CHAPTER 4: CONSTRUCTION INVESTIGATION

4.1 INTRODUCTION

The second breadth topic of this thesis report is a construction investigation of the redesigned of National Harbor Building M. The majority of this investigation will be conducted as a comparison between the originally designed steel structured building and the redesign post-tensioned concrete building. The main objective of the entire thesis report is to determine whether the redesigned building can effectively replace the original steel design. As stated at the beginning of the report, to be considered a successful replacement the redesigned building must meet or exceed the original structure in most aspects without presenting any major drawbacks. In order to completely fulfill this objective the concrete design must be comparable in the critical area of construction.

This chapter will consider the construction side of building design through the areas of cost, site layout, and schedule. These construction issues are ones which could make or break the evaluation of the redesigned structure. Even though the concrete structure may be able to measure up to all of the building's functional and structural requirements, if its cost is an appreciable amount more or takes a considerably long time to construct, it would be considered a poor alternative. Furthermore, if the site's layout does not provide ample room to construct this building it will not matter how effective the design actually is.

4.2 COMPARABLE COST

The building industry like any other industry is driven largely by financial factors. While the cost of building system is not always the bottom line when it comes to the selection of design it definitely has a high impact. With that being said, this section will evaluate the steel based structure and the concrete based structure on a comparable cost investigation.

A comparable cost investigation was selected for this section for a variety of reasons. Since the concrete redesign was done with an attempt to maintain the building's original function and layout, many aspects of the designs overlap. For example, it is assumed that the façade system used on the building's front and two sides can be applied to either system without any appreciable financial affects. Additionally, factors which consider project location as it pertains to labor and regional prices can be neglected. The comparable cost investigation then will offer its results in the form of a percentage of the design's total costs as opposed to a total project cost.

In conducting the comparable cost investigation the first step was to determine the differences that would need to be considered between the two designs. The basic gravity and lateral systems were an obvious place to start. The steel structure's cost considers all of its structural columns, beam, and braces which make up both systems. The concrete structure's cost considers its columns, shear caps, and shear walls. As for the floor systems the steel structure's decking, concrete, and reinforcement were considered while the concrete and post-tensioning cables were considered for the concrete structure. Another area considered was the rear wall façade discussed in chapter 3. The CMU shear wall system was priced for the original design and the architectural precast façade was priced for the redesign. Finally, additional cost was added to the concrete structure for the modification of the foundation system. It should be noted that this modification considered only the price of additional piles and not the cost of increase in pile cap size. It was assumed the minimal increase in the amount of concrete used was not enough to appreciably affect the overall comparison. The different system components considered are summarized in Figure 4-1.

COMPONENT	EXISTING STEEL STRUCUTRE	REDESIGNED CONCRETE STRUCTURE
Gravity/Lateral System	W-Shape Steel Columns	Reinf. Concrete Columns
	W-Shape Steel Beams	Reinf. Concrete Shear Walls
	W-Shape Steel Braces	Concrete Shear Caps
	Steel Studs	
Floor System	Steel Decking	Normal weight Concrete
	Lightweight Concrete	Post-tensioning Cables
	WWM Reinforcing	
Rear Facade	Reinforced 8" CMU Wall	Architectural Precast Wall
Foundation Modification	X	Additional Piles

Fig. 4-1

Once the components to be compared were selected, takeoffs and prices of these systems were researched. A takeoff of the total linear length of specified steel shapes used in the original design was generated from a RAM Structural System model takeoff printout. This printout also included the total square footage of floor area which was used to determine the amount of concrete, decking, and reinforcing to be priced. A manual takeoff was done on the CMU wall to determine the total square footage of wall, the amount of bond beams used, and the tonnage of reinforcement to be priced. Since the concrete redesign used the same column layout and exterior dimensions as the original structure, the same square footage of floor area was used for its pricing. Additional material takeoff for the post-tensioning floor system came from a takeoff generated by the RAM Concept model used in its design. Manual takeoffs were also performed to obtain the concrete used in the shear caps/drop panels, the architectural precast wall, and the foundation piles.

Prices for all quantities of building components were then gathered from RS MEANS 2008. The prices used for the comparable cost investigation were a total cost that included material, labor, and equipment. To stay consistent when pricing the concrete in each design the same placement and formwork details were used. For example, the price for placement of both designs is based off of pumped concrete as opposed to crane and bucket. When it came to pricing the architectural precast wall the actual size panel used in the design was not available in the RS MEANS catalog. In order to obtain an approximate price for the wall system the prices given were graphed and extrapolated to the size of wall panel required. Figure 4-2 shows a summary of the percentage difference between the components of the two designs and an overall comparable price breakdown. A more detailed spreadsheet containing all of the calculated quantities, unit prices, and component costs used can be found in the appendix.

