Lancaster County Bible Church

Manheim, Pennsylvania

Daniel Bellay – Structural Option

Thesis Consultant: Professor Behr

Date of Submission: December 17, 2009

Table of Contents

Executive summary

The purpose of this technical report is to investigate the pros and cons of alternate flooring systems for Lancaster County Bible Church. Three different flooring systems were selected for comparison; two-way flat slab, composite deck on steel frame, and hollow core concrete plank. Each of the three systems are compared against the existing floor system for unit cost, system weight/foundation impact, depth, lateral system impact, vibration control, and constructability.

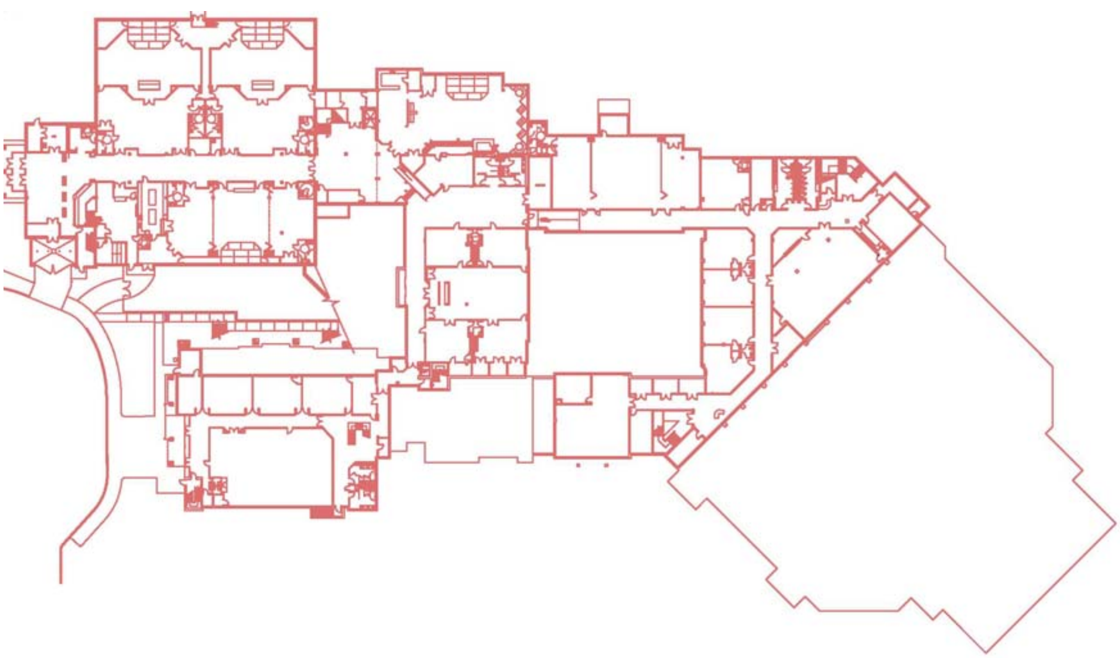
Interior bays of Lancaster County Bible Church exhibit shorter spans, 25’-0, than the exterior bays, 38’-4”. Therefore two different bay sizes were used, 38’-4” x 32’-0” (exterior bay), 25’-0” x 32’-0” (interior bay), for the accuracy. While two-way flat slab is thinner than the existing flooring system it is much heavier which could impact the foundation design. Composite metal decking on structural steel is similar to the existing system however it utilized the strength of the concrete floor with reduces the amount of steel required. Hollow core concrete planks are light enough that they would not impact the foundation design. Additionally, the hollow core planks rely upon steel framing so the existing column layout would not be severely impacted.

Introduction

LCBC (Lancaster County Bible Church) needed to expand its existing facility to accommodate the increased number of guests at it Sunday mass. The new expansion to LCBC would be focused towards the youth population and would include classrooms and youth performance areas. A three story, 78,000 square foot addition was designed by Mann Hughes Architecture. Construction began May, 2008.

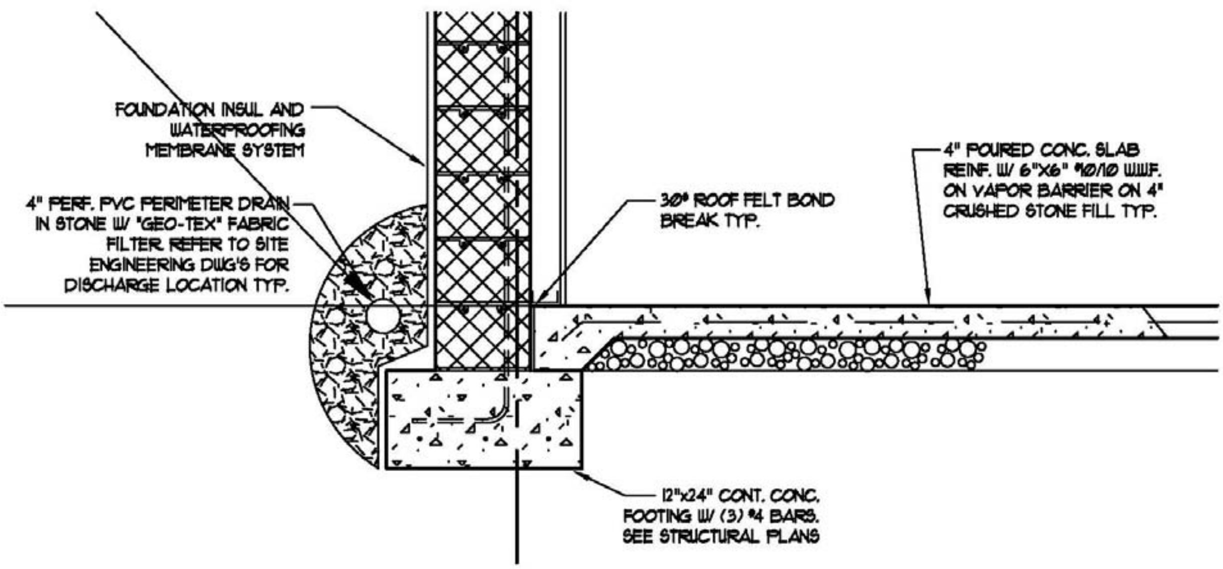
The new addition comprises three levels of multi-functional space. On the 100-level of the addition there is a large classroom and arcade areas for the younger children. Office spaces for the church's staff are the focus of the 200-level with executive offices for the pastor. In order to accommodate the needs of the adolescent population of LCBC a large performance and lounge area are provided on the 300 level. The 100-level, 200-level, and 300-level enjoy a 14'-0", 14'-0", and 15'-4" story height respectively. Total above grade height is 48'-0" to the top of the addition's parapet.

Land was not a restrictive component when the design of LCBC was made. Therefore the design of LCBC is a low profile sprawling structure with 100-level exhibiting a building footprint of 28,000 square feet. Successive levels step back from the 100-level's initial footprint giving the building its unique shape. Stucco panels were chosen as the exterior finish for the addition to complement the existing facilities façade.



Foundations

Various sized spread footings were designed to support column loads at LCBC. An F20, 2’x2’x12”, is the smallest spread footing found at LCBC. Reinforcing for an F20 footing is provided by (3) #4 bars in each direction. Interior columns require the largest spread footing and exhibit F110’s, 11’x11’x2’. Reinforcing for F110 is provided by (18) #7 bars in each direction. Typically spread footings are square however there are two rectangular footings, F 70x90 and F50x60. Load bearing masonry walls are supported by continuous spread footings that measure 24”x12”. Horizontal reinforcing for the continuous footings is provided by (3) #4 bars. Vertical reinforcing is provided by #6 dowels with 4” hooks @ 8” O.C.



