THESIS PROPOSAL

A. EXECUTIVE SUMMARY

BUILDING DESCRIPTION

The Comcast Center is located in downtown Philadelphia, Pennsylvania. The 57 story building functions primarily as office space with some retail and restaurant spaces. The structural system consists of a massive concrete core with steel member framing into the core. The floor system is a composite metal deck. The footprint of the Comcast center tower is approximately 195 feet by 135 feet.

The proposed project will include an analysis and assessment of alternative core systems. The first alternative will look at reducing the concrete core by removing the two outer web members. A steel braced frame core will be used in the second alternative. The systems will be checked for strength, serviceability, construction time, cost, and blast resistance.

With several other LEED rated buildings already completed Liberty Property Trust, the developer of the Comcast Center, strongly supports the sustainable design movement. The Comcast Center will become the largest LEED rated building upon completion. The exact level of rating for which Liberty Property Trust is applying for is not publicized. Currently the sustainable concepts that the Comcast Center will be using are waterless urinals to decrease water usage, high floor to ceiling heights to utilize natural daylight and decrease electricity usage, and an entrance to South Station to encourage the use of public transportation. The proposed thesis will determine the practicality of using energy collecting technologies such as small hidden wind turbines on the roof and photovoltaic patches in the glass façade.

The second breadth topic explored in this thesis will be on Construction Management issues such as cost estimates, site layout, scheduling, and site management. Site management will be assessed from a sustainable viewpoint since it is possible to achieve more points by maintaining an environmentally conscious construction site.

B. BACKGROUND INFORMATION

B.1 GENERAL BACKGROUND

The Comcast Center is currently under construction in downtown Philadelphia, Pennsylvania and is scheduled to be completed in the Fall of 2007. The site of the Comcast Center is defined by John F. Kennedy Boulevard, 17th Street and Arch Street. Upon completion the Comcast Center will be the tallest structure between New York and Chicago at a height of 1001 feet 6 inches (top of roof height). Robert A. M. Stern Architects designed the 57 story building. With an all glass façade the office building will resemble the modern European style skyscraper. A glass box will crown the Comcast Center and will be lit at night for a dramatic addition to the Philadelphia skyline. The office building will also have spaces for a day care, below grade parking garage, fitness center, retail, and a food court.

The developer, Liberty Property Trust, is dedicated to enhancing people's lives through extraordinary work environments. One way Liberty Property trusts achieves this goal is through sustainable design which helps instill a more environment conscience mindset. The Comcast Center occupants will be able to enjoy a 110 foot tall Winter Garden and multiple 3 story stacked atria. The Comcast Center will be the tallest LEED rated building upon completion. One of its features includes waterless urinals which significantly decrease the amount of water used in the office building. The finished floor to ceiling height will be 11 feet to allow for natural light to penetrate deep into the structure and decrease the need for an artificial light source. The Comcast Center promotes public transportation with its below grade connection to South Station.

B.2 STRUCTURAL SYSTEM BACKGROUND

The structural system of the Comcast Center consists of a concrete core that supports steel framing. Composite metal deck floors are used to minimize the floor depth as well as to allow for larger spans and fewer columns. Figure B-1 below is a typical floor plan.

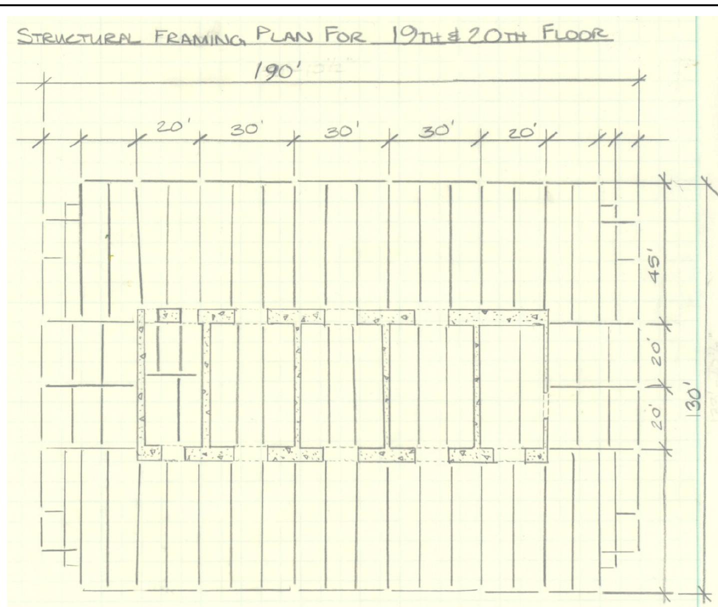

FIGURE B-1: TYPICAL FLOOR FRAMING AT 19TH FLOOR & 20TH FLOOR

The footprint of the Comcast Center is approximately 195 feet by 135 feet. The corners of the rectangular building taper inward as the skyscraper approaches the sky, creating a pleasing aesthetic.

B.2.1 Concrete Core

The concrete core of the Comcast Center provides lateral force resistance through shear walls. Refer to Figure B-2 below which represents a typical concrete core.

