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Structural Option
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The Hub on Chestnut
Philadelphia, PA
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Thesis Proposal

Proposed Structure and Breadth Topics

The HUB on Chestnut is a newly constructed building located in the University City section of Philadelphia, Pennsylvania. The structure is owned and operated by a local development group, Teres Holdings, and the original design was created planned by Piatt Associates who operate out of Massachusetts. The local architectural firm by the name of Brawer & Hauptman acts as the architect of record and assist with day-to-day operations which is managed by Domus, Inc. The nine level building, structurally design by O'Donnell & Naccarato, stands one hundred feet tall and provides housing to the local community as well as mercantile and retail services. Within this report is the proposed redesign of the structural system of The HUB on Chestnut. Based on the information and research collected in the previous three (3) technical analysis assignments, the new selection will convert the original concrete moment frame into a steel frame and incorporate shear walls to resist lateral loading. The floor system will be changed from a post-tensioned two-way slab to a hollow core pre-cast slab system. Along with the new design, two breath topics will be researched to enhance the mechanical system and the management of construction through material selection and delivery. As the author of this report, I feel that the primary design is very effective and my interpretation and suggestions to a new system do not reflect a negative attitude to the original plan.

OVERVIEW

The HUB on Chestnut is a new structure that will begin occupancy during the winter holiday season of 2006. The site of construction is located at the northeast corner of Chestnut and 40th streets, is a mid-rise, mixed-use structure which began construction in the early spring of 2005. The building is predominantly a concrete structure that stands 9-levels with one sub-grade level covering a footprint of approximately 11,000 square-feet. The north/south length of the building extends one-hundred forty-eight feet down 40th Street and the west/east width extends sixty-eight feet along Chestnut Street. The HUB provides the local community with 110 apartment units and 3-levels of retail and mercantile use. Levels three to nine are designed for a residential occupancy, while the sub-grade, first, and second levels are designed primarily for commercial occupancy. The residential space is approximately 68,000 square-feet and 30,000 square-feet are for commercial use.

The architectural accents allow this building to be very noticeable in one of the historical settings of Philadelphia. Primary accents include an exterior rainscreen that is cladded with multiple colored wood veneers, lime green aluminum paneling, and polished corrugated metal sheathing. The building's interior features include several residential levels with balconies, studio and multi-room living units, and double height ceilings in the commercial units. There are three different stairways located within the building along with two elevator shafts. All of the egresses are strategically placed to accommodate each occupancy type while isolating the commercial spaces from the residential. The roof is not a public space. It is comprised of a single-ply rubber membrane classified as an EPDM application.

A concrete moment frame is the original structural system. Starting one level below grade, the superstructure is a system of exterior and interior concrete columns that support a concrete slab throughout each level. The columns located on the lower levels are sized 30" x 30" while the upper floors (3-9) are sized 20" x 30". All reinforcement uses a #3 bar tie spaced twelve inches on center with varying vertical rebar ranging from #7 to #10 bar. Three column lines create twelve (12) nearly square bays. A typical bay size is 28' x 28'. The foundation system is comprised of concrete caissons and spread footings. All exterior walls are 12-inch reinforced cast-in-place concrete. Interior walls are a mix of CMU blocks and CIP concrete. The lower commercial spaces are designed using a 12-inch two-way slab with square concrete columns as the functional supports. The upper residential levels use a 9-inch post-tensioned two-way slab with a mixed use of rectangular and circular concrete columns. The typical two-way slab is reinforced with #4 bars spaced continuously at 30" in each direction. Additional reinforcement (5 - #8 bars) is placed at the top and bottom in both directions where mild reinforcing is needed. The post-tensioning strands are placed along each long column line and at intermediate bays. The typical tendon is a half-inch 270k seven-wire strand. The jacking forces range from 85k to 435k. The lower stressed tendons are spanned in the short direction. All columns and slabs are designed using 5,000 PSI high strength concrete. The lateral system does not include any braced frames or shear walls to resist the effects of wind and seismic loading. Therefore, the immense columns are sized to absorb, or resist, the large moments that are distributed throughout the structure under lateral loading.

