# Technical Report #2

# Virginia Advanced Shipbuilding & Carrier Integration Center
Newport News, VA

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# Executive Summary

Technical Report 2 called for a redesign of the floor system of the building, taking only gravity loads into account. For the sake of this design, a bay of the office building was selected as the laboratory building and parking deck does not meet the height requirements for the structural Thesis report. Advantages of these systems were discussed, taking into account weight, depth, cost (including construction and fire rating), and feasibility with the architecture of the building.

The existing structural system consists of a composite steel deck system. After analysis of the existing system, it was found that the composite steel deck is more than capable of carrying the loads expected. This system seemed to be the easiest to use given the shape of the building and the architectural goal of the building.

Three alternative systems were analyzed and discussed in the report;

Two-Way Flat Slab
Precast Hollow-Core Planks
Open Web Joists

While the two-way flat slab made sense architecturally and financially as it has a smallest depth and does not require extra fire-proofing, it lacked the ability to combine with the existing lateral resistance system in the building. The two-way flat slab may seem like the most cost-efficient at first glance, but when considering that a different, most like more expensive, lateral system must be designed, the system loses credibility.

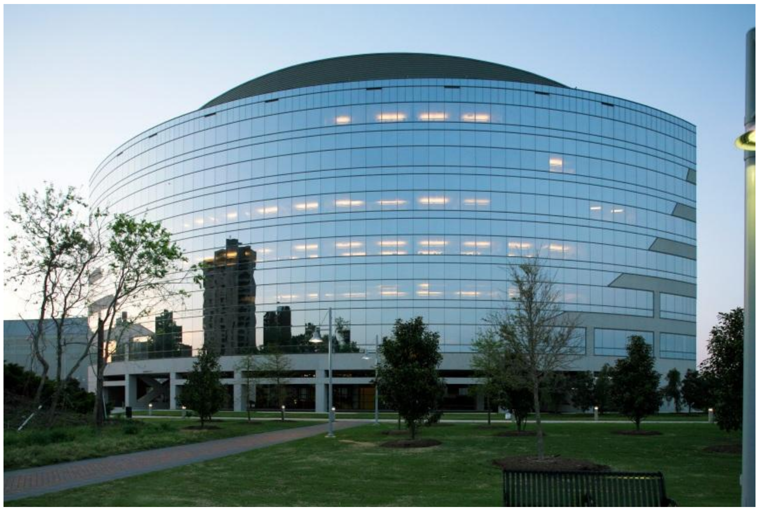
The precast hollow-core system, much like the two-way flat plate does not require fireproofing. The depth of the planks is minimal, however deeper girders are needed, and the total depth of the system is ultimately greater than that of the existing structure. The largest problem with the hollow-core planks is that it is difficult to implement into structures with irregular column layouts. The shape of the building leads to a very irregular column layout and many irregularly shaped bays. This reduces the effectiveness of the hollow-core planks.

The open web joist system has the advantage of easily being able to compromise with the lateral system as well as the column layouts. The irregular shape of the columns and bays, however, would lend to more joists being needed. The cost of fireproofing for the large amount of joists, as well as the increased depth of this system makes it disadvantageous.

# Introduction

The Virginia Advanced Shipbuilding and Carrier Integration Center was designed by Clark Nexsen. The project consists of two main buildings: the office building and the lab wing complete with lab parking and a parking deck. The office building is a typical composite steel frame design. The steel frame grid consists of wide flange beams and columns that range from W12x14 to W18x40. The Lab wing consists of concrete slab with concrete columns and precast concrete walls.

The office building is elevated on "stilts" of concrete made of concrete piles surrounding wide flange steel columns.



Source: Clark Nexsen

The first floor consists of a 5" reinforced concrete slab in the main office area, an 8" reinforced concrete slab at the front of the building and a 6" reinforced concrete slab in the stairwells. The rest of the floors consist of a grid of wide flange steel columns and beams that is shaped into the unique curved design of the Virginia Advanced Shipbuilding and Carrier Integration Center. The composite steel deck and slab is 4.5" in total thickness and consists of lightweight concrete placed on a 2" deep, .038" thick galvanized steel deck.

The lab wing consists of 24"x24" precast concrete columns, 8" precast lightweight concrete walls, and 4" reinforced concrete slabs. The roof of the lab wing consists of gable trusses with steel deck.

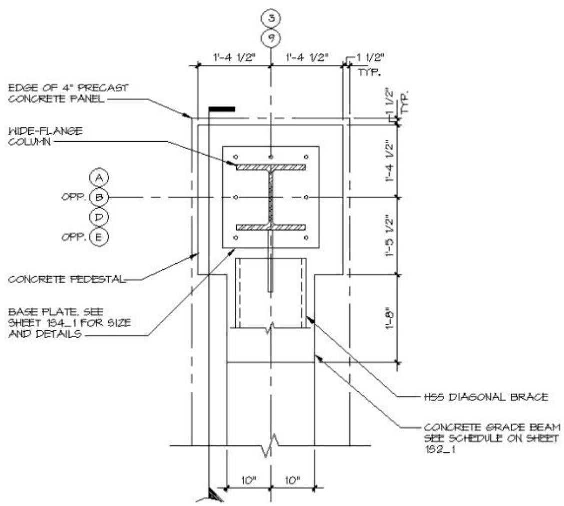
# Structural Systems Overview

## 1. Foundation

### A. Office Building

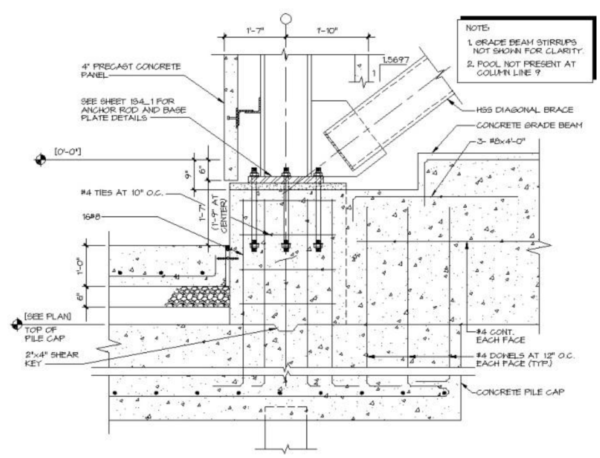
The foundation of the office building consists of a wide-flange steel column on a concrete pedestal. These concrete pedestal/steel column arrangements are placed around the perimeter of the office building in a shape that resembles a football. The soil condition on the site consists of unstable soil do to the waterfront location of the building. This shape is repeated for interior columns as well. *Figure 1* shows the plan view of the concrete pedestal/steel column arrangement and *Figure 2* shows the section view.

**FIGURE 1 –CONC. PEDESTAL PLAN**




Source: Clark-Nexsen

**FIGURE 2 – CONC.PEDESTAL SECTION**




Source: Clark-Nexsen

The concrete used in these arrangements is 3000 psi concrete. It is reinforced by #4 ties at 10"O.C, a 2"x4" shear key, and 16 #8 steel rebar. These concrete piles support the wide flange columns that are placed on them and connected with steel plates and anchor rods.

Two grade beams are used in the foundation of the office building. These grade beams are used to resist lateral column base movement as well as distribute the weight of the building over the soil. These grade beams are important due to the unstable soil condition on the site. Lateral column base movement is important in this project as it is on the coast of the James River. A bulkhead of steel sheet pile had to be constructed to resist the water pressure of the river as well as to provide slope stability and increase bearing capacity for the building foundation. They also serve to increase the bearing capacity for the building foundation. The grade beams are used to further this insurance that the building will not be affected by the river. *Table 1* shows the width, depth and reinforcing of these grade bars.

