HUNTER'S POINT SOUTH INTERMEDIATE & HIGH SCHOOL

TECHNICAL REPORT II

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EXECUTIVE SUMMARY

Technical Report ll is pro-con structural study that investigates alternate floor systems for the structure of the Hunter's Point South School in Long Island City, New York. This report will analyze the existing floor system of the structure, and then examine three alternative systems that could potentially replace the existing in a redesign of the structure. The current system is composite metal deck supported by a steel frame with composite steel beams. Substitute systems include a two-way slab on concrete beams, pre-stressed precast hollow core planks on steel beams, and composite steel deck on steel joists. Only gravity loads are considered for floor design in this thesis report.

This report first gives an overall summary of the existing structure to help introduce the different components in the existing design. Key elements of the foundation, gravity system, and lateral system are all examined. A list of design codes and building materials used for this building are also included.

Tech Report ll then introduces the existing floor system and three alternative systems by giving a description and advantages/ disadvantages of each system for this structure. A reference interior bay size of 25'x 31' was used for design. The existing system includes a 3 inch deep, 18-gage galvanized composite steel deck with a 3-½ inch topping supported by W18X50 steel beams in the 31 foot span, and W18x40 steel girders in the 26 foot span. AISC 14th edition was used to check beam sizes. Using ACI-318 08 as a reference, the first alternative system was designed with a reinforced 11 inch concrete slab on 14" x 26" reinforced concrete beams and 24" x 24" columns. The second alternative system designed uses 6"x4' hollow core pre-stressed precast concrete planks with a 2" top coat supported by W24x62 steel girders on each end. This system is designed using the Nitterhouse Concrete Design Guide. The final alternative system keeps the composite deck used in the existing system and replaces the steel frame with steel joists. Designed using Vulcraft steel joist design guides, this system uses 3 inch 18 gage composite steel deck and a 3.25 inch lightweight concrete topping with 22K5 steel joists and 28G13N9.8F girders for a typical span size.

Finally, this report sets up a comparison between the existing floor design and the three alternative designs. Factors such as system weight, depth and cost are explored to set up a comparison and determine the feasibility of each system. Due to a unique 80 foot span condition in the building design, each system was also checked for long span designs. *Table 5* on page 18 gives a summary of the comparison. This report concludes that all but alternative system two would be viable replacements for the current system. Technical Report lll will focus on lateral system analysis of this structure, which will give more insight to the feasibility of each of these alternative systems.

INTRODUCTION

Hunter's Point South School is a new 5 story educational building being constructed as part of the first phase of New York City's new mixed-use development plan on a 30 acre site of waterfront properties in Long Island City, NY. The new development focuses on creating an affordable middle-income area that includes several new mixed use housing towers, along with supporting retail spaces, a school, and new waterfront park. Hunter's Point South School is being developed by the NYC School Construction Authority (SCA) along with Skanska contracting and
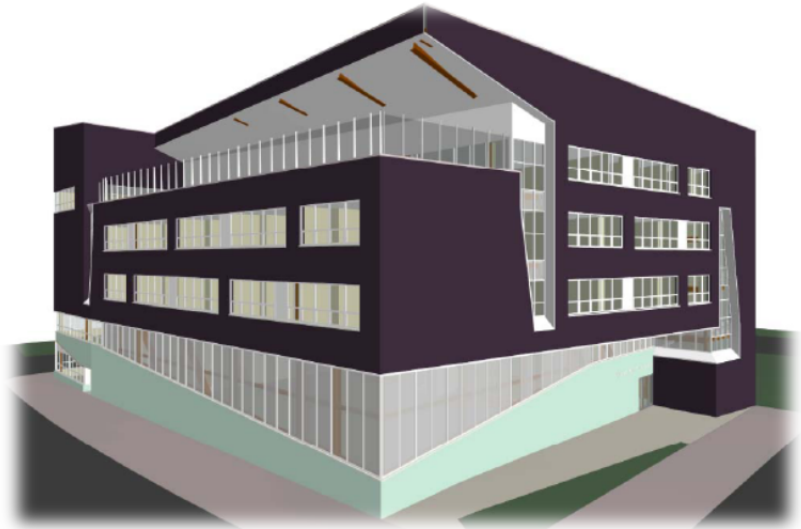

Figure 1: Building design rendering

FXFowle Architects. The structural engineer on the project is Ysreale A. Seinuk, PC. Construction of the school will last from January 2011 to October 2013, and cost approximately $61Million to complete. Project delivery is lump sum bid. It will open its doors to students in the fall of 2013.
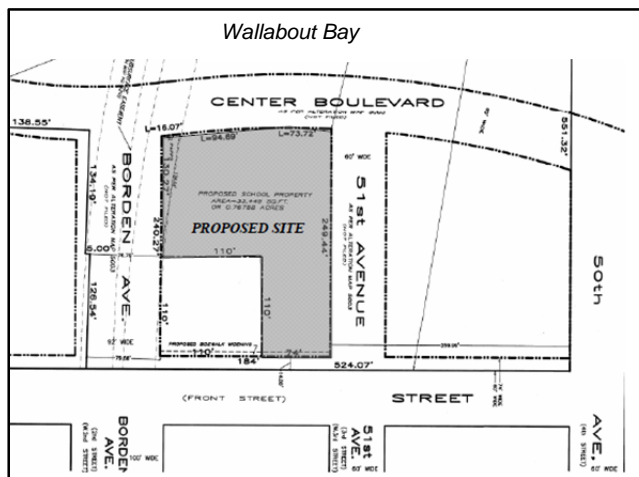

Figure 2: *Building site plan*

The mixed use intermediate and high school will be nearly 154,500 square feet and house roughly 1100 students from grades 6-12 and District 75 (special needs) from the Queens School District. Being constructed on 51st Avenue, Hunter's Point will take up almost a full city block between 2nd Street and Center Boulevard with space in the corner of the lot reserved for the construction of a new 30 story housing tower to be built right next to the school. The site layout can be seen in Figure 2. It should also be noted that the site sits right across the street from the bay.

Following along with other city development ideals, the school building has a modern architectural feel as it incorporates interesting shapes, cantilevers, and sense of solids and voids together. The cubic shape of the building is broken up with vertical shafts, horizontal windows, and slanted edges. In addition, the SCA is aiming to achieve LEED Silver certification for this building through several different sustainable features and construction procedures.
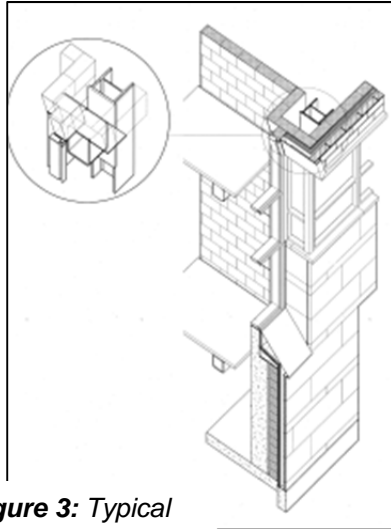
Figure 3: Typical Wall Section Axonometric Detail

The 5 story school rises roughly 75 feet off finished grade, with an irregular parapet rising as high as 98 feet on some elevations. It is mainly a structural steel building, with concrete on metal deck floors and an assorted exterior. The exterior façade is comprised of a unique blend of grey brick, slate veneer, concrete block, orange aluminum composite panels, and different types of glazing including translucent panels. Much of the shell is part of a curtain wall system that is supported by the floor above. There is, however, some load bearing masonry used in the design.

Inside, the building is vertically stacked to separate the schools, but includes ties to each other using shared spaces. The first floor contains athletic space, including a 2 story tall gymnasium and locker rooms for all grades. There are also support rooms/offices for the intermediate school and general storage areas. The second floor contains an auxiliary gym, library, and special education rooms for the District 75 students. The third floor contains a full sized 2 story auditorium that links the high school (HS) and intermediate school (IS) together, along with IS classrooms and IS

Figure 4: Building Section

support rooms/offices. The fourth floor contains high school classrooms with support rooms/offices and access to the auditorium. The fifth floor contains HS and IS cafeterias with a central kitchen space, a connecting 4000sf roof terrace, science labs, and support rooms/offices for the high school. There is a small mechanical penthouse on the top roof.

STRUCTURAL SYSTEMS

This section provides a brief overview of the different structural systems implemented in the Hunter's Point design. The structure consists of a steel framing system with concrete on metal deck floors. There are no subgrade levels, and structural height of the building is 72.3 feet to the roof level with a 13.5 foot parapet wall extending above. All exterior walls are non-loadbearing brick, slate, aluminum panel, or glazing. CMU masonry infill walls are used as a backup wall and are grout filled and reinforced against lateral forces. The steel frame makes up both the gravity and lateral load systems of this building.

