Michael Bologna

665 Meadow Ln
Rochester PA, 15074

State College, PA 16801

October 16, 2015

Linda M. Hanagan, PhD, P.E.
The Pennsylvania State University

Dear Dr. Hanagan,

The attached technical reports covers the assigned topics for Structural Notebook Submission B along with the previously submitted gravity and lateral loads analysis as part of Submission A.

Submission B is an analysis of the gravity loads for a typical bay in the existing structural system along with three alternative structural systems. This submission will help me prepare for my eventual redesign by comparing the three alternative systems by the weight, thickness, cost, advantages, and disadvantages.

In addition, I revised selected pages from Submission A for corrected loads for my new Submission. These revised pages includes the roof detail, wood level detail, and concrete level detail.

I appreciate your effort in reviewing my submission and I look forward to receiving feedback from you.

Sincerely,

Michael Bologna

Jackson Crossing | Located in Alexandria, VA

Technical Report 3

Michael Bologna

Structural Option

Advisor: Dr. Linda Hanagan

October 16, 2015

Table of Contents

Abstract

Jackson Crossing - Alexandria, VA

Michael Bologna
Structural Option

Photos courtesy of Bonstra | Haresign Architects, LLP

Building Statistics

Building Height: 54' 7 1/4"
Number of Floors: 5
Gross Square Foot: 107,740 sq. ft.
Type of Building: Multi-Family Residential
Total Project Cost: $16 Million
Construction Dates: 4/4/2014-12/17/2015

Project Team

Owner: AHC, Inc.
Construction Management: Harkins Builders, Inc.
Architect: Bonstra | Haresign Architects, LLP
Civil Engineer: VIKA, Virginia, LLC
Structural Engineer: Rathgeber Goss Associates
MEP Engineer: Metropolitan Engineering, Inc.
Landscape Architect: Landscape Architectural Bureau
Specifications Cons.: Bethel Specifications Consulting

Mechanical

-All aparment units have operable windows
-Typical floor houses a mounted vertical heat pump (DX Split System) and is provided with vibration isolation
-Roof houses condensing units
-Upper garage exhauts 12,000 CFM of air and supplies 17,250 CFM of air
-Lower Garage exhauts 5250 CFM of air

Photos courtesy of Bonstra | Haresign Architects, LLP

Electrical

-Dominion Virgina Power Service supplies power into one pad mounted transformer
-2 1600A, 208/120V Feeders run from the transformer
-All units are individually metered

Structural System

Gravity System
-18" deep wood trusses spaced at 24" o.c.
-Wood bearing walls
-12" Reinforced two-way concrete slab
-24"x16" Concrete columns typical
Lateral System
-Ordinary Reinforced Concrete Shear Walls
-Intermediate Reinforced Masonry Shear Walls
-Light Framed Walls Sheated with Wood Panels

Thesis Advisor: Linda M. Hanagan, PhD, P.E.
Website: http://www.engr.psu.edu/ae/thesis/portfolios/2016/mab6150/index.htm

Executive Summary

Jackson Crossing is a development in Alexandria, Virginia by AHC, Inc. Offering one, two, and three-bedroom apartments, it is targeted at low-income residents with families. The structure is five floors and 107,740 square feet. Included in the building is an underground parking garage. The project will be completed by December 2015 and will come to a total project cost of sixteen million dollars.

The gravity system consists of four floors of wood floors with wood trusses and bearing walls. The wood members sit on two floors of concrete, one of which is below grade. The slab on the second floor is a reinforced two-way slab while the ground floor is a reinforced one-way slab with concrete beams.

The lateral system for the top four floors includes a masonry shear wall, and wood sheathed shear wall. The wood sheathed shear wall is anchored into the second floor slab while the masonry shear wall is integrated into concrete shear walls that extend down into the foundation.

Location Plan

Figure 1 (Courtesy of Google Maps)

Site Plan

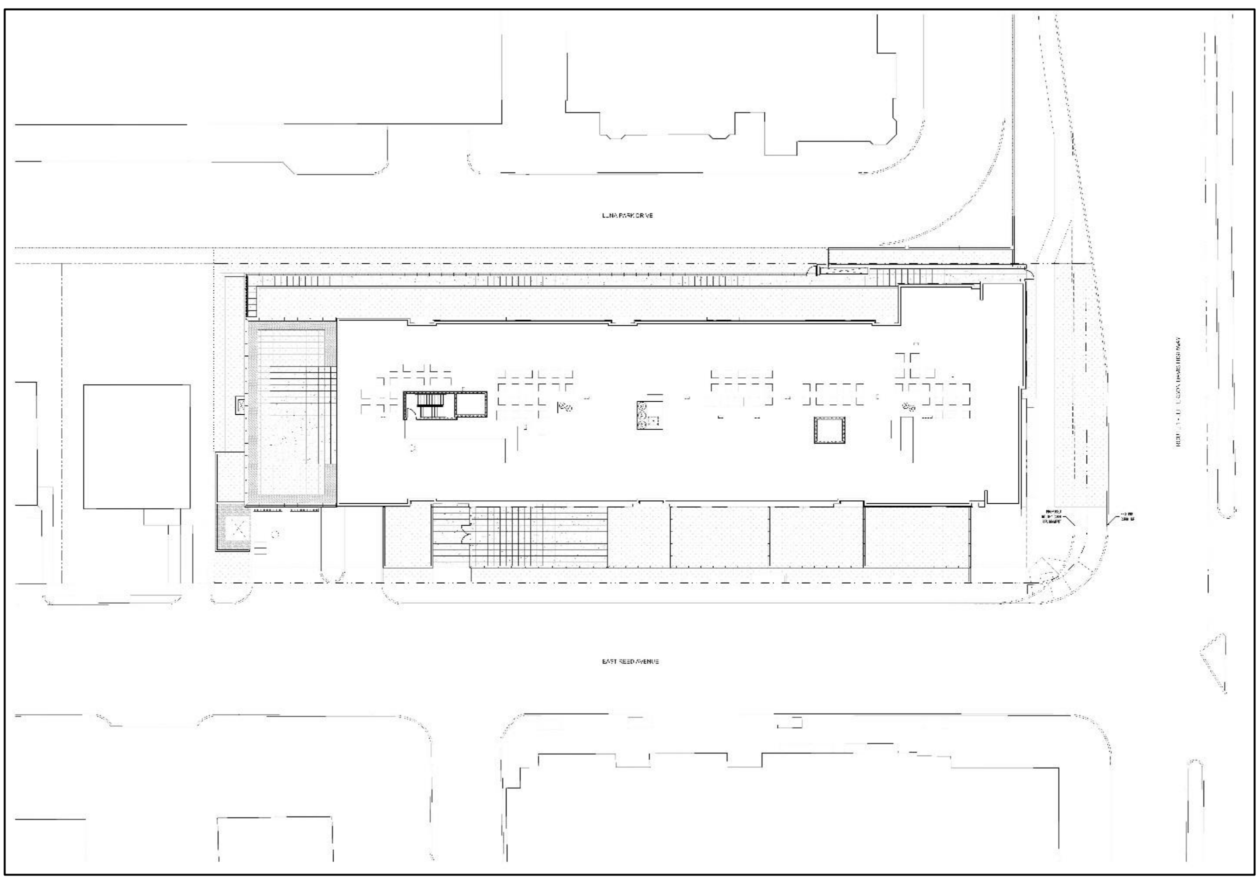


Figure 2

List of Documents Used in Report

AISC, *Steel Construction Manual*, Fourteenth Edition

Breyer, Donald, Kelly Cobeen, Kenneth Fridley, and David Pollock, *Design of Wood Structures ASD/LRFD*, 7th Edition

Usg.com, DUROCK Cement Board

Minimum Design Loads for Buildings and Other Structures (ASCE 7-10)

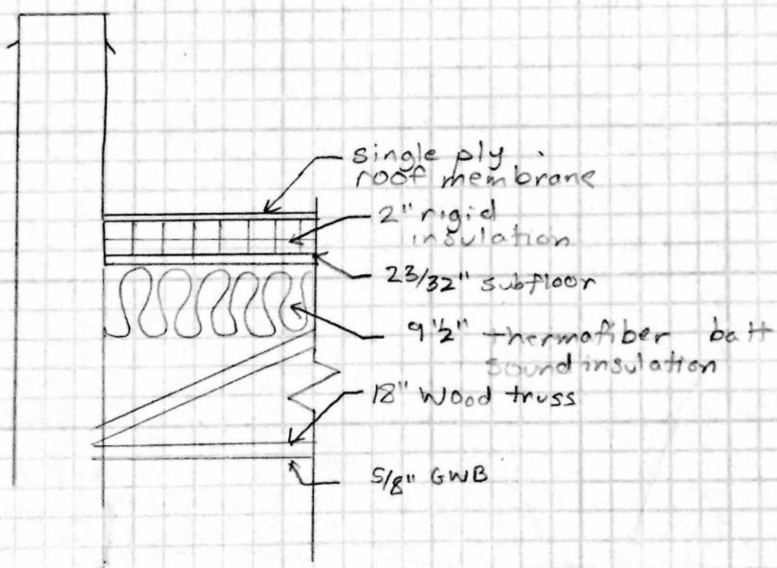
Minimum Design Loads for Buildings and Other Structures (ASCE 7-05)

RS Means Assemblies Cost Data, 2014

GRAVITY LOADS

- ROOF
  - Existing Design Loads (from General notes)
    *SUPERIMPOSED INCL. STRUCTURE
    - DEAD LOAD
      ⇒ 20psf (15psf top chord / 5psf bottom chord)
    - ROOF LIVE LOAD
      ⇒ 30psf min (unless snow load greater)
    - ROOF SNOW LOAD
      ⇒ $P_f = 17.5$ psf
      - values to find P_f
        - $P_g = 25$ psf
        - $C_e = 1.0$
        - $C_t = 1.0$
        - $I = 1.0$

