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Structural Option

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# Technical Report 2

## Evaluation of Floor System Alternatives

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# EXECUTIVE SUMMARY

This report focuses on designing and evaluating four alternative floor framing systems, including that of the original design for feasibility with the Residence Inn by Marriott:

1. Two-Way Flat Plate Slab & Concrete Columns
2. Composite Metal Deck & Composite Steel Beams
3. Precast Hollow Core Planks & Staggered Steel Trusses
4. Girder-Slab™ - Precast Hollow Core Planks & D-Beams®

Each floor system was designed for gravity loads on a typical bay (21'-6" x 22'-0") at one of the upper guest floors. By doing this preliminary design work, I was able to compare the systems based on a variety of criteria and determine each system's viability for further investigation. Of particular importance was to evaluate costs of each system, including an estimation of the structural design's impact on other load-resisting systems, such as the lateral system and foundations. In addition, systems were evaluated based on constructability, durability, serviceability, fire protection, and compatibility with the existing floor plans and architecture.

Although each system has advantages, it was apparent right away that the original design using a two-way flat plate system is a very practical and economical choice. A composite steel beam and composite metal deck system was found to be impractical from a number of perspectives. This was one of the most expensive systems and required the largest depth, increasing the height of the building significantly. This system also required sprayed-on fireproofing and a suspended ceiling, both of which increased the overall cost and construction schedule. Steel is an option, however, with the use of a staggered steel truss system. With this type of system, large open areas are possible, while maintaining a minimal slab depth using precast hollow core planks. Cost of this system proved to be only slightly greater than the two-way flat plate system. Modifications to the existing architectural floor plans will be necessary with the use of steel trusses. The patented Girder-Slab™ system is also a viable alternative, so long as the significantly increased cost can be justified after a more detailed look at the system. All of the viable systems are capable of spanning the desired suite widths with an 8" slab or plank. An in-depth look at lateral systems in the future will further refine the possibilities for the Residence Inn.

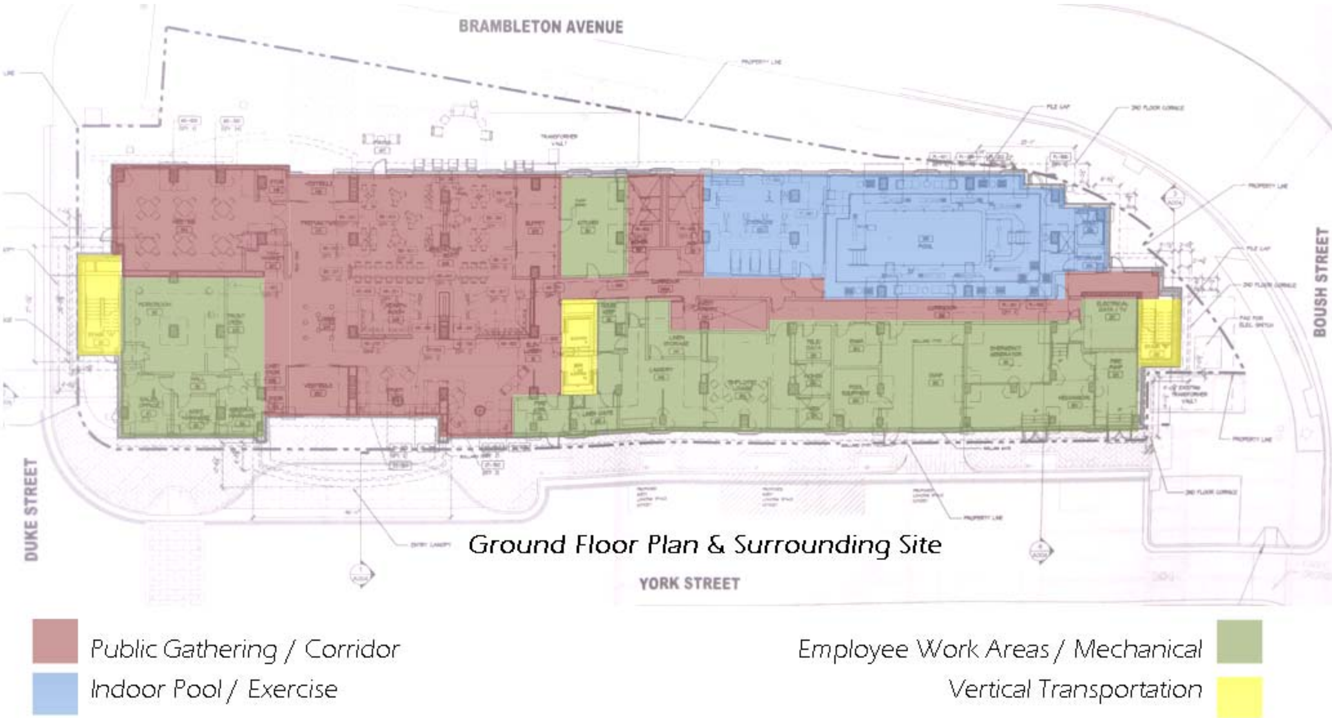
# INTRODUCTION

The new Residence Inn by Marriott will be situated in a lively downtown Norfolk, Virginia area, surrounded on all sides by busy streets. The hotel will serve as an upscale temporary residence with extensive amenities for its extended stay patrons. The building itself boasts a unique combination of simple structural components and fascinating architectural features. A tasteful combination of architectural precast, drainable EIFS, and curtain wall will be used to make this building an impressive and distinguished landmark in the community.

There will be 160 guest suites on eight upper floors, with public functions, such as lobbies, gathering areas, and an indoor swimming pool, located on the first floor. The extensive program on the first floor requires that columns are minimal, especially to create the large open spaces desired for architectural allure. The upper floors generally have the same layout; only minor differences exist to accommodate various room types. A main corridor connecting the emergency stairwells at either end of the building separates 10 guest suites each on the North and South sides of the building. A pair of elevators is located centrally along this corridor. Many of the upper floor suites will have magnificent views of the surrounding city and inner-coastal bays.

Each guest suite is approximately 22 feet wide, including the adjacent bedroom on those suites featuring living and sleeping areas separated by a partition. Typical floor-to-floor heights are 9'-4", with the first floor having a height of 19'-0". The total height of the building as designed is approximately 94 feet, excluding parapets and stair towers that extend beyond the roof. Zoning requirements for the site allow for the building height to reach 160', therefore, the choice of structure was not directly dictated by a height restriction.

This report explores alternative floor framing schemes and evaluates them based on a variety of criteria, including cost, weight and impact on foundations, depth, constructability, fire protection requirements, durability, and architectural compatibility. It is important to note that the proposed designs and comparisons made here are based solely on a gravity load analysis for a typical bay. It is understood that future analyses will consider a more accurate representation of actual conditions and include lateral loads. The goal here is to identify those flooring systems that are likely to be practical alternatives and worthy of further investigation.




(FIGURE 1) Ground Floor Plan

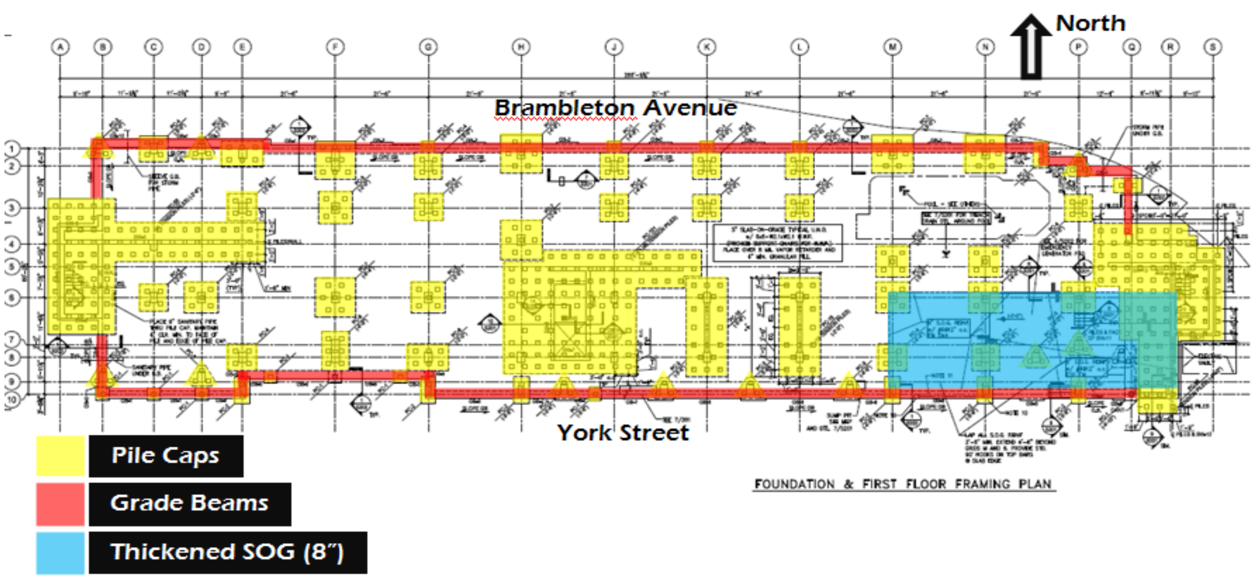

(FIGURE 2) Typical Upper Floor Plan

# STRUCTURAL SYSTEMS OVERVIEW

## SOILS & FOUNDATIONS

Located in a coastal area, the Residence Inn site requires special attention to its foundation systems. Friction piles will be necessary because of the high water table and lack of a firm bearing stratum. Due to the highly compressible soils found at the site by the geotechnical engineer, the hotel will utilize high capacity (100 ton) 12” square precast, pre-stressed concrete piles, driven to depths between 60’ and 70’. All piles shall be capable of resisting 5,000 psi in compression and up to 35 tons of uplift. Tendons are to be subjected to 700 psi of prestress. Clusters of piles will be joined together by reinforced concrete pile caps (f’c=4,000psi), the largest of which are located in areas supporting shear walls above. Depths of pile caps range from 1’-4” at a perimeter column over 3 piles to 5’-8” over 46 tension piles at the shear walls near the elevator core.

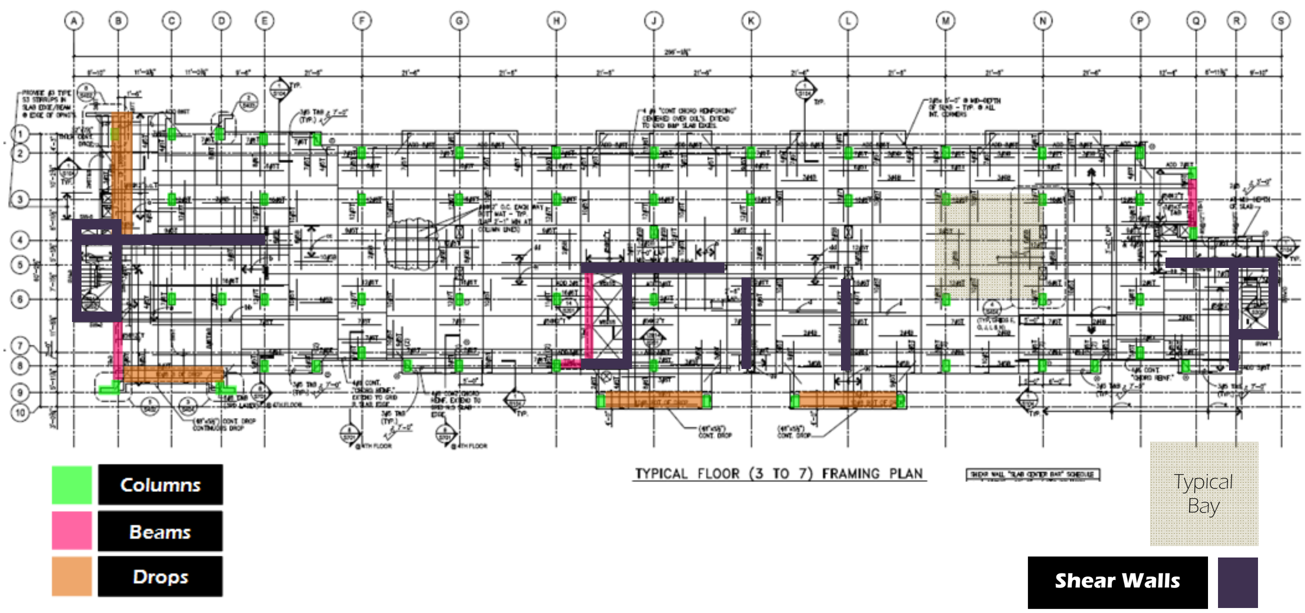
A continuous reinforced concrete grade beam (f’c=4,000psi) ranging in size from 24”x24” to 24”x40” will be utilized around the perimeter of the building to transfer loads from the walls into the piles. A 5” concrete slab on grade (f’c=3,500psi) with 6x6-W2.1xW2.1 welded wire fabric is typical of the first floor, except where additional support is required for mechanical and service areas. Here, an 8” concrete slab on grade (f’c=3,500psi) with #4@12” o.c. each way, top and bottom, will be required.




(FIGURE 3) Foundation Plan

## FLOOR SYSTEM

Like many hotels, the Residence Inn utilizes an economical 8” two-way flat-plate concrete floor system on all floors including the roof, with a typical bay spacing of 21’-6”, and a maximum span of 22’-0”. At the lower levels (third floor and below) 5,000 psi concrete is used for all slabs and beams; whereas, 4,000 psi concrete is reserved for use on the upper levels (fourth floor to the roof) in order to maintain similar column sizes under differing loads. Typical reinforcement consists of a bottom mat of #4@12” o.c. everywhere, and top reinforcement varies based on location. Reinforced concrete columns, ranging in size from 12”x24” reinforced with (8)#8 bars on the upper floors to 20”x30” with (12) #5 bars at the first floor, support the two-way slab system. Columns near the typical bay studied are 14”x30”.




(FIGURE 4) Typical Floor Framing Plan – Original Design

## LATERAL FORCE RESISTING SYSTEM

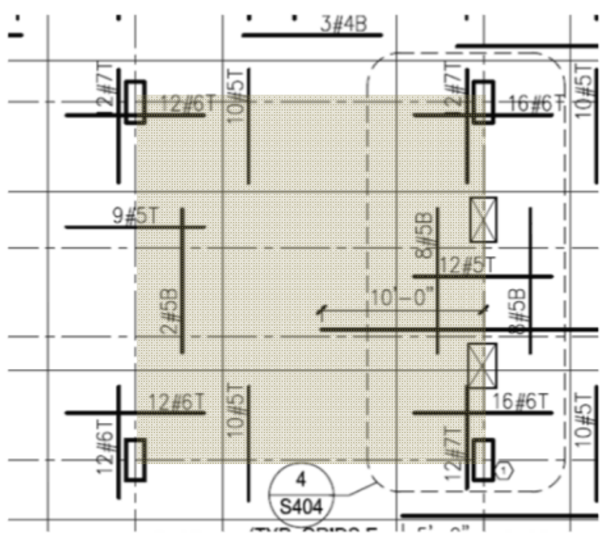
The Residence Inn by Marriott employs cast-in-place reinforced concrete shear walls to resist lateral forces. There are a total of fourteen shear walls, between 1’-0” and 1’-2” thick. These shear walls are continuous from the foundation to the top of the building, and behave as fixed cantilevers. There are more shear walls oriented from North – South, which resist an overturning moment in the more susceptible direction. Lateral loads are transmitted to the shear walls through the floor diaphragms.

# FLOOR SYSTEM ALTERNATIVES

The following floor system alternatives were chosen for evaluation after taking into consideration building dimensions, span lengths, and general feasibility of the each system with mid-rise hotel structures:

1. Two-way flat plate concrete slab supported by concrete columns (original design)
2. Composite metal deck & slab supported by composite steel beams
3. Precast hollow core plank supported by staggered steel trusses
4. Girder Slab™ system - precast hollow core plank supported by D-Beams®

Each of these systems was designed for a typical bay, as shown in Figure 4. The same bay of the original design, a two-way flat plate slab, is shown below. Please note that differences between the original design and my own design of this system are largely due to the fact that my designs consider gravity loads only. Lateral loads, openings, and other conditions that exist atypically have been excluded from these designs in an effort to make an apples-to-apples comparison of each system.




(FIGURE 5) Typical Bay Framing – Original Design

Since all of the upper guest floors are almost identical in terms of floor framing and loading, it is unnecessary to specify a particular floor; however it should be noted that in the two-way flat plate system design, concrete compressive strengths vary depending on the floor level. All assumptions are stated with each design as necessary.