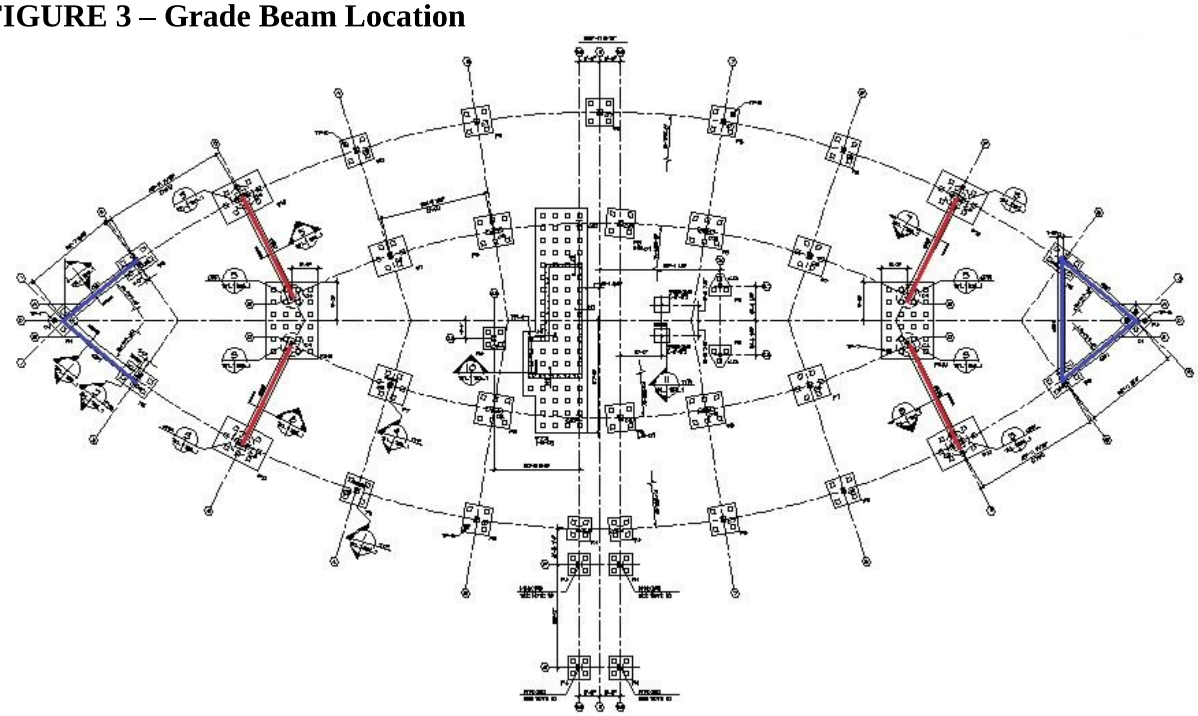
**TABLE 1 – Grade Beam Schedule**

| GRADE BEAM SCHEDULE | | | | | | |
|---|---|---|---|---|---|---|
| MARK | WIDTH | DEPTH | TOP BARS | BOTTOM BARS | STIRRUPS | |
| | | | | | SIZE | SPACING |
| GB1 | 22" | 46" | 4 - #8 | 4 - #8 | #4 | 12" O.C. |
| GB2 | 20" | 50" | 4 - #7 | 4 - #7 | #4 | 12" O.C. |
| | | | | | | |
| | | | | | | |

Source: Clark-Nexsen

*Figure 3* shows the locations of the grade beams. GB1 is indicated in blue and GB 3 is indicated in red.

**FIGURE 3 – Grade Beam Location**

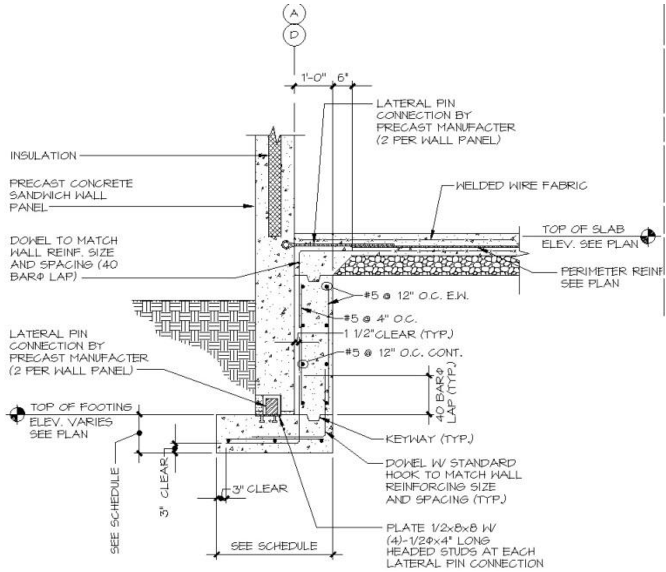


Source: Clark-Nexsen

B. <u>Lab Wing</u>

The lab wing foundation consists of concrete pillars attached to concrete footing. The pillars, which are continuous in length, contain #5 rebar at 12" O.C. and are attached to the footing by a lateral pin. *Figure 4* shows the plan view of the concrete pillars.

**FIGURE 4: Conc. Pillar Plan**




Source: Clark-Nexsen

The concrete used in the pillars for the lab wing are 3000psi concrete. They support precast concrete walls. The footings that support these walls are continuous in length. They range from 2'-0" wide by 1'-0" thick to 7'-0" by 1'-0". *Table 2* shows the footing schedule. The "A" bars indicate reinforcing in concrete deposited against the ground. The "B" bars indicate reinforcing in the concrete exposed to earth or weather.

**TABLE 2 – Footing Schedule**

| FOOTING SCHEDULE | | | | | | |
|---|---|---|---|---|---|---|
| MARK | DIMENSIONS | | | REINFORCEMENT | | NOTES |
| | W | L | T | 'A' BARS | 'B' BARS | |
| CF2.0 | 2'-0" | CONT. | 1'-0" | (2) #5's CONT. | #5's @ 4'-0" O/C | 1 |
| CF3.0 | 3'-0" | CONT. | 1'-0" | (3) #5's CONT. | #5's @ 4'-0" O/C | 1 |
| CF4.0 | 4'-0" | CONT. | 1'-0" | (4) #5's CONT. | #5's @ 6' O/C | 1 2 |
| CF7.0 | 7'-0" | CONT. | 1'-0" | (6) #5's CONT. | #5's @ 6' O/C | 1 2 |
| F4.0x4.0 | 4'-0" | 4'-0" | 1'-0" | (6) #4's | (6) #4's | 1 |
| F8.5x8.5 | 8'-6" | 8'-6" | 1'-8" | (7) #7's | (7) #7's | 1 |

Source: Clark Nexsen

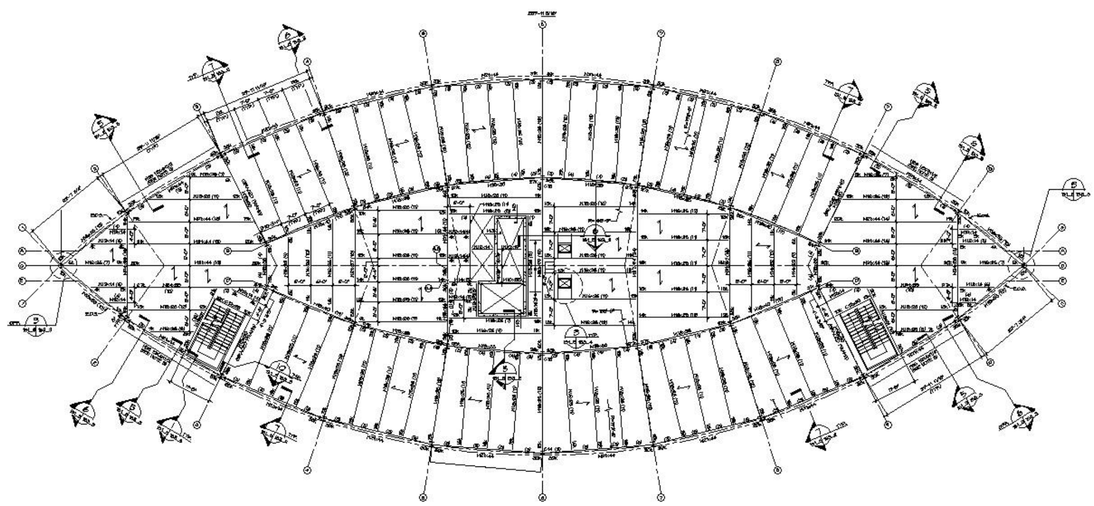
The lab wing also contains a 23"wide by 30" deep grade beam, GB1 along vertical grid line 1.5.

## 2. Floor System

### A. Office Building

The floor system of the office building is consistent from the second floor to the seventh floor. These floors contain 4.5" total thickness composite steel deck and slab. This slab consists of lightweight concrete placed on a 2" deep, .038" thick galvanized steel deck. The steel deck conforms to ASTM A653-94 specifications and has a minimum yield strength of 33ksi. The beams are wide flange steel beams arranged in various grids that form together to fit the curved shape of the building. *Figure 5* shows the floor plan from floor 2 to floor 7.

**FIGURE 5 – Floor Plan Floor 2-7**

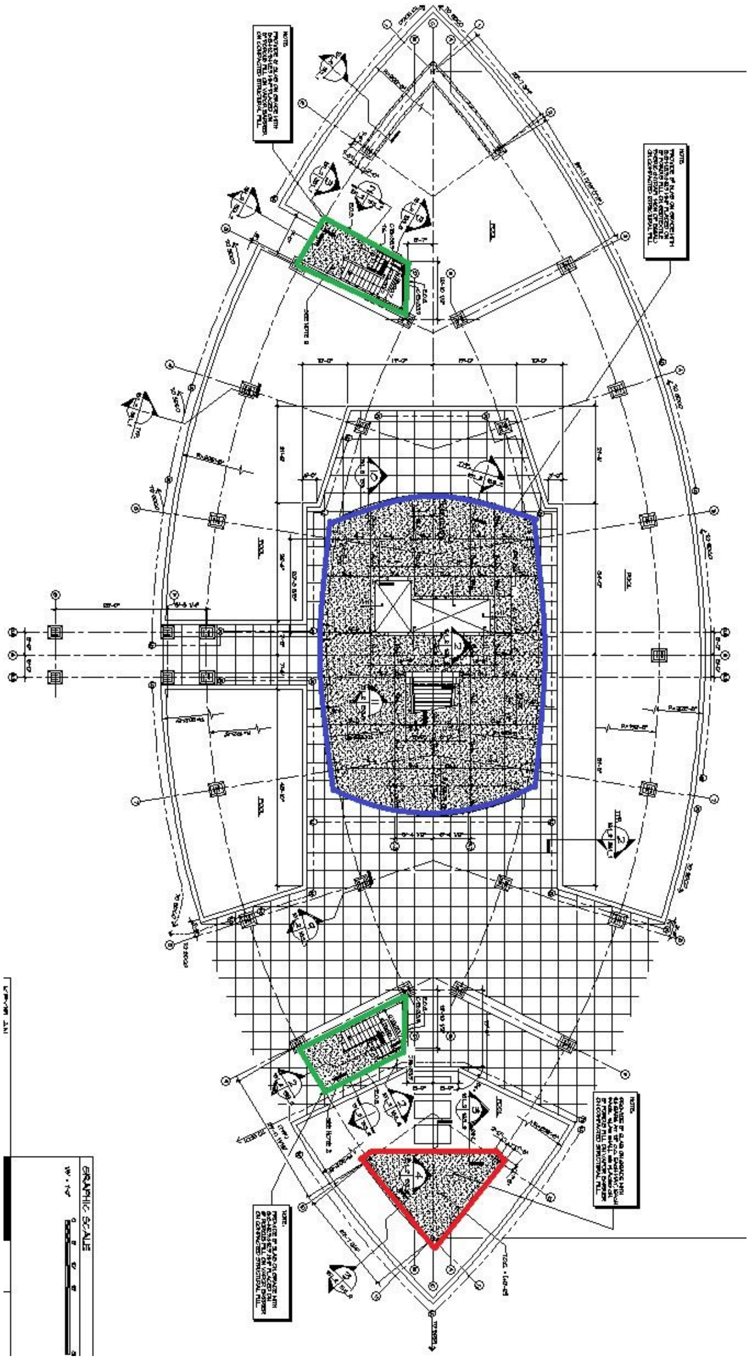


Source: Clark-Nexsen

The first floor of the office building contains three separate load-bearing reinforced concrete slabs. The first slab is at the center of the building. It consists of a 5" slab on grade with 6x6-W2.9xW2.9 WWF placed on 6" porous fill.

