TECHNICAL REPORT 2

# The New York City Bus Depot

## New York, NY

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## Executive Summary:

The following technical report gives a basic analysis of the existing one-way slab with sacrificial decking floor system present in the New York City Bus Depot design documents along with analyses of three alternative flooring systems: composite decking, precast hollow core planks, and precast double tees. The examinations of the flooring systems consist of numerical calculations for loads and sizing which are then followed by a series of comparisons involving, architecture, structure, serviceability, and construction impacts. The floor systems are then put side by side in a chart to weigh the possible options in each category. From this, the flooring systems worthy of further study are determined.

The existing one-way slab with sacrificial decking is an efficient, light-weight system that comes at a heavy cost. It maintains a sufficient clearance for bus travel and also sufficient shear capacity to handle the loads imposed on the slab by the bus tires. The system is flexible for design and requires minimal skill level for construction, but it does require a large amount of time for the necessary shoring that will need to be employed for the wet concrete pour. This system sets the precedent for comparison to the other three proposed alternative systems.

The composite deck system is a slightly cheaper alternative to the one-way slab; however, it increases the depth of the floor system, therefore decreasing the clearance for bus travel. The thick slab and deck combination provides sufficient shear capacity for the concentrated loads put forth by the busses, the controlling factor in the design; however, the exposed deck of this system would make it unfeasible due to future maintenance issues. The exposed deck cannot be expected to last the entire lifespan of the building, and, if it were to fail, a significant portion of the shear capacity of the system would be lost. This deems the system unfeasible for further study.

The 8"x 4'-0" precast hollow core planks on steel joists and girders are a lightweight alternative to the one-way slab design provided in the design documents. The lightweight design of the plank is offset by the heavy joists necessary for support of the system. The clearance is slightly higher for bus travel, but the flexibility in size and long spans of the bays are not able to exist. All bays must exist in 4' increments in order for the planks to be useful, and all bays must be shortened due to the heavy imposed live loads. Also, vertical circulation of building systems is greatly limited due to the inability to drill through the planks. For these reasons, it is deemed that the precast hollow core plank system is not worthy of further study.

The 36" x 8'-0" precast double tee system is the most cost efficient of the building systems. The ability of the double tee to carry heavy loads over long spans without additional support girders gives it this cost efficiency, as does its quick installation. It is also great for sloped spans and easy for installation on them. This system again suffers due to its lack of flexibility for bay sizes and building system vertical circulation. A reorganization of bays needs examination to determine the usefulness of this system in relation to bus travel. For this reason, it is still considered a feasible system worthy of further study.

## Building Introduction (Existing Conditions):

The New York City Bus Depot is a new design-build project that broke ground in June of 2011. This $150 million project is slated for completion in January of 2012. The building site can be seen below in Figure 1 highlighted in red. It is in an area that is currently zoned to be commercial specifically for heavy automotive repair shops that are used for community purposes. The region where this building is to be located was once the place of a river that ran through this part of the city. For this reason, the water table on the site is high and the soil is liquefiable. There is also a portion of the site where there is no solid rock creating a need for piles to be driven down as deep as 150 feet.

**Figure 1:** Aerial view of the building site highlighted in red. (*Image courtesy of Google Maps).*

The New York City Bus Depot is on a plot of land that is being reused. It was once a former trolley barn in the 1800s and, prior to the most recent demolition, an out-of-date, undersized bus depot that needed expansion for use by the New York City Transit Authority. This new and more environmentally friendly 390,000 square foot bus station will contain facilities for a fleet of 150 busses. The depot will be three stories tall, with each story at an approximate height of 25 feet. On the first floor, facilities will be available for bus refueling, servicing, fare collection, bus washing, and maintenance. The second and third floors will house parking for each of the 150 busses stationed out of the depot. Included in the space will also be offices for employees stationed at the bus depot.

**Figure 2:** Rendering of the New York City Bus Depot showing its south face and both the corrugated metal and brick veneer facades. *(Image courtesy of STV Inc.)*

Externally, this new facility has a modern appearance with a corrugated metal and brick veneer anchored onto CMU walls as seen in Figure 2. Large, rectangular expanses of windows with aluminum frames help to provide well lit spaces while using minimal electric lighting. The brise soleil that line the tops of the windows on the East façade to control the sunlight entering the building, helping to achieve the most energy efficient performance possible. To pay homage to the vibrant culture of the neighborhood in which the depot is located, artwork will be placed at street level for any passer-by to see. All of these features will help give life to an area of the borough looking to be renewed and revitalized.

In order to be an environmentally friendly facility, the New York City Bus Depot plans to employ green technologies. Two major highlights for this are located on top of the building: a green roof and a white roof. This green roof will help to minimize carbon dioxide emissions (particularly important for such a crowded borough of the city), and the white roof will help to regulate heat gain for the building. Other technologies to be included in the building are a rain water collection system, low emission boilers, heat recovery units, water efficient fixtures, recycled materials, and day-light centered lighting design. In addition to a rain water collection system, a water reclamation system is planned to recycle the water used in bus washing facility. All of these features aim to lead the New York City Bus Depot to a LEED certification upon completion of construction.

Structurally, this building is one which is steel framed. It has unique floor framing due to the multitudes of point loads applied from busses and their towing counterparts. Floors on levels two and three are also ramped like an over-sized parking garage for this bus fleet. Unique loading patterns are also created due to the busses as well as the mixed use occupancy of the building. At the present time, the building is at a 65% submittal stage with its contract documents and more information will be provided as updates are received.

## Structural Overview

The New York City Bus Depot is a three story, 80' tall building that rests on piles grouped together with caps scattered throughout the site. The piles are deep due to the site class E classification that indicates the chance for liquefaction of the soil. The building itself can be treated as three separate buildings, as shown in figure 3, due to the large expansion gaps that separate the framing systems of the building. The first floor consists of a heavily reinforced slab that is 14" to 18" thick for travel by heavy busses and towing vehicles. The framing system consists of heavy steel beams that are designed to resist the loads caused by the traveling busses. On top of each level of this steel framing sits a 6" reinforced concrete slab. This slab is supported by 2" 18 gage metal deck, however this deck is considered as sacrificial and all designs are calculated as though there is simply a concrete deck sitting upon the steel beams.

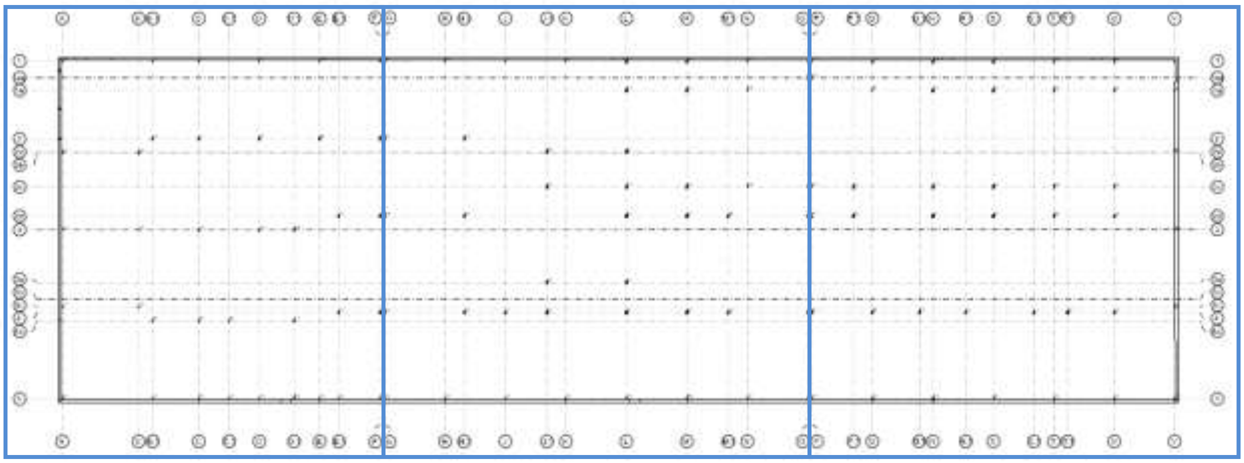


**Figure 3:** Depiction of the 2'-6" Expansions joints that separate the structure into three distinct structural systems as denoted by the blue boxes.

**Foundations:**

The New York City bus depot requires the use of deep pile foundations due to the site's soil conditions. The site contains layers of organic material that compress under long-term loading, making the site unsuitable to maintain a shallow foundation. Another reason for the pile foundation lies in the liquefaction potential of the soils. Those below the water table, which is about 8' below the site surface, consist of a stratum of sand and a stratum of silt and clay all over weathered rock and bedrock. When tested, it was deemed that these would likely not liquefy during a strong earthquake, but there were some local areas that showed liquefaction potential if the 2500-year event were to occur in the city.

The piles recommended for the site are steel HP12x102 piles that possess the ability to maintain 220 tons (or a service load of 200 tons after subtracting 20 tons of downdrag). These piles are used to support the ground floor structural slabs, columns, and heavy equipment requiring extra reinforcing. They terminate at an elevation 107'-6" above sea level. These piles are required to be driven down to bedrock, which is between 35' and 100' below grade depending on the area of the site. The piles must be hammered into the ground and have a final driving resistance no less than 5 blows per quarter inch of penetration. Also, because of the low pH of the ground water, corrosion effects must be taken into consideration. Due to the effects of this, the piles are to be analyzed for strength at a size 1/8" thinner in the webs and flanges than prescribed. In addition to being able to maintain 200 tons of compression, the piles are to withstand a lateral load of 5.5kips for a single pile and 3.8kips for each pile when analyzed in groups in the pile caps.

**Floor Systems:**

Two flooring systems are considered in the New York City Bus Depot. On the first floor, there is a slab on grade with a thickness still to be determined. This thickness is to be between 14" and 18" due to the heavy, concentrated loads imposed by the various busses and maintenance vehicles utilizing the facility and the long spans of the slab between piles.

The typical framed flooring system on the second floor, third floor, and third floor mezzanine consists of steel beams and girders supporting a 6" one-way concrete slab on a 2" gage sacrificial composite form deck. This slab on deck is to be reinforced with a rebar layout that yet to be determined on the design drawings. Analysis presented later in this report yields a theoretical value for this reinforcing. The span of this deck is also yet to be determined since the reinforcement has also yet to be determined.

What controls the design of the thickness of the slab is not the distributed load, but instead the point loads induced by the buses. Worst case loadings of the tires of the busses are treated as 4.5"x4.5" squares with the applied point loads dictated in the dead load section of this report. This 4.5"x4.5" square is used in the evaluation of punching shear, which controls the thickness of the slab.

Various beam sizes are used in construction of this structure because of the varying spans, many of which are much longer than the conventional 30 feet bays. Smaller spans under 30'-0" are generally made up of inlay beams of W14s, W16s, and W18s. Larger spans are made of W 24s, W27s, and W30s. Examples of these spans include W27x84s that span 49'-10" and W30x99s that span 55'-6". Girders utilized on these floors include W30s, W33s, W40s, and W44s.

On the west end of the building, ramps are utilized to lead busses to the parking areas on the second and third floors. These are also steel framed with same metal decking described as typical on other areas of the floor. They utilize W24x76s that span the following: 45'-0" on the North and South ends of the ramp and 44'-2" on the West end.

**Framing System**

The rest of the framing system of the New York City Bus Depot consists of steel columns. They are all W14s with the exception of one W15x655 in a moment frame that supports 1001kips of service dead load and 573kips of service live load. The columns can be expected to support rather large axial loads due to the heavy imposed loads seen in appendix B and the heavy materials.

**Lateral System**

The lateral system for this building consists of two types of frames: braced and moment. Braced frames flank the interior runs of the ramps on the west side of the building and also run east to west on the exterior lines between column lines O and P as shown in blue on Figure 4. The moment frames are those which run north and south. They are located at column lines F, H.1, J.1, L, M, P.1, Q.1, S, T, U, and V respectively as shown in Figure 4 in orange.

