Pearl Condominiums

9th & Arch Street
Philadelphia, PA

Technical Assignment #2

Structural Concepts / Structural Existing Conditions Report

December 11, 2007

Faculty Advisor:
Dr. Linda Hanagan

Joseph G. Lichman Jr. Structural Option

http://www.engr.psu.edu/ae/thesis/portfolios/2008/jgl138/

Executive Summary

The purpose of Technical Assignment #2 is to investigate alternative structural floor systems for the existing hollow core plank system used in the Pearl Condominiums. After the investigation of these systems, a comparative analysis will be done to see which of these solutions are viable based on numerous economic, construction and structural criteria.

Existing System:

The existing floor system is comprised of a 10" Precast Concrete Plank with a ¾" concrete thick topping. Theses planks are supported by 8" metal stud bearing walls.

Alternative Systems:

Four alternative systems were investigated as alternative for Pearl Condominiums:

1. Non-Composite Steel Framing
2. Composite Steel Framing
3. Flex-Frame
4. Precast Beam with Hollow Core Planks

Conclusion:

After analyzing the four alternative systems it has been determined that the existing floor system was the correct choice for Pearl Condominiums. The precast floor planks work well for use in long spans and the metal stud bearing wall type is easy to construct and is also used to resist lateral forces.

During the analysis, the non-composite and the precast beams\ hollow core planks were found not to work as well in this situation as the other two alternative systems. This is the result from the higher total depths of the floors and the higher overall building weight for the foundation to support. From the four alternatives, the best system from my analysis was the Flex Frame system.

This system is similar to the original system, but with using the Flex Frame system, the floor plan is more flexible resulting from the elimination of the need for interior load bearing walls. With this system, the floor depths will be same depth as the precast concrete planks, similar to the original system. Compared to the other two steel alternatives, the amount of steel required for the flex frame is substantially less. With respect to the fourth option, the weight of the overall building will be less. Overall the Flex Frame system is an economic and efficient alternative to load bearing walls and precast planks. The Flex Frame system will be researched further for the use in the redesign of the building.

Table of Contents

Introduction

Pearl Condominiums is a mixed use development housing including 10 retail units on the ground floor and 90 condominium units on the upper floors. The gross floor area is 111,570 square feet and has 6 stories above grade. The zoning of the area is a C-4 Commercial zone. Design considerations for the site included the site location existing above a SEPTA commuter rail tunnel.

In this report, the study will analyze a typical floor above the second level. On these levels the code required live load is 60 psf. This live load matches the engineer's decision for the required live load for the project. The engineer also required a superimposed dead load of 25 psf accounting for partitions, MEP and flooring. This is a conservative dead load based on the code required for partitions is 12 psf. This results in 13 psf left for flooring and MEP, which usually can range from 3 to 8 psf depending on the type of flooring. These loads will be used in the analysis of the alternative systems throughout this report.

<u>Structural Codes:</u>

The applicable codes used for the analysis of the floor checked in this report are:

- Building Code
  Philadelphia Building Code 2003. The Philadelphia Building Code 2003 is an adoption of the IBC 2003 with city amendments.
- Structural Concrete
  ACI 318-02 Building Code Requirements for Structural Concrete
- Concrete Masonry
  ACI 530-02 Building Code Requirement for Masonry Structures
- Structural Steel
  American Institute of Steel Construction (AISC)
  Steel Construction Manual - Thirteenth Edition
- Structural Cold Formed Studs
  Specification for the Design of Cold Formed Structural Members

Existing Structural Systems

Foundations:

The primary support for the foundation is the use of drilled piers. The drilled pier option was performed, so the loads from the building would be transferred from the pier to the soil below the SEPTA commuter train tunnel. If a shallow foundation system was chosen, special precautions to not disturb the area around the tunnel would have been needed to be performed. The drilled piers range in size of diameter from 3'-0" to 3'-6" to 4'-0". They also range in depth depending on the rock elevations in the area as described in the geotechnical report.

To help distribute the load to the drilled piers the use of grade beams was employed. They range in width from 12" to 40" and in depth from 18" to 30". The slab on grade is 6" reinforced with 6x6 W2.9xW2.9 WWR over 6" crushed stone over 6 mil. Vapor retarder. (See Figure1)

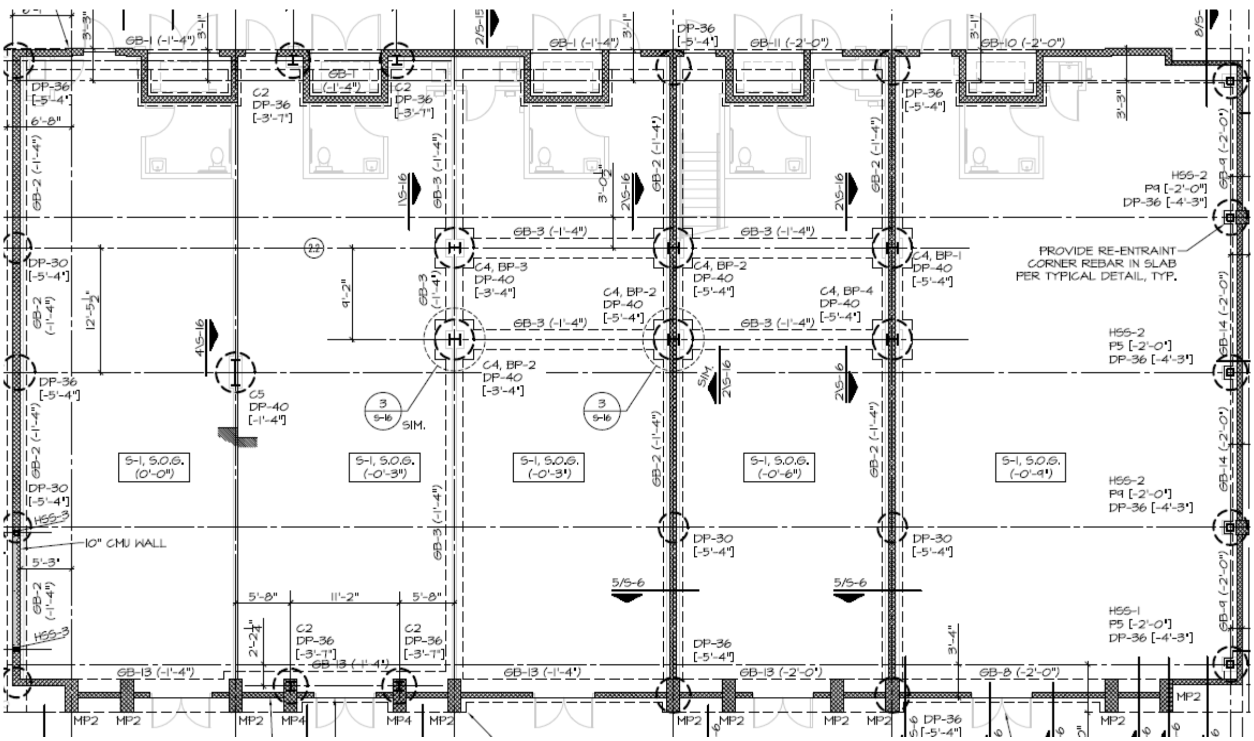


Figure 1 – South Side of Building Foundation Plan

Columns \ Load Bearing Walls:

The columns in Pearl Condominiums are used in two different types of loading. The HSS columns are used to take gravity loads, which occur at the ends of the building to support the precast concrete planks (Figure 2) and the Wide flange columns are used to resist lateral loads which occur on the ground floor in the moment frames (Figure 3)

