TECHNICAL REPORT II

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PENN COLLEGE OF TECHNOLOGY

Pro-Con Structural Study of Alternate Floor Systems

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EXECUTIVE SUMMARY

The purpose of the Technical Report II is to analyze the pros and cons of alternate floor systems of Dauphin Hall. An analysis of the existing composite deck together with three other floor systems was performed to provide different options that may be considered for the Dauphin Hall.

The following floor systems were analyzed for a typical bay size of 25’×30’:

- Composite deck on floor joists
- Composite deck on wide flange beam
- One-way slab
- Hollow-core Plank with concrete topping

By vulcraft Design Catalog and AISC Steel Construction Manual, a 3VL16 composite deck and a W18×40 beam form the composite system. The one-way slab was design using ACI318-08 and ACI Design Handbook. A 15” slab thickness with #5 @ 10” O.C. and #6 @ 7” O.C. reinforcement was found to yield for flexure, and shrinkage and temperature. Using the PCI Design handbook and the AISC Steel Construction Manual, a 4’-0”×8” hollow core plank with 2” normal weight concrete and a W21×55 beam were picked for the hollow core floor system.

Each system was analyzed based on the flowing criteria: cost of the assemblies, fire rating, structural or non-structural advantages or disadvantages, etc. All of the systems were found to be to some extend applicable; however, the composite deck on wide flange beams seems to be most cost effective and practical in this case. View table 8 for a complete system comparison.

Partial drawings and hand calculations necessary for the understanding of the flooring systems are provided in the appendices of this report.

BUILDING INTRODUCTION

The Pennsylvania College of Technology is located in the 200 block of Rose Street in Williamsport, PA. Dauphin Hall is the newest dormitory on campus constructed in August 2010 by Murray Associates Architects, P.C in collaboration with IMC as the general contractor; Woodburn & Associates, INC as the food service designer; Whitney, Bailey, Cox & Magnani, LLC as the civil engineering firm; and Gatter & Diehl, INC as the MEP firm. This new structure costs approximately $ 26,000,000 and used the design-bid-build project delivery method.

Figure1: Map

Figure 2: South facade

This latest addition of the student housing provides 268 students with suites and single rooms. A 40-50 student seating commons enclosed with glass provides a social space for student collaboration. Located within the dormitory are other amenities such as: a 460 seat dining room, two private dining rooms for faculties, a 40 station satellite fitness center, two large leisure rooms, a student grocery store, laundry facilities, student mail boxes, Resident Life Offices, campus police office, and a Hall Coordinator apartment.

To the right side are different facades provided for an understanding of the shape of the building. A set of floor plans are provided in appendix E as a supplementary documents for a better understanding.

Figure 3: South facade

STRUCTURAL OVERVIEW

Dauphin Hall rests entirely on a shallow foundation and stone piers. The exterior and interior walls are composed of masonry walls. The whole structure is made out of steel framing (joists, beams, and columns), which supports a 4" concrete slab reinforced with welded wire mesh on a composite deck.

FOUNDATIONS

Base on the analysis done by CMT Laboratories, Inc. for this site, the geotechnical engineers have determined that the site was filled with Brown Silty Clay, and Brown Silty Sand with Gravel. Furthermore, the cohesive alluvial soils beneath the fill materials have low shear strength.

In light of these conditions, the conventional spread/column and continuous footing foundations will not provide adequate allowable bearing capacity to support the building. Deep foundations such as concrete filled tapered piles could support the structure but are not the most economical approach. Therefore, a practical solution is subsurface improvement with the use of shallow foundation.

All in all, the final decision comes down to using stone piers which were considered the most technically sound and economically feasible method. Those stone piers are typically eighteen (18) to thirty-six (36) inches in diameter depending on their loading and settlement criteria.

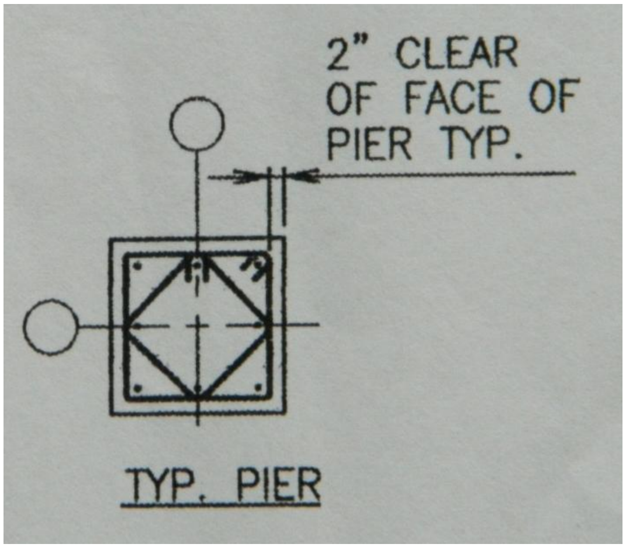


Figure 4: Typical Pier

FLOOR SYSTEMS

Due to the simplicity of the foot prints of the Dauphin hall, a typical floor consists of 4" concrete slab reinforced with 6"×6" –W2.9×W2.9 welded wire mesh. The concrete slab rests on 1 ½" - 20 gage composite deck (Vulcraft). The joists supporting the floor system are spaced equally in column bays with a maximum spacing of 2'-0" O.C in areas of floor framing.

A typical bay for the three floors above is 25'× 30'.

The figure below provides a typical bay size.

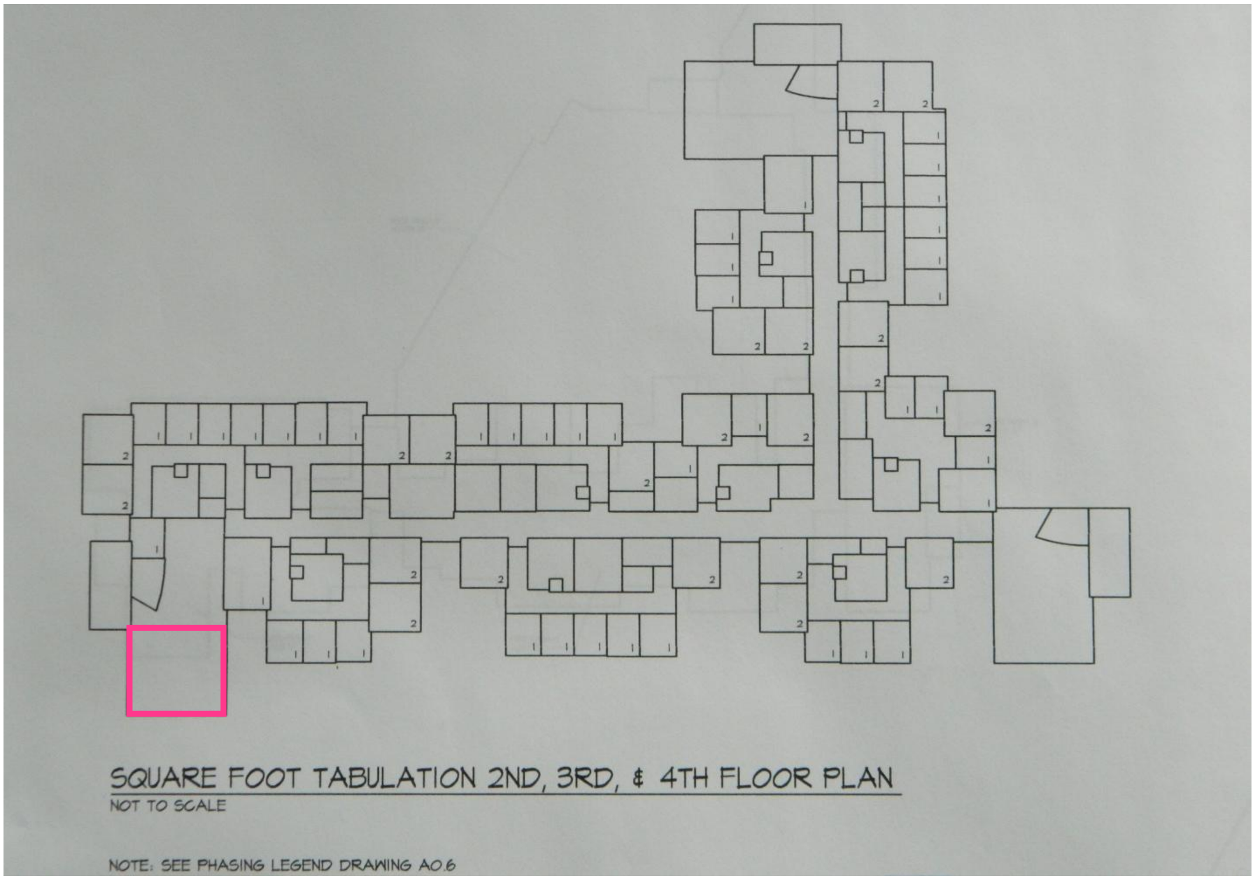
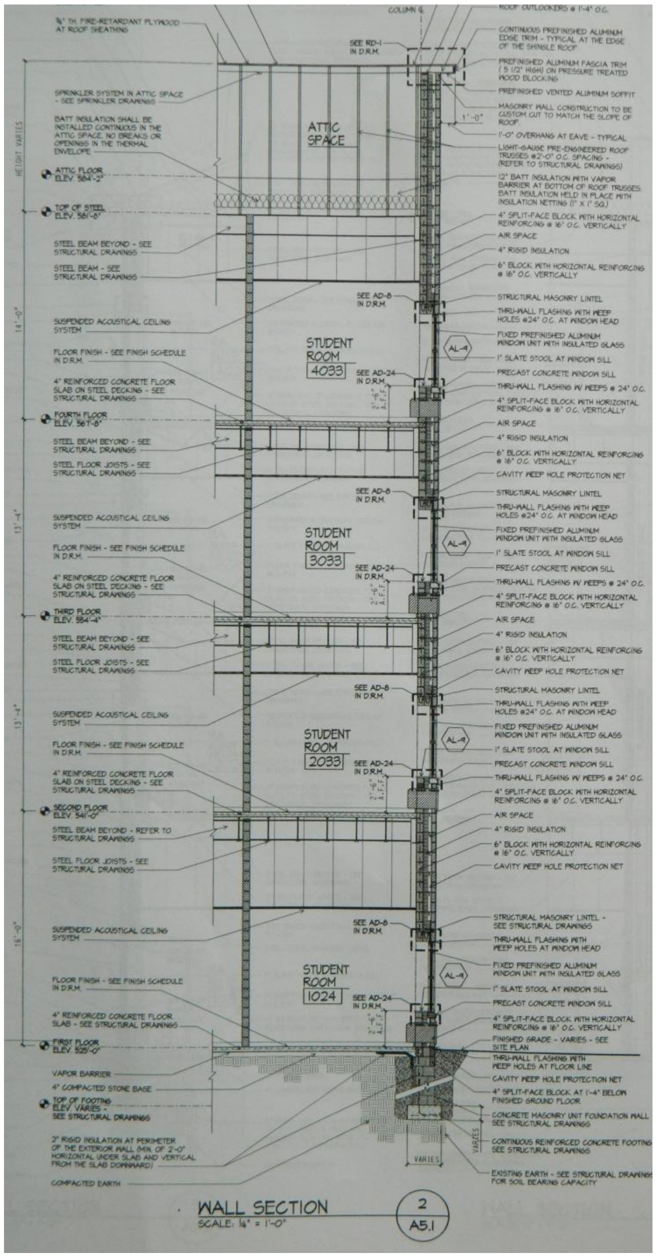