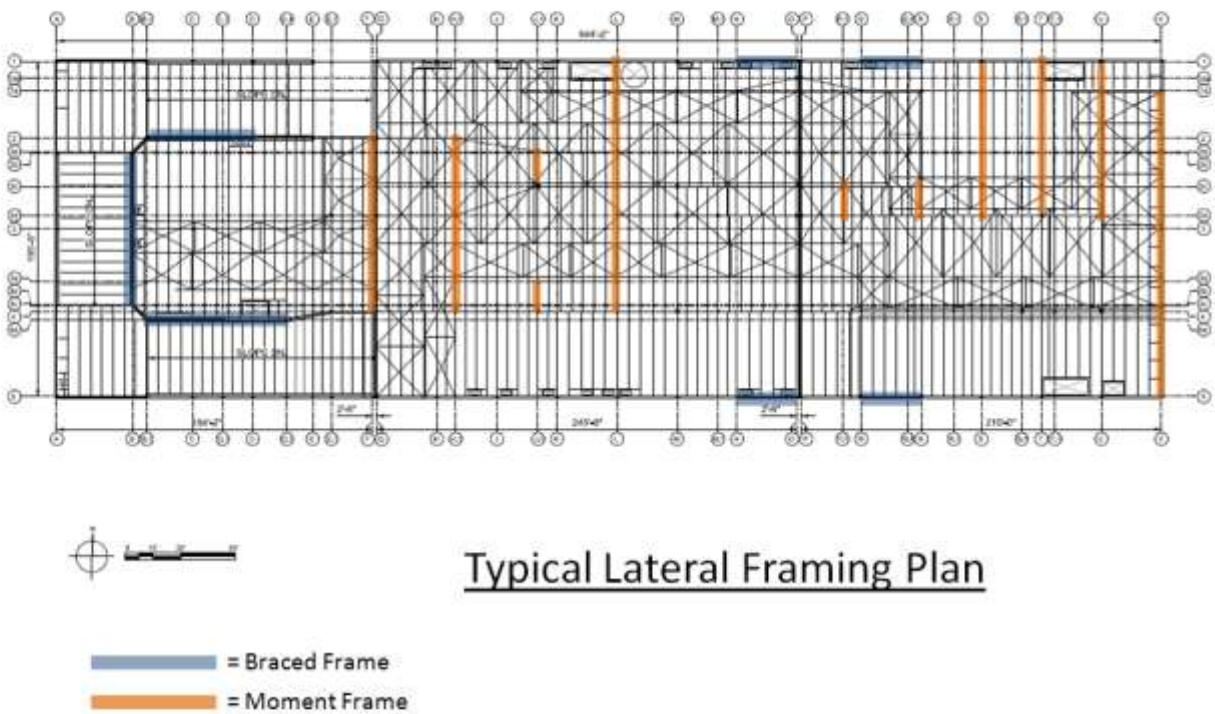



**Figure 4:** Locations of Moment and Braced Frames.

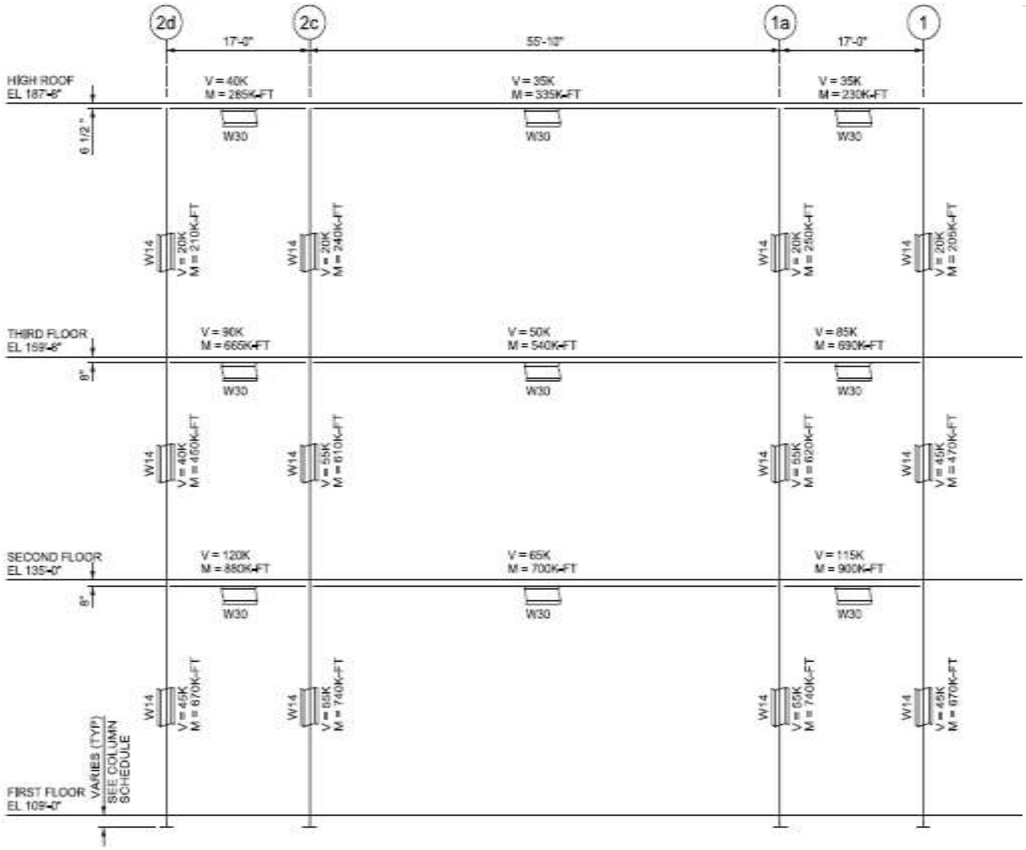



**Figure 5:** Typical moment frame construction

The moment frames are constructed of W14 columns and W30 beams assembled such that the controlling seismic loads may be resisted. The moment frames are required to resist service loads ranging from shears of 5kips along the first floor columns of the frame running along F, to 455kips on the second floor beam along column line V between columns 5 and 3c. These must also resist moments of 1895kip-ft along column line V to 65kip-ft in first-floor column 2F. A typical construction of a moment frame is shown in Figure 5.

The braced frames are constructed of W14 columns of significant weight with W12 members that act as bracing. The diagonal lines that can be seen in Figure 6 show the ramp in the garage. This location, on the west end of the bus depot, is most heavily reinforced with these braced frames due to the vibrations that the walls will have to handle from the traveling busses.

With the exception of one frame, all of the braced frames run from east to west. It is easy to use the braded frames on the west end of the building because there will be no interference with architectural features on the façade there. Windows are in place in the bus parking and office areas to the east, but not in the location of the ramp. Also, on the interior, where these are located will not interfere with bus travel lanes: a key component to the functionality of the bus depot.

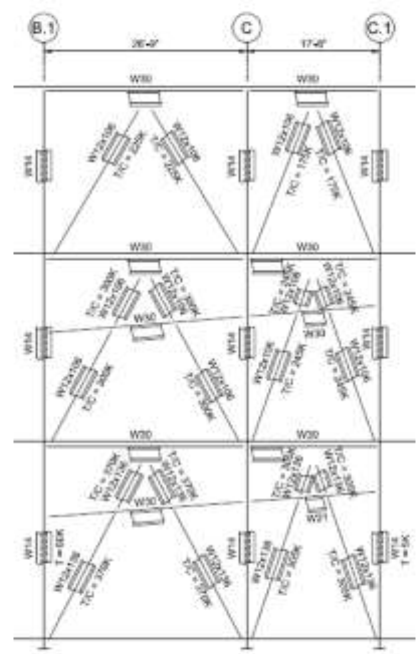



**Figure 6:** Typical braced frame construction.

**Roof Systems**

The roof of the building is framed similarly to the floors below with respect to size and bay spacing. Certain bays, particularly those above the ramp, utilize smaller W21s because they do not need to be concerned with carrying the weight of the busses. Overall, the roof maintains a similar beam sizing because significant weight is still expected to be carried by the system. The roof will be supporting a green roof as well as a series of air handlers stationed along the north and south edges of the roof.

The decking on the roof will consist of a 4 ½" concrete covering on a 2" 18 gage cold form metal deck. Reinforcement and span for the roof deck/slab system is yet to be determined at this stage of the project.

It should also be noted that the roof has two levels to it. The main roof consists of a diaphragm at 72' and a parapet extending up to 80". The 69' swath of the roof furthest east is actually a bulkhead above the 3rd floor mezzanine where the office space is located. This tops off at a level of 93.' This high level is used in computing wind loads so that the highest factor of safety is considered. See the Wind Load section for more details and Appendix B for calculations.

**Design Codes**

- 2010 Building code of New York State
  - Adopts 2006 Family of Codes (IBC, IRC, IFC, IMC, IPC, IFGC, IPMC, IEBC) and 2009 IECC
- North American Specifications for the Design of Cold Formed Structural Steel Members "AISI-NASPEC" (Metal Decking)
- 2008 New York City Building Code (Foundations)
- AISC Manual of Steel Construction – Allowable Stress Design, Thirteenth Edition
- Structural Welding Code – Steel (AWS D.1 – Modified by AISC Section J2)
- Details and Detailing of Concrete Reinforcement ACI 315
- Building Code Requirements for Structural Concrete ACI 318-08
- 2008 Building Code Requirements for Masonry Structures (ACI 530-08/ASCE 5-08/ TMS 402-08)
- Specifications for Masonry Structures (ACI 530.1-08/ASCE 6-08/TMS 602-08)

**Materials Used (continued on next page)**

| Material Properties | | |
|---|---|---|
| Material | | Strength |
| Steel | Grade | fy = ksi |
| Wide Flange Shapes | A992 | 50 |
| Hollow Structural Shapes | A500, GR. B | 46 |
| Plates | A572 | 50 |
| Pipe Shapes | A53, GR. B | 46 |
| Anchor Rods | F1554 | 36 |
| Sag Rods | A36 | 36 |

| | | |
|---|---|---|
| Welding Electrodes | E70XX | 70 |
| Welding Electrodes (Gr. 65) | E80XX | 80 |
| Steel Reinforcement | A615 | 60 |
| Bolts (3/4"-1" dia.) | A325 | N/A |
| Bolts (1-1/8" dia) | A490 | N/A |
| Deck | Gage | |
| 2" Form Galvanized Metal | 18 | |
| Concrete | Weight (pcf) | f'c = psi |
| Formed Slabs | 150 | 5,000 |
| Structural SOG | 150 | 5,000 |
| Slabs on Metal Deck | 150 | 5,000 |
| Foundations | 150 | 5,000 |
| Masonry | Grade | fy = ksi |
| Concrete Masonry Units | C90 | 1.9 |
| Mortar | C270, Type M | N/A |

**Table 1:** Material Properties

Gravity Loads:

**Dead and Live Loads:**

The dead and live load distributions on the floors and roof can be seen in the plans in Appendix B. The following charts compare the dead and live loads utilized in the design with those outlined in the New York State Building Code (2010 Edition):

Dead Loads:

| Floor | Distributed Floor Dead Load (psf) | Area (ft$^2$) | Col. Wt (lb) | Exterior Façade (lb) | Weight per floor (k): |
|---|---|---|---|---|---|
| Floor 1 | 200 | 125902 | 502.5 | 1047696 | 25682.9 |
| Floor 2 | 100 | 125902 | 922.3 | 1934208 | 13512.5 |
| Floor 3 | 100 | 125902 | 622.2 | 1450656 | 13212.4 |
| Floor 3 (Mezz) | 100 | 13489.5 | 30 | 1128288 | 1378.95 |
| Roof | 100 | 112412.5 | 189.9 | 1128288 | 11431.15 |
| High Roof | 100 | 13489.5 | 18.4 | 564144 | 1367.35 |

**Table 2:** Dead Loads and Floor Weight

In the New York State Building Code, dead loads are dictated to be the actual weight of construction materials. No superimposed loads are suggested in the code, but in this project, they are included. The distributed floor dead load in the chart above does not include these superimposed values. This includes the slab weight and a 15psf beam allowance. Added to this, for total construction weight per floor, is the weight of the columns per floor, and the weight of the exterior façade, which is assumed to be 48psf. The additional superimposed dead loads are 10psf for the first floor; 35psf for the second floor, third floor, and third floor mezzanine; and 95psf for the roves for miscellaneous permanent and semi-permanent equipment such as the air handlers on the roof, maintenance equipment on the first floor, and office materials on the third floor mezzanine.

Live Loads:

| Floor | Function | Assigned Live Load (psf) | NYS Code 2010 Perscribed LL (psf) | Notes |
|---|---|---|---|---|
| Floor 1 | Maintenance | 250 | 50 | See Chart: Concentrated Loads |
| | Storage | 300 | 250 | |
| Floor 2 | Bus Parking | 175 | 50 | See Chart: Concentrated Loads |
| | Future Shop | 250 | 250 | |
| | Office | 150 | 50 | Compact, Versitile |
| | Vault | 600 | 250 | Undisclosed Use |
| Floor 3 | Bus Parking | 100 | 50 | See Chart: Concentrated Loads |
| | Office | 150 | 50 | Compact, Versitile |
| Floor 3 (Mezz) | Office | 150 | 50 | Compact, Versitile |
| Roof | Roof | 30 | 100 | Green Roof |

**Table 2:** Live Loads analyzed vs perscriped

The live loads prescribed in the design documents (seen in appendix B) for the New York City Bus Depot are generally close to those dictated in the 2010 New York State Building Code. The reason for some of the larger discrepancies is due to the unique occupancy of the structure. Live loads for bus and truck parking garages are generally defined in linearly distributed loads along lanes and concentrated loads. Below are the New York State Building Code's minimums for bus and truck parking facilities as well as the concentrated loads expected for the facility by the design engineers. These values are show in tables 3, 4, and 5 respectively

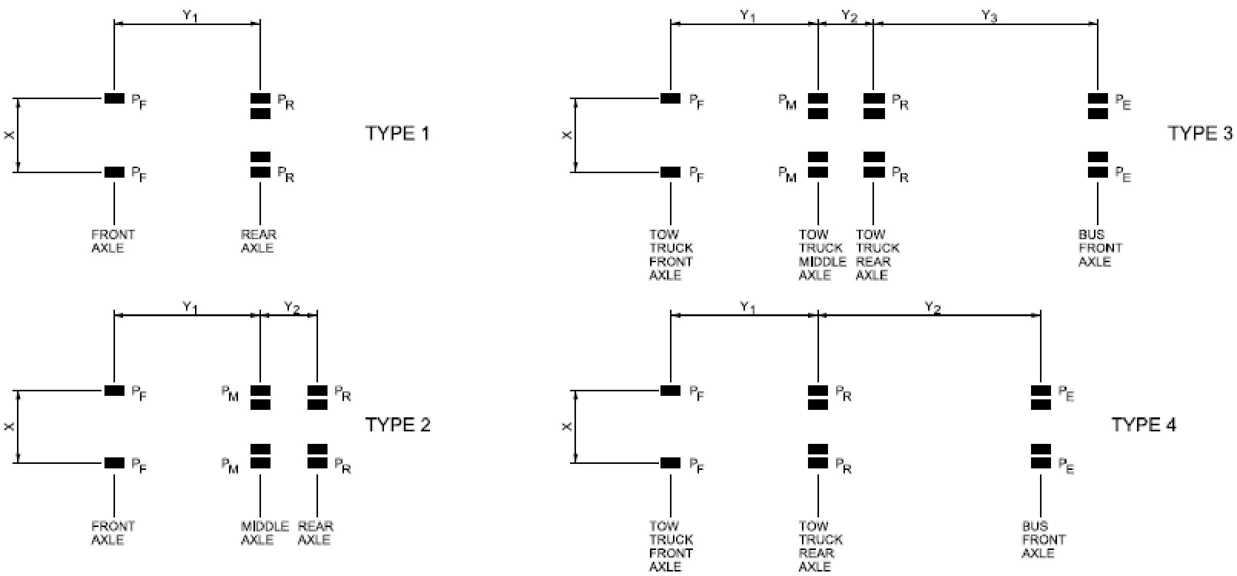
**2010 New York State Building Code:**
**TABLE 1607.6 UNIFORM AND CONCENTRATED LOADS**

| LOADING CLASS[a] | UNIFORM LOAD (pounds/linear foot of lane) | CONCENTRATED LOAD (pounds)[b] | |
|---|---|---|---|
| | | For moment design | For shear design |
| H20-44 and HS20-44 | 640 | 18,000 | 26,000 |
| H15-44 and HS15-44 | 480 | 13,500 | 19,500 |

**a.** An H loading class designates a two-axle truck with a semitrailer. An HS loading class designates a tractor truck with a semitrailer. The numbers following the letter classification indicate the gross weight in tons of the standard truck and the year the loadings were instituted.