TYPICAL PARAPET DETAIL



WL

WEIGHT OF DETAILS

- SINGLE PLY ROOF MEMBRANE ⇒ 1 psf
- 2" RIGID INSULATION ⇒ $1\frac{1}{2}\frac{psf}{1"} \cdot 2" = 3psf$
- 23/32" WOOD SUBFLOOR ⇒ $\frac{3\,psf}{3/4"} \cdot \frac{4}{8}" \cdot \frac{23}{32}" = 2.875psf$ (wood sheathing)
- 9½" BATT INSULATION ⇒ $\frac{1/2\,psf}{1"} \cdot 9.5" = 4.75psf$ (loose insulation)
- 5/8" GWB ⇒ 2½ psf
- Truss self weight ⇒ 5.5 plf / 2ft spacing = 2.75psf

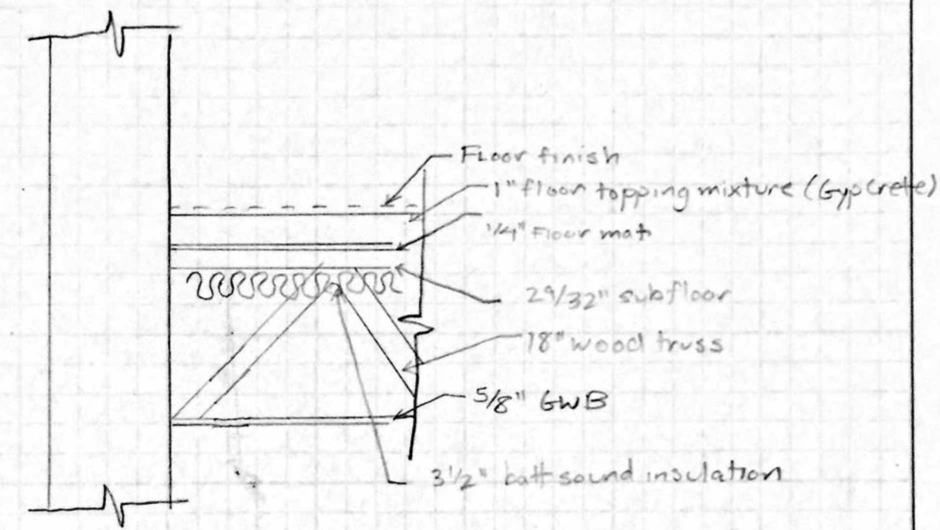
TOTAL = 16.875 psf ~ 17psf

☆WEIGHTS FROM TABLE 17-13 OF STEEL MANUAL

- TYPICAL WOOD FLOOR

- EXISTING DESIGN LOADS (from General Notes)
  & SUPERIMPOSED INCL. STRUCTURE
- DEAD LOAD
  ⇒ 25 psf (20 psf top chord / 5 psf bottom chord)

TYPICAL WOOD LEVEL DETAIL



WEIGHT OF DETAILS

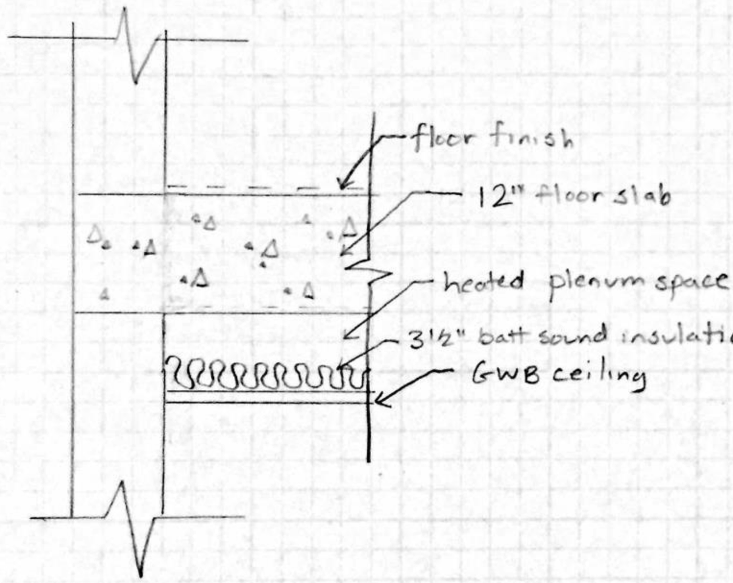
- GYPCRETE ⇒ $6.9 \frac{psf}{3/4"} \cdot 4/3" = 9.2$ psf
- 1/4" FLOOR MAT ⇒ $\frac{3\,psf}{1"} \cdot 1/4" = 0.75$ psf (plywood)
- 29/32" SUBFLOOR ⇒ $\frac{3\,psf}{3/4"} \cdot 4/3" \cdot \frac{23}{32}" = 2.875$ (wood sheathing)
- 5/8" GWB ⇒ 2 1/2 psf (5/8" drywall)
- 3 1/2" BATT INSULATION ⇒ 1/2 psf ; 3 1/2" = 1.75 psf (loose insulation)
- MECHANICAL ALLOWANCE ⇒ 4 psf
- FLOOR FINISH ⇒ 1 psf
- TRUSS SELF WEIGHT ⇒ 5.5 plf / 2 ft = 2.75 psf

TOTAL = 24.825 psf ~ 25 psf ✓ weight

★ WEIGHTS FROM - TABLE 17-13 OF STEEL MANUAL
- APPENDIX B OF DESIGN OF WOOD STRUCTURES

- TYPICAL CONCRETE LEVEL
  - EXISTING DESIGN LOADS (from General Notes)
    *SUPERIMPOSED INCL. STRUCTURE
    - DEAD LOAD
      ⇒ 15 psf

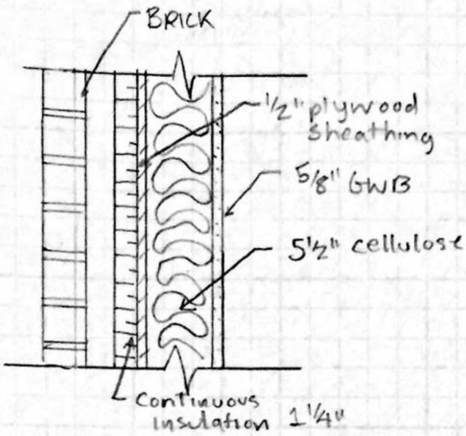
- TYPICAL CONCRETE LEVEL DETAIL



- WEIGHT OF DETAILS
  - FLOOR FINISH = 1 psf
  - 3½" BATT INSULATION = $\frac{1/2 \text{ psf}}{1"} \cdot 3\frac{1}{2}" = 1.75$ psf (loose insulation)
  - GWB ceiling = 2½ psf (5/8 drywall)
  - NORMAL WEIGHT CONCRETE = 150 pcf · 12" = 150 psf
  - MECHANICAL ALLOWANCE = 4 psf

TOTAL = 159.25 psf

TYPICAL EXTERIOR WALL DETAIL (BRICK)



WEIGHT OF DETAILS

4 IN BRICK => 40 psf

1/2" PLYWOOD => 1.5 psf

1 1/4" CONTINUOUS INSULATION => 1.88 psf

5/8" GWB => 2 1/2 psf

5 1/2" CELLULOSE INSULATION => 10 psf

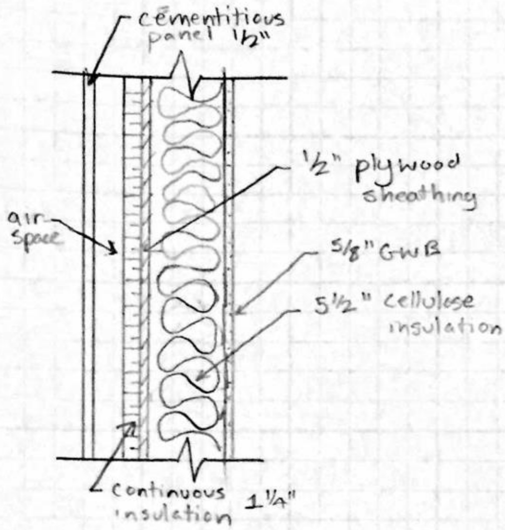
TOTAL = 55.88 psf

*WEIGHTS FROM TABLE 17-13 OF STEEL MANUAL

LOAD PATH DESCRIPTION

AT THE TOP FOUR LEVELS, GRAVITY LOADS ARE APPLIED TO THE WOOD TRUSSES. THE WOOD TRUSSES TRANSFER THEIR LOADS TO THE EXTERIOR AND INTERIOR BEARING WALLS. THEN THE BEARING WALLS REST THEIR LOADS ON A TRANSFER SLAB AT THE 2ND FLOOR.