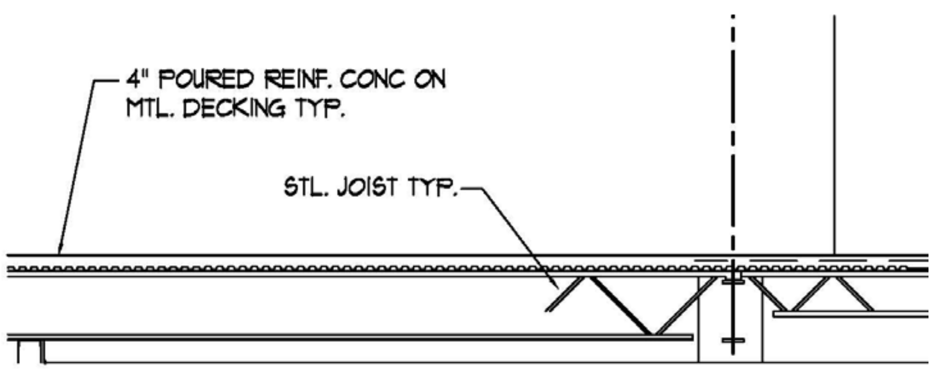
Flooring System

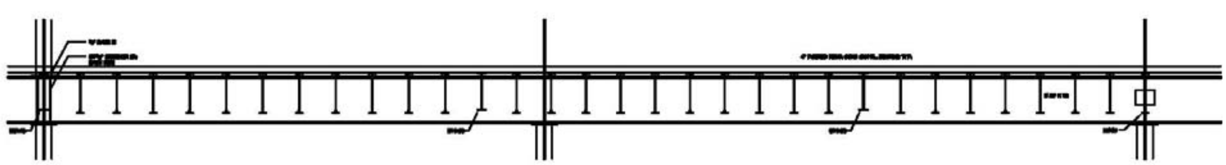
Reinforced concrete on metal decking was selected as the primary flooring system for LCBC. A 4” concrete slab is reinforced with 6x6 10/10 welded wire mesh. 1 ½”, 26 gauge metal deck provides additional strength for the concrete deck. This one-way floor system transfers gravity loads to supporting girders and columns. Concrete used be 3,000 psi strength.

The typical bay size at LCBC is 38’-4” x 25’-0”, however bay sizes vary to reflect the multi-functional nature of the building. On the 200-level floor framing the smallest bay size is 10’-9” x 16’-10” while the largest bay is 65’-0” x 38’-8”. The 300-hundred level roof framing is dominated by a massive 67’-0”x 63’-4” frame which provides a large open space required for the performance area below.

Framing for the flooring is provided by various open web steel joists. Longer spans at LCBC, typically 38’-4”, demand 26K9 or 26K10 open web steel joists. Shorter spans, typically 18’-25’, are typically supported by 18K4 open web steel joists. The lightest open web steel joist is an 8K1. In contrast the long spans located in the roof framing implement a 36LH12.

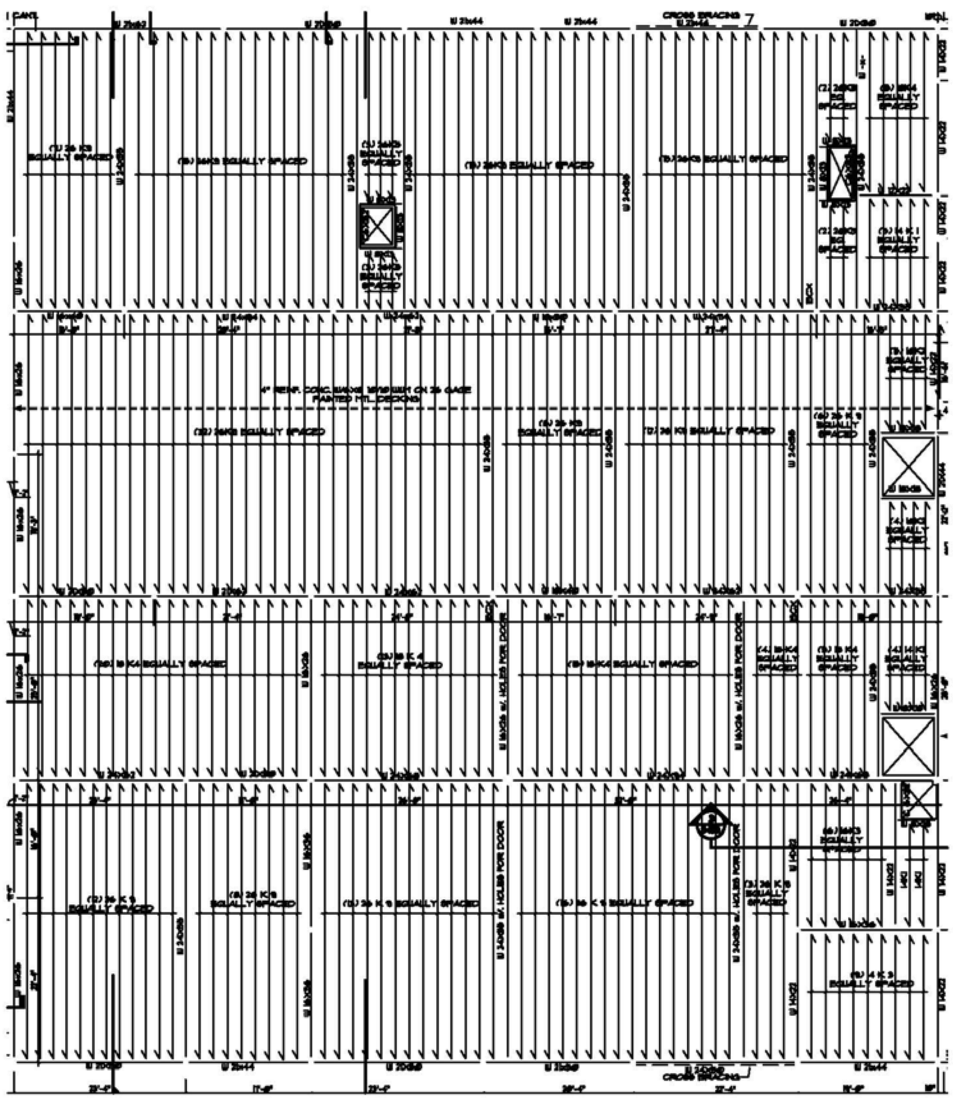
The 100-level flooring system is a slab on grade system. A 4” thick concrete slab is poured over a 6mm polyurethane vapor barrier. Underneath the vapor barrier on 4” of crushed stone on compacted earth.





