UNIVERSITY OF ROCHESTER
BME / OPTICS BUILDING

TECHNICAL ASSIGNMENT 2

Structural Study of Alternative Floor Systems

October 27, 2006

MIKE STEEHLER
PENNSYLVANIA STATE UNIVERSITY
ARCHITECTURAL ENGINEERING
STRUCTURAL OPTION
AE 481W – SENIOR THESIS
ADVISOR: PROF. KEVIN PARFITT

TABLE OF CONTENTS

EXECUTIVE SUMMARY

The goal of this report is to investigate alternative floor systems for the University of Rochester BME/Optics Building in Rochester, NY. Preliminary analysis based on design loads will determine approximate sizes of each alternative system. Each system will then be examined in terms of performance, constructability, and cost to determine which need further investigation and which are not feasible for this building.

The current floor system is composite steel beams with non-composite steel girders. The alternative systems analyzed in this report are:

1. Non-composite steel beams
2. Composite and non-composite steel joists
3. Flat slab cast-in-place concrete
4. Precast double-tee
5. Precast hollow-core plank

The current composite steel system is economical, efficient, and well suited to meet the needs of this unique building. The current system provides adequate strength required for the high design loads, meets all serviceability criteria for the laboratory environments, and is laid out in such a way to meet the architects' spatial challenges.

Some of the alternative systems investigated were simply uneconomical to meet the strength and performance requirements of this building. Fireproofing and vibration damping of steel joists is difficult and expensive. Using larger, non-composite steel beams instead of the current composite design would work, but would be more expensive. Finally, precast double-tee worked fine for the bay analyzed. But when considering the shape and conditions of the entire building, this system was complicated and inefficient. These three alternative floor systems were ruled out as feasible possibilities for this building.

Other systems seemed to work well with this building, and may be investigated further. The inherent fireproofing properties, strength and deflection control with a shallow floor depth, and ease of construction made precast hollow-core plank a viable alternative. Unlike double-tee, this type of system can be economical without extremely long spans. Also, the flexibility of cast-in-place concrete made flat slab construction probably the best alternative floor system. Although more labor intensive than the current steel system, cast-in-place concrete has a short lead time, inherent fireproofing and vibration damping, and is a shallow system. Flat slab and hollow-core plank have been deemed feasible alternatives at this point, and may be investigated further.

INTRODUCTION/SCOPE

The scope of this report is limited to preliminary investigation of alternative structural floor systems for the BME/Optics Building. The actual system designed by industry professionals for this building was explored, analyzed, and confirmed in a previous report. Composite steel framing was chosen for a variety of reasons, which will be made clear later in this report. This system was found to be effective and efficient in meeting all criteria of the project.

This report is intended to explore alternative floor system options for educational purposes only. Each alternative floor system will be *approximated* using preliminary design assumptions. Since this building is not uniform or symmetrical, there is no “typical bay” that is representative of the conditions of the entire building. For the purposes of this report, a “critical bay” will be used, which is the bay with the longest spans and highest design loads. It is a typical bay in the sense that it repeats along the west end of the building on floors 2 – 5. (See Figures 1-2)

All the possible floor systems will then be analyzed and compared in terms of feasibility, economy, and overall effects on the project. The results will be used to determine whether it is worthwhile to investigate each of the alternative floor systems further.

DESIGN CONSIDERATIONS

Since this facility will be used for the Biomedical Engineering and Optics Departments at the University of Rochester, there are a few unique design considerations. The facility includes laboratory space that is sensitive to building movements and requires a high performance of the building in serviceability. Deflection and vibration requirements will be taken into account when comparing floor system options.

It should be noted that this building has a variety of spaces, and the architectural and structural layout caters to the functionality of the building. For this reason, the column layout cannot easily be altered without having considerable impact on the intended use of spaces. For the purposes of this report, the column layout will not be changed. When a chosen floor system design is developed further in a later report, however, minor adjustments may be made if necessary.

It should also be noted that the BME/Optics Building is built adjacent to the existing Wilmot Hall on two sides. Although the floors in the current design do not line up exactly with those of Wilmot Hall, there is still some functionality between the two buildings. Therefore, reducing floor-to-floor heights significantly may not necessarily be a benefit. This will also be considered in more detail in later reports.

CURRENT BUILDING DESIGN

The University of Rochester Biomedical Engineering / Optics Building is a five-story steel framed structure with an additional mechanical penthouse and partial basement. It consists of mainly of laboratory and office space, with some classrooms. Its unique footprint is due to spatial requirements and architectural consideration of Wilmot Hall, an existing building adjacent to the BME/Optics Building on two sides. An enclosed pedestrian bridge at the second floor connects to the nearby CSB Building. The exterior of the building consists of brick façade with the exception of limestone at the first level, channel glass at stairwells, and glass curtain wall at main entrances. The architectural hallmark of the BME/O Building is the 80’ atrium inside the main entrance, lit by skylights, with cantilevered stairs that appear to be floating. See Figure 1 on p.4 for building footprint and typical column layout.

Foundation

The foundation system used in this building consists of pile caps supported by 50 ksi steel H-piles bearing on bedrock. There are several different pile configurations, but they all use HP steel shapes with a maximum size of HP10x57. The pile caps have a design lateral load capacity of 4 kips each.

The foundation system also uses grade beams at different sections of the building. All exterior walls are supported by grade beams, typically 16"x 48", with some variations in size. An existing steam/utility tunnel running under the footprint of the building is framed around by grade beams 24"x 54" and 18"x 24". Since this tunnel supplies several buildings on this section of campus, its complete functionality throughout construction of BME/O was an important design consideration. Concrete for pile caps and grade beams is normal weight with design strength of 4000 psi. All reinforcement conforms to ASTM A615 Grade 60.

Gravity System

The columns used in this building are predominately W12 shapes, ranging in weight from 40 lb/ft supporting the roof to 120 lb/ft at moment frames. Most of the columns supporting the roof above the mechanical penthouse level do not line up with columns below. W21 transfer girders distribute this roof load to nearby columns.

The typical floor system consists of 4 ½" concrete slabs on 3" composite metal deck. The load is distributed from the slab to composite steel beams, then to non-composite steel girders, and finally down to the columns and foundation. Although the loads are relatively constant throughout the building, the steel shapes vary in size due to varying spans. This is because of the irregular shape of the building and column layout designed to meet architectural and spatial challenges. The column layout is shown in Figure 1.

All structural steel is A992 Grade 50, with the exception of a few HSS columns that are ASTM A500 Grade B (46 ksi). The floor slabs are 4000 psi normal weight concrete, reinforced with 6x6 W2.9xW2.9 welded wire fabric. Slab on grade is 5" thick, 3000 psi concrete with similar WWF reinforcing.

Lateral System

Lateral forces due to wind and seismic loading were important design considerations for the BME/O Building. Since it was built adjacent to the existing Wilmot Hall on two sides, the lateral deflection was especially important. At these locations, the steel framing cantilevers out from the columns to form isolation joints that increase in size from the first floor to the roof. Accuracy in lateral calculations was necessary to determine proper clearance.

The system designed by LeMessurier Consultants uses concentric braced frames in the short (E-W) direction, and ordinary moment frames in the long (N-S) direction. There are four similar braced frames in the building using HSS7x7x1/2, 46 ksi steel shapes in the form of chevron bracing. For the purposes of analyzing floor systems in this report, lateral calculations will be ignored. However, the implications that each floor system may have on the lateral system may be considered.

Codes / Design Guides

The current design of the BME/Optics Building conforms to the Building Code of New York State (2002), which references IBC 2000 and ASCE 7-98. Various design guides were mentioned in the general notes section of the design documents. These include ACI and CRSI guides for concrete and various AISC codes, design guides, and provisions for steel framing. A detailed list of all material used is given in Technical Report #1.