Figure 5: Typical Floor Bay Size (Red Square)

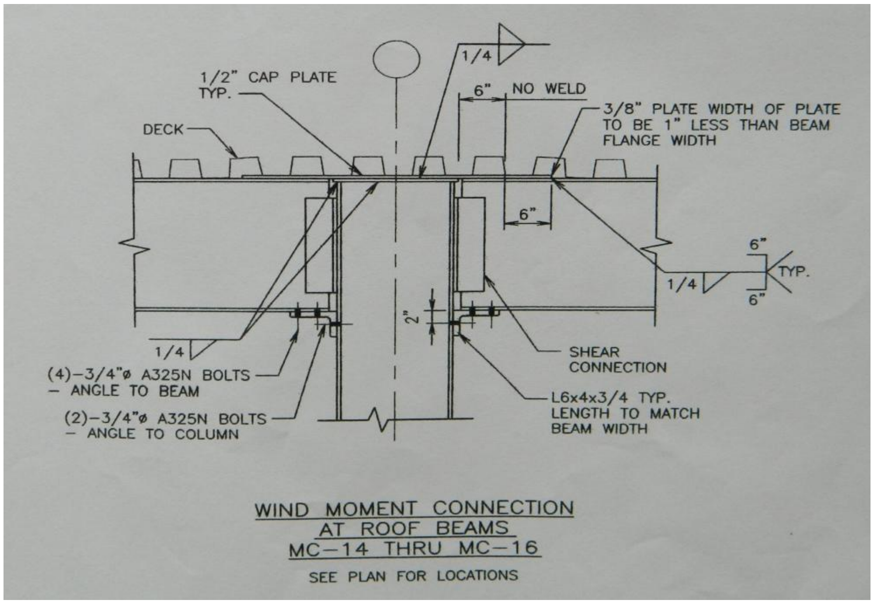
FRAMING SYSTEM

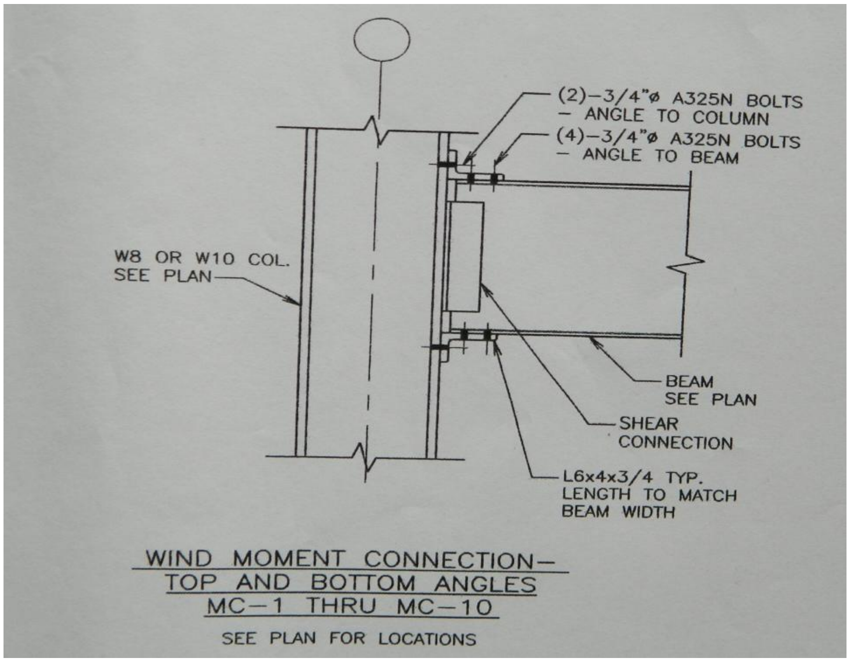
Almost all the structural columns supporting the floors are either a wide flange W10 or W8. They are all encased by 5/8" Gypsum board or 6" painted CMU. In locations near the stair cases, HSS columns were used. Concrete Masonry Units (CMU) is the typical interior partitions.



LATERAL SYSTEM

To resist the lateral system in the dauphin Hall, the structural engineers used wind moment frames with moment connections throughout the building. This configuration provides no obstruction and therefore allows a great use of the open floor plan. View the following details.





ROOF SYSTEMS

There is only one roof system on the Dauphin Hall dormitory due to the similarity of the outline of the building. The whole roof is composed of 1 1/2" – 20 gage type B roof decks, which rests on light gage trusses at 2'-0" O.C. The joists supporting the roof system are spaced at a maximum distance of 4'-0" O.C. between the column bays.

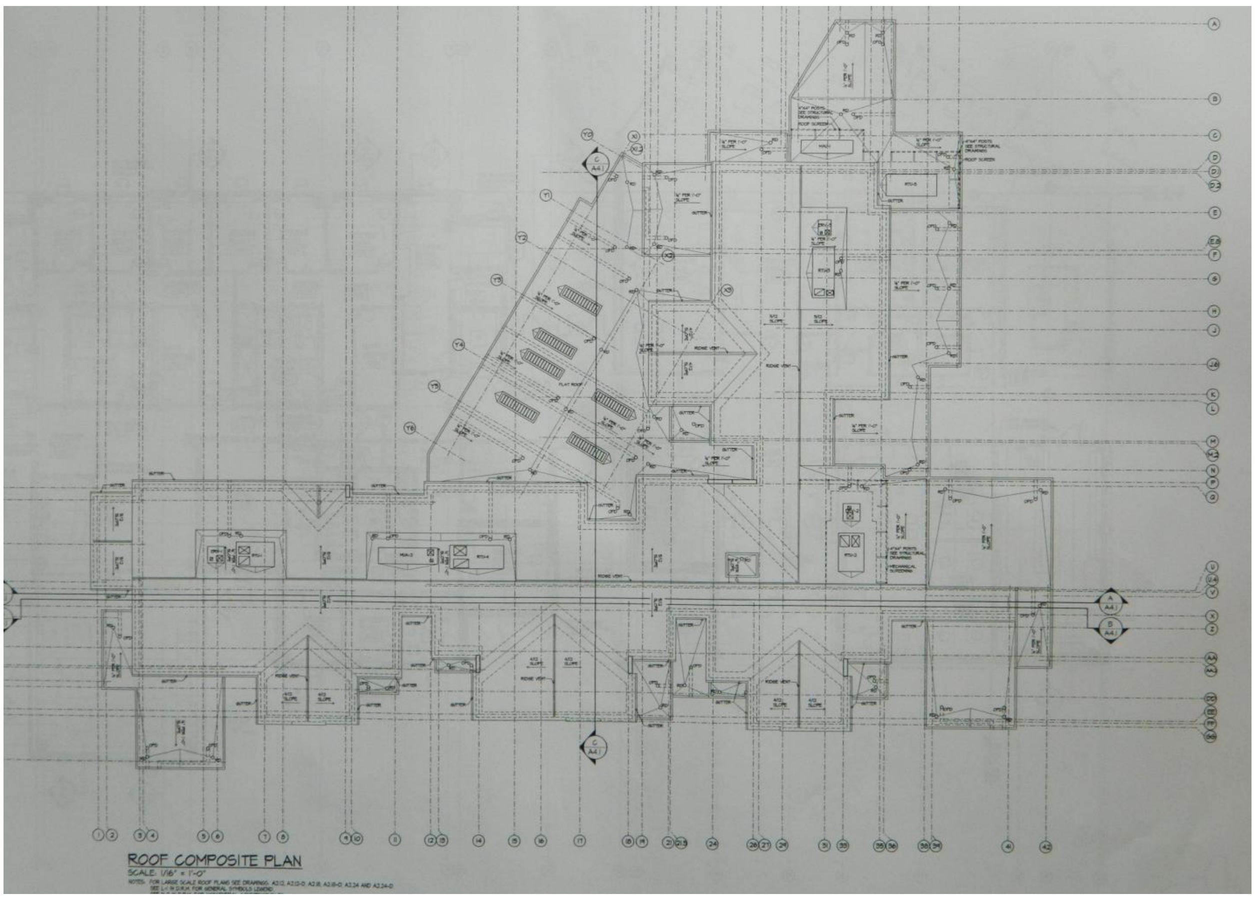


Figure 6: Roof plans

DESIGN CODES

All equipments and components of the Dauphin Hall shall comply with all applicable latest editions of articles and sections of the following codes in compliances with all Federal, State, County, and Local ordinances and regulations:

- 2006 International Building Code (IBC)
- National Electrical Code (NEC),
- Uniform Plumbing Code (UPC),
- National Sanitation Foundation (NSF)
- Specifications for structural concrete for buildings (ACI 301)
- Building Code Requirements for Reinforced Concrete (ACI 318-08)
- Recommended Practice for Hot Weather Concreting (ACI 305R)
- Recommended Practice for Cold Weather Concreting (ACI 306R)
- Recommended Practice for Concrete Formwork (ACI 347)
- American Society of Civil Engineers (ASCE 7- 10)

MATERIALS USED

The following table provides a list of materials used in the design of this building. Those values were found in the structural drawing and the specifications.