There is also a triangular slab in the back of the building. This slab is 8" slab on grade with #4 bars at 12" O.C. Finally, there is a slab on the floor of the stairwells. These slabs are a 6" slab on grade with 6x6-W2.9xW2.9 WWF. *Figure 6* shows the first floor plan. The 5" slab is outlined in blue, the 8" inch slab is outlined in red, and 6" slab is outlined in green.

**FIGURE 6 – First Floor Plan**



Source: Clark-Nexsen

B. Lab Wing

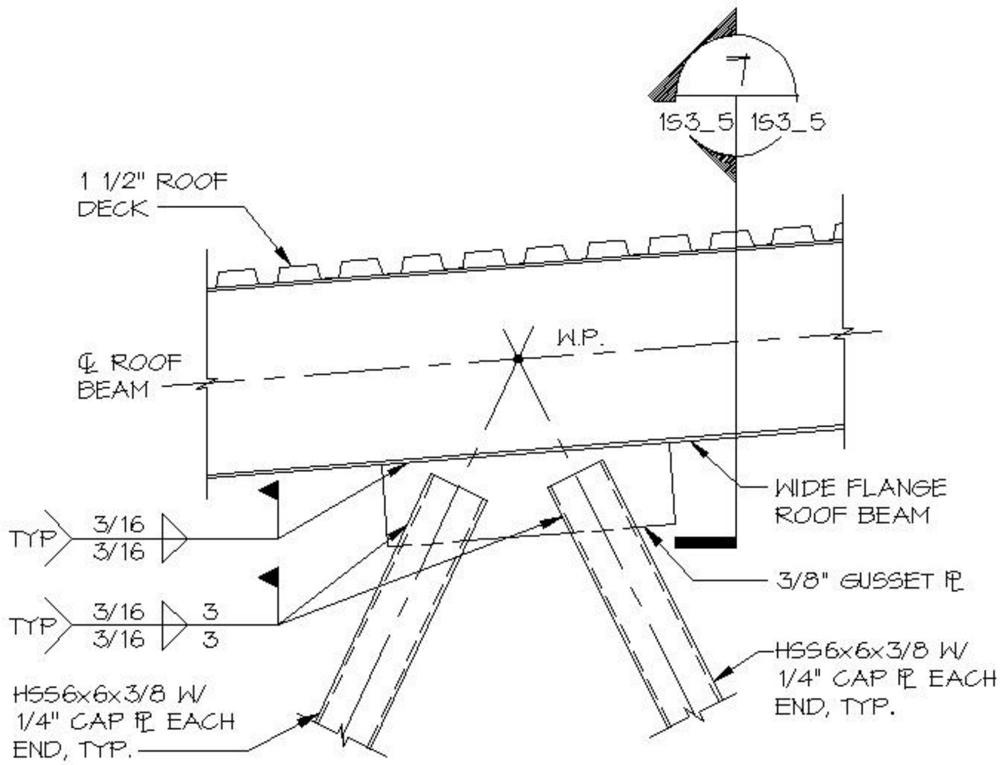
The lab wing consists of a 4" reinforced concrete slab. The slab is reinforced with 6x6 W2.0xW2.0 WWF. This concrete used in the slab is 4000psi.

# 3. Roof System

A. Office Building

The roof structure of the office building is 1 ½" corrugated composite steel deck. The deck sits on wide flange steel roof beams. *Figure 7* shows the section view of the roof.

**FIGURE 7 – Roof Section**

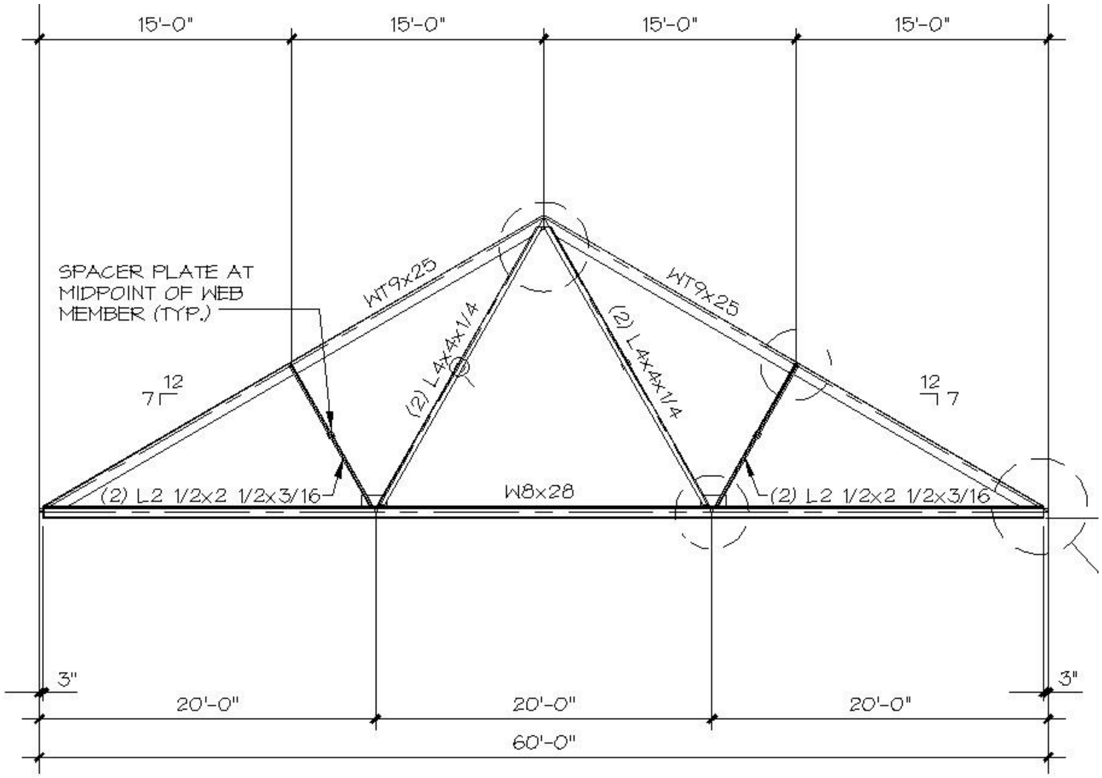



Source: Clark-Nexsen

B. Lab Wing

The roof of the lab wing involves gable trusses, spanning between concrete columns. The gable trusses are constructed using WT9x25, L2 1/2x2 1/2x3/16, and W8x28 steel members. On the gable trusses is a 20GA 1 ½" deep wide rib roof deck. *Figure 8* shows a section view of the gable trusses.

**FIGURE 8 – Gable Trusses**




Source: Clark-Nexsen

There is also a special truss located along column line 2.5. For these trusses, bottom chord members are W8x31 and the top chord members are WT9x27.5.

# 4. Columns

## A. Office Building

The office building contains steel wide flange columns. 42 columns are arranged to fit the curved shape of the building. The columns used are W8, W10, W12, and W14 steel members. These wide flange columns are encased by concrete piles on the foundation to provide extra structural stability. This is important on the foundation because, as previously stated, the building is raised off the ground to provide protection against flooding. The number of piles used for each column varies from 2 to 9.

These columns on floors 1 to 7 direct gravity loads to the foundation where the columns and concrete piles direct the loads to the earth's foundation.

B. Lab Wing

The lab wing uses concrete columns. These columns vary in size, with the most common size being 24"x24" precast concrete. The columns are accompanied by concrete piles at the foundation in order to provide extra strength at the foundation of the building.

# 5. Lateral System

A. Office Building

The lateral system of the office building consists of a "K" braced frame. This braced frame occurs at column lines 3 and 9. The frame consists of wide-flange steel members as well as HSS steel members. The wide-flange members are used as columns. The HSS members are used as diagonal bracing. The wide-flange members are W14 and range from W14x82 at the top, W14x90 in the middle, and W14x159 at the bottom. The HSS members range from HSS 8x8 at the top to HSS 10x10 in the middle, and finally HSS 12x12 at the bottom.