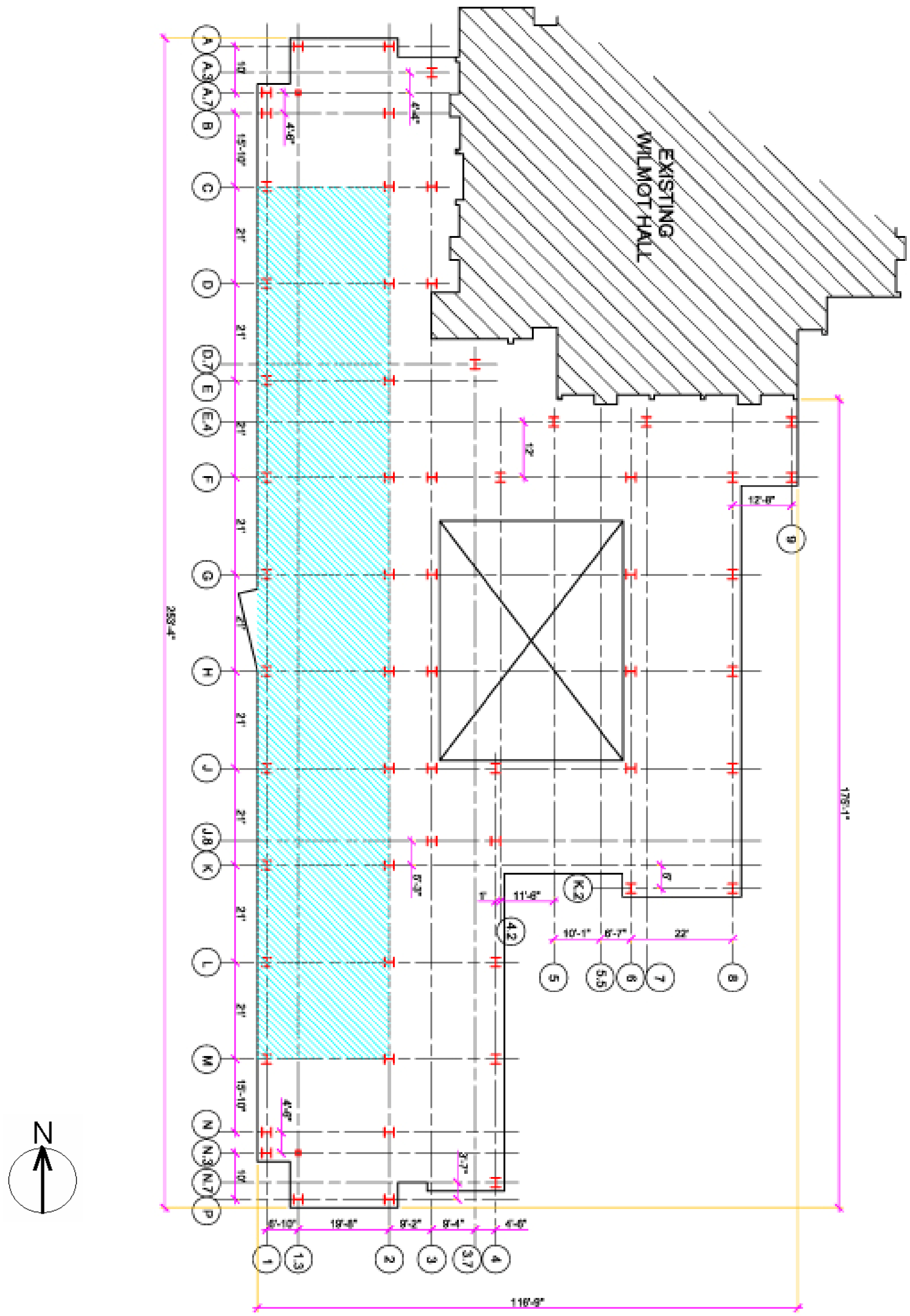


Figure 1 – Typical Column Layout, Floors 2-5, Critical Bays Shaded

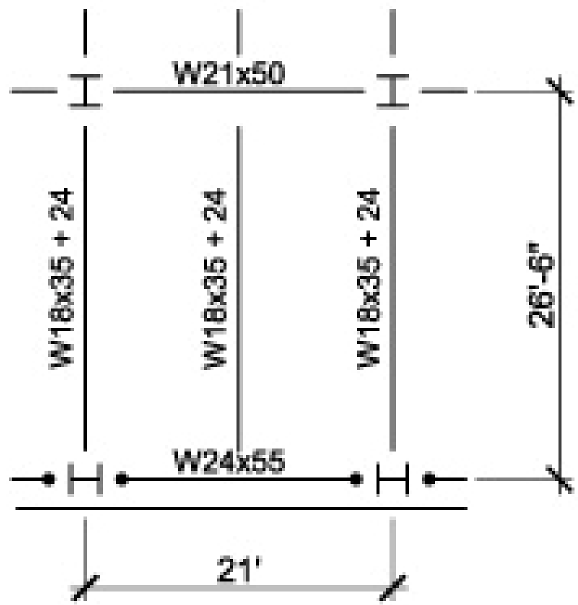


Figure 2 – Critical Bay (solid dots indicate moment connections, "+24" indicates number of ¾" diameter shear studs)

ALTERNATIVE SYSTEM DESIGN ASSUMPTIONS

For the purposes of this report, a critical bay will be analyzed as described before. The dimensions and current design of this bay is shown in Figures 1 and 2 on the following page. The design loads used for this report are based on IBC 2003 and ASCE 7-02. The dead loads vary for each alternative system. See Appendices for actual dead loads and detailed calculations.

<u>Live:</u>	Laboratory Space	80 psf	
	Partition Allowance	20 psf	
<u>Dead:</u>	Floor Slab	150 pcf (thickness varies for each floor system)	
	Metal Deck	3 psf	(where applicable)
	Framing	*varies*	
	Ceiling/Flooring 3 psf		
	MEP Allowance 10 psf		

Note: Because of the location of the critical bay, edge beams/girders must also carry a ? plf dead load for the brick façade. See Figure 2 above for bay layout.

ALTERNATIVE OPTIONS - STEEL

Non-Composite Beams

The current system designed uses primarily composite steel beams and non-composite steel girders. In a previous report, it was determined that the steel beams in the current design were sufficient (or reasonably close) in capacity without composite action. It was predicted that the composite action was used primarily to meet the strict deflection criteria for the total load of L/240, with a maximum of 1".

The material and installation cost of using shear studs can be relatively high since there is so much welding involved. Therefore, the use of non-composite beams for the floor system was investigated. Since the loading conditions and framing dimensions did not change, using non-composite beams would have no significant effect on girder, column, or foundation design. This was performed simply to compare the cost of increasing beam size to the cost of using of shear studs for composite action.

Upon investigation, the typical beam size in the critical bay was found to be W21x48, compared to the current design of W18x35 beams with (24) ¾" shear studs. A simplified method to compare the cost of these options is to use an equivalent weight of steel, assuming one installed shear stud costs the same as a 10-pound increase in the weight of a steel beam. Using this assumption, the composite steel beam was more economical for this project. See Appendix A for detailed calculations.

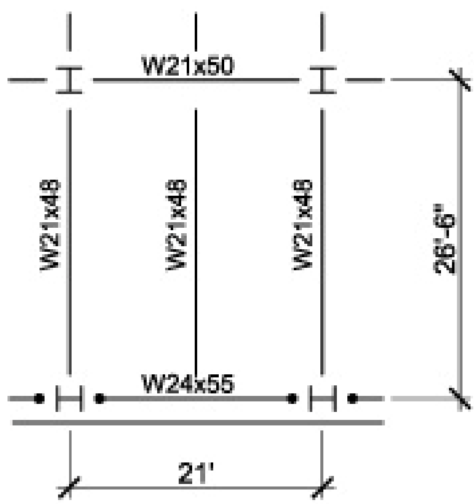


Figure 3 – Non-composite design of critical bay

In terms of scheduling, the composite system is more labor intensive. However, RSMeans Catalog states that composite systems do not have a negative impact on scheduling, as up to 1,000 studs can be installed per day with an adequate workforce.