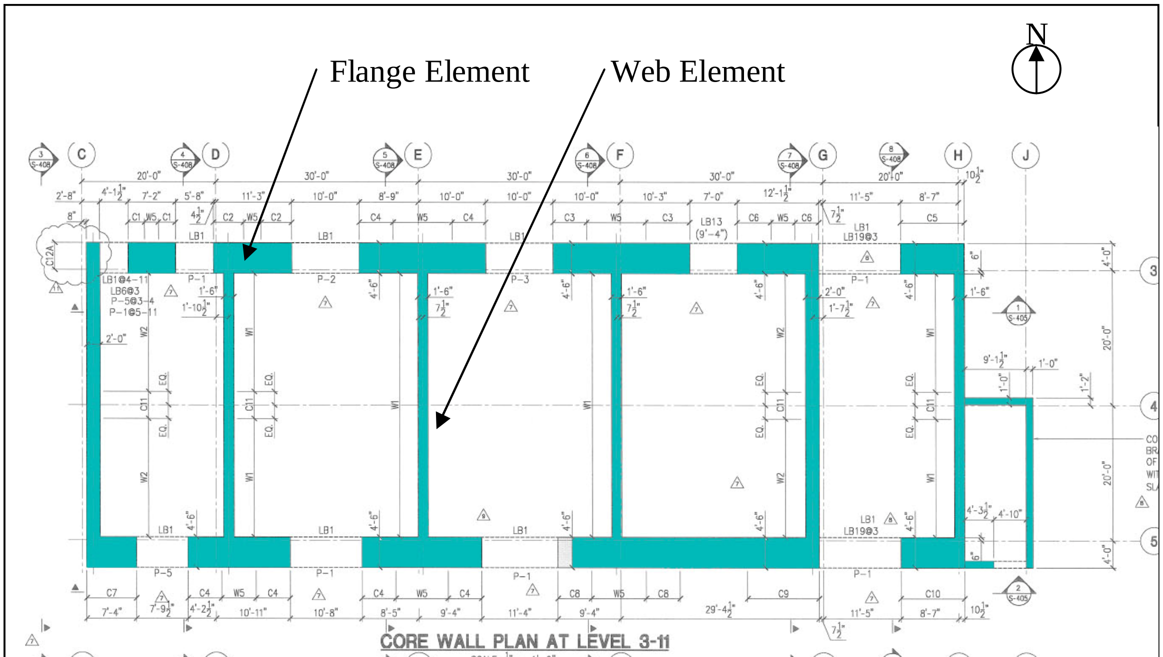

FIGURE B-2: TYPICAL CONCRETE CORE PLAN DETAIL FOR FLOORS 3-11

The concrete core can be divided into flange elements and web elements for discussion purposes as indicated in Figure B-2. The flange elements are 4 feet 6 inches at the base and decrease in a stepped fashion as the tower extends upward. The flange elements resist lateral loads applied to the east and west facades. The web elements along column lines C, D, E, F, G, and H provide lateral resistance for wind loads acting on the north and south facades.

A typical elevation of the concrete core is given in Figure B-3 below. Figure B-4 illustrates the typical reinforcing bar arrangement in the concrete core. Figure B-5 below is a photograph by R. Bradley Maule taken in April 2006 of the concrete core. The photo shows the construction sequencing; first the concrete core is formed with the steel framing following behind. A slip formed is used to create the concrete core. The image shows two cranes that are braced against the concrete core during construction. The core functions as an elevator bank and mechanical system storage.