"X" bracing is used in three bays of this structure: the outer bays on the bottom level as well as the middle bay in the penthouse level. "X" bracing is used on these floor as added bracing because of the loads on the floors. As discussed later in the "Wind Load" section, the penthouse sees the highest load in psf from wind. The penthouse also lacks the outer bays to help deflect the load like the floors below it have. The bays on the bottom level have the added weight of the floors above to take into consideration. The "X" bracing allows one diagonal brace to be in tension and one to be in compression. *Figure 9* shows the location of the "K" braced frame and *Figure 10* shows the "K" braced frame in section.

**FIGURE 9 – Source: Clark Nexsen**

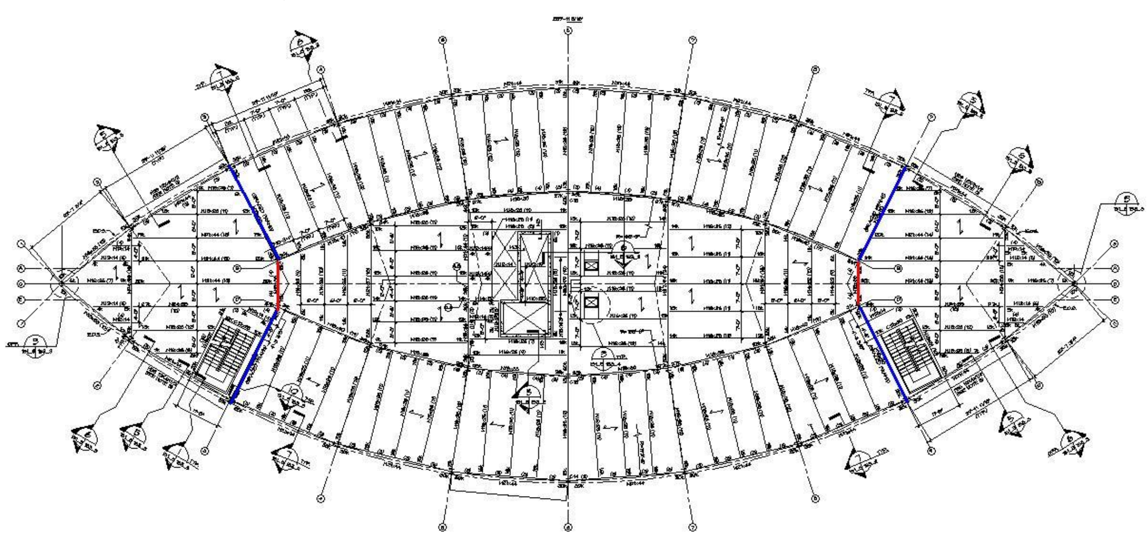
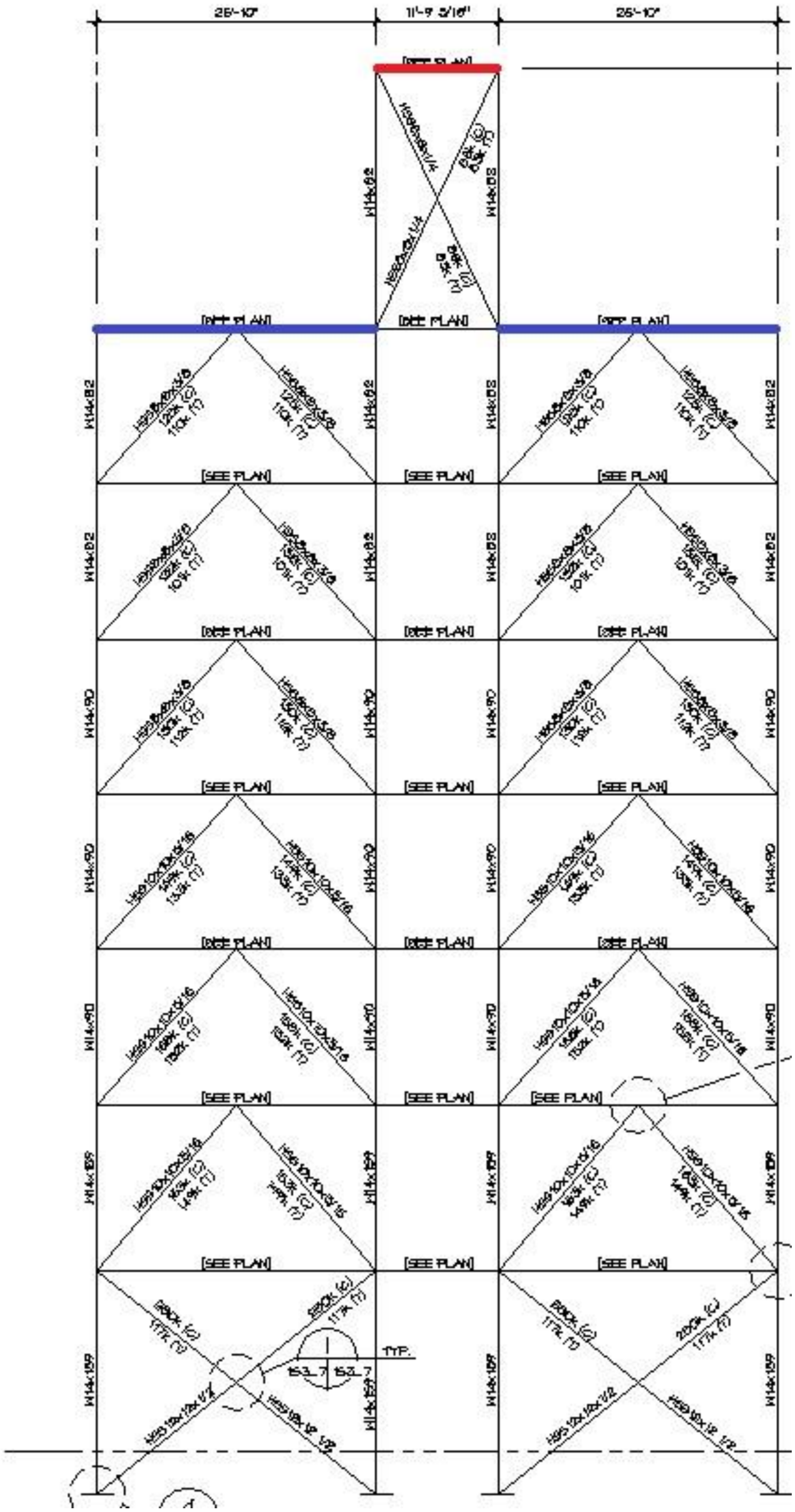
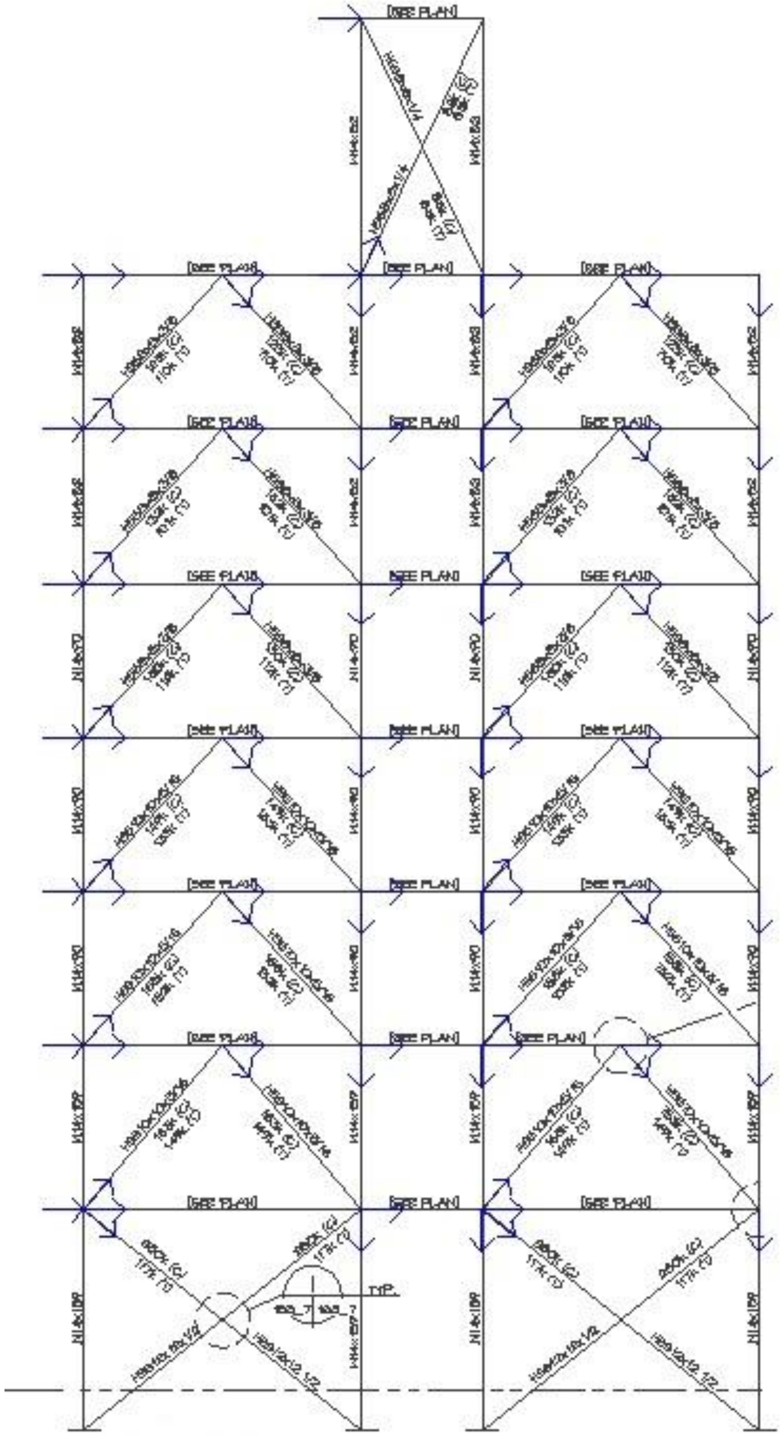


**FIGURE 10 – Source: Clark Nexsen**



The unique design of the building caters to the shape of the frame. The outer bays are perpendicular to the load and transfer the load to the middle bays as well as down through the cross bracing. *Figure 11* shows the load path of the frame.

