Rutgers University Law School

Building Addition and Renovation
Camden, NJ

Technical Assignment 2

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Structural Option
AE 481W Senior Thesis
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Executive Summary:

This report examines the feasibility of several different floor framing methods and materials in respect to the Rutgers University Law School Addition. The loading considered for this assignment included gravity loads only, no effect of wind or seismic loading was taken into consideration in this preliminary design. The purpose of this analysis was to evaluate the need for further study of certain floor framing systems and to eliminate others from practical use. In this report I discuss the advantages and disadvantages of five systems as compared to the existing composite beam system designed for the addition. These systems are:

1. Girder Slab System
2. Hollow Core Plank System
3. One-Way Slab on Steel Beams
4. One-Way Post-Tensioned T-Beam System
5. Two-Way Flat Slab with Drop Panels

A major aspect to the design of the addition was the development of large open spans conducive to classroom spaces. As a result, only one bay was created in the North-South direction allowing for two classrooms and one central corridor. As part of my study, I attempted to choose systems that would permit this design feature to be maintained, rather than requiring additional building width to be created.

After analysis, the Girder-Slab system was found to be insufficient to accommodate 47 foot by 20 foot bays. Given the design information provided by the Girder-Slab, the largest usable span I was able to obtain for my loading was 20 foot by 20 foot, which would require the addition of two column lines and creating three spans, dramatically changing the building plan. Additionally, the two-way flat slab was also found to be insufficient to span 47 feet; however, this system would only require the addition of one column line as bay sizes of 20 foot by 27 foot were able to be attained.

The one way slab on steel beams proved to be significantly less effective than the existing composite beam framing system. This system utilized the same framing plan as currently exists for the building; however, without the use of composite action much larger members were required to support the loads applied. These results, coupled with the lack of added benefits by changing from composite beams eliminate this system as a possible alternative.

The hollow core plank system is able to span the required distances, and although this system does not seem to be the best fit for the building, it is still a possible alternative floor framing system. In addition, the post-tensioned T-beam framing system presents a great deal of added benefits to the floor system; although local practice could make this an unfeasible alternative as well, for now this appears to be the best alternative framing system studied in this report. Following the guest lecture by Richard Apple, P.E., from Holbert Apple Associates, Inc, the design produced for the T-beam in this report would need to be resized to permit for the 2-1/4” by 5” post tensioning pockets.

Introduction:

The Rutgers University Law School Building and Renovation consists of an east building addition, west building renovation and addition, and the development of a connecting bridge which is used to create a student lounge. As the west building additions are minimal, I will concentrate my efforts primarily on the east building addition and will attempt to examine the bridge design project at later date.

The east building consists of two major sections, the primary classroom section, which will be referred to as the primary east addition (4 floors, with basement and penthouse, 75'-0" height) and a student law clinic, which will be referred to as the secondary east addition (2 floors, with basement, 36'-4" height). A majority of the focus in Technical Assignment #2 will be on the typical framing bays located in the primary east addition, as the largest spans and most restrictive framing systems are demanded in this space. Connected to the west edge of the primary east addition is the bridge support system. This system creates several complicated analysis procedures which will be investigated in more depth later in this semester and have been neglected in the study of potential floor framing systems for this assignment.

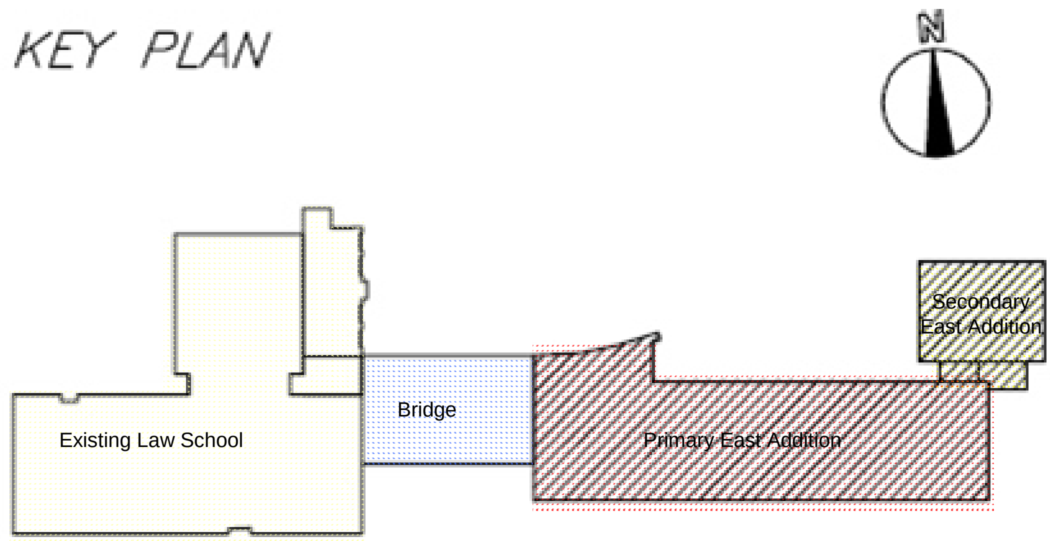


Figure 1: Plan illustrating different building components referenced in this report

Structural System:

The following sections will describe the structural elements incorporated in the design of the Rutgers University Law School Building.

Foundation System

The foundation system utilized to support the east building addition incorporates moment-resisting spread foundations, concrete pad foundations, and typical wall footing foundations. The foundation system supporting the bridge designed to cross Fifth Street includes drilled piles with pile caps along with a typical wall footing.

The spread footings supporting the moment frames, designed to resist moments generated by lateral loads, are 11'-0" x 11'-0" x 2'-6" concrete slab, reinforced with No. 8 rebar spaced at 12" on center each way, with a 40" x 40" reinforced pier to 10" below grade. In the smaller, three story section, of the east addition, the moment-resisting foundations are 7'-0" x 7'-0" x 2'0" spread footings with No. 7 rebar at 7" on center each way. Again, these foundations are supporting a 40" x 40" reinforced pier designed to transfer the moment to the ground. In addition, these spread footings have been designed to be supplemented by the displacement geopier system provided by Geostructures, Inc. to achieve an allowable bearing capacity of 5000 psf.

The typical wall footings designed around the east addition are 2'-0" wide x 1'0" deep strip footings reinforced with (3) No. 5 rebar longitudinal and No. 4 rebar spaced at 48" on center transversely. This wall footing is typical around the perimeter of the addition, where not influenced by the bridge system. In locations affected by the bridge assembly, the wall footings increase significantly in size, to 2'-6" x 1'-4" with (3) No. 5 rebar longitudinal and No. 5 rebar at 48" on center.

The final foundation system utilized in the Rutgers University Law School Addition is a drilled pile foundation located below the support of the bridge section of the building. A series of (24) 14" diameter piers are drilled to a depth of 65'-70'below grade, as required by the geotechnical report. In the east addition, the piles are capped with (4) 48" pile caps covering (6) piles each. To top off the pile caps, a grade beam, 2'-0" x 2'-0", has been designed to create a wall footing under the bridge addition.

Columns

The typical framing system used in the Rutgers University Law School is steel moment frame construction. Typical columns are attached to form a fixed connection to the foundations are A992 Grade 50 W14X159 for the primary east addition creating typical bays of 20'-0" by 46'-8", and A992 Grade 50 W14X82 for the secondary east addition which create 41'0" by 22'8" typical bays. Optional column splices have been located above the third floor for value engineering options.

Floor Systems

There are several different types of floor systems used throughout the Law School Building. Each system incorporates a composite floor slab (3/4" X 5" shear studs) with typical A992 Grade 50 steel framing systems.

The floor system used in the primary east addition consist of W21X68 wide flange beams spanning 46'-8", with intermediate beams consisting of W8X18 members spanning the 10'-0" spacing between the beams, which frame into W24X55 girders spanning 20'-0". The typical floor slab consists of 4-1/2" normal weight concrete ($f^1{}_c$ = 4000 psi), reinforced with 6X6 W2.9 X W2.9 WWF, on 3"-16ga metal floor decking which spans 10'-0". This floor system is used, with slight variations of beam sizes for all levels of the primary east addition, as well as for the secondary east addition.

In the bridge section of the building, rolled wide flange beams, W21X62, span 43'-0" to W40X235 girders spanning the 67'4" across Fifth Street. The floor slab consists of 4-1/2" normal weight concrete ($f^1{}_c$ = 5000 psi) reinforced with 6X6 W2.9 X W2.9 WWF on 3"-16ga metal floor decking spanning 11'-2" to the W21X62 beams.

Lateral Force Resisting System

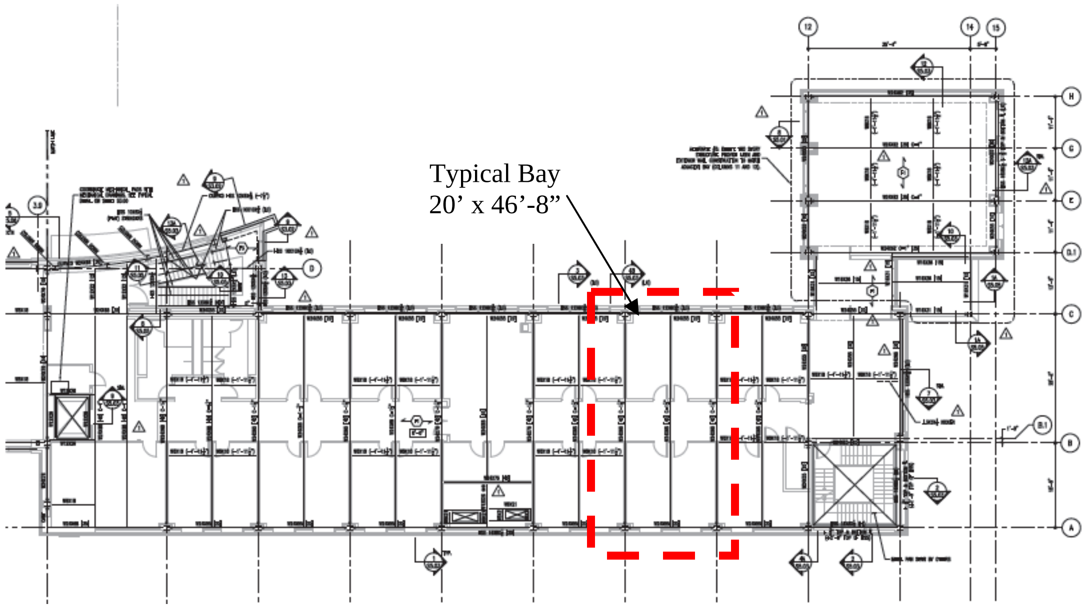
The lateral support for the entire east building addition is developed through the use of moment-resisting frames, as an open plan was critical in the architectural design of the building. There are (6) frames spaced at 20'-0" on center for the primary east addition, and (4) frames spaced at 11'-4" on center for the secondary east addition. For the bridge addition, (2) lateral wind resisting frames are required to withstand the load, these frames are spaced at 67'-4" on center. Each of the lateral support frames are created through beam-column moment connections.