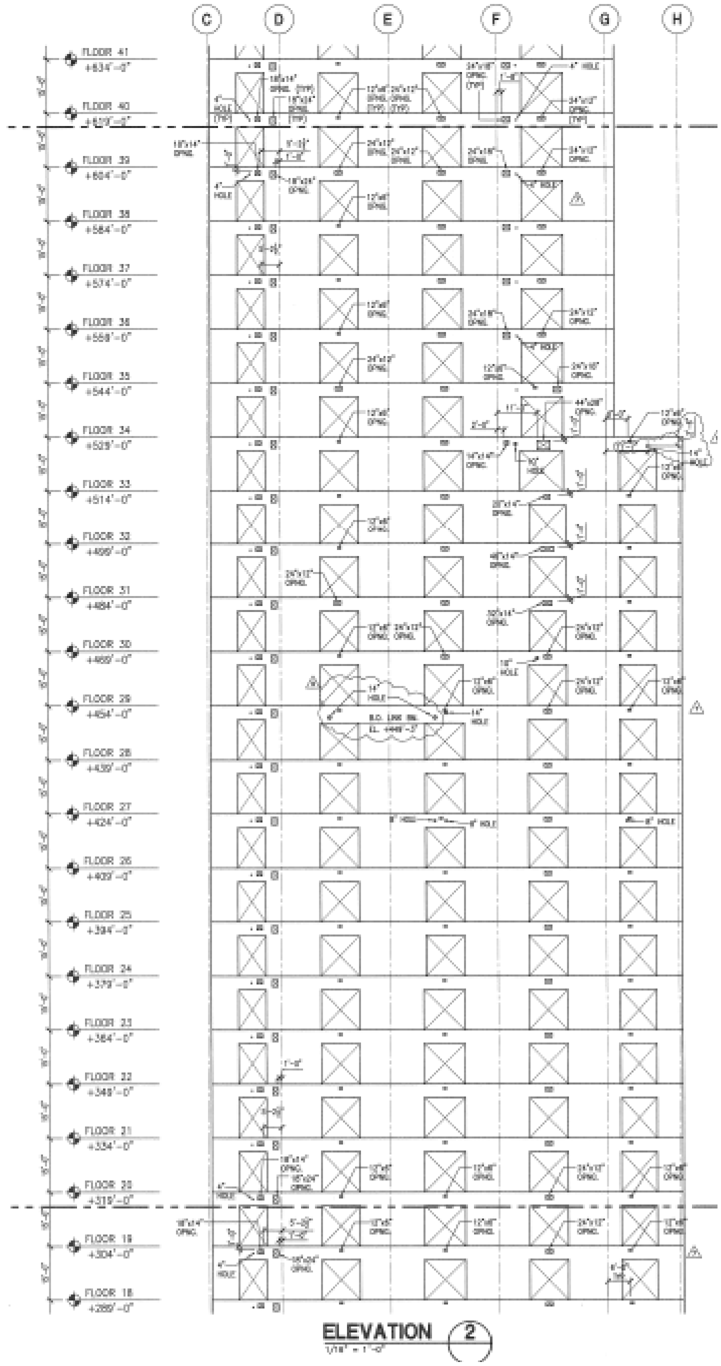

FIGURE B-3: TYPICAL ELEVATION OF CONCRETE CORE

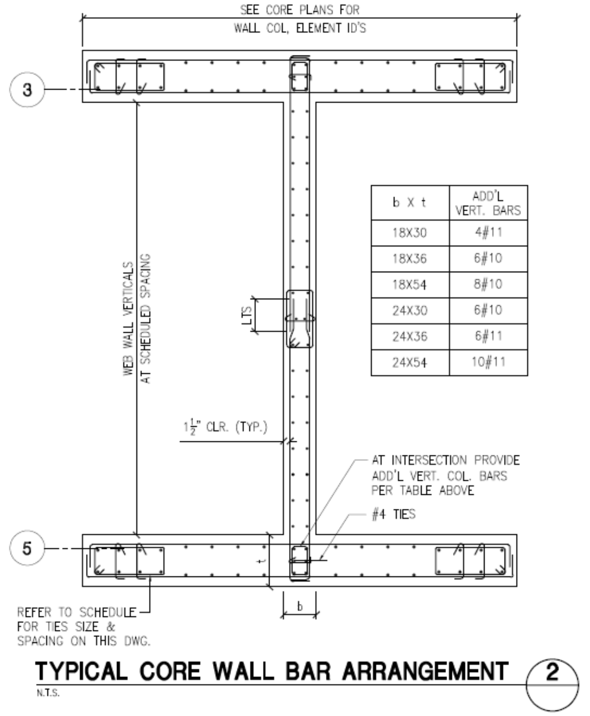

FIGURE B-4: REINFORCEMENT FOR CONCRETE CORE

Photograph Courtesy of R. Bradley Maule

FIGURE B-5: CONCRETE CORE CONSTRUCTED FIRST, STEEL ERECTION FOLLOWS

B.2.2 FRAMING AND FLOOR SYSTEM

The steel beams frame into the concrete core at embedded plates. The embedded plates are visible in Figure B-6 below. A detail of the embedded plate is featured in Figure B-7. These connections are shear connections only and therefore no moment is transferred from the floor system to the concrete core. The floor slab is a composite metal deck slab typically 3-1/4 inches on 3 inch metal deck. Lightweight concrete is used to minimize the weight of the system. Figure B-8 illustrates the typical framing of a typical bay. Forty-five foot long beams spaced 10 feet on center frame into the concrete on one end and a W-shape steel spandrel girder on the other. A section detail of the connection of the composite beam to the concrete core is given in Figure B-9.