As stated before, the composite action was used primarily to control deflection of the beams. Another option, rather than increasing beam size, would be to camber the beams. This process gives a slight upward bend in the beams prior to installation. When dead load is applied, the beam flattens, and total load deflection is greatly reduced. Cambering beams, however, is usually expensive and is often avoided by design professionals unless special circumstances dictate it.

Since the use of non-composite steel beams is uneconomical for this project and has no other significant effect on the project, it would not be an ideal choice. Further investigation of a non-composite system is not necessary for this building.

Steel Joists

Both composite and non-composite steel joists were considered using Vulcraft product information.

First I examined the use of non-composite steel joists because of its attractiveness in constructibility. However, K-Series joists by Vulcraft have a limiting constraint of 550 plf. For the bay size and loads used in this building, this would mean large joists with a spacing of 1.5' or 16". Since open-web joists are expensive, this system is uneconomical and probably not feasible. Therefore, non-composite joists were rejected. (See Appendix B)

For the composite joist system, I estimated an equal spacing of 4 joists per bay (7' spacing). 2.5" of concrete on 1.5" deck would be a typical slab size for this spacing based on Vulcraft's guides. Because these systems are light, however, I made a ballpark assumption of an additional 2" of concrete to help control vibration, making a 6" total slab depth. 18" deep joists, maintaining the current system depth would work based on an 1400 lb total load and a 26' span. A VC18 1400 / 700 / 85 designation was chosen as a preliminary design. (See Appendix C)

Any benefits for using a steel joist floor system in this building, however, are outweighed by its disadvantages for the BME/Optics Building. This type of system is traditionally quick and easy to construct. However, using composite action with the steel joists is more expensive and labor intensive, lessening any economic advantages in labor. Also, steel joists are not easily fireproofed like regular steel beams. The most effective way to accomplish this is with a gypsum barrier, which means additional cost and labor, as well as changing the architect's ceiling plan. In a high-risk laboratory environment that is also an educational facility, fire protection is an important consideration. The current system uses a 2-hour rating on all beams and columns. This rating is extremely difficult (and expensive) to obtain with steel joists. Lastly, in order to reduce vibrations, special design actions must be taken, such as stiffening joists and increasing slab thickness according to Vulcraft. These factors make steel joists even more expensive and unreasonable for this application. Joists are usually most effective in applications with lower design loads, such as roofs.

Non-composite steel joists were inadequate in capacity for this building unless the spacing is greatly reduced. Composite joists will not be further investigated because of their poor performance in fire protection and vibration, and their lack of significant advantages to counteract these downfalls.

ALTERNATIVE OPTIONS - CONCRETE

Cast-In-Place: Flat Slab

One-way cast-in-place floor systems are usually most efficient in narrow (aspect ratio of 2:1 or greater) rectangular bays and in symmetrical, repeating applications where formwork can be reused. Two-way systems, on the other hand, generally work better in square bays. Of these two-way systems, flat plate is extremely economical for smaller spans and lower design loads, whereas waffle slabs can provide much longer spans. There are also flat slab systems, which are similar to flat plate, except with drop panels or column capitals to resist punching shear around columns, thus providing higher design load capacity. Flat slab with drop panels seemed to be the most suited for the BME/Optics Building.

For an estimated size of the system, I used the CRSI Manual charts in Chapter 10. Approximating the bay as 25' square with 200 psf superimposed load (100 psf live /13 psf dead, factored), I found the total slab depth to be 8.5", with 8'-4" square, 7" deep drop panels at the columns. The slab uses #5 reinforcing bars, with a total steel weight of 3.10 psf. This two-way floor system is supported by 15" square columns. (See Appendix D)

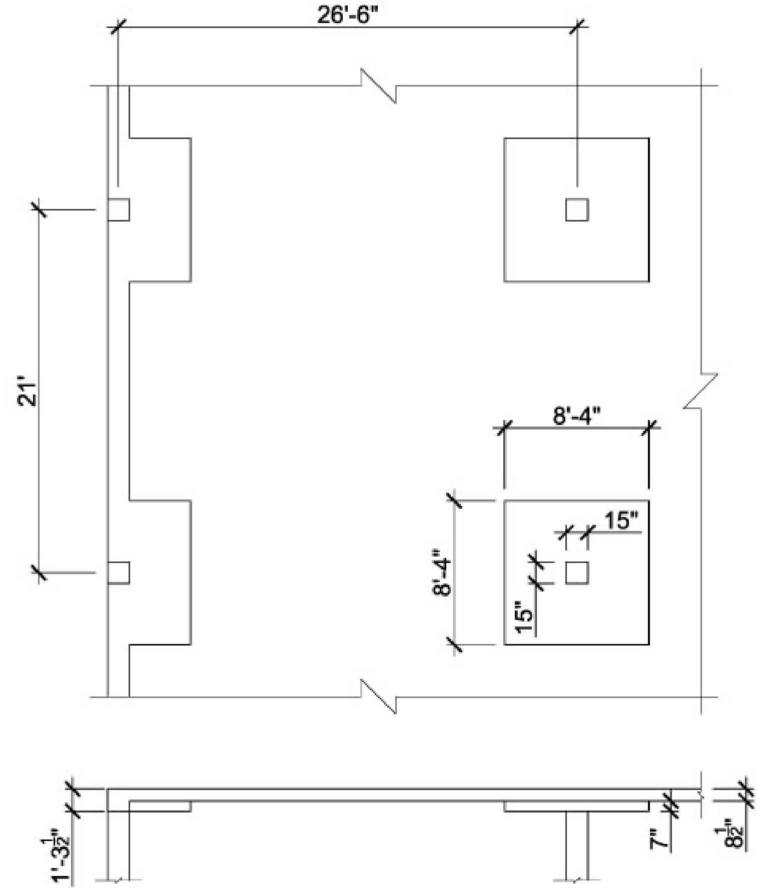


Figure 4 – Flat Slab Design of Critical Bay (see Appendix D for reinforcing size and spacing)

In the steel system, the girders at the edge of the building support the exterior brick façade. This additional dead load cannot be carried by the two-way flat slab system alone according to CRSI charts. Edge beams, equal in width to the columns, and equal in depth to the drop panels would need to be cast-in to carry the additional weight. This is common in cast-in-place buildings and relatively easy to construct.

There are several advantages to two-way cast-in-place concrete floor systems. For this building, the added weight of the overall system would provide excellent vibration damping, which was an important design consideration. It is likely that this system would meet the criteria without additional design actions taken. Also, concrete is a naturally fire-resistive material. This system is more than adequate in meeting the fire requirements of the building, and would provide a safer system in a high-risk laboratory space.

In addition to performance, cast-in-place concrete has advantages in scheduling and economy. Flat slab systems are much easier to construct than other cast-in-place systems (like waffle slabs) and the formwork can be reused to keep the construction process moving. There is no lead time in cast-in-place structures, so construction can progress much quicker in the early stages. In a design-bid-build approach with a set deadline, this can have a very significant impact.

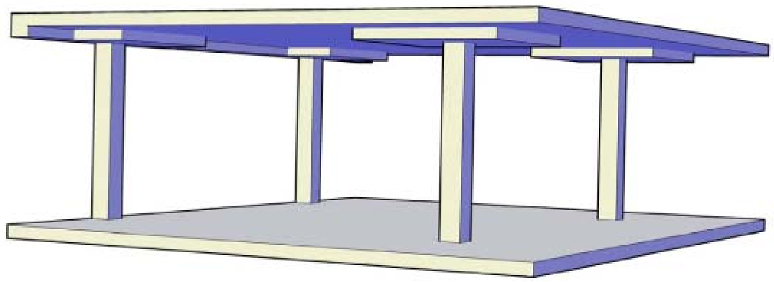


Figure 5 – Typical flat slab construction in 3D with drop panels at the columns to resist punching shear and an edge beam to support façade weight

Also, the depth of the floor system is less than that of the steel systems analyzed. This provides more plenum space for the extensive mechanical and plumbing needs of the building, and thus makes installation easier for subcontractors. More importantly, cast-in-place systems are versatile. The variation in bay sizes and lack of uniformity in this building is not an issue with a flat concrete slab, as long as the drop panels are installed where necessary. Care must me taken, however to ensure proper rebar placement. Although this report is limited to gravity design of floor systems, it should be noted that cast-in-place concrete systems have inherent moment resistance, eliminating the need for additional bracing or expensive connections like that of steel.

