The Health Care Center

Dauphin County, PA

Ken Lorenz

Construction Management

Senior Thesis – Spring 2007

Dr. David Riley

Construction Management - Ken Lorenz

Health Care Center
Central Pennsylvania

PROJECT TEAM:

- **Owner:** Anonymous
- **CM:** Gilbane Building Co.
- **Architect:** Murray Associates
- **Structural Engineer:** Whitney, Bailey, Cox, Magnani
- **MEP Engineer:** Barton Associates
- **Civil Engineer:** Pennoni Associates, Inc.

PROJECT FEATURES

- **Occupation:** Medical/Health Care Facility
- **Construction Dates:** August 06 - August 08
- **Cost:** $25 Million
- **Size:** 100,000 SF
- **Number of Stories:** 2
- **Leed Certified**

STRUCTURE

- 4" Slab and slab-on-deck
- Cast-in-place continuous footing around the perimeter of building
- Structural Steel Columns on top of cast-in-place spread footings
- Structural Steel beams and girders connecting to the columns

CONSTRUCTION

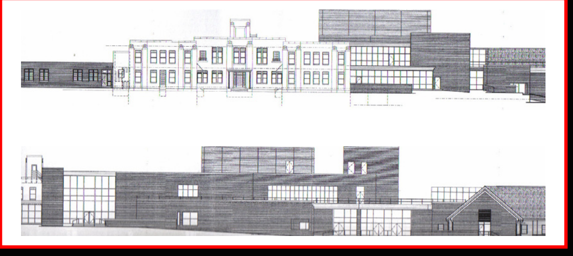
- 20% renovation work and 80% new construction
- Existing building demolition requires removal of asbestos and lead paint
- Maintain use of existing building until renovation work completed

ARCHITECTURE

- Facade consists of brick veneer and aluminum siding with aluminum clad windows to match the Art Deco style of the existing building

MECHANICAL, ELECTRICAL, & LIGHTING

- 10 Air Handling Units (3 in basement, 7 on roof)
- 500 kVA and 150kVA, 120/208V, 3 phase dry type transformers in basement
- Two 30kVA, 120/208, 3 phase dry type transformers in penthouse level
- Flourescent, Incandescent, and HID lighting throughout building



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EXECUTIVE SUMMARY

The following Spring 2007 Senior Thesis, for Penn State's Architectural Engineering program, will cover an entire school year's work and analysis on the Health Care Center, located in Dauphin County, Pennsylvania. Included in this report is a building overview, local conditions, building systems, proposal, research analysis, structural breadth analysis, mechanical breadth analysis, and recommendations to those analyses.

The building overview will give a brief introduction about the Health Care Center, the function of the building, project team involved and a brief introduction into the report. The local conditions will describe where the building is located and what the subsurface conditions are like. The building systems section discusses the structural, mechanical, and electrical systems along with other interesting facts about the building.

The proposal will briefly describe what will be analyzed in the research and breadth topics. The research topic will be analyzing the integration of value engineering and sustainability; a topic that affects the construction industry. The purpose is to incorporate value engineering to a project that is striving for LEED or another sustainable status. Value engineering will be used to find alternative solutions without affecting the building's green accreditation. The structural breadth will analyze a six inch concrete foundation wall that extends sixteen feet high to the roof elevation. The mechanical breadth will examine the Health Care Center's plumbing system, finding an alternate system to the increasing problem of highly priced copper piping.

After the analyses, a recommendation is made on the two breadth areas that will be most beneficial to the Health Care Center.

ACKNOWLEDGEMENTS

I would like to thank all of the people and companies that have helped me throughout my thesis research. First and foremost I would like to thank the anonymous boarding school and their Planning, Designing and Construction division who allowed me to use the Health Care Center and all the areas of research. Without them I would not have been able to use their building. Next I want to thank Gilbane Building Company, especially Dennis Vance and Lee Sokloski, who thought of the project and directed me to Andrew Notarfrancesco, the project manager. Andrew, thank you for answering all of my questions and supplying me with all of the drawings. I also want to thank the rest of the project team that is working on the Health Care Center. A special thanks to Terry Saad from Whitney, Bailey, Cox & Magnani for helping me with my structural analysis. Thank you to everyone in the construction industry who responded to my emails and questions. Also, thank you to all the Penn State Architectural Engineering faculty and staff, especially the construction management professors. Lastly, I would like to thank all of my family and friends for their support and help.

BUILDING OVERVIEW

INTRODUCTION

The Health Care Center, located in Dauphin County, Pennsylvania, is an addition and renovation project that will be serving a boarding school, who wishes to remain anonymous, as well as its local community. The Health Care Center's function is similar to medical facilities found on college campuses, such as the Ritenour building on Penn State's campus, which serves as an infirmary, workplace, and educational tool. The building's addition will include new rooms for patient care, office and administrative space, a cafeteria and kitchen, and a gymnasium. The work involved in this project will be extensive and costly and will need to incorporate an integrated team to deliver and meet expectations.

The project team involved in this process is the boarding school's own Planning, Designing, and Construction division, Murray Associates (architect), Whiney, Bailey, Cox, & Magnani (structural engineers), and Gilbane Building Co. (construction managers). The Health Care Center is a partial two story above grade structure with a partial basement level. The project, which will be going for LEED (Leadership in Energy and Environmental Design) certification, will be 80,000 square feet (SF) of new construction and 20,000 SF of renovation. The project delivery method chosen for the Health Care Center is design-bid-built with Gilbane contracted as a CM agent. The total duration of construction was scheduled for a full 2 years beginning in August 2006 and completing in August 2008. Due to some unexpected set-backs mentioned later in the research, the project has been delayed. The overall cost of the project is expected to reach $25 million. The intricate details of the Health Care Center's renovations and additions will be described throughout the thesis.

The following analysis will focus on the construction management aspect of the Health Care Center with special considerations in constructability, cost impact and schedule reduction. The integration between value engineering and sustainability will be analyzed and studied to help the construction industry. The integration between the two will also be used in areas of the Health Care Center where the building can save some money while still maintain its LEED certification. These areas specifically refer to the redesign of a foundation wall and an alternative use of a cross-linked polyethylene tubing, called PEX, which will replace the existing domestic water supply's copper piping. Please note that all information pertaining to the Health Care Center is Ken Lorenz's interpretation and may be different than the means and methods of construction executed by the project team.

LOCAL CONDITIONS

CLIENT

The Health Care Center is operated and owned by an anonymous boarding school that was originally founded in 1909. It started as an idea from a wealthy and successful businessman and his wife who lived in the area, to help children who were less fortunate. Since then the school grew to over 1400 students. With the increase in the student body, the existing Heath Care Center needed more room to accommodate and provide even more care for their students. The owner is very experienced in construction and the additions are one of many buildings that have expanded the boarding school.

LOCATION

The location of the Health Care Center is in Dauphin County, which is located central Pennsylvania (see Figure 1). In this particular area of Pennsylvania, structural steel framing with slab-on-deck buildings seems to be the most common method of construction. Steel buildings are typically less costly and can be erected faster than concrete buildings.

Figure 1 - Picture of Pennsylvania's counties.

SUBSURFACE CONDITIONS

The Health Care Center falls in the Valley and Ridge Physiographic Province which is predominantly made up of bedrock and limestone. Topsoil and bituminous pavement cover large parts of the construction site. Sieve and hydrometer tests were taken to determine that subsurface soil conditions also consist of sands, silts, clay, and mixtures of all of them. Based on all the information from the tests, the soils were concluded to be suitable for the proposed construction. The water table was measured at an elevation height of 380, which is 20' below the existing ground surface elevation. Since the basement elevation will be positioned at 391.7 the water table should not impact the construction of the building. The contour of the Heath Care Center site tends to slope downward in a south to southwest direction in which gradients range from 2 to 3 percent in some areas to 6 to 8 percent in other areas.

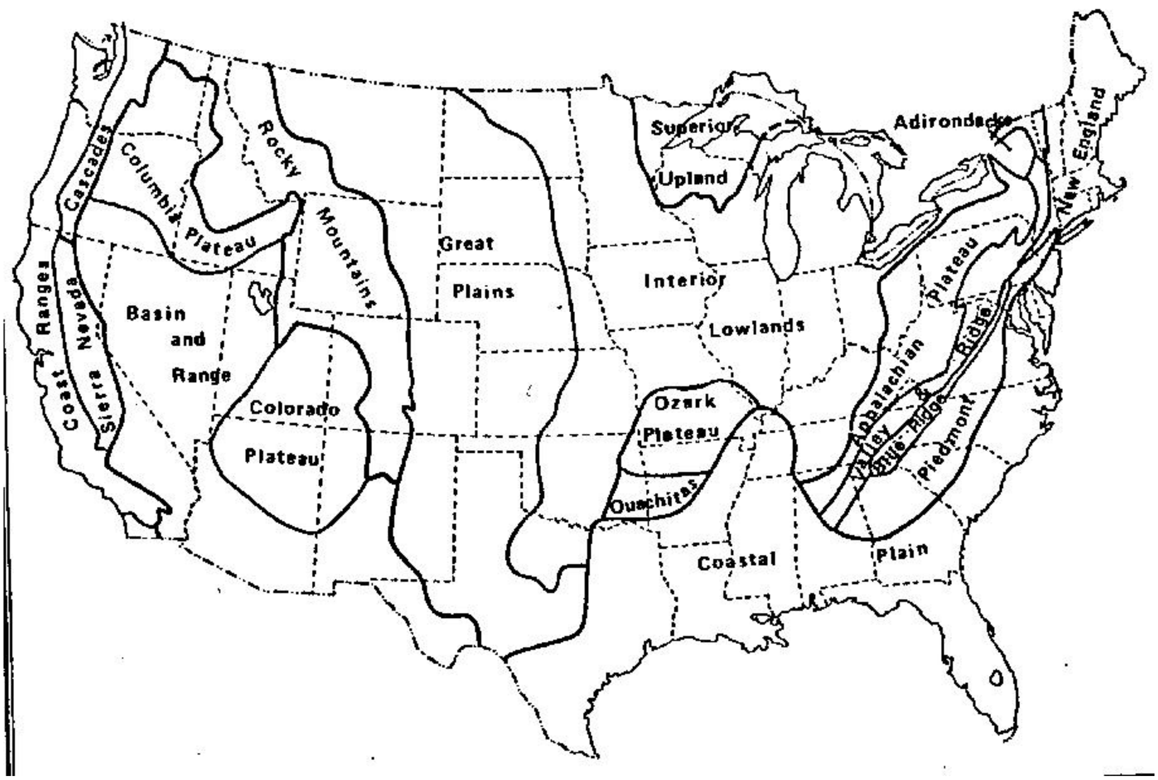


Figure 2 - The valley and ridge physiographic province.

BUILDING SYSTEMS

DEMOLITION

The Health Care Center is 80% new construction and 20% renovation work which makes up the 100,000 SF of total construction. Because the original structure was erected in the 1930's, hazardous materials were used in the original design and must be removed before any construction/renovation can take place. A special demolition contractor has to remove the hazardous materials which include asbestos and lead paint during the renovation work of the existing building. All existing HVAC and lighting, including wiring, fixtures, raceways, light switches, and receptacles are to be removed from the existing building. Before renovation work can begin all new additions must be completed. This is because the Health Care Center must remain operational during the construction process.

STRUCTURAL

The frame of the Health Care Center is a typical structural steel frame. Each steel column is erected on top of cast-in-place concrete spread footings. Cast-in-place concrete foundation walls will be poured in sections B and C (sections shown in Appendix A). Sections A and B will include the basements of the newly remodeled/constructed building. The rest of the buildings perimeter will have a 3 foot deep continuous footing. Building sections C through E will have a 4" concrete slab-on-grade. All cast-in-place concrete will use both horizontal and vertical formwork. Most of the building's framing is made up by wide flanges with metal decking and a 4"slab-on-deck. The roofing uses wide flanges in some areas and steel joists in other areas, like the gymnasium.

MECHANICAL

The mechanical system is very important for the Health Care Center. A section of the Health Care Center will be used as an infirmary which means the air must be free of germs and bacteria that are likely to spread if a good ventilation system is not in place.

The building must also maintain good, indoor air quality for the building to be LEED certified.

There are a total of ten air-handling-units throughout the Health Care Center. There are three located in the basement while the other seven are on the roof. The three in the basement will serve the existing building and cafeteria area, while the other seven will be utilized by the gymnasium, the penthouse, and other new additions. Throughout the building there are exhaust fans, variable air volume (VAV) boxes, cooling towers, and humidifiers. An Electric Control System will be in place to operate and monitor the air system to ensure the air quality stays at healthy and LEED certified levels.

ELECTRICAL/LIGHTING

The Health Care Center's electrical system is composed up of a 500 KVA, 150 KVA and two 30 KVA dry transformers. The 500 and 150 KVA transformers are located in the basement of the building. These transformers are converting the electricity down to 120/208 V and distributing the power to panel boards located on the first and second floors.

The two, smaller 30 KVA transformers are located in the penthouse area where they will convert the electricity to 120/208V. After converting the electricity, the power will be distributed to panel boards throughout the penthouse. As in many other commercial buildings, a majority of the Health Care Center's lighting fixtures are fluorescent. However, in some areas of the building, incandescent and metal halide fixtures are also used.

MASONRY / FAÇADE

The buildings façade consists mostly of brick veneer with aluminum clad windows. The brick is not load-bearing; it only needs to support its self weight. A few parts of the building, like the penthouse, have aluminum siding. The cafeteria has a curtain wall, where there are large aluminum clad windows looking into the dining room.

PROPOSAL

This proposed senior thesis study of the Health Care Center, located in Dauphin County, PA, will concentrate on the research of integrating value engineering (VE) and sustainability. The main idea of this research is to focus on a building that has been designed for LEED or other environmental/energy saving criteria to go through the VE process and not loose any of its sustainable accreditation.

After conducting research on sustainability and value engineering (Research Topic), the Health Care Center will be analyzed in two areas (Structural and Mechanical Breadths) where VE can be utilized to reduce costs, increase productivity, and ensure quality without diminishing the sustainability of the building.

RESEARCH TOPIC – Value Engineering and Sustainability

- Value Engineering and sustainability will be researched so that when executed on any one particular project, green ideas and materials will not be eliminated.
- Areas that will be examined will be the following;
    - What is value engineering?
    - What is involved to ensure a productive value engineering process?
    - Sustainable considerations that should be looked into during the conceptual planning, designing, and construction phases.

STRUCTURAL BREADTH – Redesign of Concrete Foundation Wall

- Alternative – Design foundation wall out of CMU block.
    - Proposed Benefit – Lower material and labor cost, possible schedule reduction while maintaining thermal insulation of wall.

MECHANICAL BREADTH – PEX Tubing for Domestic Water Supply

- Alternative – Replace the domestic water supply copper tubing with PEX tubing.
    - Proposed Benefit – Lower material and labor cost, and possible schedule reduction while adding sustainable design to project.

RESEARCH TOPIC

Value Engineering and Sustainability

PROBLEM

In today's world there is an increasing interest in making things environmentally friendly. The construction industry has gone into green thinking by adopting LEED (Leadership in Energy and Environmental Design) as one of their criterion to determine whether a building is sustainable. Unfortunately, green buildings tend to be a bit more expensive to design and construct than a non-green building. Green materials or products may be more expensive and labor costs may be driven higher because contractors are unfamiliar with that type of work. Not only does a green building affect the cost, but it also impacts the schedule. Special commissioning may need to take place for MEP systems, lead time may be needed for green materials that have to be shipped in, and construction can take longer for laborers who are inexperienced with the type of work.

The research that I will be investigating not only pertains to the construction industry as a whole but also to the Health Care Center. As stated earlier, the Health Care Center is striving for LEED certification and over the last few months, the project has been going through the VE process due to bids coming back over budget.

GOALS

Through my proposed research I hope to develop an approach that effectively and efficiently uses value engineering on any construction project with the outcome of maintaining or even gaining sustainability. I also hope that the construction industry can get a better understanding of how to use value engineering as a tool without reducing a building's sustainability. Lastly, I will be taking the information found from my research and applying it to the Health Care Center. I will be looking into two areas, structural and mechanical, where alternative systems will be evaluated on terms of costs, schedule, quality, and sustainability.

I will use all resources available to come up with the most important and relevant information for my research. I will begin with researching and understanding the methodology of VE. Much of this information can be found in class notes, books, and online. SAVE International (Society of American Value Engineers), which is the international society devoted to the advancement and promotion of the value methodology, will be very beneficial for value engineering ideas and methods. For more information, I will contact industry professionals who are familiar with this area. Next, I will make myself familiar to the LEED manual and research sustainable ideas.

I am confident that through researching and becoming familiar with VE and green ideas that I can develop an effective method to ensure that VE, if used correctly, can reduce project costs without loosing sustainability requirements and status. I will combine the energy saving/environmentally friendly ideas with good VE practice and methodology to make a successful integration between the two. Lastly, after developing a VE and sustainable practice, I will use it for breadth topics for the Health Care Center, which will be discussed later in this report.

ANALYSIS

Introduction

There are a few misconceptions when it comes to value engineering (VE). What is value engineering exactly and what is involved in the value engineering process? Value engineering is not cutting costs, but rather "a systematic effort to find less costly ways to meet the Owner's needs in the building without sacrificing the scope, quality, aesthetics, operating costs or long term maintenance and replacement costs." Applying VE to a sustainable building means that the environment, energy consumption and overall health of the occupants will be taken into consideration when the most value alternative is chosen.

The Value Engineering Process

The value engineering process involves information gathering, analysis, creative brainstorming, evaluation, recommendation, and lastly implementation. It is important to understand the VE process when evaluating a building's alternatives. This will be even more costly when trying to find an alternative solution that requires maintaining the buildings environmental requirements.

Information Gathering

This part of the process, a team wants to learn and gather as much information about the project as possible. Learn what the goals are from the owner, what type of quality needs to be met, what types of building systems are being used, what the budget is, what is the proposed duration of the project, and any other important information. Everything gathered will be used in the next step.

Analysis

In this next step, all the information that was gathered in the first step will be analyzed. Thoughts on why certain systems and materials chosen will come into play. Are there possible alternatives to everything that is included in the current proposed building? Many questions should arise to determine why certain objectives were chosen.

Creative Brainstorming

This part of the process is essentially where the alternative solution comes from. Every innovative and creative possible solution should be thrown out as an idea. There is no wrong idea. The main focus during this part of value engineering is to develop as many possible solutions, so they can be evaluated in the next step to see if feasible.

Evaluation

The most innovative and best ideas developed from the creative stage will now be evaluated. They will be examined closely in cost, quality, duration, and energy savings. This stage will determine the most feasible and beneficial solutions.

Recommendation

Once the alternative solutions have been picked, the VE team will propose the new ideas to the project team and owner. Here the project team along with the owner will determine what alternatives will be chosen, for the good of the building.

Implementation

The most important of the VE process, implementation involves making sure the ideas proposed and recommended are taking place. This part of the process will ensure that the new ideas are being incorporated into the building.

Value engineering, as described in the previous stages, is a process that should occur during the entire building process (see Figure 3 on the next page). It should begin very early and often in conceptual planning and continue through the design of the building, carry on through the construction, even during operation. Before ideas of sustainable alternatives should begin a few things must happen and carry out through the project. This includes building an integrated team, documenting/auditing all of the ideas and work performed, and performance strategies and implementation.

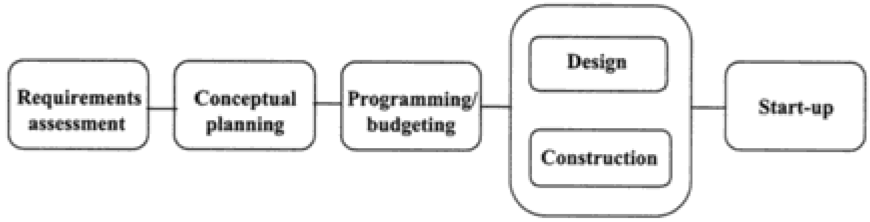


Figure 3 – The process of designing/constructing a building.

Integrated Team

It is important that at the beginning of any project the people involved sit down and form a team. The people who should generally be involved in these integrated teams include the owner, architect, engineers, construction manager, contractors, value engineers, and any other environmental /energy engineers. The first thing that should be done is to set a common goal. If individual parties are not enthusiastic or have different goals it will be harder for them to work together. This is also a good time to identify roles. Will the construction manager be acting as the value engineer or will there be a VE consultant? The only way that the team will be successful is if there is clear communication between individuals. This should be done by holding meetings every other week or in cases where a project is behind schedule or over budget, every week. At these meetings the team can:

- Establish sustainable objectives and make certain that these objects are being met.
- Make decisions about resources, materials, objectives, and short and long term building performances.
- Ensure that the contract documents are written to support sustainable design, construction and performance objectives.

Documentation and Auditing

Anything and everything should be well documented during each phase of the design and construction of a building. For one reason in particular, people may come and go, or there is a change of leadership on a project. Well documentation will help new people that are put on the job. They can get caught up in the project and become useful to the project team immediately. Another reason would be that if something unfortunate happened and someone was sued. Document should also occur for staff turnover, project delays, and budget cuts.

Performance Evaluations

The significance of performance evaluations are to determine if the sustainable goals and objects that are set in the early stages of the design process are met. There has to be some sort of measurement to make sure that the goals are on progress and will finally be met. These measurements should be determined at the beginning when the objects and goals are first established. These evaluations may vary depending on the system or product. Evaluations are still useful even if the object is not met at the end of its proposed duration. They can be used as a lesson learned, and may be useful for future projects.

Value Engineering Integrated with Sustainability

As mentioned earlier, value engineering should be implemented as early as possible in the planning, designing, and construction process. The earlier VE is involved the more sustainable and life cycle costs can be evaluated which will have an impact on the design, construction, and operation of the building. Conceptual planning and the design/construction phase are areas where sustainability can be influenced the most through VE (see Figure 4 below).

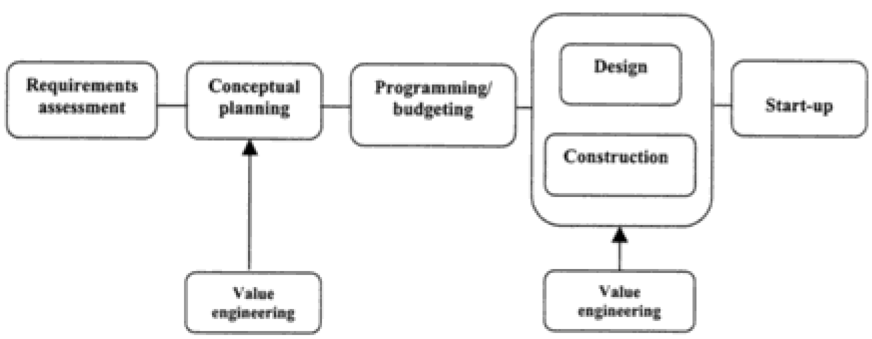


Figure 4 – VE used during conceptual planning, design and construction.

Conceptual Planning Phase

During the conceptual planning phase is where decisions determine whether or not requirements developed in the first phase can be met by an addition, renovation, or new construction. Some things that are looked into and researched are whether a building could just suffice by having upgrades or should a brand new facility need to be built. This is also the time when VE can greatly influence sustainable ideas into the analysis. The following are areas where sustainability concentration should occur.

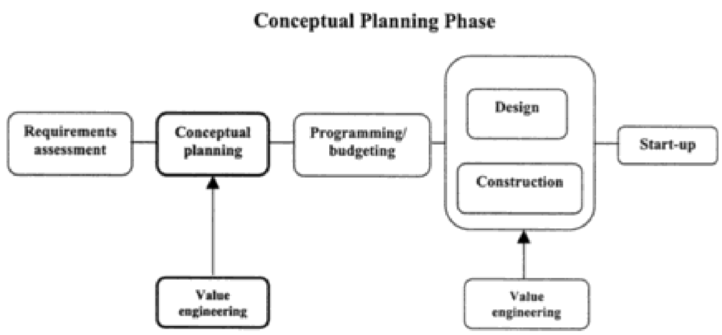


Figure 5 – VE during the conceptual planning phase.

Site

- Determine whether the site chosen is suitable for new or additional construction.
- Choose an area that is already developed to minimize the development of open space.
- Take advantage of the site's solar angle by positioning the building towards the sun.
- Integrate the building into the site's natural setting.

Energy

- Chose a site close to public transportation systems to reduce the use of fuel used by commuters.
- Use the site's natural characteristics to get the most out of the lighting, heating, cooling, and ventilation.
- Use technology to integrate the possibilities of solar and other alternative energy sources.

