MOUNTAIN STATE
BLUE CROSS BLUE SHIELD
HEADQUARTERS

PARKERSBURG, WEST VIRGINIA

DOMINIC MANNO

STRUCTURAL OPTION

FACULTY CONSULTANT: DR. ANDRES LEPAGE

Technical Report 2

10-24-08

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EXECUTIVE SUMMARY

In this second technical report alternative floor systems were analyzed for Mountain State Blue Cross Blue Shield Headquarters. Three other systems were analyzed and compared with the original system. When comparing the systems several factors came into consideration: cost, weight, fit to grid, constructability, fire protection, depth, and vibration. The original system is composite steel, spans 30', and carries the large loads. The other three systems I investigated are:

- Non-Composite Steel Floor System
- Two Way Flat Slab with Drop Panels
- Two Way Post Tension Slab

After exploring these options the concrete floor systems seem to work well for this building. They both reduce the total depth of the floor system and can still span the 30 ft. bays. There will be major changes to the lateral system and possibly foundations if further investigated. Technical report 3 will further look into the lateral systems and further decide if these systems could potentially work for Mountain State Blue Cross Blue Shield Headquarters.

INTRODUCTION TO MOUNTAIN STATE BLUE CROSS BLUE SHIELD HEADQUARTERS

Mountain State Blue Cross Blue Shield Headquarters Building consists of 4 stories that sit above grade and is mainly office space. It was designed by Burt Hill Architects. Its main purpose for being built was to expand to include an extra 170 employees that are to be hired this year. G.A. Brown was hired as the contractor and began construction in March of 2008 and is expected to be completed by April of 2009. MSBCBS is located in Parkersburg, WV, which sits on the north-western area of the state near the Ohio border. The building has a brick veneer façade which sits well into the site of downtown Parkersburg. It also has a large glass curtain wall which emphasizes the buildings entrance and gives the building a modern appeal.

The building is approximately 130,000 square feet and has mainly an open floor plan. The buildings top of steel is at a height of 67' – 6.5" above grade due to the screen wall located on the roof for the mechanical units. The floor to floor height of the building is approximately 13'-4". The typical bay size is 30' x 30' being made by composite steel structure and concrete slab on steel decking. The lateral system of the building is made up of four braced frames, two in the north/south and two in the east/west building direction. The foundation contains caissons which extend approximately 70' ft. The ground level consists of a 4" slab on grade with grade beams surrounding the perimeter of the buildings footprint.

CODE

CODE / REFERENCES

2006 International Building Code

(ACI 318-08) Building Code Requirements for Structural Concrete

Specification for the Design, Fabrication and Erection of Structural Steel Buildings
Allowable Steel Design, 13th Edition, American Institute of Steel Construction

(ASCE - 07) Minimum design loads for Buildings and other Structures
American Society of Civil Engineers

Steel Deck Institute, Design Manual

CODE / REFERENCES USED IN ORIGINAL DESIGN

2003 International Building Code

(ACI 318-05) Building Code Requirements for Structural Concrete

Specification for the Design, Fabrication and Erection of Structural Steel Buildings
Allowable Steel Design, 13th Edition, American Institute of Steel Construction

(ASCE - 07) Minimum design loads for Buildings and other Structures
American Society of Civil Engineers

Steel Deck Institute, Design Manual

MATERIALS

Concrete

Foundations	f'c = 4000 PSI
Slab On Grade	f'c = 4000 PSI
Exterior Slabs	f'c = 4500 PSI
Interior Slabs on Metal Deck	f'c = 4000 PSI

Reinforcement

Deformed Bars	ASTM A615, Grade 60
Welded Wire Fabric	ASTM A185

Steel

Structural "W" Shapes	ASTM A992
Structural "M," "S," and "HP" Shapes	ASTM A572, Grade 50
Channels	ASTM A572, Grade 50
Steel Tubes (HSS Shapes)	ASTM A500, Grade B
Steel Pipe (Round HSS)	ASTM A500, Grade B
Angles and Plates	ASTM A36

Metal Deck and Shear Studs

Composite Floor	2" 20 Gauge
Roof Deck	1 ½ " Galvanized
Studs	¾" Diam. 4 ½" Tall

GRAVITY AND DESIGN LOADS

DEAD LOADS

Construction Dead Loads

Concrete	150 PCF
Light Weight Concrete	110 PCF
Steel	490 PCF
Partitions	20 PSF
M.E.P.	10 PSF
Finishes and Misc.	5 PSF
Windows and Framing	20 PSF
Roof	20 PSF

LIVE LOADS

Public Areas	100 PSF
Lobby	100 PSF
Office First Floor Corridor	100 PSF
Office Corridors above First Floor	80 PSF
Offices	50 PSF
Light Storage	125 PSF
Heavy Storage	250 PSF
Mechanical	150 PSF
Stairs	100 PSF

EXISTING STRUCTURAL SYSTEM

FOUNDATIONS

The foundation system is drilled caissons that range from 30” in diameter to 66”. They were designed to have an allowable skin friction of 550 psf. They contain a variation No. 7 to No. 8 vertical reinforced bars, and have ties that are No. 3 reinforced bars. Depending on the location on the plan the caissons are driven into the ground 59’ to 74’ below grade. The caissons support the steel framed system and the 4” concrete slab on grade. The grade beams surrounding the perimeter of the building are 24” x 30”.

FLOOR SYSTEM

MSBCBS has a composite system with 30’ x 30’ typical bay size. A 3-1/4” light weight concrete slab sits on a 2” – 20 gauge composite steel decking with ¾” studs. The deck is supported by mainly W18 x 35 beams that are spaced 10’ center to center. The majority of the girders are W21 x 62 which transfer the loads from the beams to the columns. This floor system is used for all floors except for the roof and the 4” slab on grade. The roof is made up of an 1-1/2” 20 gauge wide rib galvanized steel deck and is 3 spans continuous with 3” of concrete. The roof floor system is mainly supported by K-series joists that are spaced 6’ center to center.

COLUMNS

The gravity columns for MSBCBS are typically W10’s. The gravity base plates have a 4 bolt connection and have a thickness varying from 1” to 1-5/8”. The lateral columns are W12’s. The lateral base plates typically have a 12 bolt connection with a thickness of 1-1/2” to 2-1/2”. The mechanical screen roof is composed of HSS 12 x 12 x 3/8 post, which connects to the beam, with a 1” thick base plate.

LATERAL SYSTEM

Four braced frames make up the lateral force resisting system for the building. The placements of these braces were based on the location of interior walls throughout the building. The purpose was to be able to conceal the braces within the walls. Several different types were used, from diagonal bracing to x bracing to uneven inverted chevron bracing. All of these braces are laid out in between floor to floor spaces. The braces range from HSS 8x8’s to HSS 10x10’s. The braces are connected using gusset plates with a minimum thickness of the beam’s web thickness. Typical base plates for these lateral columns are 2-1/2” thick with large caissons to transfer the shear forces. Below is the layout of the lateral braces and elevations (Figures 1 through 5).