Photograph Courtesy of R. Bradley Maule

FIGURE B-6: EMBEDDED STEEL PLATES FOR BEAM TO CONCRETE CORE CONNECTION

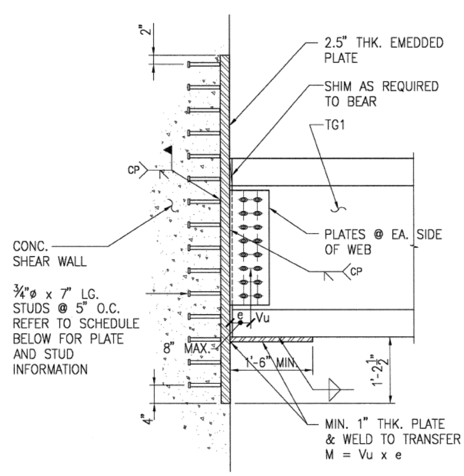

FIGURE B-7: DETAIL OF TYPICAL EMBEDDED PLATE

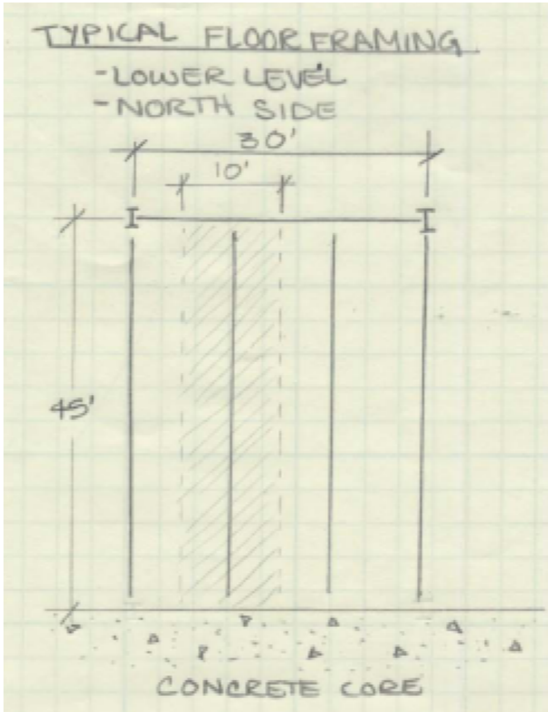

FIGURE B-8: TYPICAL FRAMING OF TYPICAL BAY

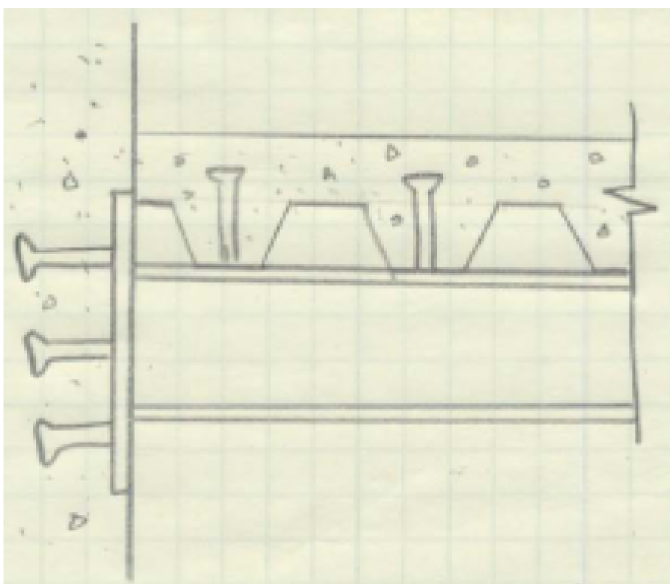

FIGURE B-9: SECTION DETAIL OF COMPOSITE METAL DECK ON BEAM AT CONCRETE CORE CONNECTION

B.3 Loads

The estimated gravity loads on the Comcast Center are given below in Table B-1. An office live load of 50 psf with a 20 psf partition load was assumed for analysis procedures in earlier reports.

Table B-1: Gravity Loads

Live Loads:	PSF	Comments
Office Live	50	
w/ Partitions	20	
Elevator Lobby & Corridors above first floor	80	
w/ Partitions	20	
Corridors above first floor	75	
All other Lobbies and Corridors	100	
Exit Facilities	100	
Retail Areas	100	
Kitchen	150	
Cafeteria	100	
Winter Garden and Atrium	100	
Light Storage Area	125	
Loading Dock	250	or AASHTO HS20-44
Mechanical Floors	150	or actual weight, whichever is greater
Mechanical / Fan Rooms	75	or actual weight, whichever is greater
Sidewalks	250	
Parking Ramp Live	50	

Dead Loads:	PSF
Office Superimposed Dead	15
Lobby Superimposed Dead	45
Mechanical Superimposed Dead	45
Storage Superimposed Dead	15
Parking Ramp Superimposed Dead	20

B.4 Codes and Code Requirements

The structural system of the Comcast Center complies with the City of Philadelphia Building Code, latest edition and the Boca Building Code, 1996 (BOCA 96). When designing the model of the Comcast Center for wind tunnel testing both the ASCE 7 requirements and the BOCA 96 requirements were met. ACI was used for concrete design and the National Electric Code was used for electrical design.

C. Main Design Change: Designing A more efficient Core system

Based on several comments made by design professionals and faculty members the proposed thesis will analyze and assess three alternative core systems with the goal of determining a more efficient system than the existing. The first system that will be explored will involve the removal of two of the web elements from either side of the concrete core. A steel braced frame core system will replace the existing concrete core system in the second alternative. The third alternative will explore reducing the thickness of the web and flange elements of the existing concrete core.

C.1 Alternative #1: Removal of two Web Elements in Concrete Core

C.1.1 Problem Background

The lateral load resisting system of the Comcast Center is composed of shear walls that are grouped in the center of the building to form a core. At the base of the structure there are six concrete web elements running north and south. Two of the web elements are 2 feet thick while the other four web elements are 1 foot 6 inches thick. The web elements are 48 feet long at the base of the structure. The flange elements are 4 feet 6 inches wide at the base of the structure. The flange elements are rather short in length due to the large openings that permit occupants to enter the elevator banks. Steel framing and composite metal deck floors make up the rest of the building. The 57 story office building reaches a height of 1001 feet 6 inches. The footprint of the structure is approximately 195 feet by 135 feet. It was determined in Technical Assignment 1 that wind loads control the lateral load resisting system.