**FIGURE 11 – Source: Clark Nexsen**



B. Lab Wing

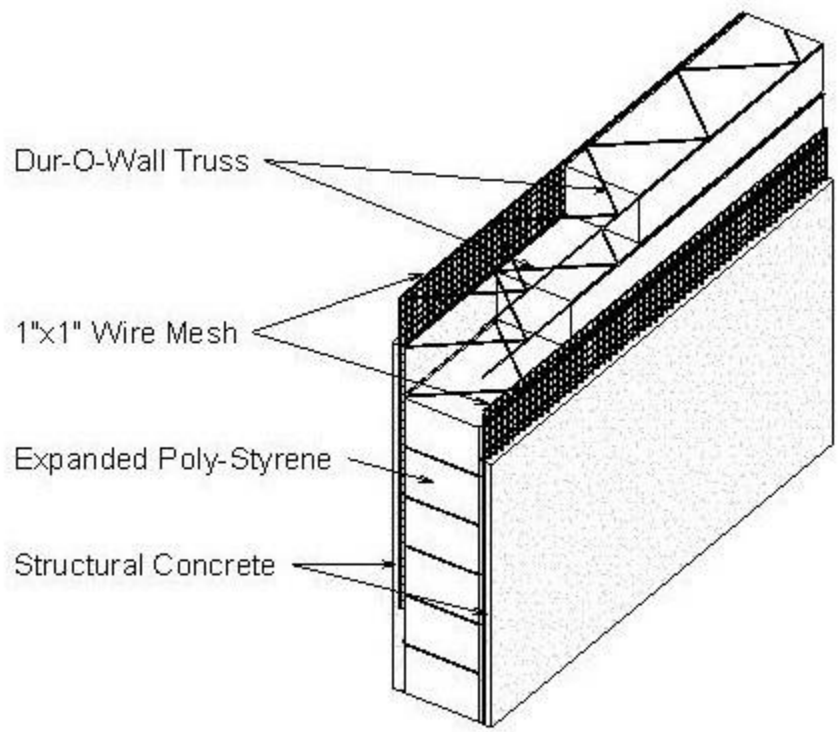
The lateral support for the lab wing is provided by shear walls. 8” precast lightweight concrete walls are used as sheer walls throughout the lab wing of the building. These walls combine with the concrete slabs to provide lateral support for the building.

# 6. Structural Details

A. Sandwich Wall

The lab wing makes use of concrete sandwich walls. Sandwich walls are resistant to many important forces of nature including, earthquakes, hurricanes, heat, cold, and flooding. Flooding is the most important natural force in the situation of the Virginia Advanced Shipbuilding & Carrier Integration Center. As stated earlier, the office building uses stilts with thick concrete piles to avoid problems caused by the flooding of the James River. The lab wall instead makes use of the sandwich wall in order to defend against flooding. *Figure 10* shows the sandwich wall in section.

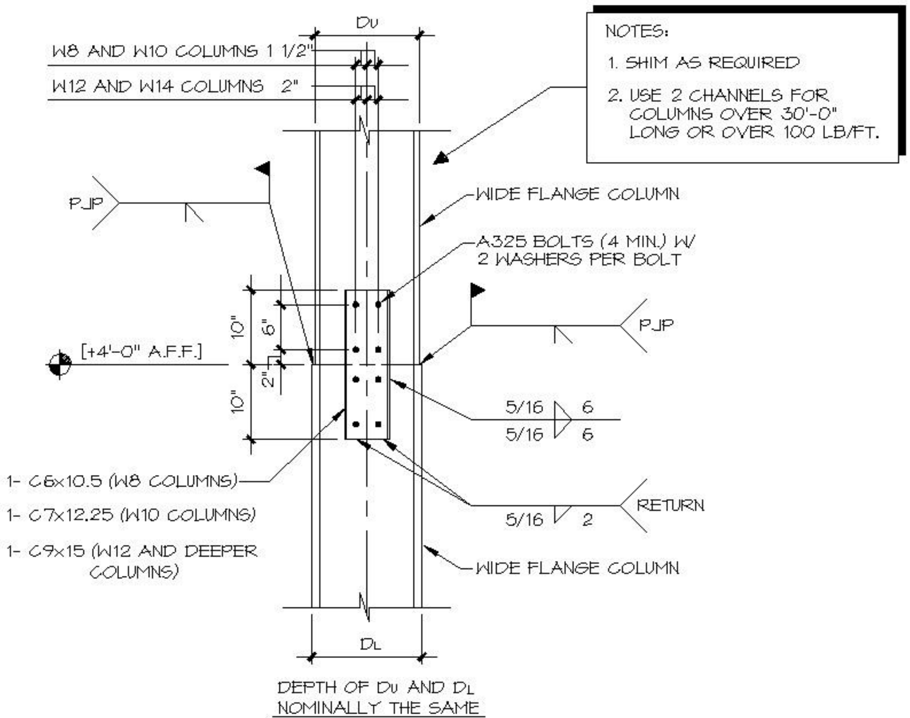
**FIGURE 12 – Source: http://www.cswall.com/CSW/Walls/index.htm**



B. Column Splice Connections

The height of the office building makes it necessary for column splice connections to be used. *Figure 11* shows the typical column splice details.

**FIGURE 13 – Source: Clark Nexsen**




It is important to note the variance of the connections from the W8 to the W14 columns. A325 bolts are used. Also, 2 channels are used for columns over 30’-0” long or over 100lb/ft.

# 7. Conclusions on Structural System

The first thing that was noticed when looking at the structural drawings is the vast difference between the office building and the lab wing. The office building makes use of steel columns and beams as well as diagonal steel bracing. The lab wing, however, makes use of concrete slabs and concrete columns as well as shear walls and sandwich walls.

Flooding is an important natural force that had to be accounted for in the structural design of the building. The building had to be designed to withstand flood loads. The use of large concrete areas on the ground floor are designed to resist these loads. The ground floor does not contain offices or any rooms. Instead, the offices are located above flood levels in the floors above the ground floor. This allowed the ground floor to keep an open feel to it even with the large areas of concrete. The office building makes use of stilts and thick concrete piles to remain above flood level. The Lab wing, however, makes use of sandwich walls.

The use of steel in the office building is most likely due to the architect wanting to keep the office building more open and spacious and not have to worry about large, cramping concrete columns. The steel columns and beams are complimented by the curtain wall that engulfs the building. This provides a light, spacious, and well-lit office building.

The lab wing, on the other hand, is designed as a seemingly heavier, less spacious building. Most business will be taking place in the office building and it is clear that the designer wanted the office building to feel more welcoming. The parking deck makes use of concrete because it is most likely cheaper to design a parking deck out of concrete. Also, while the laboratories will be operated during the day, they make more use of artificial lighting and rely less on natural light.

# Design Codes and Standards

The design of the Virginia Advanced Shipbuilding & Carrier Integration Center followed the following codes:

The BOCA National Building Code – 1996
AISC Manual of Steel Construction, Load and Resistance Factor Design, Second Edition
ACI 318-95 Building Code Requirements for Structural Concrete

This report will make use of the following codes and standards

ASCE/SEI 7-05 – Minimum Design Loads for Buildings and Other Structures
This text will be referred to as *ASCE 7-05* from now within the report. ASCE 7-05 was used to determine appropriate Live Loads, Wind Loads, Snow Loads, Seismic Loads, as well as Load Factoring and Live Load Reduction.

AISC Steel Construction Manual Thirteenth Edition
This text well be referred to as AISC from now on within the report. AISC was used to determine loads as well as sizes of steel beams and columns. LRFD was used in the calculation and determination of these loads and steel member sizes.

ACI 318-08 Building Code Requirements for Structural Concrete
This text will be referred to as ACI 318-08 from now within the report. ACE 318-08 was used to determine loads as well as sizes of concrete structural aspects including slabs and load bearing precast concrete walls as well as concrete columns.

# Material Properties

Reinforced Concrete

| **TYPE** | **F'c** | **Aggregate** |
|---|---|---|
| Slab on Grade | 4000psi | Normal Weight |
| Walls | 4000psi | Light Weight |
| Grade Beams | 3000psi | Normal Weight |
| Pile Caps | 3000psi | Normal Weight |
| Composite Deck Fill | 3000psi | Lightweight |
| All Other Concrete | 3000psi | Normal Weight |

Structural Steel

| **Shape** | **Fy (KSI)** |
|---|---|
| Wide Flanges | 50 |
| Rectangular HSS members | 46 |
| WT members | 50 |
| Channels | 50 |
| Connectors – Angles | 36 |
| Connectors – Angles | 36 |

# Gravity and Lateral Loads

## 1. Live Loads

Live Loads for the project were in accordance with the following. Live loads were determined using ASCE 7-05 S4.