Foundation

The foundation consists of a 12in. 4000psi reinforced slab on grade supported by a system of grade and strap beams, 14" caissons, and steel H-piles. All of these different foundation systems are required due to the poor soil properties on site. A geotechnical survey performed by Langan Engineering showed soil type ranges from grey silty sand fill to clay, with bedrock consisting of gneiss starting at about 40 feet below grade. Deep foundations are installed to at
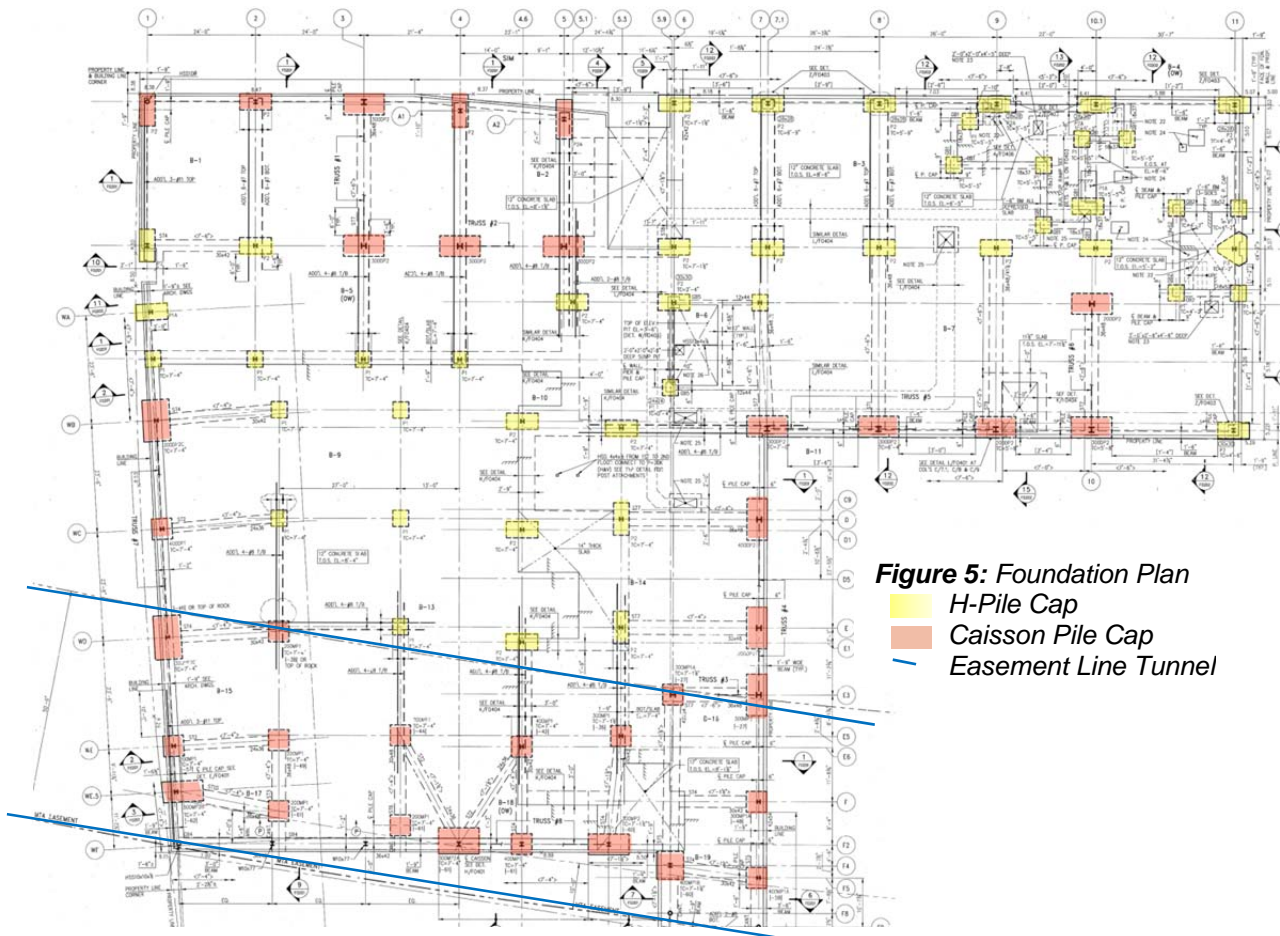
Figure 5: *Foundation Plan*
■ *H-Pile Cap*
■ *Caisson Pile Cap*
— *Easement Line Tunnel*
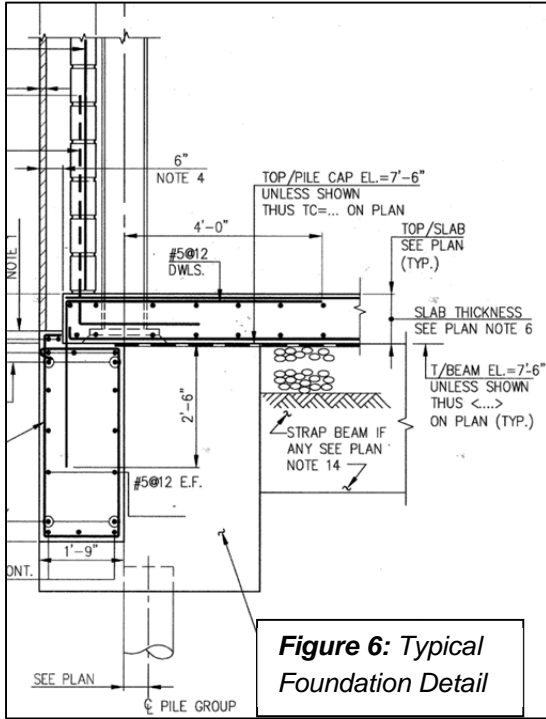
least this level. H-piles are used mainly within the interior and in the upper north east corner of the site where soil conditions are better. Caissons are installed around the perimeter to help stabilize the building and take the majority of the dead load as it passes down and outward through the structural system. Special isolation caissons, as seen in *Figure 7*, were used for locations within 50 feet of two subsurface tunnels used for the Queens-Midtown Tunnel easement lines that run E-W through the site. Each caisson has three 20" 75ksi steel threadbars within 8000psi grout, and can support up to 800kips of compressive force. Ground and strap beams are used to connect pile caps to help

Figure 6: Typical Foundation Detail
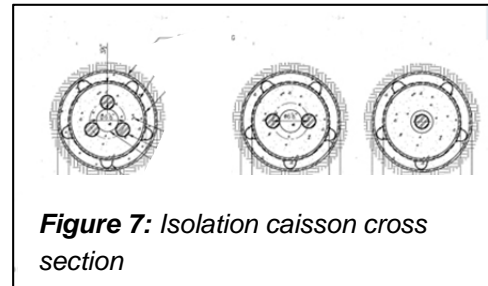
prevent lateral column base movement.

Figure 7: Isolation caisson cross section

Floor and Roof Systems

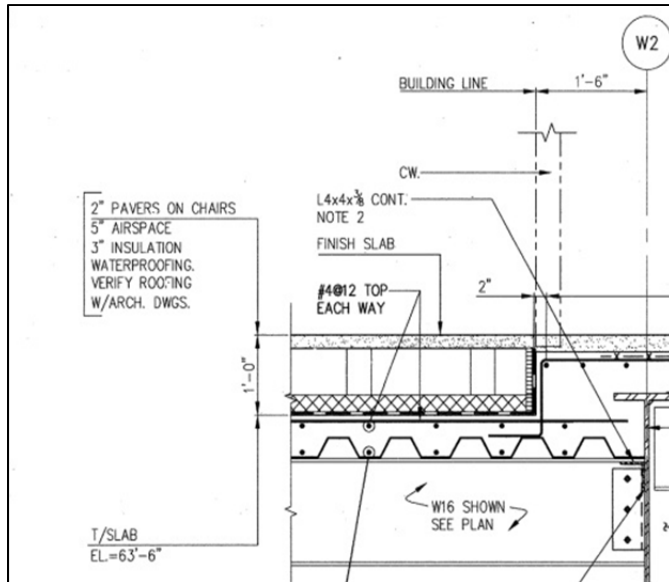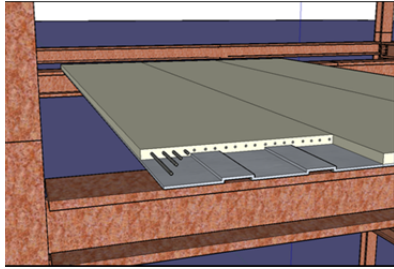As seen in *Figure 8*, the floor system consists typically of 3-¼in. thick 3500psi lightweight concrete on 3" deep composite 18 gage galvanized metal deck (6-¼in. total depth) supported by a steel framing system. Concrete is reinforced with 6x6 W2.0xW2.0 WWF. The floor system above the gymnasium uses acoustical metal deck in place of typical deck. The auditorium stadium seating floor will have 16 gage deck in place of typical deck. The typical unsupported span length for the floor deck is 12'. All cast-in-place concrete slabs are reinforced by #4 reinforcing bars spaced 12" in both directions. The top roof and terrace roof will have 2"thick lightweight concrete pavers over hot applied asphalt roofing membrane on top of the concrete slab.


