Senior Thesis:

2012 AE Senior Thesis
Office Building
Northeast, United States

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Construction Management
Dr. Robert Leicht

OFFICE BUILDING
NORTHEAST UNITED STATES

PATRICK LANINGER - CONSTRUCTION MANAGEMENT - WWW.ENGR.PSU.EDU/AE/THESIS/PORTFOLIOS/2012/PVL5016/index.html

GENERAL INFORMATION

OWNER:	CONFIDENTIAL
OWNER'S REPRESENTATIVE:	TISHMAN/AECOM
GENERAL CONTRACTOR:	CLARK CONSTRUCTION
DESIGN ARCHITECT:	PERKINS + WILL
INTERIOR ARCHITECT:	HOK
ARCHITECT OF RECORD:	WDG
TOTAL HEIGHT:	5 STORIES
GROSS AREA:	390,000 SF
CONTRACTED GMP:	APPROX. $92,000,000
CONSTRUCTION DATES:	8/31/09 - 5/3/13

STRUCTURAL SYSTEM

FOUNDATION:
- CONCRETE CAISSONS (8' x 100' MAX)
- STEEL PIERS AND CIP PILE CAPS
- CONCRETE GRADE BEAM SYSTEM
- CIP FOUNDATION WALLS

STRUCTURE:
- TWO WAY SLAB SYSTEM WITH CIP COLUMNS AND EDGE BEAMS

FACADE:
- CMU BLOCK WITH NOMINAL BRICK MASONRY FACADE
- DUAL PANE, HEAT TREATED, BLAST RATED CURTAIN WALLS

MEP SYSTEMS

MECHANICAL:
- UTILITY TUNNEL TO CENTRAL PLANT
- 8 MCQUAY VISION VAV AHU'S
- LOCALIZED VAV BOXES
- VARIOUS HEAT RECOVERY DEVICES

ELECTRICAL:
- 11 TRANSFORMERS (150 to 15 KVA)
- 408/208 POWER SUPPLY
- MED., LOW & EMERGENCY SWITCHGEAR ROOMS

PLUMBING:
- FULLY SPRINKLED WET-PIPE SYSTEM

ARCHITECTURE

- TIERED HILLSIDE STRUCTURE
- NORTH-SOUTH ORIENTED MAIN STRUCTURE WITH THREE "FINGERS" THAT EXTEND WEST
- CENTERED AROUND COMFORTABLE SPACES
- EXTRAORDINARY VIEWS OF LANDSCAPE AND SURROUNDING SKYLINE
- 29,000 SF CHILDCARE CENTER
- 102,860 SF OF GREENROOF
- 103,000 SF STORMWATER RETAINAGE POND
- LARGE INTERIOR COURTYARD TO THE EAST

CONSTRUCTION

- NEARBY HISTORICAL STRUCTURES REQUIRE IMPLEMENTATION OF ARCHEOLOGICAL PROTOCOL
- EXTENSIVE PILE AND LAGGING SOE
- PRESENCE OF FLY ASH DEMANDED CONTAMINANT REMEDIATION
- ON-SITE CONCRETE BATCH PLANT SERVICES CIP OPERATIONS
- HILLSIDE SITE DEMANDS MULTIPLE DEWATERING TECHNIQUES AND WATER DIVERSIONS
- LEED GOLD DOCUMENTATION REQUIREMENTS
- CONSTRUCTION PHASING CENTERED AROUND MAINTAINING ACCESS TO INTERIOR COURTYARD
- ABANDONED UTILITY TUNNELS REQUIRED INITIAL DECOMMISSIONING

EXECUTIVE SUMMARY

The following report represents four individual analyses that focus on research in Critical Industry Issues, Value Engineering, Constructability Review, and Schedule Reduction tactics. In addition to these construction-related areas of study, architectural engineering breadth topics including structural design and mechanical system efficiency will be explored to provide further validity to the proposed design changes as well as the final results.

Analysis #1 – Relocation of Structural Concrete Columns
The placement of the structural concrete columns at the edge of the floor slabs negatively affects the pace at which interior finish trades can place their work. In order to facilitate productive interior fit out activities, these slab edge columns could be relocated to facilitate faster interior trade work. The productivity of drywall installation and finishing are currently affected by close confines created by the proximity of the structural columns to the exterior façade. However, the structural ramifications of further cantilevering the slab-edge, the minimal effect of these activities on the overall drywall installation schedule, as well as the negligible effects on the quality of these installations may make the design alteration unappealing to some owners.

Analysis #2 – Brick Façade Simplification
Losses in productivity on the project were attributed to the multiple recesses in the exterior façade, and the custom brickwork corners associated with wrapping the brickwork around these recesses. A building facade redesign featuring minimal masonry returns and glass recessions reduces the productivity losses associated with the existing complex façade. This alteration also reduces solar gains, resulting in a reduction of annual energy costs. The replacement of the building's recesses with linear brick sections successfully maintains the architectural aesthetics of the structure, resulting in a time and money saving, architecturally consistent, and overall plausible design alteration.

Analysis #3 – BIM in the Field
A project-wide 3D model was produced by the design, engineering and mechanical subcontractor teams and was used to detect clashes between the architectural features, structural systems and mechanical equipment. However, these models were highly underutilized in the field, leaving contractors to obtain coordination information in a roundabout manner. The following study of BIM Kiosk implementation highlights the costs of such an undertaking, as well as the time savings accrued by minimizing the time each foremen spends troubleshooting in-field conflicts between the building systems. The possible savings are staggering, considering the relatively low initial costs of the BIM Kiosk infrastructure, and create a very appealing and convincing opportunity for construction teams on projects that utilize 3D modeling and coordination techniques.

Analysis #4 – Design-Build Team Selection
In today's evolving construction industry, owners are more commonly choosing the design-build method of project delivery over the traditional design-bid-build approach. The selection of a design-build project team that embodies the mindsets and personal tendencies required for the successful implementation of this growing project delivery method has proven to be challenging at times. Identifying the subcontractor teams and individuals that are most likely to assimilate with the atmosphere required to achieve design-build success is difficult. While the current process of design-build team selection focuses on the traits and abilities of the general contractor and subcontractors, it was found that little to no emphasis is put on the ability of the owner to embrace the unique requirements of a design-build approach. It is imperative that overly bureaucratic and hierarchical owner organizations begin to realize their own faults and take steps to improve their ability to properly participate in the design-build process.

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PROJECT INFORMATION

DISCLAIMER

Due to the confidential nature of this project, many details regarding the client and their needs are not releasable. Please forgive the lack of in-depth client information and understand that it was the wish of the client to maintain anonymity.

INTRODUCTION

The following report is based on the design and construction of an office building in the northeast United States. The main focus of this thesis is Building One, which accounts for approximately one third of the 1.2 million square foot, three tiered building. The 390,000 square foot Building One is connected to Building Two via two underground hallways, an outdoor patio, and a steel pedestrian bridge. The building consists primarily of open office space that will house moveable partitions and office cubicles, but also features multiple conference rooms with adjacent kitchenettes, and a 45,000 square foot childcare center.

Building One consists of numerous unique aspects, including a 2.5 Million gallon storm water retention pond, 102,865 square feet of green roof space, and blast resistant curtain walls. The design also features a mechanical, electrical and plumbing system that is entirely independent of buildings two and three. Although the buildings are not able to be quarantined from one another, the nearby central utility plant provides localized utilities to each of the three tiered structures. This greatly improves the mechanical efficiency of the building and, when coupled with the localized variable air volume boxes, extensive insulation, low conductivity glass and green roof spaces, helps the project achieve its LEED gold rating.

The design-build construction approach implemented on the project allows for accurate coordination of the high-end MEP systems, and extensive landscape irrigation systems. Detailed landscaping coordination, including a fully automated irrigation system that is controlled from a central location allows the building to effectively combine numerous green aspects in a manner that capitalizes on the benefits of the systems being used.

This project is to serve as the tenant's flagship headquarters, and was approached by the owner as a Design-Build RFP for three main reasons. Primarily, the project required an aggressive, fast tracked schedule (see Figure #1) in order to meet the owner's long term goals for the relocation of multiple properties in an attempt to streamline their operations. Secondly, the owner is very confident that the Design-Build approach will allow them to meet their sustainable goals through the integration of a design team capable of incorporating sustainable aspects in the building's design, and a contractor/subcontractor presence that will provide continual cost analyses of the proposed building features. Additionally, the owners foresaw the fact that they would most likely being making multiple changes to the original design as their future tenants developed their special and infrastructure needs. A design-build approach will allow for rapid adaptation to these changes, facilitating the timely pricing and implementation of project change orders. The owner strongly believes that together, the designer/contractor team will be able to deliver a high-end, high-value product in a substantially shorter amount of time when compared to a traditional design-bid-build approach.

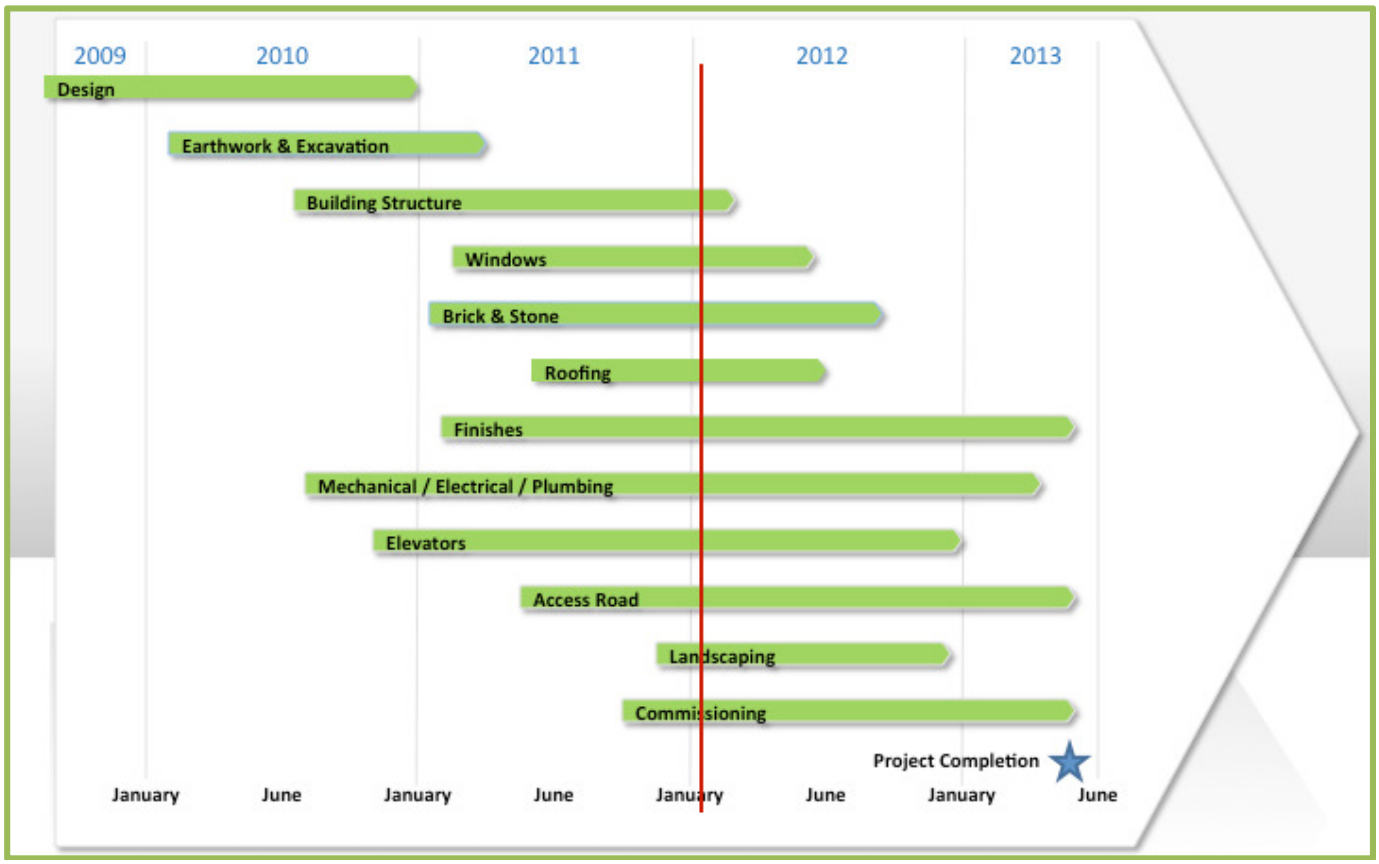


Figure #1: Total Building Schedule - Courtesy of Clark Construction

In order to successfully meet the owner's schedule acceleration desires, Clark Construction, with the help of its design subcontractors, HOK, WDG and McKissack and McKissack, developed a project plan that would allow for the excavation and foundation phases to begin soon after the design process began. This allowed the design team to produce site, civil, and foundation drawings early in the design process, expediting the release of the associated contracts which permitted groundbreaking and site development operations to begin early in the design process. This overlap of design and construction is crucial to the time-based success of the project. Additionally, the tiered design of the project was implemented in order for the phased construction of the building to operate smoothly and efficiently. Excavation efforts began on the lower part of the site and worked uphill, allowing the foundations and structure of Building One to begin shortly after the site was prepared, while excavation activities progressed up the slope. This ultimately allows for the phased construction of Buildings One, Two and Three respectively, so that the façade, MEP and interior trades can be staggered in a manner that ensures that the building is constructed in a timely manner. While phased-occupancy requirements COULD be met through this fast-tracked approach, the owner has not chosen to implement any such requirements on the design-build team at this time.

Due to the dilapidated state of the their current facilities and the fact that this office building will serve as the their main headquarters for many years to come, the owner committed to spending approximately $550M on the project in order to provide their employees with a state of the art, sustainable facility that surpasses the quality of similar facilities in the area. The owner is determined to provide a facility that will promote productivity, worker satisfaction, and provide a high level of security and safety to its occupants.

These goals are met through the utilization of ample day-lighting, extensive interior courtyards, and state of the art security systems.

In addition to their sustainable and space utilization goals, the owner also expects a high level of quality from the design-build team. To ensure that these expectations are met, Clark partnered with McKissack and McKissack's quality control division in a quality assurance subcontract separate of the CUP and Garage design contract. The quality control team is responsible for overseeing water tests on all of the MEP systems, operational tests of the vertical transportation systems, and wall close-in inspections. KTLH Engineers and ECS Testing Services were also subcontracted to oversee the quality and structural design compliance of the entire cast in place concrete and curtain wall embed system on the project. In a partnership with Harmon Glass and Atlantic Waterproofing, the glass and brick façade system will undergo stringent water tests to ensure the compliance of all waterproofing details and design facets.

BUILDING SYSTEMS OVERVIEW

The following building system summaries highlight the aspects of the design components affected by the topics of this thesis.

STRUCTURE

The elevated slabs on this project are all identical in nature. The roof slabs are as large as the floor slabs because of the added dead load from the green roof materials above. Since the building tapers as it goes up, it was not possible to calculate the area, perimeter and rebar contents of one slab and apply it to all levels. The fact that each level has slightly different undulations in the façade perimeter also makes a difference as far as concrete formwork is concerned. Because drop panels occur rather frequently, varying the slab thickness from 6" to 8", an overall slab thickness of 6.2" was used for the entire area to account for the excess concrete in these drop panels. (See Appendix B for take-off details).

All of the foundation walls, mat slabs, and elevated slabs in Building One are cast in place concrete. Clark Concrete, the concrete sub-contractor, specializes in cast-in-place concrete structures and accounts for approximately one third of the 350 workers that are on the site each day.

The concrete structure is comprised of 30' x 30' mm typical bays, with 2' x 2' columns and 7" thick floor slabs. In order to reduce the financial burden of the original 8" thick floor slab design, Clark Construction, with the help of Cagley & Associates, proposed a value engineering change that lessened the slab thicknesses to 7", while incorporating drop panels 8" in thickness around the columns that maintain the building's structural integrity and blast rating.

The foundations beneath Building One are comprised of rolled W-shaped column piers and concrete pile caps that support a system of grade beams that range in size from 2'-4" x 3'-0" to 5'-3" x 3'-0". In some places, a 4'-0" thick mat slab sits atop the grade beam system to provide adequate load distribution for the floors above, while a 5" thick slab on grade is located in areas with lesser building loads.

FACADE

The façade consists of CMU/masonry knee walls with a curtain wall façade in between. The concrete masonry units used on the headquarters building are 10 inches thick, and are reinforced with rebar that is attached to the concrete slab with HILTI bolts and fully grouted in every cell. The exterior masonry walls are sheathed with an air barrier, R13 solid foam insulation, air space and nominal clay bricks that are tied to the structure through the use of traditional brick ties and reinforcement.

In some areas, blast-rated windows are sandwiched between the under-slab concrete beams and the CMU knee walls and are surrounded by nominal clay brick. These windows are attached to the under-slab beams and CMU walls through the use of steel embeds (see Figure #2).

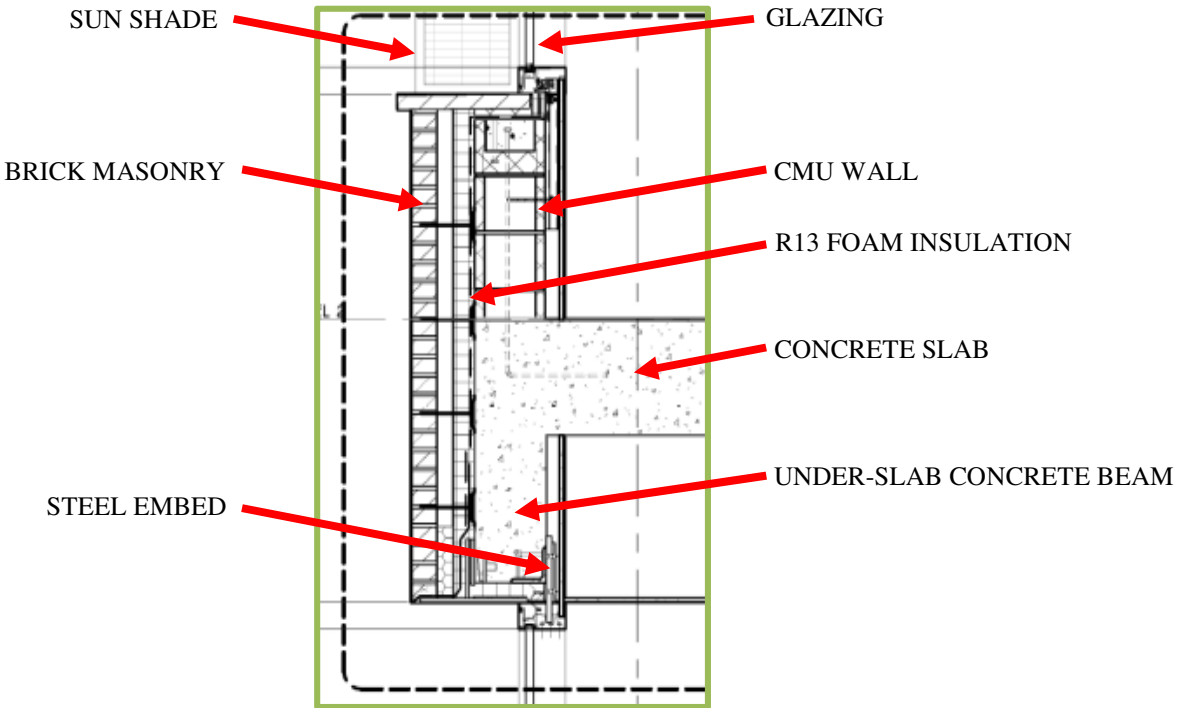


Figure #2: Façade Cross Section - Courtesy of Clark Construction

In other areas, the entire façade is comprised of curtain walls. The system is attached to embeds in the concrete slab by steel bolts. The window tops are affixed to blast absorbent brackets that are bolted to the under-slab beams. The windows themselves feature dual pane, heat treated glass, are double-sealed by polyisobutylene and silicone, and are broken up by aluminum mullions. In office areas, the exterior glazing is simply tinted. In mechanical spaces, where there are not air intake louvers, the glass is frosted and opaque to hide the equipment within but maintain the architectural aesthetics of the building. Solar shades are staggered across the entire curtain wall. Some shades are three stories in height, while others only extend one floor in height.

WATERPROOFING

Multiple waterproofing systems are used on the headquarters building. They are as follows:

Dampproofing
Continuous cold applied, emulsified-asphalt damp proofing is applied in two coats to the exterior face of concrete and masonry backup walls for exterior stone masonry retaining walls. Damp proofing must lap flashing, masonry reinforcement, veneer ties, structural members, concrete slabs and other penetrations by a minimum of ¼ inch.

Sheet Waterproofing
Vertical exposed, backfilled, and landscaping walls are waterproofed using bituminous sheet waterproofing, affixed to surfaces using cold applied, emulsified-asphalt waterproofing. Vertical installations utilize Preprufe 160R waterproofing membrane by W.R. Grace & Company.

MECHANICAL SYSTEM

Building One is serviced by eight McQuay Vision VAV air handling units, ranging in size from 40 to 50 horsepower and 26,650 CFM to 30,800 CFM, located in three mechanical rooms. Three air handling units are located in the north finger on lower level 8, two are located on lower level 8 in the middle finger (Figure #3), and the remaining three are located in the mechanical penthouse located in the south finger on lower level 6 (Figure #4). These air handling units feature water coils that are fed by chilled water and hot water pipelines from the Central Utility Plant. In order to achieve LEED points, the McQuay Vision air handling units include three energy recovery devices; heat wheels, fixed plate heat exchangers, and runaround coil loops. Heat wheels are fabricated from aluminum and synthetic fibers and provide a means through which the energy contained in the air returned to the air handling units can be captured and reintroduced to the fresh outside air intake in order to provide a level of initial heat content to this outside, unconditioned air. This greatly lowers the future heating requirements of this air that the air handling unit must provide in order to meet the desired supply conditions. Fixed plate heat exchangers consist of metal plates designed to transfer the heat contained within the hot water returned to the air handling units from the local VAV boxes to the fresh hot water delivered from the central utility plant. This additional heat recovery allows the system to recuperate the energy lost through the transmission of the incoming hot water from the central utility plant in order to maintain the desired delivery temperature of the water. Runaround coil loops add energy recovery capabilities using techniques very similar in nature to the fixed plate heat exchanger processes. The coil loops are filled with water, and are strategically placed within the exhaust stream of air that is transferred to the outdoors. These loops capture some of the heat contained within this air, heating the water, further allowing for the reheat of incoming hot water to its desired temperature.

Once conditioned, air is supplied to localized VAV's through medium and low pressure ductwork. In areas where additional heating or cooling is required, fan coil units are utilized. These units are fed by the aforementioned hot and cold water lines that are serviced from the boilers and chillers in the central utility plant. The heat recovery devices in the air handling units lend to increased efficiency of the fan coil units by limiting the degree to which the supply water needs to be heated by the boilers in the central utility plant.

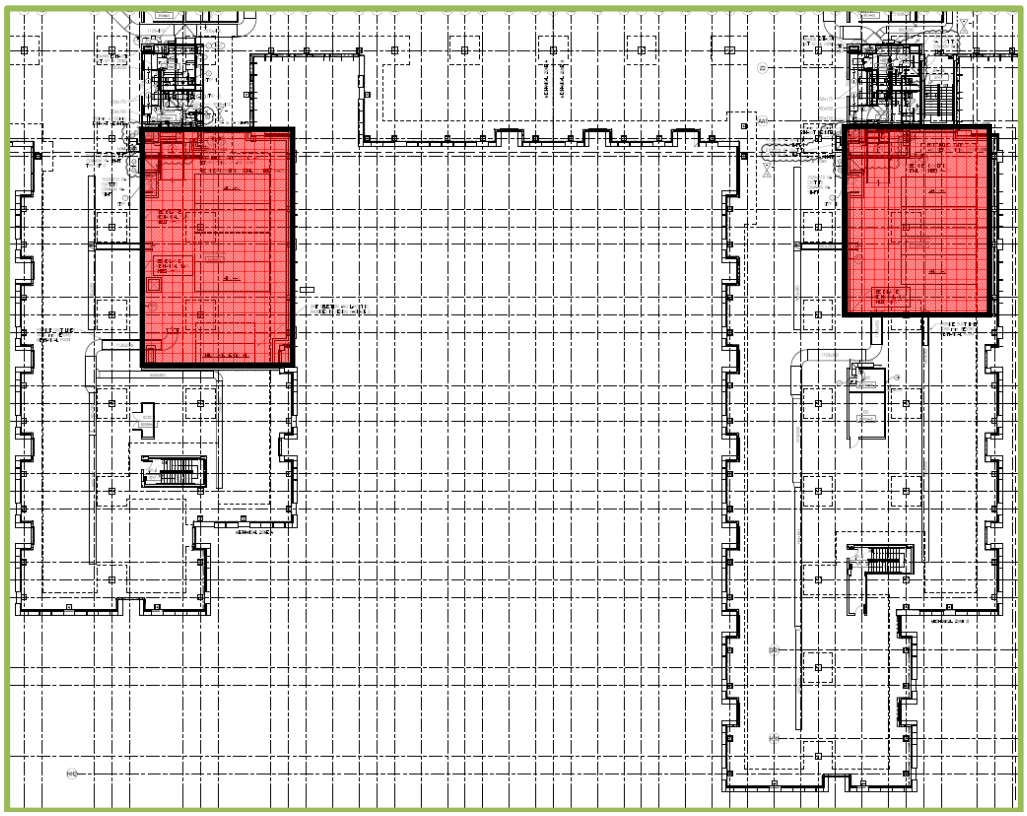


Figure #3: Lower Level 8 – Mechanical Room Locations – Courtesy of Clark Construction

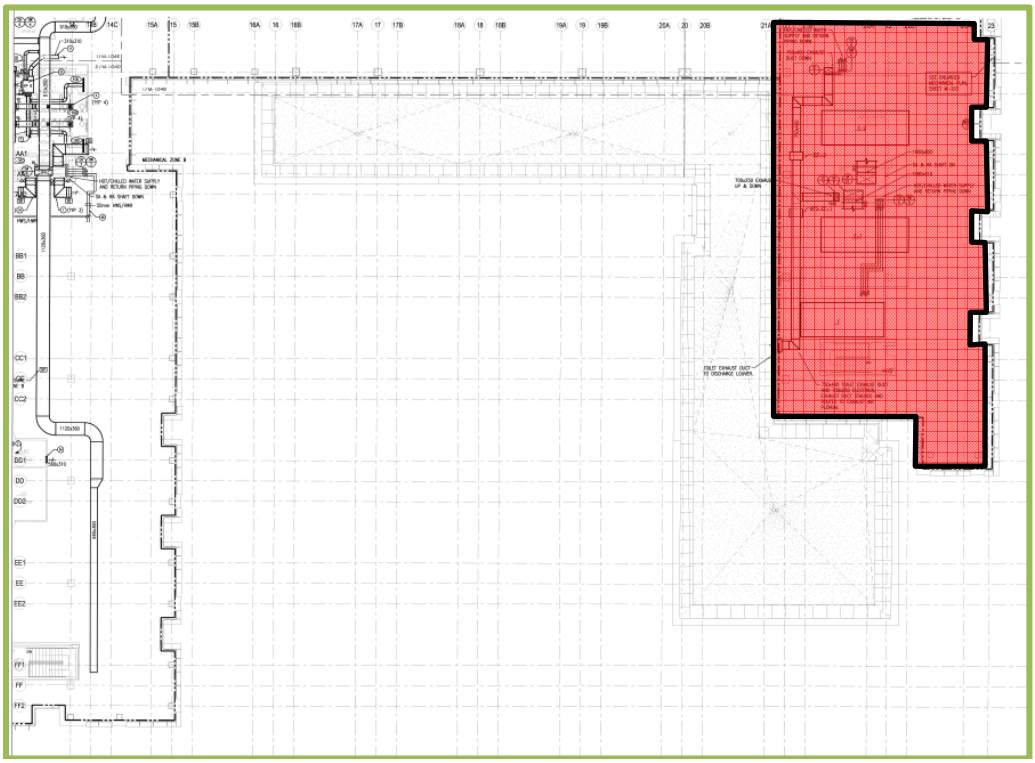


Figure #4: Lower Level 6 – Mechanical Penthouse– Courtesy of Clark Construction

THESIS TOPICS

INTRODUCTION

As previously stated, the following report proposes changes to the building's initial design aspects that are intended to improve drywall, metal stud and brick masonry production rates. Additionally, the possibilities of implementing in-field BIM model review technologies are explored to determine the feasibility of such an undertaking. Due to the overall success of the design-build delivery method approach on this project, additional research focused on pinpointing the characteristics of a successful design-build team was performed, to be used in the future selections of a design-build project team.

COLUMN RELOCATION

Introduction

The current structural design places the exterior concrete columns approximately 4" from the interior faces of the concrete masonry and curtain wall assemblies (see Figure #5). The proximity of the columns to the exterior walls results in numerous concerns pertaining to the work of the interior trades, who are forced to install their work within these confines. The productivity of drywall installation, taping and finishing are all affected by the positioning of the structural columns so near to the exterior façade.

Particularly, the drywall tradesmen are forced to spend additional time in these areas due to the decreased productivity rates of material installation. Not only is the productivity of these subcontractors affected, the current design demands the implementation of atypical tools that are capable of operating in close quarters.

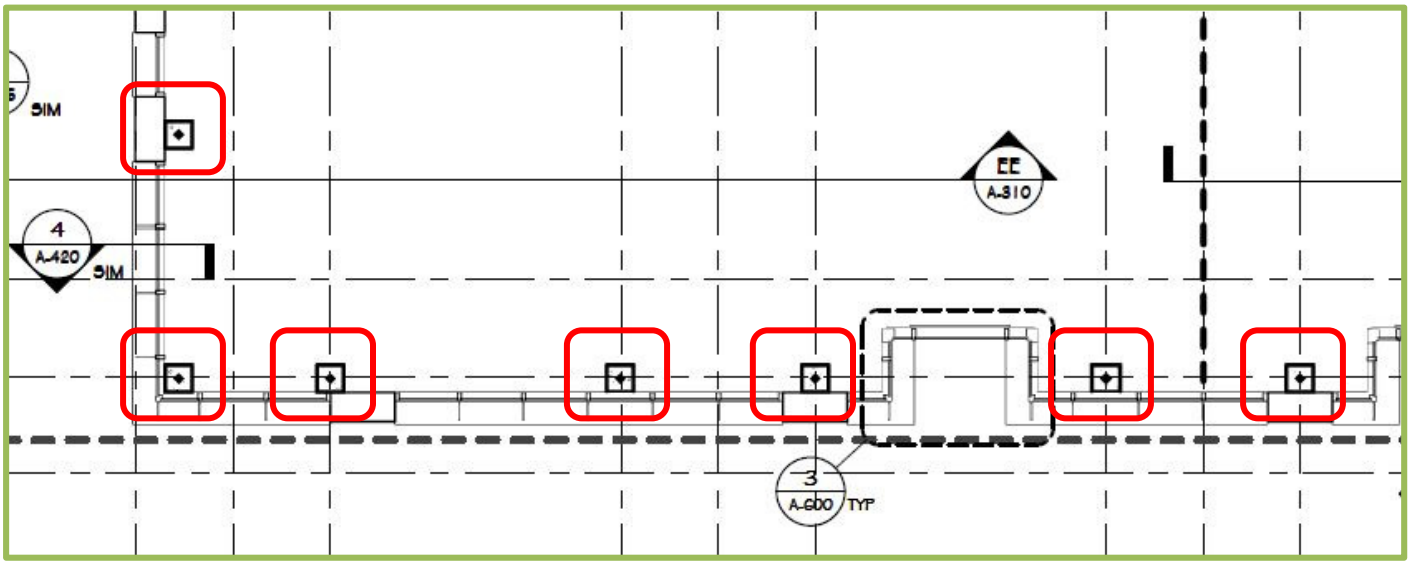


Figure #5 – Slab Edge Columns – Courtesy of Clark Construction

Potential Solutions

The close confines within which the drywall trade is to install their work is the undisputable cause of poor production rates experienced by the drywall contractor. In order to alleviate these effects, it is speculative that the concrete columns in these areas could be held back an additional foot from the interior surface of the façade. This would provide tradesmen additional space within which to perform their duties, greatly increasing the quality and productivity with which they install their work.

Research

Through the use of surveys (See Appendix B – Drywall Trade Surveys) developed for members of the drywall and metal stud trade communities, it was determined that the optimum distance between a surface requiring a drywall assembly and a nearby object ranges between 24" and 48". The existence of this spacing helps promote an adequate amount of access to physically install and finish the drywall assemblies. The distance between adjacent surfaces directly affects the tools required to attach the drywall sheets to the supportive metal studs behind. Installation in close-quartered areas is greatly inhibited by the availability of specialized tools for such an application. Special low profile and angled tools are necessary. Aside from the specialized tools, the installation of drywall in confined spaces requires the use of small, cut-up sections of drywall to fit into the tight spaces. Additionally, the ability to effectively tape and putty the drywall seams requires enough space to apply the fiberglass tape and joint compound in order to provide a quality finish and appearance. These factors lead to a significant reduction in the productivity levels of drywall installation. While there are many factors that affect the installation rate of drywall in even seemingly straightforward applications, the installation of drywall in tight spaces usually results in a productivity rate decrease of 75% in comparison to readily accessible, linear sections of drywall.[1, 2]

While the movement of columns seems drastic, the effects are less monumental than one would assume. Fortunately, the structure already features welded wire fabric reinforcement in addition to traditional round-stock rebar, reducing the effect of moments on the slab edge cantilever. The most drastically affected components of the building are the interior spaces and custom wood cabinetry. The columns within the interior spaces may encroach on the floor plans, however, many columns are located near partition walls (as seen in Figure #6 below) and could very well be built into the wall structure, minimizing their interruption on the spaces in the middle of the rooms.

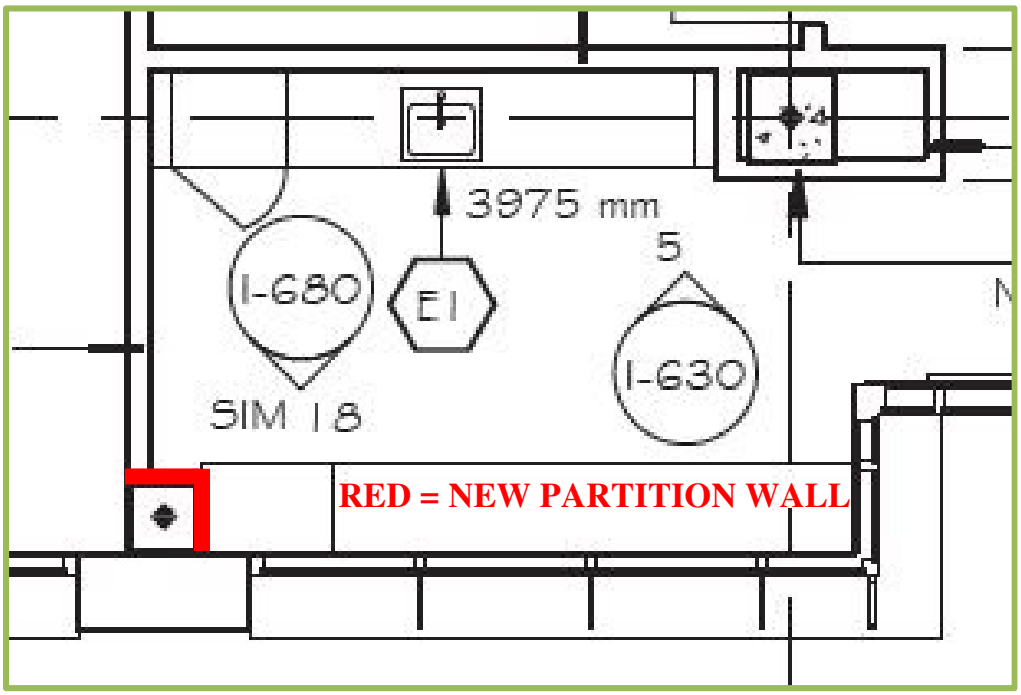


Figure #6 – Column Proximity to Partition Walls – Courtesy of Clark Construction

While not yet specified, detailed or approved, the custom wood cabinetry that is to be installed in the mixed office areas could be built in a manner that is integral to the columns located in the office areas. For example, the column in Figure #7, below, could form an alcove with the adjacent wall, providing an ideal location for file storage casework.

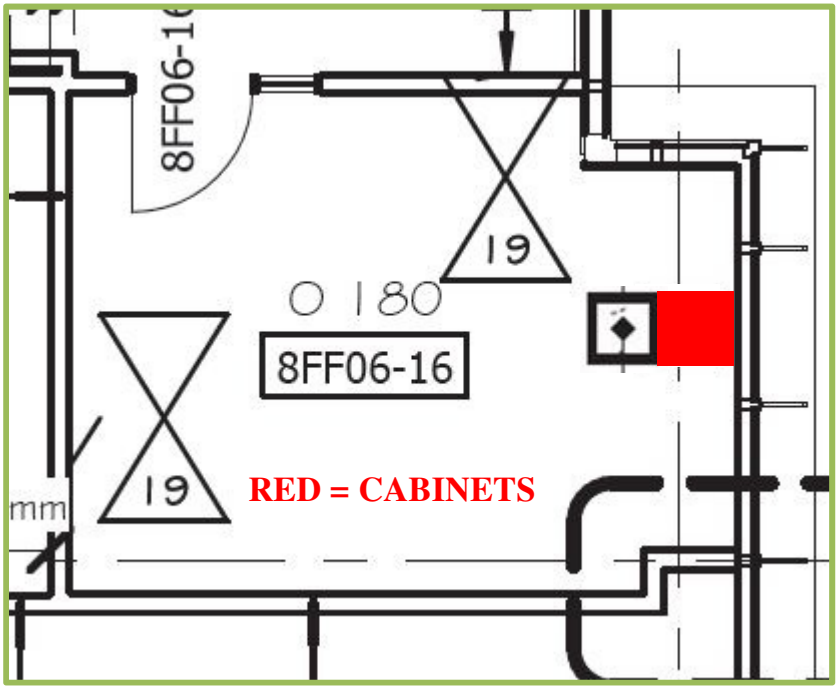


Figure #7 – Column/Casework Alignment – Courtesy of Clark Construction

Direct Effects of Column Relocation

By increasing the distance between the columns and the exterior wall, the issues associated with close-quartered installation of drywall can be reduced. Drywall tradesmen will no longer be required to install the drywall in these areas in small, maneuverable pieces, but instead will be able to lift full sized drywall sheets into the spaces, eliminating the extra cutting, taping, plastering and finishing activities otherwise necessary to the installation of the boards.

A reduction in the number of specialized tools required will allow contractors to efficiently move throughout the building without having to return to their tool storage areas to exchange their commonly used tools for ones designed for close-quartered areas every time they encounter a tightly designed space.

Most significantly, the drywall plastering and finishing process is expedited by providing a larger working area. Taping, plastering and sanding the increased number of board joints (due to the use of multiple smaller pieces) in the as-designed 4" space is very tedious. Workers are often unable to see their workspace from a direct angle, making it very difficult to determine if their finishing work is thorough, level, and neat. By providing a larger gap between the columns and the exterior walls, workers will be able to minimize the number of board joints, as well as position themselves in ways more conducive to faster, quality finishing operations.

Overall, the repositioning of the columns allows the drywall subcontractor to perform their work more quickly and efficiently by reducing or eliminating the complications of close-quartered work. While the columns were not repositioned to provide the full 48" of ideal working space that would provide productivity increases of 75%, the additional space is anticipated to decrease drywall durations at the columns by 50%. The increase in the quality of the finish work in these areas, while not directly measurable, is equally as important as the increase in drywall productivity achieved by relocating the columns. It is reasonable to assume that the visual aesthetics of the drywall corners and joints located on the columns and the adjacent exterior walls will improve due to the increased space in which the tradesman can perform his or her work.

Structural Analysis (Breadth Topic)

The direct design method was used to perform moment calculations at the column faces and mid-spans of the two-way concrete slab. This method allows for the simplified and rapid calculation of the required reinforcement sizes and spacing in order to resist the bending moments within the slab created by the dead and live loads.

Hand calculations can be found in Appendix C – Column Relocation Structural Calculations.

In order to determine the direct impacts of the alteration of the structural reinforcement, the perimeter of the building was calculated. This information was later used to calculate the increase in slab edge rebar and can be found in Table #1 below.

Slab Edge Takeoffs	
Location	**Slab Edge Perimeter (FT)**
B1 - LL9	Mat Slab - No Extra Rebar Required
B1 - LL8 - South Finger	335
B1 - LL8 - Middle Finger	502
B1 - LL8 - North Finger	392
B1 - LL8 - Child Care	272
B1 - LL8 - Spine	1000
B1 - LL7 - South Finger	335
B1 - LL7 - Middle Finger	436
B1 - LL7 - North Finger	375
B1 - LL7 - Spine	1000
B1 - LL6 - South Finger	276
B1 - LL6 - Middle Finger	436
B1 - LL6 - Spine	509
B1 - LL5 - South Finger	164
Total	**6032**

Table #1 – Slab Edge Takeoffs

The increased costs associated with the increased amount of structural reinforcement were calculated by comparing the as-designed rebar sizing and spacing with the amount of rebar required to support the concrete slabs in the new column arrangement scenario. The structural calculations produced three different rebar spacing criteria per slab direction. These criteria were averaged to obtain the values used to estimate the changes to the amount of rebar required in the slab edge to offset the effects of relocating the structural columns. The rebar size and spacing information was used to determine the amount of rebar in each 1'x1' section of slab edge perimeter. This information provides values that are easily comparable to the as-designed conditions, lending to an accurate estimate of the increased labor and material rates associated with the increase in rebar costs. The rebar sizing and spacing information, as well as averaging calculations, are shown in Tables #2 and #3, below.

Modified Rebar Sizing and Spacing						
Frame	**Location**	**Moment**	**Rebar Size & Spacing**	**Rebar Weight (Per LF)**	**Rebar Length (Per 1' Strip)**	**Rebar Weight Per 1' Strip (LBS)**
Frame B - Long Direction	Full Column Strip	+	#5's @ 4" O.C.	1.043	3	3.129
Frame B - Long Direction	Full Column Strip	-	# 5's @ 2" O.C.	1.043	6	6.258
Frame B - Long Direction	Middle Strip	+	#5's @ 6" O.C.	1.043	2	2.086
		Averages	**#5's @ 4" O.C.**	-	**3.00**	**3.129**

Table #2 – Rebar Sizing and Spacing – Long Direction

Modified Rebar Sizing and Spacing Average						
Frame	**Location**	**Moment**	**Rebar Size & Spacing**	**Rebar Weight (Per LF)**	**Rebar Length (Per 1' Strip)**	**Rebar Weight Per 1' Strip (LBS)**
Frame D - Short Direction	Full Column Strip	+	#5's @ 6" O.C.	1.043	2	2.086
Frame D - Short Direction	Full Column Strip	-	#5's @ 4" O.C.	1.043	3	3.129
Frame D - Short Direction	Middle Strip	+	#5's @ 13" O.C.	1.043	1	1.043
		Averages	**#5's @ 8" O.C.**	-	**2.00**	**2.086**

Table #3 – Rebar Sizing and Spacing – Short Direction

Once calculated, the above information was compared to the as-designed rebar layouts to determine the increase in the amount of rebar in the slab edges. This information is contained within Table #4 below.

Slab Edge Rebar Sizing and Spacing						
Design	**Edge LF**	**Rebar Size & Spacing**	**Rebar Weight (Per LF)**	**Rebar Length (Per 1' Strip)**	**Rebar Weight Per 1' Strip (LBS)**	**Total Rebar Weight (LBS)**
Original	6032	#5's @ 12" O.C. Both Ways	1.043	4	4.172	25165.50
Modified	6032	#5's @ 4" O.C. Long Way #5's @ 8" O.C. Short Ways	1.043	5	5.215	31456.88
					Differential	**6291.38**

Table #4– Rebar Sizing and Spacing Quantity Comparison

The aforementioned information was used to calculate the cost differentials between the original and altered designs. The budget analysis can be found in the "Budget Effects" section.

Schedule Effects

The effects on the project's schedule were determined by analyzing the effects on productivity stemming from the relocation of the slab edge columns. Figure #8, below, shows the justification of the assume area of influence affected by the proximity of the structural columns to the exterior walls. The 64 SF/Column figure was obtained by assuming that the productivity of drywall operations on the face of the column, as well as the first 3' of drywall along the exterior wall in either direction from the column, were affected by the proximity to one other. This 8 L.F. of influence was then multiplied by the distance from the finished floor to the acoustical ceiling tile system, which is 8' in 95% of the spaces.

