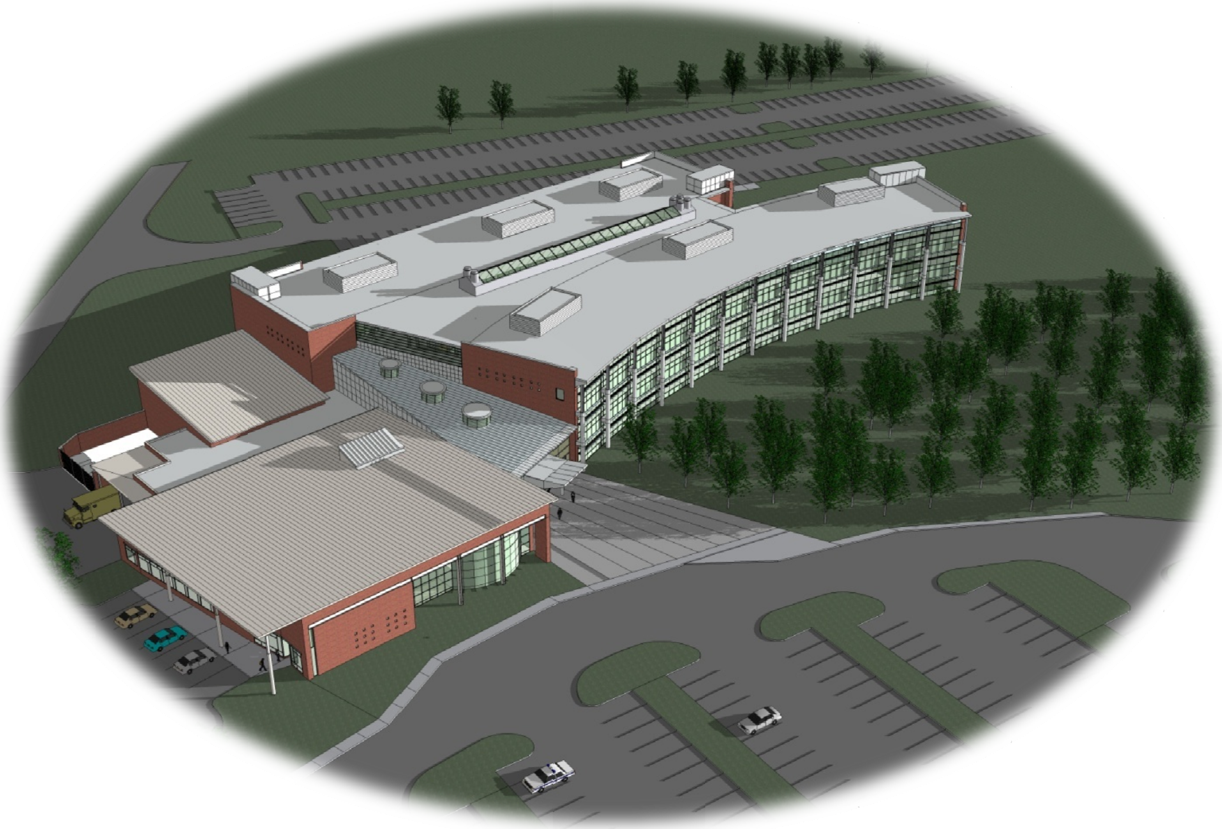
The Edward L Kelly Leadership Center
Prince William County School Administration Center



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Technical Report 2

October 29, 2007

Executive Summary

Purpose

The intent of this technical report is to report on the investigations of alternative floor systems for the Edward L Kelly Leadership Center. Each floor system that was investigated contains advantages, disadvantages, and conclusions about the system. A comparative matrix is provided as a summary of the comparisons of all five systems. The systems of interest in this report include:

- Non-composite steel/joist framing, moment connections (Existing)
- Composite steel framing
- 2-way concrete flat plate slab with drop panels
- Post-tensioned concrete slab
- Waffle slab - 2-way concrete joists

Conclusions

All the different systems each provide their own advantages and disadvantages. The existing system has a very easy to construct steel frame consisting of beams and filler joists. Joists are a very lightweight and cost-effective solution that also provides a means for passage of mechanical systems. However, moment connections as the lateral resisting systems are very laborious and costly.

The first alternative, steel composite framing, seems to be the best alternative system. The concrete is able to work with the steel to resist loads, reduce vibration, and reduce the size of the overall system. A new lateral system is likely to be considered, if possible, in this design.

The concrete systems added a great deal of dead load because of the heavy mass of the concrete. This is of great advantage when considering vibration. The total system depth is dramatically reduced compared to steel systems. The original steel system, for example, has a depth of 32" while the concrete systems have depths of 13" or 8.5". The two-way flat slab investigated will require drop panels to resist punching shear around columns. The waffle slab and two-way slab will require a new column layout for various reasons, which may be very disadvantageous. Post-tensioned systems are difficult to construct and require much attention to detail.

The steel composite framing is the only system that is relatively simple to construct and will meet the needs of the building. The waffle slab, however, although a new layout of columns will need to be done, seems to also be a good alternative. The preliminary investigation of the column layout revealed possibilities of additional columns in the east-west direction.

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Existing Structural System

FOUNDATIONS:

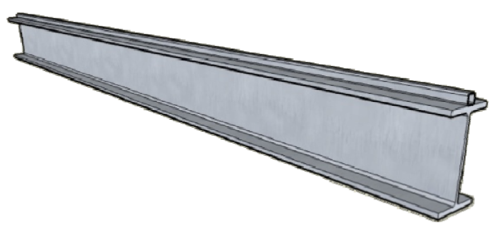
A shallow foundation type is used for this building. Foundations consist of spread footings and strip wall footings. The geotechnical engineer for the project indicated that the allowable bearing capacity of the soil is 3000 PSF. The top of the footings are set at (-2'-0") from grade. Reinforcement for spread footings range from (4)#5 BOT bars for the 3'-0"x3'-0" footings to (11)#7 TOP & BOT for the 11'-0"x11'-0" footings. Exterior column spread footings are typically 4'-0"x4'-0" to 6'-0"x6'-0" in the one-story portion and 7'-0"x7'-0" in the three-story portion. Interior column footings in the one-story portion are typically 6'-0"x6'-0" to 8'-0"x8'-0". The three-story interior column footings are 9'-0"x9'-0" to 11'-0"x11'-0". The strip wall footings are typically 2'-0" wide and 1'-0" thick. Reinforcement for strip footings are (3) continuous #5 bars. The strength of the concrete used for foundations is 3000 psi. The concrete strength for the 4" slab on grade is 3500 psi and contains 6x6-W1.4xW1.4 WWF at mid-depth.

COLUMNS:

All columns in the structural system are steel. In the one-story building, some typical interior columns include W12x79 and W10x68. Exterior columns are often rectangular HSS shapes. Typical shapes include HSS8x6x1/4 in the one-story building. In the three-story building, columns are, again, typically W-shapes for the interior and HSS shapes for the exterior. Typical shapes include W14x68 and W14x82 for the interior and circular HSS12.75x0.375 for the exterior.

FLOOR AND ROOF FRAMING:

Three-story portion:
Built up W21 shapes with HSS2½ (TOP) are typically used for beams while W24 are used for girders. The size of the bays are generally 24' wide and span approximately 30'. Steel joists are used to span inside the bays. 28K8 joists are the most common joist in the framing. Typical spacing is approximately 4' on center. Joists also frame the roof, where, to account for the heavy and asymmetric loads of mechanical equipment, KCS joists are commonly found. Roof beams are typically W18x35 and girders W21x44.


W21 with HSS2½

One-story portion:
This part of the building contains an elevated area that serves as an equipment platform. It covers a good portion of the footprint of this section. The "floor joists" are 26K9 spanning 30' in one part of this platform and 24K3/26K4 spanning 16'/19' respectively. Roof joists in the one-story portion are typically slightly larger than the 3-story building (28K10) since they span a much longer distance of around 47'. The structural plans show an area where the joists become increasingly closer to each other. This is due to the higher roof causing snow to drift onto the lower roof in addition to windward drift. A few special joists (KSP) are used in certain areas of the one-story roof framing to account for unique loading. This is generally where there

are folding partitions, causing heavy concentrated loading at points, in meeting rooms such as the School Board Meeting room.

LATERAL SYSTEM:

The lateral forces, such as wind and seismic forces, in the building are resisted entirely through moment frames. The engineer chose to implement a moment frame to resist these horizontal forces. The particular frame is a space moment frame, meaning that all of the steel frames are used in the moment frame system.

Codes and Loading

The Virginia Uniform Statewide Building Code (VUSBC), 2000 edition was used for the design of the Edward L Kelly Leadership Center. This code absorbs much of its code from the International Building Code (IBC). IBC2000 will be used when referencing the original design of this building. In addition to IBC, the following codes and specifications were also implemented into the design.

ASCE 7-98, Minimum Design Loads for Buildings and Other Structures
ACI 530-99, Building Code Requirements for Masonry Structures With Commentary
AISC Specification for Structural Steel Buildings, Allowable Stress Design and Plastic Design
AISC Code of Standard Practice for Steel Buildings and Bridges
Steel Deck Institute Design Manual for Composite Desks, Form Decks, and Roof Decks
AISI Specification for the Design of Cold Formed Steel Structural Members

Live Loads	IBC 2006	Snow Load
Meeting Rooms	50 + 20 PSF	
Office Space	50 + 20 PSF	
1st Floor Corridors	100 PSF	
Corridors above 1st Floor	80 PSF	
Stairwell	100 PSF	
Mechanical Rooms	150 PSF	
Storage	125 PSF	
Flat Roof		21 PSF
Sloped Roof		21 PSF

Floor - Superimposed Dead Loads	
Mechanical	4 PSF
Electrical / Lighting	3 PSF
Sprinklers	3 PSF
Drop Ceiling	5 PSF
Total	15 PSF

Roof - Superimposed Dead Loads	
Roofing / Insulation	5 PSF
Mechanical	4 PSF
Electrical / Lighting	3 PSF
Sprinklers	3 PSF
Drop Ceiling	5 PSF
Total	20 PSF

Existing Non-Composite Steel Moment Framing

The existing floor framing consists of non-composite steel W-shapes and joists filling in between the bays. All steel beam-to-beam connections are moment-resisting connections.