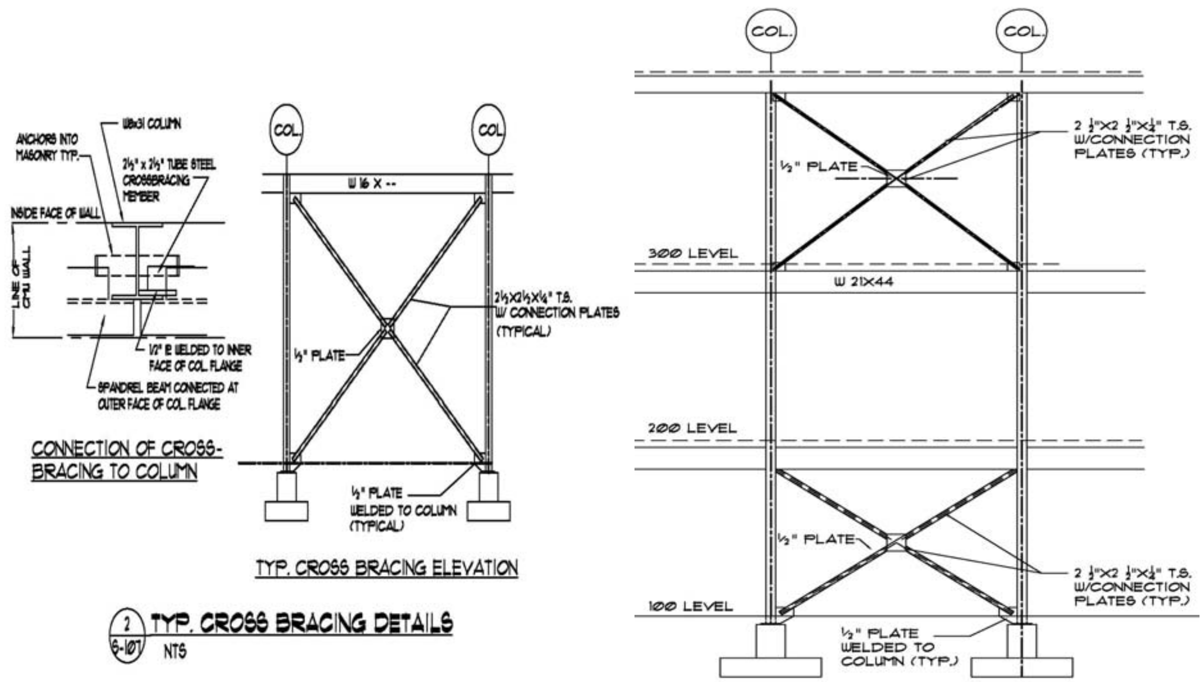
Gravity System

Gravity loads at LCBC are resisted by a simple steel framing system. The majority of the columns are W-shaped with the exception of a few HSS 4x4x3/8 columns. Typically columns will start 7" below grade and continue to the roof level. There are a few columns that start on the 200-level but they are the minority. Column sizes vary depending on how many floors the column supports and if they are interior or perimeter columns. A W10x60 is the heaviest column at LCBC and a W8x31 is the lightest. Beams and girders are W-shaped and range from a W12x16 to a W30x99.

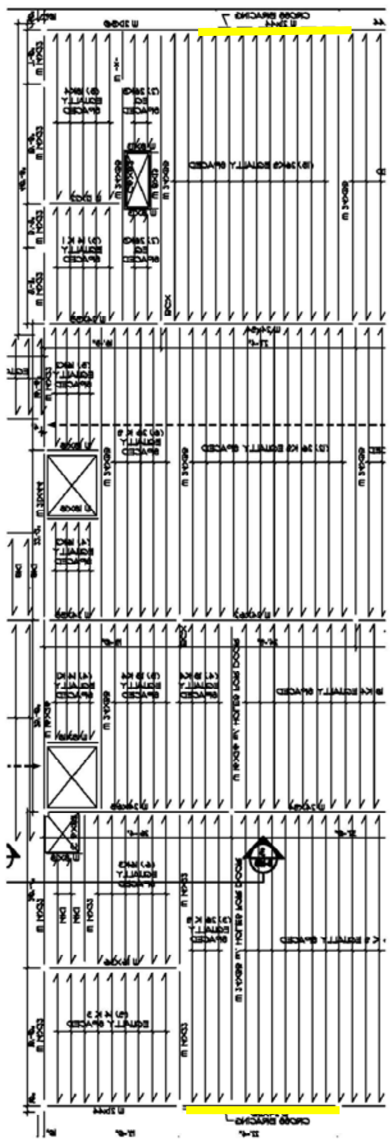


Lateral System

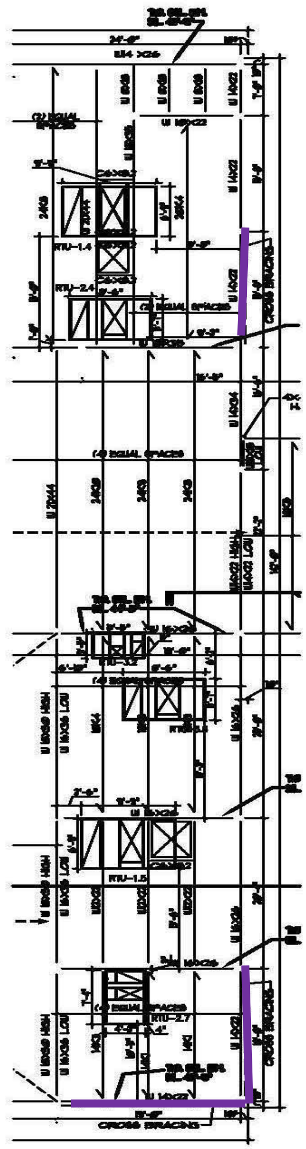
Lateral loads at LCBC are resisted by 5 braced frames. These 5 frames are all located on the perimeter column lines. The placement of the braced frames varies but is concentrated in the Southeast corner. Bracing is accomplished by welding (2) ½" steel plate to base of the column and (2) ½" steel plates the top of the same column. Then 2 ½" x 2 ½" tubular steel is welded to the steel plates in a cross arrangement. Lastly, a piece of ½" steel plate connects the cross bracing in the middle by means of welding.



Typical Cross-Bracing Detail



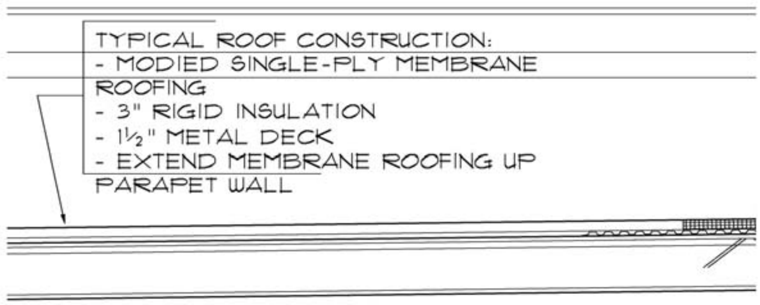
Cross-Bracing Layout 100-Level



Cross-Bracing Layout 300-Level

Roofing

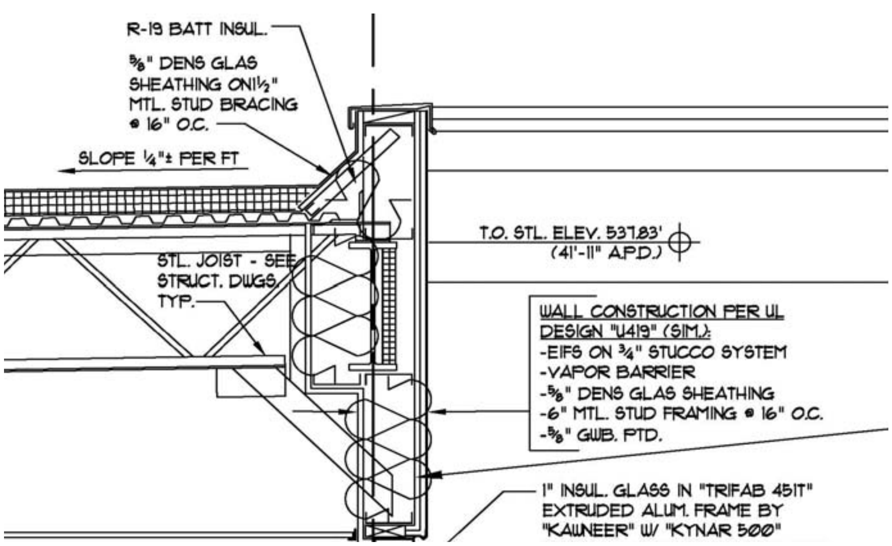
Two different flat roofing systems are implemented at Lancaster County Bible Church. The first flat roof system uses three-inch rigid insulation supported by 1 ½” metal decking. A single ply roofing membrane provides moisture protection. Tectum “E” structural roofing panels are used above the youth performance area. The panels are 6-inces thick and are constructed of: OSB sheathing, EPS insulation, and substrate.



