-#8	14-#8	11-#8	12-#7	5.27	473.2	946.3	1273.9
30	500	11.00	12.00	24	0.766	19-#5	6	13-#10	16-#8	13-#8	11-#8	6.20	545.2	1090.4	1467.9
31	100	9.00	10.33	12	0.729	14-#5	2	13-#7	16-#6	16-#5	14-#5	3.12	285.7	571.4	769.2
31	200	9.00	10.33	16	0.766	14-#5	5	13-#8	15-#7	11-#7	13-#6	3.96	364.7	729.3	981.8
31	300	11.00	10.33	19	0.683	15-#5	4	13-#9	16-#7	18-#6	15-#6	4.76	444.4	888.7	1196.4
31	400	11.00	10.33	22	0.749	18-#5	6	19-#8	15-#8	16-#7	18-#6	5.68	522.9	1045.8	1407.8
31	500	11.00	12.40	27	0.755	15-#6	4	18-#9	14-#9	12-#9	12-#8	6.78	599.3	1198.5	1613.4
32	100	9.00	10.67	12	0.794	15-#5	5	11-#8	17-#6	13-#6	15-#5	3.33	314.9	629.9	847.9
32	200	11.00	10.67	16	0.640	15-#5	2	12-#9	15-#7	13-#7	19-#5	4.27	403.4	806.8	1086.1
32	300	11.00	10.67	19	0.757	17-#5	6	18-#8	18-#7	12-#8	13-#7	5.16	490.7	981.3	1321.0
32	400	11.00	12.80	25	0.729	20-#5	5	14-#10	16-#8	11-#9	12-#8	6.21	575.3	1150.7	1549.0
32	500	11.00	12.80	30	0.718	16-#6	4	16-#10	15-#9	13-#9	13-#8	7.14	651.1	1302.2	1752.9
33	100	11.00	11.00	12	0.678	15-#5	1	16-#7	17-#6	14-#6	12-#6	3.44	347.3	694.7	935.1
33	200	11.00	11.00	16	0.743	15-#5	5	13-#9	16-#7	18-#6	15-#6	4.45	443.7	887.5	1194.7
33	300	11.00	11.00	21	0.747	19-#5	5	13-#10	15-#8	22-#6	11-#8	5.55	537.1	1074.2	1446.0
33	400	11.00	13.20	28	0.721	22-#5	6	15-#10	18-#8	12-#9	16-#7	6.55	628.5	1257.0	1692.2
33	500	11.00	13.20	33	0.680	17-#6	3	17-#10	16-#9	11-#10	14-#8	7.47	705.8	1411.6	1900.3
34	100	11.00	11.33	12	0.752	16-#5	4	14-#8	19-#6	12-#7	13-#6	3.74	380.6	761.2	1024.7
34	200	11.00	11.33	17	0.767	17-#5	6	14-#9	18-#7	12-#8	13-#7	4.83	485.4	970.8	1306.8
34	300	11.00	11.33	24	0.699	20-#5	4	17-#9	17-#8	14-#8	12-#8	5.88	584.8	1169.6	1574.5
34	400	11.00	13.60	30	0.700	17-#6	3	17-#10	19-#8	13-#9	14-#8	7.00	681.2	1362.3	1833.9
35	100	11.00	11.67	12	0.795	16-#5	6	12-#9	16-#7	13-#7	14-#6	3.95	415.9	831.9	1119.8
35	200	11.00	11.67	19	0.752	18-#5	6	19-#8	16-#8	16-#7	18-#6	4.98	528.2	1056.4	1422.1
35	300	11.00	11.67	26	0.715	22-#5	6	15-#10	18-#8	12-#9	22-#6	6.24	636.9	1273.8	1714.8
35	400	11.00	14.00	33	0.706	18-#6	5	18-#10	17-#9	14-#9	12-#9	7.34	734.7	1469.4	1978.1
36	100	11.00	12.00	14	0.767	16-#5	6	13-#9	22-#6	14-#7	12-#7	4.17	451.1	902.3	1214.6
36	200	11.00	12.00	21	0.760	20-#5	7	17-#9	16-#8	14-#8	12-#8	5.45	573.5	1147.0	1544.0
36	300	11.00	12.00	29	0.704	17-#6	5	17-#10	16-#9	13-#9	14-#8	6.66	686.8	1373.6	1849.1
36	400	11.00	14.40	36	0.660	27-#5	5	19-#10	18-#9	19-#8	13-#9	7.67	793.0	1586.1	2135.1

SQUARE INTERIOR PANEL With Drop Panel(2) No Beams

SPAN (ft)	Factored Superimposed Load (psf)	(3) Square Column Size (in.)	Reinforcing Bars (E. W.) Column Strip Top	Column Strip Bottom	Middle Strip Top	Middle Strip Bottom	Total Steel (psf)	Concrete (cu. ft / sq. ft)
h = 12 in. = TOTAL SLAB DEPTH BETWEEN DROP PANELS								
30	100	12	15-#6	15-#5	13-#5	13-#5	2.82	1.065
30	200	19	23-#5	19-#5	15-#5	13-#5	3.16	1.083
30	300	22	15-#7	17-#6	10-#7	15-#5	4.02	1.083
30	400	25	16-#7	11-#8	11-#7	18-#5	4.59	1.102
30	500	27	14-#8	13-#8	10-#8	11-#7	5.31	1.147
31	100	12	20-#5	12-#6	13-#5	13-#5	2.78	1.083
31	200	19	26-#5	11-#7	16-#5	14-#5	3.41	1.083
31	300	23	15-#7	18-#6	14-#6	12-#6	4.10	1.102
31	400	25	14-#8	16-#7	13-#7	14-#6	4.98	1.102
31	500	27	16-#8	12-#9	11-#8	13-#7	5.93	1.147
32	100	12	16-#6	18-#5	14-#5	14-#5	2.90	1.083
32	200	19	26-#5	17-#6	13-#6	15-#5	3.57	1.102
32	300	23	22-#6	15-#7	12-#7	13-#6	4.43	1.102
32	400	26	15-#8	11-#9	11-#8	12-#7	5.37	1.147
32	500	30	17-#8	13-#9	12-#8	18-#6	6.12	1.147
33	100	12	16-#6	14-#6	11-#6	14-#5	2.97	1.102
33	200	19	15-#7	18-#6	14-#6	12-#6	3.82	1.102
33	300	23	18-#7	22-#6	13-#7	11-#7	4.71	1.102
33	400	26	17-#8	12-#9	12-#8	13-#7	5.74	1.147
33	500	33	15-#9	11-#1	13-#8	11-#8	6.52	1.147
34	100	12	18-#6	22-#5	12-#6	15-#5	3.16	1.102
34	200	19	22-#6	15-#7	12-#7	13-#6	4.13	1.102
34	300	23	16-#8	14-#8	14-#7	12-#7	5.15	1.102
34	400	29	18-#8	14-#9	22-#6	14-#7	6.07	1.147
35	100	12	19-#6	17-#6	13-#6	16-#5	3.32	1.102
35	200	19	18-#7	22-#6	13-#7	20-#5	4.31	1.102
35	300	23	17-#8	20-#7	12-#8	13-#7	5.43	1.102
35	400	32	16-#9	18-#8	14-#8	12-#8	6.42	1.147
36	100	12	16-#7	14-#7	20-#5	17-#5	3.58	1.102
36	200	19	37-#5	14-#8	14-#7	12-#7	4.71	1.102
36	300	25	18-#8	17-#8	22-#6	14-#7	5.68	1.102
36	400	34	17-#9	13-#10	12-#9	22-#6	6.84	1.147

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