COMPONENT	EXISTING STEEL STRUCUTRE	REDESIGNED CONCRETE STRUCTURE
Gravity/Lateral System	Base	-204.32%
Floor System	Base	+165.55%
Rear Facade	Base	-33.50%
Foundation Modification	Base	+$36,000
TOTAL COMPARABLE PRICE	Base	-22.50%

Fig. 4-2

In analyzing the results of comparable cost investigation the overall price of the redesign post-tension system is 5.6% cheaper than the overall price of the existing steel design. This means that the design of the post-tensioned concrete building discussed in chapter 2 can be considered a viable system from a financial standpoint. Further, after breaking down this cost comparison it is confirmed that the architectural precast wall façade, selected in chapter 3, is a cheaper façade system than the existing CMU wall system. Comparison between the other component systems, while included to give a general breakdown, can be somewhat ambiguous. The comparative prices and percentages of prices greatly depend on what was included in each system. For example, the price of gravity beams and their shear studs could have easily been included in the floor system price thus dropping the differential between the two designs. Similarly the drop caps/shear caps of the concrete could have been included in its floor system prices as opposed to the prices of the gravity system. In the end all the differing elements are added so the total comparison gives the best indication of price differential between the two designs.

4.3 SITE LAYOUT INVESTIGATION

This section will explore the site surrounding the footprint of National Harbor Building M, making sure there is enough room to support all required staging and construction equipment. Since the existing site was large enough to support the original steel-based construction set up, it would be logical to assume a concrete-based set-up would work as well. This is based off the fact that steel construction requires a larger staging area for structural steel and a crane for placement, while concrete construction only requires small staging areas for rebar and tendons and room for a pump truck. Still, the site will be examined in an attempt to set up the layout efficiently.

Building M is being constructed in an entirely new development, thus eliminating some issues with finding area for staging and trailers around existing buildings. After examining construction photos and schedule information it was determined that the adjacent parking structure designed simultaneously to Building M will not begin construction until the Building M's structure is completed. Assuming this construction progression is also used in the redesign, the main construction site layout and staging area will be located over the footprint of the adjacent parking structure. This location will allow cement trucks and pump trucks used to place the concrete access to the long side of the building.

Access to the construction site of Building M will come from Waterfront Street, which runs parallel to the front of the building, and Potomac Passage, which runs parallel to the construction site (See figure 4-3). To simplify traffic, deliveries, and truck access to the site a one-way traffic pattern will be used. The traffic pattern will be one-way on Potomac Passage, traveling from Waterfront Street to Fleet Street. A turn into the site from Potomac Passage and loop around will allow trucks to make deliveries without having to turn around.

A staging area will be located close enough to the building footprint to prevent multiple transportations of materials. This means that the materials stored in the staging area can be taken directly from the staging to the structure. This eliminates unnecessary transportation that would be required if the staging area was located at a considerable distance from the structure. For waste collection on site this project will employ two separate dumpsters. One dumpster will be for concrete materials that need to be discarded and the other will be for general waste collection. Using two separate dumpsters on a concrete project can save money when it comes to waste removal. Typical dumpster removal charge is based on the weight of the material being removed. If concrete waste is included, much heavier than typical waste, in these dumpsters the cost of removal can increase significantly. Dumpsters specifically filled with concrete can be removed by a separate company which usually charges a per dumpster rate. Thus the typical light waste is removed per weight and the heavier concrete waste is removed per dumpster lowering the overall waste removal cost. Figure 4-3 is a site layout of Building M showing traffic patterns, staging locations, and dumpster locations.