Cast-in-place concrete, however, is probably the most labor-intensive construction method. With rising labor costs, this may negate some of the economic advantage of the inexpensive material cost. The scheduling is solely dependent on the labor force production. In the cold winter months of upstate New York, special consideration is needed to ensure adequate placement and curing of the concrete. This could mean additional costs and lack of production at times.

Finally, the additional weight of this system dictates an increase in foundation size and strength. This could prove to be difficult in the area where grade beams frame around the steam tunnel.

Overall, the significant advantages of a two-way cast-in-place floor system make it a feasible alternative at this point.

Precast: Double Tee

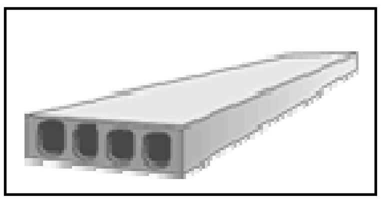
Precast concrete is an inexpensive and easily constructible solution in many applications. Double Tees are precast concrete members that are also prestressed, which means that they can achieve extremely long spans without using very large members. The BME/O Building, however, has square bays with shorter spans. As stated before, the structural layout of the building cannot be easily changed. However, removing some columns and effectively doubling the span of the critical bay would make double tee construction more feasible.

A 32” x 12’ Double Tee member with 2” concrete topping was sized using preliminary design tables from Nitterhouse Concrete Products. The double tee section adequate to carry a superimposed load of about 115 psf (unfactored) was a 32-8.6PT, based on a conservative span of 46’. (See Appendix E for chart with details and specifications) This system also uses concrete girders and columns, as well as edge beams to carry façade load.

This system has some of the same advantages as the flat slab system in terms of vibration control, fire resistance and plenum space. However, this system also has an advantage in ease and speed of construction, as no formwork, shoring, or curing time on site is needed. In a design-bid-build approach with a set deadline for completion, speed of construction is an important consideration. Also, controlled curing conditions mean better quality control and year-round construction.

Disadvantages include a longer lead time (similar to steel), transportation requirements, and the need for a stronger foundation like other concrete systems. Most notably, the square bays and lack of uniformity the building, as mentioned several times in this report, is not ideal for precast double tee construction. As stated, this type of system is most efficient and economical in long spans where larger column-free space is required. At this point, a precast double-tee system by itself seems unreasonable. Although the bay sizes can be doubled along the west face of the building to make this system more economical, the rest of the building would not need the long-span capabilities. Using double-tees in portions of the building in conjunction with another system may work well, but using double-tees for the entire structure would be complicated and not the most effective use of materials and methods.

Precast: Hollow-Core Plank



The final floor system analyzed was precast, prestressed, hollow-core concrete plank. This system also has fast, easy, year-round construction, and has inherent fire protection, vibration control, and sound resistance. Unlike double tees, however, hollow core plank is more economical in medium spans, like those in the current BME/O building. This system is the most economical of the systems analyzed.

From the Nitterhouse Products design guide, an 8”x4’ SpanDeck J917 plank with 2” concrete topping was used. It uses 5000 psi concrete with ½“ diameter 270 K Lo-Relaxation strands. The plank designed uses a 6 strand pattern, which provides for 115 psf of superimposed load over a 27’ span. (See Appendix F for calculations and details) There are several ways to support hollow-core planks. I chose steel girders, sized as W21x48 at the interior and W21x44 at the exterior to carry façade weight. Note that exterior girders will be larger than this if used as part of a moment frame like in the current system.

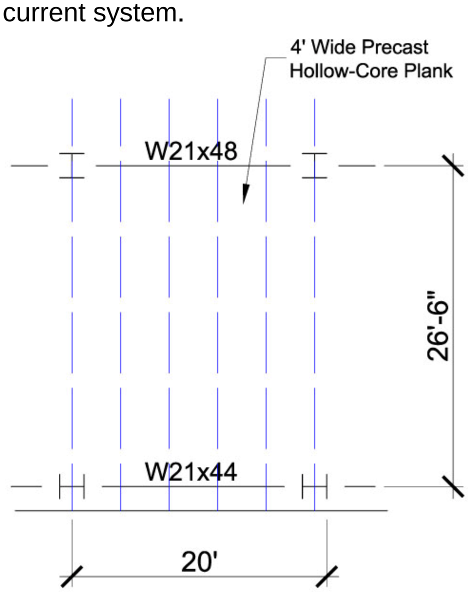


Figure 6 – Hollow Core Plank Design (Plan)

The benefits of using precast hollow-core plank in this application are numerous. Most importantly, it is inexpensive. Also, unlike the current composite steel system, there is no need for steel beams within the bays, as the plank can span the full 26.5'. This means a less labor-intensive construction as no shear studs will need to be installed. Also, the depth of the system within the bays is only 10", meaning adequate space to meet the unique mechanical demands of the building. The controlled environment that the plank is cured in makes it a durable and predictable material. Finally, hollow-core plank, as mentioned before, has excellent sound transmission characteristics, which may be in issue with office space directly above laboratory space in some instances.

Disadvantages of this system are the long lead time and lack of uniformity of the building, similar to precast double tee. This system, however, is more suitable for this particular building than a double tee system. The advantages and feasibility of a precast hollow-core floor system dictate further investigation.

SUMMARY/CONCLUSIONS

Floor System Comparison	Existing: Composite Steel Framing	Non-Composite Steel Beams	Composite Steel Joists	Flat Slab Cast-In-Place	Precast Double-Tee	Precast Hollow-Core Plank w/ Steel Girders
Weight (psf)	117	119	85	130	98	102
Max Depth	18" Beams / 24" Girders	21" Beams / 24" Girders	18" Joists	15.5" Drop Panels	32"	32" @ girders
Slab Depth	7.5"	7.5"	6"	8.5"	4"	10"
Construction	Medium	Easier	Medium	Labor Intensive	Easy	Easy
Long Lead	Yes	Yes	Yes	No	Yes	Yes
Fireproofing	Sprayed	Sprayed	Difficult/Expensive	Inherent	Inherent	Inherent/Sprayed (girders)
Vibration Control	Thick Slab	Thick Slab	Thicken slab/ Stiffen Joists	Naturally Heavy	Concrete Topping	Concrete Topping
Foundation Impact	No	No	No	Yes	No	No
Relative Cost	Medium	Slightly Higher	High	Medium-Low	Low	Low
Investigate Further?	-	No	No	Yes	No	Yes

Figure 7 – Comparison of Alternative Floor Systems

The current composite steel system is economical, efficient, and well suited to meet the needs of this unique building. The current system provides adequate strength required for the high design loads, meets all serviceability criteria for the laboratory environments, and is laid out in such a way to meet the architects' spatial challenges.

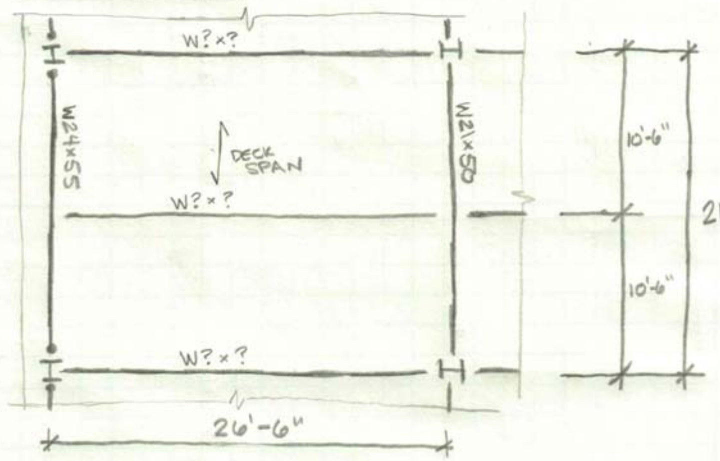
Some of the alternative systems investigated were simply uneconomical to meet the strength and performance requirements of this building. Fireproofing and vibration damping of steel joists is difficult and expensive in addition to the high material cost. Using larger, non-composite steel beams instead of the current composite design would work, but would be more expensive. Finally, precast double-tee worked fine for the bay analyzed. But when considering the shape and conditions of the entire building, this system was complicated and inefficient by itself. These three alternative floor systems were ruled out as feasible possibilities for this building.