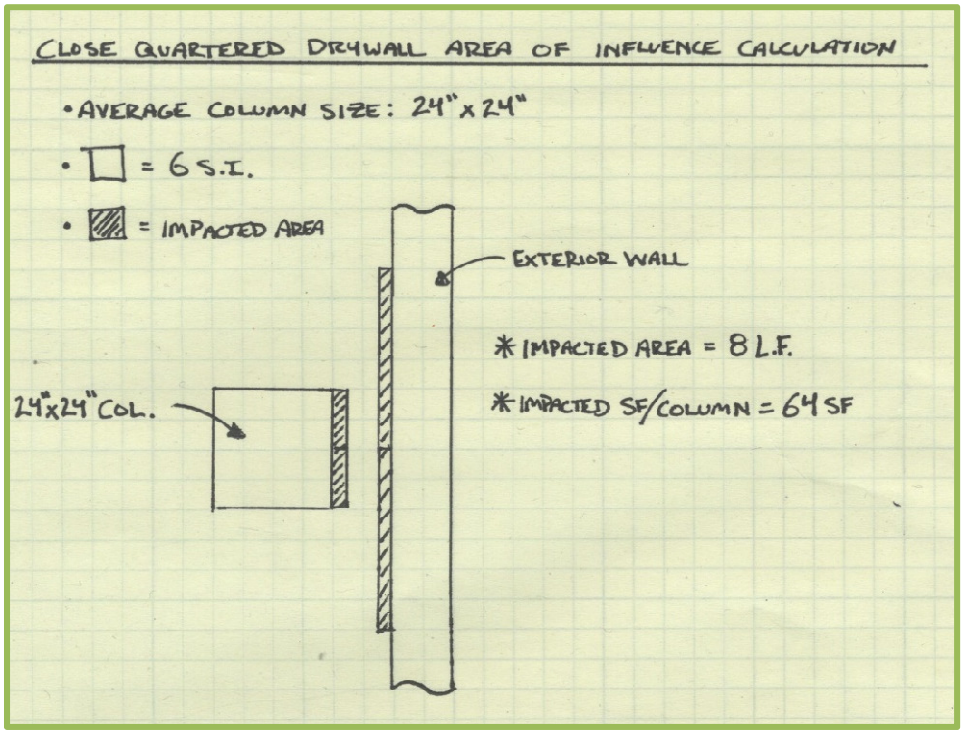


Figure #8 – Column/Wall Drywall Area of Influence Calculation

The total square footage of drywall in Building One was determined through a linear foot takeoff of the interior partition walls, which was then multiplied by the predominant height of interior partitions (8 feet). Additionally, the number of exterior columns was used to determine the percentage of drywall affected by the as-designed column-wall relationship. This percentage was then used to isolate the amount of time spent on areas affected by the columns from the schedule durations. As previously mentioned, a 50% increase in productivity effectively cuts these isolated durations in half, which equates to project schedule savings.

Tables #6 and #7, on the following two pages, show the take-offs, calculations, and final schedule reductions that could be expected if the exterior columns were repositioned as suggested.

Column Relocation Drywall Takeoffs and Productivity Analysis											
Location	Partition Drywall (SF)	# of Columns	Affected Drywall (SF Per Column)	Total Affected Drywall (SF)	% Affected	Inc. in Productivity of Affected Areas (%)	Original Dur. (Days)	Original Dur. (Hrs.)	Original Col. Dur. (Hrs.)	New Col. Dur. (Hrs.)	Updated Duration (Hrs.)	Updated Duration (Days)
B1 - LL9 - South Finger	5960	18	64	1152	0.19	50	10	80	15.46	7.73	72.27	9.03
B1 - LL9 - Middle Finger	9792	34	64	2176	0.22	50	15	120	26.67	13.33	106.67	13.33
B1 - LL9 - North Finger	9176	25	64	1600	0.17	50	15	120	20.92	10.46	109.54	13.69
B1 - LL9 - Childcare	5984	25	64	1600	0.27	50	10	80	21.39	10.70	69.30	8.66
B1 - LL9 - Spine	16272	58	64	3712	0.23	50	20	160	36.50	18.25	141.75	17.72
B1 - LL8 - South Finger	5728	18	64	1152	0.20	50	15	120	24.13	12.07	107.93	13.49
B1 - LL8 - Middle Finger	8688	34	64	2176	0.25	50	15	120	30.06	15.03	104.97	13.12
B1 - LL8 - North Finger	8360	25	64	1600	0.19	50	15	120	22.97	11.48	108.52	13.56
B1 - LL8 - Child Care	5120	16	64	1024	0.20	50	10	80	16.00	8.00	72.00	9.00
B1 - LL8 - Spine	16272	58	64	3712	0.23	50	20	160	36.50	18.25	141.75	17.72
B1 - LL7 - South Finger	9032	22	64	1408	0.16	50	15	120	18.71	9.35	110.65	13.83
B1 - LL7 - Middle Finger	6768	18	64	1152	0.17	50	12	96	16.34	8.17	87.83	10.98
B1 - LL7 - North Finger	5992	15	64	960	0.16	50	15	120	19.23	9.61	110.39	13.80
B1 - LL7 - Spine	16272	58	64	3712	0.23	50	20	160	36.50	18.25	141.75	17.72
B1 - LL6 - Middle Finger	7344	22	64	1408	0.19	50	12	96	18.41	9.20	86.80	10.85
B1 - LL6 - Spine	10112	28	64	1792	0.18	50	18	144	25.52	12.76	131.24	16.41
Totals	**146872**	**474**	**-**	**30336**	**-**	**-**	**237**	**1336**	**264**	**132**	**1204**	**213**

Note: Movement of Columns does not create benefits on LL6 and LL5 South fingers b/c of unfinished mechanical spaces.
Note: Average Column width = 2' - Area affected = 2' column side + 3' on adjacent wall on either side of the column (As Seen in Area of Influence Calculation)
Note: The column durations were decreased by a factor of 50%, a portion of the 75% reduction implied by industry professionals.

Table #6 – Column Relocation Drywall Takeoffs and Productivity Analysis (Also in Appendix A)

Column Relocation Productivity Analysis		
Item	**Units**	**Quantity**
Original Duration	Days	237
Updated Duration	Days	213
	Differential	**24**

Table #7 – Column Relocation Productivity Analysis

Aside from the central area of the structure, most areas of the building benefit equally from the drywall schedule reductions. Updates to the baseline project schedule (Appendix D – Interior Trade Schedules) evenly distributed portions of the 24 day schedule reduction to each construction zone. While the installation and finishing of drywall activities are not on the critical path of the interior trades schedules, the 24 day reduction in these activities may result in the availability of additional laborers, who can be reassigned to other areas and activities to facilitate an overall time reduction in the entire interior trade schedule.

Budget Effects

Together, the calculated amounts of additional structural reinforcement and the amount of time saved throughout the drywall installation process determine the amount of savings that could be achieved through the relocation of the structural columns on this project. Aside from drywall and rebar material and labor costs, the general conditions costs that could be saved were calculated using Table #8, below. By assuming that 5% of the drywall contractor's base bid was allotted for general conditions costs and taking into account that the contractor will be on site for approximately 3 years, the daily expenditures on general conditions items was calculated.

Drywall General Conditions Calculation				
Base Bid	**% G.C.**	**General Conditions**	**Contract Duration (Days)**	**G.C. (Per Day)**
$11,475,000.00	5	$573,750.00	780	$735.58
			Total	**$735.58**
Note: General Conditions assumed to be 5% of Drywall Contract Note: Drywall Contract Approximately (3 Years*52 Weeks*5 Days) = 780 Days Long				

Table #8 – Drywall General Conditions Calculation

The calculated quantities of additional rebar as well as the estimated reduction in the drywall schedule and general conditions savings were compiled in Table #9 below. The rebar material and labor costs were taken from the 2012 Version of R.S. Mean's Assemblies Cost Data and have been adjusted to the project's location. The drywall labor rates were obtained from the Davis Bacon Act Prevailing Wages handbook, which was utilized for all labor rates on the Office Building Project.

Column Relocation Cost Reduction Analysis				
Item	**Units**	**Quantity**	**Unit Cost**	**Total Cost**
Drywall Labor	Hours	-192	$26.11	($5,013.12)
Rebar Material	Pounds	6292	$0.69	$4,316.82
Rebar Labor	Pounds	6292	$0.47	$2,977.88
General Conditions	Days	-24	$735.58	($17,653.85)
			Total	**($15,372.27)**
Note: Drywall Labor Rate Taken From Davis Bacon Act Prevailing Wages Note: All Unit Costs Were Obtained From R.S. Means Assemblies 2012 and have been adjusted for the project's location.				

Table #9 – Column Relocation Cost Reduction Analysis

Final Recommendation

The cost reduction analysis results show that a $15,372.27 savings can be expected by relocating the exterior structural columns. As expected, most of these savings are the result of the reduction in general conditions due to the 24 day schedule reduction. While budget savings are generally desirable, the scale of the savings achieved by relocating the structural columns is undoubtedly lackluster. $15,372 amounts to a less than 0.1% budget saving on the $11,574,000 drywall contract. Aside from the schedule savings, this alteration to the original design will also lead to increased quality regarding the installation of drywall on and in the vicinity of the columns. If the quality of the rarely viewed drywall between the exterior columns and interior face of the façade are a major concern of the owner, the column relocation may be desirable. However, the intrusion of the columns on the interior spaces, along with the increased labor associated with the rebar placement (which may have been underestimated if the slab edge rebar extends any substantial distance beyond the area between the slab edge and the exterior columns) is most likely less desirable than high-quality finishes in areas that are seldom seen. For this reason, and the scale of the savings obtained by altering the base-design, the relocation of the exterior columns would most likely not be a commonly utilized or preferred design option.

FAÇADE SIMPLIFICATION

Introduction

During the initial phases of masonry façade construction, it was thought that the brick masonry contractor was not effectively maintaining the project schedule demands for façade brickwork. It was later determined that the losses in productivity could be attributed to the multiple recesses in the exterior façade, and the custom brickwork associated with wrapping the brickwork around these recesses (see Figure #9).

Figure #9 – Recessed Façade Features – Courtesy Clark Construction

Potential Solutions

If the building were designed with a linear façade, the pitfalls associated with tedious brickwork could have been avoided. At this point in time, the project team is still struggling with finding opportunities to accelerate the Building One brickwork schedule in order to maintain the milestone goals for the rest of the campus.

The recessions in the current façade design demand extensive custom cutting of bricks for placement at the complex corners. This process elongates the time necessary for brick placement by reducing the ability to keep a constant brick placement pace across the entire façade.

The simplification of the façade on areas of the building that feature complex returns and setbacks will increase the productivity of the brick laying tradesmen. The custom cutting of small brick fragments in order to maintain the interlocking stretcher pattern requires the dedication of a bricklayer solely to brick cutting operations. A simplified design would eliminate this requirement, allowing the brick crew to focus on their production rate rather than the meticulous craftsmanship associated with an undulating façade layout.

Research

Surveys (See Appendix E – Masonry Trade Surveys) were distributed to project managers, estimators and foremen in the masonry industry in order to determine the effects of masonry corner construction on the overall productivity rates of brick masonry installation. Also included in these surveys were questions aimed at determine the effects of scaffolding outriggers, which are necessary to access the façade setbacks, on the overall safety conditions of the project.

From these surveys, it was determined that while an experienced and skilled mason can install a brick corner as quickly as a straight wall, most companies experience a reduction in productivity ranging from 50-250 bricks, or 12-49 square feet (See Table #10). Typically, a mason can install 98 square feet of 2-1/4" Norman bricks per day. With an average productivity reduction of 31% for corner construction, this same mason can lay an average of 66 square feet of 2-1/4" Norman corner bricks per day.

Brick Size	Units/SF	Linear Construction		Corner Construction		Avg. % Reduction
		# Units/Mason/Day	SF/Mason/Day	# Units/Mason/Day	SF/Mason/Day	
Modular	6.75	550	81	275-500	41-74	29
Oversize	5.8	525	91	262-475	45-82	30
Closure	4.5	460	102	230-410	51-91	30
2-1/4" Norman	4.4	430	98	215-380	49-86	31
Utility	3	360	120	180-310	60-103	32
2-1/4" Emperor	3.375	395	117	198-345	59-102	31
4" Emporer	2.25	330	147	165-280	73-124	33
					Avg.	31

Table #10 – Average Effects of Brick Corner Construction on Production Rates[12]

The use of masonry corner poles can aid in the brick corner erection process by providing a guidance system at the façade corners to lay out the location of bricks around a masonry corner. [11] Poles are erected at the corners of the façade and mason's lines are strung between these guides. The masonry can then adjust the string lines so that they are a set distance from the unfinished structure (usually the width of the brick + 1/32"). Erection of the brick corner is now expedited due to the ability of the mason to set the outside face of the bricks 1/32" from the mason's lines. While this method greatly expedites the process of erecting masonry corners, the architectural details and scale of the project in review greatly limit the ability to utilize this system. The height of the building (3+ stories) would demand the use of temporary platforms along the face of the building upon which the masonry corner poles could be erected. Additionally, the brickwork around the recessed corners is located above and below strip windows, and extends for approximately 4 feet before being interrupted by the windows, and the brickwork that creates the vertical divisions between the windows runs approximately 5 vertical feet before being interrupted by the brickwork above and below the windows (see Figure #10). The masonry corner poles would not only need to extend across the strip window openings, but also feature a second mason's line at the top to which the next section of brickwork could be aligned to. The use of masonry poles to align the brickwork around the vertical divisions would be nearly impossible due to the relatively tight constraints and unreliable (when concerned with referencing a plumb surface) coursework on which it would have to rest.[11]

Figure #10 – Brick Corner Extents – Courtesy of Clark Construction

Due to the non-repetitive nature of the façade features, the set-up, take-down, and relocation of mason's plumb lines would greatly affect the productivity of the masonry erection. For this reason, the masonry corners on this project were aligned using traditional hand leveling methods, which correlates with the 50% decreases in productivity rates that were reported in the masonry surveys.

In addition to the productivity losses associated with erecting brick corners, the requirements for complex scaffold outriggers that allow masons to access the façade recesses are substantial. Due to the schedule requirements on this project, three Fraco lifts were set up on each major façade section (as seen above in Figure #10). This prevented the ability to build one set of recess outriggers and simply move one Fraco lift along the façade. Three individual outrigger platforms were required, which take additional labor and time to complete. Fortunately, the recesses on other facades are identical, allowing these outriggers to be reused on other areas of the project. However, the durability of wood is unpredictable, especially when subjected to dropped bricks and a buildup of mortar residue, and these outriggers seldom lasted beyond two

applications. With additional costs in the $75.00 per month range, these outriggers result in more expensive general conditions costs for the masonry contractor. These costs are relatively negligible on large projects, however, the use of outriggers further slows productivity rates due to worker wariness. Masons working from scaffold outriggers tend to be more careful and deliberate in their movements, reducing their ability to quickly and efficiently perform their tasks. The precise effect of laborer wariness is not traceable and will not be factored into the productivity rate analyses; however, it remains an additional motivating factor behind the reduction of the number and size of scaffolding outriggers.[3, 7, 10]

Not only are scaffolding outriggers associated with additional costs and productivity losses, but also affect the overall safety of the masonry operations. Outriggers provide additional areas from which materials and tools can fall from, exposing those below to additional dangers. While it is widely accepted that no one should be positioned below active scaffolding, there are numerous areas on this particular building where main access points were located in the vicinity of scaffold systems (See Figure #11).

Figure #11 – Access Points Near Scaffolding – Courtesy of Clark Construction

While the access point was located underneath a scaffold without outrigger extensions, and most traffic in and out of the building was limited during times of brick erection, this situation only solidifies the safety concerns surrounding conventional scaffold work. Throughout the project's duration, numerous individuals were reprimanded for working on scaffolding without the proper safety harnesses. While the onsite safety program was extremely vigilant and successful, the presence of these safety violations and the possibility of workers walking beneath scaffolding during times of masonry erection only substantiate the ever present possibility of an accident when dealing with scaffolding work. Outriggers compound these dangers, and can be avoided through smart designs that minimize the extensive need for these additional working platforms.[7]

Outriggers are usually constructed in a manner that allows their extents to be as close to the building's surface as possible. On this project, the special constraints associated with the façade setbacks required that the outriggers be built in a way that allows the Fraco lifts to flex and torque freely without causing the outriggers to come in contact with the building façade. The polled industry professionals stressed the need for outriggers to be constructed as close to the building face as possible in order to reduce safety risks, a common requirement that is unattainable given the unique characteristics of this building.

From a quality standpoint, the polled professionals overwhelming stated that the presence of a masonry corner does not affect the quality of the façade. If anything, the extra care taken to ensure that the brick coursings are level and the corners are plumb will increase the quality of the brickwork. However, there is an associated requirement for additional waterproofing details. While water tightness is not a focus of this research topic, the additional care required during the design and installation of the waterproofing in these areas is present nonetheless. Minimizing the number of corner details and installations can only improve the quality of the building's waterproofing system and should be considered by the design team during the façade design process.

Proposed Changes

To effectively analyze the effect of brick corners on the productivity of the masonry contractors, the redesign of Building One removes all of the small recesses along the length of the building's façade. The goal of this simplification is to alleviate all of the aforementioned productivity and safety concerns connected with the installation procedures associated with façade recesses. The recesses will be removed, leaving a flat building surface that promotes linear brick construction, which in turn allows masonry contractors to install their work at the maximum rates. The strip windows in these sections will be replaced with solid brick in these areas in order to mimic the architectural features and sightline effects of the original recesses, as well as eliminate the increase in solar gains that would have resulted from placing windows on the flat surface, that would not have been shaded throughout the day.

Relatedly, the removal of these recesses will affect the manner in which sunlight and ambient temperatures permeate the building, which in turn will alter the amount of thermal loading on the spaces. The replacement of the building's recesses with solid brick alternatives will decrease the amount of solar gain, as well as increase the thermal resistance of the façade in these areas. Together, these factors will lead to a decrease in the summertime cooling and wintertime heating loads that the building is subjected to. This will

later be explored and tested in order to understand the full ramifications for altering the glazing and masonry configurations.

Productivity Evaluation of Façade Simplification

Initially, research into the production rates of linear and corner masonry construction was used to determine the average increase in productivity between linear and corner construction. Table #11 below shows this data and associated calculations.[12]

Brick Size	Units/SF	Linear Construction		Corner Construction		Avg. % Reduction
		# Units/Mason/Day	SF/Mason/Day	# Units/Mason/Day	SF/Mason/Day	
Modular	6.75	550	81	275-500	41-74	29
Oversize	5.8	525	91	262-475	45-82	30
Closure	4.5	460	102	230-410	51-91	30
2-1/4" Norman	4.4	430	98	215-380	49-86	31
Utility	3	360	120	180-310	60-103	32
2-1/4" Emperor	3.375	395	117	198-345	59-102	31
4" Emporer	2.25	330	147	165-280	73-124	33
					Avg.	31

Table #11 – Average Effects of Brick Corner Construction on Production Rates[12]

A take-off of the façade area of Building One was then performed. Approximately 33% of the façade is comprised of glass, and the remaining 66% of brick. These ratios were used to calculate the total amount of brickwork on the originally designed façade. The amount of brick and glass included in the as-designed façade recesses, as well as the replacement brick sections, were calculated using the quantities outlined in Figure #12 above, and the number of recesses per building area. Table #12, on the following page, displays the quantities of brick and glass for the existing and replacement recession areas.

Brick/Glass Façade Takeoff							
Location	**Total Façade Area (SF)**	**Total Brick Area (SF)**	**Total Glass Façade (SF)**	**# of Recesses**	**Recessed Brick (SF)**	**Recessed Glass (SF)**	**Replacement Brick (SF)**
B1 - LL9 - South Finger	3350	2244.50	1105.50	4	666.80	213.32	480
B1 - LL9 - Middle Finger	5020	3363.40	1656.60	11	1833.70	586.63	1320
B1 - LL9 - North Finger	3920	2626.40	1293.60	8	1333.60	426.64	960
B1 - LL9 - Child Care	2720	1822.40	897.60	4	666.80	213.32	480
B1 - LL9 - Spine	10000	6700.00	3300.00	6	1000.20	319.98	720
B1 - LL8 - South Finger	3350	2244.50	1105.50	5	833.50	266.65	600
B1 - LL8 - Middle Finger	5020	3363.40	1656.60	11	1833.70	586.63	1320
B1 - LL8 - North Finger	3920	2626.40	1293.60	8	1333.60	426.64	960
B1 - LL8 - Child Care	2720	1822.40	897.60	4	666.80	213.32	480
B1 - LL8 - Spine	10000	6700.00	3300.00	6	1000.20	319.98	720
B1 - LL7 - South Finger	3350	2244.50	1105.50	8	1333.60	426.64	960
B1 - LL7 - Middle Finger	4360	2921.20	1438.80	3	500.10	159.99	360
B1 - LL7 - North Finger	3750	2512.50	1237.50	2	333.40	106.66	240
B1 - LL7 - Spine	10000	6700.00	3300.00	3	500.10	159.99	360
B1 - LL6 - South Finger	2760	1849.20	910.80	3	500.10	159.99	360
B1 - LL6 - Middle Finger	4360	2921.20	1438.80	4	666.80	213.32	480
B1 - LL6 - Spine	5090	3410.30	1679.70	0	0.00	0	0
B1 - LL5 - South Finger	1640	1098.80	541.20	0	0.00	0	0
Total	**60320**	**40414**	**19906**	**57**	**9502**	**3040**	**6840**
Note: Glass Quantities Obtained By Applying 33% Factor to Total Façade Area (Typical Glass-Brick Ratio for Entire Building)							

Table #12 – Brick/Glass Façade Takeoff (Also in Appendix A)

Schedule Evaluation

In order to determine the effect of removing the façade recesses, the quantities of glazing and brick on the as-designed recessions was calculated and compared to the amount of brick on the replacement masonry sections. Figure #12, below, shows the hand take-offs used to calculate the net change in glazing and brickwork due to the removal of the façade recessions.

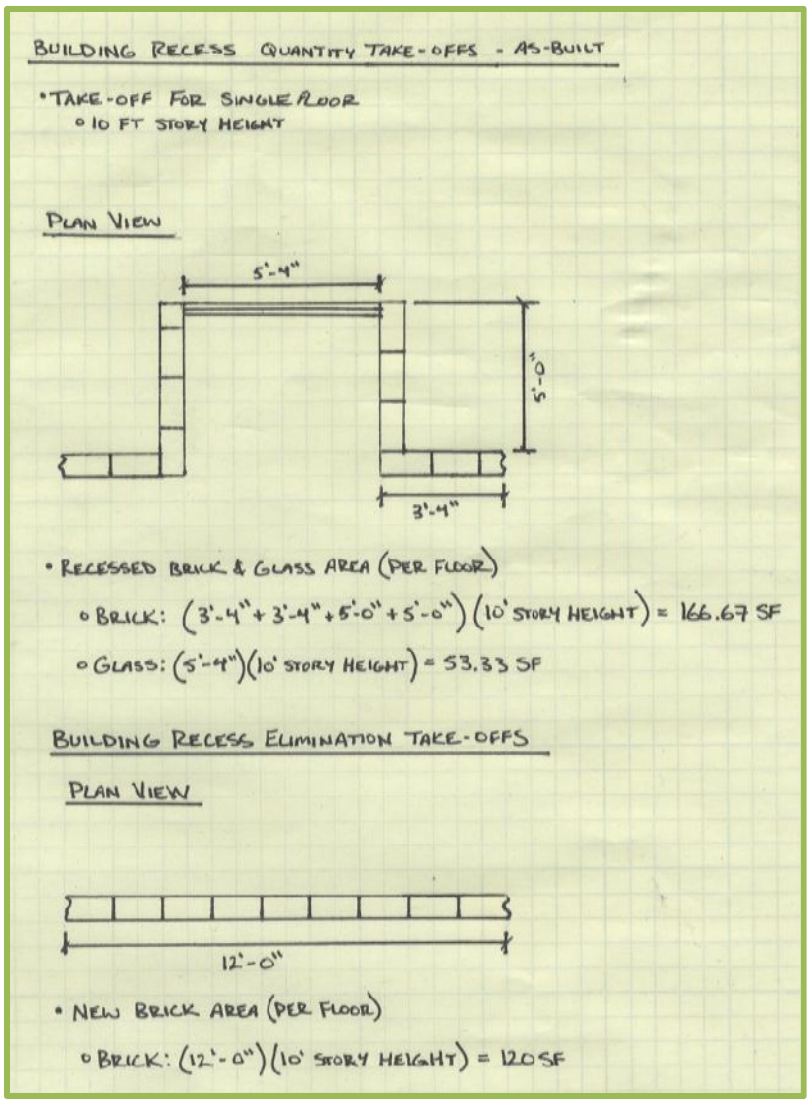


Figure #12 – Building Recess Quantity Take-Offs

In order to calculate the schedule reduction possibilities resulting from the removal of the building's façade recession removals, the previously computed brick quantities were used to calculate the amount of brick façade that is affected by the building's recesses. The percentage of linear and recessed brick was used to calculate the portion of the façade schedule dedicated to the creation of each type of masonry construction. Table #13, below, shows the calculation of the divination of the linear and recessed brick schedule durations based upon the percentage of the façade that falls into each of these categories.

As Designed Façade Productivity Analysis					
Item	**Units**	**Quantity (SF)**	**Fraction of Brick Façade**	**Total Duration (Days)**	**Individual Duration**
Linear Brick Façade (As Designed)	SF	40414	0.81	140	113.35
Recessed Brick Façade (As Designed)	SF	9502	0.19		26.65
	Totals	**49916**	**1**	**140**	**140**

Table #13 – As Designed Façade Productivity Analysis

The as-built recessed brick façade quantity and duration was then compared to the replacement quantity to determine the potential reduction in the masonry schedule that can be achieved by implementing the proposed changes. Table #14, below, documents this comparison.

Altered Facade Productivity Analysis						
Item	**Units**	**Quantity (SF)**	**Original Duration (Days)**	**% of Original Design**	**Productivity Factor**	**New Duration (Days)**
Recessed Brick Façade (As Designed)	SF	9502	27	100	1	27
Replacement Linear Brick Façade	SF	6840	27	72	1.31	15
					Differential	**12**

Table #14 – Altered Façade Productivity Analysis

Aside from a reduction of quantity and increased productivity, the general conditions costs that could be saved were calculated using Table #15, below. By assuming that 5% of the masonry contractor's base bid was allotted for general conditions costs and taking into account that the contractor will be on site for approximately 2.5 years, the daily expenditures on general conditions items was calculated.

Masonry General Conditions Calculation				
Base Bid	**% G.C.**	**General Conditions**	**Contract Duration (Days)**	**G.C. (Per Day)**
$4,541,000.00	5	$227,050.00	650	$349.31
			Total	**$349.31**
Note: General Conditions assumed to be 5% of Drywall Contract Note: Drywall Contract Approximately (2.5 Years*52 Weeks*5 Days) = 650 Days Long				

Table #15 – Masonry General Conditions Calculation

The savings resulting from the reduction of window and brick quantities, as well as the general condition savings resulting from schedule reductions are tabulated in Table #16 below.

Façade Alteration Cost Reduction Analysis							
Item	**Units**	**Quantity**	**Material Unit Cost**	**Labor Unit Cost**	**Total Material Cost**	**Total Labor Cost**	**Total Cost**
Window Reduction (Inside Recess)	SF	3040	$17.31	$25.98	($52,609.02)	($78,991.36)	($131,600.38)
Brick Reduction (Inside Recess)	SF	9502	$4.93	$12.99	($46,801.53)	($123,449.98)	($170,251.51)
Brick Addition (Recess Replacement)	SF	6840	$4.93	$12.99	$33,690.01	$88,865.28	$122,555.29
General Conditions	Days	12	-	$349.31	-	($4,191.72)	($4,191.72)
				Totals	**($65,720.55)**	**($113,576.06)**	**($183,488.33)**
Note: All Unit Costs Were Obtained From R.S. Means Assemblies 2012 and have been adjusted for the project's location.							

Table #16 – Façade Alteration Cost Reduction Analysis

The 12 days of schedule savings were evenly distributed across the façade areas with recessions. While some of these areas have more recesses than others, and would theoretically take varying times to complete, the baseline schedule featured time distributions indicative solely of brick square footages. Therefore, an even distribution was followed in the creation of the updated schedule, allowing for adjustments to be made by the general contractor in the field, as needed. The installation of brickwork on the exterior façade is on the critical path of the façade schedules, meaning that the 12 day reduction in these durations will be fully realized by completing the entire façade 12 days ahead of schedule. The waterproofing and masonry contractors can then redistribute their laborers to the remaining structures on the site, expediting the final completion date of their contracts. The baseline and updated schedules can be found in Appendix G – Façade Schedules.

Mechanical Analysis

In order to determine the heating and cooling load reductions created by the removal of 3040 S.F. of glass, a Trane Trace analysis was performed on the glass and masonry wall assemblies utilized on the Office Building project.

To perform this analysis, two 10 ft^3 rooms were created. One room was comprised entirely of brick walls, while the other completely of glass façade material. The U-Values for these systems were calculated based upon the structural make-up and project specifications of the two construction types. Table #17, below, shows the manner in which the U-Values were determined.

Façade U-Value Calculations	
Item	**R - Value**
Brick/CMU - Cold Applied Waterproofing	2
Brick/CMU - 8" Backup Blocking - Grouted Cells	3
Brick/CMU - Nominal Brick Facing	0.45
Brick/CMU - 2" Insulation of Rigid Foam	13
Total U-Value	**0.054**
Insulating Glass - Double Seals - Low-E Viracon Glazing	34.48
Total U-Value	**0.29**

Table #17 – Façade U-Value Calculations

Note: The U-value of the glazing assemblies does not include the potential of thermal bridging through the aluminum mullions on the assemblies. The thermal bridging effect of these mullions will further increase the thermal conductivity of the glass façade.

The calculated U-Values were entered into a Trane Trace analysis for two different room types, one comprised entirely of brick walls, the other of glass façade. The slab and roof types were set at 8" of LW concrete to mimic the fact that the building's spaces are sandwiched between two 8" concrete decks. The room parameters are shown below in Figures #13 and #14.

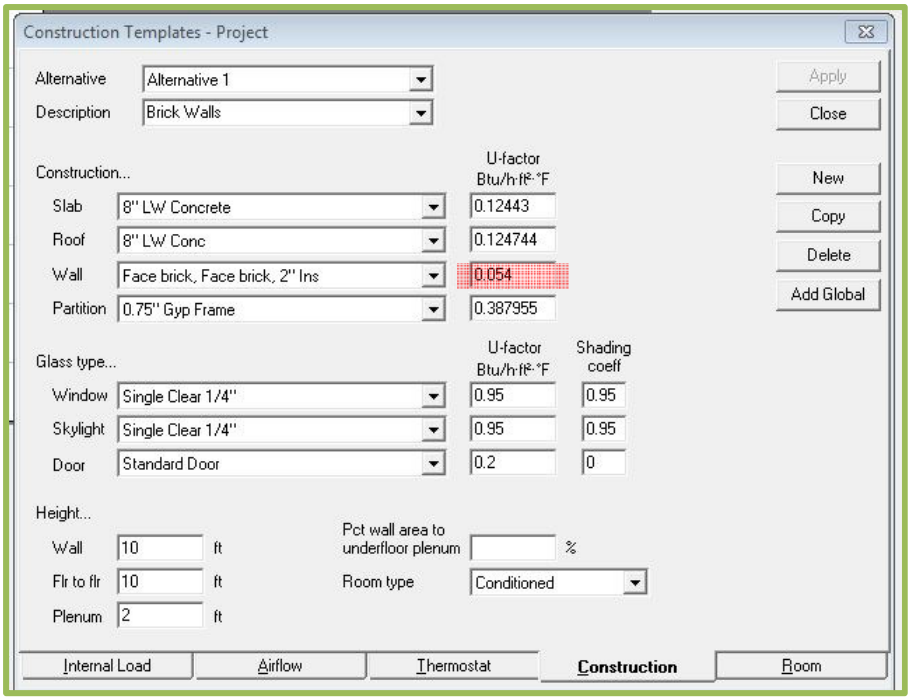


Figure #13 – Brick Façade Construction Parameters

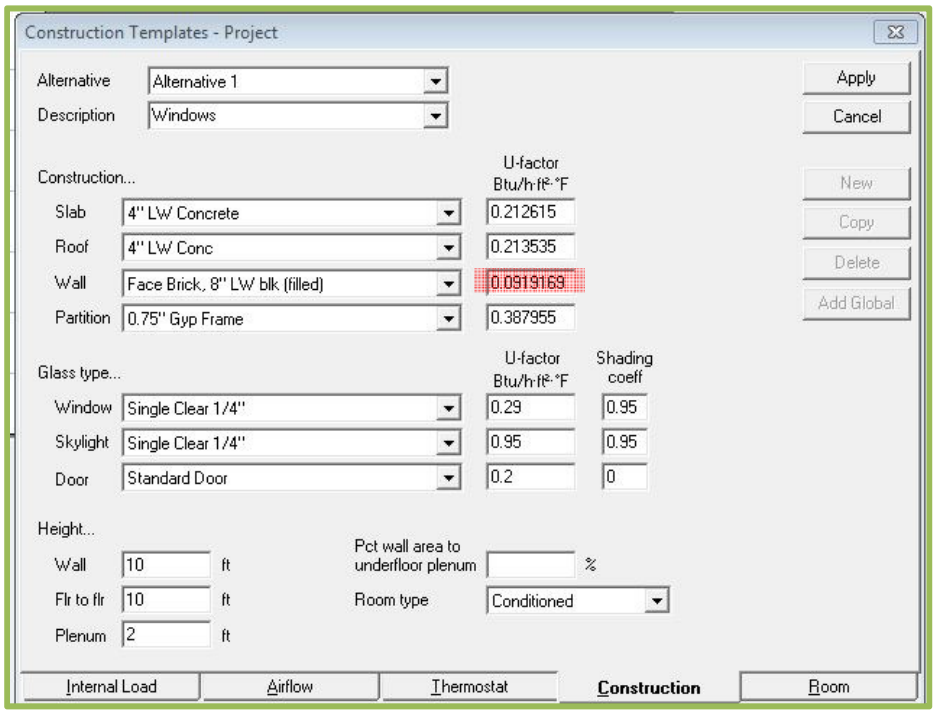


Figure #14 – Glass Façade Construction Parameters

The room dimensional parameters, as well as their orientation to project North, and the percentages of glass are shown below in Figures #15 and #16.

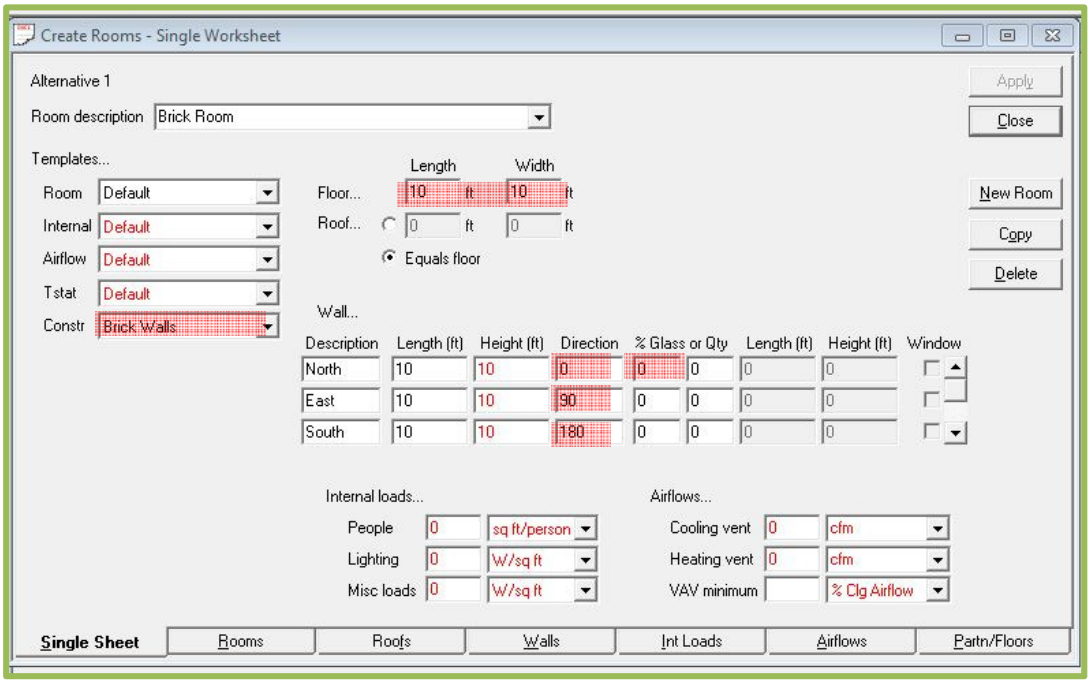


Figure #15 – Brick Façade Room Parameters

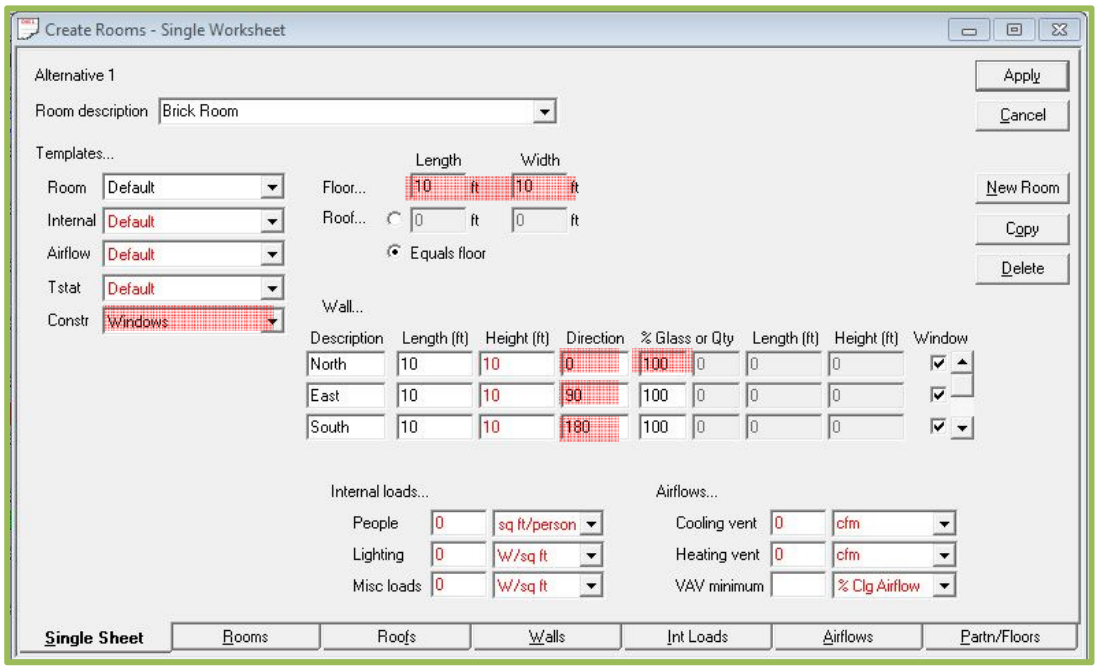


Figure #16 – Glass Façade Room Parameters

At this point, an analysis was run in order to determine the difference in the thermal conductivity of the brick and glazed facades.

The full mechanical reports can be found in Appendix F – Trane Trace Mechanical Analysis.

The most important information gained from the Trane Trace Analysis is that of the Net BTU/hr conductivity of the different systems. This information, when combined with the net changes in brick and window quantities per the suggested façade changes, can be used to determine the net reduction in the thermal load on the building. This reduction, due to the removal of glazing, leads to a reduction in the annual gas utility bills. Table #18, below, shows the calculated energy savings stemming from the reduction in the amount of glazing on the building's façade.

Thermal Load Reductions and Energy Savings												
Item	**Test Area (SF)**	**Annual Load Gain (BTU/Hr)**	**Load Gain Per SF (BTU/Hr)**	**Design Alteration (SF)**	**Annual Load Reduction (BTU/hr)**	**Peak Operation Hours**	**Annual Load Reduction (BTU)**	**Gas Conversion (BTU/Therm)**	**Gas Reduction (Therm)**	**Cost Conversion ($/Therm)**	**Heat Conversion Efficiency (%)**	**Cost Savings**
Brick Façade	400	32037	80.0925	-3040	-243481.2	1440	-350,612,928	100,000	-3506.12928	$0.50	85	-$2,062.43
Glass Façade	400	986	2	-2662	-6561.83	1440	-9,449,035	100,000	-94	$0.50	85	-$55.58
				Totals	**-250043.03**	**-**	**-360,061,963**	**-**	**-3601**	**-**		-$2,118.01
Note: Peak Operation Duration - June Through September, 12 Hours Per Day = 1440 Peak Hours Note: Gas Conversions, Costs and Efficiencies are for Natural Gas, the operating fuel of the building's central utility plant												

Table #18 – Thermal Load Reductions and Energy Savings

In order to justify the architectural changes to the building, the owner will be most concerned with the energy bill savings achieved by reducing the thermal loads that the building's system is subjected to.

According to the table above, the reduction in glazing and brick façade achieved by removing the building's façade recessions equates to annual savings in excess of $2,000. While this does not seem substantial, the cost savings will grow if the same façade simplification techniques are used on the remainder of the tier-structure. Additionally, one must keep in mind the escalating price of fossil fuels, which may skyrocket in the next decade, making the annual load reduction achievements of the proposed façade changes far more substantial.

Final Recommendation and Justifications

Unlike the column relocation proposal, the removal of the façade recessions results in a sizeable amount of project cost savings. The $183,488.33 savings equates to approximately 4% of the masonry contract. Additionally, the owner can expect to benefit from the reduction of façade glazing by reducing their annual energy consumption by approximately 3601 therms of natural gas, or $2,118.01. While the architectural ramifications include the removal of aesthetically pleasing façade recessions that help break up the horizontal sight lines of the building, the replacement brick sections effectively meet the architect's sight line divination goals. The only substantial negative result is that of daylighting capabilities. The reduction in the amount of façade glazing will reduce the amount of daylight that reaches the interior spaces of the building.

Overall, the removal of the façade recessions positively affects the project budget, schedule and the owner's utility bills, while minimally affecting the architectural features of the project, and has a strong potential of being something that the owner would be interested in pursuing.

BIM IN THE FIELD

Background

Due to owner requirements, the entire project was modeled by the design, engineering and mechanical subcontractor teams. These models were used to detect clashes between the architectural features, structural systems and mechanical equipment. Unfortunately, these models were highly underutilized in the field, leaving contractors to obtain information in a roundabout manner. If an in-field conflict was detected, contractor foremen were forced to first notify the project team, who would then review congested 2D coordination drawings in an attempt to discover the cause of the conflict. Occasionally, the required information could not be determined from these overcrowded drawings, requiring the project team to solicit further information from the 3D coordination team. The process of obtaining an image from the 3D model usually took upwards of 2 or 3 days, leaving the field personnel to abandoned their current task and move on to another area until the required information was made available.

Potential Solutions

With 3D modeling files readily available in the form of NavisWorks and Revit files, the absence of an ability to open and review those files underutilizes available project resources. At the very least, select personnel on the project team could be given the ability to rapidly access and review those files on site in order to quickly address problems in the field. Instead, the aforementioned 3 day process was initiated upon failing to obtain the required information from the 2D coordination drawings. A valid approach to this issue involves the provision of in-field BIM kiosks as well as basic training to subcontractor foremen, allowing them to review the coordinated models themselves. While this may not have solved every conflict that arose, more often than not the 3D model screenshots provided by the coordination team offered solid evidence as to who had improperly installed their work, and the steps that needed to be taken in order to remedy the situation.

Research

Modulus Consulting, LLC, a BIM consultant in the San Francisco area, is the current leader in BIM Kiosk manufacturing and implementation. As Modulus's founder and CEO, Brett Young directs the company's daily operations and development. Brett's assistance in the evaluation of the infrastructure and training requirements for the implementation of a successful BIM kiosk program was crucial throughout the process of determining the feasibility of initiating these in-field BIM techniques on this project.