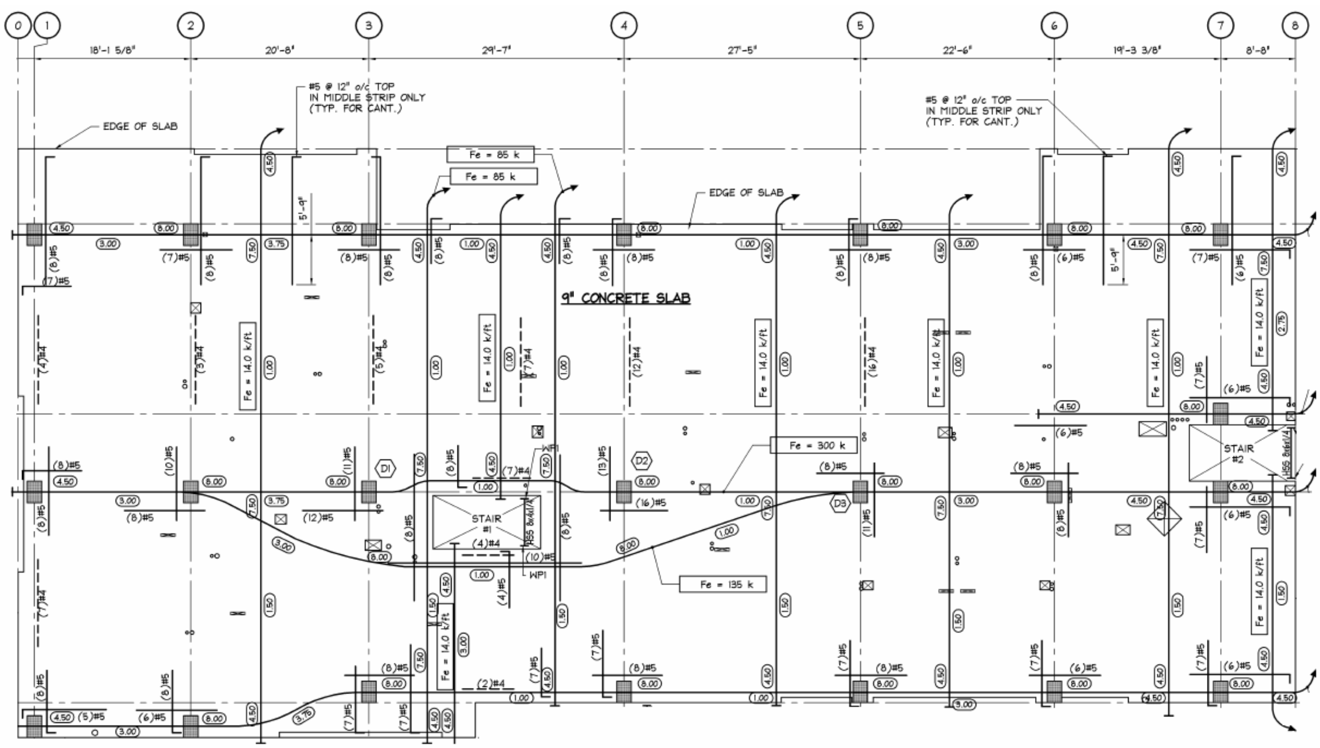
The HUB on Chestnut has been designed and constructed using the latest codes that were available at the time of development. These codes and standards will also be used in the proposed structure to emulate the conditions and services of the building.