TYPICAL EXTERIOR WALL DETAIL (CEMENTITOUS PANEL)



WEIGHT OF DETAILS

5 1/2" CELLULOSE INSULATION => $\frac{2\,psf}{1"} \cdot 5\frac{1}{2}" = 10\,psf$ (poured insulation)

1 1/4" CONTINUOUS INSULATION => $\frac{1\frac{1}{2}psf}{1"} \cdot 1\frac{1}{4}" = 1.88\,psf$ (rigid insulation)

1/2" PLYWOOD => $\frac{3\,psf}{1"} \cdot \frac{1}{2}" = 1.5\,psf$

5/8" GWB => 2 1/2 psf

1/2" CEMENTITOUS PANEL => 2.4 psf

TOTAL = 18.28 psf

* WEIGHTS FROM TABLE 17-13 OF STEEL MANUAL & USG.COM FOR DUROCK CEMENT BOARD AS AN ESTIMATE FOR CEMENTITIOUS PANEL

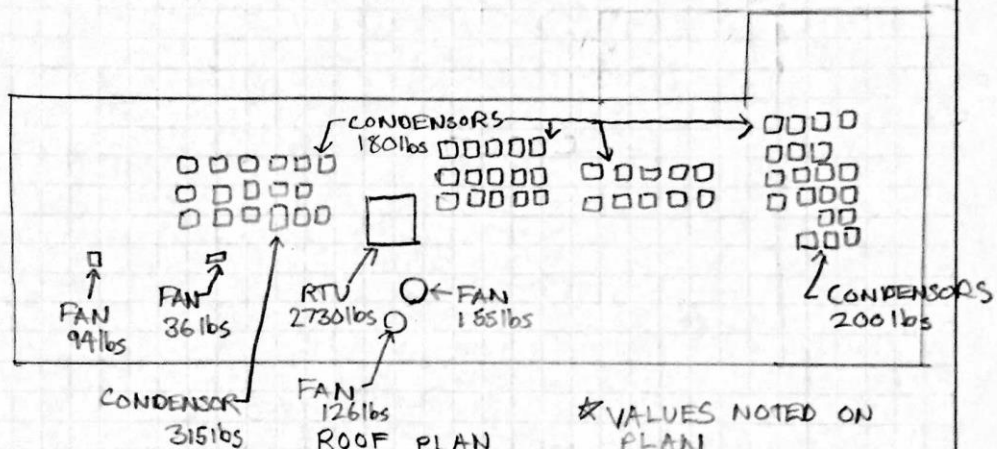
DESIGN LIVE LOADS

AREA	PSF	ASCE 7-10 MIN. (PSF)
LIVING UNITS	40	40
LOBBIES/STAIRS/ EXITS	100	100
MECHANICAL	AS NOTED	
CORRIDORS ABOVE 1ST FLOOR	80	40
PARKING DECKS	40	40
PARKING DECKS (TOP LEVEL)	70 (40LL+30 SNOW)	
ROOF TERRACE	100	100
LOADING DOCK	250	

3-0235 — 50 SHEETS — 5 SQUARES
3-0236 — 100 SHEETS — 5 SQUARES
3-0237 — 200 SHEETS — 5 SQUARES
3-0137 — 200 SHEETS — FILLER

COMET

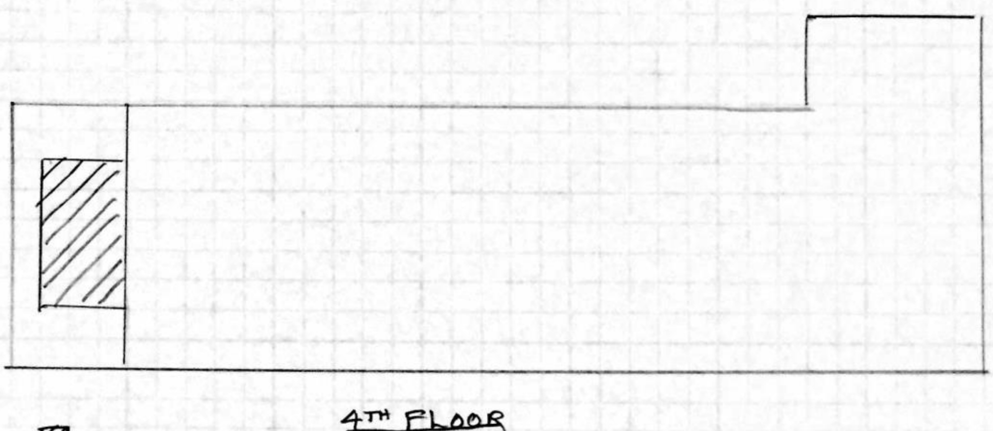
NON TYPICAL LOADS ON ROOF



ROOF PLAN

*VALUES NOTED ON PLAN

NON TYPICAL LOADS ON 4TH FLOOR



4TH FLOOR

▨ ROOF TERRACE
- DEAD LOAD: 40 PSF TOP CHORD
  5 PSF BOTTOM CHORD
- LIVE LOAD: 100 PSF

*VALUES NOTED IN GENERAL NOTES

3-0235 — 50 SHEETS — 5 SQUARES
3-0236 — 100 SHEETS — 5 SQUARES
3-0237 — 200 SHEETS — 5 SQUARES
3-0137 — 200 SHEETS — FILLER
COMET

FLAT ROOF SNOW LOAD + DRIFT

FROM GENERAL NOTES

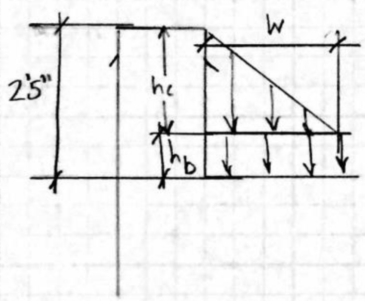
$$\left.\begin{array}{l} P_g = 25\,psf \\ C_e = 1.0 \\ I = 1.0 \\ C_t = 1.0 \end{array}\right\} P_f = 0.7\, C_e\, C_t\, I\, P_g$$

$P_f = 0.7 \cdot 1 \cdot 1 \cdot 1 \cdot 25\ psf$

$P_f = 17.5\,psf$

$P_{f\,min} = 20 \cdot I = 20 \cdot 1 = 20psf \Rightarrow$ controls

DRIFT AT PARAPET



$\gamma = 0.13\,p_g + 14 = 0.13 \cdot 25 + 14 = 17.25\,pcf < 30\,pcf$ ✓

$h_b = 20psf / 17.25pcf = 1.16\,ft \qquad h_c = 2.42 - 1.16 = 1.26\,ft$

Using $l_u = 0'$ for upper roof $\Rightarrow h_d = 1.5ft$

Using $l_u = 60'$ for lower roof $\Rightarrow h_d = 2.5ft$

$3/4\ 1.5ft = 1.125ft$, $2.5ft$ } USE 2.5ft AS DRIFT HEIGHT

★ EXCEEDS $h_c \Rightarrow \underline{h_d = h_c}$

DRIFT WIDTH, $w = 4\dfrac{h_d^2}{h_c} = 4 \cdot \dfrac{1.26ft^2}{1.26ft} = 5.04ft < 8\,h_c$

WIND LOADS

VARIABLES FROM GENERAL NOTES

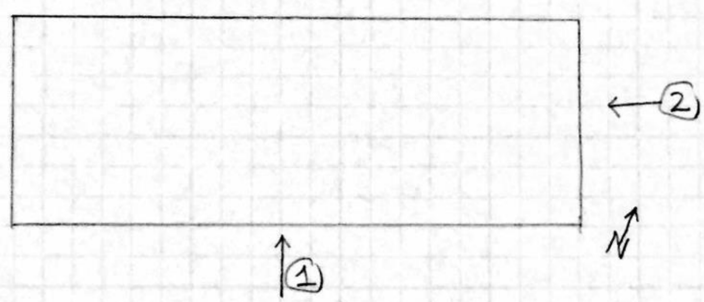
BASIC WIND SPEED: 90 MPH
IMPORTANCE FACTOR: 1.0
EXPOSURE CATEGORY: B

BUILDING HEIGHT: 54' 7 1/4"
- ★ I WILL USE THE ANALYTICAL PROCEDURE EVEN THOUGH THE SIMPLIFIED PROCUDERE, 6.4.2, MAY BE USED.
- ★ I WILL USE ASCE-7-05 AS GENERAL NOTES INDICATES

6.5.1 SCOPE

1. REGULAR SHAPED ✓
2. ✓

6.5.3
1. BASIC WIND SPEED: 90MPH
2. IMPORTANCE FACTOR I: 1.0
3. WIND DIRECTIONS CONSIDERED:



SURFACE ROUGHNESS CATEGORY: B
EXPOSURE CATEGORY: B

3-0235 — 50 SHEETS — 5 SQUARES
3-0236 — 100 SHEETS — 5 SQUARES
3-0237 — 200 SHEETS — 5 SQUARES
3-0137 — 200 SHEETS — FILLER

COMET

TABLE 6-3

	Z	K_z*
2ND FLOOR:	14.5ft	0.57
3RD FLOOR:	24.17ft	0.62
4TH FLOOR:	33.83ft	0.72
5TH FLOOR:	43.5ft	0.78
ROOF:	54.6ft	0.83

* CASE 2; EXPOSURE B, I WILL NOT DESIGN USING FIG 6-10

4.
6.5.7.1: NO APPLICABLE HILL OR ESCARPMENT
$\Rightarrow K_{ZT} = 1.$

5. ASSUME LOW-RISE BUILDING IS RIGID
$\Rightarrow G = 0.85$

6. BUILDING IS ENCLOSED

7. $GC_{pi} = \pm 0.18$, FIG 6-5

8. FIG 6-6 * NEGLECTING FIG 6-10 FOR LOW-RISE
WINDWARD: $C_p = 0.8$
LEEWARD: FOR DIRECTION ① $L/B = 99'7\frac{1}{2}'' / 256'11\frac{5}{8}'' = 0.39$
$\Rightarrow C_p = -0.5$
② $L/B = 1/0.39 = 2.58$
$\Rightarrow C_p = -0.3$