According to Mr. Young, the BIM kiosks offered by Modulus Consulting range in cost from $7,500 to $12,000, with an average cost of $9,000. These costs include the metal storage containers (see Figure #17), a computer with the processing capabilities of handling large project documents, a large LCD monitor that allows multiple individuals to observe drawings and models in a collective setting, as well as the pre-loading of project documents onto the computer's hard drive.[8, 22]

Figure #17 – BIM Kiosk – Courtesy of Modulus Consulting[8]

With companies like Modulus Consulting who are capable of setting up the initial BIM kiosk requirements, the only remaining prerequisite for the successful implementation of the BIM kiosk approach is personnel training. Fortunately, with the growth of online tools and resources, most individuals this day in age are capable of banking online, dating online, sending emails, reading informational forums, or playing games. The required model navigation abilities of the average construction worker are limited to walking through the model and both hiding and measuring different elements in the model. They do not require the ability to run clash detection or perform 3D/4D modeling tasks. These more advanced procedures are commonly performed by the subcontractor and GC coordination teams. Mr. Young has seen training sessions take as little as 1 hour, and as many as 4 hours to successfully integrate an individual with the skill requirements to effectively utilize a BIM kiosk in the field.[8, 22]

Effects of BIM Implementation

First and foremost, the amount of time required to evaluate in-field coordination issues is greatly reduced through the availability of in-field BIM technology. Rather than contact the general contractor project managers, wait for them to relay a message to the coordination teams, and further await a timely response, subcontractors who encounter clashes in the field can immediately consult the coordinate models via the use of a nearby BIM Kiosk.

BIM Kiosk technology is not limited to the retrieval of 3D coordinated models for the alleviation of system conflicts. The technology can also, and often is, paired with cloud server technology to provide an up-to-date source of project specifications, drawings, change orders, and request for information responses. Due

to today's mobile project management professionals, most projects utilize cloud server technology to store their project documents. These servers can be wirelessly linked to BIM Kiosks throughout the jobsite. More often than not, as updated specifications, drawings, contract change orders and request for information responses are received, they are integrated into the digital project documents in order to maintain an accurate account of the project's requirements. By making this accurate information rapidly available to trade contractors, project managers can actively help eliminate the possibility of work being performed off of outdated drawings. Trade contractors can quickly and efficiently verify that the hard copies they are provided for a day's work are congruent with the updated project files on the cloud server. Hopefully, their foremen have provided them with the most up-to-date drawings and sketches, however, if a discrepancy is detected, the tradesmen can easily request a hard copy of the most recent documents from their foremen. This process of verifying the accuracy of in-hand documents prior to installing work helps reduce the amount of inaccurately placed work and the associated demolition and rework.

The aforementioned effects of BIM Kiosk implementation can amount to numerous direct time and cost savings on any project. Most significantly, the time taken to address in-field conflicts is greatly reduced, allowing trade contractors to address, analyze, and remedy conflicts in a matter of minutes rather than days. The ability to navigate a 3D coordination model permits contractors to quickly locate and evaluate the location of a conflict and the manner in which it can be addressed. This ability saves not only their time, but also the time of general contractor representatives and design professionals who would otherwise be tasked with meeting with the trade contractors, reviewing coordination drawings, and consulting the coordination modelers. Alternatively, this time could be dedicated to submittal review and coordination of other project areas and systems, ensuring that the project stays on schedule by providing ample amounts of approved work for the trade contractors.

Requirements

As previously mentioned, the implementation of BIM in the field requires the appropriate hardware, as well as contractor training. Modulus Consulting's BIM systems cost approximately $9,000 on average. From the discussion with Brett Young of Modulus Consulting, the average trade foremen requires minimal intensive training, and requires only the ability to navigate the model, hide and unhide design elements, and measure the distances between, and sizes of said design elements. According to Mr. Young, these training requirements are commonly met through the implementation of a 1 or 2 hour course on 3D coordination model basics. For the purpose of estimation, a 2 hour training requirement will be assumed, and applied to each of the accumulated foreman's time savings across the duration of the project. These costs are reflected in the following section.

Cost and Schedule Savings

In the case of BIM Kiosk implementation, the effects on the project cost and schedule are directly related to one another in the sense that most cost savings stem from the amount of time that project managers and foremen DO NOT spend laboriously searching for coordination answers and details. While these "time" savings may not compound into true schedule savings, the time usually spent searching for answers can be spent actually alleviating the issue. This may result in an increased quality of the corrective work, or, if the saved time is spent efficiently, could very well result in a shortened trade schedule.

The main, and most unpredictable saving, is that of the avoidance of installing work per outdated drawings. The cost and schedule effects of this common project affliction could constitute an entire study on their own. In the case of this research analysis, it is relatively safe to say that while the cost and schedule savings associated with the assumed time savings for project managers and trade foremen may seem negligible in comparison to the overall project value, the savings associated with the minimization of improper construction off of outdated and inaccurate drawings is most likely four to five times greater than those associated with streamlined coordination resolution.

Due to its relatively new standing in the construction industry, there is not a lot of information regarding the direct impacts of the implementation of a BIM Kiosk on project sites. For this reason, the following cost and schedule impact estimates should be considered a "least effect" and are intended to be very reasonable and err on the side of underestimation.

With the availability of a BIM Kiosk for in-field conflict resolution, it is safe to say that a foreman who encounters one conflict per day could stand to save approximately 45 minutes of his or her time by utilizing the kiosk over the conventional trip to the general contractor's trailer. The Office Building Project's site was located on a very steep grade, with walking durations from the field to the trailer in excess of 15 minutes round trip. The inclusion of 45 minutes of conflict troubleshooting using 2D coordination drawings, when compared to 15 minutes of conflict troubleshooting using 3D model navigation techniques, advocates a 45 minute time savings estimate. 45 minutes of this time is also saved by the project manager, who would otherwise be called upon to review the 2D coordination drawings with the trade foreman. During construction, most conflicts arose between the MEP, Life Safety, Elevator, Drywall, Structural, Glazing and Masonry subcontractors. If each foreman from each of these subcontractors saves 45 minutes a day due to the utilization of a BIM Kiosk, ideally, the project as a whole will benefit from 6 hours of foreman labor being redistributed elsewhere on the project, and the general contractor will experience an increase in productivity equivalent to 6 man hours amongst their project managers (see Table #19). This table also includes design professionals, who were contacted for additional help on approximately 25% of the in-field conflicts encountered on this project. The hourly wages (with fringe benefits) are taken directly from the project's general conditions estimates, and provide an accurate reflection of the actual cost savings from the time savings associated with BIM Kiosk implementation.

BIM Kiosk Implementation Time and Budget Savings						
Personnel	**Hourly Wage (w/ Fringe)**	**Time Savings (Hours Per Conflict)**	**Conflicts (Per Week)**	**Job Duration (Weeks)**	**Time Saved (Hours)**	**Total Savings**
Foreman	$125.00	0.75	40	156	4680	$585,000.00
Project Manager	$165.00	0.75	40	156	4680	$772,200.00
Design Professionals	$165.00	0.75	10	156	1170	$193,050.00
				Totals	**10530**	**$1,550,250.00**

Table #19 – BIM Kiosk Implementation Savings

The MEP, Life Safety, Elevator, Drywall, Structural, Glazing and Masonry contractors were all on site at the same time for a period of approximately 3 years. This is reflected in the 156 week job duration. An average of 1 conflict per day for the 8 most commonly affected trades is represented in the 40 conflicts per week figure.

It is important to note that the monetary "savings" do not necessarily represent cost cuts on the project, but rather the amount and dollar value of labor and management hours that can be redistributed to other areas of the project. More appropriately, the $1,550,250.00 savings total represents the total added value to the project. Rather than spent tediously reviewing 2D coordination drawings and facilitating the coordination process, the foremen, project managers and design professionals can collectively re-allot 10,530 hours of their time to other areas of the project, ultimately increasing the project productivity levels.

BIM Kiosk Implementation Costs						
Personnel	**Hourly Cost**	**Time (Hours)**	**Quantity**	**Material Costs**	**Labor Costs**	**Total Cost**
Foreman Training	$125.00	2	8	$400.00	$2,000.00	$2,400.00
Project Manager Training	$165.00	2	12	$600.00	$3,960.00	$4,560.00
Instructor	$150.00	6	1	-	$900.00	$900.00
BIM Kiosk Costs	-	-	3	$9,000.00	$1,500.00	$31,500.00
Network Allowance	-	-	-	$10,000.00	$25,000.00	$35,000.00
Drawing Updates Allowance	-	-	-	$2,500.00	$35,000.00	$37,500.00
			Totals	**$22,500.00**	**$61,500.00**	**$111,860.00**

Table #20 – BIM Kiosk Implementation Costs

Table #20, above, shows the costs associated with the implementation of BIM Kiosks. It can be assumed that foremen and project managers will be paid during their training sessions, which will last 2 hours. Three individual training sessions were allotted for the training of all 20 individuals, which is reflected in the 6 hour allotment for instructor fees. A $50.00 charge per training laptop is represented in the material cost columns in the foremen and project manager rows. Three BIM Kiosk stations will allow for the provision of one kiosk on each of the major floors in Building One. This will facilitate the rapid access to the desired information, and minimize the amount of transit time between the site of conflict and the BIM Kiosks. The average cost of $9,000, as well as an installation cost of $500 was used for each BIM Kiosk. Allowances for network infrastructure and drawing updates are included to address the manpower and equipment needed to establish and maintain a network of up to date project documents.

Final Recommendation and Justifications

Table #21 compares the costs and savings associated with the implementation of three BIM Kiosk systems in Building One.

BIM Kiosk Implementation Savings and Costs Comparison				
Item	**Labor Cost**	**Material Cost**	**Labor Hours**	**Total Cost**
Foreman Time Savings	($585,000.00)	-	(4680.00)	($585,000.00)
PM Time Savings	($772,200.00)	-	(4680.00)	($772,200.00)
DP Time Savings	($193,050.00)	-	(1170.00)	($193,050.00)
Foreman Training Costs	$2,000.00	$400.00	16.00	$2,400.00
PM Training Costs	$3,960.00	$600.00	24.00	$4,560.00
Instructor Fees	$900.00	-	6.00	$900.00
BIM Kiosk Costs	$1,500.00	$9,000.00		$10,500.00
Networking Costs	$25,000.00	$10,000.00		$35,000.00
Drawing Updates Costs	$35,000.00	$2,500.00		$37,500.00
Totals	**($1,481,890.00)**	**$22,500.00**	**(10484.00)**	**($1,459,390.00)**

Table #21 – BIM Kiosk Implementation Costs and Savings Comparison

Again, as previously stated, the $1.46M "savings" is not represented as a direct reduction in the cost of the project. Rather, it represents added value to the project in the form of increased productivity and a redistribution of man hours. The true measurement of the feasibility of BIM Kiosk implementation is the labor hour reduction, highlighted in the table above. These 10,500 hours can be reallocated to other areas of the project, ultimately accelerating the process of system and installation and construction. Labor hours were not assigned to the networking and drawing maintenance costs due to the fact that these are already project requirements. The added labor costs were tabulated simply to create a "worst-case-scenerio" pay-back representation of the implementation of BIM Kiosks.

While 10,500 man hours may seem negligible on a project that tabulated millions of man hours, the fact is that the benefits of BIM Kiosk technology are not limited to the immediate reduction in coordination and conflict resolution process times. As previously stated, the immediate availability of up-to-date project documents is irreplaceable, and could amount to millions of dollars in avoided rework. The commonly encountered issue of work being installed in reference to out of date drawings can be almost avoided altogether as long as trade foremen maintain a disciplined workforce that checks the accuracy of their drawings on a daily basis.

In addition to the hard, number based support of BIM Kiosk implementation, there are multiple "soft-skill" based aspects to BIM Kiosk technology that make it appealing. The use of kiosks creates a stronger team-based situation, where multiple individuals can gather around the large screen and observe the coordinated models (see Figure #18).

Figure #18 – BIM Kiosk Team Setting – Courtesy of Modulus Consulting[8]

The ability for multiple foremen and tradesmen to gather around a single screen is far more powerful than the individualized interface provided by iPads and tablet PC's. While these technologies may be more appropriate for purchase ordering and material tracking applications, they are not as effective in delivering a team-centered coordination experience. The large monitor effectively mimics traditional paper drawings, something that tablet PC's cannot provide.

In summary, the implementation of BIM Kiosks on this project would undoubtedly pay for themselves at the very least. If initial estimates are correct, the project stands to gain over 10,000 labor hours, which can be redistributed to other activities on site. Without further investigation, it is difficult to determine the full extent of hard cost cuts that BIM Kiosks could provide. A good percentage of these savings would stem from the reduction in inaccurate installations performed off of out-of-date drawings. In its simplest applications, BIM Kiosks will alleviate the pressure on the general contractor when it comes to troubleshooting in-field coordination conflicts, as well as minimize the time it takes for foremen and tradesmen to address these issues and determine remedial steps. Brett Young, of Modulus Consulting, summarized the true meaning behind in-field BIM applications very well. He said,

"BIM exists (in part) because buildings are getting so complex that they can't be coordinated with conventional "light table' overlays. If this complexity exists, it isn't reasonable that field workers can install the work off of shop drawings alone. Put another way, BIM should not be used to lighten the load on the project managers coordinating projects without lightening the ever increasing load of the field workers who are installing the work."[8]

DESIGN BUILD PROJECT TEAM SELECTION

Background

The Office Building project implemented a design-build approach, and while most subcontractors fully embraced the collaborative atmosphere, others did not adapt to the relatively new project delivery approach as quickly and successfully. While some subcontractors swiftly adjusted to the expectations of interdisciplinary interaction, others were slow to adopt the means and methods that make rapid coordination and installation possible. Due to its prevalence in the industry today, a fair amount of research is being dedicated to the understanding of the design-build project dynamic. Future project teams can benefit from a comprehensive, research based, "guide" to selecting prospective design-build team members.

Potential Solutions

In order to promote a team-based project approach and facilitate the formation of a group-oriented project team, one would first need to determine the social and environmental factors that caused one subcontractor to adjust to a project atmosphere that promotes interdisciplinary communication and coordination more rapidly than another. After determining these factors, educational programs and methods that would help accelerate the adjustment process can be developed to address the slower developing project team members. Additional solidarity could be established amongst the team members if everyone is made aware of what is expected of them and what traditional aspects of the building construction process will be altered by the design-build approach.

Research

In order to pinpoint the characteristics and team requirements unique to the design-build project delivery approach, multiple project managers and industry tradesmen with design-build experience were surveyed. The surveys (See Appendix H – Design Build Team Dynamic Trade Surveys) provided valuable information regarding the nature of design-build requirements that differ from those of a traditional project approach, as well as insight into the subcontractor selection process and what makes some trade contractors more successful than others. Interestingly, many of those surveyed also referenced the characteristics of owners that are more likely to effectively embrace the design build delivery method. Those interviewed represent general contractors, masonry contractors and interior partition contractors. This broad survey base provides a varied type of responses from individuals who have spearheaded design-build efforts as well as served as design-build subcontractors and design-assist subcontractors.

Findings

Those surveyed were asked what types of characteristics, mentalities and team interaction techniques are prevalent among design-build project team members who serve as productive additions. Table #22 highlights the most common traits and characteristics that were reported.

Design Build Team Characteristics	
Positive Characteristics	**Negative Characteristics**
Technical Expertise	Owner Lacks Ultimate Decision Maker
Full Understanding of Work Scopes	Owner Wishes to Retain Competitive Bidding
Previous Experience	Unavailability of Project Managers
Full Disclosure	Delayed A/E Response to Design Changes
Productive Cooperation	Contractor Reluctance to Redesign/Coordinate Systems
Efficient Workers	Strong Egos
Ability to See Past "Hard Dollar" Approach	Complex Administrative Hierarchies
Active Involvement in Preconstruction	
Abilty to Produce Detailed Estimates	
Respect	
Collaboration	

Table #22 – Design-Build Team Characteristics

Of particular interest was the common response that the most technically versed and capable subcontractors are the most likely to embrace and capitalize on design-build relationships. Those polled seemed to say "The best subcontractors will be the best additions to a design-build team." However, upon further investigation, the true reasoning behind their statements surfaced. Nick Umosella highlighted the fact that most design-build jobs are intended to be fast-tracked, a schedule acceleration technique that benefits from the ability to begin site preparation and excavation long before the project team possesses final construction documents for the structure and finishes of the building. This approach, while beneficial in terms of project duration, makes the bidding process more difficult by asking potential trade contractors to provide estimates based upon bridging documents, schematic building plans that are 25% complete at best. This requires subcontractors to guess the type and extent of a good portion of the systems and components required to deliver a functioning product that meets the owner's expectations.[21] At this point, it is the technically versed and capable subcontractors that stand out from their less-technical counterparts. Part of bidding design-build projects is an art form, built on the ability to fill scope gaps and foresee the types of system components that an owner will want or need. Along with this foresight, these contractors are able to rationalize and explain their every design decision to the team, who in turn benefits greatly from this new understanding of the inner workings of another subcontractor's scope of work. Subcontractors who rely solely on the architects and engineers of record to design the building's systems, and follow bidding procedures that include "whatever is on the drawings, nothing more and nothing less", will not make suitable design-build partners. The ability to produce detailed estimates, paired with an expertise that enables a subcontractor to explain in detail each and every decision they made during the bidding process

are two characteristics of subcontractors that will most likely fully embrace the design-build mentality and process.

Many of the remaining positive characteristics are commonly sought after in every building project, regardless of the delivery method, but are especially crucial to the success of a design-build approach. Contractors who are not proponents of full disclosure, productive collaboration and cooperation, or do not possess the ability to see past a "hard-dollar" bid approach, will most likely not be able to adjust to the requirements of a design-build project team. Collaboration and cooperation require the disclosure of otherwise seemingly "internal" decisions. In order to provide a high-quality product free of defects, each subcontractor needs to be aware of the decisions being made by others. This collaborative and cooperative method allows for additional foresight regarding potential conflicts between each subcontractor's decisions in respect to means and methods of construction, as well as their design decisions. The ability to keep everyone on the same page is crucial to the success of a design-build project. The second that a subcontractor decides to go rogue and make decisions on their own without consulting those who are potentially affected, the project will falter. The whole purpose of a design-build approach is to ensure that those involved with the project are aware of the design and installation details of the entire project so as to avoid conflicts and performance issues with the final installed systems. Without full transparency and cooperation, the design-build approach begins to fail.[5, 6, 14, 21]

Ironically, one of the biggest hurdles on design-build projects is the willingness of the owner to fully embrace the unique aspects of the approach. Owners who wish to pursue a design-build approach need to be willing to let go of the traditional competitive bidding process and implement a more productive, best value selection process. As mentioned, the design development process is in its infant stages at the point when subcontractors are asked to estimate and bid the job. If a hard-bid, competitive approach is utilized, most bidders will apply minimal effort to address the potential details of the building's systems, completely negating the overall intent of the design-build approach. If approached as a best value selection process, bidders will be inclined to develop proposals that encompass and address the remaining design decisions in an attempt to showcase their trade expertise.

Additionally, owner organizations with numerous stakeholders (or individuals who perceive themselves as legitimate stakeholders) will undoubtedly hinder the design-build process. The preconstruction process common to the design-build approach is intended to allow the project team to assemble complete, coordinated drawings of the areas of the building that will be constructed first. This allows for the construction team to rapidly construct these areas while the remaining areas are being coordinated, leading to the fast-tracked abilities of the design-build approach. If an owner organization is comprised of numerous stakeholders, arranged in a complex bureaucratic hierarchy without the presence of one or two "ultimate decision makers", the ability of the project team to complete the system and component selection process is greatly reduced.[21] While major design and engineering systems are in limbo, the project clock is ticking, requiring either costly project acceleration measures or the extension of the project schedule. Prior to engaging industry professionals with the proposition of a design-build project, owners need to ensure that they select a project director with the overarching power to take into account the stakeholder inputs and

make an ultimate design decision. The presence of such a figure ensures that the project is not unwarrantedly delayed due to bureaucratic disputes.

Cost and Schedule Savings

Without a comprehensive case study comparison of the building that this project focuses on, it is nearly impossible to assign schedule and budget values to the successful implementation of a design-build project approach. However, the information obtained from the interviewees leads to a number of conclusions regarding the delivery method. Three out of four interviewees stated that they have experienced reductions in the number of project change orders of up to 50% in comparison to projects of similar size and scope. This level of success is directly related to the owner's ability and willingness to make final decisions in a timely manner. Project change orders notoriously result in the escalation of project costs due to the inherent material and labor mark-ups that accompany them. The exact magnitude of potential savings is incalculable, as change orders vary greatly in size and scope.

Interestingly, none of the interviewees was able to claim that the successful implementation of the design-build project approach reduced the number of RFI's on the project. Ideally, if all involved parties are actively involved with the preconstruction phase of the project, many design questions can be clarified and addressed at an early stage, forgoing the traditional RFI process that tends to back up and delay projects. In the future, if more projects implement intensive preconstruction design development programs, the design-build approach can help alleviate the pressure of the RFI process in addition to the reduction in the number of project change orders.

The implementation of a lengthened preconstruction phase adds overhead costs and elongates the project schedule. However, the preconstruction phase does not require the availability of the project site and can take place prior to the owner's release of the site, avoiding any change to the end date of the project. The overhead and operations costs incurred during the preconstruction phase are commonly recuperated during the construction phase in the reduced number of system conflicts, project change orders, and possibly RFI's.

Evaluation

While the following analysis was not meant to persuade an owner into utilizing the design-build project delivery method, it provides a number of aspects that an owner and a project team needs to be aware of prior to selecting team members. The surveyed industry members speak from experience and are undoubtedly worth listening to. It is crucial that an owner and their representatives take into account the aforementioned topics and characteristics prior to selecting their project team members.

More recently, The Pennsylvania State University has begun developing "360 Evaluations" that will eventually be distributed to team members on University projects. A quick review of these questionnaires reveals that while the University is effectively addressing aforementioned characteristics such as communication, timeliness, cooperation, trust, and respect are all addressed, a major stakeholder is, as commonly done so, left out. The University adequately evaluates the project team's inner workings and compatibility, but fails to address themselves in their questionnaires. Judging by the overwhelming

consensus amongst industry professionals that sometimes the biggest opponent to the success of a design-build project is a bureaucratic, hierarchical owner that has trouble making final decisions, perhaps these "360 Evaluations" should include some questions aimed at the productivity and cooperation of the University. After all, they too are an active part of the project team and should be held to the same standards communication, timeliness, and cooperation.

MAE APPLICATIONS

Many of the newer project delivery approaches require unique additions to the project contracts in order to facilitate the proper interaction between team members. Much of the discussions in AE 570 - Project Delivery Methods regarding the design-build and integrate project delivery approaches were ideally based. For example, John Tocci of Tocci Building Construction stated that most of the subcontractors on IPD projects simply "put their contracts in a drawer and forget about them after signing them". This approach is intended to facilitate the team mentality and discourage individual subcontractors from seeking restitution from their fellow "teammates".[20] However, the AE 598D - Legal Aspects course addressed the dangers of this approach. There are many clauses in a contract unrelated to team cohesion that need to be addressed by all involved in order to avoid future litigation. For example, the manner in which change orders are issued, differing site conditions are addressed, and contractors are paid for additional work are all addressed in detail within a project contract. While placing the contract "in your desk" may create an artificial sense of "teamwork", the danger of disregarding crucial clauses of the contract is imminent. The false sense of team security and solidarity will taste especially bitter when the whole team is facing owner litigation for disregarding contract details. Ironically, the project team will be able to walk into the courtroom hand-in-hand with their "teammates" when they are all found responsible for disregarding the contract.[19]

A safer approach to contracting methods that address the unique relationships on design-build and integrated delivery projects is the careful wording of additional clauses that encompass the special expectations of the team. For example, Nick Umosella referenced the contract clauses related to preconstruction that are currently being used on one of his projects. The contract makes it very clear that all involved parties are expected to devote a substantial amount of time to preconstruction efforts. While this clause resulted in increased general conditions costs for the preconstruction stages of the project, it ensures that members of the team will be present during this process, allowing for the project to benefit from a conclusive review of the preliminary documents that will most likely eventually result in lower numbers of RFI's and change orders.[21]

FINAL RECOMMENDATIONS

Table #23, below, summarizes the material, labor, general conditions and schedule savings achieved through the proposed design and project delivery changes outlined and explored in the above pages. The following summary highlights the aspects of these proposed changes that lend support (as well as opposition) to the execution of the design opportunities explored.

Schedule and Budget Savings Summary					
Item	**Material Savings**	**Labor Savings**	**General Conditions Savings**	**Total Savings**	**Schedule Reduction**
Column Relocation	$4,316.82	$2,035.24	$17,653.85	$15,372.27	24
Façade Simplification	$65,720.55	$117,767.78	$4,191.72	$187,680.05	12
BIM Kiosk Implementation	$22,500.00	$1,481,890.00	-	$1,459,390.00	See Note
Design Build Team Dynamic	-	-	-	TBD	Change Orders/RFI's
Totals	$38,903.73	$1,601,693.02	$21,845.57	$1,662,442.32	36
Note: The BIM Kiosk Implementation Reallocates Approximately 10,500 Man Hours					

Table #23 – Schedule and Budget Savings Summary

Column Relocation

The intent of this redesign was to minimize the number of close-quartered spaces in which drywall installation was to take place. The original thought was that, due to the number of exterior columns and their proximity to the inside face of the exterior wall, the drywall installation productivity gains would equate to sizeable labor savings. With savings representing roughly 0.1% of the structural subcontractor's budget, the relocation of the building's as-design structural columns in an attempt to expedite the drywall installation process undoubtedly fell short. The offsetting costs of increased rebar densities necessary to support the enlarged slab-edge cantilever nearly offset the drywall installation productivity gains. Additionally, the relocated columns somewhat "invade" the interior spaces. The only major gains that this redesign may produce are quality related. The aesthetics of the drywall currently installed in the close-quartered areas between exterior columns and the exterior walls are occasionally subpar, however, these areas are rarely observed (as they are flanked by two objects between which a human being would never pass) and the aesthetics are most likely of minimal concern to the owner. For this reason, and the scale of the savings obtained by altering the base-design, the relocation of the exterior columns would most likely not be a commonly utilized or preferred design option.

Façade Simplification

In order to expedite the installation of the brick masonry façade, a design alteration centered on the removal of the existing façade's recesses removes many of the time-consuming brick corners. Unlike the column relocation proposal, the removal of the façade recessions results in a sizeable amount of project cost savings. The $183,488.33 savings equates to approximately 4% of the masonry contract. Additionally, the owner can expect to benefit from the reduction of façade glazing by reducing their annual energy consumption by approximately 3601 therms of natural gas, or $2,118.01. An architecturally savvy owner may find the drastic changes to the façade disheartening at first, but by replacing the recesses with linear sections comprised entirely of brick, the horizontal sight line divination achieved by the original glass recessions is maintained. Additionally, the removal of the labor intensive brick and glass recessions reduces the masonry

schedule by approximately 12 days. If implemented on the remaining portions of the tiered structure, the façade simplification approach would lead to budget, schedule and energy savings over three times as great as those calculated for Building One. The budget, schedule and environmentally friendly aspects of the proposed change would make it extremely appealing to most owners.

BIM in the Field

While this project was entirely coordinated in 3D, checked for clashes, and partially fabricated from 3D spooling drawings, the application of 3D modeling technology in the field was nearly non-existent. The BIM in the Field analysis explored the possibility of utilizing BIM Kiosks throughout the site in order to provide a valuable resource to the industry tradesmen in their constant struggle to address coordination issues and in-field conflicts between the building's systems. It was determined that this approach could save the project approximately $1.46M worth of time spent troubleshooting in-field conflicts. It is important to note that this $1.46M is not represented as a direct reduction in the cost of the project. Rather, it represents added value to the project in the form of increased productivity and a redistribution of man hours. The true measurement of the feasibility of BIM Kiosk implementation is the labor hour reduction, highlighted in the table above. These 10,500 hours can be reallocated to other areas of the project, ultimately accelerating the process of system and installation and construction. The most striking figure is that of the payback period required to offset the initial costs of implementing a BIM Kiosk system. If each of the project's foremen save 45 minutes a day due to the easy access to information that the BIM Kiosks provide, the system's implementation costs will be realized within one month of full utilization of the system by all involved trade foremen.

In addition to these staggering numbers, the implementation of BIM Kiosks also helps limit the amount of work performed off of out-dated drawings by providing a reliable source containing the most up-to-date drawings provided by the architect. The commonly encountered issue of work being installed in reference to out of date drawings can be almost avoided altogether as long as trade foremen maintain a disciplined workforce that checks the accuracy of their drawings on a daily basis.

In summary, the implementation of BIM Kiosks on this project would undoubtedly pay for themselves at the very least. If initial estimates are correct, the project stands to gain over 10,000 labor hours, which can be redistributed to other activities on site. Without further investigation, it is difficult to determine the full extent of hard cost cuts that BIM Kiosks could provide, but it is safe to say that on project that are already pursuing full 3D coordination, the implementation of BIM Kiosks is a very advantageous endeavor.

Design-Build Team Dynamic

An increasingly popular topic in the building construction industry is that of design-build project delivery methods and success stories. In order to further understand the unique groundwork necessary to the successful implementation of the project delivery method, numerous industry professionals with design-build experience were surveyed in order to piece together a glimpse of the considerations that general contractors and subcontractors must keep in mind when part of a design-build team. The most successful design-build teams are able to effectively communicate, cooperate, and trust one another. Additionally,

overall transparency of these team members is crucial to ensuring that the remainder of the team is on the same page at all times, and fully understands the reasoning and ramifications behind every player's decisions.

Interestingly, one of the most common deficiencies that plagues design-build team cohesiveness and productivity is the nature of overly bureaucratic and hierarchical owners. The fast-track delivery and budget reducing advantages of the design-build approach hinge on the owner's ability to make timely ultimate decisions regarding the specifications and details of the systems and finishes that they wish to utilize. Owner organizations that have trouble making these ultimate decisions, whether it be the result of a painfully slow hierarchical process, or the inability to appoint a single decision making figure, may find that the design-build project approach results in higher project costs and elongated project schedules. Currently, most of the team-building effort is placed on the general contractor and subcontractors, while in fact there should be as much emphasis placed on the owner's ability to embrace the nature of a design-build arrangement.

APPENDIX A – QUANTITY TAKE-OFFS/SPREADSHEETS

COLUMN RELOCATION SPREADSHEETS

Slab Edge Takeoffs	
Location	**Slab Edge Perimeter (FT)**
B1 - LL9	Mat Slab - No Extra Rebar Required
B1 - LL8 - South Finger	335
B1 - LL8 - Middle Finger	502
B1 - LL8 - North Finger	392
B1 - LL8 - Child Care	272
B1 - LL8 - Spine	1000
B1 - LL7 - South Finger	335
B1 - LL7 - Middle Finger	436
B1 - LL7 - North Finger	375
B1 - LL7 - Spine	1000
B1 - LL6 - South Finger	276
B1 - LL6 - Middle Finger	436
B1 - LL6 - Spine	509
B1 - LL5 - South Finger	164
Total	**6032**

Modified Rebar Sizing and Spacing						
Frame	**Location**	**Moment**	**Rebar Size & Spacing**	**Rebar Weight (Per LF)**	**Rebar Length (Per 1' Strip)**	**Rebar Weight Per 1' Strip (LBS)**
Frame B - Long Direction	Full Column Strip	+	#5's @ 4" O.C.	1.043	3	3.129
Frame B - Long Direction	Full Column Strip	-	# 5's @ 2" O.C.	1.043	6	6.258
Frame B - Long Direction	Middle Strip	+	#5's @ 6" O.C.	1.043	2	2.086
		Averages	**#5's @ 4" O.C.**	-	**3.00**	**3.129**

Modified Rebar Sizing and Spacing Average						
Frame	**Location**	**Moment**	**Rebar Size & Spacing**	**Rebar Weight (Per LF)**	**Rebar Length (Per 1' Strip)**	**Rebar Weight Per 1' Strip (LBS)**
Frame D - Short Direction	Full Column Strip	+	#5's @ 6" O.C.	1.043	2	2.086
Frame D - Short Direction	Full Column Strip	-	#5's @ 4" O.C.	1.043	3	3.129
Frame D - Short Direction	Middle Strip	+	#5's @ 13" O.C.	1.043	1	1.043
		Averages	**#5's @ 8" O.C.**	-	**2.00**	**2.086**

Slab Edge Rebar Sizing and Spacing						
Design	**Linear Footage**	**Rebar Size & Spacing**	**Rebar Weight (Per LF)**	**Rebar Length (Per 1' Strip)**	**Rebar Weight Per 1' Strip (LBS)**	**Total Rebar Weight (LBS)**
Original	6032	#5's @ 12" O.C. Both Ways	1.043	4	4.172	25165.50
Modified	6032	#5's @ 4" O.C. Long Way #5's @ 8" O.C. Short Ways	1.043	5	5.215	31456.88
					Differential	**6291.38**

Column Relocation Drywall Takeoffs and Productivity Analysis												
Location	**Partition Drywall (SF)**	**# of Columns**	**Affected Drywall (SF Per Column)**	**Total Affected Drywall (SF)**	**% Affected**	**Inc. in Productivity of Affected Areas (%)**	**Original Dur. (Days)**	**Original Dur. (Hrs.)**	**Original Col. Dur. (Hrs.)**	**New Col. Dur. (Hrs.)**	**Updated Duration (Hrs.)**	**Updated Duration (Days)**
B1 - LL9 - South Finger	5960	18	64	1152	0.19	50	10	80	15.46	7.73	72.27	9.03
B1 - LL9 - Middle Finger	9792	34	64	2176	0.22	50	15	120	26.67	13.33	106.67	13.33
B1 - LL9 - North Finger	9176	25	64	1600	0.17	50	15	120	20.92	10.46	109.54	13.69
B1 - LL9 - Childcare	5984	25	64	1600	0.27	50	10	80	21.39	10.70	69.30	8.66
B1 - LL9 - Spine	16272	58	64	3712	0.23	50	20	160	36.50	18.25	141.75	17.72
B1 - LL8 - South Finger	5728	18	64	1152	0.20	50	15	120	24.13	12.07	107.93	13.49
B1 - LL8 - Middle Finger	8688	34	64	2176	0.25	50	15	120	30.06	15.03	104.97	13.12
B1 - LL8 - North Finger	8360	25	64	1600	0.19	50	15	120	22.97	11.48	108.52	13.56
B1 - LL8 - Child Care	5120	16	64	1024	0.20	50	10	80	16.00	8.00	72.00	9.00
B1 - LL8 - Spine	16272	58	64	3712	0.23	50	20	160	36.50	18.25	141.75	17.72
B1 - LL7 - South Finger	9032	22	64	1408	0.16	50	15	120	18.71	9.35	110.65	13.83
B1 - LL7 - Middle Finger	6768	18	64	1152	0.17	50	12	96	16.34	8.17	87.83	10.98
B1 - LL7 - North Finger	5992	15	64	960	0.16	50	15	120	19.23	9.61	110.39	13.80
B1 - LL7 - Spine	16272	58	64	3712	0.23	50	20	160	36.50	18.25	141.75	17.72
B1 - LL6 - Middle Finger	7344	22	64	1408	0.19	50	12	96	18.41	9.20	86.80	10.85
B1 - LL6 - Spine	10112	28	64	1792	0.18	50	18	144	25.52	12.76	131.24	16.41
Totals	**146872**	**474**	**-**	**30336**	**-**	**-**	**237**	**1336**	**264**	**132**	**1204**	**213**
Note: Movement of Columns does not create benefits on LL6 and LL5 South fingers b/c of unfinished mechanical spaces.												
Note: Average Column width = 2' - Area affected = 2' column side + 3' on adjacent wall on either side of the column (As Seen in Area of Influence Calculation)												
Note: The column durations were decreased by a factor of 50%, a portion of the 75% reduction implied by industry professionals.												

Column Relocation Productivity Analysis		
Item	**Units**	**Quantity**
Original Duration	Days	237
Updated Duration	Days	213
	Differential	**24**

Drywall General Conditions Calculation				
Base Bid	**% G.C.**	**General Conditions**	**Contract Duration (Days)**	**G.C. (Per Day)**
$11,475,000.00	5	$573,750.00	780	$735.58
			Total	**$735.58**
Note: General Conditions assumed to be 5% of Drywall Contract Note: Drywall Contract Approximately (3 Years*52 Weeks*5 Days) = 780 Days Long				

Column Relocation Cost Reduction Analysis				
Item	**Units**	**Quantity**	**Unit Cost**	**Total Cost**
Drywall Labor	Hours	-192	$26.11	($5,013.12)
Rebar Material	Pounds	6292	$0.69	$4,316.82
Rebar Labor	Pounds	6292	$0.47	$2,977.88
General Conditions	Days	-24	$735.58	($17,653.85)
			Total	**($15,372.27)**
Note: Drywall Labor Rate Taken From Davis Bacon Act Prevailing Wages Note: All Unit Costs Were Obtained From R.S. Means Assemblies 2012 and have been adjusted for the project's location.				

FAÇADE SIMPLIFICATION SPREADSHEETS

Brick/Glass Façade Takeoff							
Location	**Total Façade Area (SF)**	**Total Brick Area (SF)**	**Total Glass Façade (SF)**	**# of Recesses**	**Recessed Brick (SF)**	**Recessed Glass (SF)**	**Replacement Brick (SF)**
B1 - LL9 - South Finger	3350	2244.50	1105.50	4	666.80	213.32	480
B1 - LL9 - Middle Finger	5020	3363.40	1656.60	11	1833.70	586.63	1320
B1 - LL9 - North Finger	3920	2626.40	1293.60	8	1333.60	426.64	960
B1 - LL9 - Child Care	2720	1822.40	897.60	4	666.80	213.32	480
B1 - LL9 - Spine	10000	6700.00	3300.00	6	1000.20	319.98	720
B1 - LL8 - South Finger	3350	2244.50	1105.50	5	833.50	266.65	600
B1 - LL8 - Middle Finger	5020	3363.40	1656.60	11	1833.70	586.63	1320
B1 - LL8 - North Finger	3920	2626.40	1293.60	8	1333.60	426.64	960
B1 - LL8 - Child Care	2720	1822.40	897.60	4	666.80	213.32	480
B1 - LL8 - Spine	10000	6700.00	3300.00	6	1000.20	319.98	720
B1 - LL7 - South Finger	3350	2244.50	1105.50	8	1333.60	426.64	960
B1 - LL7 - Middle Finger	4360	2921.20	1438.80	3	500.10	159.99	360
B1 - LL7 - North Finger	3750	2512.50	1237.50	2	333.40	106.66	240
B1 - LL7 - Spine	10000	6700.00	3300.00	3	500.10	159.99	360
B1 - LL6 - South Finger	2760	1849.20	910.80	3	500.10	159.99	360
B1 - LL6 - Middle Finger	4360	2921.20	1438.80	4	666.80	213.32	480
B1 - LL6 - Spine	5090	3410.30	1679.70	0	0.00	0	0
B1 - LL5 - South Finger	1640	1098.80	541.20	0	0.00	0	0
Total	**60320**	**40414**	**19906**	**57**	**9502**	**3040**	**6840**
Note: Glass Quantities Obtained By Applying 33% Factor to Total Façade Area (Typical Glass-Brick Ratio for Entire Building)							

As Designed Façade Productivity Analysis					
Item	**Units**	**Quantity (SF)**	**Fraction of Brick Façade**	**Total Duration (Days)**	**Individual Duration**
Linear Brick Façade (As Designed)	SF	40414	0.81	140	113.35
Recessed Brick Façade (As Designed)	SF	9502	0.19		26.65
Totals		**49916**	**1**	**140**	**140**

Altered Facade Productivity Analysis						
Item	**Units**	**Quantity (SF)**	**Original Duration (Days)**	**% of Original Design**	**Productivity Factor**	**New Duration (Days)**
Recessed Brick Façade (As Designed)	SF	9502	27	100	1	27
Replacement Linear Brick Façade	SF	6840	27	72	1.31	15
					Differential	**12**

Masonry General Conditions Calculation				
Base Bid	**% G.C.**	**General Conditions**	**Contract Duration (Days)**	**G.C. (Per Day)**
$4,541,000.00	5	$227,050.00	650	$349.31
			Total	**$349.31**
Note: General Conditions assumed to be 5% of Drywall Contract				
Note: Drywall Contract Approximately (2.5 Years*52 Weeks*5 Days) = 650 Days Long				

Façade Alteration Cost Reduction Analysis							
Item	**Units**	**Quantity**	**Material Unit Cost**	**Labor Unit Cost**	**Total Material Cost**	**Total Labor Cost**	**Total Cost**
Window Reduction (Inside Recess)	SF	3040	$17.31	$25.98	($52,609.02)	($78,991.36)	($131,600.38)
Brick Reduction (Inside Recess)	SF	9502	$4.93	$12.99	($46,801.53)	($123,449.98)	($170,251.51)
Brick Addition (Recess Replacement)	SF	6840	$4.93	$12.99	$33,690.01	$88,865.28	$122,555.29
General Conditions	Days	12	-	$349.31	-	($4,191.72)	($4,191.72)
				Totals	**($65,720.55)**	**($113,576.06)**	**($183,488.33)**
Note: All Unit Costs Were Obtained From R.S. Means Assemblies 2012 and have been adjusted for the project's location.							

FAÇADE SIMPLIFICATION MECHANICAL ANALYSIS SPREADSHEETS

Façade U-Value Calculations	
Item	**R - Value**
Brick/CMU - Cold Applied Waterproofing	2
Brick/CMU - 8" Backup Blocking - Grouted Cells	3
Brick/CMU - Nominal Brick Facing	0.45
Brick/CMU - 2" Insulation of Rigid Foam	13
Total U-Value	**0.054**
Insulating Glass - Double Seals - Low-E Viracon Glazing	34.48
Total U-Value	**0.29**

Thermal Load Reductions and Energy Savings

Item	Test Area (SF)	Annual Load Gain (BTU/Hr)	Load Gain Per SF (BTU/Hr)	Design Alteration (SF)	Annual Load Reduction (BTU/hr)	Peak Operation Hours	Annual Load Reduction (BTU)	Gas Conversion (BTU/Therm)	Gas Reduction (Therm)	Cost Conversion ($/Therm)	Heat Conversion Efficiency (%)	Cost Savings
Brick Façade	400	32037	80.0925	-3040	-243481.2	1440	-350,612,928	100,000	-3506.12928	$0.50	85	-$2,062.43
Glass Façade	400	986	2	-2662	-6561.83	1440	-9,449,035	100,000	-94	$0.50	85	-$55.58
				Totals	**-250043.03**	**-**	**-360,061,963**	**-**	**-3601**	**-**		-$2,118.01

Note: Peak Operation Duration - June Through September, 12 Hours Per Day = 1440 Peak Hours

Note: Gas Conversions, Costs and Efficiencies are for Natural Gas, the operating fuel of the building's central utility plant

BIM IN THE FIELD SPREADSHEETS

BIM Kiosk Implementation Time and Budget Savings						
Personnel	**Hourly Wage (w/ Fringe)**	**Time Savings (Hours Per Conflict)**	**Conflicts (Per Week)**	**Job Duration (Weeks)**	**Time Saved (Hours)**	**Total Savings**
Foreman	$125.00	0.75	40	156	4680	$585,000.00
Project Manager	$165.00	0.75	40	156	4680	$772,200.00
Design Professionals	$165.00	0.75	10	156	1170	$193,050.00
				Totals	**10530**	**$1,550,250.00**

BIM Kiosk Implementation Costs						
Personnel	**Hourly Cost**	**Time (Hours)**	**Quantity**	**Material Costs**	**Labor Costs**	**Total Cost**
Foreman Training	$125.00	2	8	$400.00	$2,000.00	$2,400.00
Project Manager Training	$165.00	2	12	$600.00	$3,960.00	$4,560.00
Instructor	$150.00	6	1	-	$900.00	$900.00
BIM Kiosk Costs	-	-	3	$9,000.00	$1,500.00	$31,500.00
Network Allowance	-	-	-	$10,000.00	$25,000.00	$35,000.00
Drawing Updates Allowance	-	-	-	$2,500.00	$35,000.00	$37,500.00
			Totals	**$22,500.00**	**$61,500.00**	**$111,860.00**

BIM Kiosk Implementation Savings and Costs Comparison				
Item	**Labor Cost**	**Material Cost**	**Labor Hours**	**Total Cost**
Foreman Time Savings	($585,000.00)	-	(4680.00)	($585,000.00)
PM Time Savings	($772,200.00)	-	(4680.00)	($772,200.00)
DP Time Savings	($193,050.00)	-	(1170.00)	($193,050.00)
Foreman Training Costs	$2,000.00	$400.00	16.00	$2,400.00
PM Training Costs	$3,960.00	$600.00	24.00	$4,560.00
Instructor Fees	$900.00	-	6.00	$900.00
BIM Kiosk Costs	$1,500.00	$9,000.00		$10,500.00
Networking Costs	$25,000.00	$10,000.00		$35,000.00
Drawing Updates Costs	$35,000.00	$2,500.00		$37,500.00
Totals	**($1,481,890.00)**	**$22,500.00**	**(10484.00)**	**($1,459,390.00)**

DESIGN BUILD TEAM DYNAMICS SPREADSHEETS

Design Build Team Characteristics	
Positive Characteristics	**Negative Characteristics**
Technical Expertise	Owner Lacks Ultimate Decision Maker
Full Understanding of Work Scopes	Owner Wishes to Retain Competitive Bidding
Previous Experience	Unavailability of Project Managers
Full Disclosure	Delayed A/E Response to Design Changes
Productive Cooperation	Contractor Reluctance to Redesign/Coordinate Systems
Efficient Workers	Strong Egos
Ability to See Past "Hard Dollar" Approach	Complex Administrative Hierarchies
Active Involvement in Preconstruction	
Abilty to Produce Detailed Estimates	
Respect	
Collaboration	

APPENDIX B – DRYWALL TRADE SURVEYS

Name: Tom Budd
Company: Tri-State Drywall

Q: What is the most difficult part about installing drywall in tight spaces?