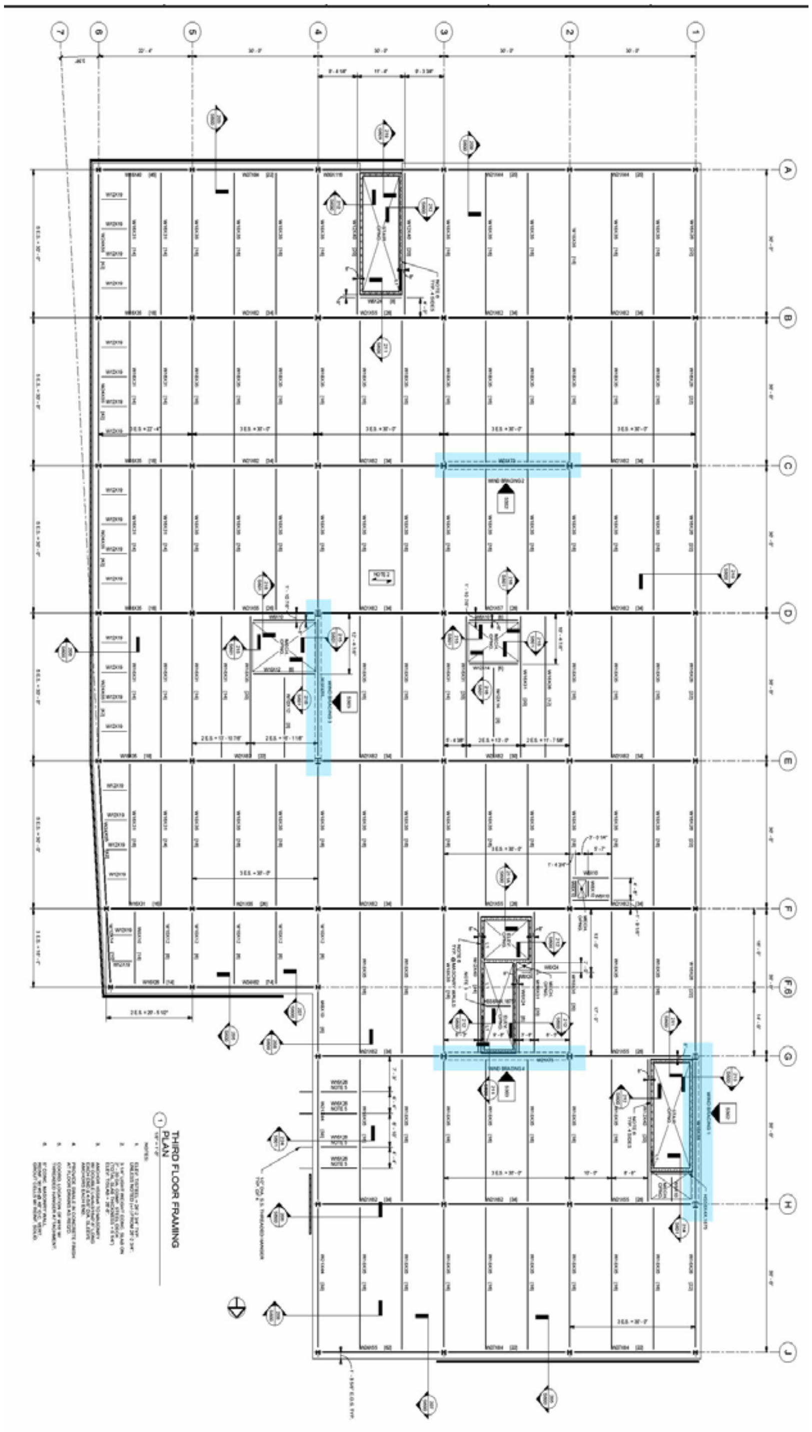


Figure 1: Lateral System Layout

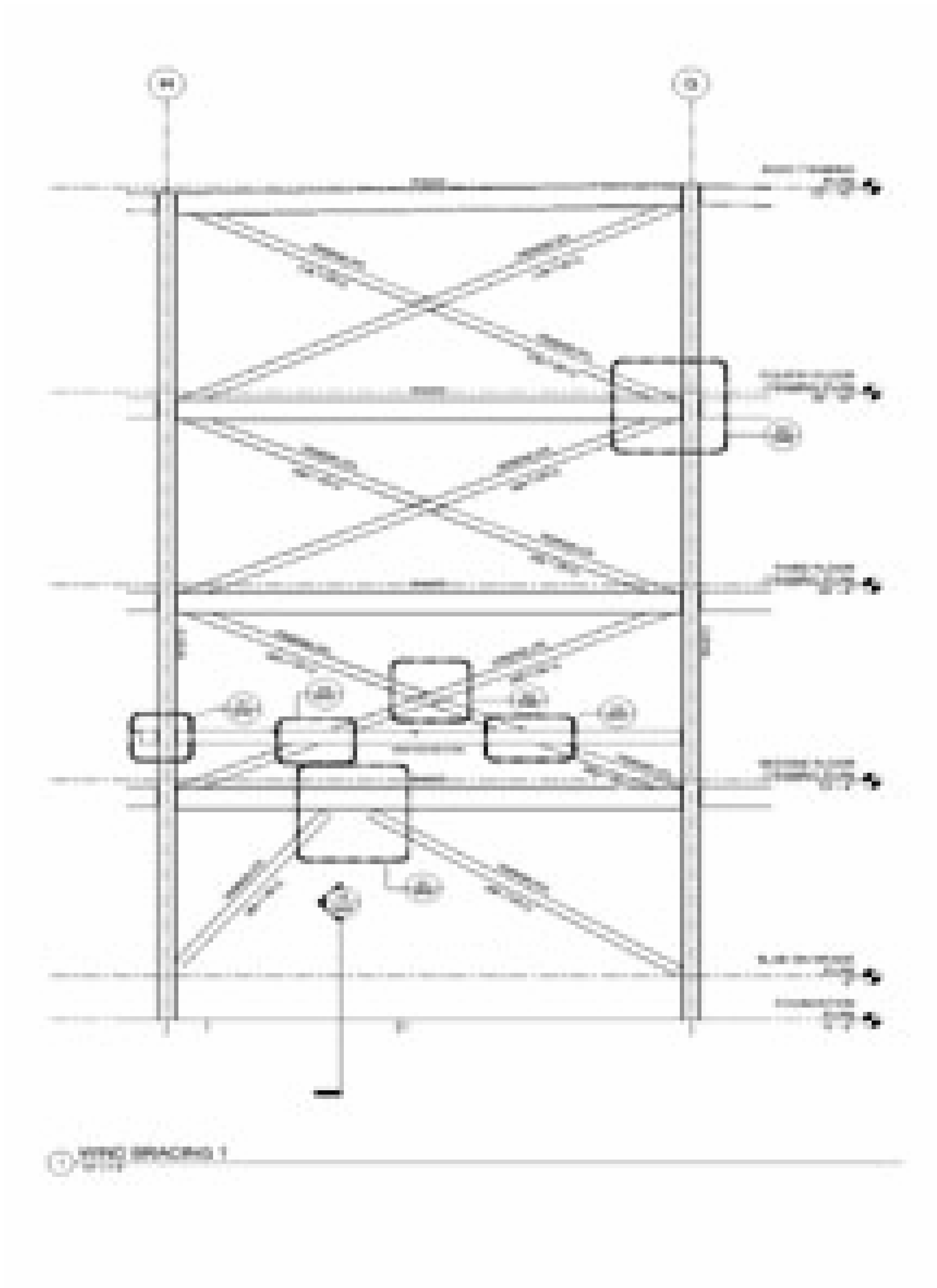


Figure 2: Lateral Brace 1 Elevation

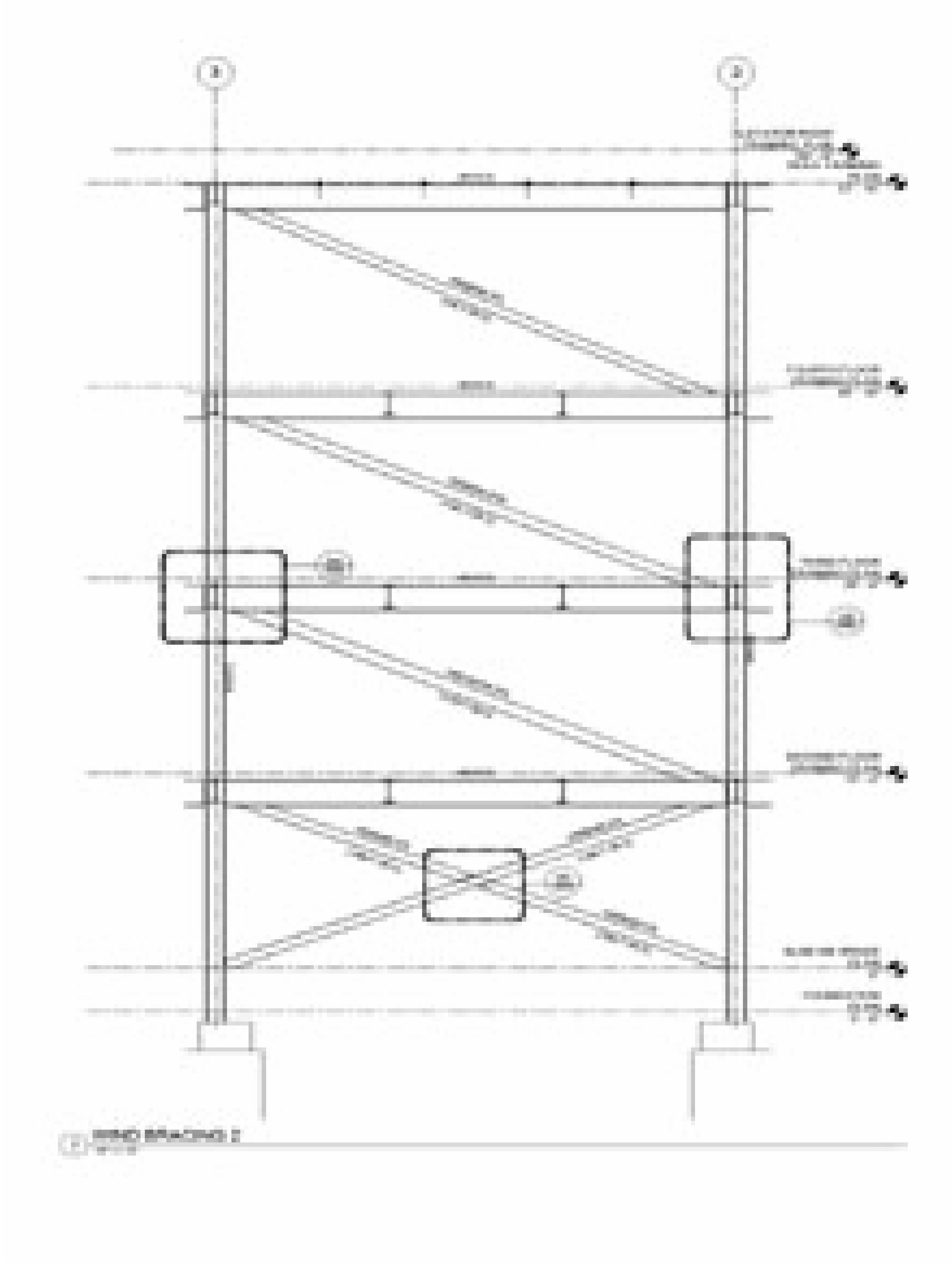


Figure 3: Lateral Brace 2 Elevation

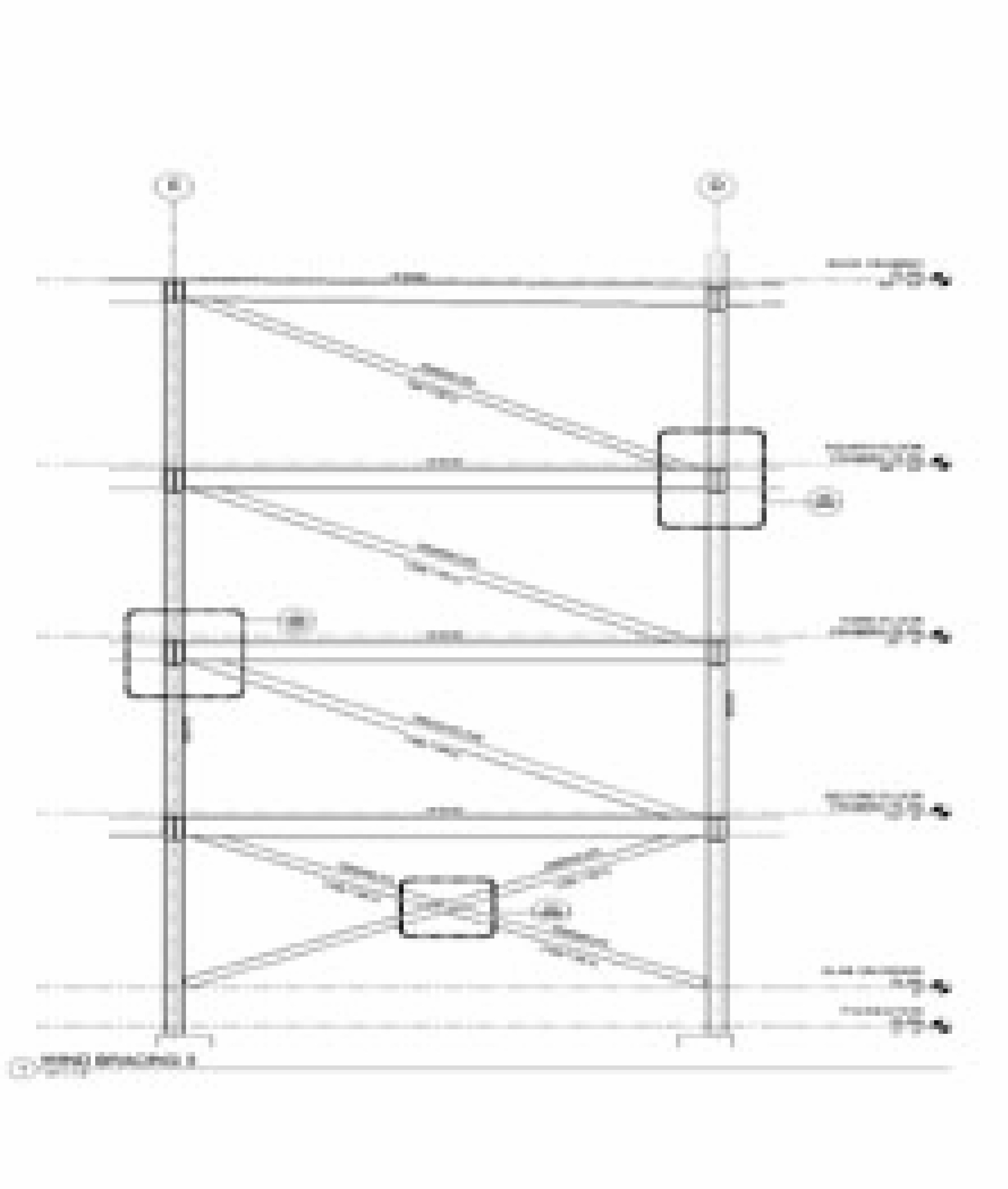


Figure 4: Lateral Brace 3 Elevation

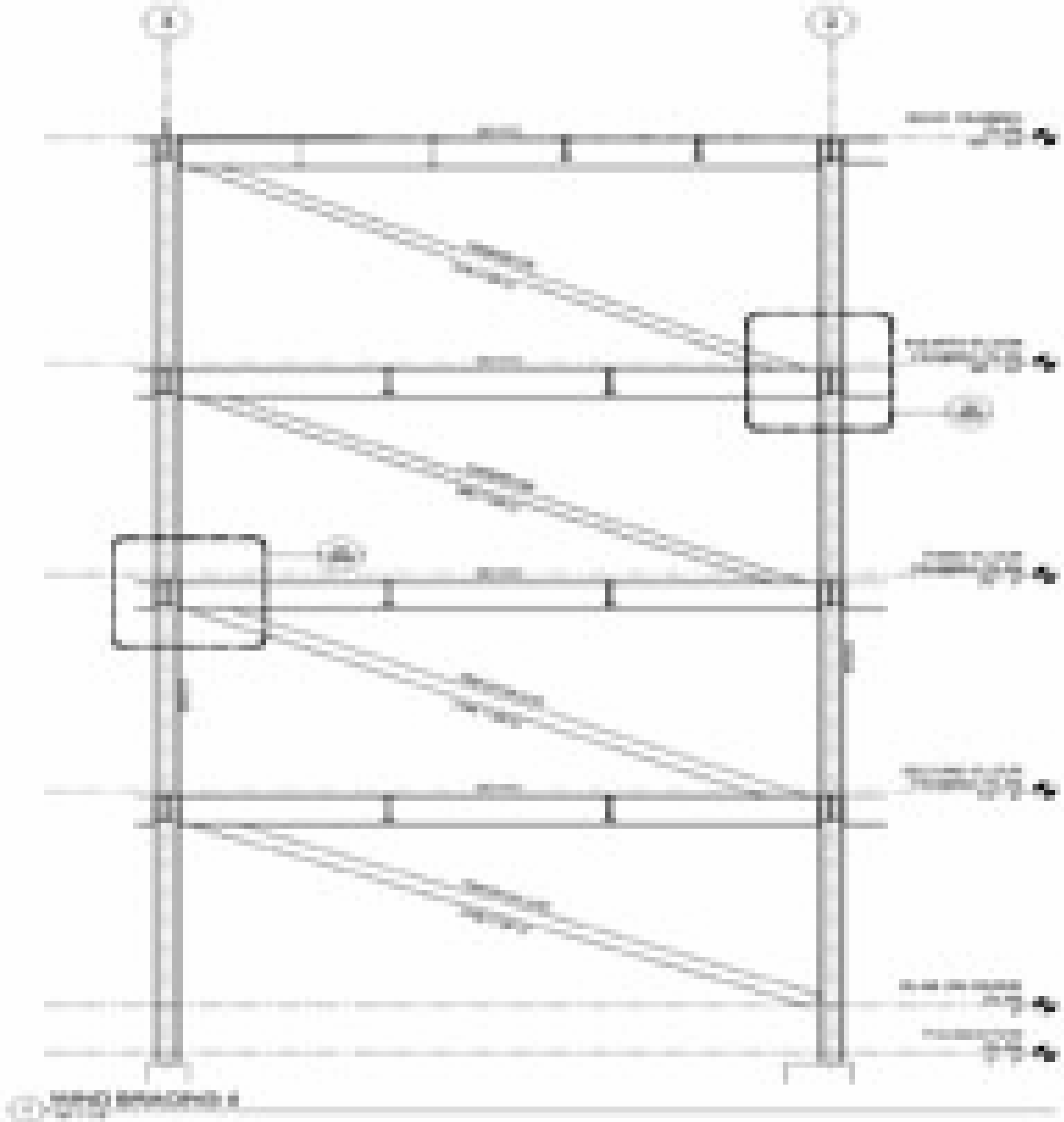


Figure 5: Lateral Brace 4 Elevation

EXISTING FLOOR SYSTEM

The composite floor system used in Mountain State Blue Cross Blue Shield is a satisfactory system. It is extremely effective in covering the long open spans needed for the building's plans and is ideal for carrying the heavy loads throughout the building. The deck and slab along with the fireproofing on the beams provide a 2 hour fire rating (Figure 6). The composite system provides a 13 foot 4 inch floor to floor height and the large beams and girders minimize deflections. Detailed calculations can be seen in Appendix B. There is no shoring or formwork needed for this system. Limited openings throughout the building result in fast pouring of the concrete. The steel system used in the building is faster and more proficient than forming and pouring a concrete beam and column system. The overall system is considerably cheap and easy to construct ($22.75).

The disadvantages of this system are the beams and girders are relatively deep. The total depth of the floor system is approximately 28 inches. With this composite system the steel beams and studs combining with the deck and concrete create a considerable amount of weight for the caissons to carry. This requires that the caissons be driven to depths reaching 74 feet.

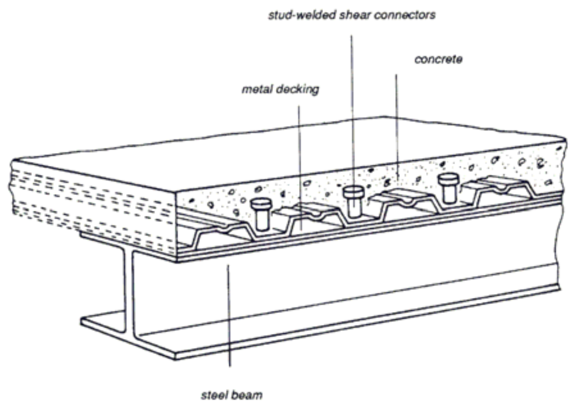


Figure 6: Composite Steel Floor System

Overall this system is a good choice for Mountain State Blue Cross Blue Shield. It covers the structural requirements of the building. It enables the building to be completed in a short amount of time and meets the architectural requirements.

ALTERNATE FLOOR SYSTEMS

For this report three different floor systems were analyzed to determine if the existing composite steel system was the most viable. In choosing three alternate systems, I looked into systems that could span large bays. The systems also needed to be able to carry heavy loads and be reasonable in price. The three systems I chose to investigate in the order which they will be presented in the next few pages are:

- **Non-Composite Steel System**
- **Two Way Flat Slab with Drop Panels**
- **Two Way Post Tension Slab**

Various Codes were used in the design of these systems:

(ACI 318-08) Building Code Requirements for Structural Concrete

Specification for the Design, Fabrication and Erection of Structural Steel Buildings Allowable Steel Design, 13th Edition, American Institute of Steel Construction

Vulcraft Steel Deck Manual

R. S. Means Assemblies and Square Foot Cost Data for Parkersburg, West Virginia, 2008