National Design Code

International Building Code 2003 Edition

Disciplinary Design Code

American Society of Civil Engineers	[ASCE 7-02]
American Concrete Institute	[ACI 318-03]
American Institute of Steel Construction	[AISC 3rd Edition]
American Society for Testing and Materials	[ASTM – *XXX*]


EDGE OF SLAB
9" CONCRETE SLAB
STAIR #1
STAIR #2

PROBLEM STATEMENT

After completing three (3) technical assignments that evaluated the preliminary service conditions, floor system application, and lateral resisting system, it was evident that the initial design was very efficient and well designed. The architectural layout was very proficient in utilizing the spaces to accommodate each occupancy type. The two-way slab system provided an open floor plan that allows for the partitions to be placed at the owner and architects' desire. Post-tensioning was also very effective in the design. The University City section prohibits high-rise buildings to be constructed due to zoning regulations. Typical buildings range from low to mid-rise. The post-tensioned slab systems contributed to thin slabs which is can allow for an added level which increases occupancy. A moment frame lateral system eliminates the use braced frames and shear walls. These elements can obstruct the focus on maintaining a flexible floor plan. With the three structural features stated above, The HUB appears to be a justified design and stresses the needs that the owner wanted to implement into the building.

However, there are areas that can be enhanced. The use of reinforced concrete can be a very problematic material to work with. The reinforcement must be placed with care and accuracy to allow for proper serviceability. When the concrete is being placed around the reinforcement there are many places for failure to occur. The rebar may move affecting cover which can initiate spalling and voids may form hindering the bonding integrity. Constructing rebar cages and detailing rebar is very labor intensive and time consuming which can prolong the project duration. The main problem is the setting time that is needed to allow for the concrete to reach strength that is adequate for construction to continue. Post-tensioning further increases this delay because of the extra strength needed in concrete to avoid cracking, camber, and the possibility of strands 'blowing out'. A two-way slab floor system also involves tedious placement of multiple bars and the extra time needed in curing the concrete.

A moment frame can significantly increase the overall cost of a project. In concrete structures, the over sizing of columns to counter the effects of high moments can greatly increase the amount of concrete needed to complete the building. An increase in the amount of concrete that is used in the project will increase construction duration, the amount of traffic due to incoming and out going delivery trucks, and the most critical issue, cost.

PROPOSED SOLUTION

The objective of the proposed building structure is to provide an alternate design to improve and redevelop the issues that were introduced in the problem statement. The proposed structure will comprise of a steel column and beam frame with a hollow core pre-cast concrete slab floor system. A composite action design between the beam and pre-cast will be considered to achieve a shallow beam depth. A lateral system constructed of concrete masonry units (CMU) located within the core of the building will be designed to provide adequate resistance to shear and overturning moment induced by wind and seismic loading. The main ideas in selecting this design are constructability, loading, and serviceability.

As previously stated, concrete is a problematic material to work with. The use of steel and pre-cast concrete has many benefits over cast-in-place concrete. Constructability of this new system is the main advantage over the initial design. Concrete construction involves many steps compared to the erection of steel. The assembly of formwork, wiring rebar, detailing the steel, and placing the actual concrete is more time consuming than the picking up of steel and making connections. The steel is prefabricated and delivered to site. A small crew of men can erect several levels of steel in the time period needed to place and set concrete.

In both structures, the gravity loads are equivalent, with the exception of self weight, because they both provide identical occupancies. The building consists of commercial and residential spaces with the residential occupancy being 75% of total floor space. The residential live load is substantially less than the required live load in the commercial space. Therefore the pre-cast concrete elements can perform more efficiently with the long spans that are desired for an open floor plan.

Construction started in the spring of 2005 and closeout is scheduled for the winter of 2006. The building construction will see two warm seasons and two cold seasons. The winter months can cause some deficiency in placing the amount of concrete that is required for the initial design. In selecting pre-cast the concrete can be caste and cured in a controlled environment to provide maximum serviceability. The hollow-core slabs are reinforced with high strength tendons to provide adequate support under loading. When they are prefabricated the tendon placement can be placed with great precision to assure maximum performance. The compressive strength of cast-in-place concrete can be decreased because the weather conditions and temperature in the winter months can have negative effects in the chemical bonding of the mix. However, winter conditions also provide disadvantages in steel erection. Steel members contract in low temperatures and cause connection tolerances to change. Flanges begin to rub and bolt holes become smaller. With the use of steel the total project schedule can be shortened by several months which expose the construction phase to undergo two warm seasons and one cold season.