**b**. See Section 1607.6.1 for the loading of multiple spans.

**Table 3**




CONCENTRATED WHEEL LOAD DIAGRAMS

NOTE: THERE ARE SLIGHT VARIATIONS IN LOAD FOR $P_F$, $P_M$, $P_R$ AND $P_E$, HOWEVER DESIGN IS BASED ON THE HIGHEST VALUE.

| CONCENTRATED WHEEL LOAD TABLE | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| VEHICLE | TYPE | LOCATION | X | $Y_1$ (DIMENSIONS IN FEET) | $Y_2$ | $Y_3$ | $P_F$ | $P_M$ (LOADS IN KIPS) | $P_R$ | $P_E$ |
| STANDARD HS20 TRUCK | 2 | 1st, 2nd, 3rd | 6.0 | 14.0 | 14.0 | - | 4.0 | 16.0 | 16.0 | - |
| MCI 2915 BUS | 2 | 1st, 2nd, 3rd | 6.67 | 26.5 | 4.0 | - | 5.7 | 8.9 | 4.8 | - |
| ORION HYBRID "NEW GEN" 3877 BUS | 1 | 1st, 2nd, 3rd | 6.17 | 23.83 | - | - | 6.0 | - | 11.35 | - |
| VAN HOOL DOUBLE DECKER BUS TD 925 | 2 | 1st, 2nd, 3rd | 7.17 | 16.58 | 4.25 | - | 5.72 | 8.91 | 5.72 | - |
| TOW TRUCK E050-08 | 2 | 1st, 2nd, 3rd | 7.0 | 21.67 | 4.0 | - | 9.75 | 8.5 | 6.6 | - |
| TOW TRUCK E052-03 | 1 | 1st | 7.0 | 23.0 | - | - | 9.9 | - | 9.1 | - |
| TOW TRUCK E050-08 LIFTING MCI 2915 BUS | 3 | 1st, 2nd, 3rd | 7.0 | 21.67 | 4.0 | 45.33 | 5.57 | 15.44 | 15.07 | 10.08 |
| TOW TRUCK E052-03 LIFTING MCI 2915 BUS | 4 | 1st | 7.0 | 23.0 | 45.33 | - | 5.88 | - | 23.94 | 10.08 |
| TOW TRUCK E050-08 LIFTING ORION 3877 BUS | 3 | 1st, 2nd, 3rd | 7.0 | 21.67 | 4.0 | 39.67 | 4.31 | 15.59 | 15.65 | 7.77 |
| TOW TRUCK E052-03 LIFTING ORION 3877 BUS | 4 | 1st | 7.0 | 23.0 | 39.67 | - | 4.73 | - | 26.57 | 7.77 |
| TOW TRUCK E050-08 LIFTING DOUBLE DECKER BUS TD 925 | 3 | 1st, 2nd, 3rd | 7.0 | 21.67 | 4.0 | 35.67 | 5.57 | 15.87 | 15.45 | 10.08 |
| TOW TRUCK E052-03 LIFTING DOUBLE DECKER BUS TD 925 | 4 | 1st | 7.0 | 23.0 | 35.67 | - | 5.88 | - | 24.69 | 10.08 |
| OPEN TOP CONTAINER TRUCK | 2 | 1st, 2nd | 7.0 | 9.0 | 4.5 | - | 13.0 | 13.5 | 13.5 | - |

NOTE: WHEN TOWED BUS LOADS ARE APPLIED SIMULTANEOUSLY WITH OTHER WHEEL LOADS ON A COMMON MEMBER, TOWED BUS WHEEL LOADS ARE REDUCED BY 25%. SIMULTANEOUS VEHICLE LOADS HAVE BEEN ANALYZED PER THE STALL LAYOUT SHOWN ON THE ARCHITECTURAL DRAWINGS. COMBINATIONS OF VEHICLE TYPES WERE PLACED IN EACH STALL GROUP IN SUCH A WAY TO PRODUCE THE WORST CASE LOADING FOR THE MEMBER BEING STUDIED.

**Table 4**: Concentrated wheel loads and values

## Snow Loads

Snow Loads for the New York City Bus Depot are minimal. It is assumed they are included in the distributed Live loads where applicable so no additional calculations were necessary for them. The chart on the right is a display of the design criteria for the snow loading.

| SNOW DESIGN CRITERIA |
|---|
| SNOW IMPORTANCE FACTOR 1ST 1.0 |
| OCCUPANCY CATEGORY: I |
| GROUND SNOW LOAD: 25 PSF |
| EXPOSURE FACTOR: CS=0.90 |
| THERMAL FACTOR: C1=1.00 |
| FLAT ROOF SNOW LOAD: 15, 75 PSF |
| SNOW DRIFT LAOD: INCLUDED WHERE APPLICABLE |

**Table 5**: Snow design criteria

Existing One-Way Slab with 2" Sacrificial Deck:

The existing floor system for the New York City Bus Depot consists of a 6" one-way, normal weight, concrete slab on a sacrificial 2" deck supported by steel beams and girders. The bay in the system analysis is 55'-10" by 46'-0", with joists spanning the 55'-10" length spaced evenly at about 6'-7" on center. By analysis, it appears that the design is controlled by the punching shear imposed by a wheel load. This maximum load of 15.45 kips would be caused by the wheel on a tow truck E050-08's rear axle while lifting a double-decker bus. The system has a slab depth of 8", with 30" joist and 40" girder depths, and a slab weight of 81.3psf due to this loading. According to RS Mean's Costworks, the cost of the system is $16.45 per square foot.

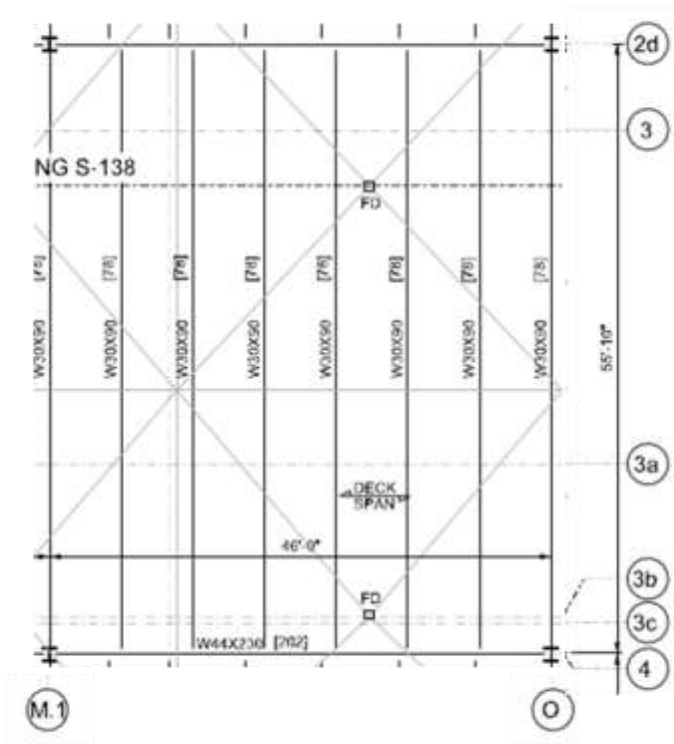



**Figure 7:** Typical Bay shown (not specific bay analyzed for sake of image clarity)

**Architectural**

Due to the traffic of such large vehicles, clearance is an important factor in the design of the New York City Bus Depot. The design of this system allows for a clearance of 21'-00" to 21'-10" on the bus parking deck; this clearance is important to maintain for busses and their tow trucks. It also upholds a two-hour fire rating as required by the Building Code of New York State (2010 edition). No architectural impacts are considered for this system as it is the existing system. It should be noted, however, that the sacrificial deck will likely not last the entire lifespan of the building.

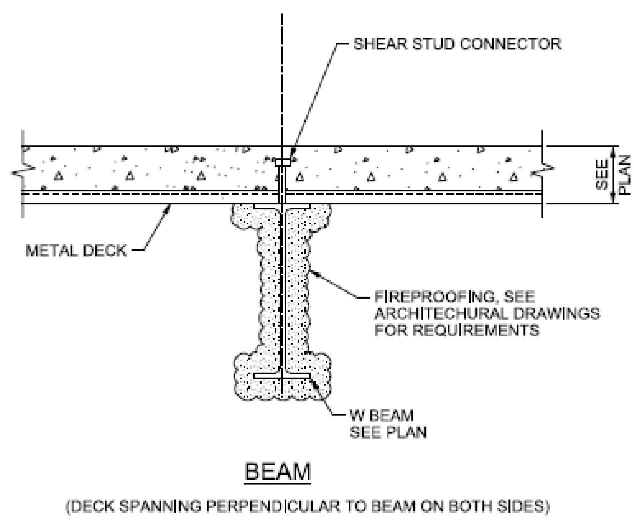



**Figure 8:** Typical Cross section through beam and slab/deck construction.

**Structural**

Since the presently designed system includes the current flooring assembly, the foundation and lateral bracing systems present are acceptable. The existing deep pier foundation system would remain, as would the moment frames and the braced frames, provided the one-way slab is considered the most efficient design.

**Serviceability**

For the purpose of this project, live load deflections and construction deflections are being analyzed. This system is acceptable for live load deflections of joists, with a maximum permitted deflection of 1.86 inches; currently, deflections of joists under live loads are at 1.04 inches. The deflection under construction loads may be no more 2.8 inches. However, analysis of the construction loads shows that the joists can be expected to deflect 3.6 inches while pouring and curing the slab. This means that shoring will be necessary for construction, increasing the building cost.

**Construction**

As mentioned above, shoring will be necessary for construction of this system, raising its cost. This sets the precedent for both cost and scheduling analysis comparisons for other systems. Other than shoring, construction is relatively easy and requires minimal skill level. Framing necessary voids for mechanical, electrical, and piping purposes will be relatively easy, as will laying and splicing the longitudinal rebar and pouring the concrete. Due to these circumstances, the constructability will receive a rating of "easy/medium."

**Pro/Con Summary**

**Pros:**
- Thin, lightweight system
- Low deflection
- Flexible Design

**Cons:**
- Shoring necessary for construction
- Expensive to Construct

**Further Consideration**

Due to the construction ease and flexibility, it is easy to see why this system is used for the parking garage. The sacrificial deck makes the concrete one-way slab easy to lay, and the system is appropriate for the various bay sizes, some of which are not even rectangular. The low deflection is suitable for the busses traveling across the parking lanes and a thin slab provides sufficient clearance for their travel. The only setback of this system is the lengthy process of installing, shoring and allowing for cure time of the concrete.

Composite Deck:

Again, analysis is performed on the 55'-10" by 46'-0" bay with 6'-7" on-center joist spacing spanning the 55'-10" length. The examined alternative composite deck consists of a 6.5 inch normal weight concrete slab on a 3VLI16 metal deck sufficient for a two hour fire rating as required by the Building Code of New York State (2010 Edition). This diaphragm type is controlled by punching shear, like the existing system, but due to differences in area able to contribute to shear resistance, the slab here must be half an inch thicker and the deck an inch higher. Increased decking and slab sizes enlarge the weight to 100.2psf, which cause a W30x108 to be necessary for load support. The thicker decking and additional concrete topping increase direct material cost minimally, but the lack of shoring decreases the construction cost more significantly in comparison to the one-way slab system. The evaluation yields a price of $23.03 per square foot.

**Architectural**

Altering the building flooring system to a composite slab would cause minimal architectural impact. The decking is still present, and the required fire rating is maintained. Clearances would be decreased by 1-1/2" which are still acceptable for bus traffic. This will keep the floor to ceiling height near 21'-8".

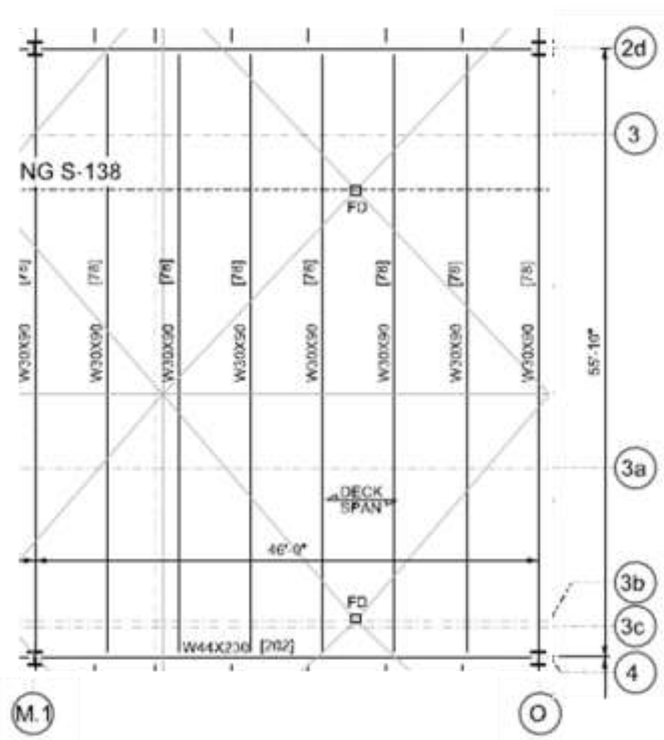



**Figure 9:** Typical Bay and Typical Spans utilized for composite system. Typical cross section remains the same as in Figure 8

**Structural**

The structural impact from this system is caused by the increased weight of the slab and deck as well as the increased joist size. Dead load is increased 18.9 pounds per linear foot from the slab causing a W30x108 to be necessary rather than a W30x99 as is present in the one way composite slab. This increase in beam size then adds an additional load of 9 pounds per linear foot that is transferred to the girder. This is a minimal increase in load and it would likely have minimal effect on the foundation design, which is controlled primarily by lateral concerns as opposed to gravity loads. This minimal increase in weight could potentially have small effects on the lateral resisting system because they span over a very large floor area. Likely the design of the both the lateral and foundations systems will be sufficient, but some members may have to be sized up to guarantee security for seismic loads. The layout of the systems will remain sufficient due to the flexibility of the flooring system.

**Serviceability**

As with the one-way slab analysis, both live loads and construction loads are analyzed for serviceability. Live load deflection is only 0.88", sufficiently below the 1.86" limit. Construction loads are also below the 2.8" limit indicating that no shoring is necessary.

**Construction**

Because no shoring is necessary to construct the composite deck, there will be a sufficient time saving factor in the scheduling. This also leads to a slight cost decrease due to the formwork not being necessary. This cost decrease for labor and framework outweighs the increase due to thicker metal decking and more concrete. This alternative appears to have many construction benefits, however maintenance may be an issue over a long period of time because the exposed deck with likely not last the lifetime of the building. This will cause maintenance issues because the deck is not a sacrificial part of the system like it is in the one-way slab floor design.

**Pro/Con Summary**

**Pros:**
- Low deflection
- Ease of construction

**Cons:**
- Future maintenance issues
- Potential increase in building weight

**Further Consideration**

The ease of construction and flexibility make this system appealing, but the long term maintenance issues that can affect load bearing capacity are a major con of the system. Because of the similarities of the systems, the one-way slab with sacrificial deck would be selected over this system.

Precast Hollow Core Planks:

Precast hollow core planks on steel beams create a system that often serves as a decent option for parking garages. This is due to their lightweight design and long span capabilities. The selected 8"x 4'-0" plank only weighs 86.3 pounds per square foot. After analyzing the Nitterhouse options for topped hollow core planks, it is deemed that the bay spacing in the design drawings is not adequate for the loads of an industrial garage without additional support. An option for a solution is maintaining the joists and their spacing present in the current design documents. This does not allow for a more efficient joist to be utilized and it greatly increases the weight of the structure. One minor benefit is that it reduces the flooring thickness to only 35 inches. The system comes with a pricing of $25.12/sf which is competitive with the existing one-way slab system, particularly when duration of project is considered. That price, however, would likely greatly increase with the additional columns and piers necessary for design.

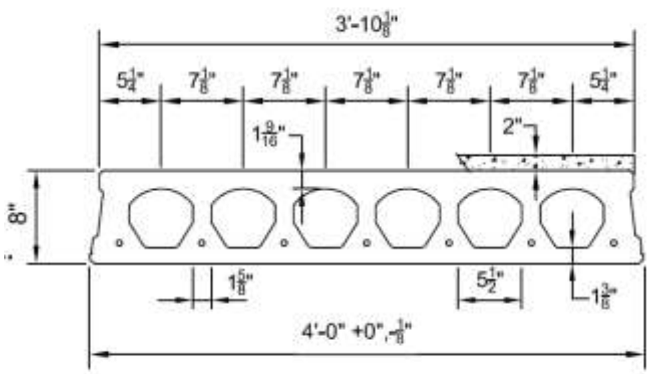


**Figure 10:** Cross section of a 8" x 4'-0" Precast Hollow Core Plank

**Architectural**

The precast hollow core with 2” topping maintains the 2 hour fire resistance rating necessary by the Building Code of New York State (2010 Edition), as well as the 21’-10” clearance set in the design drawings, but these are the only satisfactory architectural elements to this design. The inability of the hallow core planks to carry the necessary loads across at a 46’ span indicates a necessity for restructuring bays. Spans would need to be made much shorter, and they would also need to be made into more regular in 4’ increments. This could cause a number of issues with bus navigation throughout the depot.