NON-COMPOSITE STEEL SYSTEM

The non-composite steel floor system is fundamental. It is extremely similar to the existing floor structure that Mountain State Blue Cross Blue Shield utilizes. The major difference is that there are no shear studs that need to be welded to the beams for composite action (Figure 7). This cuts down on time which was a concern when designing the building's structure. 4.5" of normal weight concrete was used in my analysis for the slab. A detailed report of the results from RAM showing beam and girder results can be seen in Appendix C. This system fit into the existing grid well, and wouldn't require a different lateral system. It also provides a possibility of adding an additional floor to the building with not much extra effort needed in design.

The system actually increases the weight of the structure and the depth of the steel members used to support the slab. In order to fully utilize this floor system I believe that the column spans would have to be shorter, enabling the beam and girder sizes to decrease. The open floor plan poses a problem for this alternative and the need for extra columns and foundations. Therefore I do not believe that this system is a viable choice for Mountain State Blue Cross Blue Shield.

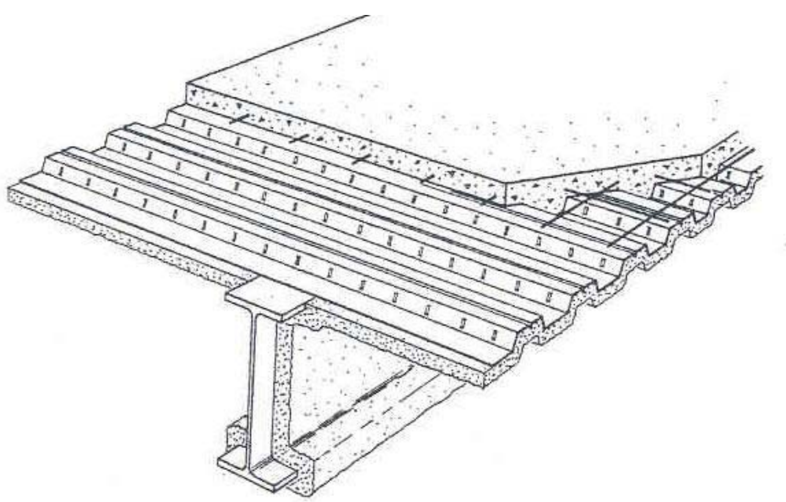


Figure 7: Non-Composite Steel Floor System

TWO WAY FLAT SLAB WITH DROP PANELS

This two way reinforced concrete slab was designed for a typical interior bay. Since Mountain State Blue Cross Blue Shield's layout is practically square forming 30' x 30' bays this system fits in well. A 20" x 20" column size was assumed in my calculations. The slab was designed with drop panels to decrease the effect of punching shear (Figure 8). The result was a slab thickness of 13", detailed calculations shown in Appendix D. Ballasts or some other techniques will need to be used to conceal the mechanical ductwork which will increase the total thickness.

This system fits almost perfectly into the existing square grid layout of Mountain State Blue Cross Blue Shield. Its total thickness is nearly half of the existing composite design. Since drop panels were used the columns could be reduced in size which could be looked into in a later analysis. This system also handles vibration well and provides a 2 hr fire rating.

Conversely, this system does add weight to the foundations of the structure which could pose problems. The drop panels cause problems with ceiling heights and the layout of the mechanical equipment. The lateral system of the building would now have to be completely different which will be looked at in Tech.3.

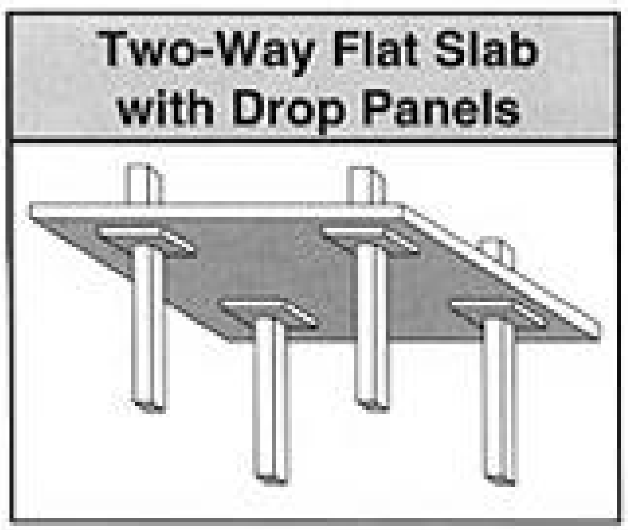


Figure 8: Two Way Flat Slab with Drop Panels

Overall this could be a possible alternative for Mountain State Blue Cross Blue Shield. Further investigation is needed to determine change of lateral system and foundation impact.