The lateral resisting system has been highlighted in the typical framing plan located in the appendix of this report.

Roof Framing System

The roof framing system designed for the entire east building addition and bridge section of the Rutgers University Law School consists of W18 beams spaced at 10'-0" or less on center framing into W18 girders with 3"-18ga galvanized roof decking.

Typical Floor Framing Plan



Building Loads

The following gravity loads were used for the analysis of the floor framing systems considered in this report. A load factor of 1.2D + 1.6L was applied to create maximum load to each system.

Dead Load

The dead load was calculated for each system through material weights and/or the use of standard charts or tables created by the manufacturer of certain systems. In all cases, a superimposed dead load of 15psf was added to account for additional lighting/electrical and mechanical systems, as well as the weight floor finish materials.

Live Load

The live load applied to the floor systems analyzed in this report is 100psf which accounts for the weight of partition walls as well as classroom occupancy or overall corridor loading. This loading was taken as a conservative value for the preliminary design to provide an indication of each system's ability to withstand the large load which will be applied to the center of the clear span in a more detailed analysis.

Design Requirements

The following sections detail the special requirements which need to be addressed within each floor framing system examined. Each of these requirements will help narrow the scope of research performed in future assignments.

Architectural Requirements

There are several architectural requirements in the design of the Rutgers University Law School Building; however, the constraint most influenced by the floor system is the clear span across the North-South direction of the primary east addition. This section includes two classrooms with a dividing corridor. Although a column could be placed on the sides of the hallway, the ability to clear span this distance provides the most flexibility in the building.

Fire Rating Requirements

This building has been designed for Type IB construction, requiring fire resistance ratings of two hours on the floor system. This will need to be taken into consideration with the use of steel members and decking as fire proofing will need to be applied.

Foundation Requirements

The subgrade material located onsite has been determined to have relatively low bearing capacity and requires geopier stabilization to support the loads being applied. As a result, the superstructure weight should be minimized so as to avoid the need of additional stabilization.

Cost Analysis

As with many projects, cost is a major factor in the choice of system design for the Rutgers University Law School Addition. Because this project is financed by the state university of New Jersey, there is not a large budget to design and develop a top of the line law school building which will attract students to attend the university. Each system will be analyzed on a low to high basis for system cost.

Vibration Requirements

Vibration will create the largest influence on the penthouse floor as the mechanical equipment (boilers, pumps, and fans) move while in operation. The majority of this movement will be absorbed by vibration isolators and inertia pads attached to the equipment; however the floor system must be rigid enough to withstand the limited vibration associated with the equipment.

Acoustic Requirements

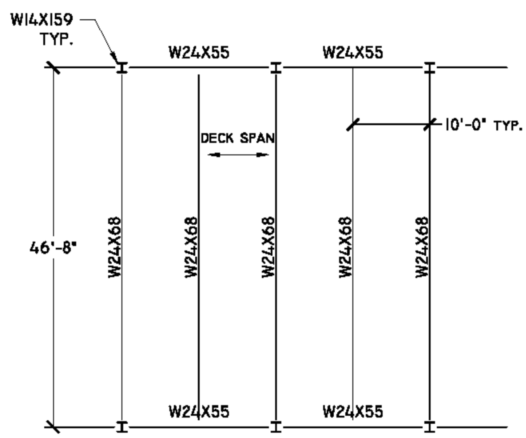
As this is a classroom building as well as a law office, the need for acoustic privacy is essential. There must be sufficient isolation of rooms through the walls as well as through the floor system.

Floor System Investigation

The following sections briefly describe the floor framing systems investigated for feasibility and economy in the Rutgers University Law School Building Addition.

Existing System: Composite Beam

The existing floor system is composed of 3" metal decking supported by a typical steel framing system. This framing system consists of W24X68 beams spanning 47 feet, with typical W24X55 girders acting as spandrel beams. Composite action is generated through the use of (40) three-quarter inch by five inch shear studs on each supporting beam. The concrete slab generated by this approach uses normal weight concrete, f^1_c = 4000 psi, with a minimal amount of reinforcement. The total slab depth required for this design is 7-1/2" creating a floor load of 75 psf from the Vulcraft Metal Decking Reference Material[1].



TYPICAL FRAMING PLAN

Following the design requirements found in the American Institute for Steel Construction Manual (AISC)[2], there are several advantages to the composite floor system: generating a much larger beam capacity, reducing deflection issues, and reducing slab thickness are the most prominent benefits. In addition, this system creates a 31.5" floor system which provides adequate room for mechanical and electrical equipment to be located within the framing system, permitting large floor to ceiling heights. This system also addresses the need for a 47 foot clear span across the North-South direction of the building.

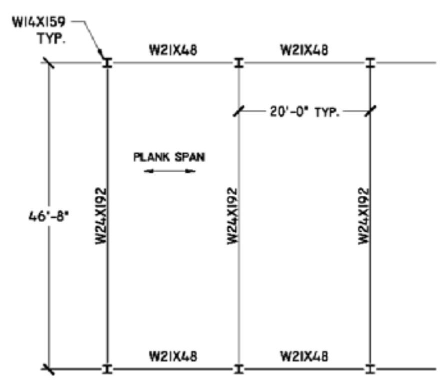
The main disadvantages of this system are the large floor system thickness and the requirement of additional fireproofing to be applied to the steel sections.

Overall, this framing system provides an excellent solution to the design issues which were considered in this assignment.

Proposed System #1: Girder-Slab/Hollow Core Plank

One of the alternate floor systems examined for the Law School was the Girder-Slab system. This system provides for expedited erection time, a critical issue when considering academic buildings. According to Thomas Farone, a senior engineer for the American Institute of Steel Construction (AISC), the system creates a concrete flat slab type system, eliminating the need for beams in the system[3]. As a result, an analysis of the capacity of the Girder-Slab system was performed, while maintaining the need for 47 foot clear spans. This proved unfeasible, so I attempted to determine the maximum capacity of this system, resulting in 24 foot maximum spans. This type of span would have required two additional columns in the framing plan as a hallway divides the 47 foot span in half. The resulting calculations have been included in the appendix[4]; however, a more typical hollow core slab system was designed as a replacement—as the typical wide flange beams permit much larger spans.

The hollow core slab system consists of typical wide flange steel beams spanning 47 feet with 10" x 4'-0" precast planks with a 2" concrete topping to provide 2-hour fire resistance rating. The typical beam framing used is 24X192 spanning 47 feet, framing into W21X48 acting as girders on the exterior of the building; see the framing plan detailed below.



TYPICAL FRAMING PLAN

There are several key advantages to the hollow core plank system. The first advantage is the erection time is greatly reduced, as curing time for the concrete is not required following placement.

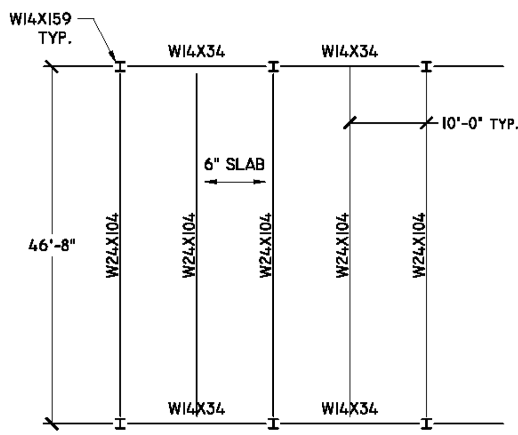
The hollow core plank system inherently has several disadvantages, including the need for a thicker floor system. Also, the trades associated with this system, concrete and steel, will increase the overall system cost and create scheduling issues with coordination of work.

This system may still be considered as an alternative floor framing system for the building, additional research would be required to remove this option.

Proposed System #2: One Way Slab on Steel Beams

This system was examined as an alternative to the existing composite beam design because of the potential to reduce slab thickness and eliminate the need for steel decking. This would permit for less

The framing system considered for the one way slab on steel beams matches the layout generated for the existing system. The slab thickness was determined from the Concrete Reinforcing Steel Institute (CRSI) manual for typical construction sizes, resulting in a 6-inch slab spanning 10 feet[5]. The beams required to support this system have been determined to be W24X55 with W14X34 girders.



TYPICAL FRAMING PLAN

The benefits of a one way slab on steel beams are a reduced slab thickness and the elimination of shear studs. The reduction in material reduces project costs; however, it will delay construction time as shoring is required for the concrete system which will require additional time to be removed.

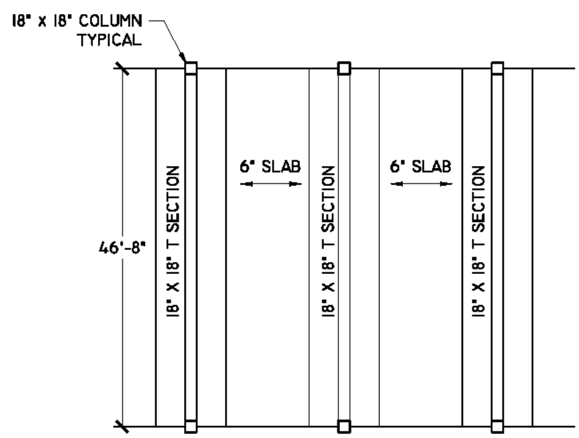
In addition to creating longer project duration, this system requires formwork not associated with a metal deck system and additional reinforcement. Also, this system requires the coordination of steel erectors with concrete laborers, which will create potential scheduling issues during the construction phase.