Tom Budd: Access and room to physically install and finish the drywall. The physical aspect involves dimensional limitations to install. Commercial drywall is installed via powered hand tools, whether corded or battery. An adequate depth off of the drywall is necessary to drive the screw into the supporting substrate. In addition, the finishing (taping, blocking, skimming) of drywall requires physical access to work the joint compound and applicable tape on the installation.

Q: Does the installation of drywall in tight spaces require special equipment or additional laborers? If so, what equipment and how many laborers?

Tom Budd: Additional laborers (or mechanics/carpenters/finishers) are not needed for installation of drywall in tight spaces, the physical nature won't allow the access. Depending on the dimension of access, a special low profile "right-angle drill/driver" may have to be used to install the drywall. Installation of drywall in tight spaces typically involves small cut-up pieces of drywall, thus doubling the number of screws to install per ASTM guidelines.

Q: Does the installation of drywall in tight spaces increase/slow down the speed (per sheet) that drywall can be installed? If so, approximately how many more/less sheets an hour are installed?

Tom Budd: Installation of drywall in tight places significantly slows production rates. Drywall in tight places typically involves less than whole sheets of drywall and less than normal access to installation conditions. There are a lot of different conditions even in high production installations that will vary a sheets/hour rate. Typically, the factors listed will result in +/- reduction in a "commodity" production rate.

Q: What is the minimum space between the following objects at which drywall can be installed at the average rate?

Tom Budd: Windows: 48" – Walls: 48"
Spaces less than the above start impacting the installation and finishing of drywall in a commodity production time.

Q: Are there any other advantages/disadvantages to installing drywall in tight spaces that you believe are important? If so, please list.

Tom Budd: Installation of drywall in tight spaces decreases production rates. Labor is a variable cost item when developing an estimate proposal. Material is a fixed cost item. A pre-finished material that can be set and secured in place quickly and easily can many times be less expensive overall, even though more expensive in the material category.

Imagining and owner or architect's initial viewpoint- drywall and the applied paint finish may appear the cheaper alternative over a pre-finished material that is set in place and additional temporary protection applied.

APPENDIX C – COLUMN RELOCATION STRUCTURAL CALCULATIONS

PATRICK LANINGER
SENIOR THESIS - STRUCTURAL BREADTH

- COLUMNS & REINFORCED SLABS: 5000 PSI → f'_c = 5000 PSI
- GRADE 60 STEEL → F_y = 60,000 PSI

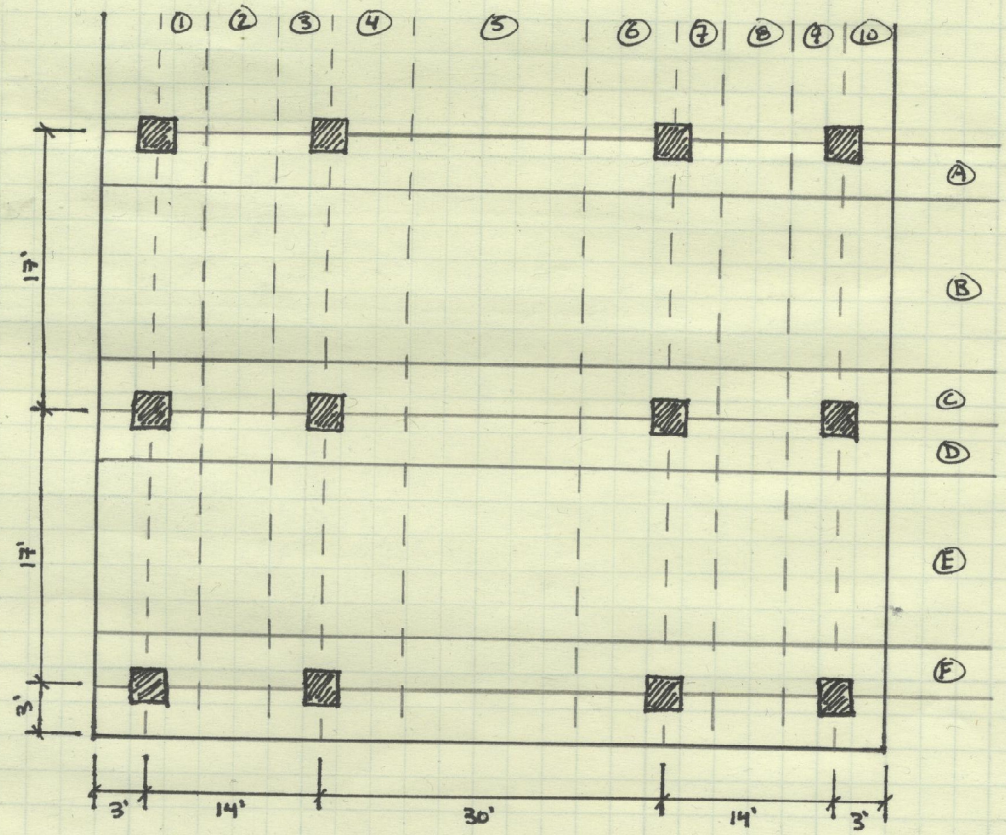
- LIVE LOADS: 60 (OFFICE) + 20 (PARTITIONS)

- SLAB DEAD LOADS: $(^8/_{12})(150\ PCF) = 100\ PSF$
- S.I. DEAD LOADS: 10 PSF FOR TYPICAL OFFICE AREAS

TOTAL LOADS

DL = 110 PSF
LL = 80 PSF

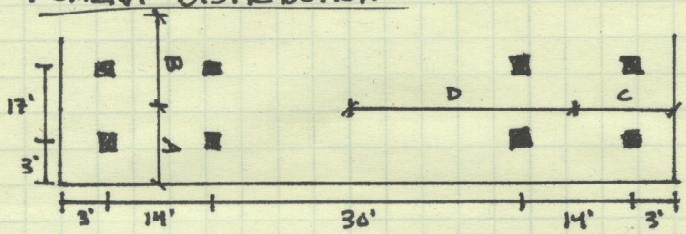
$W_u = 1.2(0.110) + 1.6(0.080) = 0.260\ KSF$



①, ③, ⑦, ⑨ = ½ COLUMN STRIP = 3.5'
②, ⑧ = MIDDLE STRIP = 7'
④, ⑥ = ½ COLUMN STRIP = 7.5'
⑤ = MIDDLE STRIP = 15'

Ⓐ, Ⓒ, Ⓓ, Ⓕ = ½ COLUMN STRIP = 4.25'
Ⓑ, Ⓔ = MIDDLE STRIP = 8.5'

MOMENT DISTRIBUTION



$W_U = 0.260\ KSF$ $\qquad M_0 = \frac{W_u l_2 l_n^2}{8}$

FRAME A

$M_0 = (0.260)(11.5')(14 - 18/12)^2 = 467.2\ ft.K$

.57M_0		.35M_0		.57M_0	
.16M_0	.7M_0	.65M_0	.65M_0	.7M_0	.16M_0

→

266.3		163.5		266.3	
74.8	327	303.7	303.7	327	74.8

FRAME B

$M_0 = (0.260)(17')(14 - 18/12)^2 = 690.6\ ft.K$

.57M_0		.35M_0		.57M_0	
.16M_0	.7M_0	.65M_0	.65M_0	.7M_0	.16M_0

→

393.6		241.7		393.6	
110.5	483.4	448.1	448.1	483.4	110.5

FRAME C

$M_0 = (0.260)(10')(11.5 - 18/12)^2 = 260\ ft.K$

.57M_0		.57M_0	
.16M_0	.7M_0	.7M_0	.16M_0

→

148.2		148.2	
41.6	182	182	41.6

FRAME D

$M_0 = (0.260)(22')(11.5 - 18/12)^2 = 572\ ft.K$

.57M_0		.57M_0	
.16M_0	.7M_0	.7M_0	.16M_0

→

326		326	
91.5	400.4	400.4	91.5

DESIGN FRAMES B & D BECAUSE THEY HAVE LARGEST MOMENTS.

Frame B

Negative Moments → $M = -483.4$ ft.k

- → 75% to Column Strip = -362.55 ft.k
- → 25% to Middle Strip = -120.85 ft.k

Positive Moments → $M = 266.3$ ft.k

- → 60% to Column Strip = 159.78 ft.k
- → 40% to Middle Strip = 106.52 ft.k

Frame D

Negative Moments → $M = -400.4$ ft.k

- → 75% to Column Strip = -300.3 ft.k
- → 25% to Middle Strip = -100.1 ft.k

Positive Moments → $M = 326$ ft.k

- → 60% to Column Strip = 195.6 ft.k
- → 40% to Middle Strip = 130.4 ft.k

* Note: Because there are no interior beams $\alpha \frac{l_1}{l_2} = 0$ and no interpolating table found in ACI 13.6.4 for column strip %'s.

Frame B: Reinforcement Design → Long Direction

	Full Column Strip		Middle Strip	
	M^+	M^-	M^+	Notes
M_u	159.78	-362.55	106.52	
Strip Width	102"	102"	102"	
Effective Depth	6.925"	6.925"	6.925"	8"-.75"-.65/2 = 6.925" #5 rebar ↑
M_u/ϕ	177.53	-409.83	118.36	$M_u/0.9$
R	435.5	1003.4	290.4	$\frac{M_n(12)(1000)}{(\text{Strip Width})(\text{Eff. Depth})^2}$
ρ	0.0078	0.019	0.0054	From Flexural Resistance Table
$A_s = \rho bd$	5.51	13.42	3.81	b = Strip Width d = Depth of Steel
$A_{s\,min} = 0.0018bt$	1.47	1.47	1.47	t = Slab Thickness
$N = \frac{X}{0.31}$	18	44	13	X = Controlling value b/t A_s & $A_{s\,min}$
$N = \frac{b}{2t}$	6.375	6.375	6.375	
Spacing	5.67"	2.32"	7.85"	

* Note - Positive Moments in Middle Strip Bear on WWF Mat Reinforcement

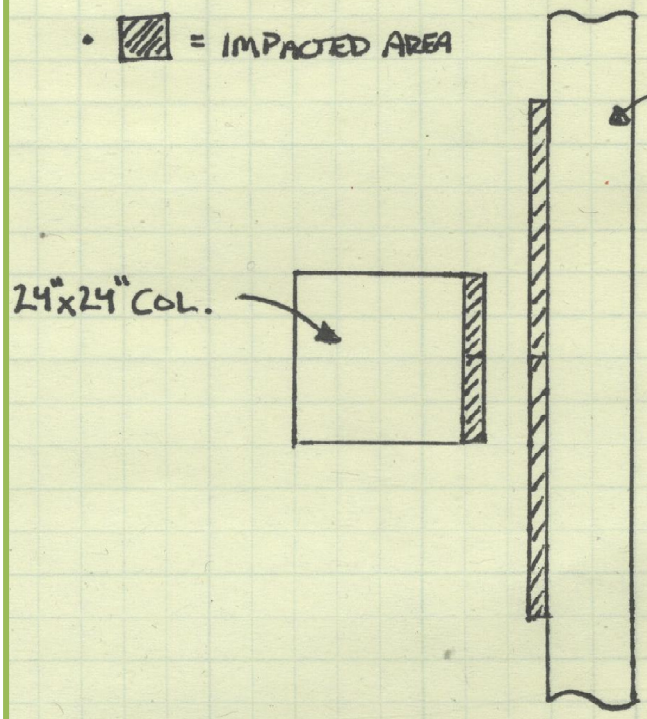
FRAME D: REINFORCEMENT DESIGN → SHORT DIRECTION

	FULL COLUMN STRIP		MIDDLE STRIP	
	M^+	M^-	M^+	NOTES
M_u	195.6	-300.3	130.4	
STRIP WIDTH	132"	132"	180"	
EFFECTIVE DEPTH	6.925"	6.925"	6.925"	8"-.75"-.65/2=6.925" #5 REBAR ↑
M_u/ϕ	217.33	-333.67	144.89	$M_u/0.9$
R	411.99	632.54	201.42	$\frac{M_n(12)(1000)}{(\text{STRIP WIDTH})(\text{EFF. DEPTH})^2}$
ρ	0.0073	0.011	0.0034	FROM FLEXURAL RESISTANCE TABLE
$A_s=\rho bd$	6.67	10.06	4.24	b= STRIP WIDTH d= DEPTH OF STEEL
$A_{s\,MIN}=0.0018bt$	1.9	1.9	1.9	t= SLAB THICKNESS
$N=\frac{x}{0.31}$	22	33	14	X= CONTROLLING VALUE B/T A_s & $A_{s\,MIN}$
$N=\frac{b}{24}$	8.25	8.25	8.25	
SPACING	6"	4"	13"	

*NOTE - POSITIVE MOMENTS IN MIDDLE STRIP BEAR ON WWF MAT REINFORCEMENT

CLOSE QUARTERED DRYWALL AREA OF INFLUENCE CALCULATION

- AVERAGE COLUMN SIZE: 24" x 24"
- □ = 6 S.I.
- ▨ = IMPACTED AREA



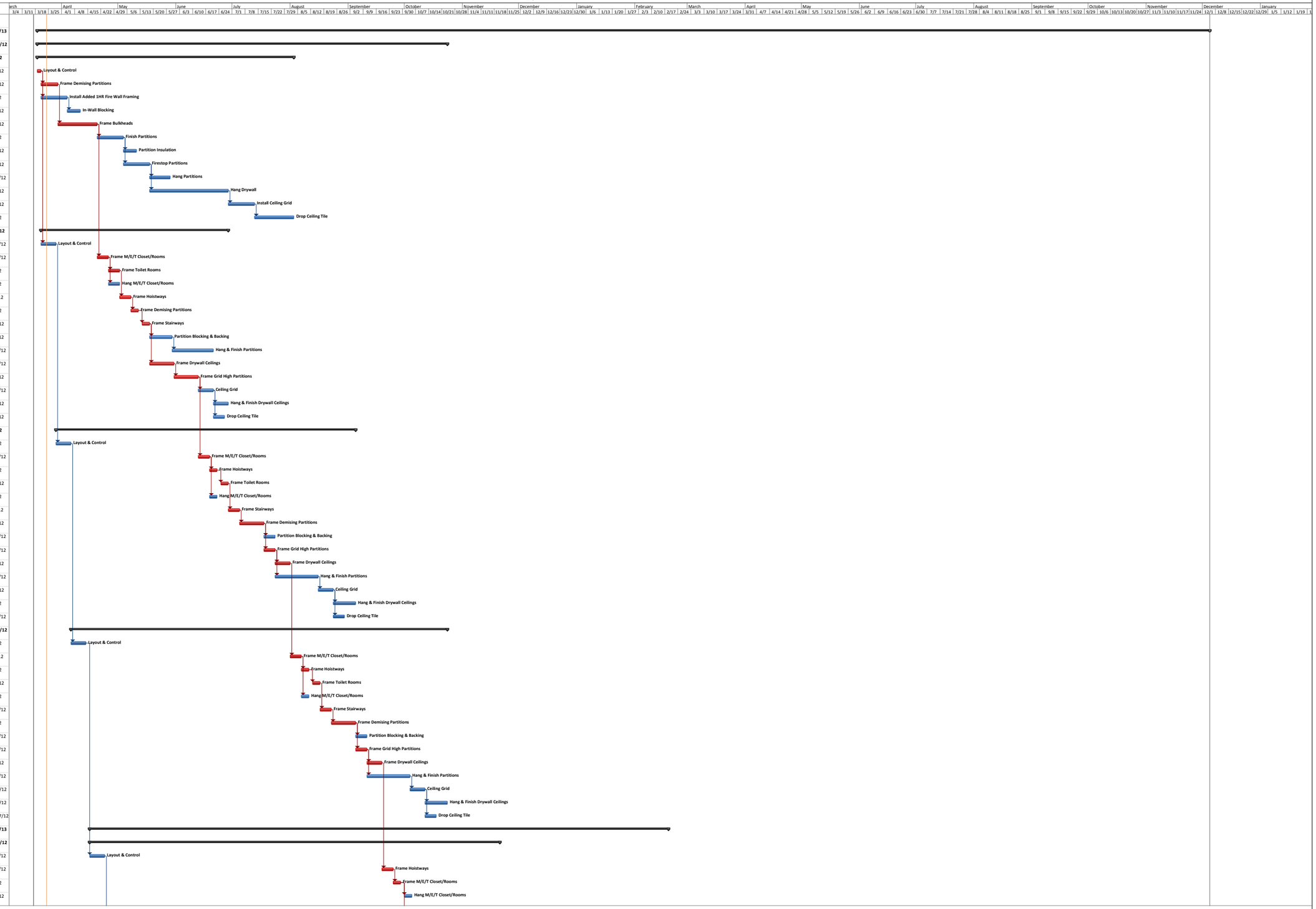
* IMPACTED AREA = 8 L.F.

* IMPACTED SF/COLUMN = 64 SF

APPENDIX D – INTERIOR TRADE SCHEDULES

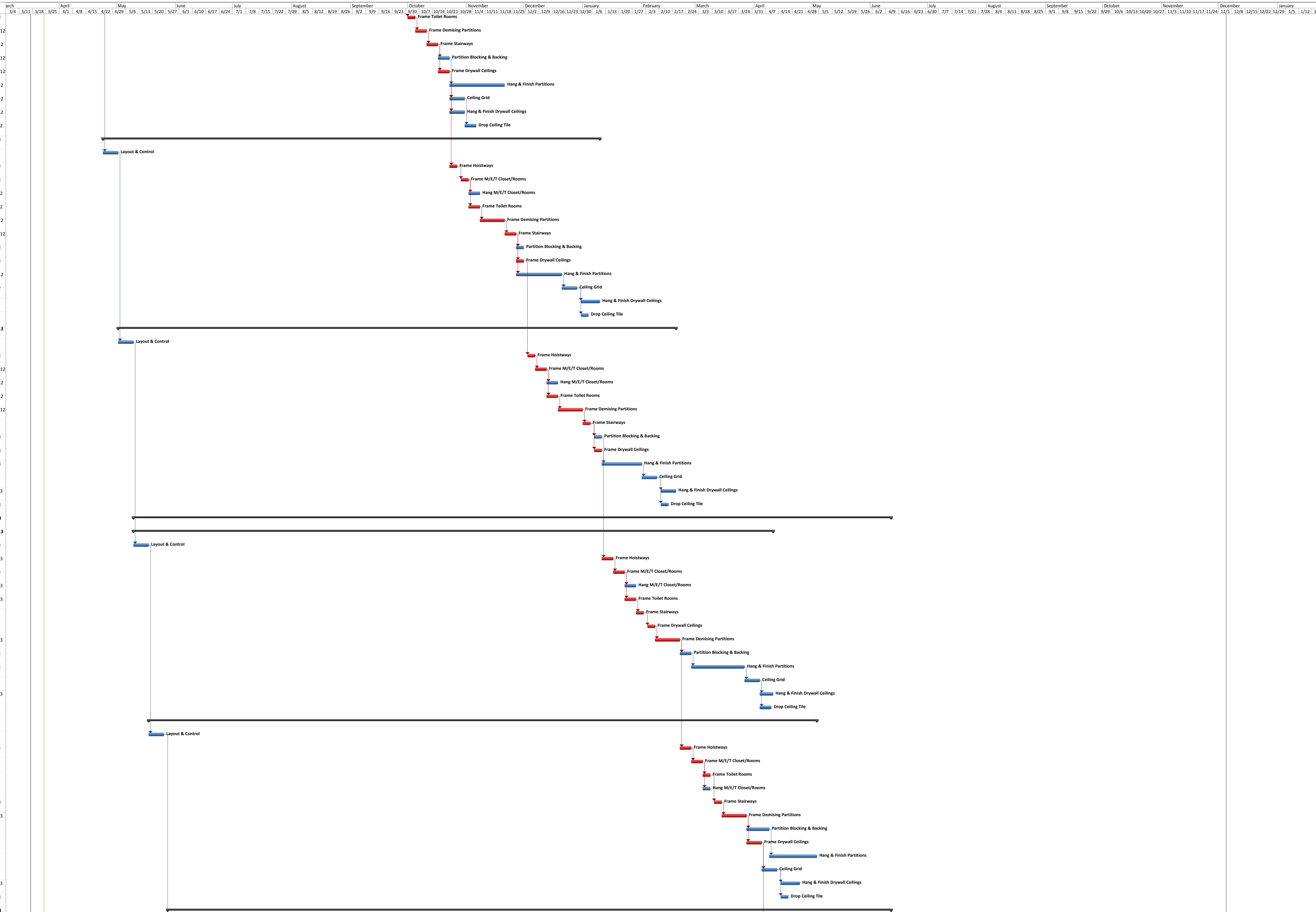
Patrick Laninger - Senior Thesis
Drywall Baseline Schedule

ID	Task Name	Duration	Start	Finish
1				
2	**Building One Drywall**	**448 days**	**Mon 3/19/12**	**Wed 12/4/13**
3	**Lower Level 9**	**157 days**	**Mon 3/19/12**	**Tue 10/23/12**
4	**Childcare Center**	**99 days**	**Mon 3/19/12**	**Thu 8/2/12**
5	Layout & Control	2 days	Mon 3/19/12	Tue 3/20/12
6	Frame Demising Partitions	7 days	Wed 3/21/12	Thu 3/29/12
7	Install Added 1HR Fire Wall Framing	10 days	Wed 3/21/12	Tue 4/3/12
8	In-Wall Blocking	5 days	Wed 4/4/12	Tue 4/10/12
9	Frame Bulkheads	15 days	Fri 3/30/12	Thu 4/19/12
10	Finish Partitions	10 days	Fri 4/20/12	Thu 5/3/12
11	Partition Insulation	5 days	Fri 5/4/12	Thu 5/10/12
12	Firestop Partitions	10 days	Fri 5/4/12	Thu 5/17/12
13	Hang Partitions	7 days	Fri 5/18/12	Mon 5/28/12
14	Hang Drywall	30 days	Fri 5/18/12	Thu 6/28/12
15	Install Ceiling Grid	10 days	Fri 6/29/12	Thu 7/12/12
16	Drop Ceiling Tile	15 days	Fri 7/13/12	Thu 8/2/12
17	**Area A (Column Lines 1-12)**	**72 days**	**Wed 3/21/12**	**Thu 6/28/12**
18	Layout & Control	6 days	Wed 3/21/12	Wed 3/28/12
19	Frame M/E/T Closet/Rooms	4 days	Fri 4/20/12	Wed 4/25/12
20	Frame Toilet Rooms	4 days	Thu 4/26/12	Tue 5/1/12
21	Hang M/E/T Closet/Rooms	4 days	Thu 4/26/12	Tue 5/1/12
22	Frame Hoistways	4 days	Wed 5/2/12	Mon 5/7/12
23	Frame Demising Partitions	4 days	Tue 5/8/12	Fri 5/11/12
24	Frame Stairways	4 days	Mon 5/14/12	Thu 5/17/12
25	Partition Blocking & Backing	8 days	Fri 5/18/12	Tue 5/29/12
26	Hang & Finish Partitions	16 days	Wed 5/30/12	Wed 6/20/12
27	Frame Drywall Ceilings	9 days	Fri 5/18/12	Wed 5/30/12
28	Frame Grid High Partitions	9 days	Thu 5/31/12	Tue 6/12/12
29	Ceiling Grid	6 days	Wed 6/13/12	Wed 6/20/12
30	Hang & Finish Drywall Ceilings	6 days	Thu 6/21/12	Thu 6/28/12
31	Drop Ceiling Tile	4 days	Thu 6/21/12	Tue 6/26/12
32	**Area B (Column Lines 12-20)**	**114 days**	**Thu 3/29/12**	**Tue 9/4/12**
33	Layout & Control	6 days	Thu 3/29/12	Thu 4/5/12
34	Frame M/E/T Closet/Rooms	4 days	Wed 6/13/12	Mon 6/18/12
35	Frame Hoistways	4 days	Tue 6/19/12	Fri 6/22/12
36	Frame Toilet Rooms	4 days	Mon 6/25/12	Thu 6/28/12
37	Hang M/E/T Closet/Rooms	4 days	Tue 6/19/12	Fri 6/22/12
38	Frame Stairways	4 days	Fri 6/29/12	Wed 7/4/12
39	Frame Demising Partitions	9 days	Thu 7/5/12	Tue 7/17/12
40	Partition Blocking & Backing	4 days	Wed 7/18/12	Mon 7/23/12
41	Frame Grid High Partitions	4 days	Wed 7/18/12	Mon 7/23/12
42	Frame Drywall Ceilings	6 days	Tue 7/24/12	Tue 7/31/12
43	Hang & Finish Partitions	17 days	Tue 7/24/12	Wed 8/15/12
44	Ceiling Grid	6 days	Thu 8/16/12	Thu 8/23/12
45	Hang & Finish Drywall Ceilings	8 days	Fri 8/24/12	Tue 9/4/12
46	Drop Ceiling Tile	4 days	Fri 8/24/12	Wed 8/29/12
47	**Area C (Column Lines 20+)**	**143 days**	**Fri 4/6/12**	**Tue 10/23/12**
48	Layout & Control	6 days	Fri 4/6/12	Fri 4/13/12
49	Frame M/E/T Closet/Rooms	4 days	Wed 8/1/12	Mon 8/6/12
50	Frame Hoistways	4 days	Tue 8/7/12	Fri 8/10/12
51	Frame Toilet Rooms	4 days	Mon 8/13/12	Thu 8/16/12
52	Hang M/E/T Closet/Rooms	4 days	Tue 8/7/12	Fri 8/10/12
53	Frame Stairways	4 days	Fri 8/17/12	Wed 8/22/12
54	Frame Demising Partitions	9 days	Thu 8/23/12	Tue 9/4/12
55	Partition Blocking & Backing	4 days	Wed 9/5/12	Mon 9/10/12
56	Frame Grid High Partitions	4 days	Wed 9/5/12	Mon 9/10/12
57	Frame Drywall Ceilings	6 days	Tue 9/11/12	Tue 9/18/12
58	Hang & Finish Partitions	17 days	Tue 9/11/12	Wed 10/3/12
59	Ceiling Grid	6 days	Thu 10/4/12	Thu 10/11/12
60	Hang & Finish Drywall Ceilings	8 days	Fri 10/12/12	Tue 10/23/12
61	Drop Ceiling Tile	4 days	Fri 10/12/12	Wed 10/17/12
62	**Lower Level 8**	**221 days**	**Mon 4/16/12**	**Mon 2/18/13**
63	**Area A (Column Lines 1-12)**	**157 days**	**Mon 4/16/12**	**Tue 11/20/12**
64	Layout & Control	6 days	Mon 4/16/12	Mon 4/23/12
65	Frame Hoistways	4 days	Wed 9/19/12	Mon 9/24/12
66	Frame M/E/T Closet/Rooms	4 days	Tue 9/25/12	Fri 9/28/12
67	Hang M/E/T Closet/Rooms	4 days	Mon 10/1/12	Thu 10/4/12



Patrick Laninger - Senior Thesis
Drywall Baseline Schedule

ID		Task Name	Duration	Start	Finish
68		Frame Toilet Rooms	4 days	Mon 10/1/12	Thu 10/4/12
69		Frame Demising Partitions	4 days	Fri 10/5/12	Wed 10/10/12
70		Frame Stairways	4 days	Thu 10/11/12	Tue 10/16/12
71		Partition Blocking & Backing	4 days	Wed 10/17/1	Mon 10/22/12
72		Frame Drywall Ceilings	4 days	Wed 10/17/1	Mon 10/22/12
73		Hang & Finish Partitions	21 days	Tue 10/23/12	Tue 11/20/12
74		Ceiling Grid	6 days	Tue 10/23/12	Tue 10/30/12
75		Hang & Finish Drywall Ceilings	6 days	Tue 10/23/12	Tue 10/30/12
76		Drop Ceiling Tile	4 days	Wed 10/31/1	Mon 11/5/12
77		**Area B (Column Lines 12-20)**	**187 days**	**Tue 4/24/12**	**Wed 1/9/13**
78		Layout & Control	6 days	Tue 4/24/12	Tue 5/1/12
79		Frame Hoistways	4 days	Tue 10/23/12	Fri 10/26/12
80		Frame M/E/T Closet/Rooms	4 days	Mon 10/29/1	Thu 11/1/12
81		Hang M/E/T Closet/Rooms	4 days	Fri 11/2/12	Wed 11/7/12
82		Frame Toilet Rooms	4 days	Fri 11/2/12	Wed 11/7/12
83		Frame Demising Partitions	9 days	Thu 11/8/12	Tue 11/20/12
84		Frame Stairways	4 days	Wed 11/21/1	Mon 11/26/12
85		Partition Blocking & Backing	4 days	Tue 11/27/12	Fri 11/30/12
86		Frame Drywall Ceilings	4 days	Tue 11/27/12	Fri 11/30/12
87		Hang & Finish Partitions	18 days	Tue 11/27/12	Thu 12/20/12
88		Ceiling Grid	6 days	Fri 12/21/12	Fri 12/28/12
89		Hang & Finish Drywall Ceilings	8 days	Mon 12/31/1	Wed 1/9/13
90		Drop Ceiling Tile	4 days	Mon 12/31/1	Thu 1/3/13
91		**Area C (Column Lines 20+)**	**209 days**	**Wed 5/2/12**	**Mon 2/18/13**
92		Layout & Control	6 days	Wed 5/2/12	Wed 5/9/12
93		Frame Hoistways	4 days	Mon 12/3/12	Thu 12/6/12
94		Frame M/E/T Closet/Rooms	4 days	Fri 12/7/12	Wed 12/12/12
95		Hang M/E/T Closet/Rooms	4 days	Thu 12/13/12	Tue 12/18/12
96		Frame Toilet Rooms	4 days	Thu 12/13/12	Tue 12/18/12
97		Frame Demising Partitions	9 days	Wed 12/19/1	Mon 12/31/12
98		Frame Stairways	4 days	Tue 1/1/13	Fri 1/4/13
99		Partition Blocking & Backing	4 days	Mon 1/7/13	Thu 1/10/13
100		Frame Drywall Ceilings	4 days	Mon 1/7/13	Thu 1/10/13
101		Hang & Finish Partitions	15 days	Fri 1/11/13	Thu 1/31/13
102		Ceiling Grid	6 days	Fri 2/1/13	Fri 2/8/13
103		Hang & Finish Drywall Ceilings	6 days	Mon 2/11/13	Mon 2/18/13
104		Drop Ceiling Tile	4 days	Mon 2/11/13	Thu 2/14/13
105		**Lower Level 7**	**284 days**	**Thu 5/10/12**	**Tue 6/11/13**
106		**Area A (Column Lines 1-12)**	**240 days**	**Thu 5/10/12**	**Wed 4/10/13**
107		Layout & Control	6 days	Thu 5/10/12	Thu 5/17/12
108		Frame Hoistways	4 days	Fri 1/11/13	Wed 1/16/13
109		Frame M/E/T Closet/Rooms	4 days	Thu 1/17/13	Tue 1/22/13
110		Hang M/E/T Closet/Rooms	4 days	Wed 1/23/13	Mon 1/28/13
111		Frame Toilet Rooms	4 days	Wed 1/23/13	Mon 1/28/13
112		Frame Stairways	4 days	Tue 1/29/13	Fri 2/1/13
113		Frame Drywall Ceilings	4 days	Mon 2/4/13	Thu 2/7/13
114		Frame Demising Partitions	9 days	Fri 2/8/13	Wed 2/20/13
115		Partition Blocking & Backing	4 days	Thu 2/21/13	Tue 2/26/13
116		Hang & Finish Partitions	20 days	Wed 2/27/13	Tue 3/26/13
117		Ceiling Grid	6 days	Wed 3/27/13	Wed 4/3/13
118		Hang & Finish Drywall Ceilings	5 days	Thu 4/4/13	Wed 4/10/13
119		Drop Ceiling Tile	4 days	Thu 4/4/13	Tue 4/9/13
120		**Area B (Column Lines 12-20)**	**251 days**	**Fri 5/18/12**	**Fri 5/3/13**
121		Layout & Control	6 days	Fri 5/18/12	Fri 5/25/12
122		Frame Hoistways	4 days	Thu 2/21/13	Tue 2/26/13
123		Frame M/E/T Closet/Rooms	4 days	Wed 2/27/13	Mon 3/4/13
124		Frame Toilet Rooms	4 days	Tue 3/5/13	Fri 3/8/13
125		Hang M/E/T Closet/Rooms	4 days	Tue 3/5/13	Fri 3/8/13
126		Frame Stairways	4 days	Mon 3/11/13	Thu 3/14/13
127		Frame Demising Partitions	9 days	Fri 3/15/13	Wed 3/27/13
128		Partition Blocking & Backing	8 days	Thu 3/28/13	Mon 4/8/13
129		Frame Drywall Ceilings	6 days	Thu 3/28/13	Thu 4/4/13
130		Hang & Finish Partitions	19 days	Tue 4/9/13	Fri 5/3/13
131		Ceiling Grid	6 days	Fri 4/5/13	Fri 4/12/13
132		Hang & Finish Drywall Ceilings	8 days	Mon 4/15/13	Wed 4/24/13
133		Drop Ceiling Tile	4 days	Mon 4/15/13	Thu 4/18/13
134		**Area C (Column Lines 20+)**	**272 days**	**Mon 5/28/12**	**Tue 6/11/13**



Patrick Laninger - Senior Thesis
Drywall Baseline Schedule

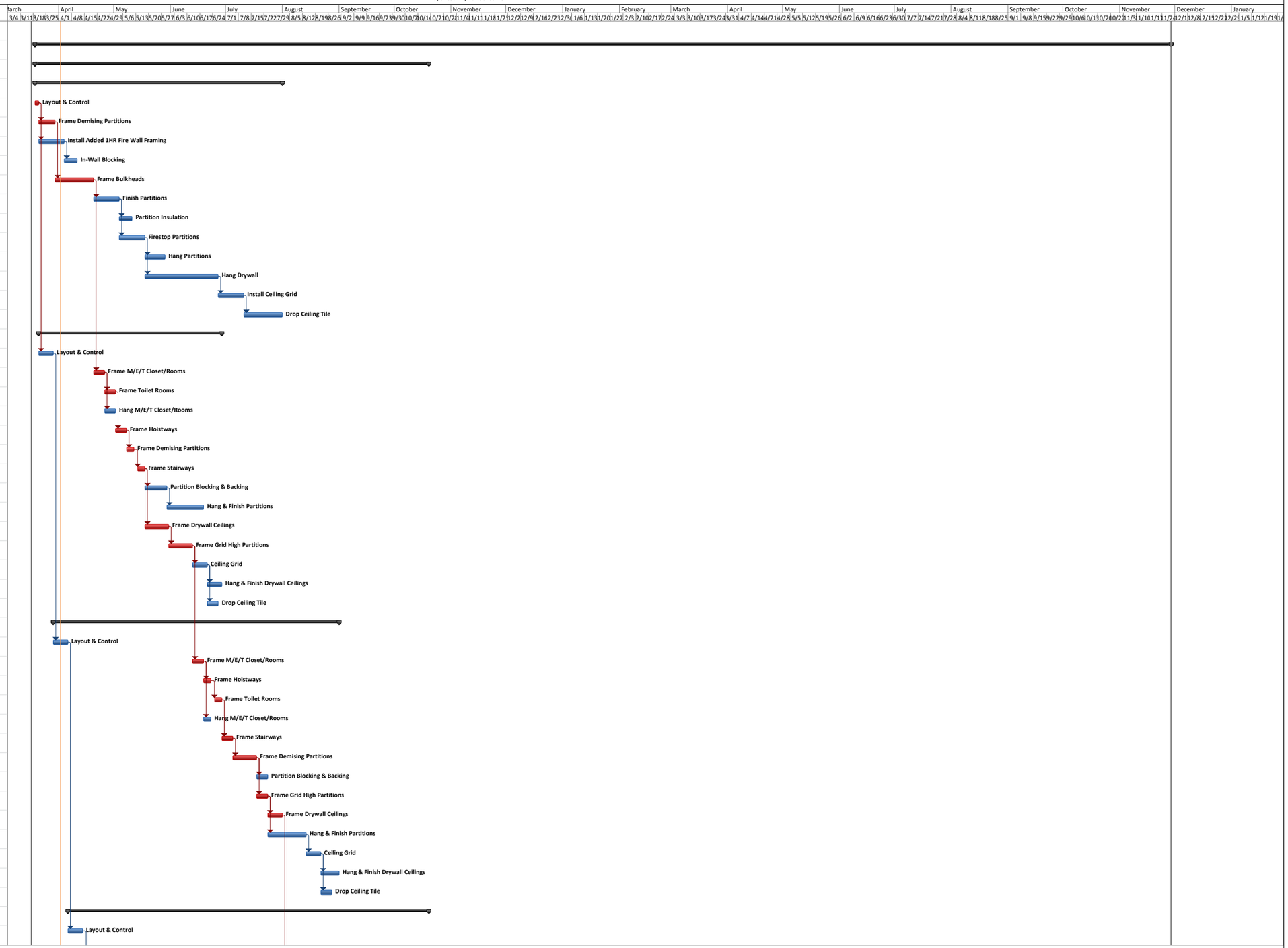
ID	Task Name	Duration	Start	Finish
135	Layout & Control	6 days	Mon 5/28/12	Mon 6/4/12
136	Frame M/E/T Closet/Rooms	4 days	Fri 4/5/13	Wed 4/10/13
137	Hang M/E/T Closet/Rooms	4 days	Thu 4/11/13	Tue 4/16/13
138	Frame Hoistways	4 days	Thu 4/11/13	Tue 4/16/13
139	Frame Toilet Rooms	4 days	Wed 4/17/13	Mon 4/22/13
140	Frame Stairways	4 days	Tue 4/23/13	Fri 4/26/13
141	Frame Demising Partitions	9 days	Mon 4/29/13	Thu 5/9/13
142	Partition Blocking & Backing	8 days	Fri 5/10/13	Tue 5/21/13
143	Frame Drywall Ceilings	4 days	Fri 5/10/13	Wed 5/15/13
144	Hang & Finish Partitions	15 days	Wed 5/22/13	Tue 6/11/13
145	Ceiling Grid	6 days	Thu 5/16/13	Thu 5/23/13
146	Hang & Finish Drywall Ceilings	5 days	Fri 5/24/13	Thu 5/30/13
147	Drop Ceiling Tile	4 days	Fri 5/24/13	Wed 5/29/13
148	**Lower Level 6**	**324 days**	**Tue 6/5/12**	**Fri 8/30/13**
149	**Area B (Column Lines 12-20)**	**310 days**	**Tue 6/5/12**	**Mon 8/12/13**
150	Layout & Control	6 days	Tue 6/5/12	Tue 6/12/12
151	Frame Hoistways	4 days	Thu 5/16/13	Tue 5/21/13
152	Frame M/E/T Closet/Rooms	4 days	Wed 5/22/13	Mon 5/27/13
153	Frame Stairways	4 days	Tue 5/28/13	Fri 5/31/13
154	Frame Toilet Rooms	4 days	Mon 6/3/13	Thu 6/6/13
155	Hang M/E/T Closet/Rooms	4 days	Tue 5/28/13	Fri 5/31/13
156	Frame Demising Partitions	9 days	Fri 6/7/13	Wed 6/19/13
157	Frame Drywall Ceilings	4 days	Thu 6/20/13	Tue 6/25/13
158	Partition Blocking & Backing	8 days	Wed 6/26/13	Fri 7/5/13
159	Hang & Finish Partitions	15 days	Mon 7/8/13	Fri 7/26/13
160	Ceiling Grid	6 days	Mon 7/29/13	Mon 8/5/13
161	Hang & Finish Drywall Ceilings	5 days	Tue 8/6/13	Mon 8/12/13
162	Drop Ceiling Tile	4 days	Tue 8/6/13	Fri 8/9/13
163	**Area C (Column Lines 20+)**	**318 days**	**Wed 6/13/12**	**Fri 8/30/13**
164	Layout & Control	6 days	Wed 6/13/12	Wed 6/20/12
165	Frame Hoistways	4 days	Wed 6/26/13	Mon 7/1/13
166	Frame M/E/T Closet/Rooms	4 days	Tue 7/2/13	Fri 7/5/13
167	Frame Stairways	4 days	Mon 7/8/13	Thu 7/11/13
168	Frame Toilet Rooms	4 days	Fri 7/12/13	Wed 7/17/13
169	Hang M/E/T Closet/Rooms	4 days	Mon 7/8/13	Thu 7/11/13
170	Frame Demising Partitions	9 days	Thu 7/18/13	Tue 7/30/13
171	Frame Drywall Ceilings	4 days	Wed 7/31/13	Mon 8/5/13
172	Partition Blocking & Backing	8 days	Wed 7/31/13	Fri 8/9/13
173	Hang & Finish Partitions	15 days	Mon 8/12/13	Fri 8/30/13
174	Ceiling Grid	6 days	Tue 8/6/13	Tue 8/13/13
175	Hang & Finish Drywall Ceilings	5 days	Wed 8/14/13	Tue 8/20/13
176	Drop Ceiling Tile	4 days	Wed 8/14/13	Mon 8/19/13
177	**Lower Level 5**	**346 days**	**Thu 6/21/12**	**Thu 10/17/13**
178	**Area C (Column Lines 20+)**	**346 days**	**Thu 6/21/12**	**Thu 10/17/13**
179	Layout & Control	4 days	Thu 6/21/12	Tue 6/26/12
180	Frame Hoistways	4 days	Tue 8/6/13	Fri 8/9/13
181	Frame M/E/T Closet/Rooms	4 days	Mon 8/12/13	Thu 8/15/13
182	Frame Demising Partitions	4 days	Fri 8/16/13	Wed 8/21/13
183	Frame Stairways	4 days	Thu 8/22/13	Tue 8/27/13
184	Frame Toilet Rooms	4 days	Wed 8/28/13	Mon 9/2/13
185	Partition Blocking & Backing	8 days	Tue 9/3/13	Thu 9/12/13
186	Hang M/E/T Closet/Rooms	4 days	Fri 8/16/13	Wed 8/21/13
187	Hang & Finish Partitions	10 days	Fri 9/13/13	Thu 9/26/13
188	Frame Drywall Ceilings	4 days	Fri 9/27/13	Wed 10/2/13
189	Ceiling Grid	6 days	Thu 10/3/13	Thu 10/10/13
190	Hang & Finish Drywall Ceilings	5 days	Fri 10/11/13	Thu 10/17/13
191	Drop Ceiling Tile	4 days	Fri 10/11/13	Wed 10/16/13
192	**Lower Level 4**	**376 days**	**Wed 6/27/12**	**Wed 12/4/13**
193	**Area C (Column Lines 20+)**	**376 days**	**Wed 6/27/12**	**Wed 12/4/13**
194	Layout & Control	4 days	Wed 6/27/12	Mon 7/2/12
195	Frame Hoistways	4 days	Thu 10/3/13	Tue 10/8/13
196	Frame M/E/T Closet/Rooms	4 days	Wed 10/9/13	Mon 10/14/13
197	Frame Demising Partitions	4 days	Tue 10/15/13	Fri 10/18/13
198	Frame Stairways	4 days	Mon 10/21/1	Thu 10/24/13
199	Frame Toilet Rooms	4 days	Fri 10/25/13	Wed 10/30/13
200	Hang M/E/T Closet/Rooms	4 days	Tue 10/15/13	Fri 10/18/13
201	Hang & Finish Partitions	10 days	Thu 10/31/13	Wed 11/13/13

Patrick Laninger - Senior Thesis
Drywall Baseline Schedule

ID	Task Name	Duration	Start	Finish
202	Frame Drywall Ceilings	4 days	Thu 11/14/13	Tue 11/19/13
203	Ceiling Grid	6 days	Wed 11/20/13	Wed 11/27/13
204	Hang & Finish Drywall Ceilings	5 days	Thu 11/28/13	Wed 12/4/13
205	Drop Ceiling Tile	4 days	Thu 11/28/13	Tue 12/3/13