## GRAVITY LOADS

The highlighted gravity loads below are applicable to the design of floor systems on an upper floor. Since the corridors on these floors have the same loads as the other spaces, calculation of loads on members was fairly straight-forward. Design of the floor system at the elevator lobbies on the upper floors would obviously need to account for additional live load.

| GRAVITY LOADS (psf) | | | | |
|---|---|---|---|---|
| Location | Design Dead Load | Assumed Dead Load | Design Live Load | IBC 2006 Live Load |
| Typical Floors Incl. Corridors Serving them | 10 | 15 | 40 + 10 (partitions) | 40 + 15 (partitions) |
| Mechanical Mezzanine | 10 | 25 | 150 | 40 |
| Roof | 25 | 30 | 30 | 20 + 46 (Snow Drift Surcharge only where necessary near parapet) |
| Canopies | N/A | 10 | 75 | 20 + 10 (Snow) + 30 (Snow Drift Surcharge) = 60 |
| Lobbies, All Floors / Public Rooms | 10 | 15 | 100 | 100 |

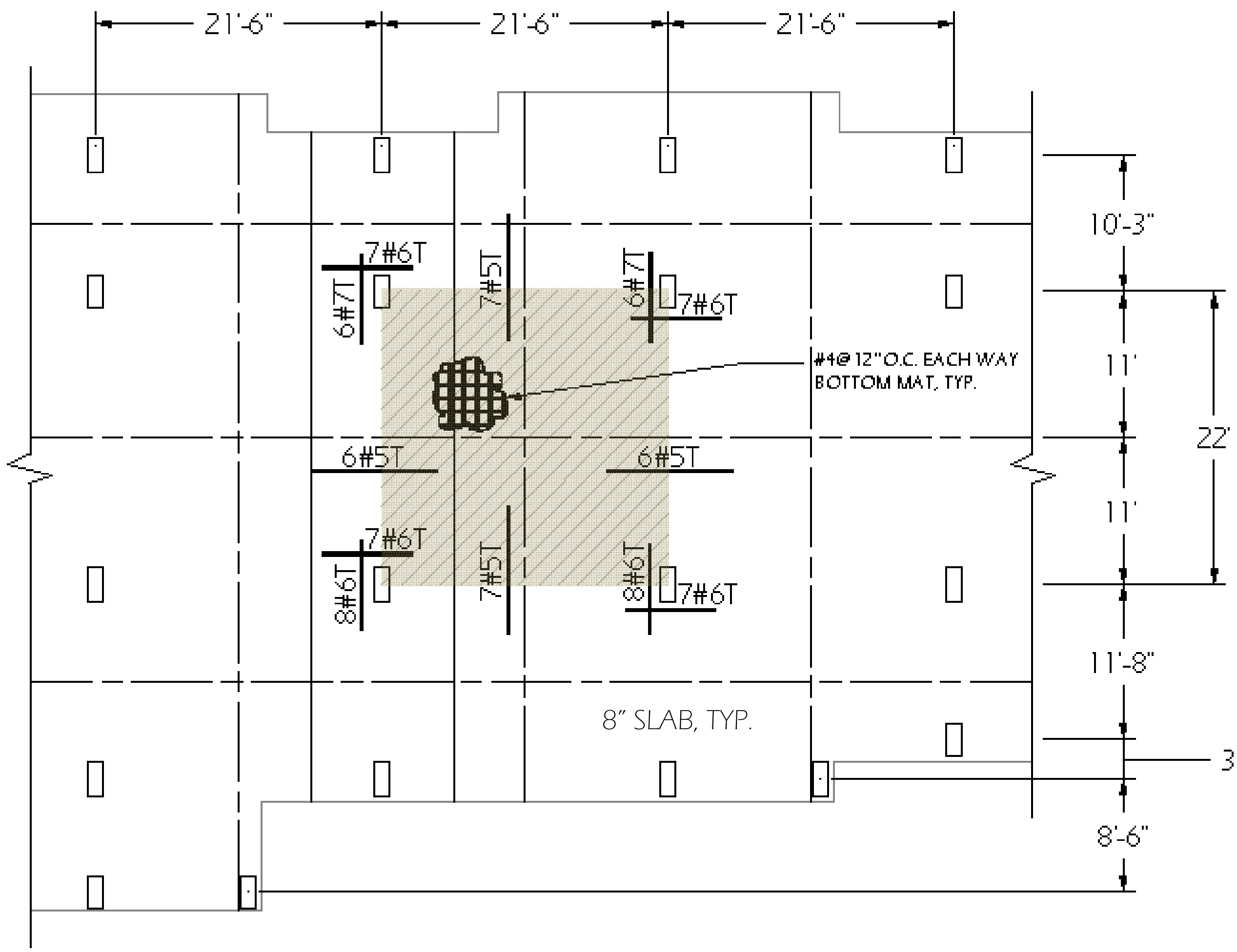
(FIGURE 6) Gravity Loads

## APPLICABLE DESIGN STANDARDS/REFERENCES

- IBC 2006
- Virginia Uniform Statewide Building Code – 2003 Edition
- ASCE 7-05
- ACI 318-08
- AISC: Manual of Steel Construction – LRFD, 13th Edition, 2005
- United Steel Deck Design Manual & Catalog of Products, 2006
- Nitterhouse Concrete Products design tables, 2007
- AISC Design Guide 14: Staggered Truss Framing Systems
- D-Beam® dimensions/properties design tables

*All deflections limited to L/360

| | |
|---|---|
| Loads: | 15 psf superimposed dead load<br>100 psf slab self weight (8" slab)<br>55 psf live load (includes allowance for partitions) |
| Materials: | $f'_c$ = 4,000 psi, NWC<br>$f_y$ = 60,000 psi (reinforcement)<br><br>8" concrete slab, typical |
| Assumptions: | Column size: 14"x30", typical<br>Neglecting openings in slab at this stage<br>Design is based strictly on gravity loads |
| Performance: | 2 hour fire rating<br>Deflection criteria met by ACI Table 9.5(c) Minimum Slab Thickness |




(FIGURE 7) System 1: Two-Way Flat Plate (Original Design) - Typical Bay

## Structural

The flat plate system is ideally suited for use with moderate spans and relatively light loads, as is the case in many hotels, including the Residence Inn. It was determined that an 8" thick mildly reinforced two-way concrete slab was adequate to resist gravity loads and punching shear at the columns without the need for drop panels. This type of floor system lacks resistance to lateral loads on its own; and therefore, is required to be used in conjunction with shear walls. As can be seen in the original foundation design, a significant number of expensive piles are required to support the mass of this structure on unstable soils. It is estimated that a typical bay of this floor system would weigh approximately 108.8 psf, with 100 psf of that being the slab dead weight and the other 8.8 psf from the concrete columns required to support the slab. This is significantly larger than some of the other alternatives, even without considering the additional weight due to the need for concrete shear walls.

## Constructability

Flat-plate slabs are one of the easiest cast-in-place concrete floor systems to construct. Formwork is very simple, especially since there are no beams or drop panels to form around. The repetitiveness of floor layouts allows formwork to be re-used. Cast-in-place concrete floors have an advantage over steel framed systems that may expedite the start of construction in that they do not require lead time for fabrication. On the other hand, steel structures are erected more quickly in the field that concrete ones. Another disadvantage of this system is the need for shoring to support formwork until the concrete has reached the necessary strength. This limits the ability for trades to work efficiently below until the shores are removed, and may inhibit a fast-track construction schedule. Weather and temperature may also inhibit the speed of construction; however, in this case, slabs were being poured during temperate months and this was not an issue.

## Cost

The upfront installed cost of this system of approximately \$18/SF (\$14.60/SF of which is flat plate floor system alone) is by far the most economical choice. The true cost savings is realized by the fact that a hung ceiling in the guest suites is unnecessary. The smooth underside of the slab may be painted directly for a finished look. Painting is estimated to cost a mere \$0.75/SF as compared with the \$3.50 cost of a suspended acoustical ceiling. In addition, structure depth is at a minimum with this system, which saves cost associated with partitions and exterior wall systems. In almost every case, the cost of maintaining a concrete structure is also significantly less than a steel structure. Foundation costs are, however, significantly larger with this type of system compared to lighter steel structures.

### Durability/Serviceability

With proper protection of steel reinforcement, concrete floors hold up very well and have a long service life. They work best with large expanses of non-rigid flooring finishes, like carpeting, which is typical of a hotel. The mass of a concrete floor is also useful in limiting vibrations and has acoustical advantages, which is especially important in a hotel.

### Fire Protection

The thickness of the slab gives this system the ability to withstand fire for at least 2 hours and no additional fireproofing is necessary.

### Architectural Compatibility

Architecturally, this system creates a seamless finished ceiling almost entirely by itself. It offers the greatest design flexibility, allowing for moderately large unobstructed bays and the ability to locate partitions freely without concern of fireproofing. The only drawback is that it may be undesirable to have electrical services and sprinklers in plain view on the finished ceiling. However, these systems can be placed within the walls, which is the solution for the Residence Inn.

## Two-Way Flat Plate (Original Design)

The two-way flat plate flooring system was a logical choice for this building. The system is capable of meeting all of the desired criteria, and is very economical from multiple perspectives. The depth of the structure is at a minimum, which not only reduces cost, but also allows for the building to meet height restrictions mandated by local zoning requirements. The list below summarizes the key advantages and disadvantages of this system:

Advantages

+ Minimal floor depth (8")
+ Architectural flexibility
+ Simple to construct
+ Minimal lead time on materials
+ Very economical
+ 2-hour fire rating w/o fireproofing
+ Durable, low maintenance

Disadvantages

- Weather dependent construction
- Shoring required
- Increased cost of foundations

*A viable alternative*

## *Alternative Floor System 2:* Composite Metal Deck & Composite Steel Beams

Loads:
- 15 psf superimposed dead load
- 42 psf slab self weight (4.5" slab on composite metal deck)
- 55 psf live load (includes allowance for partitions)

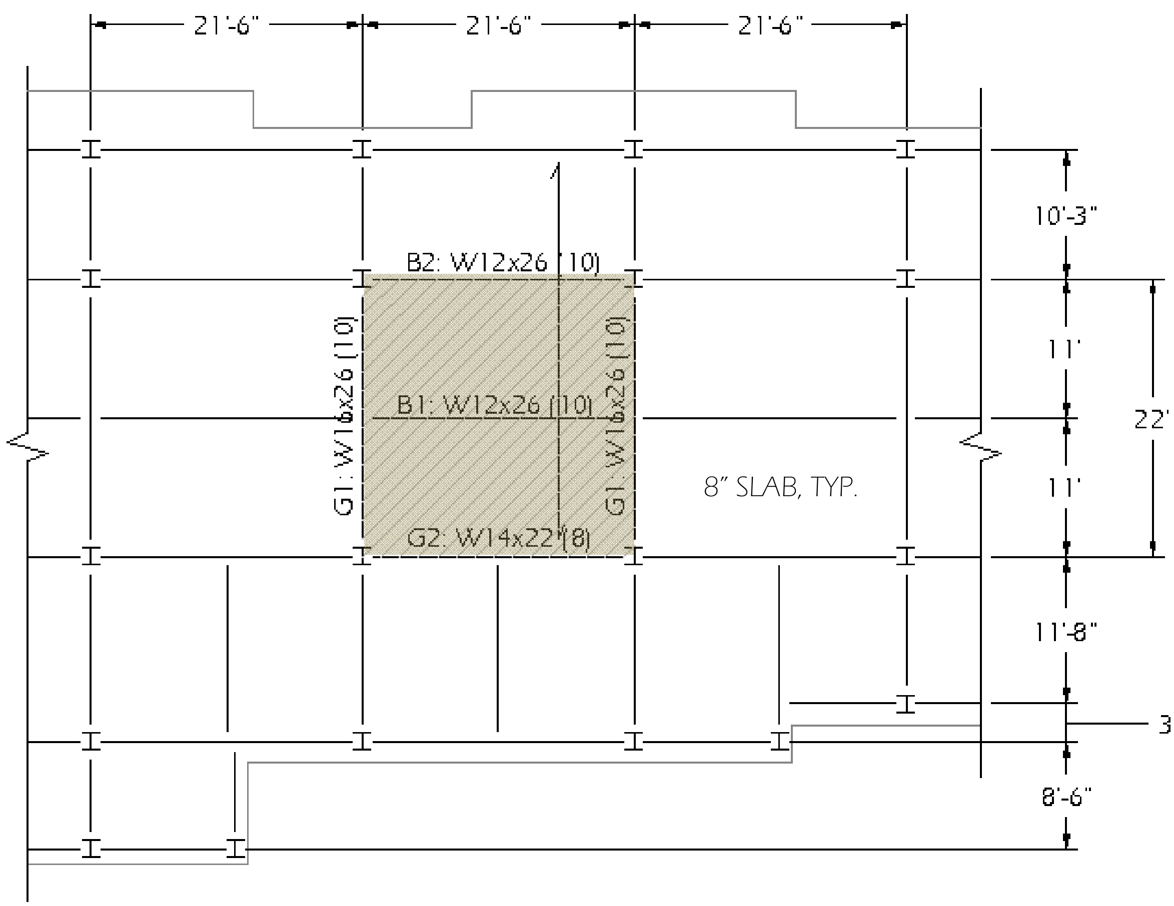
Materials:
- $f'_c$ = 3,000 psi, Normal Weight Concrete
- $F_y$ = 33,000 psi (metal deck)
- $F_y$ = 50,000 psi (steel beams)

16 gage 2.0 LOK Floor Composite Metal Deck - 4.5" slab depth (USD)
¾" $\phi$ shear studs

Assumptions:
- Design is based strictly on gravity loads
- 3-span condition for metal deck in typical bay
- Max cantilever length of metal deck: 3'-6"

Performance: 2 hr fire rating achieved in conjunction with one of the following:
- Fibrous fireproofing
- Cementitous fireproofing
- Suspended Ceiling

Deflection criteria met by design tables & hand calcs for beams ($\Delta_{max}$ = L/360)




(FIGURE 8) System 2: Composite Metal Deck & Composite Steel Beams – Typical Bay

## Structural

Column spacing for the design of the composite metal deck and composite steel beams was maintained from the original design in order to preserve the architectural layout of the guest suites. However, since this system transfers loads in one direction, it was necessary to consider how all of the steel framing would work together. In addition to the typical bay, a general layout of beam locations is presented in the figure above. Composite metal decking (2" deck, 16 gage) with a 4.5" slab depth was determined to be adequate for the 3-span condition at the typical bay. The design was governed by the maximum permissible unshored span length, and selection of the gage was governed by the maximum cantilever length. Although beams were designed to take full advantage of composite action in an effort to minimize their sizes, they still contribute a considerable amount of additional depth. After sizing member B1, all of the adjacent girders became controlled by dimensional requirements for constructability. Therefore, the overall maximum depth of the floor structure is 20.5", more than twice that of the original concrete structure. A suspended ceiling that will be necessary to conceal the unsightly underside of this structure will add an additional 14"-18" in depth, for a total depth of approximately 3 feet! One of the few structural advantages of this system is its decreased overall weight, which reduces the number of piles needed in the foundation. It is estimated that a typical bay of this system weighs approximately 46.5 psf, of which 42 psf is the slab and 4.5 psf is the structural steel and columns supporting it. If this system were used, welded moment frames would be necessary to resist lateral loads.

## Constructability

Steel framed structures with metal deck are some of the fastest to erect since the quick application of metal deck replaces formwork and shoring that would otherwise be necessary for a flat plate system. Slabs are poured directly on the metal deck and can be walked on typically by the next day. However, the initial time savings in getting the core and shell erected is lost later by having to fireproof the underside of all steel, and install a suspended ceiling to conceal this part of the structure. This type of floor system also complicates the work of the MEP contractors, having to route their systems around steel beams.

Cost

In general, composite steel with composite metal deck is an economical choice for a floor system. The estimated cost of this system is $23/SF, which includes the composite beams, deck, slab, steel columns required to support it, and the necessary sprayed fibrous fireproofing. Of this, $20/SF is directly attributed to the slab and deck system. Additional costs are incurred with the need to install a suspended ceiling, which is an additional $2.75/SF as compared with the flat plate system. Cost will also be elevated as much as $3/SF due to increased quantities of interior partitions and exterior skin with the significant increase in floor depth. Installation of MEP systems may also present increased costs for the distribution of ducts and conduits, although most of these systems are concentrated near corridors, where a suspended ceiling will be present anyway. All things considered, the resulting total relevant cost comes to $29/SF, which is 60% greater than the flat-plate system. An increased cost due to the need for welded moment frames is offset by the cost savings in the foundations supporting a lighter structure.

Durability/Serviceability

Similar to that of the two-way flat plate, this system is very durable so long as it is protected from prolonged exposure to moisture. Although the slab itself is less deep, the additional fireproofing, air space, and ceiling below reduces sound transmission. Vibrations may need to be investigated further for their impact on serviceability since the structure is significantly lighter and more susceptible to vibration issues.

Fire Protection

With the 4.5" slab on metal deck selected for this design, a two hour fire rating can be achieved by installing one of the following systems on or around all exposed steel: fibrous fireproofing, cementitious fireproofing, or a suspended ceiling.

Architectural Compatibility

A structural steel floor system is less compatible with the architectural interests of the building. There is less flexibility in terms of interior space planning simply because it is most economical to locate partitions in such a way that they can also serve as fireproofing for steel beams and columns. Another feature of this structure is a finished ceiling that conceals all mechanical/electrical chases from the public eye.

## Composite Metal Deck & Composite Steel Beams

With very few advantages over the original design, composite metal deck with composite steel beams does not appear to be a viable alternative flooring system.