Overall, this system is not a viable alternative floor system for the Rutgers University Law School Addition.

Proposed System #3: One Way Post-Tensioned T-Beam

This system was chosen as it typically generates smaller slab thicknesses and allows for greater clear spans, both very important aspects in the Rutgers University Law School Building. As building weight is an important factor in the design of the structure (the soil bearing capacity requires stabilization), creating thinner slabs while maintaining the architectural criteria create great interest in this method of construction. A one way system was chosen in an attempt to maintain only one span in the North-South direction of the building. This requirement eliminates the possibility of creating a two way post tensioned slab.

The post-tensioned design requires the incorporation of a one way slab between the post-tensioned T-beam sections. Through analysis, the T-beam section is 9’-2” wide by 47’-0” long, requiring 10’8” one way slab reinforced with No. 4 rebar spaced at 12 inches on center top reinforcement and No. 3 rebar spaced at 10 inches on center bottom reinforcement[5]. The T-beam section is reinforced with (30) ½” diameter, 270 ksi low elongation post tensioning tendons and No. 4 stirrups to improve the shear capacity of the beam[6]. This system utilizes a 6” slab thickness with a 18” wide by 18” deep beam spanning the 47 foot distance in the North-South direction. This system incorporates the use of 18” by 18” concrete columns to replace the existing steel columns of the building. These columns are sized larger than necessary to provide lateral resistance as well as to improve constructability associated with the 18” wide beam required for the span. See framing plan below for a more detailed framing layout.



TYPICAL FRAMING PLAN

The main advantage to implementing a post tensioned slab in the addition is the ability to clear span and maintain the existing column grid, while incorporating a much thinner slab than is possible with a typical system. Also, this system could be examined for feasibility in the bridge design, potentially reducing the required beam sizes spanning Fifth Street.

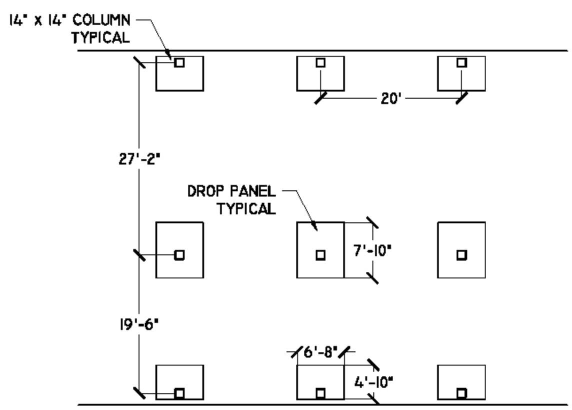
There are several disadvantages to this system, in an attempt to create a thinner floor system, shear reinforcement is required and the increased column size will generate a larger load on the foundation system. Another disadvantage associated with this system is the additional equipment required to post tension the beams and slab during construction; hence increasing project cost.

Overall, this system appears to be a potential alternative framing system for the building, increasing floor to ceiling height and decreasing slab thickness.

Proposed System #4: Two Way Flat Slab with Drop Panels

The two way flat slab system was analyzed to determine its effectiveness in large span applications. After a brief study, it was determined that an additional column was necessary for this system to achieve its intended benefits.

This system utilizes a 10.5” slab spanning the 20’-0” by 27’-8” typical bay, requiring the addition of 14-inch by 14-inch columns as located in the framing plan. Following the ACI 318-02 code requirements[7], the equivalent frame method analysis was completed by pcaSlab to obtain the necessary reinforcement for this system. A 3” drop panel was created at each support, and a column capital was added to reduce punching shear on the slab[8]. As a result, the framing plan and reinforcing elevations illustrated below were generated for the Rutgers University Law School Addition.



TYPICAL FRAMING PLAN

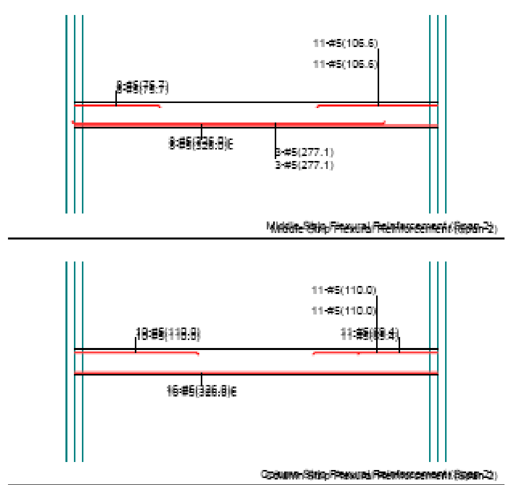


Figure 2: Typical North-South Frame Reinforcing (Generated by pcaSlab)

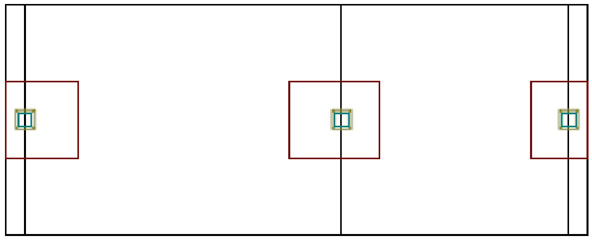


Figure 3: Typical North-South Frame

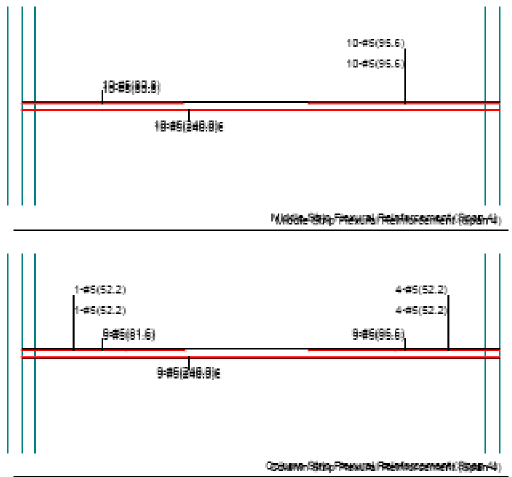


Figure 4: Typical East-West Frame Reinforcing (Generated by pcaSlab)

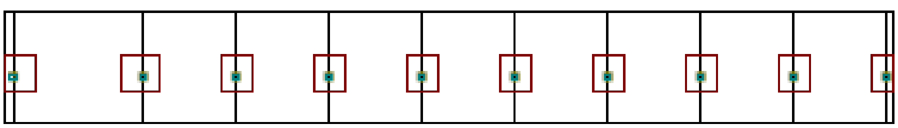


Figure 5: Typical East-West Frame

The most practical benefit to this system is the thin floor system generated without any beams or girders. Other potential benefits involve the cheap cost of cast-in-place concrete and the moment resisting capacity of this framing system, which will provide benefits in a lateral resistance analysis.

This system incorporates additional columns which limit the design of the floor plan and adds significant load to the foundation. Additionally, the size of the drop panels creates a significant amount of extra formwork to be constructed to place the concrete slab.

This system does not appear to be a feasible alternative to the existing composite beam floor framing system.

Summary:

The following chart summarizes each alternative system and its ability to accommodate required architectural and serviceability conditions.

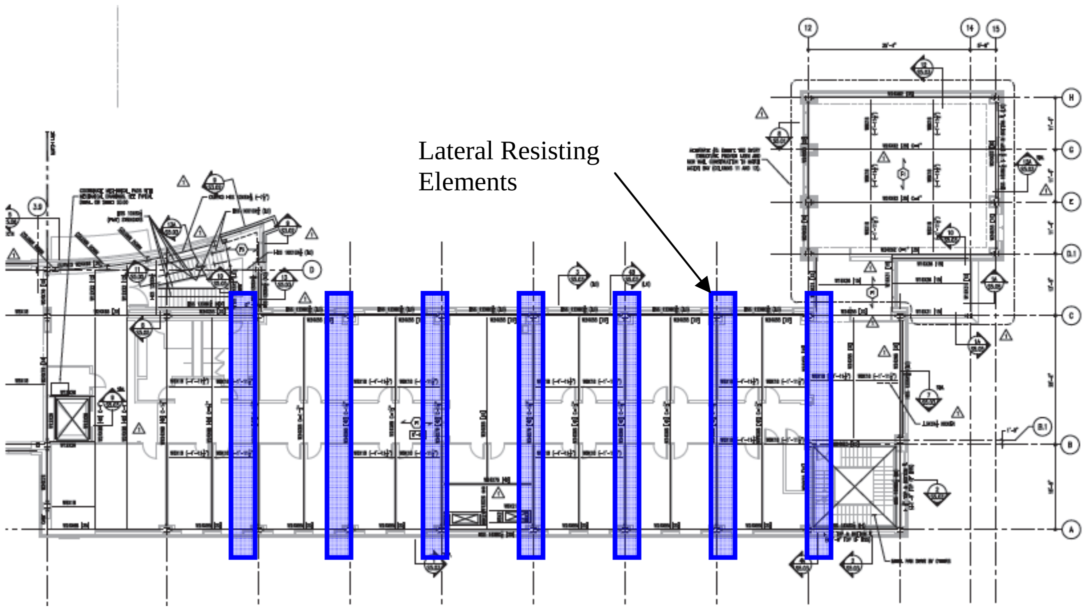
	Hollow Core Plank	One Way Slab on Steel Beams	Post-Tensioned T-Beam	Two Way Flat Slab with Drop Panels	Composite Beam
Depth	34"	30"	24"	13.5"	31.5"
Clear Span	Yes	Yes	Yes	No	Yes
Fire Proofing Required	Yes	Yes	No	No	Yes
Building Weight	Medium	Low	High	High	Low
System Cost	High	Medium	Medium	Low	Medium
Vibration Requirements	OK	OK	OK	OK	OK
Potential Alternative?	Yes	No	Yes	No	Existing