C.1.2 Problem Statement

The lateral system in a structure must be designed to meet strength, serviceability, economic, durability, cost and schedule criterion. The existing concrete core is believed to be larger than structurally necessary.

C.1.3 Proposed Solution

The first alternative system involves removing the two outer flange and web elements. Figure C-1 below indicates which elements are being removed with red shaded boxes.

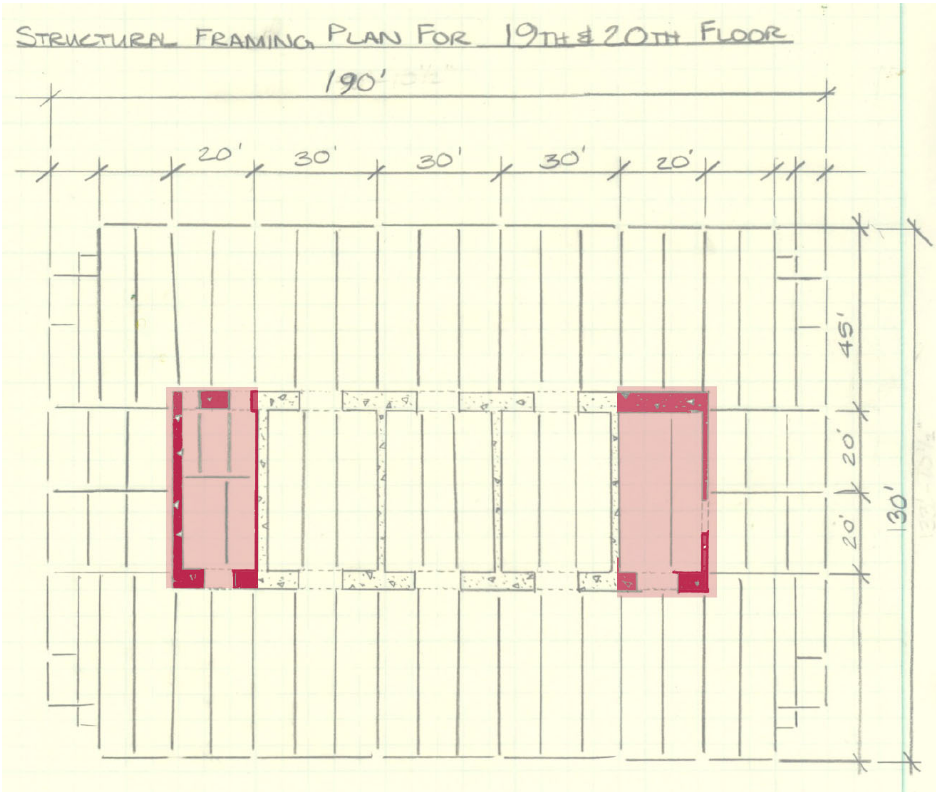

FIGURE 1: EXISTING 19TH FLOOR PLAN. RED SHADED SHEAR WALLS TO BE REMOVED FROM DESIGN

C.1.4 RESEARCH STEPS

1) Check strength and serviceability criterion using BOCA 96.
   a) Check shear strength using hand calculation
   b) Check overturning moment using load factors 0.9Dead + 1.6 Wind by hand calculation
   c) Check drift and story drift
   d) Check fundamental period.
   e) Perform spot checks of critical members by hand calculations.
2) Check cost and schedule criterion using R. S. Means for a cost estimate.
3) Check blast resistance level as compared to blast resistance of the existing structure.
   a) Determine susceptibility of structure to progressive collapse
   b) Evaluate performance in an emergency situation
      i) Accessibility of alternate egress paths
4) Adjust existing computer model in Etabs to represent alternative system.
   a) Review results and compare with hand calculations

C.1.5 Expected Outcome

C.1.5.1 Expected Advantages

Removing these pieces will result in a lighter over all structure and decrease the amount of material used. This will result in a decrease in building material, cost and labor. Removing these sections will result in added marketable floor area which could significantly affect the rate of return for the building.

C.1.5.2 Expected Disadvantages

By removing the two outermost web and flange elements of the lateral system the stiffness of the structure will be decreased significantly. It is possible that the existing shears walls are more than adequate for strength and serviceability criterion and can therefore be removed. If removing these two elements results in an inadequate stiffness it may be necessary to add material to the inner elements. This can become inefficient but would need to be checked against the financial gain of added floor area.

C.2 Alternative #2: Steel Braced Frame Core

C.2.1 Problem Background

Note: Please See Section C.1.1

C.2.2 Problem Statement

Note: Please See Section C.1.2

C.2.3 Proposed solution

The proposed thesis would analyze and assess the substitution of a steel braced frame core in place of the concrete core. Figure C-2 indicates that the braced frames will be replacing the entire concrete core.