Concrete		
Usage	**Weight**	**Strength (psi)**
Footings	Normal	4000
Foundation alls	Normal	4000
Slab-on-Grade	Normal	4000
Suspended Slabs	Normal	4000
Toppings	Normal	5000
Piers	Normal	4000

Table 1: Concrete materials

Steel		
Type	**Standard**	**Grade**
W-Shaped Structural Steel	ASTM A 572/A 572M	50
Channels, Angles-Shapes	ASTM A 36/A 36M	36
Plate and Bar	ASTM A 36/A 36M	36
Cold-Formed Hollow SS	ASTM A 500	B
Steel Pipe	ASTM A 53/A 53M	B
Bolts, Nuts, and Washers	ASTM A325/ASTM F 1852	N/A
Steel Deck	ASTM A 653	A
Reinforcing Bars	ASTM A 615/A 615M	60
Deformed Bars	ASTM 767	A
Welded Wire Fabric	ASTM A 615	65

Table 2: Steel materials

Masonry		
Type	**Standard**	**Strength (psi)**
Concrete Block	ASTM C 90/ ASTM C 145	1900
Split Face CMU	ASTM C 90lightweight	1900
Bond Beam	N/A	3000
Precast Stone	N/A	5000-7000
Concrete Brick	ASTM C 1634/ASTM C 55	N/A
Mortar	ASTM C 979	N/A
Grout	ASTM C 404	N/A

Table 3: Masonry materials

Miscellaneous	
Type	**Strength (psi)**
Concrete Fill	3000
Non-Shrink Nonmetallic Grout	ASTM C 1107

Table 4: Miscellaneous materials

GRAVITY LOADS

Included in this report is a summary of dead, live, and snow loads used in the thesis design. There were compared to the actual design loads in the structural drawings. Several members were checked in the technical report I to verify adequacy.

DEAD AND LIVE LOADS

Superimposed Dead Loads		
Description	**Design Loads**	**Thesis Loads**
Roof		
Roofing	3 PSF	3 PSF
Framing	5 PSF	10 PSF
Insulation	3 PSF	3 PSF
Ceiling	2 PSF	2 PSF
Elec./Lights	3 PSF	3 PSF
Mechanical	5 PSF	5 PSF
Sprinklers	3 PSF	3 PSF
Miscellaneous	1 PSF	1 PSF
Total	**25 PSF**	**30 PSF**
Floor		
4” Slab and Deck	44 PSF	57 PSF
Framing	5 PSF	15 PSF
Mechanical	5 PSF	5 PSF
Elec./Lights	3 PSF	3 PSF
Ceiling	2 PSF	2 PSF
Sprinklers	3 PSF	3 PSF
Miscellaneous	3 PSF	3 PSF
Total	**65 PSF**	**88 PSF**
Superimposed DL		**30 PSF**
Snow	**35 PSF**	**30 PSF**

Table 5: Design Dead Loads

Description	Quantity (ft2)
Ground floor	14,473
2nd Floor	10,320
3rd Floor	10,320
4th Floor	10,320
Roof	10,320

Table 6: Area of Typical Floor

Design Live Loads		
Description	**Design Loads**	**Thesis Loads**
Roof	35 PSF	30 PSF
First Floor	100 PSF	100 PSF
Stairs	100 PSF	100 PSF
Dorm Rooms	40 PSF	40 PSF
Corridors	100 PSF	100 PSF
Storage	125 PSF	125 PSF
Mechanical room	150 PSF	125 PSF
Common Areas	100 PSF	100 PSF

Table 7: Design Live Load

FLOOR SYSTEM ANALYSIS

A spot checked of the existing 4” normal weight concrete slab on 1-1/2 -20 gage composite steel deck was done on a typical 25’× 30’ bay and all its calculations can be found in appendix A. This system was then compared to a one-way slab, a composite deck on a beam, and a hollow-core slab of the same bay. These preliminary sizes were estimated using ACI 318-08, IBC 2009, PCI design handbook, and other design aids.

Based on the RS Means: Square Foot Costs 2011, a cost analysis was done on the four floor systems to determine which one is cost effective.

A complete hand calculation of each system can be found in the appendixes.

EXISTING FLOOR SYSTEM: SLAB & COMPOSITE DECK ON FLOOR JOISTS

Decking

Using Vulcraft Manual, a 1.5VL 20 composite deck with 4" normal weight concrete was found to be more than adequate for unshored length and has more than the required strength for loading. The deck has a 1 ½ hour fire rating. Overall the composite deck was overdesigned.

Floor Joists supporting Composite Deck

For a factored total load and live load of 604 plf and 320 plf respectively, we find in the Vulcraft manual that a 18K7, 20K6, and 22K4 are all satisfactory joists for a 25' span. Based on their weight, a 22K4 seems to be the lightest of the group. However, from the "economical joist guide" section on page 125 of the same manual, we find that a 20K5 is more economical. Therefore, we pick a 20K5 joist spaced at 2'-0" O.C. with 2 rows of bridging for our final design.

However, the existing design joists are overdesigned using 22K6 joists spaced at 2'-0" O.C. This member has 25% more strength than required.

Advantages:

One of the major advantages of using this floor system is that it provides a great space underneath the floor for mechanical and electrical equipment. All the lighting fixtures can be hanged straight on the joists. The composite deck provides a profile shape that uses less concrete than the conventional system; therefore reducing the size and cost of elements used in the primary structure and foundations. It also provides a great advantage in seismic, gravity and foundation design by reducing the weight of the structure. Moreover, temporary props can be eliminated resulting in faster erection and a shortening of the construction program. Additionally, it provides a working platform and is cost and energy efficient, and recyclable.

Disadvantages:

With this system being used throughout the building, the cost of steel on this project will increase. Moreover, steel joist floors do not provide an aesthetic ceiling for the floors below. In addition, composite decks have sagging problems due to the weight of the deck, and are temperature sensitive. Composite decks tend to expand in hot weather and contract in cold weather making many decks less suitable for bearing a lot of weight. Finally, if the deck is damaged, it must be completely replaced.

PROOSED FLOOR SYSTEM: COMPOSITE DECK ON WIDE FLANGE BEAMS

This system is a derivation of the above floor system in order to reduce the overall cost of structural steel in the project. A 3"-16 gage composite deck with 4" normal weight concrete with two wide flange beams spanning in the longer direction seems more suitable. The deck is perpendicular to the beams.

Decking:

For a 3 span condition with a total factored load of 196psf, a 3VL16 deck has 11'-4" construction span, which is more than the 8'-4" required span for unshored condition. The given strength turns out to be slightly over 25% more than the required strength when added the slab weight. The unprotected deck achieves a 1 ½ hour fire rating for a 4" normal weight concrete (Vulcraft Manual).

Composite Beam:

A W18×40 was proven to have enough flexural strength (ΦM= 294 ft-k >270 ft-k) to support the given loads. The compact section criterion is also satisfied along with live load deflection and wet concrete deflection. The live load deflection was = 0.82 in < 1 in, and the wet concrete deflection was = 0.63 in < 1.5 in. In addition, two studs per rib are required to achieve the desired strength.

Advantages:

Similarly to the previous system, this system will allow a depth of 18 inches in the ceiling for lighting fixtures and mechanical equipment for the floors below. Also, this will reduce the cost of structural steel in the project considerably. Another beneficial advantage of using this type of deck is that by applying some type of fire protection on the deck, we can achieve a higher fire rating resistance.

Disadvantages:

Compared to the previous system, the 18 inches ceiling height would be a challenge for the mechanical and electrical equipment. Flexible duck or other types of ventilation may be required if this system is chosen. Moreover, additional fire proofing material may be required on the beam, which could slightly increase the cost.

PROPOSED FLOOR SYSTEM: ONE-WAY SLAB

A thickness of 15 inches was determined to work on a 30 ft span with a live load of 100 psf and a superimposed dead load of 30 psf using PCI Design Handbook and ACI 318-08. For these load conditions, we can provide # 6 bars at 7 inches O.C. in the short direction to meet flexural requirements of 31 ft-k > 27 ft-k. To limit the effect of temperature and shrinkage, a reinforcement of the slab with # 5 bars @ 10 inches O.C. is required (Note: #6 @ 14" O.C. could be used for consistency). A spacing of 7 inches is more than enough to withstand cracking and shear. By visual inspection shear is not a controlling factor here.

Advantages:

This floor system configuration provides a greater floor to floor height. Therefore, another floor can be added to the existing system height without increasing the height too much. Another advantage of this system is that during construction, the form work can be reused multiple times. In addition, there is no need for fire protection due to the 15 inches thickness of the slab.

Disadvantages:

The ceiling will not provide a space for mechanical or electrical equipment. Vibration may be a problem in this case. In addition, the foundation of the building will need to be rechecked due to the weight of the slab.