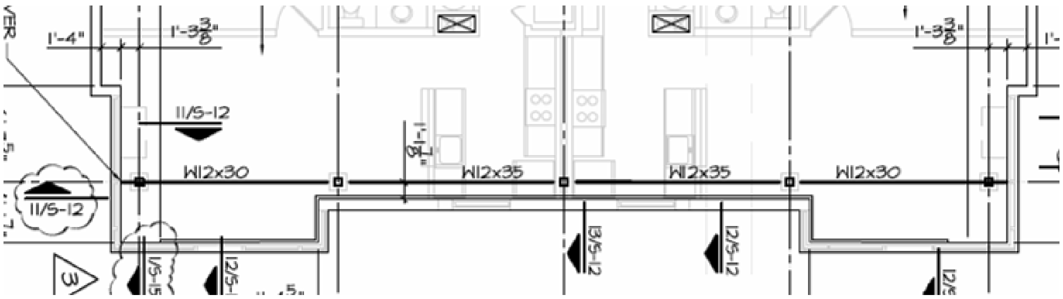


Figure 2 – HSS Columns at the south end of the building

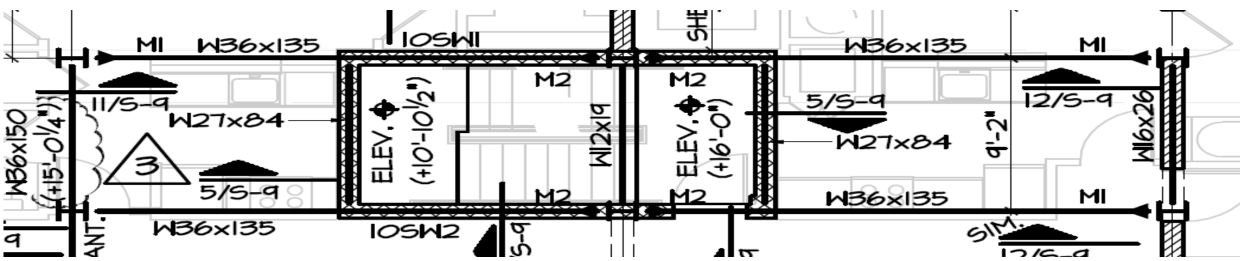


Figure 3 –Wide Flange Columns at the south side of the building

The interior bearing walls are comprised of 8 inch metal studs that are spaced at 12 inches and 16 inches on center depending on the floor location of the wall. (See Figure 4)

LOAD BEARING METAL STUD WALL SCHEDULE		
LEVEL	LOAD BEARING TYPE 1 STUD WALL	
	SIGMA STUDS	MARINOWARE STUDS
7TH - RF.	800SG300-33 @ 16"	800S200-33 @ 16"
6TH - 7TH	800SG300-33 @ 16"	800S200-54 @ 12"
5TH - 6TH	800SG300-54 @ 16"	(2) 800S200-54 @ 12"
3RD - 5TH	800SG300-68 @ 16"	(2) 800S200-54 @ 12"
2ND - 3RD	800SG300-68 @ 12"	(2) 800S200-68 @ 12"
LEVEL	LOAD BEARING TYPE 2 STUD WALL	
7TH - RF.	800SG300-33 @ 16"	800S200-33 @ 16"
6TH - 7TH	800SG300-33 @ 16"	(2) 800S200-43 @ 12"
5TH - 6TH	800SG300-54 @ 16"	(2) 800S200-54 @ 12"
3RD - 5TH	800SG300-68 @ 16"	(2) 800S200-68 @ 12"
2ND - 3RD	800SG300-68 @ 12"	(2) 800S200-97 @ 12"
LEVEL	LOAD BEARING TYPE 3 STUD WALL	
7TH - RF.	800SG300-33 @ 16"	800S200-33 @ 16"
6TH - 7TH	800SG300-33 @ 16"	(2) 800S200-54 @ 12"
5TH - 6TH	800SG300-54 @ 16"	(2) 800S200-54 @ 12"
3RD - 5TH	800SG300-68 @ 16"	(2) 800S200-68 @ 12"
2ND - 3RD	800SG300-68 @ 12"	(2) 800S200-97 @ 12"

Figure 4 – Metal Stud Bearing Wall Schedule

Floor System:

The floor system for level 2 thru 6 is comprised of a 10" Precast Concrete Plank with a ¾" concrete thick topping. (See Figure 5) The concrete strength of the precast plank is f'c equals 5,000 psi.

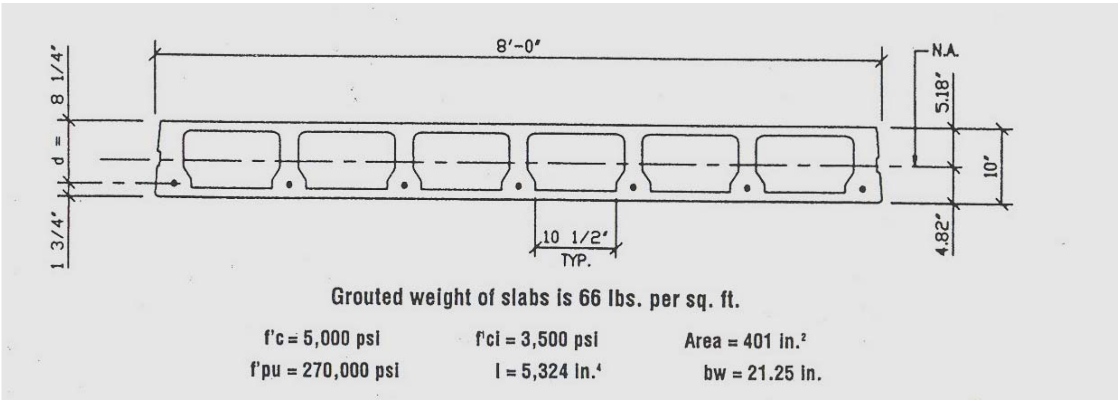


Figure 5 – Section Properties of Precast Planks

Level two acts as a transfer level, which requires the use of wide flange beam (W36). These transfer beams eliminate the need for load bearing walls to distribute the load to the foundations. The result of having these elements increases the available floor area for the retail units. (See Figure 6)

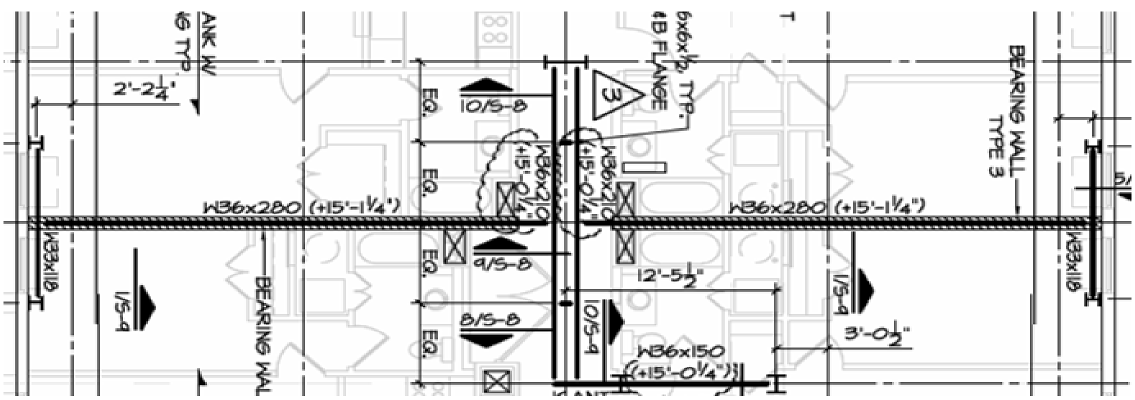


Figure 6 – Transfer Beams located on the Second Floor.

Typical Floor Plan

As shown in Figure 7, Pearl Condominiums shape and layout of the space is symmetric. This lends itself to the idea of using a structural system that is uses repetition in the design of the floor system. The floor system consisting of precast planks and metal stud bearing walls can easily duplicated from floor to floor.

Some of the pros with respect to using the precast planks and metal stud bearing walls are the easier connection types between the members. This is the result of using screws to connect the studs together into a wall. Also with the easier connections the time of construction is shorter because of the ease of building the metal stud bearing walls. The wall construction is the same from floor to floor with an exception to the size of the metal stud and spacing. The construction of the floors can continue in any weather because the structural elements are all at their full strength when they reach the site, since they are prefabricated.

Some of the cons with this flooring system are the limitability of the interior bearing walls, once their position is set it will be hard to change their location without affecting the other load bearing walls. Another one is the quantity of the metal studs required to create these load bearing walls, the higher the quantity of studs the higher the cost.

Overall this type floor system is economic and efficient type of construction. There is also a typical bay framing figure in the Appendix page A1.