Advantages

+ Lightweight structure – fdns. reduced
+ No shoring required
+ Speed of construction

Disadvantages

- Large floor depth (3')
- Limited architectural flexibility
- Significantly higher cost
- Fireproofing of steel required
- Weather dependent construction

*NOT a viable alternative*

*Alternative Floor System 3:*

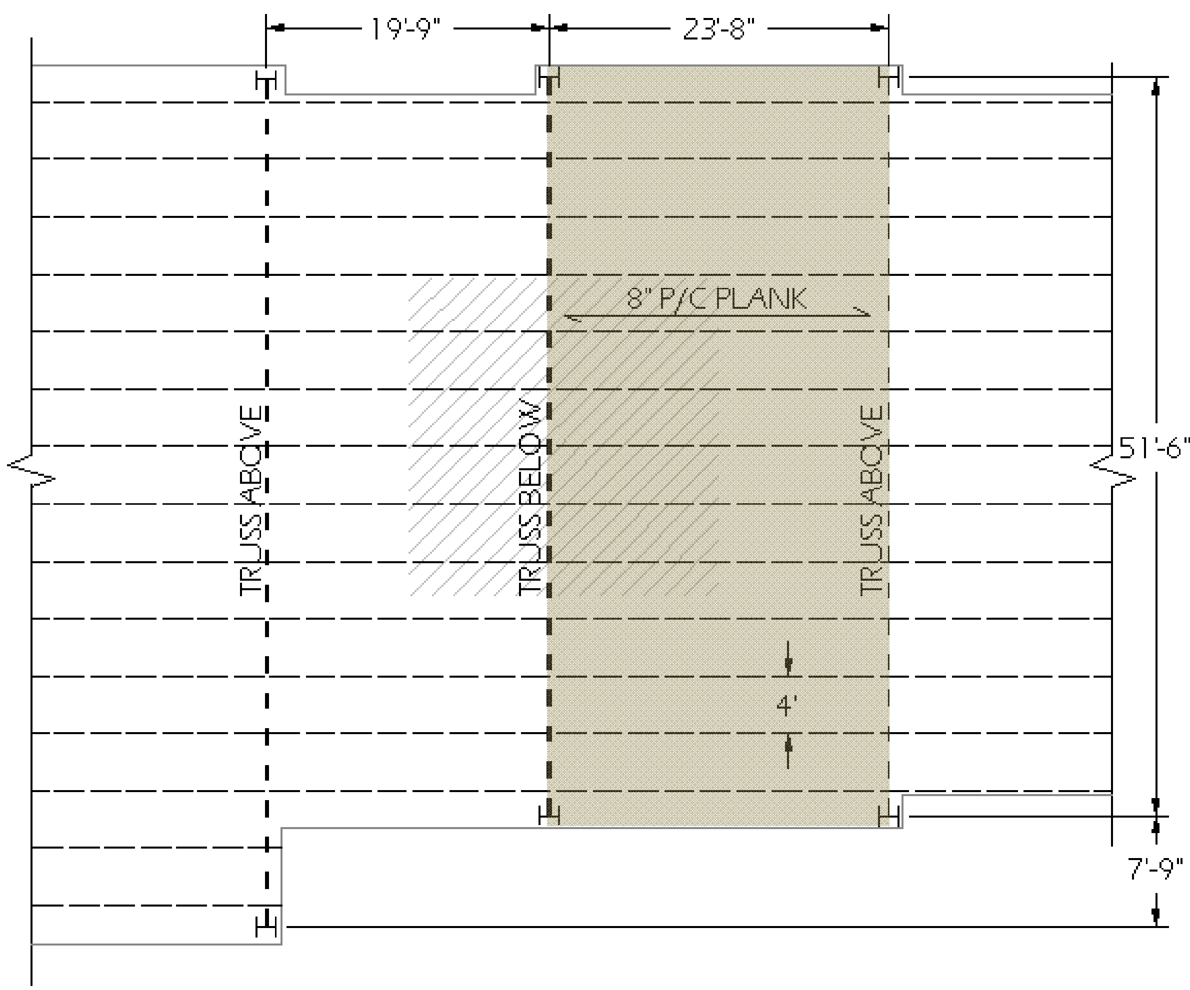
## Pre-Stressed Precast Concrete Hollow Core Plank on Staggered Steel Truss

Loads: 15 psf superimposed dead load
61.25 psf plank self weight (8" hollow core)
55 psf live load (includes allowance for partitions)

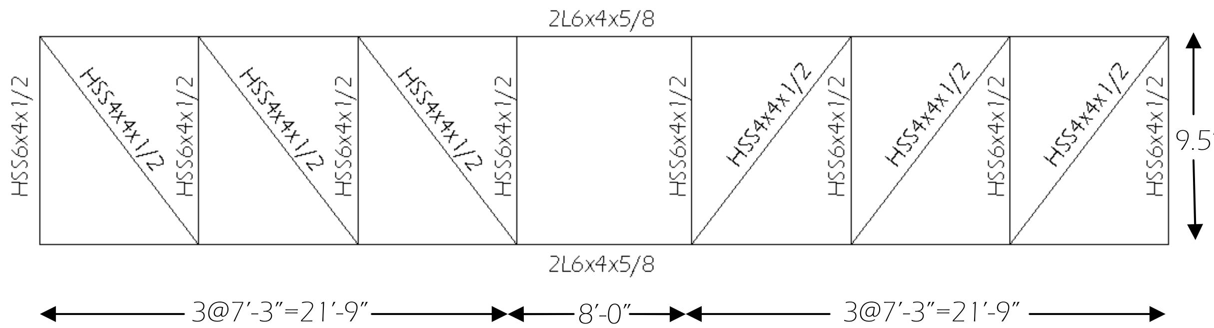
Materials: $f'_c$ = 6,000 psi
$F_y$ = 50,000 psi (steel)
7- ½" ϕ pre-stressing strands

Assumptions: Design is based strictly on gravity loads
Truss will need to be designed for lateral loads
Relocation of columns compatible with architecture

Performance: 2 hr fire rating (plank alone); Fire-rated gypsum assemblies necessary for truss
Deflection criteria met by design tables ($\Delta_{max}$ = L/360)




(FIGURE 9) System 3: Precast Concrete Hollow Core Plank on Staggered Steel Truss – Typical Bay




(FIGURE 10) Staggered Steel Truss Design

*EVALUATION* Precast Concrete Hollow Core Plank on Staggered Steel Truss

## Structural

A staggered steel truss system was chosen for analysis based on its known successful application in buildings with a doubly-loaded center corridor and repetition in framing locations, like in many hotels and apartment buildings. Trusses are staggered in such a way that floors are supported by both the upper and lower chords. In order to carry loads at façade protrusions, truss locations will need to deviate slightly from the originally designed column grid as shown in Figure 9 above. This creates a maximum distance between adjacent trusses above and below of just under 24 feet. Preliminary sizes of members were determined based on the axial forces induced by gravity loading of the chosen precast concrete plank flooring system. Four foot sections of 8" pre-stressed precast hollow core plank was determined adequate to span the 24 foot distance between trusses. Higher concrete strengths obtainable under factory conditions allow for these types of spans with a relatively thin slab. The trusses will need to be supported at their ends by steel columns, and spandrel beams may also be necessary at the perimeter to increase stiffness. A more detailed investigation of these systems will be performed as part of the lateral analysis in a future technical report. Depth of this system is kept to a minimum and is the same as that of the flat plate system. In general, the combined hollow core plank and staggered truss system is lighter than the two-way flat plate, at approximately 65 psf, but is heavier than the composite steel beam system by a similar percentage. As compared with the flat-plate system, structural foundations will likely be downsized due to the 43 psf decrease in the structure's dead weight.

## Constructability

Both precast planks and pre-fabricated steel trusses are ideally suited for use in a fast-tracked project. There are significantly fewer pieces and parts to assemble on site, and erection is expedited. Unlike the flat-plate and composite steel systems, precast concrete is immediately available for other trades to begin working at or below the level of installation and does not rely on weather conditions for placement. One significant advantage of the steel truss over a conventionally framed steel building is that a lay-down site is unnecessary; trusses can be picked by the crane directly of the trucks delivering them. This becomes important on a site, like that of the Residence Inn, where space is extremely limited.

### Cost

Based on the preliminary design of truss members, it is estimated that this system would cost approximately $21/SF, which includes the truss itself, precast planks including delivery within 100 miles, and applying a painted finish to the underside of the slab. Additional cost savings would be realized at the first floor, where massive transfer girders and interior columns would be eliminated with the use of this system.

### Durability/Serviceability

Hollow core planks are sufficiently thick and massive such that vibrations and sound transmission should not present itself as a concern. However, with the modularity of the structure (4 foot wide planks), over time, creep and shrinkage may cause these planks to deflect unevenly in the absence of a concrete topping. Both materials are durable, as are the previously discussed alternatives.

### Fire Protection

The 8" precast planks selected for design have an inherent 2-hour fire rating, which meets code requirements. The steel trusses, however, require a separate application of fireproofing. Since the trusses will coincide with interior partition locations between guest suites, no additional fireproofing measures will need to be taken, as the original design has already incorporated a fire-rated wall assembly in these locations.

### Architectural Compatibility

Architecturally, this system performs almost identically to the flat-plate system. Ceiling finishes may be directly applied to the underside of the slab, and structural members are concealed within the partitions. The small width of the trusses (6" at its thickest element) may actually allow for an increase in useable square footage within the building, as compared to the 14" thick columns in the flat-plate design. The first floor gains a significant architectural advantage with the staggered truss; large open spaces without columns are possible here. If this system is ultimately chosen as the best design solution, it should be noted that floor plans will need to be altered to accommodate the new locations of column grid lines.

*SUMMARY* Precast Concrete Hollow Core Plank on Staggered Steel Truss

The precast plank and staggered steel truss appears to be a practical design solution for this building. Although it is not the cheapest in terms of the actual floor itself, I anticipate that a significant savings in foundation costs and the elimination of columns and shear walls may prove it to be a practical alternative to the original design. This system will need to be studied further to make a more detailed comparison that accounts for the lateral load influence that may alter this preliminary design.

<u>Advantages</u>

+ Somewhat lightweight
+ Minimal floor depth (8")
+ No shoring required
+ Large, column-free spaces
+ Speed of construction
+ Economical

<u>Disadvantages</u>

- Floor plan alterations needed
- Lead time required for fabrication of steel trusses

*A viable alternative*

*Alternative Floor System 4:*

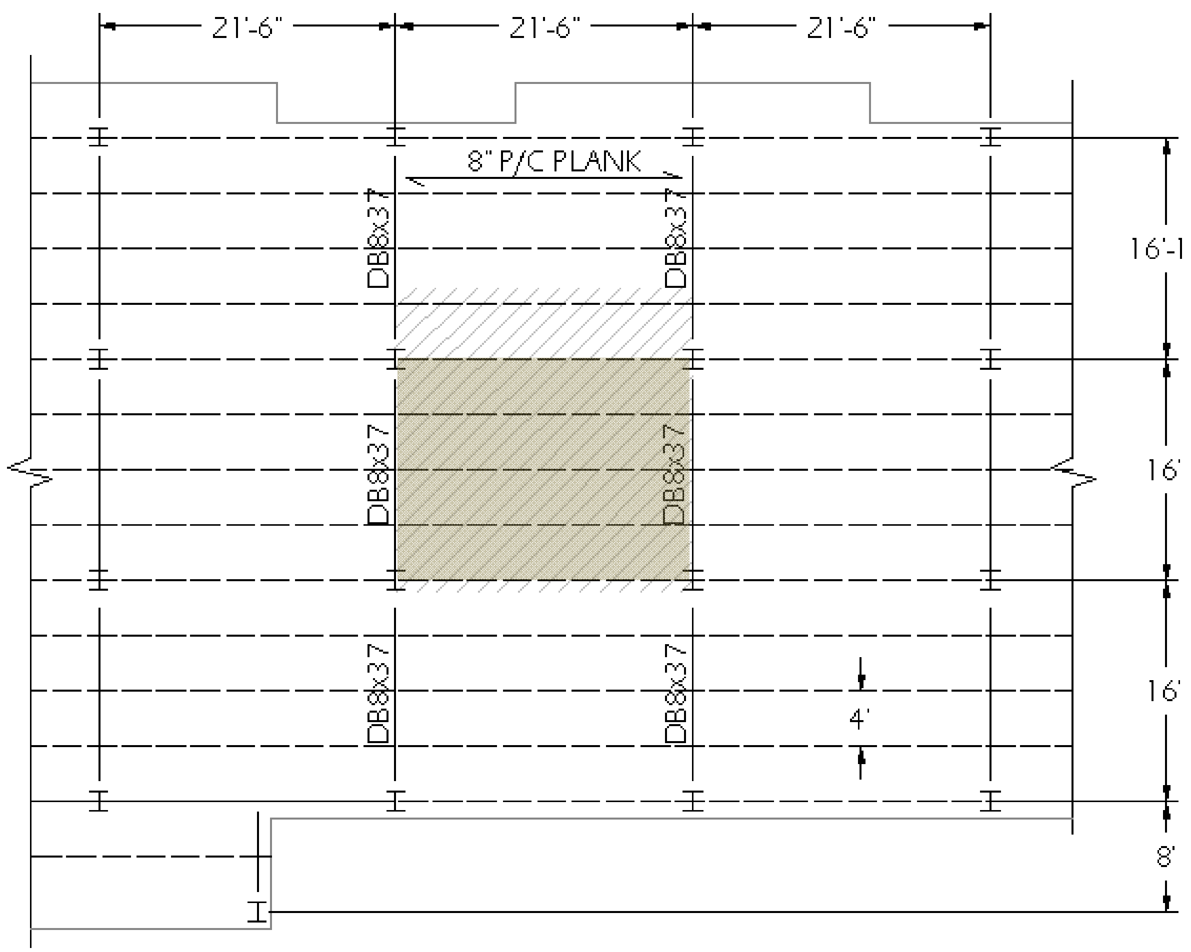
## Girder Slab™ – Composite Steel & Precast Concrete Plank

Loads: 15 psf superimposed dead load
61.25 psf plank self weight (8" hollow core)
55 psf live load (includes allowance for partitions)

Materials: $f'_c$ = 6,000 psi
$F_y$ = 50,000 psi (steel)
7- ½" ϕ pre-stressing strands

Assumptions: Design is based strictly on gravity loads
Relocation of columns compatible with architecture

Performance: 2 hr fire rating (plank alone); Fire-rated gypsum assemblies necessary to conceal and protect underside of D-Beam and steel columns; coincides with partition locations
Deflection criteria met by hand calc. ($\Delta_{max}$ = L/360)




(FIGURE 11) System 4: Girder Slab™ – Composite Steel & Precast Concrete Plank – Typical Bay

# Girder Slab™ – Composite Steel & Precast Concrete Plank

## Structural

A Girder Slab™ is a patented floor system that uses precast slabs with integral steel girders to form a monolithic structural slab. Dissymmetric steel members, shaped like inverted T's and known as D-Beams®, support precast hollow-core planks that are then grouted after assembly to develop composite action. Precast plank sizing was determined in a similar manner as with the staggered truss alternative. Using the dimensional and properties information available from Girder-Slab™ Technologies, LLC, D-Beams® were sized to accommodate loads both as a non-composite system, as is the case during construction, and as a composite system supporting service loads. It was determined that a DB8x37 would be adequate for gravity loads and to support the weight of the 8" precast planks. An additional column line in the E-W direction was added to decrease the spans of the D-Beams® and limit deflections to the acceptable criteria. This system uniquely limits the depth of the floor to a minimal 8", since planks are supported almost entirely within the depth of the beams. This system is also lightweight, at only 66 psf for the planks, D-Beams®, and steel columns supporting them. Like the staggered truss system, the Girder-Slab system is heavier than the composite steel design, and lighter than the two-way flat plate original design. Therefore, advantages related to foundation requirements may be realized with this system. However, lateral loads will need to be addressed, possibly by the use of shear walls since moment connections are not permitted with D-Beams®.

## Constructability

D-Beams® are erected just like any other steel structure, and go up fairly quickly, as do the precast planks. Once the planks have been set, grout must be injected along the D-Beams, which is what creates composite action upon curing. Because curing of the grout is important, the system is somewhat sensitive to weather conditions. Construction time is perhaps comparable to that of the staggered steel truss system. D-Beams® can be made locally by independent fabricators who pay a licensing fee to Girder-Slab™ Technologies, LLC. Therefore, availability of materials should not be an issue, but rather the lead time should be taken into consideration, especially for a project with a strict deadline.

## Cost

The Girder-Slab™ system is estimated to cost approximately $29/SF, the same cost as the composite steel design, and significantly higher than the other alternatives. This could limit the potential of using the system, as cost almost always drives the decision when all else is considered equal. While there would be a reduction in foundation costs, shear wall costs will reduce the economics of this system over the comparable staggered steel truss system.

## Durability/Serviceability

Materials used in this system are very durable. Since the structure is lighter and more flexible, it may be worthwhile to investigate vibrations. Deflections in this structure have been calculated and have met the criteria established.

## Fire Protection

The 8" precast planks selected for design have an inherent 2-hour fire rating, which meets code requirements. The D-Beams®, however, require a separate application of fireproofing. Strategic location of the D-Beams® along the guest suite partitions allows for a the same fire-rated wall assembly used in the original design to be used at these locations, which would eliminate the need to apply spray-on fireproofing directly to the underside of the beams. Steel columns will also need to be fireproofed in a similar manner.

## Architectural Compatibility

Architecturally, this system also performs almost identically to the flat-plate and staggered steel truss systems. Ceiling finishes may be directly applied to the underside of the slab, and structural members are concealed within the partitions. Floor plans are not affected by the introduction of this system.

## Girder Slab™ – Composite Steel & Precast Concrete Plank

Although the Girder Slab™ system is lightweight and architecturally unrestrictive to the existing floor plans, it was estimated here to be one of the most expensive systems out of all four alternatives. I hesitate to eliminate this system as a viable alternative because structurally, the system has advantages that warrant its use. Perhaps with a more detailed study, the advantages will shine more and the cost may be justified or additional savings may make it more economical.

