Bethesda Triangle
Bethesda, Maryland

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Bethesda Triangle
Bethesda, MD

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Construction Management
CPEP: http://www.arche.psu.edu/thesis/2004/bjg185/

Project Players:
- Owner: Bethesda Triangle LLC
- Construction Manager: Encore Development
- Architect: Architects Collaborative, Inc.
- Production Architect: Compu.Tecture, Inc.
- Civil Engineer: Vika, Inc
- Landscape Architect: Edaw, Inc.
- Structural Engineer: SK&A Assoc. P.A.
- MEP Engineer: Mendoza Ribas Farinas & Assoc.
- Electrical Subcontractor: Truland Systems Corporation

Architectural Features:
- High rise apartment building with retail and office space on the plaza level
- 580,000 sq. ft.
- Total of 18 floors, 14 above grade and 4 parking levels below grade

Structural System:
- Cast in place concrete structure
- Brick and glass curtain wall

Construction Concerns:
- Very limited site area
- Parking garage used for material storage and staging

Typical one bedroom unit

Electrical System:
- 208 / 120 volt system
- Each apartment unit has its own panelboard that is fed from main panels
- Two backup generators, one to power the building and the other to power the fire system if the first generator fails

Mechanical System:
- Each apartment unit has a separate forced hot air heater / air conditioning unit
- Retail, offices, and public areas are heated and cooled by a main unit

Unique Features:
- At times when fuel costs are less then electric costs, the backup generator will be used to power the building
- The second and third floors are open for occupancy while the rest of the building is still under construction

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Executive summary

The following thesis report provides all of the information regarding the three analyses that were performed for Bethesda Triangle. Bethesda Triangle is a 14-story apartment building located in Bethesda, Maryland. In addition to the three analyses, the topic of mold prevention is covered. The three areas of study for this report are construction management, electrical, and structural.

The first analysis was performed for the depth requirement in construction management. This analysis looks into using short interval production scheduling for the cast in place concrete structure of Bethesda Triangle. This particular building makes a good candidate for short interval production scheduling because of the repetition in floor layout. This section of the report will provide information about short interval production schedules, the original schedule, the new SIPS schedule, results from this analysis, and a recommendation for the project.

The second analysis was performed as the first part of the breadth study requirement; it is in the electrical field of study. This investigation examines the choice of generator that was used in the Bethesda Triangle project. It compares using a smaller generator to power just the emergency systems rather than the large one that can power the entire building. This section will provide information on the current generation system, the proposed generation system, a comparison of the two, and a recommendation.

The third analysis covers the second part of the breadth study in the structural field. This analysis investigates the use of a prefabricated flying truss formwork system as opposed to the hand set formwork method that was used on Bethesda Triangle. This section will show information regarding the forming method that was used for the project, the proposed method, a comparison of the two, and a recommendation.

The final section of this report deals with the topic of mold prevention in buildings. Research was conducted to establish the causes of molds in building projects and the effects that toxic molds can have on people who are exposed to it. The end of this section provides guidelines that can be followed during design and construction to help reduce the possibility of mold growth in buildings.

Proposal Letter

Brian Groark
818 Old Boalsburg Rd. Apt 3
State College, PA 16801

April 5, 2004

Mr. Gary Kirstein
Bethesda Triangle, LLC
4835 Cordell Ave.,
Bethesda, MD 20814

Dear Mr. Kirstein,

The following report is in response to the request for proposal for new ideas for the Bethesda Triangle project. The following analyses cover the topics of value engineering, constructability, schedule reduction, and research study. Each investigation will provide information regarding the current system and a comparison to the proposed system. After each analysis, a recommendation is provided which will give my opinion of which system will work better for this project. My opinions are based on the research and analyses that have been conducted as part of this recommendation report.

The first analysis deals with scheduling the cast in place concrete activities. A short interval production schedule (SIPS) is used in place of the traditional method in order to reduced overall duration and cost. The second analysis provides a comparison of two generator options in order to provide savings in the current market. The third investigation reviews the use of a flying truss forming system for the cast in place concrete slab. Flying truss systems can greatly increase productivity and decrease cost. The final topic covered is mold prevention in buildings. The prevention of mold early in a buildings life can save costly repairs in the future.

I would like to thank you for giving me the opportunity to review the current systems of Bethesda Triangle and investigate the possibilities of other systems. Also, thank you for taking the time to review my ideas that I have presented in this report.

Sincerely,

Brian J. Groark

Project Background

General Project Data

- Bethesda Triangle
- 4835 Cordell Ave., Bethesda, MD 20814
- Occupant: Bethesda Triangle LLC / Tenants
- High rise apartment building with retail and office space on the plaza level
- 580,000 sq. ft.
- Total of 18 floors, 14 above grade and 4 parking levels below grade
- Primary Project Team
    - Owner: Bethesda Triangle LLC
    - Construction Manager: Encore Development
    - Architect: Architects Collaborative, Inc.
    - Production Architect: Compu.Tecture, Inc.
    - Civil Engineer: Vika, Inc
    - Landscape Architect: Edaw, Inc.
    - Structural Engineer: SK&A Assoc. P.A.
    - MEP Engineer: Mendoza Ribas Farinas & Assoc.
    - Electrical Subcontractor: Truland Systems Corporation
- Construction started on February 14, 2002. The scheduled finish date was March 14, 2003. The new planned finish date is December 21, 2003. Partial occupancy is scheduled for September 12, 2003.
- The original budget was $25.5 million; the new budget is approximately $32 million.
- Project Delivery Method: Design-Bid-Build

Architecture

- Bethesda Triangle was designed with a brick cladding exterior using light and dark brick for contrast. There are large quantities of glass on all faces of the building to allow the most light possible into the residential areas. Precast concrete panels are used between the bay windows in vertical rows and aluminum paneling is used between the flat windows. The roof has two open aluminum frame structures that are set over the mechanical equipment towers. The interior of the building is laid out like a typical apartment building by having repetitive floor plans for efficient use and construction.
- The applicable building codes for Bethesda Triangle are the BOCA National Building Code 1996, NFPA 101 2000, and ADAG 1994 / COMAR 1995.
- Bethesda Triangle has an unlimited allowable height and an unlimited allowable area. The occupancy types are type R-2 for the residential, type B for the offices and type S-2 for the parking garage.

- The building envelope consists of a brick and glass curtain wall.

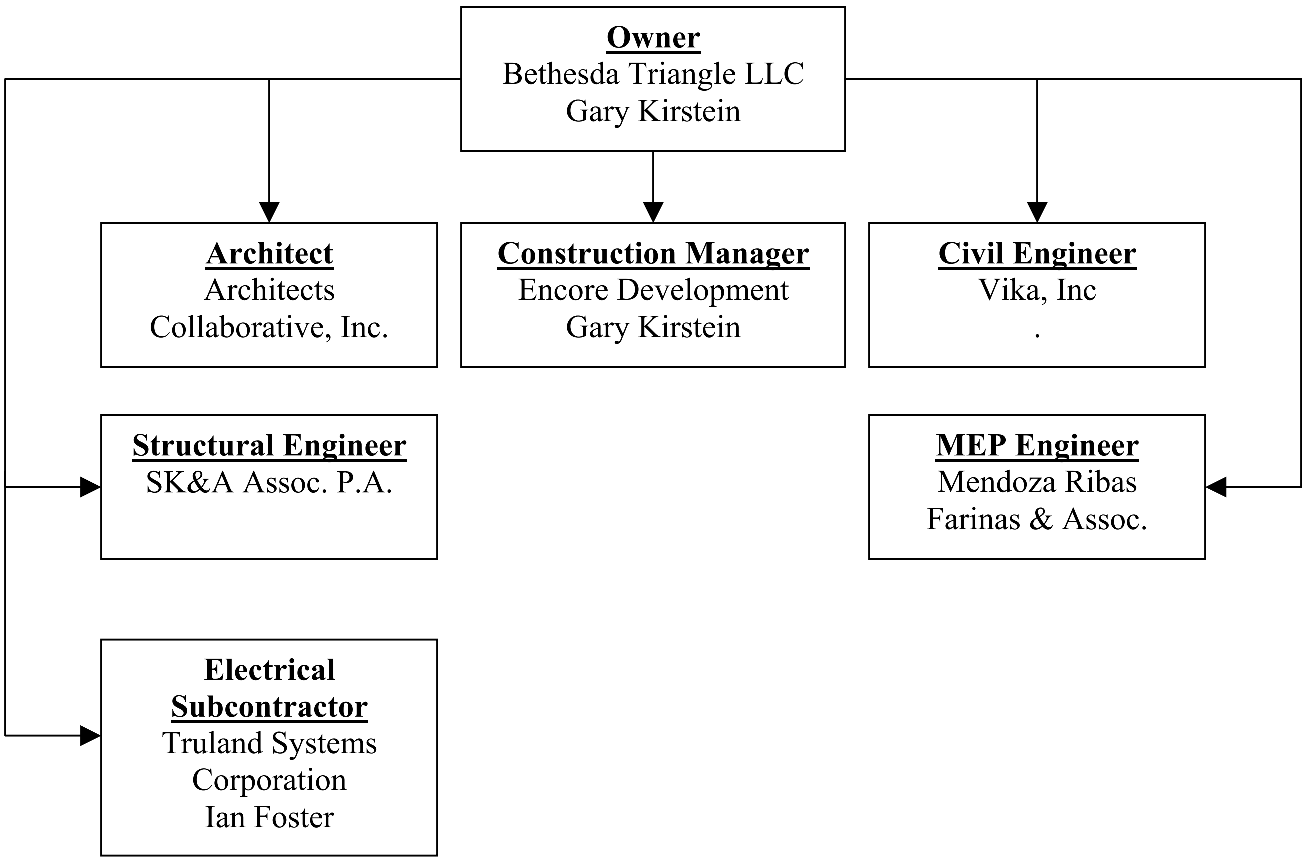
Building System I

- The incoming power for Bethesda Triangle is 13.2 kV. It is then stepped down to 480 / 277 volt for the public areas and office spaces and it is stepped down to 208 / 120 volt for the residential areas. Each apartment has its own panelboard, which is fed from a main panelboards that are located every three floors. The back up system consists of a two-megawatt generator and a smaller generator to power the fire protection system in the event that the main generator fails in an emergency.
- The lighting in the apartments is set up like a typical residence. There are fluorescent fixtures in the kitchens, incandescent hanging fixtures in the dining area, and incandescent vanity fixtures in the bathrooms. The bedrooms and living rooms have switched outlets. The public areas are illuminated with fluorescent fixtures.
- Each apartment has its own forced hot air heater and air conditioner. The unit is located centrally in the apartment, which allows for one run of duct down the center of the area. The pubic and office areas are maintained by a central unit.
- The structure for Bethesda Triangle is a cast in place concrete structure with post-tensioned slabs. It is enclosed with a brick and glass curtain wall.