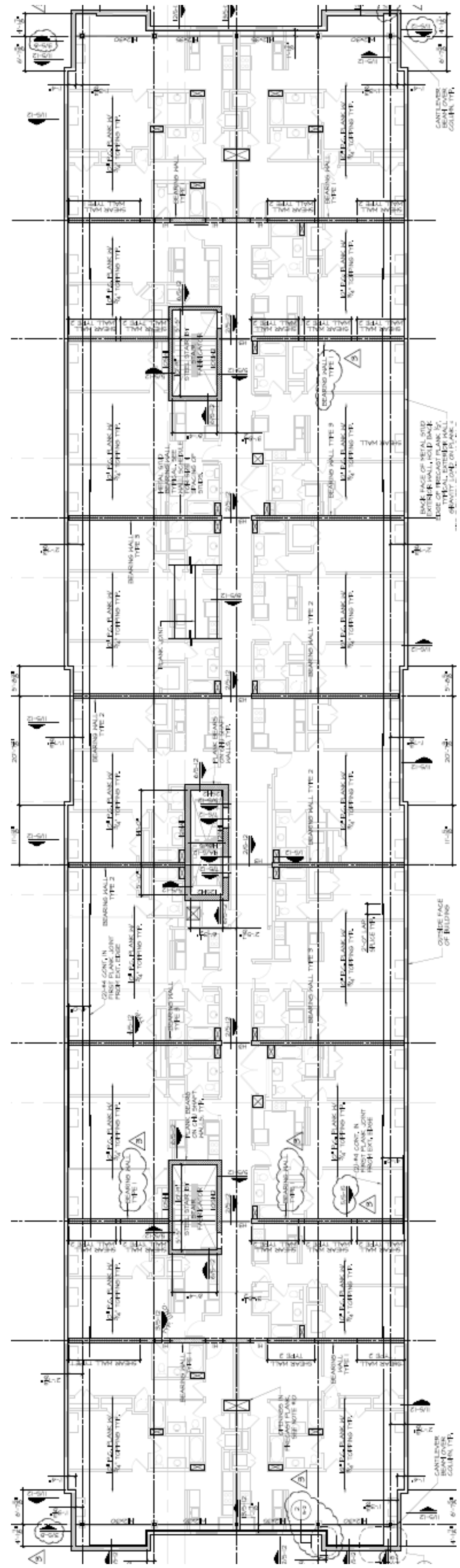


Figure 7 – Upper Floor Plan

<u>Lateral Resisting System</u>:

The Lateral System in the building is comprised of three types: concrete masonry unit (cmu) shear walls, moment frames and metal stud shear wall. (See Figure 8)

The concrete masonry unit shear walls are used around the elevator and stairway towers. These walls range from thickness of 10" in the stair areas and 12" in the elevators. The strength of the concrete masonry units (f'm) range from 1500 psi to 2000psi and 3000psi depending on the area they are used in.

The stair tower cmu walls end on the second floor, which results in the use of moment frames on the first floor to transfer the loads from the cmu shear walls on the second floor to the foundation below.

The metal stud shear walls are composed of 8" metal studs varying in thickness. The two heights of the studs are 13'-8" and 9'-0". Metal diagonal straps connected by #12 screws to the metal studs and 7/8" diameter anchor bolts connected through different boot types help to resist the lateral forces applied to the metal studs. The metal studs are covered by gypsum wall board.

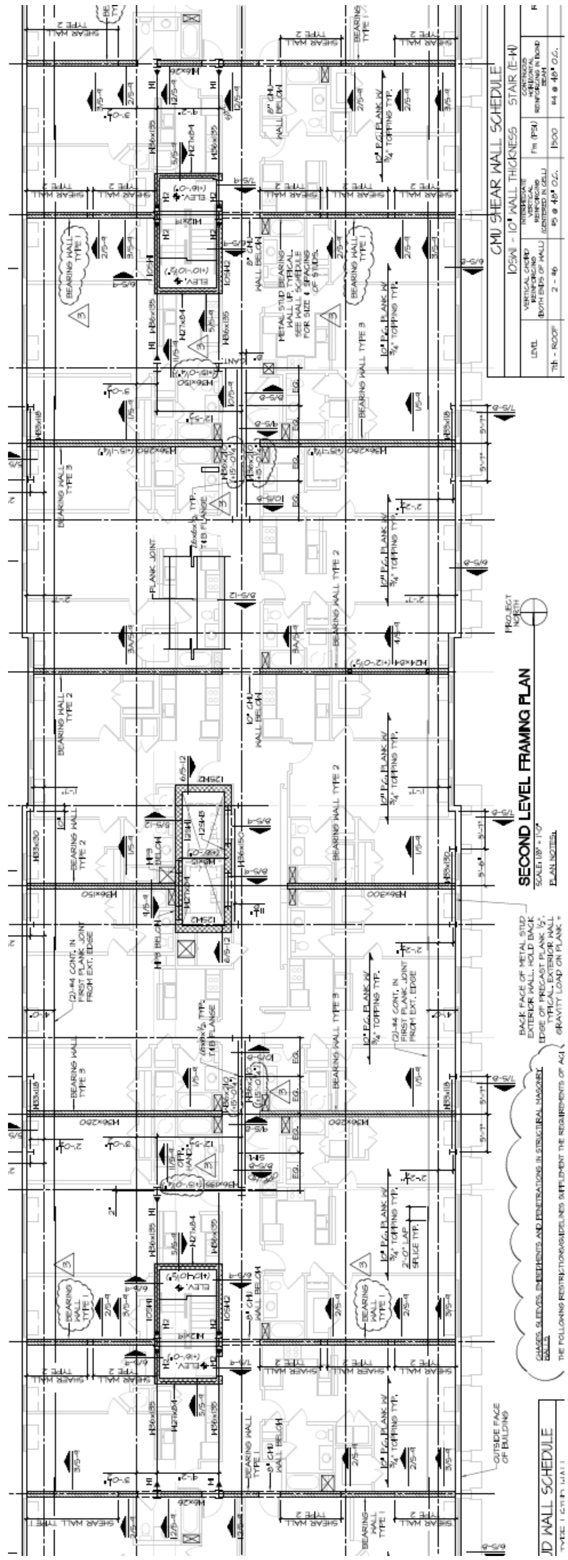


Figure 8 –Lateral Resisting System Present in Pearl Condominium

Alternative #1: Non-Composite Steel Framing

Designed Used: RAM

The first framing system considered was a non-composite steel framing system. This system consists of a 4” normal weight concrete slab placed on a 2 inch UF2X 20 Gauge Form Deck. The spacing of the beams was controlled by the allowable span of the deck for the required loading. (See Appendix page A2 for span condition and total allowable load) The 2 inch metal deck can span 6 feet in a two span condition. See Figure 9 for framing plan of this floor system

Some of the pros for this system are the time for erection of the steel structure is quicker than the original system. With the non-composite system the requirement for the interior bearing walls will not be present. The connections required for the assembly of the system will be less than the metals stud bearing wall system. The construction of a floor does not have to wait for the floor below it to be completed.

Some of the cons of this system are the material cost increase because of the increase in member depth, size and quantity. The system will also require that the beams and columns be covered with fireproofing. There will also be an increase in lead time for the steel compared to the concrete. With the removal of the metal stud walls, the lateral forces will now have to be resisted in another way. This can be resolved by the implementation of moment connections from columns to beams to transfer the loads or by the creation of braced frames. The latter suggestion will then limit that area’s open floor plan.

The impact of this proposed system on the current foundation will be the increase in overall building weight for the foundation to support. The location of the columns may require the addition of drilled piers.

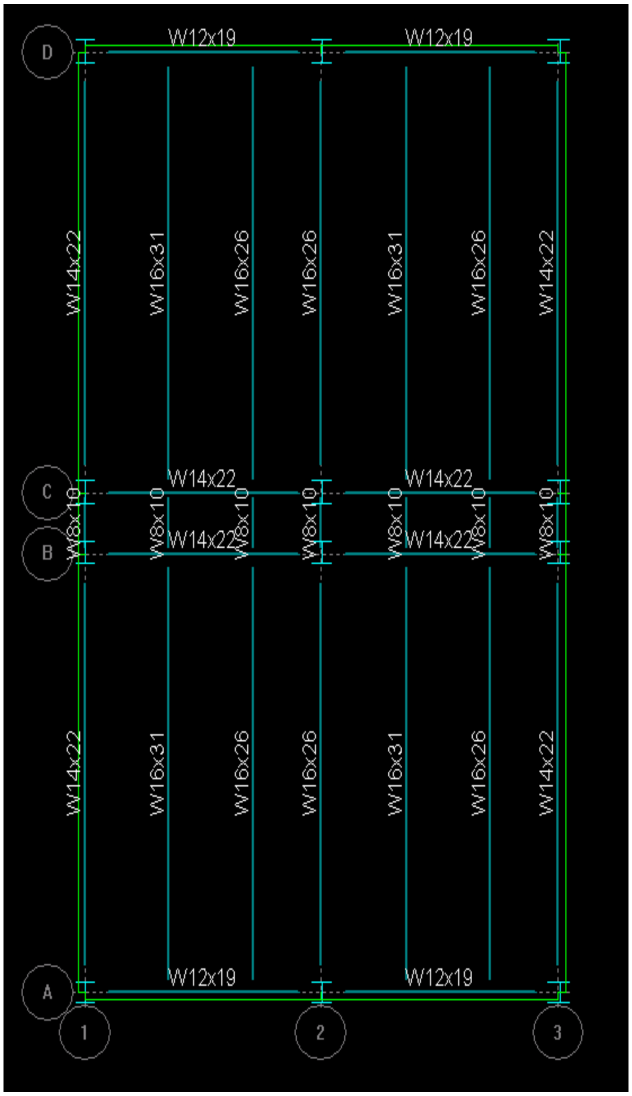


Figure 9 – Non-Composite Framing

Alternative #2: Composite Steel Framing

Designed Used: RAM

The Second framing system considered was a composite steel framing system. This system consists of a 6” normal weight concrete slab placed on a 3” LOK-Floor 20 Gauge Form Deck. (See Appendix page A3 for span condition and total allowable load) The 3 inch metal deck can span 6 feet in a two span condition. See Figure 10 for framing plan. The composite action is facilitated by ¾”Ø shear studs with length 4.5 in.