A. Office Building

| OCCUPANCY | DESIGN LOAD (psf) | THESIS LOAD (psf) |
|---|---|---|
| Penthouse Roof | 20 | 20 |
| Low Roof | 80 | 60 |
| Penthouse Floor | 125 | 125 |
| Offices | 80 | 50 |
| Conference Rooms | 100 | 100 |
| Corridors | 100 | 80 |
| Stairs | 100 | 100 |
| Toilets | 75 | 75 |

B. Lab Wing

| OCCUPANCY | DESIGN LOAD (psf) | THESIS LOAD (psf) |
|---|---|---|
| Antenna Tower Roof | 100 | 100 |
| Antenna Tower Room Floor | 125 | 125 |
| Auditorium | 60 | 60 |
| Cafeteria | 100 | 100 |
| Catwalks/Elevated Walkways | 60 | 60 |
| Corridors (1st floor) | 100 | 100 |
| Corridors (above 1st floor) | 100 | 80 |
| Exterior Service Yard | 300 | 300 |
| Garages | 50 | 40 |
| Laboratory (Elevated Floor) | 300 | 300 |
| Laboratory (Floor on Grade) | 600 | 600 |
| Laboratory (Storage Area on 2nd floor) | 250 | 250 |
| Mechanical/Electrical Equipment Rooms | 125 | 125 |
| Patio | 100 | 100 |
| Patio Planters (Dead Load) | 400 | 400 |
| Roof (UON) | 20 | 20 |
| Stairs & Exits | 100 | 100 |
| Concrete Load | 2000lbs on 2 ½ SF | 2000 lbs on 2 ½ SF |

1. Dead Loads

| **LOAD TYPE** | **LOAD** |
|---|---|
| Normal Weight Concrete | 150 pcf |
| Lightweight Concrete | 120pcf |
| MEP | 10psf |
| Partitions | 20psf |
| Finishes | 10psf |
| Curtain Wall | 15psf |

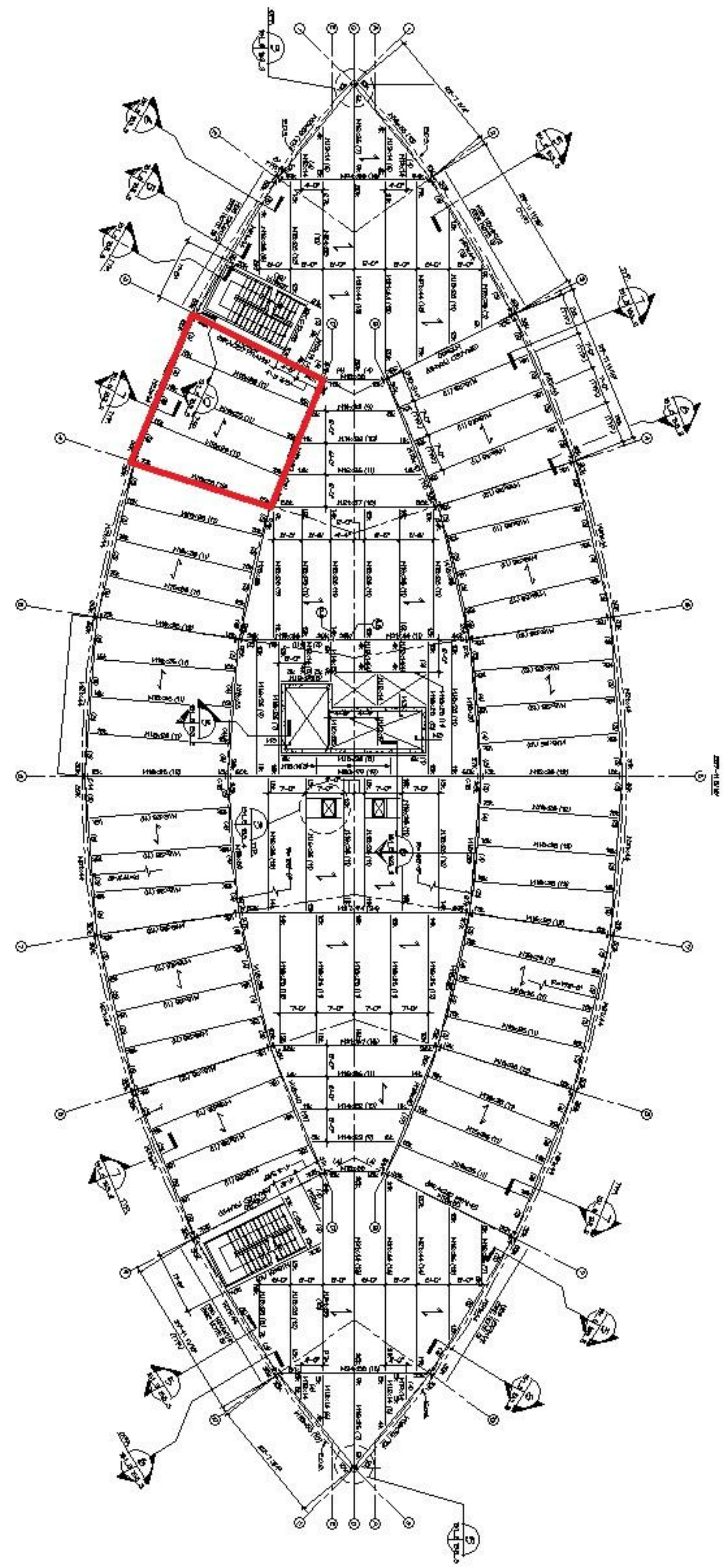
# Floor Systems

## 1. Composite Steel System – Existing System

The office building of the Virginia Advanced Shipbuilding & Carrier Integration Center is a composite floor system. The composite steel deck is 4.5" in total thickness and consists of lightweight concrete placed on a 2" deep, .0358" thick galvanized steel deck. The deck rests on W shape steel members ranging from W12x14 to W21x44.

Bays vary greatly in size and shape as the buildings unique shape makes typical rectangular bays impossible. The outer bays are 30'x26' 10". The two interior bays are trapezoids: one with parallel lengths of 11' 10" and 31'8" and angled lengths of 25' 8" and the other with parallel lengths of 31' 8" and 42' 10" and angled lengths of 26'. The first trapezoidal area encompasses a tributary area of 509 $ft^2$. The second trapezoidal area encompasses a tributary area of 940 $ft^2$. A triangular bay in the front and back of the buildings has side lengths of 22', 22', and 29' 10". This bay encompasses an area of 250 $ft^2$. Next to this triangular bay there is a uniquely shaped bay that encompasses an area of 1570$ft^2$. FIGURE 12 shows a typical structural floor plan and is displayed to help further understand the size and shapes of the bays of the office building. The 30'x26' 10" bay that is highlighted is the bay that will be used in the redesign process as the outer bays encompass a large percentage of the building. The bay contains W16x26 beams resting on W18x40 girders. Spot checks of the W16x26 steel beam were done and confirmed the beam can withstand the load applied to it. The W18x40 steel girder was also checked for adequacy and confirmed to be strong enough to withstand the load applied to it. Spot check calculations of this bay can be found in the Appendix.

**FIGURE 12: Location of Bay in Typical Floor PLan**



One of the advantages of the composite deck system for the Virginia Advanced Shipbuilding & Carrier Integration Center is the integration with the architecture. As previously discussed, the VASCIC office building is enclosed with glass curtain wall. The building tries to achieve a light, open look. The composite deck with steel girders achieves this look better than a concrete floor system, which would give the building a more bulky, heavy feel.

The use of steel is also due to the weight of the building. The abnormal bay shapes create the need for many beams and in, some instances, long spans. Using steel beams allows the use of the longer, more frequent beams while keeping the floor depth and weight at an acceptable level. The use of lightweight concrete in the deck also lowered the weight of the floor system.

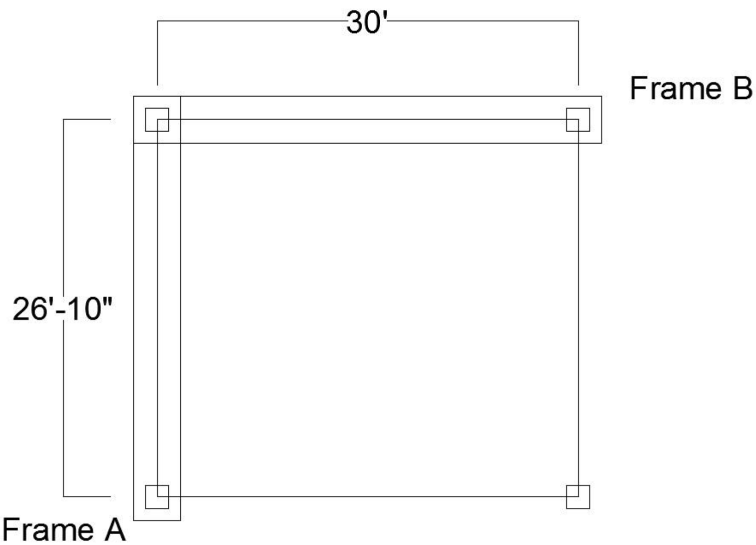
It was found that the composite beam will be able to carry the load by itself. This means that the deck was slightly overdesigned. The composite deck will provide more than enough stability for the load it intends to carry. The W18x40 girder also proved strong enough to hold the loads applied to it.

## 2. Two-Way Flat Slab

The first alternative analyzed for this report was a two-way flat slab. Two-way flat plates are commonly used in multi-story construction such as hotels, hospitals, offices, and apartment buildings. They tend to have easy formwork, simple bar placements, and minimize floor to floor heights. This is a good system to analyze because the minimal slab thickness will hopefully allow the office building to keep the light, open look it seeks and accomplished with the composite steel system.