Other systems seemed to work well with this building, and may be investigated further. The inherent fireproofing properties, strength and deflection control with a shallow floor depth, and ease of construction made precast hollow-core plank a viable alternative. Unlike double-tee, this type of system can be economical without extremely long spans. Also, the flexibility of cast-in-place concrete made flat slab construction probably the best alternative floor system. Although more labor intensive than the current steel system, cast-in-place concrete has a short lead time, inherent fireproofing and vibration damping, and is a shallow system. Flat slab and hollow-core plank have been deemed feasible alternatives at this point, and may be investigated further.

APPENDIX A: NON-COMPOSITE STEEL BEAMS

NON-COMPOSITE BEAMS

CRITICAL BAY



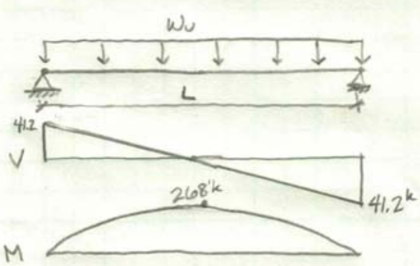
LOADS

- LIVE: LABORATORY 80 PSF
  - PARTITIONS 20 PSF
  - 100 PSF
- DEAD: 7½" SLAB 94 PSF
  - METAL DECK 3 PSF
  - FLOOR/CEILING 3 PSF
  - MEP 10 PSF
  - 110 PSF + SELF WEIGHT

★ASSUME 40 PLF SELF-WEIGHT

$1.2D + 1.6L$

$$w_u = 1.2\left[10.5'(110\ \text{PSF}) + 40\ \text{PLF}\right] + 1.6\left[10.5'(100\ \text{PSF})\right] = 3.11\ \text{KLF}$$



$$R = \frac{w_u L}{2} = \frac{(3.11\ \text{KLF})(26.5')}{2} = 41.2^k$$

$$M_u = \frac{w_u L^2}{8} = \frac{(3.11\ \text{KLF})(26.5')^2}{8} = \underline{273'k}$$

W16×40 $\phi M_p = 274'k$

★NOTE: COMPOSITE BEAMS IN EXISTING STRUCTURE USED PRIMARILY TO MEET DEFLECTION CRITERIA:

LIVE LOAD $L/360 = \underline{0.88"}$

TOTAL LOAD $L/240 = 1.3"$ USE $\underline{1.0"}$

NON-COMPOSITE BEAMS (CONTINUED)

LIVE LOAD DEFLECTION

$$\Delta_{LL} = \frac{5wL^4}{384EI}$$

$$I \geq \frac{5wL^4}{384E\Delta_{LL}} = \frac{5(100\,PSF)(10.5')(26.5')^4\,(1728)}{384\,(29\times10^6\,PSI)(0.88")}$$

$$I \geq 457\ IN^4$$

TOTAL LOAD DEFLECTION

$$I \geq \frac{5\left[(100\,PSF + 110\,PSF)\,10.5' + 40\,PLF\right](26.5')^4\,(1728)}{384\,(29\times10^6\,PSI)\,(1.0")}$$

$I \geq 859\ IN^4$ ← CONTROLS

USE W21x48 NON-COMPOSITE BEAMS $I = 959\ IN^4$

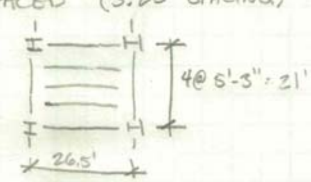
OR

TO MAINTAIN BEAM DEPTH OF EXISTING SYSTEM
USE W18x55 $I = 890\ IN^4$

APPENDIX B: NON-COMPOSITE STEEL JOISTS

STEEL JOIST - NON-COMPOSITE

· ASSUME 5 BEAMS PER BAY, EQUALLY SPACED (5.25' SPACING)



· DEAD LOAD

6" SLAB	75 PSF
DECK	3
FLOOR/CEILING	3
MEP	10
	90 PSF + 10 PLF SELF-WEIGHT

LIVE LOAD 100 PSF

TL = 190 PSF (5.25') + 10 = 1008 PLF
LL = 100 PSF (5.25') = 525 PLF

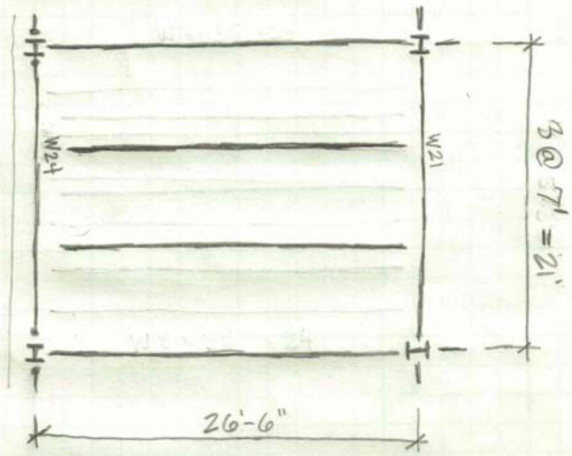
* MAX LOAD FOR K-SERIES JOISTS = 550 PLF

SPACING WOULD HAVE TO BE REDUCED TO 1.5' → UNECONOMICAL

APPENDIX C: COMPOSITE STEEL JOISTS

STEEL JOIST - COMPOSITE

ASSUME 7' SPACING



LOADS:

DEAD - 6" SLAB + 75 PSF
METAL DECK 3
FLOOR/CEILING 3
MEP 10
91 PSF + SELF-WEIGHT (ASSUME 20 PLF)

LIVE - LAB. 80 PSF
PART. 20 PSF
100 PSF (7') = 700 PLF

TL = 7' (91 + 100) + 20 = 1357 PLF

FROM VULCRAFT CHARTS:

18VC w/ 2.5" CONC ON 2" DECK
(MAX LOADS: 1400 PLF TL
1529 PLF LL FOR DEFL.)