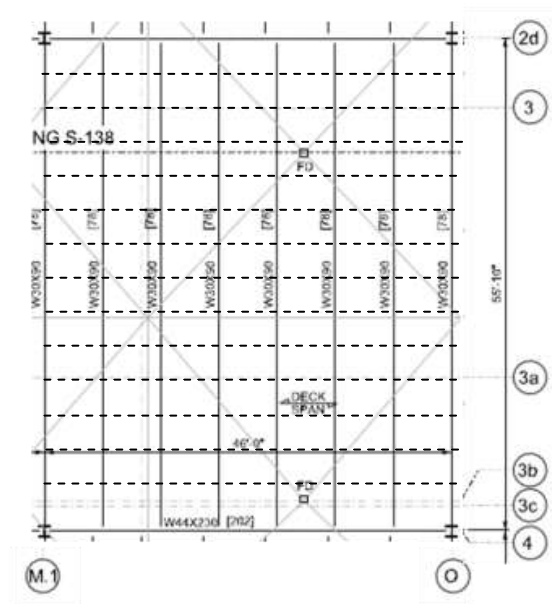



**Figure 11:** Typical Bay for Precast Hollow core Planks. Dashed lines indicate hollow core plank spans.

**Structural**

The long spans of Nitterhouse’s precast hollow core planks are sufficient for commercial parking structures, but for an industrial parking garage, they do not possess the capability to carry loads sufficient for the parking bays. Because of this, shorter spans will need to be made for the concrete planks. This system is examined using two joist arrangements in the 55’-10” by 46’-0” bay. One arrangement utilizes one joist for support, cutting the span down to 23’-0”. The other utilizes the typical 6’-7” spacing of joists present in the current design drawings. The single joist system is inefficient because of the joist deep and heavy joists that would be necessary for support. System analysis with the 6’-7” joist spacing utilizes a W27x258 beam which is not as economical as a W30x99 beam as seen in the one-way slab design. This increase in weight from both the additional columns and the heavier beams would greatly affect the lateral system, particularly its effects on earthquake loads due to the increase in weight. The foundation system would also need to be altered with the addition of point loads form the increased number of columns.

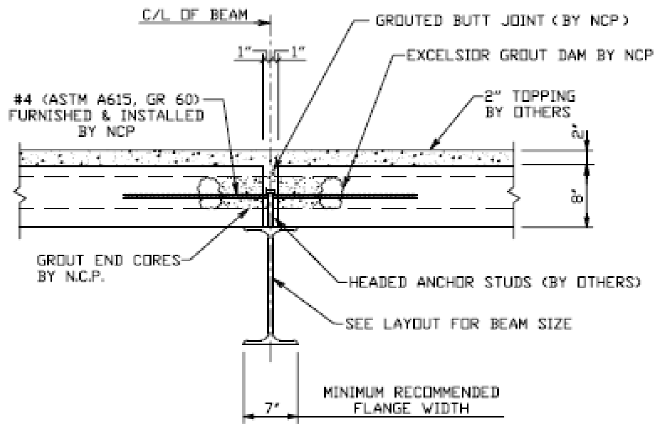



**Figure 12:** Typical connection with Steel beam courtesy of Nitterhouse

**Serviceability**

No issues are present with serviceability. In fact, deflections of this system are incredibly small. This is a benefit of this system. No concern is needed for construction deflection either because the panels are cured prior to installation.

**Construction**

Precast concrete systems are very efficient for fast-tracked construction. No time for curing is necessary as with the composite system or the one way slab. Extra crews and precision installation are important and take a more highly skilled labor set than the cast-in-place systems. Also, vertical voids are difficult to utilize with precast systems. The hallow core provides useful space for horizontal systems in its voids, but vertical systems, such as the depot's grey water system and HVAC system would suffer from use of this system.

**Pro/Con Summary**

**Pros:**
- Low deflection
- Increase in clearance
- Fast-tracked delivery

**Cons:**
- Future maintenance issues
- Potential increase in building weight
- Smaller bay sizes necessary
- Lateral System Impacts

**Further Consideration**

Due to the great increases in weight and decrease in bay sizes, this system is not likely to be a viable one. The bays need to remain large for the navigation of the busses, the key function of the depot. Also, there will be a large number of joints present with the hallow core planks. This could likely create many maintenance issues in the future, particularly relative to leakage.

Precast Double Tees:

The topped precast double tee system is frequently used for long spans under heavy loading. Most often, they are seen in bridge construction. For this analysis, a topped 36"x 8'-0" double tee spanning 56'-0" is deemed adequate for use in the New York City Bus Depot. The system is weighty compared to other systems at 115 pounds per square foot, however it eliminates the need for steel joists, making it more efficient in terms of cost. The cost of this system is very low in comparison to the other systems at $16.15 per square foot (estimated at $19.15 per square foot with additional fireproofing). Depth of floor system satisfactory at 39" – only one inch deeper than the one-way slab system prescribed in the design drawings.

**Architectural**

The double tee provided by Innovative Concrete Solutions does not come with a fire rating, so additional fire proofing would be required for the structure, potentially increasing its cost. Clearance is maintained between 21'-00" and 21'-9": satisfactory for bus clearance. The major impact the double tees could have on the bus depot lie in the necessary reorganization of the bays. Bay size does not necessarily have to decrease, but bays will need to maintain widths at increments of 8'-0". There is a chance that this will interfere with the flow of busses, but further study would need to be done to determine this effect.

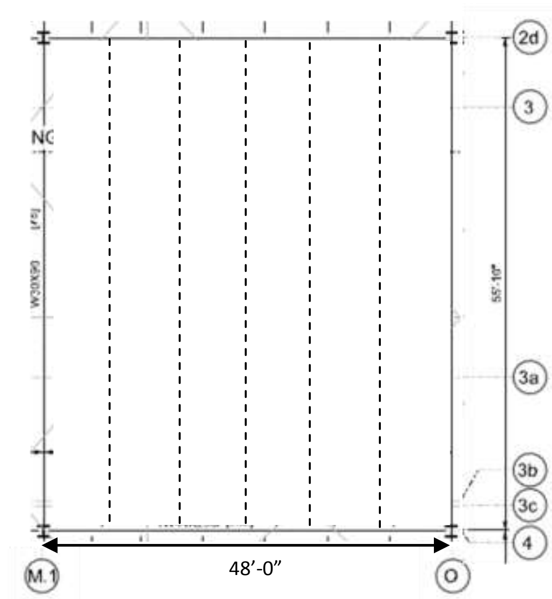



Figure 13: Typical bay necessary for 36"x 8'-0" double tees. The dashed lines show the double tee spans. An increased bay size of 48'-0" would be necessary to fit an exact number of tees.

**Structural**

Due to the reorganization of bays, the foundation system of the building would need to be altered for piers to be located under the point loads of the columns. The lateral system would also be reorganized, but minimal effects due to weight change would occur. The lateral system would not likely require additional reinforcement, just relocation.

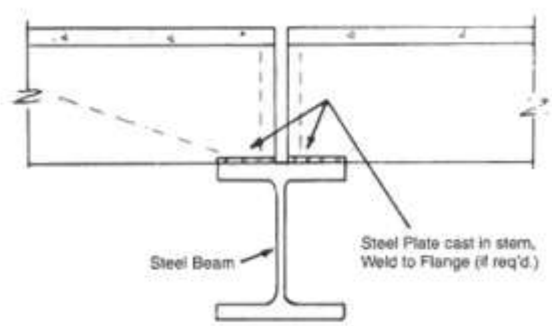



Figure 14: Typical double tee and steel beam connection detail.

**Serviceability**

This system deflects the most out of the four analyzed because of its long spans. The deflection due to the live loads is 1.22 inches which is still sufficiently below the maximum of 1.86 inches permitted at the 55'-10" span. Deflections due to dead loads are considered, but do not play a major role in the construction of the precast system. Under dead loads, the system just passes deflection requirements, deflecting 2.29 inches when the maximum permitted is 3.20 inches.

**Construction**

With precast systems, structural systems are easily fast tracked. More works are needed for precision installation, but there is minimal maintenance involved with the system long term. Also, this system is well suited to sloped conditions as present in the depot's garage. The decreased cost and the increased speed on the schedule are of great benefit to a contractor. As stated above, a major issue with this system is that additional fireproofing would be needed in order to meet New York State's Building Code. Also, precast systems make for difficult vertical circulation as is necessary for mechanical, plumbing, electrical, and fire suppression systems.

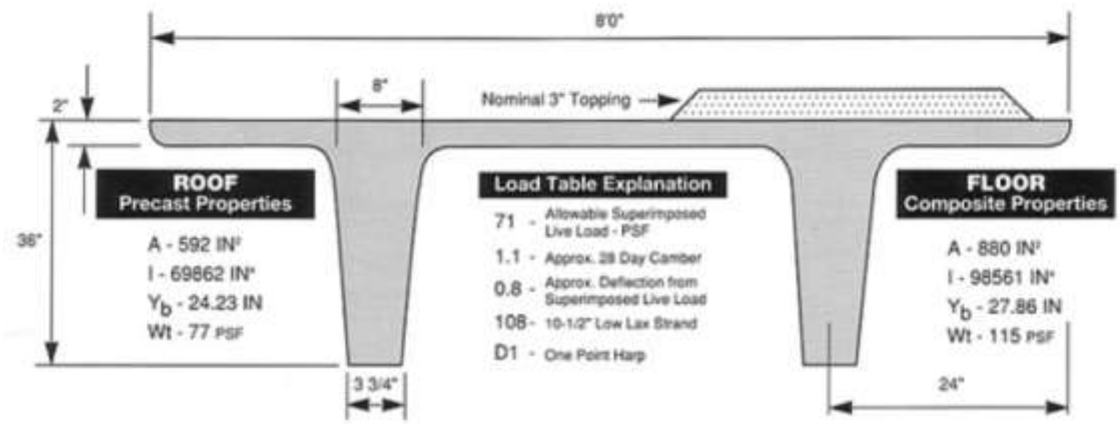



**Figure 15:** Typical Cross section of a 36" x 8'-0" Precast Double Tee.

**Pro/Con Summary**

**Pros:**
- Low Cost
- Fast-tracked delivery
- Lack of inherent fire rating

**Cons:**
- Reorganization of Bays
- Difficult Vertical circulation

**Further Consideration**

Further consideration should be given to this system due to its cost benefits and fast tracked scheduling opportunities. The reorganization of bays needs to be closely analyzed to ensure that busses will be able to safely and easily travel from one end of the depot to the other.

Comparison of Values:

| CONSIDERATIONS | | SYSTEMS | | | |
|---|---|---|---|---|---|
| | | One Way Composite Slab | Composite Decking System | Hollow Core Precast System | Double Tee Precast System |
| General | Weight | 98 psf | 117 psf | 125 psf | 115 psf |
| General | Cost ($/sf) | $28.48 | $24.45 | $25.12 | $19.15 |
| General | Floor Depth (in) | 8" slab/deck 30" beams | 9.5" slab/deck 30" beams | 8" slab 27" beams | 39" depth |
| Architectural | Fire Rating | 2 hour | 2 hour | 2 hour | 0 hour |
| Architectural | Clearance (ft-in) | 21'-10" | 21'-8" | 21'-10" | 21'-9" |
| Architectural | Other Impacts | None | Decking will wear easily | Reorganization of bays | Reorganization of bays |
| Structural | Foundation Impacts | None | Minimal if any | Reorganization of Piers | Reorganization of piers |
| Structural | Lateral System Impacts | None | Minimal if any | Reorganization of system; increases weight | Relocation of system; |
| Serviceability | Live Load Δ(in) (max 1.86") | 1.04" | 0.88" | 0.007" | 1.22" |
| Serviceability | Construction Δ(in) (max 2.8") | 3.6" | 1.19" | 0.008" | 2.29" |
| Construction | Additional Fireproofing | None | None | None | Additional 2 hours |
| Construction | Schedule Impact | None | Decrease Time | Decrease time | Decrease time |
| Construction | Constructability (Difficulty) | Easy/Medium | Easy | Medium | Medium |
| Feasibility | | **Yes** | **No** | **No** | **Maybe** |

**General:**

When analyzing the general considerations of the flooring systems, each system has its own individual benefits. The one way slab is an expensive system, but it is the lightest. The precast double tees are a heavy system, but the cost benefits are significant. The additional weight of the composite deck system and hollow core plank systems make them less feasible, and though they are more cost efficient than the one-way slab, it is not likely that there will be enough benefit for it to be applied.

**Architectural**:

The one-way slab with sacrificial deck and the composite decking system are the two most beneficial architecturally because they allow for the unique bay sizes and shapes present in the bus depot. The precast systems severely eliminate the ability for any bay variety. The double tee's lack of a fire rating also makes it very unappealing architecturally. Clearances are comparable and acceptable for all of the systems.

**Structural**:

All alternative systems appear to impact the structural system negatively, mainly due to increased weight of the flooring system. This increased weight will adversely affect seismic loads on the lateral systems. The foundation system is also potentially affected by this increased weight shown by the examined systems. The most adversely affected foundation would result from the hollow core plank system because of its need for decreased bay sizes and therefore a need for more axial support points. For these reasons, the one-way slab present in the design documents appears to be the most beneficial choice with respect to structural considerations.

**Serviceability**:

All systems pass live load deflection requirements, making them all adequate for design. The construction loads imposed on the one way slab are the major downside of the floor system option. The need for shoring will cause for a longer schedule duration that is not necessary for the other three systems.

**Construction**:

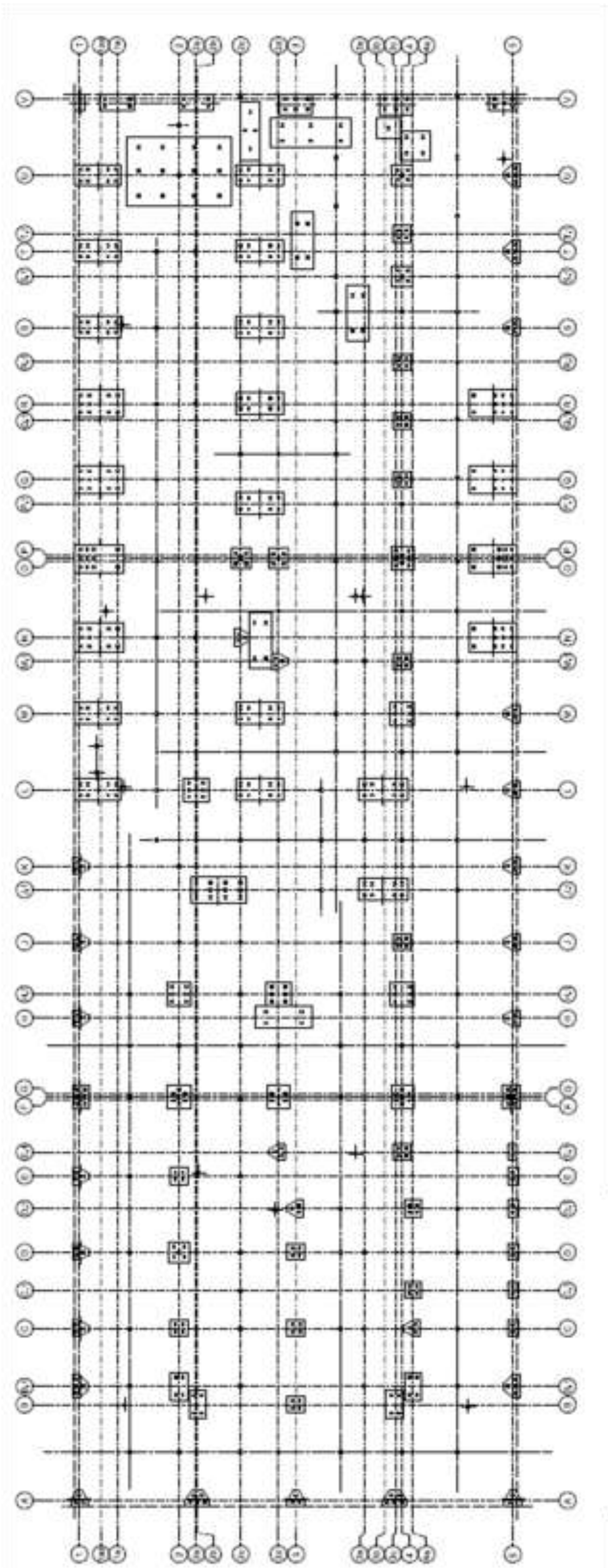
The systems all have pros and cons for construction. In terms of scheduling, the precast systems are far beneficial over the cast in place systems. The cast-in-place systems, however, have the benefit of flexibility, particularly when it comes to vertical circulation of systems through the building.