TWO WAY POST TENSION SLAB

This option utilizes a two way post tension concrete slab and columns. To achieve post tension, the steel tendons are tensioned after the concrete has hardened to a compressive strength of approximately 3,000 psi (Figure 10). The tendons are anchored at the ends within the concrete and have a vertical profile (Figure 9). This system can cover large spans economically. Only a typical interior bay was designed for this report. Column sizes were assumed to be 20" x 20". The resulting thickness of the slab was 8". Detailed calculations can be seen in Appendix E. This system could span even a greater distance while still maintaining a relatively thin slab thickness. This could reduce the amount of columns and foundations in Mountain State Blue Cross Blue Shield. With this minimal slab thickness the addition of another floor could be achieved since this depth is less than half of the original deck. The post tension slab also deals well with deflection and vibrations. It reduces the amount of mild-steel reinforcement.

The post tension slab has a significant increase in weight compared to the original floor system. This system also requires an experienced team for construction and the need to make sure everything is laid out correctly. It is also difficult to run the tendons around openings in the building. After construction adding of openings throughout the building is extremely difficult because of the possibility of rupturing a tendon. This means preconstruction planning must be precise. There must be a different lateral system used in this design.

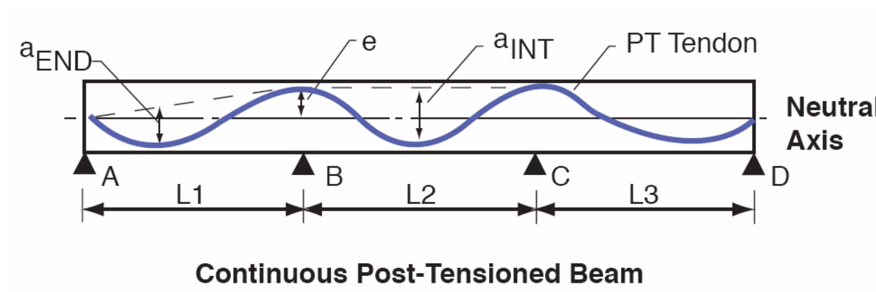


Figure 9: Vertical Tendon Layout

Figure 10: Horizontal Tendon Layout

Overall this system is an exceptional choice. Further investigation will be needed in order to determine if larger bays and a different lateral system could fit into Mountain State Blue Cross Blue Shield's layout.

OVERALL SYSTEM COMPARISON

The following chart shows a comparison of all floor systems (Table 1).

Criteria	Floor Systems			
	Composite Steel	Non-Composite Steel	Two Way Flat Slab	Post Tension
Weight (psf)	59	67	119	100
Slab Depth	5.25"	4.5"	9.5"	8"
System Depth	28"	33"	13"	10"
Constructability	Moderate	Moderate - Low	Moderate	Moderate - High
Foundation Impact	-	-	Little	Little
Fire Rating	1 - 2 hr	1 - 2 hr	2 hr	2 hr
Vibration	Average	Average	Superb	Superb
Material and Labor Cost per ft^2	$22.75	$20.98	$16.55	$26.17
Viable System	Yes	No	Yes	Yes
Further Investigation	-	No	Yes	Yes

Table 1: System Comparison

Weight comparison shows that the existing composite system is the lightest meaning that the other systems could cause changes to the caissons used for the buildings foundations. The year long construction time frame favors the existing design seeing that the concrete flat slab and the post tension slab could possibly increase construction time due to the difficulty of constructing these systems. I believe that either concrete structure could be a viable alternative depending on the experience of the contractor in those areas and the lee way in construction time.

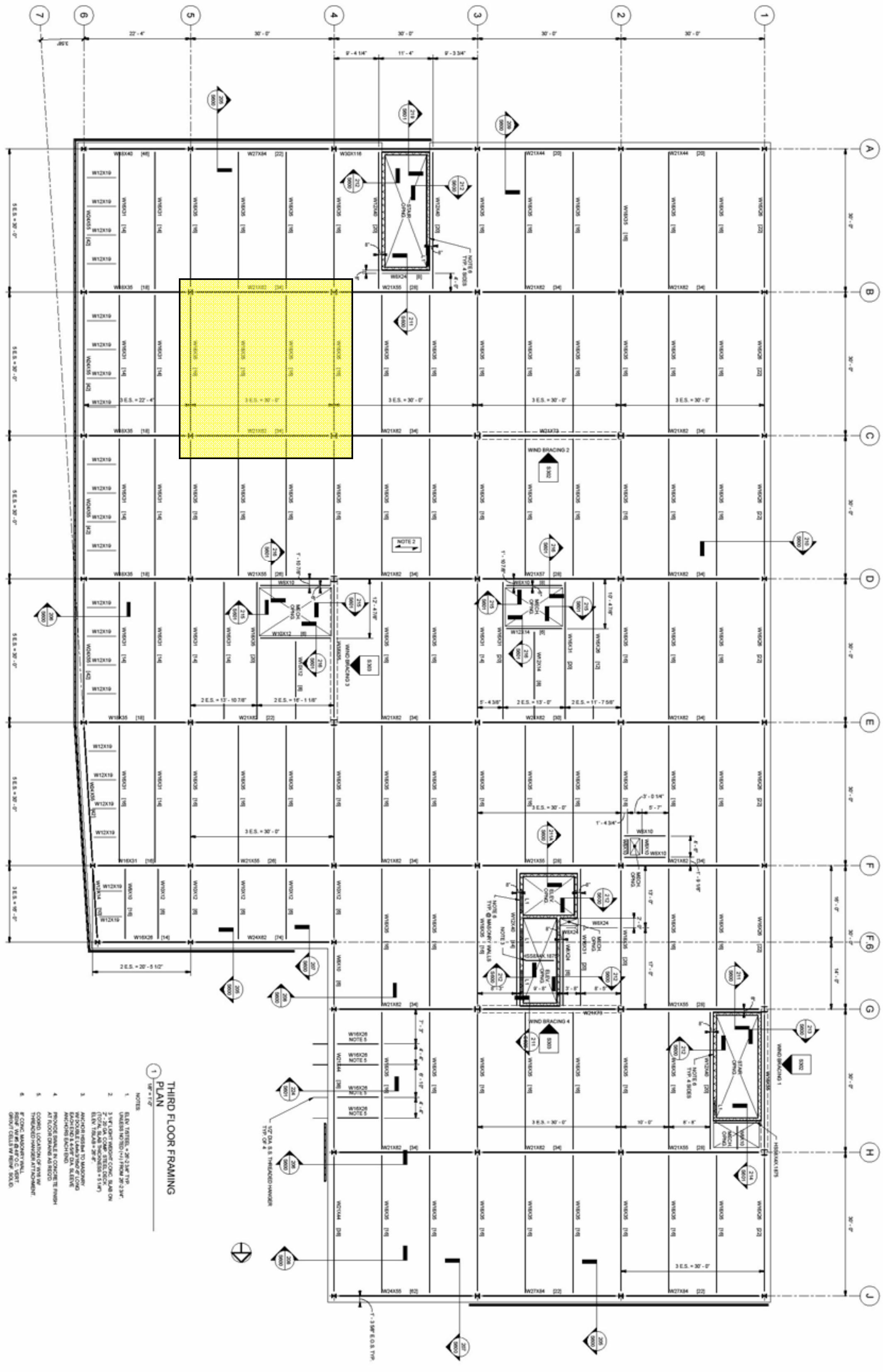
CONCLUSION

After investigating all these different floor systems it is not difficult to see why the original design was a composite steel floor system. The composite floor system is relatively cheap and easy to construct. Its large bay spans allow for the open floor plan needed in this office building layout. The easy construction allows for the building to be erected and completed in just over a year time frame. The cost of this system is relatively average compared to the others only due to the fact that light weight concrete was used. This system is lightest of the steel systems and has the smallest depth. All these contribute to making it the definite steel design choice.

However, the two way flat slab and two post tension slabs offer different advantages to the project. They present the building with the opportunity of minimizing the total depth of the floor system. This could allow for the addition of another floor. The post tension slab also proposes the possibility of increasing the span size to increase the open space throughout the building. I believe that either of these choices could be a possible alternative. Further analysis will be needed to determine a viable lateral system for these options.

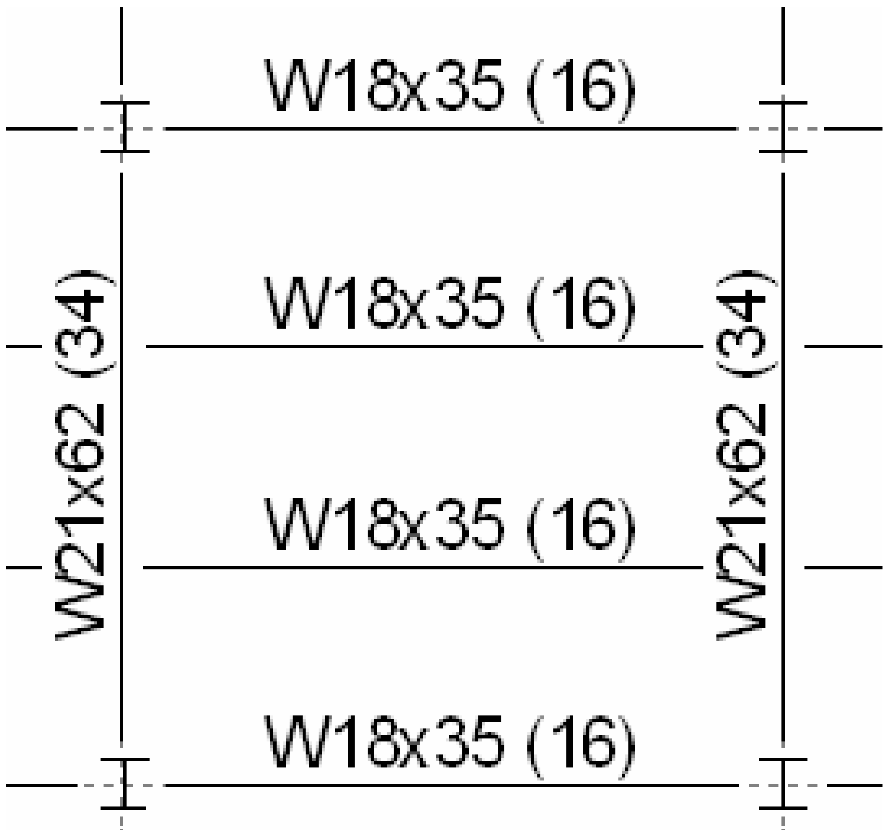
All design values used were in accordance with the codes referenced. Detailed calculations and notes are available for review in the appendices. Any questions or comments can be aimed at Dominic Manno via email: dam336@psu.edu.

APPENDIX A:
TYPICAL BAY USED FOR ALL CALCULATIONS



Typical Bay Used for Analysis

APPENDIX B:
EXISTING COMPOSITE STEEL FLOOR SYSTEM


W18x35 (16)
W18x35 (16)
W18x35 (16)
W18x35 (16)
W21x62 (34)
W21x62 (34)

Gravity Beam Design

RAM Steel v11.2
DataBase: 06265_00^RAM_Added Stair 04/01/08 16:58:17
Building Code: IBC Steel Code: ASD 9th Ed.