Some of the pros for the composite steel framing consist of the flexural added resistance from the use of shear studs. The depths and the weights of the steel beams are reduced with respect to the non-composite system. Vibration issues within this system are reduced. An open floor plan will be created by the elimination of the need for interior load bearing walls. Also on the ground floor the concrete masonry load bearing walls will be eliminated, which will increase the area of retail space.

Some of the cons of this system are the required additional fireproofing for the beams and columns. Another one is the increased lead time for steel compared to concrete. The cost of construction will be increased because of the additional time and materials needed to install the shear studs.

Regarding the change to the lateral system by removing the metal stud shear walls, the steel frames will know have to help resist the lateral forces by the concept of moment frames or braced frames. Also with the increased weight aspect the seismic force will be increased.

The foundation will now have a greater building weight to support; this may need to be resolved by adding more drilled piers or increasing the size of the grade beams and drilled piers.

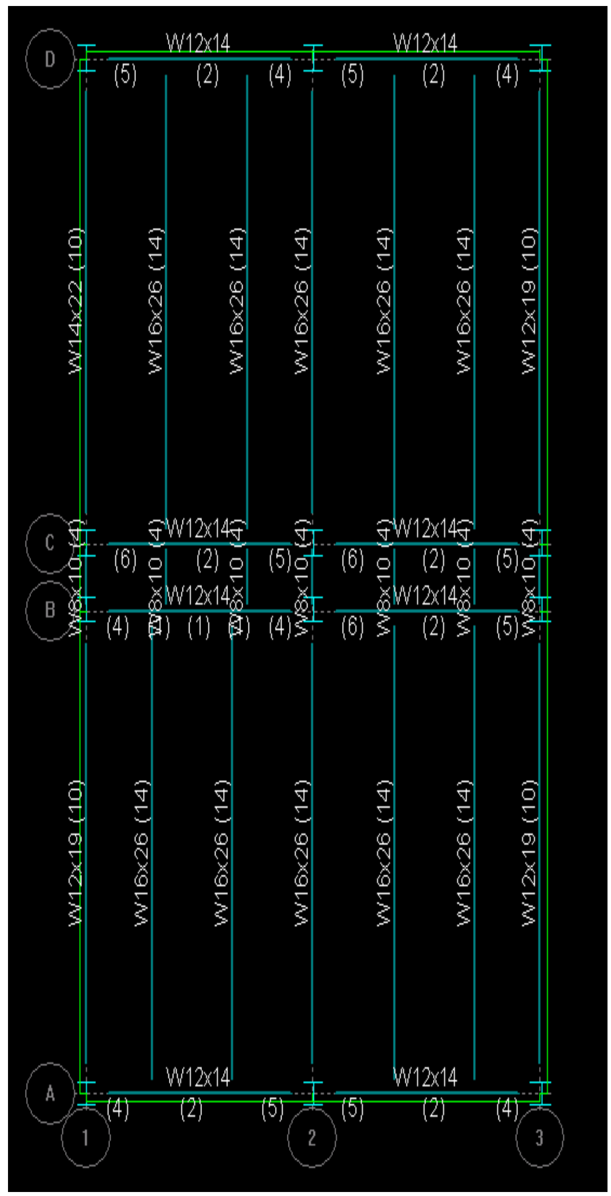


Figure 10 – Composite Framing

Alternative #3: Flex Frame System

Designed Used: RAM and STRESCON Product Specifications

The Third framing system considered was the use of a Flex Frame System. This system is comprised of a unique steel beam (D-beam), whose top flange is smaller than the bottom and the depth is the same as the precast plank's depth. The concept of the two elements having the same height helps to create an even floor elevation. For the sizing of the beam elements, a wide flange beam was chosen to simplify the design. If the flex frame system is chosen for the system to be used in the redesign of the building the beams will be analyzed using the D-beams. See Figure 11 for the framing design and Appendix page A4 for Strescon precast plank information.

Some of the pros for this system consist of lower costs, low floor to floor height, and fast erection. The prefabrication of the two elements, the steel and the precast concrete are done under controlled conditions. The construction can be done under most weather conditions. The elimination of the interior load bearing walls because of the new system will increase the flexibility of an open floor plan.

Some of the cons for this flex frame system are the increase in required area need to stage the steel and precast planks on the site. The cost for the D-beams will be higher than for the typical wide flange beam sizes because of the unique section size. The required time on site of construction equipment to lift the precast planks and steel members will be increased than just for placing the precast planks for the original system. The transportation cost will be increased because of the addition of steel members.

The overall building weight will be lighter than the previous two alternatives, which will reduce the seismic forces. To resist the lateral forces the use of braced frames can be used. The foundations may not change much from the original system just the location of some of the drilled piers.

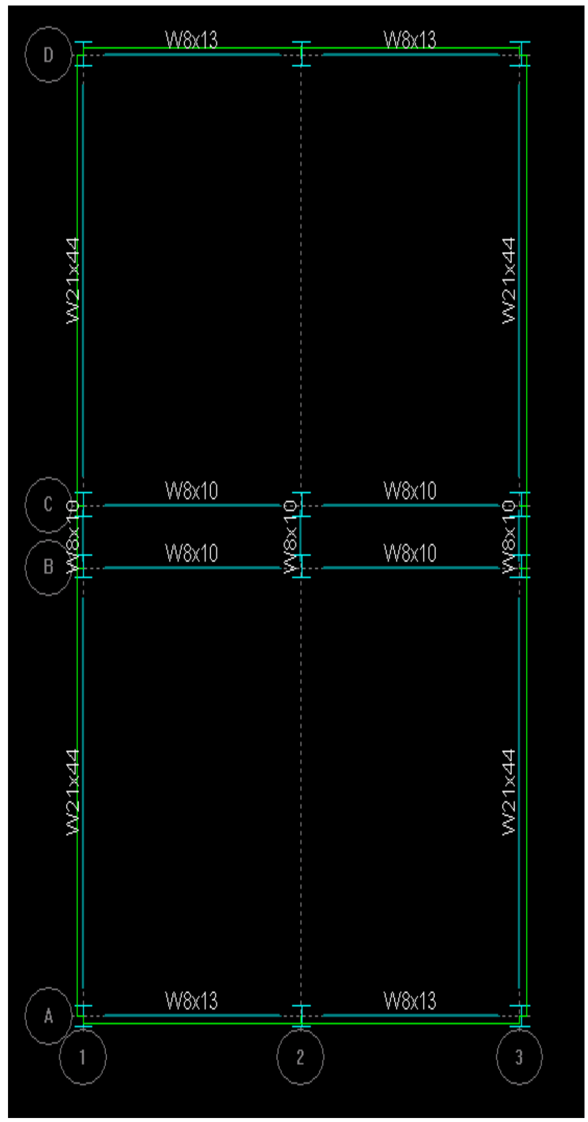


Figure 11 – Flex Frame System

Alternative #4: Precast Beams and Hollow Core Planks

Designed Used: PCI Handbook Sixth Edition

The Fourth framing system considered was a combination of precast beams and hollow core planks. This system is composed of precast columns, L-shape and inverted t-shape beams, and hollow core planks. The hollow core planks span 17' with a depth of 10" and a 2" concrete topping. The added 2" of concrete will allow for the top of the planks to be flush with the precast beams. The concrete columns required will need to be a minimum dimension of 8" by 8" reinforced by (4) #5 bars for vertical reinforcing. See Figure 12 for framing plan. See Appendix for loading specifications and sizes chosen for precast beams and planks.

The pros for this system are no added fireproofing required. The vibration action with this system is minimal. Open floor plans are gained with use of precast beams compared to stud bearing walls. There is a minimal amount of formwork and shorting required. The lateral stiffness of the building will be increased by the relative stiffness of concrete.

The cons for this system are longer lead time than typical concrete construction. The required depth of the precast concrete beams (24") is deeper than required for steel construction (11-7/8").

The lateral effect of this system is in the increase in weight, which will increase in seismic shear force. To resist the lateral forces applied, they will have to be distributed into the beams and columns which will cause them to be designed for both gravity and lateral loads.