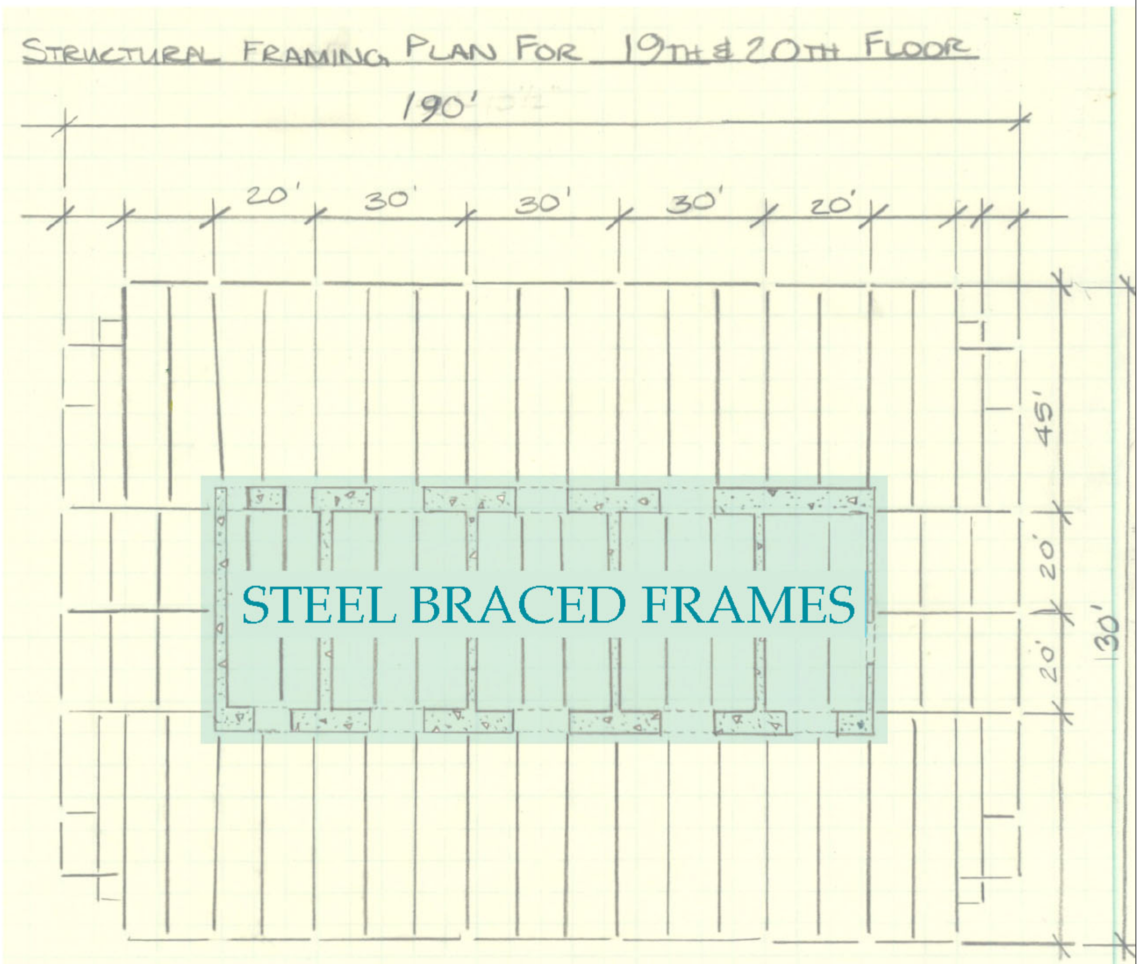

FIGURE C-2: STEEL BRACED FRAMES REPLACE THE EXISTING CONCRETE CORE AS A SECOND ALTERNATIVE

C.2.4 RESEARCH STEPS & SOLUTION METHOD

1. Check strength and serviceability criterion using BOCA 96.
   1.1. Check shear strength using hand calculation
   1.2. Check overturning moment using load factors 0.9Dead + 1.6 Wind by hand calculation
   1.3. Check drift and story drift
   1.4. Check fundamental period.
2. Perform spot checks of critical members by hand calculations.
3. Check cost and schedule criterion using R. S. Means for a cost estimate.
4. Check blast resistance level as compared to blast resistance of the existing structure.
   4.1. Determine susceptibility of structure to progressive collapse
   4.2. Evaluate performance in an emergency situation
      4.2.1. Accessibility of alternate egress paths

5. Adjust existing computer model in Etabs to represent alternative system.
6. Review results and compare with hand calculations

C.2.5 Expected Outcome

C.2.5.1 expected Advantages

The overall core would likely be much lighter than the existing concrete structure. Using a braced steel frame in place of a concrete core will likely decrease construction time.

C.2.5.2 expected disadvantages

Since the braced frame system is not as rigid as the existing concrete system the drift may be greater. The temporary cranes were easily braced by the existing concrete. The steel framed core will not allow for such an easy connection.

C.3: Alternative #3: Reducing thickness of web elements and Flange Elements

C.3.1 Problem Background

Note: Please See Section C.1.1

C.3.2 Problem Statement

Note: Please See Section C.1.2

C.3.3 Proposed solution

A significant amount of weight can be removed from the concrete core by reducing the thickness of the web and flange elements. This theory will be applied to a 6 wall concrete core system.