<u>Advantages</u>

+ Somewhat lightweight
+ Minimal floor depth (8")
+ No shoring required
+ Architectural flexibility
+ Speed of construction

<u>Disadvantages</u>

-Shorter beam spans, more columns
- Lead time required for fabrication of D-Beams®
- Somewhat weather dependent
- Significantly higher cost

*A viable alternative…for now*

# CONCLUSIONS

Based on the designs of four different floor framing alternatives and corresponding evaluations above, it appears as though the flooring structure chosen by the designer may be the most economical and advantageous system. However, the staggered steel truss system with precast hollow-core planks may prove to be a viable alternative, due to its relatively low cost and potential savings in reducing the size of foundations. The Girder-Slab™ system is comparable in this study to the staggered truss, however lacks competitiveness in terms of cost. The advantages of this system, however, warrant a more detailed study of this system. A composite steel framing system was deemed unviable for the Residence Inn. Not only is it uneconomical, but it also significantly increases the floor-to-floor heights and presents undesirable challenges related to ceiling construction and fireproofing.

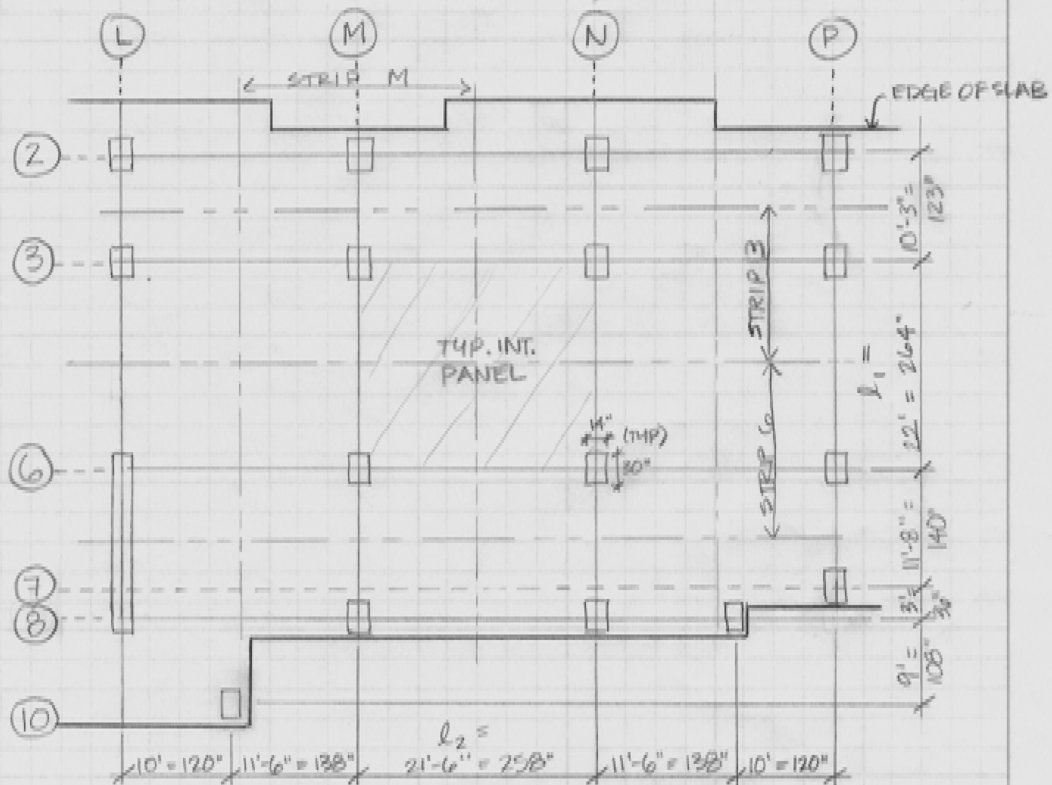
| | Alternative Floor Systems | | | |
|---|---|---|---|---|
| Criteria | 1 | 2 | 3 | 4 |
| | 2-Way Flat Plate (Original Design) | Composite Metal Deck & Composite Steel Beams | Precast H/C Plank & Staggered Steel Trusses | Girder-Slab™ |
| Cost | $18 / SF | $29 / SF | $21 / SF | $29 / SF |
| Structural Weight | 109 PSF | 47 PSF | 65 PSF | 66 PSF |
| Required Foundations | -⊓⊓⊓⊓⊓⊓⊓⊓⊓⊓- | -⊓⊓⊓⊓- | -⊓⊓⊓⊓⊓- | -⊓⊓⊓⊓⊓⊓- |
| Slab Depth | 8" | 4.5" | 8" | 8" |
| Floor Depth | 8" | 36" | 8" | 8" |
| Fireproofing Requirements | - | Significant SOFP needed | Gyp. assemblies provide | Gyp. assemblies provide |
| Construction Difficulty | Medium | Medium | Easy | Medium |
| Lead Time | Short | Long | Long | Long |
| Formwork? | Yes | No | No | No |
| Shoring? | Yes | No | No | No |
| Weather Dependent? | Yes | Yes | No | Yes |
| Vibration Issues? | Not likely | Likely | Not likely | Possibly |
| Effect on Column Grid | No | No | Yes | Yes |
| Durability | High | Medium-High | Medium-High | Medium-High |
| OVERALL FEASIBILITY | Appears to be best possible solution | Little advantage over original design | A likely contender for the best solution | Feasible, but costly - need to investigate |

(FIGURE 12) Comparison of Alternative Floor Systems Summary

## APPENDIX A: Two Way Flat Plate Design

| FLR. FRAMING – TWO-WAY FL. PL. | RESIDENCE INN | 10.6.08 KMR | 1/6 |
|---|---|---|---|

ORIGINAL SYSTEM – 2-WAY FLAT PLATE CONC.




ASSUMPTIONS:

$f'_c = 4000$ PSI  ALL COLS. 14 × 30" (TYP.)

$f_y = 60000$ PSI

LOADS: (USING MY OWN CALC DL & IBC 2006 LL FROM TECH 1)

$w_{DL,\,superimposed} = 15$ PSF

SEE PG. 2 FOR DETERMINATION

$w_{DL,\,slab\ weight} = \frac{8"}{12} \times 150\ PCF = 100$ PSF

$w_{DL,\,TOTAL} = 15 + 100 = 115$ PSF

$w_{LL} = 55\ PSF \times 0.65\ LLR = 35.75$ PSF

$w_u = 1.2(115\ PSF) + 1.6(35.75\ PSF) = 195.2\ PSF = 0.195$ KSF

(FIGURE 13) Two-Way Flat Plate Design (1 of 6)

| FLR FRAMING – TWO-WAY FL. FR. | RESIDENCE INN | 10.6.08 KMR | 2/6 |
|---|---|---|---|

MIN. THICKNESS OF SLAB W/O INT. BMS. (FOR DEFL. CONTROL)

TBL. 9.5(c) $\quad t \geq \frac{l_n}{33} = \frac{(22 \times 12) - 30}{33} = 7.09" \sim \boxed{8"}$

CRITERIA FOR DDM:

1) 3 CONT. SPANS ✓ OK
2) $\frac{l_2}{l_1} \leq 2 \rightarrow \frac{21.5}{22} = 0.98 < 2 \therefore$ OK
3) $l_2 - l_1 < \frac{1}{3} l_2 \rightarrow |21.5 - 22| = 0.5 < \frac{1}{3}(21.5) = 7.17' \therefore$ OK
4) $w_{LL} \leq 2\, w_{DL} \rightarrow 55 < 2(115) = 230 \therefore$ OK

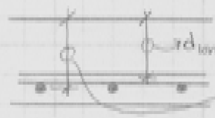
$\therefore$ DDM MAY BE USED

STRIP M

$$M_o = \frac{(0.195\text{ KSF})(21.5')(22 - \frac{30}{12})^2}{8} = 199.3^{\prime k}$$

CHECK WIDE BM ACTION SHEAR (ONE-WAY)

$$V_u = 0.195 \text{ KSF}\left(21.5/2 - \frac{\frac{14"}{12}}{2} - \frac{6.75}{12}\right) = 1.53^k / 12" \text{ OF SLAB}$$



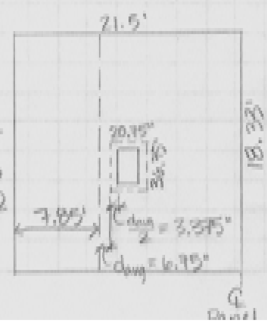
$d_{long} = 8" - 0.75" - 0.50" - \frac{1}{2}(0.50") = 6.5"$

$d_{short} = 8" - 0.75 - \frac{1}{2}(0.50") = 7"$

$d_{avg} = 6.75"$

$$\phi V_c = \phi 2 \sqrt{f'_c}\, bd$$
$$= 0.75(2)\sqrt{4000}\,(12")(6.75")/1000 = 7.68^k > V_u = 1.53^k \therefore \text{OK}$$

12" STRIP




$\beta = \frac{30}{14} = 2.14$

$b_o = 2(14) + 2(30) = 88"$

CHECK PUNCHING SHEAR (TWO-WAY)

$$V_u = 0.195\text{ KSF}\left((21.5' \times 18.33) - \left(\frac{20.75}{12} \times \frac{36.75}{12}\right)\right) = 75.82^k$$

$$\phi V_c = \text{smallest of} \begin{cases} 0.75\left(2 + \frac{4}{2.14}\right)\sqrt{4000}\,(88")(6.75")/1000 = \boxed{109^k} \text{ governs} \\ 0.75\left(\frac{40(6.75)}{88} + 2\right)\sqrt{4000}\,(88)(6.75)/1000 = 143^k \\ 0.75(4)\sqrt{4000}\,(88)(6.75)/1000 = 113^k \end{cases}$$

$V_u = 76^k < \phi V_c = 109^k \therefore$ 8" SLAB OK

(FIGURE 14) Two-Way Flat Plate Design (2 of 6)

FLR FRAMING – TWO-WAY FL. PL. | RESIDENCE INN | 10.6.08 KMR | 3/6

## DISTRIBUTION OF $M_o$ – STRIP M

INT. SPAN :

POS. $\quad 0.35M_o = 0.35(199.3'^k) = 69.8'^k$

INT. NEG. $\quad 0.65M_o = 0.65(199.3'^k) = 129.5'^k$

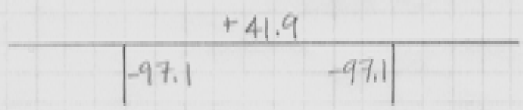
CS & MS :

SINCE NO BMS, $\alpha = 0 \therefore \alpha\frac{\ell_2}{\ell_1} = 0$

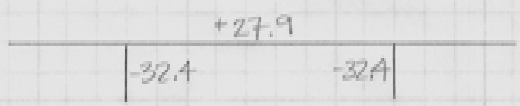
$\frac{\ell_2}{\ell_1} = 0.98$

| | CS MOMENT | (2) ½ MS MOMENT |
|---|---|---|
| POS | $0.60(69.8) = 41.9'^k$ | $+27.9'^k$ |
| NEG. | $0.75(129.5) = -97.1'^k$ | $-32.4'^k$ |

CS




MS




(FIGURE 15) Two-Way Flat Plate Design (3 of 6)

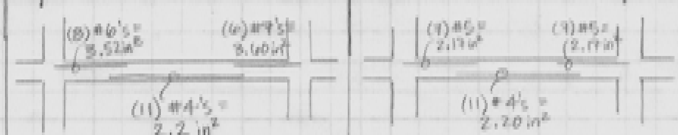
| FLR FRAMING<br>TWO-WAY FL. P. | RESIDENCE INN | 10.6.08<br>KMR | 4/6 |
|---|---|---|---|

## DESIGN OF SLAB REINF.

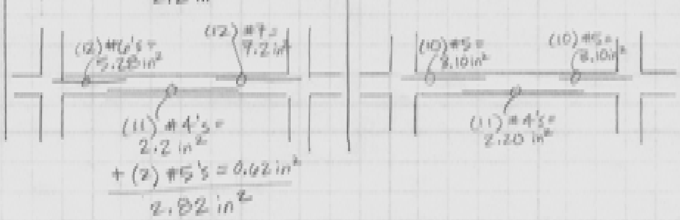
[STRIP M]

| Item #/Description | CS $M^+$ | CS $M^-$ | MS $M^+$ | MS $M^-$ |
|---|---|---|---|---|
| ① Moment $M_u$ | +41.9 | -97.1 | +27.9 | -32.4 |
| ② Slab Width b (in) | 129" | 129" | 129" | 129" |
| ③ Eff. Depth d (in) | 6.75" | 6.75" | 6.75" | 6.75" |
| ④ $M_n = \frac{M_u}{\phi} = \frac{M_u}{0.9}$ | +46.6 | -107.9 | +31 | -36 |
| ⑤ $\frac{M_u(12)}{b}$ $\left(\frac{\text{k-in}}{\text{in}}\right)$ | +3.90 | -9.03 | +2.60 | -3.01 |
| ⑥ $R = \frac{M_n(12000)}{bd^2} = 2.042M_n$ | 95 | 220 | 63 | 74 |
| ⑦ $\rho$ - TBL A-5 (TEXT) | 0.00160 | 0.00379 | 0.00107 | 0.00125 |
| ⑧ $A_{st} = \rho bd$ (in²) $= 870.75\rho$ | 1.39 | ✓3.30 | 0.93 | 1.09 |
| ⑨ $A_{st,min} = 0.002bt$ | 2.06✓ | 2.06 | 2.06✓ | ✓2.06 |
| ⑩ N = Larger of ⑧/⑨ #4's → 0.20 | 10.3 = 11 | 16.5 = 17 | 11 | 11 |
| ⑪ $N_{min} = \frac{\text{width strip}}{2t}$ | 9 | 9 | 9 | 9 |

RESULTS:




$A_{s,provided}$ [PER DWGS]




(FIGURE 16) Two-Way Flat Plate Design (4 of 6)

STRIP 3

$$M_o = \frac{(0.195\ KSF)\left(\frac{10.25'}{2} + \frac{22'}{2}\right)\left(21.5 - \frac{14}{12}\right)^2}{8} = 162.5'^k$$

INT. SPAN:

POS. $0.35\,M_o = 0.35(162.5'^k) = 56.9'^k$
INT. NEG. $0.65\,M_o = 0.65(162.5'^k) = -105.6'^k$

CS & MS

| | CS MOM. | MS MOM. |
|---|---|---|
| POS. | 0.60(56.9) = 34.1 | +22.8 |
| NEG. | 0.75(105.6) = 79.2 | -26.4 |

CS

+34.1
-79.2   -79.2

MS

+22.8
-26.4   -26.4

STRIP 6

$$M_o = \frac{(0.195\ KSF)\left(\frac{22'}{2} + \frac{14.67'}{2}\right)\left(21.5 - \frac{14}{12}\right)^2}{8} = 184.8'^k$$

INT. SPAN

POS. $0.35M_o = 0.35(184.8'^k) = 64.7'^k$
INT. NEG. $0.65\,M_o = 0.65(184.8'^k) = 120.1'^k$

CS

+38.8
-90.1   -90.1

MS

+25.9
-30   -30

(FIGURE 17) Two-Way Flat Plate Design (5 of 6)

| FLR FRAMING TWO-WAY FL. PL | RESIDENCE INN | 10.6.08 KMR | 6/6 |
|---|---|---|---|

## DESIGN OF SLAB REINF.

CS WIDTH = 96.75" | MS WIDTH = 96.75"

| STRIP 3 — Item #/Description | CS $M^+$ | CS $M^-$ | MS $M^+$ | MS $M^-$ |
|---|---|---|---|---|
| ① Moment $M_u$ | +34.1 | −79.2 | +22.8 | −26.4 |
| ② Slab Width b (in) | 96.75" | 96.75" | 96.75" | 96.75" |
| ③ Eff. Depth d (in) | 6.75" | 6.75" | 6.75" | 6.75" |
| ④ $M_n = \frac{M_u}{\Phi} = \frac{M_u}{0.9}$ | +37.9 | −88 | +25.3 | −29.3 |
| ⑤ $\frac{M_u(12)}{b} = 0.124\ M_u$ | +4.23 | −9.82 | +2.83 | −3.27 |
| ⑥ $R = \frac{M_n(12000)}{bd^2} = 2.722 M_n$ | 103 | 240 | 69 | 80 |
| ⑦ $\rho$ − TBL. A-5 (TEXT) | 0.00174 | 0.00415 | 0.00117 | 0.00135 |
| ⑧ $A_{st} = \rho bd = 653.1\rho$ | 1.14 | 2.71 | 0.76 | 0.88 |
| ⑨ $A_{st,min} = 0.002bt$ | 1.55 | 1.55 | 1.55 | 1.55 |
| RESULTS | (7) #6 = 3.08 in²; (8) #4 = 1.60 in² | (7) #6 = 3.08 in² | (5) #5 = 1.55 in²; (8) #4 = 1.60 in² | (5) #5 = 1.55 in² |
| $A_{s,provided}$ | (12) #6 = 5.28 in²; (9) #4 = 1.80 in² | (12) #6 = 5.28 in² | (9) #5 = 2.79 in²; (9) #4 = 1.80 in² | (9) #5 = 2.79 in² |