SIDE WALLS: $C_p = -0.7$
ROOF: FOR DIRECTION ① $h/L = 54.6' / 99'7\frac{1}{2}'' = 0.55$
AREA ≥ 1000 sqft
$\Rightarrow$ USE REDUCTION OF 0.8 WHEN APPLICABLE
FOR $0-h \Rightarrow C_p = -0.9$
$>h \Rightarrow C_p = -0.5$
② $h/L = 54.6' / 256'11\frac{5}{8}'' = 0.21$
$0-h \Rightarrow C_p = -0.9$
$h-2h \Rightarrow C_p = -0.5$
$>2h \Rightarrow C_p = -0.3$

9 $q_z = 0.00256 K_z K_{zt} K_d V^2 I$

$K_d = 0.85$

	q_z
2ND FLOOR:	10.0
3RD FLOOR:	11.0
4TH FLOOR:	12.7
5TH FLOOR:	13.8
ROOF:	14.7

10. $p = qGC_p - q_i(GC_{pi})$ (psf)

FOR DIRECTION ①

WINDWARD WALLS	p(+GCpi) (psf)	p(-GCpi) (psf)
2ND FLOOR	4.2 (10)*	9.5 (10)
3RD FLOOR	4.9 (10)	10.2
4TH FLOOR	6.0 (10)	11.3
5TH FLOOR	6.8 (10)	12.1
~~LEEWARD~~ ROOF	7.4 (10)	12.7
LEEWARD WALLS	−8.9 (−10)	−3.6 (−10)
SIDE WALLS	−11.4	−6.1 (−10)
0−h	−13.9	−8.6 (−10)
> h	−8.9 (−10)	−3.6 (−10)

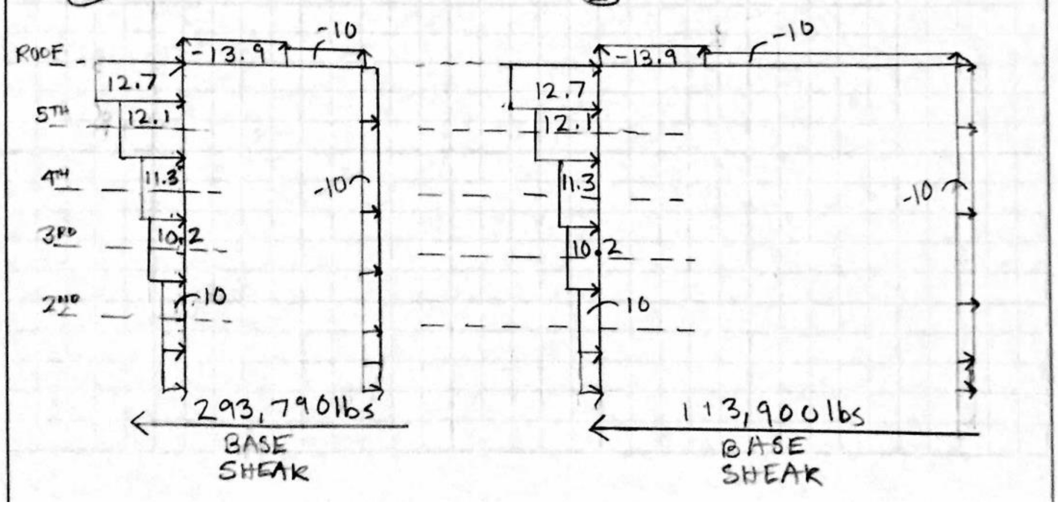
* 6.1.4.1 $p > 10$ psf

FOR DIRECTION ②

WINDWARD WALLS	p(+GCpi) (psf)	p(-GCpi) (psf)
2ND FLOOR	4.2 (10)	9.5 (10)
3RD FLOOR	4.9 (10)	10.2
4TH FLOOR	6.0 (10)	11.3
5TH FLOOR	6.8 (10)	12.1
ROOF	7.4 (10)	12.7
LEEWARD WALLS	−6.4 (−10)	−1.1 (−10)
SIDE WALLS	−8.9 (−10)	−3.6 (−10)
0−h	−13.9	−8.6 (−10)
h−2h	−8.9 (−10)	−3.6 (−10)
>2h	−6.4 (−10)	−1.1 (−10)

DIAGRAMS

① ②



3-0235 — 50 SHEETS — 5 SQUARES
3-0236 — 100 SHEETS — 5 SQUARES
3-0237 — 200 SHEETS — 5 SQUARES
3-0137 — 200 SHEETS — FILLER
COMET

SEISMIC LOADS

FROM GENERAL NOTES

OCCUPANCY CATEGORY: II

SEISMIC IMPORTANCE FACTOR: IE=1.0

$S_S = 0.153$

$S_1 = 0.050$

SITE CLASS: D

$S_{DS} = 0.163$

$S_{D1} = 0.081$

SEISMIC DESIGN CATEGORY: B

SEISMIC RESPONSE COEFFICIENTS:

CONCRETE SHEAR WALLS: CS=0.041

MASONRY SHEAR WALLS: CS=0.047

RESPONSE MODIFICATION FACTORS:

CONCRETE SHEAR WALLS: R=4

MASONRY SHEAR WALLS: R=3.5

WOOD SHEAR WALLS: R=6.5

EFFECTIVE SEISMIC WEIGHT

	SQ FT.	DL(psf)	W(K)
ROOF	14,000	20	280
5TH	14,000	25	350
4TH	16,460	25	411.5
3RD	16,460	25	411.5
2ND	16,460	15	246.9
ROOF TERRACE (ON 4TH)	704	45	31.68
ON ROOF		CONDENSERS	14.5
		FANS	0.3
		RTU	2.73
		TOTAL W=	1,750 Kips

EQUIVALENT LATERAL FORCE DESIGN (ASCE-7-05)

N-S DIRECTION

APPROXIMATE FUNDAMENTAL PERIOD

$T_a = C_t h_n^x$

TABLE 12.8-2 ⇒ $C_t = 0.02$, $x = 0.75$

$T_a = 0.02 \cdot 54.6\text{ft}^{0.75} = 0.4\text{s}$

$T_L = 8\text{s}$ FIG 22-15

$C_S = \dfrac{S_{DS}}{\left(\frac{R}{I}\right)}$ MOST STRINGENT R IN N-S DIRECTION $\Rightarrow R = 3.5$

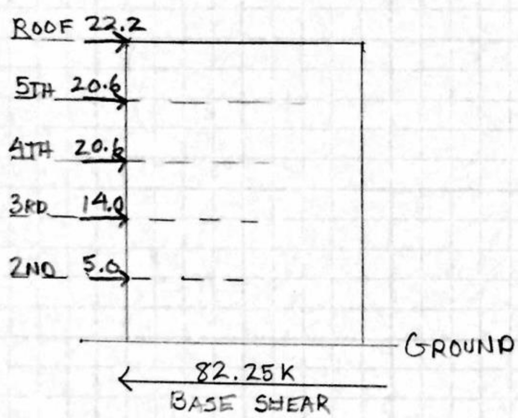
$C_S = \dfrac{0.163}{\left(\frac{3.5}{1}\right)} = 0.047$

$T \le T_L \Rightarrow C_S \le \dfrac{0.081}{0.4\left(\frac{3.5}{1}\right)} \le 0.058$

$V = 1,750K \cdot 0.047 = 82.25K$

STORY	$W_x h_x^{K}$*	C_{vx}	$F_x(K)$
ROOF	16,245	0.27	22.2
5TH	15,225	0.25	20.6
4TH	14,993	0.25	20.6
3RD	9,946	0.17	14.0
2ND	3,580	0.06	5.0
	$\Sigma = 59,989$		

*K=1



E-W DIRECTION

* CONTROLLING R VALUE SAME AS N-S
FORCES DISTRIBUTED EQUAL TO N-S
BASE SHEAR VALUE EQUAL TO N-S

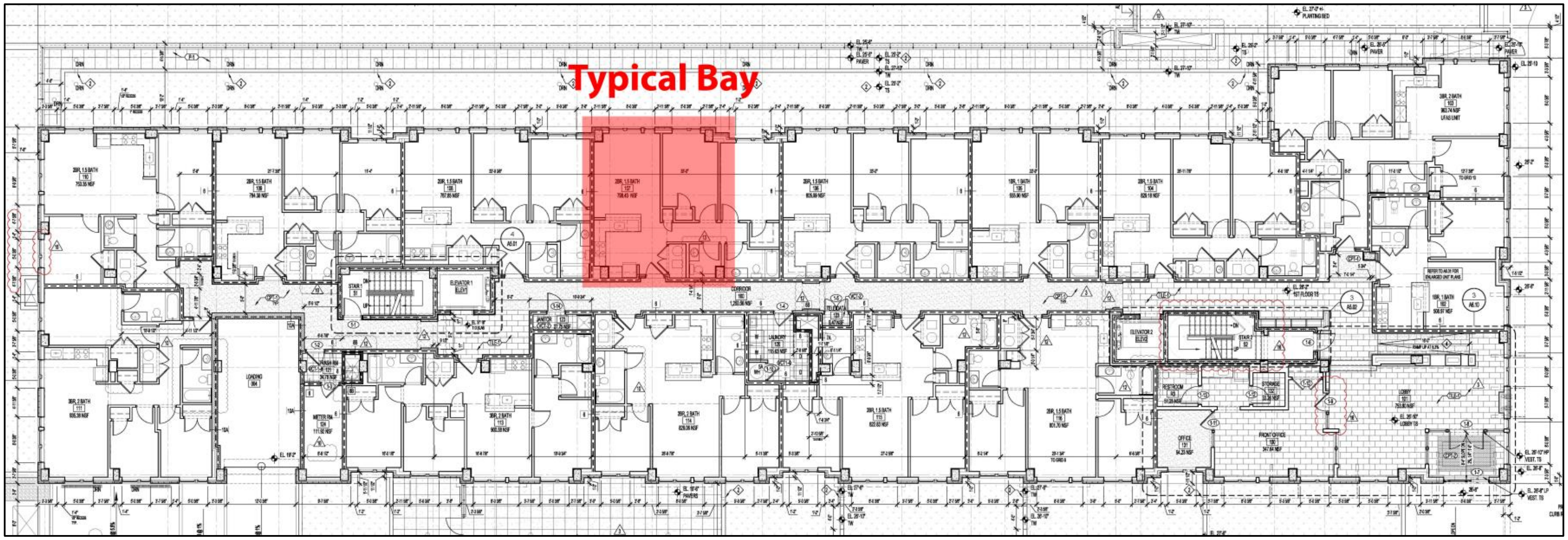
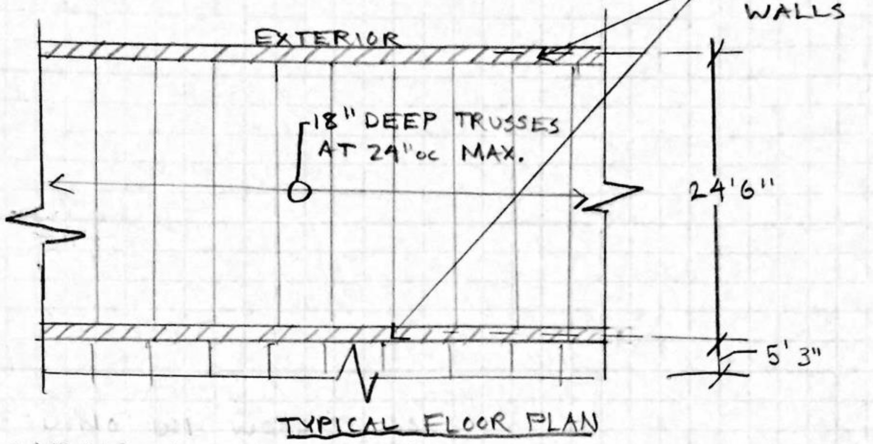