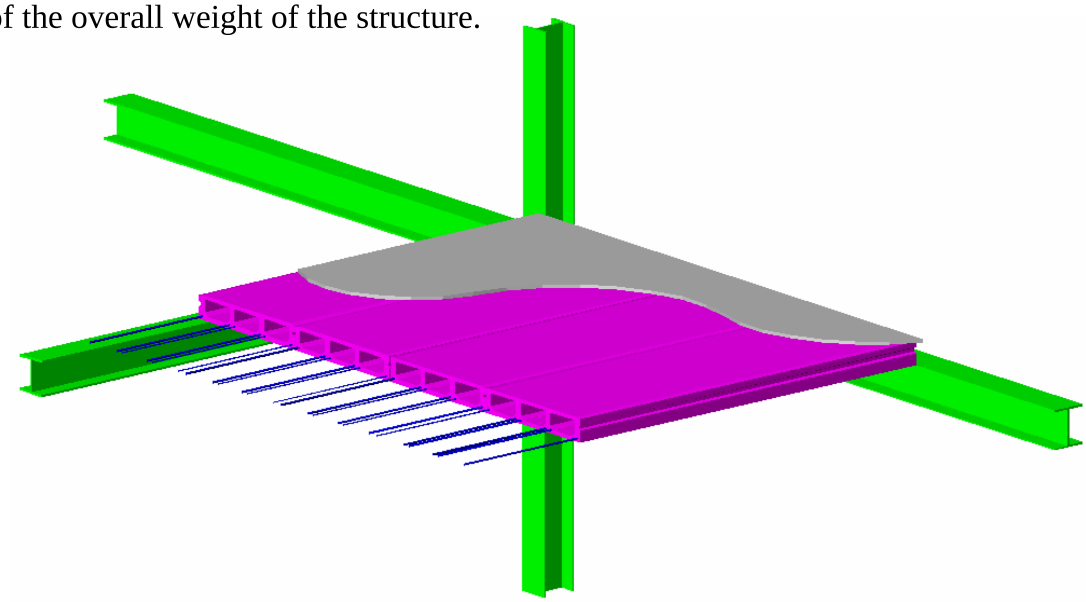
The concrete masonry units also provide an advantage over the initial moment frame. The main service stair is located within the center of the building. CMU blocks can be constructed within this center core, from ground level to roof, enclosing the stairwell for structural support as well as sufficient fireproofing. Braced frames may also be incorporated into the design to provide extra strength. Cast-in-place concrete walls may also be used in the place of CMU blocks, but the setting time of the mortar is much less than a thick poured wall.

SOLUTION METHOD

In Technical Assignment 2, alternate floor systems were designed to interchange with the initial design. With the 'point' system that I had devised in that particular assignment, the hollow core slab system was presented as the supreme floor system over the post-tensioning slab. The steel column and beam frame will be designed using the Load and Resistance Factor Design (LRFD) outlined in the 3rd Edition of the AISC manual. The most common and economical wide flanged columns and beams will be selected to support the gravity loads obtained from the 2003 International Building Code in accordance with ASCE 7-02 standards. All wide flange members will be formed using high-strength low-alloy A992 steel with a steel grade of 50 PSI. These applicable codes with be used to justify the proposed design with the original design.

The structural members will be selected using all relevant tables and will be supported with extensive hand calculations. Also, several computer-aided design programs will be implemented to assist with the selection process. Such program may include RAM Concept and ETABS.

The columns and beams will be designed to provide adequate support of gravity and lateral loads and perform well with minimum deflection criterion. A selected manufacture of pre-cast products will be chosen to supply an acceptable product. The chosen product will be designed based on the specifications and design guides provided by the manufacturer. A previous primary design had used an 8" x 4' hollow core slab by Nitterhouse Concrete Products to span 30 feet. A specification on this product posted in the last section of this report. The product is a U.L. J917 with a 2" CIP top coat. A two-inch concrete coating will be placed above the set pre-cast slab to establish a smooth and durable finish floor surface. Openings and penetrations in the floor will be considered to allow for egress and mechanical components. The CMU shear walls will be checked the see that they are capable to resist the effects of torsion and overturning moment based on the geometry of the walls and the influence of the overall weight of the structure.