Patrick Laninger - Senior Thesis
Updated Drywall Schedule

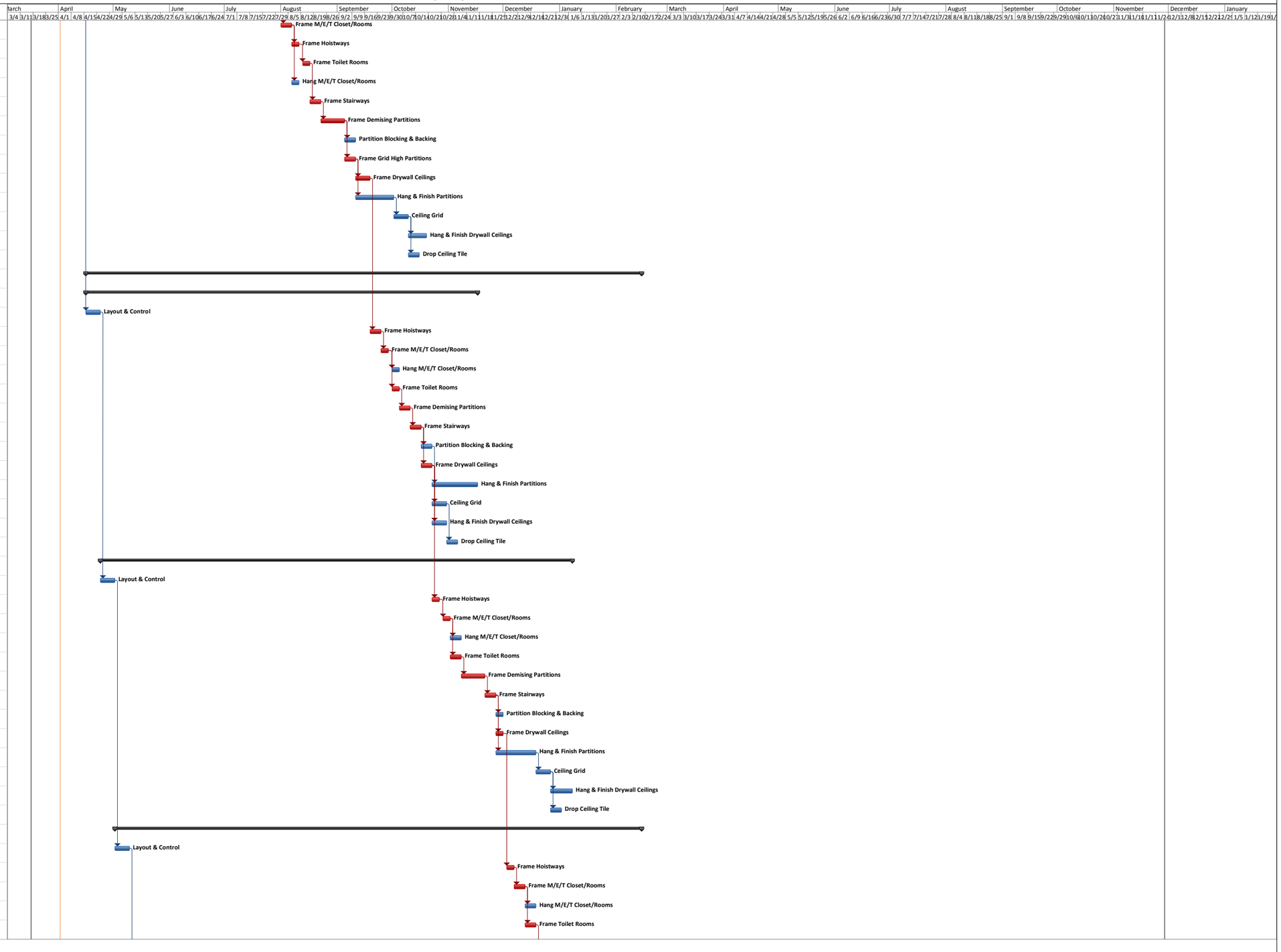
ID	Task Name	Duration	Start	Finish	Predecessors
1					
2	**Building One Drywall**	**444 days**	**Mon 3/19/12**	**Thu 11/28/13**	
3	**Lower Level 9**	**155 days**	**Mon 3/19/12**	**Fri 10/19/12**	
4	**Childcare Center**	**97 days**	**Mon 3/19/12**	**Tue 7/31/12**	
5	Layout & Control	2 days	Mon 3/19/12	Tue 3/20/12	
6	Frame Demising Partitions	7 days	Wed 3/21/12	Thu 3/29/12	5
7	Install Added 1HR Fire Wall Framing	10 days	Wed 3/21/12	Tue 4/3/12	5
8	In-Wall Blocking	5 days	Wed 4/4/12	Tue 4/10/12	7
9	Frame Bulkheads	15 days	Fri 3/30/12	Thu 4/19/12	6
10	Finish Partitions	10 days	Fri 4/20/12	Thu 5/3/12	9
11	Partition Insulation	5 days	Fri 5/4/12	Thu 5/10/12	10
12	Firestop Partitions	10 days	Fri 5/4/12	Thu 5/17/12	10
13	Hang Partitions	7 days	Fri 5/18/12	Mon 5/28/12	12
14	Hang Drywall	28 days	Fri 5/18/12	Tue 6/26/12	12
15	Install Ceiling Grid	10 days	Wed 6/27/12	Tue 7/10/12	14
16	Drop Ceiling Tile	15 days	Wed 7/11/12	Tue 7/31/12	15
17	**Area A (Column Lines 1-12)**	**72 days**	**Wed 3/21/12**	**Thu 6/28/12**	
18	Layout & Control	6 days	Wed 3/21/12	Wed 3/28/12	5
19	Frame M/E/T Closet/Rooms	4 days	Fri 4/20/12	Wed 4/25/12	9
20	Frame Toilet Rooms	4 days	Thu 4/26/12	Tue 5/1/12	19
21	Hang M/E/T Closet/Rooms	4 days	Thu 4/26/12	Tue 5/1/12	19
22	Frame Hoistways	4 days	Wed 5/2/12	Mon 5/7/12	20
23	Frame Demising Partitions	4 days	Tue 5/8/12	Fri 5/11/12	22
24	Frame Stairways	4 days	Mon 5/14/12	Thu 5/17/12	23
25	Partition Blocking & Backing	8 days	Fri 5/18/12	Tue 5/29/12	24
26	Hang & Finish Partitions	14 days	Wed 5/30/12	Mon 6/18/12	25
27	Frame Drywall Ceilings	9 days	Fri 5/18/12	Wed 5/30/12	24
28	Frame Grid High Partitions	9 days	Thu 5/31/12	Tue 6/12/12	27
29	Ceiling Grid	6 days	Wed 6/13/12	Wed 6/20/12	28
30	Hang & Finish Drywall Ceilings	6 days	Thu 6/21/12	Thu 6/28/12	29
31	Drop Ceiling Tile	4 days	Thu 6/21/12	Tue 6/26/12	29
32	**Area B (Column Lines 12-20)**	**112 days**	**Thu 3/29/12**	**Fri 8/31/12**	
33	Layout & Control	6 days	Thu 3/29/12	Thu 4/5/12	18
34	Frame M/E/T Closet/Rooms	4 days	Wed 6/13/12	Mon 6/18/12	28
35	Frame Hoistways	4 days	Tue 6/19/12	Fri 6/22/12	34
36	Frame Toilet Rooms	4 days	Mon 6/25/12	Thu 6/28/12	35
37	Hang M/E/T Closet/Rooms	4 days	Tue 6/19/12	Fri 6/22/12	34
38	Frame Stairways	4 days	Fri 6/29/12	Wed 7/4/12	36
39	Frame Demising Partitions	9 days	Thu 7/5/12	Tue 7/17/12	38
40	Partition Blocking & Backing	4 days	Wed 7/18/12	Mon 7/23/12	39
41	Frame Grid High Partitions	4 days	Wed 7/18/12	Mon 7/23/12	39
42	Frame Drywall Ceilings	6 days	Tue 7/24/12	Tue 7/31/12	41
43	Hang & Finish Partitions	15 days	Tue 7/24/12	Mon 8/13/12	41
44	Ceiling Grid	6 days	Tue 8/14/12	Tue 8/21/12	43
45	Hang & Finish Drywall Ceilings	8 days	Wed 8/22/12	Fri 8/31/12	44
46	Drop Ceiling Tile	4 days	Wed 8/22/12	Mon 8/27/12	44
47	**Area C (Column Lines 20+)**	**141 days**	**Fri 4/6/12**	**Fri 10/19/12**	
48	Layout & Control	6 days	Fri 4/6/12	Fri 4/13/12	33



Project: Drywall Schedule - After C
Date: Mon 4/2/12

Task | Milestone | Project Summary | External Milestone | Inactive Milestone | Manual Task | Manual Summary Rollup | Start-only | Deadline | Critical Split
Split | Summary | External Tasks | Inactive Task | Inactive Summary | Duration-only | Manual Summary | Finish-only | Critical | Progress

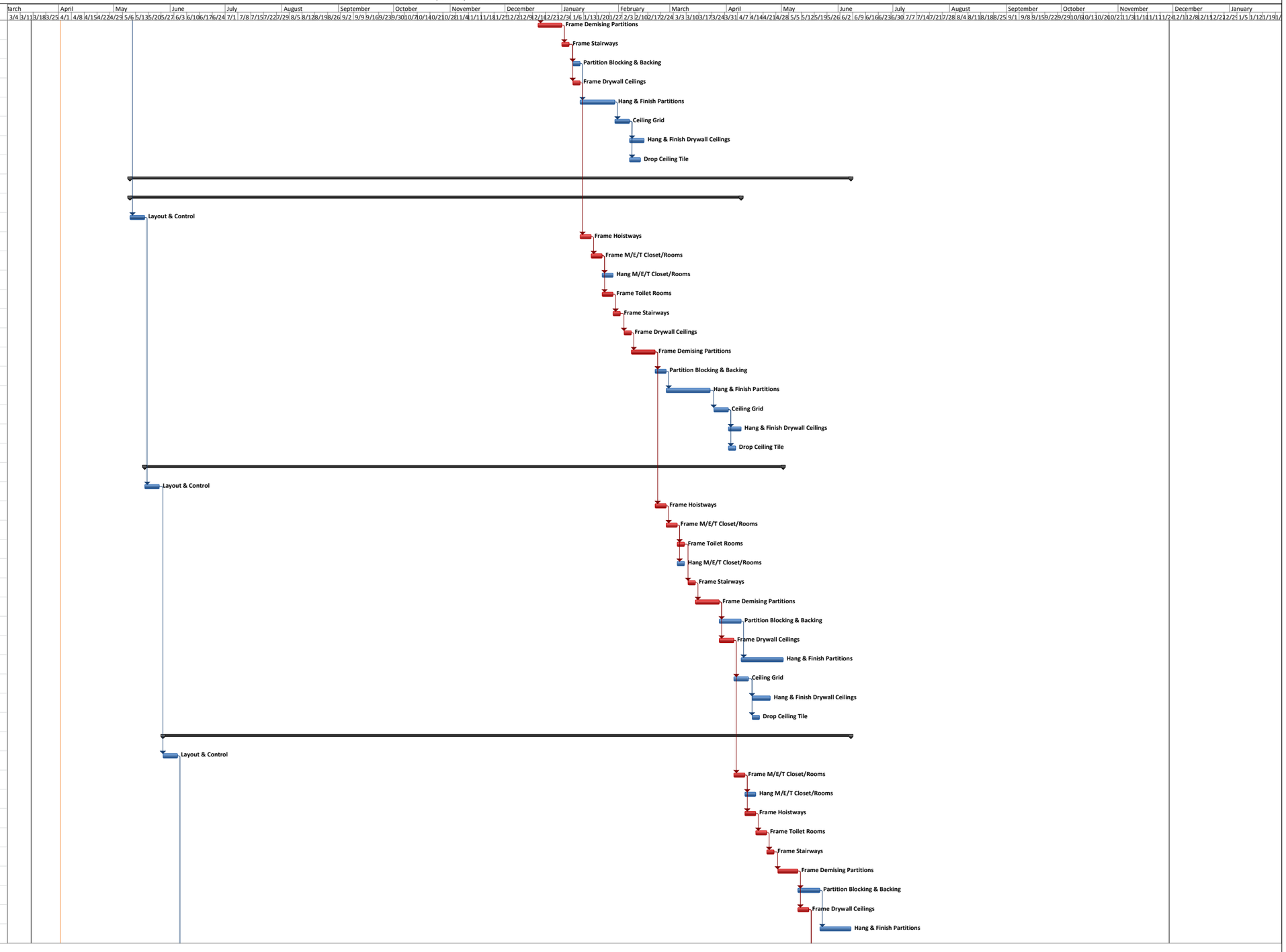
ID	Task Name	Duration	Start	Finish	Predecessors
49	Frame M/E/T Closet/Rooms	4 days	Wed 8/1/12	Mon 8/6/12	42
50	Frame Hoistways	4 days	Tue 8/7/12	Fri 8/10/12	49
51	Frame Toilet Rooms	4 days	Mon 8/13/12	Thu 8/16/12	50
52	Hang M/E/T Closet/Rooms	4 days	Tue 8/7/12	Fri 8/10/12	49
53	Frame Stairways	4 days	Fri 8/17/12	Wed 8/22/12	51
54	Frame Demising Partitions	9 days	Thu 8/23/12	Tue 9/4/12	53
55	Partition Blocking & Backing	4 days	Wed 9/5/12	Mon 9/10/12	54
56	Frame Grid High Partitions	4 days	Wed 9/5/12	Mon 9/10/12	54
57	Frame Drywall Ceilings	6 days	Tue 9/11/12	Tue 9/18/12	56
58	Hang & Finish Partitions	15 days	Tue 9/11/12	Mon 10/1/12	56
59	Ceiling Grid	6 days	Tue 10/2/12	Tue 10/9/12	58
60	Hang & Finish Drywall Ceilings	8 days	Wed 10/10/12	Fri 10/19/12	59
61	Drop Ceiling Tile	4 days	Wed 10/10/12	Mon 10/15/12	59
62	**Lower Level 8**	**219 days**	**Mon 4/16/12**	**Thu 2/14/13**	
63	**Area A (Column Lines 1-12)**	**155 days**	**Mon 4/16/12**	**Fri 11/16/12**	
64	Layout & Control	6 days	Mon 4/16/12	Mon 4/23/12	48
65	Frame Hoistways	4 days	Wed 9/19/12	Mon 9/24/12	57
66	Frame M/E/T Closet/Rooms	4 days	Tue 9/25/12	Fri 9/28/12	65
67	Hang M/E/T Closet/Rooms	4 days	Mon 10/1/12	Thu 10/4/12	66
68	Frame Toilet Rooms	4 days	Mon 10/1/12	Thu 10/4/12	66
69	Frame Demising Partitions	4 days	Fri 10/5/12	Wed 10/10/12	68
70	Frame Stairways	4 days	Thu 10/11/12	Tue 10/16/12	69
71	Partition Blocking & Backing	4 days	Wed 10/17/12	Mon 10/22/12	70
72	Frame Drywall Ceilings	4 days	Wed 10/17/12	Mon 10/22/12	70
73	Hang & Finish Partitions	19 days	Tue 10/23/12	Fri 11/16/12	71
74	Ceiling Grid	6 days	Tue 10/23/12	Tue 10/30/12	72
75	Hang & Finish Drywall Ceilings	6 days	Tue 10/23/12	Tue 10/30/12	72
76	Drop Ceiling Tile	4 days	Wed 10/31/12	Mon 11/5/12	74
77	**Area B (Column Lines 12-20)**	**185 days**	**Tue 4/24/12**	**Mon 1/7/13**	
78	Layout & Control	6 days	Tue 4/24/12	Tue 5/1/12	64
79	Frame Hoistways	4 days	Tue 10/23/12	Fri 10/26/12	72
80	Frame M/E/T Closet/Rooms	4 days	Mon 10/29/12	Thu 11/1/12	79
81	Hang M/E/T Closet/Rooms	4 days	Fri 11/2/12	Wed 11/7/12	80
82	Frame Toilet Rooms	4 days	Fri 11/2/12	Wed 11/7/12	80
83	Frame Demising Partitions	9 days	Thu 11/8/12	Tue 11/20/12	82
84	Frame Stairways	4 days	Wed 11/21/12	Mon 11/26/12	83
85	Partition Blocking & Backing	4 days	Tue 11/27/12	Fri 11/30/12	84
86	Frame Drywall Ceilings	4 days	Tue 11/27/12	Fri 11/30/12	84
87	Hang & Finish Partitions	16 days	Tue 11/27/12	Tue 12/18/12	84
88	Ceiling Grid	6 days	Wed 12/19/12	Wed 12/26/12	87
89	Hang & Finish Drywall Ceilings	8 days	Thu 12/27/12	Mon 1/7/13	88
90	Drop Ceiling Tile	4 days	Thu 12/27/12	Tue 1/1/13	88
91	**Area C (Column Lines 20+)**	**207 days**	**Wed 5/2/12**	**Thu 2/14/13**	
92	Layout & Control	6 days	Wed 5/2/12	Wed 5/9/12	78
93	Frame Hoistways	4 days	Mon 12/3/12	Thu 12/6/12	86
94	Frame M/E/T Closet/Rooms	4 days	Fri 12/7/12	Wed 12/12/12	93
95	Hang M/E/T Closet/Rooms	4 days	Thu 12/13/12	Tue 12/18/12	94
96	Frame Toilet Rooms	4 days	Thu 12/13/12	Tue 12/18/12	94



Project: Drywall Schedule - After C
Date: Mon 4/2/12

Task | Split | Milestone | Summary | Project Summary | External Tasks | External Milestone | Inactive Task | Inactive Milestone | Inactive Summary | Manual Task | Duration-only | Manual Summary Rollup | Manual Summary | Start-only | Finish-only | Deadline | Critical | Critical Split | Progress

ID	Task Name	Duration	Start	Finish	Predecessors
97	Frame Demising Partitions	9 days	Wed 12/19/12	Mon 12/31/12	96
98	Frame Stairways	4 days	Tue 1/1/13	Fri 1/4/13	97
99	Partition Blocking & Backing	4 days	Mon 1/7/13	Thu 1/10/13	98
100	Frame Drywall Ceilings	4 days	Mon 1/7/13	Thu 1/10/13	98
101	Hang & Finish Partitions	13 days	Fri 1/11/13	Tue 1/29/13	99
102	Ceiling Grid	6 days	Wed 1/30/13	Wed 2/6/13	101
103	Hang & Finish Drywall Ceilings	6 days	Thu 2/7/13	Thu 2/14/13	102
104	Drop Ceiling Tile	4 days	Thu 2/7/13	Tue 2/12/13	102
105	**Lower Level 7**	**282 days**	**Thu 5/10/12**	**Fri 6/7/13**	
106	**Area A (Column Lines 1-12)**	**238 days**	**Thu 5/10/12**	**Mon 4/8/13**	
107	Layout & Control	6 days	Thu 5/10/12	Thu 5/17/12	92
108	Frame Hoistways	4 days	Fri 1/11/13	Wed 1/16/13	100
109	Frame M/E/T Closet/Rooms	4 days	Thu 1/17/13	Tue 1/22/13	108
110	Hang M/E/T Closet/Rooms	4 days	Wed 1/23/13	Mon 1/28/13	109
111	Frame Toilet Rooms	4 days	Wed 1/23/13	Mon 1/28/13	109
112	Frame Stairways	4 days	Tue 1/29/13	Fri 2/1/13	111
113	Frame Drywall Ceilings	4 days	Mon 2/4/13	Thu 2/7/13	112
114	Frame Demising Partitions	9 days	Fri 2/8/13	Wed 2/20/13	113
115	Partition Blocking & Backing	4 days	Thu 2/21/13	Tue 2/26/13	114
116	Hang & Finish Partitions	18 days	Wed 2/27/13	Fri 3/22/13	115
117	Ceiling Grid	6 days	Mon 3/25/13	Mon 4/1/13	116
118	Hang & Finish Drywall Ceilings	5 days	Tue 4/2/13	Mon 4/8/13	117
119	Drop Ceiling Tile	4 days	Tue 4/2/13	Fri 4/5/13	117
120	**Area B (Column Lines 12-20)**	**249 days**	**Fri 5/18/12**	**Wed 5/1/13**	
121	Layout & Control	6 days	Fri 5/18/12	Fri 5/25/12	107
122	Frame Hoistways	4 days	Thu 2/21/13	Tue 2/26/13	114
123	Frame M/E/T Closet/Rooms	4 days	Wed 2/27/13	Mon 3/4/13	122
124	Frame Toilet Rooms	4 days	Tue 3/5/13	Fri 3/8/13	123
125	Hang M/E/T Closet/Rooms	4 days	Tue 3/5/13	Fri 3/8/13	123
126	Frame Stairways	4 days	Mon 3/11/13	Thu 3/14/13	124
127	Frame Demising Partitions	9 days	Fri 3/15/13	Wed 3/27/13	126
128	Partition Blocking & Backing	8 days	Thu 3/28/13	Mon 4/8/13	127
129	Frame Drywall Ceilings	6 days	Thu 3/28/13	Thu 4/4/13	127
130	Hang & Finish Partitions	17 days	Tue 4/9/13	Wed 5/1/13	128
131	Ceiling Grid	6 days	Fri 4/5/13	Fri 4/12/13	129
132	Hang & Finish Drywall Ceilings	8 days	Mon 4/15/13	Wed 4/24/13	131
133	Drop Ceiling Tile	4 days	Mon 4/15/13	Thu 4/18/13	131
134	**Area C (Column Lines 20+)**	**270 days**	**Mon 5/28/12**	**Fri 6/7/13**	
135	Layout & Control	6 days	Mon 5/28/12	Mon 6/4/12	121
136	Frame M/E/T Closet/Rooms	4 days	Fri 4/5/13	Wed 4/10/13	129
137	Hang M/E/T Closet/Rooms	4 days	Thu 4/11/13	Tue 4/16/13	136
138	Frame Hoistways	4 days	Thu 4/11/13	Tue 4/16/13	136
139	Frame Toilet Rooms	4 days	Wed 4/17/13	Mon 4/22/13	138
140	Frame Stairways	4 days	Tue 4/23/13	Fri 4/26/13	139
141	Frame Demising Partitions	9 days	Mon 4/29/13	Thu 5/9/13	140
142	Partition Blocking & Backing	8 days	Fri 5/10/13	Tue 5/21/13	141
143	Frame Drywall Ceilings	4 days	Fri 5/10/13	Wed 5/15/13	141
144	Hang & Finish Partitions	13 days	Wed 5/22/13	Fri 6/7/13	142



Project: Drywall Schedule - After C
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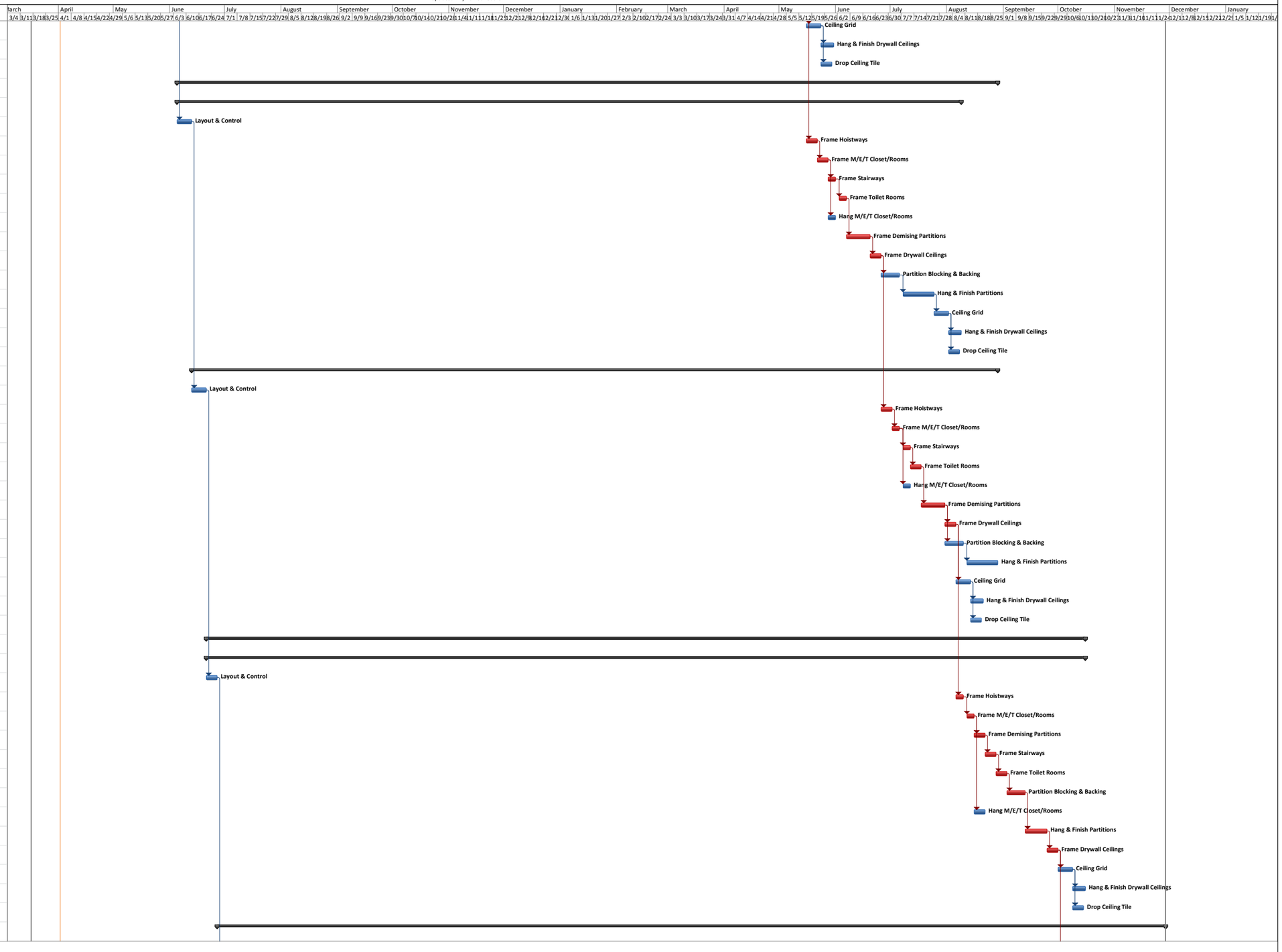
Task, Split, Milestone, Summary, Project Summary, External Tasks, External Milestone, Inactive Task, Inactive Milestone, Inactive Summary, Manual Task, Duration-only, Manual Summary Rollup, Manual Summary, Start-only, Finish-only, Deadline, Critical, Critical Split, Progress

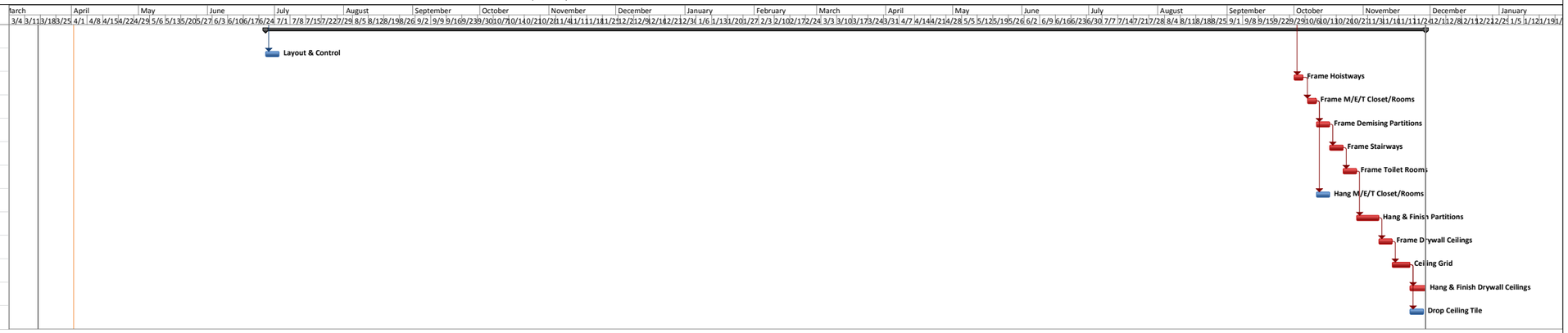
ID	Task Name	Duration	Start	Finish	Predecessors
145	Ceiling Grid	6 days	Thu 5/16/13	Thu 5/23/13	143
146	Hang & Finish Drywall Ceilings	5 days	Fri 5/24/13	Thu 5/30/13	145
147	Drop Ceiling Tile	4 days	Fri 5/24/13	Wed 5/29/13	145
148	**Lower Level 6**	**322 days**	**Tue 6/5/12**	**Wed 8/28/13**	
149	**Area B (Column Lines 12-20)**	**308 days**	**Tue 6/5/12**	**Thu 8/8/13**	
150	Layout & Control	6 days	Tue 6/5/12	Tue 6/12/12	135
151	Frame Hoistways	4 days	Thu 5/16/13	Tue 5/21/13	143
152	Frame M/E/T Closet/Rooms	4 days	Wed 5/22/13	Mon 5/27/13	151
153	Frame Stairways	4 days	Tue 5/28/13	Fri 5/31/13	152
154	Frame Toilet Rooms	4 days	Mon 6/3/13	Thu 6/6/13	153
155	Hang M/E/T Closet/Rooms	4 days	Tue 5/28/13	Fri 5/31/13	152
156	Frame Demising Partitions	9 days	Fri 6/7/13	Wed 6/19/13	154
157	Frame Drywall Ceilings	4 days	Thu 6/20/13	Tue 6/25/13	156
158	Partition Blocking & Backing	8 days	Wed 6/26/13	Fri 7/5/13	157
159	Hang & Finish Partitions	13 days	Mon 7/8/13	Wed 7/24/13	158
160	Ceiling Grid	6 days	Thu 7/25/13	Thu 8/1/13	159
161	Hang & Finish Drywall Ceilings	5 days	Fri 8/2/13	Thu 8/8/13	160
162	Drop Ceiling Tile	4 days	Fri 8/2/13	Wed 8/7/13	160
163	**Area C (Column Lines 20+)**	**316 days**	**Wed 6/13/12**	**Wed 8/28/13**	
164	Layout & Control	6 days	Wed 6/13/12	Wed 6/20/12	150
165	Frame Hoistways	4 days	Wed 6/26/13	Mon 7/1/13	157
166	Frame M/E/T Closet/Rooms	4 days	Tue 7/2/13	Fri 7/5/13	165
167	Frame Stairways	4 days	Mon 7/8/13	Thu 7/11/13	166
168	Frame Toilet Rooms	4 days	Fri 7/12/13	Wed 7/17/13	167
169	Hang M/E/T Closet/Rooms	4 days	Mon 7/8/13	Thu 7/11/13	166
170	Frame Demising Partitions	9 days	Thu 7/18/13	Tue 7/30/13	168
171	Frame Drywall Ceilings	4 days	Wed 7/31/13	Mon 8/5/13	170
172	Partition Blocking & Backing	8 days	Wed 7/31/13	Fri 8/9/13	170
173	Hang & Finish Partitions	13 days	Mon 8/12/13	Wed 8/28/13	172
174	Ceiling Grid	6 days	Tue 8/6/13	Tue 8/13/13	171
175	Hang & Finish Drywall Ceilings	5 days	Wed 8/14/13	Tue 8/20/13	174
176	Drop Ceiling Tile	4 days	Wed 8/14/13	Mon 8/19/13	174
177	**Lower Level 5**	**344 days**	**Thu 6/21/12**	**Tue 10/15/13**	
178	**Area C (Column Lines 20+)**	**344 days**	**Thu 6/21/12**	**Tue 10/15/13**	
179	Layout & Control	4 days	Thu 6/21/12	Tue 6/26/12	164
180	Frame Hoistways	4 days	Tue 8/6/13	Fri 8/9/13	171
181	Frame M/E/T Closet/Rooms	4 days	Mon 8/12/13	Thu 8/15/13	180
182	Frame Demising Partitions	4 days	Fri 8/16/13	Wed 8/21/13	181
183	Frame Stairways	4 days	Thu 8/22/13	Tue 8/27/13	182
184	Frame Toilet Rooms	4 days	Wed 8/28/13	Mon 9/2/13	183
185	Partition Blocking & Backing	8 days	Tue 9/3/13	Thu 9/12/13	184
186	Hang M/E/T Closet/Rooms	4 days	Fri 8/16/13	Wed 8/21/13	181
187	Hang & Finish Partitions	8 days	Fri 9/13/13	Tue 9/24/13	185
188	Frame Drywall Ceilings	4 days	Wed 9/25/13	Mon 9/30/13	187
189	Ceiling Grid	6 days	Tue 10/1/13	Tue 10/8/13	188
190	Hang & Finish Drywall Ceilings	5 days	Wed 10/9/13	Tue 10/15/13	189
191	Drop Ceiling Tile	4 days	Wed 10/9/13	Mon 10/14/13	189
192	**Lower Level 4**	**372 days**	**Wed 6/27/12**	**Thu 11/28/13**	



Project: Drywall Schedule - After C
Date: Mon 4/2/12

Task, Split, Milestone, Summary, Project Summary, External Tasks, External Milestone, Inactive Task, Inactive Milestone, Inactive Summary, Manual Task, Duration-only, Manual Summary Rollup, Manual Summary, Start-only, Finish-only, Deadline, Critical, Critical Split, Progress

ID	Task Name	Duration	Start	Finish	Predecessors
193	**Area C (Column Lines 20+)**	**372 days**	**Wed 6/27/12**	**Thu 11/28/13**	
194	Layout & Control	4 days	Wed 6/27/12	Mon 7/2/12	179
195	Frame Hoistways	4 days	Tue 10/1/13	Fri 10/4/13	188
196	Frame M/E/T Closet/Rooms	4 days	Mon 10/7/13	Thu 10/10/13	195
197	Frame Demising Partitions	4 days	Fri 10/11/13	Wed 10/16/13	196
198	Frame Stairways	4 days	Thu 10/17/13	Tue 10/22/13	197
199	Frame Toilet Rooms	4 days	Wed 10/23/13	Mon 10/28/13	198
200	Hang M/E/T Closet/Rooms	4 days	Fri 10/11/13	Wed 10/16/13	196
201	Hang & Finish Partitions	8 days	Tue 10/29/13	Thu 11/7/13	199
202	Frame Drywall Ceilings	4 days	Fri 11/8/13	Wed 11/13/13	201
203	Ceiling Grid	6 days	Thu 11/14/13	Thu 11/21/13	202
204	Hang & Finish Drywall Ceilings	5 days	Fri 11/22/13	Thu 11/28/13	203
205	Drop Ceiling Tile	4 days	Fri 11/22/13	Wed 11/27/13	203



APPENDIX E – MASONRY TRADE SURVEYS

Masonry Trade Survey
The purpose of this survey is to determine how simplifying a brick façade can affect the productivity at which brick masonry can be erected. My thesis work focuses on encouraging designers to consider construction productivity when designing their buildings.

Name: Mike Dorment
Company: WEI Construction

Name: Glenn Feldstein
Company: Telligent Masonry, LLC.

Name: Delayne Horton
Company: Falls Church Construction Corporation

Name: Bob Plutko
Company: Harris Masonry, Inc.

Name: Ray Sekowski
Company: Cost Construction

Name: Steve Sullivan
Company: Genco Masonry

Q: Is the construction of a brick corner assembly faster or slower than the construction of a straight wall? Approximately how much more/less time is dedicated to the construction of a corner compared to a straight wall?

Mike Dorment: Construction of a brick corner is much slower than running straight line production work. Generally, a more experienced (expensive) mason builds the corners and the young guys "beat the line". I would guesstimate the corners are 30-40 slower than line work.

Glenn Feldstein: Corners require more skill to construction and only the most qualified masons should build corners. Masonry walls should always start at the corners, so the corner is considered the lead and is typically ahead of the adjacent straight walls. No additional time is necessary to construct a corner if the properly qualified mason is laying it.

Delayne Horton: Brick corners are typically slower production than a straight wall. Usually you would start one of your best bricklayers about an hour before the rest to build a "lead" or corner. By starting the bricklayer about an hour earlier allows you to establish the lead or corner so that when the rest of the bricklayers come to the wall, the corner and lines will be established to allow your bricklayers to start at full speed. Corners do require more level and square work to determine your proper brick coursing. There is not much more work required with a corner other than the level work. If you are working an estimate then you would be looking at a difference of approximately 50-100 brick production at a corner.

Bob Plutko: If one hour is spent dropping a string plumb line or setting a plumb corner pole, a mason can construct either an inside or outside corner with the same ease as constructing a straight wall.

Ray Sekowski: The construction of a corner is much slower than a straight wall. Approximately double the time to do the same square footage (corner vs. straight).

Steve Sullivan: A corner is much slower to build because the bricklayer has to put down his trowels and pick up a level in order to plumb the corner. This makes building a corner about 50% slower than a straight wall.

Q: Does the installation of a brick corner require special equipment or additional laborers? If so, what equipment and how many laborers?

Mike Dorment: Yes, special equipment is needed. Corner poles, brackets, clamps and lines are used. You do not need additional laborers.

Glenn Feldstein: On large scale masonry projects aluminum corner poles are used to expedite construction and avoid uneven coursing by the masons. No additional equipment or labor is required to lay a corner. If your masonry sub is charging to use corner poles you've hired the wrong masonry company; they are typical and help with QC and production.

Delayne Horton: Usually at a brick corner you want to set up a corner pole. To set up a corner pole you basically need a tape measure, level, corner pole, mounting bracket, clamps, and maybe a laser if you have one available. You would require a laborer just to help hold the pole in the right location to clamp it in place. Other than that it does not take much to set up for a corner if done right.

Bob Plutko: There is no special equipment or additional laborers needed.

Ray Sekowski: There are no additional laborers required to do a corner. The bricklayer would need a level to make sure the corner is straight.

Steve Sullivan: On multi-story buildings we sometimes drop jack lines from above to assist the bricklayer in making sure the corner stays plumb. There is actually less labor needed because the installation is so much slower.

Q: If recessions in the façade require outriggers on scaffolding, how much more/less expensive are these outriggers (on average)? How much time is allotted for the construction of these outriggers?

Mike Dorment: Figure an outrigger costs $1.50 per month to rent and the planking on tip is an additional $5.60. The cost to install them is minimal. Usually, the install is picked up under general scaffold erection.

Glenn Feldstein: All masonry scaffolds should be constructed with outriggers for maximum production. The outriggers allow the masons to always be at the optimal production height and since the main scaffold behind the masons is higher, it limits bending by the masons when picking up brick and therefore increases production. No substantial time is needed to install outriggers. However, scaffold construction time can be substantially limited by the use of mast-climbing scaffold (instead of typical scaffold frames) such as Fraco or Hydromobile. Mast-climbing units only have to be built once and require very limited additional labor or materials as it is raised.

Delayne Horton: This all depends on the type of scaffolding being used. If a hydraulic platform scaffold is being used, it is just a matter of proper placement of the unit and the outrigger locations. There are attachments however that can be used to add outriggers which only cost about $25.00 - $75.00 a month. If you use tube scaffolding then it is all in the set up location of the scaffolding to determine if longer outriggers will be required. If there are longer outriggers required then it would only cost you about $.50 - $1.00 more per outrigger per month.

Bob Plutko: Extension outriggers are used an they are typically 25% more expensive than standard outriggers. Competent scaffold builders are required on all jobs, and along with the training and experience, they are able to erect the most complex scaffolding with minimal additional labor time.

Ray Sekowski: All masonry work is performed off of outriggers. The only difference would be the size (length) of the outrigger. The difference between the size of outriggers is approximately $0.10 per outrigger on a monthly rental.

Steve Sullivan: If you are using a swing scaffold or a Fraco platform scaffold, once your outriggers are built, they will be consistent up the façade so the cost of building them is minimal. The real cost is that if you have a recess in the façade it indicates that you will have corners, which increase your cost. Also, when bricklayers are working on outriggers, they are not as stable and the bricklayers are more careful and move slower, thereby further reducing your production.

Q: Does the use of outriggers for façade construction affect the safety of the workers on and below the platform? If so, it what way?

Mike Dorment: I think safety is increased by using outriggers. Production is increased by using outriggers. The masons have a straight run and materials can be stored behind them.

Glenn Feldstein: Nobody should ever be working below any type of scaffold where personnel are working above. Safety on the scaffold is increased slightly since the masons and their tenders (laborers) are not crossing paths. Overall the use of outriggers has very little effect on safety.

Delayne Horton: Yes, if the outriggers are too short then there is a concern of falling materials from between the outriggers and the face of the wall. Not to mention the loss of production from the bricklayers for being uncomfortable with the condition. Anytime you are under a mason's scaffold there is a safety concern. Usually the only people allowed under the scaffold would be the masons who are aware of all of the hazards.

Bob Plutko: As mentioned before, competent, trained scaffold erectors see that safety is never compromised. Daily inspections of scaffolding are mandatory.

Ray Sekowski: The use of outriggers does not affect the safety of the workers on the outriggers. If the surface is fully planked, it will be safe. However, the use of outriggers can present a safety issue with regards to workers under the platform. It is a good practice to not allow any workers under the platform due to the possibility of falling debris.

Steve Sullivan: Depending on the depth of the setback, the outriggers almost act as a diving board. This makes the bricklayers move at a slower pace and that reduces their production. The areas below the scaffold should always be roped off as a no access zone.

Q: Does the presence of numerous brick corners affect the quality of the brick façade? If so, in what way?

Mike Dorment: The quality of work depends on the mechanic installing the corners. Again, usually the better mechanic will work the corners. The quality of the façade is increased because the corners help tie the walls together and also break up the site lines.

Glenn Feldstein: The structural quality is increased as corners are the strongest part of a masonry wall, but there is a risk that the finished product could appear to "wander" or twist when viewed from directly below. i.e. the corner would not appear to be a true 90 degree corner.

Delayne Horton: I do not feel it affects the quality of the brick façade. It would however affect the cost of labor. If anything it provides visual depth to the building which some find more appealing. As far as if additional brick corners provide any structural strength, I would not know.

Bob Plutko: No.

Ray Sekowski: If done correctly, the presence of brick corners should NOT affect the quality of the façade.

Steve Sullivan: The quality should not be affected. As a matter of fact, the quality should be better because the installation happens at a slower pace.

Q: Does the presence of numerous brick corners affect the water tightness of the brick façade? If so, in what way?

Mike Dorment: Anytime there is a break in flashing or waterproofing, be it at a window, door or corner, there is more of a change of failure. I don't think it's a tremendous risk, but the chance is greater.

Glenn Feldstein: Corners in brick work have no effect on the water tightness of a brick façade because brick are not waterproof, they are porous. Brick is always installed with a cavity behind it when there is a climate-controlled, livable space behind. The cavity is typically backed with a vapor barrier full height and through-wall flashing at the base of the cavity. Weep vents are installed in the brick head joints (usually every 24") so that any water that gets inside the cavity can drain out through the weeps.

Delayne Horton: It could. Multiple corners provide a challenge for the installation of flashing and require more overlaps, which could lead to a lap not being sealed properly. This all falls under the company's quality control policy.

Bob Plutko: No

Ray Sekowski: If installed correctly, corners should not affect the water tightness of the façade.

Steve Sullivan: Corners should not affect the water tightness as long as the flashing is properly installed. Because of all the corners, the cost of flashing and the installation will increase.