Materials

- Use local materials when ever possible.
- Avoid products that are non-renewable or non-reusable.
- Establish goals to maximize the use of environmentally preferred products in the buildings design.
- Review the life-cycle and first costs of materials and products.

Water

- Develop strategies for irrigation runoff.
- Use facilities that accommodate watershed drainage.
- Develop a rainwater catchment that can segregate the dirty water from potable water systems

Indoor Environment Quality

- Use natural ventilation.
- Establish lighting and acoustical criteria for design.
- Establish goals for using materials that minimize toxic emissions.
- Develop objectives to maximize daylight.

Operation & Maintenance

- Conduct continuous commissioning.
- Get information about indoor air quality and energy consumption from existing facilities.
- Ensure the delivery of a complete and thorough building operations manual.

Design Phase

Once the owner is confident they have sufficient funds to pay for the construction of a building, the designing phase begins. During this time the choice of materials, quality of design and construction, building layout, and types of systems will be explored. At this point and time of the process, VE can be used to analyze sustainable alternatives into the design of the building. The following are areas where sustainability concentration should occur.

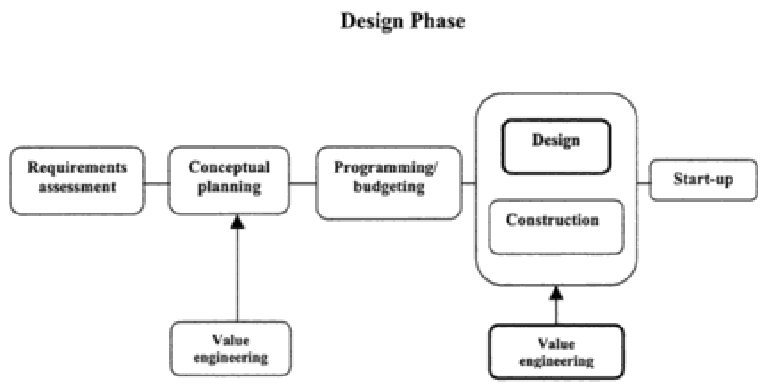


Figure 6 – VE during the design phase.

Contract

- Determine what level of sustainability should be achieved (LEED certification?).
- Determine what contract methods will best support the achievement of sustainability.
- Determine what delivery method should be used.
- Determine what, if any, incentives should be included.
- Determine who will be the party enforcing sustainability.
- Determine what levels of commissioning should be required.

Site

- Choose the orientation of the building, taking advantage of the climatic features.
- Promote less automobile transportation by providing a pedestrian friendly setting and bicycle racks.

- Save all trees and shrubbery.

Energy

- Incorporate solar power into the design.
- Use shades and blinds for the summer and stone masonry for the winter.
- Plant trees to block the wind and provide shade.
- Enhance thermal properties by increasing wall mass.
- Use low-e and argon filled windows.

Materials

- Use demountable and reusable materials for interior components.
- Use low maintenance materials.
- Use locally available materials.
- Avoid materials that pollute and are toxic when manufactured.
- Use alternate materials.

Water

- Incorporate water conserving cooling towers.
- Use ultra low fixtures and waterless urinals.
- Eliminate lead-bearing products in potable water.
- Recover non-sewage water for on site use.

Indoor Environment Quality

- Provide thermal comfort with maximum personal control over temperature and humidity.
- Control dust and odors with proper ventilation.
- Comply with indoor air quality standards.
- Keep air intake ducts away from loading docks and driveways.
- Avoid materials that contain hazardous or toxic materials.

Operation & Maintenance

- Specify durable and low-maintenance materials and equipment.
- Position equipment for easy access for maintenance.
- Include the facility manager or building engineer on project team.

Construction Phase

The construction phase will begin when the scopes of work are developed during the design phase. The biggest challenge during the construction phase is managing changes that result from change in scope, errors and omissions in the plans and specifications, unforeseen conditions, and cost overruns. This is a point in time when VE is used to find alternatives to these problems. It is important that the building maintains its sustainability. The following are areas where sustainability concentration should occur.

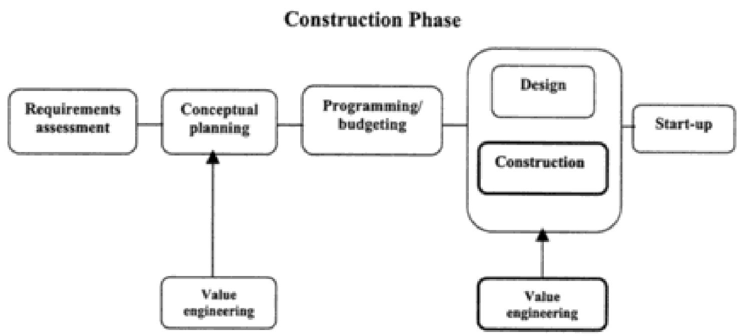


Figure 7 – VE during the construction phase.

Site

- Preserve all trees and vegetation.
- Stock pile soils during excavation and redistribute later.
- Replant trees.
- Install a retention pond to prevent pollution of watershed.
- Have designated parking, storage, recycling, waste and cleaning areas.

Energy

- Conserve energy during construction operations.
- Have prefabricated materials shipped to site so systems can be assembled and installed easier.

Materials

- Incorporate a waste management plan including ideas for recycling and salvaging construction waste.
- Reuse concrete forms as much as possible.

- Ensure that green materials and products are being met by specifications.

Water

- Preserve the watershed from pollution by installing filtration barriers.
- Conserve and maintain the waste of water.

Indoor Environment Quality

- Flush out entire building of dust and dirt before deeming the building operational.
- Implement the commissioning plan to ensure proper operation and performance of all energy serving equipment.

Operation & Maintenance

- Conduct building commissioning to ensure all systems are working as specified.
- Make sure operations staff is familiar with procedures maintaining efficient performance.
- Provide a digital control system to maintain peak performance of systems.

CONCLUSION

There are many misconceptions about value engineering. It is not a quick and cheap way to cut costs, when a project is over budget. It is important to truly understand, what value engineering is and what is involved in the process. Value engineering can be a very effective tool when used, and when used properly it can maintain environmental and energy saving criterion.

When starting the VE process for a sustainable building, the one performing the value engineering should be well aware and understand the process involved. When gathering information, analyzing, creative brainstorming, and evaluating, the environment should be kept as a high priority.

Once the VE process is understood, an integrated team should begin to form to get the best results for the building. The better the team works together, the smoother the project will go. It is also critical to grasp the importance of documenting all of the ideas and work during the process. Performance evaluations and measurements should also be created to ensure that all sustainable objectives are being met.

Lastly, for VE to be most successful for maintaining a building's sustainability, it is important VE be implemented at the very beginning and continues throughout the projects duration. VE can be mostly influenced during the conceptual planning, designing, and construction phases. It is important that the site, energy, materials, water, indoor environment quality, operation and maintenance, and even contracts are geared towards finding the best possible way to ensure a building's sustainability.

With the lessening of natural resources, the construction industry should really use value engineering to its fullest capability with helping buildings become more energy efficient and environmentally friendly.

STRUCTURAL BREADTH

Redesign of Foundation Wall

BACKGROUND

As stated earlier, the Health Care Center is going for LEED certification. This is not only a stepping stone for future buildings for the boarding school but for future medical facilities that lean towards better sustainability. The south addition has a six inch concrete foundation wall that extends in height from three feet below grade to the top of the first floor, a total of sixteen feet. A pitched roof rests on top of the first floor elevation. This design was chosen due to the good thermal insulation of concrete. The better the insulation the less amount of energy will be used which will result in cheaper energy bills. This is very important to medical facilities, like the Health Care Center, which consume an exuberant amount of energy on any given day.

PROBLEM

The foundation wall that extends a total height of 16 feet will be placed around the entire footprint of the lower half of the south addition (see Figure 8 below). An extensive amount of concrete will have to be poured to construct the foundation wall. This poses a great amount of problems in cost and in the schedule. Along with the cost of the concrete, costs for placing/pouring, forming and stripping the concrete are included. These factors mean more labor, which means a longer duration extending the overall length of the project.

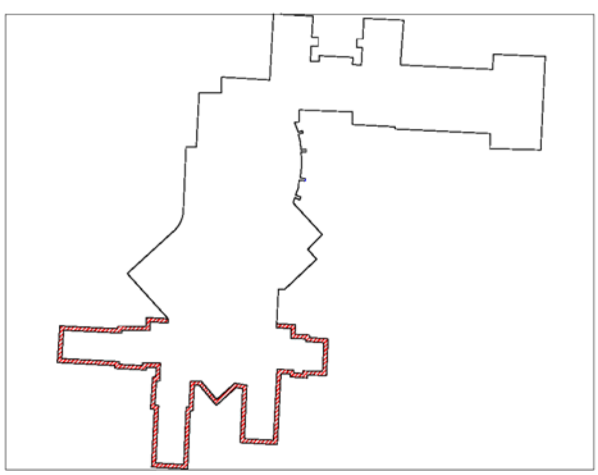


Figure 8 - Cast-in-place concrete foundation wall location. Red indicates location of wall.

PROPOSAL

Through value engineering, an alternative solution of redesigning the concrete foundation wall out of unreinforced CMU (concrete masonry unit also known as concrete block) will be analyzed. The analysis will include a comparison of the original design and the new proposed design in the areas of construction costs and schedule reduction. A thermal comparison showing the difference in R-values between the two designs will also be included. This should show that the block wall design can still meet sustainability criteria by not being significantly lower than the concrete wall's R-value. R-values measure the resistance to heat flow, the higher the R-value, the less heat loss.

GOALS

The goal of the proposed analysis is to show that the new design of the CMU wall can save construction costs and even shorten the duration of the Health Care Center while maintaining its sustainable status. This should also show that by using value engineering, alternative solutions can be evaluated to determine if they can significantly impact the overall cost and schedule of a project without affecting a building's sustainable design and function.

ANALYSIS

Original Design

The original design of the concrete foundation wall is shown below (see Figure 9). The 1' x 2' footing rests three feet below the frost depth elevation. The six inch concrete wall that extends 16 feet up to the roof level is reinforced accordingly. Included with the concrete wall are two, two and a half inch rigid insulation boards, a two inch air gap, and four inch thick brick veneer.

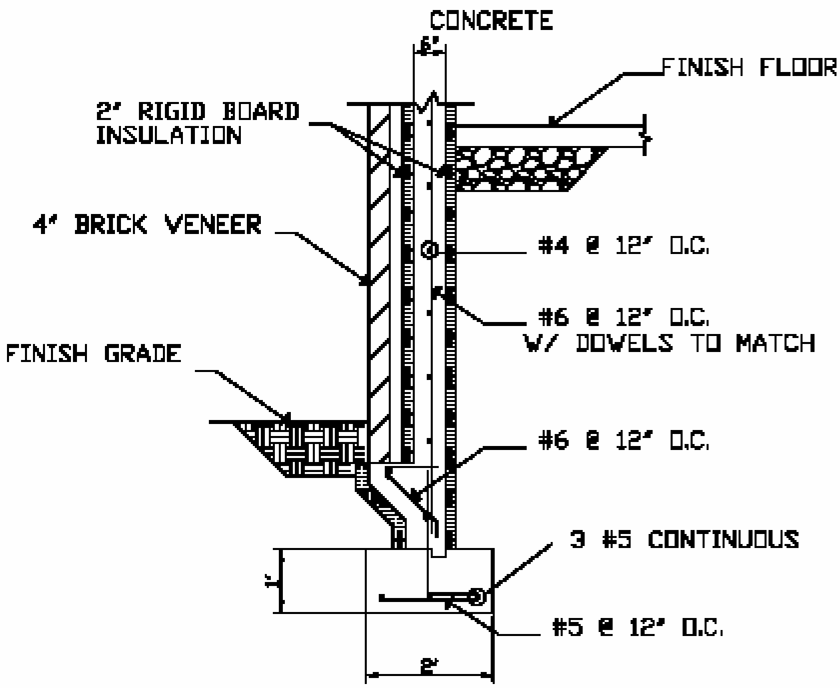


Figure 9 - Drawing of original concrete design, not to scale.

CMU Design

When starting the design, the following assumptions were made.

Assumptions

- The brick veneer is non-loading bearing and will only have to support its self weight.
- The wall's self weight is 100 psf. The self weight x height of the wall = the total weight of the wall.

- Total weight of the wall = 100 psf x 16 ft = 1.6 kip
- Proper installation and function of a drainage system will prevent hydrostatic pressure and uplift forces.

The next thing determined was the total load acting on the wall. To find the load, a structural analysis of the pitched roof (Figure 10) was performed using STAAD Pro (a structural analysis computer program). The following are assumptions used for the roof analysis.

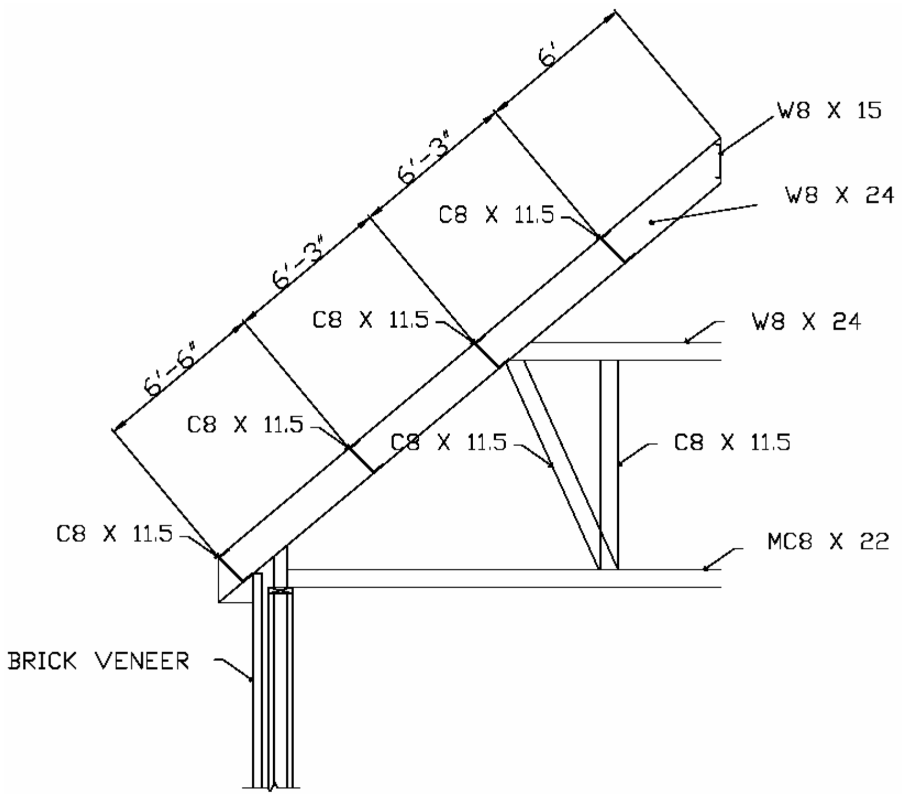


Figure 10 - Drawing of roof structure, not to scale.

Assumptions

Roof Dead Loads	
Assupmtions	**PSF**
Shingles	2
Insulation	1
Plywood	3
Felt	2
Total	**8**

- The load will be acting directly in the center of the wall, preventing any moments cause by eccentricity.

- Arbitrary width, A_t = 11.5 ft
- Roof Dead Load = A_t x total psf = 11.5 ft x 8 psf = 92 plf (pounds per linear foot)
- Length of beam x roof dead load = 25 ft x 92 plf = 2300 lbs
- The C-channels that make up part of the roof structure were turned into point loads.
- Self weight of C-Channel = 11.5 plf x A_t = 11.5 plf x 15 ft = 172.5 lbs
- The dead load was then turned into point loads along the length of the beam and placed on top of the points loads created by the C-channels. See Appendix B for all calculations.
- Through the structural analysis, the load acting on the foundation wall was found to be 1.5 kips.

The empirical design of concrete masonry walls, which is a conservative method to design a masonry wall, was used to find what the CMU size needed to be to support the roof load of 3.1 kips (self weight of wall + roof load). By using empirical design, vertical and lateral load resistance is governed by prescriptive criteria which include wall height to thickness ratios, shear wall length and spacing, minimum wall thickness, maximum building height, and other criteria, which has been proven effective through years of experience.

Empirical Design of Concrete Masonry Walls

- Height / thickness = 18 => 16ft (12inches) / t = 18, solve fort, t = 10.667.
- A 10 inch CMU block would be too small, so a 12 inch block will be used.
- Tables from R.S. Means were used to double check (Figure 11).

Table B2010-116 Unreinforced Masonry Wall Capacities Per L.F. (Kips & In-Kips)

Thk. T (Nom.) (in)	Earthquake Zones 0 & 1 Only: Length Or Height h' (Ft.)	h'/t (in/in)	Type of Wall	Allowable Vertical Wall Loads: Eccentric Loads 7.0 (K/Ft.)	Eccentric Loads 3.5 (K/Ft.)	Without Wind or Eccentric Loads (K/Ft.)	With Wind 15 psf (K/Ft.)	With Wind 30 psf (K/Ft.)	Allowable Wall Moments (Without Vertical Wall Loads): Not Wind or Earthquake Inspection No (in-K/Ft.)	Not Wind or Earthquake Inspection Yes (in-K/Ft.)	Wind or Earthquake Inspection No (in-K/Ft.)	Wind or Earthquake Inspection Yes (in-K/Ft.)
12"	8'	8	Solid Brick	12.30	14.10	15.90	15.90	15.90	2.70	5.40	3.60	7.20
			Solid CM Units	18.50	20.30	22.10	22.10	22.10	1.60	3.20	2.15	4.30
			Hollow CM Units	7.85	9.10	10.40	10.40	10.40	1.10	2.25	1.50	3.00
			Brick & Hollow CMU	5.50	7.80	10.05	10.05	10.05	1.35	2.70	1.80	3.60
	12'	12	Solid Brick	12.05	13.80	15.55	15.55	15.55	2.70	5.40	3.60	7.20
			Solid CM Units	13.45	14.75	16.05	16.05	16.05	1.60	3.20	2.15	4.30
			Hollow CM Units	7.65	8.90	10.15	10.15	10.15	1.10	2.25	1.50	3.00
			Brick & Hollow CMU	5.40	7.65	9.85	9.85	9.05	1.35	2.70	1.80	3.60
	16'	16	Solid Brick	11.55	13.20	14.90	14.90	14.35	2.70	5.40	3.60	7.20
			Solid CM Units	17.35	19.05	20.70	20.70	20.70	1.60	3.20	2.15	4.30
			Hollow CM Units	7.35	8.55	9.75	9.75	9.05	1.10	2.25	1.50	3.00
			Brick & Hollow CMU	5.20	7.30	9.45	9.10	—	1.35	2.70	1.80	3.60

Figure 11 – R.S. Means load tables for masonry walls.

With 30 psf wind, a hollow twelve inch CMU block will be sufficient for the total load of 3 kips. The figure below shows the new wall design.

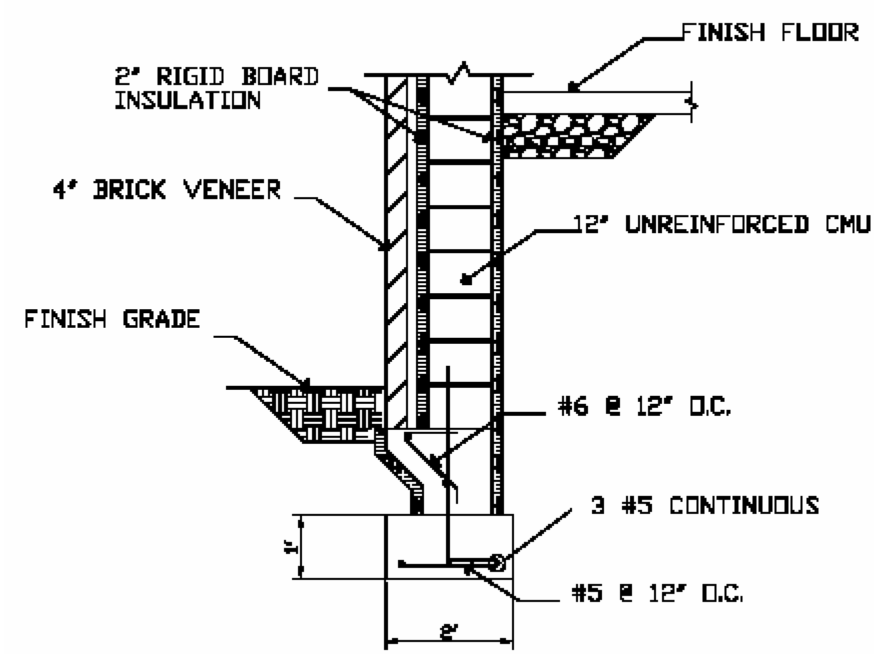


Figure 12 – Drawing of CMU foundation wall, not to scale.

Retention Wall

As seen in the last figure, part of the foundation wall will be acting as a retention wall. The wall sits down three feet below the frost line on the exterior of the wall. The interior wall extends down seven feet four inches into the soil. To make sure the twelve inch CMU wall is suitable, the moment acting on the wall due to the soil must be less then what the wall can handle. The following are steps used to find the moment.

Given

- Internal angle of friction, φ, = 28°
- Unit weight of soil, γ, = 130 pcf
- At Rest $K_o = 1 - \sin\varphi = 0.53$
- $V = P \Rightarrow V = (K_o\ \gamma H^2)/2 = (0.53 \times 130 \times 7.25^2)/2 = 1810.8$ ft-lb/ft
- Moment = (1810.8)(7.25/3) = 4376/1000 = 4.376 ft-K/ft = 0.364 in-K/ft

Table B2010-116 Unreinforced Masonry Wall Capacities Per L.F. (Kips & In-Kips)

Thk. T (Nom.) (in)	Earthquake Zones 0 & 1 Only: Length Or Height h′ (Ft.)	h′/t (in/in)	Type of Wall	Allowable Vertical Wall Loads: Eccentric Loads 7.0 (K/Ft.)	Eccentric Loads 3.5 (K/Ft.)	Without Wind or Eccentric Loads (K/Ft.)	With Wind 15 psf (K/Ft.)	With Wind 30 psf (K/Ft.)	Allowable Wall Moments (Without Vertical Wall Loads): Not Wind or Earthquake Inspection No (in-K/Ft.)	Not Wind or Earthquake Inspection Yes (in-K/Ft.)	Wind or Earthquake Inspection No (in-K/Ft.)	Wind or Earthquake Inspection Yes (in-K/Ft.)
12″	8′	8	Solid Brick	12.30	14.10	15.90	15.90	15.90	2.70	5.40	3.60	7.20
			Solid CM Units	18.50	20.30	22.10	22.10	22.10	1.60	3.20	2.15	4.30
			Hollow CM Units	7.85	9.10	10.40	10.40	10.40	1.10	2.25	1.50	3.00
			Brick & Hollow CMU	5.50	7.80	10.05	10.05	10.05	1.35	2.70	1.80	3.60
	12′	12	Solid Brick	12.05	13.80	15.55	15.55	15.55	2.70	5.40	3.60	7.20
			Solid CM Units	13.45	14.75	16.05	16.05	16.05	1.60	3.20	2.15	4.30
			Hollow CM Units	7.65	8.90	10.15	10.15	10.15	1.10	2.25	1.50	3.00
			Brick & Hollow CMU	5.40	7.65	9.85	9.85	9.05	1.35	2.70	1.80	3.60
	16′	16	Solid Brick	11.55	13.20	14.90	14.90	14.35	2.70	5.40	3.60	7.20
			Solid CM Units	17.35	19.05	20.70	20.70	20.70	1.60	3.20	2.15	4.30
			Hollow CM Units	7.35	8.55	9.75	9.75	9.05	1.10	2.25	1.50	3.00
			Brick & Hollow CMU	5.20	7.30	9.45	9.10	—	1.35	2.70	1.80	3.60

Figure 13 – R.S. Means load tables for masonry walls.

Looking at the R.S. Means load tables, the maximum allowable wall moment for twelve inch CMU wall is 3 in-K/ft. This proves that the walls design is acceptable.

Thermal Comparison

When analyzing the two walls between their thermal insulation properties, they were actually close in value. As shown in the figure below, the original concrete foundation wall design is comprised of two, two and a half inch rigid insulation boards, a two inch air gap, and four inch thick brick veneer. Their respective thermal resistance R-values is as follows.

Concrete Design	
Material	R value
Outside Air Film	0.17
4" Brick Veneer	0.8
2" Air Gap	1
2" Rigid Insulation Board	16
6" Concrete Pour	0.48
2" Rigid Insulation Board	16
5/8" Gypsum Board	0.56
Inside Air Film	0.68
Total Thermal Resistance	**35.69**

Figure 14 – Thermal properties of the concrete wall.