Figure 6: Alternative System Comparison Chart

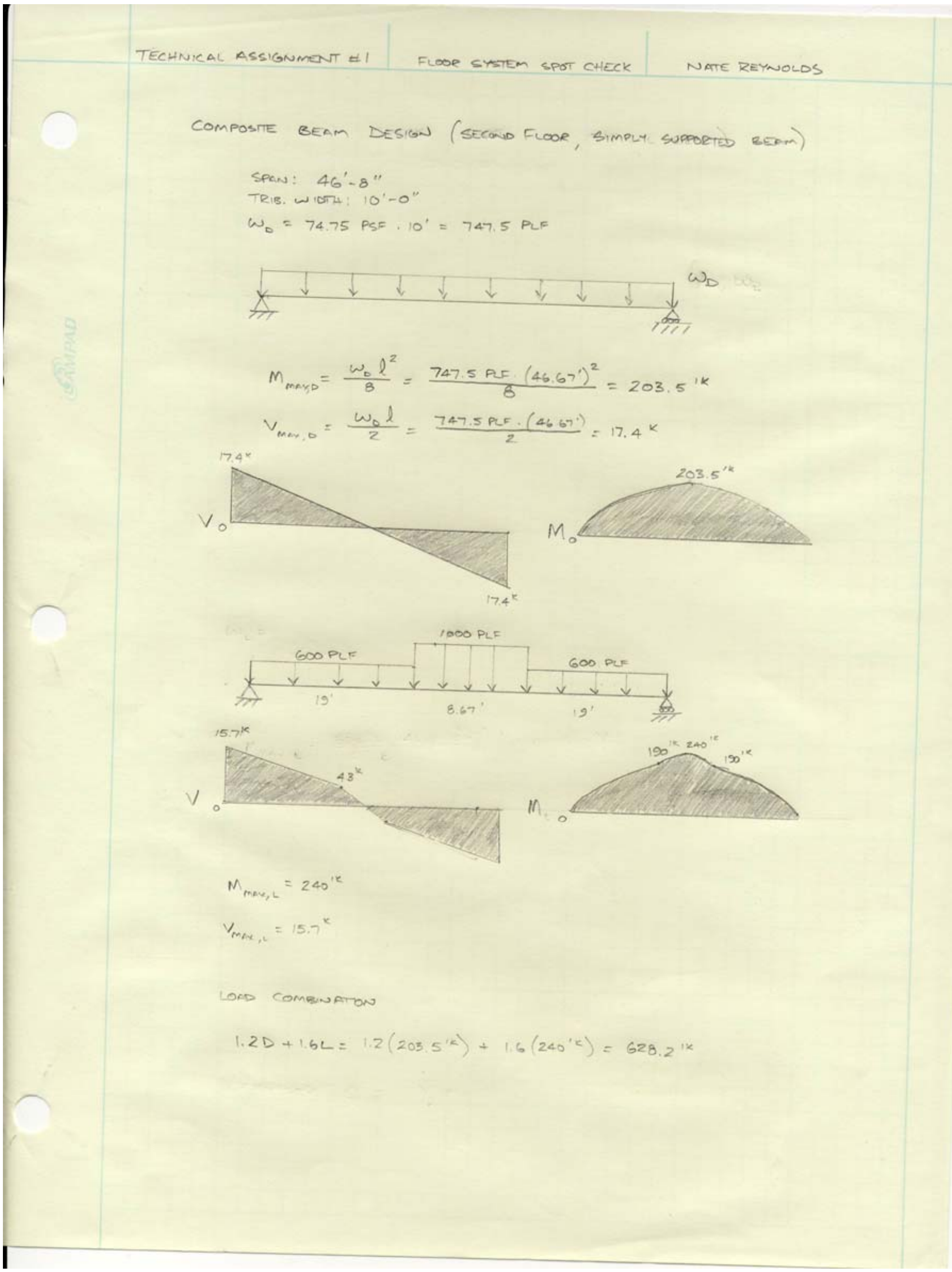
In conclusion, through the several alternative floor systems analyzed, the post-tensioned T-beam system appears to require additional study to determine its potential effectiveness in this building case. Other alternatives such as the Girder-Slab system and the two way flat slab system fail to attain the architectural requirements, eliminating their benefit to the Rutgers University Law School Addition. While the one way slab on steel beam system permits adequate spans to be attained, it fails to improve upon the existing composite beam floor system. Finally, another floor system which may provide additional potential for the framing system is the hollow core plank system studied in this report; however, the supports associated with this system are greater than those provided for the existing system.

Appendix:

Typical Floor Framing Plan:



Composite Beam Floor System Calculations:



TECHNICAL ASSIGNMENT #1 | FLOOR SYSTEM SPOT CHECK | NATE REYNOLDS

COMPOSITE BEAM DESIGN (SECOND FLOOR, SIMPLY SUPPORTED BEAM)

SPAN: 46'-8"
TRIB. WIDTH: 10'-0"
ω_D = 74.75 PSF · 10' = 747.5 PLF

$M_{max,D} = \frac{\omega_D l^2}{8} = \frac{747.5 \text{ PLF} \cdot (46.67')^2}{8} = 203.5'^{k}$

$V_{max,D} = \frac{\omega_D l}{2} = \frac{747.5 \text{ PLF} \cdot (46.67')}{2} = 17.4^{k}$

$M_{max,L} = 240'^{k}$

$V_{max,L} = 15.7^{k}$

LOAD COMBINATION

$1.2D + 1.6L = 1.2(203.5'^{k}) + 1.6(240'^{k}) = 628.2'^{k}$

CHECK LIVE LOAD DEFLECTION

ASSUMPTION: 1000 PLF ACROSS FULL BEAM, FOR EASE OF CALCULATION, CONSERVATIVE ANALYSIS

$$\frac{L}{360} = \frac{46.67' \cdot 12''/'}{360} = 1.54 \text{ IN}$$

$$\Delta_{LL} = \frac{5wl^4}{384EI} = \frac{5(1000 \text{ PLF})(46.67')^4(1728 \text{ IN}^3/\text{FT}^3)}{384(29000 \text{ KSI})(1000 \text{ LB/K})I}$$

$$I \geq 2360 \text{ IN}^4$$

CHECK TOTAL LOAD DEFLECTION

$$\frac{L}{240} = \frac{46.67' \cdot 12''/'}{240} = 2.33 \text{ IN}$$

$$\Delta_{TL} = \frac{5wl^4}{384EI} = \frac{5(1750 \text{ PLF})(46.67')^4(1728 \text{ IN}^3/\text{FT}^3)}{384(29000 \text{ KSI})(1000 \text{ LB/K})I}$$

$$I \geq 2765 \text{ IN}^4$$

MEMBER SELECTION

ASSUMPTION: $T = C$
$Y_2 = 4.0$

CHOOSE * W24X55 $\phi M_n = 959'^K$ $I = 3370 \text{ IN}^4$ $\Sigma Q_n = 810^K$

W21X68 $\phi M_n = 1090'^K$ $I = 3600 \text{ IN}^4$ $\Sigma Q_n = 1000^K$

* # OF SHEAR STUDS REQUIRED: $\frac{810^K}{21} = 39 = 40$ STUDS = 80 STUDS

SHEAR STUD CAPACITY SPECIFIED IN DRAWINGS: 20 STUDS $\cdot 21^K = 410^K$

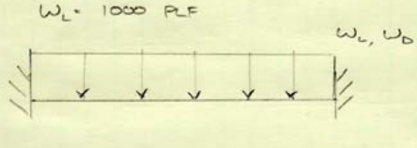
THIS WILL REQUIRE PNA TO BE POSITION 6 OR 7

CHOOSE W24X62 $\phi M_n = 891'^K$ $I = 2850 \text{ IN}^4$ $\Sigma Q_n = 362^K$

TECHNICAL ASSIGNMENT #1 | FLOOR SYSTEM SPOT CHECK | NATE REYNOLDS

COMPOSITE BEAM DESIGN (SECOND FLOOR, MOMENT FRAME BEAM)
[USED IN LATERAL FRAME ANALYSIS]

SPAN: 46'-8"
TRIB WIDTH: 10'-0"
$w_D = 747.5$ PLF
$w_L = 1000$ PLF



ASSUME LIVE LOAD IS UNIFORM

$$M_{MAX,D} = \frac{wl^2}{12} = \frac{0.75 \text{ KLF } (46.67')^2}{12} = 136.1'^K \text{ AT ENDS}$$

$$M_{MIDSPAN,D} = \frac{wl^2}{24} = 68.1'^K$$

$$M_{MAX,L} = \frac{1.0 \text{KLF } (46.67')^2}{12} = 181'^K$$

$$M_{MIDSPAN,L} = 90.8'^K$$

THESE MOMENTS WILL BE USED TO CALCULATE FORCES ON LATERAL RESISTING FRAME

ASSUME ½ MOMENT CARRIES INTO COLUMN

$$M_{COL} = 90.8'^K$$

CHECK BEAM CAPACITY (WET CONCRETE)

$w_D = 75$ PSF (WT OF CONCRETE AND DECKING ONLY)

$M_{MAX} = \frac{w_D l^2}{8} = \frac{1.4(75\text{ PSF})(10')(47')^2}{8} = 290'^k$

$\Delta_{TL} = \frac{l}{240} = 2.33$ IN

$2.33\text{ IN} = \frac{5(75\text{ PSF})(10')(47')^4(1728)}{384(29000\text{ KSI})(1000)(I)}$

$I \geq 1220\text{ IN}^4$

CHOOSE W24 × 55

$\phi M_n = 503'^k > 290'^k$ ✓

$I_x = 1350\text{ IN}^4 > 1220\text{ IN}^4$ ✓

Girder Slab/Hollow Core Plank Calculations:

Girder-Slab® System
D-Beam® Calculator Reference Tool
10/25/2007

Project Name: Rutgers University Law School
Job Number:

Design Information

Dead Load =	60	psf
Partition Load =	15	psf
Live Load =	40	psf
Topping Load =	25	psf
DB Span =	20	ft
Plank Span =	20	ft
Grout f'c =	5500	psi
Allowable Δ_{LL} = L /	360	
Allowable Δ_{LL} =	0.67	in