DESIGNATION

$\boxed{\text{18VC 1400/700/100}}$

VULCRAFT

WEIGHT TABLE AND DESIGN GUIDE
VULCRAFT COMPOSITE STEEL JOISTS, VC SERIES

Based on Allowable Tensile Stress of 30,000 psi

Joist Span	Joist Depth	Slab Design																		
		Normal Weight Concrete (145 pcf) f 'c = 3.0 ksi																		
		tc (in)	2.00	2.00	2.00	2.00	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	3.00	3.00	3.00	3.00
		hr (in)	1.0	1.0	1.0	1.0	1.5	1.5	1.5	1.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	3.0	3.0	3.0	3.0
		Js (ft)	3.5	4.0	4.0	4.5	5.0	6.0	6.5	7.0	8.0	8.5	9.0	10.0	10.0	10.0	10.0	11.0	12.0	12.0	12.0
		Total Uniformly Distributed Joist Load in Pounds Per Linear Foot																		
(ft)	(in)	TL	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1800	2000	2200	2400	2700	3000
24	10	Wti (plf)	8	9	10	11	11	12	13	14	16	17	19	20	21	24	28	29	31	36	41
		W360 (plf)	340	392	468	563	692	787	843	905	1042	1122	1228	1231	1322	1379	1551	1999	2123	2290	2539
		N-ds	16-1/2	16-1/2	18-1/2	20-1/2	20-1/2	22-1/2	24-1/2	26-1/2	28-1/2	32-1/2	34-1/2	24-5/8	26-5/8	28-5/8	30-3/4	34-5/8	32-3/4	38-3/4	44-3/4
	12	Wtj (plf)	8	8	9	10	11	12	12	13	14	15	17	18	19	21	24	26	28	30	36
		W360 (plf)	367	459	535	609	776	885	950	1008	1160	1242	1324	1428	1552	1690	1758	2183	2345	2499	2891
		N-ds	14-1/2	14-1/2	16-1/2	20-1/2	18-1/2	20-1/2	22-1/2	22-1/2	24-1/2	26-1/2	28-1/2	32-1/2	34-1/2	26-5/8	28-5/8	24-3/4	30-5/8	32-3/4	38-3/4
	14	Wtj (plf)	8	8	9	9	10	11	12	12	13	15	16	17	18	20	23	24	26	28	31
		W360 (plf)	399	487	558	661	817	959	1070	1147	1311	1388	1478	1579	1580	1884	2027	2440	2593	2792	2996
		N-ds	14-1/2	14-1/2	16-1/2	18-1/2	18-1/2	18-1/2	20-1/2	22-1/2	22-1/2	24-1/2	26-1/2	28-1/2	20-5/8	24-5/8	26-5/8	22-3/4	24-3/4	30-5/8	30-3/4
	16	Wtj (plf)	8	8	8	9	10	10	11	12	12	13	14	15	17	18	21	23	23	27	29
		W360 (plf)	434	515	611	704	882	961	1112	1263	1333	1423	1517	1627	1701	1852	2192	2555	2585	2979	3168
		N-ds	14-1/2	14-1/2	16-1/2	16-1/2	16-1/2	18-1/2	18-1/2	20-1/2	20-1/2	20-1/2	22-1/2	24-1/2	18-5/8	20-5/8	24-5/8	20-3/4	20-3/4	42-1/2	28-3/4
	18	Wtj (plf)	8	8	8	9	10	10	10	11	11	13	13	15	16	17	19	21	22	25	28
		W360 (plf)	485	524	599	718	915	1041	1122	1282	1353	1492	1593	1699	1808	1914	2095	2609	2858	3106	3296
		N-ds	14-1/2	14-1/2	16-1/2	16-1/2	14-1/2	16-1/2	18-1/2	20-1/2	18-1/2	20-1/2	20-1/2	22-1/2	24-1/2	18-5/8	20-5/8	20-5/8	24-5/8	38-1/2	24-3/4
	20	Wtj (plf)	8	8	8	9	9	10	10	11	11	12	13	14	15	17	18	20	21	23	26
		W360 (plf)	546	557	646	724	881	1063	1152	1246	1400	1533	1682	1787	1919	1940	2112	2680	2931	3193	3538
		N-ds	14-1/2	14-1/2	14-1/2	16-1/2	16-1/2	16-1/2	18-1/2	18-1/2	16-1/2	18-1/2	20-1/2	20-1/2	22-1/2	16-5/8	18-5/8	20-5/8	22-5/8	22-3/4	26-5/8
	22	Wtj (plf)	8	8	8	8	9	10	10	10	11	12	13	13	13	15	18	19	20	23	24
		W360 (plf)	596	617	652	744	945	1034	1178	1308	1459	1530	1643	1826	1843	2090	2263	2672	2923	3420	3507
		N-ds	14-1/2	14-1/2	14-1/2	16-1/2	16-1/2	16-1/2	16-1/2	18-1/2	16-1/2	16-1/2	18-1/2	20-1/2	20-1/2	22-1/2	18-5/8	18-5/8	20-5/8	20-3/4	22-3/4
	24	Wtj (plf)	8	8	8	8	9	9	10	10	11	11	12	13	13	15	16	19	20	23	24
		W360 (plf)	653	662	704	783	1027	1109	1239	1391	1511	1650	1755	1927	1957	2237	2399	2961	3092	3628	3698
		N-ds	14-1/2	14-1/2	14-1/2	14-1/2	12-1/2	16-1/2	16-1/2	16-1/2	16-1/2	16-1/2	18-1/2	20-1/2	20-1/2	22-1/2	24-1/2	20-5/8	20-5/8	24-5/8	20-3/4
26	10	Wtj (plf)	9	10	11	12	12	14	16	17	20	20	21	24	25	27	32	35	36	42	48
		W360 (plf)	308	359	446	503	617	725	772	832	992	996	1075	1112	1181	1272	1447	1862	1876	2072	2259
		N-ds	18-1/2	18-1/2	20-1/2	22-1/2	24-1/2	26-1/2	28-1/2	34-1/2	24-5/8	24-5/8	26-5/8	28-5/8	30-5/8	34-5/8	36-3/4	36-3/4	38-3/4	46-3/4	48-3/4
	12	Wtj (plf)	8	9	10	11	12	13	14	16	17	18	20	20	21	25	28	28	31	36	40
		W360 (plf)	348	433	487	587	703	812	877	993	1074	1157	1269	1271	1384	1534	1644	2051	2176	2373	2638
		N-ds	16-1/2	18-1/2	20-1/2	22-1/2	22-1/2	22-1/2	24-1/2	28-1/2	28-1/2	32-1/2	24-5/8	24-5/8	26-5/8	44-1/2	28-3/4	30-3/4	32-3/4	42-5/8	46-3/4
	14	Wtj (plf)	8	9	10	10	11	11	13	14	15	17	18	19	21	22	25	27	29	32	36
		W360 (plf)	370	455	530	616	770	875	993	1072	1222	1314	1414	1391	1518	1661	1738	2256	2440	2606	2843
		N-ds	16-1/2	18-1/2	18-1/2	18-1/2	18-1/2	20-1/2	24-1/2	24-1/2	26-1/2	28-1/2	32-1/2	20-5/8	24-5/8	26-5/8	24-3/4	26-3/4	34-5/8	32-3/4	38-3/4
	16	Wtj (plf)	8	9	9	10	10	11	12	13	14	15	16	17	19	21	23	24	27	31	34
		W360 (plf)	421	502	584	693	840	926	1036	1115	1256	1347	1453	1534	1644	1797	2000	2330	2503	2836	3017
		N-ds	16-1/2	16-1/2	18-1/2	18-1/2	18-1/2	18-1/2	22-1/2	22-1/2	22-1/2	24-1/2	26-1/2	28-1/2	20-5/8	24-5/8	26-5/8	22-3/4	28-5/8	30-3/4	32-3/4
	18	Wtj (plf)	8	8	8	9	10	11	11	12	13	14	15	16	19	20	22	23	24	29	33
		W360 (plf)	410	503	580	683	835	957	1064	1187	1343	1428	1529	1638	1671	1855	2091	2395	2643	2947	3216
		N-ds	16-1/2	16-1/2	18-1/2	18-1/2	16-1/2	18-1/2	20-1/2	22-1/2	20-1/2	22-1/2	24-1/2	26-1/2	20-5/8	20-5/8	24-5/8	20-3/4	22-3/4	26-3/4	30-3/4
	20	Wtj (plf)	8	8	8	9	10	10	11	12	13	13	15	16	16	18	21	22	23	28	31
		W360 (plf)	458	543	605	703	885	1037	1100	1190	1404	1482	1583	1691	1792	1929	2122	2625	2657	3040	3306
		N-ds	16-1/2	16-1/2	18-1/2	18-1/2	16-1/2	18-1/2	18-1/2	20-1/2	20-1/2	20-1/2	22-1/2	24-1/2	26-1/2	20-5/8	22-5/8	24-5/8	20-3/4	24-3/4	28-3/4
	22	Wtj (plf)	8	8	8	9	9	10	11	11	13	13	14	15	16	17	19	21	23	26	30
		W360 (plf)	503	541	625	718	899	1062	1149	1230	1383	1517	1633	1726	1849	1970	2136	2611	2855	3137	3360
		N-ds	16-1/2	16-1/2	18-1/2	18-1/2	14-1/2	16-1/2	18-1/2	20-1/2	18-1/2	20-1/2	20-1/2	22-1/2	24-1/2	18-5/8	20-5/8	20-5/8	20-3/4	26-5/8	24-3/4
	24	Wtj (plf)	8	8	8	9	9	10	11	11	12	13	13	14	16	17	19	21	23	25	29
		W360 (plf)	549	555	662	751	880	1071	1162	1247	1494	1479	1641	1762	1863	1990	2290	2610	2801	3082	3391
		N-ds	16-1/2	16-1/2	18-1/2	18-1/2	14-1/2	16-1/2	18-1/2	18-1/2	18-1/2	18-1/2	20-1/2	20-1/2	22-1/2	18-5/8	20-5/8	16-3/4	18-3/4	24-5/8	22-3/4
	26	Wtj (plf)	8	8	8	9	9	10	11	11	12	13	13	14	15	17	19	21	23	25	28
		W360 (plf)	597	605	714	799	925	1134	1239	1327	1440	1554	1746	1754	1873	2129	2203	2739	2962	3264	3561
		N-ds	16-1/2	16-1/2	16-1/2	18-1/2	14-1/2	14-1/2	16-1/2	16-1/2	16-1/2	18-1/2	20-1/2	20-1/2	20-1/2	16-5/8	16-3/4	16-3/4	18-3/4	24-5/8	22-3/4
Bridging Rows											1									0	

Joist weights to the left of the heavy red line have 2 1/2 inch depth bearings. Joist weights to the right of the heavy red line have 5 inch depth bearings.