## Conclusion:

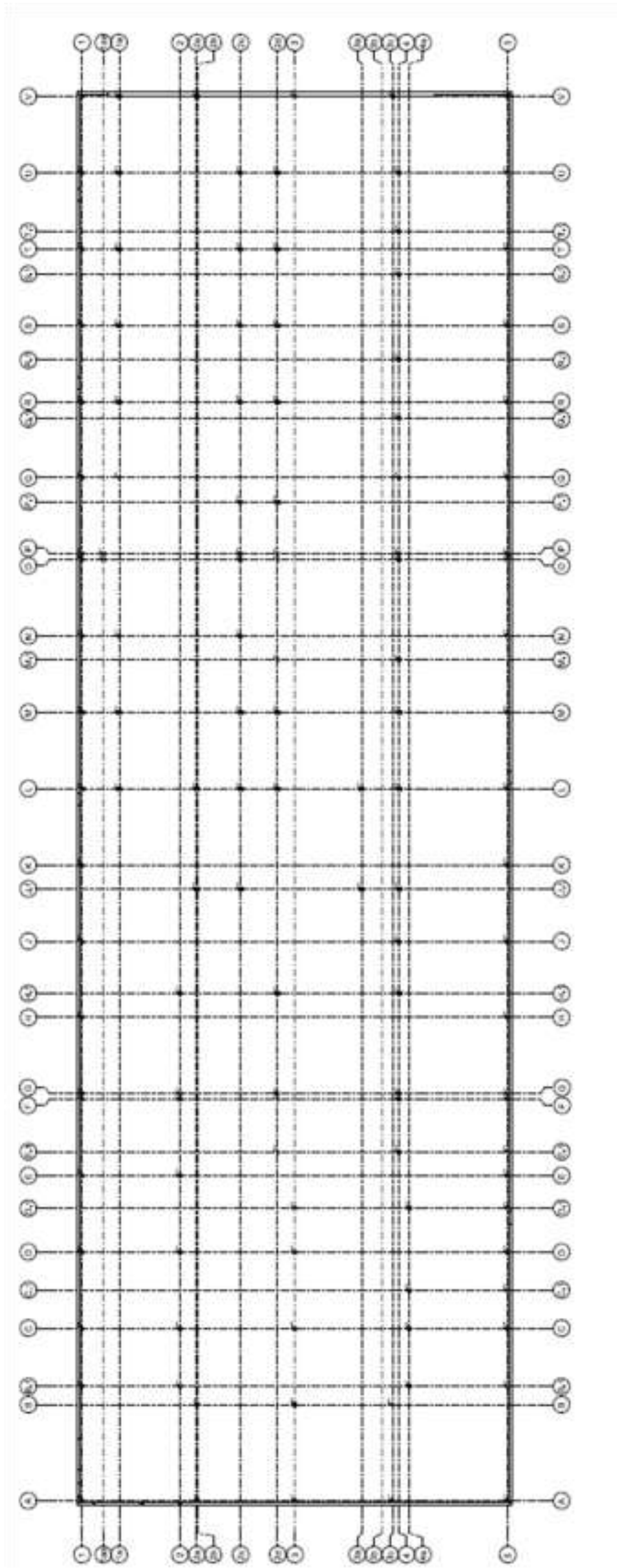
After considering the factors affecting the evaluated flooring systems, the one-way slab system appears to be the most beneficial. The only other system worthy of further analysis would be the precast double tee system. This has its own down

falls, however, with a lack of a fire rating, resistance to vertical circulation, and potential interference with bus travel, it is not likely that this system would be beneficial to the design of the building. The other two systems are not feasible for construction because the deck of the composite system cannot be relied on, and the hollow core presents future maintenance problems along with an increased structure weight. The one-way slab system has the most flexibility of any of the systems and the easiest construction, with the exception of the eliminated composite deck. Though the price is higher than that of the other systems, potential obstacles make the other systems unappealing. For these reasons, the one-way slab on the sacrificial 2" deck is most sufficient for supporting the shear loads of the busses and the clearances necessary for them to navigate the depot.

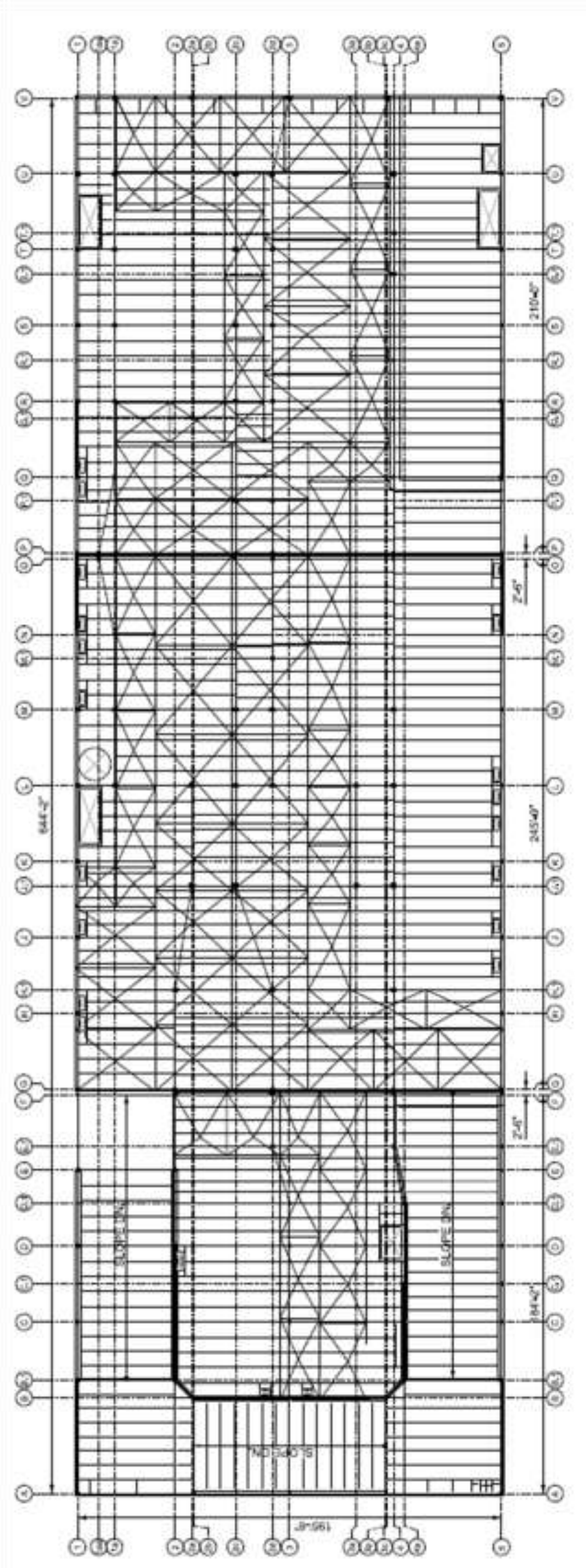
**Appendix A:** Typical Floor Framing Plans