Figure 8: Typical floor system

Framing System

The superstructure of Hunter's Point is typically comprised of W10-W14 steel columns

supporting W24 girders and either W14 beams at the building core or W16 beams towards the perimeter of the structure. Overall, sizes and span lengths vary greatly throughout the building and across every floor. The third floor includes special long span plate girders over the gymnasium space (red box, *Figure 10*). Spanning roughly 80feet each with a flange thickness of 2-4 inches and overall depth of up to 3 feet, these large transfer beams allow for open gym space while adequately supporting the load transferred from the auditorium and cafeteria

Figure 9: Typical frame layout

space in the floors directly above. Gravity loads are transferred from the floor slab to the wide flange beams then to interior and exterior columns down to the foundation system. Exterior walls and cladding transfer their weight to exterior beams.
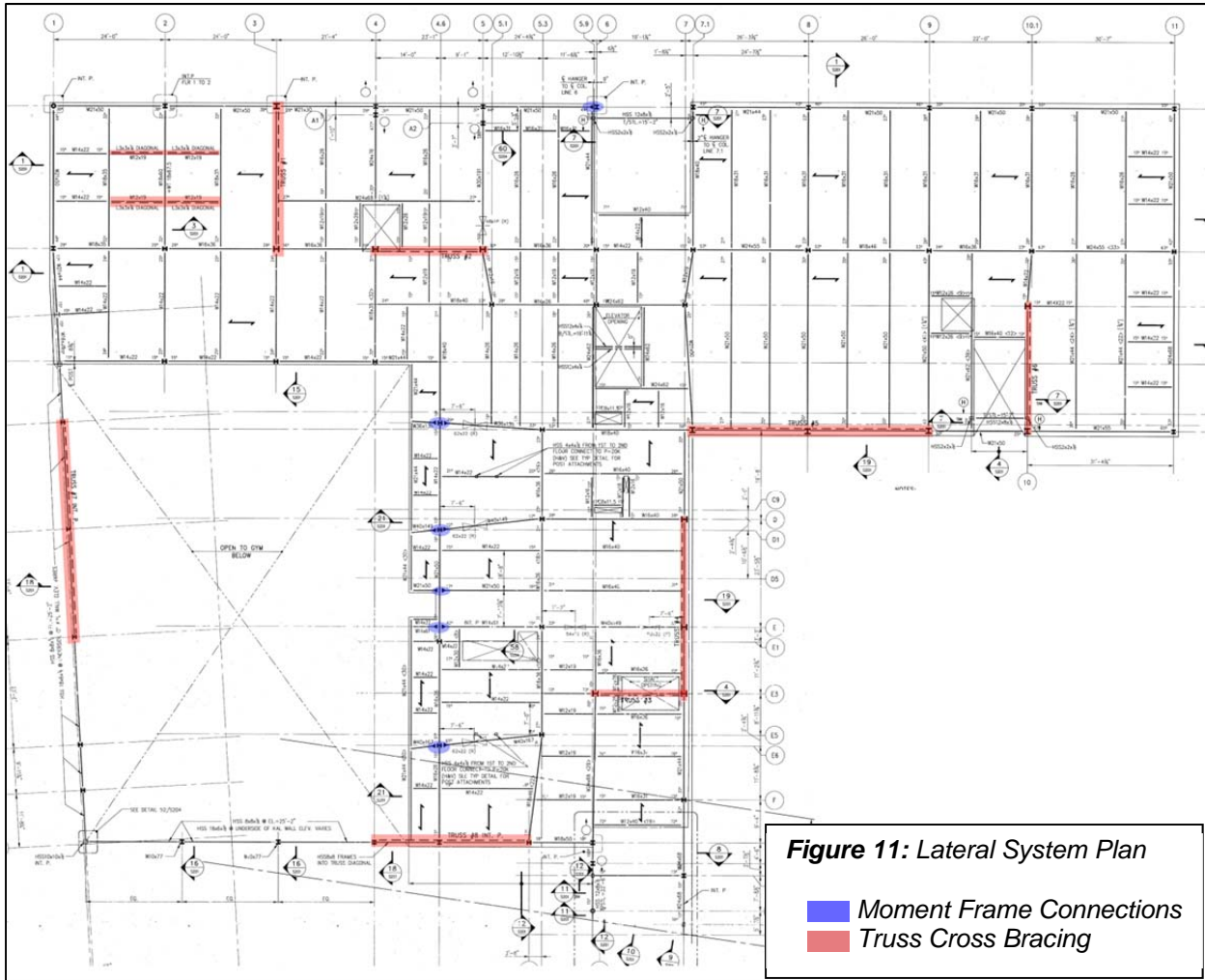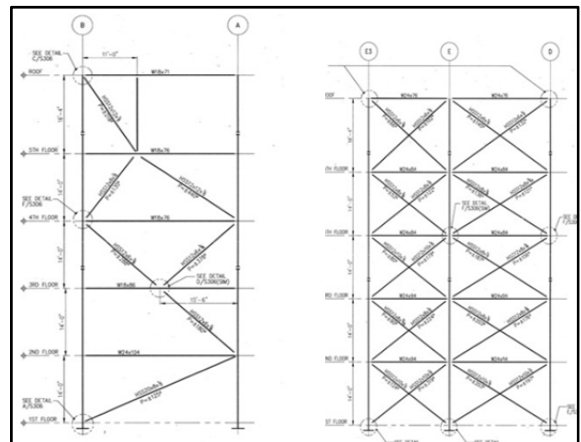

Figure 10: Partial 3rd Floor Framing Plan:
long Span Plate Girders
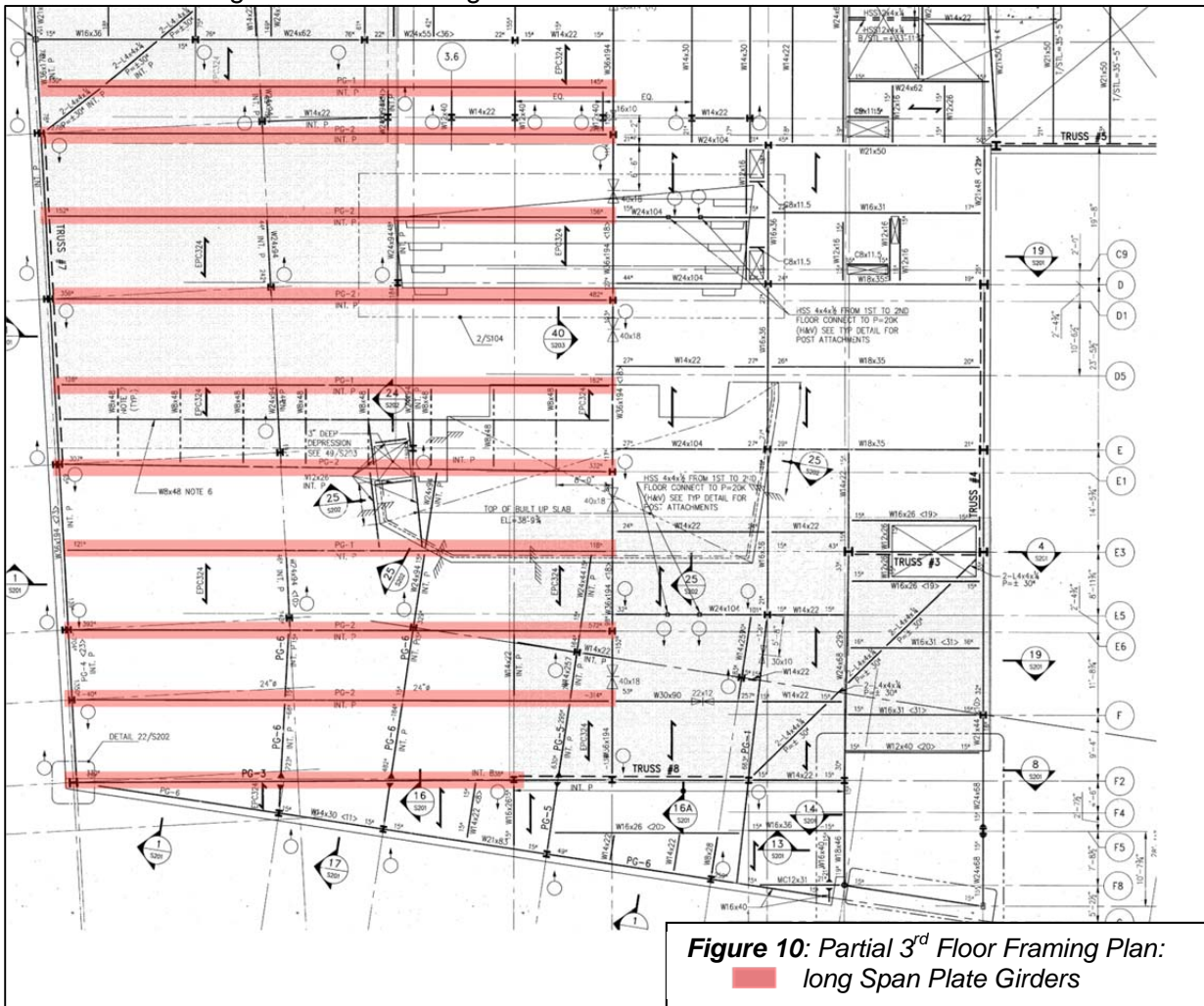
Figure 11: Lateral System Plan

■ *Moment Frame Connections*
■ *Truss Cross Bracing*

Lateral System

The lateral force resisting system consists of both HSS and wide flange lateral truss bracing (red box, **Figure 10**), along with steel moment connections at columns around the gymnasium and auditorium spaces (blue circles, **Figure 11**). There are six different types of truss bracing systems, two of which are shown in **Figure 12** to the right. Single bay trusses are primarily used along interior spaces, while stronger double bay trusses are implemented along the exterior wall where there is more room. Several of the truss systems allow for architectural use and have odd cross bracing, such as the left truss in **Figure 12.** Trusses run in both the N-S and E-W directions. The

Figure 12: Two types of lateral bracing used in the design

first three floors implement lateral force resisting systems the most. This is due to the 3 story cavity formed in the framing system to allow for open gym and auditorium space.

DESIGN CRITERIA

This section provides data regarding codes, materials, and gravity loads for the design of Hunter's Point South. This thesis project will differ from the original design in that it will implement design criteria from ASCE7-10 and IBC 2009 rather than the NYCBC 2008 building code. There are several reasons for doing this. First of all, obtaining outdated copies of the NYCBC and other code books is not an option due to availability. The NYCBC also references the IBC and ASCE7 throughout; so much of the design will be the same. The only issue with using newer codes is that they may have different design procedures, which may change the design slightly. However, I feel using codes up to today's standards will be most beneficial to me as I go from analysis to redesign.

CODES & REFERENCES

Design Codes

Building Code

- New York City Building Code, NYCBC 2008, (2008)

Reference Codes

- American Concrete Institute Building Code, ACI 318-02, (2002)

- American Institute of Steel Construction, AISC 9th edition (1989)

Thesis Codes

Building Code

- International Building Code, IBC 2009 (2009)

Reference Codes

- American Concrete Institute Building Code, ACI 318-08 (2008)

- American Institute of Steel Construction, AISC 14th edition (2011)

- American Society of Civil Engineers, ASCE 7-10 (2010)

MATERIAL STRENGTHS

Design Materials and strengths were found in the construction drawings on page S001.