Similarly to the original design, the CMU foundation wall design has similar components. The only difference being that the six inch thick concrete is replaced by twelve inch CMU hollow block. The respective thermal resistance R-values is as follows for the new design.

CMU Design	
Material	R value
Outside Air Film	0.17
4" Brick Veneer	0.8
2" Air Gap	1
2" Rigid Insulation Board	16
8" CMU with Grout	1.81
2, 2" Rigid Insulation Board	16
5/8" Gypsum Board	0.56
Inside Air Film	0.68
Total Thermal Resistance	**37.02**

Figure 15 – Thermal properties of the CMU wall.

After comparing the two systems, the block wall has a higher R-value than the concrete wall. This proves that by using the CMU foundation wall design, no more heat loss will be lost than the original design. In fact, the CMU wall shows that less heat will be lost through heat transfer. Another factor deciding in if this alternative solution will be sustainable.

Cost Analysis

When comparing the cost between the two designs it's simple to see that the original design will cost more to construct than the CMU design. The main factor for this is the cost for more materials in the concrete design, and labor. A total of $64,718 will be saved by switching to the CMU foundation wall design.

Concrete Design							
Concrete	Notes	Quantity	Unit	Material	Labor	Equipment	Total
4000 psi		233	CY	84	0	0	19572
Placing							
Pumped	Includes vibrating	233	CY	0	12.5	5	4077.5
Forms							
Exterior walls 8'-16' 4 uses	Includes erecting, bracing, stripping & cleaning	23937	SFCA	0.7	4.05	0	113700.8
Reinforcement							
Walls, #3 to #7		14.5	TON	760	405		16892.5
Total Cost							**154242.8**

CMU Design							
CMU Block	Notes	Quantity	Unit	Material	Labor	Equipment	Total
12' hollow block		11968.5	SF	2.51	4.97		89524.38
Total Cost							**89524.38**

Figure 16 – Cost comparison between the two designs.

Also, the block wall design will take less labor and fewer crews to construct. The new design eliminates the need for a three crew process including a rebar crew for setting the reinforcement, a carpenter crew for the formwork, and the concrete crew for placing and vibrating the concrete. Only one group of masons needs to erect the CMU wall. By having one crew performing all the work, there will be no need for coordination between different crews and confusion due to the lack of coordination.

Schedule Analysis

As seen in Figure 18 on the next page, there will be a few days shed off of the schedule by using the CMU foundation wall design. The south addition was split into three sections, A, B and C (see Figure 17). There is more labor involved when constructing a concrete wall including, the formwork, rebar placement, and concrete placement. That is why there are a few days saved from the schedule. It seems nothing significant right now, but those few days will be used to start the steel erection earlier and can affect the overall duration of the project. Full scale schedule can be found in Appendix B.

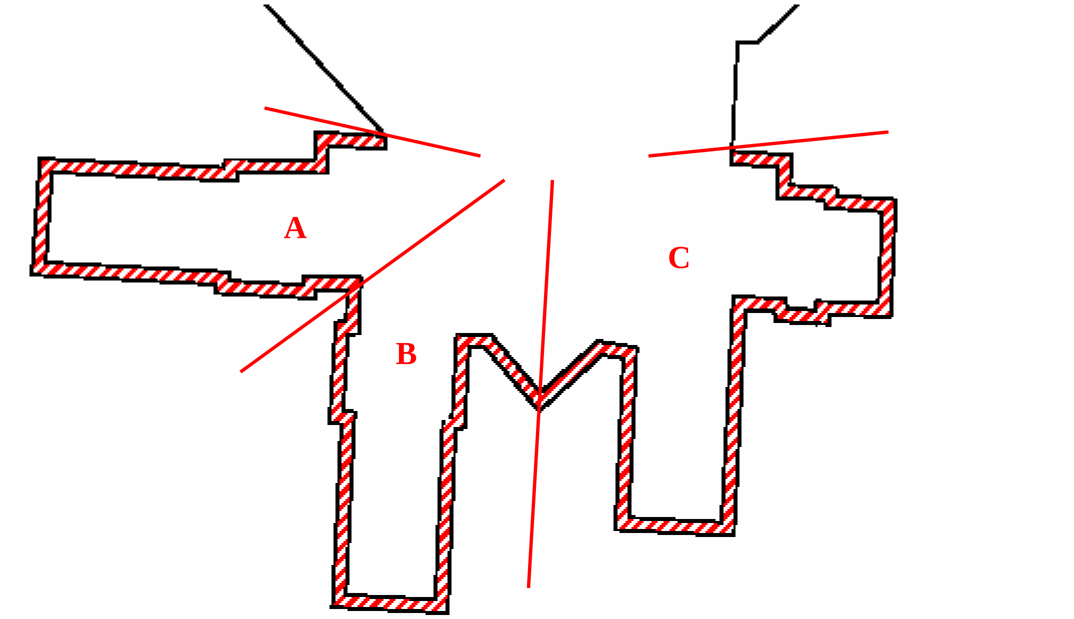
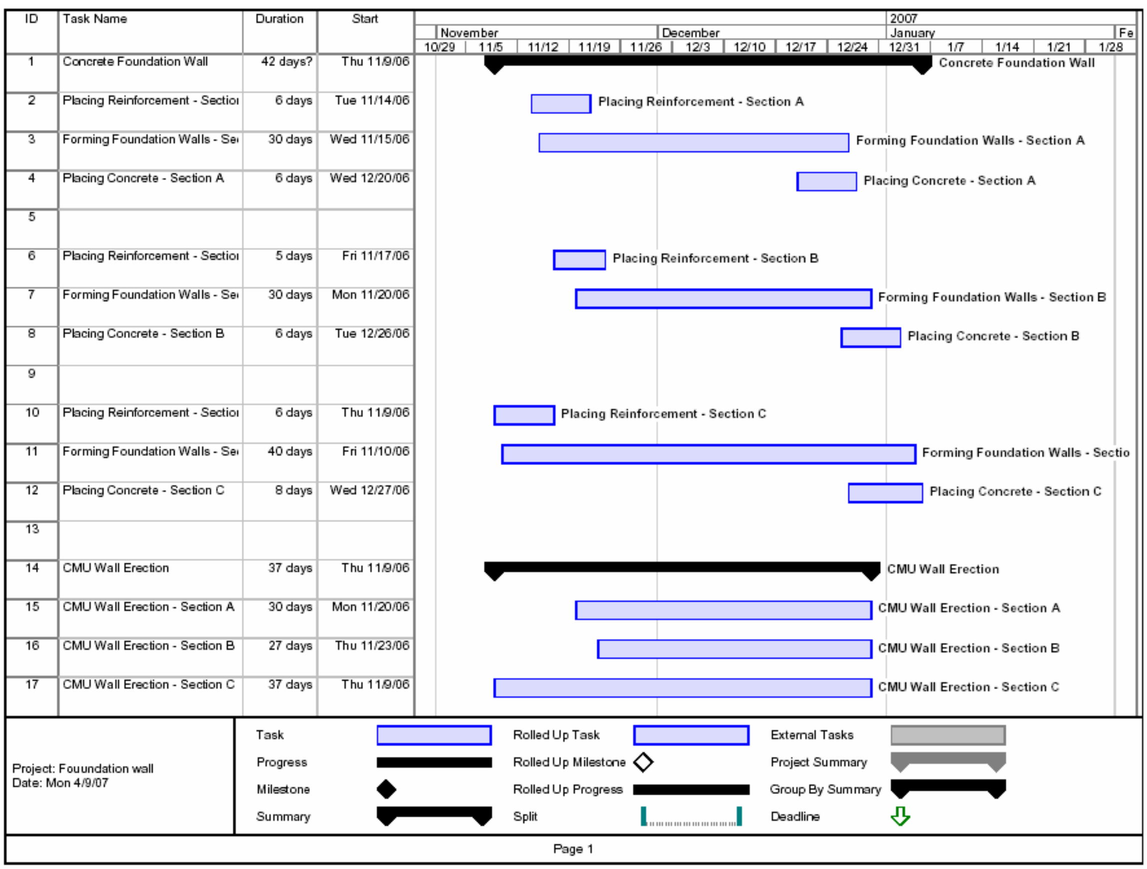


Figure 17 - Foundation wall split in section A, B & C.



ID	Task Name	Duration	Start
1	Concrete Foundation Wall	42 days?	Thu 11/9/06
2	Placing Reinforcement - Sectio	6 days	Tue 11/14/06
3	Forming Foundation Walls - Se	30 days	Wed 11/15/06
4	Placing Concrete - Section A	6 days	Wed 12/20/06
5			
6	Placing Reinforcement - Sectio	5 days	Fri 11/17/06
7	Forming Foundation Walls - Se	30 days	Mon 11/20/06
8	Placing Concrete - Section B	6 days	Tue 12/26/06
9			
10	Placing Reinforcement - Sectio	6 days	Thu 11/9/06
11	Forming Foundation Walls - Se	40 days	Fri 11/10/06
12	Placing Concrete - Section C	8 days	Wed 12/27/06
13			
14	CMU Wall Erection	37 days	Thu 11/9/06
15	CMU Wall Erection - Section A	30 days	Mon 11/20/06
16	CMU Wall Erection - Section B	27 days	Thu 11/23/06
17	CMU Wall Erection - Section C	37 days	Thu 11/9/06

Figure 18 - Schedule comparison between cast-in-place concrete and CMU.

CONCLUSION

Through the value engineering analysis, the alternative solution to use twelve inch CMU block, replacing the cast-in-place concrete foundation wall seems very feasible. Through the design and engineering analysis, the un-reinforced CMU foundation wall will be structurally sound. The CMU will also act as better insulation, proving to have a higher R-value than the concrete wall. This higher R-value should have a good impact on the mechanical system in the building. It can be concluded that the sustainability of the Health Care Center has been maintained. When comparing costs, it's shown that a total of $64,718 can be shed off of the project. Also, when comparing the durations between the two designs, the CMU foundation wall will be finished a few days earlier. This time can become beneficial in unforeseen delays that can occur later in the construction process. Through the analysis, the construction of a twelve inch un-reinforced CMU foundation wall is feasible and will maintain its sustainable value for the Health Care Center.

MECHANICAL BREADTH

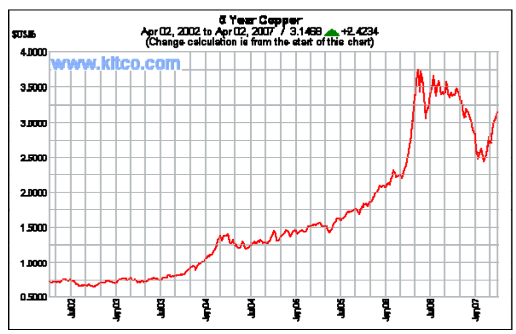
Replacement of Domestic Water Supply Copper Piping with PEX Tubing

BACKGROUND

Like most typical plumbing systems found in buildings, the Health Care Center relies extensively on copper piping for its domestic water supply. The domestic water supply enters the building from the basement level and splits into two directions. The one half starts to circulate through the basement level then up to the other levels continuing with the rest of the building. The other half enters the mechanical room where the water is either heated by one of the four water heaters or sent to another part of the building. The domestic water supply will then circulate throughout the building with the hot water supply re-circulating back to the hot water heaters and back again throughout the building.

PROBLEM

The price of copper in today's market is exceedingly high, and according to market trends (shown in the figures to the right) the price will not be decreasing any time soon. The price per pound has gone up over the past five years and has been increasing within the past couple months (to see the full scale of these charts please refer to Appendix C). In almost all of construction, commercial or residential, copper piping is used for plumbing. With the economic growth in Asia, China is buying up all the copper. This leads to plumbing systems used in buildings to be more expensive. Another issue with using copper piping is the labor. The labor can become very extensive, thus time consuming, when it comes to running pipe around an angle or obstacle. It needs to be cut and a 90 degree elbow needs to be added. The Health Care Center is facing this issue right now with copper tubing.



As mentioned earlier, the building's domestic water supply is constructed out of copper piping. As a result the Health Care Center is not benefiting from the cost and duration of installing copper piping. The cost for copper piping and labor, not including all of the fittings and elbows used, is close to $100,000.

PROPOSAL

The idea is to use value engineering to find a sustainable alternative to the problem identified in the previous paragraph so the Health Care Center can still maintain its LEED certification. The alternative chosen to replace the copper tubing is cross-linked polyethylene, better know as PEX tubing. PEX will be replacing the copper pipes used for the domestic water supply in the building. A remote manifold system, which uses PEX tubing, will be used through out the building. Manifolds will be placed in locations around the building where groups of fixtures are located distributing the domestic water.

Figure 19 – Picture of PEX tubing.

GOALS

The goal of the proposed alternative design is to reduce material costs, labor costs, and energy costs for the Health Care Center by replacing the existing copper piping for domestic water with PEX tubing. This should also show that by using value engineering, sustainability can be maintained and in this case gained.

ANALYSIS

PEX piping has been successfully used in Europe for years before its use came over to America. It was originally used in residential and commercial construction for radiant floor heating and not until recently has PEX been used for plumbing systems. The following will include the advantages of using PEX tubing over copper and other rigid metals, the remote manifold system design, and a cost analysis for the domestic water supply in the Health Care Center.

<u>Advantages</u>

Ease of Installation

- PEX is manufactured in long coils which eliminate the need for coupling joints.
- The natural flexibility allows the piping to bend gently around obstructions minimizing the need for fittings.
- The pipe is lightweight making it easy to transport.

Durability

- PEX is not affected by reduced interior dimension, corrosion, filming, mineral buildup, and water velocity wear.
- It will expand when frozen then reach its original size when water thaws.

Cost Effective

- Lower installation time and labor time is greatly reduced.
- The use of water and energy is reduced by delivering the water to the fixtures faster and by reducing losses in the piping.

Energy Efficient

- PEX offers reduced heat loss and improved thermal characteristics.
- Less energy is used by the water heater because there is a shorter delivery time to the fixtures.

Noise Reduction

- Reduces occurrences of water hammer due to the flexibility and ability to absorb pressure surges.

Remote Manifold Design

There are a few systems that could have been chosen for the Health Care Center. There is an extensive amount of piping that needs to be installed from the basement, where the water heater and cold water supply line is located, to the entire building. For this reason the remote manifold system was chosen. The remote manifold system combines your typical branch plumbing system and the home-run system.

The Health Care Center will be split into four sections, a water heater for each section. These four sections include the first floor split into three sub-sections and the second floor. Hot and cold water will be sent from the mechanical room, located in the basement, to their particular manifold (Figure 20 shown on the right) located around the building. From there the hot and cold water pipes will be split and sent off to individual fixtures. A couple of advantages to this design are that it will allow for a quicker hot water delivery during sequential flows, reduce the amount of fittings needed to be installed, and individual shut-off values located at the remote manifolds.

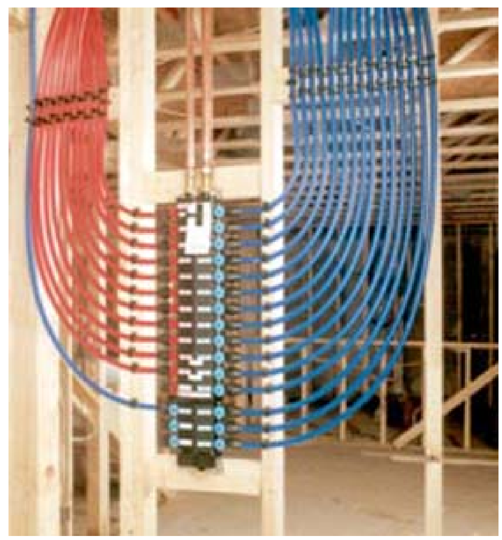
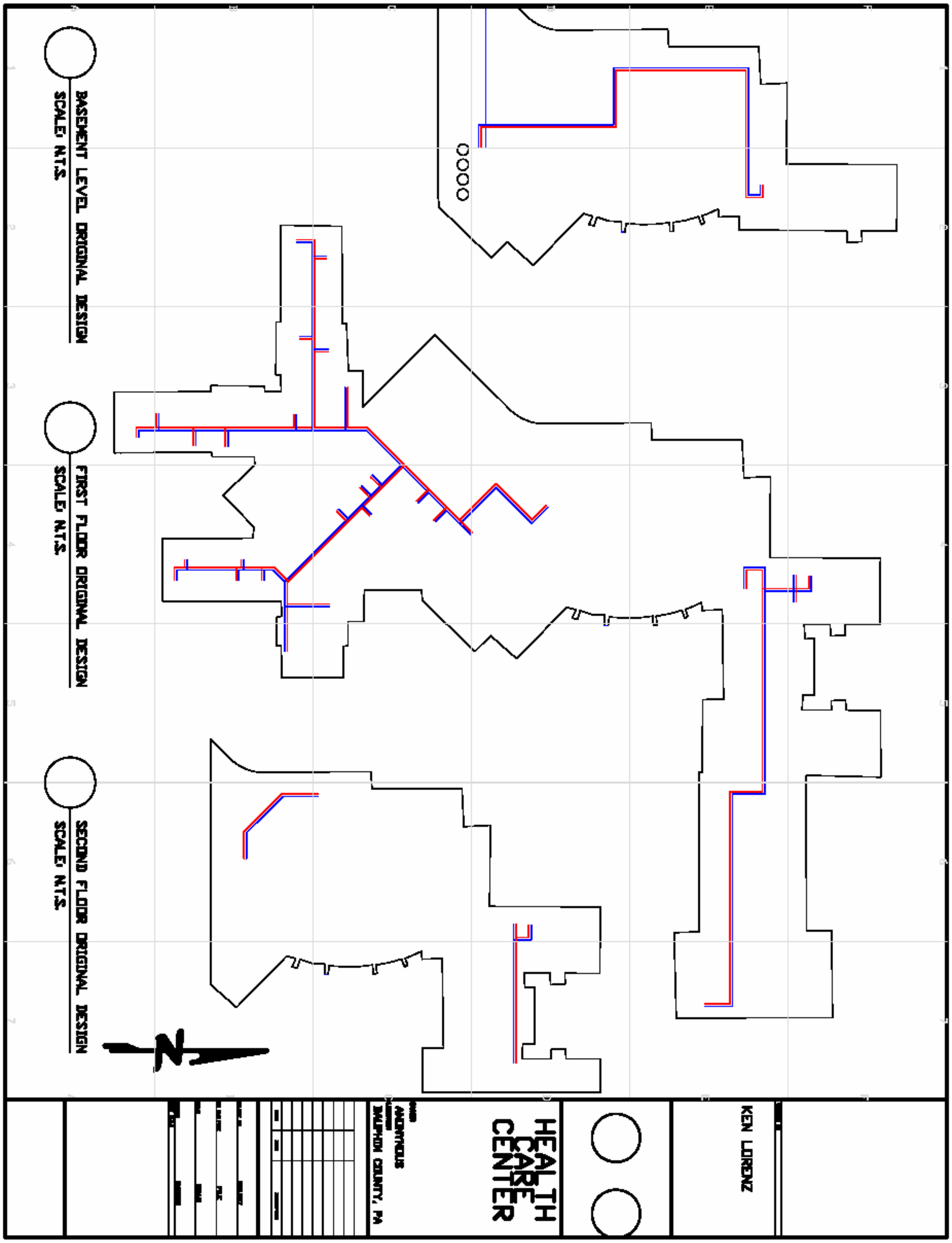


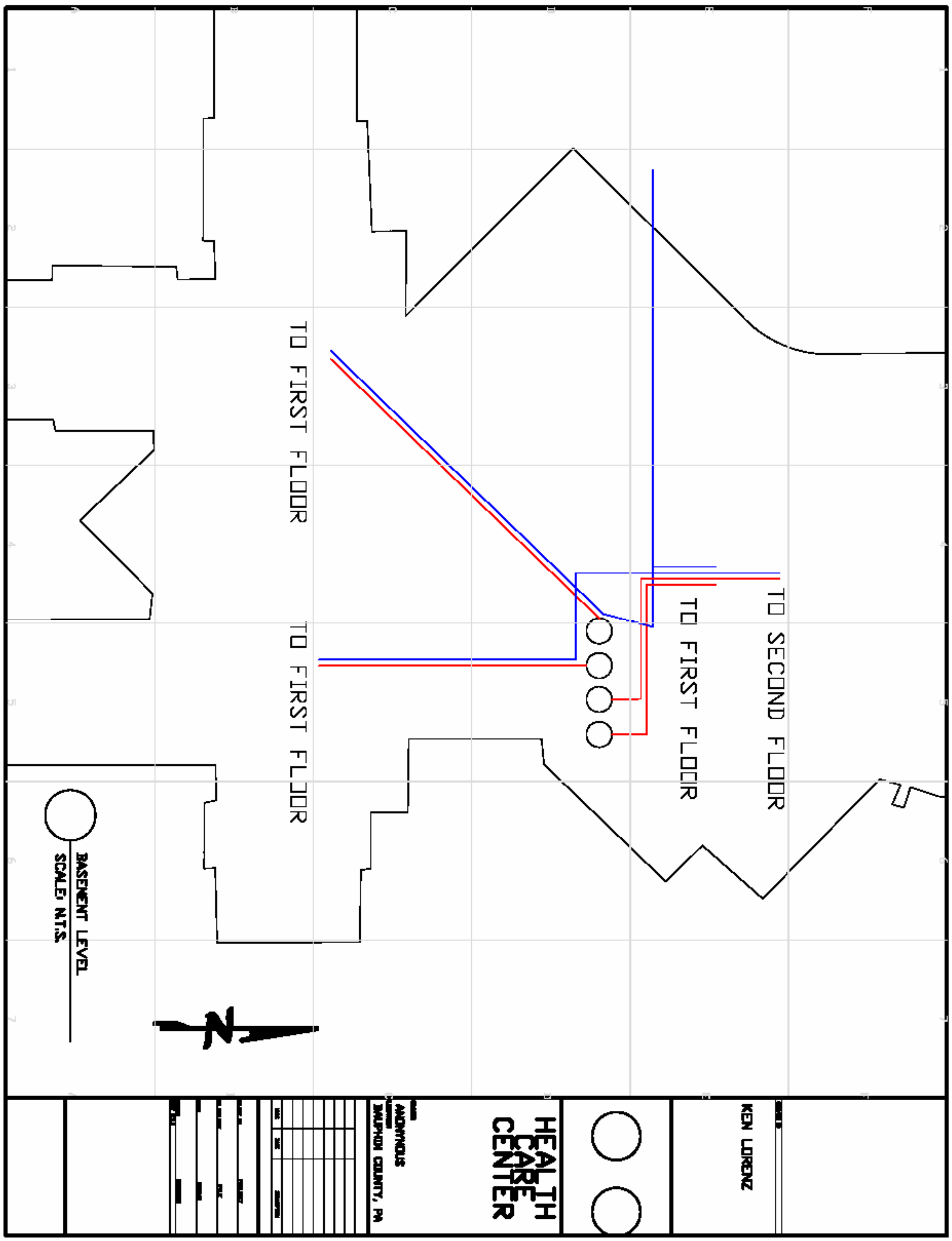
Figure 20 – PEX tubing and remote manifold.

The following AutoCAD drawings show the original plumbing design and the new PEX remote manifold design. In the drawings one can see exactly how the remote manifold system works. The four circles in the basement level represent the water heaters and the green box, □, signifies the manifolds. The red and blue lines that branch out of the manifold represent the PEX supply water traveling to fixtures. The red and blue lines that are extending out of the hot water tanks are still copper piping. All figures drawn are not to scale. In the First Floor Section B drawing, there was not enough space to show how the piping will be will be split from the remote manifold, so it is just assumed.