Floor Type: 2nd Floor Alt 2 **Beam Number = 120**

SPAN INFORMATION (ft): I-End (30.00,42.33) J-End (60.00,42.33)

Beam Size (Optimum) W18X35 Fy = 50.0 ksi
Total Beam Length (ft) = 30.00

COMPOSITE PROPERTIES (Not Shored):

	Left	Right
Concrete thickness (in)	3.25	3.25
Unit weight concrete (pcf)	115.00	115.00
f'c (ksi)	4.00	4.00
Decking Orientation	perpendicular	perpendicular
Decking type	USD 2" Lok-Floor	USD 2" Lok-Floor

beff (in)	90.00	Y bar(in)	=	17.78
Seff (in3) =	77.66	Str (in3)	=	96.50
Ieff (in4)	1113.61	Itr (in4)	=	1680.47
Stud length (in) =	4.00	Stud diam (in)	=	0.75

Stud Capacity (kips) q = 8.6
\# of studs: Full 50 Partial 16 Actual 16
Number of Stud Rows = 1 Percent of Full Composite Action = 26.59

LINE LOADS (k/ft):

Load	Dist	DL	CDL	LL	Red%	Type	CLL
1	0.000	0.640	0.570	0.800	13.8%	Red	0.200
	30.000	0.640	0.570	0.800			0.200

SHEAR: Max V (DL+LL) = 19.95 kips fv = 3.95 ksi Fv = 19.13 ksi

MOMENTS:

Span	Cond	Moment kip-ft	@ ft	Lb ft	Cb	Tension Flange fb	Tension Flange Fb	Compr Flange fb	Compr Flange Fb
Center	PreCmp +	86.6	15.0	0.0	1.00	18.05	33.00	18.05	33.00
	Max +	149.6	15.0	---	---				
	Mmax/Seff					23.12	33.00	---	---
	Mconst/Sx+Mpost/Seff					26.57	45.00		
Controlling		149.6	15.0	---	---	23.12	33.00	---	---

fc (ksi) = 0.31 Fc = 1.80

REACTIONS (kips):

	Left	Right
Initial reaction	11.55	11.55
DL reaction	9.60	9.60
Max +LL reaction	10.35	10.35
Max +total reaction	19.95	19.95

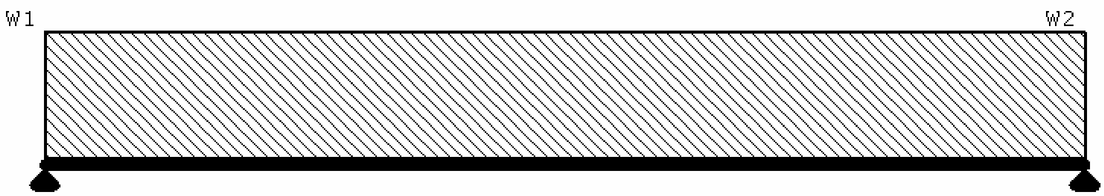
DEFLECTIONS:

Initial load (in)	at	15.00 ft	-0.702	L/D	513
Live load (in)	at	15.00 ft =	-0.389	L/D =	925
Post Comp load (in)	at	15.00 ft	-0.429	L/D =	839
Net Total load (in)	at	15.00 ft =	-1.131	L/D	318

Load Diagram

RAM Steel v11.2
DataBase: 06265_00^RAM_Added Stair 04/01/08 16:58:17
Building Code: IBC

Floor Type: 2nd Floor Alt 2 **Beam Number = 120**
Span information (ft): I-End (30.00,42.33) J-End (60.00,42.33)



Load	Dist	DL	LL+	LL-	Max Tot
	ft	k/ft	k/ft	k/ft	k/ft
W1	0.000	0.640	0.690	0.000	1.330
W2	30.000	0.640	0.690	0.000	1.330

Gravity Beam Design

RAM Steel v11.2
DataBase: 06265_00°RAM_Added Stair — 04/01/08 16:58:17
Building Code: IBC — Steel Code: ASD 9th Ed.

Floor Type: 2nd Floor Alt 2 **Beam Number = 7**

SPAN INFORMATION (ft): I-End (30.00,22.33) J-End (30.00,52.33)

Maximum Depth Limitation specified = 22.00 in
Beam Size (User Selected) = W21X62 Fy = 50.0 ksi
Total Beam Length (ft) = 30.00

COMPOSITE PROPERTIES (Not Shored):

	Left	Right
Concrete thickness (in)	3.25	3.25
Unit weight concrete (pcf)	115.00	115.00
f'c (ksi)	4.00	4.00
Decking Orientation	parallel	parallel
Decking type	USD 2" Lok-Floor	USD 2" Lok-Floor

beff (in) =	90.00	Y bar(in) =	19.28
Seff (in3)	159.66	Str (in3)	189.35
Ieff (in4) =	2501.74	Itr (in4) =	3566.80
Stud length (in)	4.00	Stud diam (in)	0.75

Stud Capacity (kips) q = 11.4
# of studs: Full = 123 Partial = 33 Actual = 34
Number of Stud Rows = 1 Percent of Full Composite Action = 27.44

POINT LOADS (kips):

Dist	DL	CDL	RedLL	Red%	NonRLL	StorLL	Red%	RoofLL	Red%	CLL
10.000	19.20	17.10	24.00	31.7	0.00	0.00	0.0	0.00	Snow	6.00
20.000	19.20	17.10	24.00	31.7	0.00	0.00	0.0	0.00	Snow	6.00

SHEAR: Max V (DL+LL) = 35.59 kips fv = 4.24 ksi Fv = 20.00 ksi

MOMENTS:

Span	Cond	Moment	@	Lb	Cb	Tension Flange		Compr Flange	
		kip-ft	ft	ft		fb	Fb	fb	Fb
Center	PreCmp	231.0	10.0	0.0	1.00	21.83	33.00	21.83	33.00
	Max +	355.9	10.0		---				
	Mmax/Seff					26.75	33.00	---	---
	Mconst/Sx+Mpost/Seff					30.06	45.00	---	---
Controlling		355.9	10.0	---	---	26.75	33.00	---	---

fc (ksi) 0.43 Fc 1.80

REACTIONS (kips):

	Left	Right
Initial reaction	23.10	23.10
DL reaction	19.20	19.20
Max +LL reaction	16.39	16.39
Max + total reaction	35.59	35.59

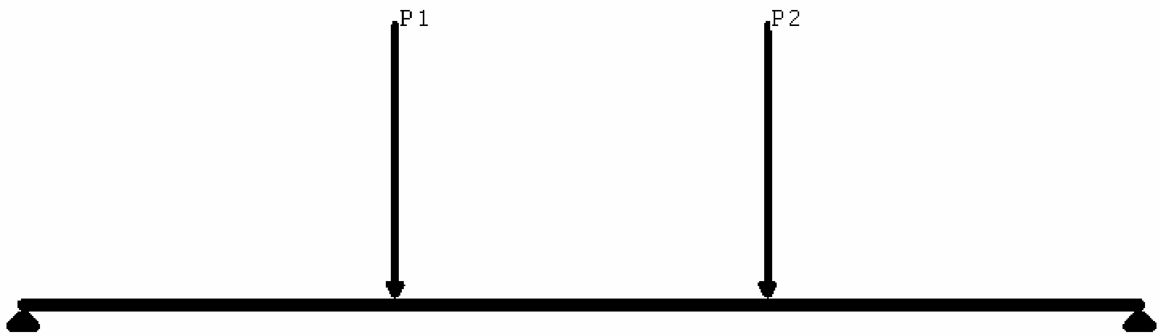
DEFLECTIONS:

Initial load (in)	at	15.00 ft =	-0.734	L/D = 490
Live load (in)	at	15.00 ft =	-0.374	L/D = 962
Post Comp load (in)	at	15.00 ft =	-0.422	L/D = 853

Load Diagram

RAM Steel v11.2
DataBase: 06265_00^RAM_Added Stair 04/01/08 16:58:17
Building Code: IBC

Floor Type: 2nd Floor Alt 2 **Beam Number = 7**
Span information (ft): I-End (30.00,22.33) J-End (30.00,52.33)



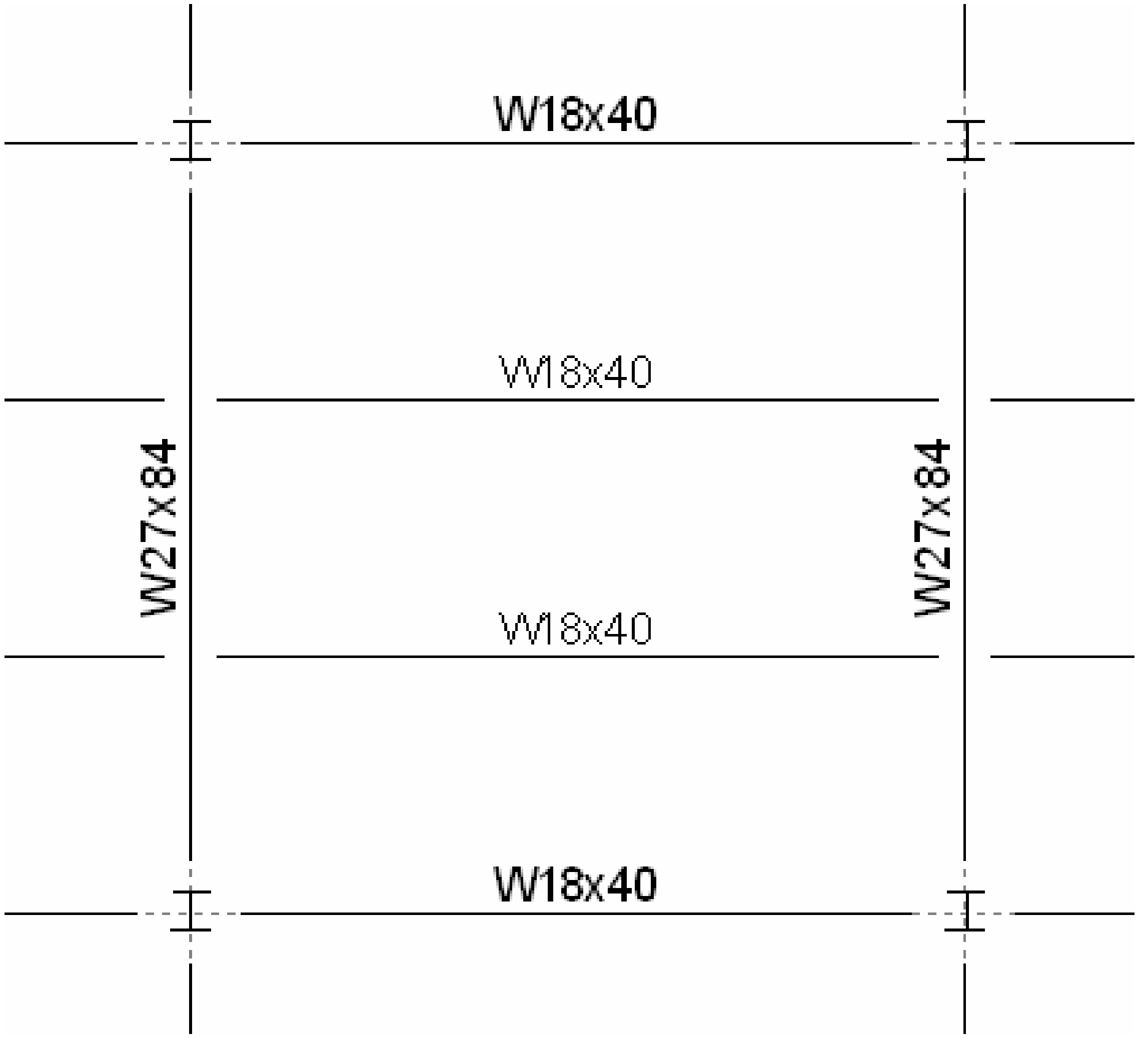
Load	Dist ft	DL kips	LL+ kips	LL- kips	Max Tot kips
P1	10.000	19.199	16.392	0.000	35.591
P2	20.000	19.199	16.392	0.000	35.591