C.3.4 Research Steps & solution Method

1. Size a new concrete core
    - 1.1. Determine the loads acting on the concrete core using previous calculations
    - 1.2. Check construction loads from crane on concrete core
    - 1.3. Determine the strength and serviceability criterion
    - 1.4. Size the web and flange elements of the concrete core
2. Perform Cost estimate using R. S. Means

C.3.5 Expected Outcome

C.3.5.1 Expected Advantages

Reducing the thickness of the flange and web elements of the concrete core will decrease the weight of the structure. Less material will be used which will decrease the cost of the structure.

C.3.5.2 Expected Disadvantages

Decreasing the thickness of the concrete core elements may eliminate some of the redundancy built into the structure to avoid progressive collapse.

D. Breadth Topics

D.1 Sustainability & LEED Rating Breadth: Energy Collection Systems

D.1.1 Problem Background

The Comcast Center has a very large surface which is exposed to a tremendous amount of energy from the sun. Low-E tinted glass makes up the entire façade. The Comcast Center will be just one of the many LEED Rated buildings developed by Liberty Property Trust.

D.1.2 Problem Statement

A tremendous amount of energy from the sun reaches the façade of the Comcast Center. If this energy can be collected and stored in an economical way, it could be enough to power the Comcast Center.

D.1.3 Proposed solution

The proposed breadth topic will assess the feasibility of adding an energy collecting system to the Comcast Center. The first possible system involves placing small wind turbines at the parapet. The small turbines are not visible and generate a large amount of energy. The second system would collect the energy of the façade by using glazing that has photovoltaic (PV) patches between the two plates of glass. The patches can vary in size and would be hardly visible.

D.1.4 Research Steps & Solution Method

1. Research PV patch glazing
   - 1.1. Research existing PV patch glazing systems for problems and suggestions
   - 1.2. Locate Manufacturers to determine accessibility
   - 1.3. Research Cost to determine feasibility
   - 1.4. Sketch or Render image to show the minor architectural affects
2. Research miniature wind turbines for roof parapet
   - 2.1. Research existing systems on high rise structures for efficiency
   - 2.2. Locate Manufacturer for Cost, Procurement issues
   - 2.3. Determine where exact location of the miniature wind turbines will be placed
   - 2.4. Identify any possible issues specific to the Comcast Center
3. Research energy storage systems
   - 3.1. Determine a location for the energy storage system
   - 3.2. Assess the effects of the location on the structural system

D.1.5 Expected Outcome

The miniature wind turbines may prove more effective since they do not impact the architecture of the building. Both systems might be necessary to collect enough energy to run the entire building. Using both systems may prove to be more effective in that on a clear sunny day there is no wind but on a cloudy day there is likely much more wind.

D.1.5.1 Expected Advantage

The energy collected could be enough to power all of the electrical elements of the Comcast Center.

D.1.5.2 Expected Disadvantage

A likely disadvantage of the energy collecting system is the high upfront cost of the system. Since these systems are relatively new maintenance and repairs on them may cost a significant amount more than a traditional system.

D.2 Construction Management Breadth

D.2.1 Problem Background

The Comcast Center is located in downtown Philadelphia. The lot is defined by John F. Kennedy Boulevard, Arch Street and 17th Street. The Comcast Center will be the new tallest building between New York and Chicago.

D.2.2 Problem Statement

This urban location limits the space available for the site layout and causes site scheduling to become very critical. The site layout out is also restricted by the limited space The Comcast Center will be the new tallest building in Philadelphia making it a potential terrorist target. With the goal of obtaining a LEED Rating, the upfront costs will likely be rather high.

D.2.3 Proposed solution

The proposed breadth topic will evaluate the current construction management components of the Comcast Center project. Alternative methods and techniques will be assessed to determine the efficiency of the current construction management aspect of the building. One such topic to be explored is the site management for LEED rating.

D.2.4 Research Steps & Solution Method

1. Perform Cost Estimate Analysis of Existing Structure and Alternative Structures
2. Determine current construction schedule
3. Evaluate possible site layout based on flow of trades
4. Contact Construction Manager, L.F. Driscoll
5. Visit Site
6. Refer to monthly photo documentation of Comcast Center on Phillyskyline.com

D.2.5 Expected Outcome

D.2.5.1 Expected Advantages

The analysis of the current construction management techniques will identify areas that can be improved to earn a higher LEED Rating.

D.2.5.2 Expected Disadvantages

The changes needed to earn a higher LEED Rating may be difficult to implement or costly.

E. Time Table

The following calendar tables indicate the schedule for the proposed thesis.