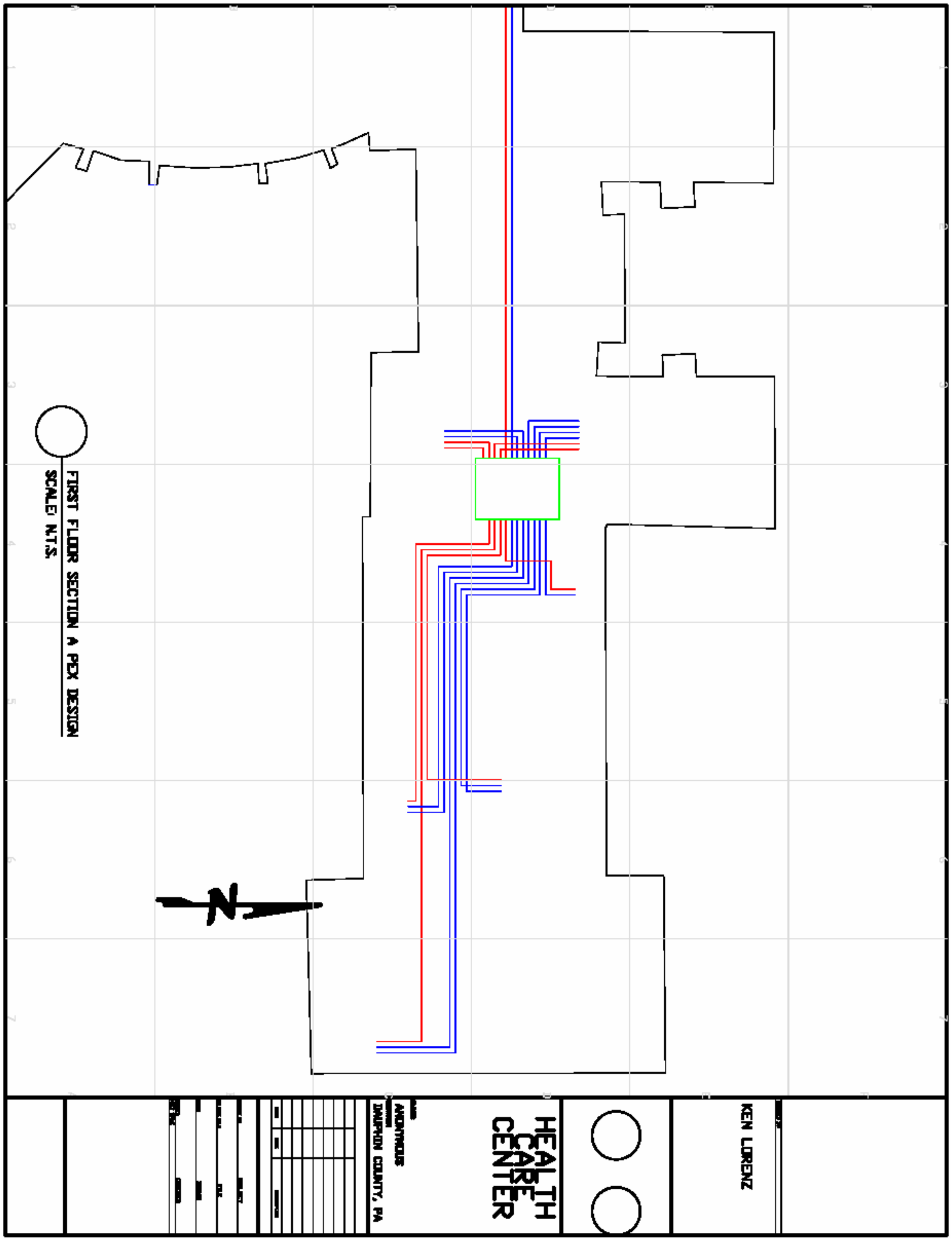
Original Design



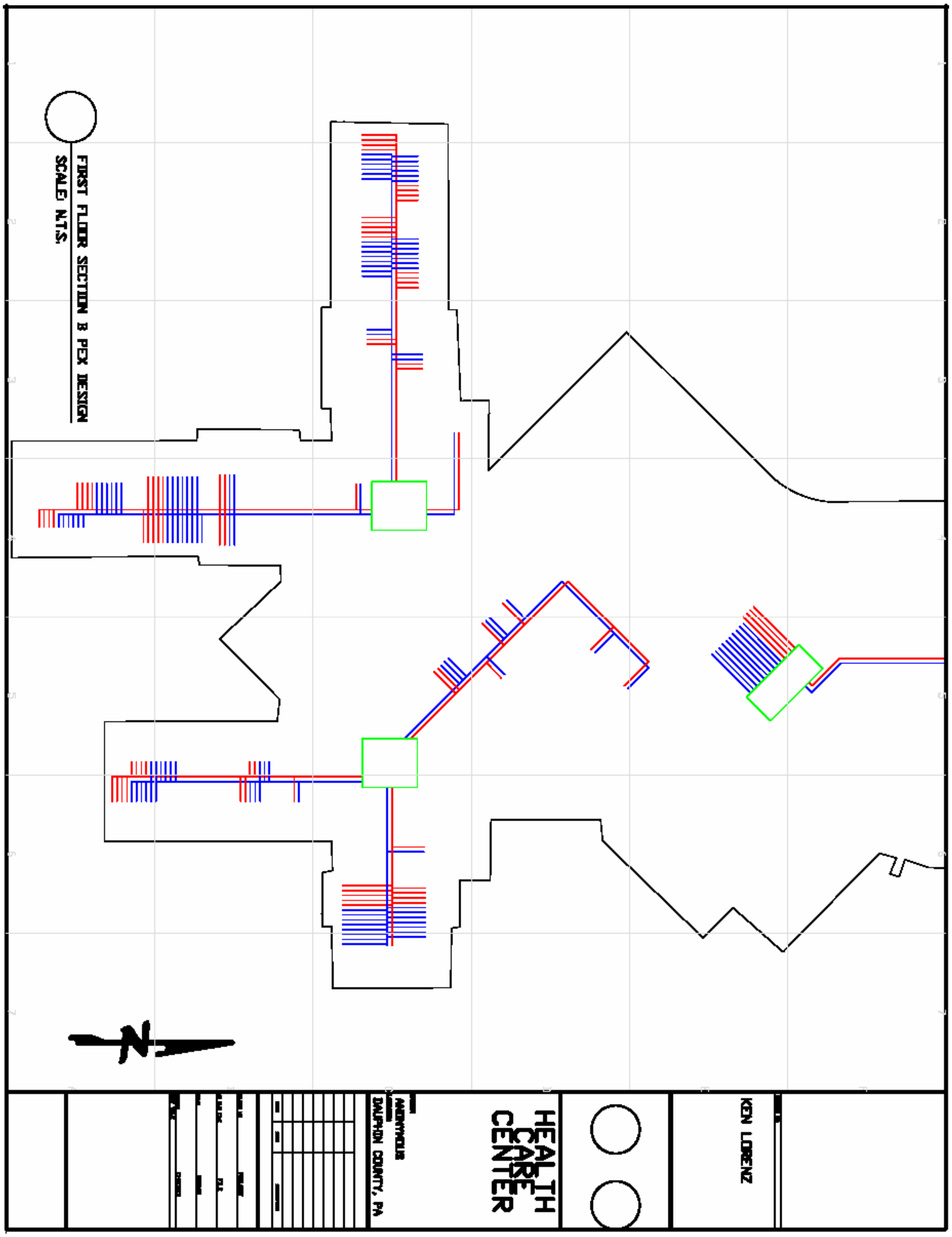
PEX Design – Basement Level



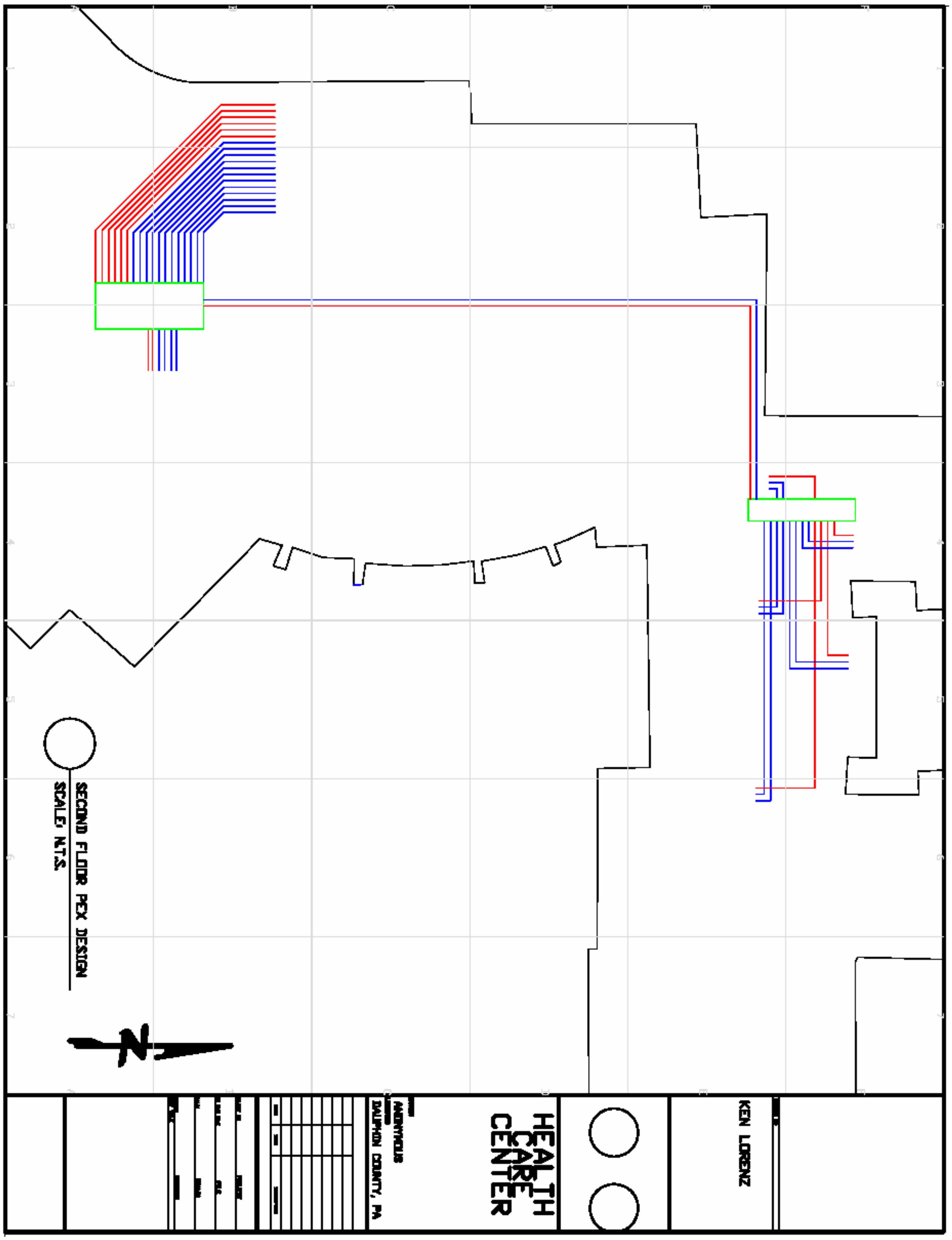
PEX Design – First Floor Section A



PEX Design – First Floor Section B



PEX Design – Second Floor



PEX tubing is only manufactured in sizes shown in the table below. Due to the fact that PEX only comes in sizes two inches and smaller, the new design had to incorporate the smaller tubing. This was not a significant factor since the copper piping runs from the mechanical room to the manifolds, and most fixtures only need a 3/8 inch or 1/2 inch fitting. Copper tubing will still be used from the water heaters to the remote manifolds. PEX tubing will be used for the tubing from the manifold to the fixtures.

Table 3.1 – PEX Pipe Dimensions

Nominal Diameter	OD inches[1]	Wall inches[2]	ID inches	Weight lb/ft
3/8"	0.500	0.075	0.350	0.05
1/2"	0.625	0.075	0.475	0.06
3/4"	0.875	0.102	0.671	0.10
1"	1.125	0.130	0.865	0.16
1 1/4"	1.375	0.160	1.055	0.25
1 1/2"	1.625	0.190	1.245	0.35
2"	2.125	0.248	1.629	0.60

[1] Average OD from ASTM F 876
[2] Average wall thickness from ASTM F 876

Figure 21 – PEX Pipe Dimensions

The remote manifold design will have savings on energy and water consumption. The new design provides direct lines from the manifold to the fixtures, reducing the amount of water that goes through the pipes allowing less time for hot water to reach the fixture. In the design the direct lines were sized to the fixture requirements, further reducing the amount of time to wait for hot water. Faster hot water delivery reduces water waste and the amount of times the water heater must cycle to supply hot water. Another way the remote manifold system reduces water is by having fewer fittings. Fittings are only required at the fixtures and the manifold. This reduces the possibility of leaks, which wastes water and increases utility costs. The smoothness of the plastic tube also increases the flow of water, again making it quicker to reach the fixtures (see Appendix C for charts).

Cost Analysis

Original Plumbing Design							
Copper Pipe	**Quantity**	**Unit**	**Mat.**	**Mat. Total**	**MH**	**Tot. Hours**	**Total Cost**
Pipe, 1/2"	2366	LNFT	1.75	4140.5	0.06	142	12573.89
Pipe, 3/4"	2251	LNFT	2.7	6077.7	0.06	135.1	14303.93
Pipe, 1"	875	LNFT	3.84	3360	0.08	70	7653.32
Pipe, 1-1/4"	1214	LNFT	5.4	6555.6	0.08	97.1	12692.18
Pipe, 1-1/2"	722	LNFT	6.96	5025.12	0.08	57.8	8788.44
Pipe, 2"	879	LNFT	10.96	9633.84	0.09	79.1	15066.97
Pipe, 2-1/2"	681	LNFT	16.59	11297.79	0.12	81.7	17044.69
Pipe, 3"	172	LNFT	22.26	3828.72	0.14	24.1	5571.98
Pipe, 4"	80	LNFT	37.18	2974.4	0.18	14.4	4084.64
Copper Fittings							
90 ELL, 1/2"	644	EACH	0.39	251.16	0.33	211.2	12205.63
90 ELL, 3/4"	120	EACH	0.88	105.6	0.43	51.8	3043.27
90 ELL, 1"	186	EACH	2.16	401.76	0.48	89.3	5484.1
90 ELL, 1-1/4"	61	EACH	3.26	198.86	0.57	34.6	2175.49
90 ELL, 1-1/2"	37	EACH	5.1	188.7	0.59	21.9	1444.33
90 ELL, 2"	37	EACH	9.27	342.99	0.69	25.5	1814.79
90 ELL, 2-1/2"	20	EACH	19.57	391.4	1.1	21.9	1668.26
90 ELL, 3"	7	EACH	26.14	182.98	1.31	9.2	719.93
90 ELL, 4"	4	EACH	66.92	267.68	1.75	7	690.21
Total							**127026.05**

Figure 22 – Material and labor costs for original design.

Alternative Plumbing Design							
Copper Pipe	**Quantity**	**Unit**	**Mat.**	**Mat. Total**	**MH**	**Tot. Hours**	**Total Cost**
PEX Pipe, 1/2"	2	1000ft/COIL	364	728	0.06	138	9008
PEX Pipe, 1/2"	1	300ft/COIL	109	109			
PEX Pipe, 3/4"	4	500ft/COIL	299.95	1199.8	0.06	131	9059.8
PEX Pipe, 3/4"	1	300ft/COIL	178.5	178.5			
PEX Pipe, 1"	9	100ft/COIL	104.95	944.55	0.08	68	6384.55
PEX Pipe, 1-1/4"	4	300ft/COIL	749.95	2999.8	0.08	94	10519.8
PEX Pipe, 1-1/4"	1	100ft/COIL	279.95	279.95			
PEX Pipe, 1-1/2"	3	300ft/COIL	864.95	2594.85	0.08	56	7074.85
PEX Pipe, 1-1/2"	1	100ft/COIL	294.95	294.95			
Copper Pipe, 2"	879	LNFT	10.96	9633.84	0.09	79.1	15066.97
Copper Pipe, 2-1/2"	681	LNFT	16.59	11297.79	0.12	81.7	17044.69
Copper Pipe, 3"	172	LNFT	22.26	3828.72	0.14	24.1	5571.98
Copper Pipe, 4"	80	LNFT	37.18	2974.4	0.18	14.4	4084.64
Copper Fittings							
90 ELL, 2"	37	EACH	9.27	342.99	0.69	25.5	1814.79
90 ELL, 2-1/2"	20	EACH	19.57	391.4	1.1	21.9	1668.26
90 ELL, 3"	7	EACH	26.14	182.98	1.31	9.2	719.93
90 ELL, 4"	4	EACH	66.92	267.68	1.75	7	690.21
Total							**88708.47**

Figure 23 – Material and labor costs for new design.

When looking at the cost comparison between the two designs, the remote manifold design including PEX tubing will save $38,317.58. This is a significant amount of money that can be used in other areas of the project. Since PEX tubing is flexible, it can easily be bent around corners and obstructions eliminating the need for ninety degree elbow fittings. The elbow fittings alone will save $29,246. That is a reason alone to switch to the new plumbing design. When consulting with a plumber, he stated that a factor of 0.0286 can be deducted for the labor on PEX tubing. With that information a total of 353.9 man hours will be saved. That will shorten the overall duration of the project.

CONCLUSION

Through value engineering, an alternative solution to the plumbing system in the Health Care Center was analyzed. The use of the remote manifold system using PEX piping was the intended solution. Through the evaluation, the new plumbing design will be successful. An overall cost of $38,317.58 can be saved from the project cost and an approximate total of 354 man hours can be saved from the schedule. Most importantly, the Health Care Center will not loose any LEED points. Along with PEX's ability to reduce less energy used by the water heater, PEX tubing is also less toxic than the manufacturing of copper piping.

RECOMMENDATIONS

The following recommendations are from the interpretations and analyses from the two breadth topics covering the redesign of the foundation wall and the remote manifold plumbing system for the Health Care Center.

Both the structural and mechanical breadths were analyzed using value engineering. The purpose was to follow the considerations mentioned in the research topic to ensure that the Health Care Center would still maintain its LEED accreditation. The information in the research topic should be used for all buildings that are trying to strive for a sustainable status and going through the value engineering process.

Through the analysis and evaluation of the foundation wall, an un-reinforced twelve inch CMU foundation wall will be sufficient. To make certain that the wall will be structurally sound; the empirical design of concrete masonry walls was used. The wall was also checked for the moments acting on it due to pressure from the soil. This area was checked because approximately seven feet of the wall acts as a retention wall. After assuring the CMU wall would hold due to all of the forces acting on it, an analysis between the cost and duration of the wall was comprised. It has been found that the CMU wall costs approximately $64,718 less and will take less time to construct. Lastly, keeping in mind that the buildings energy conservation should not be affected, a comparison between heat transfers was examined. The CMU wall has a higher R-value than the six inch concrete wall. With the new design having a higher R-value, energy will be saved from the mechanical system not having to compensate for the heat loss.

Through the analysis and evaluation of the plumbing system, the remote manifold system using PEX tubing is an appropriate solution. The remote manifold system including PEX tubing has proven many advantages over the typical branch system with copper tubing. The remote manifold system has the advantage of reducing heat loss due to the faster water flow from the water heater to the fixtures, easy shut off valves for individual fixtures without shutting the rest of the water off, and less water loss due to fewer fittings installed in the system. PEX tubing has shown its advantages of costing less than copper tubing, being able to bend around obstructions due to its flexibility, quicker water velocity due to the smoothness of the plastic, and creates fewer toxins than the manufacturing of copper. All of these reasons proving the remote manifold system, with the use of PEX piping, being energy and environmentally friendly. It is shown that the replacing of the plumbing system will save approximately $38,317.58.

The final recommendation for the Health Care Center would be to implement the two proposed solutions. With both the CMU foundation wall and remote manifold plumbing system installed with PEX tubing maintaining the Health Care Center's LEED status, the value engineering performed was successful. The project will save over $100,000 by switching to both of the alternative solutions and even shorten the total duration of the project.

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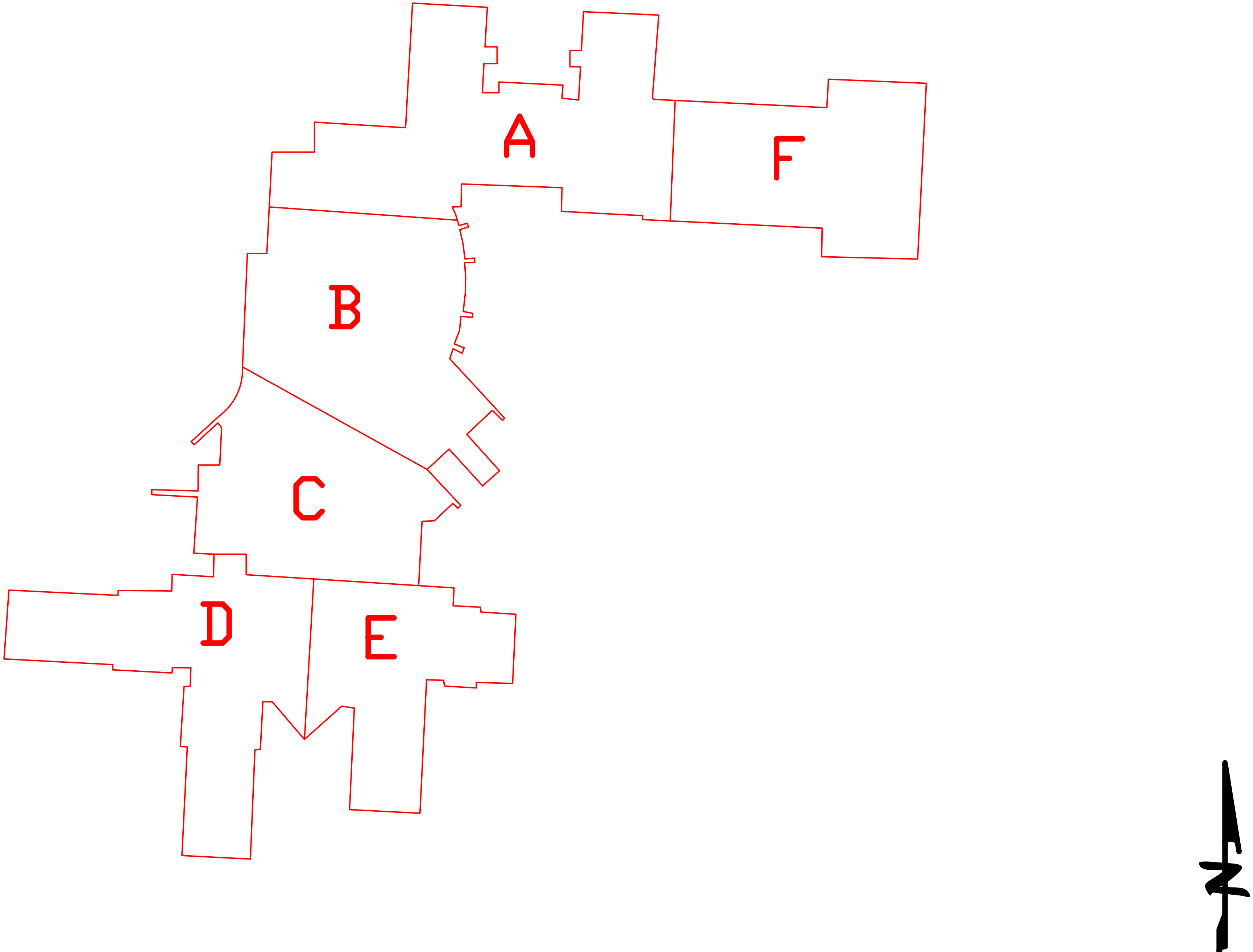
APPENDIX A

Project Overview-Research Topic



ERECTION SEQUENCE

QUESTIONNAIRE	
1	How would you define value engineering (VE)?
2	Have you ever performed VE on a specific job?
	If so what type of project (ie. health care, office building, airport, education, etc)?
4	Is there a difference in VE and cutting costs?
5	Who should be involved in the VE process (ie. owner, architect, CM)?
6	When should VE occur?
	Should this change, if the building was going for LEED or some sustainability status?
7	How would VE for a sustainable building differ from a regular building?
8	What are the steps or logistical thinking process you take during VE?
	Can this be applied to sustainable buildings also? If not, what should be different?
10	What is first looked at when doing VE for a building?
11	How do you get the best results out of VE or evalutate the best alternatives?
12	How do you communicate these VE ideas?
13	How would you integrate VE and sustainability?
14	What is more important first cost or life cycle cost? Why?

15	How do you manage quality during VE?
16	Should there be any future follow up or implementation?
	If so how and what should be done?
18	How do you educate or get the information out about VE and sustainability?