Typical Roof Construction Detail

Building Envelope

The predominate façade of Lancaster County Bible Church is stucco. A ¾”prefabricated stucco panel called EIFS is installed on top of 5/8” dense glass. A vapor barrier provides moisture protection. 6” metal studs placed 16” on center provide support for the building’s façade. R-19 batt insulation provides thermal resistance for the wall construction. Gypsum board is used for the interior finish.



Typical Wall Section

Codes:

Building Code
IBC 2003

Structural Steel
AISC Specification for Structural Steel Buildings
AISC Manual of Steel Construction – Allowable Stress Design, 9th Addition
Vulcraft Steel Joist and Steel Girders 2003

Concrete
ACI Details and Detailing of Concrete Reinforcement, ACI 315
ACI Manual of Engineering and Placing Drawings for Reinforced Concrete Structures, ACI 315R

Design Loads
International Building Code 2000
American Society of Civil Engineers (ASCE), ASC- 7

Gravity Loads (Dead & Live Loads):

Live Loads	
Area	Design Load (psf)
Corridor	100
Office	100
Stairs	60
Storage Rooms	80
Roof	30
Dead Loads	
Description	Design Load (psf)
Floor Dead Load	50
Partitions	20
Framing	8
Ceilings	3
Mechanical Ductwork	3

Existing System: Metal decking on Open Web Steel Joist

Material Properties:

Concrete:	4 ½" Normal Weight Concrete Slabe
	f'c = 3,000 psi
Decking:	1 ½" 26 gauge galvanized metal deck
Steel:	A992 W-shape

Loading:

Dead (self weight):	56 psf
Live:	100 psf
SDL:	26 psf

Description:

The existing flooring system at LCBC utilizes various sized open web steel joist to transfer floor loads to girders. Open web steel joists steel joists are oriented perpendicular to girders. Pinned connections are used to secure joists to girders. Metal decking is placed on top of the steel joists where a concrete floor is poured.

Advantages:

Open web steel joists provide many advantages to comparable flooring systems. Steel joists are pre-fabricated which promises a great degree of quality control. Economy is the main driving force for using steel joists; they are cheap and readily available. Construction of a steel joist floor is simple and does not require shoring or special tools.

Disadvantages:

Steel joist flooring is a very economical flooring solution because it uses very little steel. While this is economically effective it causes problems for vibration control. Acoustical control poses a problem to open web steel joists because sound is not absorbed by steel very well. The biggest problem with a floor supported by steel joist is fireproofing. There is a very large cost associated with fireproofing open web steel joists. Due to the open nature of the joists fireproofing is very difficult to apply.

Composite Deck

Material Properties:

Concrete:	4 ½" Normal Weight Concrete Slab
	f'c = 3,000 psi
Decking:	16 Gauge 2" LOK-Floor (USD)
Steel:	A992 W-Shaped
	Beams:
	Girders:

Loading:

Dead (self weight):	45.1 psf
Live:	100 psf
SDL:	26 psf

Description:

Composite steel beam on composite steel deck is a flooring system that utilized concrete's compressive strength and steel's tensile strength. W-shaped beams replaced the existing steel bar joist and metal studs were added to the metal decking and beams. Beams transfer gravity load to W-shaped girder which are supported by W-shaped columns. A 16 gauge metal deck was required to withstand the greater forces from the longer spans. Metal decking is oriented perpendicular to steel beams to obtain composite action. Appendix B contains the supporting calculations for the composite steel decking.

Advantages:

Very little impact is made to the original design by using composite steel beam on composite steel decking. The weight and depth of the composite flooring system is similar to steel joist which leaves no need to redesign the foundation system. Required form work is limited when using composite flooring system which increases erection speed. Using the composite flooring produced a system with less members and similar slab thickness that is comparable in strength and weight.

Disadvantages:

Additional framing is needed when using a composite steel flooring system. Beams need to be supported by girders this requires the design and construction of additional supports. This is costly and adds lead time to the steel package. The placement of shear studs in a composite flooring system slows construction time and adds to labor costs. Additionally, open web steel joist allow for mechanical and electrical equipment to easily pass through the open webs. Being that and exposed ceiling system is in place at LCBC this poses a problem in routing the buildings supporting systems.

Two-Way Flat Plate

Material Properties:

Loading:

Dead (Self Weight):

Live Load: 100 psf

SDL: 26 psf

Description:

A two-way flat plate system has steel reinforcing bars running in both directions which allows for gravity loads to be distributed in four directions. It was assumed that all columns were 18" x 18" and are to be constructed using f'c = 5,500 psi concrete. The Direct Design Method, ACI 318-08 was implemented in the design of the two-way slab. A slab thickness of 14.75" was ultimately used and drop panels were required to control punching shear. High strength concrete was also used to control punching shear.

Advantages:

Two-way flat plates seldom require additional fireproofing. This cuts down on construction and lead time. The minimal depth smooth finish provided by the two-way slab would ease the installation of the buildings mechanical and electrical systems. Construction of a two-way flat plate requires simple formwork and simple construction techniques. Concrete and steel reinforcing bars are widely available which cuts down on lead time.

Disadvantages:

Two-way flat plates are not intended for long spans or live loads in excess of 50 psf. The long spans and 100 psf live loads present at LCBC yielded a thick two-way plat that was packed with reinforcing bars. Ideally the column layout would need to be changed in order to warrant the use of a two-way flat plate. Increased dead loads from the two-way plate and concrete columns would certainly demand a redesign of the buildings foundation system. Additionally, punching shear was controlled using high strength concrete which is costly and ultimately impractical.

Hollow Core Concrete Plank on Steel Framing

Material Properties:

Concrete:

Steel: A992 W-Shaped

Loading:

Dead Load (Self Weight):

Live Load: 100 psf

SDL: 26 psf

Description:

Hollow core concrete plank incorporate pre-stress steel tendons which allow for longer spans and higher loads than normal concrete. The concrete planks bear directly on structural steel members and a 2" concrete topping is poured over the connection to provide a stable connection.

Advantages:

Pre-fabricated concrete planks have some major advantages over site fabricated flooring system. Since the concrete planks are prefabricated they are held to a higher degree of quality than a site fabricated flooring system. Factory conditions are controlled which guarantees proper curing and planks can be produced despite weather conditions. Because the concrete planks are cured before reaching the construction site there is no wait time for concrete curing or need for form work.

Disadvantages:

Being that concrete planks are pre-fabricated they cannot be altered on site. With the bay size of 32'-0 x 38'-4" bay size modification would be necessary but not be significant. However, the concrete planks do restrain designers to certain bay sizes because the planks cannot be altered. Therefore irregular shaped structures, such as curved buildings, would find it nearly impossible to use concrete planks.