CS WIDTH = 110" | MS WIDTH = 110"

| STRIP 6 | CS $M^+$ | CS $M^-$ | MS $M^+$ | MS $M^-$ |
|---|---|---|---|---|
| ① $M_u$ | +38.8 | −90.1 | +25.9 | −30 |
| ② Slab Width b | 110" | 110" | 110" | 110" |
| ③ Eff. Depth d | 6.75" | 6.75" | 6.75" | 6.75" |
| ④ $M_n$ | +43.1 | −100.1 | +28.8 | −33.3 |
| ⑤ $\frac{M_u(12)}{b} = 0.1091\ M_u$ | +4.23 | −9.83 | +2.83 | −3.27 |
| ⑥ $R = \frac{M_n(12000)}{bd^2} = 2.394 M_n$ | 103 | 240 | 69 | 80 |
| ⑦ $\rho$ − TBL A-5 (TEXT) | 0.00174 | 0.00415 | 0.00117 | 0.00135 |
| ⑧ $A_{st} = \rho bd = 742.5\rho$ | 1.29 | 3.08 | 0.87 | 1.00 |
| ⑨ $A_{st,min} = 0.002bt$ | 1.76 | 1.76 | 1.76 | 1.76 |
| RESULTS | (7) #6 = 3.08 in²; (9) #4 = 1.80 in² | (7) #6 = 3.08 in² | (6) #5 = 1.86 in²; (9) #4 = 1.80 in² | (6) #5 = 1.86 in² |
| $A_{s,provided}$ | (12) #6 = 5.28 in²; (10) #4 = 2.0 in² | (12) #6 = 5.28 in² | (9) #5 = 2.79 in²; (10) #4 = 2.0 in² | (9) #5 = 2.79 in² |

(FIGURE 18) Two-Way Flat Plate Design (6 of 6)

# APPENDIX B:

## Composite Metal Deck Selection

From United Steel Deck Catalog:

- If possible, use 4.5” slab depth to reduce overall building height
- Minimum gage required for 3’-6” cantilever (4.5” depth) = 18 gage for 2.0 LOK-Floor
- Max unshored span for 18 gage 2.0 LOK for 3-span condition = 10.83’ < 11’ max span
- »16 gage 2.0 LOK required–Max unshored span for 3-span condition = 12.02’ >11’, OK
- Max uniform live load for 11’ span = 180 psf > 1.6(55) = 88 psf, OK

Use 16 gage 2.0 LOK Floor Composite Metal Deck ($f_y$ = 33 ksi) with 4.5” depth

2 hr fire rating can be achieved with this system using one of the following:

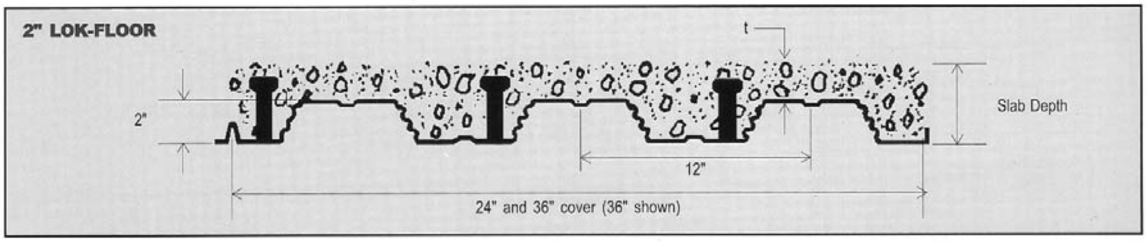
- Fibrous fireproofing
- Cementitous fireproofing
- Suspended Ceiling

Overall system depth, max = 15.7” + 4.5” = 20.2” (+ additional space required for suspended ceiling to conceal fireproofed underside of structure and give finished look architecturally) ~say 12” = TOTAL STRUCTURE DEPTH = approx. 33”

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

**USD United Steel Deck, Inc.** LRFD

## 2" LOK-FLOOR




The **Deck Section Properties** are per foot of width. The **I** value is for positive bending (in.[4]); **t** is the gage thickness in inches; **w** is the weight in pounds per square foot; $S_p$ and $S_n$ are the section moduli for positive and negative bending (in.[3]); $R_b$ and $\phi V_n$ are the interior reaction and the shear in pounds (per foot of width); studs is the number of studs required per foot in order to obtain the full resisting moment, $\phi M_{nf}$.

| DECK PROPERTIES | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Gage | t | w | As | I | $S_p$ | $S_n$ | $R_b$ | $\phi V_n$ | studs |
| 22 | 0.0295 | 1.5 | 0.440 | 0.338 | 0.284 | 0.302 | 714 | 1990 | 0.36 |
| 20 | 0.0358 | 1.8 | 0.540 | 0.420 | 0.367 | 0.387 | 1010 | 2410 | 0.43 |
| 19 | 0.0418 | 2.1 | 0.630 | 0.490 | 0.445 | 0.458 | 1330 | 2810 | 0.51 |
| 18 | 0.0474 | 2.4 | 0.710 | 0.560 | 0.523 | 0.529 | 1680 | 3180 | 0.57 |
| 16 | 0.0598 | 3.1 | 0.900 | 0.700 | 0.654 | 0.654 | 2470 | 3990 | 0.72 |

The **Composite Properties** are a list of values for the composite slab. The **slab depth** is the distance from the bottom of the steel deck to the top of the slab in inches as shown on the sketch. U.L. ratings generally refer to the cover over the top of the deck so it is important to be aware of the difference in names. $\phi M_{nf}$ is the factored resisting moment provided by the composite slab when the "full" number of studs as shown in the upper table are in place; inch kips (per foot of width). $A_c$ is the area of concrete available to resist shear, in.[2] per foot of width. **Vol.** is the volume of concrete in ft.[3] per ft.[2] needed to make up the slab; no allowance for frame or deck deflection is included. **W** is the concrete weight in pounds per ft.[2]. $S_c$ is the section modulus of the "cracked" concrete composite slab; in.[3] per foot of width. $I_{av}$ is the average of the "cracked" and "uncracked" moments of inertia of the transformed composite slab; in.[4] per foot of width. The $I_{av}$ transformed section analysis is based on steel; therefore, to calculate deflections the appropriate modulus of elasticity to use is 29.5 x $10^6$ psi. $\phi M_{no}$ is the factored resisting moment of the composite slab if there are <u>no studs</u> on the beams (the deck <u>is attached</u> to the beams or walls on which it is resting) inch kips (per foot of width). $\phi V_{nt}$ is the factored vertical shear resistance of the composite system; it is the sum of the shear resistances of the steel deck and the concrete but is not allowed to exceed $\phi\, 4(f'_c)^{1/2} A_c$; pounds (per foot of width). The next three columns list the **maximum unshored spans** in feet; these values are obtained by using the construction loading requirements of the SDI; combined bending and shear, deflection, and interior reactions are considered in calculating these values. $A_{wwf}$ is the minimum area of welded wire fabric recommended for temperature reinforcing in the composite slab; square inches per foot.

| COMPOSITE PROPERTIES | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Slab Depth | $\phi M_{nf}$ in.k | $A_c$ in² | Vol. ft³/ft² | W psf | $S_c$ in³ | $I_{av}$ in⁴ | $\phi M_{no}$ in.k | $\phi V_{nt}$ lbs. | Max. unshored spans, ft. 1span | 2span | 3span | $A_{wwf}$ |
| 22 gage | 4.50 | 40.27 | 32.6 | 0.292 | 42 | 1.05 | 5.9 | 29.40 | 5030 | 5.82 | 7.83 | 7.92 | 0.023 |
| | 5.00 | 46.44 | 37.5 | 0.333 | 48 | 1.23 | 8.0 | 34.53 | 5480 | 5.54 | 7.47 | 7.56 | 0.027 |
| | 5.25 | 49.53 | 40.0 | 0.354 | 51 | 1.32 | 9.2 | 37.16 | 5720 | 5.41 | 7.31 | 7.39 | 0.029 |
| | 5.50 | 52.61 | 42.6 | 0.375 | 54 | 1.42 | 10.5 | 39.81 | 5960 | 5.30 | 7.16 | 7.24 | 0.032 |
| | 6.00 | 58.78 | 48.0 | 0.417 | 60 | 1.61 | 13.5 | 45.21 | 6460 | 5.09 | 6.89 | 6.97 | 0.036 |
| | 6.25 | 61.87 | 50.8 | 0.438 | 63 | 1.71 | 15.3 | 47.95 | 6720 | 5.03 | 6.76 | 6.84 | 0.038 |
| | 6.50 | 64.95 | 53.6 | 0.458 | 66 | 1.81 | 17.1 | 50.70 | 6980 | 4.97 | 6.65 | 6.72 | 0.041 |
| | 7.00 | 71.12 | 59.5 | 0.500 | 73 | 2.01 | 21.2 | 56.26 | 7530 | 4.85 | 6.43 | 6.51 | 0.045 |
| | 7.25 | 74.21 | 61.9 | 0.521 | 76 | 2.11 | 23.5 | 59.07 | 7750 | 4.79 | 6.32 | 6.41 | 0.047 |
| | 7.50 | 77.29 | 64.3 | 0.542 | 79 | 2.21 | 26.0 | 61.88 | 7970 | 4.74 | 6.22 | 6.31 | 0.050 |
| 20 gage | 4.50 | 48.60 | 32.6 | 0.292 | 42 | 1.26 | 6.3 | 35.43 | 5450 | 6.81 | 8.97 | 9.27 | 0.023 |
| | 5.00 | 56.18 | 37.5 | 0.333 | 48 | 1.48 | 8.6 | 41.65 | 5900 | 6.47 | 8.55 | 8.83 | 0.027 |
| | 5.25 | 59.96 | 40.0 | 0.354 | 51 | 1.60 | 9.8 | 44.84 | 6140 | 6.32 | 8.36 | 8.63 | 0.029 |
| | 5.50 | 63.75 | 42.6 | 0.375 | 54 | 1.71 | 11.3 | 48.07 | 6380 | 6.18 | 8.18 | 8.45 | 0.032 |
| | 6.00 | 71.32 | 48.0 | 0.417 | 60 | 1.95 | 14.5 | 54.63 | 6880 | 5.94 | 7.85 | 8.11 | 0.036 |
| | 6.25 | 75.11 | 50.8 | 0.438 | 63 | 2.07 | 16.3 | 57.96 | 7140 | 5.86 | 7.70 | 7.95 | 0.038 |
| | 6.50 | 78.90 | 53.6 | 0.458 | 66 | 2.19 | 18.2 | 61.31 | 7400 | 5.79 | 7.56 | 7.80 | 0.041 |
| | 7.00 | 86.47 | 59.5 | 0.500 | 73 | 2.43 | 22.6 | 68.09 | 7950 | 5.65 | 7.29 | 7.53 | 0.045 |
| | 7.25 | 90.26 | 61.9 | 0.521 | 76 | 2.55 | 25.0 | 71.50 | 8170 | 5.58 | 7.17 | 7.41 | 0.047 |
| | 7.50 | 94.05 | 64.3 | 0.542 | 79 | 2.67 | 27.6 | 74.93 | 8390 | 5.52 | 7.05 | 7.28 | 0.050 |
| 19 gage | 4.50 | 55.85 | 32.6 | 0.292 | 42 | 1.45 | 6.7 | 40.69 | 5850 | 7.65 | 9.76 | 10.08 | 0.023 |
| | 5.00 | 64.68 | 37.5 | 0.333 | 48 | 1.71 | 9.0 | 47.87 | 6300 | 7.26 | 9.30 | 9.61 | 0.027 |
| | 5.25 | 69.10 | 40.0 | 0.354 | 51 | 1.84 | 10.4 | 51.56 | 6540 | 7.09 | 9.09 | 9.39 | 0.029 |
| | 5.50 | 73.52 | 42.6 | 0.375 | 54 | 1.97 | 11.9 | 55.30 | 6780 | 6.93 | 8.90 | 9.19 | 0.032 |
| | 6.00 | 82.35 | 48.0 | 0.417 | 60 | 2.24 | 15.2 | 62.90 | 7280 | 6.65 | 8.54 | 8.83 | 0.036 |
| | 6.25 | 86.77 | 50.8 | 0.438 | 63 | 2.38 | 17.1 | 66.76 | 7540 | 6.56 | 8.38 | 8.66 | 0.038 |
| | 6.50 | 91.19 | 53.6 | 0.458 | 66 | 2.52 | 19.2 | 70.65 | 7800 | 6.48 | 8.23 | 8.50 | 0.041 |
| | 7.00 | 100.03 | 59.5 | 0.500 | 73 | 2.80 | 23.8 | 78.50 | 8350 | 6.32 | 7.94 | 8.20 | 0.045 |
| | 7.25 | 104.44 | 61.9 | 0.521 | 76 | 2.94 | 26.3 | 82.46 | 8570 | 6.24 | 7.81 | 8.07 | 0.047 |
| | 7.50 | 108.86 | 64.3 | 0.542 | 79 | 3.08 | 29.0 | 86.45 | 8790 | 6.17 | 7.68 | 7.94 | 0.050 |
| 18 gage | 4.50 | 62.08 | 32.6 | 0.292 | 42 | 1.62 | 7.0 | 45.34 | 6080 | 8.42 | 10.48 | 10.83 | 0.023 |
| | 5.00 | 72.04 | 37.5 | 0.333 | 48 | 1.90 | 9.5 | 53.36 | 6670 | 7.98 | 9.99 | 10.32 | 0.027 |
| | 5.25 | 77.02 | 40.0 | 0.354 | 51 | 2.05 | 10.9 | 57.48 | 6910 | 7.79 | 9.77 | 10.10 | 0.029 |
| | 5.50 | 82.00 | 42.6 | 0.375 | 54 | 2.20 | 12.4 | 61.66 | 7150 | 7.61 | 9.56 | 9.88 | 0.032 |
| | 6.00 | 91.95 | 48.0 | 0.417 | 60 | 2.50 | 15.9 | 70.18 | 7650 | 7.30 | 9.18 | 9.49 | 0.036 |
| | 6.25 | 96.93 | 50.8 | 0.438 | 63 | 2.66 | 17.9 | 74.50 | 7910 | 7.20 | 9.01 | 9.31 | 0.038 |
| | 6.50 | 101.91 | 53.6 | 0.458 | 66 | 2.81 | 20.0 | 78.85 | 8170 | 7.11 | 8.85 | 9.14 | 0.041 |
| | 7.00 | 111.87 | 59.5 | 0.500 | 73 | 3.13 | 24.8 | 87.66 | 8720 | 6.93 | 8.54 | 8.82 | 0.045 |
| | 7.25 | 116.85 | 61.9 | 0.521 | 76 | 3.28 | 27.4 | 92.10 | 8940 | 6.85 | 8.40 | 8.68 | 0.047 |
| | 7.50 | 121.83 | 64.3 | 0.542 | 79 | 3.44 | 30.2 | 96.57 | 9160 | 6.77 | 8.26 | 8.54 | 0.050 |
| 16 gage | 4.50 | 62.08 | 32.6 | 0.292 | 42 | 1.99 | 7.7 | 45.34 | 6080 | 9.58 | 11.63 | 12.02 | 0.023 |
| | 5.00 | 72.04 | 37.5 | 0.333 | 48 | 2.35 | 10.4 | 53.36 | 6980 | 9.08 | 11.10 | 11.47 | 0.027 |
| | 5.25 | 77.02 | 40.0 | 0.354 | 51 | 2.53 | 11.9 | 57.48 | 7450 | 8.85 | 10.85 | 11.22 | 0.029 |
| | 5.50 | 82.00 | 42.6 | 0.375 | 54 | 2.72 | 13.6 | 61.66 | 7940 | 8.65 | 10.63 | 10.98 | 0.032 |
| | 6.00 | 91.95 | 48.0 | 0.417 | 60 | 3.10 | 17.4 | 70.18 | 8460 | 8.29 | 10.21 | 10.55 | 0.036 |
| | 6.25 | 96.93 | 50.8 | 0.438 | 63 | 3.29 | 19.5 | 74.50 | 8720 | 8.17 | 10.02 | 10.35 | 0.038 |
| | 6.50 | 101.91 | 53.6 | 0.458 | 66 | 3.48 | 21.8 | 78.85 | 8980 | 8.07 | 9.84 | 10.17 | 0.041 |
| | 7.00 | 111.87 | 59.5 | 0.500 | 73 | 3.88 | 27.0 | 87.66 | 9530 | 7.86 | 9.50 | 9.82 | 0.045 |
| | 7.25 | 116.85 | 61.9 | 0.521 | 76 | 4.08 | 29.8 | 92.10 | 9750 | 7.77 | 9.35 | 9.66 | 0.047 |
| | 7.50 | 121.83 | 64.3 | 0.542 | 79 | 4.28 | 32.8 | 96.57 | 9970 | 7.67 | 9.20 | 9.50 | 0.050 |