APPENDIX B

Structural Breadth

```
****************************************************
*                                                  *
*           STAAD.Pro                              *
*           Version  2006    Bld 1002.US           *
*           Proprietary Program of                 *
*           Research Engineers,  Intl.             *
*           Date=    APR  6, 2007                  *
*           Time=    22: 0: 8                      *
*                                                  *
*      USER ID: ae                                 *
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INPUT FILE: Structure2A.STD
     2. START JOB INFORMATION
     3. ENGINEER DATE 31-MAR-07
     4. END JOB INFORMATION
     5. INPUT WIDTH 79
     6. UNIT FEET POUND
     7. JOINT COORDINATES
     8. 1 0 0 0; 2 38 0 0; 3 2 1.579 0; 4 36 1.579 0; 5 19 15 0; 6 12.5 1.579 0
     9. 7 25.5 1.579 0; 8 12.5 8.5 0; 9 25.5 8.5 0; 10 10.767 8.5 0; 11 27.233 8.5 0
    10. 12 5.102 4.028 0; 13 32.898 4.028 0; 14 10.008 7.901 0; 15 27.992 7.901 0
    11. 16 14.914 11.774 0; 17 23.086 11.774 0
    12. MEMBER INCIDENCES
    13. 3 3 4; 4 8 6; 5 10 11; 6 9 7; 7 11 7; 8 10 6; 9 1 3; 10 3 12; 11 12 14
    14. 12 14 10; 13 10 16; 14 16 5; 15 2 4; 16 4 13; 17 13 15; 18 15 11; 19 11 17
    15. 20 17 5
    16. DEFINE MATERIAL START
    17. ISOTROPIC STEEL
    18. E 4.176E+009
    19. POISSON 0.3
    20. DENSITY 489.024
    21. ALPHA 6.5E-006
    22. DAMP 0.03
    23. END DEFINE MATERIAL
    24. MEMBER PROPERTY AMERICAN
    25. 5 9 TO 20 TABLE ST W8X24
    26. 4 6 TO 8 TABLE ST C8X11
    27. 3 TABLE ST MC8X22
    28. CONSTANTS
    29. MATERIAL STEEL ALL
    30. SUPPORTS
    31. 3 6 7 PINNED
    32. 4 FIXED BUT FX MZ
    33. LOAD 1 LOADTYPE NONE  TITLE LOAD CASE 1
    34. JOINT LOAD
    35. 1 2 12 TO 17 FY -126.5
    36. 5 FY -165
    37. 1 2 FY -299
    38. 12 13 FY -586.5
    39. 14 15 FY -575
    40. 16 17 FY -563.5
```

```
41. 5 FY -552
42. PERFORM ANALYSIS


       P R O B L E M   S T A T I S T I C S
       -----------------------------------

 NUMBER OF JOINTS/MEMBER+ELEMENTS/SUPPORTS =    17/    18/     4
 ORIGINAL/FINAL BAND-WIDTH=    12/     4/     27 DOF
 TOTAL PRIMARY LOAD CASES =    1, TOTAL DEGREES OF FREEDOM =     89
 SIZE OF STIFFNESS MATRIX =        3 DOUBLE  KILO-WORDS
 REQRD/AVAIL. DISK SPACE  =     12.1/ 137514.5 MB



43. LOAD LIST ALL
44. PRINT SUPPORT REACTION ALL
```

SUPPORT REACTIONS -UNIT POUN FEET STRUCTURE TYPE = SPACE

JOINT	LOAD	FORCE-X	FORCE-Y	FORCE-Z	MOM-X	MOM-Y	MOM Z
3	1	4.40	1458.95	0.00	0.00	0.00	0.00
6	1	-361.79	1429.78	0.00	0.00	0.00	0.00
7	1	357.38	1429.04	0.00	0.00	0.00	0.00
4	1	0.00	1459.23	0.00	0.00	0.00	0.00

************** END OF LATEST ANALYSIS RESULT **************

45. PRINT MAXFORCE ENVELOPE ALL

MEMBER FORCE ENVELOPE

ALL UNITS ARE POUN FEET

MAX AND MIN FORCE VALUES AMONGST ALL SECTION LOCATIONS

MEMB		FY/ FZ	DIST	LD	MZ/ MY	DIST	LD	FX		DIST	LD
3	MAX	0.25	0.00	1	-22.54	0.00	1				
		0.00	0.00	1	0.00	0.00	1	649.40	T	0.00	1
	MIN	0.25	34.00	1	-31.19	34.00	1				
		0.00	34.00	1	0.00	34.00	1	649.40	T	34.00	1
4	MAX	0.00	0.00	1	0.00	0.00	1				
		0.00	0.00	1	0.00	0.00	1	0.00		0.00	1
	MIN	0.00	6.92	1	0.00	6.92	1				
		0.00	6.92	1	0.00	6.92	1	0.00		6.92	1
5	MAX	-0.01	0.00	1	22.96	16.47	1				
		0.00	0.00	1	0.00	0.00	1	560.66	T	0.00	1
	MIN	-0.01	16.47	1	22.72	0.00	1				
		0.00	16.47	1	0.00	16.47	1	560.66	T	16.47	1
6	MAX	0.00	0.00	1	0.00	6.34	1				
		0.00	0.00	1	0.00	0.00	1	0.00		0.00	1
	MIN	0.00	6.92	1	0.00	0.00	1				
		0.00	6.92	1	0.00	6.92	1	0.00		6.92	1
7	MAX	-0.43	0.00	1	0.00	7.13	1				
		0.00	0.00	1	0.00	0.00	1	1473.05	C	0.00	1
	MIN	-0.43	7.13	1	-3.06	0.00	1				
		0.00	7.13	1	0.00	7.13	1	1473.05	C	7.13	1
8	MAX	3.66	0.00	1	26.14	0.00	1				
		0.00	0.00	1	0.00	0.00	1	1474.84	C	0.00	1
	MIN	3.66	7.13	1	0.00	7.13	1				
		0.00	7.13	1	0.00	7.13	1	1474.84	C	7.13	1
9	MAX	-333.96	0.00	1	851.00	2.55	1				
		0.00	0.00	1	0.00	0.00	1	263.66	T	0.00	1
	MIN	-333.96	2.55	1	0.00	0.00	1				
		0.00	2.55	1	0.00	2.55	1	263.66	T	2.55	1
10	MAX	405.80	0.00	1	873.54	0.00	1				
		0.00	0.00	1	0.00	0.00	1	1153.38	C	0.00	1
	MIN	405.80	3.95	1	-730.27	3.95	1				
		0.00	3.95	1	0.00	3.95	1	1153.38	C	3.95	1
11	MAX	-153.79	0.00	1	231.02	6.25	1				
		0.00	0.00	1	0.00	0.00	1	711.57	C	0.00	1

MIN	-153.79	6.25	1	-730.27	0.00	1			
	0.00	6.25	1	0.00	6.25	1	711.57 C	6.25	1
12 MAX	-704.36	0.00	1	912.05	0.97	1			
	0.00	0.00	1	0.00	0.00	1	277.01 C	0.00	1
MIN	-704.36	0.97	1	231.02	0.00	1			
	0.00	0.97	1	0.00	0.97	1	277.01 C	0.97	1
13 MAX	294.57	0.00	1	863.20	0.00	1			
	0.00	0.00	1	0.00	0.00	1	1318.94 C	0.00	1
MIN	294.57	5.28	1	-693.22	5.28	1			
	0.00	5.28	1	0.00	5.28	1	1318.94 C	5.28	1
14 MAX	-247.01	0.00	1	592.73	5.21	1			
	0.00	0.00	1	0.00	0.00	1	891.38 C	0.00	1
MIN	-247.01	5.21	1	-693.22	0.00	1			
	0.00	5.21	1	0.00	5.21	1	891.38 C	5.21	1
15 MAX	-333.96	0.00	1	851.00	2.55	1			
	0.00	0.00	1	0.00	0.00	1	263.66 T	0.00	1
MIN	-333.96	2.55	1	0.00	0.00	1			
	0.00	2.55	1	0.00	2.55	1	263.66 T	2.55	1
16 MAX	409.15	0.00	1	882.19	0.00	1			
	0.00	0.00	1	0.00	0.00	1	1150.41 C	0.00	1
MIN	409.15	3.95	1	-734.86	3.95	1			
	0.00	3.95	1	0.00	3.95	1	1150.41 C	3.95	1
17 MAX	-150.44	0.00	1	205.49	6.25	1			
	0.00	0.00	1	0.00	0.00	1	708.60 C	0.00	1
MIN	-150.44	6.25	1	-734.86	0.00	1			
	0.00	6.25	1	0.00	6.25	1	708.60 C	6.25	1
18 MAX	-701.01	0.00	1	883.29	0.97	1			
	0.00	0.00	1	0.00	0.00	1	274.04 C	0.00	1
MIN	-701.01	0.97	1	205.49	0.00	1			
	0.00	0.97	1	0.00	0.97	1	274.04 C	0.97	1
19 MAX	294.59	0.00	1	863.39	0.00	1			
	0.00	0.00	1	0.00	0.00	1	1318.96 C	0.00	1
MIN	294.59	5.28	1	-693.12	5.28	1			
	0.00	5.28	1	0.00	5.28	1	1318.96 C	5.28	1
20 MAX	-246.99	0.00	1	592.73	5.21	1			
	0.00	0.00	1	0.00	0.00	1	891.39 C	0.00	1
MIN	-246.99	5.21	1	-693.12	0.00	1			
	0.00	5.21	1	0.00	5.21	1	891.39 C	5.21	1

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46. FINISH

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     *********** END OF THE STAAD.Pro RUN ***********

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 *   Research Engineers Offices at the following locations  *
 *                                                          *
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 *  UK        +44(1454)207-000       support@reel.co.uk     *
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 *  NORWAY    +47 67 57 21 30        staad@edr.no           *
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 *  INDIA     +91(033)2357-3575 support@calcutta.reiusa.com *
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 *  Asia                            support@reiasia.net     *
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Information about the key files in the current distribution

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07/18/2006	0x100	05738496	SProStaadStl.exe
09/19/2003	0x2fc0	00081970	CMesh.dll
05/31/2006	0x3c0	02486272	dbSectionInterface.dll
01/24/2001	0x9b40	00073728	LoadGen.dll
09/25/2003	0x6340	00704512	MeshEngine.dll
09/22/2003	0xce00	00069632	QuadPlateEngine.dll
12/22/2005	0x4181	00094208	SurfMesh.dll
01/03/2006	0x81c1	00493568	aiscsections.mdb
06/13/2006	0xd4c1	01204224	AISCSectionsRCeco.mdb
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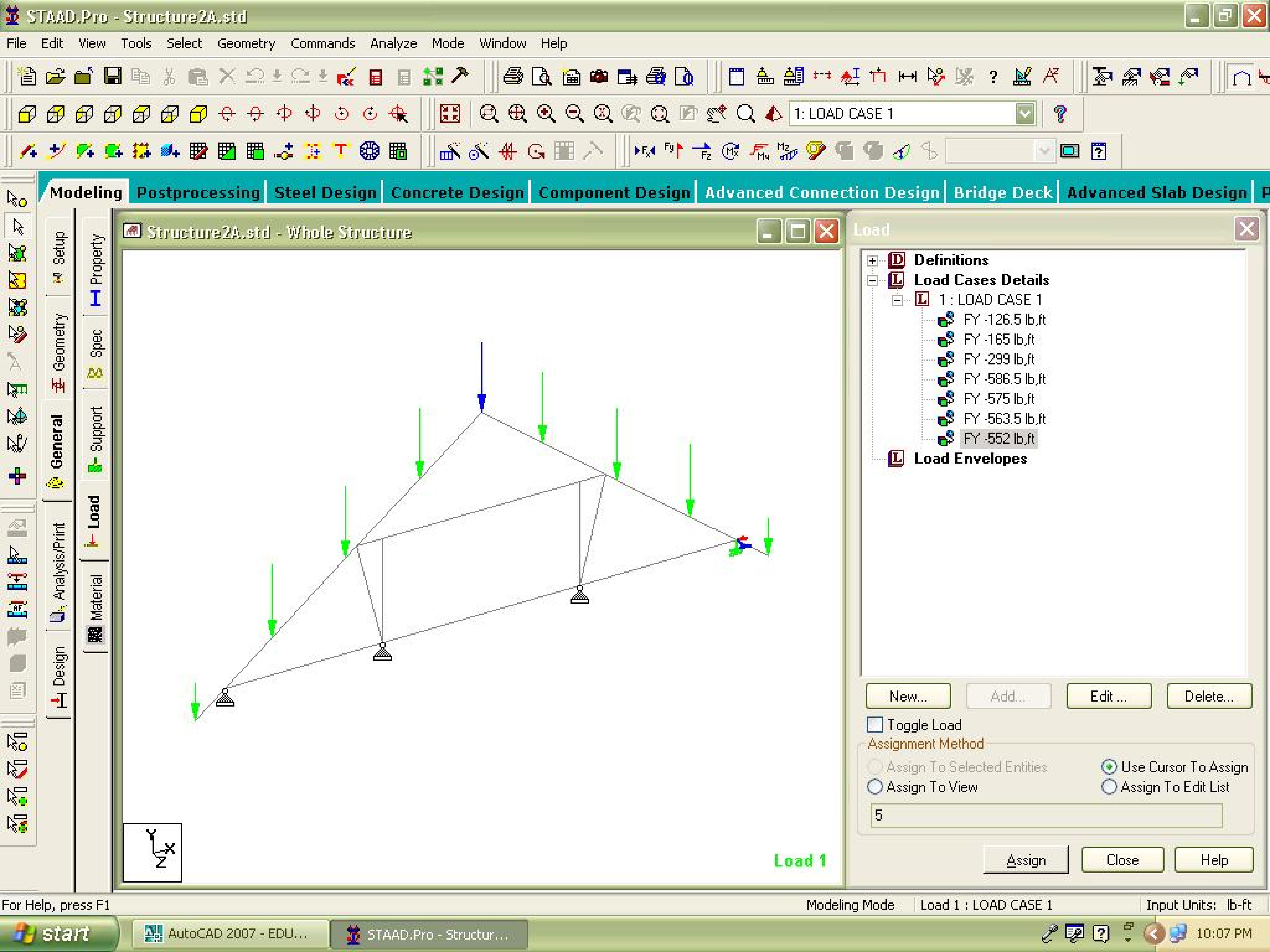
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File Edit View Tools Select Geometry Commands Analyze Mode Window Help
1: LOAD CASE 1
Modeling
Postprocessing
Steel Design
Concrete Design
Component Design
Advanced Connection Design
Bridge Deck
Advanced Slab Design
Setup
Geometry
General
Analysis/Print
Design
Property
Spec
Support
Load
Material
Structure2A.std - Whole Structure
Load 1
Load
Definitions
Load Cases Details
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FY -126.5 lb,ft
FY -165 lb,ft
FY -299 lb,ft
FY -586.5 lb,ft
FY -575 lb,ft
FY -563.5 lb,ft
FY -552 lb,ft
Load Envelopes
New...
Add...
Edit ...
Delete...
Toggle Load
Assignment Method
Assign To Selected Entities
Use Cursor To Assign
Assign To View
Assign To Edit List
5
Assign
Close
Help
For Help, press F1
Modeling Mode
Load 1 : LOAD CASE 1
Input Units: lb-ft
start
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STAAD.Pro - Structur...
10:07 PM

Table B2010-112 Partially and Fully Grouted Reinforced Concrete Masonry Wall Capacities Per L.F. (Kips & In-Kips)

Earthquake Zones 1, 2 & 3					Allowable Vertical Wall Loads									Allowable Wall Moments (Without Vertical Wall Loads)	
Thk.	Length Or Height		Grouted Core & Rebar		Eccentric Loads				Without Wind or Eccentric Loads		With Wind			Not Wind or Earthquake	
					7.0 in-K/Ft.		3.5 in-K/Ft.				Inspection				
					Inspection		Inspection		Inspection		No		Yes	Inspection	
T (Nom.) (in)	h′ (Ft.)	h′/T (in/in)	(spacing) (in O.C.)	Rebar Size (@ ¢L)	No (K/Ft.)	Yes (K/Ft.)	No (K/Ft.)	Yes (K/Ft.)	No (K/Ft.)	Yes (K/Ft.)	15 psf (K/Ft.)	30 psf (K/Ft.)	15 & 30 (K/Ft.)	No (in.-K/Ft.)	Yes (in.-K/Ft.)
8″ Conc. Block	8′	12	48″	#8	5.10	12.55	6.25	13.70	7.75	14.90	7.45	7.45	14.90	7.55	12.20
			32″	#5	5.45	13.35	6.65	14.60	7.90	15.80	7.90	7.90	15.80	6.45	9.60
			16″		6.50	15.80	7.90	17.15	9.25	18.50	9.25	9.25	18.50	7.95	12.85
			8″	↓	10.10	23.40	11.70	25.00	13.30	26.55	13.30	13.30	26.55	10.20	17.15
	12′	18	48″	#8	4.70	11.60	5.80	12.65	6.85	13.75	6.85	6.85	13.75	7.55	12.20
			32″	#5	5.05	12.35	6.15	13.45	7.30	14.60	7.30	7.30	14.60	6.45	9.60
			16″		6.00	14.55	7.30	15.85	8.55	17.10	8.55	8.55	17.10	7.95	12.85
			8″	↓	9.30	21.60	10.80	23.05	12.25	24.55	12.25	12.25	24.55	10.20	17.15
	16′	24	48″	#8	3.95	9.70	4.85	10.60	5.75	11.55	5.75	—	11.55	7.55	12.20
			32″	#5	4.20	12.25	5.15	11.30	6.10	12.25	6.10	—	12.25	6.45	9.60
			16″		5.05	12.20	6.10	13.30	7.15	14.35	7.15	—	14.35	7.95	12.85
			8″	↓	7.80	18.10	9.05	19.35	10.30	20.60	10.30	9.65	20.60	10.20	17.15
10″ Conc. Block	8′	9.6	48″	#8	7.25	16.45	8.20	17.40	9.15	—	9.15	9.15	18.35	13.10	21.05
			32″	↓	7.80	17.60	8.80	18.60	9.80	19.55	9.80	9.80	19.55	14.55	24.15
			16″	#5	9.45	21.15	10.55	22.25	11.65	23.35	11.65	11.65	23.35	13.90	22.35
			8″	↓	14.50	31.65	15.80	32.95	17.10	34.25	17.10	17.10	34.25	18.45	30.15
	12	14.4	48″	#8	7.05	16.00	8.00	16.90	8.90	17.85	8.90	8.90	17.85	13.10	21.05
			32″	↓	7.60	17.10	8.55	18.05	9.50	19.05	9.50	9.50	19.05	14.55	24.15
			16″	#5	9.20	20.55	10.25	21.60	11.35	22.70	11.35	11.35	22.70	13.90	22.35
			8″	↓	14.10	30.75	15.35	32.05	16.65	33.00	16.65	16.65	33.30	18.35	30.15
	16′	19.2	48″	#8	6.70	15.10	7.55	16.00	8.40	16.85	8.40	8.40	16.85	13.10	21.05
			32″	↓	7.15	16.15	8.05	17.05	9.00	17.95	9.00	9.00	17.95	14.55	24.15
			16″	#5	8.70	19.40	9.70	20.40	10.70	21.45	10.70	10.70	21.45	13.90	22.35
			8″	↓	13.35	29.05	14.50	30.25	15.70	31.45	15.70	15.70	31.45	18.35	30.15
	20′	24	48″	#8	6.05	13.65	6.80	14.45	7.60	15.20	7.60	—	15.20	13.10	21.05
			32″	↓	6.45	14.60	7.30	15.40	8.10	16.25	8.10	0.70	16.25	14.55	24.15
			16″	#5	7.85	17.50	8.75	18.45	9.65	19.35	9.65	0.25	19.35	13.90	22.35
			8″	↓	12.05	26.25	13.10	27.30	14.20	28.40	14.20	13.40	28.40	18.35	30.15
12″ Conc. Block	8′	8	48″	#8	9.20	20.00	10.00	20.75	10.75	21.55	10.75	10.75	21.55	15.30	24.40
			32″	↓	9.90	21.50	10.75	22.30	11.55	23.15	11.55	11.55	23.15	17.10	28.10
			16″	#5	12.10	26.05	13.00	26.95	13.90	27.85	13.90	13.90	27.85	16.20	25.90
			8″	↓	18.60	39.35	19.65	40.40	20.75	41.50	20.75	20.75	41.50	21.45	35.10
	12′	12	48″	#8	9.00	19.55	9.75	20.35	10.55	21.10	10.55	10.55	21.10	15.30	24.40
			32″	↓	9.70	21.05	10.50	21.85	11.30	22.65	11.30	11.30	22.65	17.10	28.10
			16″	#5	11.85	25.50	12.75	26.40	13.65	27.30	13.65	13.65	27.30	16.20	25.90
			8″	↓	18.20	38.50	19.25	39.55	20.30	40.60	20.30	20.30	40.60	21.45	35.10
	16′	16	48″	#8	8.65	18.75	9.35	19.50	10.10	20.20	10.10	10.10	20.20	15.30	24.40
			32″	↓	9.30	20.15	10.05	20.90	10.85	21.70	10.85	10.85	21.70	17.10	28.10
			16″	#5	11.35	24.40	12.20	25.25	13.05	26.15	13.05	13.05	26.15	16.20	25.90
			8″	↓	17.45	36.90	18.45	37.90	19.45	38.90	19.45	19.45	38.90	21.45	35.10
	24′	24	48″	#8	7.05	15.35	7.65	15.95	8.30	16.55	8.30	—	16.55	15.30	24.40
			32″	↓	7.60	16.55	8.25	17.15	8.90	17.80	8.90	—	17.80	17.10	28.10
			16″	#5	9.30	20.00	10.00	20.70	10.70	21.45	10.40*	—	21.45	16.20	25.90
			8″	↓	14.30	30.25	15.10	31.10	15.95	31.90	15.55*	15.15	31.90	21.45	35.10

*Zone 3 only

Table B2010-114 Fully Grouted Reinforced Masonry Wall Capacities Per L.F. (Kips & In-Kips)