The foundations will have a higher load compared to the original and the other three alternatives. This will increase the size of grade beams and drilled piers to support this added gravity force.

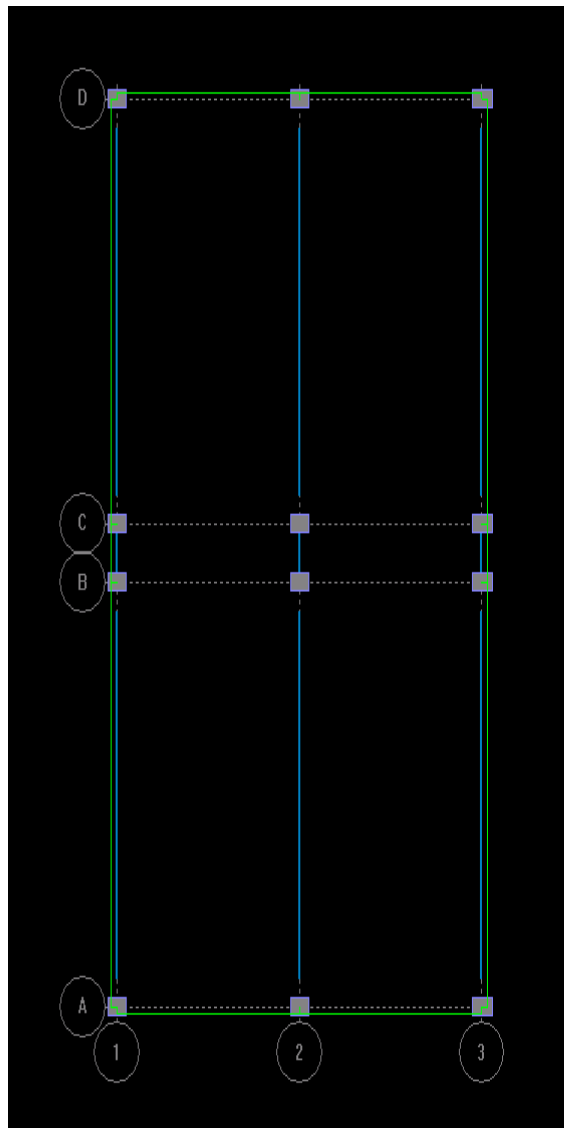


Figure 12 –Precast Option Framing

Comparison & Conclusion

Criteria	Hollow Core Planks\Metal Stud Wall	Non-Composite	Composite	Flex Frame System	Precast Beams\ Hollow Core Planks
Cost/SF	18.12	20.30	21.65	19.55	22.35
Slab Depth	10-3/4”	4”	6”	10-3/4”	12”
Total Depth	10-3/4”	21-7/8”	19-3/4”	11”	24”
Added Fire Protection	Yes	Yes	Yes	Yes	No
Vibration Issue	Average	Average	Average	Average	Above Average
Long Lead Time	Yes	Yes	Yes	Yes	Yes
Form Work	No	No	No	No	No
Construction Difficulty	Easy	Easy	Medium	Easy	Easy
Fast Erection Time	No	Yes	Yes	Yes	Yes
Foundation Impact	-	Yes*	Yes*	Yes*	Yes
Lateral System Effect	-	Yes	Yes	Yes	Yes
Viable Solution	-	No	Yes	Yes	Yes

* With steel construction, the building weight has the possibility for a reduced building weight

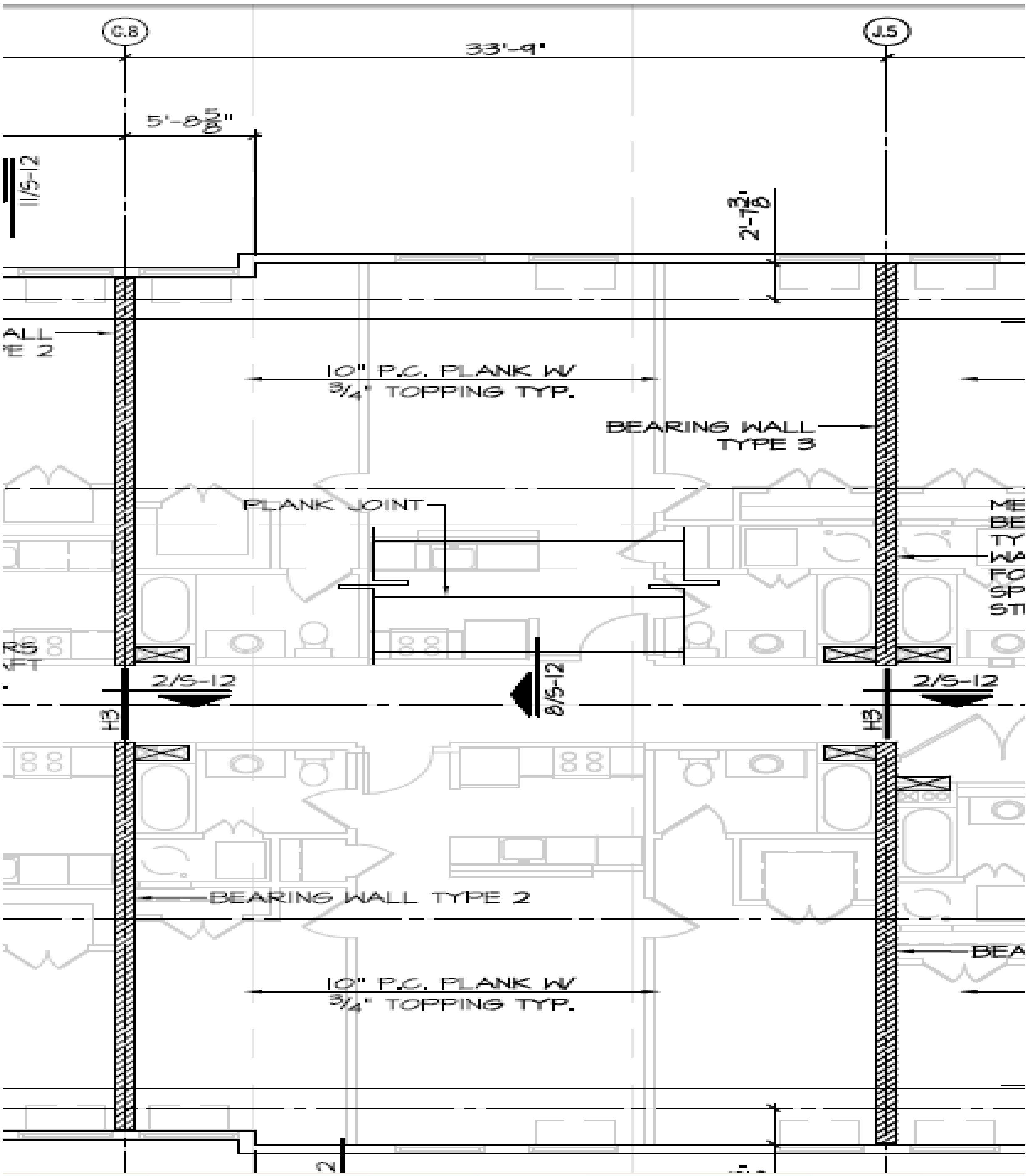
Conclusion:

After analyzing the four alternative systems it was clear that the existing floor system was the correct choice for Pearl Condominiums. The precast floor planks work well for use in long spans and the metal stud bearing wall type is easy to construct and is also used to resist lateral forces.

From the four alternatives, the best system from my analysis was the Flex Frame system. This system is similar to the original system, but with using the Flex Frame system, the floor plan is more flexible because of the elimination of the need for interior load bearing walls. With this system, the floor depths will be same depth as the precast concrete planks, similarly like the original system. Compared to the other two steel alternatives, the amount of steel required for the flex frame is substantially less. With respect to the fourth option the weight of the overall building will be less. Overall the Flex Frame system is an economic and efficient alternative to load bearing walls and precast planks.