APPENDIX F – TRANE TRACE MECHANICAL ANALYSIS

PROJECT INFORMATION

Location	
Building owner	
Program user	
Company	
Comments	

By	**ACADEMIC**
Dataset name	**I:\Thesis\Thesis Work\Final Thesis\Facade Simplification\Trane Analysis\Thermal Analysis.trc**

Calculation time	**08:11 PM on 04/01/2012**	
TRACE® 700 version	**6.2.6.5**	
Location	**Washington, D.C.**	
Latitude	**38.0**	**deg**
Longitude	**77.0**	**deg**
Time Zone	**5**	
Elevation	**14**	**ft**
Barometric pressure	**29.9**	**in. Hg**
Air density	**0.0760**	**lb/cu ft**
Air specific heat	**0.2444**	**Btu/lb·°F**
Density-specific heat product	**1.1147**	**Btu/h·cfm·°F**
Latent heat factor	**4,906.9**	**Btu·min/h·cu ft**
Enthalpy factor	**4.5604**	**lb·min/hr·cu ft**
Summer design dry bulb	**91**	**°F**
Summer design wet bulb	**77**	**°F**
Winter design dry bulb	**17**	**°F**
Summer clearness number	**0.85**	
Winter clearness number	**0.85**	
Summer ground reflectance	**0.20**	
Winter ground reflectance	**0.20**	
Carbon Dioxide Level	**400**	**ppm**
Design simulation period	**January - December**	
Cooling load methodology	**TETD-TA1**	
Heating load methodology	**UATD**	

ENGINEERING CHECKS

By ACADEMIC

System	Zone	Room	Type	Floor Area ft²	COOLING % OA	COOLING cfm/ft²	COOLING cfm/ton	COOLING ft²/ton	COOLING Btu/hr·ft²	HEATING % OA	HEATING cfm/ft²	HEATING Btu/hr·ft²
Alternative 1												
	Brick Room		Zone	100	0.00	0.31	372.5	1,216.8	9.86	0.00	0.09	-15.55
System - 001			**System - VAV w/Baseboard Heating**	**100**	**0.00**	**0.31**	**372.5**	**1,216.8**	**9.86**	**0.00**	**0.09**	**-15.55**

Room Checksums

By ACADEMIC

Brick Room

COOLING COIL PEAK

Peaked at Time: Mo/Hr: 7 / 22
Outside Air: OADB/WB/HR: 80 / 73 / 109

	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)
Envelope Loads				
Skylite Solar	0	0	0	0
Skylite Cond	0	0	0	0
Roof Cond	0	524	524	53
Glass Solar	0	0	0	0
Glass/Door Cond	0	0	0	0
Wall Cond	400	62	462	47
Partition/Door	0		0	0
Floor	0		0	0
Adjacent Floor	0	0	0	0
Infiltration	0		0	0
Sub Total ==>	400	586	986	100
Internal Loads				
Lights	0	0	0	0
People	0	0	0	0
Misc	0	0	0	0
Sub Total ==>	0	0	0	0
Ceiling Load	282	-282	0	0
Ventilation Load	0	0	0	0
Adj Air Trans Heat	0		0	0
Dehumid. Ov Sizing			0	0
Ov/Undr Sizing	0		0	0
Exhaust Heat		0	0	0
Sup. Fan Heat			0	0
Ret. Fan Heat		0	0	0
Duct Heat Pkup		0	0	0
Underflr Sup Ht Pkup			0	0
Supply Air Leakage		0	0	0
Grand Total ==>	682	304	986	100.00

CLG SPACE PEAK

Mo/Hr: 7 / 22
OADB: 80

	Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads		
Skylite Solar	0	0
Skylite Cond	0	0
Roof Cond	0	0
Glass Solar	0	0
Glass/Door Cond	0	0
Wall Cond	400	59
Partition/Door	0	0
Floor	0	0
Adjacent Floor	0	0
Infiltration	0	0
Sub Total ==>	400	59
Internal Loads		
Lights	0	0
People	0	0
Misc	0	0
Sub Total ==>	0	0
Ceiling Load	282	41
Ventilation Load	0	0
Adj Air Trans Heat	0	0
Ov/Undr Sizing	0	0
Grand Total ==>	682	100.00

HEATING COIL PEAK

Mo/Hr: Heating Design
OADB: 17

	Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	0	0.00
Roof Cond	0	-472	27.63
Glass Solar	0	0	0.00
Glass/Door Cond	0	0	0.00
Wall Cond	-916	-1,079	63.17
Partition/Door	0	0	0.00
Floor	0	0	0.00
Adjacent Floor	0	0	0.00
Infiltration	0	0	0.00
Sub Total ==>	-916	-1,551	90.79
Internal Loads			
Lights	0	0	0.00
People	0	0	0.00
Misc	0	0	0.00
Sub Total ==>	0	0	0.00
Ceiling Load	-480	0	0.00
Ventilation Load	0	0	0.00
Adj Air Trans Heat	0	0	0
Ov/Undr Sizing	0	0	0.00
Exhaust Heat		0	0.00
OA Preheat Diff.		0	0.00
RA Preheat Diff.		-4	0.22
Additional Reheat		-154	8.99
System Plenum Heat		0	0.00
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	-1,396	-1,709	100.00

TEMPERATURES

	Cooling	Heating
SADB	55.0	70.0
Ra Plenum	83.9	54.8
Return	83.9	54.8
Ret/OA	83.9	54.8
Fn MtrTD	0.0	0.0
Fn BldTD	0.0	0.0
Fn Frict	0.0	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	31	9
Terminal	31	9
Main Fan	31	9
Sec Fan	0	0
Nom Vent	0	0
AHU Vent	0	0
Infil	0	0
MinStop/Rh	9	9
Return	31	9
Exhaust	0	0
Rm Exh	0	0
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	0.0	0.0
cfm/ft²	0.31	0.09
cfm/ton	372.46	
ft²/ton	1,216.84	
Btu/hr·ft²	9.86	-15.55
No. People	0	

COOLING COIL SELECTION

	Total Capacity ton	Total Capacity MBh	Sens Cap. MBh	Coil Airflow cfm	Enter DB °F	Enter WB °F	Enter gr/lb	Leave DB °F	Leave WB °F	Leave gr/lb
Main Clg	0.1	1.0	1.0	31	83.9	60.3	40.5	55.0	48.5	40.2
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Opt Vent	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	0.1	1.0								

AREAS

	Gross Total ft²	Glass ft²	Glass (%)
Floor	100		
Part	0		
Int Door	0		
ExFlr	0		
Roof	100	0	0
Wall	400	0	0
Ext Door	0	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-1.6	0	0.0	0.0
Aux Htg	0.0	0	0.0	0.0
Preheat	0.0	31	54.8	55.0
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-1.6			

SYSTEM SUMMARY

DESIGN COOLING CAPACITIES

By ACADEMIC

Alternative 1

Building Airside Systems and Plant Capacities

Plant / System	Peak Plant Loads: Main Coil ton	Aux Coil ton	Opt Vent Coil ton	Misc Load ton	Stg 1 Desic Cond ton	Stg 2 Desic Cond ton	Base Utility ton	Peak Total ton	Block Plant Loads: Time Of Peak mo/hr	Main Coil ton	Aux Coil ton	Opt Vent Coil ton	Misc Load ton	Stg 1 Desic Cond ton	Stg 2 Desic Cond ton	Base Utility ton	Block Total ton
Unassigned Cooling Loads	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	8/22	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1
System - 001	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	8/22	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Building totals	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1		0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1

Building peak load is 0.1 tons.

Building maximum block load of 0.1 tons occurs in August at hour 22 based on system simulation.

SYSTEM SUMMARY

DESIGN HEATING CAPACITIES

By ACADEMIC

Alternative 1

System Coil Capacities

System Description	System Type	Main System Btu/h	Aux System Btu/h	Preheat Btu/h	Reheat Btu/h	Humid. Btu/h	Optional Vent Btu/h	Stg 1 Desic Regen Btu/h	Stg 2 Desic Regen Btu/h	Stg 1 Frost Prevention Btu/h	Stg 2 Frost Prevention Btu/h	Heating Totals Btu/h
System - 001	VAV w/Baseboard Heating	-1,550	0	-5	-154	0	0	0	0	0	0	-1,555
Totals		**-1,550**	**0**	**-5**	**-154**	**0**	**0**	**0**	**0**	**0**	**0**	**-1,555**

Building Plant Capacities

Plant	System	Peak Loads												
		Main Coil MBh	Preheat Coil MBh	Reheat Coil MBh	Humid. Coil MBh	Aux Coil MBh	Opt Vent Coil MBh	Misc Load MBh	Stg 1 Desic. Regen. MBh	Stg 2 Desic. Regen. MBh	Stg 1 Frost Prev. MBh	Stg 2 Frost Prev. MBh	Base Utility MBh	Absorption Load MBh
Unassigned Heating Loads		2	0	0	0	0	0	0	0	0	0	0	0	0
	System - 001	2	0	0	0	0	0	0	0	0	0	0	0	0

Building peak load is 1.6 MBh.

BUILDING COOL HEAT DEMAND

By ACADEMIC

January	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	33.3	30.1	-625	0.0	-916	0.0	-916	0.0	-916	0.0	-916	0.0
2	31.6	28.5	-648	0.0	-918	0.0	-918	0.0	-918	0.0	-918	0.0
3	30.1	27.2	-676	0.0	-925	0.0	-925	0.0	-925	0.0	-925	0.0
4	28.9	25.8	-707	0.0	-935	0.0	-935	0.0	-935	0.0	-935	0.0
5	28.0	25.3	-740	0.0	-948	0.0	-948	0.0	-948	0.0	-948	0.0
6	27.4	24.7	-772	0.0	-964	0.0	-964	0.0	-964	0.0	-964	0.0
7	27.2	24.7	-803	0.0	-981	0.0	-981	0.0	-981	0.0	-981	0.0
8	27.8	25.2	-833	0.0	-1,000	0.0	-1,000	0.0	-1,000	0.0	-1,000	0.0
9	29.3	26.5	-861	0.0	-1,019	0.0	-1,019	0.0	-1,019	0.0	-1,019	0.0
10	31.6	28.3	-886	0.0	-1,038	0.0	-1,038	0.0	-1,038	0.0	-1,038	0.0
11	34.4	30.4	-904	0.0	-1,055	0.0	-1,055	0.0	-1,055	0.0	-1,055	0.0
12	37.5	32.5	-910	0.0	-1,066	0.0	-1,066	0.0	-1,066	0.0	-1,066	0.0
13	40.3	34.5	-903	0.0	-1,072	0.0	-1,072	0.0	-1,072	0.0	-1,072	0.0
14	42.6	36.5	-882	0.0	-1,071	0.0	-1,071	0.0	-1,071	0.0	-1,071	0.0
15	44.1	37.4	-851	0.0	-1,063	0.0	-1,063	0.0	-1,063	0.0	-1,063	0.0
16	44.7	37.5	-810	0.0	-1,050	0.0	-1,050	0.0	-1,050	0.0	-1,050	0.0
17	44.5	37.5	-763	0.0	-1,031	0.0	-1,031	0.0	-1,031	0.0	-1,031	0.0
18	43.9	37.6	-715	0.0	-1,009	0.0	-1,009	0.0	-1,009	0.0	-1,009	0.0
19	43.0	37.2	-670	0.0	-986	0.0	-986	0.0	-986	0.0	-986	0.0
20	41.8	36.8	-635	0.0	-965	0.0	-965	0.0	-965	0.0	-965	0.0
21	40.3	35.7	-613	0.0	-948	0.0	-948	0.0	-948	0.0	-948	0.0
22	38.6	34.5	-602	0.0	-934	0.0	-934	0.0	-934	0.0	-934	0.0
23	36.9	33.3	-601	0.0	-924	0.0	-924	0.0	-924	0.0	-924	0.0
24	35.0	31.5	-609	0.0	-917	0.0	-917	0.0	-917	0.0	-917	0.0

February	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	34.4	30.4	-535	0.0	-888	0.0	-888	0.0	-888	0.0	-888	0.0
2	33.0	29.3	-562	0.0	-893	0.0	-893	0.0	-893	0.0	-893	0.0
3	31.8	28.3	-595	0.0	-902	0.0	-902	0.0	-902	0.0	-902	0.0
4	30.8	27.4	-631	0.0	-913	0.0	-913	0.0	-913	0.0	-913	0.0
5	30.1	26.7	-667	0.0	-927	0.0	-927	0.0	-927	0.0	-927	0.0
6	29.6	26.2	-703	0.0	-942	0.0	-942	0.0	-942	0.0	-942	0.0
7	29.5	26.2	-737	0.0	-959	0.0	-959	0.0	-959	0.0	-959	0.0
8	29.9	26.8	-770	0.0	-977	0.0	-977	0.0	-977	0.0	-977	0.0
9	31.1	27.9	-799	0.0	-994	0.0	-994	0.0	-994	0.0	-994	0.0
10	33.0	28.8	-823	0.0	-1,011	0.0	-1,011	0.0	-1,011	0.0	-1,011	0.0
11	35.3	29.9	-838	0.0	-1,025	0.0	-1,025	0.0	-1,025	0.0	-1,025	0.0
12	37.8	31.8	-840	0.0	-1,033	0.0	-1,033	0.0	-1,033	0.0	-1,033	0.0
13	40.1	33.0	-828	0.0	-1,036	0.0	-1,036	0.0	-1,036	0.0	-1,036	0.0
14	41.9	34.7	-802	0.0	-1,032	0.0	-1,032	0.0	-1,032	0.0	-1,032	0.0
15	43.2	35.5	-766	0.0	-1,023	0.0	-1,023	0.0	-1,023	0.0	-1,023	0.0
16	43.6	35.8	-721	0.0	-1,008	0.0	-1,008	0.0	-1,008	0.0	-1,008	0.0
17	43.4	35.9	-671	0.0	-989	0.0	-989	0.0	-989	0.0	-989	0.0
18	43.0	35.8	-618	0.0	-968	0.0	-968	0.0	-968	0.0	-968	0.0
19	42.3	36.0	-570	0.0	-945	0.0	-945	0.0	-945	0.0	-945	0.0
20	41.3	35.9	-532	0.0	-925	0.0	-925	0.0	-925	0.0	-925	0.0
21	40.1	35.0	-509	0.0	-910	0.0	-910	0.0	-910	0.0	-910	0.0
22	38.7	34.0	-500	0.0	-898	0.0	-898	0.0	-898	0.0	-898	0.0
23	37.3	32.9	-502	0.0	-891	0.0	-891	0.0	-891	0.0	-891	0.0
24	35.8	31.5	-514	0.0	-887	0.0	-887	0.0	-887	0.0	-887	0.0

BUILDING COOL HEAT DEMAND

By ACADEMIC

March	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	44.1	39.1	-178	0.0	-557	0.0	-557	0.0	-557	0.0	-557	0.0
2	42.3	37.7	-211	0.0	-563	0.0	-563	0.0	-563	0.0	-563	0.0
3	40.6	36.3	-250	0.0	-574	0.0	-574	0.0	-574	0.0	-574	0.0
4	39.2	35.1	-294	0.0	-588	0.0	-588	0.0	-588	0.0	-588	0.0
5	38.2	34.7	-339	0.0	-607	0.0	-607	0.0	-607	0.0	-607	0.0
6	37.6	34.1	-383	0.0	-627	0.0	-627	0.0	-627	0.0	-627	0.0
7	37.4	34.0	-426	0.0	-649	0.0	-649	0.0	-649	0.0	-649	0.0
8	37.9	34.5	-466	0.0	-673	0.0	-673	0.0	-673	0.0	-673	0.0
9	39.6	35.5	-503	0.0	-696	0.0	-696	0.0	-696	0.0	-696	0.0
10	42.3	37.0	-531	0.0	-718	0.0	-718	0.0	-718	0.0	-718	0.0
11	45.5	39.1	-547	0.0	-736	0.0	-736	0.0	-736	0.0	-736	0.0
12	48.9	41.4	-546	0.0	-747	0.0	-747	0.0	-747	0.0	-747	0.0
13	52.1	43.5	-530	0.0	-751	0.0	-751	0.0	-751	0.0	-751	0.0
14	54.7	45.5	-500	0.0	-747	0.0	-747	0.0	-747	0.0	-747	0.0
15	56.4	46.4	-457	0.0	-734	0.0	-734	0.0	-734	0.0	-734	0.0
16	57.0	46.9	-405	0.0	-714	0.0	-714	0.0	-714	0.0	-714	0.0
17	56.8	46.2	-346	0.0	-688	0.0	-688	0.0	-688	0.0	-688	0.0
18	56.1	46.2	-285	0.0	-661	0.0	-661	0.0	-661	0.0	-661	0.0
19	55.1	46.2	-228	0.0	-633	0.0	-633	0.0	-633	0.0	-633	0.0
20	53.7	46.4	-182	0.0	-607	0.0	-607	0.0	-607	0.0	-607	0.0
21	52.1	45.6	-152	0.0	-586	0.0	-586	0.0	-586	0.0	-586	0.0
22	50.2	44.4	-139	0.0	-570	0.0	-570	0.0	-570	0.0	-570	0.0
23	48.2	42.7	-140	0.0	-560	0.0	-560	0.0	-560	0.0	-560	0.0
24	46.1	40.8	-154	0.0	-556	0.0	-556	0.0	-556	0.0	-556	0.0

April	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	52.3	47.4	0	0.0	0	0.0	-308	0.0	-308	0.0	-308	0.0
2	50.4	45.9	0	0.0	-203	0.0	-318	0.0	-318	0.0	-318	0.0
3	48.7	44.8	0	0.0	-333	0.0	-333	0.0	-333	0.0	-333	0.0
4	47.3	43.5	-45	0.0	-351	0.0	-351	0.0	-351	0.0	-351	0.0
5	46.2	42.8	-124	0.0	-373	0.0	-373	0.0	-373	0.0	-373	0.0
6	45.6	42.2	-171	0.0	-396	0.0	-396	0.0	-396	0.0	-396	0.0
7	45.3	42.2	-216	0.0	-421	0.0	-421	0.0	-421	0.0	-421	0.0
8	45.8	42.1	-257	0.0	-446	0.0	-446	0.0	-446	0.0	-446	0.0
9	47.0	42.4	-293	0.0	-470	0.0	-470	0.0	-470	0.0	-470	0.0
10	49.0	43.2	-317	0.0	-491	0.0	-491	0.0	-491	0.0	-491	0.0
11	51.6	44.5	-326	0.0	-507	0.0	-507	0.0	-507	0.0	-507	0.0
12	54.3	46.5	-320	0.0	-515	0.0	-515	0.0	-515	0.0	-515	0.0
13	57.1	49.0	-299	0.0	-514	0.0	-514	0.0	-514	0.0	-514	0.0
14	59.6	50.7	-264	0.0	-504	0.0	-504	0.0	-504	0.0	-504	0.0
15	61.6	52.3	-219	0.0	-485	0.0	-485	0.0	-485	0.0	-485	0.0
16	62.9	53.3	-164	0.0	-459	0.0	-459	0.0	-459	0.0	-459	0.0
17	63.4	53.6	-104	0.0	-429	0.0	-429	0.0	-429	0.0	-429	0.0
18	63.1	53.6	-43	0.0	-398	0.0	-398	0.0	-398	0.0	-398	0.0
19	62.5	53.8	0	0.0	-369	0.0	-369	0.0	-369	0.0	-369	0.0
20	61.4	53.8	0	0.0	-343	0.0	-343	0.0	-343	0.0	-343	0.0
21	60.0	53.3	0	0.0	-323	0.0	-323	0.0	-323	0.0	-323	0.0
22	58.3	52.2	0	0.0	-310	0.0	-310	0.0	-310	0.0	-310	0.0
23	56.4	50.5	0	0.0	-303	0.0	-303	0.0	-303	0.0	-303	0.0
24	54.3	48.9	0	0.0	-303	0.0	-303	0.0	-303	0.0	-303	0.0

BUILDING COOL HEAT DEMAND

By ACADEMIC

May	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	63.1	55.6	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
2	61.3	54.4	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
3	59.9	53.2	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
4	58.8	52.4	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
5	58.1	51.9	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
6	57.9	52.4	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
7	58.5	52.8	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
8	60.3	53.1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
9	63.1	54.4	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
10	66.5	56.4	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
11	70.1	58.8	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
12	73.4	60.3	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
13	76.2	62.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
14	78.0	63.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
15	78.6	62.9	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
16	78.4	62.9	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
17	77.7	62.5	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
18	76.6	62.2	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
19	75.2	61.7	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
20	73.4	61.7	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
21	71.5	61.8	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
22	69.4	60.5	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
23	67.2	59.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
24	65.1	57.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0

June	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	72.2	65.5	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
2	70.1	63.8	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
3	68.3	62.4	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
4	66.9	61.1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
5	66.1	60.5	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
6	65.8	60.3	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
7	66.2	60.3	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
8	67.4	60.3	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
9	69.2	60.5	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
10	71.6	61.2	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
11	74.3	62.2	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
12	77.1	63.6	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
13	79.8	65.1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
14	82.2	66.8	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
15	84.0	68.2	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
16	85.2	69.2	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
17	85.6	69.2	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
18	85.3	69.6	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
19	84.5	70.6	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
20	83.1	70.9	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
21	81.3	70.8	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
22	79.2	70.2	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
23	76.9	68.8	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
24	74.5	67.2	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0

BUILDING COOL HEAT DEMAND

By ACADEMIC

July	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	73.3	66.8	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
2	72.0	66.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
3	71.0	65.6	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
4	70.4	65.3	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
5	70.2	65.4	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
6	70.6	66.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
7	71.8	66.9	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
8	73.6	67.6	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
9	75.9	68.5	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
10	78.5	69.7	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
11	81.0	70.8	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
12	83.3	71.7	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
13	85.1	71.9	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
14	86.3	72.3	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
15	86.7	71.8	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
16	86.5	71.6	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
17	85.9	71.6	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
18	84.9	71.5	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
19	83.6	71.8	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
20	82.0	71.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
21	80.3	71.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
22	78.5	70.2	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
23	76.6	69.1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
24	74.9	67.8	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0

August	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	70.7	64.2	0	0.1	0	0.0	0	0.0	0	0.0	0	0.0
2	69.2	63.3	0	0.1	0	0.0	0	0.0	0	0.0	0	0.0
3	68.0	62.5	0	0.1	0	0.0	0	0.0	0	0.0	0	0.0
4	67.1	62.1	0	0.1	0	0.0	0	0.0	0	0.0	0	0.0
5	66.6	61.8	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
6	66.4	61.8	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
7	66.9	62.3	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
8	68.4	63.2	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
9	70.7	64.5	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
10	73.5	65.8	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
11	76.5	66.6	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
12	79.3	68.2	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
13	81.6	69.6	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
14	83.0	70.2	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
15	83.6	69.9	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
16	83.4	69.3	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
17	82.8	69.3	0	0.1	0	0.0	0	0.0	0	0.0	0	0.0
18	81.9	69.1	0	0.1	0	0.0	0	0.0	0	0.0	0	0.0
19	80.7	69.1	0	0.1	0	0.0	0	0.0	0	0.0	0	0.0
20	79.3	69.0	0	0.1	0	0.0	0	0.0	0	0.0	0	0.0
21	77.6	68.8	0	0.1	0	0.0	0	0.0	0	0.0	0	0.0
22	75.9	67.9	0	0.1	0	0.0	0	0.0	0	0.0	0	0.0
23	74.1	66.6	0	0.1	0	0.0	0	0.0	0	0.0	0	0.0
24	72.3	65.6	0	0.1	0	0.0	0	0.0	0	0.0	0	0.0

BUILDING COOL HEAT DEMAND

By ACADEMIC

September	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	65.8	59.7	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
2	64.1	58.5	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
3	62.6	57.5	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
4	61.5	56.5	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
5	60.6	56.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
6	60.0	55.3	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
7	59.8	55.5	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
8	60.6	55.7	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
9	62.6	56.5	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
10	65.8	57.9	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
11	69.5	59.9	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
12	73.1	61.9	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
13	76.3	63.9	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
14	78.4	65.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
15	79.1	65.1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
16	78.9	64.5	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
17	78.4	64.1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
18	77.5	63.8	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
19	76.3	63.9	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
20	74.8	64.6	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
21	73.1	64.2	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
22	71.3	63.6	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
23	69.5	62.5	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
24	67.6	61.1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0

October	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	50.4	46.4	0	0.0	0	0.0	0	0.0	-376	0.0	-376	0.0
2	48.9	44.9	0	0.0	0	0.0	0	0.0	-386	0.0	-386	0.0
3	47.6	43.8	0	0.0	0	0.0	0	0.0	-399	0.0	-399	0.0
4	46.6	42.9	0	0.0	0	0.0	0	0.0	-416	0.0	-416	0.0
5	45.8	42.4	0	0.0	0	0.0	0	0.0	-435	0.0	-435	0.0
6	45.3	42.0	0	0.0	0	0.0	0	0.0	-456	0.0	-456	0.0
7	45.1	41.8	0	0.0	0	0.0	0	0.0	-477	0.0	-477	0.0
8	46.1	42.7	0	0.0	0	0.0	0	0.0	-500	0.0	-500	0.0
9	48.7	44.2	0	0.0	0	0.0	0	0.0	-522	0.0	-522	0.0
10	52.5	46.7	0	0.0	0	0.0	0	0.0	-542	0.0	-542	0.0
11	56.8	49.4	0	0.0	0	0.0	0	0.0	-556	0.0	-556	0.0
12	60.6	52.0	0	0.0	0	0.0	0	0.0	-564	0.0	-564	0.0
13	63.2	53.2	0	0.0	0	0.0	0	0.0	-563	0.0	-563	0.0
14	64.1	53.0	0	0.0	0	0.0	0	0.0	-554	0.0	-554	0.0
15	64.0	52.7	0	0.0	0	0.0	0	0.0	-537	0.0	-537	0.0
16	63.5	52.0	0	0.0	0	0.0	0	0.0	-514	0.0	-514	0.0
17	62.7	51.7	0	0.0	0	0.0	0	0.0	-487	0.0	-487	0.0
18	61.7	51.9	0	0.0	0	0.0	0	0.0	-458	0.0	-458	0.0
19	60.4	52.0	0	0.0	0	0.0	0	0.0	-431	0.0	-431	0.0
20	58.9	52.2	0	0.0	0	0.0	0	0.0	-408	0.0	-408	0.0
21	57.2	51.2	0	0.0	0	0.0	-304	0.0	-390	0.0	-390	0.0
22	55.5	50.3	0	0.0	0	0.0	-379	0.0	-379	0.0	-379	0.0
23	53.8	49.1	0	0.0	0	0.0	-373	0.0	-373	0.0	-373	0.0
24	52.0	47.7	0	0.0	0	0.0	-372	0.0	-372	0.0	-372	0.0

BUILDING COOL HEAT DEMAND

By ACADEMIC

November	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	45.3	40.3	-252	0.0	-517	0.0	-517	0.0	-517	0.0	-517	0.0
2	43.6	39.0	-277	0.0	-524	0.0	-524	0.0	-524	0.0	-524	0.0
3	42.2	37.9	-306	0.0	-535	0.0	-535	0.0	-535	0.0	-535	0.0
4	41.1	36.7	-338	0.0	-550	0.0	-550	0.0	-550	0.0	-550	0.0
5	40.5	36.3	-371	0.0	-567	0.0	-567	0.0	-567	0.0	-567	0.0
6	40.2	36.5	-404	0.0	-587	0.0	-587	0.0	-587	0.0	-587	0.0
7	40.8	37.3	-437	0.0	-608	0.0	-608	0.0	-608	0.0	-608	0.0
8	42.6	39.4	-468	0.0	-630	0.0	-630	0.0	-630	0.0	-630	0.0
9	45.3	41.4	-496	0.0	-652	0.0	-652	0.0	-652	0.0	-652	0.0
10	48.6	44.0	-521	0.0	-673	0.0	-673	0.0	-673	0.0	-673	0.0
11	52.1	46.0	-536	0.0	-688	0.0	-688	0.0	-688	0.0	-688	0.0
12	55.4	47.6	-539	0.0	-697	0.0	-697	0.0	-697	0.0	-697	0.0
13	58.1	49.0	-528	0.0	-698	0.0	-698	0.0	-698	0.0	-698	0.0
14	59.8	49.9	-504	0.0	-691	0.0	-691	0.0	-691	0.0	-691	0.0
15	60.4	49.2	-469	0.0	-677	0.0	-677	0.0	-677	0.0	-677	0.0
16	60.2	48.8	-425	0.0	-657	0.0	-657	0.0	-657	0.0	-657	0.0
17	59.6	49.2	-377	0.0	-633	0.0	-633	0.0	-633	0.0	-633	0.0
18	58.5	49.6	-328	0.0	-606	0.0	-606	0.0	-606	0.0	-606	0.0
19	57.1	49.1	-285	0.0	-581	0.0	-581	0.0	-581	0.0	-581	0.0
20	55.4	48.0	-254	0.0	-559	0.0	-559	0.0	-559	0.0	-559	0.0
21	53.5	46.8	-234	0.0	-541	0.0	-541	0.0	-541	0.0	-541	0.0
22	51.4	45.4	-225	0.0	-528	0.0	-528	0.0	-528	0.0	-528	0.0
23	49.3	44.0	-225	0.0	-519	0.0	-519	0.0	-519	0.0	-519	0.0
24	47.2	41.9	-234	0.0	-516	0.0	-516	0.0	-516	0.0	-516	0.0

December	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	33.0	29.9	-573	0.0	-833	0.0	-833	0.0	-833	0.0	-833	0.0
2	32.7	29.7	-594	0.0	-845	0.0	-845	0.0	-845	0.0	-845	0.0
3	32.9	29.8	-619	0.0	-860	0.0	-860	0.0	-860	0.0	-860	0.0
4	33.5	30.7	-646	0.0	-877	0.0	-877	0.0	-877	0.0	-877	0.0
5	34.5	31.6	-673	0.0	-895	0.0	-895	0.0	-895	0.0	-895	0.0
6	35.7	33.1	-700	0.0	-913	0.0	-913	0.0	-913	0.0	-913	0.0
7	37.2	34.8	-726	0.0	-931	0.0	-931	0.0	-931	0.0	-931	0.0
8	38.9	36.5	-751	0.0	-947	0.0	-947	0.0	-947	0.0	-947	0.0
9	40.6	38.2	-774	0.0	-961	0.0	-961	0.0	-961	0.0	-961	0.0
10	42.2	39.5	-795	0.0	-972	0.0	-972	0.0	-972	0.0	-972	0.0
11	43.7	40.4	-809	0.0	-979	0.0	-979	0.0	-979	0.0	-979	0.0
12	45.0	41.2	-813	0.0	-980	0.0	-980	0.0	-980	0.0	-980	0.0
13	45.9	41.8	-805	0.0	-974	0.0	-974	0.0	-974	0.0	-974	0.0
14	46.5	41.9	-785	0.0	-962	0.0	-962	0.0	-962	0.0	-962	0.0
15	46.7	41.9	-755	0.0	-945	0.0	-945	0.0	-945	0.0	-945	0.0
16	46.5	41.5	-718	0.0	-925	0.0	-925	0.0	-925	0.0	-925	0.0
17	45.6	40.8	-676	0.0	-903	0.0	-903	0.0	-903	0.0	-903	0.0
18	44.3	40.2	-634	0.0	-880	0.0	-880	0.0	-880	0.0	-880	0.0
19	42.6	38.9	-598	0.0	-859	0.0	-859	0.0	-859	0.0	-859	0.0
20	40.7	37.2	-571	0.0	-843	0.0	-843	0.0	-843	0.0	-843	0.0
21	38.7	35.7	-555	0.0	-831	0.0	-831	0.0	-831	0.0	-831	0.0
22	36.8	33.8	-548	0.0	-825	0.0	-825	0.0	-825	0.0	-825	0.0
23	35.1	32.1	-549	0.0	-823	0.0	-823	0.0	-823	0.0	-823	0.0
24	33.8	30.7	-558	0.0	-826	0.0	-826	0.0	-826	0.0	-826	0.0

Design Cooling Load Summary

By ACADEMIC

System - System - 001

Type - VAV w/Baseboard Heating

Coil Location - System

Coil Peak Calculation Time: July, hour 22
Ambient DB/WB/HR: 80 / 73 / 109

COOLING COIL LOAD INFORMATION

Load Component	Sensible Btu/h	Latent Btu/h	Total Btu/h	Percent of Total
Solar Gain	0		0	0.0%
Glass Transmission	0		0	0.0%
Wall Transmission	400		400	40.6%
Roof Transmission	0		0	0.0%
Floor Transmission	0		0	0.0%
Adj Floor Transmission	0		0.00	0.0%
Partition Transmission	0		0	0.0%
Net Ceiling Load	0		0	0.0%
Lighting	0		0	0.0%
People	0	0	0	0.0%
Misc. Equipment Loads	0	0	0	0.0%
Cooling Infiltration	0	0	0	0.0%
Sub-Total ==>	400	0	400	40.6%
Ventilation Load	0	0	0	0.0%
Exhaust Heat	0	0	0	0.0%
Supply Fan Load	0		0	0.0%
Return Fan Load	0		0	0.0%
Net Duct Heat Pickup	0		0	0.0%
Wall Load to Plenum	62		62	6.2%
Roof Load to Plenum	524		524	53.2%
Adj Floor to Plenum	0		0	0.0%
Lighting Load to Plenum	0		0	0.0%
Misc. Equip. Load to Plenum	0	0	0	0.0%
Glass Transmission to Plenum	0		0	0.0%
Glass Solar to Plenum	0		0	0.0%
Over/Under Sizing	0		0	0.0%
Reheat at Design	0	0	0	0.0%
Underfloor Sup Heat Pickup	0		0	0.0%
Supply Air Leakage	0	0	0	0.0%
Total Cooling Loads	986	0	986	100.0 %

COOLING COIL SELECTION

Coil Selection Parameters

Coil Entering Air (DB / WB)	83.9 / 60.3	°F
Coil Entering Humidity Ratio	40.54	gr/lb
Coil Leaving Air (DB / WB)	55.0 / 48.5	°F
Coil Leaving Humidity Ratio	40.19	gr/lb
Coil Sensible Load	0.99	MBh
Coil Total Load	0.99	MBh
Cooling Supply Air Temperature	55.00	°F
Total Cooling Airflow	30.61	cfm
Resulting Room Relative Humidity	31.38	%

General Engineering Checks

Total Cooling Load	0.1	ton
Area / Load	1,216.84	ft²/ton
Total Floor Area	100	ft²
Cooling Airflow	0.31	cfm/ft²
Airflow / Load	372.46	cfm/ton
Percent Outdoor Air	0.0	%
Cooling Load Methodology	TETD-TA1	

PROJECT INFORMATION

Location	
Building owner	
Program user	
Company	
Comments	

By	**ACADEMIC**
Dataset name	**I:\Thesis\Thesis Work\Final Thesis\Facade Simplification\Trane Analysis\Thermal Analysis - Glass.trc**

Calculation time	**08:28 PM on 04/01/2012**	
TRACE® 700 version	**6.2.6.5**	
Location	**Washington, D.C.**	
Latitude	**38.0**	**deg**
Longitude	**77.0**	**deg**
Time Zone	**5**	
Elevation	**14**	**ft**
Barometric pressure	**29.9**	**in. Hg**
Air density	**0.0760**	**lb/cu ft**
Air specific heat	**0.2444**	**Btu/lb·°F**
Density-specific heat product	**1.1147**	**Btu/h·cfm·°F**
Latent heat factor	**4,906.9**	**Btu·min/h·cu ft**
Enthalpy factor	**4.5604**	**lb·min/hr·cu ft**
Summer design dry bulb	**91**	**°F**
Summer design wet bulb	**77**	**°F**
Winter design dry bulb	**17**	**°F**
Summer clearness number	**0.85**	
Winter clearness number	**0.85**	
Summer ground reflectance	**0.20**	
Winter ground reflectance	**0.20**	
Carbon Dioxide Level	**400**	**ppm**
Design simulation period	**January - December**	
Cooling load methodology	**TETD-TA1**	
Heating load methodology	**UATD**	

ENGINEERING CHECKS

By ACADEMIC

System	Zone	Room	Type	Floor Area ft²	COOLING % OA	COOLING cfm/ft²	COOLING cfm/ton	COOLING ft²/ton	COOLING Btu/hr·ft²	HEATING % OA	HEATING cfm/ft²	HEATING Btu/hr·ft²
Alternative 1												
	Brick Room		Zone	100	0.00	13.86	519.0	37.5	320.37	0.00	4.16	-132.44
System - 001			**System - VAV w/Baseboard Heating**	**100**	**0.00**	**13.86**	**519.0**	**37.5**	**320.37**	**0.00**	**4.16**	**-132.44**

Room Checksums

By ACADEMIC

Brick Room

COOLING COIL PEAK

Peaked at Time: Mo/Hr: 9 / 16
Outside Air: OADB/WB/HR: 83 / 69 / 85

	Space Sens. + Lat.	Plenum Sens. + Lat	Net Total	Percent Of Total
	Btu/h	Btu/h	Btu/h	(%)
Envelope Loads				
Skylite Solar	0	0	0	0
Skylite Cond	0	0	0	0
Roof Cond	0	1,166	1,166	4
Glass Solar	29,966	0	29,966	94
Glass/Door Cond	905	0	905	3
Wall Cond	0	0	0	0
Partition/Door	0		0	0
Floor	0		0	0
Adjacent Floor	0	0	0	0
Infiltration	0		0	0
Sub Total ==>	30,871	1,166	32,037	100
Internal Loads				
Lights	0	0	0	0
People	0	0	0	0
Misc	0	0	0	0
Sub Total ==>	0	0	0	0
Ceiling Load	23	-23	0	0
Ventilation Load	0	0	0	0
Adj Air Trans Heat	0		0	0
Dehumid. Ov Sizing			0	0
Ov/Undr Sizing	0		0	0
Exhaust Heat		0	0	0
Sup. Fan Heat			0	0
Ret. Fan Heat		0	0	0
Duct Heat Pkup		0	0	0
Underflr Sup Ht Pkup			0	0
Supply Air Leakage		0	0	0
Grand Total ==>	30,895	1,143	32,037	100.00

CLG SPACE PEAK

Mo/Hr: 9 / 16
OADB: 83

	Space Sensible	Percent Of Total
	Btu/h	(%)
Envelope Loads		
Skylite Solar	0	0
Skylite Cond	0	0
Roof Cond	0	0
Glass Solar	29,966	97
Glass/Door Cond	905	3
Wall Cond	0	0
Partition/Door	0	0
Floor	0	0
Adjacent Floor	0	0
Infiltration	0	0
Sub Total ==>	30,871	100
Internal Loads		
Lights	0	0
People	0	0
Misc	0	0
Sub Total ==>	0	0
Ceiling Load	23	0
Ventilation Load	0	0
Adj Air Trans Heat	0	0
Ov/Undr Sizing	0	0
Grand Total ==>	30,895	100.00

HEATING COIL PEAK

Mo/Hr: Heating Design
OADB: 17

	Space Peak Space Sens	Coil Peak Tot Sens	Percent Of Total
	Btu/h	Btu/h	(%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	0	0.00
Roof Cond	0	-1,085	5.37
Glass Solar	0	0	0.00
Glass/Door Cond	-6,223	-6,223	30.81
Wall Cond	0	0	0.00
Partition/Door	0	0	0.00
Floor	0	0	0.00
Adjacent Floor	0	0	0.00
Infiltration	0	0	0.00
Sub Total ==>	-6,223	-7,308	36.19
Internal Loads			
Lights	0	0	0.00
People	0	0	0.00
Misc	0	0	0.00
Sub Total ==>	0	0	0.00
Ceiling Load	-69	0	0.00
Ventilation Load	0	0	0.00
Adj Air Trans Heat	0	0	0
Ov/Undr Sizing	0	0	0.00
Exhaust Heat		0	0.00
OA Preheat Diff.		0	0.00
RA Preheat Diff.		-5,936	29.39
Additional Reheat		-6,951	34.42
System Plenum Heat		0	0.00
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	-6,292	-20,195	100.00

TEMPERATURES

	Cooling	Heating
SADB	55.0	70.0
Ra Plenum	75.7	67.8
Return	75.7	67.8
Ret/OA	75.7	67.8
Fn MtrTD	0.0	0.0
Fn BldTD	0.0	0.0
Fn Frict	0.0	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	1,386	416
Terminal	1,386	416
Main Fan	1,386	416
Sec Fan	0	0
Nom Vent	0	0
AHU Vent	0	0
Infil	0	0
MinStop/Rh	416	416
Return	1,386	416
Exhaust	0	0
Rm Exh	0	0
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	0.0	0.0
cfm/ft²	13.86	4.16
cfm/ton	519.05	
ft²/ton	37.46	
Btu/hr·ft²	320.37	-132.44
No. People	0	

COOLING COIL SELECTION

	Total Capacity		Sens Cap.	Coil Airflow	Enter DB/WB/HR			Leave DB/WB/HR		
	ton	MBh	MBh	cfm	°F	°F	gr/lb	°F	°F	gr/lb
Main Clg	2.7	32.0	32.0	1,386	75.7	57.2	40.5	55.0	48.5	40.2
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Opt Vent	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	2.7	32.0								

AREAS

	Gross Total	Glass	
		ft²	(%)
Floor	100		
Part	0		
Int Door	0		
ExFlr	0		
Roof	100	0	0
Wall	400	400	100
Ext Door	0	0	0

HEATING COIL SELECTION

	Capacity	Coil Airflow	Ent	Lvg
	MBh	cfm	°F	°F
Main Htg	-13.2	0	0.0	0.0
Aux Htg	0.0	0	0.0	0.0
Preheat	0.0	0	0.0	0.0
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-13.2			

SYSTEM SUMMARY

DESIGN COOLING CAPACITIES

By ACADEMIC

Alternative 1

Building Airside Systems and Plant Capacities

Plant / System	Peak Plant Loads: Main Coil ton	Aux Coil ton	Opt Vent Coil ton	Misc Load ton	Stg 1 Desic Cond ton	Stg 2 Desic Cond ton	Base Utility ton	Peak Total ton	Block Plant Loads: Time Of Peak mo/hr	Main Coil ton	Aux Coil ton	Opt Vent Coil ton	Misc Load ton	Stg 1 Desic Cond ton	Stg 2 Desic Cond ton	Base Utility ton	Block Total ton
Unassigned Cooling Loads	2.7	0.0	0.0	0.0	0.0	0.0	0.0	2.7	9/16	2.7	0.0	0.0	0.0	0.0	0.0	0.0	2.7
System - 001	2.7	0.0	0.0	0.0	0.0	0.0	0.0	2.7	9/16	2.7	0.0	0.0	0.0	0.0	0.0	0.0	2.7
Building totals	2.7	0.0	0.0	0.0	0.0	0.0	0.0	2.7		2.7	0.0	0.0	0.0	0.0	0.0	0.0	2.7

Building peak load is 2.7 tons.

Building maximum block load of 2.7 tons occurs in September at hour 16 based on system simulation.

SYSTEM SUMMARY

DESIGN HEATING CAPACITIES

By ACADEMIC

Alternative 1

System Coil Capacities

System Description	System Type	Main System Btu/h	Aux System Btu/h	Preheat Btu/h	Reheat Btu/h	Humid. Btu/h	Optional Vent Btu/h	Stg 1 Desic Regen Btu/h	Stg 2 Desic Regen Btu/h	Stg 1 Frost Prevention Btu/h	Stg 2 Frost Prevention Btu/h	Heating Totals Btu/h
System - 001	VAV w/Baseboard Heating	-13,244	0	0	-6,951	0	0	0	0	0	0	-13,244
Totals		**-13,244**	**0**	**0**	**-6,951**	**0**	**0**	**0**	**0**	**0**	**0**	**-13,244**

Building Plant Capacities

Plant	System	Peak Loads: Main Coil MBh	Preheat Coil MBh	Reheat Coil MBh	Humid. Coil MBh	Aux Coil MBh	Opt Vent Coil MBh	Misc Load MBh	Stg 1 Desic. Regen. MBh	Stg 2 Desic. Regen. MBh	Stg 1 Frost Prev. MBh	Stg 2 Frost Prev. MBh	Base Utility MBh	Absorption Load MBh
Unassigned Heating Loads		13	0	0	0	0	0	0	0	0	0	0	0	0
	System - 001	13	0	0	0	0	0	0	0	0	0	0	0	0

Building peak load is 13.2 MBh.