Earthquake Zones 1, 2 & 3					Allowable Vertical Wall Loads									Allowable Wall Moments Without Vertical Wall Loads	
Thk.	Length Or Height		Type Wall	Rebar	Eccentric Loads				Without Wind or Eccentric Loads		With Wind			Not Wind or Earthquake	
					7.0 in-K/Ft.		3.5 in-K/Ft.				Inspection				
T (Nom.) (in)	h′ (Ft.)	h′/T (in/in)	Brick Grout Conc. M.U.	Size and Spacing (in. O.C.)	Inspection No (K/Ft.)	Inspection Yes (K/Ft.)	Inspection No (K/Ft.)	Inspection Yes (K/Ft.)	Inspection No (K/Ft.)	Inspection Yes (K/Ft.)	No 15 psf (K/Ft.)	No 30 psf (K/Ft.)	Yes 15 & 30 (K/Ft.)	Inspection No (in.-K/Ft.)	Inspection Yes (in.-K/Ft.)
8″	8′	12	4″0″4″	#5@32	10.10	23.35	11.70	24.50	13.30	26.55	13.30	13.30	26.55	6.90	9.65
			Solid CMU		12.75	28.70	14.35	30.30	15.95	31.90	15.95	15.95	31.90	7.80	9.75
	12′	18	4″0″4″		9.30	21.60	10.80	23.05	12.25	24.55	12.25	12.25	24.55	6.90	9.65
			Solid CMU		16.65	26.50	18.15	28.00	14.70	29.45	14.70	14.70	29.45	7.80	9.75
	16′	24	4″0″4″		7.80	18.10	9.05	19.35	10.30	20.60	10.30	9.65	20.60	6.90	9.65
			Solid CMU	↓	9.85	22.20	11.10	23.45	12.35	24.70	12.35	12.35	12.70	7.80	9.75
10″	8′	9.6	4″0″6″	#5@24	14.45	31.50	15.75	32.80	17.05	34.10	17.05	17.05	34.10	11.20	16.20
			Solid CMU		17.85	38.35	19.15	39.65	20.45	40.90	20.45	20.45	40.90	12.65	16.35
			4″2″4″		14.45	31.50	15.75	32.80	17.05	34.10	17.05	17.05	34.10	11.20	16.20
	12′	14.4	4″0″6″		13.90	30.35	15.15	31.60	16.40	32.80	16.40	16.40	32.80	11.20	16.20
			Solid CMU		17.20	36.90	18.45	38.15	19.70	39.40	19.70	19.70	39.40	12.65	16.35
			4″2″4″		13.90	30.35	15.15	31.60	16.40	32.80	16.40	16.40	32.80	11.20	16.20
	16′	19.2	4″0″6″		12.85	28.05	14.00	29.20	15.15	30.35	15.15	15.15	30.35	11.20	16.20
			Solid CMU		15.90	34.10	17.05	35.25	18.20	36.40	13.20	13.20	36.40	12.65	16.35
			4″2″4″		12.85	23.05	14.00	29.20	15.15	30.35	15.15	15.15	30.35	11.20	16.20
	20′	24	4″0″6″		11.15	24.25	12.10	25.25	13.10	26.20	13.10	12.40	26.20	11.20	16.20
			Solid CMU		13.75	29.50	14.75	30.50	15.75	31.50	15.75	15.75	31.50	12.65	16.35
			4″2″4″	↓	11.15	24.25	12.10	25.25	13.10	26.20	13.10	12.40	26.20	11.20	16.20
12″	8′	8	4″0″8″	#8@48	18.60	39.35	19.65	40.40	20.75	41.50	20.75	20.75	41.50	16.65	24.90
			Solid CMU		22.75	47.65	23.80	48.70	24.90	49.80	24.90	24.90	49.80	18.80	25.10
			4″2″6″	#5@20	18.60	39.35	19.65	40.40	20.75	41.50	20.75	20.75	41.50	11.90	18.75
	12′	12	4″0″8″	#8@48	18.20	38.50	19.25	39.55	20.30	40.60	20.30	20.30	40.60	16.65	24.90
			Solid CMU	↓	22.25	46.65	23.30	47.70	24.35	48.75	24.35	24.35	48.75	18.80	25.10
			4″2″6″	#5@20	18.20	38.50	19.25	39.55	20.30	40.60	20.30	20.30	40.60	11.90	18.75
	16′	16	4″0″8″	#8@48	17.45	36.90	18.45	37.90	19.45	38.90	19.45	19.45	38.90	16.65	24.90
			Solid CMU	↓	21.30	44.70	22.35	45.70	23.35	46.70	23.25	23.35	46.70	18.80	25.10
			4″2″6″	#5@20	17.45	36.90	18.45	37.90	19.45	38.90	19.45	19.45	38.90	11.90	18.75
	24′	24	4″0″8″	#8@48	14.30	30.25	15.10	31.10	15.95	31.90	15.95	15.15	31.90	16.65	24.90
			Solid CMU	↓	17.15	36.65	18.30	37.45	19.15	38.30	19.15	19.15	38.30	18.80	25.10
			4″2″6″	#5@20	14.30	30.25	15.10	31.10	15.95	31.90	15.95	15.15	31.90	11.90	18.75
16″	8′	6	4″0″12″	#8@32	26.40	54.40	27.20	55.20	28.00	56.05	28.00	28.00	56.05	31.20	49.10
			Solid CMU	↓	32.00	65.65	32.80	66.45	33.60	67.25	33.60	33.60	67.25	35.25	50.40
			4″2″10″	#5@15	26.40	54.40	27.20	55.20	28.00	56.05	28.00	28.00	56.05	14.75	24.10
	12′	9	4″0″12″	#8@32	26.15	53.95	26.95	54.75	27.75	55.55	27.75	27.75	55.55	31.20	49.10
			Solid CMU	↓	31.70	66.05	32.50	65.85	33.30	66.65	33.00	33.30	66.65	35.25	50.40
			4″2″10″	#5@15	26.15	53.95	26.95	54.75	27.75	55.55	27.75	27.75	55.55	14.75	24.10
	16′	12	4″0″12″	#8@32	25.70	53.05	26.50	53.80	28.30	54.60	27.30	27.30	54.60	31.20	49.10
			Solid CMU		31.20	63.95	31.95	64.75	32.75	65.50	32.75	32.75	65.50	35.25	50.40
			4″2″10″	↓	25.70	53.05	26.50	53.80	27.30	54.60	27.30	27.30	59.60	14.75	24.10
	32′	24	4″0″12″	#8@32	20.35	41.95	20.95	42.55	21.60	43.20	18.75*	18.75*	43.20	31.20	49.10
			Solid CMU	↓	24.65	50.60	25.30	51.20	25.90	51.85	24.55*	24.55*	51.85	35.25	50.40
			4″2″10″	#5@15	20.35	41.95	20.95	42.55	21.60	43.20	18.75*	18.75*	43.20	14.75	24.10

*Zone 3 Only

Table B2010-116 Unreinforced Masonry Wall Capacities Per L.F. (Kips & In-Kips)

Thk. T (Nom.) (in)	Earthquake Zones 0 & 1 Only: Length Or Height h′ (Ft.)	h′/t (in/in)	Type of Wall	Allowable Vertical Wall Loads: Eccentric Loads 7.0 (K/Ft.)	Eccentric Loads 3.5 (K/Ft.)	Without Wind or Eccentric Loads (K/Ft.)	With Wind 15 psf (K/Ft.)	With Wind 30 psf (K/Ft.)	Allowable Wall Moments (Without Vertical Wall Loads): Not Wind or Earthquake Inspection No (in-K/Ft.)	Not Wind or Earthquake Inspection Yes (in-K/Ft.)	Wind or Earthquake Inspection No (in-K/Ft.)	Wind or Earthquake Inspection Yes (in-K/Ft.)
8″	8′	12	Solid Brick	4.85	7.50	10.15	10.15	10.15	1.15	2.30	1.55	3.10
			Solid CM Units	8.85	11.50	14.15	14.15	14.15	.70	1.40	.95	1.85
			Hollow CM Units	7.95	10.60	13.30	13.30	13.30	.70	1.40	.60	1.25
	10′	15	Solid Brick	4.70	7.30	9.85	9.85	9.85	1.15	2.30	1.55	3.10
			Solid CM Units	8.55	11.15	13.75	13.75	13.75	.70	1.40	.90	1.85
			Hollow CM Units	—	4.45	6.30	6.30	6.05	.45	.95	.60	1.25
	12′	18	Solid Brick	—	6.95	9.40	9.40	7.95	1.15	2.30	1.55	3.10
			Solid CM Units	8.15	10.60	13.10	13.10	12.90	.70	1.40	.90	1.85
			Hollow CM Units	—	4.25	6.00	6.00	4.75	.45	.95	.60	1.25
12″	8′	8	Solid Brick	12.30	14.10	15.90	15.90	15.90	2.70	5.40	3.60	7.20
			Solid CM Units	18.50	20.30	22.10	22.10	22.10	1.60	3.20	2.15	4.30
			Hollow CM Units	7.85	9.10	10.40	10.40	10.40	1.10	2.25	1.50	3.00
			Brick & Hollow CMU	5.50	7.80	10.05	10.05	10.05	1.35	2.70	1.80	3.60
	12′	12	Solid Brick	12.05	13.80	15.55	15.55	15.55	2.70	5.40	3.60	7.20
			Solid CM Units	13.45	14.75	16.05	16.05	16.05	1.60	3.20	2.15	4.30
			Hollow CM Units	7.65	8.90	10.15	10.15	10.15	1.10	2.25	1.50	3.00
			Brick & Hollow CMU	5.40	7.65	9.85	9.85	9.05	1.35	2.70	1.80	3.60
	16′	16	Solid Brick	11.55	13.20	14.90	14.90	14.35	2.70	5.40	3.60	7.20
			Solid CM Units	17.35	19.05	20.70	20.70	20.70	1.60	3.20	2.15	4.30
			Hollow CM Units	7.35	8.55	9.75	9.75	9.05	1.10	2.25	1.50	3.00
			Brick & Hollow CMU	5.20	7.30	9.45	9.10	—	1.35	2.70	1.80	3.60
16″	12′	9	Solid Brick	18.60	19.95	21.30	21.30	21.30	4.85	9.75	6.50	13.00
			Solid CM Units	26.95	28.30	29.60	29.60	29.60	2.90	5.85	3.90	7.80
			Hollow CM Units	10.85	12.10	13.30	13.30	13.30	1.50	3.05	2.00	4.05
			Brick & Hollow CMU	9.30	11.10	12.85	12.85	12.85	2.20	4.40	2.90	5.85
	16′	12	Solid Brick	18.30	19.60	20.90	20.90	20.90	4.85	9.75	6.50	13.00
			Solid CM Units	26.50	27.80	29.10	29.10	29.10	2.90	5.85	3.90	7.80
			Hollow CM Units	10.70	11.90	13.10	13.10	13.10	1.50	3.05	2.00	4.05
			Brick & Hollow CMU	9.15	10.90	12.65	12.65	11.10	2.20	4.40	2.90	5.85
	20′	15	Solid Brick	17.80	19.05	20.30	20.30	20.30	4.85	9.75	6.50	13.00
			Solid CM Units	25.75	27.00	28.25	28.25	28.25	2.90	5.85	3.90	7.80
			Hollow CM Units	10.40	11.55	12.70	12.70	10.95	1.50	3.05	2.00	4.05
			Brick & Hollow CMU	8.90	10.60	12.30	12.00	—	2.20	4.40	2.90	5.85
20″	12′	7.2	Solid Brick	24.80	25.85	26.90	26.90	26.90	7.70	15.40	10.25	20.50
			Solid CM Units	35.30	36.40	37.45	37.45	37.45	4.60	9.20	6.15	12.30
			Hollow CM Units	16.15	17.15	18.15	18.15	18.15	2.50	5.05	3.35	6.75
			Brick & Hollow CMU	16.10	17.25	18.45	18.45	18.45	4.05	8.10	5.40	10.80
	16′	9.6	Solid Brick	24.55	25.60	26.70	26.70	26.70	7.70	15.40	10.25	20.50
			Solid CM Units	35.00	36.10	37.15	37.15	37.15	4.60	9.20	6.15	12.30
			Hollow CM Units	16.00	17.00	18.00	18.00	18.00	2.50	5.05	3.35	6.75
			Brick & Hollow CMU	15.95	17.10	18.30	18.30	18.30	4.05	8.10	5.40	10.80
	24′	14.4	Solid Brick	23.70	24.70	25.75	25.75	25.75	7.70	15.40	10.25	20.50
			Solid CM Units	33.80	34.80	35.80	35.80	35.80	4.60	9.20	6.15	12.30
			Hollow CM Units	15.45	16.40	17.40	17.40	16.05	2.50	5.05	3.35	6.75
			Brick & Hollow CMU	15.40	16.50	17.65	17.65	15.25	4.05	8.10	5.40	10.80

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3 Concrete — 2005 National Average Costs

03200 Concrete Reinforcement — Union

BLDG PROD

- CONCRETE ADMIXTURES & SU
- AGGREGATE
- CEMENT
- CRIBBING
- CUTTING
- DAMPPROOFING
- EQUIPMENT
- LIFT SLAB
- SAWING CONCRETE
- WATERPROOFING AND DAMP
- WINTER PROTECTION
- orms & Accessories
- einforcement
- ce Concrete
- ral Concrete
- CONCRETE, FIELD MIX
- CONCRETE, READY MIX
- CONCRETE IN PLACE
- INSULATING CONCRETE
- PLACING CONCRETE
- te Finishing
- lly Placed Concrete
- te Curing
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- us Decks & Underlayments
- estoration & Cleaning

03240 Fibrous Reinforcing	Crew	Daily Output	Labor Hours	Unit	Bare Mat.	Bare Labor	Bare Equip.	Bare
FIBROUS REINFORCING								
1-1/2 lb. per C.Y.				C.Y.	6			
Steel fibers, add to concrete				Lb.	.44			
25 lb. per C.Y.				C.Y.	11			
50 lb. per C.Y.				C.Y.	22			
75 lb. per C.Y.				C.Y.	34			
100 lb. per C.Y.				C.Y.	44			
:00 Cast-In-Place Concrete								
03310 Structural Concrete								
CONCRETE, FIELD MIX FOB forms 2250 psi				C.Y.	72.50			
3000 psi				C.Y.	75.50			
CONCRETE, READY MIX Normal weight								
2000 psi				C.Y.	77.50			
2500 psi				C.Y.	79.50			
3000 psi				C.Y.	81			
3500 psi				C.Y.	82			
4000 psi				C.Y.	84			
4500 psi				C.Y.	86			
5000 psi				C.Y.	90			
6000 psi				C.Y.	103			
8000 psi				C.Y.	167			
10,000 psi				C.Y.	238			
12,000 psi				C.Y.	287			
For high early strength cement, add				C.Y.	10.0%			
For structural lightweight with regular sand, add				C.Y.	25.0%			
For all lightweight aggregate, add				C.Y.	45.0%			
For integral colors, 2500 psi, 5 bag mix								

Settings | Estimator | Unit Costs | Assembly Costs | Project Costs | Square Foot Models | Residential Models

03 310 220 0300 — Structural concrete, ready mix, normal weight, 4000 PSI, includes material only

Qty	1.000	To List	Crew		Output		Hours		Unit	C.Y.
Material	84		Labor		Equip.		Total	84	O&P	92.50

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CostWorks 2005 - [No Active Project]

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S.Y.

3 Concrete | 2005 National Average Costs

03100 Concrete Forms & Accessories | Union

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10 Structural C.I.P. I
03110300 EXPANS
03110405 FORMS
03110410 FORMS
03110415 FORMS
03110420 FORMS
03110425 FORMS
03110430 FORMS
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03110 Structural C.I.P. Forms	Crew	Daily Output	Labor Hours	Unit	Bare Mat.	Bare Labor	Bare Equip.	Bare Total	Total In O&P
FORMS IN PLACE, WALLS									
Corbel or haunch, to 12" wide, add to wall forms, 1 use	C2	150	.320	L.F.	2.06	10.65		12.71	18.
2 use	C2	170	.282	L.F.	1.13	9.40		10.53	15.
3 use	C2	175	.274	L.F.	.83	9.15		9.98	15.
4 use	C2	180	.267	L.F.	.67	8.90		9.57	14.
Wall, below grade, job-built plywood, to 8' high, 1 use	C2	300	.160	SFCA	2.37	5.35		7.72	10.
2 use	C2	365	.132	SFCA	1.50	4.38		5.88	8.
3 use	C2	425	.113	SFCA	1.09	3.76		4.85	7.
4 use	C2	435	.110	SFCA	.88	3.68		4.56	6.
Over 8' to 16' high, 1 use	C2	280	.171	SFCA	4.51	5.70		10.21	13.
2 use	C2	345	.139	SFCA	1.89	4.64		6.53	9.
3 use	C2	375	.128	SFCA	1.57	4.27		5.84	8.
4 use	C2	395	.122	SFCA	1.40	4.05		5.45	7.
Exterior wall, 8' to 16' high, 1 use	C2	280	.171	SFCA	2.18	5.70		7.88	11.
2 use	C2	345	.139	SFCA	1.20	4.64		5.84	8.
3 use	C2	375	.128	SFCA	.85	4.27		5.12	7.
4 use	C2	395	.122	SFCA	.70	4.05		4.75	7.
Over 16' high, 1 use	C2	235	.204	SFCA	2.40	6.80		9.20	13.
2 use	C2	290	.166	SFCA	1.32	5.50		6.82	10.
3 use	C2	315	.152	SFCA	.96	5.10		6.06	8.
4 use	C2	330	.145	SFCA	.78	4.85		5.63	8.
For architectural finish, add	C2	1,825	.026	SFCA	5.40	.88		6.28	7.
Radial, smooth curved, job-built plywood, 1 use	C2	245	.196	SFCA	2.48	6.55		9.03	12.
2 use	C2	300	.160	SFCA	1.36	5.35		6.71	9.
3 use	C2	325	.148	SFCA	.99	4.92		5.91	8.
4 use	C2	335	.143	SFCA	.81	4.78		5.59	8.
Below grade, job-built plywood, 1 use	C2	225	.213	SFCA	2.99	7.10		10.09	14.
2 use	C2	225	.213	SFCA	1.65	7.10		8.75	12.

Settings | Estimator | Unit Costs | Assembly Costs | Project Costs | Square Foot Models | Residential Models

03 110 455 2550 C.I.P. concrete forms, wall, job built, plywood, exterior, 8 to 16' high, 4 use, includes erecting, bracing, stripping and cleaning

Qty	1.000	To List	Crew	C2	Output	395	Hours	.122	Unit SFCA
Material	.70		Labor	4.05	Equip.		Total	4.75	O&P 7.05

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S.Y.

3 Concrete | 2005 National Average Costs

03200 Concrete Reinforcement | Union

Requirements
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Basic Concrete Materials & Methoc
Concrete Forms & Accessories
Concrete Reinforcement
210 Reinforcing Steel
03210100 ACCESSORIES
03210200 COATED REINFORCI
03210600 REINFORCING IN PL/
03210700 SPLICING REINFORC
220 Welded Wire Fabric
230 Stressing Tendons
240 Fibrous Reinforcing
Cast-In-Place Concrete
Precast Concrete
Cementitious Decks & Underlayme
Grouts
Concrete Restoration & Cleaning

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and Moisture Protection
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03210 Reinforcing Steel	Crew	Daily Output	Labor Hours	Unit	Bare Mat.	Bare Labor	Bare Equip.	Bare
REINFORCING IN PLACE A615 Grade 60, incl. access. labor								
Spirals, hot rolled, 8" to 15" diameter	4 Rodm	2.20	14.545	Ton	1,125	550		1,6
15" to 24" diameter	4 Rodm	2.20	14.545	Ton	1,075	550		1,6
24" to 36" diameter	4 Rodm	2.30	13.913	Ton	1,025	530		1,5
36" to 48" diameter	4 Rodm	2.40	13.333	Ton	970	505		1,4
48" to 64" diameter	4 Rodm	2.50	12.800	Ton	1,075	485		1,5
64" to 84" diameter	4 Rodm	2.60	12.308	Ton	1,125	465		1,5
84" to 96" diameter	4 Rodm	2.70	11.852	Ton	1,175	450		1,6
Elevated slabs, #4 to #7	4 Rodm	2.90	11.034	Ton	850	420		1,2
Footings, #4 to #7	4 Rodm	2.10	15.238	Ton	760	580		1,3
Footings, #4 to #7	4 Rodm	4,200	.008	Lb.	.42	.29		
#8 to #18	4 Rodm	3.60	8.889	Ton	720	335		1,0
#8 to #18	4 Rodm	7,200	.004	Lb.	.42	.17		
Slab on grade, #3 to #7	4 Rodm	2.30	13.913	Ton	760	530		1,2
Slab on grade, #3 to #7	4 Rodm	4,200	.008	Lb.	.40	.29		
Walls, #3 to #7	4 Rodm	3	10.667	Ton	760	405		1,1
#8 to #18	4 Rodm	4	8	Ton	760	305		1,0
Use the following for a rough estimate guide								
Typical in place, average, under 10 ton job, #3 to #7	4 Rodm	1.80	17.778	Ton	825	675		1,5
#8 to #18	4 Rodm	2.70	11.852	Ton	845	450		1,2
10 - 50 ton job, #3 to #7	4 Rodm	2.10	15.238	Ton	810	580		1,3
#8 to #18	4 Rodm	3	10.667	Ton	830	405		1,2
50 - 100 ton job, #3 - #7	4 Rodm	2.20	14.545	Ton	790	550		1,3
#8 to #18	4 Rodm	3.10	10.323	Ton	810	390		1,2
Over 100 ton job, #3 - #7	4 Rodm	2.30	13.913	Ton	785	530		1,3
#8 - #18	4 Rodm	3.20	10	Ton	800	380		1,1
High strength steel, Grade 75, #14 bars only, add				Ton	60			
Unloading & sorting, add to above	C5	100	.560	Ton		20.50	6.15	

Settings | Estimator | Unit Costs | Assembly Costs | Project Costs | Square Foot Models | Residential Models

03 210 600 0700 | Reinforcing steel, in place, walls, #3 to #7, A615, grade 60, incl access. Labor

Qty	1.000	To List	Crew 4 Rodm	Output	3	Hours 10.667	Unit Ton
Material	760	Labor	405	Equip.		Total 1,165	O&P 1,500

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CostWorks 2005 - [No Active Project]

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S.Y.

4 Masonry

2005 National Average Costs

04800 Masonry Assemblies

Union

BLDG PROD

ssemblies
 BRICK
CLAVED AERATED CONCRETE E
VENEER
SIZED BRICK
EY
EY BLOCK
MNS
RETE BLOCK, BACK-UP,
RETE BLOCK BOND BEAM
RETE BLOCK COLUMN
RETE BLOCK, DECORATIVE
RETE BLOCK, EXTERIOR
RETE BLOCK FOUNDATION WAI
RETE BLOCK, HIGH STRENGTH
RETE BLOCK INSULATION INSE
RETE BLOCK, INTERLOCKING
RETE BLOCK, LINTELS
RETE BLOCK, PARTITIONS
RETE BRICK
RETE SCREEN BLOCK
G
G PANELS
 BLOCK
D CONCRETE BLOCK
 COTTA
 COTTA TILE

04810 Unit Masonry Assemblies	Crew	Daily Output	Labor Hours	Unit	Bare Mat.	Bare Labor	Bare Equip.	Bare
CONCRETE BLOCK, DECORATIVE C90, 2000 psi								
For bullnose block, add					10.0%			
For special color, add					13.0%			
CONCRETE BLOCK, EXTERIOR C90, 2000 psi								
Reinforced alt courses, tooled joints 2 sides								
Normal weight, 8" x 16" x 6" thick	D8	395	.101	S.F.	1.67	3.23		
8" thick	D8	360	.111	S.F.	2.48	3.55		
10" thick	D8	290	.138	S.F.	3	4.40		
12" thick	D9	250	.192	S.F.	3.01	5.95		
Lightweight, 8" x 16" x 6" thick	D8	450	.089	S.F.	1.96	2.84		
8" thick	D8	430	.093	S.F.	2.65	2.97		
10" thick	D8	395	.101	S.F.	2.99	3.23		
12" thick	D9	350	.137	S.F.	4.31	4.26		
CONCRETE BLOCK FOUNDATION WALL C90/C145								
Normal-weight, cut joints, horiz joint reinf, no vert reinf								
Hollow, 8" x 16" x 6" thick	D8	455	.088	S.F.	1.67	2.81		
8" thick	D8	425	.094	S.F.	1.80	3		
10" thick	D8	350	.114	S.F.	2.43	3.65		
12" thick	D9	300	.160	S.F.	2.51	4.97		
Solid, 8" x 16" block, 6" thick	D8	440	.091	S.F.	1.81	2.90		
8" thick	D8	415	.096	S.F.	2.59	3.08		
12" thick	D9	350	.137	S.F.	3.76	4.26		
CONCRETE BLOCK, HIGH STRENGTH Normal weight								
Hollow, reinforced alternate courses, 8" x 16" units								
3500 psi, 4" thick	D8	440	.091	S.F.	1.24	2.90		
6" thick	D8	395	.101	S.F.	1.64	3.23		
8" thick	D8	360	.111	S.F.	2.44	3.55		
12" thick	D9	250	.192	S.F.	2.96	5.95		

Settings | Estimator | Unit Costs | Assembly Costs | Project Costs | Square Foot Models | Residential Models

04 810 186 0350 Concrete masonry unit (CMU), foundation wall, trowel cut joints, normal weight, hollow, 2000 psi, 12" x 8" x 16", includes mortar and horizontal joint reinforcing every other

Qty	1.000	To List	Crew	D9	Output	300	Hours	.160	Unit S.F.
Material	2.51		Labor	4.97	Equip.		Total	7.48	O&P 10.35

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Crews

Crew B-95A	Bare Costs Hr.	Bare Costs Daily	Incl. Subs O & P Hr.	Incl. Subs O & P Daily	Cost Per Labor-Hour Bare Costs	Cost Per Labor-Hour Incl. O&P
1 Equip. Oper. (crane)	$35.90	$287.20	$54.10	$432.80	$31.30	$47.83
1 Laborer	26.70	213.60	41.55	332.40		
1 Hyd. Excavator, 5/8 C.Y.		432.40		475.65	27.03	29.73
16 L.H., Daily Totals		$933.20		$1240.85	$58.33	$77.56

Crew B-95B	Hr.	Daily	Hr.	Daily	Bare Costs	Incl. O&P
1 Equip. Oper. (crane)	$35.90	$287.20	$54.10	$432.80	$31.30	$47.83
1 Laborer	26.70	213.60	41.55	332.40		
1 Hyd. Excavator, 1.5 C.Y.		720.40		792.45	45.03	49.53
16 L.H., Daily Totals		$1221.20		$1557.65	$76.33	$97.36

Crew B-95C	Hr.	Daily	Hr.	Daily	Bare Costs	Incl. O&P
1 Equip. Oper. (crane)	$35.90	$287.20	$54.10	$432.80	$31.30	$47.83
1 Laborer	26.70	213.60	41.55	332.40		
1 Hyd. Excavator, 2.5 C.Y.		1215.00		1336.50	75.94	83.53
16 L.H., Daily Totals		$1715.80		$2101.70	$107.24	$131.36

Crew C-1	Hr.	Daily	Hr.	Daily	Bare Costs	Incl. O&P
3 Carpenters	$34.25	$822.00	$53.35	$1280.40	$32.36	$50.40
1 Laborer	26.70	213.60	41.55	332.40		
32 L.H., Daily Totals		$1035.60		$1612.80	$32.36	$50.40