Appendix

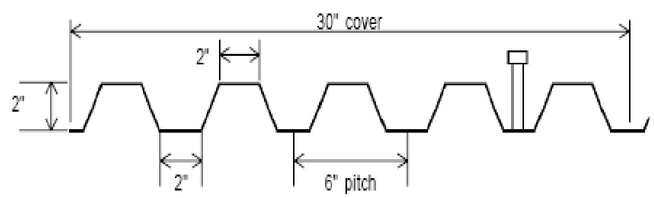
Typical Bay Framing



USD - UF2X Metal Form Deck

SECTION PROPERTIES						ASD			LRFD		
Metal Thickness		Wt.	I_p	S_p	S_n	V	R_1	R_2	ϕV	ϕR_1	ϕR_2
Gage	Inches	(psf)	(in.⁴)	(in.³)	(in.3)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)
24	0.0239	1.50	0.232	0.192	0.200	2360	360	836	3223	532	1156
22	0.0295	2.00	0.300	0.252	0.263	4205	528	1484	5477	736	1992
20	0.0358	2.00	0.379	0.325	0.339	6062	728	2224	8067	1004	3064
18	0.0474	3.00	0.523	0.468	0.485	8796	1204	3948	11182	1648	5388

UF2X



The bottom flange can accept a ¾" shear stud.

approx. scale: 1½" = 1'0"

UNIFORM TOTAL LOAD / Load that Produces l/180 Deflection, psf										
Gage	Span Condition	Span								
		6'0"	6'6"	7'0"	7'6"	8'0"	8'6"	9'0"	9'6"	10'0"
20	Single	217 / 154	185 / 121	159 / 97	139 / 79	122 / 65	108 / 54	96 / 46	86 / 39	78 / 33
	Double	224 / 370	191 / 291	165 / 233	144 / 189	126 / 156	112 / 130	100 / 110	90 / 93	81 / 80
	Triple	279 / 289	238 / 228	205 / 182	179 / 148	158 / 122	140 / 102	125 / 86	112 / 73	101 / 63

The form deck that was selected is USD – 2 inch UF2X 20 Gauge Form Deck Double Span Condition 6feet with uniform total allowable load of 224 psf.

USD – 3” LOK-Floor Deck

3 x 12" DECK F_y = 33ksi f'_c = 3 ksi   145 pcf concrete

	L, Uniform Live Loads, psf *														
	Slab Depth	φMn in.k	9.00	9.50	10.00	10.50	11.00	11.50	12.00	12.50	13.00	13.50	14.00	14.50	15.00
20 gage	5.50	62.81	285	250	225	200	180	160	145	130	115	105	95	85	80
	6.00	71.37	325	285	255	225	205	185	165	150	135	120	110	100	90
	6.50	79.92	365	320	285	255	230	205	185	165	150	135	125	110	100
	7.00	88.48	400	355	315	285	255	225	205	185	165	150	135	125	110
	7.50	97.03	400	390	350	310	280	250	225	205	185	165	150	135	125
	8.00	105.59	400	400	380	340	305	270	245	220	200	180	165	150	135
	8.25	109.87	400	400	395	350	315	285	255	230	210	190	170	155	140
	8.50	114.15	400	400	400	365	330	295	265	240	215	195	180	160	145

LRFD

NO STUDS

* The **Uniform Live Loads** are based on the LRFD equation $\phi M_n = (1.6L + 1.2D)l^2/8$. Although there are other load combina-

The floor deck that was selected is 3” LOK-Floor 20 Gauge Form Deck Span 9 feet and 6 inch concrete slab with uniform total allowable load of 335 psf.

10” Precast Plank from STRESCON

10” x 96” SECTION WITH NO TOPPING

SPAN-DECK

STRESCON INDUSTRIES, INCORPORATED

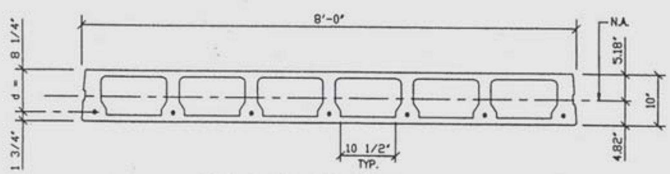
UNIFORMLY DISTRIBUTED SUPERIMPOSED* LOAD IN LBS. PER SQ. FT.

Standard Designation	7-Wire P/S Strand Combination	P/S Strand Area Sq. In.	Ultimate Bending Moment, ø Mn in Kip. Ft. per Unit	SIMPLE SPAN IN FEET 16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	ø Vcw in Kips per Unit
10S148	14-1/2"ø	2.142	320.9								262	249	236	225	205	186	170	155	142	130	119	109	100	91	84	49.44
10S138	13-1/2"ø	1.989	301.4								256	243	229	208	189	172	156	143	130	119	108	99	90	82	75	48.54
10S128	12-1/2"ø	1.836	280.4							264	250	232	210	190	172	156	142	129	117	107	97	88	80	73	66	47.64
10S118	11-1/2"ø	1.683	259.3						273	258	234	210	190	171	155	140	127	115	104	95	86	78	70	63	57	46.75
10S108	10-1/2"ø	1.530	237.6					283	263	234	210	188	169	152	137	124	112	101	91	82	74	67	60	53	48	45.85
10S98	9-1/2"ø	1.377	215.5			313	294	263	233	208	185	166	149	133	120	107	96	87	78	69	62	55	49			44.95
10S88	8-1/2"ø	1.224	193.0		327	296	260	229	203	180	160	143	127	114	101	90	81	72	64	57	50					44.06
10S78	7-1/2"ø	1.071	170.0	336	292	254	223	196	172	152	135	119	106	94	83	73	65	57	50							43.16
10S52	5-1/2"ø 2-3/8"ø	0.935	149.4	289	250	217	189	165	145	127	112	98	86	76	66	58	50									42.36

* INCLUDES THE LIVE LOAD PLUS ANY DEAD LOAD THAT IS ADDITIONAL TO THE WEIGHT OF THE BARE GROUTED SLABS IN PLACE.

NOTES

1. Design Criteria: ACI 318-95
2. For complete and detailed calculations consult Strescon Industries
3. For longer spans, heavier loads, or special conditions consult Strescon Industries
4. The table indicates maximum safe loads. Camber and deflection must always be investigated by the architect, and/or engineer for the contemplated loading and span so that these factors are compatible with the contiguous materials in the proposed structure.
5. Spans to the right of the heavy vertical line are recommended for roof applications only. However, this is a guide line and not a limit.
6. Values to the left and above the heavy stepped line are controlled by shear. This value may be increased by the use of a plant cast solid core. Consult Strescon Industries.



Grouted weight of slabs is 66 lbs. per sq. ft.

f'c = 5,000 psi | f'ci = 3,500 psi | Area = 401 in.²
f'pu = 270,000 psi | I = 5,324 in.⁴ | bw = 21.25 in.

JANUARY, 1996

The precast plank that was selected is 10”, designation 10S148 with a span of 34 feet and with a uniform total allowable load of 109 psf.

Alternative #1: Non-Composite Steel Framing

Beam Calculation:

Gravity Beam Design

RAM Steel v11.0
DataBase: Non Composite
Building Code: IBC

12/11/07 11:31:15
Steel Code: ASD 9th Ed.

Floor Type: Third Floor **Beam Number = 103**

SPAN INFORMATION (ft): I-End (6.00,33.17) J-End (6.00,62.33)

Beam Size (Optimum) = W16X31 Fy = 50.0 ksi
Total Beam Length (ft) = 29.16

LINE LOADS (k/ft):

Load	Dist	DL	LL	Red%	Type
1	0.000	0.019	0.000	---	NonR
	29.160	0.019	0.000		
2	0.000	0.150	0.360	0.0%	Red
	29.160	0.150	0.360		
3	0.000	0.031	0.000	---	NonR
	29.160	0.031	0.000		

SHEAR: Max V (DL+LL) = 8.16 kips fv = 1.98 ksi Fv = 19.67 ksi

MOMENTS:

Span	Cond	Moment	@	Lb	Cb	Tension Flange		Compr Flange	
		kip-ft	ft	ft		fb	Fb	fb	Fb
Center	Max +	59.5	14.6	0.0	1.00	15.12	33.00	15.12	33.00
Controlling		59.5	14.6	0.0	1.00	15.12	33.00	---	---

REACTIONS (kips):

	Left	**Right**
DL reaction	2.91	2.91
Max +LL reaction	5.25	5.25
Max +total reaction	8.16	8.16

DEFLECTIONS:

Dead load (in)	at	14.58 ft	=	-0.299	L/D	=	1172
Live load (in)	at	14.58 ft	=	-0.539	L/D	=	650
Net Total load (in)	at	14.58 ft	=	-0.837	L/D	=	418

Alternative #2: Composite Steel Framing

Beam Calculation:

Gravity Beam Design

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

12/11/07 11:31:48
Steel Code: ASD 9th Ed.