Assembly B10102542300 **Based on National Average Costs**

Floor, composite metal deck, 5" slab, 30'x30' bay, 29" total depth, 75 PSF superimposed load, 129 PSF total load

Description	Quantity	Unit	Material	Installation	Total
Welded wire fabric, sheets, 6 x 6 - W1.4 x W1.4 (10 x 10) 121 lb. per C.S.F., A185	0.011	C.S.F.	0.15	0.34	0.50
Structural concrete, ready mix, normal weight, 3000 psi, includes local aggregate, sa...	0.011	C.Y.	1.25	0.00	1.25
Structural concrete, placing, elevated slab, pumped, less than 6" thick, includes vibra...	0.011	C.Y.	0.00	0.31	0.31
Concrete finishing, floors, monolithic, machine trowel finish	1.000	S.F.	0.00	0.76	0.76
Curing, sprayed membrane compound	0.010	C.S.F.	0.05	0.08	0.13
Structural steel project, apartment, nursing home, etc, 100-ton project, 3 to 6 stories...	9.100	Lb.	10.47	3.37	13.83
Metal decking, steel, non-cellular, composite, galvanized, 3" D, 20 ga	1.050	S.F.	2.07	0.89	2.96
Metal decking, steel edge closure form, galvanized, with 2 bends, 12" wide, 18 ga	0.033	L.F.	0.12	0.07	0.18
Cementitious Fireproofing, sprayed mineral fiber or cementious for fireproofing, bea...	0.790	S.F.	0.39	0.66	1.04
Cementitious Fireproofing, sprayed mineral fiber or cementious for fireproofing, corr...	1.000	S.F.	0.74	1.00	1.74
Total			**$15.25**	**$7.50**	**$22.75**

APPENDIX C: NON-COMPOSITE STEEL FLOOR SYSTEM


W18x40
W18x40
W27x84
W27x84
W18x40
W18x40

Gravity Beam Design

RAM Steel v11.2
DataBase: noncomp
Building Code: IBC

10/20/08 10:29:33
Steel Code: ASD 9th Ed.

Floor Type: noncomp **Beam Number = 34**

SPAN INFORMATION (ft): I-End (30.00,50.00) J-End (60.00,50.00)

Beam Size (Optimum) = W18X40 Fy = 50.0 ksi
Total Beam Length (ft) = 30.00

LINE LOADS (k/ft):

Load	Dist	DL	LL	Red%	Type
1	0.000	0.850	0.800	13.8%	Red
	30.000	0.850	0.800		
2	0.000	0.040	0.000	---	NonR
	30.000	0.040	0.000		

SHEAR: Max V (DL+LL) = 23.70 kips fv = 4.20 ksi Fv = 20.00 ksi

MOMENTS:

Span	Cond	Moment	@	Lb	Cb	Tension Flange		Compr Flange	
		kip-ft	ft	ft		fb	Fb	fb	Fb
Center	Max +	177.8	15.0	0.0	1.00	31.19	33.00	31.19	33.00
Controlling		177.8	15.0	0.0	1.00	31.19	33.00	---	---

REACTIONS (kips):

	Left	**Right**
DL reaction	13.35	13.35
Max +LL reaction	10.35	10.35
Max +total reaction	23.70	23.70

DEFLECTIONS: (Camber = 1/2)

Dead load (in)	at	15.00 ft	=	-0.914	L/D	=	394
Live load (in)	at	15.00 ft	=	-0.708	L/D	=	508
Net Total load (in)	at	15.00 ft	=	-1.123	L/D	=	321

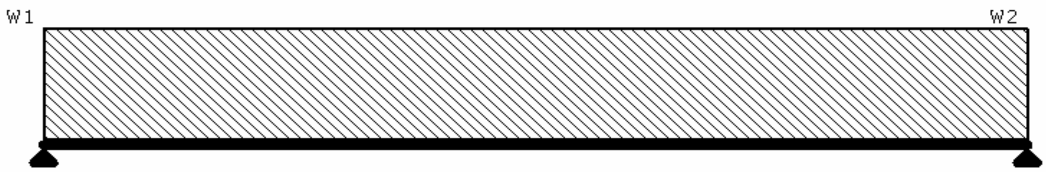
Load Diagram

RAM Steel v11.2
DataBase: noncomp
Building Code: IBC

10/20/08 10:29:33

Floor Type: noncomp **Beam Number = 34**

Span information (ft): I-End (30.00,50.00) J-End (60.00,50.00)



Load	Dist	DL	LL+	LL-	Max Tot
	ft	k/ft	k/ft	k/ft	k/ft
W1	0.000	0.890	0.690	0.000	1.580
W2	30.000	0.890	0.690	0.000	1.580

Gravity Beam Design

RAM Steel v11.2
DataBase: noncomp
Building Code: IBC

10/20/08 10:29:33
Steel Code: ASD 9th Ed.

Floor Type: noncomp **Beam Number = 12**

SPAN INFORMATION (ft): I-End (60.00,30.00) J-End (60.00,60.00)

Beam Size (Optimum) = W27X84 Fy = 50.0 ksi
Total Beam Length (ft) = 30.00

POINT LOADS (kips):

Dist	DL	RedLL	Red%	NonRLL	StorLL	Red%	RoofLL	Red%
10.000	13.35	12.00	31.7	0.00	0.00	0.0	0.00	Snow
10.000	13.35	12.00	31.7	0.00	0.00	0.0	0.00	Snow
20.000	13.35	12.00	31.7	0.00	0.00	0.0	0.00	Snow
20.000	13.35	12.00	31.7	0.00	0.00	0.0	0.00	Snow

LINE LOADS (k/ft):

Load	Dist	DL	LL	Red%	Type
1	0.000	0.084	0.000	---	NonR
	30.000	0.084	0.000		

SHEAR: Max V (DL+LL) = 44.36 kips fv = 3.79 ksi Fv = 19.44 ksi

MOMENTS:

Span	Cond	Moment	@	Lb	Cb	Tension Flange		Compr Flange	
		kip-ft	ft	ft		fb	Fb	fb	Fb
Center	Max +	440.5	15.0	10.0	1.00	24.81	30.00	24.81	29.55
Controlling		440.5	15.0	10.0	1.00	---	---	24.81	29.55

REACTIONS (kips):

	Left	**Right**
DL reaction	27.97	27.97
Max +LL reaction	16.39	16.39
Max +total reaction	44.36	44.36

DEFLECTIONS:

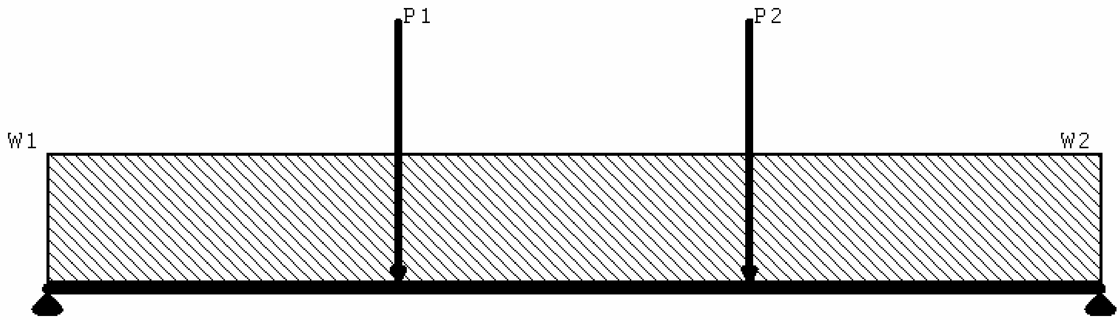
Dead load (in)	at	15.00 ft	=	-0.554	L/D	=	650
Live load (in)	at	15.00 ft	=	-0.328	L/D	=	1096
Net Total load (in)	at	15.00 ft	=	-0.882	L/D	=	408

Load Diagram

RAM Steel v11.2
DataBase: noncomp
Building Code: IBC

10/20/08 10:29:33

Floor Type: noncomp **Beam Number = 12**
Span information (ft): I-End (60.00,30.00) J-End (60.00,60.00)



Load	Dist	DL	LL+	LL-	Max Tot
	ft	kips	kips	kips	kips
P1	10.000	26.704	16.392	0.000	43.096
P2	20.000	26.704	16.392	0.000	43.096
	ft	k/ft	k/ft	k/ft	k/ft
W1	0.000	0.084	0.000	0.000	0.084
W2	30.000	0.084	0.000	0.000	0.084

Assembly B10102414000 **Based on National Average Costs**
W beam and girder, 25'x20' bay, 125 PSF superimposed load, 21" deep, fireproofing .827 SF/SF, 175 PSF total load

Description	Quantity	Unit	Material	Installation	Total
Structural steel project, offices, hospitals, etc, 100-ton project, 3 to 6 stories, A992 s...	8.800	Lb.	10.12	3.43	13.55
Cementitious Fireproofing, sprayed mineral fiber or cementious for fireproofing, bea...	0.827	S.F.	0.41	0.69	1.09
Total			**$10.55**	**$4.12**	**$14.67**

Assembly B10102581020 **Based on National Average Costs**
Floor, metal deck, 18 ga, 3" deep, concrete slab, 11' span, 5" deep, 125 PSF superimposed load, 169 PSF total load

Description	Quantity	Unit	Material	Installation	Total
C.I.P. concrete forms, elevated slab, edge forms, to 6" high, 4 use, includes shoring,...	0.050	L.F.	0.01	0.17	0.18
Welded wire fabric, sheets, 6 x 6 - W1.4 x W1.4 (10 x 10) 121 lb. per C.S.F., A185	0.011	C.S.F.	0.15	0.34	0.50
Structural concrete, ready mix, normal weight, 3000 psi, includes local aggregate, sa...	0.009	C.Y.	1.03	0.00	1.03
Structural concrete, placing, elevated slab, pumped, less than 6" thick, includes vibra...	0.009	C.Y.	0.00	0.25	0.25
Concrete finishing, floors, monolithic, machine trowel finish	1.000	S.F.	0.00	0.76	0.76
Curing, sprayed membrane compound	0.010	C.S.F.	0.05	0.08	0.13
Metal decking, steel, non-cellular, composite, galvanized, 3" D, 18 ga	1.050	S.F.	2.54	0.93	3.48
Total			**$3.78**	**$2.53**	**$6.31**