Advantages:

- Fast construction
- Cheaper materials (Joists)
- Long spans

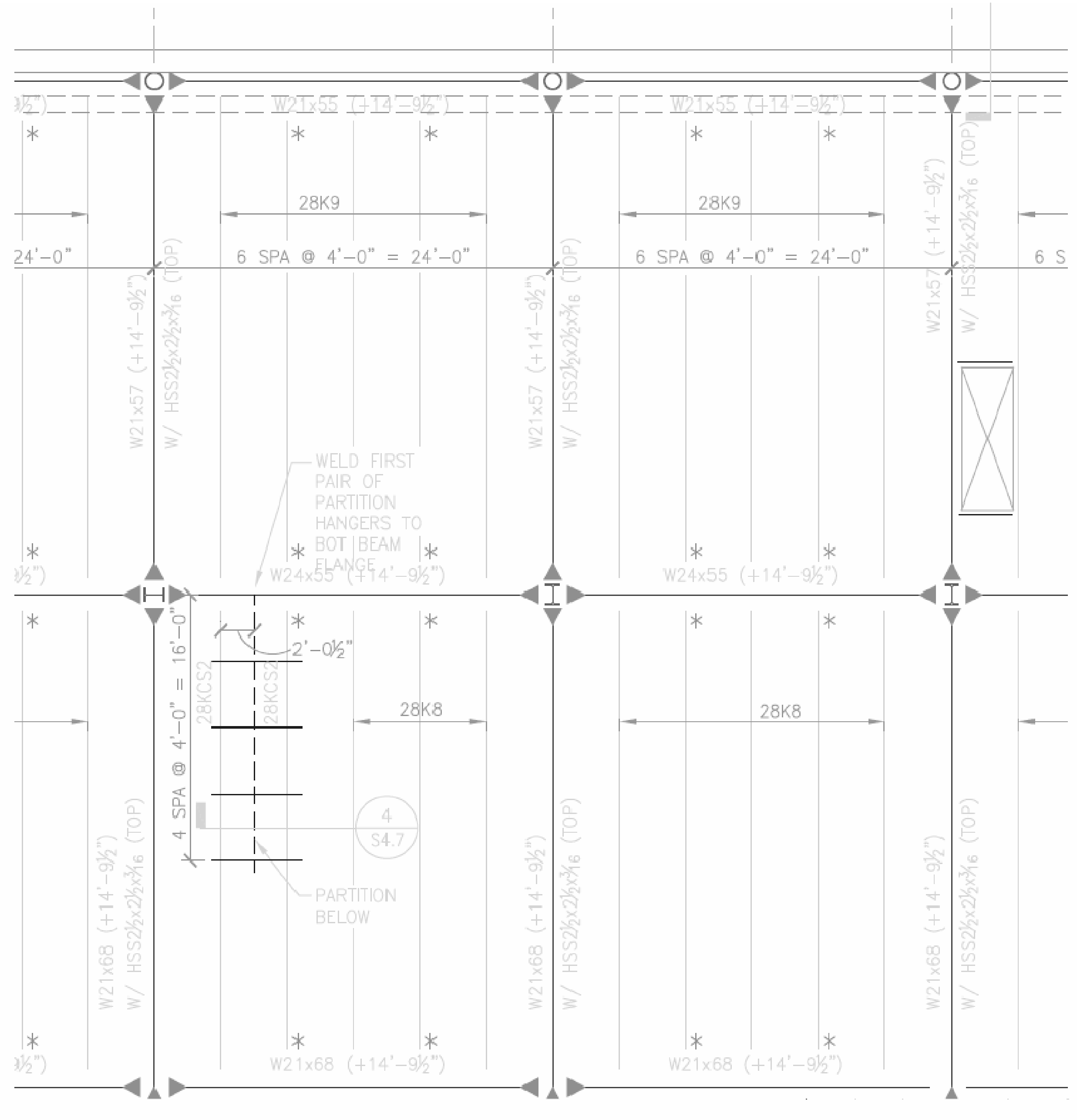
The use of steel framing enables a fast construction time. In addition, the use of non-composite steel framing (without the use of shear studs) allows more expeditious erection. Steel joists are relatively inexpensive compared to other framing systems. The long spans enabled by the steel framing is advantageous to the “open-office” type of architectural layout. In addition, steel framing fairs relatively well with vibration issues.

Disadvantages:

- Expensive and laborious connections
- Fire proofing needed
- Deep sections
- Vibration problems

Conclusions:

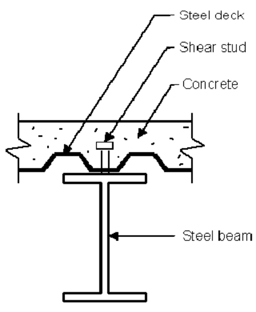
All steel beam-to-beam connections are moment connections. It is difficult to find good, quality welders to perform the connections which are very intricate and time-consuming to produce. Therefore, it is likely that cost and time savings from the lack of shear studs will be consumed by the time and money for moment connections. Also, because the concrete slab does not have composite action with the steel beams, the beams will tend to be of deeper section and heavy weight. The beams are not as much a factor in the depth of the system as much as the joists. Each joist has a section 28” deep. However, joists are very advantageous as they enable the passage of mechanical and electrical systems. Fireproofing of steel members is also necessary. Steel joists, in particular, are more difficult to fireproof.



Typical Bay 24'-0" x ≈31'-6"

Alternate One: Composite Floor Framing

Composite steel framing consists of steel beams or steel joists "compositely" interconnected with the concrete floor slab. By comparison, non-composite framing consists of beams or joists with steel decking that merely serves as formwork for the above concrete floor slab. In composite decking, the decking contains perforations and deformations that allow a mechanical connection to the concrete slab. Even more, steel studs are welded to the steel beams or joists and provide further mechanical fastening to the slab, allowing the slab and beam to act together to resist loading. Steel joists were used in the original design and *can* be used to provide a composite connection; however, this alternative design will consist of steel beams only acting compositely with the floor slab. The steel sections were able to be reduced from W21 (d=21.1", weight = 68 plf) to W16 (d=15.7", weight = 16 plf) resulting in significant cost and space savings. The slab thickness increases by only 0.5" from 4" to 4.5".



Composite Steel Beam/Deck Detail

Advantages:

- Light-weight sections compared to concrete
- Vibration control
- Greater economy/efficiency

Again, steel construction can be performed very quickly and relatively easy. Long bays can be designed by the use of composite construction much more than non-composite construction. Because the concrete acts in addition to the steel alone, more load can be carried overall. The steel beams need not carry as much load and, therefore, beams will be smaller in depth and weight per linear foot. Composite construction also allows better control of vibrations.

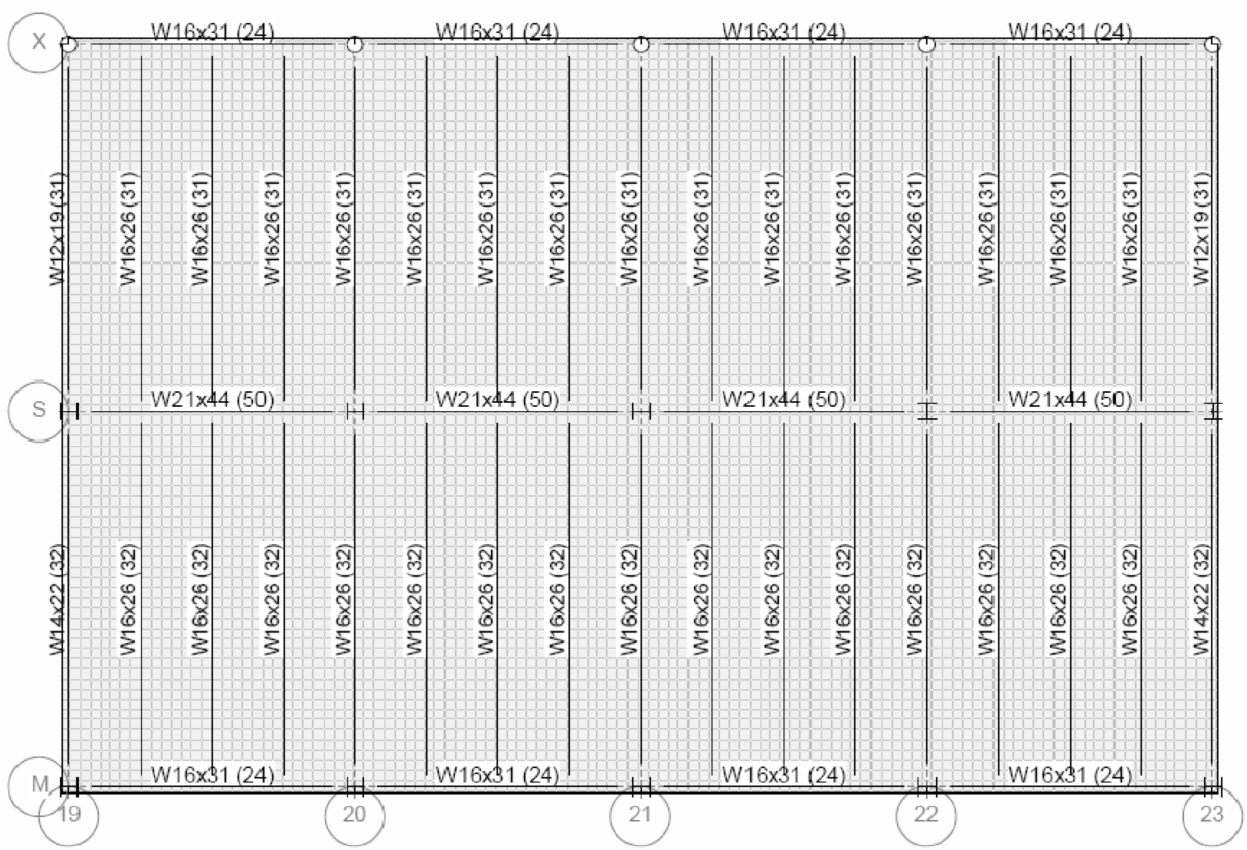
Disadvantages:

- Increased labor to add shear studs
- More expensive than concrete
- Fire protection needed

The use of shear studs will add labor to construction. As with all exposed steel, fireproofing is necessary. Cost of composite materials and labor is slightly more than non-composite construction. It is likely that alternative lateral resisting systems will be investigated for use with this system.

Conclusions:

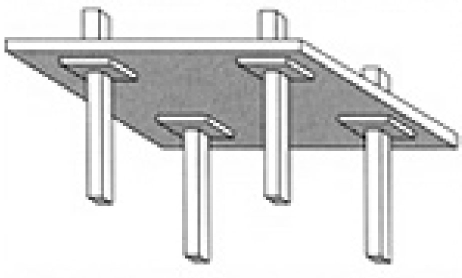
Composite steel construction has many advantages and seems to be a very good solution for the floor system.



Composite Floor Framing - RAM Structural System Output

Alternate Two: 2-way Concrete Flat Slab with Drop Panels

Concrete structural systems are good alternatives if a small slab thickness is required. However, 2-way systems generally perform better when bays span less than about 25 feet. Because the original design called for dimensions of 24'-0" x 31'-6", the dimensions needed to be dropped down. This required an additional column in the N-S direction and made the dimensions approximately 24'-0" x 21'-0". The slab thickness is governed by deflection and is set at 9". Due to punching shear around columns, drop panels were added at an addition thickness of 4". The total depth of the system is 13".



2-way Flat Slab with Drop Panels

Advantages:

The use of concrete offers several advantages over the existing steel construction. Overall, the structural floor system is generally decreased with mildly-reinforced concrete slabs. However, there are other considerations that need to be accounted for. Drop panels and column capitals could be a necessary part of the design, increasing the depth of the structural system at certain locations. Fireproofing is also a non-issue with concrete construction because fire protection for structural concrete. Vibrations and sound transmissions are also limited due to the solid mass that is required for the floor.