Floor Type: Third Floor **Beam Number = 106**

SPAN INFORMATION (ft): I-End (28.87,33.17) J-End (28.87,62.33)
Beam Size (Optimum) = W16X26
Total Beam Length (ft) = 29.16
Fy = 50.0 ksi

COMPOSITE PROPERTIES (Not Shored):

	Left	Right
Concrete thickness (in)	2.50	2.50
Unit weight concrete (pcf)	115.00	115.00
f'c (ksi)	3.00	3.00
Decking Orientation	perpendicular	perpendicular
Decking type	USD 3" Lok-Floor	USD 3" Lok-Floor

beff (in) =	65.25	Y bar(in) =	15.35
Seff (in3) =	53.36	Str (in3) =	67.20
Ieff (in4) =	666.62	Itr (in4) =	1004.84
Stud length (in) =	4.50	Stud diam (in) =	0.75

Stud Capacity (kips) q = 7.4
\# of studs: Max = 58 Partial = 14 Actual = 14
Number of Stud Rows = 1 Percent of Full Composite Action = 26.98

LINE LOADS (k/ft):

Load	Dist	DL	CDL	LL	Red%	Type	CLL
1	0.000	0.225	0.225	0.000	---	NonR	0.000
	29.160	0.225	0.225	0.000			0.000
2	0.000	0.136	0.000	0.326	0.0%	Red	0.000
	29.160	0.136	0.000	0.326			0.000
3	0.000	0.026	0.026	0.000	---	NonR	0.000
	29.160	0.026	0.026	0.000			0.000

SHEAR: Max V (DL+LL) = 10.40 kips fv = 2.77 ksi Fv = 17.89 ksi

MOMENTS:

Span	Cond	Moment kip-ft	@ ft	Lb ft	Cb	Tension Flange fb	Tension Flange Fb	Compr Flange fb	Compr Flange Fb
Center	PreCmp+	26.7	14.6	0.0	1.00	8.35	33.00	8.35	33.00
	Max +	75.8	14.6	---	---				
	Mmax/Seff					17.06	33.00	---	---
	Mconst/Sx+Mpost/Seff					19.40	45.00	---	---
Controlling		75.8	14.6	---	---	17.06	33.00	---	---

fc (ksi) = 0.29 Fc = 1.35

REACTIONS (kips):

	Left	Right
Initial reaction	3.67	3.67
DL reaction	5.65	5.65
Max +LL reaction	4.76	4.76
Max +total reaction	10.40	10.40

DEFLECTIONS:

Initial load (in)	at	14.58 ft =	-0.469	L/D =	747
Live load (in)	at	14.58 ft =	-0.275	L/D =	1275
Post Comp load (in)	at	14.58 ft =	-0.389	L/D =	900
Net Total load (in)	at	14.58 ft =	-0.858	L/D =	408

Alternative #3: Flex Frame System

Beam Calculation:

Gravity Beam Design

RAM Steel v11.0
DataBase: Flex Frame
Building Code: IBC

12/11/07 11:10:46
Steel Code: ASD 9th Ed.

Floor Type: Third Floor **Beam Number = 4**

SPAN INFORMATION (ft): I-End (33.75,33.17) J-End (33.75,62.33)
Beam Size (Optimum) = W21X44
Total Beam Length (ft) = 29.16
Fy = 60.0 ksi

LINE LOADS (k/ft):

Load	Dist	DL	LL	Red%	Type
1	0.000	0.052	0.000	---	NonR
	29.160	0.052	0.000		
2	0.000	0.422	1.013	27.2%	Red
	29.160	0.422	1.013		
3	0.000	0.002	0.000	---	NonR
	29.160	0.002	0.000		
4	0.000	0.044	0.000	---	NonR
	29.160	0.044	0.000		

SHEAR: Max V (DL+LL) = 18.33 kips fv = 2.65 ksi Fv = 20.80 ksi

MOMENTS:

Span	Cond	Moment kip-ft	@ ft	Lb ft	Cb	Tension Flange fb	Tension Flange Fb	Compr Flange fb	Compr Flange Fb
Center	Max +	133.6	14.6	0.0	1.00	19.65	39.60	19.65	39.60
Controlling		133.6	14.6	0.0	1.00	19.65	39.60	---	---

REACTIONS (kips):

	Left	**Right**
DL reaction	7.58	7.58
Max +LL reaction	10.75	10.75
Max +total reaction	18.33	18.33

DEFLECTIONS:

Dead load (in)	at	14.58 ft	=	-0.346	L/D =	1011
Live load (in)	at	14.58 ft	=	-0.491	L/D =	713
Net Total load (in)	at	14.58 ft	=	-0.837	L/D =	418

Alternative #4: Precast Beams and Hollow Core Planks

Hollow Core Planks

<u>Loading</u>
Span – 17’
Superimposed Dead Load – 25 psf
Live Load Maximum – 80 psf
Total Required Load – 1.2(25) +1.6(80) = 158psf
Therefore the depth of the precast plank is controlled by the depth for the precast plank to frame into the precast beams of 12”.
10” Precast Plank Selected – 48-S

Strand Pattern Designation
48-S

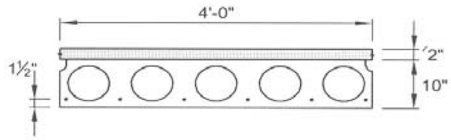
- S = straight
- Diameter of strand in 16ths
- No. of Strand (4)

Safe loads shown include dead load of 10 psf for untopped members and 15 psf for topped members. Remainder is live load. Long-time cambers include superimposed dead load but do not include live load.

Capacity of sections of other configurations are similar. For precise values, see local hollow-core manufacturer.

Key
258 – Safe superimposed service load, psf
0.3 – Estimated camber at erection, in.
0.4 – Estimated long-time camber, in.

HOLLOW-CORE
4’-0” x 10”
Normal Weight Concrete



$f'_c = 5{,}000$ psi
$f_{pu} = 270{,}000$ psi

Section Properties

		Untopped		Topped	
A	=	259	$in.^2$	355	$in.^2$
I	=	3,223	$in.^4$	5,328	$in.^4$
y_b	=	5.00	in.	6.34	in.
y_t	=	5.00	in.	5.66	in.
S_b	=	645	$in.^3$	840	$in.^3$
S_t	=	645	$in.^3$	941	$in.^3$
wt	=	270	plf	370	plf
DL	=	68	psf	93	psf
V/S	=	2.23	in.		

4HC10

Table of safe superimposed service load (psf) and cambers (in.) — **No Topping**

Strand Designation Code	Span, ft																										
	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46
48-S	258	234	209	187	168	151	136	123	111	100	90	82	74	66	60	54	48	43	38	34	30	26					
	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.1	0.1	0.0	–0.1	–0.2	–0.3	–0.4	–0.6	–0.7	–0.9					
	0.4	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.2	0.2	0.1	0.0	–0.1	–0.2	–0.3	–0.5	–0.7	–0.8	–1.1	–1.3	–1.3	–1.9					
58-S	267	249	237	223	211	197	179	162	148	134	122	112	102	93	85	77	70	64	58	53	48	43	39	35	30	26	
	0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.3	0.2	0.2	0.1	0.0	–0.1	–0.3	–0.4	–0.6	–0.7	–0.9	–1.2	
	0.5	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.5	0.5	0.4	0.3	0.2	0.1	0.0	–0.1	–0.3	–0.5	–0.7	–1.0	–1.2	–1.5	–1.8	–2.2	–2.6	
68-S	273	255	243	229	217	206	196	187	176	162	153	141	129	118	109	100	92	84	78	71	65	60	54	49	44	39	34
	0.5	0.5	0.6	0.6	0.6	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.6	0.6	0.5	0.5	0.4	0.3	0.2	0.1	–0.1	–0.2	–0.4	–0.6	–0.8
	0.7	0.7	0.7	0.8	0.8	0.8	0.8	0.9	0.9	0.8	0.8	0.8	0.7	0.7	0.6	0.5	0.4	0.2	0.1	–0.1	–0.3	–0.6	–0.8	–1.1	–1.4	–1.8	–2.2
78-S	282	264	249	235	223	212	202	193	185	174	165	153	144	136	129	119	113	104	96	89	82	76	69	63	57	52	47
	0.6	0.7	0.7	0.7	0.8	0.8	0.9	0.9	0.9	0.9	0.9	1.0	1.0	1.0	0.9	0.9	0.9	0.8	0.8	0.7	0.6	0.5	0.4	0.3	0.1	0.0	–0.2
	0.8	0.9	0.9	1.0	1.0	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.0	1.0	0.9	0.8	0.6	0.5	0.3	0.1	–0.1	–0.4	–0.7	–1.0	–1.3
88-S	288	270	255	241	229	218	208	199	188	180	174	165	153	145	135	128	122	115	106	101	96	91	84	77	71	65	59
	0.7	0.8	0.8	0.9	0.9	1.0	1.0	1.1	1.1	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.1	1.1	1.0	0.9	0.8	0.7	0.5	0.3
	1.0	1.0	1.1	1.2	1.2	1.3	1.3	1.4	1.4	1.4	1.4	1.5	1.5	1.4	1.4	1.4	1.3	1.2	1.2	1.0	0.9	0.7	0.6	0.3	0.1	–0.2	–0.5