Building System II

- The entire building is protected by a wet type sprinkler system. In the apartments, smoke detectors are located in the hallways outside of the bedrooms. The rest of the building is protected by a main fire alarm system. Spray on fire proofing is not needed for the structure of this building since it is cast in place concrete.
- Bethesda Triangle utilizes four passenger elevators and one cargo elevator for vertical transportation. There are also two stairwells located in the building. The elevators are located in the middle of the building and the stairs are on either end.
- Telecommunications do not have a major role in this building. It is a very basic set up consisting of pre-wired cable television connections in each apartment along with telephone connections.

Figure 1: Project Delivery System



Project Schedule Summary

The schedule seen below is an approximate schedule created using a few key dates. There is not a schedule for the project at this time, but some dates are known. The construction start date was February 14, 2002. The superstructure was topped out in September of 2002. The building was declared enclosed in April of 2003, although the roof is not yet fully completed to this date. On September 12, 2003, the 2nd and 3rd floors opened for occupancy along with garage levels 1-3 and part of the plaza level. The next phase of occupancy should be on October 22, 2003; this will be the opening of the 4th and 5th floors. There should be two floors completed and turned over for occupancy every six weeks. At that rate, the finish date will be pushed back again from December 2003 to March 2004. The original finish date was March 14, 2003.

Figure 2: Original Schedule

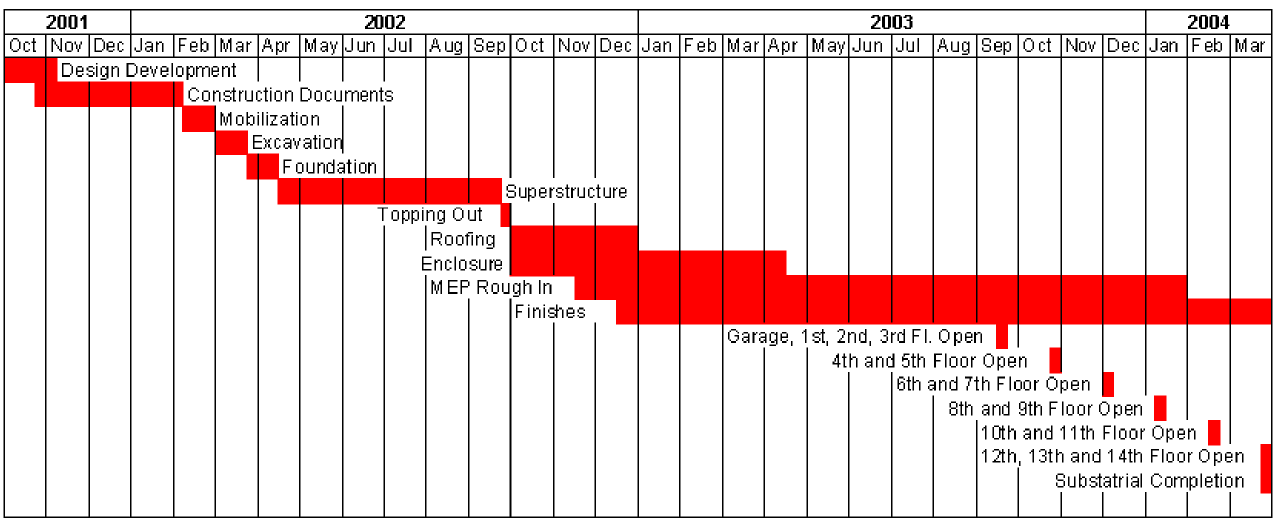
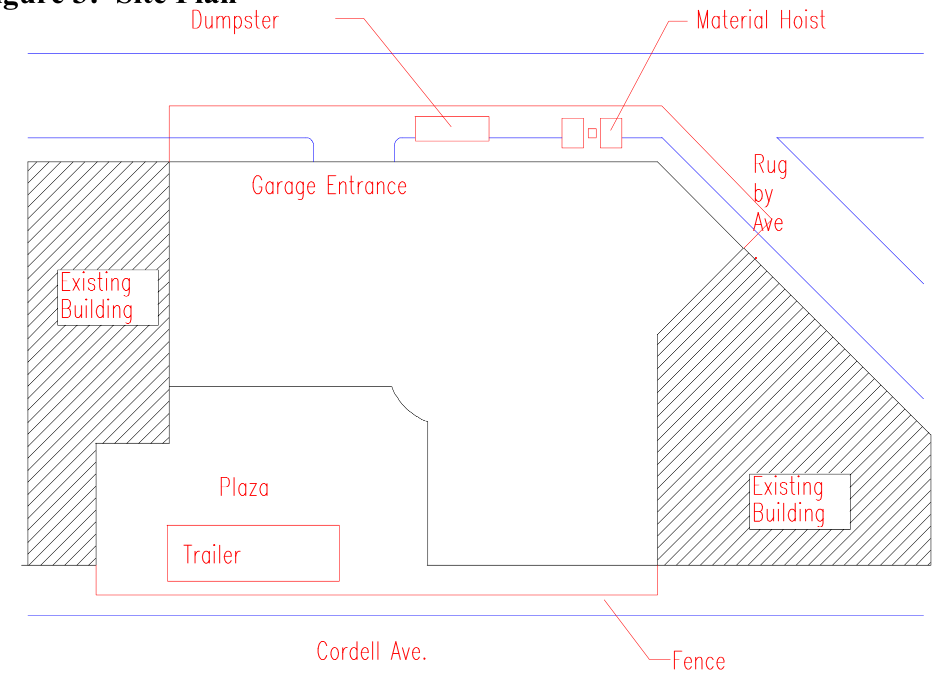


Figure 3: Site Plan



The picture above shows the current site plan for the building. The parking garage is the used for material storage and parking. Since the exterior of the building is complete, there is not much need for temporary facilities on the site. There is still one trailer on site, which is used as a rental office since the second and third floors are open for occupancy. The material hoist and dumpsters are located in the back of the building, near the parking garage. Trucks use Del Ray Ave. to unload, since the entrance to the parking garage is located there and this is where the materials will be stored. Some material, however, will be stored in the plaza area. This material is for the landscaping of the plaza. Such things as brick and sand will be stored there.

Due to the lack of site space, the fencing along the back of the building had to be put in the street. The street is set back about twelve feet from the back of the building. This does not allow for enough room for the material hoist, dumpsters and unloading of trucks without placing the fence in the street.

Client Information

Bethesda Triangle is being built by Encore Development, which created Bethesda Triangle LLC to be the owner. The owner is building this apartment building because they are a developer and they wanted a building that would bring a combination of retail space, office and, apartments. Also this building will be offering high-end apartments. Because of these high-end apartments, quality will be a major issue for the owner. These apartments are going to be expensive and it will much harder to find a renter for them if the quality is not up to par.

One of the main interests of the owner would be to get the building open as soon as possible because they can start collecting rent on the apartments. This is why there will be phased occupancy. The second and third floors are already open and the apartments are available for rent. The owner will be satisfied if the rest of the floors can be opened before the building is complete. This will allow them to take in revenue on the project before it is complete.

Estimate Summary

The original budget for this project was $25.5 million; the new budget is approximately $32 million. (Very limited cost information is available at this time)

Parametric Estimate Using D4 Cost 2002

Building Costs

Code	Division Name	%	Sq. Cost	Projected
01	General Requirements	9.28	4.89	2,838,285
02	Site Work	8.04	4.24	2,461,358
03	Concrete	7.97	4.21	2,439,639
04	Masonry	4.06	2.14	1,242,447
05	Metals	7.14	3.76	2,183,680
06	Wood & Plastics	9.59	5.06	2,933,247
07	Thermal & Moisture Protection	2.23	1.18	682,065
08	Doors & Windows	4.20	2.22	1,285,265
09	Finishes	16.89	8.91	5,166,941
10	Specialties	1.56	0.82	476,749
11	Equipment	2.80	1.48	856,826
12	Furnishings	2.93	1.55	896,169
13	Special Construction	0.58	0.31	177,639

14	Conveying Systems	2.80	1.48	857,336
15	Mechanical	12.73	6.72	3,894,981
16	Electrical	7.20	3.80	2,202,360
	Total Building Costs	100.00	52.75	30,594,987

Square Foot Estimate Using RS Means

Apartments - High Rise (8 - 24 stories)

Cost Per SF	Total SF	Total Cost	Cost Multiplier	Modified Cost
$85.25	451,100	$38,456,275	0.91	$34,995,210