Disadvantages:

The use of concrete will add considerable weight to the structure. At 150 PCF for normal weight concrete, the self-weight of the system increase by 12.5 pounds per square foot for each inch of floor thickness. The self-weight of the slab is increased from 4.5 inches (composite alternate) to 9 inches which increases the self-weight of the slab by 56.25 pounds per square foot. Subtracting the weight of the steel, the net increase will still be increased by about 45 PSF. Seismic loads will therefore need to be investigated further. Changes in the original column layout will be necessary to complete a design in a two-way concrete system. These columns may interfere with the architectural goals of the project. A new lateral system will need to be investigated. The lead time of the project will need to be adjusted because of the time-consuming labor involved in installing and removing formwork during the curing of the concrete.

Conclusions:

Due to the fact that the original spans cannot likely be reproduced with a two-way flat plate design, this design does not seem like a likely alternative.

Alternate Three: Post-tensioned Concrete Slab

This prestressed concrete system will enable a significantly reduced slab thickness. The slab thickness, however, will be based on deflection characteristics and not strength issues. An 8.5" slab compares to the original design of about 32". Lightweight concrete was used in the design in order to keep loading down. As shown in Appendix A, a preliminary analysis with NWC and f'_c= 4000 psi yields failing results of concrete stresses. Research indicated that f'_c= 6000 psi is more appropriate, but still not the solution. It seemed that the loading would need to be dramatically decreased. The 6000 psi concrete was maintained and the NWC was replaced with LWC of 110 PCF. Results were adequate. Other design changes can be made, but involves changing the column layout, which is undesirable in the N-S direction under preliminary investigation.

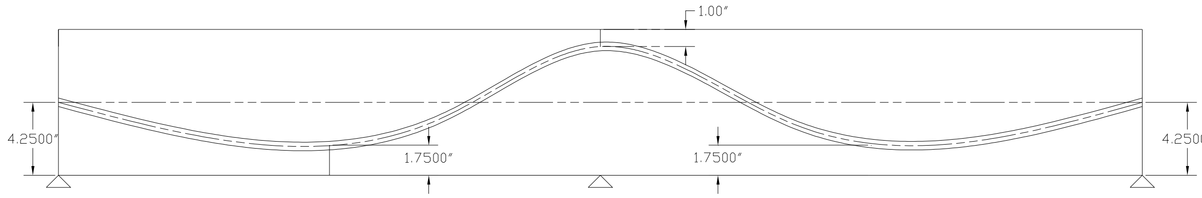


Diagram of Tendon Layout

Advantages:

- Long spans
- Slim slab thickness
- Quick construction / ability to remove formwork early

A Post-tensioned concrete system offers the advantage of creating larger spans when compared with a typical 2-way system. Therefore, the original design of the column grid, which includes bays approximately 32' in length, will not necessarily have to be altered. The system will offer the opportunity for significantly reduced floor depths as well. The system has the potential to be reduced from 2'-8" down to 8.5". Formwork is generally removed earlier in the construction process after only a few days, allowing a faster project schedule. Also, because this is a mass concrete system, sound and vibrations will deaden quickly.

Disadvantages:

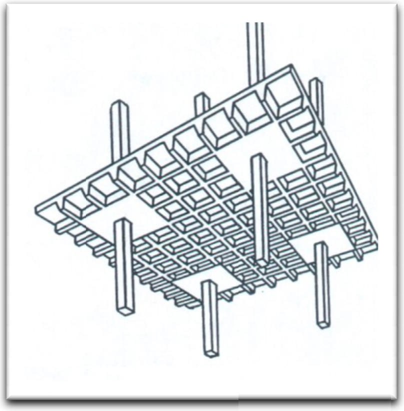
- Necessary experience
- Potential material cost savings

Post-tensioning requires contractors knowledgeable and familiar with the system. Experienced contractors can be difficult to find and will be looked into if this system continues to be a considered alternative.

Conclusions:

Although the system will provide a much thinner slab, this does not seem to be of concern to the owner. The original design called for 28” joists with 4” non-composite slab. With a floor-to-floor distance of 15’-4” and a drop ceiling at 11’-0”, it seems that reducing the system thickness is a non-issue. This system will be studied further to determine the effects of using lightweight concrete in a prestressed situation. If it will work, this system seems to be an acceptable alternative.

Alternate Four: Waffle Slab



Waffle slabs are a 2-way concrete joist slab system. The "dome" form used will be 30" x 30" and have a 3" slab above 10" ribs serving as the joists, resulting in a system depth of 13". In preliminary investigations, it seems that there are some options for additional columns. The best option seems to be increasing the E-W dimension of the bays to 30' which would eliminate 2 bays altogether and produce a relatively square bay (30'x31'-6"). These preliminary investigations do not seem to impose on the architectural layout of the space; however, a more in-depth inspection will need to be conducted.

Advantages:

- Medium to long spans
- Lightweight
- Carries heavy loading
- Good vibration characteristics

Waffle slabs can span long distances, which is advantageous for this project with the already long spans designed. The waffle is efficient in utilizing only the usable concrete by creating square voids where it is not needed. Thus, there will be considerable material savings and decrease in dead loads. Fireproofing is a non-issue and this system is very good at keeping vibrations to a minimum.

Disadvantages:

- High formwork costs / increased labor
- Deeper slab system
- Time-consuming construction
- Deeper section relative to other concrete systems
- Little deflection

Conclusions:

Although long spans can be created, the ideal system for a waffle slab has the same dimensions on all sides of the bay. The column grid will need to be altered for this design to work due to the fact that the bays are long and rectangular. Construction of this type of slab is very difficult and time-consuming because of the difficult, domed formwork to create individual voids. More investigation will need to be made regarding a new column layout for this to be a viable alternative.

Comparative Matrix and Overall Conclusions

Structural System	Non-Composite Steel Beam/Joist Moment Frame	Composite Steel Frame	2-way Flat Plate w/ Drop Panels	Post-tensioned Slab	2-way Concrete Joists (Waffle Slab)
System Depth	32"	25.5"	13"	8.5"	13"
Maximum Self Weight	67	64	162.5	78	162.5
Difficulty of Construction	Hard	Medium	Medium	Hard	Medium
Vibration	Poor	Good	Better	Better	Best
Fireproofing	Required	Required	Not Required	Not Required	Not Required
Changes to Lateral System	NA	Likely	Yes	Yes	Yes
Changes to Column Grid	NA	No	Yes	No	Yes
Costs -					
Material Cost	$ 9.40	$ 9.95	$ 6.90	$ 7.93	$ 10.05
Labor Cost	4.98*	$ 4.87	$ 8.05	$ 10.97	$ 9.60
System Cost (per SF)	$ 14.38	$ 14.82	$ 14.95	$ 18.90	$ 19.65
Feasible	NA	Yes	No	Yes	Yes

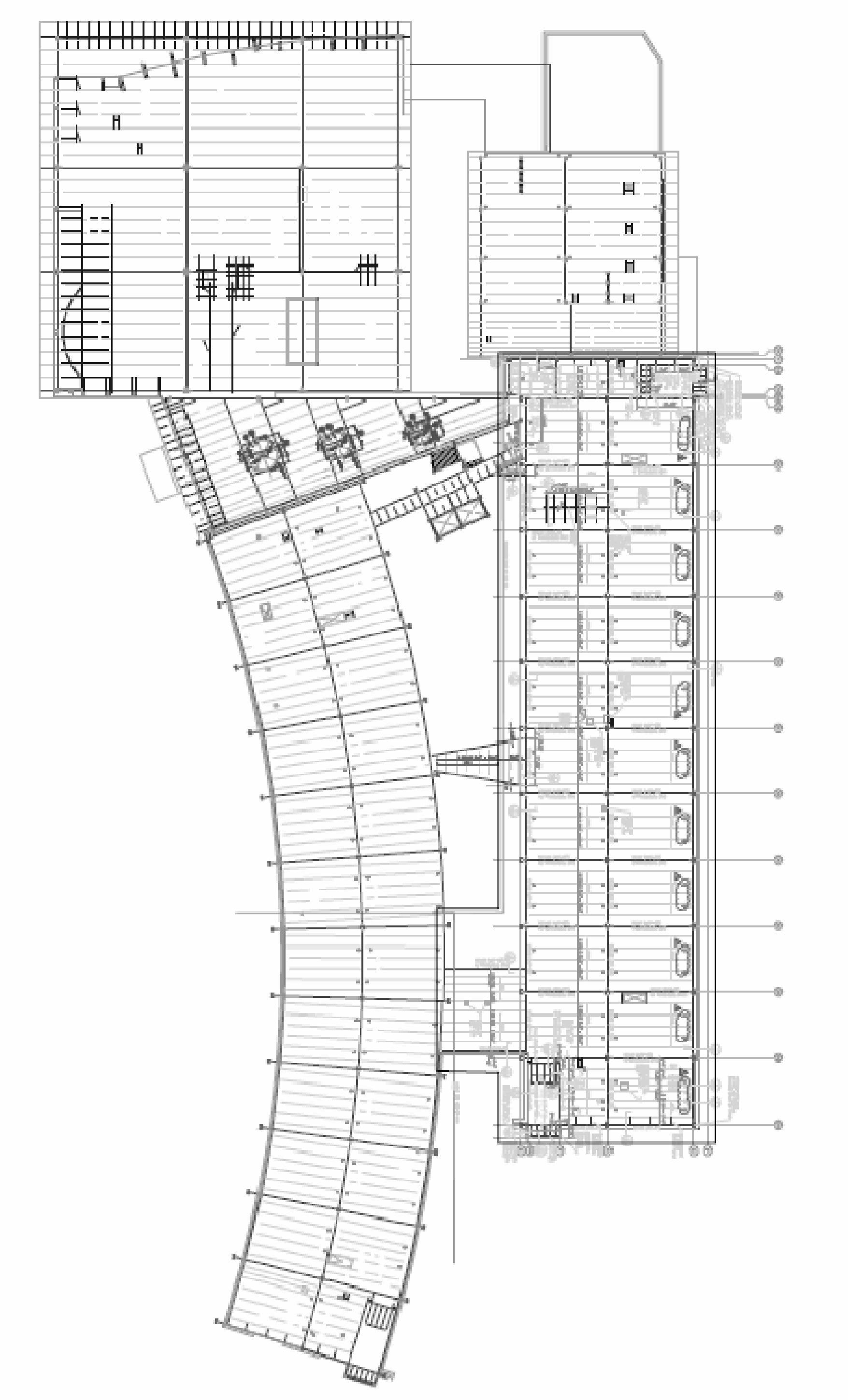
*Cost of moment connections not included in data

Overall Conclusions:

The matrix clearly shows how all five systems each have individual qualities that are beneficial. The key is to decide which factors are desired in the design that is reflected by the architect. Clearly, the Edward L Kelly Leadership center is not meant to pack as many floors as possible into the space. The building is three stories tall to fit the needs of the owner and is certainly not cramped for space. Future expansion was incorporated to the site design, but, as for now, the building provides adequate space. There are also no height restrictions in the area. The building floor-to floor height is 15'-4" with 11'-0" drop ceiling heights. There is certainly no *need* to limit the system depth for a reason other than cost. The current system provides adequate space for mechanical systems and other conduit though the use of open web steel joists. The 2-way concrete flat plate slab is eliminated based upon the severe impact to the column layout. The waffle slab also requires rearrangement of the column layout in the form of additional columns. It seems likely that additional columns in the east-west direction would not severely impact the architectural goals and would nearly make 30'-0" x 30'-0" bays. Overall, the system that stands out and seems most worthy of additional study is the composite steel framing. The system offers a low cost, reduction is depth, good vibration characteristics, and would not impact the column grid.