PROPOSED FLOOR SYSTEM: HOLLOW-CORE ON BEAM

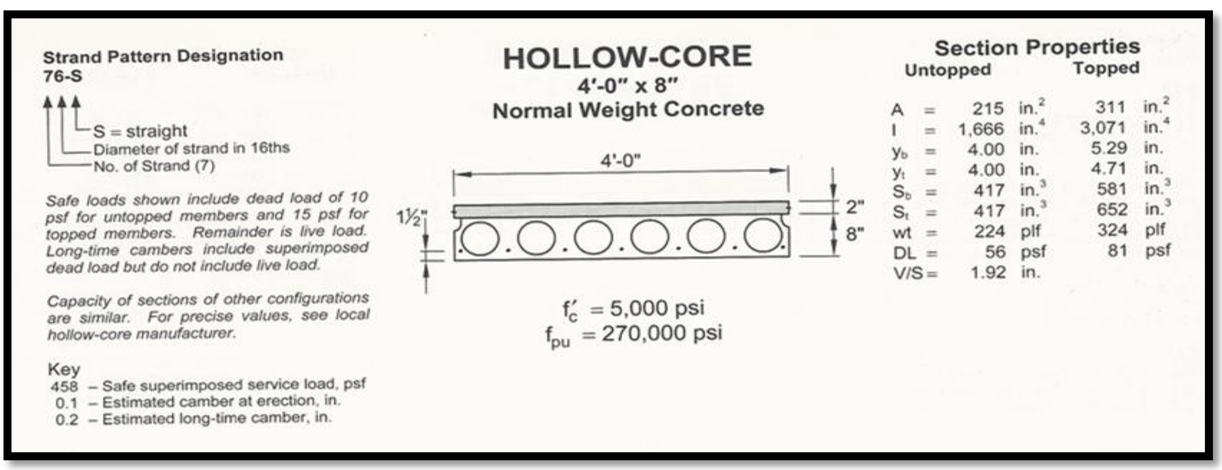
Precast hollow-core planks were proposed for the same 25’×30’ bay. Using the PCI Design Handbook, a 4’-0” × 8” with 2” normal weight concrete was found to be sufficient to support the load across the 25’ span. A W 21×55 was used to support the hollow core planks in the 30’ direction. This beam was checked for deflection and all supporting calculations can be found in Appendix D.

Advantages:

The hollow core planks being precast meaning the system was constructed under controlled conditions providing a maximum strength capacity to be attained. Since the system is being produced in a factory, the general contractor can save time in the erection process and storage space.

Disadvantages:

The steel beam supporting the hollow core planks will need fire protection for the whole system to achieve a 2 hours fire rating.


Strand Pattern Designation
76-S
S = straight
Diameter of strand in 16ths
No. of Strand (7)

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
458 – Safe superimposed service load, psf
0.1 – Estimated camber at erection, in.
0.2 – Estimated long-time camber, in.

HOLLOW-CORE
4’-0” x 8”
Normal Weight Concrete

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

Section Properties

	Untopped		Topped	
A =	215	in.^{2}	311	in.^{2}
I =	1,666	in.^{4}	3,071	in.^{4}
y_b =	4.00	in.	5.29	in.
y_t =	4.00	in.	4.71	in.
S_b =	417	in.^{3}	581	in.^{3}
S_t =	417	in.^{3}	652	in.^{3}
wt =	224	plf	324	plf
DL =	56	psf	81	psf
V/S =	1.92	in.		

SYSTEM COMPARISON

Floor System Comparison					
		Floor systems			
		Existing Composite Deck on Floor joists	Composite Deck on Wide Flange Beam	One-way Slab	Hollow Core Plank
limitations	**System Weight (psf)**	66.2	109	188	166
	Slab depth (in)	5.5	7	15	10
	Total depth (in)	27.5	25	15	31
Cost and safety	**Fire rating**	1 ½	1 ½	2	2
	Extra fire proofing Required	No	Yes	No	Yes
	Total Cost($/SF)	20.70 + cost of joists	15.70	19.20	23.22
Impact	**Foundation impact**	N/A	Yes	Yes	Yes
	Architectural impact	N/A	Yes	Yes	Yes
	Constructability	Easy	Easy	Moderate	Easy
Consideration	**Vibration concerns**	Some	Some	Minimal	Minimal
	Possible alternative	N/A	Yes	Yes	Yes
	Additional study	N/A	Yes	Yes	Yes

Table 8: System Comparison

CONCLUSION

Three alternative systems were studied in addition to the existing system. These systems are: a composite deck on a wide flange beam, a one way slab, and a hollow core plank on steel beams. All the analyses were done on a typical bay of 25 feet by 30 feet.

The composite deck and beam were designed using the Vulcraft Design Catalog and the AISC Steel Construction manual. The composite system consists of a 4" normal weight concrete with a 3VL16 composite deck and a W18×40 beam. The one-way slab system is composed of a 15" normal weight slab reinforced with #5 @ 10" O.C. in the 30 feet direction and #6 @ 7" O.C. in the 25 feet direction for flexure, shrinkage and temperature respectively. The one-way slab was designed using ACI 318-08 and ACI Design Handbook (Volume 1). Based on the loading conditions, the PCI Design Handbook (6^{th} Edition) recommends a 4'-0"×8" hollow core plank. A W21×55 beam will support the hollow core planks.

After reviewing the advantages and disadvantages of each system, two systems were determined to not be viable alternative: The hollow core planks and the one-way slab. Both systems increase the weight of the building considerably. The hollow core planks are more expensive and have the greatest total depth of all the systems. Therefore, the best alternative system may be the composite deck on a wide flange beam. However, this system will have a slightly higher cost due to additional fire proofing required. A further study of the composite deck on wide flange beam system will need to be done.

APPENDICES

APPENDIX A: EXISTING SYSTEM: COMPOSITE DECK ON FLOOR JOISTS

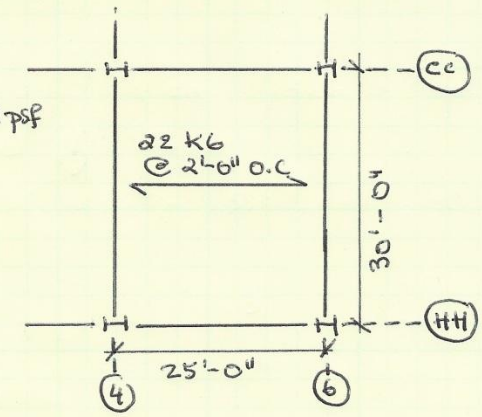
1

Existing Floor system: composite deck on floor joists.

A- DECK

Loads

LL = 100 psf slab weight = 57 psf
SDL = 30 psf



Composite deck

4" Concrete slab
1-1/2" - 20 gage steel deck

Normal weight Concrete
t = 5.5"
f'_c = 4000 psi

Load combination:

W = 1.2 DL + 1.6 LL = 1.2(30+57) + 1.6(100) = 264 psf

Vulcraft Decking Catalog

3 span Condition

Try 1.5 VL 20

Check unshored length

7'-10" > 2' (joist spacing) ∴ OK

Check superimposed LL

For 5-0" clear span, 400 psf > 264 psf ∴ OK
For loading

Recommended reinforcement

6x6 - W2.1 x W2.1 for t = 5.5"

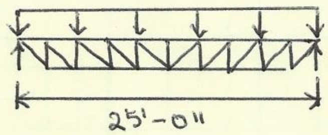
USE DECK 1.5VL20

Note: An 4" Normal weight unprotected 1.5VL20 deck has 1 1/2 hr fire rating by Vulcraft Catalog.

2

B- Floor Joist supporting composite deck

(Vulcraft)



Loads

LL = 100 psf
SDL = 30 psf
DL = 88 psf ← Includes slab/deck.

Conditions

Spacing = 2'-0" o.c.
Span = 25'-0"

Load combination.

Total load = 1.6 LL + 1.2 DL

= 1.6(100) + 1.2(30+88) = 302 psf

Total load = (302)(2) = 604 plf
↖ spacing

Live load = 1.6(100)(2) = 320 plf

Possibilities (LRFD)

Joist size	Total load (plf)	Live load (plf)	wt / ft
18K7	727	337	9
20K6	669	350	8.2
22K4	657	381	8

Select 22K4 joist as the lightest from the list above

From "economical joist guide" p. 125

For 25' length, select 20K5 (weight = 8.2 lb/ft)
Total load = (446) 1.5 = 669 plf > 604 plf
Live load = 350 plf > 320 plf

USE 20K5 Joist For FINAL DESIGN

* **Bridging requirements:**

From Vulcraft p. 43 → Section number 5
Span = over 19' thru 29' } use 2 rows of bridging

Use 20K5 joist @ 2'-0" O.C with 2 rows bridging

3

* **Design Joists**

22K6

Total load = 805 plf > 604 plf ∴ OK

Live load = 464 plf > 320 plf ∴ OK

weight = 9.2 lbs/ft

> 22K6 joists checks out

APPENDIX B: COMPOSITE DECK ON WIDE FLANGE BEAM

1

Proposed Floor system: Composite deck on wide flange beams

A- Composite deck (Vulcraft)

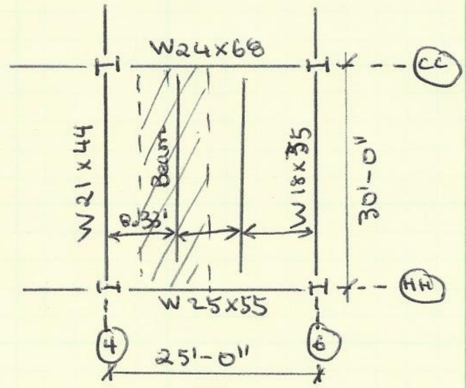
Floor Construction

3"- 16 gage Composite deck

4" Normal weight concrete

Total slab depth: t = 7"

f'_c = 4000 psi



Loads

LL = 100 psf
SDL = 30 psf

Total = 130 psf

W = 1.2(30) + 1.6(100) = 196 psf

Vulcraft Deck Catalog

Try 3VL16 , (slab weight = 69 psf)

Check shored length (3 span condition)

11'-4" > 8.33" ∴ OK

Check superimposed live load

8'-6" clear span

379 psf > 196 psf

W_u = 1.2(69) + 196 = 279 psf < 379 psf ∴ OK

Fire resistance : 1 ½ Hr. rating for 4" NW unprotected deck.