DB Properties

DB Size ------------> DB 9 x 46

Steel Section			**Transformed Section**		
I_s =	195	in^4	I_t =	356	in^4
S_t =	33.7	in^3	S_t =	68.6	in^3
S_b =	50.8	in^3	S_b =	80.6	in^3
M_{scap} =	84.0	ft-k			
t_w =	0.375	in			
b =	5.75	in			

Live Load Reduction (IBC 00/03/06)

Include LLR ☐ (Check for Yes)
% Reduction = N/A
Reduced Load = N/A

Initial Load - Precomposite

M_{DL} =	60.0	ft-k	<	84.0	ft-k	OK
Δ_{DL} =	0.76	in				
Δ Ratio = L /	314					
Camber D-Beam ☐		(Check for Yes)				
D-Beam Camber	1	in				

Total Load - Composite

M_{sup} =	80.0	ft-k				
M_{TL} =	140.0	ft-k				
S_{REQ} =	56.0	in^3	<	68.6	in^3	OK
Δ_{SUP} =	0.56	in	<	0.67	in	OK
Δ_{TOT} =	1.32	in	= L/	182		

Superimposed Compressive Stress on Concrete

N value =	6.86					
S_{tc} =	471	in^3				
f_c =	2.04	ksi				
F_c =	2.48	ksi	>	2.04	ksi	OK

Bottom Flange Tension Stress (Total Load)

f_b =	26.1	ksi				
F_b =	45	ksi	>	26.1	ksi	OK

Shear Check

Total Load =	140	psf				
w =	2.80	klf				
R =	28.0	k				
f_v =	13.0	ksi				
Fv =	20	ksi	>	13.0	ksi	OK

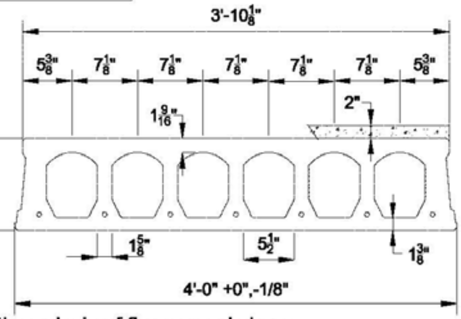
Figure 7: Girder-Slab Preliminary Design Aid from Girder-Slab website

Prestressed Concrete
10"x4'-0" Hollow Core Plank

2 Hour Fire Resistance Rating With 2" Topping

PHYSICAL PROPERTIES
Composite Section

A_c = 327 in.^{2} Precast S_{bc} = 824 in.^{3}
I_c = 5102 in.^{4} Topping S_{tc} = 1242 in.^{3}
Y_{bc} = 6.19 in. Precast S_{tc} = 1340 in.^{3}
Y_{tc} = 3.81 in. Wt.= 272 PLF
Wt.= 68.00 PSF



DESIGN DATA

1. Precast Strength @ 28 days = 6000 PSI
2. Precast Strength @ release = 3500 PSI or 4000 PSI.
3. Precast Density = 150 PCF
4. Strand = 1/2"Ø and 0.6"Ø 270K Lo-Relaxation.
5. Strand Height = 1.75 in.
6. Ultimate moment capacity (when fully developed)...
   7-1/2"Ø, 270K = 192.2 k-ft
   7-0.6"Ø, 270K = 256.4 k-ft
7. Maximum bottom tensile stress is $7.5\sqrt{f'c}$ = 580 PSI
8. All superimposed load is treated as live load in the strength analysis of flexure and shear.
9. Flexural strength capacity is based on stress/strain strand relationships.
10. Deflection limits were not considered when determining allowable loads in this table.
11. Topping Strength @ 28 days = 3000 PSI. Topping Weight = 25 PSF.
12. These tables are based upon the topping having a uniform 2" thickness over the entire span. A lesser thickness might occur if camber is not taken into account during design, thus reducing the load capacity.
13. Load values to the left of the solid line are controlled by ultimate shear strength.
14. Load values to the right are controlled by ultimate flexural strength or fire endurance limits.
15. Load values may be different for IBC 2000 & ACI 318-99. Load tables are available upon request.
16. Camber is inherent in all prestressed hollow core slabs and is a function of the amount of eccentric prestressing force needed to carry the superimposed design loads along with a number of other variables. Because prediction of camber is based on empirical formulas it is at best an estimate, with the actual camber usually higher than calculated values.

SAFE SUPERIMPOSED SERVICE LOADS — IBC 2003 & ACI 318-02 (1.2 D + 1.6 L)

Strand Pattern		SPAN (FEET)																		
		26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44
7 - 1/2"ø	LOAD (PSF)	234	210	189	170	153	137	123	110	98	87	77	68	60	52					
7 - 0.6"ø	LOAD (PSF)			256	244	233	222	202	185	168	154	140	128	116	106	96	87	78	70	63

NITTERHOUSE
CONCRETE PRODUCTS
2655 Molly Pitcher Hwy. South, Box N
Chambersburg, PA 17201-0813
717-267-4505 Fax 717-267-4518

This table is for simple spans and uniform loads. Design data for any of these span-load conditions is available on request. Individual designs may be furnished to satisfy unusual conditions of heavy loads, concentrated loads, cantilevers, flange or stem openings and narrow widths. The allowable loads shown in this table reflect a 2 Hour & 0 Minute fire resistance rating.

05/14/07

10F2.0T

Figure 8: Nitterhouse Concrete Products Spec Sheet

TECHNICAL ASSIGNMENT 2 | N. REYNOLDS | HOLLOW CORE PLANK SYSTEM

LOADING:

SUPERIMPOSED DEAD LOAD: 15 PSF
LIVE LOAD: 100 PSF

MAXIMUM SPAN: 28'0"
TYPICAL SPAN: 20'-0"

$w_u = 1.2(15\text{ PSF}) + 1.6(100\text{ PSF}) = 178\text{ PSF}$

GO TO CHARTS

CHOOSE 10" x 4'-0" PRECAST HOLLOW CORE PLANK
W/ 7 - ½" φ 270 K LO-RELAXATION CABLES
WEIGHT: 68 PSF

DESIGN BEAM

SPAN: 47'-0"
SPACING: 20'-0"

ASSUME MOMENT CONNECTION EXISTS, FULL LATERAL SUPPORT ONLY OCCURS BETWEEN COLUMNS, ALSO CHECK SIMPLE SUPPORT

$w_u = 1.2(68\text{ PSF}) + 178\text{ PSF} = 260\text{ PSF}$

$260\text{ PSF}(20') = 5.19\text{ KLF}$

$M_u = \frac{5.19\text{ KLF}(47')^2}{8} = 1433'^{K}$

CHECK DEFLECTION CRITERIA:

$\Delta_{LL} = \frac{L}{360} = 1.57'' = \frac{5wl^4}{384EI} = \frac{5(100\text{ PSF})(20')(47')^4(1728)}{384(29000\text{ KSI})(I)(1000)}$

$I \geq 4823\text{ IN}^4$

$\Delta_{TL} = \frac{L}{240} = 2.33'' = \frac{5wl^4}{384EI} = \frac{5(183\text{ PSF})(20')(47')^4(1728)}{384(29000\text{ KSI})(I)(1000)}$

$I \geq 5947\text{ IN}^4$

CHOOSE W24x192 $\phi M_n = 2100'^{K} > 1433'^{K}$ ✓

$I = 6260\text{ IN}^4 > 5947\text{ IN}^4$ ✓

TECHNICAL ASSIGNMENT #2 | N. REYNOLDS | HOLLOW CORE PLANK SYSTEM

DESIGN GIRDER

$A_T = \frac{47'}{2} \times 20' = 470$ SF

ASSUME POINT LOAD IN CENTER OF SPAN
MOMENT CONNECTION TO COLUMNS

SPAN: 20'-0"

$P = 470\text{SF}(260\text{PSF}) = 122^k$

$M_u = \frac{Pl}{8} = \frac{122^k(20')}{8} = 306'^k$

CHECK DEFLECTION

$$\Delta_{LL} = \frac{L}{360} = 0.667'' = \frac{Pl^3}{192EI} = \frac{470\text{SF}(100\text{PSF})(20')^3}{192(29000\text{ KSI})(1000)(I)}(1728)$$

$I \geq 175$ IN^4

$$\Delta_{TL} = \frac{L}{240} = 1.0'' = \frac{Pl^3}{192EI} = \frac{470\text{SF}(183\text{PSF})(20')^3(1728)}{192(29000\text{KSI})(1000)(I)}$$

$I \geq 215$ IN^4

CHOOSE W21×48 $\phi M_n = 348'^k$ @ 10' UNSUPPORTED
$I = 959$ IN^4

One Way Slab on Steel Beam Calculations:

TECHNICAL ASSIGNMENT 2 N. REYNOLDS ONE WAY SLAB ON STEEL BEAMS

LOADS: SUPERIMPOSED DEAD LOAD: 15 PSF
LIVE LOAD: 100 PSF

MATERIAL PROPERTIES

$f'_c = 3000$ PSI
$f_y = 60\,000$ PSI

$W_u = 1.2(15\text{ PSF}) + 1.6(100\text{ PSF}) = 178\text{ PSF}$

FROM CRSI DESIGN TABLES

6" SLAB, SLAB WT = 75 PSF

BEAM DESIGN

ASSUME: FULL LATERAL SUPPORT
SIMPLE SUPPORT

$W_u = 178\text{ PSF} + 1.2(75\text{ PSF}) = 270\text{ PSF}$

$M_u = \dfrac{270\text{ PSF}(10')(47')^2}{8} = 746\ '^{K}$

$\Delta_{LL} = 1.57'' = \dfrac{5 \cdot 100\text{ PSF}(10')(47')^4(1728)}{384(29000\text{ KSI})(1000)(I)}$

$I \geq 2411\text{ IN}^4$

$\Delta_{TL} = 2.33'' = \dfrac{5 \cdot 190\text{ PSF}(10')(47')^4(1728)}{384(29000\text{ KSI})(1000)(I)}$

$I \geq 3087\text{ IN}^4$

CHOOSE W24 × 104 $\phi M_n = 1080\ '^{K} > 746\ '^{K}$
$I = 3100\text{ IN}^4 > 3087\text{ IN}^4$