Appendix
A

Typical Plans



Composite Framing

Floor Type: Floor 2 **Beam Number = 27**

SPAN INFORMATION (ft): I-End (318.63,228.76) J-End (318.63,259.68)

Beam Size (Optimum) = W16X26 Fy = 50.0 ksi
Total Beam Length (ft) = 30.92

COMPOSITE PROPERTIES (Not Shored):

	Left	Right
Concrete thickness (in)	3.00	3.00
Unit weight concrete (pcf)	150.00	150.00
f'c (ksi)	3.00	3.00
Decking Orientation	perpendicular	perpendicular
Decking type	VULCRAFT 1.5VL	VULCRAFT 1.5VL

beff (in)	=	72.00	Y bar(in)	=	16.13
Seff (in3)	=	58.10	Str (in3)	=	62.40
Ieff (in4)	=	882.53	Itr (in4)	=	1009.43
Stud length (in)	=	3.50	Stud diam (in)	=	0.75

Stud Capacity (kips) q = 8.6
\# of studs: Full = 46 Partial = 31 Actual = 31
Number of Stud Rows = 1 Percent of Full Composite Action = 67.38

LINE LOADS (k/ft):

Load	Dist	DL	CDL	LL	Red%	Type	CLL
1	0.000	0.283	0.283	0.000	---	NonR	0.000
	30.916	0.283	0.283	0.000			0.000
2	0.000	0.090	0.000	0.480	---	NonR	0.000
	30.916	0.090	0.000	0.480			0.000
3	0.000	0.026	0.026	0.000	---	NonR	0.000
	30.916	0.026	0.026	0.000			0.000

SHEAR: Max V (DL+LL) = 13.59 kips fv = 3.62 ksi Fv = 17.89 ksi

MOMENTS:

Span	Cond	Moment	@	Lb	Cb	Tension Flange		Compr Flange	
		kip-ft	ft	ft		fb	Fb	fb	Fb
Center	PreCmp+	36.9	15.5	0.0	1.00	11.54	33.00	11.54	33.00
	Max +	105.0	15.5	---	---				
	Mmax/Seff					21.69	33.00	---	---
	Mconst/Sx+Mpost/Seff					25.60	45.00	---	---
Controlling		105.0	15.5	---	---	21.69	33.00	---	---

fc (ksi) = 0.37 Fc = 1.35

REACTIONS (kips):

	Left	Right
Initial reaction	4.78	4.78
DL reaction	6.17	6.17
Max +LL reaction	7.42	7.42
Max +total reaction	13.59	13.59

DEFLECTIONS:

Initial load (in)	at	15.46 ft	=	-0.728	L/D	=	510
Live load (in)	at	15.46 ft	=	-0.386	L/D	=	962
Post Comp load (in)	at	15.46 ft	=	-0.458	L/D	=	810
Net Total load (in)	at	15.46 ft	=	-1.185	L/D	=	313

Floor Type: Floor 2

2-way Flat Slab

Output from PCA Slab

East-West Reinforcement

```
==========================================================================================
[2] DESIGN RESULTS
==========================================================================================

Top Reinforcement:
==================
   Units: Width (ft), Mmax (k-ft), Xmax (ft), As (in^2), Sp (in)
   Span Strip  Zone     Width          Mmax     Xmax    AsMin    AsMax    SpReq    AsReq     Bars
   ---- ------ ------ -------- ------------ -------- -------- -------- -------- -------- -------
      1 Column Left      10.50        40.93    1.000    2.041   19.245   18.000    1.278    7-#5
               Middle    10.50         0.00   12.000    0.000   19.245    0.000    0.000     ---
               Right     10.50       212.81   23.000    2.041   19.245    5.478    6.957   23-#5

        Middle Left      10.50        -0.00    1.000    2.041   19.245   18.000    0.000    7-#5
               Middle    10.50         0.00   12.000    0.000   19.245    0.000    0.000     ---
               Right     10.50        70.94   23.000    2.041   19.245   15.750    2.232    8-#5

      2 Column Left      10.50       212.81    1.000    2.041   19.245    5.478    6.957   23-#5
               Middle    10.50         0.00   12.000    0.000   19.245    0.000    0.000     ---
               Right     10.50        40.93   23.000    2.041   19.245   18.000    1.278    7-#5

        Middle Left      10.50        70.94    1.000    2.041   19.245   15.750    2.232    8-#5
               Middle    10.50         0.00   12.000    0.000   19.245    0.000    0.000     ---
               Right     10.50        -0.00   23.000    2.041   19.245   18.000    0.000    7-#5

Top Bar Details:
================
   Units: Length (ft)
                           Left                       Continuous               Right
   Span Strip      Bars  Length    Bars  Length      Bars  Length      Bars  Length    Bars  Length
   ---- ------ -------- ------- ------- -------   ------- -------   ------- ------- ------- -------
      1 Column    7-#5    8.26     ---                 ---             12-#5    8.26   11-#5    5.40
        Middle    7-#5    5.84     ---                 ---              8-#5    8.12     ---

      2 Column   12-#5    8.26   11-#5    5.40                          7-#5    8.26
        Middle    8-#5    8.12     ---                 ---              7-#5    5.84     ---

Bottom Reinforcement:
=====================
   Units: Width (ft), Mmax (k-ft), Xmax (ft), As (in^2), Sp (in)
   Span Strip      Width         Mmax     Xmax    AsMin    AsMax    SpReq    AsReq     Bars
   ---- ------ -------- ------------ -------- -------- -------- -------- -------- -------


      1 Column     10.50       111.54   10.000    2.041   19.245   10.500    3.546   12-#5
        Middle     10.50        74.36   10.000    2.041   19.245   15.750    2.342    8-#5

      2 Column     10.50       111.54   14.000    2.041   19.245   10.500    3.546   12-#5
        Middle     10.50        74.36   14.000    2.041   19.245   15.750    2.342    8-#5

Bottom Bar Details:
===================
   Units: Start (ft), Length (ft)
                 _______Long Bars_______   ______Short Bars_______
   Span Strip       Bars   Start  Length      Bars   Start  Length
   ---- -------  ------- ------- -------   ------- ------- -------
      1 Column     12-#5    0.00   24.00       ---
        Middle      7-#5    0.00   24.00      1-#5    3.60   16.80

      2 Column     12-#5    0.00   24.00       ---
        Middle      7-#5    0.00   24.00      1-#5    3.60   16.80


      Slab Shear Capacity:
      ====================
         Units: b, d (in), Xu (ft), PhiVc, Vu(kip)
         Span        b        d   Vratio        PhiVc           Vu           Xu
         ---- -------- -------- -------- ------------ ------------ ------------
            1   252.00     7.19    1.000       192.11        68.97        22.40
            2   252.00     7.19    1.000       192.11        68.97         1.60
```

```
Punching Shear Around Columns:
==============================

   Units: Vu (kip), Munb (k-ft), vu (psi), Phi*vc (psi)
   Supp           Vu       vu         Munb Comb Pat  GammaV       vu   Phi*vc
   ---- ------------ -------- ------------ ---- ---- ------ -------- --------
      1 --- Not checked ---
      2       154.47    208.2        -0.00 U2   All   0.442    208.2    212.1
      3 --- Not checked ---

Punching Shear Around Drops:
============================
   Units: Vu (kip), vu (psi), Phi*vc (psi)
   Supp           Vu Comb Pat        vu   Phi*vc
   ---- ------------ ---- ---- -------- --------
      1 --- Not checked ------
      2       180.40 U2   All      51.0    144.8
      3 --- Not checked ------

Maximum Deflections:
====================
   Units: Dz (in)
        __________Frame_____________  ________Column Strip_________  ________Middle Strip_______
   Span Dz(DEAD) Dz(LIVE) Dz(TOTAL)   Dz(DEAD) Dz(LIVE) Dz(TOTAL)    Dz(DEAD) Dz(LIVE) Dz(TOTAL)
   ---- -------- -------- ---------   -------- -------- ---------    -------- -------- ---------
      1   -0.107   -0.073    -0.180     -0.157   -0.108    -0.265      -0.056   -0.038    -0.094
      2   -0.107   -0.073    -0.180     -0.157   -0.108    -0.265      -0.056   -0.038    -0.094
```

Output from PCA Slab

North-South Reinforcement

Top Reinforcement:

Units: Width (ft), Mmax (k-ft), Xmax (ft), As (in^2), Sp (in)

Span	Strip	Zone	Width	Mmax	Xmax	AsMin	AsMax	SpReq	AsReq	Bars
1	Column	Left	10.50	40.93	1.000	2.041	19.245	18.000	1.278	7-#5
		Middle	10.50	0.00	12.000	0.000	19.245	0.000	0.000	---
		Right	10.50	212.81	23.000	2.041	19.245	5.478	6.957	23-#5
	Middle	Left	10.50	-0.00	1.000	2.041	19.245	18.000	0.000	7-#5
		Middle	10.50	0.00	12.000	0.000	19.245	0.000	0.000	---
		Right	10.50	70.94	23.000	2.041	19.245	15.750	2.232	8-#5
2	Column	Left	10.50	212.81	1.000	2.041	19.245	5.478	6.957	23-#5
		Middle	10.50	0.00	12.000	0.000	19.245	0.000	0.000	---
		Right	10.50	40.93	23.000	2.041	19.245	18.000	1.278	7-#5
	Middle	Left	10.50	70.94	1.000	2.041	19.245	15.750	2.232	8-#5
		Middle	10.50	0.00	12.000	0.000	19.245	0.000	0.000	---
		Right	10.50	-0.00	23.000	2.041	19.245	18.000	0.000	7-#5

Top Bar Details:

Units: Length (ft)

		Left				Continuous		Right			
Span	Strip	Bars	Length	Bars	Length	Bars	Length	Bars	Length	Bars	Length
1	Column	7-#5	8.26	---		---		12-#5	8.26	11-#5	5.40
	Middle	7-#5	5.84	---		---		8-#5	8.12	---	
2	Column	12-#5	8.26	11-#5	5.40	---		7-#5	8.26	---	
	Middle	8-#5	8.12	---		---		7-#5	5.84	---	

Bottom Reinforcement:

Units: Width (ft), Mmax (k-ft), Xmax (ft), As (in^2), Sp (in)

Span	Strip	Width	Mmax	Xmax	AsMin	AsMax	SpReq	AsReq	Bars
1	Column	10.50	111.54	10.000	2.041	19.245	10.500	3.546	12-#5
	Middle	10.50	74.36	10.000	2.041	19.245	15.750	2.342	8-#5
2	Column	10.50	111.54	14.000	2.041	19.245	10.500	3.546	12-#5
	Middle	10.50	74.36	14.000	2.041	19.245	15.750	2.342	8-#5

Bottom Bar Details:

Units: Start (ft), Length (ft)

		Long Bars			Short Bars		
Span	Strip	Bars	Start	Length	Bars	Start	Length
1	Column	12-#5	0.00	24.00	---		
	Middle	7-#5	0.00	24.00	1-#5	3.60	16.80
2	Column	12-#5	0.00	24.00	---		
	Middle	7-#5	0.00	24.00	1-#5	3.60	16.80