# 2" LOK-FLOOR

(FIGURE 19) United Steel Deck Catalog – Page 28

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

LRFD

| | | | L, Uniform Live Service Loads, psf * | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Slab Depth | φMn in.k | 6.00 | 6.50 | 7.00 | 7.50 | 8.00 | 8.50 | 9.00 | 9.50 | 10.00 | 10.50 | 11.00 | 11.50 | 12.00 |
| 22 gage | 4.50 | 40.27 | 400 | 365 | 310 | 265 | 230 | 200 | 175 | 155 | 135 | 120 | 105 | 95 | 85 |
| | 5.00 | 46.44 | 400 | 400 | 360 | 305 | 265 | 230 | 200 | 175 | 155 | 140 | 125 | 110 | 95 |
| | 5.50 | 52.61 | 400 | 400 | 400 | 350 | 300 | 260 | 230 | 200 | 175 | 155 | 140 | 125 | 110 |
| | 6.00 | 58.78 | 400 | 400 | 400 | 390 | 335 | 295 | 255 | 225 | 200 | 175 | 155 | 140 | 125 |
| | 6.50 | 64.95 | 400 | 400 | 400 | 400 | 370 | 325 | 285 | 250 | 220 | 195 | 175 | 155 | 135 |
| | 7.00 | 71.12 | 400 | 400 | 400 | 400 | 400 | 355 | 310 | 275 | 240 | 215 | 190 | 170 | 150 |
| | 7.25 | 74.21 | 400 | 400 | 400 | 400 | 400 | 370 | 325 | 285 | 250 | 225 | 200 | 175 | 155 |
| | 7.50 | 77.29 | 400 | 400 | 400 | 400 | 400 | 385 | 340 | 295 | 260 | 230 | 205 | 185 | 165 |
| 20 gage | 4.50 | 48.60 | 400 | 400 | 380 | 325 | 285 | 245 | 215 | 190 | 170 | 150 | 135 | 120 | 110 |
| | 5.00 | 56.18 | 400 | 400 | 400 | 380 | 330 | 285 | 250 | 220 | 195 | 175 | 155 | 140 | 125 |
| | 5.50 | 63.75 | 400 | 400 | 400 | 400 | 375 | 325 | 285 | 250 | 225 | 200 | 175 | 160 | 140 |
| | 6.00 | 71.32 | 400 | 400 | 400 | 400 | 400 | 365 | 320 | 285 | 250 | 225 | 200 | 180 | 160 |
| | 6.50 | 78.90 | 400 | 400 | 400 | 400 | 400 | 400 | 355 | 315 | 280 | 245 | 220 | 195 | 175 |
| | 7.00 | 86.47 | 400 | 400 | 400 | 400 | 400 | 400 | 390 | 345 | 305 | 270 | 240 | 215 | 195 |
| | 7.25 | 90.26 | 400 | 400 | 400 | 400 | 400 | 400 | 400 | 360 | 320 | 285 | 255 | 225 | 205 |
| | 7.50 | 94.05 | 400 | 400 | 400 | 400 | 400 | 400 | 400 | 375 | 330 | 295 | 265 | 235 | 210 |
| 19 gage | 4.50 | 55.85 | 400 | 400 | 400 | 380 | 330 | 290 | 255 | 225 | 200 | 180 | 160 | 145 | 130 |
| | 5.00 | 64.68 | 400 | 400 | 400 | 400 | 385 | 335 | 295 | 260 | 230 | 205 | 185 | 165 | 150 |
| | 5.50 | 73.52 | 400 | 400 | 400 | 400 | 400 | 380 | 335 | 295 | 265 | 235 | 210 | 190 | 170 |
| | 6.00 | 82.35 | 400 | 400 | 400 | 400 | 400 | 400 | 375 | 335 | 295 | 265 | 235 | 215 | 190 |
| | 6.50 | 91.19 | 400 | 400 | 400 | 400 | 400 | 400 | 400 | 370 | 330 | 295 | 265 | 235 | 210 |
| | 7.00 | 100.03 | 400 | 400 | 400 | 400 | 400 | 400 | 400 | 400 | 360 | 320 | 290 | 260 | 235 |
| | 7.25 | 104.44 | 400 | 400 | 400 | 400 | 400 | 400 | 400 | 400 | 375 | 335 | 300 | 270 | 245 |
| | 7.50 | 108.86 | 400 | 400 | 400 | 400 | 400 | 400 | 400 | 400 | 395 | 350 | 315 | 280 | 255 |
| 18 gage | 4.50 | 62.08 | 400 | 400 | 400 | 400 | 370 | 325 | 285 | 255 | 225 | 200 | 180 | 160 | 145 |
| | 5.00 | 72.04 | 400 | 400 | 400 | 400 | 400 | 375 | 335 | 295 | 260 | 235 | 210 | 190 | 170 |
| | 5.50 | 82.00 | 400 | 400 | 400 | 400 | 400 | 400 | 380 | 335 | 300 | 265 | 240 | 215 | 195 |
| | 6.00 | 91.95 | 400 | 400 | 400 | 400 | 400 | 400 | 400 | 375 | 335 | 300 | 270 | 245 | 220 |
| | 6.50 | 101.91 | 400 | 400 | 400 | 400 | 400 | 400 | 400 | 400 | 375 | 335 | 300 | 270 | 245 |
| | 7.00 | 111.87 | 400 | 400 | 400 | 400 | 400 | 400 | 400 | 400 | 400 | 365 | 330 | 295 | 270 |
| | 7.25 | 116.85 | 400 | 400 | 400 | 400 | 400 | 400 | 400 | 400 | 400 | 385 | 345 | 310 | 280 |
| | 7.50 | 121.83 | 400 | 400 | 400 | 400 | 400 | 400 | 400 | 400 | 400 | 400 | 360 | 325 | 290 |
| 16 gage | 4.50 | 62.08 | 400 | 400 | 400 | 400 | 370 | 325 | 285 | 255 | 225 | 200 | 180 | 160 | 145 |
| | 5.00 | 72.04 | 400 | 400 | 400 | 400 | 400 | 375 | 335 | 295 | 260 | 235 | 210 | 190 | 170 |
| | 5.50 | 82.00 | 400 | 400 | 400 | 400 | 400 | 400 | 380 | 335 | 300 | 265 | 240 | 215 | 195 |
| | 6.00 | 91.95 | 400 | 400 | 400 | 400 | 400 | 400 | 400 | 375 | 335 | 300 | 270 | 245 | 220 |
| | 6.50 | 101.91 | 400 | 400 | 400 | 400 | 400 | 400 | 400 | 400 | 375 | 335 | 300 | 270 | 245 |
| | 7.00 | 111.87 | 400 | 400 | 400 | 400 | 400 | 400 | 400 | 400 | 400 | 365 | 330 | 295 | 270 |
| | 7.25 | 116.85 | 400 | 400 | 400 | 400 | 400 | 400 | 400 | 400 | 400 | 385 | 345 | 310 | 280 |
| | 7.50 | 121.83 | 400 | 400 | 400 | 400 | 400 | 400 | 400 | 400 | 400 | 400 | 360 | 325 | 290 |
| 22 gage | 4.50 | 29.40 | 305 | 255 | 215 | 185 | 160 | 135 | 120 | 105 | 90 | 80 | 70 | 60 | 50 |
| | 5.00 | 34.53 | 360 | 305 | 255 | 220 | 185 | 160 | 140 | 120 | 105 | 95 | 80 | 70 | 65 |
| | 5.50 | 39.81 | 400 | 350 | 295 | 255 | 215 | 190 | 165 | 140 | 125 | 110 | 95 | 85 | 75 |
| | 6.00 | 45.21 | 400 | 400 | 340 | 290 | 250 | 215 | 185 | 160 | 140 | 125 | 110 | 95 | 85 |
| | 6.50 | 50.70 | 400 | 400 | 380 | 325 | 280 | 240 | 210 | 185 | 160 | 140 | 125 | 110 | 95 |
| | 7.00 | 56.26 | 400 | 400 | 400 | 360 | 310 | 270 | 235 | 205 | 180 | 155 | 140 | 120 | 105 |
| | 7.25 | 59.07 | 400 | 400 | 400 | 380 | 325 | 285 | 245 | 215 | 190 | 165 | 145 | 130 | 115 |
| | 7.50 | 61.88 | 400 | 400 | 400 | 400 | 345 | 295 | 260 | 225 | 200 | 175 | 155 | 135 | 120 |
| 20 gage | 4.50 | 35.43 | 375 | 315 | 270 | 230 | 200 | 170 | 150 | 130 | 115 | 100 | 90 | 80 | 70 |
| | 5.00 | 41.65 | 400 | 375 | 315 | 270 | 235 | 205 | 175 | 155 | 135 | 120 | 105 | 95 | 85 |
| | 5.50 | 48.07 | 400 | 400 | 365 | 315 | 270 | 235 | 205 | 180 | 160 | 140 | 125 | 110 | 95 |
| | 6.00 | 54.63 | 400 | 400 | 400 | 360 | 310 | 270 | 235 | 205 | 180 | 160 | 140 | 125 | 110 |
| | 6.50 | 61.31 | 400 | 400 | 400 | 400 | 350 | 300 | 265 | 230 | 205 | 180 | 160 | 140 | 125 |
| | 7.00 | 68.09 | 400 | 400 | 400 | 400 | 390 | 335 | 295 | 260 | 230 | 200 | 180 | 160 | 140 |
| | 7.25 | 71.50 | 400 | 400 | 400 | 400 | 400 | 355 | 310 | 270 | 240 | 210 | 190 | 165 | 150 |
| | 7.50 | 74.93 | 400 | 400 | 400 | 400 | 400 | 370 | 325 | 285 | 250 | 225 | 200 | 175 | 155 |
| 19 gage | 4.50 | 40.69 | 400 | 370 | 315 | 270 | 230 | 200 | 175 | 155 | 135 | 120 | 105 | 95 | 85 |
| | 5.00 | 47.87 | 400 | 400 | 370 | 315 | 275 | 240 | 210 | 185 | 160 | 145 | 125 | 115 | 100 |
| | 5.50 | 55.30 | 400 | 400 | 400 | 365 | 320 | 275 | 240 | 215 | 190 | 165 | 150 | 130 | 120 |
| | 6.00 | 62.90 | 400 | 400 | 400 | 400 | 365 | 315 | 275 | 245 | 215 | 190 | 170 | 150 | 135 |
| | 6.50 | 70.65 | 400 | 400 | 400 | 400 | 400 | 355 | 310 | 275 | 245 | 215 | 190 | 170 | 155 |
| | 7.00 | 78.50 | 400 | 400 | 400 | 400 | 400 | 395 | 350 | 305 | 270 | 240 | 215 | 190 | 170 |
| | 7.25 | 82.46 | 400 | 400 | 400 | 400 | 400 | 400 | 365 | 320 | 285 | 255 | 225 | 200 | 180 |
| | 7.50 | 86.45 | 400 | 400 | 400 | 400 | 400 | 400 | 385 | 340 | 300 | 265 | 235 | 210 | 190 |
| 18 gage | 4.50 | 45.34 | 400 | 400 | 350 | 300 | 260 | 230 | 200 | 175 | 155 | 140 | 125 | 110 | 100 |
| | 5.00 | 53.36 | 400 | 400 | 400 | 355 | 310 | 270 | 235 | 210 | 185 | 165 | 145 | 130 | 115 |
| | 5.50 | 61.66 | 400 | 400 | 400 | 400 | 360 | 315 | 275 | 240 | 215 | 190 | 170 | 150 | 135 |
| | 6.00 | 70.18 | 400 | 400 | 400 | 400 | 400 | 360 | 315 | 275 | 245 | 220 | 195 | 175 | 155 |
| | 6.50 | 78.85 | 400 | 400 | 400 | 400 | 400 | 400 | 355 | 310 | 275 | 245 | 220 | 195 | 175 |
| | 7.00 | 87.66 | 400 | 400 | 400 | 400 | 400 | 400 | 395 | 350 | 310 | 275 | 245 | 220 | 195 |
| | 7.25 | 92.10 | 400 | 400 | 400 | 400 | 400 | 400 | 400 | 365 | 325 | 290 | 260 | 230 | 210 |
| | 7.50 | 96.57 | 400 | 400 | 400 | 400 | 400 | 400 | 400 | 385 | 340 | 305 | 270 | 245 | 220 |
| 16 gage | 4.50 | 45.34 | 400 | 400 | 350 | 300 | 260 | 230 | 200 | 175 | 155 | 140 | 125 | 110 | 100 |
| | 5.00 | 53.36 | 400 | 400 | 400 | 355 | 310 | 270 | 235 | 210 | 185 | 165 | 145 | 130 | 115 |
| | 5.50 | 61.66 | 400 | 400 | 400 | 400 | 360 | 315 | 275 | 240 | 215 | 190 | 170 | 150 | 135 |
| | 6.00 | 70.18 | 400 | 400 | 400 | 400 | 400 | 360 | 315 | 275 | 245 | 220 | 195 | 175 | 155 |
| | 6.50 | 78.85 | 400 | 400 | 400 | 400 | 400 | 400 | 355 | 310 | 275 | 245 | 220 | 195 | 175 |
| | 7.00 | 87.66 | 400 | 400 | 400 | 400 | 400 | 400 | 395 | 350 | 310 | 275 | 245 | 220 | 195 |
| | 7.25 | 92.10 | 400 | 400 | 400 | 400 | 400 | 400 | 400 | 365 | 325 | 290 | 260 | 230 | 210 |
| | 7.50 | 96.57 | 400 | 400 | 400 | 400 | 400 | 400 | 400 | 385 | 340 | 305 | 270 | 245 | 220 |

☐ 1 STUD/FT.

▩ NO STUDS

* The **Uniform Live Loads** are based on the LRFD equation $\phi M_n = (1.6L + 1.2D)l^2/8$. Although there are other load combinations that may require investigation, this will control most of the time. The equation assumes there is no negative bending reinforcement over the beams and therefore each composite slab is a single span. Two sets of values are shown; $\phi M_{nf}$ is used to calculate the uniform load when the full required number of studs is present; $\phi M_{no}$ is used to calculate the load when no studs are present. A straight line interpolation can be done if the average number of studs is between zero and the required number needed to develop the "full" factored moment. The tabulated loads are checked for shear controlling (it seldom does), and also limited to a live load deflection of 1/360 of the span.

An upper limit of 400 psf has been applied to the tabulated loads. This has been done to guard against equating large concentrated to uniform loads. Concentrated loads may require special analysis and design to take care of servicibility requirements not covered by simply using a uniform load value. On the other hand, for any load combination the values provided by the composite properties can be used in the calculations.

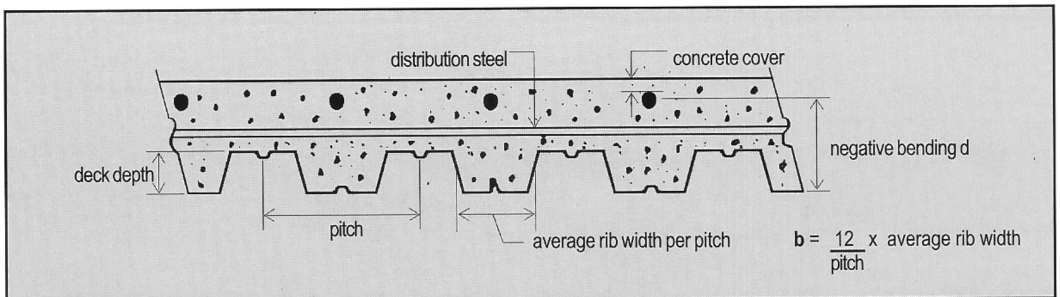
Welded wire fabric in the required amount is assumed for the table values. If welded wire fabric is not present, deduct 10% from the listed loads.

Refer to the example problems for the use of the tables.

**2" LOK-FLOOR**

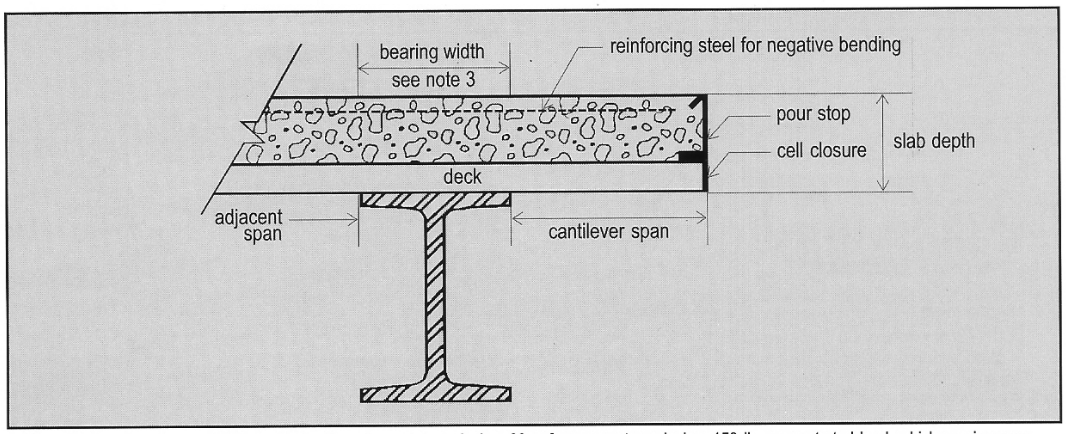
(FIGURE 20) United Steel Deck Catalog – Page 29

USD United Steel Deck, Inc.




| DECK SECTION | PITCH | AVERAGE RIB WIDTH | b WIDTH FOR NEGATIVE BENDING |
|---|---|---|---|
| B-LOK | 6" | 2.25" | 4.5" |
| INV B-LOK | 6" | 3.75" | 7.5" |
| LOK FLOOR | 12" | 6" | 6" |

Use Standard concrete design procedures as per ACI.




1. Allowable bending stress of 20 ksi with loading of concrete + deck + 20 psf or concrete + deck + 150 lb. concentrated load, whichever is worse.
2. Allowable deflection of free edge (based on fixed end cantilever) of 1/120 of cantilever span under loading of concrete + deck.
3. Bearing width of 3½" assumed for web crippling check; concrete + deck + 20 psf over cantilever and adjacent span: if width is less than 3½" check with the Summit, New Jersey office.