Garages, Parking

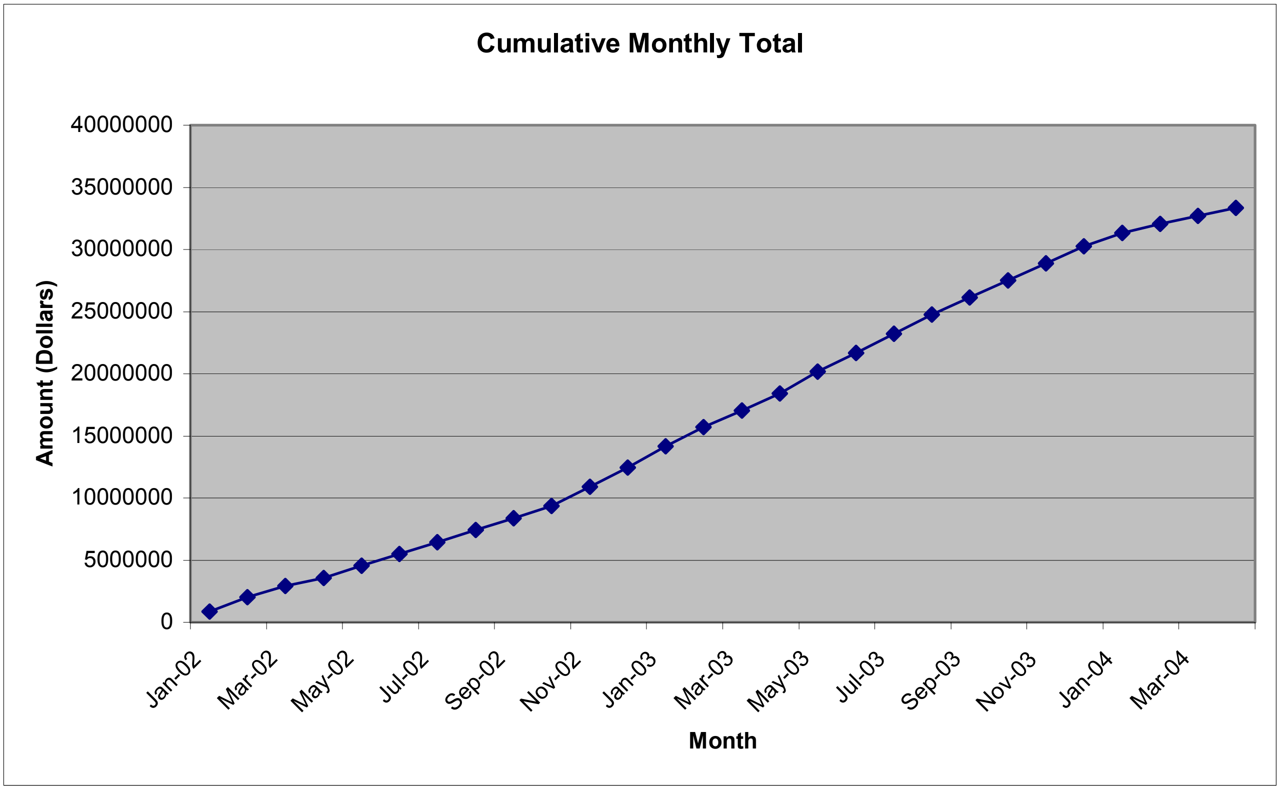
Cost Per SF	Total SF	Total Cost	Cost Multiplier	Modified Cost
$34.05	128,900	$4,389,045	1.05	$4,608,497

Total Cost of Apartment and Garage=	$39,603,708
Location Factor=	0.886
Final Modified Cost=	**$35,088,884**

Data taken from: *RS Means – 2003 Building Cost Data 61st Annual Edition*

The two estimates produced were fairly close to the actual project cost. The D4 estimate was about $1.4 million lower, while the square foot estimate was about $3 million higher than the $32 million budget. These estimates may not have taken into account the high-end apartments that will be in the Bethesda Triangle building or it is possible that the higher estimate did not take the affordable apartments that will be in the building. The square foot estimate also took the parking garage into consideration whereas the D4 estimate did not. Overall, these estimate were reasonably close the actual budget.

Figure 4: Cash Flow Curve



Short Interval Production Schedule Analysis

Introduction

Short interval production schedules or SIPS are used on construction projects where there is a large amount of repetitiveness in the building design such as apartment buildings and hotels. The basic principle of SIPS is to keep the crews working on the same activity and consistently moving through the building in a pattern following immediately behind the preceding activity. This not only allows for fewer conflicts between the trades, but also, by keeping crews working on the same activity, productivity will increase.

SIP schedules work by first breaking down the building into manageable sections. The section sizes are determined by the durations for the amount of work that needs to be completed. For example, if the SIPS is for pouring slabs, it would be most efficient to break the floor plan up into sections no larger than the maximum square footage of concrete that can be poured in one day. Next, the sequence of activities for each section needs to be developed. This can be done for the entire building form start to finish or for separate systems such as the structure or electrical work. The following step is to balance the durations for each activity so that every crew is constantly moving through the building. This is done by either increasing or decreasing the crew size.

Bethesda Triangle could be a good project to implement short interval production scheduling on. The floor plans are repetitive for floors 2 – 14 and are almost the same for floors G4 – Plaza level. Using SIPS could help to reduce the overall duration of the project by taking advantage of the repetitiveness of the design. For this analysis, a detailed SIP schedule has been created for the cast in place concrete structure. The duration of the new SIPS was compared to the original duration for the structure.

Original Schedule

The original duration for the cast in place concrete structure was approximately 44 weeks. This activity began in mid April of 2002 and finished in mid February of 2003. The original schedule can be seen below.

SIPS

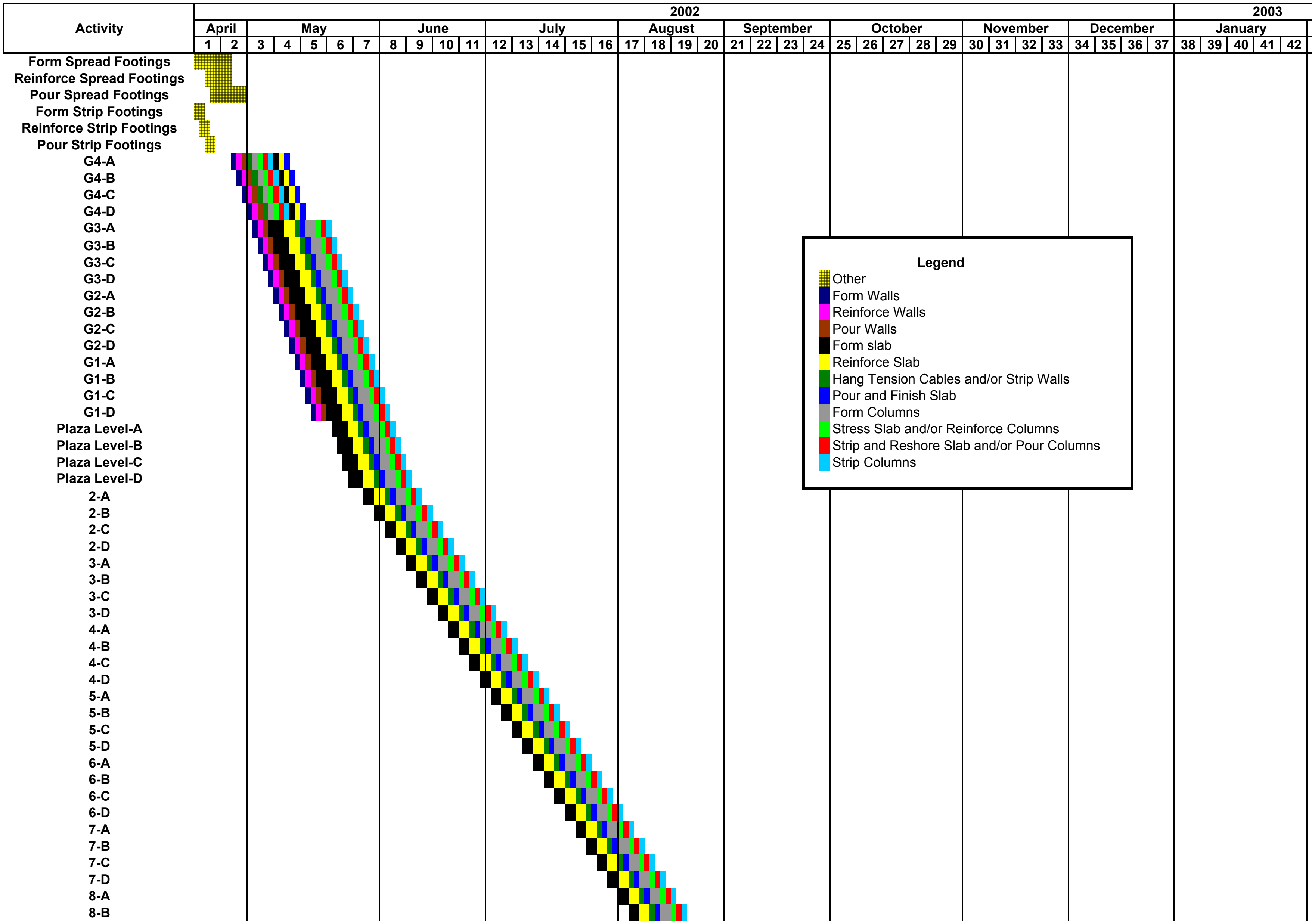
This SIP schedule was created for the cast in place concrete activity for floors G4 through the plaza level and for floors 2 –14. These two areas are shown on the same schedule but are not related SIPS due to the difference in floor size and design. The main concentration of this analysis was on the schedule for floors 2-14.