DESIGN GIRDER

ASSUME FIXED AT ENDS
POINT LOAD AT MIDSPAN

SPAN: 20'-0"

$P_U = 10' \times \frac{47'}{2} \times 270PSF = 63.5^k$

$M_U = \frac{63.5^k(20')}{8} = 158.6^{'k}$

$\Delta_{LL} = 0.67'' = \frac{235\,SF\,(100PSF)(20')^3}{192\,(29000\,KSI)(1000)(I)}(1728)$

$I \geq 90\ IN^4$

$\Delta_{TL} = 1.0\ IN = \frac{235\ SF\,(190\ PSF)(20')^3(1728)}{192\,(29000\,KSI)(1000)(I)}$

$I \geq 110\ IN^4$

CHOOSE W14×34 $\phi M_n = 172^{'k} > 159^{'k}$ ✓
$I = 340\ IN^4 > 110\ IN^4$ ✓

SOLID ONE-WAY SLABS—INTERIOR SPAN — $f'_c = 3{,}000$ psi — Grade 60 Bars — Recommended Minimum Steel Top and Bottom

Thickness (in.)	4	4½	5	5½	6	6½	7	7½	8	8½	9	9½	10
Top Bars	#4	#4	#4	#4	#4	#4	#4	#4	#4	#4	#4	#4	#4
Spacing (in.)	12	12	12	12	12	12	12	12	12	12	12	11	11
Bottom Bars	#3	#3	#3	#3	#3	#3	#3	#3	#4	#4	#4	#4	#4
Spacing (in.)	12	12	12	11	10	9	8	7	12	12	12	11	11
T-S Bars	#3	#3	#3	#3	#4	#4	#4	#4	#4	#4	#4	#5	#5
Spacing (in.)	15	13	12	11	18	17	15	14	13	13	12	18	17
Areas of Steel ($in.^2/ft$) Top Interior	.200	.200	.200	.200	.200	.200	.200	.200	.200	.200	.200	.218	.218
Bottom	.110	.110	.110	.120	.132	.147	.165	.189	.200	.200	.200	.218	.218
Slab Wt. (psf)	50	56	63	69	75	81	88	94	100	106	113	119	125
CLEAR SPAN	**FACTORED USABLE SUPERIMPOSED LOAD (psf)**												
6′-0″	579	680	781	969									
6′-6″	483	568	652	811									
7′-0″	407	479	550	686	851								
7′-6″	345	407	468	585	727	903	990						
8′-0″	295	348	400	502	627	780	855	931					
8′-6″	253	299	344	434	543	678	743	810	876	942			
9′-0″	218	259	298	377	473	592	650	708	766	824	881	940	998
9′-6″	189	224	258	328	414	520	571	622	673	725	775	826	878
10′-0″	163	194	224	287	363	458	503	548	594	640	684	729	775
10′-6″	142	169	195	251	319	362	397	434	470	507	542	578	615
11′-0″	123	147	170	220	282	320	351	383	416	448	479	512	544
11′-6″	106	128	148	193	249	283	311	340	369	398	425	454	483
12′-0″	92	111	129	169	220	251	275	301	327	353	378	404	429
12′-6″	79	96	112	148	194	222	244	267	290	314	336	359	382
13′-0″	68	83	96	130	172	197	216	237	258	279	298	319	340
13′-6″	58	71	83	113	152	174	191	210	229	248	265	284	303
14′-0″	49	61	71	99	134	154	169	186	203	220	235	252	269
14′-6″	41	51	60	85	117	136	149	165	180	195	209	224	239
15′-0″		43	50	73	103	119	132	145	159	172	185	198	212
15′-6″			42	63	90	105	115	128	140	152	163	175	187
16′-0″				53	78	91	101	112	122	133	143	154	165
16′-6″				44	67	79	87	97	107	117	125	135	144
17′-0″					57	68	75	84	92	101	108	117	126
17′-6″					47	57	64	72	79	87	93	101	109
18′-0″						48	54	60	67	74	80	87	93
18′-6″							44	50	56	62	67	73	79
19′-0″								41	46	51	55	61	66
19′-6″										41	44	49	54
20′-0″													42

Note: CRSI recommendations for minimum reinforcement are based on practical considerations of rigidity against deplacement under normal construction traffic. In all cases, these minimums satisfy minimums prescribed in ACI 10.5. See Fig. 7-1 for reinforcing bar details.

7-14 CONCRETE REINFORCING STEEL INSTITUTE

Figure 9: CRSI Slab Thickness Design Guide—Interior Span

SOLID ONE-WAY SLABS—END SPAN — Recommended Minimum Reinforcement

$f'_c = 3{,}000$ psi — Grade 60 Bars — $\rho \geq 0.0018bh$

Thickness (in.)	4	4½	5	5½	6	6½	7	7½	8	8½	9	9½	10
Top Bars	#4	#4	#4	#4	#4	#4	#4	#4	#4	#4	#4	#4	#4
Spacing (in.)	12	12	12	12	12	12	12	12	12	12	11	10	9
Bottom Bars	#3	#3	#3	#3	#3	#3	#3	#3	#4	#4	#4	#4	#4
Spacing (in.)	12	12	12	11	10	9	8	7	12	12	12	11	11
Top Bars Free End	#4	#4	#4	#4	#4	#4	#4	#4	#4	#4	#4	#4	#4
Spacing (in.)	12	12	12	12	12	12	12	12	12	12	12	12	12
T-S Bars	#3	#3	#3	#3	#4	#4	#4	#4	#4	#4	#4	#5	#5
Spacing (in.)	15	13	12	11	18	17	15	14	13	13	12	18	17
Areas of Steel ($in.^2/ft$) Top Interior	.200	.200	.200	.200	.200	.200	.200	.200	.200	.200	.218	.240	.267
Bottom	.110	.110	.110	.120	.132	.141	.165	.189	.200	.200	.200	.218	.218
Slab Wt. (psf)	50	56	63	69	75	81	88	94	100	106	113	119	125
CLEAR SPAN	**FACTORED USABLE SUPERIMPOSED LOAD (psf)**												
6′-0″	376	443	509	636	789	926							
6′-6″	310	366	421	527	657	772							
7′-0″	258	305	350	441	552	650	859						
7′-6″	215	255	294	372	467	552	733	926					
8′-0″	181	215	247	315	398	471	629	798	911	980			
8′-6″	152	181	209	268	340	404	543	691	791	851	910		
9′-0″	128	153	177	229	292	348	471	602	691	743	795	937	995
9′-6″	108	129	150	195	251	301	410	527	605	652	697	824	875
10′-0″	90	109	126	167	217	261	358	463	533	574	614	727	773
10′-6″	75	92	106	142	187	226	313	382	415	447	534	642	685
11′-0″	62	76	89	121	161	196	274	337	365	394	473	570	608
11′-6″	51	63	74	102	138	169	240	297	322	348	419	508	542
12′-0″	41	52	61	86	118	146	211	262	285	307	372	452	483
12′-6″		41	49	72	101	126	185	231	251	272	330	404	432
13′-0″				59	85	108	161	203	222	240	293	361	386
13′-6″				48	71	92	141	179	195	212	261	322	345
14′-0″					59	77	122	157	172	186	231	288	308
14′-6″					48	64	105	138	151	164	205	257	276
15′-0″						53	90	120	132	143	181	229	246
15′-6″						42	77	104	114	125	159	204	219
16′-0″							64	89	99	108	140	181	195
16′-6″							53	76	84	92	122	161	173
17′-0″							43	64	71	78	106	142	153
17′-6″								53	59	66	91	124	134
18′-0″								43	48	54	77	108	117
18′-6″										43	65	94	102
19′-0″											53	80	87
19′-6″											42	68	74
20′-0″												56	62

Note: CRSI recommendations for minimum reinforcement are based on practical considerations of rigidity against deplacement under normal construction traffic. In all cases, these minimums satisfy minimums prescribed in ACI 10.5. See Fig. 7-1 for reinforcing bar details.

7-10 CONCRETE REINFORCING STEEL INSTITUTE

Figure 10: CRSI Slab Thickness Design Guide—End Span

One Way Post-Tensioned T-Beam Calculations:

Material Strengths		
F'_C	5000	psi
F_{CI}	4000	psi
w	150	pcf
F_Y	60	ksi
tendons	270	ksi
A_S	0.153	in^2/tendon

Loads		
Superimposed	15	psf
Live Load	100	psf

Assumptions		
h	6	in
B_W	18	in
B_H	18	in
span	47	ft
spacing	20	ft
cover	3.75	in
PT loss	14	ksi

Determine Flange Width		
Span/4	141	in
(16 x h) + B_W	114	in
Spacing/2	120	in

Section Properties		
A	1008	in^2
Y_B	17.14	in
Y_T	6.86	in
I_G	42459	in^4
Sb	2477	in^3
St	6192	in^3

Required Number of Tendons		
e	13.39	in
$6f'c^{0.5}$	424	psi
F	799	k
Fse	175	ksi
N	30	tendons
A_{PS}	4.59	in^2

Load Type	Load (k/ft)	Moment (ft*k)	Top Stress (ksi)	Bottom Stress (ksi)
Slab	1.500	414	-0.803	2.007
Beam	0.338	93	-0.181	0.452
Superimposed	0.300	83	-0.161	0.401
Live Load	2.000	552	-1.070	2.676
Total		1142	-2.214	5.535

	Stresses (ksi)	
Description	Top	Bottom
Dead Load: beam + slab	-0.983	2.458
P.T. Initial	-0.861	-0.861
Fe/S_T	1.876	
Fe/S_B		-4.691
1. at transfer	0.032	-3.093
Dead Load		
beam + slab + super.	-1.144	2.860
P.T. Final	-0.797	-0.797
Fe/S_T	1.737	
Fe/S_B		-4.343
2. under permanent load	-0.203	-2.281
Live Load	-1.070	2.676
3. under full service load	-1.274	0.395
0.395	<	0.424
	OK	

Check Flexural Strength

M_U	1592 ft*k			
β_1	0.80			
γ_P	0.28			
P_P	0.00199			
F_{PS}	260 ksi			
a	2.46 in	<	6 in	OK
ΦM_N	1701 ft*k	>	1592 ft*k	OK