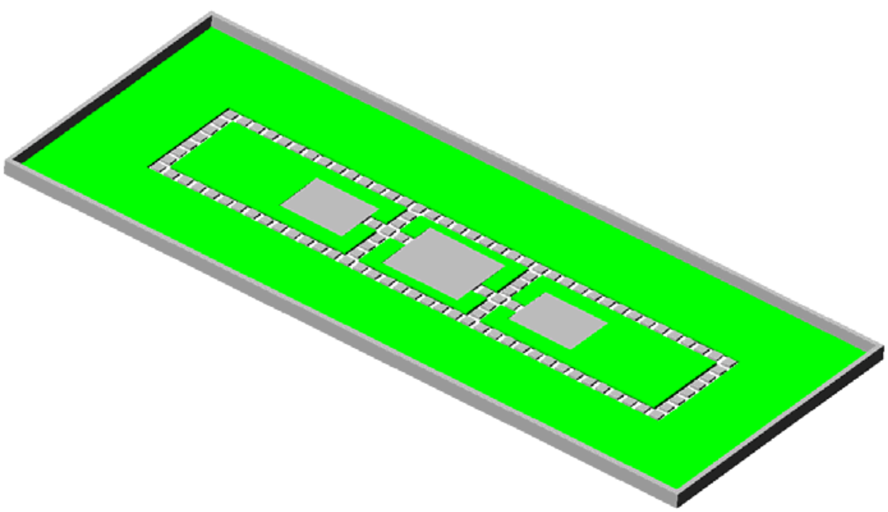


BREADTH TOPICS

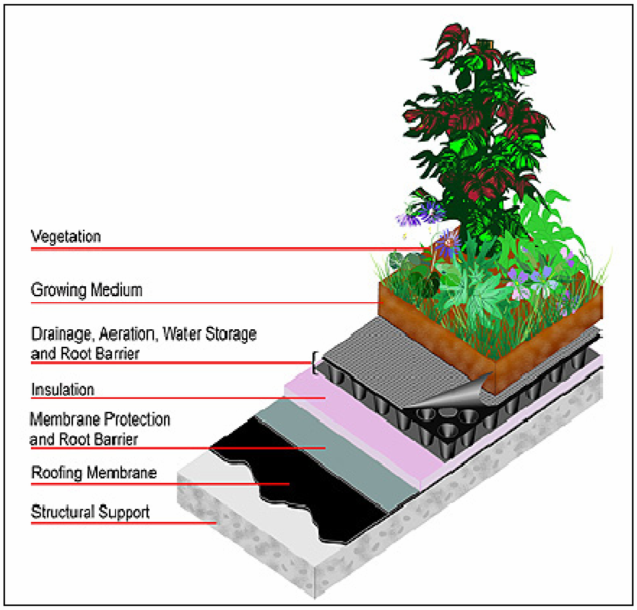
Two breadth topics have been chosen to enhance other aspects of the building design. They include (1) a redeveloped mechanical system with the aid of a green roof and (2) a cost analysis to compare materials, scheduling, and project delivery. These two particular research areas were desired to be incorporated with the proposed structural redesign to develop a LEED building package. The main focus is to promote a safe and sustainable building that will be beneficial to the owner, occupants and the environment.

Improved Mechanical and Plumbing System

A revamped mechanical system with the aid of a green roof will provide the owner with a more efficient HVAC system, low energy costs, and an incentive to provide a sustainable building system to the surrounding community. The focus of this redesign is the application of a green roof. There are many benefits to placing vegetation on the roof of a building. The cooling costs can be reduced from 20-70% per year, stormwater management, and the enclosure thermal efficiency is increased. The design will have grass flats placed on the entire roof with three mechanical pads for equipment and concrete pavers for maintenance personnel to walk on roof. The structural floor system will need to be designed to support the equipment and fully saturated soil and vegetation.