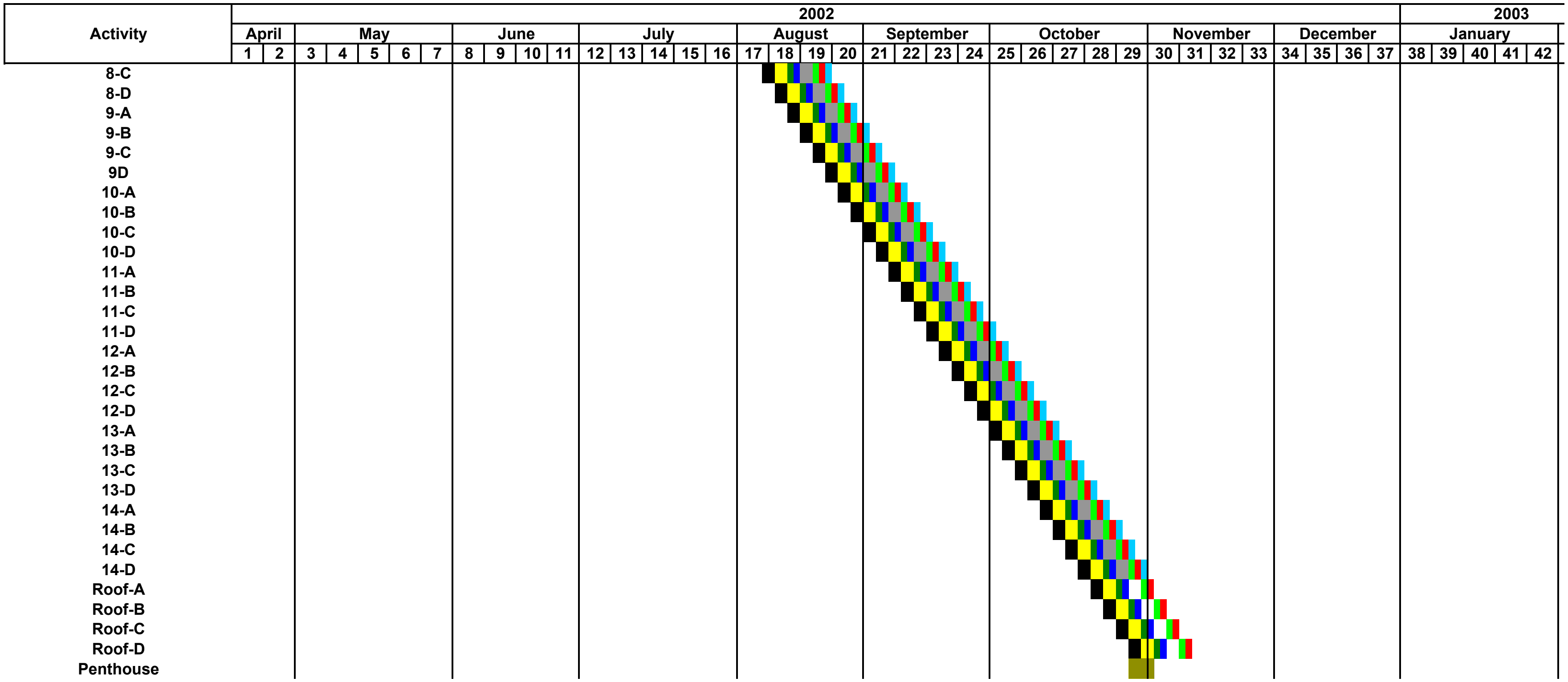
First the floors were broken up in to four sections labeled A through D. Each section is roughly 6,250 square feet. This size allows for most of the activity durations to be one day. Next the sequence was developed for each section. The sequence for floors 2-14 is as follows

1. Form the slab
2. Reinforce the slab
3. Hang tension cables
4. Pour and finish slab
5. Form columns
6. Stress slab and reinforce columns
7. Strip and re-shore slab and pour columns
8. Strip columns

The durations for each activity were calculated by using daily output data from R.S. Means. The crew sizes were altered to have the durations of each activity be as close to the others as possible. However, some of the activities, such as forming the slab, could not be reduced to one-day durations without out compromising the productivity due to too many people working in one area. Having varying durations in a SIPS schedule can cause problems with movement of crews through the building. If one activity takes three days and the following activities take one day, the crews with the shorter duration activities will be not be able to continually move on to the next section without being delayed by the preceding crew.

For the Bethesda Triangle SIP schedule, this problem could be corrected by setting the crew sizes so that the durations for the shorter activities would allow the crew to perform a similar but different activity on a different section. For example, the crew responsible for pouring the slab has a one-day duration. If they just poured the slab, then they would only have work every other day. However, this was corrected by having them pour the columns on a different section on alternate days. This problem could not be avoided with the post tensioning work. This work would be complete by a specialty contractor so there would not always be work on this project for them. Since it is a specialty contractor, this may still work well for them if they have another project that they could work on alternate days. It is difficult to show the sequence precisely on the graphic SIPS schedule because of the lack of ability to show durations that are fractions of a day. Some of the durations that were slightly less than a full day where rounded up to allow time for movement of the crew and their tools to the next work area. Others that were slightly higher than the whole day were rounded down to show a more accurate picture of the overall duration. These durations would most likely decrease as the project progresses due to the learning curve. Once the crews learned their portion of the work and became accustomed to the project, their productivity would increase.


Activity
2002
2003
April
May
June
July
August
September
October
November
December
January
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42
Form Spread Footings
Reinforce Spread Footings
Pour Spread Footings
Form Strip Footings
Reinforce Strip Footings
Pour Strip Footings
G4-A
G4-B
G4-C
G4-D
G3-A
G3-B
G3-C
G3-D
G2-A
G2-B
G2-C
G2-D
G1-A
G1-B
G1-C
G1-D
Plaza Level-A
Plaza Level-B
Plaza Level-C
Plaza Level-D
2-A
2-B
2-C
2-D
3-A
3-B
3-C
3-D
4-A
4-B
4-C
4-D
5-A
5-B
5-C
5-D
6-A
6-B
6-C
6-D
7-A
7-B
7-C
7-D
8-A
8-B
Legend
Other
Form Walls
Reinforce Walls
Pour Walls
Form slab
Reinforce Slab
Hang Tension Cables and/or Strip Walls
Pour and Finish Slab
Form Columns
Stress Slab and/or Reinforce Columns
Strip and Reshore Slab and/or Pour Columns
Strip Columns


Activity
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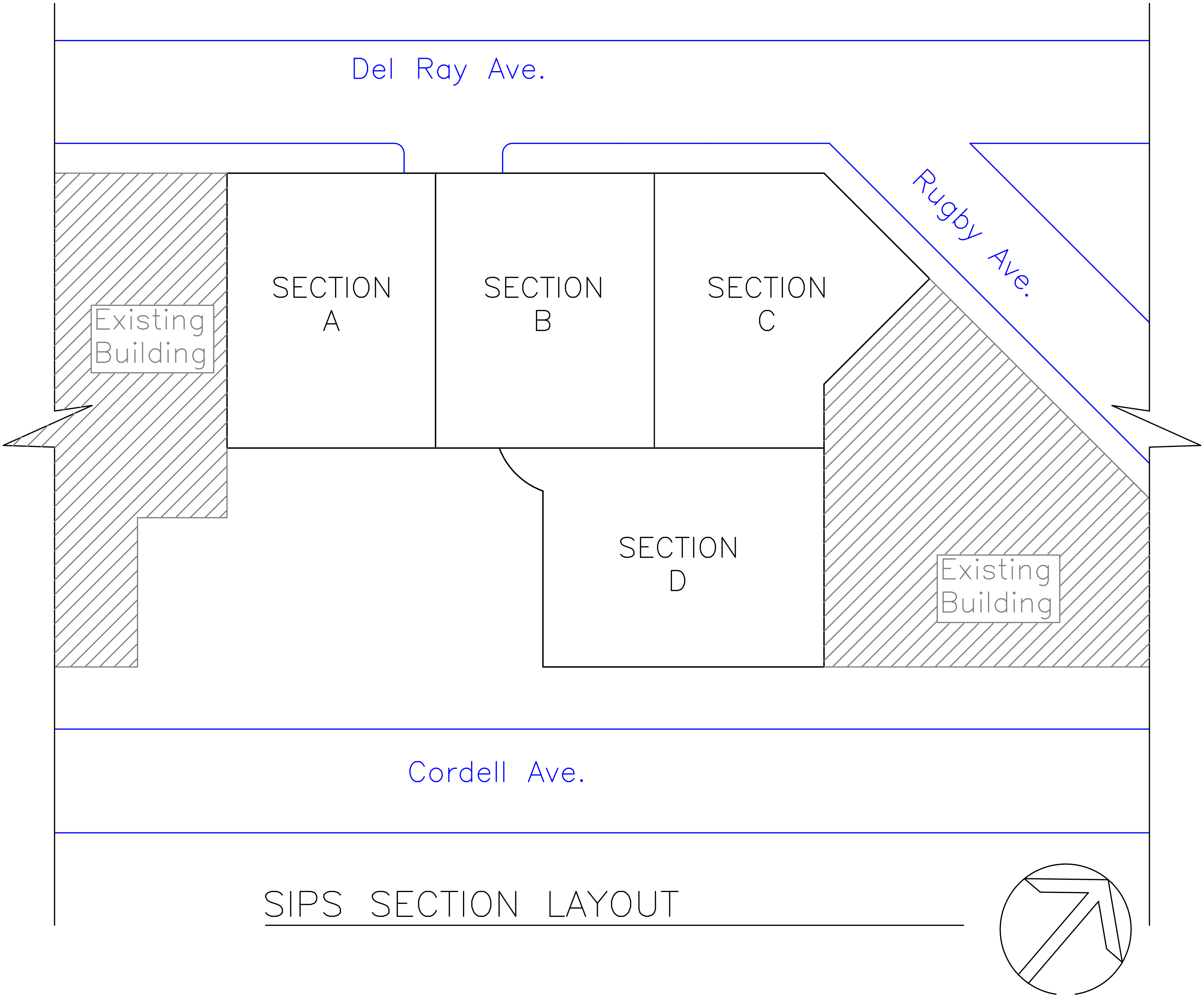
Roof-A
Roof-B
Roof-C
Roof-D
Penthouse



SIPS SECTION LAYOUT

Results

After completing the SIP schedule for the cast in place concrete structure, it was found that the task could be completed in 31 weeks. If this were inserted into the original schedule, it would begin in mid April of 2002 and be completed in mid November of the same year. This is 13 weeks shorter than the original schedule duration for this activity.

If this method of scheduling was implemented for all activities, such as enclosures and finishes, the overall duration could have the potential to be drastically decreased.

Conclusion

After completing this analysis it has been found that the Bethesda Triangle apartment building project would have benefited by using short interval production scheduling. Although the SIP schedule's accuracy relies heavily on the lack of unforeseen delays, the drastic decrease in duration of approximately three months would still allow for delays in the SIPS and still be completed earlier than the original schedule.

If this type of scheduling was implemented for the rest of the project, there could have potentially been a time savings of six to nine months on the entire duration. This would depend heavily on the actual durations compared to the estimated ones used in the SIP schedule. Further analysis would need to be completed to establish actual time savings. In addition to saving time, general conditions costs would be decreased because of the shortened duration. A cost savings of approximately $200,000 would be saved from the general conditions costs with this reduction in schedule.