Slab Shear Capacity:

Units: b, d (in), Xu (ft), PhiVc, Vu(kip)

Span	b	d	Vratio	PhiVc	Vu	Xu
1	252.00	7.19	1.000	192.11	68.97	22.40
2	252.00	7.19	1.000	192.11	68.97	1.60

Punching Shear Around Columns:

Units: Vu (kip), Munb (k-ft), vu (psi), Phi*vc (psi)

Supp	Vu	vu	Munb	Comb	Pat	GammaV	vu	Phi*vc
1	--- Not checked ---							
2	154.47	208.2	-0.00	U2	All	0.442	208.2	212.1
3	--- Not checked ---							

Punching Shear Around Drops:

Units: Vu (kip), vu (psi), Phi*vc (psi)

Supp	Vu	Comb	Pat	vu	Phi*vc
1	--- Not checked ------				
2	138.48	U2	All	51.0	144.3
3	--- Not checked ------				

Maximum Deflections:

Units: Dz (in)

	Frame			Column Strip			Middle Strip		
Span	Dz(DEAD)	Dz(LIVE)	Dz(TOTAL)	Dz(DEAD)	Dz(LIVE)	Dz(TOTAL)	Dz(DEAD)	Dz(LIVE)	Dz(TOTAL)
1	-0.107	-0.073	-0.180	-0.157	-0.108	-0.265	-0.056	-0.038	-0.094
2	-0.107	-0.073	-0.180	-0.157	-0.108	-0.265	-0.056	-0.038	-0.094

Post-Tensioned Concrete Slab

NORMAL WEIGHT CONCRETE = 150 PCF
f'_c = 4000 PSI
f'_{ci} = 3000 PSI
f_y = 60000 PSI

TENDONS: UNBONDED

FROM TABLE A.15 1/2" ϕ, 7-WIRE STRANDS
A = 0.153 in^2
f_{pu} = 270 KSI
PRESTRESS LOSS = 15 KSI (ACI 18.6)
f_{se} = 0.70 (270) - 15 KSI = 174 KSI (ACI 18.5.1)
P_{eff} = A × f_{se} = 0.153 (174) = 26.6 K / TENDON

DETERMINE PRELIM SLAB THICKNESS

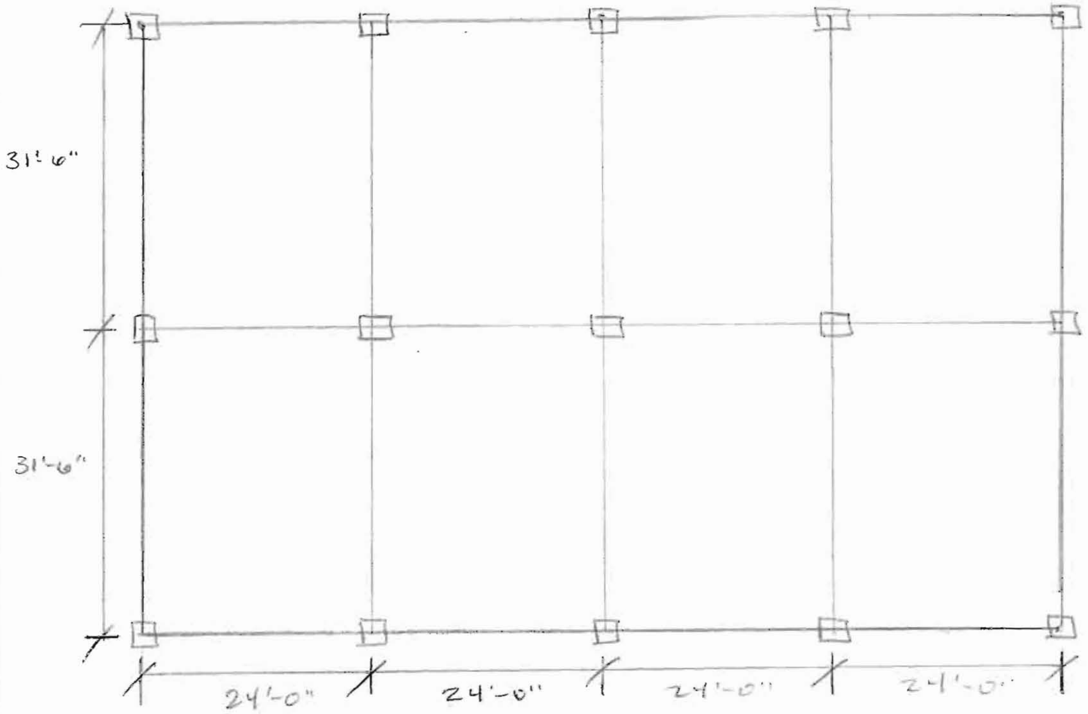
L/h = 45 → h = L/45
h = h = 31.5 × 12/45 = 8.4 inches

USE 8.5 IN SLAB

LOADING

DL = SELFWEIGHT = (8.5)(~~150~~ 110 PCF) = ~~106.25~~ 78 PSF 78
SIDL = 15 PSF
LL = 70 PSF (50 PSF OFFICE + 20 PARTITION ALLOWANCES)

NO LIVE LOAD REDUCTION



NORTH - SOUTH DIRECTION

WIDTH = 24' = 288 = b

$A = bh = 288(8.5) = 2448\ in^2$

$S = bh^2/6 = 288(8.5)^2/6 = 3468$

AT TIME OF JACKING (ACI 18.33, 18.4.1, 18.4.2)

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

f'_c = ~~4000~~ 6000 PSI

COMPRESSION = $0.45 f'_c = 0.45($~~4000~~ 6000$)$ = ~~2250~~ 2700

TENSION = $6\sqrt{f'_c} = 6\sqrt{}$~~4000~~ 6000 = ~~379.5 → 380~~ 465

AVERAGE PRECOMPRESSION LIMITS (ACI 18.12.4)

P/A = 125 MIN

300 MAX

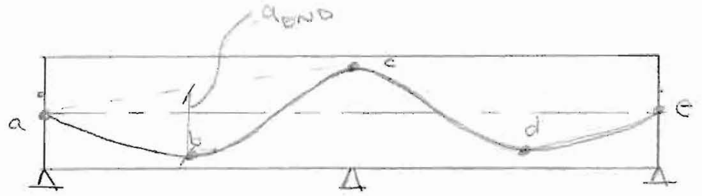
TARGET LOAD BALANCE (60% - 80%)

75% OF SELFWEIGHT

0.75 (~~106.25~~ 78) = ~~80~~ PSF 58.5 = 59

COVER REQUIREMENTS

RESTRAINED 3/4" BOT.
UNRESTRAINED 1 1/2" BOT
TOP 3/4"



CG LOCATION (FROM BOTTOM OF SLAB)

a	4.25" (NA)
b	1.5" + 0.25" = 1.75"
c	8.5" - 0.75 - 0.25 = 7.5"
d	1.5" + 0.25" = 1.75"
e	4.25" (NA)

$a_{END} = (4.25" + 7.5")/2 - 1.75" = 4.125"$

FORCE REQUIRED TO BALANCE 75% SW (~~80 PSF~~ 59)

$W_b =$ ~~80~~ 59 PSF (24 FT) = ~~1.92~~ 1.42 K/FT

$P = \frac{W_b (L)^2}{8 a_{END}} = \frac{~~1.92~~\ 1.42 \text{ K/FT} \times (31.5')^2}{8 (4.125)/12} =$ ~~693~~ 513 K

DETERMINE PRECOMPRESSION ALLOWANCES

\# TENDONS = ~~693~~ 513 K / 26.6 K/TENDON = ~~26.05~~ 20 TENDONS

USE ~~26~~ 20 TENDONS

CALCULATE ACTUAL FORCE IN TENDONS

26.6 K/TENDON × ~~26~~ 20 TENDONS = ~~692~~ 532 K

NORMALLY, BALANCED LOAD WOULD BE RE-DETERMINED AT THIS POINT HOWEVER, THE ACTUAL FORCE IS VERY CLOSE TO THE BALANCE FORCE

ACTUAL PRECOMPRESSION STRESS

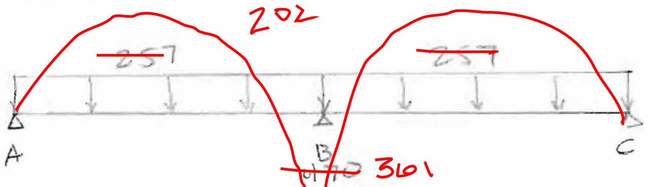
$$\frac{P_{ACTUAL}}{A} = \frac{~~692~~\ 513^{K} \times 1000\ ^{lb}/_{K}}{2448\ in^2} = ~~283~~\ 210\ \text{PSI}$$

~~228~~ 210 > 125 OK
210 < 300 OK

NO INTERIOR SPAN TO CHECK
∴ END SPAN CALCULATIONS WILL CONTROL

EFFECTIVE PRESTRESS FORCE, P_{EFF} = ~~692~~ 513 K

DEAD LOAD MOMENTS: ~~121.25~~ 78+15 = 93 PSF × 31.25 / 1000 = ~~3.79~~ 2.91 K/FT



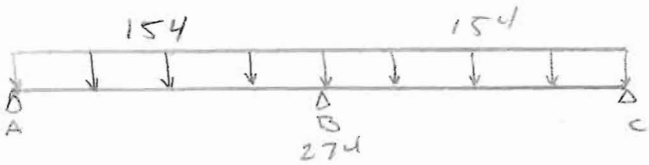
$wL^2 = ~~3.79~~\ 2.91\ (31.5)^2$
$= ~~3760.6~~\ 2888$

USING CONTINUOUS SPAN
AISC MOMENT COEFFICIENTS

TABLE 3-22C

$M_A = 0.07\ (wl^2) = 0.07\ (~~3760.6~~\ 2888) = ~~257~~\ 202\ ^{1K}$
$M_B = 0.125\ (wl^2) = 0.125\ (~~3760.6~~) = ~~470~~\ 361\ ^{1K}$
$M_C = M_A = ~~257~~^{1K}\ 202$

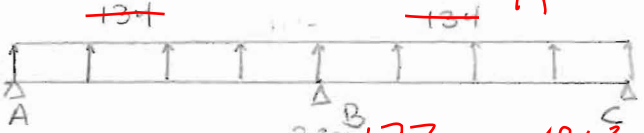
LIVE LOAD MOMENTS: 70 PSF × 31.25 / 1000 = 2.205 K/FT



$wl^2 = 2.21\ (31.5)^2$
$= 2193$

$M_A = 0.07\ (2193) = 153.5\ ^{1K}$
$M_B = 0.125\ (2193) = 274\ ^{1K}$
$M_A = M_C = 153.5^{1K}$

BALANCING MOMENT : w_b = ~~1.92~~ 1.42 k/ft



$w\ell^2$ = ~~1.92~~ 1.42 $(31.5)^2$
= ~~1905.12~~ 1409

M_A = 0.07 (1905.12) = ~~133.36~~ 98.63 ≈ ~~134~~ 99
M_B = 0.125 (1905.12) = ~~238.14~~ 176.125 ≈ ~~239~~ 177 (~~237~~ 177)
$M_C = M_A$ = ~~133.36~~ 99