It was found that a 10" slab with 3" drop panels would be required to sustain the loads of the building. Thirty-eight #5 bars would be used as reinforcement on the column strip for Frame A. Forty-two #5 bars would be used for the column strip for Frame B. *Figure 13* shows the bay layout. 20"x20" columns were assumed for the analysis.

FIGURE 13: Two-Way Flat Slab Bay Layout




The two-way slab is very useful structurally and spatially. The total depth of the system is 13". This is less than the 22.5" depth of the girder + deck system that exists in the office already. This would prove useful with the architecture of the building and with the minimal floor-to-floor heights would have a positive financial impact as well. The cost of fireproofing would be minimal as well as concrete provides natural fireproofing. The biggest problem with using a concrete flat plate system, however, is that the building would need to make use of an alternate lateral force resistance system. The K-braced system discussed in *Structural Systems Overview* section is flawlessly used within the building due to the existing steel structure. The use of a concrete structure would disrupt this frame and an alternative system would need to be considered. The concrete structure would also add weight to the building, taking away from the "light" feel the building looks to achieve. The combination of the heavier concrete and the lower floor-to-floor heights would take away drastically from the open and light look of the building. Calculations for the two-way flat slab can be found in the Appendix.

## 3. Precast Hollow-Core Planks

The second alternative analyzed for this report was a precast hollow-core plank system. PCI Design Handbook 6th Edition was used in the design of this structure. Using the PCI Handbook it was found that an 8”x4’-0” hollow core plank with 2” topping would be used. This would achieve a 2 hour fire rating and sustain the loads of the building. A W27x84 beam and W24x62 girders would be used to frame the planks.

The largest advantage of this system is its ability to span long distances while maintaining low depths. Again, this is useful in the open look of the building. However, when added with the depth of the beams and girders, the system is actually deeper than the existing structure. The biggest disadvantage of the hollow core plank system is the irregular shape of the building creates irregular column layouts. Hollow core planks are most commonly used with repeating bays. Redesigning the building using hollow core planks would require not only redesign of the floor system but a redesign of the columns as well. Concrete columns would be used in compliance with the hollow-core plank floor system instead of the existing steel columns. The hollow-core system would create different loads on the columns as well as the hollow-core system is a different weight than the existing composite steel deck. Due to the shape of the building, a hollow core plank system seems unrealistic to use as a floor system. Calculations for the precast hollow core plank system can be found in the Appendix.

## 4. Open Web Joist System

The third alternative floor system analyzed was an open web joist system. Nicholas J. Bouras, Inc. Steel Joist Catalog was used to design the floor system according to this alternative. It was found that an 18K9 joist was most advantageous. A W24x62 beam would be used to frame the joist system.

Open web joist systems have many advantages to them. They often have fast installation and are generally inexpensive. Their light weight seems advantageous to the architecture of the building. This building, however, sees little gain in using this type of system. The depth of the system is much greater than the depth of the existing structure, making it actually detrimental to the architecture of the building. Unlike the hollow core system, columns would not need to be rearranged, however fireproofing is needed. Also, there would need to be more joists as the joists span a large distance and cover large bays. The need for fireproofing, combined with the sheer number of joists needed in the system would drive the cost up and negate the low cost of the joists themselves. Calculations for the open web joist system can be found in the Appendix.

# APPENDIX:

# APPENDIX A: Existing Structure

Steel Beam W16x26

Tributary Area = 188sf

DL:

Conc: $120(\frac{4.5}{12}) = 45$psf
MEP: 10psf
Partition: 10psf
Curtain Wall: 15psf
**TOTAL**: 80psf

LL: 80psf (corridor)

$W_u = 1.2(80) + 1.6(80) = 224$psf
$W_u = 224(7.5) = 1.58$klf

$$Mu = \frac{1.68\left(26+\frac{10}{12}\right)^2}{8} = 151$$

151<166 ok

<u>Deflection</u>

Construction Load: .08ksf

$$\Delta = \frac{5(.08)(7.5)\left(26+\frac{10}{12}\right)^4(1728)}{384(29000)(301)} = .8''$$

$$\Delta_{allow} = \frac{\left(26+\frac{10}{12}\right)(12)}{360} = .89''$$

.89” > .8” ok

Girder W18x40

P = $\frac{188(224)}{2}$ = 21.06k

No shear, moment & deflection diagram given in table 3-23 of AISC so load converted to distributed load.

$\frac{21.06(3)}{30}$ = 2.1 klf

Mu = $\frac{2.1(30^2)}{8}$ = 237 ft-k

294 > 237 ok

Deflection

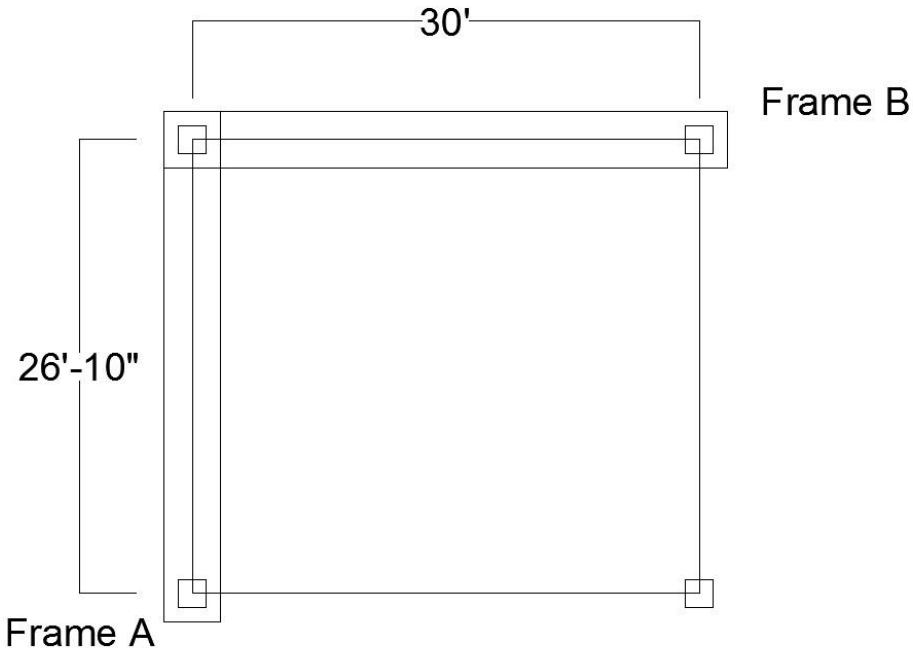
Construction Load = $\frac{.08(188)}{2}$ = 7.52 k

$\frac{7.52(30)}{30}$ = .752

$\Delta = \frac{5(.752)(30^4)(1728)}{384(29000)(612)}$ = .77"

$\Delta_{allow} = \frac{30(12)}{360}$ = 1"

# APPENDIX B: Two-Way Flat Plate System




Assume:

$F'_c$ = 4000 psi
$F_y$ = 60000 psi
20"x20" columns
Normal Weight Concrete

DL: MEP: 10psf
Partitions: 20psf
Curtain Wall: 15 psf
**TOTAL**: 45 psf + sw

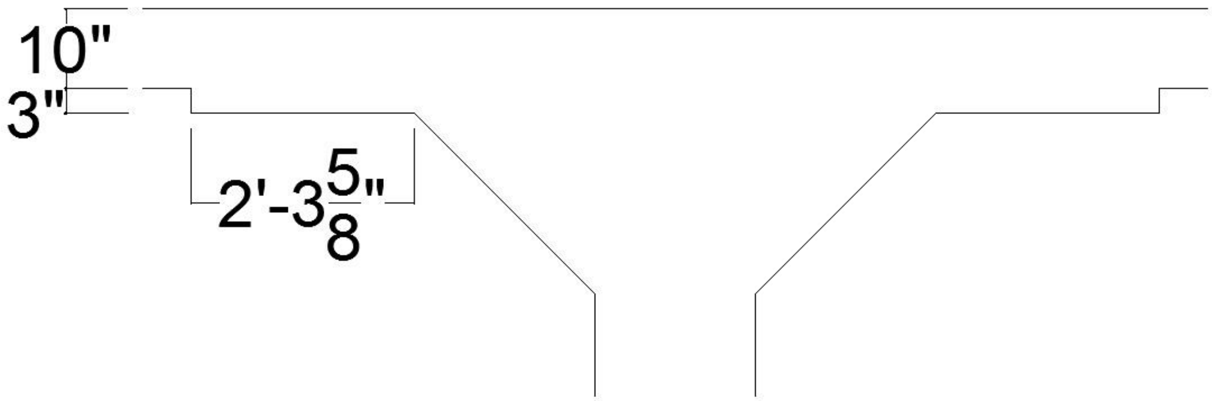
LL: 80 psf (corridor)

<u>Slab Thickness</u>
w/ drop panels

$T_{min} = \frac{Ln}{36} = \frac{30(12)-20}{36}$ = 9.44" => 10" (Table 9.5(c))

$W_u = 1.2(\frac{10}{12}(150)+45) + 1.6(80) = 332$ psf

Drop Panel




Avg span = .2(26 + $\frac{10}{12}$ ) = 5.4"
a = 5- $\frac{5.4}{2}$ = 2.3"
thickness = $\frac{10}{4}$ = 2.5" => use 3"