Alternate Generator Analysis

Introduction

Many owners are attempting to add value to their buildings by implementing value-engineering ideas. The costs of using these different systems are compared to the original system or a typical system. The new systems are not always the less expensive option but will always add value to the building or have a certain payback period. However, problems can arise with the cost calculations if they involve projected costs of items that are constantly changing such as fuel or electricity costs. There is no way to accurately predict the future costs of such items. If there is some unexpected change in a certain market, the once value adding or profitable idea could turn out to be costing more than was expected.

This analysis will compare the current generation system of Bethesda Triangle to an alternate system. The current system was designed to be a profitable system when it was proposed almost two years ago. However, there have been fluctuations in the diesel fuel and electricity market that may show that this system is not returning a profit at this time. The two different systems, current and proposed, will be explained, and then a comparison of costs will be shown, followed by a recommendation/conclusion.

Current Generation System

The current generation system at Bethesda Triangle consists of an oversized generator that will power the entire building in the event of a blackout. The generator also has the potential to run at times when it is more cost effective to run it rather than purchase electricity from the utility company, PEPCO. At the times when it is running to power the building rather than purchasing power, the power that is not consumed by the building's needs will be sold back to the grid.

The current generator that is in place in Bethesda Triangle is a 2 mega-watt standby power and 1.8 mega-watt prime power generator. The standby power is for supplying power during normal power interruption. The prime power is used to power the building instead of purchasing electricity from the utility. The prime power is the maximum power available at a varying load for a number of hours. Therefore, the generator is capable of producing 2 mega-watts of power in the event of an emergency or a

blackout for a short period of time. At times when the generator would be run instead of purchasing power and selling extra electricity, it will have a maximum output of 1.8 mega-watts. In addition to this large generator, there is a smaller one (shown on the previous page) that is used to power the emergency fire systems.

This system was designed as a value adding idea. Its main purpose is to save money at peak electricity times. This is how the installation of such a large and expensive piece of equipment is justified. The first cost of this generator is much larger than using a smaller one so it creates a higher first cost of the overall project. However, since the analysis originally performed on this generator shows that it will payback the cost of itself in years down the road through savings in electricity costs, this value engineering idea was implemented in this building.

The electricity savings are not the only benefit of having this generator in this particular building. In the event of a black out, this generator will power the entire building as if there were no problem at all. This is a great sales point when renting out the apartments. This feature of the building may make this particular apartment building more attractive to perspective tenants, especially with the recent blackouts that occurred all over the northeast United States. Also, the high-end apartments that are located on the upper floors of this building may be leased out much easier than they would have if this luxury feature were not in place.

This system was priced at $540,000. This includes the 2 mega-watt generator and the switchgear.

Proposed Generation System

The proposed generation system for Bethesda Triangle is one that would just power the emergency systems in the event of a blackout or fire. This generator was sized using Kohler's QuickSize program. It was found that a 350 KW generator would be sufficient to power the emergency systems of the building. This would be standby power since the generator would only be used in an emergency and would never be used to power the building and sell power back. The systems that were taken into account when sizing this generator were:

- Emergency lighting
- Fire alarm
- Fire pump
- Stair well pressurization
- Smoke exhaust
- Emergency elevator

The proposed system was setup to have two steps for starting the different equipment. The first step would include the life safety equipment (emergency lighting and fire alarms), the stairwell pressurization fans and the smoke exhaust fans. The second step would include the fire pump and the elevator. The loads for life safety were established using a one tenth watt per square foot factor. This brought that load to be approximately

60 KW. The other loads for the motors were based on the horsepower of the equipment. The generator set sizing output from the QuickSize program can be found in Appendix B.

This generator was priced at $40,000. This includes the 350-kilowatt generator and two automatic transfer switches.

Calculations - all of the spreadsheets for the following calculations can be found in Appendix B.

In order to perform a comparison of the current system to the proposed system, the costs associated with the current system needed to be found. The daily loads for the building were found on an hourly basis for both the summer and the winter months. The summer is considered to be from June to October and the winter is considered to be from November to May. The building was split into two sections for the load calculations. Floors 1 – 14 were considered to have residential loads. The garage was calculated separate and used a 1-watt per square foot load for all hours of the day. The cost of purchasing electricity was found by using peak, off-peak and intermediate electric rates found on the PEPCO website. Once the hourly rate was found, the totals were then multiplied out to obtain the monthly electric costs.

Next, the net costs of running the generator were found. The 2 mega-watt generator consumes approximately 130 gallons of number 2 diesel fuel per hour when running at full load. The price of diesel fuel as per Energy Information Administration / Petroleum Marketing Monthly was found to be 90.1 cents per gallon for the state of Maryland in December 2003. Hence, it will cost approximately $117 to run the generator for one hour at full load. Once the cost of running the generator was know the profit made from selling the extra power back could be added and the hours in which it would be profitable to run the generator would be known. The costs per kilowatt-hour were assumed to be the same whether Bethesda Triangle was purchasing the electricity from the utility company or selling it back to the grid.

Results

After performing the above calculations, it was found that it would never be profitable to run the generator to power the building. All times of the day in both the winter and summer seasons showed a loss on running the generator. In fact, even if all of the 1.8 mega-watts generated were sold back at PEPCO's prices, there would still be a loss.

Cost Comparison of Both Generators

Generator	Purchase Cost	Gallons per Hour	Fuel Costs	Generation Costs
350 KW	$40,000	25	$0.90	$22.53
2 MW	$540,000	130	$0.90	$117.13

NOTE: Other costs such as installation and maintenance costs are unknown but are assumed to be significantly less for the 350-kilowatt generator than the 2 mega-watt system.

Conclusion

After completing this analysis, it is found that it is not value adding to the project to have the current system. There would be significant savings in initial costs of the project if the small generator were used to just power the emergency systems of the building. This is mainly due to the current prices of electricity and fuel. Historical fuel cost data shows that when the current system was designed and found to be profitable, the cost of diesel fuel was lower than the cost today. It is possible that the current system will become profitable once again if the cost of fuel drops. In addition, if it is found that the "no blackout" feature of this building proves to have a higher rental price than that of an apartment building without that feature, it may be value adding to install the larger generator. This then becomes a quality issue and a market study would need to be analyzed to establish whether or not a large generator is value adding.

Alternate Formwork Analysis

Introduction

Companies that specialize in concrete forming systems are developing new systems that can improve productivity and lower costs. Traditional, hand-set formwork is very labor intensive, which carry a high labor cost for the forming activities. The best way to lower the cost of forming activities is to lower the amount of labor involved. The problem with hand set formwork is that it can only be installed a few square feet at a time. If this problem can be overcome, productivity will increase.

Symons Corporation, a company specializing in concrete forming systems, has developed a system that allows large amounts of formwork to be placed at once. This system utilizes a large aluminum truss structure that is put into place with a crane. This type of forming system is known as a flying truss system. This analysis will compare the original hand set forming system to the crane set flying truss system.

Original Forming System

The structure for Bethesda Triangle is a cast in place concrete structure. The majority of the columns are 24-inch square columns. The slab is a cast in place flat slab with drop panels type slab. The slab thickness is 8 inches and the drop panels are 6 inches.

The forming system that was used to form the cast in place structure for Bethesda Triangle was a traditional, hand set system. This system was put in place using shores to support the weight of the concrete. Once the concrete had cured sufficiently, the shoring and the forms were removed and re-shoring was put in place. This is a very labor-intensive system since only a few square feet can be installed at a time.

Proposed Forming System

The proposed forming system for Bethesda Triangle is the Symons Corporations Flying Truss Forming System. This system is made up of aluminum trusses and aluminum cross members to support the forming deck. Large sections can be flown into place by a crane in much less time than tradition forming systems. The system can use a one or two truss section, depending on the width of the bay. The forming tables can be from four to six feet tall and jacks are used to raise the table to the correct height. The maximum of floor to ceiling height is 12 feet for this system. The procedure for this system is as follows:

- The flying truss tables are hooked to the crane using nylon straps that pass through knockout panels and hook to the truss
- The table and all of its components are flown into position at the same time
- The tables are set in final position by setting the jacks or legs to the correct height
- Stripping is done by lowering the screw jacks or leg adjustments for the initial release
- The tables are then lowered to floor rollers or truss mounted casters by hydraulic jacks
- The tables can be rolled clear of the structure by four workers
- The cycle then repeats

This system works very well with high-rise buildings that have a repetitive concrete slab design. However, this system is only compatible with flat plate slab designs.

For this analysis, the drop panels were eliminated from the original design and a flat plate slab was designed. The new design calculations showed that a 10-inch slab thickness would be sufficient. These calculations were performed using the direct design method and the calculations can be found in the Appendix C.

Comparison of the Two Systems

All data for the hand set forming for a flat slab with drop panels was taken for R.S. Means Cost Data. All data for Symons flying truss forming system was obtained form Symons Corporation. The cost data for the flat plate slab was taken from R.S. Means.

<u>Duration and labor costs comparison</u>

System	Sq Ft of Slab	Sq ft /day	Duration (Days)	Labor Costs / Day	Total Labor Costs
Hand Set - Flat Slab w/ Drop Panels	380,000	544	699	$1,544	$1,078,529
Flying Truss - Flat Plate	380,000	7500	51	$1,544	$78,229

<u>Form cost comparison</u>

System	Sq Ft of Slab	Form Costs / SF	Total Mat. Costs
Hand Set - Flat Slab w/ Drop Panels	380,000	$0.92	$349,600
Flying Truss - Flat Plate	380,000	$0.40	$152,000

Slab system cost comparison

System	Sq Ft of Slab	Slab Costs / SF	Total Slab Costs
Hand Set - Flat Slab w/ Drop Panels	380,000	$5.15	$1,957,000
Flying Truss - Flat Plate	380,000	$5.82	$2,211,600

Total Costs

System	Total Costs
Hand Set - Flat Slab w/ Drop Panels	$3,385,129
Flying Truss - Flat Plate	$2,441,829

The square foot per day productivity rates for both systems are based on a crew of six workers. The labor costs for these crews were based on an average pay for one foreman, four carpenters, and one laborer. These are the bare costs from R.S. Means.