- STRESSES IMMEDIATELY AFTER JACKING (f'_{ci} = 3000)

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

END SPAN

f_{TOP} = [(~~-257 + 134~~ -202+99)(12)(1000)/3468 - ~~283~~ 210] = ~~-708.6~~ -566.4
< $0.6 f'_{ci}$ = 1800 OK

f_{BOT} = [(~~257 - 134~~ 202 - 99)(12)(1000)/3468 - ~~283~~ 210] =
= 142.60 < $3\sqrt{f'_{ci}}$ = 164 PSI OK

SUPPORT STRESSES

f_{TOP} = (-470 + 239) (-361 + 177)(12)(1000)/3468 - ~~283~~ 210
= ~~-1082.3~~ -316 < $3\sqrt{f'_{ci}}$ = 164 OK

f_{BOT} = (~~470 - 239~~ 361 - 177)(12)(1000)/3468 - ~~283~~ 210
= ~~516.3~~
212 < 1800 OK

STRESSES AT SERVICE LOAD (DL + LL + PT)

$-M_{DL} - M_{LL} + M_{BAL}$
$+M_{DL} + M_{LL} - M_{BAL}$

MIDSPAN OF END SPAN

$f_{TOP} = (-$ ~~257~~ 202 $-$ 154 $+$ ~~134~~ 99$)(12)(1000)/3468 -$ ~~283~~ 210
$=$ ~~-1241.5~~ $-1105 < 0.45 f'_c = 1800$ OK

$f_{BOT} = ($~~257~~ 202 $+$ 154 $-$ ~~134~~ 99$)(12)(1000)/3468 -$ ~~283~~ 210
$=$ ~~675.5~~ 679 $> 6\sqrt{f'_c} = 379.5$ OK

SUPPORT STRESS

$f_{TOP} = ($~~-470~~ -361 $-$ 274 $+$ ~~239~~ 177$)(12)(1000)/3468 -$ ~~283~~
$=$ ~~-2030.4~~ $-1795 < 6\sqrt{f'_c} = 379.5$ OK

$f_{BOT} = ($~~470~~ 361 $+$ 274 $-$ ~~239~~ 177$)(12)(1000)/3468$ ~~283~~ 210
$=$ ~~1467.4~~ 1375 $< 0.45\sqrt{f'_c} = 1800$ OK

ULTIMATE STRENGTH

PRIMARY POST-TENSIONING MOMENTS, M_1

$M_1 = P \times e$

$e = 0$ AT EXTERIOR SUPPORT
$e = 7.5 - 4.25'' = 3.25''$

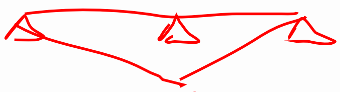
$M_1 =$ ~~692~~ 513 $(3.25)/12 =$ ~~187.42~~ 139

SECONDARY POST-TENSIONING MOMENTS, M_{SEC}

VARIES LINEARLY

$M_{SEC} = M_{BAL} - M_1$
$=$ ~~231~~ 177 $-$ ~~187.42~~ 139 $=$ ~~46.6~~ 38 ^{1K} AT INTERIOR SUPPORT

TYPICAL LOAD FOR ULTIMATE STRENGTH



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

MIDSPAN: $1.2($~~257~~ 202$) + 1.6(154) + \frac{1}{2}($~~46.6~~ 38$) =$ ~~578.1~~ 353
SUPPORT: $1.2($~~-470~~ 361$) + 1.6($~~-274~~$) +$ ~~46.6~~ 19 $=$ ~~955.8~~ -852.6

-12465

MINIMUM BONDED REINFORCEMENT

fbot midstress

EXTERIOR SPAN: $f_t =$ ~~675.5~~ 679 > $2\sqrt{f'_c}$) = ~~+126.5~~ 155
6000

- MIN. POSITIVE MOMENT REINFORCEMENT REQUIRED

$y = f_t / (f_t + f_c) h$ = ~~675.5~~ 679 / (~~675.5~~ 679 + ~~1241.5~~ 1100) × 8.5 = ~~3.00~~ 3.24 in

$N_c = M_{DL+LL} / S \times 0.5 \times y \times l_2$
= (~~257~~ 202 + 154) ×12 / 3408 × 0.5 × ~~12~~ 3.24 × (24)(12) = ~~204.79~~ 575
~~575~~

$A_{s,min} = N_c / 0.5 f_y$
= ~~204.79~~ 575 / 0.5 (60) = ~~6.83~~ 19.17 in²

~~6.83~~ 19.17 in² / 24 = ~~0.285~~ 0.80 in²/ft

USE # ~~5~~ 9 12 in OC

MINIMUM LENGTH SHALL BE 1/3 CLEAR SPAN
CENTERED IN POSITIVE MOMENT REGION

- NEGATIVE MOMENT REGION

$A_{s,min} = 0.00075 A_{cf}$ =
= 0.00075 (2448)
= ~~1.836~~ in²
USE (10) # 4 = 2.0 in²

$A_{cf} = \max \begin{cases} h\, b_{avg} = 8.5 \times \frac{31.5}{2} = 267.8 \\ h\, W \times 12 \text{ in/ft} = 24 \times 12 \\ = 2448 \end{cases}$

MUST SPAN MINIMUM OF 1/6 CLEAR SPAN EA SIDE OF SUPPORT
AT LEAST 4 BARS REQ. IN EA. DIRECTION
PLACE TOP BARS W/IN 1.5h AWAY FROM SUPPORT OF EA. SIDE
= 1.5 (8.5) ≈ 12.75
≈ 12 ≈ 12

MAX SPACING IS 12"

MIN. REINFORCEMENT FOR ULTIMATE STRENGTH

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

$A_{ps} = 0.153 \text{ in}^2 \times$ ~~26~~ 20 $=$ ~~3.978~~ 3.06 in^2

$f_{ps} = f_{se} + 10000 + (f'_c bd)/300 A_{ps}$ FOR SLABS $> L/h = 35$

$= 174000 + 10000 +$ (~~4000~~ 6000 $\times 24 \times 12 \times d)/(300 \times 3.978)$

$= 184000 + 1152000d / 1193.4$

$= 184000 +$ ~~965.3~~ 1448 d

$a = \dfrac{A_s f_y + A_{ps} f_{ps}}{0.85 f'_c b}$

AT SUPPORT $d = 8.5 - 3/4 - 1/4 = 7.5$

$f_{ps} = 184000 +$ ~~965.3~~ 1448 $(7.5) =$ ~~191239.75~~ PSI ~~191 KSI~~ 195 KSI

$a = \dfrac{2.0 \times 60 + \text{~~3.978~~ 3.06 (~~191~~ 195 KSI)}}{0.85(4)(24 \times 12)} =$

$=$ ~~0.898~~ 0.719

$\phi M_n = \phi[A_s f_y + A_{ps} f_{ps}] \times (d - \frac{a}{2})$

$= 0.9[2.0 \times 60 +$ ~~3.978~~ 3.06 $\times$ ~~191~~ 195$] \times (7.5 - \frac{0.868}{2})$

$=$ ~~433~~ 319 'K GOVERNS

91175 74

Waffle Slab

11-20

CONCRETE REINFORCING STEEL INSTITUTE

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

f'_c = 4,000 psi
Grade 60 Bars

SQUARE EDGE PANELS

Total Depth = 13 in. Rib Depth = 10 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	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)
18'-0" D= 6.500 RIB ON COLUMN LINE 0.597 CF/SF	50	1.86	12	0.664		13-#5+ 0	3	2-#4	13-#5	3	#4	#4	5-#5	28	56	76
	100	1.86	12	0.687		13-#5+ 0	3	2-#4	13-#5	3	#4	#4	5-#5	37	77	98
	150	1.92	12	0.711		13-#5+ 0	3	1-#4 and 1-#5	13-#5	3	#4	#4	5-#5	45	106	121
	200	1.98	12	0.735		13-#5+ 0	3	2-#5	13-#5	3	#4	#4	5-#5	53	132	144
	300	2.16	12	0.782		13-#5+ 0	3	1-#5 and 1-#6	13-#5	3	#4	#5	5-#5	70	185	189
	400	2.61	12	0.830		13-#5+ 0	3	1-#6 and 1-#7	13-#5	3	#5	#6	5-#5	87	236	235
21'-0" D= 9.500 RIB NOT ON COLUMN LINE 0.637 CF/SF	50	1.84	12	0.735		15-#5+ 0	4	2-#4	15-#5	3	#4	#4	6-#5	47	93	125
	100	1.84	12	0.763		15-#5+ 0	4	2-#4	15-#5	3	#4	#4	6-#5	60	128	162
	150	2.01	12	0.791		15-#5+ 0	4	2-#5	15-#5	3	#4	#5	6-#5	74	174	199
	200	2.19	12	0.818		15-#5+ 0	4	1-#5 and 1-#6	15-#5	3	#5	#5	6-#5	87	218	236
	300	2.63	12 *	0.874		15-#5+ 0	4	1-#6 and 1-#7	15-#5	3	#6	#6	6-#5	115	302	309
	400	3.13	12 *	0.634		15-#5+ 0	4	2-#7	18-#5	3	#7	#7	6-#5	142	385	383
24'-0" D= 9.500 RIB NOT ON COLUMN LINE 0.613 CF/SF	50	1.92	12	0.801		18-#5+ 0	4	1-#4 and 1-#5	18-#5	4	#4	#4	7-#5	69	138	186
	100	1.98	12	0.831		18-#5+ 0	4	2-#5	18-#5	4	#4	#4	7-#5	90	190	242
	150	2.32	12	0.862		18-#5+ 0	4	2-#6	18-#5	4	#5	#5	7-#5	111	260	298
	200	2.57	12 *	0.892		18-#5+ 0	4	1-#6 and 1-#7	18-#5	4	#5	#6	7-#5	131	325	353
	300	3.32	12 *	0.634		18-#5+ 0	4	2-#8	16-#6	4	#6	#7	7-#5	172	453	464
	400	4.07	16 *	0.628		18-#5+ 1	4	2-#9	20-#6	4	#7	#7	9-#5	210	564	565
27'-0" D= 9.500 RIB NOT RIB NOT ON COLUMN LINE 0.597 CF/SF	50	1.96	13	0.824		20-#5+ 0	4	2-#5	20-#5	5	#4	#4	8-#5	98	196	264
	100	2.22	13	0.860		20-#5+ 0	4	2-#6	20-#5	5	#4	#5	8-#5	127	263	343
	150	2.49	13 *	0.896		20-#5+ 0	4	2-#7	20-#5	5	#5	#5	8-#5	157	363	422
	200	3.03	13 *	0.632		20-#5+ 0	4	2-#8	25-#5	5	#5	#6	8-#5	188	455	502
	300	3.99	18 *	0.626		20-#5+ 1	4	2-#9	23-#6	5	#6	#7	8-#6	240	617	647
30'-0" D=12.500 RIB ON COLUMN LINE 0.624 CF/SF	50	2.12	15	0.829		22-#5+ 0	5	1-#5 and 1-#6	22-#5	5	#4	#5	9-#5	136	272	367
	100	2.31	15 *	0.887		22-#5+ 3	5	2-#6	23-#5	5	#5	#5	9-#5	177	353	475
	150	2.95	15 *	0.933		22-#5+ 6	5	2-#7	28-#5	5	#6	#6	9-#5	217	483	584
	200	3.53	18 *	0.628		22-#5+ 3	5	2-#8	24-#6	5	#6	#7	11-#5	255	604	686
33'-0" D=12.500 RIB ON COLUMN LINE 0.609 CF/SF	50	2.25	16 *	0.867		25-#5+ 2	5	2-#6	25-#5	6	#4	#5	10-#5	180	360	485
	100	2.71	16 *	0.922		25-#5+ 6	5	2-#7	31-#5	6	#5	#5	10-#5	234	467	629
	150	3.42	19 *	0.931		25-#5+10	5	2-#8	27-#6	6	#6	#6	13-#5	285	614	768
	200	4.05	25 *	0.621	3 S 4 1	25-#5+ 3	5	2-#9	32-#6	6	#6	#7	15-#5	331	711	892
36'-0" D=12.500 RIB ON COLUMN LINE 0.597 CF/SF	50	2.52	18 *	0.875		27-#5+ 3	5	2-#7	31-#5	7	#5	#5	11-#5	231	463	623
	100	3.15	19 *	0.926		27-#5+ 9	5	2-#8	40-#5	7	#5	#6	13-#5	300	601	808
	150	3.93	27 *	0.620	3 S 4 1	27-#5+ 5	5	2-#9	35-#6	7	#6	#6	11-#6	362	725	976