The main idea of the redesign is to collect rainwater and distribute it into the building as grey water to be used as flushing water in toilets and supply water for washing machines. The vegetation will absorb, filter, and drain the rainwater into a main collection tank within the lower level of the structure where it can be mechanically filtered and supplied to the wash facilities in the commercial and residential spaces. Research has shown that 30% of fresh water supplied to a building is used to flush toilets and in washing devices. Since the water system will already incorporate a filtration system the fresh water that is discarded can be routed into the roof drainage lines and be recirculated back into the system. This large percent can be very efficient to the owner's water supply cost.



Green roof cross-section
(Source: American Wick Drain Corp.)

A benefit to the surrounding community is the stormwater management. The HUB is placed in a historic section of the city with an out dated street drainage system. By collecting the water from the building's impervious footprint the local community can reduce the amount of water running into the local streets to avoid possible flooding and pollution.

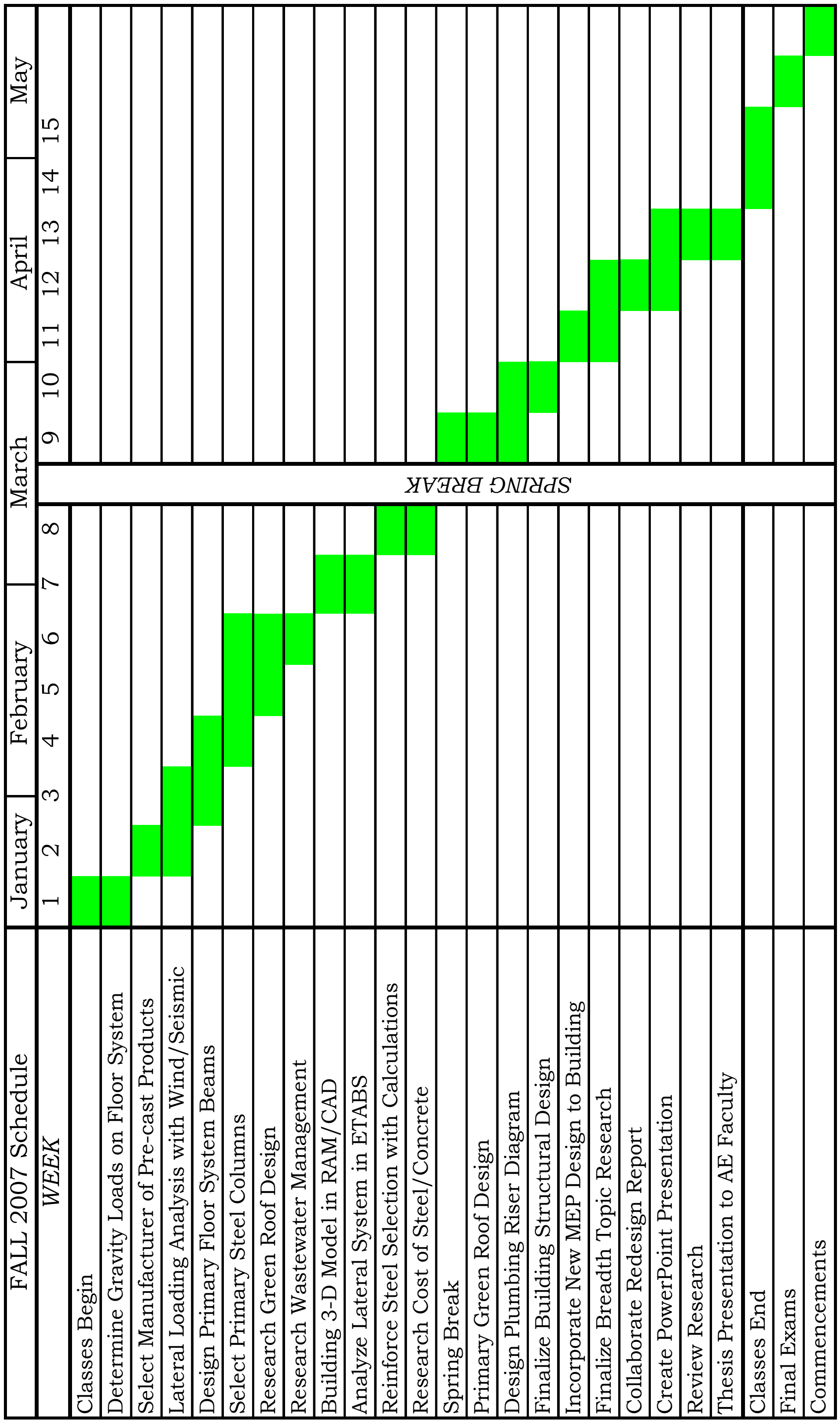
The green roof also makes the upper levels more efficient in cooling and heating months. The increased thermal performance of the roof allows the units below to maintain a stable indoor air temperature and quality that eliminates the need for constant mechanical adjustment. In effect, less energy is used in the entire building lowering costs each year and through the life span of the whole building.