Advantages and Disadvantages

System	Advantages	Disadvantages
Hand Set Forming System	• Allows for original slab with drop panels to be used • Original systems allows for larger plenum space • Does not require crane time	• Takes either much longer to place forms or requires a much larger crew • Labor costs are higher • Material costs are higher
Symons Flying Truss Forming System	• Much better productivity • Shortens duration for overall project • Reduced labor costs • Reduced material costs	• Only compatible with flat plate slab design • New slab design reduces plenum space and adds load to the structure • Requires crane time so crane is not available for other activities

Conclusion

After completing this analysis, it is recommended that Symons' flying truss forming system be used. It greatly reduces labor and material costs for the project. It was found that a reduction of approximately $940,000 might be possible with using the flying truss system over the hand set method. The savings would most likely be slightly less then this because the productivity rate for the flying truss system does not take into consideration the area between columns that would not be cover by the truss table. These areas would need to utilize a different method such as had set forms. Also, crane time is another issue that would need to be investigated based on the rest of the construction schedule. If the crane were needed elsewhere during the forming activities, schedule delays would be inevitable. Although, at this time, the cast in place operation is the activity that requires the use of the crane for the majority of the time. If the reduction in plenum space would cause major problems to the design of the building systems then the flying truss system will not work. The extra load of the thicker slabs may require larger columns or foundations, which would increase the overall cost of the structure.

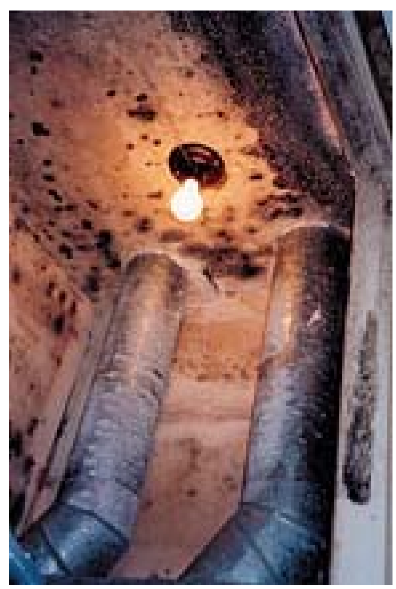
Mold Prevention

Introduction

Mold has become an increasingly larger problem in the building industry. It's not that mold is just starting to grow in buildings or that it is just starting to have an effect on people who are exposed to it, but rather that new discoveries of links between mold exposure and certain illnesses. Mold growth is worst in buildings where the occupants are inside for long periods of time, such as homes, offices, and apartment buildings. Occupants of these spaces are exposed to the inside air of the building for at least eight to ten hours per day. In addition, if the building is older, then it may have poor or inoperable ventilation systems, which would cause the indoor air quality to be even more harmful.

Bethesda Triangle, while it most likely does not have a mold problem now, like every building, has the potential to develop a problem in the future. Since, for the most part, this is a residential building, extra care should be taken during design and construction to prevent the onset of mold growth in the future. The purpose of this research is to develop a set of guidelines that contractors can follow in the construction of a building project. First, the causes and effects of mold will be discussed then a set of guidelines will be presented.

Causes and Effects of Mold



The number one cause of mold is moisture. If there is no moisture then there will be no mold growth. In addition, there also needs to be a nutrient source and the temperature needs to right, roughly around 70 degrees Fahrenheit or higher. Both nutrient sources and warm temperatures are most commonly found inside buildings. The most common materials that provide the nutrients for molds are wood, paper, carpet, and foods (United States, 2004). The paper backing of drywall makes an excellent environment if it gets wet. When microscopic spores, which are produced from growing mold for reproduction and travel in the air, land on an environment such as wet drywall, growth will begin in as little as 24 to 48 hours (Ruffe, 2002).

Since moisture is most important factor in mold growth in buildings, any leaks in the enclosure should be remedied immediately. Some of the most common sources of water leaks are:

- Leaks in roofs or exterior walls

- Capillary action can cause water to be pulled in through walls that are exposed to moisture
- Humid air can leak in through cracks
- Spilled water in the building from things such as leaky plumbing and fire fighting (Small, 2002)

Many of these problems can be avoided if care is taken when considering the design and construction of the building. Extra care should be taken in the design of the building enclosure. The architect should ensure that all of the details for the roof and walls, especially around openings such as windows and vent pipes, are shown clearly on the plans. If even one detail is missing or not properly shown, a small leak can occur and, over time, cause a costly mold problem. In addition to the architect taking special care to ensure all the proper details are shown, the contractor needs to follow these details precisely. The contractor must not take any shortcuts, whether it is to save time or money, without the architect's approval. Building inspectors need to closely look at areas where leaking could be a problem. If all parties overlook these details then there will not be any steps taken to prevent the growth of harmful mold.

The effects of mold-induced diseases can be extremely severe if it goes untreated, which can happen fairly often since the first symptoms of the disease are flu-like. People can be affected in different ways from different types of molds. Some are allergic to less toxic types of molds, mildew, and fungus. Symptoms of allergic reaction to molds are:

- Asthma
- Skin rashes
- Fatigue
- Irritability
- Congestion
- Coughing
- Nausea
- Headaches
- Arthritic aches and joint pain (Macdonald, 2004).

These symptoms are often acute and less serious, however there are much more harmful reactions to toxic mold. Mycotoxins, which are poisonous mold byproducts, are very destructive to the human body and cause much more serious, chronic health problems. These symptoms include:

- Impaired breathing
- Memory loss
- Hearing, speech, and eyesight degradation
- Loss of balance
- Epileptic-like seizures
- Brain damage (Macdonald, 2004)

The most harmful types of molds are known as black molds. Other types are usually only cause slightly irritating problems or no problems at all, however, the black molds are the species that are the most toxic to humans. There are many different species that make up the black mold class but the most common ones that are found in residential, commercial, and industrial buildings are stachbotrys, penicillium, and aspergillus (Macdonald, 2004). The spores produced by these molds are extremely small and, when inhaled, can bypass all of the body's defense mechanisms and travel all the way to the lungs air sacs called the aveoli. Since the inside of the lungs are a dark, warm, moist space, the mold can begin to grow and cause those parts of the lungs to not function correctly. The body attempts to defend against the mold and lung scarring is the usual outcome. This will cause the lung to not work as efficiently as it once did and this will last the rest of the person's life.

These problems not only occur with the buildings occupants but also often affect construction workers during renovation projects of older buildings. Many times workers disregard the signs of mold and continue working as usual. Without the proper safety equipment, such as respirators, safety glasses, and gloves, workers can very easily develop diseases related to toxic mold poisoning.

Guidelines for Prevention of Mold Growth During Construction

1. Clear details of all exterior penetrations
    - Architect should provide clear and accurate details for all exterior penetrations of the buildings enclosure, including doors, windows, piping, conduit, and vents. Without accurate details, proper construction techniques may not be used allowing for possible leaks.

2. Design must provide for adequate roof drainage
    - The roof of any building must be properly designed to shed water off and away from the building. Sloping and drainage should be designed with adequate capacity to ensure that water does not back up into areas that are not designed to hold water.
    - Proper construction techniques must be used to ensure that the drainage system functions as designed.

3. No changes to design of enclosure without architects approval
    - The contractor should not change any designs or take any shortcuts when constructing the enclosure for any reason with out the architect's approval. Taking shortcuts to save time or money can cause low quality work and mistakes can happen. A small mistake in the enclosure can cause leaks and costly repairs in the future.

4. Proper slope of grading around the building
   - The slope of the earth and paved areas should provide adequate drainage of rainwater away from the building to help prevent water from penetrating the building below grade. It is also important that this slope is properly maintained during the construction of the building.

5. Drywall must remain dry prior to installation
   - Drywall must be kept protected from moisture prior to installation. Drywall should only be delivered to areas that are completely sealed or the drywall should be in watertight packaging until it is ready to be used. All measures should be taken to keep it dry.

6. Complete enclosure of building prior to drywall installation
   - Before drywall is removed from its protective packaging or storage area to be installed, the area in which it will be installed should be completely enclosed and free of any leaks.

7. Use drywall designed to reduce mold growth
   - Drywall that has a high resistance to mold growth can be used in areas where moisture could become a problem. These areas can include the inside of exterior walls, areas that have large amounts of plumbing, bathrooms, and ceilings.

8. Proper inspection
   - Extra care should be taken when inspecting areas that could cause potential leaks in the future. If the problems are caught before they actually become a problem, then the likelihood of mold growth and expensive repairs is reduced.

9. Proper operation of equipment
   - If proper operation procedures are not followed for equipment, mostly HVAC units, moisture may be introduced in the form of leaks or condensation.

Conclusion

Mold can create serious problems in all types of buildings, especially in apartment buildings or other residential buildings, due to the long hours that the occupants will spend inside. Not only can the growth of mold bring about expensive and time consuming delays in renovation projects, it also can cause serious health problems for building occupants and construction workers. These health concerns can be avoided in construction workers if proper techniques are used in the removal of mold, however, people may live with mold in their home for many years before discovering it. They are then put at risk of developing health problems from something that they did not even know about.

If these guidelines are followed as carefully as possible, many of the issues concerning mold can be avoided. Architects need to be sure that all detail drawings are present and accurate to help prevent mistakes in the construction of the building enclosure. Also, contractors need to use correct procedures when handling exterior enclosures and interior finishes so that moisture is not allowed to penetrate the building and provide a good environment for mold growth.

Conclusion

The use of short interval production scheduling (SIPS) in the cast in place concrete structure activities provides for a large reduction in schedule duration. This approach utilizes the repetition of the building's design and creates a repetitive construction sequence, which allows crews to continuously move through the project working on the same activity throughout. This increases the productivity of this portion of work, which reduces duration and decreases costs.