Crew C-2	Hr.	Daily	Hr.	Daily	Bare Costs	Incl. O&P
1 Carpenter Foreman (out)	$36.25	$290.00	$56.45	$451.60	$33.33	$51.90
4 Carpenters	34.25	1096.00	53.35	1707.20		
1 Laborer	26.70	213.60	41.55	332.40		
48 L.H., Daily Totals		$1599.60		$2491.20	$33.33	$51.90

Crew C-2A	Hr.	Daily	Hr.	Daily	Bare Costs	Incl. O&P
1 Carpenter Foreman (out)	$36.25	$290.00	$56.45	$451.60	$33.09	$51.01
3 Carpenters	34.25	822.00	53.35	1280.40		
1 Cement Finisher	32.85	262.80	48.35	386.80		
1 Laborer	26.70	213.60	41.55	332.40		
48 L.H., Daily Totals		$1588.40		$2451.20	$33.09	$51.01

Crew C-3	Hr.	Daily	Hr.	Daily	Bare Costs	Incl. O&P
1 Rodman Foreman	$39.95	$319.60	$65.90	$527.20	$34.78	$56.15
4 Rodmen (reinf.)	37.95	1214.40	62.60	2003.20		
1 Equip. Oper. (light)	33.05	264.40	49.80	398.40		
2 Laborers	26.70	427.20	41.55	664.80		
3 Stressing Equipment		40.80		44.90		
.5 Grouting Equipment		76.40		84.05	1.83	2.01
64 L.H., Daily Totals		$2342.80		$3722.55	$36.61	$58.16

Crew C-4	Hr.	Daily	Hr.	Daily	Bare Costs	Incl. O&P
1 Rodman Foreman	$39.95	$319.60	$65.90	$527.20	$38.45	$63.43
3 Rodmen (reinf.)	37.95	910.80	62.60	1502.40		
3 Stressing Equipment		40.80		44.90	1.28	1.40
32 L.H., Daily Totals		$1271.20		$2074.50	$39.73	$64.83

Crew C-5	Hr.	Daily	Hr.	Daily	Bare Costs	Incl. O&P
1 Rodman Foreman	$39.95	$319.60	$65.90	$527.20	$36.82	$59.39
4 Rodmen (reinf.)	37.95	1214.40	62.60	2003.20		
1 Equip. Oper. (crane)	35.90	287.20	54.10	432.80		
1 Equip. Oper. Oiler	30.10	240.80	45.35	362.80		
1 Hyd. Crane, 25 Ton		616.80		678.50	11.01	12.12
56 L.H., Daily Totals		$2678.80		$4004.50	$47.83	$71.51

Crew C-6	Hr.	Daily	Hr.	Daily	Bare Costs	Incl. O&P
1 Labor Foreman (outside)	$28.70	$229.60	$44.70	$357.60	$28.06	$43.15
4 Laborers	26.70	854.40	41.55	1329.60		
1 Cement Finisher	32.85	262.80	48.35	386.80		
2 Gas Engine Vibrators		48.00		52.80	1.00	1.10
48 L.H., Daily Totals		$1394.80		$2126.80	$29.06	$44.25

Crew C-7	Hr.	Daily	Hr.	Daily	Bare Costs	Incl. O&P
1 Labor Foreman (outside)	$28.70	$229.60	$44.70	$357.60	$28.87	$44.22
5 Laborers	26.70	1068.00	41.55	1662.00		
1 Cement Finisher	32.85	262.80	48.35	386.80		
1 Equip. Oper. (med.)	34.65	277.20	52.20	417.60		
1 Equip. Oper. (oiler)	30.10	240.80	45.35	362.80		
2 Gas Engine Vibrators		48.00		52.80		
1 Concrete Bucket, 1 C.Y.		16.00		17.60		
1 Hyd. Crane, 55 Ton		895.40		984.95	13.33	14.66
72 L.H., Daily Totals		$3037.80		$4242.15	$42.20	$58.88

Crew C-7A	Hr.	Daily	Hr.	Daily	Bare Costs	Incl. O&P
1 Labor Foreman (outside)	$28.70	$229.60	$44.70	$357.60	$27.16	$42.06
5 Laborers	26.70	1068.00	41.55	1662.00		
2 Truck Drivers(Heavy)	27.55	440.80	42.00	672.00		
2 Conc. Transit Mixers		1480.80		1628.90	23.14	25.45
64 L.H., Daily Totals		$3219.20		$4320.50	$50.30	$67.51

Crew C-7B	Hr.	Daily	Hr.	Daily	Bare Costs	Incl. O&P
1 Labor Foreman (outside)	$28.70	$229.60	$44.70	$357.60	$28.53	$43.99
5 Laborers	26.70	1068.00	41.55	1662.00		
1 Equipment Operator (heavy)	35.90	287.20	54.10	432.80		
1 Equipment Oiler	30.10	240.80	45.35	362.80		
1 Conc. Bucket, 2 C.Y.		24.60		27.05		
1 Truck Crane, 165 Ton		1912.00		2103.20	30.26	33.29
64 L.H., Daily Totals		$3762.20		$4945.45	$58.79	$77.28

Crew C-7C	Hr.	Daily	Hr.	Daily	Bare Costs	Incl. O&P
1 Labor Foreman (outside)	$28.70	$229.60	$44.70	$357.60	$28.94	$44.61
5 Laborers	26.70	1068.00	41.55	1662.00		
2 Equipment Operator (medium)	34.65	554.40	52.20	835.20		
2 Wheel Loader, 4 C.Y.		891.20		980.30	13.93	15.32
64 L.H., Daily Totals		$2743.20		$3835.10	$42.87	$59.93

Crew C-7D	Hr.	Daily	Hr.	Daily	Bare Costs	Incl. O&P
1 Labor Foreman (outside)	$28.70	$229.60	$44.70	$357.60	$28.12	$43.52
5 Laborers	26.70	1068.00	41.55	1662.00		
1 Equipment Operator (med.)	34.65	277.20	52.20	417.60		
1 Concrete Conveyer		152.80		168.10	2.73	3.00
56 L.H., Daily Totals		$1727.60		$2605.30	$30.85	$46.52

Crew C-8	Hr.	Daily	Hr.	Daily	Bare Costs	Incl. O&P
1 Labor Foreman (outside)	$28.70	$229.60	$44.70	$357.60	$29.88	$45.36
3 Laborers	26.70	640.80	41.55	997.20		
2 Cement Finishers	32.85	525.60	48.35	773.60		
1 Equip. Oper. (med.)	34.65	277.20	52.20	417.60		
1 Concrete Pump (small)		704.20		774.60	12.58	13.83
56 L.H., Daily Totals		$2377.40		$3320.60	$42.46	$59.19

Crew C-8A	Hr.	Daily	Hr.	Daily	Bare Costs	Incl. O&P
1 Labor Foreman (outside)	$28.70	$229.60	$44.70	$357.60	$29.08	$44.23
3 Laborers	26.70	640.80	41.55	997.20		
2 Cement Finishers	32.85	525.60	48.35	773.60		
48 L.H., Daily Totals		$1396.00		$2128.40	$29.08	$44.23

Crew C-14D	Bare Costs Hr.	Bare Costs Daily	Incl. Subs O & P Hr.	Incl. Subs O & P Daily	Bare Costs	Incl. O&P
1 Carpenter Foreman (out)	$36.25	$290.00	$56.45	$451.60	$33.98	$53.01
18 Carpenters	34.25	4932.00	53.35	7682.40		
2 Rodmen (reinf.)	37.95	607.20	62.60	1001.60		
2 Laborers	26.70	427.20	41.55	664.80		
1 Cement Finisher	32.85	262.80	48.35	386.80		
1 Equip. Oper. (med.)	34.65	277.20	52.20	417.60		
1 Gas Engine Vibrator		24.00		26.40		
1 Concrete Pump (small)		704.20		774.60	3.64	4.01
200 L.H., Daily Totals		$7524.60		$11405.80	$37.62	$57.02

Crew C-14E	Hr.	Daily	Hr.	Daily	Bare Costs	Incl. O&P
1 Carpenter Foreman (out)	$36.25	$290.00	$56.45	$451.60	$33.59	$53.29
2 Carpenters	34.25	548.00	53.35	853.60		
4 Rodmen (reinf.)	37.95	1214.40	62.60	2003.20		
3 Laborers	26.70	640.80	41.55	997.20		
1 Cement Finisher	32.85	262.80	48.35	386.80		
1 Gas Engine Vibrator		24.00		26.40	.27	.30
88 L.H., Daily Totals		$2980.00		$4718.80	$33.86	$53.59

Crew C-14F	Hr.	Daily	Hr.	Daily	Bare Costs	Incl. O&P
1 Laborer Foreman (out)	$28.70	$229.60	$44.70	$357.60	$31.02	$46.20
2 Laborers	26.70	427.20	41.55	664.80		
6 Cement Finishers	32.85	1576.80	48.35	2320.80		
1 Gas Engine Vibrator		24.00		26.40	.33	.37
72 L.H., Daily Totals		$2257.60		$3369.60	$31.35	$46.57

Crew C-14G	Hr.	Daily	Hr.	Daily	Bare Costs	Incl. O&P
1 Laborer Foreman (out)	$28.70	$229.60	$44.70	$357.60	$30.50	$45.69
2 Laborers	26.70	427.20	41.55	664.80		
4 Cement Finishers	32.85	1051.20	48.35	1547.20		
1 Gas Engine Vibrator		24.00		26.40	.43	.47
56 L.H., Daily Totals		$1732.00		$2596.00	$30.93	$46.16

Crew C-14H	Hr.	Daily	Hr.	Daily	Bare Costs	Incl. O&P
1 Carpenter Foreman (out)	$36.25	$290.00	$56.45	$451.60	$33.71	$52.55
2 Carpenters	34.25	548.00	53.35	853.60		
1 Rodman (reinf.)	37.95	303.60	62.60	500.80		
1 Laborer	26.70	213.60	41.55	332.40		
1 Cement Finisher	32.85	262.80	48.35	386.80		
1 Gas Engine Vibrator		24.00		26.40	.50	.55
48 L.H., Daily Totals		$1642.00		$2551.60	$34.21	$53.10

Crew C-15	Hr.	Daily	Hr.	Daily	Bare Costs	Incl. O&P
1 Carpenter Foreman (out)	$36.25	$290.00	$56.45	$451.60	$32.06	$49.60
2 Carpenters	34.25	548.00	53.35	853.60		
3 Laborers	26.70	640.80	41.55	997.20		
2 Cement Finishers	32.85	525.60	48.35	773.60		
1 Rodman (reinf.)	37.95	303.60	62.60	500.80		
72 L.H., Daily Totals		$2308.00		$3576.80	$32.06	$49.60

Crew C-16	Hr.	Daily	Hr.	Daily	Bare Costs	Incl. O&P
1 Labor Foreman (outside)	$28.70	$229.60	$44.70	$357.60	$31.67	$49.19
3 Laborers	26.70	640.80	41.55	997.20		
2 Cement Finishers	32.85	525.60	48.35	773.60		
1 Equip. Oper. (med.)	34.65	277.20	52.20	417.60		
2 Rodmen (reinf.)	37.95	607.20	62.60	1001.60		
1 Concrete Pump (small)		704.20		774.60	9.78	10.76
72 L.H., Daily Totals		$2984.60		$4322.20	$41.45	$59.95

Crew C-17	Hr.	Daily	Hr.	Daily	Bare Costs	Incl. O&P
2 Skilled Worker Foremen	$36.85	$589.60	$57.30	$916.80	$35.25	$54.82
8 Skilled Workers	34.85	2230.40	54.20	3468.80		
80 L.H., Daily Totals		$2820.00		$4385.60	$35.25	$54.82

Crew C-17A	Hr.	Daily	Hr.	Daily	Bare Costs	Incl. O&P
2 Skilled Worker Foremen	$36.85	$589.60	$57.30	$916.80	$35.26	$54.81
8 Skilled Workers	34.85	2230.40	54.20	3468.80		
.125 Equip. Oper. (crane)	35.90	35.90	54.10	54.10		
.125 Crane, 80 Ton, & Tools		124.38		136.80	1.54	1.69
81 L.H., Daily Totals		$2980.28		$4576.50	$36.80	$56.50

Crew C-17B	Hr.	Daily	Hr.	Daily	Bare Costs	Incl. O&P
2 Skilled Worker Foremen	$36.85	$589.60	$57.30	$916.80	$35.27	$54.80
8 Skilled Workers	34.85	2230.40	54.20	3468.80		
.25 Equip. Oper. (crane)	35.90	71.80	54.10	108.20		
.25 Crane, 80 Ton, & Tools		248.75		273.65		
.25 Walk Behind Power Tools		6.15		6.75	3.11	3.42
82 L.H., Daily Totals		$3146.70		$4774.20	$38.38	$58.22

Crew C-17C	Hr.	Daily	Hr.	Daily	Bare Costs	Incl. O&P
2 Skilled Worker Foremen	$36.85	$589.60	$57.30	$916.80	$35.27	$54.79
8 Skilled Workers	34.85	2230.40	54.20	3468.80		
.375 Equip. Oper. (crane)	35.90	107.70	54.10	162.30		
.375 Crane, 80 Ton & Tools		373.13		410.45	4.50	4.95
83 L.H., Daily Totals		$3300.83		$4958.35	$39.77	$59.74

Crew C-17D	Hr.	Daily	Hr.	Daily	Bare Costs	Incl. O&P
2 Skilled Worker Foremen	$36.85	$589.60	$57.30	$916.80	$35.28	$54.79
8 Skilled Workers	34.85	2230.40	54.20	3468.80		
.5 Equip. Oper. (crane)	35.90	143.60	54.10	216.40		
.5 Crane, 80 Ton & Tools		497.50		547.25	5.92	6.51
84 L.H., Daily Totals		$3461.10		$5149.25	$41.20	$61.30

Crew C-17E	Hr.	Daily	Hr.	Daily	Bare Costs	Incl. O&P
2 Skilled Worker Foremen	$36.85	$589.60	$57.30	$916.80	$35.25	$54.82
8 Skilled Workers	34.85	2230.40	54.20	3468.80		
1 Hyd. Jack with Rods		79.00		86.90	.99	1.09
80 L.H., Daily Totals		$2899.00		$4472.50	$36.24	$55.91

Crew C-18	Hr.	Daily	Hr.	Daily	Bare Costs	Incl. O&P
.125 Labor Foreman (out)	$28.70	$28.70	$44.70	$44.70	$26.92	$41.90
1 Laborer	26.70	213.60	41.55	332.40		
1 Concrete Cart, 10 C.F.		49.80		54.80	5.53	6.09
9 L.H., Daily Totals		$292.10		$431.90	$32.45	$47.99

Crew C-19	Hr.	Daily	Hr.	Daily	Bare Costs	Incl. O&P
.125 Labor Foreman (out)	$28.70	$28.70	$44.70	$44.70	$26.92	$41.90
1 Laborer	26.70	213.60	41.55	332.40		
1 Concrete Cart, 18 C.F.		76.80		84.50	8.53	9.39
9 L.H., Daily Totals		$319.10		$461.60	$35.45	$51.29

Crew C-20	Hr.	Daily	Hr.	Daily	Bare Costs	Incl. O&P
1 Labor Foreman (outside)	$28.70	$229.60	$44.70	$357.60	$28.71	$44.08
5 Laborers	26.70	1068.00	41.55	1662.00		
1 Cement Finisher	32.85	262.80	48.35	386.80		
1 Equip. Oper. (med.)	34.65	277.20	52.20	417.60		
2 Gas Engine Vibrators		48.00		52.80		
1 Concrete Pump (small)		704.20		774.60	11.75	12.93
64 L.H., Daily Totals		$2589.80		$3651.40	$40.46	$57.01

Crews

Crew C-21	Bare Costs Hr.	Bare Costs Daily	Incl. Subs O & P Hr.	Incl. Subs O & P Daily	Cost Per Labor-Hour Bare Costs	Cost Per Labor-Hour Incl. O&P
1 Labor Foreman (outside)	$28.70	$229.60	$44.70	$357.60	$28.71	$44.08
5 Laborers	26.70	1068.00	41.55	1662.00		
1 Cement Finisher	32.85	262.80	48.35	386.80		
1 Equip. Oper. (med.)	34.65	277.20	52.20	417.60		
2 Gas Engine Vibrators		48.00		52.80		
1 Concrete Conveyer		152.80		168.10	3.14	3.45
64 L.H., Daily Totals		$2038.40		$3044.90	$31.85	$47.53

Crew C-22	Hr.	Daily	Hr.	Daily	Bare Costs	Incl. O&P
1 Rodman Foreman	$39.95	$319.60	$65.90	$527.20	$38.10	$62.62
4 Rodmen (reinf.)	37.95	1214.40	62.60	2003.20		
.125 Equip. Oper. (crane)	35.90	35.90	54.10	54.10		
.125 Equip. Oper. Oiler	30.10	30.10	45.35	45.35		
.125 Hyd. Crane, 25 Ton		77.10		84.80	1.84	2.02
42 L.H., Daily Totals		$1677.10		$2714.65	$39.94	$64.64

Crew C-23	Hr.	Daily	Hr.	Daily	Bare Costs	Incl. O&P
2 Skilled Worker Foremen	$36.85	$589.60	$57.30	$916.80	$34.88	$53.93
6 Skilled Workers	34.85	1672.80	54.20	2601.60		
1 Equip. Oper. (crane)	35.90	287.20	54.10	432.80		
1 Equip. Oper. Oiler	30.10	240.80	45.35	362.80		
1 Crane, 90 Ton		1325.00		1457.50	16.56	18.22
80 L.H., Daily Totals		$4115.40		$5771.50	$51.44	$72.15

Crew C-23A	Hr.	Daily	Hr.	Daily	Bare Costs	Incl. O&P
1 Labor Foreman (outside)	$28.70	$229.60	$44.70	$357.60	$29.62	$45.45
2 Laborers	26.70	427.20	41.55	664.80		
1 Equip. Oper. (crane)	35.90	287.20	54.10	432.80		
1 Equip. Oper. Oiler	30.10	240.80	45.35	362.80		
1 Crane, 100 ton capacity		1519.00		1670.90		
3 Conc. bucket, 8 C.Y.		465.60		512.15	49.62	54.58
40 L.H., Daily Totals		$3169.40		$4001.05	$79.24	$100.03

Crew C-24	Hr.	Daily	Hr.	Daily	Bare Costs	Incl. O&P
2 Skilled Worker Foremen	$36.85	$589.60	$57.30	$916.80	$34.88	$53.93
6 Skilled Workers	34.85	1672.80	54.20	2601.60		
1 Equip. Oper. (crane)	35.90	287.20	54.10	432.80		
1 Equip. Oper. Oiler	30.10	240.80	45.35	362.80		
1 Truck Crane, 150 Ton		1445.00		1589.50	18.06	19.87
80 L.H., Daily Totals		$4235.40		$5903.50	$52.94	$73.80

Crew C-25	Hr.	Daily	Hr.	Daily	Bare Costs	Incl. O&P
2 Rodmen (reinf.)	$37.95	$607.20	$62.60	$1001.60	$29.78	$49.70
2 Rodmen Helpers	21.60	345.60	36.80	588.80		
32 L.H., Daily Totals		$952.80		$1590.40	$29.78	$49.70

Crew C-27	Hr.	Daily	Hr.	Daily	Bare Costs	Incl. O&P
2 Cement Finishers	$32.85	$525.60	$48.35	$773.60	$32.85	$48.00
1 Concrete Saw		114.40		125.85	7.15	7.87
16 L.H., Daily Totals		$640.00		$899.45	$40.00	$55.87

Crew C-28	Hr.	Daily	Hr.	Daily	Bare Costs	Incl. O&P
1 Cement Finisher	$32.85	$262.80	$48.35	$386.80	$32.85	$48.00
1 Portable Air Compressor		17.30		19.05	2.16	2.37
8 L.H., Daily Totals		$280.10		$405.85	$35.01	$50.37

Crew D-1	Hr.	Daily	Hr.	Daily	Bare Costs	Incl. O&P
1 Bricklayer	$35.25	$282.00	$53.70	$429.60	$31.08	$47.35
1 Bricklayer Helper	26.90	215.20	41.00	328.00		
16 L.H., Daily Totals		$497.20		$757.60	$31.08	$47.35

Crew D-2	Hr.	Daily	Hr.	Daily	Bare Costs	Incl. O&P
3 Bricklayers	$35.25	$846.00	$53.70	$1288.80	$32.12	$49.05
2 Bricklayer Helpers	26.90	430.40	41.00	656.00		
.5 Carpenter	34.25	137.00	53.35	213.40		
44 L.H., Daily Totals		$1413.40		$2158.20	$32.12	$49.05

Crew D-3	Hr.	Daily	Hr.	Daily	Bare Costs	Incl. O&P
3 Bricklayers	$35.25	$846.00	$53.70	$1288.80	$32.02	$48.85
2 Bricklayer Helpers	26.90	430.40	41.00	656.00		
.25 Carpenter	34.25	68.50	53.35	106.70		
42 L.H., Daily Totals		$1344.90		$2051.50	$32.02	$48.85

Crew D-4	Hr.	Daily	Hr.	Daily	Bare Costs	Incl. O&P
1 Bricklayer	$35.25	$282.00	$53.70	$429.60	$30.53	$46.38
2 Bricklayer Helpers	26.90	430.40	41.00	656.00		
1 Equip. Oper. (light)	33.05	264.40	49.80	398.40		
1 Grout Pump, 50 C.F./hr		107.75		118.55		
1 Hoses & Hopper		15.20		16.70		
1 Accessories		11.90		13.10	4.22	4.64
32 L.H., Daily Totals		$1111.65		$1632.35	$34.75	$51.02

Crew D-5	Hr.	Daily	Hr.	Daily	Bare Costs	Incl. O&P
1 Bricklayer	$35.25	$282.00	$53.70	$429.60	$35.25	$53.70
8 L.H., Daily Totals		$282.00		$429.60	$35.25	$53.70

Crew D-6	Hr.	Daily	Hr.	Daily	Bare Costs	Incl. O&P
3 Bricklayers	$35.25	$846.00	$53.70	$1288.80	$31.20	$47.59
3 Bricklayer Helpers	26.90	645.60	41.00	984.00		
.25 Carpenter	34.25	68.50	53.35	106.70		
50 L.H., Daily Totals		$1560.10		$2379.50	$31.20	$47.59

Crew D-7	Hr.	Daily	Hr.	Daily	Bare Costs	Incl. O&P
1 Tile Layer	$32.70	$261.60	$48.05	$384.40	$29.03	$42.65
1 Tile Layer Helper	25.35	202.80	37.25	298.00		
16 L.H., Daily Totals		$464.40		$682.40	$29.03	$42.65