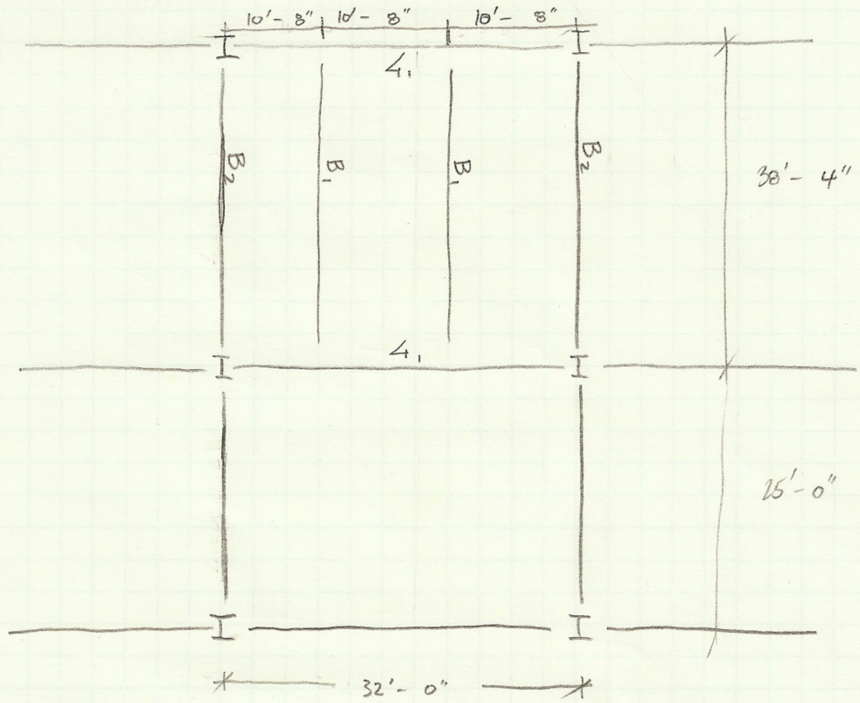
Conclusions

Comparison Chart of Floor Systems				
	Floor Systems			
	Existing (Open Web Steel joist)	Composite Steel	Two-Way Flat Slab	Hollow Core Pre-Cast Concrete Planks
System Weight	50	50	185	81
Slab Depth (in)	4	4.5	15	10
Total Depth(in)	30.5	20.6	15	42.9
Fireproofing	Requires Fireproofing	Requires Fireproofing	Does not Require Fireproofing	Requires Fireproofing
Cost $/S.F.	20.71	18.10	23.04	13.54
Foundation Impact	None	Minimal	Major	Moderate
Architectural Impact	No	No	Yes	Yes
Constructability	Easy	Easy	Moderate	Easy
Vibration Control	Poor	Poor	Excellent	Good
Feasibility	N/A	Excellent	Minimal	Good

None of the alternative flooring systems proved to be superior to the existing flooring system. However, of the alternative flooring systems the composite steel flooring system seemed to be the most practical. While the tabulated results above do not depict a clear winner other factors must be considered. A composite steel flooring system would eliminate the need for additional contractors beyond the required steel erector. The hollow core concrete planks on steel would require a separate contractor for installation and special consideration for delivery. However, the hollow core concrete planks are the cheapest flooring system which makes them an attractive alternative. A two-way flat slab would require a complete redesign of the entire building. Everything from the floor plans to the foundations would need to be redesigned. The two-way flat slab does not incorporate any aspect of the existing design deeming its implementation impractical.

APPENDIX A: Composite Deck

COMPOSITE STEEL ON METAL DECK



L_L = 100 psf

SDL = 26 psf

DL = SLAB

DECK PROPERTIES

USE 16 GUAGE DECK :

t = 0.0598	I = 0.700	R_b = 2470
w = 3.1 psf	S_p = 0.654	ϕV_n = 3990
A_s = 6.900	S_n = 0.654	Studs = 0.72

COMPOSITE PROPERTIES (16 guage WITH 4 1/2" CONC:

SLAB DEPTH = 4.5"

ϕM_{nf} = 62.08

W = 42 psf

MAX UNSHORED SPANS

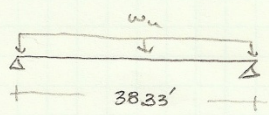
3 SPANS = 12.02'

L_L UNIFORM SERVICE LOADS, psf

FOR 4 ½" N.W.C. WITH 10'-8" & 11'-0" SPANS

UNIFORM L_L = 180 psf > 100 psf ∴ ok ✓

BEAM DESIGN



T_{WIDTH} = 10.66'

LOADS: D_L = 42 + 3.1 = 45.1

SDL = 26 psf

L_L = 100 psf

$W_u = 1.2(71.1) + 1.6(100) = 245.3$ psf

$W_u = \frac{245.3(10.66)}{1000} = 2.62$ klf

$M_u = \frac{wl^2}{8} = \frac{2.62(38.33)^2}{8} = 481'^{k}$

$V_u = \frac{wl}{2} = \frac{2.62(38.33)}{2} = 50.2^{k}$

DECK

ASSUME $a = 1.5"$ ∴ $Y_2 = 4.5 - 1.5/2 = 3.75"$ ⇒ USE 3.5

TRY: W16x45 ⇒ $\phi M_p = 249$

$\phi M_n = 521$

$Y_1 = 3$

$\Sigma Q_n = 464$

STUDS $= \frac{\Sigma Q_n}{Q_n} = \frac{464}{17.2} = 27$ STUDS

ACROSS BEAM = 54 STUDS

CHECK ASSUMPTIONS

$b_{eff} = 10.66$ or $\frac{38.33}{4} = 9.58$

$b_{eff} = 9.58\,(12) = 115''$ $\quad a = \frac{\Sigma Q_n}{0.85 f'c\, b_{eff}} = \frac{464}{0.85(3)(115)} = 1.5'' \leq$

VERY CLOSE BUT OK ✓

CHECK DEFLECTIONS

LIVE LOAD DEFLECT.

$D_{LL} = \frac{5 w l^4}{384 E I} \Rightarrow \frac{5\,(0.1)(38.33)^4(1728)}{384\,(29{,}000)(1320)} = 0.13'' < l/360$

$l/360 = \frac{38.33\,(12)}{360} = 1.28''$

CHECK SHEAR

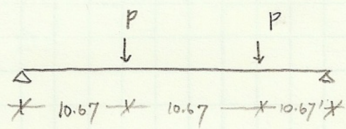
$V_u: 50.2^K < \phi V_n = 167^K \therefore$ OK

USE W16x45 (34) FOR B_1 & B_2

$d = 16.1''$

*BECAUSE B_1 TRIB AREA IS GREATER THAN TRIB AREA B_2 ITS OKAY TO USE FOR BOTH BEAMS

GIRDER DESIGN



$P = 50.2^k$

FROM ONE SIDE ONLY (38.33' DIR)

FROM 25'-0 DIR

$V_u = \frac{w\ell}{2} = \frac{2.62(25)}{2} = 32.8^k$

$P_L = 50.2 + 32.8 = 83.0$

FOR WORST SITUATION:

$V_u = 32.8 + 50.2 = 83^k$

$M_u = P(x) \Rightarrow 83.0(10.67) = 886'^k$

ASSUME $a = 2$ $\therefore$ $Y_2 = 4.5 - 2/2 = 3.5''$

TRY 24x62
$\phi M_p = 574'^k$
$\phi M_n = 993'^k$
$\Sigma Q_n = 703^k$
$Y_1 = 3$

3/4" STUDS PARRALLEL TO DECK $Q_n = 17.1^k$

$\# \text{ STUDS} = \frac{703}{17.1} = 41.1 \Rightarrow 42$ TOTAL STUDS = 82

- CHECK a

$b_{eff} = 10.66$
OR
$\frac{25}{4} = 6.25' \times 12 = 75'$

$a = \frac{\Sigma Q_n}{0.85 f'_c b_{eff}} = \frac{703}{0.85(3)(75)} = 3.68'' > 2.0''$ $\therefore$ NO GOOD