The current generator in Bethesda Triangle allows for the generation of enough power to keep the building fully operational during a blackout. In addition, it can be run to power the building and sell power back to the grid at times when it is profitable. However, through this analysis, it was found that due to the current market prices for diesel fuel and electricity, it is not profitable to operate this generator in this manner. It is recommended that Bethesda Triangle use a smaller generator that is sized to power just the systems that will be needed in the event of an emergency.

The use of a prefabricated, aluminum, flying truss forming system has the potential to greatly reduce the cost of the cast in place concrete slab activity. It has a much better productivity rate than that of the traditional hand set system. There are some disadvantages to using the flying truss system, but if they do not pose a major problem to the outcome of the project, then it is a much better system to use.

Mold growth in buildings can cause major health problems for the occupants, especially when the building is one where people will be inside for many hours at a time, such as apartments and offices. The growth of toxic mold can be prevented by carefully following the guidelines outlined in the preceding section about mold prevention. There is no building that can be one hundred percent mold proof; however, following these guidelines can add value to the building by helping to reduce the possibility of expensive repairs in the future.

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Appendix A:

Calculations for SIPS

Spread Footings						
Activity	Total	Units	Daily output	# of crews	total daily output	duration
Forms	18440	SF	414	6	2484	7
Reinforce	38	TON	3.6	2	7.2	5
Place	2065	CY	120	3	360	6
Finish	18398	SF	900	3	2700	7

Strip Footings						
Activity	Total	Units	Daily output	# of crews	total daily output	duration
Forms	2424	SF	485	2	970	2
Reinforce	3.6	TON	2.1	1	2.1	2
Place	236	CY	140	1	140	2
Finish	4840	SF	900	3	2700	2

Wall - G4							
Activity	Total	Units	Daily output	# of crews	total daily output	duration	section
Forms	18160	SF	395	8	3160	6	1.4
Reinforce	3.75	TON	4	1	4	1	0.2
Place	336	CY	100	1	100	3	0.8

Slab on Grade							
Activity	Total	Units	Daily output	# of crews	total daily output	duration	section
Reinforce	55861	SF	3500	3	10500	5	1.3
Place	1034	CY	92	3	276	4	0.9
Finish	55861	SF	900	9	8100	7	1.7

Columns (All) - G4, G3							
Activity	Total	Units	Daily output	# of crews	total daily output	duration	section
Forms	8682	SF	238	6	1428	6	1.5
Reinforce	1.8	TON	2.7	1	2.7	1	0.2
Place	172	CY	92	1	92	2	0.5

Wall - G3, G2							
Activity	Total	Units	Daily output	# of crews	total daily output	duration	section
Forms	15560	SF	395	6	2370	7	1.6
Reinforce	3.2	TON	4	1	4	1	0.2
Place	288	CY	100	1	100	3	0.7

Elevated Slab - G3, G2							
Activity	Total	Units	Daily output	# of crews	total daily output	duration	section
Forms	51183	SF	544	8	4352	12	2.9
Reinforce	51.5	TON	2.9	5	14.5	4	0.9
Place	1273	CY	160	2	320	4	1.0
Finish	51200	SF	900	10	9000	6	1.4

Columns (All) - G2, G1							
Activity	Total	Units	Daily output	# of crews	total daily output	duration	section
Forms	10609	SF	238	7	1666	6	1.6
Reinforce	2.1	TON	2.7	1	2.7	1	0.2
Place	181	CY	92	1	92	2	0.5

Wall - G1							
Activity	Total	Units	Daily output	# of crews	total daily output	duration	section
Forms	9740	SF	395	6	2370	4	1.0
Reinforce	2	TON	4	1	4	1	0.1
Place	180	CY	100	1	100	2	0.5

Elevated Slab - G1, Plaza Level							
Activity	Total	Units	Daily output	# of crews	total daily output	duration	section
Forms	55645	SF	544	8	4352	13	3.2
Reinforce	56	TON	2.9	3	8.7	6	1.6
Place	1384	CY	160	2	320	4	1.1
Finish	55645	SF	900	10	9000	6	1.5

Columns (All) - Plaza							
Activity	Total	Units	Daily output	# of crews	total daily output	duration	section
Forms	9575	SF	238	5	1190	8	2.0
Reinforce	2	TON	2.7	1	2.7	1	0.2
Place	167	CY	92	1	92	2	0.5

Elevated Slab - 2-14							
Activity	Total	Units	Daily output	# of crews	total daily output	duration	section
Forms	25321	SF	544	5	2720	9.3	2.3
Reinforce	25.5	TON	2.9	1	2.9	8.8	2.2
Place	630	CY	160	1	160	3.9	1.0
Finish	25500	SF	900	7	6300	4.0	1.0

Columns (All) - 2-14							
Activity	Total	Units	Daily output	# of crews	total daily output	duration	section
Forms	7021	SF	238	4	952	7.4	1.8
Reinforce	1.43	TON	2.7	1	2.7	0.5	0.1
Place	123	CY	92	1	92	1.3	0.3

Elevated Slab - Roof							
Activity	Total	Units	Daily output	# of crews	total daily output	duration	section
Forms	25321	SF	544	6	3264	8	1.9
Reinforce	25.5	TON	2.9	1	2.9	9	2.2
Place	630	CY	160	1	160	4	1.0
Finish	25500	SF	900	7	6300	4	1.0

Columns - Penthouse							
Activity	Total	Units	Daily output	# of crews	total daily output	duration	section
Forms	1225	SF	238	3	714	2	0.4
Reinforce	0.23	TON	2.7	1	2.7	0	0.0
Place	15.1	CY	92	1	92	0	0.0

Appendix B:

Calculations for Generator Analysis

QuickSize
Generator Set Sizing

Project	Bethesda Triangle
Customer	

Generator Set

Model No.	350REOZV	**Gensets**	1
Engine	D350 12.1A65 (Diesel)		
Alternator	5M4027		

Performance Summary

LN / LL Voltage	277/480	volts	**Altitude**	500	feet
Frequency	60	hertz	**Ambient Temp.**	70	F
Phase(s)	3	phase			

Genset Rating @ 130C Rise	355.00 kW	
Genset Derated Rating	355.00 kW	
Total Running Power	177.53 kW	
Percent of Available kW Used	50.01 %	
Alternator Starting kVA	885.71 kVA @ 20% dip	
Peak Starting kVA	593.90 kVA	
Percent of Available kVA Used	67.05 %	
Maximum Voltage Dip	14.30 %	
Maximum Frequency Dip	2.21 %	(20% allowed)
Voltage THD	2.66 %	(no restriction)

Informational

Program Version	8.0.2
Database Version	1.11
Project Created	February 6, 2004; 02:23:52 PM
Project Last Saved	March 29, 2004; 06:27:57 PM
Report Created	April 4, 2004; 08:33:40 PM
Project Created By	

Summer											
APARTMENT						GARAGE					
Hour	Watts/SF	Total SF	Total KWHr	Weekday	Weekend	Hour	Watts/SF	Total SF	Total KWHr	Weekday	Weekend
0	1	380000	380	1900	760	0	1	200000	200	1000	400
1	0.75	380000	285	1425	570	1	1	200000	200	1000	400
2	0.65	380000	247	1235	494	2	1	200000	200	1000	400
3	0.6	380000	228	1140	456	3	1	200000	200	1000	400
4	0.5	380000	190	950	380	4	1	200000	200	1000	400
5	0.6	380000	228	1140	456	5	1	200000	200	1000	400
6	0.65	380000	247	1235	494	6	1	200000	200	1000	400
7	0.8	380000	304	1520	608	7	1	200000	200	1000	400
8	1.15	380000	437	2185	874	8	1	200000	200	1000	400
9	1.2	380000	456	2280	912	9	1	200000	200	1000	400
10	1.3	380000	494	2470	988	10	1	200000	200	1000	400
11	1.25	380000	475	2375	950	11	1	200000	200	1000	400
12	1.2	380000	456	2280	912	12	1	200000	200	1000	400
13	1.2	380000	456	2280	912	13	1	200000	200	1000	400
14	1.15	380000	437	2185	874	14	1	200000	200	1000	400
15	1.15	380000	437	2185	874	15	1	200000	200	1000	400
16	1.15	380000	437	2185	874	16	1	200000	200	1000	400
17	1.25	380000	475	2375	950	17	1	200000	200	1000	400
18	1.35	380000	513	2565	1026	18	1	200000	200	1000	400
19	1.4	380000	**532**	2660	1064	19	1	200000	200	1000	400
20	1.35	380000	513	2565	1026	20	1	200000	200	1000	400
21	1.3	380000	494	2470	988	21	1	200000	200	1000	400
22	1.35	380000	513	2565	1026	22	1	200000	200	1000	400
23	1.25	380000	475	2375	950	23	1	200000	200	1000	400

Totals	KWH	Dist	Tran	Generation	Total cost (week)
Off peak	47563	0.289	0.266	1.99	$1,210.48
On peak	26715	0.289	0.266	4.121	$1,249.19
Inter	27285	0.289	0.266	3.485	$1,102.31
					$3,561.99

Per Month	$14,247.94
+	261.16
	$14,509.10

30 minute max demand				+	
	KW	Dist	Tran	Generation	
On peak	732	0.9506	0.6958	7.73	$68.64
Maximum	713	0.392	0.2842	3.18	$27.49
					$14,605.23 Total Monthly Cost