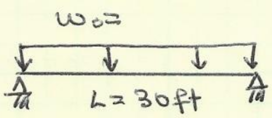
USE 3VL16 composite deck

2

B- Composite Beam

Loads:

LL = 100 psf
SDL = 30 psf
DL = 69 psf + 6 psf (Allowance) = 75 psf



Span = 30 ft
Trib. Area = 8.33 ft

DL = (105)(8.33) = 875 plf

LL = (100)(8.33 = 833 plf

$W_u = 1.2(875) + 1.6(833) = 2.4\ k/ft$

$V_u = \frac{wL}{2} = \frac{(2.4)(30)}{2} = 36^K$

$M_u = \frac{wl^2}{8} = \frac{(2.4)(30)^2}{8} = 270\ ft\text{-}K$

Using Z_x table (Table 3-2 Steel Manual):

Try W 18 X 40 $\phi_b M_{px} = 294\ ft\text{-}K > 270\ ft\text{-}K$ ∴ OK

Check compact section criteria:

$\phi V_{nx} = 169^K >> 36^K$

Section properties

$A_g = 11.8\ in^2$ $F_y = 50\ ksi$

$I_x = 612\ in^4$ A 992

check Δ_{LL}:

$\Delta_{LL} = \frac{l}{360} = \frac{(30)(12)}{360} = 1.0\ in$ Maximum deflection

$\Delta_{LL} = \frac{5 W_{LL} L^4}{384 E I_x} = \frac{5(0.8)(30)^4(1728)}{384(29000)(612)} = 0.82\ in < 1\ in$ ∴ OK

wet concrete check: $w = [(69)(8.33) + 40] = 615$

$\Delta_{max} = \frac{L}{240} = \frac{(30)(12)}{240} = 1.5\ in$

$\Delta_{DL} = \frac{5 W_{DL} L^4}{384 E I_x} = \frac{5(0.615)(30)^4(1728)}{384(29000)(612)} = 0.63\ in < 1.5\ in$ ∴ OK

3

Composite behavior

$b_{eff} = \min \begin{cases} \text{span}/4 = \frac{(30)(12)}{4} = 90 \text{ in} \leftarrow \text{Controls.} \\ \text{spacing} = (8.33)(12) = 99.96 \text{ in} \end{cases}$

From table 3-19 (Steel Manual)

Location of neutral axis:

$V'_c = 0.85(4)(90)(4) = 1224^k$

$V'_s = 50(11.8) = 590^k$

$V'_c > V'_s$ ∴ Neutral axis in Concrete

Table 3-19 (Steel manual) W18X40, PNA=7 ⇒ $\Sigma Q_n = 294$ K

$a = \frac{\Sigma Q_n}{0.85 f'_c b_{eff}} = \frac{294}{0.85(4)(90)} = 0.96 < 1.0$ use $1.0 = a$

$Y_2 = t_{slab} - \frac{a}{2} = 7 - \frac{1}{2} = 6.5$ in

From table 3-19 ∴ $\phi M_n = 440$ ft-K > 270 ft-K
$\phi V_n = 217^K > V_u = 36^K$ ∴ OK

$Q_n = \frac{294}{17.2} = 17.09 \approx 18$ ∴ 36 studs Required > 30 ∴ N.G

↖ table 3-21 (Steel Manual) ⇒ Need 2 studs/rib.

APPENDIX C: PROPOSED FLOOR SYSTEM: ONE-WAY SLAB

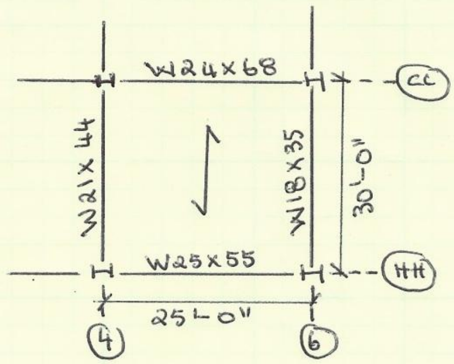
Proposed Floor System : One-way slab

Loads

LL = 100 psf
SDL = 30 psf

f'_c = 4000 psi
f_y = 40 ksi

Normal weight concrete.



Using ACI 318-08, table 9.5(a),

For a solid one-way slab with one end continuous:

$$h = \frac{l}{24} \Rightarrow h_{min} = \frac{(30)(12)}{24} \times \left(0.4 + \frac{40}{100}\right) = 12 \text{ in}$$

↑ because $f_y = 40$ ksi

USE $h = 15$ in

Assume : $d = 15 - 1 = 14$ in

$$W_{slab} = \frac{(15)(12)}{144} \times 150 = 188 \text{ psf}$$

$$W_u = 1.2 DL + 1.6 LL = 1.2(188 + 30) + 1.6(100) = 422 \text{ psf}$$

$$M_u = \frac{w_u l^2}{14} = \frac{(422)(30)^2}{14} = 27 \text{ ft-K}$$

Using slab table, $\rho = 0.004$ for $\phi M_n = 23.8$ ft-K

$\rho = 0.005$ for $\phi M_n = 29.5$ ft-K

Interpolate $\rho = 0.00456$ for $\phi M_n = 26.1$ ft-K

$$A_s = \rho b d = (0.00456)(12)(14) = 0.766 \text{ in}^2/\text{ft}$$

⇒ Provide #6 @ 7 in o.c. ($A_s = 0.76$ in²/ft)

2

* Check flexural requirement $\phi M_n > M_u$

$d = h - cover - \frac{d_{bar}}{2} = 15 - 0.75 - \frac{0.750}{2} = 13.875$ in

Assume $\varepsilon_s > \varepsilon_y$

$a = \frac{A_s f_y}{0.85 f'_c b} = \frac{(0.76)(40)}{0.85(4)(12)} = 0.7509$ in

$c = \frac{a}{\beta_1} = \frac{0.7509}{0.85} = 0.8835$ in

$0.85 \leftarrow$ for $f'_c \leq 4000$ psi

$\varepsilon_s = \frac{\varepsilon_u}{c}(d - c) = \frac{0.003}{0.8835}(13.875 - 0.8835) = 0.04411$

$\varepsilon_s = 0.04411 > 0.005 \Rightarrow$ use $\phi = 0.9$

$\phi M_n = \phi A_s f_y (d - \frac{a}{2}) = 0.9(0.766)(40)(13.875 - \frac{0.7509}{2})/12$

$\phi M_n = 31$ ft-k > 27 ft-k $\therefore$ OK

* Check temperature & shrinkage reinforcement

ACI 318-08 § 7-12-2.1

$A_{T\&S} = 0.0020 bh \leftarrow$ for $f'_c = 4000$ psi

$A_{T\&S} = 0.0020(12)(15) = 0.36$ in²/ft

$\Rightarrow$ Provide # 5 @ 10 in O.C.

$A_{T\&S} = 0.37$ in²/ft > 0.36 in²/ft $\therefore$ OK

Could use #6 @14" for consistency (As = 0.38 in²/ft)

* Crack control

ACI 318-08 § 10.6.4

$S \leq 15\left(\frac{40{,}000}{f_y}\right) - 2.5 C_c$ ← clear cover

$f_y \leftarrow 2/3 f_y$

$S \leq 15\left(\frac{40}{26.66}\right) - 2.5(0.75) = 20.6" > 7"$ $\therefore$ OK

3

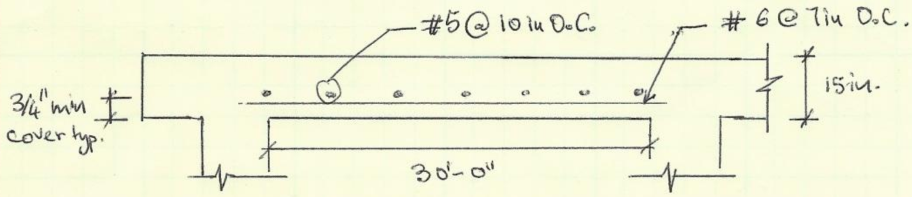
- Check shear $\phi V_c \geq V_u$

$$\phi V_c = \phi (2\sqrt{f'_c})\, b_w\, d$$

$$= 0.9 (2\sqrt{4})(12)(13.875) = 599^k$$

$$\phi V_c = 599^k \geq V_u = 6.3\,k = \quad ^k \quad \therefore ok$$

- Sketch



F
L
E
X
U
R
E
7.2

FLEXURE 7.2—Design moment strength ϕM_n for sections 12 in. wide; f'_c = 4000 psi