## floor deck cantilevers

| NORMAL WEIGHT CONCRETE (150 PCF) | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | United Steel Deck, Inc. DECK PROFILE | | | | | | | | | | | | | | | |
| | B-LOK | | | | 1.5 LOK-FLOOR | | | | 2.0 LOK-FLOOR | | | | 3.0 LOK-FLOOR | | | |
| SLAB DEPTH | 22 GAGE | 20 GAGE | 18 GAGE | 16 GAGE | 22 GAGE | 20 GAGE | 18 GAGE | 16 GAGE | 22 GAGE | 20 GAGE | 18 GAGE | 16 GAGE | 22 GAGE | 20 GAGE | 18 GAGE | 16 GAGE |
| 4.00" | 1'11" | 2'3" | 2'10" | 3'4" | 1'11" | 2'4" | 3'0" | 3'6" | | | | | | | | |
| 4.50" | 1'10" | 2'2" | 2'9" | 3'3" | 1'10" | 2'3" | 2'10" | 3'4" | 2'6" | 2'11" | 3'8" | 4'3" | | | | |
| 5.00" | 1'10" | 2'2" | 2'8" | 3'2" | 1'10" | 2'3" | 2'9" | 3'3" | 2'5" | 2'10" | 3'6" | 4'1" | 3'8" | 4'3" | 5'3" | 6'0" |
| 5.50" | 1'9" | 2'1" | 2'7" | 3'0" | 1'9" | 2'2" | 2'9" | 3'2" | 2'4" | 2'9" | 3'5" | 4'0" | 3'7" | 4'1" | 5'0" | 5'9" |
| 6.00" | 1'9" | 2'0" | 2'6" | 2'11" | 1'9" | 2'1" | 2'8" | 3'1" | 2'3" | 2'8" | 3'4" | 3'10" | 3'5" | 3'11" | 4'10" | 5'7" |
| 6.50" | 1'8" | 2'0" | 2'6" | 2'11" | 1'9" | 2'1" | 2'7" | 3'0" | 2'3" | 2'8" | 3'3" | 3'9" | 3'4" | 3'10" | 4'8" | 5'5" |
| 7.00" | 1'8" | 1'11" | 2'5" | 2'10" | 1'8" | 2'0" | 2'6" | 2'10" | 2'2" | 2'7" | 3'2" | 3'8" | 3'3" | 3'9" | 4'6" | 5'3" |
| 7.50" | 1'8" | 1'11" | 2'4" | 2'9" | 1'8" | 2'0" | 2'6" | 2'10" | 2'2" | 2'6" | 3'1" | 3'7" | 3'2" | 3'8" | 4'5" | 5'1" |
| 8.00" | 1'7" | 1'11" | 2'4" | 2'8" | 1'7" | 1'11" | 2'5" | 2'10" | 2'1" | 2'5" | 3'0" | 3'6" | 3'1" | 3'6" | 4'3" | 4'11" |

(FIGURE 21) United Steel Deck Catalog – Page 44

# APPENDIX C:

## Composite Steel Beam Design

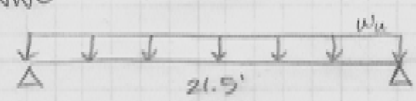
FLR FRAMING – COMP. MTL DECK/ STL BMS. | RESIDENCE INN | 10.15.08 KMR | 1/4

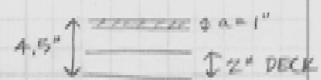
3½" LESS TRIB, CONSIDERING SAME AS B1

COMPOSITE BMS B1/B2

16 GA. 4.5" DEPTH
2" LOK–STL FLR DECK

$f'_c = 3000$ psi, NWC
$f_y = 50$ ksi




$w = 1.2(15 + 42) + 1.6(55) = 156.4$ PSF

$M_u = \dfrac{\overbrace{(0.1564)(11')}^{w_u}(21.5')^2}{8} = 99.4'^k$

assuming $a = 1"$ → $Y_2 = 4.5" - \frac{1"}{2} = 4"$

TBL 3-19

W10×12 $\quad \phi M_{pc} = 99.4'^k$ @ PNA #4

$\Sigma Q_n = 114^k$ @ PNA #4

$b_{eff} = 11' = 132"$
$\frac{1}{4}(21.5') = 64.5"$ *CRITICAL

$a = \dfrac{114}{0.85(3)(64.5")} = 0.69" < a = 1"$ (assumed)
∴ CONSERVATIVE

¾" φ SHEAR STUDS : $\dfrac{114^k}{21^k} = 6 \times 2 = \boxed{12}$

OTHER OPTIONS : $(\Sigma Q_n \le 164^k)$

| | # SS | WT. | Approx. installed cost | |
|---|---|---|---|---|
| W10×15 | 8 | 323# + 8(10 $/s.s.) = | 403 | 3 |
| W10×17 | 6 | | 426 | |
| W12×14 | 8 | | 381* | 2 |
| W12×16 | 6 | | 404 | |
| W10×12 | 12 | | 378* | 1 |

W10×12 MOST ECONOMICAL – CHECK FURTHER

Bare Stl. Bm: $\phi M_n = 47.3'^k$

(FIGURE 22) Composite Steel Beam Design (1 of 4)

FLR FRAMING. COMP. MTL. DECK/ STL. BMS. | RESIDENCE INN | 10.15.08 KMR | 2/4

$W_{deck\,\&\,conc} = 42$ PSF × 11' = 462 PLF

$W_{bm} = 12$ PLF

$W_{CONSTR.\,LL} = 20$ PSF × 11' = 220 PLF

$W_u = 1.2(462 + 12) + 1.6(220) = 921$ PLF

$M_u = \frac{(0.921)(21.5)^2}{8} = 53'^k > \phi M_n = 47.3'^k \therefore$ NG

→ TRY $\boxed{W12 \times 14}$ → $M_u = 53.1'^k$

$\phi M_n = 65.5'^k > M_u \therefore$ OK

CHECK $\Delta$: (SERVICE)

$w = 0.476 + 0.220 = 0.696$ KLF

$I_{W12\times14} = 88.6\ in^4$

$\Delta = \frac{5}{384} \frac{(0.696)(21.5)^4(1728)}{29000(88.6)} = 1.30'' > 1''$ MIN OF

$> l/360 = 0.72''$ // $\Delta_{max}$ ∴ NG

$\Delta_{W12\times16} = 1.12''$ NG

$\Delta_{W12\times19} = 0.89'' > 0.72'' \therefore$ NG.

$\Delta_{W12\times22} = 0.75''$ ∴ NG.

$\Delta_{W12\times26}$ (10 S.S.) $= 0.58'' < 0.72'' \therefore$ OK → WT = 659#

ALSO TRY $\Delta_{W14\times22}$ (8 S.S.) $= 0.59'' < 0.72'' \therefore$ OK → WT = 553# *

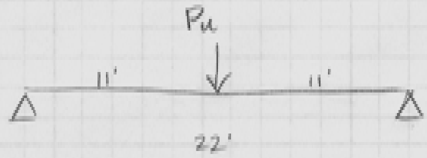
→ COULD USE EITHER $\boxed{W12 \times 26 \text{ w/ } (10)\ 3/4'' \text{ S.S.}}$

OR W14 × 22 w/ (8) 3/4" S.S. * MORE ECONOMICAL

(FIGURE 23) Composite Steel Beam Design (2 of 4)

FLR FRAMING COMP. MTL DECK/ STL. BMS. | RESIDENCE INN | 10.15.08 KMR | 3/4

COMPOSITE GIRDERS (G1)




$P_u = 1.2(13.95^k) + 1.6(13.01^k) = 37.6^k$

$M_u = \frac{(37.6^k)(22')}{4} = 207'^k$

TBL. 3-19 $(Y_2 = 4")$ $\Sigma Q_{n,max} = 168$ for assumption $a = 1"$

W12×26 $\phi M_{pc} = 212'^k$ @ BFL

$\Delta_{W12\times26} = \frac{Pl^3}{48EI} = \frac{(10.54^k + 4.73^k)(22')^3(144)}{48(29000)(204)} = 0.082"$

$\Delta_{allow} = \frac{22(12)}{360} = 0.73"$

HOWEVER THIS IS NOT DEEP ENOUGH FOR W14×22 TO FRAME INTO. . .

$\therefore$ W18×35 $(T = 15.5" > d_{W14\times22} = 13.7")$

OR $\boxed{W16\times26}$ $(T = 13.63" > d_{W12\times26} = 12.2")$ IF B1/B2 = W12×26

$\phi M_{pc} = 237'^k$ @ PNA #7 $> M_u = 207'^k \therefore$ OK

$\Sigma Q_n = 96^k < 168 \therefore$ OK

$\#S.S. = \frac{96}{21} \times 2 = \boxed{(10)\ 3/4"\ S.S.'s}$

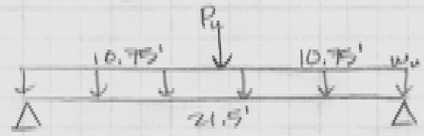
BY INSPECTION W/ ABOVE CALC FOR $\Delta_{W12\times26}$, $\Delta$ NOT CRITICAL

CHECK BARE STL. BM: $P_u = 1.2(10.54^k) + 1.6(4.73^k) = 20.2^k$

$M_u = \frac{(20.2)(22)}{4} = 111'^k < \phi M_n = 166'^k \therefore$ OK

(FIGURE 24) Composite Steel Beam Design (3 of 4)

COMPOSITE GIRDER (G2)




Assuming bm. that frames into is approx. 15#/ft.

$w_u = 1.2(57\ psf \times \frac{11'}{2}) + 1.6(55\ psf \times \frac{11'}{2}) = 860\ PLF = 0.86\ k/ft$

$M_{u,UDL} = \dfrac{0.86(21.5')^2}{8} = 50'^k$

$P_u = 1.2(4.5^k) + 1.6(4.34^k) = 12.4^k$

$M_{u,P} = \dfrac{12.4(21.5)}{4} = 67'^k$

$M_{u,TOTAL} = 50 + 67 = 117'^k$

TBL. 3-19 ($Y_2 = 4"$) $\Sigma Q_{n,max} = 164^k$

$\boxed{W14 \times 22} \rightarrow \phi M_{pc}$ @ PNA #7 $= 180'^k > M_u = 117'^k \therefore$ OK

$\Sigma Q_n = 81.2^k \rightarrow \boxed{(8)\ 3/4"\ \phi\ S.S.'s}$

$\Delta_{W14 \times 22} = \dfrac{5}{384}\dfrac{(0.363)(21.5)^4 1728}{29000(199)} + \dfrac{5^k(21.5)^3(144)}{48(29000)(199)} =$

$= 0.30" + 0.026" = 0.33" < \Delta_{allow} \therefore$ OK

$\Delta_{allow} = 1"$ OR $\dfrac{21.5(12)}{360} = 0.72"$

BARE STL. BM:

$w_u = 1.2(253\ PLF) + 1.6(110\ PLF) = 0.48\ k/ft$

$M_{UDL} = \dfrac{0.48(21.5)^2}{8} = 28'^k$

$P_u = 1.2(3.42^k) + 1.6(1.6^k) = 6.66^k$

$M_{Pu} = \dfrac{(6.66)(21.5)}{4} = 36'^k$

$M_{u,TOTAL,SERVICE} = 28 + 36 = 64'^k < \phi M_n = 125'^k \therefore$ OK

(FIGURE 25) Composite Steel Beam Design (4 of 4)

# APPENDIX D:

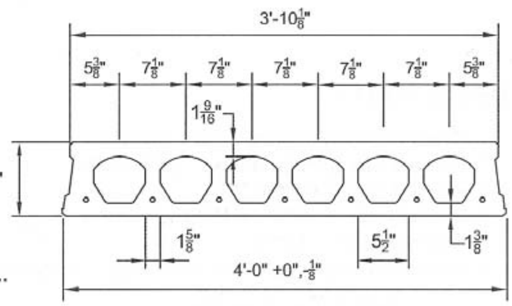
## Precast Hollow Core Plank Selection

### Prestressed Concrete
### 8"x4'-0" Hollow Core Plank

2 Hour Fire Resistance Rating (Untopped)

**PHYSICAL PROPERTIES**
Precast

| | |
|---|---|
| $A = 235$ in.$^2$ | $S_b = 459$ in.$^3$ |
| $I = 1838$ in.$^4$ | $S_t = 459$ in.$^3$ |
| $Y_b = 4.00$ in. | Wt.= 245 PLF |
| $Y_t = 4.00$ in. | Wt.= 61.25 PSF |
| $e = 2.25$ in. | |




### DESIGN DATA

1. Precast Strength @ 28 days = 6000 PSI
2. Precast Strength @ release = 3500 PSI.
3. Precast Density = 150 PCF
4. Strand = 1/2"Ø 270K Lo-Relaxation.
5. Strand Height = 1.75 in.
6. Ultimate moment capacity (when fully developed)...
   4-1/2"Ø, 270K = 72.8 k-ft
   7-1/2"Ø, 270K = 119.8 k-ft
7. Maximum bottom tensile stress is $7.5\sqrt{f'c}$ = 580 PSI
8. All superimposed load is treated as live load in the strength analysis of flexure and shear.
9. Flexural strength capacity is based on stress/strain strand relationships.
10. Deflection limits were not considered when determining allowable loads in this table.
11. Load values to the left of the solid line are controlled by ultimate shear strength.
12. Load values to the right are controlled by ultimate flexural strength or structural fire endurance.
13. Load values may be different for IBC 2000 & ACI 318-99. Load tables are available upon request.
14. Camber is inherent in all prestressed hollow core slabs and is a function of the amount of eccentric prestressing force needed to carry the superimposed design loads along with a number of other variables. Because prediction of camber is based on empirical formulas it is at best an estimate, with the actual camber usually higher than calculated values.

SAFE SUPERIMPOSED SERVICE LOADS — IBC 2003 & ACI 318-02 (1.2 D + 1.6 L)

| Strand Pattern | | SPAN (FEET) | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 |
| 4 - 1/2"ø | LOAD (PSF) | 218 | 188 | 162 | 140 | 121 | 105 | 91 | 78 | 67 | 58 | 49 | 41 | 34 | | | | | | |
| 7 - 1/2"ø | LOAD (PSF) | 288 | 269 | 252 | 236 | 222 | 210 | 196 | 176 | 157 | 141 | 126 | 113 | 101 | 90 | 81 | 72 | 64 | 57 | 50 |


NITTERHOUSE
CONCRETE PRODUCTS
2655 Molly Pitcher Hwy. South, Box N
Chambersburg, PA 17201-0813
717-267-4505 Fax 717-267-4518


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. The allowable loads shown in this table reflect a 2 Hour & 0 Minute fire resistance rating.

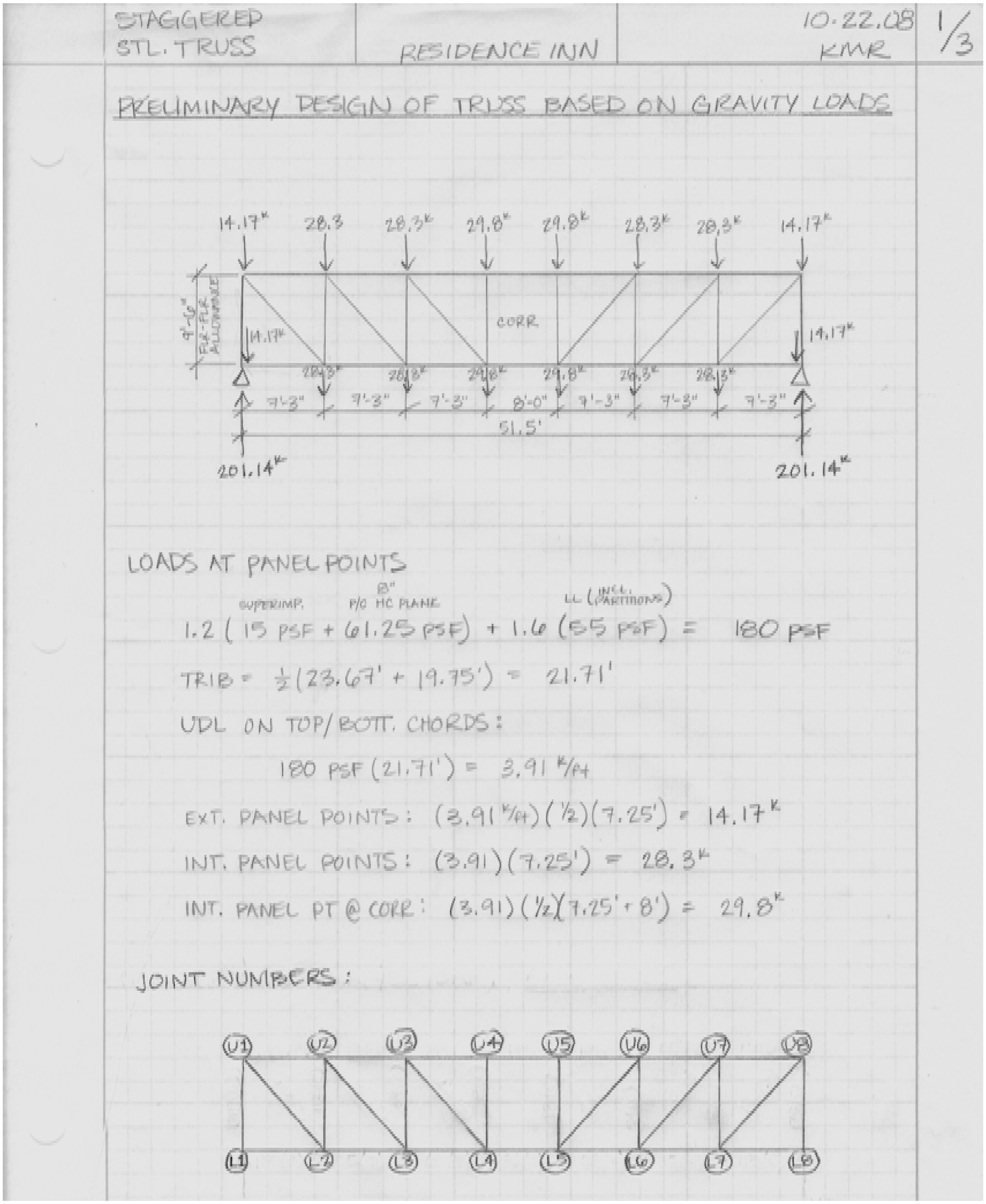
08/10/07

8SF2.0

(FIGURE 26) Nitterhouse Precast Hollow Core Plank Design Table

# APPENDIX E:

## Staggered Steel Truss Design


STAGGERED STL. TRUSS | RESIDENCE INN | 10.22.08 KMR | 1/3

PRELIMINARY DESIGN OF TRUSS BASED ON GRAVITY LOADS



LOADS AT PANEL POINTS

SUPERIMP. | 8" P/C HC PLANK | LL (INCL. PARTITIONS)