Winter

APARTMENT						GARAGE					
Hour	Watts/SF	Total SF	Total KW	Weekday	Weekend	Hour	Watts/SF	Total SF	Total KWHr	Weekday	Weekend
0	2	380000	760	3800	1520	0	1	200000	200	1000	400
1	1.85	380000	703	3515	1406	1	1	200000	200	1000	400
2	1.75	380000	665	3325	1330	2	1	200000	200	1000	400
3	1.8	380000	684	3420	1368	3	1	200000	200	1000	400
4	1.85	380000	703	3515	1406	4	1	200000	200	1000	400
5	1.95	380000	741	3705	1482	5	1	200000	200	1000	400
6	2.25	380000	855	4275	1710	6	1	200000	200	1000	400
7	2.85	380000	1083	5415	2166	7	1	200000	200	1000	400
8	3.1	380000	1178	5890	2356	8	1	200000	200	1000	400
9	3.35	380000	**1273**	6365	2546	9	1	200000	200	1000	400
10	3.2	380000	1216	6080	2432	10	1	200000	200	1000	400
11	3	380000	1140	5700	2280	11	1	200000	200	1000	400
12	2.75	380000	1045	5225	2090	12	1	200000	200	1000	400
13	2.5	380000	950	4750	1900	13	1	200000	200	1000	400
14	2.3	380000	874	4370	1748	14	1	200000	200	1000	400
15	2.25	380000	855	4275	1710	15	1	200000	200	1000	400
16	2.3	380000	874	4370	1748	16	1	200000	200	1000	400
17	2.75	380000	1045	5225	2090	17	1	200000	200	1000	400
18	3.05	380000	1159	5795	2318	18	1	200000	200	1000	400
19	3.1	380000	1178	5890	2356	19	1	200000	200	1000	400
20	3	380000	1140	5700	2280	20	1	200000	200	1000	400
21	2.9	380000	1102	5510	2204	21	1	200000	200	1000	400
22	2.8	380000	1064	5320	2128	22	1	200000	200	1000	400
23	2.5	380000	950	4750	1900	23	1	200000	200	1000	400

Totals	KWH	Dist	Tran	Generation	Total cost (week)
Off peak	77444	0.289	0.266	1.699	$1,745.59
On peak	39900	0.289	0.266	3.43	$1,590.02
Inter	45315	0.289	0.266	2.902	$1,566.54
					$4,902.14

Per Month	$19,608.57
+	261.16
	$19,869.73

30 minute max demand				+	
	KW	Dist	Tran	Generation	
On peak					
Maximum	1473	0.392	0.2842	3.18	$56.80

$19,926.53 Total Monthly Cost

Summer Analysis

Total KWHr	Plus Garage	Cost per KWH	total cost	Total cost to run gen	Extra Power (KWH)	profit from selling power	Net Cost	Profit from running (
380	580	2.545	$14.76	$117.13	1220	$31.05	$86.08	-$71.32
285	485	2.545	$12.34	$117.13	1315	$33.47	$83.66	-$71.32
247	447	2.545	$11.38	$117.13	1353	$34.43	$82.70	-$71.32
228	428	2.545	$10.89	$117.13	1372	$34.92	$82.21	-$71.32
190	390	2.545	$9.93	$117.13	1410	$35.88	$81.25	-$71.32
228	428	2.545	$10.89	$117.13	1372	$34.92	$82.21	-$71.32
247	447	2.545	$11.38	$117.13	1353	$34.43	$82.70	-$71.32
304	504	2.545	$12.83	$117.13	1296	$32.98	$84.15	-$71.32
437	637	4.04	$25.73	$117.13	1163	$46.99	$70.14	-$44.41
456	656	4.04	$26.50	$117.13	1144	$46.22	$70.91	-$44.41
494	694	4.04	$28.04	$117.13	1106	$44.68	$72.45	-$44.41
475	675	4.04	$27.27	$117.13	1125	$45.45	$71.68	-$44.41
456	656	4.676	$30.67	$117.13	1144	$53.49	$63.64	-$32.96
456	656	4.676	$30.67	$117.13	1144	$53.49	$63.64	-$32.96
437	637	4.676	$29.79	$117.13	1163	$54.38	$62.75	-$32.96
437	637	4.676	$29.79	$117.13	1163	$54.38	$62.75	-$32.96
437	637	4.676	$29.79	$117.13	1163	$54.38	$62.75	-$32.96
475	675	4.676	$31.56	$117.13	1125	$52.61	$64.53	-$32.96
513	713	4.676	$33.34	$117.13	1087	$50.83	$66.30	-$32.96
532	732	4.676	$34.23	$117.13	1068	$49.94	$67.19	-$32.96
513	713	4.04	$28.81	$117.13	1087	$43.91	$73.22	-$44.41
494	694	4.04	$28.04	$117.13	1106	$44.68	$72.45	-$44.41
513	713	4.04	$28.81	$117.13	1087	$43.91	$73.22	-$44.41
475	675	4.04	$27.27	$117.13	1125	$45.45	$71.68	-$44.41

Totals	Dist	Tran	Generation	Total Cost (Cents)
Off peak	0.289	0.266	1.99	2.545
On peak	0.289	0.266	4.121	4.676
Inter	0.289	0.266	3.485	4.04

Winter Analysis

Total KWHr	Plus Garage	Cost per KWH	total cost	Total cost to run gen	Extra Power (KWH)	profit from selling power	Net Cost	Profit from running
380	760	2.254	$17.13	$117.13	1040	$23.44	$93.69	-$76.56
285	703	2.254	$15.85	$117.13	1097	$24.73	$92.40	-$76.56
247	665	2.254	$14.99	$117.13	1135	$25.58	$91.55	-$76.56
228	684	2.254	$15.42	$117.13	1116	$25.15	$91.98	-$76.56
190	703	2.254	$15.85	$117.13	1097	$24.73	$92.40	-$76.56
228	741	2.254	$16.70	$117.13	1059	$23.87	$93.26	-$76.56
247	855	2.254	$19.27	$117.13	945	$21.30	$95.83	-$76.56
304	1083	2.254	$24.41	$117.13	717	$16.16	$100.97	-$76.56
437	1178	3.457	$40.72	$117.13	622	$21.50	$95.63	-$54.90
456	1273	3.457	$44.01	$117.13	527	$18.22	$98.91	-$54.90
494	1216	3.457	$42.04	$117.13	584	$20.19	$96.94	-$54.90
475	1140	3.457	$39.41	$117.13	660	$22.82	$94.31	-$54.90
456	1045	3.985	$41.64	$117.13	755	$30.09	$87.04	-$45.40
456	950	3.985	$37.86	$117.13	850	$33.87	$83.26	-$45.40
437	874	3.985	$34.83	$117.13	926	$36.90	$80.23	-$45.40
437	855	3.985	$34.07	$117.13	945	$37.66	$79.47	-$45.40
437	874	3.985	$34.83	$117.13	926	$36.90	$80.23	-$45.40
475	1045	3.985	$41.64	$117.13	755	$30.09	$87.04	-$45.40
513	1159	3.985	$46.19	$117.13	641	$25.54	$91.59	-$45.40
532	1178	3.985	$46.94	$117.13	622	$24.79	$92.34	-$45.40
513	1140	3.457	$39.41	$117.13	660	$22.82	$94.31	-$54.90
494	1102	3.457	$38.10	$117.13	698	$24.13	$93.00	-$54.90
513	1064	3.457	$36.78	$117.13	736	$25.44	$91.69	-$54.90
475	950	3.457	$32.84	$117.13	850	$29.38	$87.75	-$54.90

Totals	Dist	Tran	Generation	Total Cost (Cents)
Off peak	0.289	0.266	1.699	2.254
On peak	0.289	0.266	3.43	3.985
Inter	0.289	0.266	2.902	3.457

Appendix C:

Calculations Formwork Analysis

(1)

$LL = 40\ psf$ Columns $24'' \times 24''$

$f'_c = 4000\ psi$ Spans $24' \times 24'$

$f_y = 60{,}000\ psi$

Ratio longer span / shorter span $= 24/24 = 1.00 < 2.0$

$\therefore$ Two way action

Assume thickness of 9"

$w_d = \frac{9}{12} \times 150 = 112.5\ psf$ $2w_d = 225$

$w_l = 40 psf < 2w_d \therefore ok$

$l_{n_1} = 24 \times 12 - \frac{24}{2} - \frac{24}{2} = 264\ in$

$l_{n_2} = 24 \times 12 - \frac{24}{2} - \frac{24}{2} = 264\ in$

ratio of longer to shorter clear span $\beta = \frac{264}{264} = 1.00$

$h = \frac{l_n}{30}$ increase by 10% when no edge beam is used

$l_n = 264$

$h = \frac{264}{30} \times 1.1 = 9.68\ in$

new $w_d = \frac{10}{12} \times 150 = 125\ psf$

$2w_d = 250$

$w_l = 40 psf < 2w_d \therefore ok$

(2)

Shear Thickness Requirements

$$W_u = 1.6L + 1.2D = 1.6(40) + 1.2(125) = 214 \text{ psf}$$

$$V_u = [(\ell_1 \times \ell_2) - (c_1 + d)(c_2 + d)]\, W_u \qquad d = h - 1 = 10 - 1 = 9 \text{ in}$$

$$= \left[(24 \times 24) - \left(\frac{24+9}{12}\right)\left(\frac{24+9}{12}\right)\right] 214$$

$$= (576 - 7.56)(214)$$

$$= 121,646$$

$$V_n = \frac{V_u}{\phi} = \frac{121,646}{0.75} = 162,195 \text{ lb}$$

$$b_o = 2(c_1 + c_2 + 2d) = 2(24 + 24 + 18) = 132$$

perimetric shear surface

$$A_c = b_o d = 2d(c_1 + c_2 + 2d) = 2(9)(24 + 24 + 18)$$

$$= 1188 \text{ in}^2$$

Ratio of longer to shorter side of column

$$\beta_c = \frac{24}{24} = 1.0$$

(3)

Available nominal shear V_c is least of:

$$V_c = \left(2 + \frac{4}{\beta_c}\right)\sqrt{f'_c}\, b_o d$$

$$= \left(2 + \frac{4}{1.0}\right)\sqrt{4000}\,(1188)$$

$$= 450{,}814 \text{ lb}$$

OR

$$V_c = \left(\frac{\alpha_s d}{b_o} + 2\right)\sqrt{f'_c}\, b_o d$$

$$= \left(\frac{40(4)}{132} + 2\right)\sqrt{4000}\,(1188)$$

$$= 355{,}187 \text{ lb}$$

OR

$$V_c = 4\sqrt{f'_c}\, b_o d = 4\sqrt{4000}\,(1188) = \underline{300{,}543} \text{ lb}$$

Controlling $V_c = 300{,}543$ lb > required $V_n = 162{,}195$ lb

∴ Thickness is adequate