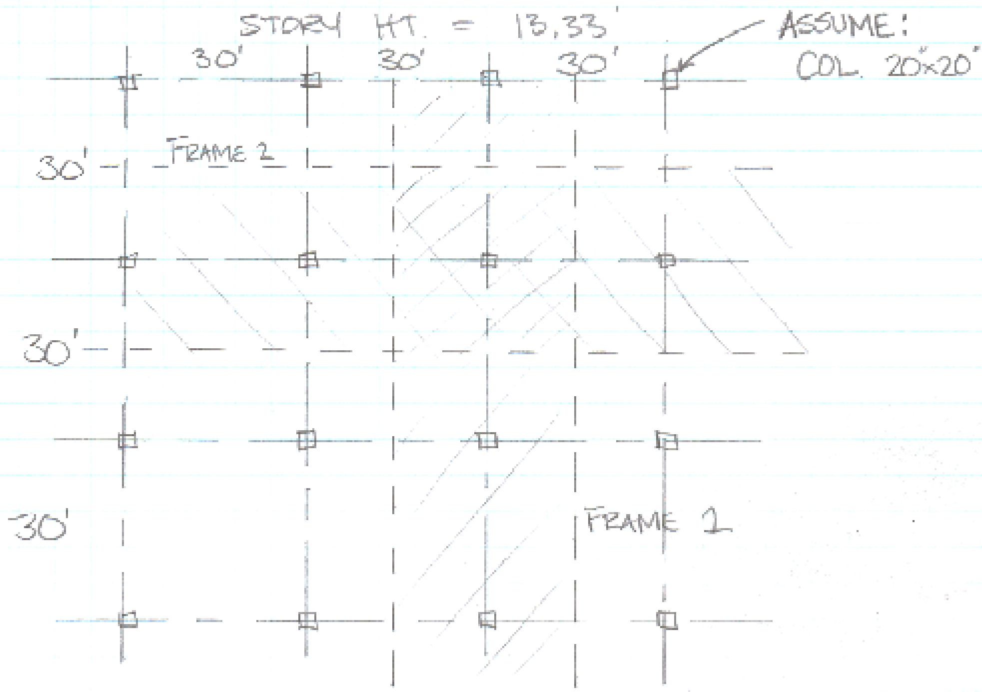
APPENDIX D:
TWO WAY FLAT SLAB WITH DROP PANELS

TWO WAY FLAT SLAB
WITH DROP PANELS

ASSUME: f'_c = 5,000 PSI
f_y = 60,000 PSI

LIVE LOAD = 80 PSF
PARTITION = 20 PSF
S.I.D.L. = 10 PSF

TYP INT. BAY



SLAB THK: TABLE 9.5 (c) ACI

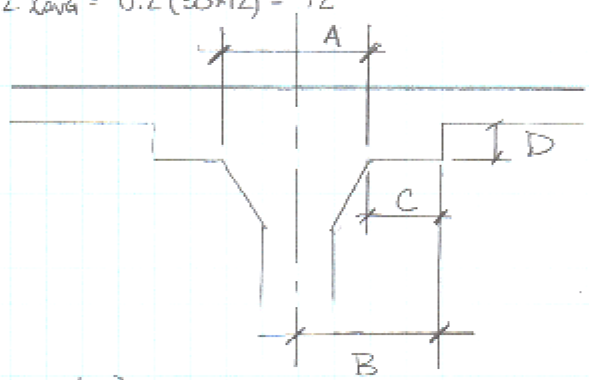
TRIAL $t = \frac{l_n}{36}$

$l_n = 30' - 20/12 = 28.3'$

$t_{min} = \frac{28.3'(12)}{36} = 9.43'' \approx 9.5''$

SIZE DROP PANEL

$A = 0.2\, l_{avg} = 0.2(30 \times 12) = 72''$



$B = \frac{l}{6} = \frac{30(12)}{6} = 60''$ $C = 60 - 36 = 24''$

$D \geq t/4$ BUT $< \frac{1}{4} C$ USE $D = 3.5''$

$W_u = (1.2)\left[\frac{9.5}{12}(150) + 30\right] + 1.6\left[80\right] = 307$ PSF

FRAME 1 & 2 ANALYSIS WILL BE SAME SINCE BAY DIMENSIONS AND COL DIMENSIONS ARE THE SAME.

FRAME 1 & 2:

$M_o = \left(\frac{1}{8}\right) 307 \text{ PSF} (30')(28.3')^2 = 922'^k$

MOMENTS

$M^- = 0.65M_o = -599'^k$

$M^+ = 0.35M_o = 323'^k$

ACI TABLES 13.6.4.1 & 13.6.4.4

M^- 75% TO C.S. 25% TO M.S.

M^+ 60% TO C.S. 40% TO M.S.

COL. ST. = 15' MID ST. = 15'

FRAME 1 & 2

M_{TOT}	-599	323	-599
$M_{C.S.}$	-449	194	-449
$M_{M.S.}$	-150	129	-150

ASSUME #7 BARS

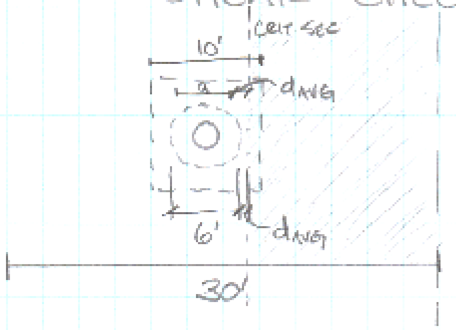
$d_{PANEL} = 15" - \frac{0.875}{2} - 0.75 = 11.81"$

$d_{SLAB} = 9.5 - \frac{0.875}{2} - 0.75 = 8.31"$

FRAME 1 & 2

ITEM	DESCRIPTION	CS		MS	
		M^-	M^+	M^-	M^+
1	MOMENT	-449	194	-150	129
2	b	120"	180"	180"	180"
3	d	11.81	8.31	8.31	8.31
4	M_n	-499	216	-167	143
5	R	358	209	161	138
6	ρ	0.0062	0.0036	0.0027	0.0023
7	A_s	8.79	5.38	4.04	3.44
8	$A_{s\,min}$	3.12	3.42	3.42	3.42
9	N	15	9	7	6
10	N_{min}	5	10	10	10

SHEAR CHECK:



$d_{AVG} = 11.81"$

CRIT SEC =

$$a^2 = \frac{\pi (6^2)}{4}$$

$$a = 5.32'$$

$$15' - \frac{5.32'}{2} - \frac{11.81}{12} = 11.36'$$

$W_u = 307$ PSF

$V_u = 307(30 \times 11.36) = 105^k$

CONS.

$\phi V_c = 0.75(2)\sqrt{5000}\,(30 \times 12)(8.31)$

$\phi V_c = 317^k > 105$ OK

PUNCHING SHEAR

DROP PANEL AREA

DROP PANEL $V_u = 307[30 \times 30 - 121]$

$V_u = 239^k$

$$V_c = \min \begin{cases} 4\sqrt{5000}\,(480)(11.81)/1000 = 1603^k \\ \left[\frac{40}{(480/11.81)} + 2\right]\sqrt{5000}\,(480)(11.81)/1000 = 1196^k \end{cases}$$

$\phi V_c = 0.75(1196) = 897 > 239$ OK

CAPITAL AREA

CAPITAL $V_u = 307[(30 \times 30) - 38.31]$

$= 265^k$

$$V_c = \min \begin{cases} 4\sqrt{5000}\,(263)(11.81)/1000 = 879^k \\ \left[2 + \frac{4}{1}\right]\sqrt{5000}\,(263)(11.81)/1000 = 1318^k \\ \left[\frac{40}{(263/11.18)} + 2\right]\sqrt{5000}\,(263)(11.81)/1000 = 813^k \end{cases}$$

$\phi V_c = 0.75(813) = 610^k > 265^k$ OK

CUTOFFS IN FRAMES 1 & 2

COLUMN STRIP

−M REINF FROM CENTERLINE OF COL

$0.33 \ell_n = 9.35'$ 15 #7 BARS

+M REINF CONTINUOUS ACROSS BOTTOM OF SLAB

10 #7 BARS

MIDDLE STRIP

−M REINF

$0.22 \ell_n = 6.25'$ 10 #7 BARS

+M REINF CONTINUOUS ACROSS BOTTOM OF SLAB

10 #7 BARS

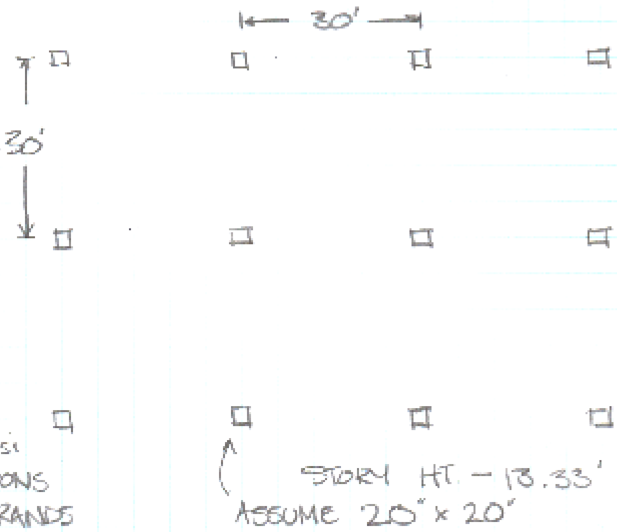
Assembly B10102226600 **Based on National Average Costs**

Flat slab, concrete, with drop panels, 10.5" slab/7.5" panel, 18" column, 30'x30' bay, 75 PSF superimposed load, 217 PSF total load

Description	Quantity	Unit	Material	Installation	Total
C.I.P. concrete forms, beams and girders, exterior spandrel, plywood, 12" wide, 4 us...	0.035	SFCA	0.05	0.30	0.35
C.I.P. concrete forms, elevated slab, flat slab with drop panels, to 15' high, 4 use, in...	0.997	S.F.	1.75	4.90	6.65
Reinforcing steel, in place, elevated slabs, #4 to #7, A615, grade 60, incl labor for a...	4.088	Lb.	2.08	1.51	3.60
Structural concrete, ready mix, normal weight, 3000 psi, includes local aggregate, sa...	0.944	C.F.	4.00	0.00	4.00
Structural concrete, placing, elevated slab, pumped, 6" to 10" thick, includes vibratin...	0.944	C.F.	0.00	1.05	1.05
Concrete finishing, floors, monolithic, machine trowel finish	1.000	S.F.	0.00	0.76	0.76
Curing, sprayed membrane compound	0.010	C.S.F.	0.05	0.08	0.13
Total			**$7.95**	**$8.60**	**$16.55**

APPENDIX E:
TWO WAY POST TENSION SLAB

TWO WAY POST TENSIONED DESIGN



LOADS:

DL: SELFWT.
SID: 10 PSF
LIVE LOAD: 50 PSF

MATERIALS:

NORMAL WT CONC.
$f'_c = 5{,}000$
$f'_{ci} = 3{,}000$
REBAR: $f_y = 60{,}000$ psi
PT: UNBONDED TENDONS
½" φ 7-WIRE STRANDS
$A = 0.153$ in²
$f_{pu} = 270$ ksi
ESTIMATED PRESTRESS LOSSES
15 ksi (ACI 18.6)
$f_{se} = 0.7(270) - 15 = 174$ ksi (ACI 18.5.1)
$P_{eff} = A(f_{se}) = (0.153)(174) = 26.6$ kips/TENDONS

SLAB THICKNESS

START WITH $L/h = 45$
SPAN = 30 ft

$h = 30(12)/45 = 8"$

DL = 100 PSF
SID = 10 PSF
LL_o = 80 PSF

$K_{LL} = 1$
AI = 900 ft^2

LL REDUCTION = $80\left(0.25 + 15/\sqrt{A_I}\right)$
= 60 PSF

SECTION PROPERTIES

CLASS U (ACI. 18.3.3, 18.3.4)