4HC10 + 2

Table of safe superimposed service load (psf) and camber (in.) — **2 in. Normal Weight Topping**

Strand Designation Code	Span, ft																										
	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46
48-S	308	287	256	228	204	183	165	148	133	119	107	96	86	74	63	52	43	34	26								
	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.1	0.1	0.0	–0.1	–0.2	–0.3	–0.4								
	0.3	0.3	0.3	0.2	0.2	0.2	0.1	0.1	0.0	–0.1	–0.2	–0.3	–0.4	–0.6	–0.8	–1.0	–1.2	–1.4	–1.7								
	317	298	282	267	252	237	219	198	180	163	148	134	120	105	92	80	69	59	50	41	33	26					

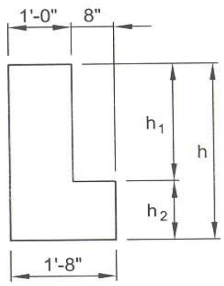
Alternative #4: Precast Beams and Hollow Core Planks

L-Shape Precast Beam

<u>Loading</u>
Span – 30’
Superimposed Dead Load – 25 psf
Live Load Maximum – 60 psf
Total Required Load – 1.2(25) +1.6(60) = 126psf
Tributary width – 8’-6”
Weight transferred to L-shape beam – 126psf * (8’-6”) = 1071 plf
H1 equals 12”, which is determined from Inverted T-shape beam to create a flush floor height
L-Shape Selected - 20LB24

L-BEAMS

Normal Weight Concrete



f'_c = 5,000 psi
f_{pu} = 270,000 psi
½ in. diameter
low-relaxation strand

Designation	h in.	h_1/h_2 in./in.	A $in.^2$	I $in.^4$	y_b in.	S_b $in.^3$	S_t $in.^3$	wt plf
20LB20	20	12/8	304	10,160	8.74	1,163	902	317
20LB24	24	12/12	384	17,568	10.50	1,673	1,301	400
20LB28	28	16/12	432	27,883	12.22	2,282	1,767	450
20LB32	32	20/12	480	41,600	14.00	2,971	2,311	500
20LB36	36	24/12	528	59,119	15.82	3,737	2,930	550
20LB40	40	24/16	608	81,282	17.47	4,653	3,608	633
20LB44	44	28/16	656	108,107	19.27	5,610	4,372	683
20LB48	48	32/16	704	140,133	21.09	6,645	5,208	733
20LB52	52	36/16	752	177,752	22.94	7,749	6,117	783
20LB56	56	40/16	800	221,355	24.80	8,926	7,095	833
20LB60	60	44/16	848	271,332	26.68	10,170	8,143	883

1. Check local area for availability of other sizes.
2. Safe loads shown include 50% superimposed dead load and 50% live load. 800 psi top tension has been allowed, therefore, additional top reinforcement is required.
3. Safe loads can be significantly increased by use of structural composite topping.

Key
6566 – Safe superimposed service load, plf.
0.3 – Estimated camber at erection, in.
0.1 – Estimated long-time camber, in.

Table of safe superimposed service load (plf) and cambers (in.)

Desig-nation	No. Strand	y_s(end) in. y_s(center) in.	Span, ft 16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50
20LB20	98-S	2.44 2.44	6566 0.3 0.1	5131 0.4 0.2	4105 0.5 0.2	3345 0.6 0.2	2768 0.7 0.2	2318 0.8 0.2	1961 0.9 0.3	1674 1.0 0.3	1438 1.0 0.3	1243 1.1 0.3	1079 1.2 0.2							
20LB24	108-S	2.80 2.80	9577 0.3 0.1	7495 0.3 0.1	6006 0.4 0.1	4904 0.5 0.1	4066 0.5 0.1	3414 0.6 0.2	2896 0.7 0.2	2479 0.8 0.2	2137 0.9 0.2	1854 0.9 0.2	1617 1.0 0.1	1416 1.0 0.1	1244 1.1 0.1	1097 1.1 0.0	969 1.2 0.0			
20LB28	128-S	3.33 3.33			8228 0.4 0.1	6733 0.4 0.1	5596 0.5 0.2	4711 0.6 0.2	4009 0.6 0.2	3443 0.7 0.2	2979 0.8 0.2	2595 0.9 0.2	2273 0.9 0.2	2000 1.0 0.2	1768 1.1 0.2	1567 1.1 0.2	1394 1.2 0.1	1243 1.2 0.1	1110 1.2 0.0	992 1.3 0.0

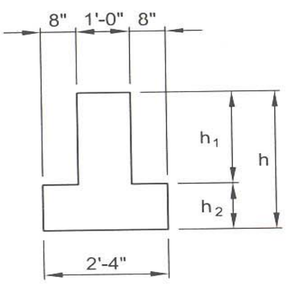
Alternative #4: Precast Beams and Hollow Core Planks

Inverted T-Shape Precast Beam

<u>Loading</u>
Span – 30’
Superimposed Dead Load – 25 psf
Live Load Maximum – 60 psf
Total Required Load – 1.2(25) +1.6(60) = 126psf
Tributary width – 17’
Weight transferred to L-shape beam – 126psf * (17’) = 2142 plf
Inverted T-Shape Selected - 281T24

INVERTED TEE BEAMS

Normal Weight Concrete



Section Properties								
Designation	h in.	h_1/h_2 in./in.	A $in.^2$	I $in.^4$	y_b in.	S_b $in.^3$	S_t $in.^3$	wt plf
28IT20	20	12/8	368	11,688	7.91	1,478	967	383
28IT24	24	12/12	480	20,275	9.60	2,112	1,408	500
28IT28	28	16/12	528	32,076	11.09	2,892	1,897	550
28IT32	32	20/12	576	47,872	12.67	3,778	2,477	600
28IT36	36	24/12	624	68,101	14.31	4,759	3,140	650
28IT40	40	24/16	736	93,503	15.83	5,907	3,869	767
28IT44	44	28/16	784	124,437	17.43	7,139	4,683	817
28IT48	48	32/16	832	161,424	19.08	8,460	5,582	867
28IT52	52	36/16	880	204,884	20.76	9,869	6,558	917
28IT56	56	40/16	928	255,229	22.48	11,354	7,614	967
28IT60	60	44/16	976	312,866	24.23	12,912	8,747	1,017

1. Check local area for availability of other sizes.
2. Safe loads shown include 50% superimposed dead load and 50% live load. 800 psi top tension has been allowed, therefore, additional top reinforcement is required.
3. Safe loads can be significantly increased by use of structural composite topping.

f'_c = 5,000 psi
f_{pu} = 270,000 psi
½ in. diameter
low-relaxation strand

Key
6511 – Safe superimposed service load, plf.
0.2 – Estimated camber at erection, in.
0.1 – Estimated long-time camber, in.

Table of safe superimposed service load (plf) and cambers (in.)

Desig-nation	No. Strand	y_s(end) in. y_s(center) in.	Span, ft																	
			16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50
28IT20	98-S	2.44 2.44	6511 0.2 0.1	5076 0.3 0.1	4049 0.4 0.1	3289 0.4 0.1	2711 0.5 0.1	2262 0.5 0.1	1905 0.6 0.0	1617 0.7 0.0	1381 0.7 0.0	1186 0.7 0.0	1022 0.8 –0.1							
28IT24	188-S	2.73 2.73	9612 0.2 0.1	7504 0.3 0.1	5997 0.3 0.1	4882 0.4 0.1	4034 0.4 0.1	3374 0.5 0.1	2850 0.6 0.1	2427 0.6 0.1	2081 0.7 0.1	1795 0.7 0.1	1555 0.7 0.0	1351 0.8 0.0	1178 0.8 –0.1	1029 0.8 –0.2				
28IT28	138-S	3.08 3.08			8353 0.3 0.1	6822 0.3 0.1	5657 0.4 0.1	4750 0.5 0.1	4031 0.5 0.1	3451 0.6 0.1	2976 0.6 0.1	2582 0.7 0.1	2252 0.7 0.1	1973 0.8 0.1	1735 0.8 0.0	1530 0.8 0.0	1352 0.9 –0.1	1197 0.8 –0.2	1061 0.8 –0.2	
28IT32	158-S	3.47 3.47				9049 0.3 0.1	7521 0.4 0.1	5333 0.4 0.1	5389 0.5 0.1	4628 0.5 0.1	4006 0.6 0.1	3490 0.6 0.1	3057 0.7 0.1	2691 0.7 0.1	2379 0.8 0.1	2110 0.8 0.1	1876 0.9 0.0	1673 0.9 0.0	1495 0.9 0.0	1337 0.9 –0.1