$1.2(15\text{ PSF} + 61.25\text{ PSF}) + 1.6(55\text{ PSF}) = 180\text{ PSF}$

$\text{TRIB} = \frac{1}{2}(23.67' + 19.75') = 21.71'$

UDL ON TOP/BOTT. CHORDS:

$180\text{ PSF}(21.71') = 3.91\ ^{k}/_{ft}$

EXT. PANEL POINTS: $(3.91\ ^{k}/_{ft})(\frac{1}{2})(7.25') = 14.17^{k}$

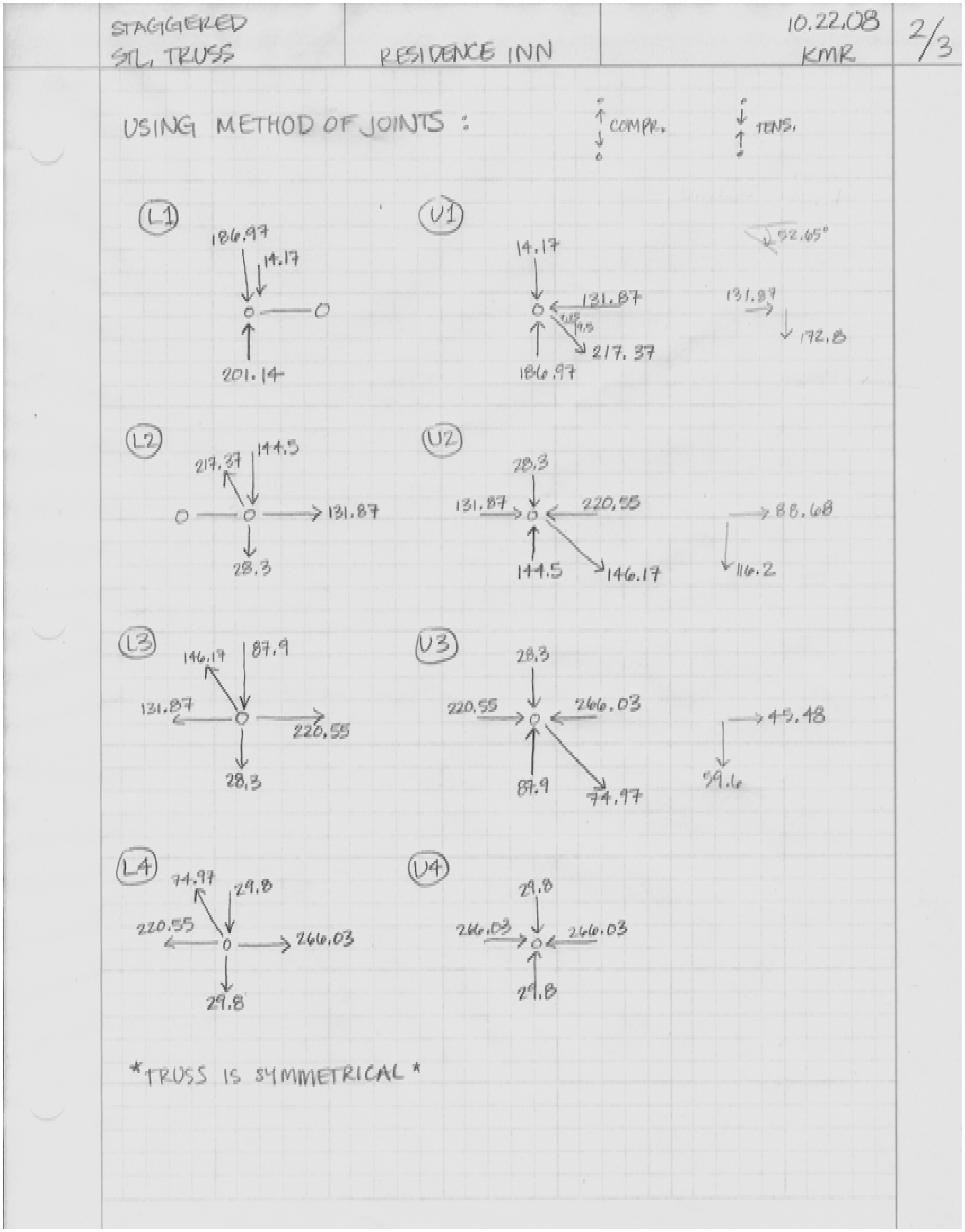
INT. PANEL POINTS: $(3.91)(7.25') = 28.3^{k}$

INT. PANEL PT @ CORR: $(3.91)(\frac{1}{2})(7.25' + 8') = 29.8^{k}$

JOINT NUMBERS:



(FIGURE 27) Staggered Steel Truss Design (1 of 3)




(FIGURE 28) Staggered Steel Truss Design (2 of 3)

| STAGGERED STL TRUSS | RESIDENCE INN | 10.22.08 KMR | 3/3 |
|---|---|---|---|

SELECTION OF DIAG. MEMBERS:

TBL. 5-5, AISC MANUAL

$\boxed{\text{HSS } 4 \times 4 \times 1/2} \rightarrow \phi P_n = 249^k > T_u = 218^k \therefore$ OK

$T_{u,max} = 218^k$

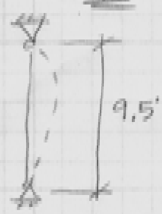
SELECTION OF VERT. COMPR. MEMBERS:

TBL. 4-3, AISC MANUAL

$\boxed{\text{HSS } 6 \times 4 \times 1/2} \rightarrow \phi P_n = 221^k > P_u = 187^k \therefore$ OK

K = 1 (PINNED-PINNED)

KL = 9.5'




$P_{u,max} = 187^k$

SELECTION OF CHORD MEMBERS:

BOTT. CHORD $\rightarrow$ $266.03^k$ MAX TENSION

$\rightarrow$ TRY (2) $L6 \times 4 \times 1/2$, $\phi P_n = 308^k$ (TBL. 5-2, AISC MANUAL)

DBL ANGLES: $\phi P_n = 292^k > 266.03^k \therefore$ OK

TOP CHORD $\rightarrow$ 266.03 MAX COMPR.

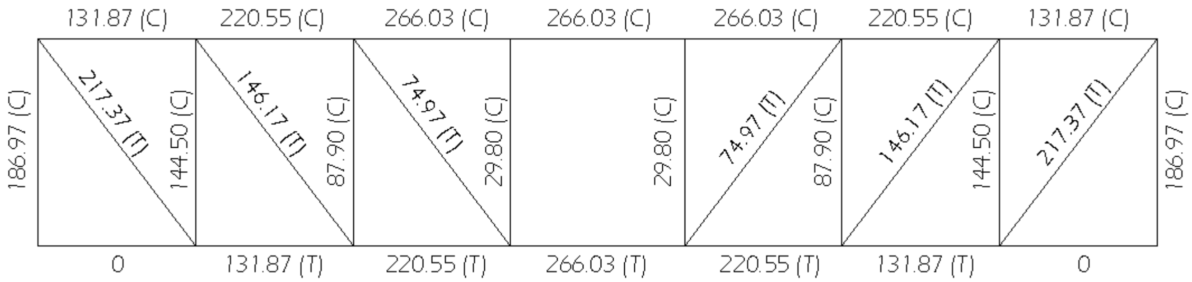
KL = 8' (MAX)

$\rightarrow$ TRY $2L6 \times 4 \times 1/2$, $\phi P_{n,\,y\text{-}y\ (\text{CRITICAL DIR.})} = 227^k < 266.03^k \therefore$ NG

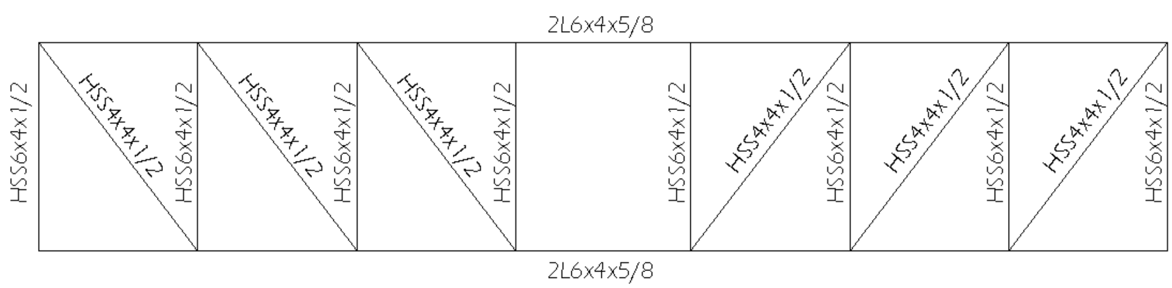
$\rightarrow$ USE $2L6 \times 4 \times 5/8$ $\quad \phi P_{n,x\text{-}x} = 332^k$, $\phi P_{n,y\text{-}y} = 293^k$ $> 266.03^k \therefore$ OK

$\boxed{\text{USE } 2L6 \times 4 \times 5/8 \text{ FOR BOTH TOP \& BOTT. CHORDS}}$

(FIGURE 29) Staggered Steel Truss Design (3 of 3)




(FIGURE 30) Staggered Steel Truss – Axial Forces in Each Member

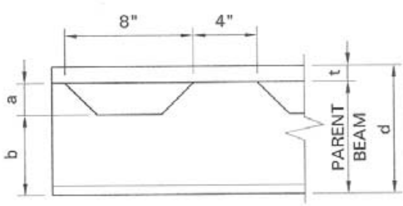



(FIGURE 31) Staggered Steel Truss Member Sizes

# APPENDIX F:
## D-Beam® Design

### D-Beam® Dimensions Table

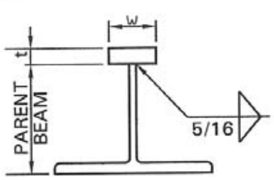
| Designation | Web Included | | Depth | Web | Parent Beam | | | Top Bar |
|---|---|---|---|---|---|---|---|---|
| | Weight | Avg. Area | d | Thickness $t_w$ | Size | a | b | w x t |
| | lb/ft | in² | in | in | | in | in | in x in |
| DB 8 x 35 | 34.7 | 10.2 | 8 | .340 | W10 x 49 | 4 | 3 | 3 x 1 |
| DB 8 x 37 | 36.7 | 10.8 | 8 | .345 | W12 x 53 | 2 | 5 | 3 x 1 |
| DB 8 x 40 | 39.8 | 11.7 | 8 | .340 | W10 x 49 | 3 | 3.5 | 3 x 1.5 |
| DB 8 x 42 | 41.8 | 12.3 | 8 | .345 | W12 x 53 | 1 | 5.5 | 3 x 1.5 |
| DB 9 x 41 | 40.7 | 11.9 | 9.645 | .375 | W14 x 61 | 3.375 | 5.25 | 3 x 1 |
| DB 9 x 46 | 45.8 | 13.4 | 9.645 | .375 | W14 x 61 | 2.375 | 5.75 | 3 x 1.5 |




**D-Beam® Reference Calculator is Available on Website. www.girder-slab.com**

(FIGURE 32) *D-Beam® Dimensional Information*

### D-Beam® Properties Table




| Designation | Steel Only / Web Ignored | | | | | | Transformed Section / Web Ignored | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ix | C bot | C top | S bot | S top | Allowable Moment Fy=50 KSI $f_b$=0.6 Fy | Ix | C bot | C top | S bot | S top |
| | in⁴ | in | in | in³ | in³ | kft | in⁴ | in | in | in³ | in³ |
| DB 8 x 35 | 102 | 2.80 | 5.20 | 36.5 | 19.7 | 49 | 279 | 4.16 | 4.40 | 67.1 | 63.5 |
| DB 8 x 37 | 103 | 2.76 | 5.24 | 37.3 | 19.7 | 49 | 282 | 4.16 | 4.42 | 67.7 | 63.8 |
| DB 8 x 40 | 122 | 3.39 | 4.61 | 36.1 | 26.5 | 66 | 289 | 4.26 | 4.30 | 67.9 | 67.2 |
| DB 8 x 42 | 123 | 3.35 | 4.65 | 36.9 | 26.5 | 66 | 291 | 4.26 | 4.32 | 68.4 | 67.5 |
| DB 9 x 41 | 159 | 3.12 | 6.51 | 51.0 | 24.4 | 61 | 332 | 4.27 | 5.35 | 77.7 | 62.1 |
| DB 9 x 46 | 195 | 3.84 | 5.79 | 50.8 | 33.7 | 84 | 356 | 4.43 | 5.20 | 80.6 | 68.6 |

(FIGURE 33) *D-Beam® Section Properties Information*

FLR FRAMING – PRECAST HC PLANK | RESIDENCE INN | 10.20.08 KMR | 1/2

PLANK DL = 61.25 PSF (8" HC, UNTOPPED) & SUPERIMPOSED DL = 15 PSF

LIVE LOAD = 55 PSF (INCL. PARTITIONS)

PLANK $f'_c$ = 6,000 PSI

GROUT $f'_c$ = 4000 PSI

8" HC PLANK SPAN = 21'-6" (TYP. BAY)

D-BM SPAN = 16' (TYP. BAY)

$$\Delta_{LL,ALLOW} = \frac{L}{360} = \frac{(16)(12)}{360} = 0.53"$$

<u>INITIAL LOAD – PRECOMPOSITE</u>

$$M_{DL} = \frac{(21.5')(0.06125\ KSF)(16')^2}{8} = 42.1'^{k}$$

→ TRY DB8×35 → $M_{allow} = 49'^{k} > M_{DL} = 42.1'^{k}$ ∴ <u>OK</u>

($I_x = 102\ in^4$) – STL. ONLY

$$\Delta_{DL} = \frac{5(21.5')(0.06125\ KSF)(16')^4(1728)}{384(102\ in^4)(29000\ KSI)} = 0.656"$$

<u>TOTAL LOAD – COMPOSITE</u>

$$M_{SUP} = \frac{(21.5')(0.015 + 0.055\ KSF)(16')^2}{8} = 48.16'^{k}$$

$$M_{TOTAL} = 42.1'^{k} + 48.16'^{k} = 90.26'^{k}$$

$$S_{REQ} = \frac{(90.26'^{k})(12\ in/ft)}{0.6(50\ KSI)} = 36.1\ in^3 < S_{DB8\times35} = 63.5\ in^3 \ \therefore \underline{OK}$$

$$\Delta_{SUP} = \frac{5(21.5')(0.015 + 0.055\ KSF)(16')^4(1728)}{384(279\ in^4)(29000\ KSI)} = 0.27" < \Delta_{allow} = 0.53"$$

∴ <u>OK</u>

TRANSFORMED SECTION, DB8×35

<u>CHECK SUPERIMPOSED COMPRESSIVE STRESS – CONC.</u>

$$N = \frac{E_{STEEL}}{E_{CONC.}} = \frac{29000\ KSI}{57000\sqrt{4000\ PSI}/1000} = \frac{29000}{3605} = 8.04$$

$f_{grout}$

$$S_{tc} = 8.04(63.5\ in^3) = 510.5\ in^3$$

(FIGURE 34) D-Beam® Design (1 of 2)

$$f_c = \frac{(48.16'^k)(12\ ^{in}/_{ft})}{(510.5\ in^3)} = 1.13\ ksi$$

$$F_c = 0.45\,(4\ ksi) = 1.80\ ksi > 1.13\ ksi \therefore \underline{OK}$$

<u>CHECK BOTTOM FLANGE TENSION STRESS (TOTAL LOAD)</u>

$$f_b = \frac{(48.16'^k)(12\ ^{in}/_{ft})}{\underbrace{(36.5\ in^3)}_{S_{bott},\ STL\ ONLY}} + \frac{(48.16'^k)(12\ ^{in}/_{ft})}{\underbrace{(67.1\ in^3)}_{S_{bott},\ TRANS.\ SECT.}} = 15.83 + 8.61 = 24.4\ ksi$$

$$F_b = 0.9\,(50\ ksi) = 45\ ksi > 24.4\ ksi \therefore \underline{OK}$$

<u>CHECK SHEAR</u>:

$$\text{TOTAL LOAD} = (61.25 + 15 + 55\ psf) = 131.25\ psf$$

$$w = (0.13125\ ksf)(21.5') = 2.82\ ^k/_{ft}$$

$$R_{v,N} = \frac{(2.82\ ^k/_{ft})(16')}{2} = 22.6^k$$

$$f_v = \frac{22.6^k}{(\underbrace{0.34''}_{t_{web}})(3'')} = 22.1\ ksi$$

$$F_v = 0.4\,(50\ ksi) = 20\ ksi < f_v = 22.1\ ksi \therefore \underline{NG}$$

→ TRY DB8×37

$$f_v = \frac{22.6^k}{(0.345'')(5'')} = 13.1\ ksi < F_v = 20\ ksi \therefore \underline{OK}$$

→ $\boxed{\text{USE DB8×37}}$

(FIGURE 35) D-Beam® Design (2 of 2)