$A = bh = 30(12)(8) = 2880\ in^2$

$S = bh^2/6 = 360(8)^2/6 = 3840\ in^3$

DESIGN PARAMETERS

ALLOWABLE STRESSES: CLASS U (ACI 18.3.3)

TIME OF JACKING (ACI 18.4.1)

$f'_{ci} = 3000$ PSI

COMPRESSION = $0.6 f'_{ci} = 0.6(3000) = 1800$ psi

TENSION = $3\sqrt{f'_{ci}} = 3\sqrt{3000} = 164$ psi

AT SERVICE LOADS (ACI 18.4.2, 18.3.3)

$f'_c = 5000$ psi

COMPRESSION = $0.45 f'_c = 0.45(5000) = 2{,}250$ psi

TENSION = $6\sqrt{f'_c} = 6\sqrt{5000} = 424$ psi

AVG. PRECOMP LIMITS:

$P/A = 125$ psi min   300 psi max

TARGET LOAD BALANCES:

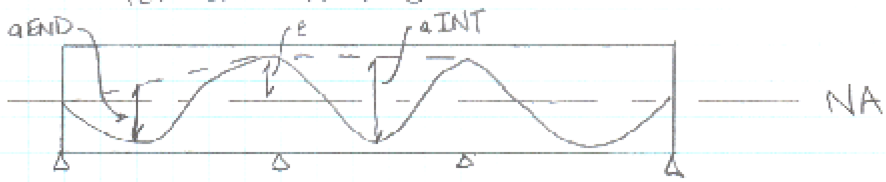
$0.75(W_{DL}) = 0.75(100) = 75$ PSF

COVER REQ. (2 HR FIRE RATING, ASSUME CARBONATE AGGREGATE)

RESTRAINED SLABS = 3/4" BOTTOM

UNRESTRAINED SLABS = $1\frac{1}{2}$" BOTTOM
= 3/4" TOP

TENDON PROFILE



TENDON ORDINATE	TENDON (CG) LOCATION*
EXT. SUP. - ANCHOR	4.0"
INT. SUP. - TOP	7.0"
INT. SPAN - BOT	1.0"
END SPAN - BOT	1.75"

$a_{INT} = 7 - 1 = 6"$ $a_{END} = (4+7)/2 - 1.75 = 3.75"$

e = VARIES

PRESTRESS FORCE REQ TO BAL 0.75 OF DL

$W_b = 0.75\, W_{DL} = 100(0.75)(30)/1000 = 2.25$ KLF

FORCE NEEDED IN TENDONS TO COUNTERACT LOAD IN END BAY =

$P = w_b L^2 / 8 a_{END}$
$= 2.25(30)^2 / 8\,(3.75/12) =$
$= 810^k$

CHECK PRECOMPRESSION ALLOWANCE

$\# \text{TENDONS} = 810/26.6$
$= 30.4 \Rightarrow$ USE 30 TENDONS

$P_{ACTUAL} = 30(26.6) = 798$

$W_b = (798/810)(2.25) = 2.22^{k}/ft$

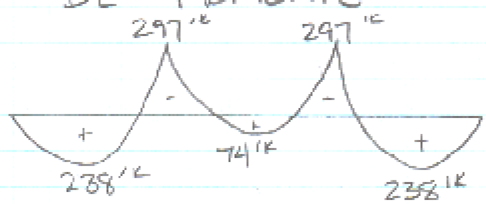
ACTUAL PRECOMPRESSION STRESS

$P_{ACTUAL}/A = 798(1000)/2880 = 277 \text{ psi}$ ✓ OK

EFFECTIVE PRESTRESS FORCE
$P_{EFF} = 798^{k}$

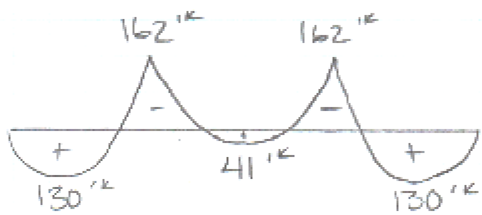
DL MOMENTS

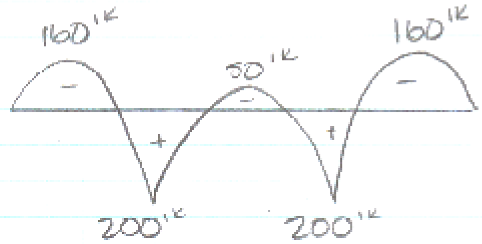
$W_{DL} = 110(30)/1000 = 3.3 \text{ k/ft}$



LL MOMENTS

$W_{LL} = 60(30)/1000 = 1.8 \text{ k/ft}$





BALANCING
$w_b = 2.22\ ^k/_{ft}$

STAGE 1: STRESSES IMMEDIATELY AFTER JACKING
ACI (18.4.1)

MIDSPAN STRESSES

$f_{TOP} = (-M_{DL} + M_{BAL}) / S - P/A$

$f_{BOT} = (+M_{DL} - M_{BAL}) / S - P/A$

INT SPAN.

$f_{TOP} = [(-74 + 50)(12)(1000)] / (3840) - 277$

$= -352$ psi COMPRESSION $< 0.6 f'_{ci} = 1800$ psi ✓

$f_{BOT} = [(74 - 50)(12)(1000)] / (3840) - 277$

$= -202$ psi $< 0.6 f'_{ci}$ ✓

END SPAN.

$f_{TOP} = [(-238 + 160)(12)(1000)] / 3840 - 277$

$= -521$ psi $< 0.6 f'_{ci}$ ✓

$f_{BOT} = [(238 - 160)(12)(1000)] / 3840 - 277$

$= -33.25 < 0.6 f'_{ci}$ ✓

SUPPORT STRESSES

$f_{TOP} = (+M_{DL} - M_{BAL})/S - P/A$

$f_{BOT} = (-M_{DL} + M_{BAL})/S - P/A$

$f_{TOP} = [(297 - 200)(12000)]/3840 - 277$

$= 26 \text{ psi} < 3\sqrt{f'_{ci}} = 164$ ✓

$f_{BOT} = [(-297 + 200)(12000)]/3840 - 277$

$= -580 < 0.6 f'_{ci}$ ✓

STAGE 2 : (18.3.3 & 18.4.2)

STRESSES AT SERVICE LOAD

MIDSPAN STRESSES

$f_{TOP} = (-M_{DL} - M_{LL} + M_{BAL})/S - P/A$

$f_{BOT} = (+M_{DL} + M_{LL} - M_{BAL})/S - P/A$

INT SPAN

$f_{TOP} = [(-74 - 41 + 50)(12000)]/3840 - 277$

$= -480 < 0.45 f'_c = 2250$ ✓

$f_{BOT} = [(74 + 41 - 50)(12000)]/3840 - 277$

$= -74 < 2250 \text{ psi}$ ok ✓

END SPAN

$f_{TOP} = [(-238 - 130 + 160)(12000)]/3840 - 277$

$= -927 < 2250 \text{ psi}$ ✓

$f_{BOT} = [(238 + 130 - 160)(12000)]/3840 - 277$

$= 373 \text{ psi} < 6\sqrt{f'_c} = 424$ ✓

SUPPORT STRESSES

$f_{TOP} = (+M_{DL} + M_{LL} - M_{BAL})/S - P/A$

$f_{BOT} = (-M_{DL} - M_{LL} + M_{BAL})/S - P/A$

$f_{TOP} = [(297 + 162 - 200)(12000)]/3840 - 277$

$= 533 > 6\sqrt{f'_c} \therefore 0.6 f_y$ REINF.

$f_{BOT} = [(-297 - 162 + 200)(12000)]/3840 - 277$

$= -1086 < 2250$ ✓

ULTIMATE STRENGTH

$M_1 = P(e)$

$e = 0$ AT EXT SUP.

$e = 3.0$ AT INT SUP.

$M_1 = (798)(3)/12 = 200$ ft-k

$M_{SEC} = M_{BAL} - M_1$

$= 200 - 200 = 0$ AT INT SUP.

$M_u = 1.2 M_{DL} + 1.6 M_{LL} + 1.0 M_{SEC}$

@ MIDSPAN $1.2(238) + 1.6(130) = 494$ ft-k

@ SUPPORT $1.2(-297) + 1.6(-162) = 616$ ft-k

DETERMINE MINIMUM BONDED REINFORCEMENT:

POS MOMENT REGION:

INT SPAN: $f_t = 26$ psi $< 2\sqrt{f'_c} = 141$ psi
NO POSITIVE REINF. REQ (ACI 18.9.3.1)

NEG MOMENT REGION:

$A_{s,min} = 0.00075 A_{cf}$ (ACI 18.9.3.3)

INTER. SUP.

$A_{cf} = 8(30)(12) = 2880$ in^2

$A_{s,min} = 0.00075(2880) = 2.16$ in^2
$= 11 - \#4$ (2.20 in^2) TOP

EXT. SUP.

$A_{cf} = 2880$ in^2

$A_{s,min} = 0.00075(2880) = 2.16$ in^2
$= 11 - \#4$ (2.20 in^2) TOP

ACI 18.9.4.2 MUST SPAN MIN OF 1/6 THE CLEAR SPAN ON EACH SIDE OF SUPPORT

ACI 18.9.3.3 MIN 4 BARS EACH DIRECTION

ACI 18.9.3.3 PLACE TOP BARS WITHIN 1.5h AWAY FROM THE FACE OF THE SUPPORT ON EACH SIDE

$1.5(8) = 12"$

MAX SPACING = 12' ACI 18.9.3.3

CHECK MIN REINF.

$M_n = (A_s f_y + A_{ps} f_{ps})(d - a/2)$

$A_{ps} = 0.153(30) = 4.59$

$f_{ps} = f_{se} + 10000 + (f'_c b d)/(300 A_{ps})$

$= 174000 + 10000 + [5000(30 \times 12) d] / 300(4.59)$

$= 184000 + 1307 d$

$a = (A_s f_y + A_s f_{ps}) / (0.85 f'_c b)$

AT SUPPORTS

$d = 8'' - 3/4'' - 1/4'' = 7''$

$f_{ps} = 184000 + 1307(7) = 193{,}149$ psi

$a = [(2.20)(60) + 4.59(193)] / [0.85(5)(30 \times 12)] = 0.67$

$\phi M_n = 0.9[(2.20)(60) + (4.59)(193)][(7 - \frac{0.67}{2})] / 12$

$= 509 < 616$

$A_{s\ REQ} = 5.8\ in^2$ USE 29 #4 TOP AT INT. SUP. BOTH DIRECTIONS

ACI 18.9.4.3

AT MIDSPAN (END SPAN)

$d = 8 - 1\tfrac{1}{2} - 1/4 = 6\tfrac{1}{4}$

$f_{ps} = 184000 + 1307(6.25) = 192$ ksi

$a = [(7.33)(60) + (4.59)(192)] / [(0.85)(5)(30 \times 12)] = 0.86$

$$\phi M_u = 0.9\left[(1.33)(60) + 4.59(192)\right]\left[6.25 - \frac{0.66}{2}\right]/12$$

$$= 577^{1k} > 494^{1k}$$

#5 @ 12" OC BOTTOM AT END SPANS