Reference: ACI 318-89 Sections 9.3.2, 10.2, and 10.3.1–10.3.3 and ACI 318R-89 Sections 10.3.1 and 10.3.3

$$\phi M_n = \phi\left[A_s f_y d\left(1 - 0.59\rho\frac{f_y}{f'_c}\right)\right] \Big/ 12{,}000 \text{ ft-kips; } \phi = 0.90$$

f_y, psi	ρ	d, in.																ρ
		3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	
	0.002	0.6	0.9	1.1	1.4	1.8	2.2	2.6	3.0	3.5	4.6	5.8	7.1	8.6	10.2	12.0	13.9	0.002
	0.003	1.0	1.3	1.7	2.1	2.7	3.2	3.8	4.5	5.2	6.8	8.6	10.6	12.8	15.3	17.9	20.8	0.003
	0.004	1.3	1.7	2.2	2.8	3.5	4.3	5.1	5.9	6.9	9.0	11.4	14.1	17.0	20.2	23.8	27.6	0.004
	0.005	1.6	2.1	2.8	3.5	4.4	5.3	6.3	7.4	8.6	11.2	14.1	17.5	21.1	25.2	29.5	34.2	0.005
	0.006	1.9	2.6	3.3	4.2	5.2	6.3	7.5	8.8	10.2	13.3	16.9	20.8	25.2	30.0	35.2	40.8	0.006
	0.007	2.2	3.0	3.9	4.9	6.0	7.3	8.7	10.2	11.8	15.5	19.6	24.2	29.2	34.8	40.8	47.4	0.007
	0.008	2.5	3.4	4.4	5.6	6.9	8.3	9.9	11.6	13.4	17.6	22.2	27.4	33.2	39.5	46.4	53.8	0.008
	0.009	2.8	3.8	4.9	6.2	7.7	9.3	11.0	13.0	15.0	19.6	24.9	30.7	37.1	44.2	51.8	60.1	0.009
	0.010	3.0	4.1	5.4	6.9	8.5	10.2	12.2	14.3	16.6	21.7	27.4	33.9	41.0	48.8	57.3	66.4	0.010
	0.011	3.3	4.5	5.9	7.5	9.3	11.2	13.3	15.6	18.1	23.7	30.0	37.0	44.8	53.3	62.6	72.6	0.011
	0.012	3.6	4.9	6.4	8.1	10.0	12.1	14.5	17.0	19.7	25.7	32.5	40.1	48.6	57.8	67.8	78.7	0.012
	0.013	3.9	5.3	6.9	8.8	10.8	13.1	15.6	18.3	21.2	27.7	35.0	43.2	52.3	62.2	73.0	84.7	0.013
	0.014	4.2	5.7	7.4	9.4	11.6	14.0	16.6	19.5	22.7	29.6	37.5	46.2	55.9	66.6	78.1	90.6	0.014
40,000	0.015	4.4	6.0	7.9	10.0	12.3	14.9	17.7	20.8	24.1	31.5	39.9	49.2	59.6	70.9	83.2	96.5	0.015
	0.016	4.7	6.4	8.3	10.6	13.0	15.8	18.8	22.0	25.6	33.4	42.3	52.2	63.1	75.1	88.2	102.2	0.016
	0.017	5.0	6.7	8.8	11.1	13.8	16.7	19.8	23.3	27.0	35.2	44.6	55.1	66.6	79.3	93.1	107.9	0.017
	0.018	5.2	7.1	9.3	11.7	14.5	17.5	20.9	24.5	28.4	37.1	46.9	57.9	70.1	83.4	97.9	113.5	0.018
	0.019	5.5	7.4	9.7	12.3	15.2	18.4	21.9	25.7	29.8	38.9	49.2	60.7	73.5	87.5	102.6	119.0	0.019
	0.020	5.7	7.8	10.2	12.9	15.9	19.2	22.9	26.8	31.1	40.6	51.4	63.5	76.8	91.4	107.3	124.5	0.020
	0.022	6.2	8.4	11.0	14.0	17.2	20.8	24.8	29.1	33.8	44.1	55.8	68.9	83.4	99.2	116.5	135.1	0.022
	0.024	6.7	9.1	11.9	15.0	18.5	22.4	26.7	31.3	36.3	47.5	60.1	74.2	89.7	106.8	125.3	145.4	0.024
	0.026	7.1	9.7	12.7	16.0	19.8	24.0	28.5	33.5	38.8	50.7	64.2	79.2	95.9	114.1	133.9	155.3	0.026
	0.028	7.6	10.3	13.5	17.0	21.0	25.5	30.3	35.6	41.2	53.9	68.2	84.1	101.8	121.2	142.2	164.9	0.028
	0.030	8.0	10.9	14.2	18.0	22.2	26.9	32.0	37.6	43.6	56.9	72.0	88.9	107.5	128.0	150.2	174.2	0.030
	0.032	8.4	11.4	15.0	18.9	23.4	28.3	33.6	39.5	45.8	59.8	75.7	93.5	113.1	134.6	157.9	183.2	0.032
	0.034	8.8	12.0	15.7	19.8	24.5	29.6	35.2	41.3	47.9	62.6	79.3	97.8	118.4	140.9	165.4	191.8	0.034
	0.036	9.2	12.5	16.3	20.7	25.5	30.9	36.7	43.1	50.0	65.3	82.7	102.1	123.5	147.0	172.5	200.1	0.036
	ρ_{max}	9.4	12.8	16.7	21.1	26.1	31.6	37.6	44.1	51.1	66.8	84.5	104.4	126.3	150.3	176.4	204.6	0.037
	0.002	0.8	1.1	1.4	1.8	2.2	2.7	3.2	3.7	4.3	5.7	7.2	8.9	10.7	12.8	15.0	17.4	0.002
	0.003	1.2	1.6	2.1	2.7	3.3	4.0	4.8	5.6	6.5	8.4	10.7	13.2	16.0	19.0	22.3	25.9	0.003
	0.004	1.6	2.1	2.8	3.5	4.4	5.3	6.3	7.4	8.6	11.2	14.1	17.5	21.1	25.2	29.5	34.2	0.004
	0.005	2.0	2.7	3.5	4.4	5.4	6.6	7.8	9.2	10.6	13.9	17.6	21.7	26.2	31.2	36.6	42.5	0.005
	0.006	2.3	3.2	4.1	5.2	6.5	7.8	9.3	10.9	12.6	16.5	20.9	25.8	31.2	37.2	43.6	50.6	0.006
	0.007	2.7	3.7	4.8	6.0	7.5	9.0	10.8	12.6	14.6	19.1	24.2	29.9	36.1	43.0	50.5	58.6	0.007
	0.008	3.0	4.1	5.4	6.9	8.5	10.2	12.2	14.3	16.6	21.7	27.4	33.9	41.0	48.8	57.3	66.4	0.008
	0.009	3.4	4.6	6.0	7.7	9.5	11.4	13.6	16.0	18.5	24.2	30.6	37.8	45.8	54.4	63.9	74.1	0.009
	0.010	3.8	5.1	6.7	8.4	10.4	12.6	15.0	17.6	20.4	26.7	33.8	41.7	50.4	60.0	70.4	81.7	0.010
	0.011	4.1	5.6	7.3	9.2	11.4	13.8	16.4	19.2	22.3	29.1	36.8	45.5	55.0	65.5	76.9	89.1	0.011
	0.012	4.4	6.0	7.9	10.0	12.3	14.9	17.7	20.8	24.1	31.5	39.9	49.2	59.6	70.9	83.2	96.5	0.012
50,000	0.013	4.8	6.5	8.5	10.7	13.2	16.0	19.0	22.3	25.9	33.9	42.8	52.9	64.0	76.2	89.4	103.7	0.013
	0.014	5.1	6.9	9.0	11.4	14.1	17.1	20.3	23.9	27.7	36.2	45.8	56.5	68.4	81.4	95.5	110.7	0.014
	0.015	5.4	7.4	9.6	12.2	15.0	18.2	21.6	25.4	29.4	38.4	48.6	60.0	72.6	86.4	101.5	117.7	0.015
	0.016	5.7	7.8	10.2	12.9	15.9	19.2	22.9	26.8	31.1	40.6	51.4	63.5	76.8	91.4	107.3	124.5	0.016
	0.017	6.0	8.2	10.7	13.5	16.7	20.2	24.1	28.3	32.8	42.8	54.2	66.9	81.0	96.3	113.1	131.1	0.017
	0.018	6.3	8.6	11.2	14.2	17.6	21.2	25.3	29.7	34.4	45.0	56.9	70.2	85.0	101.2	118.7	137.7	0.018
	0.019	6.6	9.0	11.8	14.9	18.4	22.2	26.5	31.1	36.0	47.1	59.6	73.5	89.0	105.9	124.2	144.1	0.019
	0.020	6.9	9.4	12.3	15.5	19.2	23.2	27.6	32.4	37.6	49.1	62.1	76.7	92.8	110.5	129.7	150.4	0.020
	0.022	7.5	10.2	13.3	16.8	20.7	25.1	29.9	35.0	40.6	53.1	67.2	82.9	100.4	119.4	140.2	162.6	0.022
	0.024	8.0	10.9	14.2	18.0	22.2	26.9	32.0	37.6	43.6	56.9	72.0	88.9	107.5	128.0	150.2	174.2	0.024
	0.026	8.5	11.6	15.1	19.1	23.6	28.6	34.0	40.0	46.3	60.5	76.6	94.6	114.4	136.2	159.8	185.3	0.026
	ρ_{max}	8.9	12.1	15.8	20.0	24.7	29.9	35.5	41.7	48.4	63.2	80.0	98.7	119.5	142.2	166.9	193.5	0.027
	0.002	1.0	1.3	1.7	2.1	2.7	3.2	3.8	4.5	5.2	6.8	8.6	10.6	12.8	15.3	17.9	20.8	0.002
	0.003	1.4	1.9	2.5	3.2	3.9	4.8	5.7	6.7	7.7	10.1	12.8	15.8	19.1	22.7	26.7	30.9	0.003
	0.004	1.9	2.6	3.3	4.2	5.2	6.3	7.5	8.8	10.2	13.3	16.9	20.8	25.2	30.0	35.2	40.8	0.004
	0.005	2.3	3.2	4.1	5.2	6.5	7.8	9.3	10.9	12.6	16.5	20.9	25.8	31.2	37.2	43.6	50.6	0.005
	0.006	2.8	3.8	4.9	6.2	7.7	9.3	11.0	13.0	15.0	19.6	24.9	30.7	37.1	44.2	51.8	60.1	0.006
	0.007	3.2	4.3	5.7	7.2	8.9	10.7	12.8	15.0	17.4	22.7	28.7	35.5	42.9	51.1	59.9	69.5	0.007
	0.008	3.6	4.9	6.4	8.1	10.0	12.1	14.5	17.0	19.7	25.7	32.5	40.1	48.6	57.8	67.8	78.7	0.008
	0.009	4.0	5.5	7.2	9.1	11.2	13.5	16.1	18.9	21.9	28.6	36.2	44.7	54.1	64.4	75.6	87.7	0.009
	0.010	4.4	6.0	7.9	10.0	12.3	14.9	17.7	20.8	24.1	31.5	39.9	49.2	59.6	70.9	83.2	96.5	0.010
60,000	0.011	4.8	6.6	8.6	10.9	13.4	16.2	19.3	22.7	26.3	34.3	43.4	53.6	64.9	77.2	90.6	105.1	0.011
	0.012	5.2	7.1	9.3	11.7	14.5	17.5	20.9	24.5	28.4	37.1	46.9	57.9	70.1	83.4	97.9	113.5	0.012
	0.013	5.6	7.6	9.9	12.6	15.5	18.8	22.4	26.2	30.4	39.8	50.3	62.1	75.2	89.5	105.0	121.8	0.013
	0.014	6.0	8.1	10.6	13.4	16.6	20.0	23.8	28.0	32.5	42.4	53.6	66.2	80.1	95.4	111.9	129.8	0.014
	0.015	6.3	8.6	11.2	14.2	17.6	21.2	25.3	29.7	34.4	45.0	56.9	70.2	85.0	101.2	118.7	137.7	0.015
	0.016	6.7	9.1	11.9	15.0	18.5	22.4	26.7	31.3	36.3	47.5	60.1	74.2	89.7	106.8	125.3	145.4	0.016
	0.017	7.0	9.6	12.5	15.8	19.5	23.6	28.1	33.0	38.2	49.9	63.2	78.0	94.4	112.3	131.8	152.9	0.017
	0.018	7.4	10.0	13.1	16.5	20.4	24.7	29.4	34.5	40.0	52.3	66.2	81.7	98.9	117.7	138.1	160.2	0.018
	0.019	7.7	10.5	13.7	17.3	21.3	25.8	30.7	36.1	41.8	54.6	69.1	85.3	103.3	122.9	144.2	167.3	0.019
	0.020	8.0	10.9	14.2	18.0	22.2	26.9	32.0	37.6	43.6	56.9	72.0	88.9	107.5	128.0	150.2	174.2	0.020
	ρ_{max}	8.4	11.5	15.0	19.0	23.4	28.3	33.7	39.5	45.9	59.0	75.8	93.6	113.3	134.8	158.2	183.5	0.021