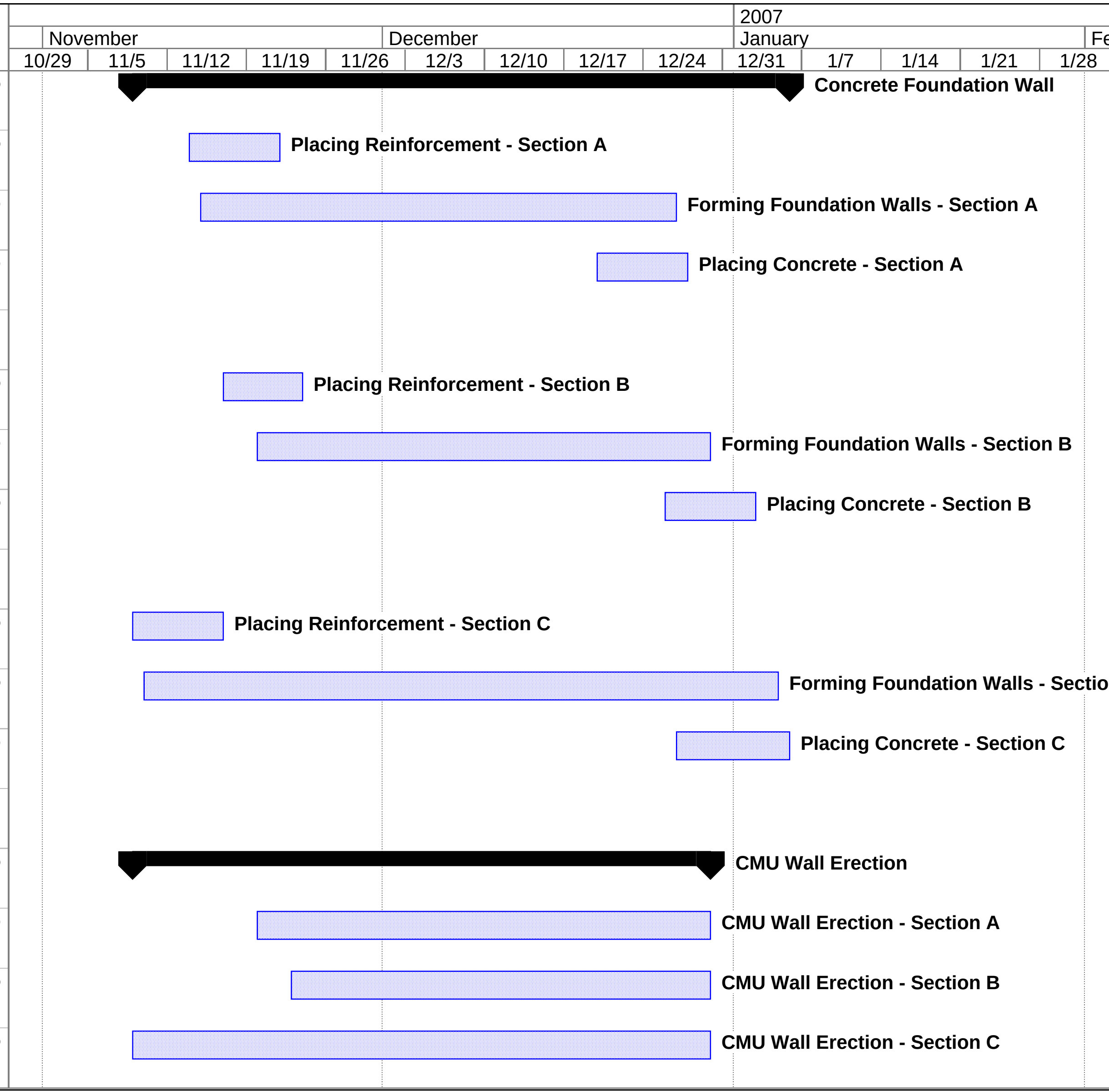
Crew D-8	Hr.	Daily	Hr.	Daily	Bare Costs	Incl. O&P
3 Bricklayers	$35.25	$846.00	$53.70	$1288.80	$31.91	$48.62
2 Bricklayer Helpers	26.90	430.40	41.00	656.00		
40 L.H., Daily Totals		$1276.40		$1944.80	$31.91	$48.62

Crew D-9	Hr.	Daily	Hr.	Daily	Bare Costs	Incl. O&P
3 Bricklayers	$35.25	$846.00	$53.70	$1288.80	$31.08	$47.35
3 Bricklayer Helpers	26.90	645.60	41.00	984.00		
48 L.H., Daily Totals		$1491.60		$2272.80	$31.08	$47.35

Crew D-10	Hr.	Daily	Hr.	Daily	Bare Costs	Incl. O&P
1 Bricklayer Foreman	$37.25	$298.00	$56.75	$454.00	$32.44	$49.31
1 Bricklayer	35.25	282.00	53.70	429.60		
2 Bricklayer Helpers	26.90	430.40	41.00	656.00		
1 Equip. Oper. (crane)	35.90	287.20	54.10	432.80		
1 Truck Crane, 12.5 Ton		505.80		556.40	12.65	13.91
40 L.H., Daily Totals		$1803.40		$2528.80	$45.09	$63.22

Crew D-11	Hr.	Daily	Hr.	Daily	Bare Costs	Incl. O&P
1 Bricklayer Foreman	$37.25	$298.00	$56.75	$454.00	$33.13	$50.48
1 Bricklayer	35.25	282.00	53.70	429.60		
1 Bricklayer Helper	26.90	215.20	41.00	328.00		
24 L.H., Daily Totals		$795.20		$1211.60	$33.13	$50.48

ID	Task Name	Duration	Start
1	Concrete Foundation Wall	42 days?	Thu 11/9/06
2	Placing Reinforcement - Sectio	6 days	Tue 11/14/06
3	Forming Foundation Walls - Se	30 days	Wed 11/15/06
4	Placing Concrete - Section A	6 days	Wed 12/20/06
5			
6	Placing Reinforcement - Sectio	5 days	Fri 11/17/06
7	Forming Foundation Walls - Se	30 days	Mon 11/20/06
8	Placing Concrete - Section B	6 days	Tue 12/26/06
9			
10	Placing Reinforcement - Sectio	6 days	Thu 11/9/06
11	Forming Foundation Walls - Se	40 days	Fri 11/10/06
12	Placing Concrete - Section C	8 days	Wed 12/27/06
13			
14	CMU Wall Erection	37 days	Thu 11/9/06
15	CMU Wall Erection - Section A	30 days	Mon 11/20/06
16	CMU Wall Erection - Section B	27 days	Thu 11/23/06
17	CMU Wall Erection - Section C	37 days	Thu 11/9/06



Project: Fouundation wall
Date: Mon 4/9/07

Task	Rolled Up Task	External Tasks
Progress	Rolled Up Milestone	Project Summary
Milestone	Rolled Up Progress	Group By Summary
Summary	Split	Deadline

APPENDIX C

Mechanical Breadth

DETAIL REPORT

PLUMBING DD 070706

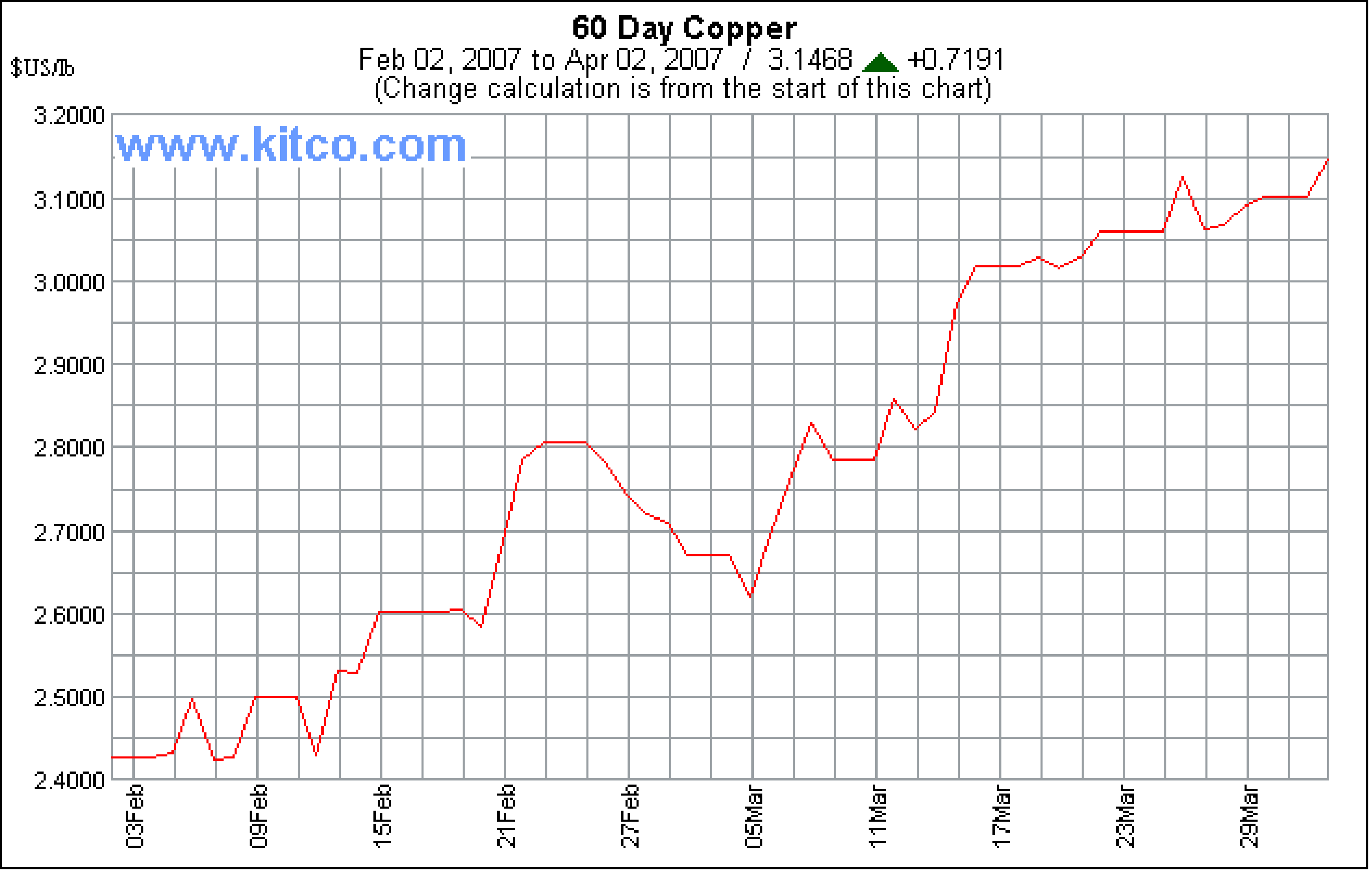
Estimator: JAM
Project Size: 99100 SQFT

PLUMBING DD 070706

PA

Detail - With Taxes and Insurance ,Indirect Costs are Spread
Group 1: Subdivision
Group 2: Element

	Element Description	Quantity	UM	Mat.Unit	Mat.Total	MH/Unit	Tot.Hours	Sub.Total	Eqp.Total	TotalCost	$/
	PLUMBING ESTIMATE										
	DOMESTIC WATER SUPPLY										
0800	ALLOWANCE FOR MECH ROOM	1.00	LS	13,780.00	13,780.00	200.00	200.0			26,451.92	0.267
0800	DOMESTIC SERVICE ENTRANCE	1.00	EA	2,968.00	2,968.00	40.00	40.0			5,523.58	0.056
0800	FLANGE PACK,2-1/2"	8.00	EACH	6.63	53.00	0.24	1.9			166.27	0.002
0800	FLANGE PACK,3"	2.00	EACH	6.89	13.78	0.25	0.5			43.28	
0800	FLANGE PACK,4"	2.00	EACH	11.93	23.85	0.36	0.7			66.78	0.001
0800	COPPER PIPE (TUBING)		****								
0800	TYPE L		****								
0800	PIPE,1/2"	2,366.00	LNFT	1.75	4,143.15	0.06	142.0			12,573.89	0.127
0800	PIPE,3/4"	2,251.00	LNFT	2.70	6,070.14	0.06	135.1			14,303.93	0.144
0800	PIPE,1"	875.00	LNFT	3.84	3,364.04	0.08	70.0			7,653.32	0.077
0800	PIPE,1-1/4"	1,214.00	LNFT	5.40	6,552.59	0.08	97.1			12,692.18	0.128
0800	PIPE,1-1/2"	722.00	LNFT	6.96	5,024.33	0.08	57.8			8,788.44	0.089
0800	PIPE,2"	879.00	LNFT	10.96	9,636.06	0.09	79.1			15,066.97	0.152
0800	PIPE,2-1/2"	681.00	LNFT	16.59	11,300.00	0.12	81.7			17,044.69	0.172
0800	PIPE,3"	172.00	LNFT	22.26	3,829.27	0.14	24.1			5,571.96	0.056
0800	PIPE,4"	80.00	LNFT	37.18	2,974.11	0.18	14.4			4,084.68	0.041
0800	COPPER FITTINGS		****								
0800	95/5 SOLDER		****								
0800	90 ELL,1/2"	644.00	EACH	0.39	252.24	0.33	211.2			12,205.63	0.123
0800	90 ELL,3/4"	120.00	EACH	0.88	105.35	0.43	51.8			3,043.27	0.031
0800	90 ELL,1"	186.00	EACH	2.16	402.27	0.48	89.3			5,484.10	0.055
0800	90 ELL,1-1/4"	61.00	EACH	3.26	199.03	0.57	34.6			2,175.49	0.022
0800	90 ELL,1-1/2"	37.00	EACH	5.10	188.57	0.59	21.9			1,444.33	0.015
0800	90 ELL,2"	37.00	EACH	9.27	343.00	0.69	25.5			1,814.79	0.018
0800	90 ELL,2-1/2"	20.00	EACH	19.57	391.32	1.10	21.9			1,668.26	0.017
0800	90 ELL,3"	7.00	EACH	26.14	183.01	1.31	9.2			719.93	0.007
0800	90 ELL,4"	4.00	EACH	66.92	267.70	1.75	7.0			690.21	0.007
0800	TEE,1/2"	54.00	EACH	0.67	35.93	0.47	25.5			1,478.82	0.015
0800	TEE,3/4"	7.00	EACH	1.62	11.31	0.62	4.3			255.94	0.003
0800	TEE,1-1/2"	2.00	EACH	11.08	22.17	0.86	1.7			121.97	0.001
0800	REDUCING TEE,3/4"	67.00	EACH	1.55	104.14	0.55	37.0			2,203.02	0.022
0800	REDUCING TEE,1"	48.00	EACH	5.28	253.42	0.69	33.0			2,143.62	0.022
0800	REDUCING TEE,1-1/4"	44.00	EACH	9.97	438.64	0.77	33.8			2,390.72	0.024
0800	REDUCING TEE,1-1/2"	56.00	EACH	16.54	926.43	0.82	45.7			3,599.51	0.036
0800	REDUCING TEE,2"	45.00	EACH	22.47	1,011.16	0.94	42.1			3,490.78	0.035
0800	REDUCING TEE,2-1/2"	23.00	EACH	50.89	1,170.49	1.51	34.8			3,251.33	0.033
0800	REDUCING TEE,3"	8.00	EACH	73.07	584.59	1.84	14.7			1,474.28	0.015


60 Day Copper
Feb 02, 2007 to Apr 02, 2007 / 3.1468 +0.7191
(Change calculation is from the start of this chart)
$US/lb
www.kitco.com
3.2000
3.1000
3.0000
2.9000
2.8000
2.7000
2.6000
2.5000
2.4000
03Feb
09Feb
15Feb
21Feb
27Feb
05Mar
11Mar
17Mar
23Mar
29Mar

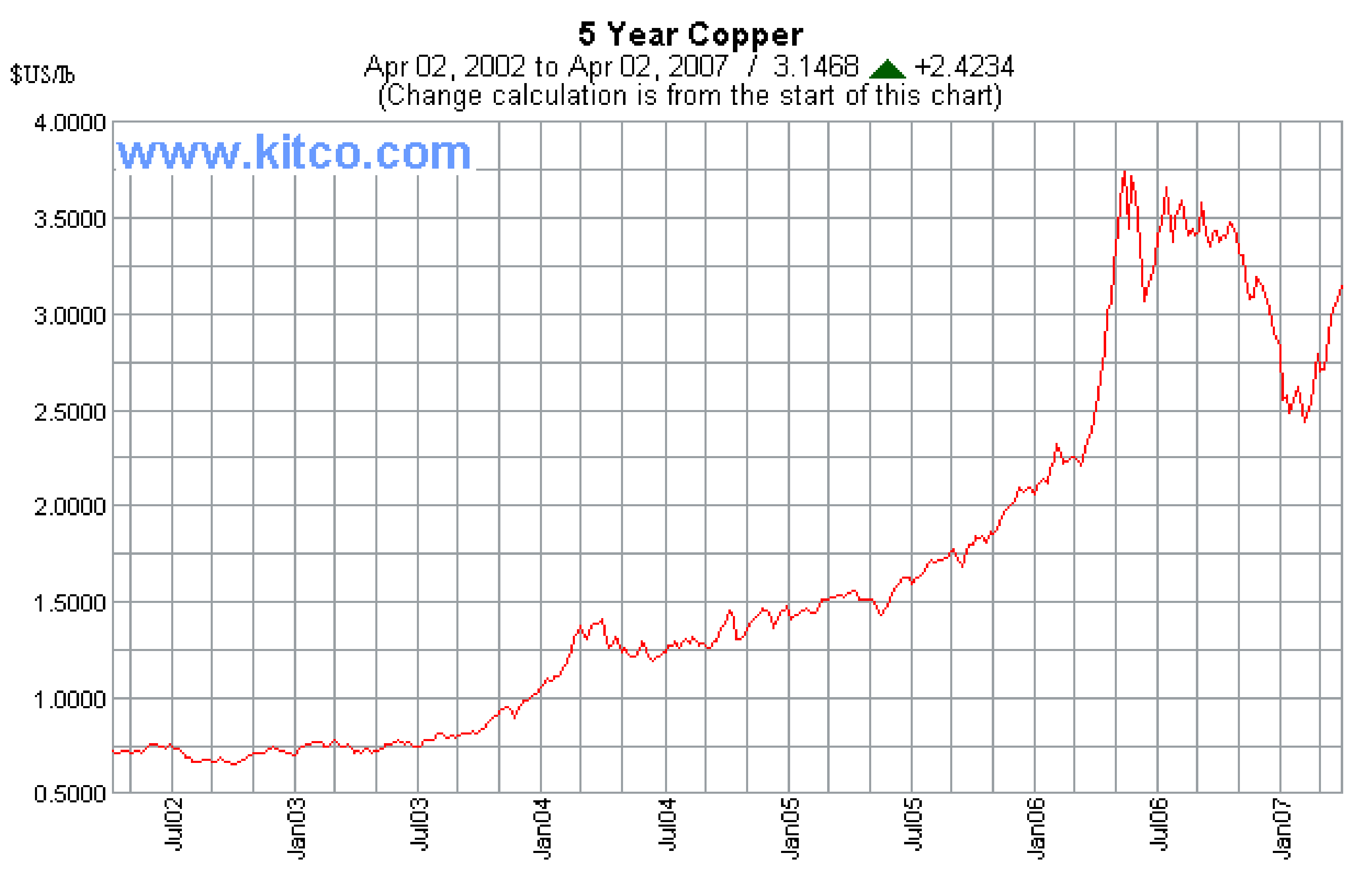

5 Year Copper
Apr 02, 2002 to Apr 02, 2007 / 3.1468 +2.4234
(Change calculation is from the start of this chart)
$US/lb
www.kitco.com
4.0000
3.5000
3.0000
2.5000
2.0000
1.5000
1.0000
0.5000
Jul02
Jan03
Jul03
Jan04
Jul04
Jan05
Jul05
Jan06
Jul06
Jan07

Table 3.2 – Flow Velocity								
Flow Rate	**ft/sec**							
GPM	**3/8"**	**1/2"**	**5/8"**	**3/4"**	**1"**	**1 1/4"**	**1 1/2"**	**2"**
0.2	0.67	0.36	0.25	0.18	0.11	0.07	0.05	0.03
0.3	1.00	0.54	0.37	0.27	0.16	0.11	0.08	0.05
0.4	1.33	0.72	0.50	0.36	0.22	0.15	0.11	0.06
0.5	1.67	0.91	0.62	0.45	0.27	0.18	0.13	0.08
0.6	2.00	1.09	0.74	0.54	0.33	0.22	0.16	0.09
0.7	2.33	1.27	0.87	0.64	0.38	0.26	0.18	0.11
0.8	2.67	1.45	0.99	0.73	0.44	0.29	0.21	0.12
0.9	3.00	1.63	1.12	0.82	0.49	0.33	0.24	0.14
1.0	3.33	1.81	1.24	0.91	0.55	0.37	0.26	0.15
1.1	3.67	1.99	1.36	1.00	0.60	0.40	0.29	0.17
1.2	4.00	2.17	1.49	1.09	0.66	0.44	0.32	0.18
1.3	4.34	2.35	1.61	1.18	0.71	0.48	0.34	0.20
1.4	4.67	2.53	1.74	1.27	0.76	0.51	0.37	0.22
1.5	5.00	2.72	1.86	1.36	0.82	0.55	0.40	0.23
1.6	5.34	2.90	1.98	1.45	0.87	0.59	0.42	0.25
1.7	5.67	3.08	2.11	1.54	0.93	0.62	0.45	0.26
1.8	6.00	3.26	2.23	1.63	0.98	0.66	0.47	0.28
1.9	6.34	3.44	2.36	1.72	1.04	0.70	0.50	0.29
2.0	6.67	3.62	2.48	1.81	1.09	0.73	0.53	0.31
2.5	8.34	4.53	3.10	2.27	1.36	0.92	0.66	0.38
3.0	10.00	5.43	3.72	2.72	1.64	1.10	0.79	0.46
3.5	11.67	6.34	4.34	3.18	1.91	1.28	0.92	0.54
4.0		7.24	4.96	3.63	2.18	1.47	1.05	0.62
4.5		8.15	5.58	4.08	2.46	1.65	1.19	0.69
5.0		9.05	6.20	4.54	2.73	1.84	1.32	0.77
6.0		10.86	7.44	5.44	3.28	2.20	1.58	0.92
7.0			8.68	6.35	3.82	2.57	1.84	1.08
8.0			9.92	7.26	4.37	2.94	2.11	1.23
9.0			11.16	8.17	4.91	3.30	2.37	1.39

Table 3.2 – Flow Velocity *(continued)*								
Flow Rate	**ft/sec**							
GPM	**3/8"**	**1/2"**	**5/8"**	**3/4"**	**1"**	**1 1/4"**	**1 1/2"**	**2"**
10.0				9.07	5.46	3.67	2.64	1.54
11.0				9.98	6.01	4.04	2.90	1.69
12.0				10.89	6.55	4.40	3.16	1.85
13.0					7.10	4.77	3.43	2.00
14.0					7.64	5.14	3.69	2.16
15.0					8.19	5.51	3.95	2.31

Table 3.3 – Pressure Loss

60°F (16°C) Water

Flow Rate	Pressure Loss psi/100 ft of Pipe							
GPM	3/8"	1/2"	5/8"	3/4"	1"	1 1/4"	1 1/2"	2"
0.2	0.427	0.099	0.040	0.019	0.006	0.002	0.001	0.0003
0.3	0.880	0.204	0.083	0.039	0.012	0.005	0.002	0.001
0.4	1.470	0.341	0.138	0.065	0.019	0.008	0.003	0.001
0.5	2.189	0.508	0.205	0.097	0.029	0.011	0.005	0.001
0.6	3.032	0.703	0.284	0.135	0.040	0.015	0.007	0.002
0.7	3.993	0.926	0.374	0.177	0.053	0.020	0.009	0.003
0.8	5.069	1.175	0.475	0.225	0.067	0.026	0.012	0.003
0.9	6.258	1.450	0.586	0.278	0.082	0.032	0.014	0.004
1.0	7.555	1.751	0.707	0.335	0.099	0.038	0.017	0.005
1.1	8.960	2.076	0.839	0.397	0.118	0.046	0.021	0.006
1.2	10.47	2.425	0.980	0.464	0.138	0.053	0.024	0.007
1.3	12.08	2.799	1.131	0.535	0.159	0.061	0.028	0.008
1.4	13.80	3.195	1.291	0.611	0.181	0.070	0.032	0.009
1.5	15.61	3.615	1.460	0.691	0.205	0.079	0.036	0.010
1.6	17.52	4.058	1.639	0.776	0.230	0.089	0.040	0.011
1.7	19.53	4.523	1.827	0.865	0.256	0.099	0.045	0.012
1.8	21.64	5.010	2.023	0.958	0.284	0.110	0.050	0.014

Table 3.3 – Pressure Loss *(continued)*

60°F (16°C) Water

Flow Rate	Pressure Loss psi/100 ft of Pipe							
GPM	3/8"	1/2"	5/8"	3/4"	1"	1 1/4"	1 1/2"	2"
1.9	23.84	5.519	2.229	1.055	0.313	0.121	0.055	0.015
2.0	26.14	6.050	2.443	1.157	0.343	0.133	0.060	0.017
2.5	39.00	9.024	3.643	1.724	0.511	0.197	0.089	0.025
3.0	54.10	12.51	5.050	2.390	0.708	0.274	0.124	0.034
3.5	71.36	16.50	6.658	3.150	0.933	0.360	0.163	0.045
4.0		20.97	8.459	4.002	1.185	0.458	0.207	0.057
4.5		25.90	10.45	4.943	1.463	0.565	0.256	0.071
5.0		31.30	12.63	5.972	1.768	0.683	0.309	0.085
6.0		43.44	17.52	8.284	2.451	0.946	0.428	0.118
7.0			23.11	10.93	3.232	1.248	0.564	0.156
8.0			29.38	13.89	4.108	1.585	0.717	0.198
9.0			36.32	17.17	5.076	1.959	0.885	0.244
10.0				20.75	6.134	2.367	1.070	0.295
11.0				24.63	7.281	2.808	1.269	0.350
12.0				28.81	8.514	3.284	1.484	0.409
13.0					9.832	3.792	1.713	0.472
14.0					11.24	4.332	1.957	0.539
15.0					12.72	4.905	2.216	0.610

Shown is pressure loss in units of psi per 100 feet of pipe.