Figure 3- Area in red highlights location of typical bay

Typical Bay Location

Figure 3 shades in red the location of the typical bay I will use to analyze the existing structural system and the three alternative systems.

GRAVITY LOADS SPOT CHECK



TYPICAL FLOOR PLAN

- LOADING ON WOOD TRUSS

DEAD LOAD

$25\,psf \cdot 24"oc\ max = 50\,plf$

LIVE LOAD

$40\,psf \cdot 24"oc\ max = 80\,plf$

- LOADING ON EXTERIOR BEARING WALL FROM FLOOR

DEAD LOAD

$(25\,psf \cdot 24.5')/2 = 307\,plf$

LIVE LOAD

$(40\,psf \cdot 24.5')/2 = 490\,plf$

- LOADING ON INTERIOR WALL FROM FLOOR

DEAD LOAD

$[25\,psf \cdot (24.5' + 5.25')]/2 = 335\,plf$

LIVE LOAD

$[40\,psf \cdot (24.5' + 5.25')]/2 = 595\,plf$

3-0235 — 50 SHEETS — 5 SQUARES
3-0236 — 100 SHEETS — 5 SQUARES
3-0237 — 200 SHEETS — 5 SQUARES
3-0137 — 200 SHEETS — FILLER

COMET

- LOADING ON EXTERIOR BEARING WALL FROM ROOF

DEAD LOAD

$(17\,psf \cdot 24.5')/2 = 208.25\,plf$

LIVE LOAD

$(30\,psf \cdot 24.5')/2 = 367.5\,plf$

- LOADING ON INTERIOR BEARING WALL FROM ROOF

DEAD LOAD

$[17\,psf \cdot (24.5' + 5.25')]/2 = 253\,plf$

LIVE LOAD

$[30\,psf \cdot (24.5' + 5.25')]/2 = 447\,plf$

- EXTERIOR WALL DEAD LOAD

$\Rightarrow 48\,psf \cdot 29ft + 11\,psf \cdot 10.6ft = 1,508.6\,plf$

- INTERIOR BEARING WALL DEAD LOAD

WEIGHT OF WALL ESTIMATE:

5/8 GWB BOTH SIDES: $2\frac{1}{2}\,psf \cdot 2 =$	5 psf
2×6 STUDS:	1.4 psf
INSULATION:	1 psf
	8 psf

$\Rightarrow 8\,psf \cdot (39.6ft) = 317\,plf$

TOTAL LOAD ON 2ND FLOOR BEARING WALL

EXTERIOR - $(307 + 490) \cdot 3 + (209 + 368) + 1,509$

$\Rightarrow 4,477\,plf$

INTERIOR - $(335 + 598) \cdot 3 + (253 + 447) + 317$

$\Rightarrow 3,807\,plf$

USING ASD

- FOR SAWN LUMBER

$$F'_c = C_D \times C_M \times C_t \times C_F \times C_i \times C_p \times F_c$$

- STUD INFORMATION
  - HEIGHT = 9.7ft
  - (1) 2x6 @ 16" oc
  - 19% MAXIMUM MOISTURE CONTENT
  - SPF/HF No.1/No.2
  - F_c (PARA) = 1,150 psi
  - E'_{min} = 0.51E6 psi

- FOR D+L ⇒ $C_D = 1.0$

- MAX M.C. = 19% ⇒ $C_M = 1$

- ASSUMING NO ELEVATED TEMPERATURES ⇒ $C_t = 1$

- FOR 2x6 ⇒ $C_F = 1.1$

- ASSUME $C_i = 1$

- SLENDERNESS ASSUMING SHEATHING BRACES WEAK AXIS:

$$\frac{K l_1}{d_1} = \frac{9.7ft \cdot 12}{5.5in} = 21.2 < 50 \checkmark \quad \text{*CONTROLS}$$

$$\frac{K l_2}{d_2} = 0$$

$$F_c^* = 1{,}150 \times 1 \times 1 \times 1 \times 1.1 \times 1 = 1{,}265\ psi$$

$$F_{cE} = \frac{0.822 \cdot 0.51E6}{(21.2)^2} = 936\ psi$$

$$F_{cE}/F_c^* = 0.74$$

$$C_P = \frac{1+0.74}{2\cdot 0.8} - \sqrt{\left[\frac{1+0.74}{2\cdot 0.8}\right]^2 - \frac{0.74}{0.8}}$$

$C_P = 0.58$

$F_c' = 1{,}265\,psi \cdot 0.58 = 733.5\,psi$

$$733.5\,psi \cdot 1.5\,in \cdot 5.5\,in = \frac{6{,}051\,lbs}{\left(16''/12\right)} = 4{,}538\,plf$$

CAPACITY OF (1) 2x6@16"oc SPF No1/No2:

$\Rightarrow$ 4,538plf

LOAD CHECK

EXTERIOR WALL:

D+L = 4,477plf < 4,538plf

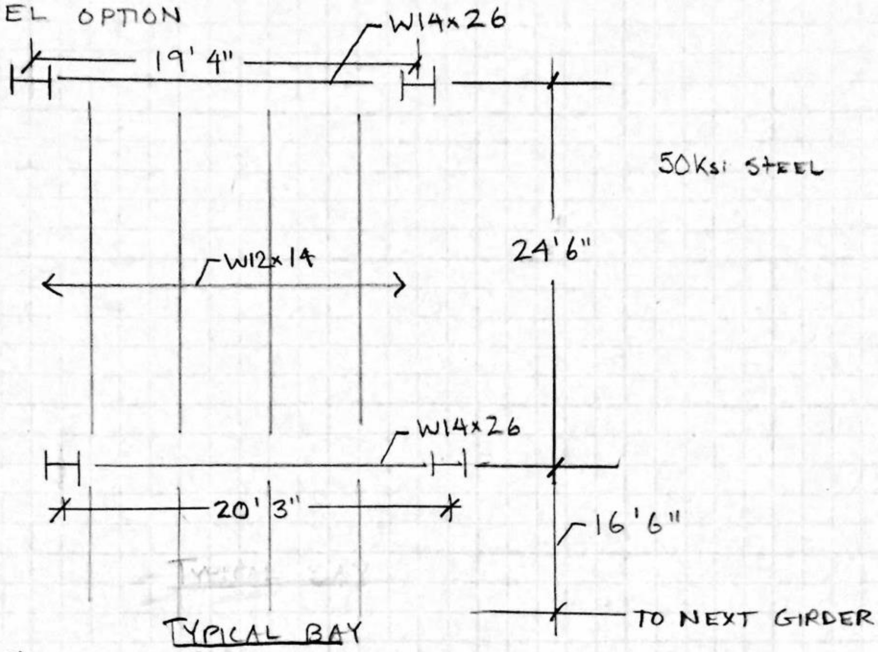
$\therefore$ GOOD

INTERIOR WALL:

D+L = 3,807plf < 4,538plf

$\therefore$ GOOD

NONCOMPOSITE
STEEL OPTION



50Ksi STEEL

LOADING

- DEAD LOAD
  - ALLOW 35 PSF FOR DECK & CONCRETE TOPPING PLUS FINISH
  - 2 PSF FOR SOUND INSULATION
  - 4 PSF FOR MECHANICAL DUCTS
  - 5 PSF FOR SELF WEIGHT
  - 2½ PSF FOR CEILING DRYWALL
  - TOTAL 48.5 PSF
    ⇒ USE 49 PSF