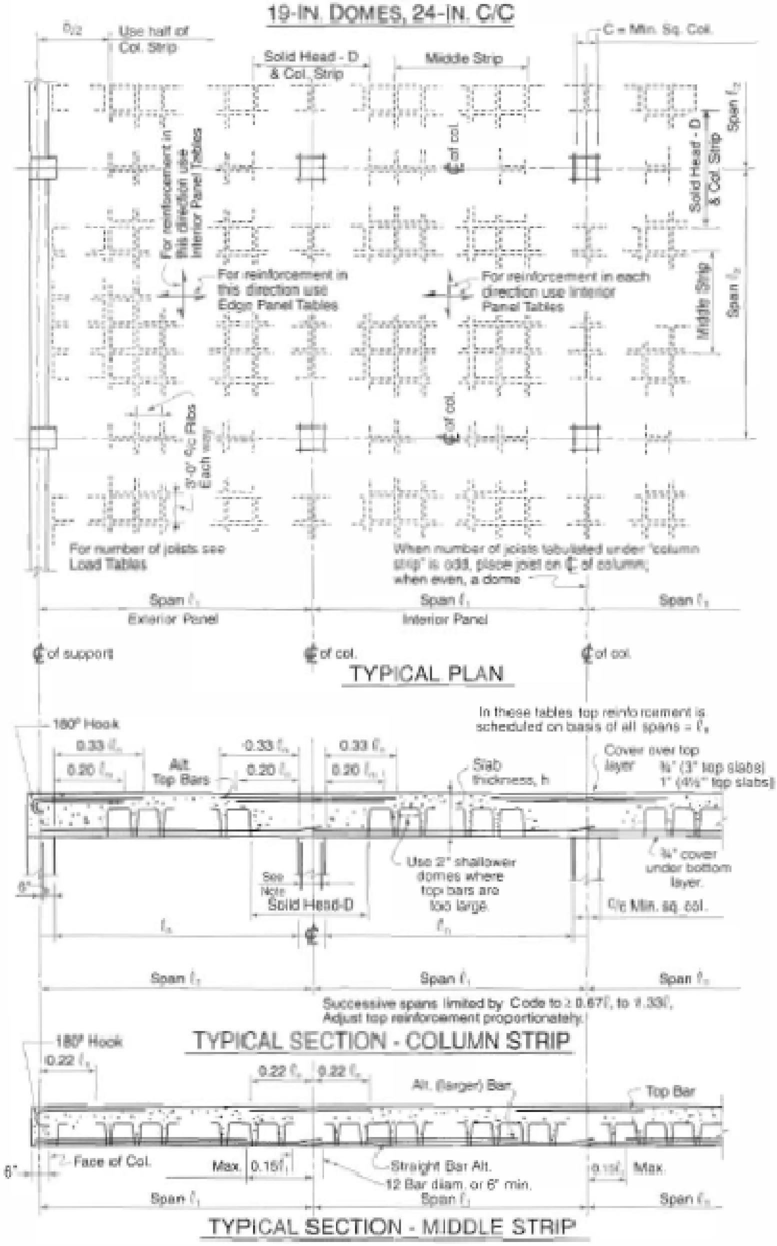
SQUARE INTERIOR PANELS

Total Depth = 13 in. Rib Depth = 10 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	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
18'-0"	50	1.84	12		3	2-#4	13-#5	3	#4	#4	5-#5
	100	1.84	12		3	2-#4	13-#5	3	#4	#4	5-#5
	150	1.84	12		3	2-#4	13-#5	3	#4	#4	5-#5
	200	1.84	12		3	2-#4	13-#5	3	#4	#4	5-#5
	300	1.95	12	3 S 4 1	3	1-#4 and 1-#5	13-#5	3	#4	#4	5-#5
	400	2.28	12	3 S 4 1	3	1-#5 and 1-#6	13-#5	3	#4	#5	5-#5
21'-0"	50	1.82	12		4	2-#4	15-#5	3	#4	#4	6-#5
	100	1.82	12		4	2-#4	15-#5	3	#4	#4	6-#5
	150	1.82	12		4	2-#4	15-#5	3	#4	#4	6-#5
	200	1.93	12		4	1-#4 and 1-#5	15-#5	3	#4	#4	6-#5
	300	2.22	12	3 S 4 1	4	2-#5	15-#5	3	#5	#5	6-#5
	400	2.69	12 *	3 S 4 1	4	2-#6	17-#5	3	#5	#6	6-#5
24'-0"	50	1.86	12		4	2-#4	18-#5	4	#4	#4	7-#5
	100	1.86	12		4	2-#4	18-#5	4	#4	#4	7-#5
	150	2.05	12		4	2-#5	18-#5	4	#4	#4	7-#5
	200	2.25	12	3 S 4 1	4	1-#5 and 1-#6	18-#5	4	#4	#5	7-#5
	300	2.78	12 *	3 S 4 1	4	1-#6 and 1-#7	21-#5	4	#5	#5	7-#5
	400	3.49	13 *	3 S 4 1	4	2-#7	18-#6	4	#6	#6	9-#5
27'-0"	50	1.86	13		4	2-#4	20-#5	5	#4	#4	8-#5
	100	2.02	13		4	2-#5	20-#5	5	#4	#4	8-#5
	150	2.13	13	3 S 4 1	4	1-#5 and 1-#6	20-#5	5	#4	#4	8-#5
	200	2.61	13 *	3 S 4 1	4	1-#6 and 1-#7	23-#5	5	#4	#5	8-#5
	300	3.55	14 *	3 S 4 2	4	1-#7 and 1-#8	21-#6	5	#5	#6	10-#5
30'-0"	50	1.94	15		5	1-#4 and 1-#5	22-#5	5	#4	#4	9-#5
	100	2.03	15		5	2-#5	22-#5	5	#4	#4	9-#5
	150	2.63	15 *	3 S 4 1	5	2-#6	26-#5	5	#5	#5	9-#5
	200	3.12	15 *	3 S 4 1	5	1-#6 and 1-#7	22-#6	5	#5	#6	10-#5
33'-0"	50	2.06	16		5	2-#5	25-#5	6	#4	#4	10-#5
	100	2.46	16 *	3 S 4 1	5	2-#6	28-#5	6	#4	#5	10-#5
	150	3.07	16 *	3 S 4 1	5	1-#6 and 1-#7	25-#6	6	#5	#5	12-#5
	200	3.63	18 *	3 S 4 2	5	2-#7	30-#6	6	#5	#6	10-#6
36'-0"	50	2.16	18	3 S 4 1	5	1-#5 and 1-#6	28-#5	7	#4	#4	11-#5
	100	2.79	18 *	3 S 4 1	5	1-#6 and 1-#7	37-#5	7	#4	#5	12-#5
	150	3.62	18 *	3 S 4 2	5	1-#7 and 1-#8	33-#6	7	#5	#5	15-#5

See the notes on page 11-19.

30-IN. DOMES, 36-IN. C/C
19-IN. DOMES, 24-IN. C/C



NOTE: Integrity reinforcement is required (ACI 13.3.8.5*). All bottom bars in the column strip must be continuous or spliced over the support with Class A tension lap splices. At least two of the column strip bottom bars in each direction must pass within the column core and be anchored at exterior supports.

For other end support conditions; see Figs. 11-2 and 11-3.

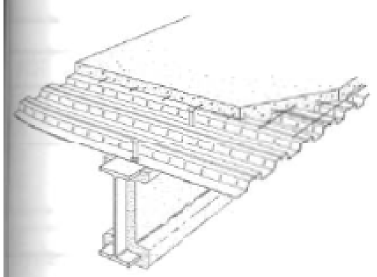
Figure 11-1 Reinforcing Bar Details and Layout

*All references to ACI 318-99 are given as "ACI" followed by the appropriate section number.

11-2 CONCRETE REINFORCING STEEL INSTITUTE

Cost Analysis Data

- Composite Floor System



Description: Table below lists costs ($/S.F.) for a floor system using composite steel beams with welded shear studs, composite steel deck, and light weight concrete slab reinforced with W.W.F. Price includes sprayed fiber fireproofing on steel beams.

Design and Pricing Assumptions:
Structural steel is A36, high strength bolted.
Composite steel deck varies from 22 gauge to 16 gauge, galvanized.
Shear Studs are 3/4".
W.W.F., 6 x 6 – W1.4 x W1.4 (10 x 10)
Concrete f'c = 3 KSI, lightweight.
Steel trowel finish and cure.
Fireproofing is sprayed fiber (non-asbestos).
Spandrels are assumed the same as interior beams and girders to allow for exterior wall loads and bracing or moment connections.

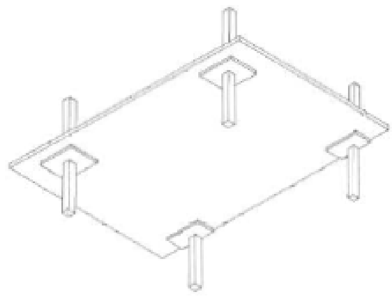
System Components	QUANTITY	UNIT	COST PER S.F. MAT.	COST PER S.F. INST.	COST PER S.F. TOTAL
SYSTEM B1010 256 2400					
20X25 BAY, 40 PSF S. LOAD, 5-1/2" SLAB, 17-1/2" TOTAL THICKNESS					
Structural steel	4.320	Lb.	4.97	1.60	6.57
Welded shear connectors 3/4" diameter 4-7/8" long	.163	Ea.	.10	.28	.38
Metal decking, non-cellular composite, galv. 3" deep, 22 gauge	1.050	S.F.	1.85	.84	2.69
Sheet metal edge closure form, 12", w/2 bends, 18 ga, galv	.045	L.F.	.16	.10	.26
Welded wire fabric rolls, 6 x 6 - W1.4 x W1.4 (10 x 10), 21 lb/csf	1.000	S.F.	.14	.31	.45
Concrete ready mix, light weight, 3,000 PSI	.333	C.F.	2.41		2.41
Place and vibrate concrete, elevated slab less than 6", pumped	.333	C.F.		.43	.43
Finishing floor, monolithic steel trowel finish for finish floor	1.000	S.F.		.76	.76
Curing with sprayed membrane curing compound	.010	C.S.F.	.05	.08	.13
Shores, erect and strip vertical to 10' high	.020	Ea.		.35	.35
Sprayed mineral fiber/cement for fireproof, 1" thick on beams	.483	S.F.	.24	.40	.64
TOTAL			9.92	5.15	15.07

3400	25x30	40	5-1/2	1 - 11-1/2	83	9.95	4.87	14.82
3600		75	5-1/2	1 - 11-1/2	119	10.70	4.92	15.62
3800		125	5-1/2	1 - 11-1/2	170	12.40	5.55	17.95
4000		200	6-1/4	2 - 6-1/4	252	15.35	6.30	21.65

Total System Cost: $14.82

- 2-way Flat Slab with Drop Panels

B1010 Floor Construction



General: Flat Slab: Solid uniform depth concrete two-way slabs with drop panels at columns and no column capitals.