APPENDIX D: FLAT SLAB CAST-IN-PLACE CONCRETE

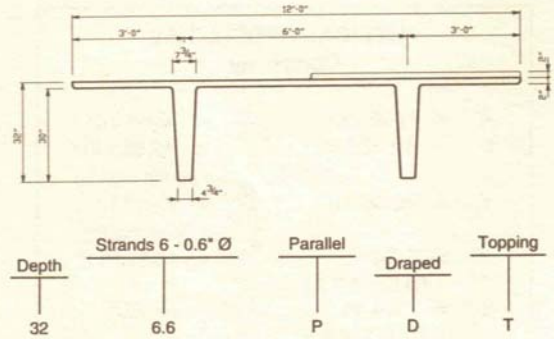
$f'_c = 3{,}000$ psi Grade 60 Bars — FLAT SLAB SYSTEM — SQUARE EDGE PANEL With Drop Panels — No Beams

SPAN c.-c. $\ell_1 = \ell_2$ (ft)	Factored Superimposed Load (psf)	Square Drop Panel Depth (in.)	Square Drop Panel Width (ft)	Square Column $\ell_c = 12'$-$0''$ (3) Size (in.)	Square Column α_{ec}	Reinforcing Bars (E. W.) Column Strip (1) Top Ext.	Column Strip Bot.	Column Strip Top Int.	Middle Strip Bot.	Middle Strip Top Int.	Total Steel (psf)	Moments Edge (−) (ft-k)	Moments Bot. (+) (ft-k)	Moments Int. (−) (ft-k)
$h = 8\frac{1}{2}$ in. = TOTAL SLAB DEPTH BETWEEN DROP PANELS (CONTINUED)														
20	100	2.50	6.66	12	0.325	10-#4	8-#5	10-#5	10-#4	10-#4	1.97	36.0	126.6	163.7
20	200	2.50	6.66	14	0.537	10-#4	16-#4	10-#6	11-#4	10-#4	2.29	69.0	163.6	219.9
20	300	4.00	6.66	16	0.781	12-#4	13-#5	22-#4	13-#4	11-#4	2.61	110.4	196.4	273.4
20	400	5.50	6.66	18	1.070	15-#4	15-#5	15-#5	10-#5	13-#4	3.03	157.0	231.9	326.3
20	500	7.00	8.00	20	1.318	11-#5	11-#7	11-#6	13-#5	16-#4	3.88	203.3	297.1	381.2
20	600	8.50	8.00	20	1.269	11-#5	13-#7	16-#5	16-#5	12-#5	4.53	230.9	357.2	440.8
21	100	2.50	7.00	12	0.318	11-#4	15-#4	12-#5	10-#4	11-#4	2.03	41.1	147.6	190.5
21	200	4.00	7.00	14	0.499	11-#4	19-#4	10-#6	8-#5	11-#4	2.36	77.4	191.9	256.2
21	300	5.50	7.00	16	0.726	12-#4	15-#5	15-#5	10-#5	13-#4	2.75	123.7	231.7	320.2
21	400	7.00	7.00	18	1.000	10-#5	18-#5	11-#6	12-#5	10-#5	3.29	176.8	266.4	380.6
21	500	8.50	8.39	20	1.232	11-#5	17-#6	16-#5	8-#7	12-#5	4.19	229.9	340.7	445.2
21	600	8.50	8.39	20	1.232	13-#5	15-#7	10-#7	8-#8	10-#6	5.02	265.0	401.5	513.0
22	100	2.50	7.33	12	0.311	11-#4	11-#5	20-#4	11-#4	11-#4	2.14	46.7	170.9	220.2
22	200	4.00	7.33	14	0.487	11-#4	15-#5	11-#6	10-#5	8-#5	2.64	88.1	222.6	296.6
22	300	5.50	7.33	16	0.707	13-#4	18-#5	12-#6	12-#5	10-#5	3.13	141.0	269.1	371.1
22	400	7.00	7.33	18	0.973	11-#5	11-#7	20-#5	10-#6	12-#5	3.69	202.0	309.9	441.5
22	500	8.50	8.80	20	1.198	13-#5	11-#8	16-#6	9-#7	10-#6	4.54	262.0	376.4	514.4
23	100	4.00	7.66	12	0.289	12-#4	13-#5	13-#5	13-#4	12-#4	2.23	50.9	198.0	254.0
23	200	5.50	7.66	15	0.563	12-#4	9-#7	11-#6	11-#5	9-#5	2.76	111.1	250.9	338.6
23	300	7.00	7.66	17	0.797	14-#4	20-#5	17-#5	13-#5	17-#4	3.27	172.5	302.6	422.3
23	400	8.50	9.20	19	0.996	17-#4	10-#8	28-#4	11-#6	10-#6	3.98	235.1	355.3	507.4
24	100	4.00	8.00	12	0.283	12-#4	22-#4	15-#5	10-#5	12-#4	2.38	57.2	226.2	289.8
24	200	5.50	8.00	15	0.550	12-#4	19-#5	18-#5	19-#4	16-#4	2.91	125.0	287.4	387.1
24	300	7.00	8.00	17	0.777	16-#4	17-#6	14-#6	15-#5	13-#5	3.68	194.5	347.2	483.1
24	400	8.50	9.60	21	1.308	15-#5	11-#8	15-#6	9-#7	11-#6	4.32	303.1	387.7	570.4
25	100	5.50	8.33	12	0.268	13-#4	9-#7	15-#5	11-#5	9-#5	2.54	62.3	258.6	330.2
25	200	7.00	8.33	15	0.518	13-#4	22-#5	18-#5	14-#5	12-#5	3.10	136.8	329.5	441.4
25	300	8.50	8.33	17	0.733	16-#4	11-#8	20-#5	10-#7	15-#5	4.05	214.1	398.4	551.1

Prestressed Concrete
32" × 12' Double Tee
(2" C.I.P. TOPPING)

PHYSICAL PROPERTIES
Composite

$A' = 951$ in.^{2}	$S'_b = 3198$ in.^{3}
$I' = 80{,}182$ in.^{4}	$S'_t = 11{,}570$ in.^{3} (at top of D.T.)
$Y_b = 25.07$ in.	$S'_{tt} = 8{,}979$ in.^{3} (at top of topping)
$Y'_t = 6.93$ in. (to top of D.T.)	Wt'. = 991 PLF
$Y'_{tt} = 8.93$ in. (to top of topping)	Wt'. = 83 PSF



DESIGN DATA

1. Precast strength @ RELEASE = 3000 PSI (min.)
2. Precast strength @ 28 days = 6000 PSI
3. Precast Density = 150 PCF
4. Strand = 0.6" Ø 270k LO-relaxation
5. Topping Strength = 3,000 PSI
6. Topping Density = 150 PCF
7. Maximum bottom tensile stress is $12\sqrt{f'c} = 930$ PSI.
8. All superimposed load is treated as live load in the flexural strength analysis.
9. Flexural capacity is based on stress/strain strand relationships.
10. Maximum moment capacity is critical at midspan for parallel stands and is critical near 0.4 span for draped strands.
11. All loads shown refer to allowable loads after the topping has hardened.