Material Strengths			
Material	**Element**	**Type**	**Strength**
Cast-in-Place Concrete	Pile Caps under Columns	Normal Weight Concrete	f'c= 5950 psi
	Grade & Strap Beams	Normal Weight Concrete	f'c= 4000 psi
	Column Pier and Buttress	Normal Weight Concrete	f'c= 4000 psi
	Slab on Grade	Normal Weight Concrete	f'c= 4000 psi
	Floor Slab	Light Weight Concrete	f'c= 3500 psi
Reinforcing Steel	Concrete Reinforcing bars		FY= 60 ksi
	Caisson Steel threadbars		Fy= 75 ksi
Structural Steel	Steel Wide Flange Members	ASTM A992	Fy= 50 ksi
	Steel HSS Tubes	ASTM A500	Fy= 46 ksi
	Steel Base Plates	ASTM A572 gr 50	Fy= 50 ksi
	Steel Deck	ASTM A653	Fy= 40 ksi
	Steel Bolts	ASTM A325	Fu= 120 ksi
		ASTM A490	Fu= 150 ksi

Table 1

DESIGN LOADS

Hunter's Point South was designed for gravity loads using the Allowable Strength Design (ASD) Method. This thesis project will implement the Load and Resistance Factor Design (LRFD) Method instead due to the fact that it is becoming the industry standard. All thesis design loads have been taken from tables out of ASCE7-10 unless original design loads controlled.

Dead Load		
	Design (psf)	**Thesis (psf)**
NW Concrete	150	150
LW Concrete + Deck	49	49
Masonry Wall	90	90
Roof Paver	15	15
MEP	20	25
Ceiling	10	
Partitions	12	12
Curtain Wall	20	20

Table 2

Live Load		
	Design (psf)	**ASCE7-10**
first floor, lobby, stair, corridor	100	100
classrooms	40	40
art room/ science lab	60	60
office	50	50
library stacks	100	**150**
library reading	60	60
mechanical space	75	**100**
book storage	150	150
roof (main)	45	45
Gymnasium	100	100
Cafeteria	100	100
Kitchen	150	150
Auditorium Stage	150	150
toilets	60	60
terrace	100	**1.5LL<100psf**
corridor 2nd floor+	80	80
Auditorium	100	100
stadium seating	60	60

Table 3

Snow Load		
	Design	**ASCE7-10**
Ground Snow Load:	25 psf	25
Flat Roof Snow Load	22 psf	22
Snow Exposure Factor CB	1.1	1.1
Snow Load Importance IS	1.1	1.1
Thermal Factor Ct	1.0 main roof/terrace	1
	1.1 mech. bulkhead	

Table 4

FLOOR SYSTEM ANALYSIS

The following is an analysis of four different floor systems. A comparison between the existing floor system and three alternative floor systems is developed. The existing floor system is composite metal deck on composite steel beams and girders. The alternative floor systems include: two-way concrete slab on concrete beams, pre-cast hollow core planks on steel beams, and steel deck on steel joists. A reference bay with a span of 25' x 31' is used to represent the most typical bay size in Hunter's Point South. The reference bay is considered an interior bay that is continuous in both directions. Along with the typical bay size, long span conditions are also considered for each system to develop a usable design for the 80 foot spans found in the gymnasium space (**Figure 14**).

Figure 13: Bay Size Taken as Reference Bay Size

Figure 14: Partial 3rd Floor Framing Plan: long Span Plate Girders
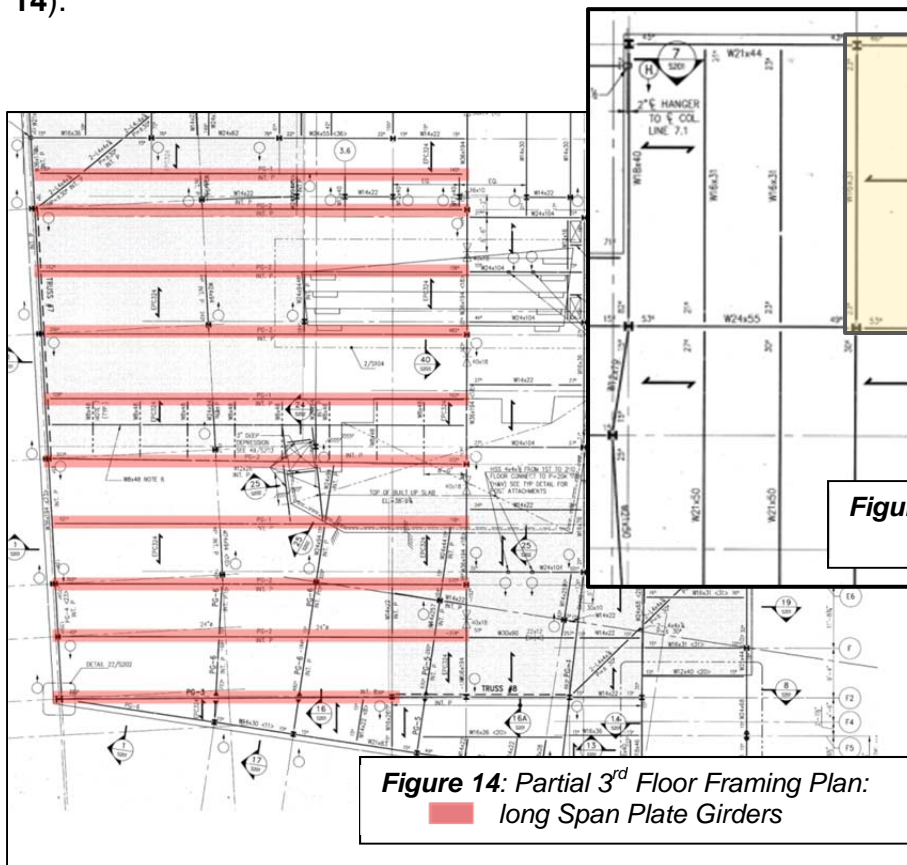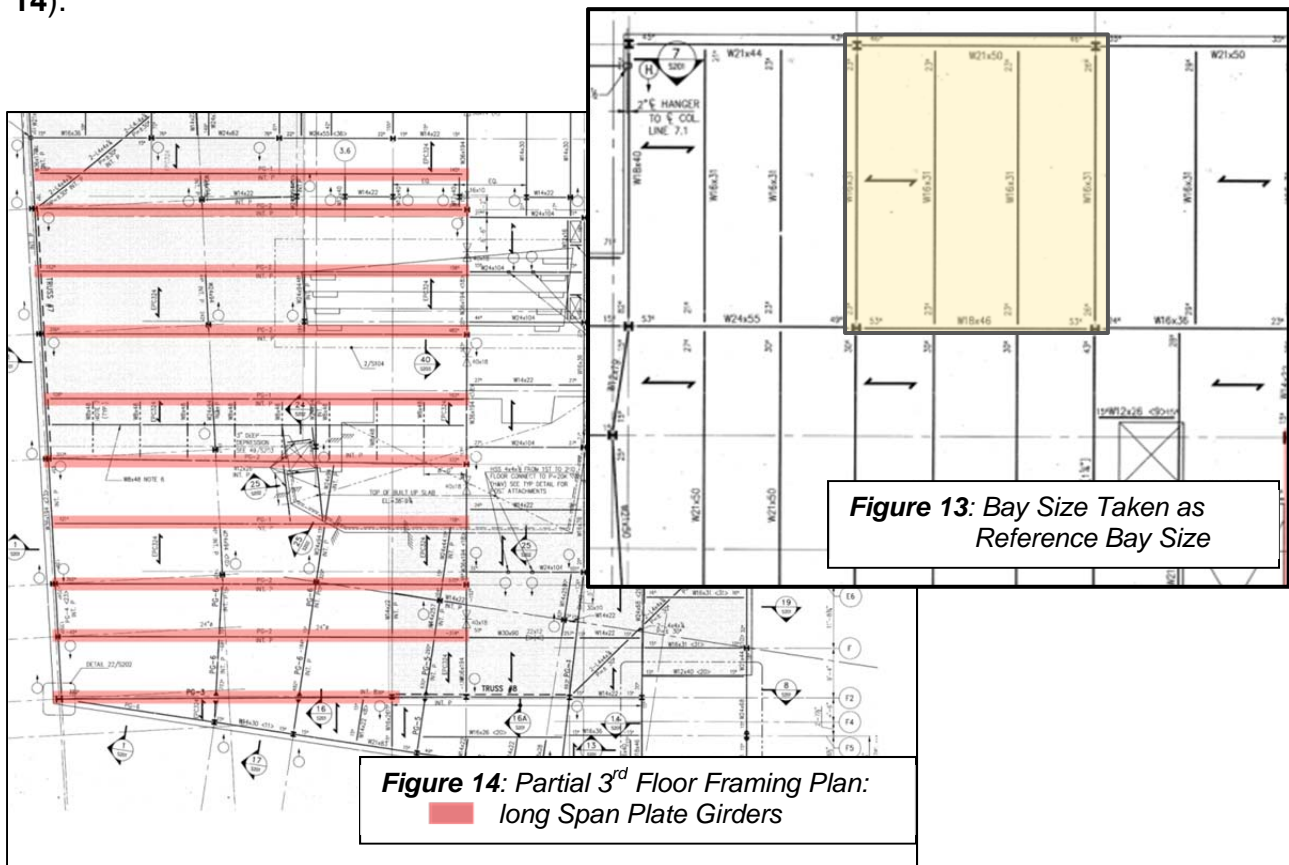
It is important to note that this is just a preliminary analysis that only takes into account gravity loads. Lateral load effects will be affected by changing the floor and framing systems, and each design would have to be addressed further before a system can be determined as adequate. All preliminary design hand calculations can be found in the appendices of this report.