Design and Pricing Assumptions:
Concrete f'c = 3 KSI, placed by concrete pump.
Reinforcement, fy = 60 KSI.
Forms, four use.
Finish, steel trowel.
Curing, spray on membrane.
Based on 4 bay x 4 bay structure.

System Components	QUANTITY	UNIT	COST PER S.F. MAT.	COST PER S.F. INST.	COST PER S.F. TOTAL
SYSTEM B1010 222 1700 15'X15' BAY 40 PSF S. LOAD, 12" MIN. COL. 6" SLAB, 1-1/2" DROP, 117 PSF					
Forms in place, flat slab with drop panels, to 15' high, 4 uses	.993	S.F.	1.75	4.88	6.63
Forms in place, exterior spandrel, 12" wide, 4 uses	.034	SFCA	.04	.29	.33
Reinforcing in place, elevated slabs #4 to #7	1.588	Lb.	.81	.59	1.40
Concrete ready mix, regular weight, 3000 psi	.513	C.F.	2.18		2.18
Place and vibrate concrete, elevated slab, 6" to 10" pump	.513	C.F.		.57	.57
Finish floor, monolithic steel trowel finish for finish floor	1.000	S.F.		.76	.76
Cure with sprayed membrane curing compound	.010	C.S.F.	.05	.08	.13
TOTAL			4.83	7.17	12

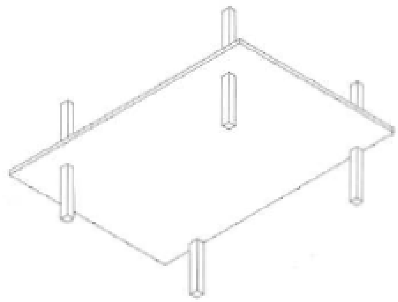
5000	25 x 30	40	14	9-1/2 - 7	168	6.90	8.05	14.95
5200		75	18	9-1/2 - 7	203	7.35	8.35	15.70
5600		125	22	9-1/2 - 8	256	7.70	8.55	16.25
5800		200	24	10 - 10	342	8.15	8.80	16.95

Total System Cost: $14.95

- Post-tensioned Slab

For this cost analysis, a 2-way flat slab will be used for the base cost. The tendon strands will be added for the final cost.

2-way flat slab



General: Flat Plates: Solid uniform depth concrete two-way slab without drops or interior beams. Primary design limit is shear at columns.

Design and Pricing Assumptions:
Concrete f'c to 4 KSI, placed by concrete pump.
Reinforcement, fy = 60 KSI.
Forms, four use.
Finish, steel trowel.
Curing, spray on membrane.
Based on 4 bay x 4 bay structure.

System Components	QUANTITY	UNIT	COST PER S.F. MAT.	COST PER S.F. INST.	COST PER S.F. TOTAL
SYSTEM B1010 223 2000					
15'X15' BAY 40 PSF S. LOAD, 12" MIN. COL.					
Forms in place, flat plate to 15' high, 4 uses	.992	S.F.	1.56	4.73	6.29
Edge forms to 6" high on elevated slab, 4 uses	.065	L.F.	.01	.22	.23
Reinforcing in place, elevated slabs #4 to #7	1.706	Lb.	.87	.63	1.50
Concrete ready mix, regular weight, 3000 psi	.459	C.F.	1.95		1.95
Place and vibrate concrete, elevated slab less than 6", pump	.459	C.F.		.60	.60
Finish floor, monolithic steel trowel finish for finish floor	1.000	S.F.		.76	.76
Cure with sprayed membrane curing compound	.010	C.S.F.	.05	.08	.13
TOTAL			4.44	7.02	11.46

The slab thickness used is 8.5" despite the bay size, so a cost of $13.40 is used as the base cost.

5600	20 x 25	40	18	8-1/2	146	5.95	7.45	13.40
6000		75	20	9	188	6.15	7.55	13.70
6400		125	26	9-1/2	244	6.65	7.75	14.40
6600		175	30	10	300	6.90	7.85	14.75

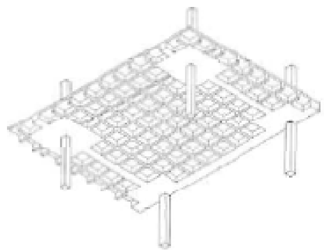
$5.50 is used at the cost for the post-tensioned tendons

03 23 05.50 Prestressing Steel	Crew	Output	Hours	Unit	Material	Labor	Equipment	Total	Incl O&P
0010 PRESTRESSING STEEL									
0100 Grouted strand, post-tensioned in field, 50' span, 100 kip	C-3	1200	.053	Lb.	1.98	2.02	.08	4.08	5.50
0150 300 kip		2700	.024		.87	.90	.04	1.81	2.43
0300 100' span, 100 kip		1700	.038		1.98	1.43	.06	3.47	4.53

Total System Cost: $18.90

- Waffle Slab

B1010 Floor Construction



General: Waffle slabs are basically flat slabs with hollowed out domes on bottom side to reduce weight. Solid concrete heads at columns function as crops without increasing depth. The concrete ribs function as two-way right angle joist.

Joists are formed with standard sized domes. Thin slabs cover domes and are usually reinforced with welded wire fabric. Ribs have bottom steel and may have stirrups for shear.

Design and Pricing Assumptions:
Concrete f'c = 4 KSI, normal weight placed by concrete pump.
Reinforcement, fy = 60 KSI.
Forms, four use.
4-1/2" slab.
30" x 30" voids.
6" wide ribs.
(ribs @ 36" O.C.).
Rib depth filler beams as required.
Solid concrete heads at columns.
Finish, steel trowel.
Curing, spray on membrane.
Based on 4 bay x 4 bay structure.

System Components	QUANTITY	UNIT	COST PER S.F. MAT.	COST PER S.F. INST.	COST PER S.F. TOTAL
SYSTEM B1010 227 3900					
20X20' BAY, 40 PSF S. LOAD, 12" MIN. COLUMN					
Formwork, floor slab with 30" fiberglass domes, 4 uses	1.000	S.F.	5.25	6.40	11.65
Edge forms, to 6" high on elevated slab, 1 use	.052	SFCA	.03	.28	.31
Forms in place, bulkhead for slab with keyway, 1 use, 3 piece	.010	L.F.	.02	.06	.08
Reinforcing in place, elevated slabs #4 to #7	1.580	Lb.	.81	.58	1.39
Welded wire fabric rolls, 6 x 6 - W4 x W4 (4 x 4) 58 lb/c.s.f	1.000	S.F.	.31	.40	.71
Concrete ready mix, regular weight, 4000 psi	.690	C.F.	3.05		3.05
Place and vibrate concrete, elevated slab, over 10", pump	.690	C.F.		.80	.80
Finish floor, monolithic steel trowel finish for finish floor	1.000	S.F.		.76	.76
Cure with sprayed membrane curing compound	.010	C.S.F.	.05	.08	.13
TOTAL			9.52	9.36	18.88

5700	25 x 30	40	14	10	154	10.05	9.60	19.65
5800		75	16	10	189	10.30	9.75	20.05
5900		125	18	10	239	10.50	9.90	20.40
6000		200	20	12	329	11.40	10.35	21.75

Total System Cost: $19.65

- Existing System – Non-composite steel beam/joist

B1010 Floor Construction

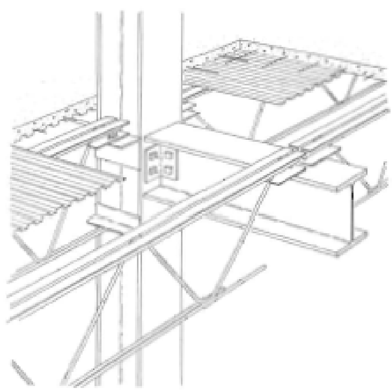


Table below lists costs for a floor system on steel columns and beams using open web steel joists, galvanized steel slab form, and 2-1/2" concrete slab reinforced with welded wire fabric.

Design and Pricing Assumptions:
- Structural Steel is A36.
- Concrete f'c = 3 KSI placed by pump.
- WWF 6 x 6 – W1.4 x W1.4 (10 x 10)
- Columns are 12' high.
- Building is 4 bays long by 4 bays wide.
- Joists are 2' O.C. ± and span the long direction of the bay.

Joists at columns have bottom chords extended and are connected to columns.

Slab form is 28 gauge galvanized. Column costs in table are for columns to support 1 floor plus roof loading in a 2-story building; however, column costs are from ground floor to 2nd floor only. Joist costs include appropriate bridging. Deflection is limited to 1/360 of the span. Screeds and steel trowel finish.

Design Loads	Min.	Max.
S.S. & Joists	6.3 PSF	15.3 PSF
Slab Form	1.0	1.0
2-1/2" Concrete	27.0	27.0
Ceiling	3.0	3.0
Misc.	5.7	1.7
	43.0 PSF	48.0 PSF

System Components	Quantity	Unit	Cost per S.F. Mat.	Cost per S.F. Inst.	Cost per S.F. Total
SYSTEM B1010 250 2350					
15'X20' BAY 40 PSF S. LOAD, 17" DEPTH, 83 PSF TOTAL LOAD					
Structural steel	1.974	Lb.	2.23	.73	[illegible]
Open web joists	3.140	Lb.	2.45	1	[illegible]
Slab form, galvanized steel 9/16" deep, 28 gauge	1.020	S.F.	1.02	.65	[illegible]
Welded wire fabric rolls, 6 x 6 - W1.4 x W1.4 (10 x 10), 21 lb/csf	1.000	S.F.	.14	.31	
Concrete ready mix, regular weight, 3000 psi	.210	C.F.	.89		
Place and vibrate concrete, elevated slab less than 6", pumped	.210	C.F.		.28	
Finishing floor, monolithic steel trowel finish for finish floor	1.000	S.F.		.76	
Curing with sprayed membrane curing compound	.010	S.F.	.05	.08	
TOTAL			6.78	3.81	[illegible]

5700	25x30	40	29	84		9.40	4.98	14.38
5800					column	.87	.29	1.16

Total System Cost: $14.38**

Significant cost will be added for the moment connections