Table of Safe Superimposed Loads (lbs. per sq. ft.)

Section	$\varnothing M_n$ (in. Kips)	Span in Feet																				
		46	48	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86
32 - 6.6 PT	9,334	76	64	54	45	36																
32 - 8.6 PT	11,900	116	101	88	76	66	56	48	40	33												
32 - 10.6 PT	14,322	153	135	119	105	92	81	71	62	53	46	39	33									
32 - 12.6 PT	16,423	185	165	146	130	116	103	91	81	71	63	55	48	41	35	30						
32 - 14.6 DT	20,943	256	230	206	186	167	151	136	123	110	99	89	80	72	64	57	51	45	39	33		
32 - 16.6 DT	22,860							161	146	132	120	109	99	88	78	69	60	53	48	42	38	33
32 - 18.6 DT	24,486													105	94	84	75	66	58	51	44	39

This table is for simple spans and uniform loads. Design data for any of these span-load conditions is available on request. Individual designs may be furnished to satisfy unusual conditions of heavy loads, concentrated loads, cantilevers, flange or stem openings and narrow widths.

NITTERHOUSE
CONCRETE PRODUCTS

2655 Molly Pitcher Hwy. South, Box N
Chambersburg, PA 17201-0813
717-267-4505 • FAX: 717-267-4518

WD 5M 5/94

APPENDIX F: PRECAST HOLLOW-CORE PLANK

PRECAST HOLLOW-CORE PLANK

LIVE LOAD: LABORATORY 80 PSF
PARTITIONS 20 PSF
100 PSF

SUPERIMPOSED DEAD LOAD:
FLOORING/CEILING 3 PSF
MEP 10 PSF
13 PSF

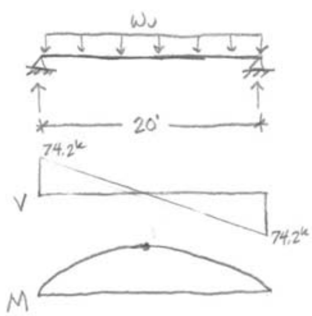
TOTAL SUPERIMPOSED LOAD ≈ 115 PSF SPAN = 26.5', USE 27'

FROM CHARTS, USE 8" × 4' SPANDECK J917 w/ (6) 1/2" ϕ STRANDS

WEIGHT = 82.5 PSF

SIZE INTERIOR GIRDER

$$\omega_u = [1.2\ (100\ \text{PSF}) + 1.6\ (100\ \text{PSF})]\ 26.5' = 7.42\ \text{KLF}$$



$$R = \frac{\omega_u L}{2} = \frac{7.42(20)}{2} = 74.2^k$$

$$M_u = \frac{\omega_u L^2}{8} = \frac{7.42(20)^2}{8} = 371'k$$

USE W21x48 $\phi M_p = 398'k$

CHECK DEFLECTIONS

$\Delta_{LL} \leq L/360 = 0.67"$

$\Delta_{TL} \leq L/240 = 1.0"$

$$\Delta_{LL} = \frac{5wL^4}{384EI} = \frac{5(100\,\text{PSF})(26.5)(20)^4(1728)}{384(29{,}000{,}000)(959\ \text{IN}^4)} = 0.34"\ \text{OK}$$

$$\Delta_{TL} = \frac{5(200)(20)^4(1728)}{384(29\times10^6)(959)} = 0.69"\ \text{OK}$$

SIZE EXTERIOR GIRDER

$$\omega_u = [1.2(100) + 1.6(100)]\ \frac{26.5'}{2} + \underset{\text{FACADE WEIGHT}}{1.2(587\,\text{PLF})} = 2.94\ \text{KLF}$$

$$M_u = \frac{2.94\,\text{KLF}(20')^2}{8} = 147'k$$ USE W16×31 $\phi M_p = 203'k$

BY INSPECTION, LIVE LOAD DEFLECTION WILL NOT CONTROL

$$\Delta_{TL} = \frac{5\,[200(26.5) + 587]\,(20)^4\,(1728)}{384\,(29\times10^6)\,(375)} = 1.95"\ \times$$

$$I \geq \frac{5\,[200(26.5) + 587]\,(20)^4\,(1728)}{384\,(29\times10^6)\,(1.0")}$$

$I \geq 730.8\ \text{IN}^4$ USE W21 × 44 $I = 847\ \text{IN}^4$

Prestressed Concrete

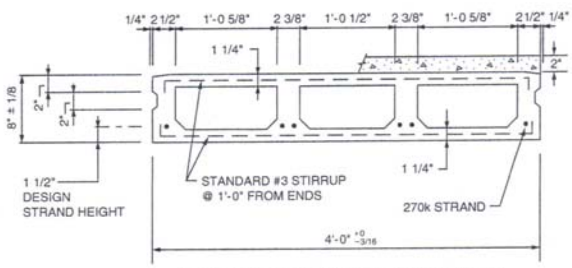
8" x 4' SpanDeck – U.L. – J917

(2" C.I.P. TOPPING)

PHYSICAL PROPERTIES

Composite

A' = 254 in.^{2}	S'$_b$ = 547 in.^{3}
I' = 2944 in.^{4}	S'$_t$ = 1124 in.^{3} (At Top of SpanDeck)
Y$_{b'}$ = 5.38 in.	S'$_{tt}$ = 637 in.^{3} (At Top of Topping)
Y$_t$' = 2.62 in. (To Top of SpanDeck)	Wt.' = 330 PLF
Y'$_{tt}$ = 4.62 in. (To Top of Topping)	Wt.' = 82.5 PSF



8" SPANDECK CROSS SECTION

UL FIRE RATED J917

DESIGN DATA

1. Precast Strength @ 28 days = 5000 PSI.
2. Precast Density = 150 PCF
3. Strand = 1/2"ø, 270K Lo-Relaxation.
4. Composite Strength = 3000 PSI.
5. Composite Density = 150 PCF.
6. Strand Height = 1.5 in.
7. Ultimate moment capacities (when fully developed) . . .
   4 – 1/2"ø, 270K = 94.6'K
   6 – 1/2"ø, 270K = 133.3'K
8. Maximum bottom tensile stress is $6\sqrt{f'c}$ = 424 PSI.
9. All superimposed load is treated as live load in the strength analysis of flexure and shear.
10. Flexural strength capacity is based on stress/strain strand relationships.
11. Load values to the left of the solid line are controlled by ultimate strength. Load values to the right are controlled by service stress.
12. Shear values are the maximum allowable before shear reinforcement is required.
13. Deflection limits were not considered when determining allowable loads in this table.
14. All loads shown refer to allowable loads applied after topping has hardened.

8" SPANDECK W/2" TOPPING				ALLOWABLE SUPERIMPOSED LOAD (PSF)																						
STRAND PATTERN				SPAN (FEET)																						
				10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
Flexure	4	–	1/2"ø	795	718	650	590	500	426	366	317	275	240	210	184	162	142	125	110	96	84	73	60	49	39	
Shear	4	–	1/2"ø	571	509	458	415	378	347	320	296	275	257	240	222	199	178	160	145	133	126	115	103	93	84	
Flexure	6	–	1/2"ø	1155	1040	945	859	732	629	544	474	416	366	324	287	256	228	204	183	164	147	132	118	103	90	77
Shear	6	–	1/2"ø	589	525	472	428	391	360	331	308	286	266	249	235	220	207	195	184	175	160	145	132	120	110	100

NITTERHOUSE
CONCRETE PRODUCTS

This table is for simple spans and uniform loads. Design data for any of these span-load conditions is available on request. Individual designs may be furnished to satisfy unusual conditions of heavy loads, concentrated loads, cantilevers, flange or stem openings and narrow widths.

2655 Molly Pitcher Hwy. South, Box N
Chambersburg, PA 17201-0813
717-267-4505 • FAX: 717-267-4518

REVISED 12/93