For use of this Design Aid, see Flexure Examples 4, 5, and 8.

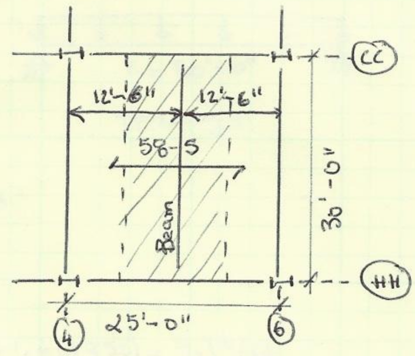
APPENDIX D: HOLLOW CORE PLANKS ON BEAM

1

Proposed Floor System: Hollow-core

Try 4'-0" x 8" Hollow core with 2" topping.

SDL = 30 psf
LL = 100 psf



Slab weight = $\frac{(2)(12)}{144} \times 150 = 25$ psf

W = 30 + 100 + 25 = 155 psf

Span = 25'-0"

$f'_c = 5{,}000$ psi

$f_{pu} = 270{,}000$ psi

For a design span of 25 ft,

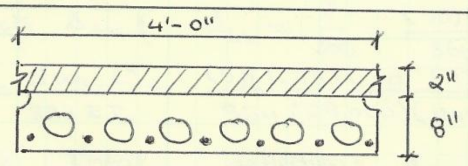
Try 4'-0" x 8" Hollow-core with 2" normal weight topping with 58-S strand: (PCI Design Handbook)

177 psf > 155 psf ∴ ok

Section properties

A = 233 in² y_b = 5.16 in   I = 3,205 in⁴
wt = 86 psf

USE 58-S strand 4'-0" x 8" Hollow-core with 2" NW topping



2

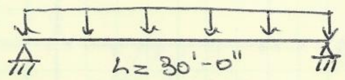
Beam Supporting Hollow core Floor

4'-0" X 8" Hollow core

Span = 30'-0"

f'_c = 5,000 psi

f_{pu} = 270,000 psi



Spacing=

Loads

LL = 100 psf

SDL = 30 psf

Floor DL = 86 psf ← includes slab wt

DL = (86 + 30)(12.5) = 1450 plf

LL = (100)(12.5) = 1250 plf

Factored loads: $W_u = 1.2(1450) + 1.6(1250) = 3.7^k/ft$

$$V_u = \frac{wL}{2} = \frac{(3.7)(30)}{2} = 55.5^K$$

$$M_u = \frac{wL^2}{8} = \frac{(3.7)(30)^2}{8} = 416 \text{ ft-K}$$

Using Z_x - table (table 3-2 Steel Manual)

Try W 21 X 55 $\phi M = 473$ ft-K > 416 ft-K ∴ OK

$\phi V = 234^K > 55.5^K$ ∴ OK

For compact section

- **Section properties**

$A_g = 16.2 \text{ in}^2$ $I_x = 1140 \text{ in}^4$ $F_y = 50$ ksi

- **Check Δ_{LL}:** $\Delta_{LL} = \frac{l}{360} = \frac{(30)(12)}{360} = 1.0$ in

$$\Delta_{LL} = \frac{5 w_{LL} L^4}{384 E I_x} = \frac{(5)(1.25)(30)^4(1728)}{384(29{,}000)(1140)} = 0.69 \text{ in} < 1.0 \text{ in} \therefore OK$$

- **Check Total deflection:** $\Delta_{TL} = \frac{L}{240} = \frac{(30)(12)}{240} = 1.5$ in

$$\Delta_{TL} = \frac{(5)(2.7)(30)^4(1728)}{384(29{,}000)(1140)} = 1.48 \text{ in} < 1.5 \text{ in} \therefore OK$$

USE W 21 X 55

Strand Pattern Designation
76-S

- S = straight
- Diameter of strand in 16ths
- No. of Strand (7)

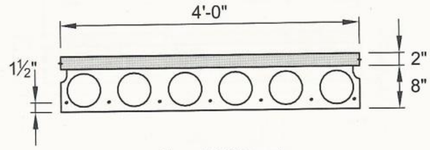
Safe loads shown include dead load of 10 psf for untopped members and 15 psf for topped members. Remainder is live load. Long-time cambers include superimposed dead load but do not include live load.

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

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

HOLLOW-CORE

4′-0″ x 8″
Normal Weight Concrete



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

Section Properties

		Untopped		Topped	
A	=	215	in.^{2}	311	in.^{2}
I	=	1,666	in.^{4}	3,071	in.^{4}
y_b	=	4.00	in.	5.29	in.
y_t	=	4.00	in.	4.71	in.
S_b	=	417	in.^{3}	581	in.^{3}
S_t	=	417	in.^{3}	652	in.^{3}
wt	=	224	plf	324	plf
DL	=	56	psf	81	psf
V/S	=	1.92	in.		

4HC8

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

Strand Designation Code	Span, ft																													
	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
66-S	458	415	378	346	311	269	234	204	179	158	140	124	110	98	87	77	69	61	54	48	43	38	33	29						
	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.1	0.0	0.0	−0.1	−0.2	−0.3	−0.5	−0.6						
	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.1	0.0	−0.1	−0.2	−0.3	−0.5	−0.7	−0.9	−1.2	−1.4						
76-S	470	424	387	355	326	303	276	242	213	188	167	149	133	119	106	95	86	77	69	62	55	50	44	39	35	31	26			
	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.2	0.2	0.1	0.0	−0.1	−0.2	−0.4	−0.5	−0.7	−0.9			
	0.2	0.2	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.2	0.1	0.0	−0.1	−0.2	−0.4	−0.6	−0.8	−1.1	−1.4	−1.7	−2.0			
58-S	464	421	384	352	323	300	280	260	244	229	211	194	177	160	144	130	118	107	97	88	80	72	66	60	54	48	42	37	32	28
	0.2	0.2	0.3	0.3	0.3	0.4	0.4	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.6	0.6	0.6	0.5	0.5	0.5	0.4	0.3	0.2	0.1	0.0	−0.4	−0.3	−0.5	−0.7	−0.9
	0.3	0.3	0.4	0.4	0.5	0.5	0.6	0.6	0.6	0.7	0.7	0.7	0.7	0.7	0.7	0.6	0.6	0.5	0.4	0.3	0.2	0.0	−0.2	−0.4	−0.6	−0.9	−1.2	−1.6	−2.0	−2.4
68-S	476	430	393	361	332	309	286	269	253	235	223	209	200	180	165	153	142	132	121	110	101	92	84	77	70	63	56	51	45	40
	0.3	0.3	0.3	0.4	0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.7	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.7	0.7	0.6	0.5	0.4	0.2	0.1	−0.1	−0.3
	0.3	0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.8	0.8	0.9	0.9	1.0	1.0	1.0	1.0	0.9	0.9	0.9	0.8	0.7	0.6	0.4	0.2	0.0	−0.2	−0.5	−0.8	−1.1	−1.5
78-S	488	442	402	370	341	318	295	275	259	241	229	215	203	195	180	168	157	144	135	126	118	110	101	92	84	77	70	64	58	52
	0.3	0.3	0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.8	0.9	0.9	1.0	1.0	1.0	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.0	0.9	0.8	0.7	0.6	0.5	0.3
	0.4	0.5	0.5	0.6	0.7	0.8	0.8	0.9	1.0	1.0	1.1	1.2	1.2	1.2	1.3	1.3	1.3	1.3	1.3	1.2	1.2	1.1	1.0	0.8	0.7	0.5	0.3	0.0	−0.3	−0.7