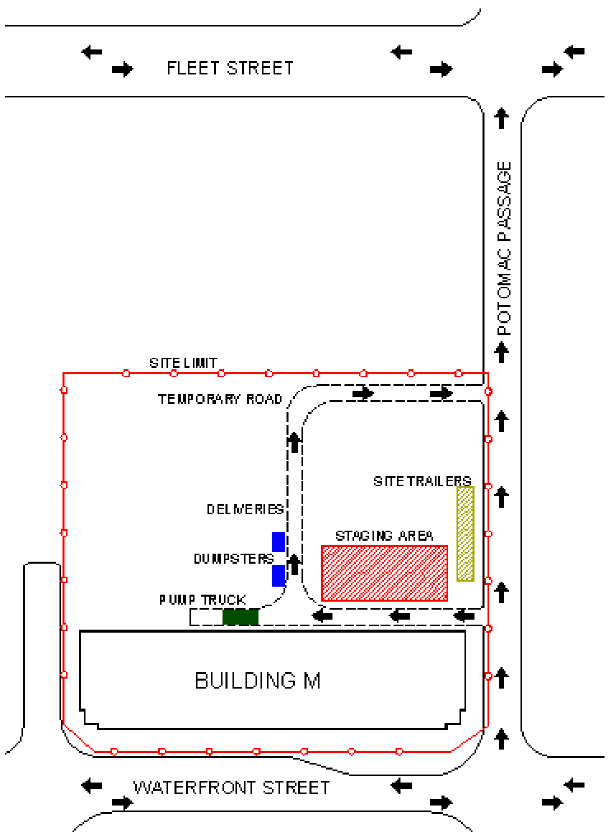

Fig. 4-3

4.4 SCHEDULE INVESTIGATION

The schedule of a project lays out the approximate time it will take for a building to be constructed. When it comes to an office/retail tenant fill out building, like is the case for Building M, the faster the building can be constructed, the earlier the owner can begin collecting rent from the tenants. That being said, the efficiency of the concrete redesign cannot be fully evaluated without investigating its project schedule. This section will discuss some differences between typical steel construction and concrete construction schedule and present the concrete redesign schedule.

The main difference between typical steel construction and concrete construction is what parts of the construction process take the longest for each respective case. In steel construction a large amount of time is spent detailing steel members and connections and preparing shop drawings. Also it takes a considerable amount of time to order, produce, and ship the steel members. A typical job could take approximately six weeks to complete the drawings, two weeks to have them approved and an additional twelve weeks to order and ship the members. However, once the paperwork and ordering is completed a steel structure can be erected at a relatively fast pace.

In concrete construction the opposite is true; the majority of the construction time is spent erecting the structure. Concrete plans and shop drawings are typically not as complicated as steel plans and approximately take three weeks to be prepared. Once erection begins a concrete structure moves along at a relatively slow pace due to the construction of formwork and required curing time for the concrete.

To determine an approximate length for the construction of the concrete redesign a schedule was created covering the shop drawing process and erection of the structure. Durations used for different stages of the schedule were obtained through discussions held with a professional engineer familiar with post-tensioned construction. The schedule for the redesign was broken into three main components; Detailing/Shop Drawings, Columns/Shear Walls, and Slabs.

The detailing and shop drawing section of the schedule is the initial step in the construction process. Once the design has been completed shop drawings and construction details are created and approved by all appropriate parties. It was determined that this process for a job the size of Building M would take approximately three weeks to be completed.

The construction of the columns and shear walls of the design was broken into two different stages and considered on a per floor basis. The first stage contains the construction of the formwork the columns and walls, the placement of their reinforcement, and the pouring of their concrete through the use of a pump truck. This stage was determined to take three days per floor. The second stage considers a three day curing period, at the end of which test cylinders are broken and checked, and the stripping of the formwork. This stage is to last four days, three for the curing and one for striping, for a total of seven days per floor for the columns and shear walls.

The slab construction was broken into three separate stages of construction. The first stage, as is the case for the columns and shear walls, was forming, reinforcing, and pouring at a duration of five days per floor. The second slab stage was the curing process, again lasting three days. The final stage of the slab construction consists of stressing the tendons in the slab, then striping the formwork and re-shoring the slab. The re-shoring of the slab allows work to continue proceeding even though the slab has yet to reach it ultimate strength. This stage is considered to last 2 days per floor for a total 10 days to construct a slab at one floor level.

The sequencing considered for construction has the construction of stage one of a slab beginning after stage two of the columns from the level below is completed. The construction of stage one of the next levels of columns and shear walls can begin once stage two of the slab below has been completed. A summary of the components of the schedule can be seen in figure 4-4 and a complete version of the schedule can found in the appendix.

Summary of Schedule Components:

Component	**Stage**	**Procedure**	**Duration (days/fl.)**
Detailing/Shop Drawings	--	Completion/Approval	21
Columns/Shear Walls	1	Formwork/Reinforcing/Pouring	3
	2	Curing/Stripping of Formwork	4
Slab	1	Formwork/Reinforcing/Pouring	5
	2	Curing	3
	3	Stressing Tendons/Stripping Formwork	2

Fig. 4-4

The sequencing of the five stories of columns, shear walls, and slabs end up totaling a duration of just over four months (see complete schedule in appendix). In looking at the total construction time of the existing steel structure, the total construction time was from March 2007 to February 2008, or twelve months. It is reasonable to assume that if the core structure of the building can be completed in four months or one-third of the total construction time, then the redesign construction can be completed in a comparable amount of time to the original design.