IF $a = 4''$ $Y_2 = 4.5 - 4/2 = 2.5$ $\phi M_n = 941'^k$

$\phi M_n = 941'^k > 886'^k$ $\therefore$ USE 24x68

PNA STILL WITHIN CONC OKAY

CHECK GIRDER DEFLECTIONS

$$DEF_{LL} = \frac{P\ell^3}{48EI} = \frac{(33.8)(32)^3(1728)}{48(29{,}000)(3040)} = 0.452''$$

↳ $P_L = (0.1)(10.67)(31.67) = 33.8^k$

LIVE LOAD DEFLECTION LIMIT $\ell/360 = \frac{32 \times 12}{360} = 1'' > 0.452''$ ∴ ok ✓

USE W24x62

FOR GIRDERS

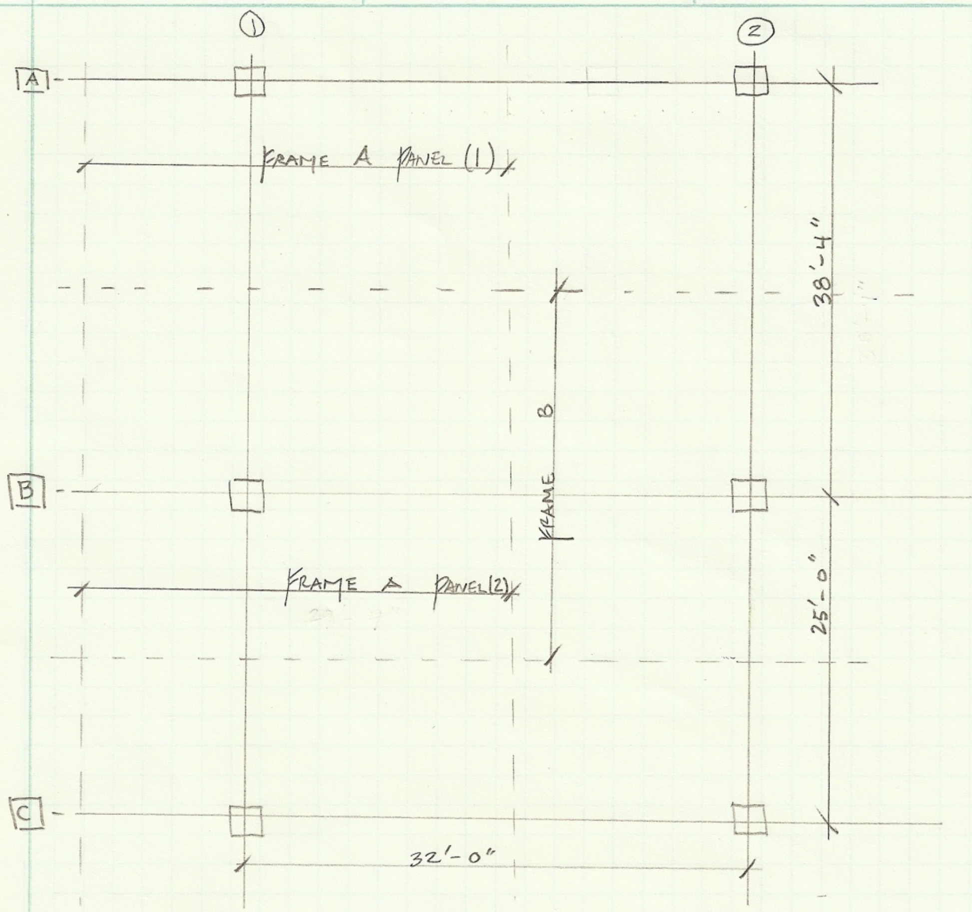
Information from USD (United Steel Deck) Design Manual

DECK PROPERTIES									
Gage	t	w	As	I	S_p	S_n	R_b	ϕV_n	studs
22	0.0295	1.5	0.440	0.338	0.384	0.302	714	1990	0.36
20	0.0358	1.8	0.540	0.420	0.367	0.387	1010	2410	0.43
19	0.0418	2.1	0.630	0.490	0.445	0.458	1330	2810	0.51
18	0.0474	2.4	0.710	0.560	0.523	0.529	1690	3180	0.57
16	0.0598	3.1	0.900	0.700	0.654	0.654	2470	3890	0.72

2 x 12" DECK F_y = 33ksi f

	L, Uniform Live Service Loads, psf *														
	Slab Depth	ϕMn in.k	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	10.50	11.00	11.50	12.00
…ge	4.50	40.27	400	365	310	262	230	200	175	155	135	120	105	95	85
	5.00	46.44	400	400	360	305	265	230	200	175	155	140	125	110	95
	[illegible]	[illegible]	400	400	400	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	7.50	121.83	400	400	400	400	400	400	400	400	400	400	360	325	290
16 gage	4.50	62.08	400	400	400	400	370	325	285	255	225	200	180	160	145
	5.00	72.04	400	400	400	400	400	375	335	285	260	235	210	190	170
	5.50	82.00	400	400	400	400	400	400	380	335	300	265	240	215	195
	6.00	91.95	400	400	400	400	400	400	400	375	335	300	270	245	220
	6.50	101.91	400	400	400	400	400	400	400	400	375	335	300	270	245
	7.00	111.87	400	400	400	400	400	400	400	400	400	365	330	295	270
	7.25	116.85	400	400	400	400	400	400	400	400	400	385	345	310	280
	7.50	121.83	400	400	400	400	400	400	400	400	400	400	360	325	290

APPENDIX B: Two-way Flat Plate



f'_c = 3000 psi

F_y = 60,000 psi

18"x18" COLUMNS

SUPER IMPOSED DEAD LOAD: 26 psf

LIVE LOAD : 100 psf

$$W_u = 1.2\left(\left[\left(\frac{14.73}{12}\right)\times 150\right] + 26\right) + 1.6\,(100) = 412 \text{ psf}$$

TWO - WAY SLAB CHECKLIST

- MINIMUM OF THREE CONTINOUS SLABS IN EACH DIRECTION: YES
- panes shall be rectanglular with a ratio of longer to shorter span center to center of supports not to exceed 2: Yes
- ALL LOADS TO BE GRAVITY LOADS & UNIFORMLY DISTRIBUTED OVER THE ENTIRE PANEL WITH THE UNFACTORED LIVE LOAD NOT TO EXCEED TWO TIMES UNFACTORED TIMES LIVE LOAD

DETERMINE SLAB THICKNESS

• PANEL A-B-1-2

MIN SLAB THICKNESS : $\frac{l_n}{30} = \frac{(38.33 \times 12) - 18}{30} = \boxed{14.73''}$ GOVERNS

• PANEL B-C-1-2

MIN SLAB THICKNESS : $\frac{l_n}{33} = \frac{(32 \times 12) - 18}{33} = 11.10''$

CHECK PUNCHING SHEAR @ COLUMNS A1 & B1

COLUMN A-1

$V_u = 412 \left[19.17' \times 32' - 1.5 \times 1.5 \right] = 252^k$

ASSUME # 5 BARS

$d = 14.7 - 0.75 \;\; 0.625 = 13.4''$

$b_o = (18 + 13.4)3 = 94.2''$

$\frac{b_1}{b_o} = 1.0$ * ACI 11-35

$V_c = 4 \cdot \sqrt{f'_c} \cdot b_o \cdot d \Rightarrow 4\sqrt{3000} \cdot 94.2 \cdot 13.4 = 276.6^k$

$\phi V_c = 0.75(276.6) = 207 < 252^k$ ∴ NEED DROP PANELS @ EXT. COLS.