BUILDING COOL HEAT DEMAND

By ACADEMIC

January	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	33.3	30.1	-11,120	0.5	-11,078	0.5	-11,078	0.5	-11,078	0.5	-11,078	0.5
2	31.6	28.5	-11,225	0.5	-11,274	0.5	-11,274	0.5	-11,274	0.5	-11,274	0.5
3	30.1	27.2	-11,314	0.5	-11,455	0.5	-11,455	0.5	-11,455	0.5	-11,455	0.5
4	28.9	25.8	-11,391	0.5	-11,602	0.5	-11,602	0.5	-11,602	0.5	-11,602	0.5
5	28.0	25.3	-11,429	0.5	-11,734	0.5	-11,734	0.5	-11,734	0.5	-11,734	0.5
6	27.4	24.7	-11,425	0.5	-11,821	0.5	-11,821	0.5	-11,821	0.5	-11,821	0.5
7	27.2	24.7	-11,359	0.5	-11,888	0.5	-11,888	0.5	-11,888	0.5	-11,888	0.5
8	27.8	25.2	-11,222	0.5	-11,880	0.5	-11,880	0.5	-11,880	0.5	-11,880	0.5
9	29.3	26.5	-3,907	0.5	-7,518	0.5	-7,518	0.5	-7,518	0.5	-7,518	0.5
10	31.6	28.3	0	0.6	-1,686	0.5	-1,686	0.5	-1,686	0.5	-1,686	0.5
11	34.4	30.4	0	1.7	0	0.6	0	0.6	0	0.6	0	0.6
12	37.5	32.5	0	2.1	0	0.7	0	0.7	0	0.7	0	0.7
13	40.3	34.5	0	2.1	0	0.9	0	0.9	0	0.9	0	0.9
14	42.6	36.5	0	2.0	0	0.9	0	0.9	0	0.9	0	0.9
15	44.1	37.4	0	2.2	0	1.0	0	1.0	0	1.0	0	1.0
16	44.7	37.5	0	2.2	0	1.0	0	1.0	0	1.0	0	1.0
17	44.5	37.5	0	1.8	0	0.8	0	0.8	0	0.8	0	0.8
18	43.9	37.6	0	0.9	0	0.7	0	0.7	0	0.7	0	0.7
19	43.0	37.2	0	0.7	-4,570	0.6	-4,570	0.6	-4,570	0.6	-4,570	0.6
20	41.8	36.8	-9,891	0.6	-10,139	0.5	-10,139	0.5	-10,139	0.5	-10,139	0.5
21	40.3	35.7	-10,441	0.6	-10,285	0.5	-10,285	0.5	-10,285	0.5	-10,285	0.5
22	38.6	34.5	-10,662	0.5	-10,469	0.5	-10,469	0.5	-10,469	0.5	-10,469	0.5
23	36.9	33.3	-10,846	0.5	-10,662	0.5	-10,662	0.5	-10,662	0.5	-10,662	0.5
24	35.0	31.5	-10,998	0.5	-10,876	0.5	-10,876	0.5	-10,876	0.5	-10,876	0.5

February	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	34.4	30.4	-10,917	0.5	-10,990	0.5	-10,990	0.5	-10,990	0.5	-10,990	0.5
2	33.0	29.3	-11,002	0.5	-11,147	0.5	-11,147	0.5	-11,147	0.5	-11,147	0.5
3	31.8	28.3	-11,077	0.5	-11,301	0.5	-11,301	0.5	-11,301	0.5	-11,301	0.5
4	30.8	27.4	-11,137	0.5	-11,422	0.5	-11,422	0.5	-11,422	0.5	-11,422	0.5
5	30.1	26.7	-11,167	0.5	-11,529	0.5	-11,529	0.5	-11,529	0.5	-11,529	0.5
6	29.6	26.2	-11,166	0.5	-11,608	0.5	-11,608	0.5	-11,608	0.5	-11,608	0.5
7	29.5	26.2	-11,116	0.5	-11,647	0.5	-11,647	0.5	-11,647	0.5	-11,647	0.5
8	29.9	26.8	-7,315	0.5	-9,540	0.5	-9,540	0.5	-9,540	0.5	-9,540	0.5
9	31.1	27.9	0	0.5	-4,465	0.5	-4,465	0.5	-4,465	0.5	-4,465	0.5
10	33.0	28.8	0	1.1	0	0.5	0	0.5	0	0.5	0	0.5
11	35.3	29.9	0	2.1	0	0.6	0	0.6	0	0.6	0	0.6
12	37.8	31.8	0	2.2	0	0.9	0	0.9	0	0.9	0	0.9
13	40.1	33.0	0	2.1	0	0.9	0	0.9	0	0.9	0	0.9
14	41.9	34.7	0	2.1	0	0.9	0	0.9	0	0.9	0	0.9
15	43.2	35.5	0	2.2	0	1.0	0	1.0	0	1.0	0	1.0
16	43.6	35.8	0	2.3	0	1.1	0	1.1	0	1.1	0	1.1
17	43.4	35.9	0	2.2	0	1.0	0	1.0	0	1.0	0	1.0
18	43.0	35.8	0	1.3	0	0.7	0	0.7	0	0.7	0	0.7
19	42.3	36.0	0	0.7	-173	0.6	-173	0.6	-173	0.6	-173	0.6
20	41.3	35.9	-6,106	0.6	-9,171	0.5	-9,171	0.5	-9,171	0.5	-9,171	0.5
21	40.1	35.0	-10,358	0.6	-10,357	0.5	-10,357	0.5	-10,357	0.5	-10,357	0.5
22	38.7	34.0	-10,542	0.5	-10,504	0.5	-10,504	0.5	-10,504	0.5	-10,504	0.5
23	37.3	32.9	-10,699	0.5	-10,667	0.5	-10,667	0.5	-10,667	0.5	-10,667	0.5
24	35.8	31.5	-10,819	0.5	-10,837	0.5	-10,837	0.5	-10,837	0.5	-10,837	0.5

BUILDING COOL HEAT DEMAND

By ACADEMIC

March	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	44.1	39.1	-9,881	0.5	-9,822	0.5	-9,822	0.5	-9,822	0.5	-9,822	0.5
2	42.3	37.7	-10,004	0.5	-10,050	0.5	-10,050	0.5	-10,050	0.5	-10,050	0.5
3	40.6	36.3	-10,102	0.5	-10,251	0.5	-10,251	0.5	-10,251	0.5	-10,251	0.5
4	39.2	35.1	-10,184	0.5	-10,425	0.5	-10,425	0.5	-10,425	0.5	-10,425	0.5
5	38.2	34.7	-10,229	0.5	-10,567	0.5	-10,567	0.5	-10,567	0.5	-10,567	0.5
6	37.6	34.1	-10,221	0.5	-10,668	0.5	-10,668	0.5	-10,668	0.5	-10,668	0.5
7	37.4	34.0	-9,631	0.5	-10,443	0.5	-10,443	0.5	-10,443	0.5	-10,443	0.5
8	37.9	34.5	-2,625	0.5	-6,740	0.5	-6,740	0.5	-6,740	0.5	-6,740	0.5
9	39.6	35.5	0	0.6	-1,399	0.5	-1,399	0.5	-1,399	0.5	-1,399	0.5
10	42.3	37.0	0	1.8	0	0.6	0	0.6	0	0.6	0	0.6
11	45.5	39.1	0	2.2	0	0.9	0	0.9	0	0.9	0	0.9
12	48.9	41.4	0	2.2	0	1.3	0	1.3	0	1.3	0	1.3
13	52.1	43.5	0	2.1	0	1.4	0	1.4	0	1.4	0	1.4
14	54.7	45.5	0	2.1	0	1.3	0	1.3	0	1.3	0	1.3
15	56.4	46.4	0	2.3	0	1.3	0	1.3	0	1.3	0	1.3
16	57.0	46.9	0	2.4	0	1.3	0	1.3	0	1.3	0	1.3
17	56.8	46.2	0	2.3	0	1.1	0	1.1	0	1.1	0	1.1
18	56.1	46.2	0	1.8	0	0.9	0	0.9	0	0.9	0	0.9
19	55.1	46.2	0	0.9	0	0.7	0	0.7	0	0.7	0	0.7
20	53.7	46.4	0	0.7	-3,215	0.6	-3,215	0.6	-3,215	0.6	-3,215	0.6
21	52.1	45.6	-8,436	0.6	-8,937	0.6	-8,937	0.6	-8,937	0.6	-8,937	0.6
22	50.2	44.4	-9,365	0.6	-9,137	0.6	-9,137	0.6	-9,137	0.6	-9,137	0.6
23	48.2	42.7	-9,575	0.6	-9,351	0.6	-9,351	0.6	-9,351	0.6	-9,351	0.6
24	46.1	40.8	-9,745	0.6	-9,591	0.5	-9,591	0.5	-9,591	0.5	-9,591	0.5

April	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	52.3	47.4	-8,984	0.6	-8,856	0.6	-8,856	0.6	-8,856	0.6	-8,856	0.6
2	50.4	45.9	-9,095	0.6	-9,081	0.6	-9,081	0.6	-9,081	0.6	-9,081	0.6
3	48.7	44.8	-9,196	0.5	-9,286	0.6	-9,286	0.6	-9,286	0.6	-9,286	0.6
4	47.3	43.5	-9,271	0.5	-9,458	0.5	-9,458	0.5	-9,458	0.5	-9,458	0.5
5	46.2	42.8	-9,316	0.5	-9,607	0.5	-9,607	0.5	-9,607	0.5	-9,607	0.5
6	45.6	42.2	-9,306	0.5	-9,710	0.5	-9,710	0.5	-9,710	0.5	-9,710	0.5
7	45.3	42.2	-4,119	0.5	-6,907	0.5	-6,907	0.5	-6,907	0.5	-6,907	0.5
8	45.8	42.1	0	0.6	-2,637	0.5	-2,637	0.5	-2,637	0.5	-2,637	0.5
9	47.0	42.4	0	1.3	0	0.6	0	0.6	0	0.6	0	0.6
10	49.0	43.2	0	2.0	0	0.7	0	0.7	0	0.7	0	0.7
11	51.6	44.5	0	2.1	0	1.3	0	1.3	0	1.3	0	1.3
12	54.3	46.5	0	2.1	0	1.5	0	1.5	0	1.5	0	1.5
13	57.1	49.0	0	1.9	0	1.4	0	1.4	0	1.4	0	1.4
14	59.6	50.7	0	2.0	0	1.5	0	1.5	0	1.5	0	1.5
15	61.6	52.3	0	2.1	0	1.4	0	1.4	0	1.4	0	1.4
16	62.9	53.3	0	2.3	0	1.3	0	1.3	0	1.3	0	1.3
17	63.4	53.6	0	2.3	0	1.1	0	1.1	0	1.1	0	1.1
18	63.1	53.6	0	1.9	0	1.0	0	1.0	0	1.0	0	1.0
19	62.5	53.8	0	1.2	0	0.8	0	0.8	0	0.8	0	0.8
20	61.4	53.8	0	0.8	-474	0.7	-474	0.7	-474	0.7	-474	0.7
21	60.0	53.3	-5,625	0.6	-7,768	0.6	-7,768	0.6	-7,768	0.6	-7,768	0.6
22	58.3	52.2	-8,505	0.6	-8,189	0.6	-8,189	0.6	-8,189	0.6	-8,189	0.6
23	56.4	50.5	-8,701	0.6	-8,392	0.6	-8,392	0.6	-8,392	0.6	-8,392	0.6
24	54.3	48.9	-8,858	0.6	-8,625	0.6	-8,625	0.6	-8,625	0.6	-8,625	0.6

BUILDING COOL HEAT DEMAND

By ACADEMIC

May	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	63.1	55.6	-7,463	0.6	-7,599	0.6	-7,599	0.6	-7,599	0.6	-7,599	0.6
2	61.3	54.4	-7,590	0.6	-7,814	0.6	-7,814	0.6	-7,814	0.6	-7,814	0.6
3	59.9	53.2	-7,696	0.6	-8,002	0.6	-8,002	0.6	-8,002	0.6	-8,002	0.6
4	58.8	52.4	-7,789	0.6	-8,154	0.6	-8,154	0.6	-8,154	0.6	-8,154	0.6
5	58.1	51.9	-7,839	0.6	-8,261	0.6	-8,261	0.6	-8,261	0.6	-8,261	0.6
6	57.9	52.4	-5,791	0.6	-7,071	0.6	-7,071	0.6	-7,071	0.6	-7,071	0.6
7	58.5	52.8	0	0.6	-2,894	0.6	-2,894	0.6	-2,894	0.6	-2,894	0.6
8	60.3	53.1	0	0.9	0	0.6	0	0.6	0	0.6	0	0.6
9	63.1	54.4	0	1.9	0	0.7	0	0.7	0	0.7	0	0.7
10	66.5	56.4	0	2.1	0	1.4	0	1.4	0	1.4	0	1.4
11	70.1	58.8	0	2.1	0	1.6	0	1.6	0	1.6	0	1.6
12	73.4	60.3	0	2.0	0	1.6	0	1.6	0	1.6	0	1.6
13	76.2	62.0	0	1.9	0	1.5	0	1.5	0	1.5	0	1.5
14	78.0	63.0	0	1.9	0	1.5	0	1.5	0	1.5	0	1.5
15	78.6	62.9	0	2.1	0	1.7	0	1.7	0	1.7	0	1.7
16	78.4	62.9	0	2.3	0	1.7	0	1.7	0	1.7	0	1.7
17	77.7	62.5	0	2.4	0	1.5	0	1.5	0	1.5	0	1.5
18	76.6	62.2	0	2.2	0	1.3	0	1.3	0	1.3	0	1.3
19	75.2	61.7	0	1.7	0	1.0	0	1.0	0	1.0	0	1.0
20	73.4	61.7	0	0.9	0	0.8	0	0.8	0	0.8	0	0.8
21	71.5	61.8	0	0.8	-1,020	0.7	-1,020	0.7	-1,020	0.7	-1,020	0.7
22	69.4	60.5	-5,685	0.6	-6,859	0.6	-6,859	0.6	-6,859	0.6	-6,859	0.6
23	67.2	59.0	-7,136	0.6	-7,110	0.6	-7,110	0.6	-7,110	0.6	-7,110	0.6
24	65.1	57.0	-7,313	0.6	-7,359	0.6	-7,359	0.6	-7,359	0.6	-7,359	0.6

June	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	72.2	65.5	-6,554	0.6	-6,521	0.6	-6,521	0.6	-6,521	0.6	-6,521	0.6
2	70.1	63.8	-6,676	0.6	-6,775	0.6	-6,775	0.6	-6,775	0.6	-6,775	0.6
3	68.3	62.4	-6,780	0.6	-7,002	0.6	-7,002	0.6	-7,002	0.6	-7,002	0.6
4	66.9	61.1	-6,865	0.6	-7,190	0.6	-7,190	0.6	-7,190	0.6	-7,190	0.6
5	66.1	60.5	-6,914	0.6	-7,321	0.6	-7,321	0.6	-7,321	0.6	-7,321	0.6
6	65.8	60.3	-4,136	0.6	-5,844	0.6	-5,844	0.6	-5,844	0.6	-5,844	0.6
7	66.2	60.3	0	0.6	-1,825	0.6	-1,825	0.6	-1,825	0.6	-1,825	0.6
8	67.4	60.3	0	1.2	0	0.6	0	0.6	0	0.6	0	0.6
9	69.2	60.5	0	2.1	0	0.9	0	0.9	0	0.9	0	0.9
10	71.6	61.2	0	2.2	0	1.6	0	1.6	0	1.6	0	1.6
11	74.3	62.2	0	2.2	0	1.7	0	1.7	0	1.7	0	1.7
12	77.1	63.6	0	2.1	0	1.6	0	1.6	0	1.6	0	1.6
13	79.8	65.1	0	1.9	0	1.5	0	1.5	0	1.5	0	1.5
14	82.2	66.8	0	1.9	0	1.5	0	1.5	0	1.5	0	1.5
15	84.0	68.2	0	2.1	0	1.7	0	1.7	0	1.7	0	1.7
16	85.2	69.2	0	2.3	0	1.7	0	1.7	0	1.7	0	1.7
17	85.6	69.2	0	2.4	0	1.6	0	1.6	0	1.6	0	1.6
18	85.3	69.6	0	2.4	0	1.4	0	1.4	0	1.4	0	1.4
19	84.5	70.6	0	2.0	0	1.2	0	1.2	0	1.2	0	1.2
20	83.1	70.9	0	1.2	0	0.8	0	0.8	0	0.8	0	0.8
21	81.3	70.8	0	0.8	0	0.7	0	0.7	0	0.7	0	0.7
22	79.2	70.2	-3,124	0.7	-4,317	0.6	-4,317	0.6	-4,317	0.6	-4,317	0.6
23	76.9	68.8	-6,245	0.6	-5,979	0.6	-5,979	0.6	-5,979	0.6	-5,979	0.6
24	74.5	67.2	-6,415	0.6	-6,251	0.6	-6,251	0.6	-6,251	0.6	-6,251	0.6

BUILDING COOL HEAT DEMAND

By ACADEMIC

July	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	73.3	66.8	-6,110	0.6	-6,443	0.6	-6,443	0.6	-6,443	0.6	-6,443	0.6
2	72.0	66.0	-6,213	0.6	-6,611	0.6	-6,611	0.6	-6,611	0.6	-6,611	0.6
3	71.0	65.6	-6,297	0.6	-6,749	0.6	-6,749	0.6	-6,749	0.6	-6,749	0.6
4	70.4	65.3	-6,366	0.6	-6,845	0.6	-6,845	0.6	-6,845	0.6	-6,845	0.6
5	70.2	65.4	-6,406	0.6	-6,898	0.6	-6,898	0.6	-6,898	0.6	-6,898	0.6
6	70.6	66.0	-5,450	0.6	-6,329	0.6	-6,329	0.6	-6,329	0.6	-6,329	0.6
7	71.8	66.9	0	0.6	-2,504	0.6	-2,504	0.6	-2,504	0.6	-2,504	0.6
8	73.6	67.6	0	0.8	0	0.6	0	0.6	0	0.6	0	0.6
9	75.9	68.5	0	2.0	0	0.8	0	0.8	0	0.8	0	0.8
10	78.5	69.7	0	2.2	0	1.5	0	1.5	0	1.5	0	1.5
11	81.0	70.8	0	2.3	0	1.8	0	1.8	0	1.8	0	1.8
12	83.3	71.7	0	2.2	0	1.8	0	1.8	0	1.8	0	1.8
13	85.1	71.9	0	2.0	0	1.7	0	1.7	0	1.7	0	1.7
14	86.3	72.3	0	2.0	0	1.7	0	1.7	0	1.7	0	1.7
15	86.7	71.8	0	2.2	0	1.8	0	1.8	0	1.8	0	1.8
16	86.5	71.6	0	2.4	0	1.8	0	1.8	0	1.8	0	1.8
17	85.9	71.6	0	2.5	0	1.7	0	1.7	0	1.7	0	1.7
18	84.9	71.5	0	2.4	0	1.4	0	1.4	0	1.4	0	1.4
19	83.6	71.8	0	1.9	0	1.1	0	1.1	0	1.1	0	1.1
20	82.0	71.0	0	1.2	0	0.8	0	0.8	0	0.8	0	0.8
21	80.3	71.0	0	0.8	0	0.7	0	0.7	0	0.7	0	0.7
22	78.5	70.2	-2,950	0.7	-5,051	0.6	-5,051	0.6	-5,051	0.6	-5,051	0.6
23	76.6	69.1	-5,842	0.6	-6,039	0.6	-6,039	0.6	-6,039	0.6	-6,039	0.6
24	74.9	67.8	-5,987	0.6	-6,246	0.6	-6,246	0.6	-6,246	0.6	-6,246	0.6

August	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	70.7	64.2	-6,540	0.6	-6,744	0.6	-6,744	0.6	-6,744	0.6	-6,744	0.6
2	69.2	63.3	-6,643	0.6	-6,928	0.6	-6,928	0.6	-6,928	0.6	-6,928	0.6
3	68.0	62.5	-6,733	0.6	-7,082	0.6	-7,082	0.6	-7,082	0.6	-7,082	0.6
4	67.1	62.1	-6,811	0.6	-7,208	0.6	-7,208	0.6	-7,208	0.6	-7,208	0.6
5	66.6	61.8	-6,850	0.6	-7,293	0.6	-7,293	0.6	-7,293	0.6	-7,293	0.6
6	66.4	61.8	-6,846	0.6	-7,338	0.6	-7,338	0.6	-7,338	0.6	-7,338	0.6
7	66.9	62.3	-2,111	0.6	-4,664	0.6	-4,664	0.6	-4,664	0.6	-4,664	0.6
8	68.4	63.2	0	0.6	-11	0.6	-11	0.6	-11	0.6	-11	0.6
9	70.7	64.5	0	1.6	0	0.6	0	0.6	0	0.6	0	0.6
10	73.5	65.8	0	2.2	0	1.3	0	1.3	0	1.3	0	1.3
11	76.5	66.6	0	2.4	0	1.8	0	1.8	0	1.8	0	1.8
12	79.3	68.2	0	2.3	0	1.9	0	1.9	0	1.9	0	1.9
13	81.6	69.6	0	2.2	0	1.8	0	1.8	0	1.8	0	1.8
14	83.0	70.2	0	2.2	0	1.8	0	1.8	0	1.8	0	1.8
15	83.6	69.9	0	2.4	0	1.8	0	1.8	0	1.8	0	1.8
16	83.4	69.3	0	2.5	0	1.8	0	1.8	0	1.8	0	1.8
17	82.8	69.3	0	2.5	0	1.6	0	1.6	0	1.6	0	1.6
18	81.9	69.1	0	2.2	0	1.3	0	1.3	0	1.3	0	1.3
19	80.7	69.1	0	1.4	0	0.8	0	0.8	0	0.8	0	0.8
20	79.3	69.0	0	0.8	0	0.8	0	0.8	0	0.8	0	0.8
21	77.6	68.8	-816	0.7	-2,993	0.7	-2,993	0.7	-2,993	0.7	-2,993	0.7
22	75.9	67.9	-6,078	0.6	-6,131	0.6	-6,131	0.6	-6,131	0.6	-6,131	0.6
23	74.1	66.6	-6,268	0.6	-6,340	0.6	-6,340	0.6	-6,340	0.6	-6,340	0.6
24	72.3	65.6	-6,417	0.6	-6,548	0.6	-6,548	0.6	-6,548	0.6	-6,548	0.6

BUILDING COOL HEAT DEMAND

By ACADEMIC

September	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	65.8	59.7	-7,274	0.6	-7,302	0.6	-7,302	0.6	-7,302	0.6	-7,302	0.6
2	64.1	58.5	-7,390	0.6	-7,506	0.6	-7,506	0.6	-7,506	0.6	-7,506	0.6
3	62.6	57.5	-7,491	0.6	-7,688	0.6	-7,688	0.6	-7,688	0.6	-7,688	0.6
4	61.5	56.5	-7,574	0.6	-7,839	0.6	-7,839	0.6	-7,839	0.6	-7,839	0.6
5	60.6	56.0	-7,621	0.6	-7,963	0.6	-7,963	0.6	-7,963	0.6	-7,963	0.6
6	60.0	55.3	-7,613	0.6	-8,052	0.6	-8,052	0.6	-8,052	0.6	-8,052	0.6
7	59.8	55.5	-5,505	0.6	-6,984	0.6	-6,984	0.6	-6,984	0.6	-6,984	0.6
8	60.6	55.7	0	0.6	-2,829	0.6	-2,829	0.6	-2,829	0.6	-2,829	0.6
9	62.6	56.5	0	1.1	0	0.6	0	0.6	0	0.6	0	0.6
10	65.8	57.9	0	2.2	0	0.9	0	0.9	0	0.9	0	0.9
11	69.5	59.9	0	2.5	0	1.6	0	1.6	0	1.6	0	1.6
12	73.1	61.9	0	2.4	0	1.8	0	1.8	0	1.8	0	1.8
13	76.3	63.9	0	2.3	0	1.9	0	1.9	0	1.9	0	1.9
14	78.4	65.0	0	2.4	0	1.8	0	1.8	0	1.8	0	1.8
15	79.1	65.1	0	2.6	0	1.8	0	1.8	0	1.8	0	1.8
16	78.9	64.5	0	2.7	0	1.6	0	1.6	0	1.6	0	1.6
17	78.4	64.1	0	2.5	0	1.4	0	1.4	0	1.4	0	1.4
18	77.5	63.8	0	1.8	0	1.0	0	1.0	0	1.0	0	1.0
19	76.3	63.9	0	0.9	0	0.8	0	0.8	0	0.8	0	0.8
20	74.8	64.6	0	0.8	-1,312	0.7	-1,312	0.7	-1,312	0.7	-1,312	0.7
21	73.1	64.2	-5,523	0.6	-6,462	0.6	-6,462	0.6	-6,462	0.6	-6,462	0.6
22	71.3	63.6	-6,765	0.6	-6,665	0.6	-6,665	0.6	-6,665	0.6	-6,665	0.6
23	69.5	62.5	-6,972	0.6	-6,874	0.6	-6,874	0.6	-6,874	0.6	-6,874	0.6
24	67.6	61.1	-7,138	0.6	-7,091	0.6	-7,091	0.6	-7,091	0.6	-7,091	0.6

October	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	50.4	46.4	-8,996	0.6	-9,081	0.6	-9,081	0.6	-9,081	0.6	-9,081	0.6
2	48.9	44.9	-9,116	0.6	-9,255	0.5	-9,255	0.5	-9,255	0.5	-9,255	0.5
3	47.6	43.8	-9,209	0.5	-9,423	0.5	-9,423	0.5	-9,423	0.5	-9,423	0.5
4	46.6	42.9	-9,292	0.5	-9,556	0.5	-9,556	0.5	-9,556	0.5	-9,556	0.5
5	45.8	42.4	-9,337	0.5	-9,668	0.5	-9,668	0.5	-9,668	0.5	-9,668	0.5
6	45.3	42.0	-9,330	0.5	-9,745	0.5	-9,745	0.5	-9,745	0.5	-9,745	0.5
7	45.1	41.8	-9,257	0.5	-9,794	0.5	-9,794	0.5	-9,794	0.5	-9,794	0.5
8	46.1	42.7	-2,528	0.5	-6,056	0.5	-6,056	0.5	-6,056	0.5	-6,056	0.5
9	48.7	44.2	0	0.6	-405	0.5	-405	0.5	-405	0.5	-405	0.5
10	52.5	46.7	0	2.0	0	0.6	0	0.6	0	0.6	0	0.6
11	56.8	49.4	0	2.3	0	1.0	0	1.0	0	1.0	0	1.0
12	60.6	52.0	0	2.3	0	1.2	0	1.2	0	1.2	0	1.2
13	63.2	53.2	0	2.2	0	1.2	0	1.2	0	1.2	0	1.2
14	64.1	53.0	0	2.3	0	1.2	0	1.2	0	1.2	0	1.2
15	64.0	52.7	0	2.5	0	1.3	0	1.3	0	1.3	0	1.3
16	63.5	52.0	0	2.5	0	1.3	0	1.3	0	1.3	0	1.3
17	62.7	51.7	0	2.1	0	1.0	0	1.0	0	1.0	0	1.0
18	61.7	51.9	0	1.1	0	0.7	0	0.7	0	0.7	0	0.7
19	60.4	52.0	0	0.7	-1,349	0.6	-1,349	0.6	-1,349	0.6	-1,349	0.6
20	58.9	52.2	-6,095	0.6	-8,120	0.6	-8,120	0.6	-8,120	0.6	-8,120	0.6
21	57.2	51.2	-8,255	0.6	-8,300	0.6	-8,300	0.6	-8,300	0.6	-8,300	0.6
22	55.5	50.3	-8,501	0.6	-8,492	0.6	-8,492	0.6	-8,492	0.6	-8,492	0.6
23	53.8	49.1	-8,703	0.6	-8,691	0.6	-8,691	0.6	-8,691	0.6	-8,691	0.6
24	52.0	47.7	-8,869	0.6	-8,890	0.6	-8,890	0.6	-8,890	0.6	-8,890	0.6

BUILDING COOL HEAT DEMAND

By ACADEMIC

November	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	45.3	40.3	-9,548	0.5	-9,645	0.5	-9,645	0.5	-9,645	0.5	-9,645	0.5
2	43.6	39.0	-9,670	0.5	-9,852	0.5	-9,852	0.5	-9,852	0.5	-9,852	0.5
3	42.2	37.9	-9,773	0.5	-10,030	0.5	-10,030	0.5	-10,030	0.5	-10,030	0.5
4	41.1	36.7	-9,857	0.5	-10,173	0.5	-10,173	0.5	-10,173	0.5	-10,173	0.5
5	40.5	36.3	-9,906	0.5	-10,284	0.5	-10,284	0.5	-10,284	0.5	-10,284	0.5
6	40.2	36.5	-9,897	0.5	-10,341	0.5	-10,341	0.5	-10,341	0.5	-10,341	0.5
7	40.8	37.3	-9,825	0.5	-10,321	0.5	-10,321	0.5	-10,321	0.5	-10,321	0.5
8	42.6	39.4	-6,694	0.5	-8,386	0.5	-8,386	0.5	-8,386	0.5	-8,386	0.5
9	45.3	41.4	0	0.6	-3,280	0.5	-3,280	0.5	-3,280	0.5	-3,280	0.5
10	48.6	44.0	0	1.1	0	0.6	0	0.6	0	0.6	0	0.6
11	52.1	46.0	0	2.1	0	0.7	0	0.7	0	0.7	0	0.7
12	55.4	47.6	0	2.2	0	1.0	0	1.0	0	1.0	0	1.0
13	58.1	49.0	0	2.2	0	1.0	0	1.0	0	1.0	0	1.0
14	59.8	49.9	0	2.2	0	1.1	0	1.1	0	1.1	0	1.1
15	60.4	49.2	0	2.3	0	1.1	0	1.1	0	1.1	0	1.1
16	60.2	48.8	0	2.2	0	1.1	0	1.1	0	1.1	0	1.1
17	59.6	49.2	0	1.5	0	0.8	0	0.8	0	0.8	0	0.8
18	58.5	49.6	0	0.8	0	0.7	0	0.7	0	0.7	0	0.7
19	57.1	49.1	-2,924	0.7	-6,048	0.6	-6,048	0.6	-6,048	0.6	-6,048	0.6
20	55.4	48.0	-8,483	0.6	-8,506	0.6	-8,506	0.6	-8,506	0.6	-8,506	0.6
21	53.5	46.8	-8,765	0.6	-8,710	0.6	-8,710	0.6	-8,710	0.6	-8,710	0.6
22	51.4	45.4	-9,019	0.6	-8,936	0.6	-8,936	0.6	-8,936	0.6	-8,936	0.6
23	49.3	44.0	-9,238	0.6	-9,174	0.6	-9,174	0.6	-9,174	0.6	-9,174	0.6
24	47.2	41.9	-9,409	0.6	-9,419	0.5	-9,419	0.5	-9,419	0.5	-9,419	0.5

December	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	33.0	29.9	-10,547	0.5	-11,162	0.5	-11,162	0.5	-11,162	0.5	-11,162	0.5
2	32.7	29.7	-10,632	0.5	-11,233	0.5	-11,233	0.5	-11,233	0.5	-11,233	0.5
3	32.9	29.8	-10,707	0.5	-11,253	0.5	-11,253	0.5	-11,253	0.5	-11,253	0.5
4	33.5	30.7	-10,766	0.5	-11,222	0.5	-11,222	0.5	-11,222	0.5	-11,222	0.5
5	34.5	31.6	-10,796	0.5	-11,142	0.5	-11,142	0.5	-11,142	0.5	-11,142	0.5
6	35.7	33.1	-10,788	0.5	-11,027	0.5	-11,027	0.5	-11,027	0.5	-11,027	0.5
7	37.2	34.8	-10,736	0.5	-10,861	0.5	-10,861	0.5	-10,861	0.5	-10,861	0.5
8	38.9	36.5	-10,631	0.5	-10,681	0.5	-10,681	0.5	-10,681	0.5	-10,681	0.5
9	40.6	38.2	-3,583	0.5	-6,578	0.5	-6,578	0.5	-6,578	0.5	-6,578	0.5
10	42.2	39.5	0	0.6	-1,021	0.5	-1,021	0.5	-1,021	0.5	-1,021	0.5
11	43.7	40.4	0	1.7	0	0.6	0	0.6	0	0.6	0	0.6
12	45.0	41.2	0	2.0	0	0.7	0	0.7	0	0.7	0	0.7
13	45.9	41.8	0	2.0	0	0.9	0	0.9	0	0.9	0	0.9
14	46.5	41.9	0	2.0	0	1.0	0	1.0	0	1.0	0	1.0
15	46.7	41.9	0	2.1	0	1.0	0	1.0	0	1.0	0	1.0
16	46.5	41.5	0	2.0	0	0.9	0	0.9	0	0.9	0	0.9
17	45.6	40.8	0	1.3	0	0.7	0	0.7	0	0.7	0	0.7
18	44.3	40.2	0	0.7	-997	0.6	-997	0.6	-997	0.6	-997	0.6
19	42.6	38.9	-5,832	0.6	-9,220	0.5	-9,220	0.5	-9,220	0.5	-9,220	0.5
20	40.7	37.2	-9,809	0.6	-10,190	0.5	-10,190	0.5	-10,190	0.5	-10,190	0.5
21	38.7	35.7	-10,002	0.5	-10,410	0.5	-10,410	0.5	-10,410	0.5	-10,410	0.5
22	36.8	33.8	-10,179	0.5	-10,638	0.5	-10,638	0.5	-10,638	0.5	-10,638	0.5
23	35.1	32.1	-10,332	0.5	-10,848	0.5	-10,848	0.5	-10,848	0.5	-10,848	0.5
24	33.8	30.7	-10,450	0.5	-11,030	0.5	-11,030	0.5	-11,030	0.5	-11,030	0.5

Design Cooling Load Summary

By ACADEMIC

System - System - 001

Type - VAV w/Baseboard Heating

Coil Location - System

Coil Peak Calculation Time: September, hour 16
Ambient DB/WB/HR: 83 / 69 / 85

COOLING COIL LOAD INFORMATION

Load Component	Sensible Btu/h	Latent Btu/h	Total Btu/h	Percent of Total
Solar Gain	29,966		29,966	93.5%
Glass Transmission	905		905	2.8%
Wall Transmission	0		0	0.0%
Roof Transmission	0		0	0.0%
Floor Transmission	0		0	0.0%
Adj Floor Transmission	0		0.00	0.0%
Partition Transmission	0		0	0.0%
Net Ceiling Load	0		0	0.0%
Lighting	0		0	0.0%
People	0	0	0	0.0%
Misc. Equipment Loads	0	0	0	0.0%
Cooling Infiltration	0	0	0	0.0%
Sub-Total ==>	30,871	0	30,871	96.4%
Ventilation Load	0	0	0	0.0%
Exhaust Heat	0	0	0	0.0%
Supply Fan Load	0		0	0.0%
Return Fan Load	0		0	0.0%
Net Duct Heat Pickup	0		0	0.0%
Wall Load to Plenum	0		0	0.0%
Roof Load to Plenum	1,166		1,166	3.6%
Adj Floor to Plenum	0		0	0.0%
Lighting Load to Plenum	0		0	0.0%
Misc. Equip. Load to Plenum	0	0	0	0.0%
Glass Transmission to Plenum	0		0	0.0%
Glass Solar to Plenum	0		0	0.0%
Over/Under Sizing	0		0	0.0%
Reheat at Design	0	0	0	0.0%
Underfloor Sup Heat Pickup	0		0	0.0%
Supply Air Leakage	0	0	0	0.0%
Total Cooling Loads	32,037	0	32,037	100.0 %

COOLING COIL SELECTION

Coil Selection Parameters

Coil Entering Air (DB / WB)	75.7 / 57.2	°F
Coil Entering Humidity Ratio	40.48	gr/lb
Coil Leaving Air (DB / WB)	55.0 / 48.5	°F
Coil Leaving Humidity Ratio	40.23	gr/lb
Coil Sensible Load	32.04	MBh
Coil Total Load	32.04	MBh
Cooling Supply Air Temperature	55.00	°F
Total Cooling Airflow	1,385.74	cfm
Resulting Room Relative Humidity	31.34	%

General Engineering Checks

Total Cooling Load	2.7	ton
Area / Load	37.46	ft²/ton
Total Floor Area	100	ft²
Cooling Airflow	13.86	cfm/ft²
Airflow / Load	519.05	cfm/ton
Percent Outdoor Air	0.0	%
Cooling Load Methodology	TETD-TA1	

APPENDIX G – FAÇADE SCHEDULES

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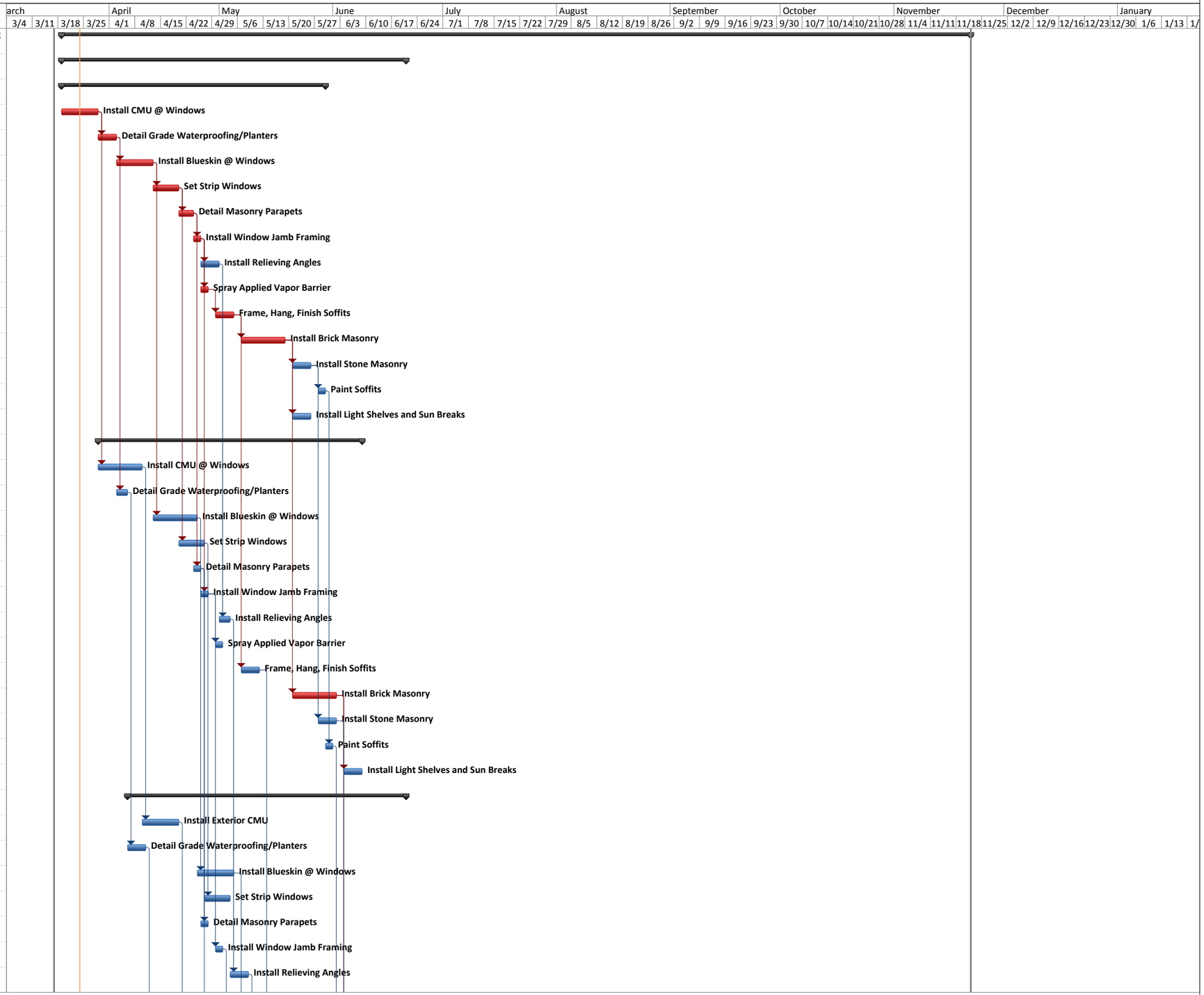
Skin Baseline Schedule

ID	Task Name	Duration	Start	Finish
1	**Building 1 Skin**	**178 days**	**Mon 3/19/12**	**Wed 11/21/12**
2	**Childcare Center**	**68 days**	**Mon 3/19/12**	**Wed 6/20/12**
3	**North Elevation**	**52 days**	**Mon 3/19/12**	**Tue 5/29/12**
4	Install CMU @ Windows	8 days	Mon 3/19/12	Wed 3/28/12
5	Detail Grade Waterproofing/Planters	3 days	Thu 3/29/12	Mon 4/2/12
6	Install Blueskin @ Windows	8 days	Tue 4/3/12	Thu 4/12/12
7	Set Strip Windows	5 days	Fri 4/13/12	Thu 4/19/12
8	Detail Masonry Parapets	2 days	Fri 4/20/12	Mon 4/23/12
9	Install Window Jamb Framing	2 days	Tue 4/24/12	Wed 4/25/12
10	Install Relieving Angles	3 days	Thu 4/26/12	Mon 4/30/12
11	Spray Applied Vapor Barrier	2 days	Thu 4/26/12	Fri 4/27/12
12	Frame, Hang, Finish Soffits	5 days	Mon 4/30/12	Fri 5/4/12
13	Install Brick Masonry	10 days	Mon 5/7/12	Fri 5/18/12
14	Install Stone Masonry	5 days	Mon 5/21/12	Fri 5/25/12
15	Paint Soffits	2 days	Mon 5/28/12	Tue 5/29/12
16	Install Light Shelves and Sun Breaks	5 days	Mon 5/21/12	Fri 5/25/12
17	**East Elevation**	**52 days**	**Thu 3/29/12**	**Fri 6/8/12**
18	Install CMU @ Windows	8 days	Thu 3/29/12	Mon 4/9/12
19	Detail Grade Waterproofing/Planters	3 days	Tue 4/3/12	Thu 4/5/12
20	Install Blueskin @ Windows	8 days	Fri 4/13/12	Tue 4/24/12
21	Set Strip Windows	5 days	Fri 4/20/12	Thu 4/26/12
22	Detail Masonry Parapets	2 days	Tue 4/24/12	Wed 4/25/12
23	Install Window Jamb Framing	2 days	Thu 4/26/12	Fri 4/27/12
24	Install Relieving Angles	3 days	Tue 5/1/12	Thu 5/3/12
25	Spray Applied Vapor Barrier	2 days	Mon 4/30/12	Tue 5/1/12
26	Frame, Hang, Finish Soffits	5 days	Mon 5/7/12	Fri 5/11/12
27	Install Brick Masonry	10 days	Mon 5/21/12	Fri 6/1/12
28	Install Stone Masonry	5 days	Mon 5/28/12	Fri 6/1/12
29	Paint Soffits	2 days	Wed 5/30/12	Thu 5/31/12
30	Install Light Shelves and Sun Breaks	5 days	Mon 6/4/12	Fri 6/8/12
31	**West Elevation**	**54 days**	**Fri 4/6/12**	**Wed 6/20/12**
32	Install Exterior CMU	8 days	Tue 4/10/12	Thu 4/19/12
33	Detail Grade Waterproofing/Planters	3 days	Fri 4/6/12	Tue 4/10/12
34	Install Blueskin @ Windows	8 days	Wed 4/25/12	Fri 5/4/12
35	Set Strip Windows	5 days	Fri 4/27/12	Thu 5/3/12
36	Detail Masonry Parapets	2 days	Thu 4/26/12	Fri 4/27/12
37	Install Window Jamb Framing	2 days	Mon 4/30/12	Tue 5/1/12
38	Install Relieving Angles	3 days	Fri 5/4/12	Tue 5/8/12



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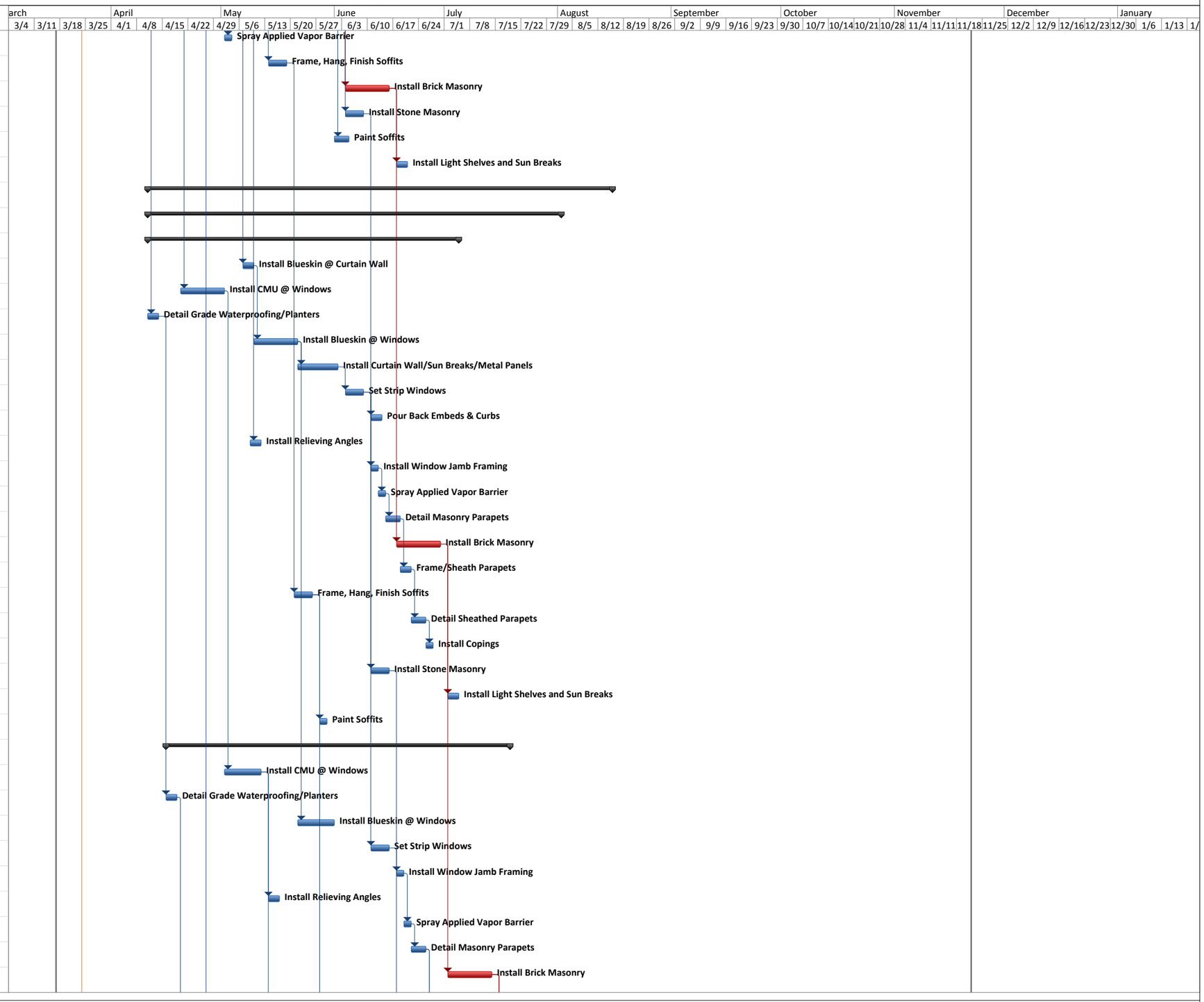
Skin Baseline Schedule