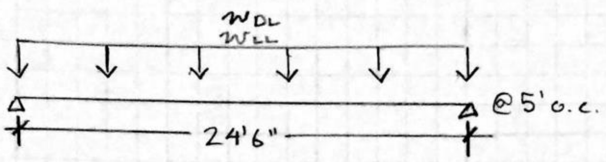
- LIVE LOAD
  - 40 PSF

INFILL BEAMS

- 24' 6" LENGTH
- TRY 5' SPACING

LRFD

-JOISTS



STRENGTH

$w_{DL} = 49\text{ PSF} \cdot 5' = 245\text{ PLF}$

$w_{LL} = 40\text{ PSF} \cdot 5' = 200\text{ PLF} \Rightarrow K_{LL}A_T = 2 \cdot 24.5 \cdot 5 = 245\text{ ft}^2 < 400\text{ ft}^2$

LL UNREDUCIBLE

$1.2D + 1.6L$

$w_{D+L} = 1.2(245) + 1.6(200) = 614\text{ PLF}$

$M_U = \dfrac{614\text{ PLF} \cdot (24.5\text{ ft})^2}{8} = 46.1\text{ K-ft}$

ASSUMING DECK BRACES COMPRESSION FLANGE

FOR W10X12

$\phi M_n = 46.9\text{ K-ft} > M_U = 46.1\text{ K-ft} \quad \therefore \text{GOOD}$

SERVICABILITY

FOR W10X12, $I_x = 53.8\text{ in}^4$

$L/360 = 24.5\text{ ft}/360 = 0.817"$

$\Delta_{LL} = \dfrac{5 \cdot 0.200\text{ KLF} \cdot (24.5\text{ ft})^4 \cdot (1728\text{ in}^3/\text{ft}^3)}{384 \cdot 29{,}000\text{ Ksi} \cdot 53.8\text{ in}^4}$

$\Delta_{LL} = 1.04\text{ in} > 0.817\text{ in} \quad \therefore \text{NO GOOD}$

REQ'D I_x

$I_x = \dfrac{5 \cdot 0.200\text{ KLF} \cdot (24.5\text{ ft})^4 (1728\text{ in}^3/\text{ft}^3)}{384 \cdot 29{,}000\text{ Ksi} \cdot 0.817"}$

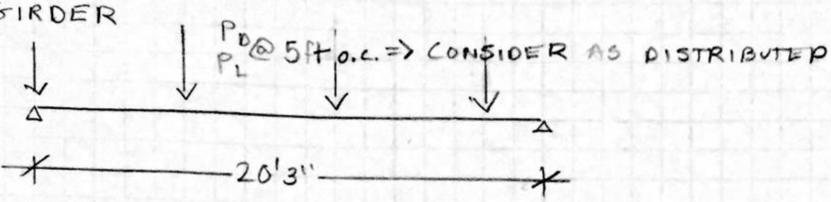
$I_x = 68.5\text{ in}^4$

FOR W12X14

$I_x = 88.6\text{ in}^4 > 68.5\text{ in}^4 \quad \therefore \text{GOOD}$

WEIGHT CHECK $\Rightarrow$ $14\text{ PLF}/5\text{ ft} = 2.8\text{ psf} < 5\text{ psf}$ ✓

INTERIOR
GIRDER



STRENGTH

$w_{DL} = 49\ \text{psf} \cdot (24.5+16.5)/2 = 1{,}004.5\ \text{PLF}$

$w_{LL} = 40\ \text{psf} \cdot (24.5+16.5)/2 = 820\ \text{PLF}$

$1.2D + 1.6L$

$w_{D+L} = 1.2(1{,}004.5) + 1.6(820) = 2{,}517.4\ \text{PLF}$

$$M_U = \frac{2{,}517.4\ \text{PLF}\ (20.25\ \text{ft})^2}{8} = 129.1\ \text{K-ft}$$

FOR W14x26: L_b of 5 ft, $C_b = 1$, $F_y = 50$ Ksi

$M_U = 141\ \text{K-ft} > 129.1\ \text{K-ft}$ ∴ GOOD

SERVICABILITY

FOR W14x26, $I_x = 245\ \text{in}^4$

$L/360 = 20.25'/360 = 0.675\ \text{in}$

$$\Delta_{LL} = \frac{5 \cdot 0.82\ \text{KLF} \cdot (20.25\ \text{ft})^4 \cdot (1728\ \text{in}^3/\text{ft}^3)}{384 \cdot 29{,}000\ \text{Ksi} \cdot 245\ \text{in}^4}$$

$\Delta_{LL} = 0.437" < 0.675"$ ∴ GOOD

WEIGHT ASSUMPTION => $26\ \text{PLF} / [(24'6" + 16'6")/2] = 1.27\ \text{psf} < 5$ ✓

3-0235 — 50 SHEETS — 5 SQUARES
3-0236 — 100 SHEETS — 5 SQUARES
3-0237 — 200 SHEETS — 5 SQUARES
3-0137 — 200 SHEETS — FILLER
COMET

NON COMPOSITE DECK

TOTAL LOAD = 49 PSF + 40 PSF = 89 PSF

TRY 1.0C24

5'0" SPAN
CONTINUOUS OVER 3 SPANS

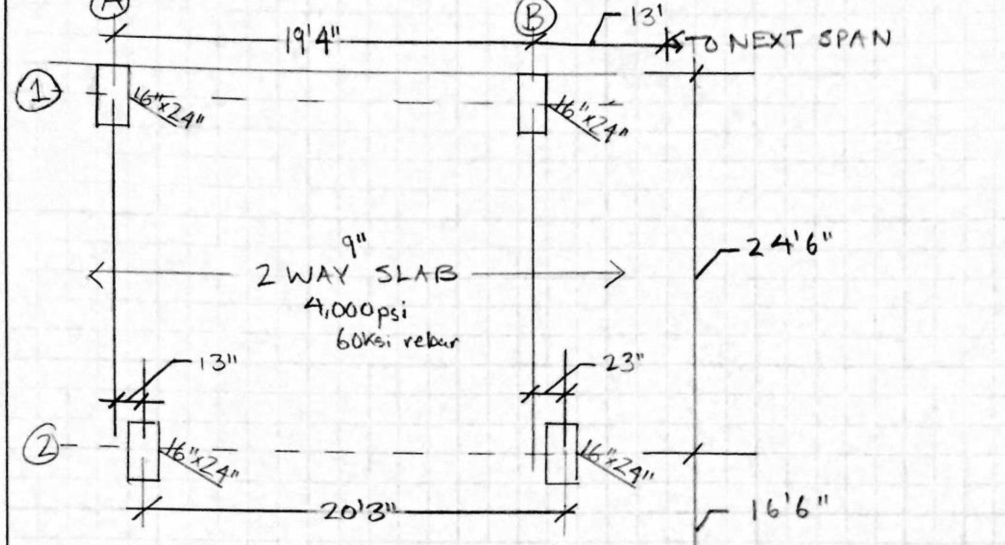
FOR 1.0C24
- ALLOWABLE TOTAL UNIFORM LOAD
$\Rightarrow$ 123 psf > 89 psf

$\therefore$ GOOD

- L/240
$\Rightarrow$ 57 psf > 40 psf

$\therefore$ GOOD

TWO WAY SLAB OPTION (4,000 psi)



TYPICAL LAYOUT (PRELIMINARY COLUMN SIZES SHOWN)

DIRECT DESIGN METHOD

-REQUIRMENTS

1) 3 CONTINUOUS SPANS EACH DIRECTION ✓

2) LONG/SHORT SPAN = 24'6"/19'4" = 1.3 < 2 ✓

3) 19'4" − 13' = 6'4" < 1/3(19'4") = 6'5⅓" ✓

24'6" − 16'6" = 8' < 1/3(24'6") = 8'2" ✓

4) 0.1 × 19'4" = 23.2" > 23" ✓

5) GRAVITY LOADS ONLY ✓

6) DEAD LOAD (ASSUMING 10" SLAB)

FLOOR FINISH = 1 psf
BATT INSULATION = 1.75 psf
GWB CEILING = 2.5 psf
SELF WEIGHT = (10/12) 150 = 125 psf
MECHANICAL = 4 psf

TOTAL = 135 psf

LIVE LOAD = 40 psf < 2(135) = 270 psf ✓

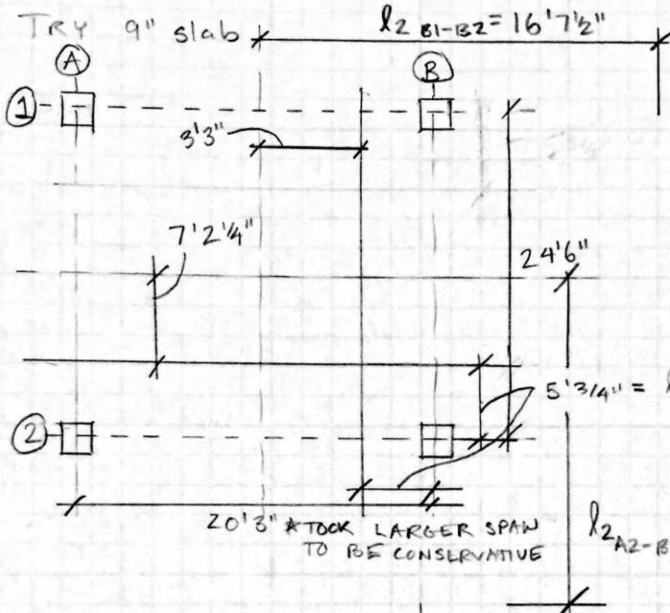
7) NO BEAMS ✓

TRIAL THICKNESS FROM ACI TABLE 9.5(c)

EXTERIOR PANEL ⇒ $\ell_n / 30$

$(24'6" - 2')/30 = 9$ in

TRY 9" slab



ASSUMPTIONS

f'c = 4000 psi

fy = 60,000

SPAN:

A2–B2	B1–B2
$\ell_1 = 20'3"$	$\ell_1 = 24'6"$
$\ell_n = 18'11"$	$\ell_n = 22'6"$
$\ell_2 = 15'6"$	$\ell_2 = 16'7\frac{1}{2}"$
$A_T = 415.1\ ft^2$ ($K_{LL}=1$) L = 39.5 psf ★JUST USE 40 psf	$A_T = 396 < 400$ L = 40 psf
q_u(Ksf) = 0.226	q_u(Ksf) = 0.226
M_0(k-ft) = 156.7	M_0(K-ft) = 237.8
COEFFICIENTS −0.65 0.35 −0.65	COEFFICIENTS −0.26 0.52 −0.70
MOMENTS(K-ft) −102 55 −102	MOMENTS(K-ft) −62 124 −166.5

3-0235 — 50 SHEETS — 5 SQUARES
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COMET

SPAN A2-B2

-POSITIVE MOMENT

- COLUMN STRIP

$\alpha_f = 0 \Rightarrow +M_c = 0.6(55) = 33 \text{ K-ft}$

- ESTIMATE d as $9\text{in} - 1.6\text{in} = 7.4\text{in}$ & j as 0.95

$- As_{req} = \dfrac{33\text{ K-ft} \cdot 12''/_1}{0.9 \times 60 \times 0.95 \times 7.4} = 1.04\text{in}^2$

$a = \dfrac{1.04\text{in}^2 \times 60}{0.85 \times 4 \times (10'\ 1\tfrac{1}{2}'')} = 0.15\text{in}$

$c = 0.15\text{in} / 0.85 = 0.178\text{in}$

$3/8(7.4) = 2.8\text{in} > c \Rightarrow \phi = 0.9$

$jd = 7.4\text{in} - \frac{0.15}{2} = 7.32\text{in}$

$As_{req} = \dfrac{33\text{K-ft} \times 12''/_1}{0.9 \times 60 \times 7.32\text{in}} = 1.00\text{in}^2$

$As_{min} = 0.0018 \times 10'1\tfrac{1}{2}'' \times 9'' = 1.97\text{in}^2$ ☆ CONTROLS

- MIDDLE STRIP (HALF OF STRIP)

$+M_M = 22\text{K-ft}/2 = 11\text{K-ft}$

$d = 7.4\text{in.}$

$As_{min} = 0.0018 \times 7'2\tfrac{1}{4}'' \times 9'' = 1.4\text{in}^2$

$As_{req} = \dfrac{11\text{K-ft} \times 12''/_1}{0.9 \times 60 \times 0.95 \times 7.4} = 0.3\text{in}^2$

☆USE Asmin

- NEGATIVE MOMENT

- COLUMN STRIP

$\alpha_f = 0 \Rightarrow -M_c = 0.75(102) = 76.5\text{K-ft}$

$-As_{req} = \frac{76.5\text{K-ft} \cdot 12''/_1}{0.9 \times 60 \times 0.95 \times 7.4} = 2.42\text{in}^2$

$a = \frac{2.42\text{in}^2 \times 60}{0.85 \times 4 \times (10'1\frac{1}{2}'')} = 0.35$

$c = 0.41 < \frac{3}{8}d \Rightarrow \phi = 0.9$

$jd = 7.4 - 0.35/2 = 7.22\text{in}$

$As_{req} = \frac{76.5\text{K-ft} \times 12''/_1}{0.9 \times 60 \times 7.22} = 2.35\text{in}^2$

- MIDDLE STRIP (HALF OF STRIP)

$-M_M = (102 - 76.5)/2 = 12.75\text{K-ft}$

$-As_{req} = \frac{12.75\text{K-ft} \cdot 12''/_1}{0.9 \times 60 \times 0.95 \times 7.4} = 0.40\text{in}^2$

★ USE As_{min} of 1.4in^2

SPAN B1-B2

- POSITIVE MOMENT

- COLUMN STRIP

$\alpha_f = 0 \Rightarrow +M_c = 0.6(124) = 74.4\text{k-ft}$

$-As_{req} = \frac{74.4\text{K-ft} \cdot 12''/_1}{0.9 \times 60 \times 0.95(7.4 + 0.5)} = 2.20\text{in}^2$

$a = \frac{2.20\text{in}^2 \times 60}{0.85 \times 4 \times (10'1\frac{1}{2}'')} = 0.32$

$c = 0.32/0.85 = 0.38 < \frac{3}{8}(7.9) = 2.96\text{in} \Rightarrow \phi = 0.9$

$jd = 7.9\text{in} - 0.32/2 = 7.74\text{in}$

$-As_{req} = \frac{74.4K\text{-}ft \cdot 12''/1}{0.9 \times 60 \times 7.74in} = 2.14in^2$ * CONTROLS

$-As_{min} = 1.97in^2$

- MIDDLE STRIP (HALF OF STRIP)

$+M_M = (124 - 74.4)/2 = 24.8K\text{-}ft$

$-As_{req} = \frac{24.8K\text{-}ft \cdot 12''/1}{0.9 \times 60 \times 0.95 \times 7.9} = 0.73in^2$

$-As_{min} = 0.0018 \times 3'3'' \times 9'' = 0.63in^2$

$a = \frac{0.73in^2 \times 60}{0.85 \times 4 \times (3'3'')} = 0.33in$

$c = 0.33/0.85 = 0.39in < 2.96in \Rightarrow \phi = 0.9$

$jd = 7.9in - 0.33/2 = 7.73in$

$As_{req} = \frac{24.8K\text{-}ft \cdot 12''/1}{0.9 \times 60 \times 7.73in} = 0.71in^2$

- NEGATIVE MOMENT

- COLUMN STRIP

$\alpha_f = 0 \Rightarrow -M_c = 0.75(166.5) = 124.9K\text{-}ft$

$-As_{req} = \frac{124.9K\text{-}ft \cdot 12''/1}{0.9 \times 60 \times 0.95 \times 7.9in} = 3.70in$

$-As_{min} = 1.97in^2$

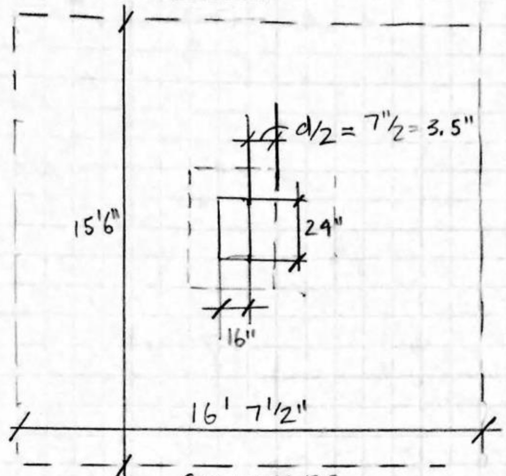
$a = \frac{3.70in^2 \times 60}{0.85 \times 4 \times (10'1\tfrac{1}{2}'')} = 0.537in$

$c = 0.537/0.85 = 0.63in < 2.96in \Rightarrow \phi = 0.9$

$jd = 7.9in - 0.537in/2 = 7.63in$

$As_{req} = \frac{124.9K\text{-}ft \cdot 12''/1}{0.9 \times 60 \times 7.63in} = 3.64in^2$

TWO-WAY
SHEAR CHECK



COLUMN B2

$b_0 = 2(16" + 7" + 24" + 7") = 108\ in$

$V_u = 0.226\ Ksf \cdot [(16'7½")(15'6") - (23" \times 31")] = 58\ K$

$\phi V_c = 4\lambda\sqrt{f'c}\ b_o \cdot d \cdot 0.75$

$\phi V_c = 4 \cdot 1 \cdot \sqrt{4000} \cdot 108\ in \cdot 7\ in \cdot 0.75$

$\phi V_c = 143\ K > V_u$

∴ CONCRETE STRENGTH ADEQUATE

USE MINIMUM SHEAR REINFORCEMENT

- MIDDLE STRIP (HALF OF STRIP)

$(-M_u) = (166.5 - 124.4)/2 = 29.14\ K\text{-}ft$

$-As_{req} = \dfrac{29.14K\text{-}ft \cdot 12''/'}{0.9 \times 60 \times 0.95 \times 7.9in} = 0.863\ in^2$

$-As_{min} = 0.63\ in^2$

$a = \dfrac{0.863in^2 \times 60}{0.85 \times 4 \times (3'3'')} = 0.39in$

$c = a/0.85 = 0.46in < 2.96in \Rightarrow \phi = 0.9$

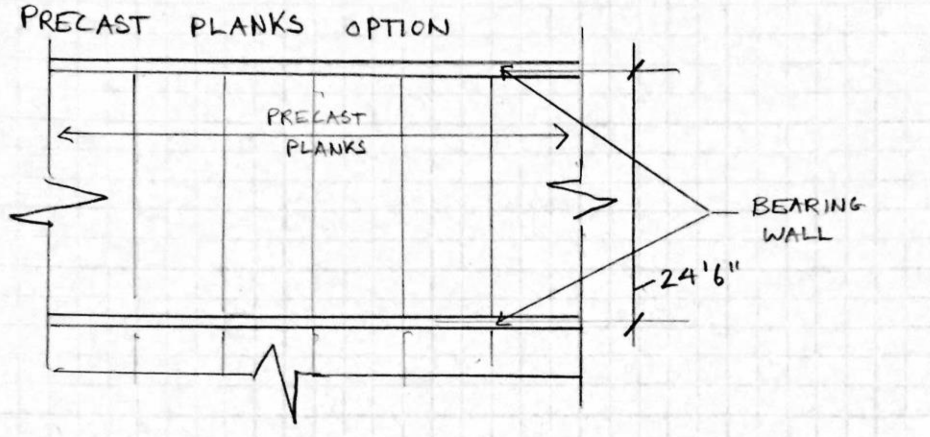
$jd = 7.9in - 0.39in/2 = 7.70in$

$As_{req} = \dfrac{29.14K\text{-}ft \cdot 12''/'}{0.9 \times 60 \times 7.70in} = 0.84in^2$