Moments

A: $M_o = \frac{1}{8}(332)(30)(26 + \frac{10}{12} - \frac{20}{12})^2$ = 789 ft-k

B: $M_o = \frac{1}{8}(332)(26 + \frac{10}{12})(30 - \frac{20}{12})^2$ = 894 ft-k

| A | M- | M+ |
|---|---|---|
| Total Moment | $.65M_o = 513$ | $.35M_o = 276$ |
| Column Strip | $.75M_t = 385$ | $.6M_t = 166$ |
| Middle Strip | $.25M_t = 128$ | $.4M_t = 110$ |

| B | M- | M+ |
|---|---|---|
| Total Moment | $.65M_o = 581$ | $.35M_o = 313$ |
| Column Strip | $.75M_t = 436$ | $.6M_t = 235$ |
| Middle Strip | $.25M_t = 145$ | $.4M_t = 78$ |

Slab Reinforcement in Column Strip (Assume #5 bars)

Frame A

| M- = 385 | M+ = 166 |
|---|---|
| b = 180 | b = 180 |
| $d = 10 - \frac{3}{4} - 1.5(.625) = 8.3$ | d = 8.3 |
| $M_n = \frac{385}{.9} = 428$ | $M_n = \frac{166}{.9} = 184$ |
| $R = \frac{(428)(12)(1000)}{180(8.3^2)} = 414$ | R = 178 |
| ρ = .0076 | ρ = .0033 |
| $As_{req} = .0076(8.3)(18) = 11.35$ | $As_{req} = .0033(8.3)(18) = 4.93$ |
| $As_{min} = .002(180)(18) = 3.6$ | $As_{min} = .002(180)(18) = 3.6$ |
| $N = \frac{11.35}{.31} = 36.6$ => use 38 | $N = \frac{4.93}{.31} = 15.9$ => use 16 |
| $N_{min} = \frac{3.6}{.31} = 11.6$ | Nmin = 11.6 |

Frame B (same procedure as A)

| M- = 436 | M+ = 235 |
|---|---|
| b = 161 | b = 1.61 |
| d = 8.3 | d = 8.3 |
| $M_n = 484$ | $M_n = 261$ |
| R = 524 | R = 283 |
| ρ = .0096 | ρ= .005 |
| $As_{req} = 12.83$ | $As_{req} = 6.68$ |
| $As_{min} = 3.22$ | $As_{min} = 3.22$ |
| N = 41.4 => 42 | N = 21.5 => 22 |
| $N_{min} = 10.39$ | $N_{min} = 10.39$ |

Shear

d = 8.3 + 3 = 11.3

bo = 4(20 +11.3) = 125.2

$Vc = 4\sqrt{4000}(125.2)(11.3) = 358k$

$Vu = .332(26.83(30) - \frac{31.3}{12})^2 = 265$

$.75(358) = 269 \geq 269$

# APPENDIX C: Precast Hollow-Core Plank System

DL: 45psf + SW
LL: 80psf

Span: 30’

Service Load: 125psf

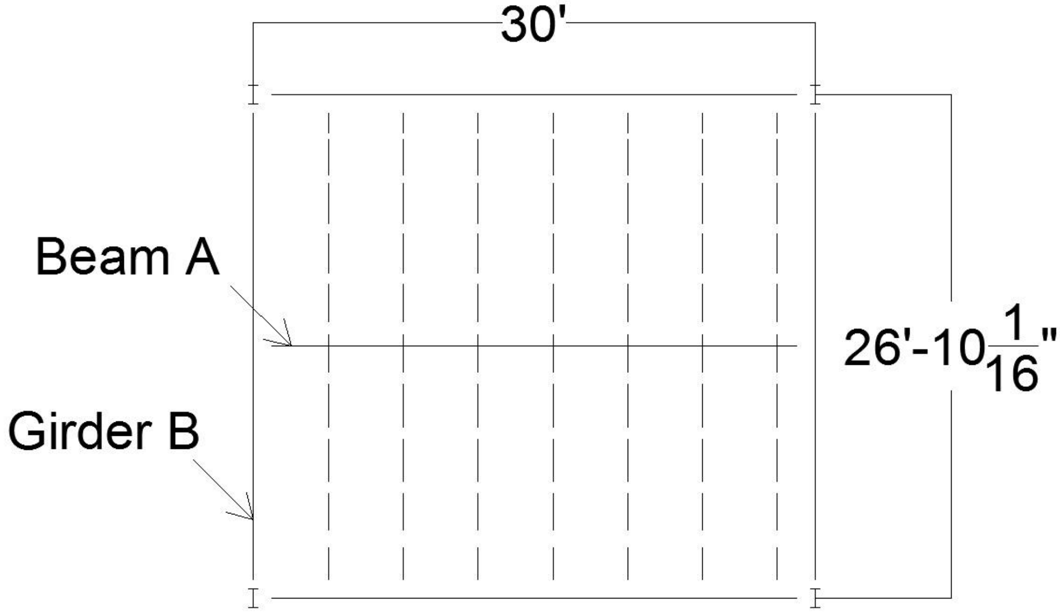
**Table of safe superimposed service load (psf) and cambers (in.)** **2 in. Normal Weight Topping**

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

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

8”x4’-0” Hollow Core Plank w/ 2” topping (2 hr. fire resistance rating)

149psf > 125psf



DL: 45psf + 61.25psf = 106.25 psf

$LL_{red}$: $80(.25+\frac{15}{\sqrt{2(30)(26.83)}}) = 50psf$

$W_u = 1.2(106.25) + 1.6(50) = 207.5psf$

<u>Beam A</u>

$W_u = \frac{207.5(26.83)}{2} = 2.78klf$

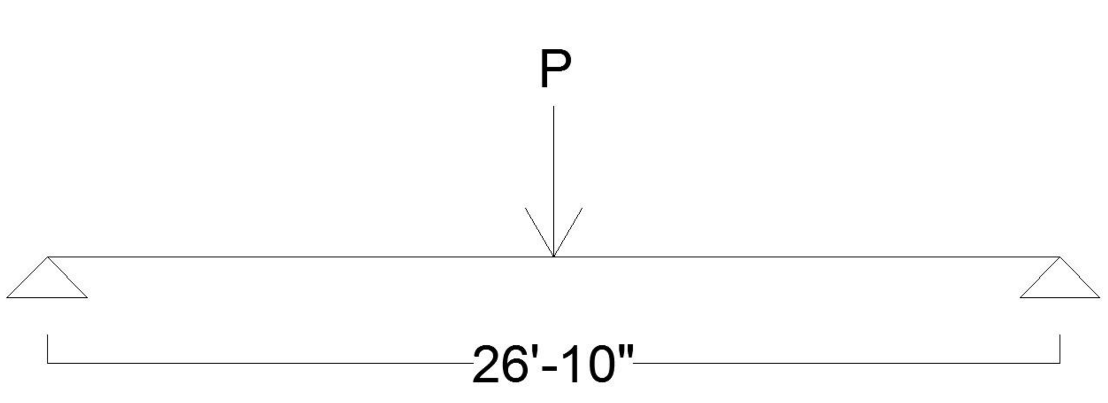
$M_u = \frac{2.78(30^2)}{8} = 313ft\text{-}k$

$I_{req} = \frac{5(.08)(26.83)(30^4)(1728)}{348(29000)(I)} = \frac{30(12)}{480} \Rightarrow I_{req} = 1984$

$I_{req} = \frac{5(.208)(26.83)(30^4)(1728)}{348(29000)(I)} = \frac{30(12)}{240} \Rightarrow I_{req} = 2580$

Use W27x84
M: 915 > 313
I: 2850 > 2580

Girder B




P = 2.78(30) = 83.4k

$P_L$ = 32.2k

$M_u = \frac{83.4(26.83)}{4} = 559.48$

$I_{req} = \frac{32.2(26.83)^3(1728)}{48(29000)I} = \frac{(26.83)(12)}{480}$ => $I_{req} = 1151$

$I_{req} = \frac{83.4(26.83)^3(1728)}{48(29000)I} = \frac{(26.83)(12)}{240}$ => $I_{req} = 1490$

Use W24x62
M: 574 > 559
I: 1550 > 1490

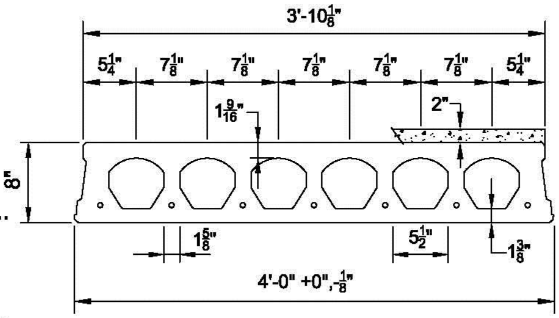
# Prestressed Concrete
# 8"x4'-0" Hollow Core Plank

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 D: Open Web Joist System

Use 3' spacing.
$26\frac{10}{12}$' => 27' span

DL = 45psf + sw
LL = 80psf

DL = 45(3) = 135plf
LL = 80(3) = 240plf
Total Load = 375plf

16K9 sw = 10plf 439 > 375 246 > 240
18K7 sw = 9plf 415 > 375 267 > 240

Use 18K9

Beam Size

DL = $45(\frac{26.83}{12}) + 9 = 613$plf

Wu = 1.2(613) + 1.6(80) = 863.6plf

$$Mu = \frac{.864(30^2)}{8} = 97.2\text{ft-k}$$

$$Ireq = \frac{5(.08)(26.83)(30^4)(1728)}{348(29000)I} = \frac{30(12)}{360} \Rightarrow Ireq = 1489$$

Use W24x62
M: 574 > 97.2
I: 1550 > 1489