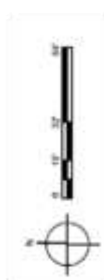
Foundation Plan

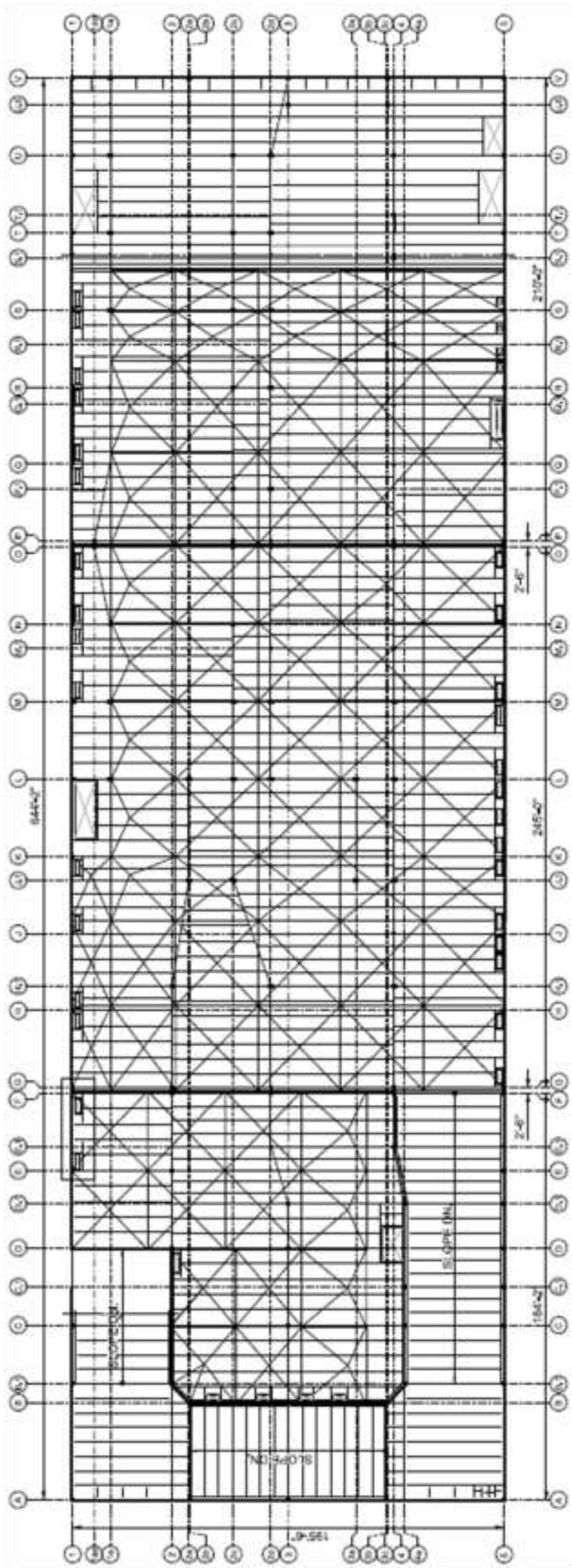


First Floor Plan

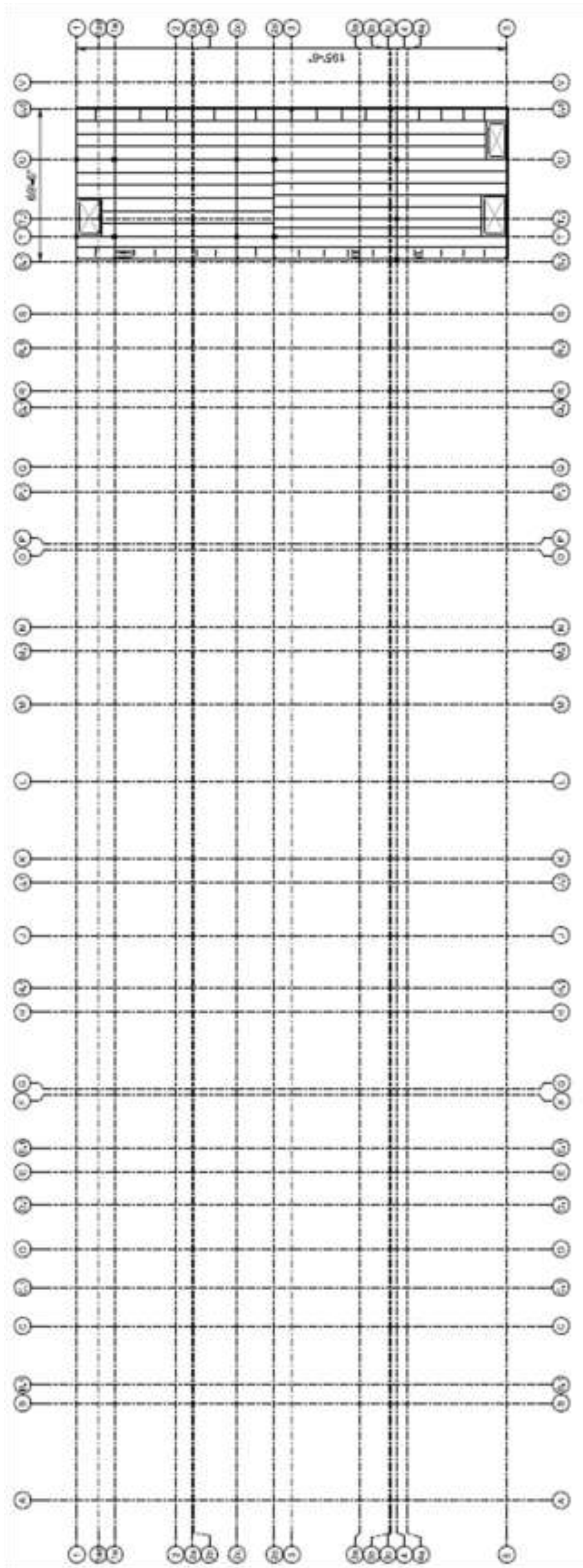


Second Floor Framing Plan

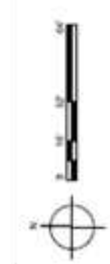


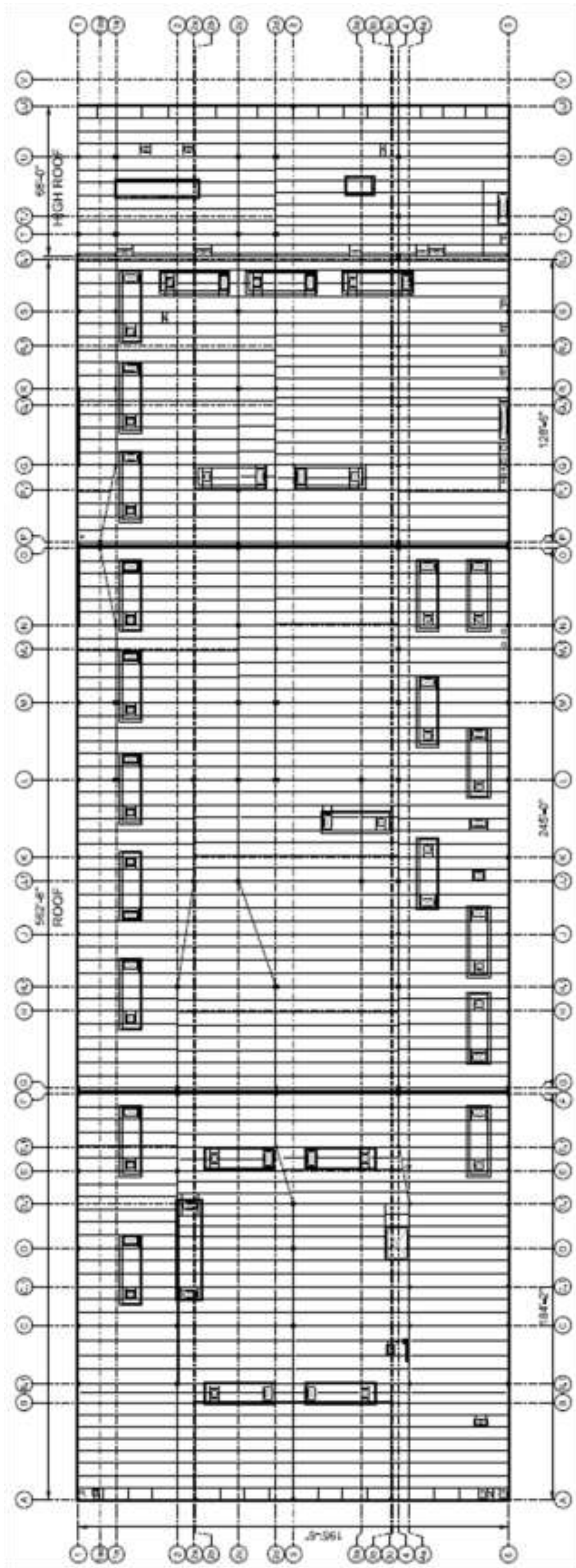


Third Floor Framing Plan



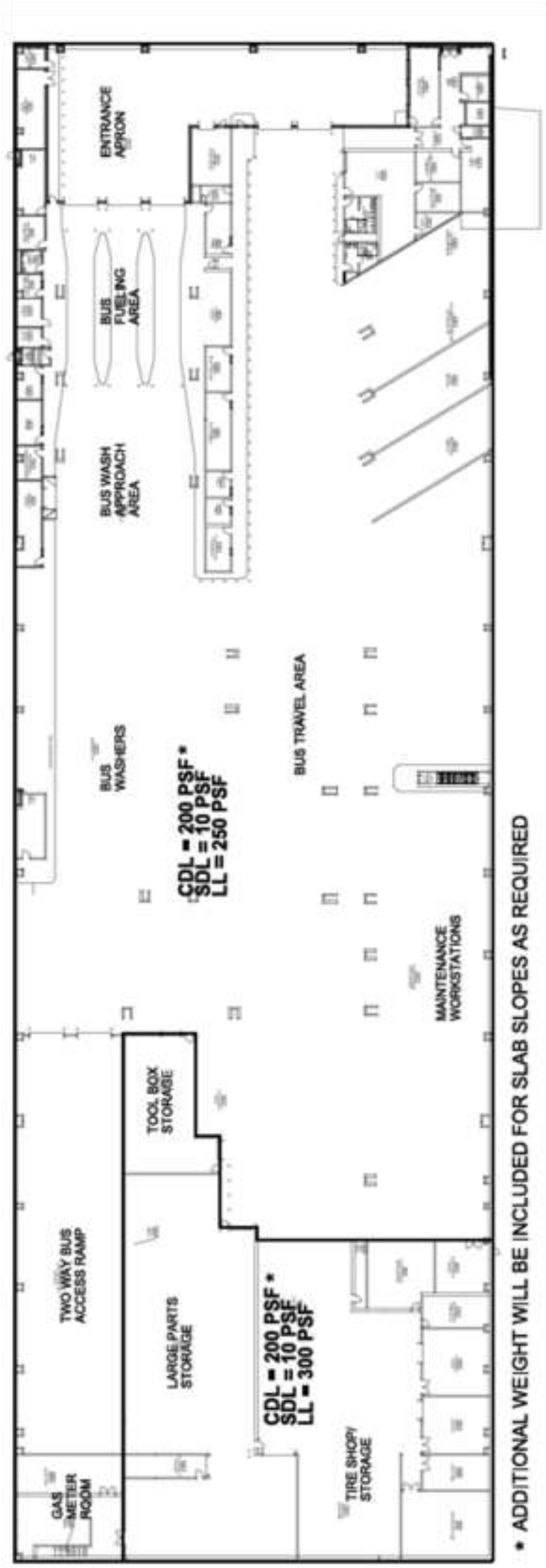
Third Floor Mezzanine Framing Plan



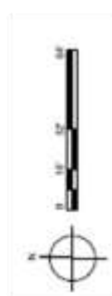


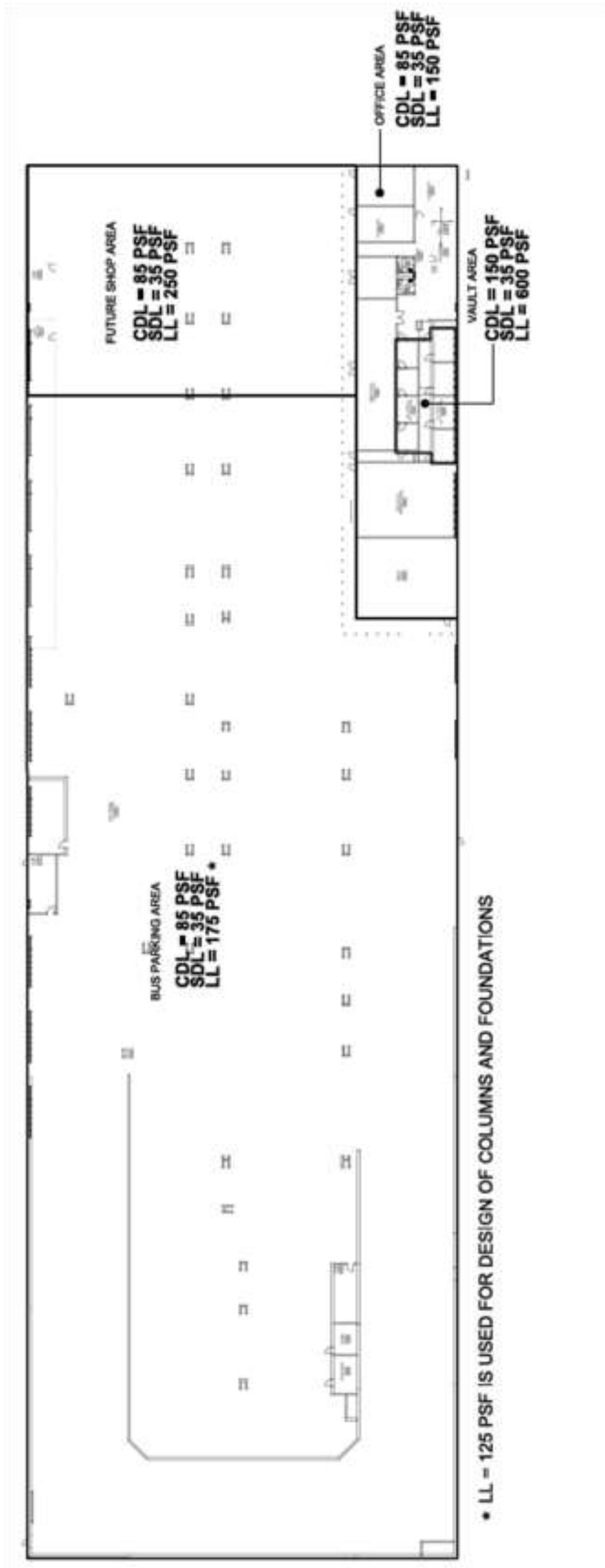
Composite Roof and High Roof Framing Plan

**Appendix B**: Distributed Loads

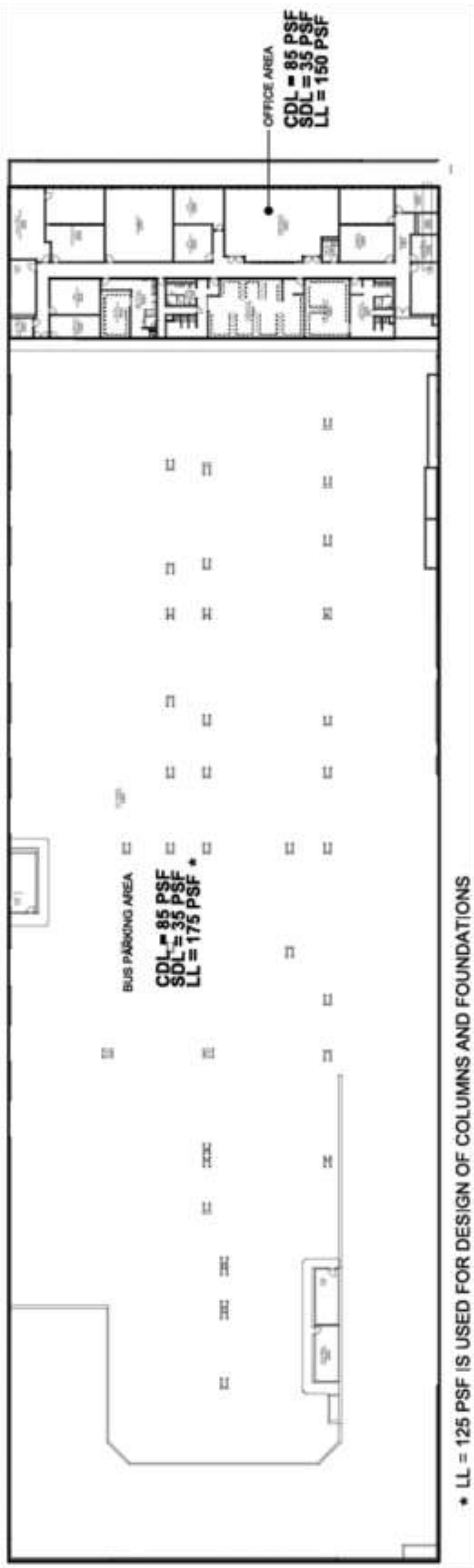



First Floor Load Map

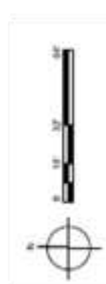


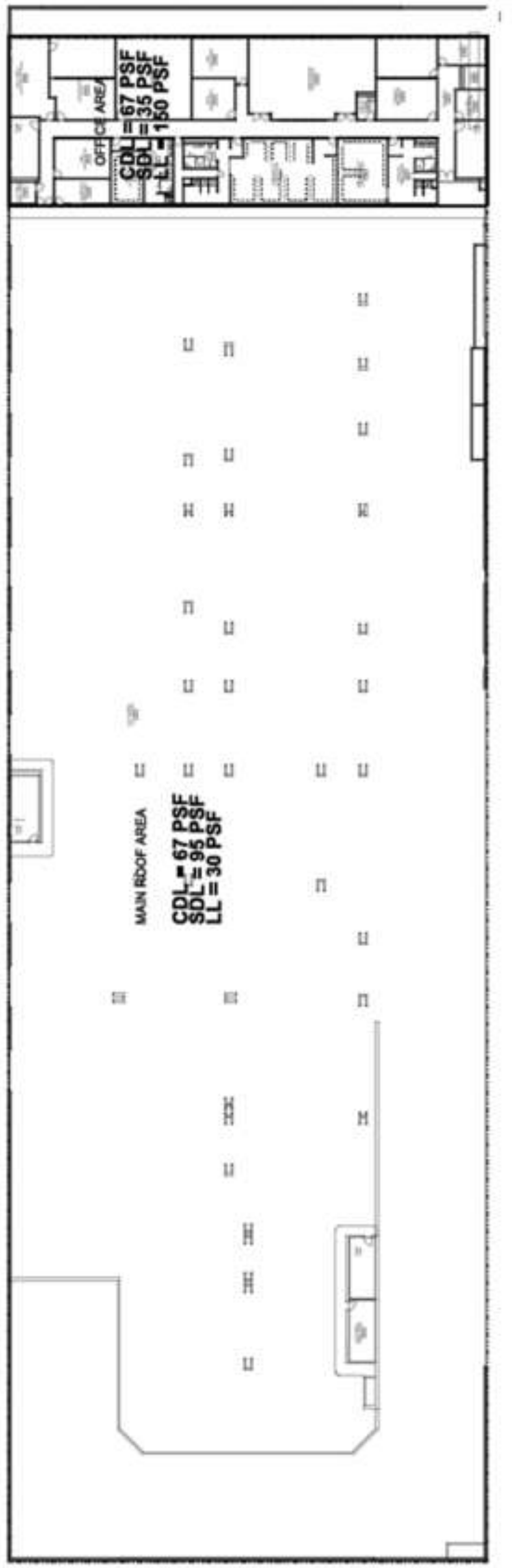



Second Floor Load Map



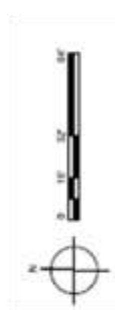

Third Floor Load Map






Roof and Third Floor Mezzanine Load Map


High Roof Load Map

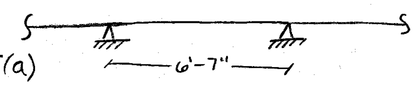


**Appendix C**: One-Way Slab on Sacrificial 2" Deck (Existing System)

| Kaitlyn Triebl | TECH II | EXISTING ONE-WAY SLAB w/ 2" SACRIFICIAL DECK | 1 |
|---|---|---|---|

Bay: 55'-10" × 46'-0"
↳ Treat as 12" wide, spanning 6'-7" w/ #9 bars ($A = 1\,in^2$, dia = 1.125 in)

Givens: SDL = 35 psf    t = 6"
LL = 175 psf    ↳ DL = 75 psf
$f'_c$ = 5000 psi    $f_y$ = 60,000 psi




Check Minimum Thickness: ACI Table 9.5(a)

$* \ell/28 = (6 \times 12 + 7)"/28 \rightarrow 79"/28 = 2.8"$ min < 6" ✓ OK

Calculate Reinforcement Depth:

$d = 6" - 3/4" - (1.125/2)" = 4.7"$

$\omega, M_u, V_u$

$\omega = 1.2(75+35) + 1.6(175)$
$= 410$ psf

$\omega(A_T) = 410$ psf( 1' ) = 410 plf

$V = \omega \ell / 2$
$= 410$ plf$(6'-7")/2$
$= 1.4$ k

$M_u = \omega \ell^2 / 8$
$= (410$ plf$)(6'-7")^2/8$
$= 2.4$ k·ft

Area of Steel:

$A_s \geq \frac{M_u}{\phi F_y (jd)}$
$\geq \frac{2.4(12)}{0.9(60)(.95 \times 4.7")}$
$= 0.12\ in^2$ per ft
(estimate)