Assumptions

$A_S = A'_S$

$w = w' = 0$

Check reinforcing Limits

c	3.08 in			
ε_T	0.017	>	0.005	OK, TENSION CONTROLED

Check Minimum Reinforcing

M_{CR}	1170 ft*k			
F_R	530 psi			
$1.2*M_{CR}$	1405 ft*k	<	1701 ft*k	OK

Shear Design

W_U	5.765	K/FT			
V_U	127	K			
MIN	52	K			
V_C	129	K	>	127 K	OK
MAX	129	K			
V_U*D/M_U	1.09				
$ÖV_C/2$	48	K	<	127 K	SHEAR REINFORCEMENT REQUIRED
A_V/S	0.016	IN^2			
	0.014	IN^2	GOVERNS		
$A_{V\ \#4\ BARS}$	0.40	IN^2			
$S_{REQUIRED}$	29	IN			
S_{MAX}	18	IN			

Check Deflection

δ_{LL}	1.28	IN	OK
L/360	1.57	IN	

Two Way Flat Slab with Drop Panels Calculations:

TECHNICAL ASSIGNMENT 2 — N. REYNOLDS — FLAT PLATE WITH DROP PANELS 1

MATERIAL PROPERTIES

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

TYPICAL BAY SIZE: 20' × 46'8" (IN AN ATTEMPT TO RETAIN COLUMN FREE FLOOR PLAN)

LOADS APPLIED TO FLOOR SLAB

$\omega_D = 15$ PSF (SUPERIMPOSED)

$\omega_L = 100$ PSF (CORRIDOR LOADING ASSUMED ON ENTIRE FLOOR FOR EASE OF CALCULATION AND WILL PROVIDE A CONSERVATIVE SOLUTION)

$\omega_u = 1.2(15\text{ PSF}) + 1.6(100\text{ PSF}) = 178\text{ PSF}$

* TYPICAL BAY SIZE GENERATES A RATIO OF LONG TO SHORT DISTANCES GREATER THAN 2.0

ADDITIONAL COLUMN WILL BE REQUIRED, AND WILL BE USED TO GENERATE BAYS OF 20' × 19'6 AND 20' × 27'2, THE LARGER BAY WILL BE DESIGNED

ASSUME A 16" × 16" COLUMN, WILL BE ANALYZED LATER IN THIS CALCULATION

$t_{min} = \frac{l_n}{36}$ FOR INTERIOR PANELS AND $\frac{l_n}{33}$ FOR EXTERIOR PANELS W/O EDGE BEAMS OR $\frac{l_n}{36}$ FOR EXTERIOR PANELS W/ EDGE BEAMS

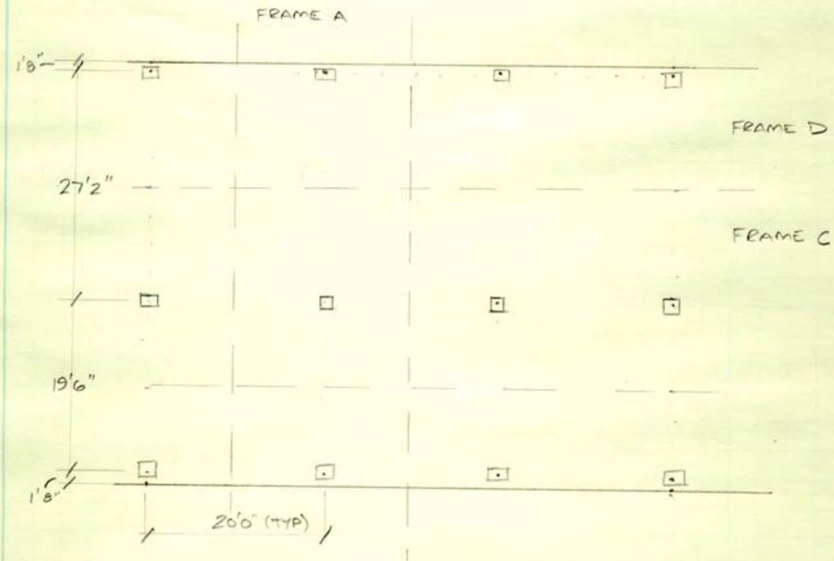
$l_n = 27.167' - \frac{16}{12} = 25.83'$

$\frac{l_n}{36} = 8.6"$ OR 9" SLAB

$\frac{l_n}{33} = 9.4"$ OR 9.5" SLAB

TECHNICAL ASSIGNMENT 2 | N. REYNOLDS | FLAT PLATE WITH DROP PANEL

SKETCH OF TYPICAL FRAMING LAYOUT:



DROP PANELS: 7' × 8', MIN t = 2.5"

SIZE REQUIRED COLUMNS:

FLOOR DEAD LOAD:

CONCRETE: $\frac{9.5''}{12} \times 150$ PCF = 120 PSF

SUPERIMPOSED: 15 PSF

FLOOR LIVE LOAD: 100 PSF (CONSERVATIVE VALUE USED FOR EASE)

TRIBUTARY WIDTH OF INTERIOR COLUMN: 23'4 × 20'0 = 467 SF

INFLUENCE AREA OF INTERIOR COLUMN: 1868 SF

LIVE LOAD REDUCTION: $\left(0.25 + \frac{15}{\sqrt{3 \cdot 1868}}\right) = 0.45$

$L = 0.45\,(100\text{ PSF}) = 45$ PSF

LOAD CASE: $1.2D + 1.6L + 0.5L_R$

TECHNICAL ASSIGNMENT 2 | N. REYNOLDS | FLAT PLATE WITH DROP PANELS | 3

COLUMN SIZING (CON'T):

$$P = 1.2\,(5\,D_{FLOOR} + 4\,D_{SUPER}) + 1.6\,(L_{PENTHOUSE} + 3L_{FLOOR}) + 0.5\,L_R$$

$$= 1.2\,(5(56.0^k) + 4(7.0^k)) + 1.6\,(70.0^k + 3\,(21.0^k)) + 0.5\,(7.0^k)$$

$$= 590^k \text{ TO INTERIOR COLUMN}$$

MINIMUM AREA FOR SQUARE COLUMN, $f'_c = 4000$ PSI, $\phi = 0.9$

$$\frac{P}{A} = \phi f'_c = 0.9\,(4\text{KSI}) = 3.6\text{KSI}$$

$$A \geq 164 \text{ IN}^2$$

MINIMUM DIMENSION: 12.8", USE 14" × 14" COLUMN

ECCENTRICITY OF LOAD AS COLUMN IS NOT CENTERED

$$e = 1.92'$$

$$K_n = \frac{P_u}{\phi f'_c A_g} = \frac{590^k}{0.9\,(4\text{KSI})(14" \times 14")} = 0.84$$

$$R_n = \frac{P_u e}{\phi f'_c A_g h} = \frac{590^k(1.92')}{0.9\,(4\text{KSI})(14" \times 14")(15')} = 0.11$$

USE $\rho = 0.025$ FROM GRAPH A.6 (NILSON, DARWIN, DOLAN)
ATTACHED TO APPENDIX

$$A_s = 0.025\,(196 \text{ IN}^2) = 4.9 \text{ IN}^2$$

USE (12) #6 BARS $A_s = 5.28 \text{ IN}^2$
OR (8) #8 BARS $A_s = 6.32 \text{ IN}^2$

EXTERIOR COLUMN SIZING:

TRIBUTARY WIDTH: 15'3" × 20'0 = 305 SF

INFLUENCE AREA OF EXTERIOR COLUMN: 1150 SF

LIVE LOAD REDUCTION: $\left(0.25 + \frac{15}{\sqrt{3 \cdot 1150}}\right) = 0.51$

$P = 395^k$ USE 12" × 14" COLUMN

$K_n = 0.65$

$e = 5.96'$ $\rho = 0.058$ (TOO LARGE)

$R_n = 0.26$

TECHNICAL ASSIGNMENT 2 | N. REYNOLDS | FLAT PLATE W/ DROP PANELS | 4

COLUMN SIZING (CON'T):

EXTERIOR COLUMN SIZING

TRY 14" x 14" COLUMN

$K_n = 0.56 \quad R_n = 0.22 \quad \rho = 0.040$

$A_s = 0.040 (196 \text{ IN}^2) = 7.84 \text{ IN}^2$

USE (12) #8's $A_s = 9.48 \text{ IN}^2$
OR (8) #9's $A_s = 8.00 \text{ IN}^2$

* ONLY DESIGNING WORST CASE EXTERIOR COLUMN, NOT CONCERNED ABOUT SMALLER EXTERIOR COLUMN, PRELIMINARY ANALYSIS

FLAT PLATE SLAB DESIGN AS PRESCRIBED BY DIRECT DESIGN METHOD NOT PERMITTED, ONLY TWO CONTINUOUS SPANS IN THE NORTH-SOUTH DIRECTION