Construction Management

The construction management research will cover a design that utilizes the cost of materials, scheduling, and project delivery tasks. The main cost analysis will be the selection of steel and concrete. Due to the current economy, steel prices are at an all time high which has many designers resorting to concrete structures. With a development that can save cost in other areas of construction such as productivity and project delivery time the difference in cost of the two materials may balance to an efficient design.

The use of pre-cast elements was selected to increase production. The corner of 40th and Chestnut Streets in Philadelphia is a very congested intersection. The streets in this part of the city are one-way directions and accommodate the traffic of local businesses and the commuters of the several schools and universities in the surrounding communities. Also, the limited space presents no staging areas to store materials onsite. The use of pre-cast concrete and steel can be very beneficial in shortening the project duration. The manufacturers of both materials can dispatch their delivery trucks to site when the material is needed. An onsite crane can unload the materials off the trucks and put them in place. The truck can leave and have the next truck follow in sequence.

THESIS RESEARCH SCHEDULE (SPRING 2007)



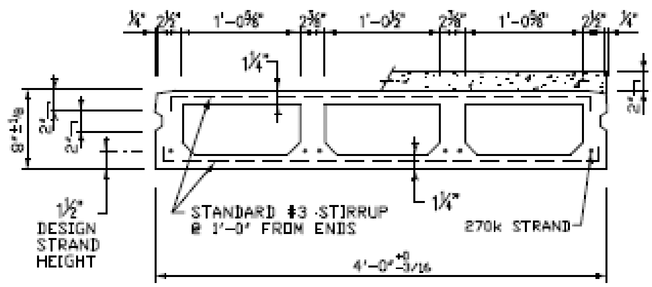
SELECTED PRE-CAST PRODUCT

[Nitterhouse Concrete Products]

Prestressed Concrete
8"x4' SpanDeck–U.L.–J917
(2" C.I.P. TOPPING)

PHYSICAL PROPERTIES
Composite

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



8" SPANDECK CROSS SECTION
UL FIRE RATED J917

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

8" SPANDECK W/2" TOPPING				ALLOWABLE SUPERIMPOSED LOAD (PSF)																			
STRAND PATTERN	SPAN (FEET)																						
	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
Flexure 4 – 1/2"ø	795	718	650	590	500	426	366	317	275	240	210	184	162	142	125	110	96	84	73	60	49	39	X
Shear 4 – 1/2"ø	571	509	458	415	378	347	320	296	275	257	240	222	199	178	160	145	133	126	115	103	93	84	X
Flexure 6 – 1/2"ø	1156	1040	945	859	732	629	544	474	416	366	324	287	256	228	204	183	164	147	132	118	103	90	77
Shear 6 – 1/2"ø	589	525	472	428	391	360	331	308	286	266	249	235	220	207	195	184	175	160	145	132	120	110	100

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.

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