∴ NEED DROP PANEL INT COLUMNS

$t_{slab\,(min)} = \frac{(38.33 \times 12) - 18}{33} = \boxed{13.4''}$ – GOVERNS USE 13.5″

OR $\frac{(32 \times 12) - 18}{36} = 10.2''$

USE 2″ DROP PANEL

PUNCHING SHEAR AT DROP PANELS

DROP PANEL = 2"

$d = 14.75" - 0.75 - \frac{0.625}{2} = 14.4"$

$b_o = (18 + 14.4)4 = 130"$

$\phi V_c = 0.75(4)\sqrt{3000}(14.4)(130) = 308^k > 252^k$

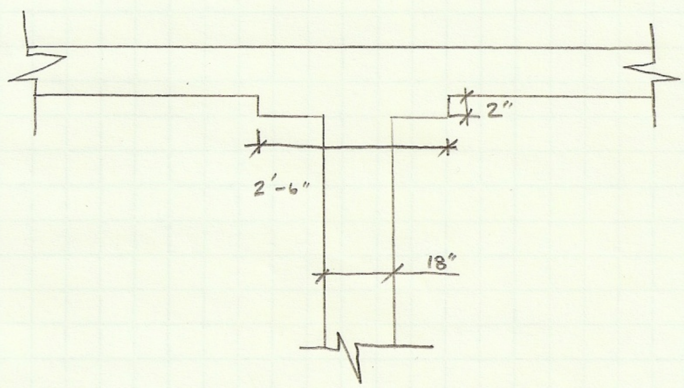
COLUMN A-2

$V_u = 412[31.67 \times 32 - 1.5 \times 1.5] = 417^k >> 308^k$

NEED TO USE $f'c = 5500$ INCREASE THE CONC. STRENGTH

$\phi V_c = 0.75(4)\sqrt{5500}(14.4)(130) = 417^k > 417^k$

∴ OK BUT VERY CLOSE USE $f'c = 5500$ psi



TOTAL FACTORED MOMENT:

FRAME A: PANEL 1

$$M_o = \frac{(0.412)(32)(36.8)^2}{8} = 2092'^k$$

$l_2 = 32'-0"$

$l_n = 38.33 - 18/12 = 36.8'$

FRAME A: PANEL 2

$$M_o = \frac{(0.412)(32)(23.5)^2}{8} = 910.1'^k$$

$l_2 = 32'-0$

$l_n = 25 - 18/12 = 23.5$

FRAME B

$$M_o = \frac{(0.412)(31.67)(32 - 18/12)^2}{8} = 1521'^k$$

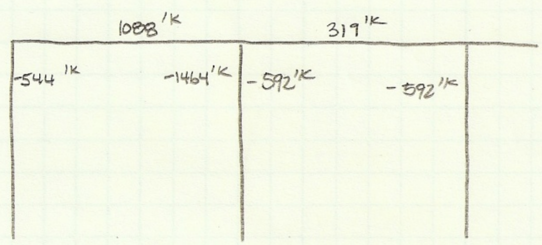
$l_2 = \frac{25 + 38.33}{2} = 31.67'$

DISTRIBUTION OF M_o (NO EDGE BEAMS OR INT. BEAMS)

FRAME A:

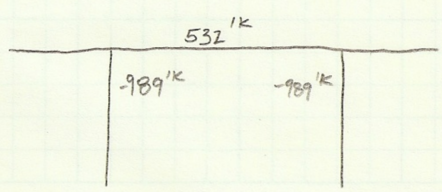
$M^-_{EXT} = 0.26\, M_o = 544$ $\quad M^+ = 0.52 M_o = 1088$ $\quad M^-_{INT} = 1464$

$M^+ = 0.35\, M_o = 319$ $\quad M^- = 0.65\, M_o = 592$



FRAME B:

$M^+ = 0.35\, M_o = 532'^k$ $\quad M^- = -0.65\, M_o = 989'^k$



DIST OF MOMENTS IN CS, BEAM, MS:

FRAME A, PANEL 1:

a) NEG MOM @ EXT. FACE

$\frac{l_2}{l_1} = \frac{32}{38.33} = 0.835$

$\beta_t = 0$, $\alpha = 0$ ⇒ 100 % TO C.S. ⇒ -544 < 100 % TO C.S. / 0 % TO M.S.

b) NEG. MOM @ INT. FACE

-1464 < 75% TO C.S. = -1098 / 25% TO M.S. = -366

c) POSITIVE MOMENTS

1088 < 60 % TO C.S. = 653 / 40 % TO M.S. = 435

FRAME A, PANEL 2:

a) NEG MOMENT @ INT FACES

-592 < 0.75 to C.S. = 444 / 0.25 to MS = 148

b) POS. MOM

319 < 60 % CS = 191 / 40% MS = 128

FRAME B:

a) NEG. MOM @ INT. FACES

-989 < 75 % CS = -742 / 25 % MS = -247

532 < 60 % CS = 319 / 40 % MS = 213

SUMMARY OF MOMENTS

FRAME A : TOTAL WIDTH: 32'-0" C.S. WIDTH: 16'-0" M.S. WIDTH: 16'-0"

TOTAL MOM.	-544	1088	-1464	-592	319	-592
CS MOM	-544	653	-1098	-444	191	-444
MS MOM	0	435	-366	-148	128	-148

FRAME B : TOTAL WIDTH: 32'-0 CS. 16'-0" MS = 16'-0"

TOTAL MOM	-989	532	-989
C.S. MOM	-742	319	-742
M.S. MOM	-247	213	-247

SAMPLE CALCS FOR TABLES

CS, b ⇒ 16'-0 - beam = 16' x 12 = 192"

EFFECTIVE DEPTH, d ⇒ CLEAR COVER = 0.75"

BAR DIAMETER = #5 ⇒ 0.625"

$d_{SHORT} = t_{SLAB} - \text{CLR COVER} - \frac{1}{2} d_b = 13.4"$

$d_{LONG} = t_{SLAB} - \text{CLR COVER} - \frac{1}{2} d_b - d_b = 13.0"$

$R = M_n / b \cdot d^2 \Rightarrow [34 / (192)(13)^2] \times 1000 \times 12 =$

$\rho_{req'd} \Rightarrow R = \rho F_y (1 - 0.59\, F_y / f'_c)$

$A_{s\,req'd} = \rho_{req'd} \cdot b \cdot d$

$A_{s,min} = 0.002\; b \cdot t = 5.61$

LARGER #8, #9 / #5 BAR = 0.31 in²

$N_{min} = \frac{b}{2t} = \frac{190}{2(14.75)} = 6.44 \Rightarrow 7$

Reinforcement Design for Frame (A) Column Strip						
Item	Description	Exterior Span			Interior Span	
		M^-_{EXT}	M^+	M^-_{INT}	M^-	M^+
1	M_U	-544	653	-1098	-444	191
2	CS width, b	192	192	192	192	192
3	Effective Depth, d	13.0”	13.0”	13.0”	13.0”	13.0”
4	M_U*12/b	-34	41	-69	-28	12
5	$M_n = M_U /0.9$	-604	726	-1220	-493	212
6	R	223	269	451	182	79
7	ρ_{required}	.00482	.00523	.00892	.00328	.00164
8	$A_{s,REQ'D}$	12.03	13.05	22.03	8.10	4.05
9	$A_{s,min}$	5.61	5.61	5.61	5.61	5.61
10	N	39	42	71	26	18
11	N_{MIN}	7	7	7	7	7