FLOOR SYSTEM ANALYSIS

COMPOSITE METAL DECK WITH STEEL BEAMS

Description

The existing floor system is a 3 inch deep, 18-gage galvanized composite steel deck with a 3-½ inch topping. The reinforcement within the slab is 6x6 W2.0xW2.0 Welded Wire Fabric. The deck slab system is supported by W18X50 steel beams in the 31 foot span, and W18x40 steel girders in the 26 foot span. Welded plate girders (comprised of 2"x32" web plates and 4"x36" flange plates) are used for the long span conditions. The entire system is spray-fireproofed for a 2-hour rating. *Figure 15* shows a composite deck system detail. Hand calculations for the design of this floor system can be found in Appendix A.

Advantages

Composite deck and beam systems have a lot of advantages. The steel deck acts as formwork during construction, and also takes some of the moment allowing the slab not to need reinforcing. This saves time from not having to place formwork or reinforcing, and also lowers the construction costs. Also, composite action in the beams and deck allow for a lighter, shallower floor system. Lightweight topping decreases floor weight, frame member sizes, and foundation sizes. This can save a lot of money. Finally, steel deck is very light, easy to work with, and can be cut into irregular shapes to fit in any situation.

Figure 15: Existing System

Disadvantages

Though composite deck can save money and time in some areas, it can also add to both. Because steel studs need to be welded to the beams in the field, composite floor systems can add construction time and cost. Also, having a bare metal deck or sprayed deck can be an ugly architectural feature, so a hung ceiling must be provided to hide the structure. This again adds time and money, and decreases the floor to ceiling height of each story. The most influential disadvantage to steel deck systems is fireproofing. Spraying fireproofing to acquire the necessary rating is messy, time consuming, and expensive.
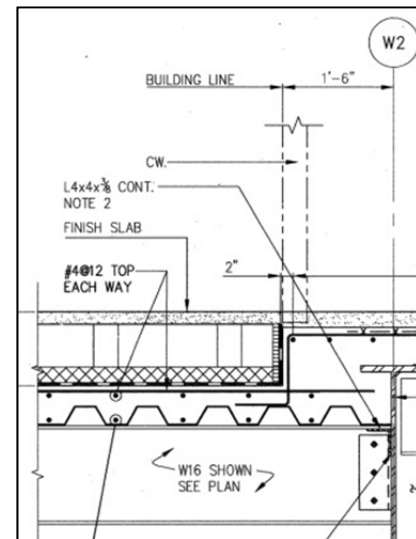
FLOOR SYSTEM ANALYSIS

TWO WAY SLAB ON CONCRETE BEAMS

Description

The first alternative floor system tested was a two-way slab on concrete beam system (*Figure 16 & 17*). ACI-318 08 was used as a design guide for this system. After span inspection, it was determined that the dimensions of the bay will require a two-way slab system. Design analysis gives an 11 inch reinforced 4000psi normal weight concrete slab on 14" x 26" reinforced concrete beams and 24" x 24" columns. Slab reinforcement consists of #5 top and bottom bars placed at various spacing in the column strips and middle strips. No shear reinforcing is required in the slab. Concrete beams are reinforced with 6 #8 bars on top to resist negative moments at the column face and 5 #8 bars on bottom to resist positive moments at mid span. #7 bars were used every 6 inches to increase the shear strength of the beam. Both the beam and slab were checked for deflection limits and complied with minimum code requirements. When
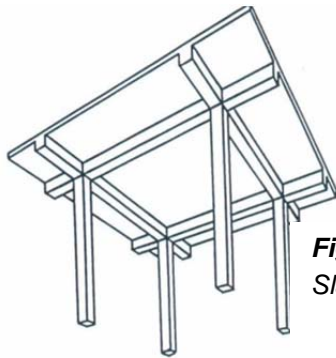
Figure 16: Two Way Slab on Beams
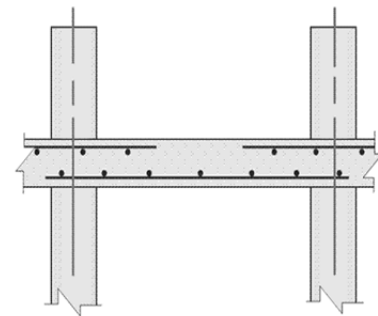
Figure 17: Two Way Slab Section

inspecting the long span condition, it was determined that a 72" x 50" beam would be required to support the slab. To help reduce the size, pre-stressed tendons and camber could be used. However, this was not analyzed in this report. The hand calculations for this system can be found in Appendix B.

Advantages

There are several advantages to using this floor system in building design. Concrete is inherently fireproof, so no additional fireproofing is required on the entire system. Also, because concrete is a shallower system and it is an acceptable finished surface, no additional celling is required and helps create a higher floor to ceiling height (though dropped ceiling may be used to hide MEP systems). Changing from steel to a properly reinforced concrete framing system also creates a building that will hold up better in lateral loading.

Disadvantages

The two main disadvantages to concrete systems are the weight and the construction costs. Buildings made with concrete weigh considerable amount more than steel structures. This creates the need for larger member sizes in the beams, columns, and foundations to be able to support this weight. Column size increase can have negative architectural effects by decreasing the usable floor space. Foundation size increase creates a more expensive system. During construction, formwork must be used to erect the system. This can cost a lot of money and take a longer time to build than a steel building. Also, it takes time for concrete to cure and gain the strength to continue building on top of it. This time creates a longer construction process and increases the project cost

FLOOR SYSTEM ANALYSIS
PRE-STRESSED PRECAST HOLLOW CORE PLANKS

Description

This system was designed using the Nitterhouse Concrete Design Guide, and is comprised of 6"x4' hollow core pre-stressed precast concrete planks with a 2" top coat supported by a steel framing system. Concrete planks are 3500psi lightweight concrete with 7-1/2" diameter 270kip pre-stressed tendons. Planks span in the short
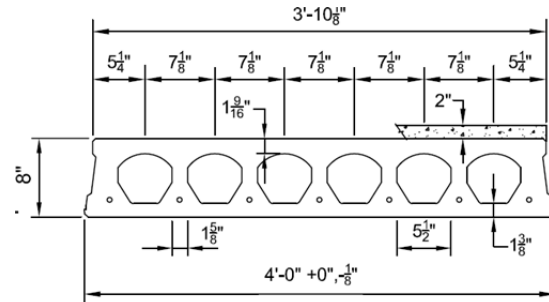

Figure 18: Hollow Core Plank System

direction (26 feet) to allow for a thinner member size. They are supported by W24x62 steel girders on each end. Fireproofing is achieved by the 2" lightweight top coat. Due to the similarity in weight to the existing system, columns and foundations for this system did not really change much. Also, long span conditions will not change the plank design because it will be placed in the short span direction. Like the current system, plate girders will be used to support the load. Detail of the hollow core plank floor can be seen in *Figure 18*. All hand calculations for this floor design can be found in Appendix C.

Advantages

Like steel deck, concrete planks arrive to the jobsite premade and are easy and fast to construct. Because they are precast, these planks don't require formwork or curing time for full strength. Because they are lightweight and pre-stressed, they can span long distances and carry a lot of load effectively without adding too much weight to the structural system. Though supporting beams may still require fireproofing, hollow core planks with 2" topping are rated at 2 hours for fire, and require no additional fireproofing.
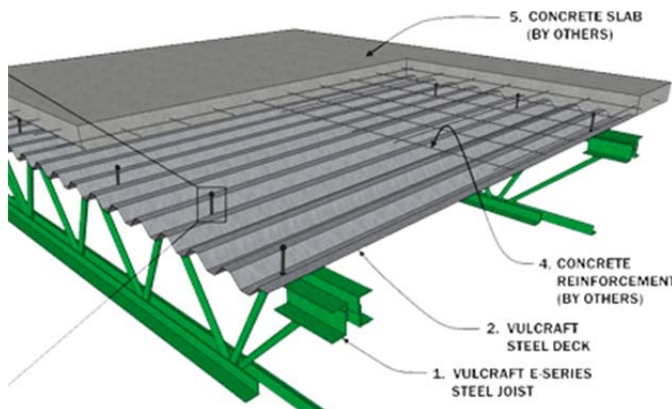
Disadvantages

One disadvantage to hollow core planks is they add additional depth to the existing system. This can be avoided, however, by using shelf angles to place the planks in between girders rather than on top (an added cost). Another disadvantage is the cost of this system. Though installation is cheap, material costs are not. Overall, this system is almost twice as expensive per square foot as the existing system. Also, because these planks come in straight, 4 foot sizes they may require column layouts and angled spans to change to create usable spans.

FLOOR SYSTEM ANALYSIS

STEEL DECK ON STEEL JOISTS

Description

The steel deck and joist system was developed using the design guides from Vulcraft. This alternative floor system is much like the existing system except the steel beams are replaced by steel web joists and girders and composite action between the frame and slab no longer exists. It uses 3 inch 18 gage composite steel deck and a 3.25 inch lightweight concrete topping with 6x6 W2.0xW2.0 Welded Wire Fabric reinforcing. Typical steel joists span in the 31 foot direction and are sized as 22K5 joists. Joist girders are sized as 28G13N9.8F girders. Long span design analysis came up with 68DLH19 joists spanning the 80' gymnasium supported by 28G12N37.7F girders on each side. All joists have a spacing of 2 feet on center. A composite steel deck on steel joist system can be seen in *Figure 19.* All hand calculations for this system can be found in appendix D.