POSITIVE INTERIOR MOMENT	As_{req}/As_{min} (in^2)	(No.) BAR SIZE
COLUMN STRIP		
A2-B2	1.97	(5)#6
B1-B2	2.14	(5)#6
MIDDLE STRIP		
A2-B2	1.40	(4)#6
B1-B2	0.71	(4)#4
NEGATIVE INTERIOR MOMENT		
COLUMN STRIP		
A2-B2	2.35	(3)#9
B1-B2	3.64	(4)#9
MIDDLE STRIP		
A2-B2	1.40	(4)#6
B1-B2	0.84	(5)#4

3-0235 — 50 SHEETS — 5 SQUARES
3-0236 — 100 SHEETS — 5 SQUARES
3-0237 — 200 SHEETS — 5 SQUARES
3-0137 — 200 SHEETS — FILLER
COMET

PRECAST PLANKS OPTION



MANUFACTERER: OLD CASTLE PRECAST

PRODUCT: ELEMATIC HOLLOW-CORE PLANK

TRY E8"x48" w/ NO TOPPING (ADD 1/2" GYPCRETE FOR FIRE RATING)

UNIFORMELY DISTRIBUTED SUPER IMPOSED LOAN
- LIVE LOAD PLUS DEAD LOAD ADDITIONAL TO S.W.

1/2" GYPCRETE => $6.9 \text{ psf}/3/4" \cdot 4/3" \cdot 1/2" = 6.13$ psf

1/4" FLOOR MAT => 0.75 psf

29/32" SUBFLOOR => 3 psf

5/8 GWB => 2 1/2 psf

3 1/2" BATT INSULATION => 1.75 psf

MECHANICAL => 4 psf

FLOOR FINISH => 1 psf

DEAD TOTAL = 20 psf

DEAD + LIVE = 20 psf + 40 psf
= 60 psf

3-0235 — 50 SHEETS — 5 SQUARES
3-0236 — 100 SHEETS — 5 SQUARES
3-0237 — 200 SHEETS — 5 SQUARES
3-0137 — 200 SHEETS — FILLER

COMET

ULTIMATE
BENDING ⇒
MOMENT
(PER UNIT)

$$\frac{(60\,psf)\cdot 4ft\cdot(24'6")^2}{8} = M_u$$

$M_u = 18$ K-ft

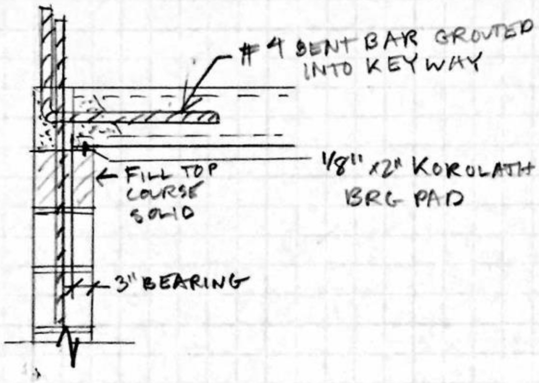
FOR 20_ 08704

MAX TOTAL LOAD = 877 psf > 60 psf

$\phi M_n = 58.88$ K-ft > 18. K-ft

∴ GOOD

CONNECTION TO CMU BEARING WALL

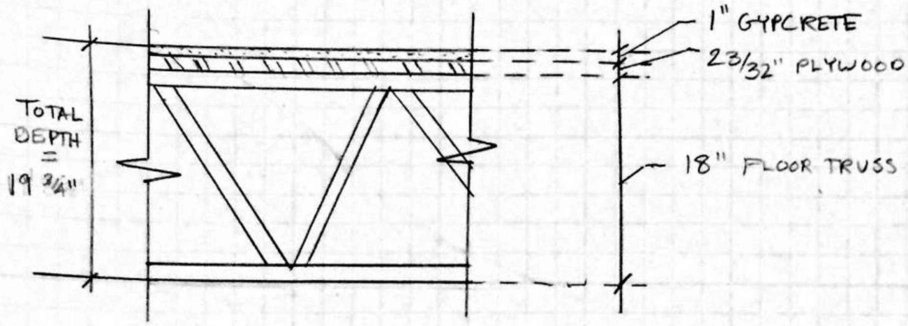


System Comparison

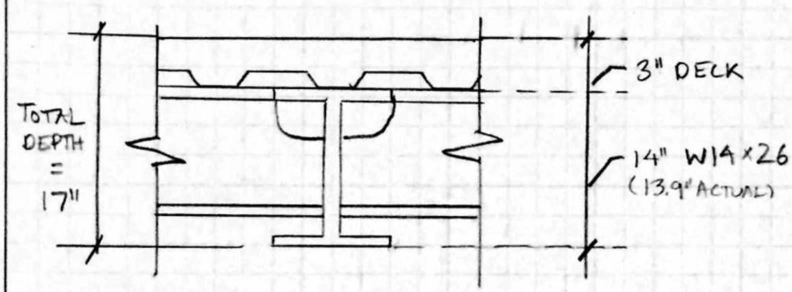
	Systems			
Parameters	Existing Wood Truss Joists	Non-Composite Joists and Girder	Flat Plate Two-Way Slab	Precast Planks
Thickness (in)	19	17	9	8
Weight (psf)	13	40	113	61
Fire Rating (Hr)	1	2	3+	2
Material Cost ($/sq.ft.)	6.24	8.80	5.95	7.80
Installation Cost ($/sq.ft.)	4.01	3.19	9.20	2.57
Total Cost ($/sq.ft.)	10.25	11.99	15.15	10.37
Advantages	-Lowest Cost -Lightest -Voids for Mechanical -Stable during construction	-Light weight system -Relatively Low Cost	-Small slab thickness -Durable	-Thinnest thickness -Low Cost -Efficient with prestressed strands -Easy construction
Disadvantages	-Largest Structural depth	-Vibrations could cause uncomfortablility	-Heaviest -Most Expensive	-Heavy Structure -Transportation can cause trouble as planks are fragile and large
Potential for In-depth Investigation		Yes	No	Yes

STRUCTURE THICKNESSES

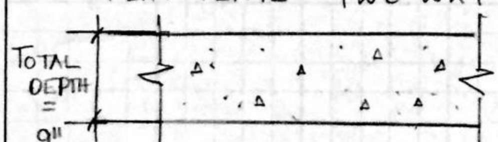
- EXISTING SYSTEM (WOOD TRUSSES)



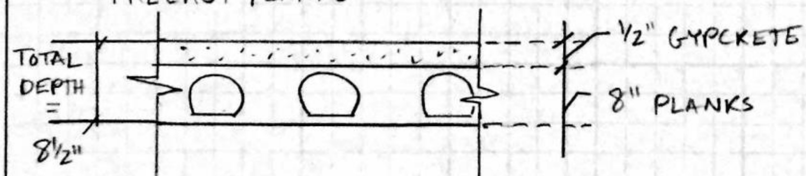
- NON COMPOSITE STEEL



- FLAT PLATE TWO WAY SLAB



- PRECAST PLANKS



WEIGHT OF SYSTEMS

EXISTING WOOD SYSTEM

- 18" FLOOR JOIST = 3 PSF
- GYPCRETE = 10 PSF

TOTAL = 13 PSF

NON COMPOSITE STEEL

- JOISTS = 3 PSF
- GIRDERS = 1.5 PSF
- DECKING - 35 PSF

TOTAL = 40 PSF

FLAT PLAT TWO-WAY

- 9 IN SLAB = 113 PSF

TOTAL = 113 PSF

PRECAST PLANKS

- GYPCRETE = 7 PSF
- PLANKS = 54 PSF

TOTAL = 61 PSF

3-0235 — 50 SHEETS — 5 SQUARES
3-0236 — 100 SHEETS — 5 SQUARES
3-0237 — 200 SHEETS — 5 SQUARES
3-0137 — 200 SHEETS — FILLER

COMET

3-0235 — 50 SHEETS — 5 SQUARES
3-0236 — 100 SHEETS — 5 SQUARES
3-0237 — 200 SHEETS — 5 SQUARES
3-0137 — 200 SHEETS — FILLER

COMET

ASSEMBLY COSTS

(RSMEANS 2014)

- NON COMPOSITE STEEL OPTION

20x25 BAY, TOTAL LOAD = 90 PSF, 4 JOISTS

COST PER SQ FT.

MAT = 8.80 INST. = 3.19 TOTAL = 11.99

- FLAT PLATE TWO-WAY SLAB

20x25 BAY, 75 PSF SUPERIMP. LOAD, 20 MIN COLUMN SIZE
9 in SLAB, 188 PSF TOTAL LOAD

COST PER SQ FT.

MAT = 5.95 INST. = 9.20 TOTAL = 15.15

- PRECAST PLANKS

25 FT SPAN, 75 PSF SUPERIMPOSED LOAD, 8 in DEPTH
55 PSF DL, 130 PSF TOTAL LOAD.

COST PER SQ FT.

MAT = 7.80 INST. = 2.57 TOTAL = 10.37

- EXISTING SYSTEM

16" OPEN WEB JOISTS, 16" O.C.
* COST ESTIMATE COULD BE INFLATED DUE TO ACTUAL SPACING BEING 24" O.C NOT 16" O.C

COST PER SQ FT.

MAT = 6.24 INST. 4.01 TOTAL = 10.25