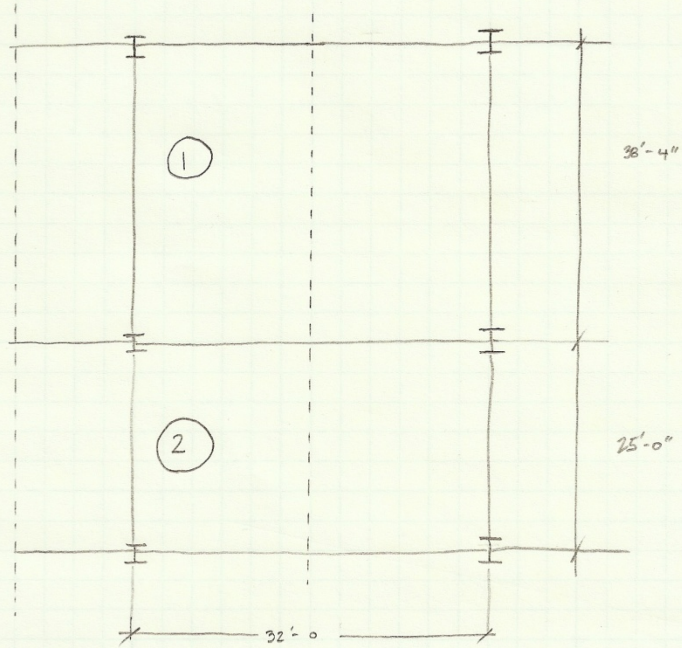
Reinforcement Design for Frame (A) Middle Strip						
Item	Description	Exterior Span			Interior Span	
		M^-_{EXT}	M^+	M^-_{INT}	M^-	M^+
1	M_U	0	435	-366	-148	128
2	CS width, b	192	192	192	192	192
3	Effective Depth, d	13.0”	13.0”	13.0”	13.0”	13.0”
4	M_U*12/b	0	27	-23	-9	8
5	$M_n = M_U /0.9$	0	483	-407	-164	142
6	R	0	178	151	61	53
7	ρ_{required}	0	.00317	.00293	.00142	.00131
8	$A_{s,REQ'D}$	0	7.92	7.13	3.54	3.27
9	$A_{s,min}$	5.61	5.61	5.61	5.61	5.61
10	N	18	26	23	18	18
11	N_{MIN}	7	7	7	7	7

Reinforcing Design for Frame (B) Column Strip			
Item	Description	Interior Span	
		M^-	M^+
1	M_U	-742	319
2	CS width, b	192	192
3	Effective Depth, d	13.0”	13.0”
4	M_U*12/b	-46.4	20.0
5	$M_n = M_U/0.9$	-824.4	354.4
6	R	304.7	131.1
7	$\rho_{required}$	.00612	.00231
8	$A_{s,REQ'D}$	15.28	5.77
9	$A_{s,min}$	5.61	5.61
10	N	50	19
11	N_{MIN}	7	7

Reinforcing Design for Frame (B) Column Strip			
Item	Description	Interior Span	
		M^-	M^+
1	M_U	-247	213
2	CS width, b	192	192
3	Effective Depth, d	13.0”	13.0”
4	M_U*12/b	-15.4	13.3
5	$M_n = M_U/0.9$	-274.4	236.7
6	R	101.5	87.6
7	$\rho_{required}$	.00191	.00174
8	$A_{s,REQ'D}$	4.77	4.34
9	$A_{s,min}$	5.61	5.61
10	N	18	18
11	N_{MIN}	7	7

APPENDIX C: Hollow Core Concrete Plank

• HOLLOW CORE PRECAST PLANK ON STEEL FRAMING



BAY 1:

SDL = 26 (MEP & PARTIONS)

L_L = 100 psf

TOTAL SERVICE LOAD = 126 psf

GIRDER DESIGN

$D_L = 26 + (56)^{*} = 91$ psf *56 - DEAD LOAD OF PLANK WITHOUT 2" CONC. TOPPING

L_L = 100 psf

LIVE LOAD REDUX

$L = L_0 \left[0.25 + \frac{15}{\sqrt{A_I}} \right]$ WHERE $A_I = 2[(32' \times 38.33')] = 2453$

$L = 0.55\, L_0 > 0.5\, L_0 \therefore$ USE $0.55\, L_0$

FACTORED LOADS

$1.2(91) + 1.6(55) = 197$ psf

$W_u = \frac{197(32)}{1000} = 6.3$ klf

$M_u = \frac{w \cdot l^2}{8} = \frac{6.3(38.33)^2}{8} = 1157'^{k}$

TOTAL LOAD DEFLECTIONS

$l/240 = \frac{38.33(12)}{240} = 1.92''$

$I_{req'd} \Rightarrow \frac{5 \cdot w \cdot l^4}{384\, EI} = \frac{5(6.3)(38.33)^4(1728)}{384(29{,}000)\, I} = 1.92''$

$I_{req'd} = 5{,}499\ in^4$

TRY W 33 x 118 $I_x = 5{,}900$ (*NOTE: W 33 x 118 IS MOST ECONOMICAL WHILE W 24 x 176 IS THE SHALLOWEST)

$\phi M_p = 1560'^{k}$

LL DEFL.

$l/360 = \frac{38.33(12)}{360} = 1.28''$

$I_{req'd\,(LL)} = \frac{5\left(\frac{100 \times 32}{1000}\right)(38.33)^4(1728)}{384(29{,}000)(1.28)} = 4188\ in^4 < 5{,}900\ in^4 \therefore ok$ ✓

USE W 33 x 118 FOR ECONOMY

USE W 24 x 176 FOR NO DISTURBANCE IN ORIGINAL DESIGN

W 33 x 118 $d = 32.9''$

Table of safe superimposed servi 2 in. Normal We

Strand Designation Code	13	14	15	16	17	18	31	32	33	34	35	36
66-S	489	445	394	340	294	256	2 36	26				
	0.2	0.2	0.2	0.2	0.2	0.2	0.2	–0.3				
	0.2	0.2	0.2	0.2	0.2	0.2	1.2	–1.4				
76-S	498	457	420	387	347	304	2 51	41	31			
	0.2	0.2	0.3	0.3	0.3	0.3	0.0	–0.1	–0.2			
	0.2	0.2	0.3	0.3	0.3	0.3	0.9	–1.2	–1.4			
58-S	492	451	414	384	357	333	3 82	70	59	49	40	32
	0.3	0.3	0.3	0.4	0.4	0.5	0.1	0.3	0.2	0.1	0.0	–0.1
	0.3	0.3	0.4	0.4	0.4	0.4	0.4	–0.6	–0.9	–1.2	–1.5	–1.8
68-S		463	426	393	366	342	3 10	97	84	73	62	53
		0.4	0.4	0.5	0.5	0.6	0.8	0.7	0.7	0.6	0.5	0.4
		0.4	0.5	0.5	0.6	0.6	0.0	–0.2	–0.4	–0.6	–0.9	–1.2 -
78-S		472	435	402	375	348	3 33	119	106	94	83	73
		0.5	0.5	0.6	0.6	0.7	1.1	1.1	1.1	1.0	0.9	0.9
		0.5	0.6	0.6	0.7	0.7	0.4	0.3	0.1	–0.1	–0.3	–0.6 -

Strength is based on strain compatibility; botgh 2–10 for explanation.

2–32