Figure 19: Steel Deck and Joist System

Advantages

Steel deck on joists systems can span long lengths and support gravity loads efficiently without adding much weight to the structural system. For example, the steel joists designed in the long span condition for this thesis project weigh less than 1/20th the amount of the steel plate girders used in the existing design. This can be very effective in cutting down the cost of the structure and the size of columns and foundations. Also, steel joists come to the project site prefabricated, and erection is quick and simple. Because of the spaces in the joists, MEP systems can be run both parallel and perpendicular to the floor system without taking up any extra space.

Disadvantages

Although steel joists can save money on weight reduction and construction ease, they cost a lot of money to fabricate. Also, like the existing system, spray fireproofing is required to meet code standards. Because of the web spaces in joists, spraying fireproofing is extremely messy and time consuming. This also adds a lot to the cost of the system. Steel joist systems also require additional bridging between spans to help against lateral loading.

FLOOR SYSTEM ANALYSIS

FLOOR SYSTEM COMPARISON

The three alternative systems chosen in this report were analyzed and compared to the existing system. When designing the floor systems, many different factors were taken into account. *Table 5* below shows the different design factors for each system and compares them with each other and the original design. Then, a brief summary of certain design factors are dissected more fully.

Floor System Comparison

	Existing System: Composite Deck with Steel Beams	Alternative #1 Two Way Slab on Concrete Beams	Alternative #2 Pre-Stressed Precast Hollow Core Planks	Alternative #3 Steel Deck on Steel Joists
Slab Depth (in)	3.25 (Lightweight)	11 (Normalweight)	10 (Lightweight)	3.25 (Lightweight)
System Depth (in)	27	26	33.7	28
System Weight (psf)	78.2	145	61.25	76.3
Deflection D+L (in)	1.27	1.1	1.53	1.55
Fireproofing	Sprayed	Inherent	Inerent Plank/ Sprayed Beam	Sprayed
Fire Rating (hour)	2	2	2	2
System Cost ($/sq ft)	23.4	24.9	43.9	21.4
Foundation Impact	N/A	Yes	Yes	No
Lateral System Impact	N/A	Yes	Yes	Yes
Architectural Impact	N/A	Yes	Yes	Yes
Formwork Required	No	Yes	No	No
Long Span Design	Plate Girder	Concrete Beam	Plate Girder	DLH Joist
Depth (in)	40	72	40	68
Weight (klf)	1.42	4.5	1.42	0.067
Feasibility	Yes	Yes	No	Yes

Table 5

System Depth

Depth is important when considering floor to ceiling heights. Three of the four systems analyzed had very similar system depths, while the hollow core plank system was almost 10 inches deeper. With its open web design, steel joists allow for MEP systems to travel within the structural depth in both directions, helping free up more vertical space.

System Weight

System weight affects a lot in a structure. More weight means bigger members and larger costs. However, more weight can help cut down on vibrations. The precast planks were the lightest system overall, and the two-way slab system was the heaviest (being about 2 times the weight of the other systems).

Deflection

Deflection was checked in each system to make sure that total load deflection in the floor and beams met with deflection criteria set in IBC2009. All systems were within the allowable deflection of 1.55 inches

Fireproofing

Fireproofing is a time consuming and expensive process. Alternative system 1 is the only system that does not require any additional fireproofing to meet the design requirement of 2 hours. Steel beams, decks, and joists all need sprayed.

System Cost

System cost is important when considering structures. *RS Means Assemblies Cost Data 2012* was used to determine the rough cost per square foot of each system. A location factor of 129.8% was determined for a more accurate cost in Long Island City, New York. All floor systems except for the hollow core plank design cost roughly the same amount per square foot. The increase in price for the second alternate system is most likely due to the manufacturers cost of the specialty product.

Foundation Impact

The two-way slab design will change the foundation because of how much extra weight it will add to the structure. The foundation will probably need to be strengthened to hold the increased load. The hollow core plank system will also change the foundation. Though it does not add extra weight to the structure, the 4 foot planks require column spacing to change which will ultimately affect the foundation. The Steel Joist system will have no effect on the current foundation design.

Lateral System Impact

Although lateral loads were not considered in this report, it is important to speculate how the different systems would change due to the horizontal loads and how the overall lateral system is affected. The two-way slab design would add weight to the structure, increasing seismic load and increasing stiffness which would decrease vibrations. Because alternate systems 2 and 3 no longer have composite connection with the beams and floor, the lateral stiffness of the building will go down. Also, steel joists have less lateral strength in the weak direction than steel beams (but bridging is used to help).

Architectural Impact

The only major architectural impact is loss of usable floor area. The two way slab requires much larger column sections than the steel systems. Column sizes change from roughly 1 foot squared to 4 feet squared. This will make the building lose a lot of floor space, and could potentially create layout issues that would require a redesign of the floor plans.

Long Span Design

Hunter's Point South School has a gymnasium, auditorium, and cafeteria all stacked on top of each other. The gymnasium requires 80 foot transfer girders to carry the large

load transferred from the floors above and to create open gym space. It is necessary to consider this span condition when analyzing floor systems. The existing system uses large plate girders to carry the load from the floor deck. At 40 inches deep and weighing 1420pounds per foot this is a large heavy beam. The hollow core plank system is laid out such that the planks go girder to girder (23.5 foot span) so size does not change. Beam size is also very similar, so it is assumed that the existing system would be ok for this design as well.

The concrete two way slab design would require at least a 72" X 60" simple beam with no other design to be able to carry the load in an 80 foot span. After including slab depth, the beam would hang down 6 feet from the ceiling. Camber and pre-stressing could be used to help shrink this size, but it still creates a large member that weighs about 4000 pounds per foot. The last alternate system, which uses a giant 68DLH19 steel joist to span the 80 foot length, is the most efficient. According to Vulcraft, this member is only 67 pounds per foot, which dwarfs the weight of the other systems. However, at 68 inches deep, this system takes away 2 more feet of floor to ceiling height than the existing condition.

EVALUATION AND SUMMARY

Technical Report ll analyzes and evaluates the feasibility of three different alternative floor systems to replace the existing system in a redesign of the structure for Hunter's Point South. This report uses different criteria, which is listed in ***Table 5*** on page 18, to compare each system with the others and determine whether or not it is a practical floor design. After analysis was complete for each design, it was determined that only alternate system one and three would be viable solutions for floor redesign. However, each new system had specific disadvantages that should be noted.

The first alternate system is a two-way slab on concrete beams and concrete columns. It improves in system depth, fireproofing, and deflection from the existing design, but adds twice the weight, takes up twice the floor area, and seems to be the least favorable design for long span conditions of all the systems analyzed in this report. Slight design changes, such as pre-stressing, camber, and concrete type could help improve this system. Cost for this design is very similar to the existing cost. Overall, this could potentially be an effective alternative to the current design.

The second alternative system is pre-stressed precast hollow core concrete planks on steel beams. It was determined that this system would not be a viable substitute to the existing system. Though it was the lightest system tested, most of the criteria checked came up with undesirable results. This system was deeper than the other systems, 75% more expensive than the others, and had little chance of fitting into the architectural layout due to its straight, 4 foot wide sizing. Though a layout change could be done, the different angles present in the building design would create issues with the planks unless expensive custom shapers were created.

The final alternate system consists of composite steel deck on steel joist and joist girders. Analysis for this system proves that this design would be a good substitute for the existing condition. The only negative aspect of this design is the fireproofing. It is tedious and time consuming due to the shape and holes, and it most likely would cost the most to create a 2-hour rating. Overall, though, it compares evenly or better to the existing system. When looking at the long span condition in the gymnasium, steel joists, by far, are the most effective design tested with a weight of a mere 67pounds per foot compared to 1400 pounds per foot in the existing design.

Technical Report III will build on the analysis of this report and analyze and discuss the lateral system of the structure in detail. Once a lateral system analysis is performed, a better understanding of these floor designs can be determined.

APPENDIX A

COMPOSITE METAL DECK WITH STEEL BEAMS

CRSI

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www.crsi.org

Project	Hunters Point South		Sheet No. 1 of 1
Made By Mike Payne		Checked By tech 11	Date
Subject Assemblies Cost Analysis			Project No.

Uset 2012 RSMeans Assemblies COST DATA

Location Long Islac,   material   Instalatn   total
Factol   City, NY :   103.0   63.8   129.8
Bay: 31x26 Area = 806   Asson 25+10=   Area: 750   Superimposed load
                                                      = 40+25=65
                                                      use 75 psf

Existing System 1) "Composite Beams, Deck & Slab   B1010 256

Mat	Inst	Total	LF	
12.25	5.75	$18.00/sq Ft	x (1.298) =	$23.4/sq Ft

Alt 1 System 2) "Cast in Place Beams & Slab 2-way   B1010 220

Mat	Inst	total	#	
7.15	12.05	19.20	x(1.298) =	$24.9/sq Ft

Alt 2 System 3) "Precast Plank w/ 2" topping   B1010 230

	Mat	Inst	total	LF	
planks	8.10	5.15	13.25 × (1298)		$43.9/sq Ft
Beam	14.80	5.75	20.55 × (1298)		

Alt 3 System 4) "Steel Joists, Beams & Slab on Colums"   B1010 250

Mat	Inst	total	LF	
10.80	5.65	16.45/sq Ft	× (1.298) =	$21.4/sq Ft

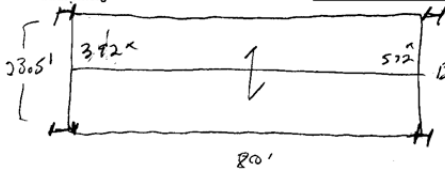**CRSI**

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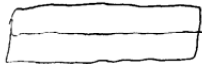| Project Hunters Point South		Sheet No. 1 of 1
Made By Mike Payne	Checked By Tech II	Date
Subject Long Span Considerations		Project No.