4HC8 + 2

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

Strand Designation Code	Span, ft																											
	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
66-S	489	445	394	340	294	256	224	197	173	153	135	119	105	93	82	68	56	45	36	26								
	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.1	0.0	−0.0	−0.1	−0.2	−0.3								
	0.2	0.2	0.2	0.2	0.2	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	−1.2	−1.4								
76-S	498	457	420	387	347	304	267	235	208	184	164	146	130	116	103	88	74	62	51	41	31							
	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.2	0.2	0.1	−0.0	−0.1	−0.2							
	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.1	0.0	−0.1	−0.2	−0.4	−0.5	−0.7	−0.9	−1.2	−1.4							
58-S	492	451	414	384	357	333	310	293	274	245	219	196	177	159	143	126	110	95	82	70	59	49	40	32				
	0.3	0.3	0.3	0.4	0.4	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.6	0.6	0.6	0.5	0.5	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	0.5	0.5	0.5	0.5	0.4	0.3	0.3	0.3	0.2	0.1	−0.1	−0.2	−0.4	−0.6	−0.9	−1.2	−1.5	−1.8				
68-S		463	426	393	366	342	319	299	282	267	251	239	216	195	177	158	140	124	110	97	84	73	62	53	44	36	28	
		0.4	0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.7	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.7	0.7	0.6	0.5	0.4	0.2	0.1	−0.1	
		0.4	0.5	0.5	0.6	0.6	0.6	0.6	0.7	0.7	0.7	0.6	0.6	0.6	0.5	0.4	0.3	0.2	0.0	−0.2	−0.4	−0.6	−0.9	−1.2	−1.6	−2.0	−2.4	
78-S		472	435	402	375	348	325	305	288	273	257	245	232	220	207	186	167	149	133	119	106	94	83	73	64	55	46	38
		0.5	0.5	0.6	0.6	0.7	0.7	0.8	0.9	0.9	1.0	1.0	1.0	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.0	0.9	0.9	0.7	0.6	0.5	0.3
		0.5	0.6	0.6	0.7	0.7	0.8	0.8	0.8	0.9	0.9	0.9	0.9	0.8	0.8	0.7	0.7	0.6	0.4	0.3	0.1	−0.1	−0.3	−0.6	−0.9	−1.3	−1.7	−2.2

Strength is based on strain compatibility; bottom tension is limited to $7.5\sqrt{f'_c}$ *; see pages 2–7 through 2–10 for explanation.*

APPENDIX E: FLOOR PLANS

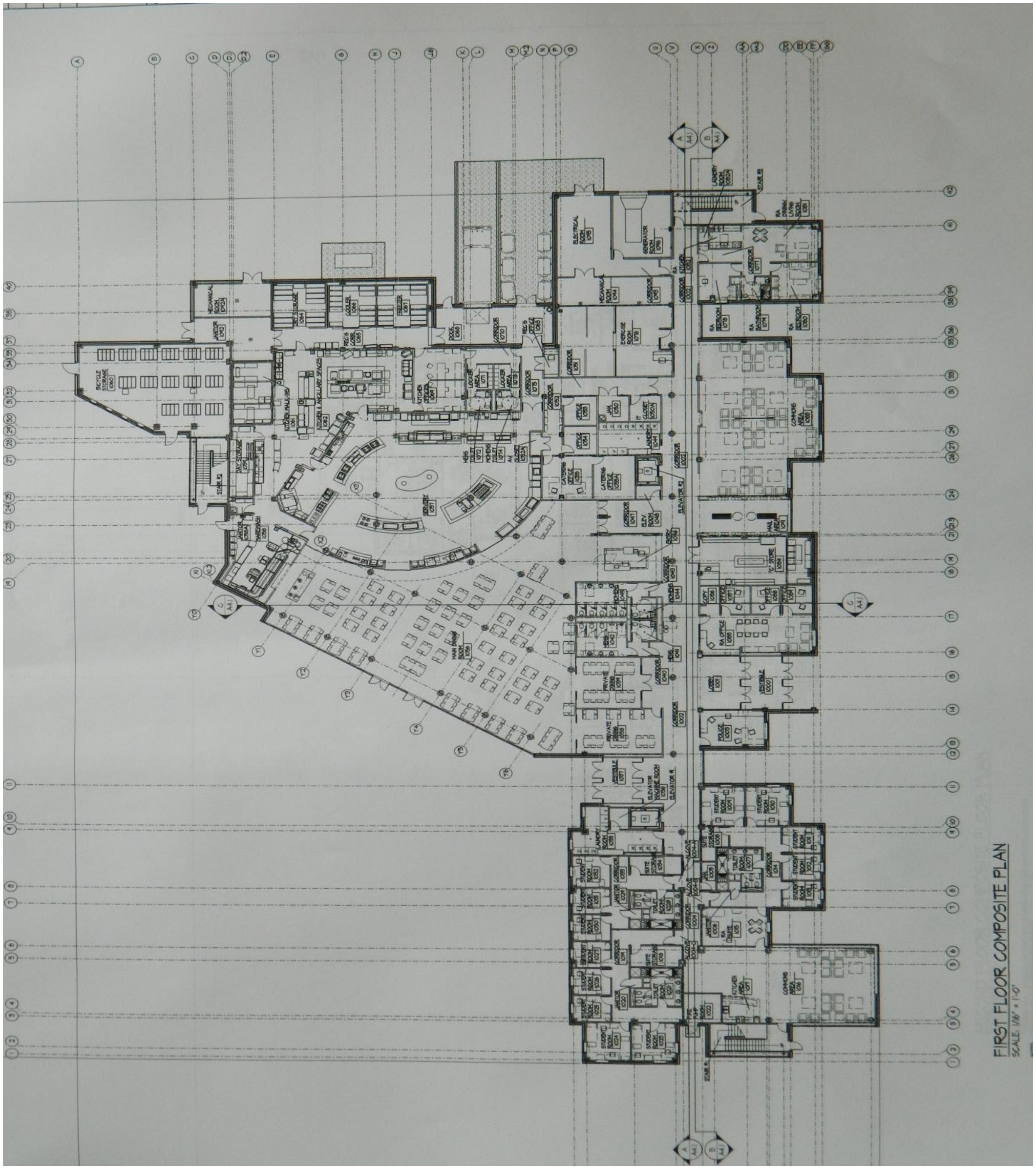


Figure 17: Ground floor

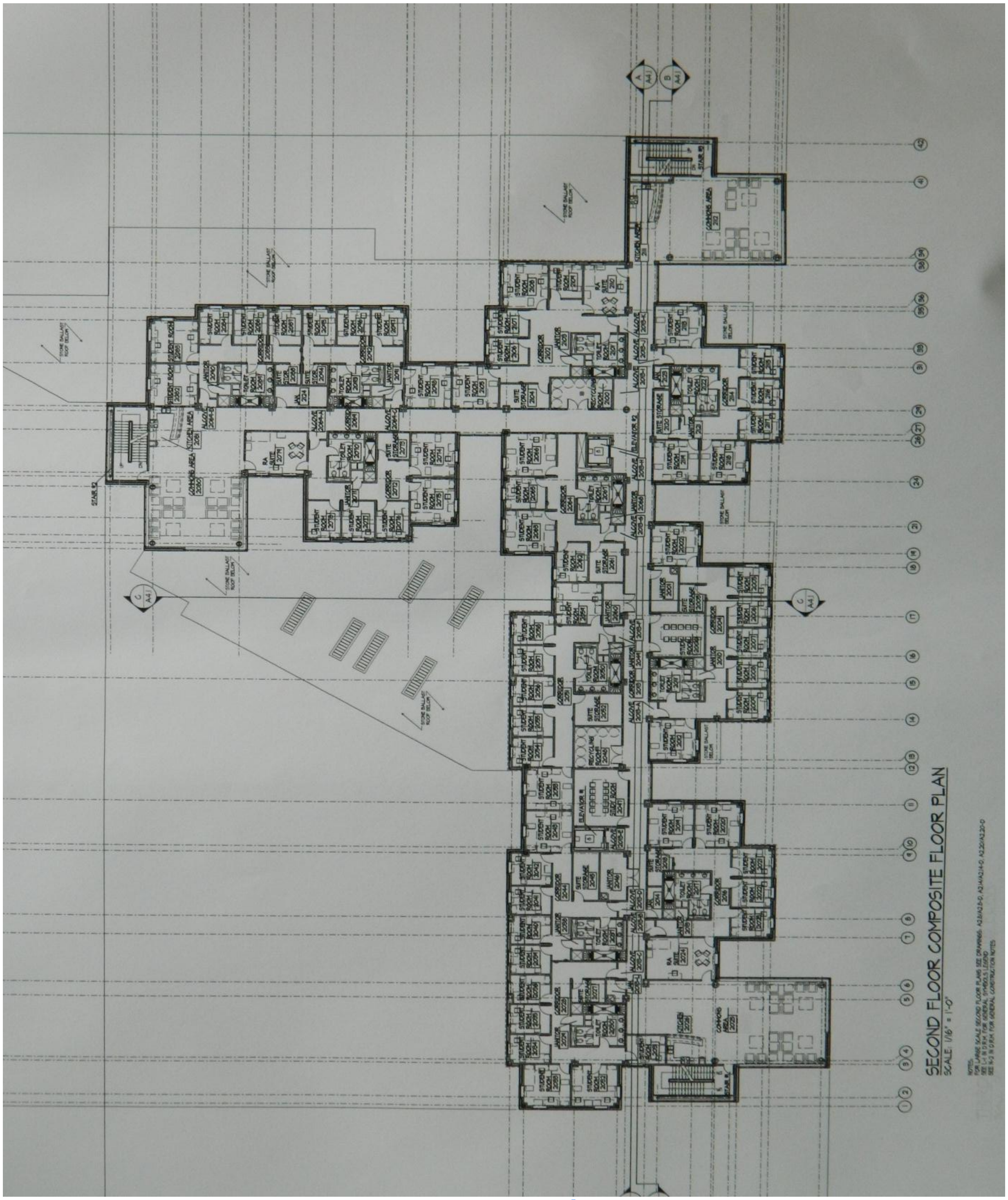


Figure 18: Upper Floors