			January			
Sunday	**Monday**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**
	1	**2**	**3**	**4**	**5**	**6**
7	**8**	**9**	**10**	**11**	**12**	**13**
14	**15** Interview in Boston	**16** First Day of Classes	**17** Alt. #1 Hand Calcs Strength & Servicability	**18** Alt. #1 Hand Calcs Spot Checks Cost Analysis	**19** Alt. #1 Etabs Model: Geometry	**20**
21	**22** Alt. #1 Etabs Model Loads	**23** Alt. #1 Etabs Model Assessment	**24** Alt. #1 Meet with Advisor to discus work	**25** Alt. #1 Write up Findings	**26** Alt. #1 Write up Findings	**27**
28	**29** Alt. #2 Hand Calcs Strength & Serviceability	**30** Alt. #2 Hand Calcs Spot Checks	**31** Alt #2 Research if Necessary			

			FEBRUARY			
SUNDAY	**MONDAY**	**TUESDAY**	**WEDNESDAY**	**THURSDAY**	**FRIDAY**	**SATURDAY**
				1 Alt. #2 Etabs Model Geometry	**2** Catch Up Day	**3**
4	**5** Alt. #2 Etabs Model Loads	**6** Alt. #2 Etabs Model Assessment	**7** Alt. #2 Meet with Advisor to discuss work	**8** Alt. #2 Write Up Findings	**9** Alt. #2 Write Up Findings	**10**
11	**12** Catch up Day	**13** Alt #3 Hand Calcs Strength & Serviceability	**14** Alt #3 Hand Calcs Strength & Serviceability	**15** Alt #3 Meet with Advisor to discuss work	**16** Alt #3 Hand Calcs Spot Checks & Cost Analy	**17**
18	**19** Catch up Day	**20** Alt #3 Etabs Model Geometry	**21** Alt #3 Etabs Model Apply Loads Run Model	**22** Alt #3 Write Up Findings	**23** Alt #3 Write Up Findings	**24**
25	**26** Catch Up Day	**27** Catch Up Day	**28** Visit Job Site & Meet with CM			

			MARCH			
SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
				1 Visit Job Site & Meet with CM	2 Write Up Info from Site Visit	3
4	5 Breadth #1 Research	6 Breadth #1 Research	7 Breadth #1 Research	8 Breadth #1 Cost Analysis	9 Breadth #1 Misc.	10
11	12 Spring Break	13 Spring Break	14 Spring Break	15 Spring Break	16 Spring Break	17
18	19 Breadth #1 Write up Findings	20 Breadth #1 Write up Findings	21 Catch up Day	22 Breadth #2 Research	23 Breadth #2 Research	24
25	26 Catch up Day	27 Breadth #2 Cost Analysis	28 Breadth #2 Cost Analysis	29 Breadth #2 Misc	30 Breadth #2 Write up Findings	31

			APRIL			
SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
1	2 Write Report Work on Presentation	3 Write Report Work on Presentation	4 Write Report Work on Presentation	5 Write Report Work on Presentation	6 Write Report Work on Presentation	7
8	9 Write Report Work on Presentation	10 Write Report Work on Presentation	11 Make final adjustments to report	12 Written Report Due	13 Rehearse Presentation	14
15	16 Presentations	17 Presentations	18 Presentations	19 Presentations	20 Presentations	21
22	23	24	25	26	27	28
29	30					

E. Tasks and Tools

ALTERNATIVE CORE SYSTEMS 1 AND 2

1. Check strength and serviceability criterion using BOCA 96.
   1.1. Check shear strength using hand calculation
   1.2. Check overturning moment using load factors 0.9Dead + 1.6 Wind by hand calculation
   1.3. Check drift and story drift
   1.4. Check fundamental period.
2. Perform spot checks of critical members by hand calculations.
3. Check cost and schedule criterion using R. S. Means for a cost estimate.
4. Check blast resistance level as compared to blast resistance of the existing structure.
   4.1. Determine susceptibility of structure to progressive collapse
   4.2. Evaluate performance in an emergency situation
      4.2.1. Accessibility of alternate egress paths
5. Adjust existing computer model in Etabs to represent alternative system.
6. Review results and compare with hand calculations

ALTERNATIVE CORE SYSTEM 3

1. Size a new concrete core
   1.1. Determine the loads acting on the concrete core using previous calculations
   1.2. Check construction loads from crane on concrete core
   1.3. Determine the strength and serviceability criterion
   1.4. Size the web and flange elements of the concrete core
2. Perform Cost estimate using R. S. Means

BREADTH #1: SUSTAINABILITY: ENERGY COLLECTION SYSTEM:

1. Research PV patch glazing
   1.1. Research existing PV patch glazing systems for problems and suggestions
   1.2. Locate Manufacturers to determine accessibility
   1.3. Research Cost to determine feasibility
   1.4. Sketch or Render image to show the minor architectural effects
2. Research miniature wind turbines for roof parapet
   2.1. Research existing systems on high rise structures for efficiency
   2.2. Locate Manufacturer for Cost, Procurement issues
   2.3. Determine where exact location of the miniature wind turbines will be placed
   2.4. Identify any possible issues specific to the Comcast Center
3. Research energy storage systems
   3.1. Determine a location for the energy storage system
   3.2. Assess the effects of the location of the energy storage system on the structural system

BREADTH #2: CONSTRUCTION MANAGEMENT:

1. Perform Cost Estimate Analysis of Existing Structure and Alternative Structures
2. Determine current construction schedule
3. Evaluate possible site layout based on flow of trades
4. Contact Construction Manager, L.F. Driscoll
5. Visit Site
6. Refer to monthly photo documentation of Comcast Center on Phillyskyline.com