Beam FL → Assume load: $\frac{864^k}{80} \cdot 1.4 = 10.85$ KLF

self wt of PG-2

so use $W_v = 10.65$ KLF

$w_u =$

Existing system

Plate-Girder, 40" deep   1.42 klf

as per design

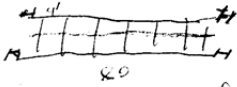Alternate System 1

$10.65 \times \frac{1.42}{28} \approx 19$ K/F

Beams: $w_v = 10.65$ KLF = 453 psf

$\frac{5wl^4}{384 EI} = \frac{(5)(.19 KIF)(80)^4}{384 \cdot 3854(.I)} = \frac{80 \cdot 12}{240} = \frac{C}{240}$

$I = \frac{5(.19)(80)^4}{384 (3834)(4)} = 640000$

$I = 640000 \cdot 4 = \frac{bh^3}{12}$ 1370/408 $b = 72$ $h = 60$

Alternate System 2

W_u similar to Existing System . 1.3 = 10.1 KLF
Use same Plate Girder .

 - p...

 - w...

Alternate System 3

$10.55 KLF \div 23.5' = 450$ psf - slab = 445 psf

use 2' spcg → $2 \times 445 = 890$ PLF

$68 DLH 19 → 998 [644]$ $998 > 890$ ✓

$+52$ selfwght = $943 [883 84]$

Depth 68"
$w = 0.067$ KLF

Grdr: $943 \times 90 = 37.7$ k   144 selfwght PLF
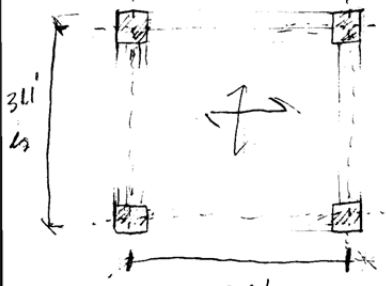
Grdr: $28G1237.7F$

APPENDIX B

TWO WAY SLAB ON CONCRETE BEAMS

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Project	Hunters Point South		Sheet No. 2 of
Made By Mike Payne		Checked By Tech II	Date
Subject 2 way Slab + beams Floor system			Project No.

Frame A

$\alpha \frac{\ell_2}{\ell_1} = 11.83 \times .83 > 1.0$

+moment	0.5	0.83	1.0
+moment	80	80.1	75
-moment	90	80.1	75

Frame C

$\alpha \frac{\ell_2}{\ell_1} = 7.34(.833) > 1.0$

	.5	.85	1.0
+mom	80	80.1	75
-mom	90	80.1	75

85% beam
bots < 80% to col strip 15% slab
15.5% to middle strip

Frame A
tot mom	-333.3	+178	-333.3
Beam mom.	-227	121.9	-227
mom in col strip slab	-40	21.5	-40
mom in mid strip slab	-66.3	35.6	-66.3

Frame C (moment)
tot	-406.8	219.1	-406.8
Beam	-277.0	149.2	-277
col strip slab	48.8	26.3	48.8
mid strip slab	-81.0	43.6	-80

Assume #5 bar w/ 1" C

Frame A

	Frame A	col strip		middle strip	
1	moment mu	48	21.5	86.3	35.6
2	width, b	102	102	93	93
3	eff depth	9.375	9.375	9.375	9.375
4	Mu/Ø 0.9	44.5	23.9	23.7	38.6
5	R=Mn/bd²	36.4	19.6	60.3	28.2
6	ρ from tb 4.5.4	.0008	.0005	0.0012	0.0007
7	As=ρbd	1.215	0.78	1.01	0.60
8	As min .0018b	3.1125	3.1125	1.7	1.7
9	Ns=larger of 7 or 8	10.04	10.04	5.5	5.5
10	Nmin = w/ 2t	7.54	7.54	4.1	4.1
11	Nreq larger of 9 or 10	11	11	6	6

deff
11-1-.625
= 9.375

Frame C

1	Mu	48.8	26.3	81.0	43.6
2	b	142	142	78	78
3	d	9.7	9.7	9.7	9.7
4	Mu/Ø	54.2	29.2	90	48.4
5	R	48.7	26.2	80.83	43.5
6	ρ	.0010	.0005	.0015	.0012
7	As	1.33	0.67	1.13	0.9
8	As min	2.75	2.75	1.51	1.51
9	Ns	8.9	8.9	4.9	4.9
10	Nmin	6.45	6.45	3.5	3.5
11	Nreq	9	9	5	5
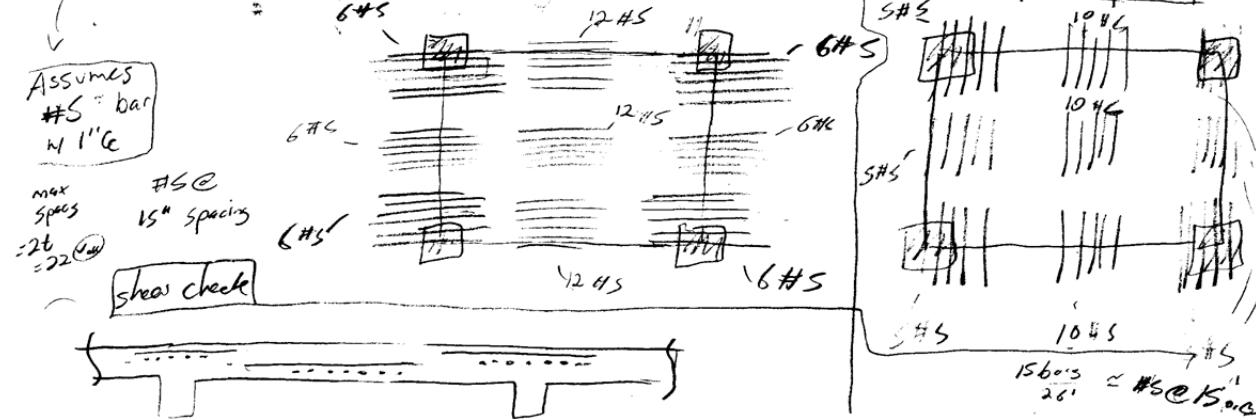
Assumes #5 bar w/ 1" C

max specs
#5 @ 15" spacing
=2t
=22

shear check

6#5   12#5   6#5   5#5   10#5   6#5
6#5   12#5   6#5   5#5   10#5
6#5   12#5   6#5   #5   10#5   #5

15 bars = #5 @ 15" o.c.
26'

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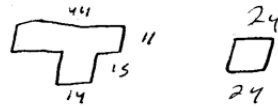| Project Hunters Point South		Sheet No. 3 of
Made By M.ke Payne	Checked By Tech II	Date
Subject 2 way slab & beam floor system		Project No.

Shear Check

$$V_u = (\lambda W_u)(1'\text{thickness})(\text{Col strp} - \frac{b_w}{2} - \frac{deff}{12})$$
$$= (0.229)(1)(15 - \frac{26/12}{2} - \frac{9.375}{12}) = 3.0^k$$

wide beam $\phi V_c = \phi 2\sqrt{Fc}\, bd = (0.75)(2)(\sqrt{4000})(12'')(9.375) \div 1000 = 10.67 > 3$ ⓞk

2way action $\frac{l_L}{l_S} = \frac{31}{26} < 2 \rightarrow V_c \leq 4\sqrt{Fc}\,bd$: $4\sqrt{4000}(72'')(9.375) \div 1000 = 28.5 > 3$ ⓞk
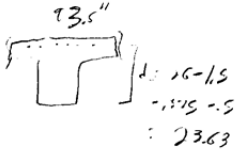
[No Shear reinforcing required]

$$w = (132.5125 \times 31) + \frac{14 \times 15}{144} \times 150 + 40 \times 31) = 6.5^{KIF}$$

Beam Deflection

live $\frac{5wl^4}{384 EI} \stackrel{?}{<} \frac{l}{360} \rightarrow \frac{(5)(1.3)(31-2)^4 \cdot 1728}{(589)(3834)(25200)} = 0.24 < 1.03$ OK

total $\frac{(5)(6.5)(29)^4 \cdot 1728}{(384)(3834)(25200)} = (\text{Not in}) < \frac{31.0 \times 2}{240} = 1.65$ (OK)

Strength

Flexure $w = 229 psF \times 31 + \frac{14 \times 15}{144} \times 150 = 7.36 KIF$

$\frac{wl^2}{11} = \frac{(7.36)(26)^2}{11} = 452 \, k\,Ft$

$\frac{wl^2}{16} = \frac{7.36(26)^2}{16} = 311^{k \cdot Ft}$

93.5"

d = 16 - 1.5
  - .375 - .5
  = 23.63

beff ≥ in 2 sections
  = 93.5"

shear
$V_u = 236 (26)$ 114
$\frac{}{2}$
$\phi c = (.75)(2)\sqrt{4000}(10)(9363) = 31$
$V_{smin} = 114 - 31 = 83/.75 = 111 = \frac{Asfy}{s}$
$A_v = 0.42^{in} \quad \#7 bar = 0.6 in$

[#7 bar @ 6" spacing]

top bars $As = \frac{Mu}{4d} = \frac{452.0}{4(58.63)} = 4.78 in^2$ use 6 #8 → 4.74

use 6#8 bars on top

$a = \frac{As Fy}{.85 Fcb} = \frac{(4.74)(60)}{(.85)(14)(935} = 0.89$ $C = \frac{a}{\beta_1} = \frac{.89}{.85} = 1.05$ tension controls $\phi = 0.7$