$a = \frac{A_s f_y}{0.85 f'_c (b)} = \frac{0.12(60)}{0.85(5)(12)} = 0.141$

$A_s \geq \frac{M_u}{\phi f_y (d - a/2)} = \frac{2.4(12)}{0.9(60)(4.7 - 0.141/2)} = 0.115$

$\rho = \frac{A_s}{bd} = \frac{0.115}{(12)(4.7)} = 0.002 > .0018$ ✓

| KAITLYN TRIEBL | TECH II | EXISTING ONE-WAY SLAB W/ 2" SACRIFICIAL DECK | 2 |
|---|---|---|---|

Check for Shear Adquacy (PUNCHING SHEAR)

$V_u = 1.15 w_u l_n / 2$
$= 1.15(410)(6.583')/2$
$= 1552 \text{ lb} + 15450 \text{ lb} = 17002 \sim 17k$

$A_c = [b_o d]4$
$* \, b_o = (4.5 + d) \times 2$

$V_c = 2\lambda \sqrt{f'c} \, A_c$
$= 2(1)(\sqrt{5000})[(9.2)(4.7)4]$
$= 24460 \text{ lb}$

$\phi V_c = 0.75 V_c$
$= 0.75(24460 \text{ lb})$
$= 18345 \text{ lb} > 17002 \text{ k}$ ✓

$\phi V_c > V_u \therefore \quad h = 6"$ OK

$A_s = 0.115 \text{ in}^2$

Use 1 #4/ft

$d = 6" - 3/4" - 0.25"$
$d = 5"$

$A_s = \frac{M_u}{\phi f_y (jd)} = \frac{2.4(12)}{0.9(60)(.95 \times 5)} = 0.11 \text{ in}^2$ per ft

$a = \frac{0.11(60)}{0.85(5)(12)} = 0.13 \text{ in}$

$A_s \geq \frac{M_u}{\phi f_y (d - a/2)} = \frac{2.4(12)}{0.9(60)(5 - 0.13/2)} = 0.114 \text{ in}^2$

#4 @ 12" OK

Check Reinforcement Spacing for Crack Control

$S_{max} = \min \begin{cases} 15\left(\frac{40{,}000}{f_s}\right) - 2.5 c_c \\ 12\left(\frac{40{,}000}{f_s}\right) \end{cases} = \begin{cases} 15\left(\frac{40{,}000}{(2/3 \times 60{,}000)}\right) - 2.5(0.75) = 13.125 \\ 12\left(\frac{40{,}000}{2/3 \times 60{,}000}\right) = 12" \end{cases}$ ← CONTROLS ✓

Shrinkage : Temperature Reinforcing

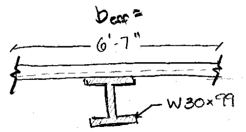
$f_y = 60 \text{ ksi} \quad \rho_{min} = 0.0018$

$A_s = 0.0018(12" \times 6") = 0.13 \text{ in}^2$ per ft

$S_{max} = \begin{cases} 3h = 18" \\ 18" \end{cases}$ ✓

Use #4 @ 12 in

| KAITLYN TRIEBL | TECH II | EXISTING ONE-WAY SLAB w/ 2" SACRIFICIAL DECK | 3 |
|---|---|---|---|




$M/\Omega = 778 \text{ k·ft} > 747 \text{ k·ft}$ ✓

$M_u = (81.3 + 35 + 175)(6.583)(55.83')^2/8 = 747 \text{ k·ft}$

↑ addition of 2" sacrificial deck

$V'_s = A_s f_y = 50(29.1 \text{ in}^2) = 1455 \text{ k}$

$V'_c = 0.85 f'_c (b_{eff}) t = 0.85(5)(79")(6) = 2015 \text{ k}$ ← PNA in Concrete

STUDS:

$\frac{\Sigma Q_n}{Q_n} = \frac{1455}{17.2} \approx 86$ studs @ 7.5"

Spacing $> 3"$, $< 36"$ $(4 \times 3/4")$ ✓

Therefore 115 studs = Ok

$a = \frac{1455 \text{ k}}{.85(5)(79)} = 4.33"$

$Y_2 = 8" - 4.33/2" = 5.8"$

Check LL Deflection:

$\Delta_{LL\,MAX} = L/360 = 670/360 = 1.86$

$\Delta_{LL} = \frac{5 w l^4}{384 E I_{LB}} = \frac{5(.210 \times 6.583')(55.83)^4(1728)}{384(29000)(9990)} = 1.04"$ ✓

Check Construction Deflection:

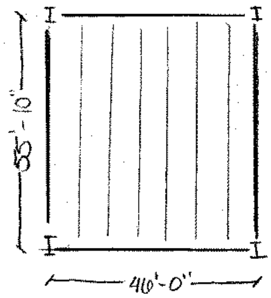
$\Delta_{c\,MAX} = l/240 = 670/240 = 2.8"$

$\Delta_c = \frac{5 w l^4}{384 E I_x} = \frac{5(0.291 \times 6.583)(55.83)^4(1728)}{384(29000)(3990)} = 3.6"$

* SHORING REQUIRED

**Appendix D:** Composite Steel Deck

Kaitlyn Triebl | Tech II | COMPOSITE SLAB | 1




LOADING:
SDL: 35 psf
LL: 175 psf } 210 psf

Try: 2VLI19 w/ t=2"

231 psf > 210 psf ✓
7'-0" > 6'-7" ✓
12'-4" > 6'-7" ✓

Check Shear (pg 66 Vulcraft Steel Decking Manual)

$V_u = 15450$

$V_n = V_c + V_D$
$= 2\beta_c\sqrt{f'c}\ A_c + 3190$
$= 2(1.0)\sqrt{5000}(36\ in^2) + 3190$
$= 6053 < 15000$

* $A_c = 4.5" \times 4.5"$ (ASCE 7-05)
depth: 2"
$A_c = [4.5"(2")]4 = 36 in^2$

FAILS

Try 2VLI16 t=4.5 in

$V_n = 2(1.0)\sqrt{5000}[4(4.5")(4.5")] + 3618$
$= 15073$ lbs

$\phi = 0.75$

$\phi V_n = 11304 < 15450$ FAILS

TRY 3VLI16 t=4.5"

$V_n = 2(1.0)\sqrt{5000}[4(4.5)(4.5)] + 5309$
$= 16764$ lb

$\phi V_n = 0.75 V_n = 12573$ lb $< 15450$

FAILS

* Note: topping depth would need to increase to 6.5" on 3VLI16 decking in order to handle shear capacity. This value is not available in the Vulcraft Steel decking Manual.

| KAITLYN TRIEBL | TECH II | COMPOSITE SLAB | 2 |
|---|---|---|---|

Assuming a 3VLI16 w/ t = 6.5" was available, check deflection:

$DL = (0.668\ ft^3/ft^2 \times 150\ lb/ft^3) = 100.2\ psf$
$SDL = 35\ psf$
$LL = 175\ psf$

STEEL JOISTS: ASD Load Combinations

$\omega = (100.2 + 35 + 175)\ psf\ (6'\text{-}7")$
$= 2042\ plf$

$V = \omega l/2 = 2.042(55'\text{-}10")/2$
$= 57\ kip$

$M = \omega l^2/8$
$= 2.042(55'\text{-}10")^2/8$
$= 795.8\ k \cdot ft$

Beam Selection: Table 3-2
Use 30×108

$M_n/\Omega = 863\ k \cdot ft > 796\ k \cdot ft$ ✓

$V_n/\Omega = 325\ k > 57\ k$ ✓

FIND $b_{eff}$:

$b_{eff} = 79"$ or $\frac{667"}{8} = 83"$

$V'_c = 0.85 f'_c (b_{eff}) t$
$= 0.85(5000)(79)(9.5)$
$= 3190\ k$
$V'_s = A_s f_y$
$= 31.7(60)$
$= 1902\ k$
* PNA in Concrete

$1902 = 0.85(5)(79)a$
$a = 5.66"$

$\frac{\Sigma Q_n}{Q_n} = \frac{1902}{17.2} = 110.5 \rightarrow 112$ studs @ 5" spacing (1 stud/rib)

Spacing: $> 4(3/4") = 3"$ ✓
$< 36"$ ✓

Equivalent Weight:

$108\ plf(55.83') + 112(10\ lb) = 7.15\ k$

| KAITLYN TRIEBL | TECH II | COMPOSITE SLAB | 3 |
|---|---|---|---|

CHECK $\Delta_{LL}$:

$\Delta_{LL\,MAX} = l/360 = 670/360 = 1.86"$

$* \, Y_2 = 9.5" - \frac{5.66}{2} = 6.67"$

$\Delta_{LL} = \frac{5 w l^4}{384 E I_{LB}} = \frac{5(210 \cdot 6.58)(55.83)^4 (1728)}{384 (29000)(11800)} = 0.88" < 1.86" \checkmark$

<u>Check $\Delta_{WET\,CONC}$</u>

$\Delta_{WC,MAX} = l/240 = 670/240 = 2.8"$

$\Delta_{WC} = \frac{5 w l^4}{384 E I_x} = \frac{5(.100 \times 6.583 + .05)(55.83)^4 (1728)}{384 (29000)(4470)} = 1.19" < 2.8" \checkmark$

**Appendix E:** Precast Hollow Core Plank

Kaitlyn Triebl | Tech II | PRECAST

MAX. BAY SIZE: 55'-10" × 46'-0"

J. 1,3a to L,2c

FIRE RATING: 2 hour

Loading: Service

LL+SDL

175 + 35 = 210 psf

* Self weight assumed to be accounted for in chart

PLANKS CAPABLE OF MAINTAINING: 210 psf

6" × 4'-0" : 214 psf @ 21' span (7-½" ø) w/ 2" topping

8" × 4'-0" : 221 psf @ 24' span (7-½" ø) w/ 2" topping

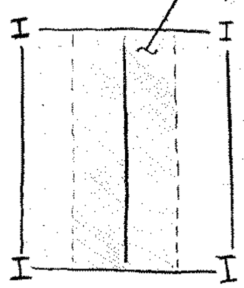
10" × 4'-0" : 222 psf @ 27' span (7-½" ø) w/ 2" topping

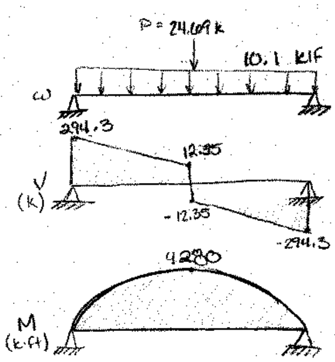
One Joist Added: 23'-0" span

• Try: 8" × 4'-0"

DESIGN JOIST:

$A_T = 23'(55.83') = 1284\ ft^2$






Concrete Wt: 150 pcf × $\frac{2}{12}$ = 25 psf

$w = 1.2(61.3\ psf + 25\ psf) + 1.6(210)\ psf$
$= 440\ psf$

$w = 23'(440\ psf) = 10.1\ klf$

$V_u \le \phi V_n = 683$ @ 56'-0" ✓

$M_u = 4280\ k{\cdot}ft$

Use W 36 × 441
(Table 3-10) ✓

2

Check Deflection:

$\Delta_{LL,max} = l/360 = (55\times12+10)/360 = 1.86''$

$\omega_L = 1.6(210) = 336\ psf$
$\times 6'-\cancel{0}''$
$2409\ plf$
$/12$
$= 201\ lb/in$

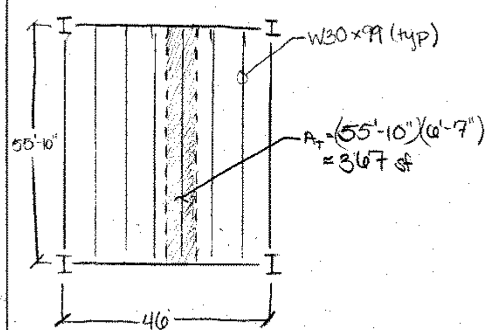
$\Delta_{LL} = \dfrac{5\omega_L l^4}{384EI} = \dfrac{5(.201)(55\times12+10)^4}{384(57000\sqrt{3000})(32100)} = 0.007''$ ✓

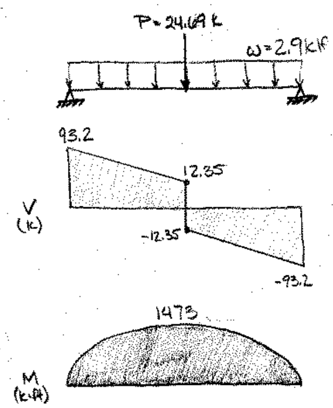
$\Delta_{TL,max} = l/240 = (55\times12+10)/240 = 2.79''$

$\Delta_{TL} = \dfrac{5\omega_T l^4}{384EI} = \dfrac{5(225)(55\times12+10)^4}{384(57000\sqrt{3000})(32100)} = 0.008''$ ✓

$\omega_T = 1.2(86.3) + 1.6(210) = 440\ psf$

Design with Current Joist System:




$\omega = 440\ psf(6'-7'') = 2.9\ klf$

$M_u = 1473\ k\text{-}ft$

Use W27×258 ← Not as economical as W30×99

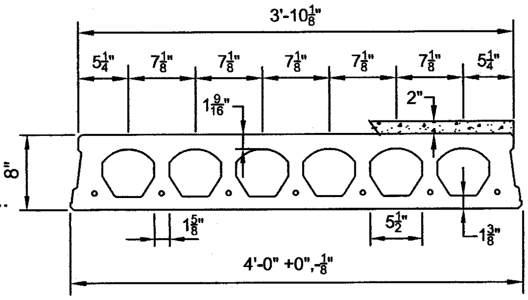
# Prestressed Concrete
# 8"x4'-0" Hollow Core Plank

2 Hour Fire Resistance Rating With 2" Topping

**PHYSICAL PROPERTIES**
Composite Section

| | |
|---|---|
| $A_c$ = 301 in.$^2$ | Precast $b_w$ = 13.13 in. |
| $I_c$ = 3134 in.$^4$ | Precast $S_{bcp}$ = 616 in.$^3$ |
| $Y_{bcp}$ = 5.09 in. | Topping $S_{tct}$ = 902 in.$^3$ |
| $Y_{tcp}$ = 2.91 in. | Precast $S_{tcp}$ = 1076 in.$^3$ |
| $Y_{tct}$ = 4.91 in. | Precast Wt. = 245 PLF |
| | Precast Wt. = 61.25 PSF |

## 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 = 92.3 k-ft at 60% jacking force
   6-1/2"Ø, 270K = 130.6 k-ft at 60% jacking force
   7-1/2"Ø, 270K = 147.8 k-ft at 60% jacking force
7. Maximum bottom tensile stress is $10\sqrt{f'c}$ = 775 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. Topping Strength @ 28 days = 3000 PSI. Topping Weight = 25 PSF.
12. These tables are based upon the topping having a uniform 2" thickness over the entire span. A lesser thickness might occur if camber is not taken into account during design, thus reducing the load capacity.
13. Load values to the left of the solid line are controlled by ultimate shear strength.
14. Load values to the right are controlled by ultimate flexural strength or fire endurance limits.
15. Load values may be different for IBC 2000 & ACI 318-99. Load tables are available upon request.
16. 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 2006 & ACI 318-05 (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) | 280 | 248 | 214 | 185 | 159 | 138 | 118 | 102 | 87 | 74 | 62 | 52 | 42 | | | | | | |
| 6 - 1/2"ø | LOAD (PSF) | 366 | 341 | 318 | 299 | 271 | 239 | 211 | 187 | 165 | 146 | 129 | 114 | 101 | 88 | 77 | 67 | 58 | 50 | 42 |
| 7 - 1/2"ø | LOAD (PSF) | 367 | 342 | 320 | 300 | 282 | 265 | 243 | 221 | 202 | 181 | 161 | 144 | 128 | 114 | 101 | 90 | 79 | 70 | 61 |

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.