UTILIZE PCA SLAB TO DESIGN NECESSARY REINFORCING

DROP PANEL DEPTHS VARIED FROM ORIGINAL DESIGN TO PREVENT NEED FOR SHEAR REINFORCING

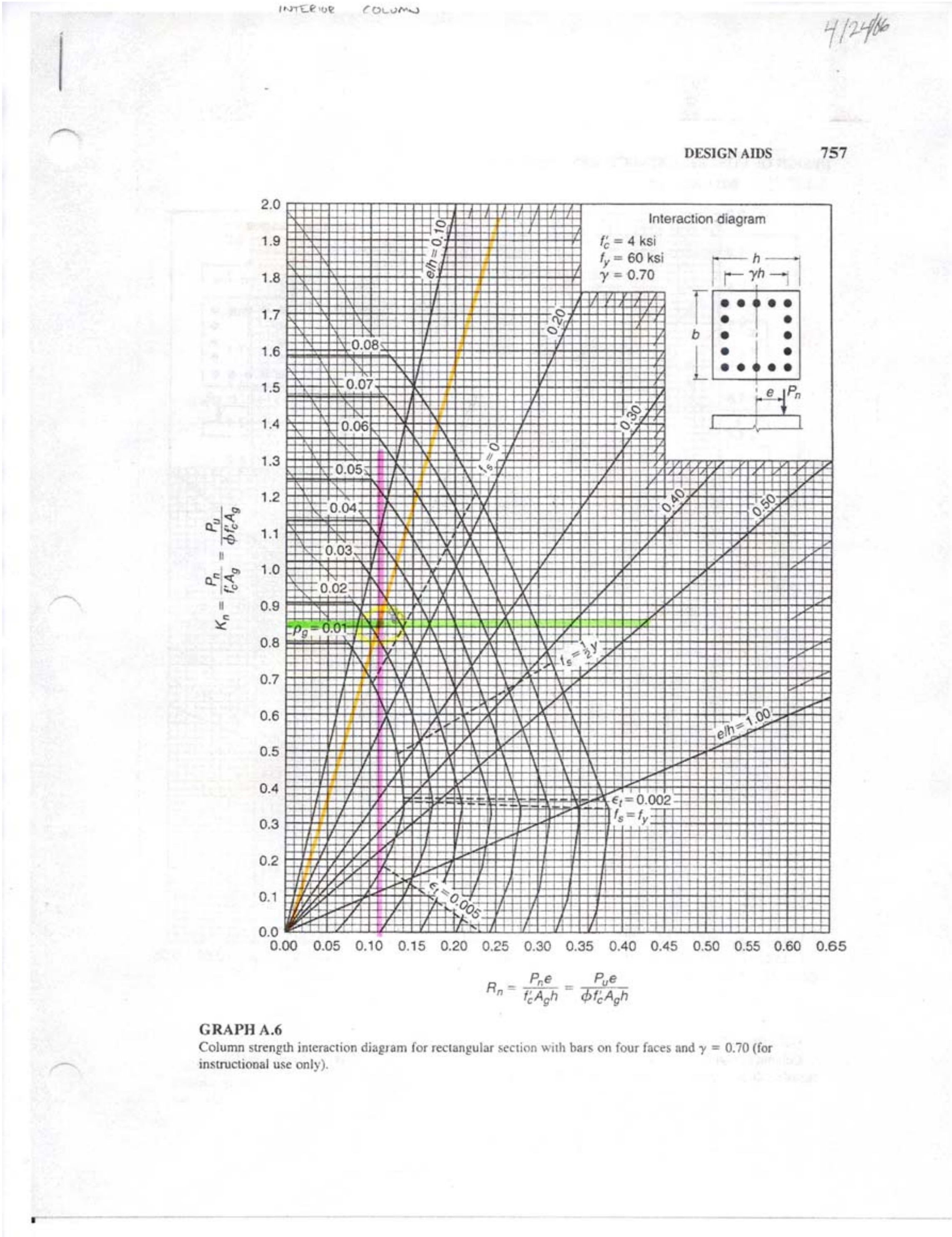


Figure 11: Interior Column Design Chart from Design of Concrete Structures 13th Edition (Nilson, Darwin, Dolan)

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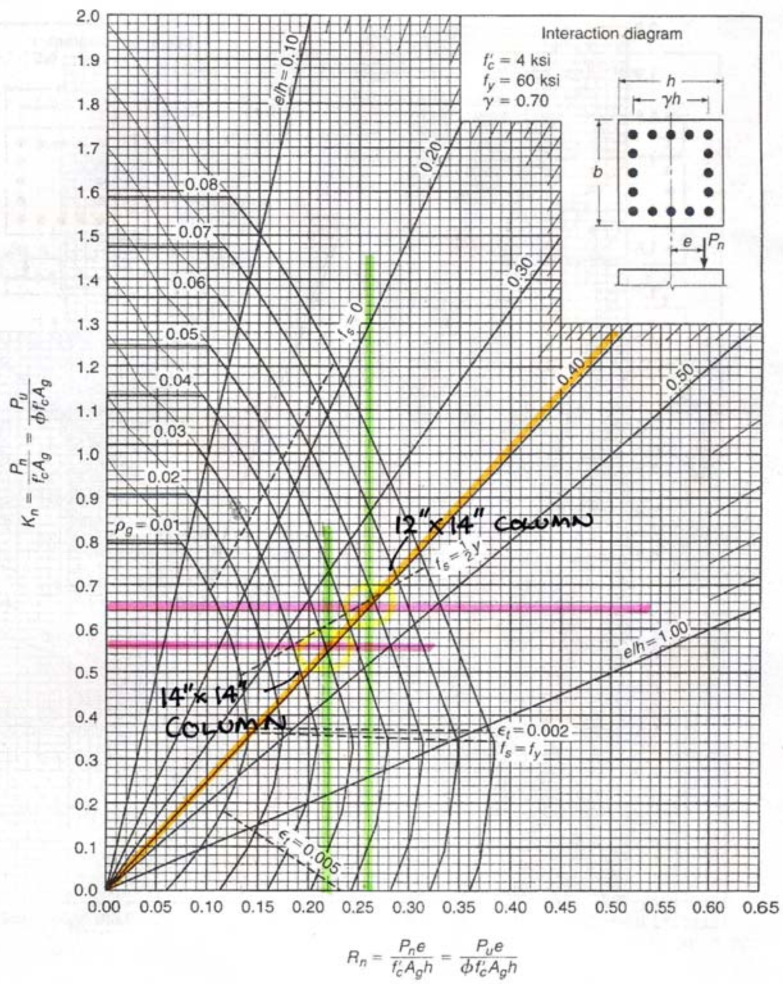

GRAPH A.6

Column strength interaction diagram for rectangular section with bars on four faces and γ = 0.70 (for instructional use only).

Figure 12: Exterior Column Design Chart from Design of Concrete Structures 13th Edition (Nilson, Darwin, Dolan)

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[2] DESIGN RESULTS

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Top Bar Details:

Units: Length (ft)

Span	Strip	Left Bars	Left Length	Left Bars	Left Length	Continuous Bars	Continuous Length	Right Bars	Right Length	Right Bars	Right Length
1	Column	---		---		9-#5	1.67	---		---	
	Middle	---		---		8-#5	1.67	---		---	
2	Column	9-#5	9.16	---		---		12-#5	9.16	11-#5	5.78
	Middle	8-#5	6.30	---		---		10-#5	8.63	---	
3	Column	8-#5	6.73	7-#5	4.25	8-#5	19.50	1-#5	6.63	---	
	Middle	2-#5	4.62	---		8-#5	19.50	---		---	
4	Column	---		---		9-#5	1.67	---		---	
	Middle	---		---		8-#5	1.67	---		---	

Bottom Bar Details:

Units: Start (ft), Length (ft)

Span	Strip	Long Bars Bars	Long Bars Start	Long Bars Length	Short Bars Bars	Short Bars Start	Short Bars Length
1	Column	---			---		
	Middle	---			---		
2	Column	16-#5	0.00	27.17	---		
	Middle	8-#5	0.00	27.17	3-#5	0.00	23.09
3	Column	8-#5	0.00	19.50	---		
	Middle	8-#5	0.00	19.50	---		
4	Column	---			---		
	Middle	---			---		

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[2] DESIGN RESULTS

Top Bar Details:

Units: Length (ft)

		Left				Continuous		Right			
Span	Strip	Bars	Length	Bars	Length	Bars	Length	Bars	Length	Bars	Length
1	Column	---		---		10-#5	1.67	1-#5	1.58	---	
	Middle	---		---		9-#5	1.67	---		---	
2	Column	11-#5	9.44	---		---		14-#5	9.44	13-#5	5.95
	Middle	9-#5	6.49	---		---		12-#5	8.58	---	
3	Column	10-#5	7.97	9-#5	4.35	8-#5	20.00	2-#5	6.80	---	
	Middle	2-#5	4.73	---		10-#5	20.00	---		---	
4	Column	9-#5	6.80	1-#5	4.35	---		9-#5	7.97	4-#5	4.35
	Middle	10-#5	6.73	---		---		10-#5	7.97	---	
5	Column	5-#5	6.80	---		8-#5	20.00	3-#5	6.80	---	
	Middle	---		---		10-#5	20.00	---		---	
6	Column	9-#5	8.22	2-#5	4.35	---		9-#5	8.21	3-#5	4.35
	Middle	10-#5	8.21	---		---		10-#5	8.21	---	
7	Column	4-#5	6.80	---		8-#5	20.00	4-#5	6.80	---	
	Middle	---		---		10-#5	20.00	---		---	
8	Column	9-#5	8.21	3-#5	4.35	---		9-#5	7.72	2-#5	4.35
	Middle	10-#5	8.21	---		---		10-#5	7.72	---	
9	Column	3-#5	6.80	---		8-#5	20.00	7-#5	6.80	---	
	Middle	---		---		10-#5	20.00	---		---	
10	Column	9-#5	7.47	6-#5	4.35	---		9-#5	6.80	---	
	Middle	10-#5	7.47	---		---		10-#5	4.73	---	
11	Column	---		---		9-#5	1.67	---		---	
	Middle	---		---		10-#5	1.67	---		---	

Bottom Bar Details:

Units: Start (ft), Length (ft)

		Long Bars			Short Bars		
Span	Strip	Bars	Start	Length	Bars	Start	Length
1	Column	---			---		
	Middle	---			---		
2	Column	21-#5	0.00	28.00	---		
	Middle	9-#5	0.00	28.00	5-#5	0.00	23.80
3	Column	8-#5	0.00	20.00	---		
	Middle	10-#5	0.00	20.00	---		
4	Column	9-#5	0.00	20.00	---		
	Middle	10-#5	0.00	20.00	---		
5	Column	8-#5	0.00	20.00	---		
	Middle	10-#5	0.00	20.00	---		
6	Column	8-#5	0.00	20.00	---		
	Middle	10-#5	0.00	20.00	---		
7	Column	8-#5	0.00	20.00	---		
	Middle	10-#5	0.00	20.00	---		
8	Column	8-#5	0.00	20.00	---		
	Middle	10-#5	0.00	20.00	---		
9	Column	8-#5	0.00	20.00	---		
	Middle	10-#5	0.00	20.00	---		
10	Column	10-#5	0.00	20.00	---		
	Middle	10-#5	0.00	20.00	---		
11	Column	---			---		
	Middle	---			---		

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