$\phi M_n = \phi As Fy (a - \frac{a}{2}) = .9(4.74)(60)(23.63 - \frac{.89}{2}) = 494 > 452$ ⓞk

bottom bars $As = \frac{311}{4(28.63)} = 3.3$ use 5#8 → 3.95

use 5#8 bars on bottom

$a = \frac{As Fy}{.85 Fcb} = \frac{(3.95)(60)}{(.85)(4)(93.5)} = 0.74$ $C = \frac{.74}{.85} = 0.87 < .375d$ tension controls ($\phi = .9$)

$\phi M_n = \phi As Fy (d - \frac{a}{2}) = .9(3.95)(60)(28.63 - \frac{.74}{2}) = 411 k\,Ft > 311$ ⓞk
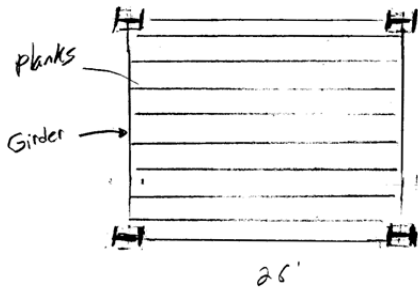
11"
15

APPENDIX C

PRE-STRESSED PRECAST HOLLOW CORE PLANKS

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Project: Hunters Point South
Sheet No. 1 of 3
Made By: Mike Payne
Checked By: Tech II
Date:
Subject: Prestressed precast Hollow Core planks
Project No.

planks

Girder

26'

$SDL = 10+12 \approx 25 psf$
$LL = 40 psf$ (classroom) $\}$ $65 psf$

$31.1'$ Use Nitterhouse Concrete Prestressed Hollow Core Design Catalog for Design.

$Span = 26$ Feet
Superimposed loads $= 1.2(25) + 1.6(40) = 96 PSF$

Try $8" \times 4'$ hollow core planks w/ 2hr resistance & 2" topping

$\frac{31.1'}{4}$ = 7.7
need 8 planks

For $7 - 1/2" \phi$ 270k Lo relaxation pretension strands per plank, ∴ safe superimposed load $= 181 psf > 96 psf$ ok

per 4 foot plank $\{$
self weight $= 61.25 psf$
$DL = 61.25 + 25 = 86.25 psf \longrightarrow \times 4Ft = 345 plf$
$LL = 80 psf \longrightarrow \times 4ft = 160 plf$
$W_u = 1.2(345) + 1.6(160) = 670 plf$

Deflection check

$I = 3134 in^4$ $E_c = 33+(150)^{1.5} \sqrt{6000} \times \frac{1}{1000} = 4696 ksi$

$\Delta_{LL} = \frac{Sw\ell^4}{384EI} = \frac{(5)(0.14)(26)^4 \times 1728}{(384)(4696)(3134)} = 0.12 in$

$\frac{\ell}{360} = \frac{26+12}{360} = 0.867 in > 0.12$ ok

$\Delta_{DL} = \frac{(5)(0.51)(26)^4 \times 1728}{(384)(4696)(3134)} = 0.36 in$

$\frac{\ell}{240} = \frac{26+12}{240} = 1.3 > 0.36$ ok

∴ use $8" \times 4'$ planks

Steel Girder Design

$DL = 86.25 psf \longrightarrow \times 26' = 2.243 KIF$
$LL = 40 psf \longrightarrow \times 26' = 1.04 KIF$

$W_u = 1.2(2.243) + 1.6(1.04) = 4.36 KIF$

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Project	Hunters Point South		Sheet No. 2 of 3
Made By _Mike Payne_		Checked By _Tech II_	Date
Subject Prestressed Precast Hollow Core Plank			Project No.

$$V_u = \frac{w\ell}{2} = \frac{(4.36)(31.1)}{2} = 67.8^K$$

$$M_u = \frac{w\ell^2}{8} = \frac{(4.36)(31.1)^2}{8} = 527.2 \; Ft\text{-}K$$

$M_u = \phi Fy Z_x$

$\frac{527}{.9(50)} = Z_x$

$140.6 = Z_x$

$$\frac{(31.1)(12)}{360} = \frac{\ell}{360} = \frac{5 w_{u} \ell_n^4}{384 EI} = \frac{(5)(1.04)(31.1)^4 \cdot 1728}{(384)(29,000) I}$$

$I_{min} = 728.15 in^4$

$$\frac{(31.1)(12)}{240} = \frac{\ell}{240} = \frac{5 w_{u} \ell_n^4}{384 EI} \quad \frac{(5)(3.28)(31.1)^4}{384(29,000) I}$$

$I_{min} = 1531.0 in^4$

controls

Using AISC I_x tables (3-3)

   try W24×62 → $I_x = 1550 > 1531$ ✓ controls $\phi M_n = 574$
                                                 > 527 (ok)

Using AISC Z_x tables (3-2)

   try W21×62

∴ USE 8"+4' Prestressed Hollow Core Plank w/ 2" topping & 2hr Fire rating, 7 - ½"⌀ 270k strands, & W24×62 Girder
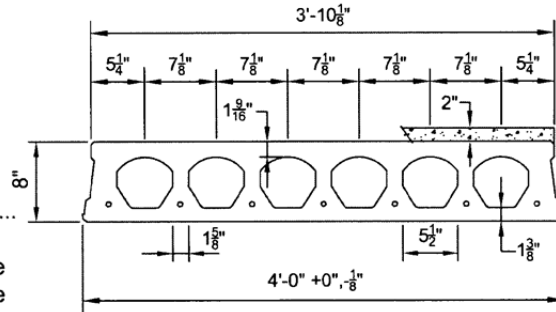
3/3

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

NITTERHOUSE
CONCRETE PRODUCTS

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

11/03/08

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.
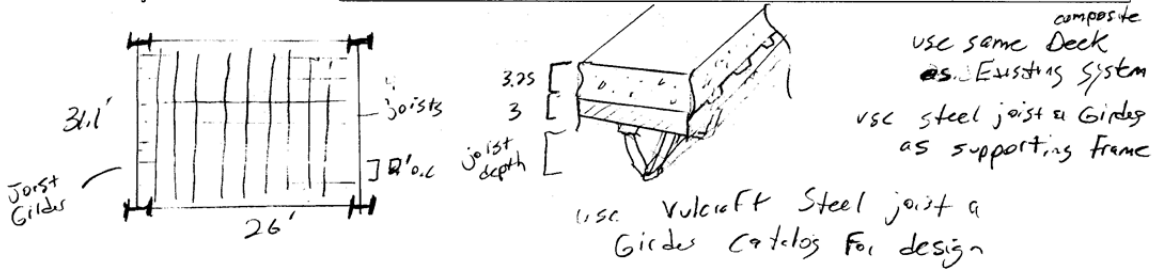
8SF2.0T

APPENDIX D

STEEL DECK ON STEEL JOISTS

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Project: Hunters Point South   Sheet No. 1 of 1
Made By: Mike Payne   Checked By: Tech II   Date:
Subject: Steel Deck on Steel Joist   Project No.

composite
use same Deck
as Existing System

use steel joist & Girder
as supporting Frame

use Vulcraft Steel joist &
Girder Catalog For design

Dead load / 49 psF – Slab
25 psF – SDL
SelF ≈ 10 assumed

Live load / 80 psF

$W_u = 1.2(75) + 1.6(80) = 218$ psF + self

spacing of 2' = 13 joist spaces

$W_u = 2(218 psF) = 436$ p/F

Span = 31'   Spacing = 2'   Allowable load ≥ (436 [160])

ASD: $(75+80) \times 2 = (310 [160])$

Using economical joist guide ⟶ try 22K5   (379 [222])

22K5 Joist / weight = 2.2 p/F, Depth = 18"

$W_L = 310 + 8.7 = 318.7 < 379$ (ok)

$\Delta_{TL}: \frac{L}{240} ⟶ 222 \times 1.5 = 333 > 310$ ok   } table takes into account deflection.

$\Delta_{LL}: \frac{L}{360} ⟶ 222 > 160$ (ok)

Joist Girder /   span : 31.1' w/ 14 joist loads on it

$W_u = 1.2(25 \times 2 + 8.7) + 1.6(80) = 318.5$ p/F

$P_u = 318.5(31.1) \div 1000 = 9.9^k$

$n = 13$
(2' spaces)   depth

choose 28G13N 8.8 F

∴ use 22K5 joists spaced 2' O.C.
w/ a 28G13N 8.8F joist Girder

$\Delta_{TL} = 1.55"$

APPENDIX E

REFERENCES

The following is a list of reference materials used in this thesis project for research, analysis, and design aids.

1. "Vulcraft Steel Joists & Steel Girders". Nucor Vulcraft Group. 2007

2. "Nitterhouse Prestressed Concrete Hollow Core Planks". Nitterhouse Concrete Products. 2008. http://www.nitterhouse.com/DrawingSpecs/DrawingsSpecs.html.

3. "Designing With Vulcraft". Nucor Vulcraft Group. 2nd Edition

4. "Steel Plate Weight Calculator". Portland Bolt & Manufacturing Company. 2011 http://www.portlandbolt.com/steel-plate-weight.html

5. "RSMeans: Assemblies Cost Data 2012". RSMeans Reference Guides. 2012

6. Figure 16: "Two Way Slab on Beams". University of Purdue.

7. Figure 17: "Two Way Slab Section". University of Purdue.

8. Figure 18: "Hollow Core Plank System". Nitterhouse Concrete Products

9. Figure 19: "Steel Deck and Joist System". Nucon Steel. http://www.nuconsteel.com/_images/ecospan_diagram.gif

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