**NITTERHOUSE**
CONCRETE PRODUCTS

2655 Molly Pitcher Hwy. South, Box N
Chambersburg, PA 17202-9203
717-267-4505 Fax 717-267-4518

11/03/08

8SF2.0T

**Appendix F:** Precast Double Tees

Kaitlyn Triebl | Tech II | PreCast Double Tees | 1

Max Bay Size: 55'-10" × 46'-0" (J.1 3a – L2c)

Fire Rating: 2 hours

Loading: Note 9: Super Imposed treated as Live Load and should be computed using the following:

$$\text{Allowable LL} = \frac{1.6LL + 1.2SDL}{1.6} = \frac{1.6(175\,psf) + 1.2(35\,psf)}{1.6} = 201\,psf$$

Double Tees Capable of Carrying 201 psf:
@ 56'-0" Span

36" × 8'-0" 168-D1
↳ Supports Super Imposed Live Load of 213 psf
1.9" 28 Day Camber
0.9" deflection from LL

Check Deflection of Girder: (W40×481")

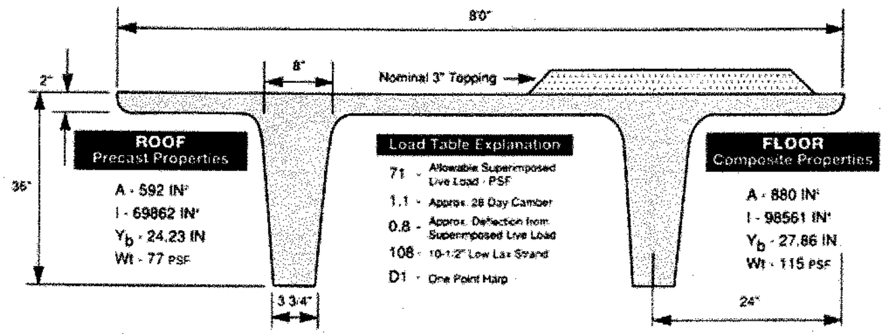
$$\Delta_{LL,MAX} = l/360 = (46\times12)/360 = 1.53"$$

$$\Delta_{LL} = \frac{5\left(\frac{201\times56}{12}\right)(552)^4}{384(29{,}000{,}000)(34800)} = 1.22" < 1.53" \checkmark$$

$$\Delta_{TOT} = l/240 = (46\times12)/240 = 2.3"$$

$$\Delta_{TOT} = \frac{5wl^4}{384EI} = \frac{5\left(\frac{410\times56}{12}\right)(552)^4}{384(29000000)(34800)} = 2.29" < 2.3" \checkmark$$

## 36" — 36" x 8'0" Double Tee




### PRECAST LOAD TABLE-ROOF

| SPAN IN FEET | | 66 | 68 | 70 | 72 | 74 | 76 | 78 | 80 | 82 | 84 | 86 | 88 | 90 | 92 | 94 | 96 | 98 | 100 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 108-D1 | Load | 71 | 64 | 56 | 50 | 44 | | | | | | | | | | | | | |
| | Camber | 1.1 | 1.1 | 1.0 | 0.9 | 0.8 | | | | | | | | | | | | | |
| | Deflection | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | | | | | | | | | | | | | |
| 128-D1 | Load | 95 | 86 | 78 | 70 | 63 | 56 | 50 | 45 | | | | | | | | | | |
| | Camber | 1.5 | 1.4 | 1.4 | 1.3 | 1.3 | 1.2 | 1.1 | 0.9 | | | | | | | | | | |
| | Deflection | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | | | | | | | | | | |
| 148-D1 | Load | 120 | 109 | 99 | 90 | 82 | 75 | 68 | 61 | 55 | 50 | 44 | 40 | | | | | | |
| | Camber | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.8 | 1.7 | 1.6 | 1.5 | 1.4 | 1.2 | 1.0 | | | | | | |
| | Deflection | 1.4 | 1.4 | 1.4 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | | | | | | |
| 168-D1 | Load | 142 | 129 | 118 | 107 | 97 | 88 | 80 | 73 | 67 | 61 | 56 | 52 | 47 | 42 | | | | |
| | Camber | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.1 | 2.0 | 1.9 | 1.8 | 1.7 | 1.5 | 1.3 | 1.1 | | | | |
| | Deflection | 1.6 | 1.7 | 1.7 | 1.7 | 1.7 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | | | | |
| 188-D1 | Load | 159 | 145 | 133 | 121 | 111 | 101 | 92 | 84 | 76 | 69 | 62 | 57 | 52 | 48 | 44 | 40 | | |
| | Camber | 2.4 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.4 | 2.4 | 2.3 | 2.2 | 2.1 | 2.0 | 1.8 | 1.6 | 1.4 | 1.1 | | |
| | Deflection | 1.8 | 1.9 | 1.9 | 2.0 | 2.0 | 2.0 | 2.0 | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 | | |
| 208-D1 | Load | | | | | | 115 | 105 | 96 | 88 | 80 | 73 | 66 | 60 | 54 | 48 | 44 | 41 | |
| | Camber | | | | | | 2.9 | 2.9 | 2.9 | 2.8 | 2.7 | 2.6 | 2.5 | 2.4 | 2.2 | 2.0 | 1.8 | 1.6 | |
| | Deflection | | | | | | 2.3 | 2.3 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | |
| 228-D1 | Load | | | | | | | | | | 89 | 82 | 74 | 68 | 62 | 56 | 50 | 45 | 40 |
| | Camber | | | | | | | | | | 3.0 | 2.9 | 2.8 | 2.7 | 2.6 | 2.4 | 2.2 | 1.9 | 1.7 |
| | Deflection | | | | | | | | | | 2.7 | 2.7 | 2.7 | 2.7 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 |

### 3" COMPOSITE LOAD TABLE-FLOOR

| SPAN IN FEET | | 52 | 54 | 56 | 58 | 60 | 62 | 64 | 66 | 68 | 70 | 72 | 74 | 76 | 78 | 80 | 82 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 108-D1 | Load | 141 | 124 | 108 | 95 | 82 | 71 | 61 | 52 | | | | | | | | |
| | Camber | 1.1 | 1.1 | 1.2 | 1.2 | 1.2 | 1.2 | 1.1 | 1.1 | | | | | | | | |
| | Deflection | 0.4 | 0.4 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | | | | | | | | |
| 128-D1 | Load | 182 | 162 | 144 | 128 | 114 | 100 | 88 | 77 | 67 | 58 | 50 | | | | | |
| | Camber | 1.3 | 1.4 | 1.4 | 1.4 | 1.5 | 1.5 | 1.5 | 1.5 | 1.4 | 1.4 | 1.3 | | | | | |
| | Deflection | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | | | | | |
| 148-D1 | Load | [redacted] | | 180 | 162 | 145 | 130 | 116 | 104 | 92 | 82 | 72 | 63 | 55 | | | |
| | Camber | | | 1.7 | 1.8 | 1.8 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.8 | | | |
| | Deflection | 0.7 | 0.7 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | | | |
| **168-D1** | **Load** | | | 213 | 193 | 174 | 157 | 141 | 127 | 112 | 99 | 89 | 79 | 70 | 61 | 52 | |
| | **Camber** | | | 1.9 | 2.0 | 2.1 | 2.1 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.1 | 2.0 | |
| | **Deflection** | | | 0.9 | 0.9 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | |
| 188-D1 | Load | | | | | | | | 149 | 132 | 117 | 103 | 90 | 78 | 69 | 61 | 54 |
| | Camber | | | | | | | | 2.4 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.4 | 2.4 | 2.3 |
| | Deflection | | | | | | | | 1.2 | 1.2 | 1.2 | 1.2 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 |
| 208-D1 | Load | | | | | | | | | | | | | 95 | 83 | 72 | 62 |
| | Camber | | | | | | | | | | | | | 2.9 | 2.9 | 2.9 | 2.8 |
| | Deflection | | | | | | | | | | | | | 1.3 | 1.3 | 1.3 | 1.3 |

**Appendix G:** Cost Estimates:

One-Way

**Assembly B10102178000** **Based on National Average Costs**

Cast-in-place concrete slab, 9" thick, one way, 20' multi span, 200 PSF superimposed load, 313 PSF total load

| Description | Quantity | Unit | Material | Installation | Total |
|---|---|---|---|---|---|
| C.I.P. concrete forms, elevated slab, floor, hung from steel beams, 4 use, includes sh... | 1.00000 | S.F. | 1.45 | 5.45 | 6.90 |
| C.I.P. concrete forms, elevated slab, edge forms, alternate pricing, to 6" high, 1 use, i... | 0.05000 | SFCA | 0.03 | 0.31 | 0.34 |
| Reinforcing Steel, in place, elevated slabs, #4 to #7, A615, grade 60, incl labor for acc... | 3.99000 | Lb. | 2.03 | 1.72 | 3.75 |
| Structural concrete, ready mix, normal weight, 3000 psi, includes local aggregate, san... | 0.75000 | C.F. | 3.02 | 0.00 | 3.02 |
| Structural concrete, placing, elevated slab, pumped, less than 6" thick, includes strike... | 0.75000 | C.F. | 0.00 | 1.12 | 1.12 |
| Concrete finishing, floors, for specified Random Access Floors in ACI Classes 1, 2, 3 a... | 1.04000 | S.F. | 0.00 | 0.85 | 0.85 |
| Concrete surface treatment, curing, sprayed membrane compound | 0.01000 | C.S.F. | 0.06 | 0.09 | 0.15 |
| Total | | | $6.60 | $9.54 | $16.14 |

*Steel Girder Price was added to this cost from the Composite System Estimate ($12.03/sf)

Composite Deck:

**Assembly B10102564000** **Based on National Average Costs**

Floor, composite metal deck, shear connectors, 6.25" slab, 25'x30' bay, 30.25" total depth, 200 PSF superimposed load, 252 PSF total load

| Description | Quantity | Unit | Material | Installation | Total |
|---|---|---|---|---|---|
| Welded wire fabric, sheets, 6 x 6 - W1.4 x W1.4 (10 x 10) 121 lb. per C.S.F., A185 | 0.01100 | C.S.F. | 0.15 | 0.39 | 0.54 |
| Structural concrete, placing, elevated slab, pumped, less than 6" thick, includes strike... | 0.39500 | C.F. | 0.00 | 0.59 | 0.59 |
| Structural concrete, ready mix, lightweight, 110 #/C.F., 3000 psi, includes local aggre... | 0.39500 | C.F. | 2.86 | 0.00 | 2.86 |
| Concrete finishing, floors, for specified Random Access Floors in ACI Classes 1, 2, 3 a... | 1.00000 | S.F. | 0.00 | 0.82 | 0.82 |
| Concrete surface treatment, curing, sprayed membrane compound | 0.01000 | C.S.F. | 0.06 | 0.09 | 0.15 |
| Weld shear connector, 3/4" dia x 4-7/8" L | 0.19500 | Ea. | 0.14 | 0.37 | 0.51 |
| Structural steel project, apartment, nursing home, etc, 100-ton project, 3 to 6 stories... | 7.20600 | Lb. | 9.08 | 3.03 | 12.11 |
| Metal floor decking, steel, non-cellular, composite, galvanized, 3" D, 16 gauge | 1.05000 | S.F. | 3.11 | 1.12 | 4.23 |
| Metal decking, steel edge closure form, galvanized, with 2 bends, 12" wide, 18 gauge | 0.03700 | L.F. | 0.12 | 0.09 | 0.20 |
| Sprayed cementitious fireproofing, sprayed mineral fiber or cementitious for fireproo... | 0.67700 | S.F. | 0.39 | 0.65 | 1.04 |
| Total | | | $15.90 | $7.15 | $23.05 |

Precast Plank:

**Assembly B10102303200** **Based on National Average Costs**

Precast concrete plank, 2" topping, 8" total thickness, 25' span, 75 PSF superimposed load, 150 PSF total load

| Description | Quantity | Unit | Material | Installation | Total |
|---|---|---|---|---|---|
| C.I.P. concrete forms, elevated slab, edge forms, to 6" high, 4 use, includes shoring, ... | 0.10000 | L.F. | 0.02 | 0.40 | 0.42 |
| Welded wire fabric, sheets, 6 x 6 - W1.4 x W1.4 (10 x 10) 121 lb. per C.S.F., A185 | 0.01000 | C.S.F. | 0.14 | 0.36 | 0.49 |
| Structural concrete, ready mix, normal weight, 3000 psi, includes local aggregate, san... | 0.17000 | C.F. | 0.69 | 0.00 | 0.69 |
| Structural concrete, placing, elevated slab, pumped, less than 6" thick, includes strike... | 0.17000 | C.F. | 0.00 | 0.25 | 0.25 |
| Concrete finishing, floors, basic finishing for unspecified flatwork, bull float, manual fl... | 1.00000 | S.F. | 0.00 | 1.09 | 1.09 |
| Concrete surface treatment, curing, sprayed membrane compound | 0.01000 | C.S.F. | 0.06 | 0.09 | 0.15 |
| Precast slab, roof/floor members, grouted, solid, 6" thick, prestressed | 1.00000 | S.F. | 7.15 | 2.85 | 10.00 |
| Total | | | $8.05 | $5.04 | $13.09 |

*Steel Girder Price was added to this cost from the Composite System Estimate ($12.03/sf)

Precast Double Tee:

**Assembly B10102359450** **Based on National Average Costs**

Precast concrete double T beam, lightweight, 2" topping, 32" deep x 10' wide, 60' span, 100 PSF superimposed load, 173 PSF total load

| Description | Quantity | Unit | Material | Installation | Total |
|---|---|---|---|---|---|
| C.I.P. concrete forms, elevated slab, edge forms, to 6" high, 4 use, includes shoring, ... | 0.05000 | L.F. | 0.01 | 0.20 | 0.21 |
| Prestressing steel, ungrouted strand, 50' span, 100 kip, post-tensioned in field | 0.47300 | Lb. | 0.32 | 0.94 | 1.26 |
| Structural concrete, ready mix, normal weight, 3000 psi, includes local aggregate, san... | 0.25000 | C.F. | 1.01 | 0.00 | 1.01 |
| Structural concrete, placing, elevated slab, pumped, less than 6" thick, includes strike... | 0.25000 | C.F. | 0.00 | 0.37 | 0.37 |
| Concrete finishing, floors, for specified Random Access Floors in ACI Classes 1, 2, 3 a... | 1.00000 | S.F. | 0.00 | 0.82 | 0.82 |
| Concrete surface treatment, curing, sprayed membrane compound | 0.01000 | C.S.F. | 0.06 | 0.09 | 0.15 |
| Precast tees, double, roof, 60' span, 32" x 10' wide, prestressed, lightweight | 0.00167 | Ea. | 11.50 | 0.83 | 12.33 |
| Total | | | $12.90 | $3.25 | $16.15 |

*Allowance for fireproofing added to price