ID	Task Name	Duration	Start	Finish
39	Spray Applied Vapor Barrier	2 days	Wed 5/2/12	Thu 5/3/12
40	Frame, Hang, Finish Soffits	5 days	Mon 5/14/12	Fri 5/18/12
41	Install Brick Masonry	10 days	Mon 6/4/12	Fri 6/15/12
42	Install Stone Masonry	5 days	Mon 6/4/12	Fri 6/8/12
43	Paint Soffits	2 days	Fri 6/1/12	Mon 6/4/12
44	Install Light Shelves and Sun Breaks	3 days	Mon 6/18/12	Wed 6/20/12
45	**Area A (Column Lines 1-12)**	**91 days**	**Wed 4/11/12**	**Wed 8/15/12**
46	**North Finger**	**81 days**	**Wed 4/11/12**	**Wed 8/1/12**
47	**North Elevation**	**61 days**	**Wed 4/11/12**	**Wed 7/4/12**
48	Install Blueskin @ Curtain Wall	3 days	Mon 5/7/12	Wed 5/9/12
49	Install CMU @ Windows	8 days	Fri 4/20/12	Tue 5/1/12
50	Detail Grade Waterproofing/Planters	3 days	Wed 4/11/12	Fri 4/13/12
51	Install Blueskin @ Windows	8 days	Thu 5/10/12	Mon 5/21/12
52	Install Curtain Wall/Sun Breaks/Metal Panels	9 days	Tue 5/22/12	Fri 6/1/12
53	Set Strip Windows	5 days	Mon 6/4/12	Fri 6/8/12
54	Pour Back Embeds & Curbs	3 days	Mon 6/11/12	Wed 6/13/12
55	Install Relieving Angles	3 days	Wed 5/9/12	Fri 5/11/12
56	Install Window Jamb Framing	2 days	Mon 6/11/12	Tue 6/12/12
57	Spray Applied Vapor Barrier	2 days	Wed 6/13/12	Thu 6/14/12
58	Detail Masonry Parapets	2 days	Fri 6/15/12	Mon 6/18/12
59	Install Brick Masonry	10 days	Mon 6/18/12	Fri 6/29/12
60	Frame/Sheath Parapets	3 days	Tue 6/19/12	Thu 6/21/12
61	Frame, Hang, Finish Soffits	5 days	Mon 5/21/12	Fri 5/25/12
62	Detail Sheathed Parapets	2 days	Fri 6/22/12	Mon 6/25/12
63	Install Copings	2 days	Tue 6/26/12	Wed 6/27/12
64	Install Stone Masonry	5 days	Mon 6/11/12	Fri 6/15/12
65	Install Light Shelves and Sun Breaks	3 days	Mon 7/2/12	Wed 7/4/12
66	Paint Soffits	2 days	Mon 5/28/12	Tue 5/29/12
67	**West Elevation**	**68 days**	**Mon 4/16/12**	**Wed 7/18/12**
68	Install CMU @ Windows	8 days	Wed 5/2/12	Fri 5/11/12
69	Detail Grade Waterproofing/Planters	3 days	Mon 4/16/12	Wed 4/18/12
70	Install Blueskin @ Windows	8 days	Tue 5/22/12	Thu 5/31/12
71	Set Strip Windows	5 days	Mon 6/11/12	Fri 6/15/12
72	Install Window Jamb Framing	2 days	Mon 6/18/12	Tue 6/19/12
73	Install Relieving Angles	3 days	Mon 5/14/12	Wed 5/16/12
74	Spray Applied Vapor Barrier	2 days	Wed 6/20/12	Thu 6/21/12
75	Detail Masonry Parapets	2 days	Fri 6/22/12	Mon 6/25/12
76	Install Brick Masonry	10 days	Mon 7/2/12	Fri 7/13/12



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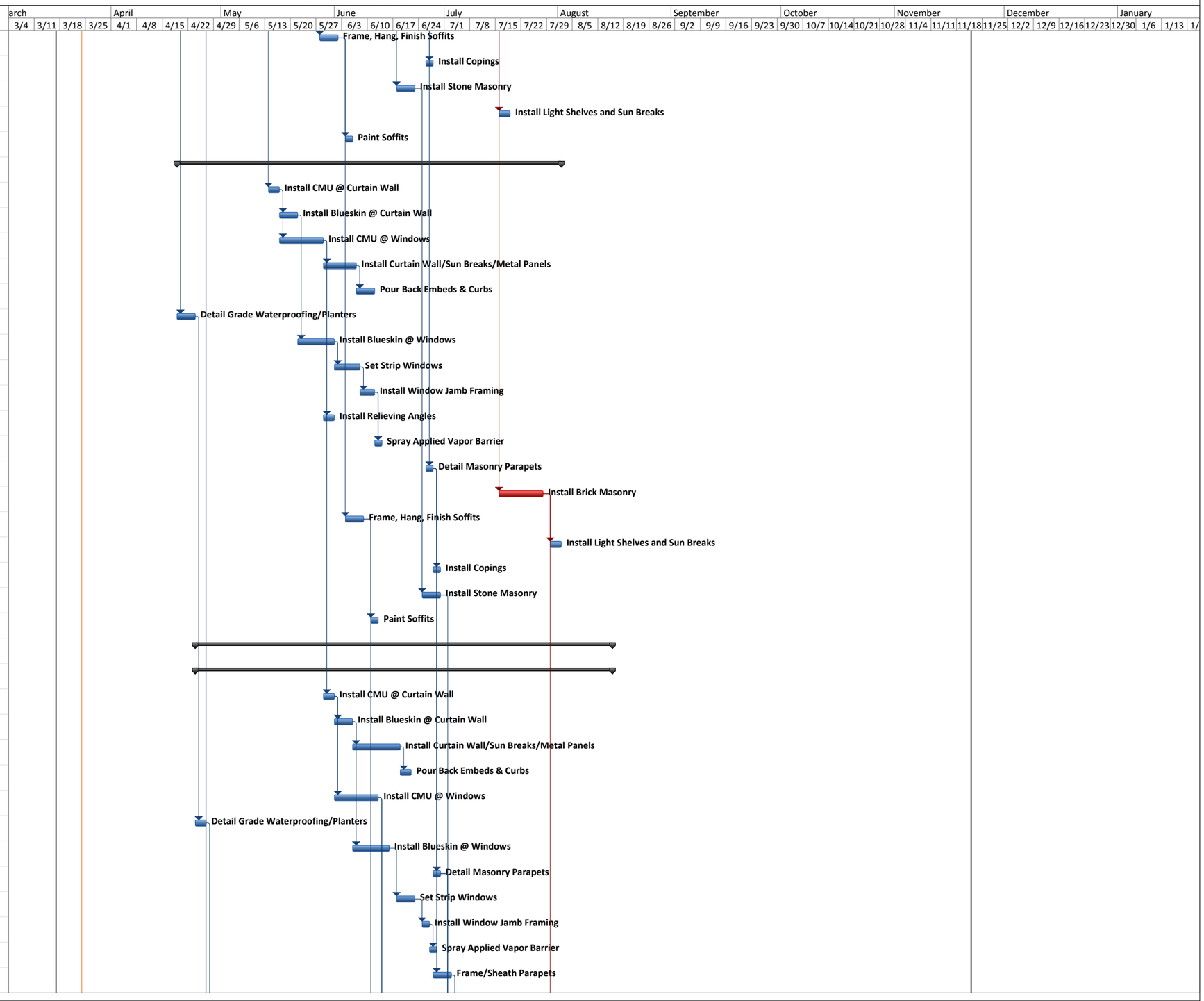
Skin Baseline Schedule

ID	Task Name	Duration	Start	Finish
77	Frame, Hang, Finish Soffits	5 days	Mon 5/28/12	Fri 6/1/12
78	Install Copings	2 days	Tue 6/26/12	Wed 6/27/12
79	Install Stone Masonry	5 days	Mon 6/18/12	Fri 6/22/12
80	Install Light Shelves and Sun Breaks	3 days	Mon 7/16/12	Wed 7/18/12
81	Paint Soffits	2 days	Mon 6/4/12	Tue 6/5/12
82	**South Elevation**	**75 days**	**Thu 4/19/12**	**Wed 8/1/12**
83	Install CMU @ Curtain Wall	3 days	Mon 5/14/12	Wed 5/16/12
84	Install Blueskin @ Curtain Wall	3 days	Thu 5/17/12	Mon 5/21/12
85	Install CMU @ Windows	8 days	Thu 5/17/12	Mon 5/28/12
86	Install Curtain Wall/Sun Breaks/Metal Panels	7 days	Tue 5/29/12	Wed 6/6/12
87	Pour Back Embeds & Curbs	3 days	Thu 6/7/12	Mon 6/11/12
88	Detail Grade Waterproofing/Planters	3 days	Thu 4/19/12	Mon 4/23/12
89	Install Blueskin @ Windows	8 days	Tue 5/22/12	Thu 5/31/12
90	Set Strip Windows	5 days	Fri 6/1/12	Thu 6/7/12
91	Install Window Jamb Framing	2 days	Fri 6/8/12	Mon 6/11/12
92	Install Relieving Angles	3 days	Tue 5/29/12	Thu 5/31/12
93	Spray Applied Vapor Barrier	2 days	Tue 6/12/12	Wed 6/13/12
94	Detail Masonry Parapets	2 days	Tue 6/26/12	Wed 6/27/12
95	Install Brick Masonry	10 days	Mon 7/16/12	Fri 7/27/12
96	Frame, Hang, Finish Soffits	5 days	Mon 6/4/12	Fri 6/8/12
97	Install Light Shelves and Sun Breaks	3 days	Mon 7/30/12	Wed 8/1/12
98	Install Copings	2 days	Thu 6/28/12	Fri 6/29/12
99	Install Stone Masonry	5 days	Mon 6/25/12	Fri 6/29/12
100	Paint Soffits	2 days	Mon 6/11/12	Tue 6/12/12
101	**North Spine**	**82 days**	**Tue 4/24/12**	**Wed 8/15/12**
102	**West Elevation**	**82 days**	**Tue 4/24/12**	**Wed 8/15/12**
103	Install CMU @ Curtain Wall	3 days	Tue 5/29/12	Thu 5/31/12
104	Install Blueskin @ Curtain Wall	3 days	Fri 6/1/12	Tue 6/5/12
105	Install Curtain Wall/Sun Breaks/Metal Panels	9 days	Wed 6/6/12	Mon 6/18/12
106	Pour Back Embeds & Curbs	3 days	Tue 6/19/12	Thu 6/21/12
107	Install CMU @ Windows	8 days	Fri 6/1/12	Tue 6/12/12
108	Detail Grade Waterproofing/Planters	3 days	Tue 4/24/12	Thu 4/26/12
109	Install Blueskin @ Windows	8 days	Wed 6/6/12	Fri 6/15/12
110	Detail Masonry Parapets	2 days	Thu 6/28/12	Fri 6/29/12
111	Set Strip Windows	5 days	Mon 6/18/12	Fri 6/22/12
112	Install Window Jamb Framing	2 days	Mon 6/25/12	Tue 6/26/12
113	Spray Applied Vapor Barrier	2 days	Wed 6/27/12	Thu 6/28/12
114	Frame/Sheath Parapets	3 days	Thu 6/28/12	Mon 7/2/12



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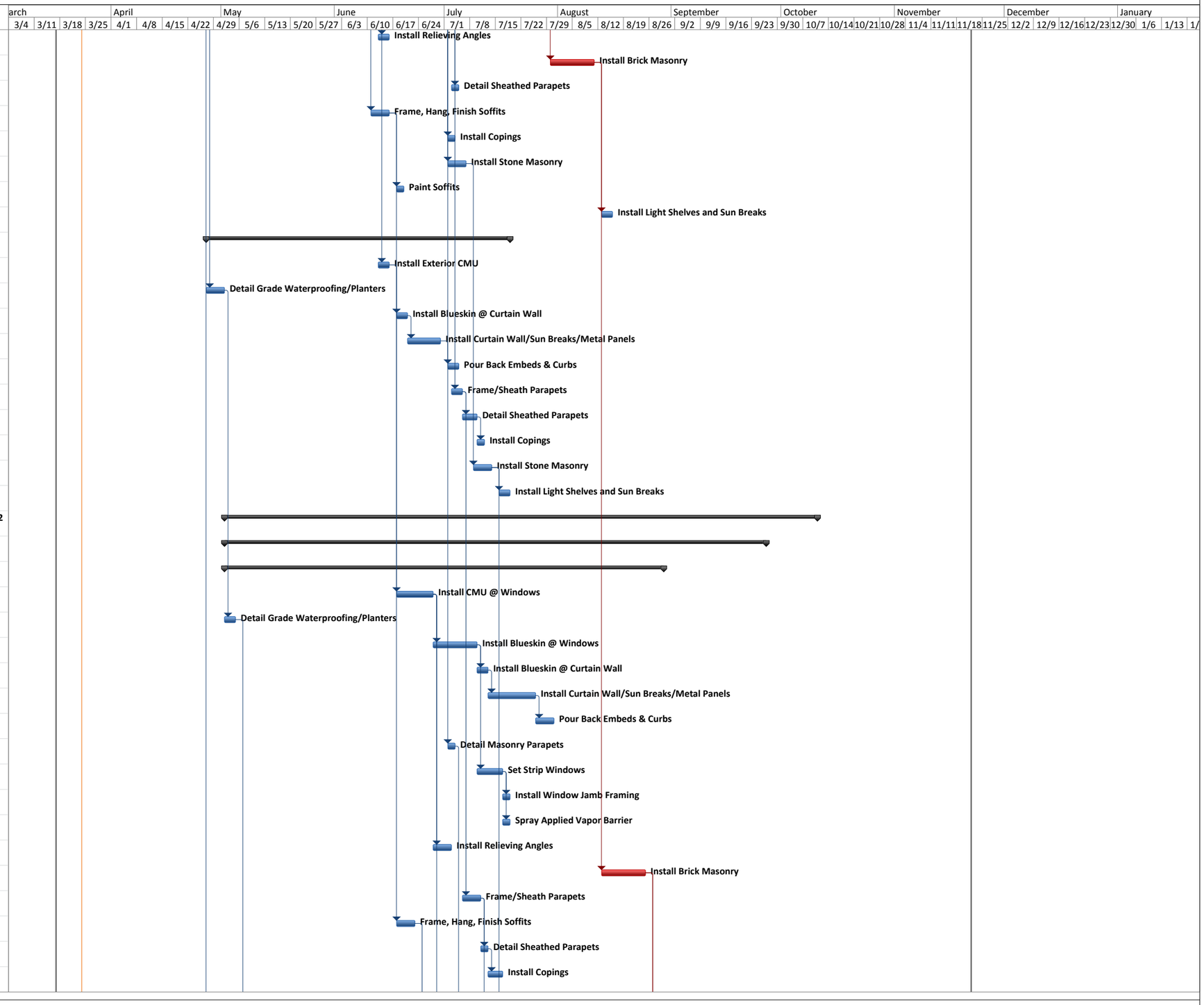
Skin Baseline Schedule

ID	Task Name	Duration	Start	Finish
115	Install Relieving Angles	3 days	Wed 6/13/12	Fri 6/15/12
116	Install Brick Masonry	10 days	Mon 7/30/12	Fri 8/10/12
117	Detail Sheathed Parapets	2 days	Tue 7/3/12	Wed 7/4/12
118	Frame, Hang, Finish Soffits	5 days	Mon 6/11/12	Fri 6/15/12
119	Install Copings	2 days	Mon 7/2/12	Tue 7/3/12
120	Install Stone Masonry	5 days	Mon 7/2/12	Fri 7/6/12
121	Paint Soffits	2 days	Mon 6/18/12	Tue 6/19/12
122	Install Light Shelves and Sun Breaks	3 days	Mon 8/13/12	Wed 8/15/12
123	**East Elevation**	**59 days**	**Fri 4/27/12**	**Wed 7/18/12**
124	Install Exterior CMU	3 days	Wed 6/13/12	Fri 6/15/12
125	Detail Grade Waterproofing/Planters	3 days	Fri 4/27/12	Tue 5/1/12
126	Install Blueskin @ Curtain Wall	3 days	Mon 6/18/12	Wed 6/20/12
127	Install Curtain Wall/Sun Breaks/Metal Panels	7 days	Thu 6/21/12	Fri 6/29/12
128	Pour Back Embeds & Curbs	3 days	Mon 7/2/12	Wed 7/4/12
129	Frame/Sheath Parapets	3 days	Tue 7/3/12	Thu 7/5/12
130	Detail Sheathed Parapets	2 days	Fri 7/6/12	Mon 7/9/12
131	Install Copings	2 days	Tue 7/10/12	Wed 7/11/12
132	Install Stone Masonry	5 days	Mon 7/9/12	Fri 7/13/12
133	Install Light Shelves and Sun Breaks	3 days	Mon 7/16/12	Wed 7/18/12
134	**Area B (Column Lines 12-20)**	**116 days**	**Wed 5/2/12**	**Wed 10/10/12**
135	**Middle Finger**	**106 days**	**Wed 5/2/12**	**Wed 9/26/12**
136	**North Elevation**	**86 days**	**Wed 5/2/12**	**Wed 8/29/12**
137	Install CMU @ Windows	8 days	Mon 6/18/12	Wed 6/27/12
138	Detail Grade Waterproofing/Planters	3 days	Wed 5/2/12	Fri 5/4/12
139	Install Blueskin @ Windows	8 days	Thu 6/28/12	Mon 7/9/12
140	Install Blueskin @ Curtain Wall	3 days	Tue 7/10/12	Thu 7/12/12
141	Install Curtain Wall/Sun Breaks/Metal Panels	9 days	Fri 7/13/12	Wed 7/25/12
142	Pour Back Embeds & Curbs	3 days	Thu 7/26/12	Mon 7/30/12
143	Detail Masonry Parapets	2 days	Mon 7/2/12	Tue 7/3/12
144	Set Strip Windows	5 days	Tue 7/10/12	Mon 7/16/12
145	Install Window Jamb Framing	2 days	Tue 7/17/12	Wed 7/18/12
146	Spray Applied Vapor Barrier	2 days	Tue 7/17/12	Wed 7/18/12
147	Install Relieving Angles	3 days	Thu 6/28/12	Mon 7/2/12
148	Install Brick Masonry	10 days	Mon 8/13/12	Fri 8/24/12
149	Frame/Sheath Parapets	3 days	Fri 7/6/12	Tue 7/10/12
150	Frame, Hang, Finish Soffits	5 days	Mon 6/18/12	Fri 6/22/12
151	Detail Sheathed Parapets	2 days	Wed 7/11/12	Thu 7/12/12
152	Install Copings	2 days	Fri 7/13/12	Mon 7/16/12



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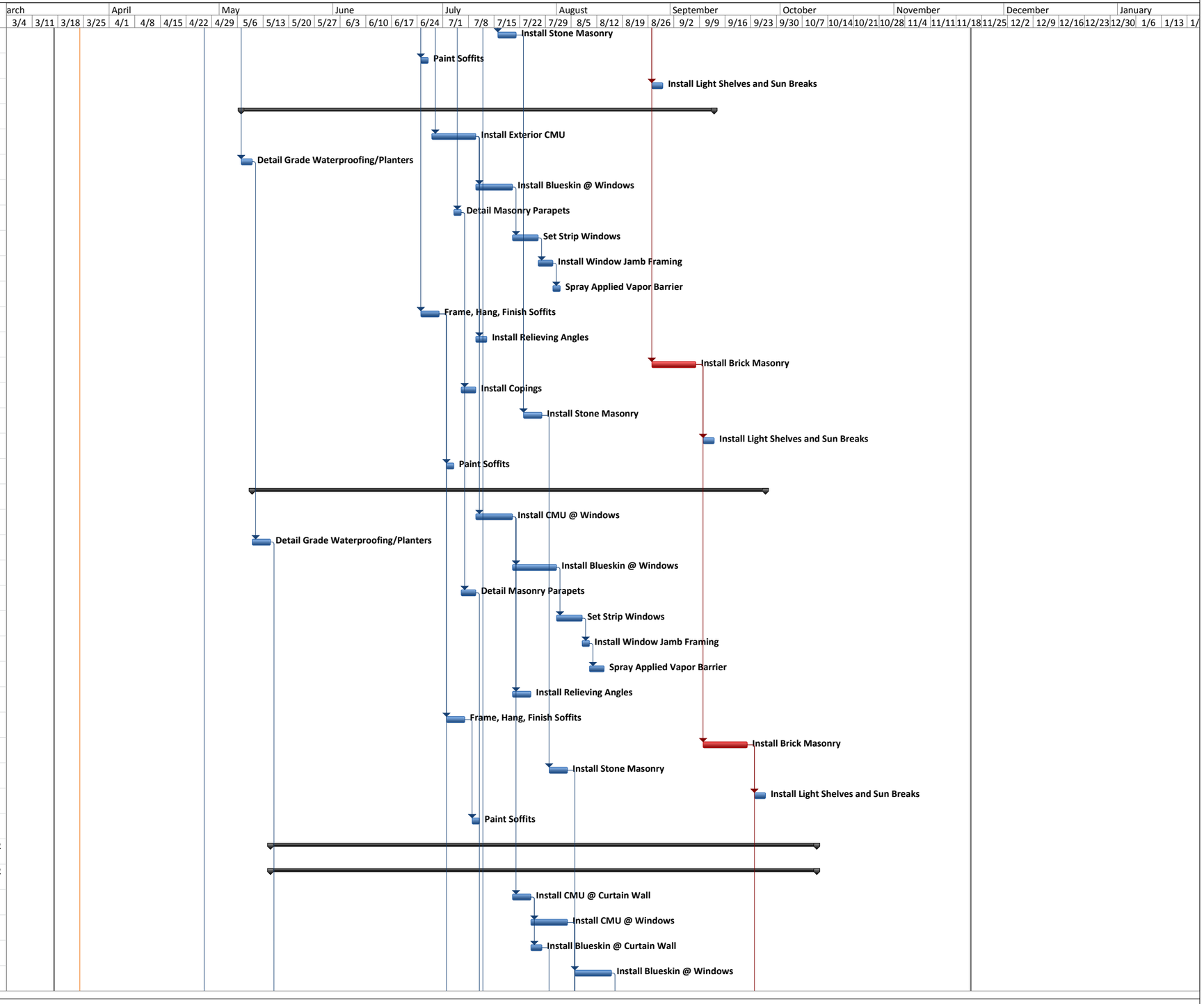
Skin Baseline Schedule

ID	Task Name	Duration	Start	Finish
153	Install Stone Masonry	5 days	Mon 7/16/12	Fri 7/20/12
154	Paint Soffits	2 days	Mon 6/25/12	Tue 6/26/12
155	Install Light Shelves and Sun Breaks	3 days	Mon 8/27/12	Wed 8/29/12
156	**West Elevation**	**93 days**	**Mon 5/7/12**	**Wed 9/12/12**
157	Install Exterior CMU	8 days	Thu 6/28/12	Mon 7/9/12
158	Detail Grade Waterproofing/Planters	3 days	Mon 5/7/12	Wed 5/9/12
159	Install Blueskin @ Windows	8 days	Tue 7/10/12	Thu 7/19/12
160	Detail Masonry Parapets	2 days	Wed 7/4/12	Thu 7/5/12
161	Set Strip Windows	5 days	Fri 7/20/12	Thu 7/26/12
162	Install Window Jamb Framing	2 days	Fri 7/27/12	Mon 7/30/12
163	Spray Applied Vapor Barrier	2 days	Tue 7/31/12	Wed 8/1/12
164	Frame, Hang, Finish Soffits	5 days	Mon 6/25/12	Fri 6/29/12
165	Install Relieving Angles	3 days	Tue 7/10/12	Thu 7/12/12
166	Install Brick Masonry	10 days	Mon 8/27/12	Fri 9/7/12
167	Install Copings	2 days	Fri 7/6/12	Mon 7/9/12
168	Install Stone Masonry	5 days	Mon 7/23/12	Fri 7/27/12
169	Install Light Shelves and Sun Breaks	3 days	Mon 9/10/12	Wed 9/12/12
170	Paint Soffits	2 days	Mon 7/2/12	Tue 7/3/12
171	**South Elevation**	**100 days**	**Thu 5/10/12**	**Wed 9/26/12**
172	Install CMU @ Windows	8 days	Tue 7/10/12	Thu 7/19/12
173	Detail Grade Waterproofing/Planters	3 days	Thu 5/10/12	Mon 5/14/12
174	Install Blueskin @ Windows	8 days	Fri 7/20/12	Tue 7/31/12
175	Detail Masonry Parapets	2 days	Fri 7/6/12	Mon 7/9/12
176	Set Strip Windows	5 days	Wed 8/1/12	Tue 8/7/12
177	Install Window Jamb Framing	2 days	Wed 8/8/12	Thu 8/9/12
178	Spray Applied Vapor Barrier	2 days	Fri 8/10/12	Mon 8/13/12
179	Install Relieving Angles	3 days	Fri 7/20/12	Tue 7/24/12
180	Frame, Hang, Finish Soffits	5 days	Mon 7/2/12	Fri 7/6/12
181	Install Brick Masonry	10 days	Mon 9/10/12	Fri 9/21/12
182	Install Stone Masonry	5 days	Mon 7/30/12	Fri 8/3/12
183	Install Light Shelves and Sun Breaks	3 days	Mon 9/24/12	Wed 9/26/12
184	Paint Soffits	2 days	Mon 7/9/12	Tue 7/10/12
185	**South Spine**	**107 days**	**Tue 5/15/12**	**Wed 10/10/12**
186	**West Elevation**	**107 days**	**Tue 5/15/12**	**Wed 10/10/12**
187	Install CMU @ Curtain Wall	3 days	Fri 7/20/12	Tue 7/24/12
188	Install CMU @ Windows	8 days	Wed 7/25/12	Fri 8/3/12
189	Install Blueskin @ Curtain Wall	3 days	Wed 7/25/12	Fri 7/27/12
190	Install Blueskin @ Windows	8 days	Mon 8/6/12	Wed 8/15/12



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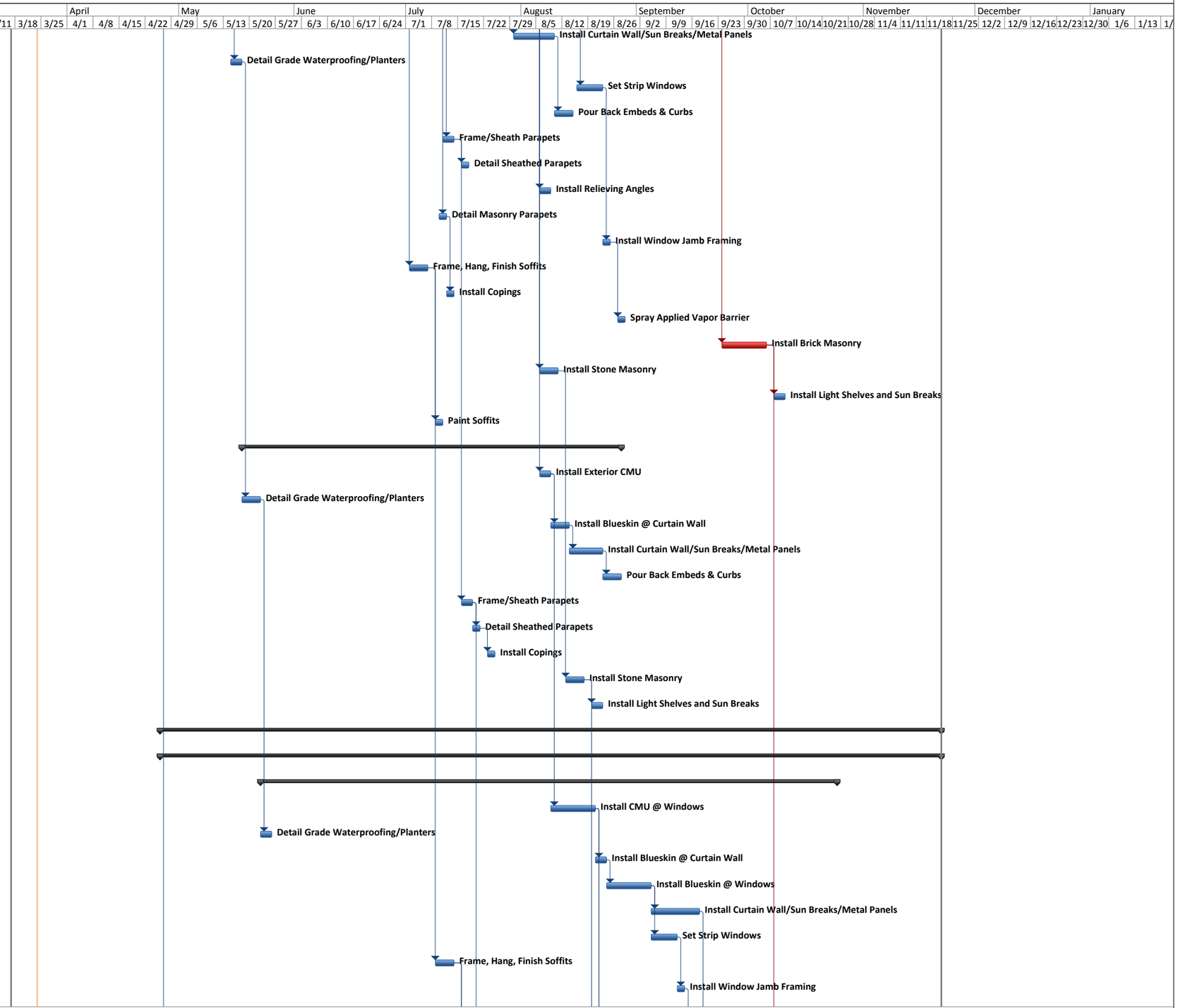
Skin Baseline Schedule

ID	Task Name	Duration	Start	Finish
191	Install Curtain Wall/Sun Breaks/Metal Panels	9 days	Mon 7/30/12	Thu 8/9/12
192	Detail Grade Waterproofing/Planters	3 days	Tue 5/15/12	Thu 5/17/12
193	Set Strip Windows	5 days	Thu 8/16/12	Wed 8/22/12
194	Pour Back Embeds & Curbs	3 days	Fri 8/10/12	Tue 8/14/12
195	Frame/Sheath Parapets	3 days	Wed 7/11/12	Fri 7/13/12
196	Detail Sheathed Parapets	2 days	Mon 7/16/12	Tue 7/17/12
197	Install Relieving Angles	3 days	Mon 8/6/12	Wed 8/8/12
198	Detail Masonry Parapets	2 days	Tue 7/10/12	Wed 7/11/12
199	Install Window Jamb Framing	2 days	Thu 8/23/12	Fri 8/24/12
200	Frame, Hang, Finish Soffits	5 days	Mon 7/2/12	Fri 7/6/12
201	Install Copings	2 days	Thu 7/12/12	Fri 7/13/12
202	Spray Applied Vapor Barrier	2 days	Mon 8/27/12	Tue 8/28/12
203	Install Brick Masonry	10 days	Mon 9/24/12	Fri 10/5/12
204	Install Stone Masonry	5 days	Mon 8/6/12	Fri 8/10/12
205	Install Light Shelves and Sun Breaks	3 days	Mon 10/8/12	Wed 10/10/12
206	Paint Soffits	2 days	Mon 7/9/12	Tue 7/10/12
207	**East Elevation**	**72 days**	**Fri 5/18/12**	**Mon 8/27/12**
208	Install Exterior CMU	3 days	Mon 8/6/12	Wed 8/8/12
209	Detail Grade Waterproofing/Planters	3 days	Fri 5/18/12	Tue 5/22/12
210	Install Blueskin @ Curtain Wall	3 days	Thu 8/9/12	Mon 8/13/12
211	Install Curtain Wall/Sun Breaks/Metal Panels	7 days	Tue 8/14/12	Wed 8/22/12
212	Pour Back Embeds & Curbs	3 days	Thu 8/23/12	Mon 8/27/12
213	Frame/Sheath Parapets	3 days	Mon 7/16/12	Wed 7/18/12
214	Detail Sheathed Parapets	2 days	Thu 7/19/12	Fri 7/20/12
215	Install Copings	2 days	Mon 7/23/12	Tue 7/24/12
216	Install Stone Masonry	5 days	Mon 8/13/12	Fri 8/17/12
217	Install Light Shelves and Sun Breaks	3 days	Mon 8/20/12	Wed 8/22/12
218	**Area C (Column Lines 20+)**	**150 days**	**Thu 4/26/12**	**Wed 11/21/12**
219	**South Finger**	**150 days**	**Thu 4/26/12**	**Wed 11/21/12**
220	**North Elevation**	**111 days**	**Wed 5/23/12**	**Wed 10/24/12**
221	Install CMU @ Windows	8 days	Thu 8/9/12	Mon 8/20/12
222	Detail Grade Waterproofing/Planters	3 days	Wed 5/23/12	Fri 5/25/12
223	Install Blueskin @ Curtain Wall	3 days	Tue 8/21/12	Thu 8/23/12
224	Install Blueskin @ Windows	8 days	Fri 8/24/12	Tue 9/4/12
225	Install Curtain Wall/Sun Breaks/Metal Panels	9 days	Wed 9/5/12	Mon 9/17/12
226	Set Strip Windows	5 days	Wed 9/5/12	Tue 9/11/12
227	Frame, Hang, Finish Soffits	5 days	Mon 7/9/12	Fri 7/13/12
228	Install Window Jamb Framing	2 days	Wed 9/12/12	Thu 9/13/12



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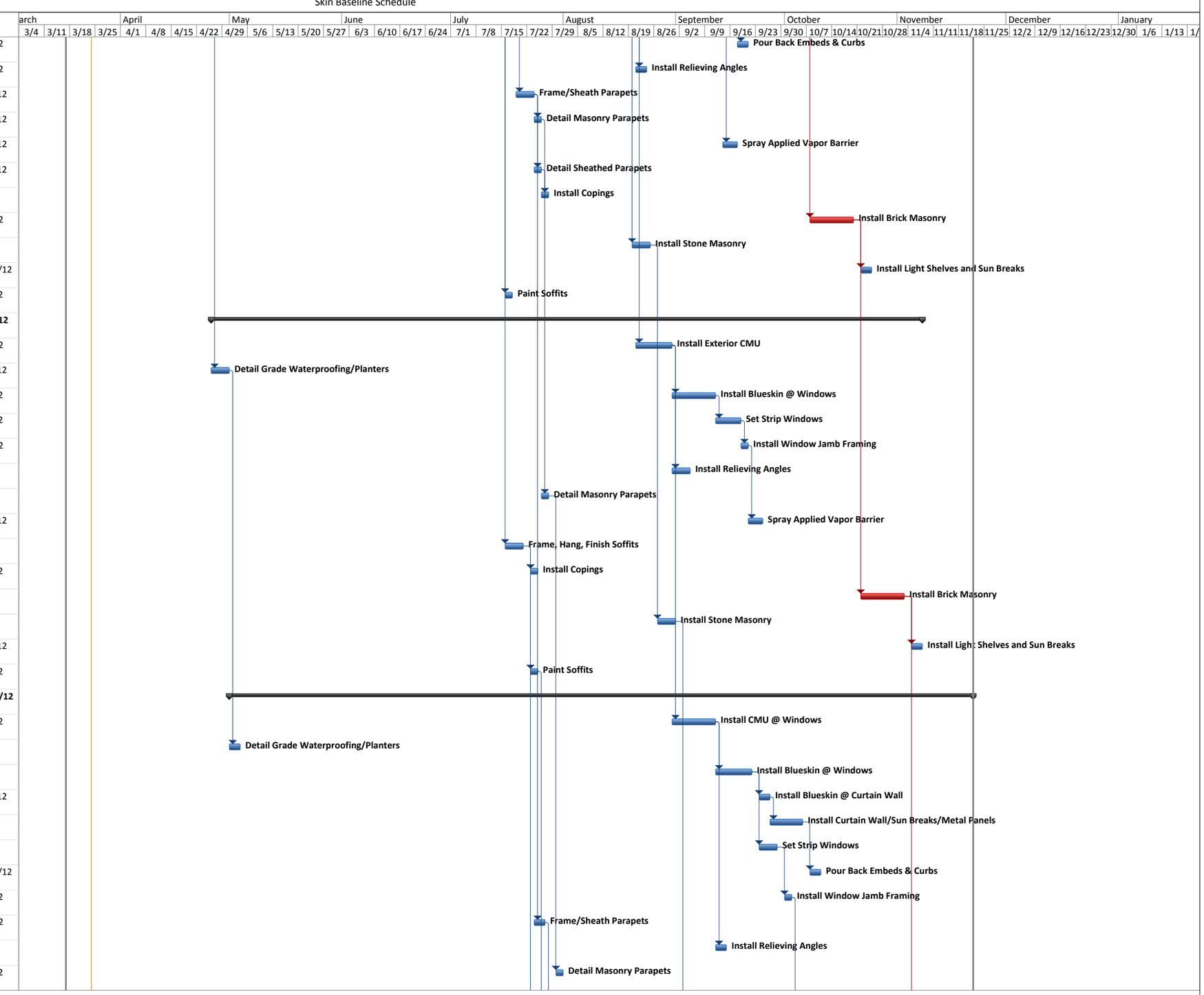
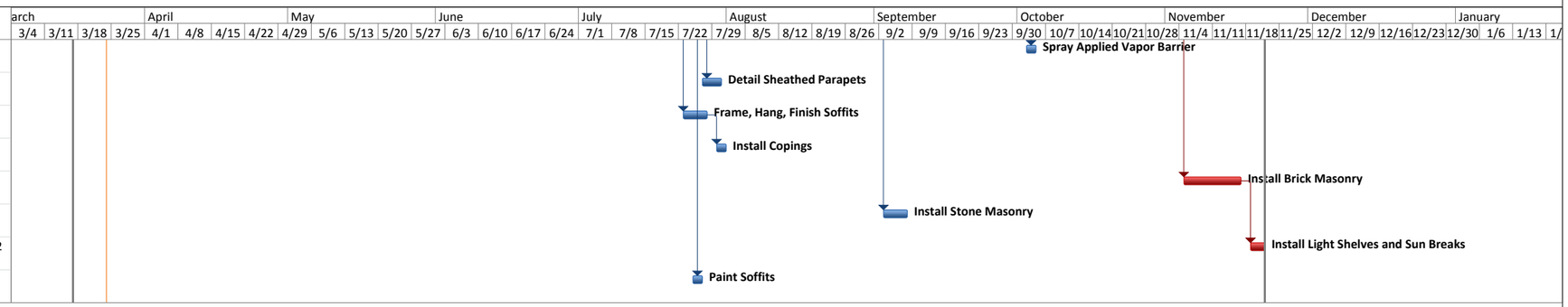
Skin Baseline Schedule

ID	Task Name	Duration	Start	Finish
229	Pour Back Embeds & Curbs	3 days	Tue 9/18/12	Thu 9/20/12
230	Install Relieving Angles	3 days	Tue 8/21/12	Thu 8/23/12
231	Frame/Sheath Parapets	3 days	Thu 7/19/12	Mon 7/23/12
232	Detail Masonry Parapets	2 days	Tue 7/24/12	Wed 7/25/12
233	Spray Applied Vapor Barrier	2 days	Fri 9/14/12	Mon 9/17/12
234	Detail Sheathed Parapets	2 days	Tue 7/24/12	Wed 7/25/12
235	Install Copings	2 days	Thu 7/26/12	Fri 7/27/12
236	Install Brick Masonry	10 days	Mon 10/8/12	Fri 10/19/12
237	Install Stone Masonry	5 days	Mon 8/20/12	Fri 8/24/12
238	Install Light Shelves and Sun Breaks	3 days	Mon 10/22/12	Wed 10/24/12
239	Paint Soffits	2 days	Mon 7/16/12	Tue 7/17/12
240	**West Elevation**	**140 days**	**Thu 4/26/12**	**Wed 11/7/12**
241	Install Exterior CMU	8 days	Tue 8/21/12	Thu 8/30/12
242	Detail Grade Waterproofing/Planters	3 days	Thu 4/26/12	Mon 4/30/12
243	Install Blueskin @ Windows	8 days	Fri 8/31/12	Tue 9/11/12
244	Set Strip Windows	5 days	Wed 9/12/12	Tue 9/18/12
245	Install Window Jamb Framing	2 days	Wed 9/19/12	Thu 9/20/12
246	Install Relieving Angles	3 days	Fri 8/31/12	Tue 9/4/12
247	Detail Masonry Parapets	2 days	Thu 7/26/12	Fri 7/27/12
248	Spray Applied Vapor Barrier	2 days	Fri 9/21/12	Mon 9/24/12
249	Frame, Hang, Finish Soffits	5 days	Mon 7/16/12	Fri 7/20/12
250	Install Copings	2 days	Mon 7/23/12	Tue 7/24/12
251	Install Brick Masonry	10 days	Mon 10/22/12	Fri 11/2/12
252	Install Stone Masonry	5 days	Mon 8/27/12	Fri 8/31/12
253	Install Light Shelves and Sun Breaks	3 days	Mon 11/5/12	Wed 11/7/12
254	Paint Soffits	2 days	Mon 7/23/12	Tue 7/24/12
255	**South Elevation**	**147 days**	**Tue 5/1/12**	**Wed 11/21/12**
256	Install CMU @ Windows	8 days	Fri 8/31/12	Tue 9/11/12
257	Detail Grade Waterproofing/Planters	3 days	Tue 5/1/12	Thu 5/3/12
258	Install Blueskin @ Windows	8 days	Wed 9/12/12	Fri 9/21/12
259	Install Blueskin @ Curtain Wall	3 days	Mon 9/24/12	Wed 9/26/12
260	Install Curtain Wall/Sun Breaks/Metal Panels	7 days	Thu 9/27/12	Fri 10/5/12
261	Set Strip Windows	5 days	Mon 9/24/12	Fri 9/28/12
262	Pour Back Embeds & Curbs	3 days	Mon 10/8/12	Wed 10/10/12
263	Install Window Jamb Framing	2 days	Mon 10/1/12	Tue 10/2/12
264	Frame/Sheath Parapets	3 days	Tue 7/24/12	Thu 7/26/12
265	Install Relieving Angles	3 days	Wed 9/12/12	Fri 9/14/12
266	Detail Masonry Parapets	2 days	Mon 7/30/12	Tue 7/31/12



Patrick Laninger - Senior Thesis
Skin Baseline Schedule

ID	Task Name	Duration	Start	Finish
267	Spray Applied Vapor Barrier	2 days	Wed 10/3/12	Thu 10/4/12
268	Detail Sheathed Parapets	2 days	Fri 7/27/12	Mon 7/30/12
269	Frame, Hang, Finish Soffits	5 days	Mon 7/23/12	Fri 7/27/12
270	Install Copings	2 days	Mon 7/30/12	Tue 7/31/12
271	Install Brick Masonry	10 days	Mon 11/5/12	Fri 11/16/12
272	Install Stone Masonry	5 days	Mon 9/3/12	Fri 9/7/12
273	Install Light Shelves and Sun Breaks	3 days	Mon 11/19/12	Wed 11/21/12
274	Paint Soffits	2 days	Wed 7/25/12	Thu 7/26/12



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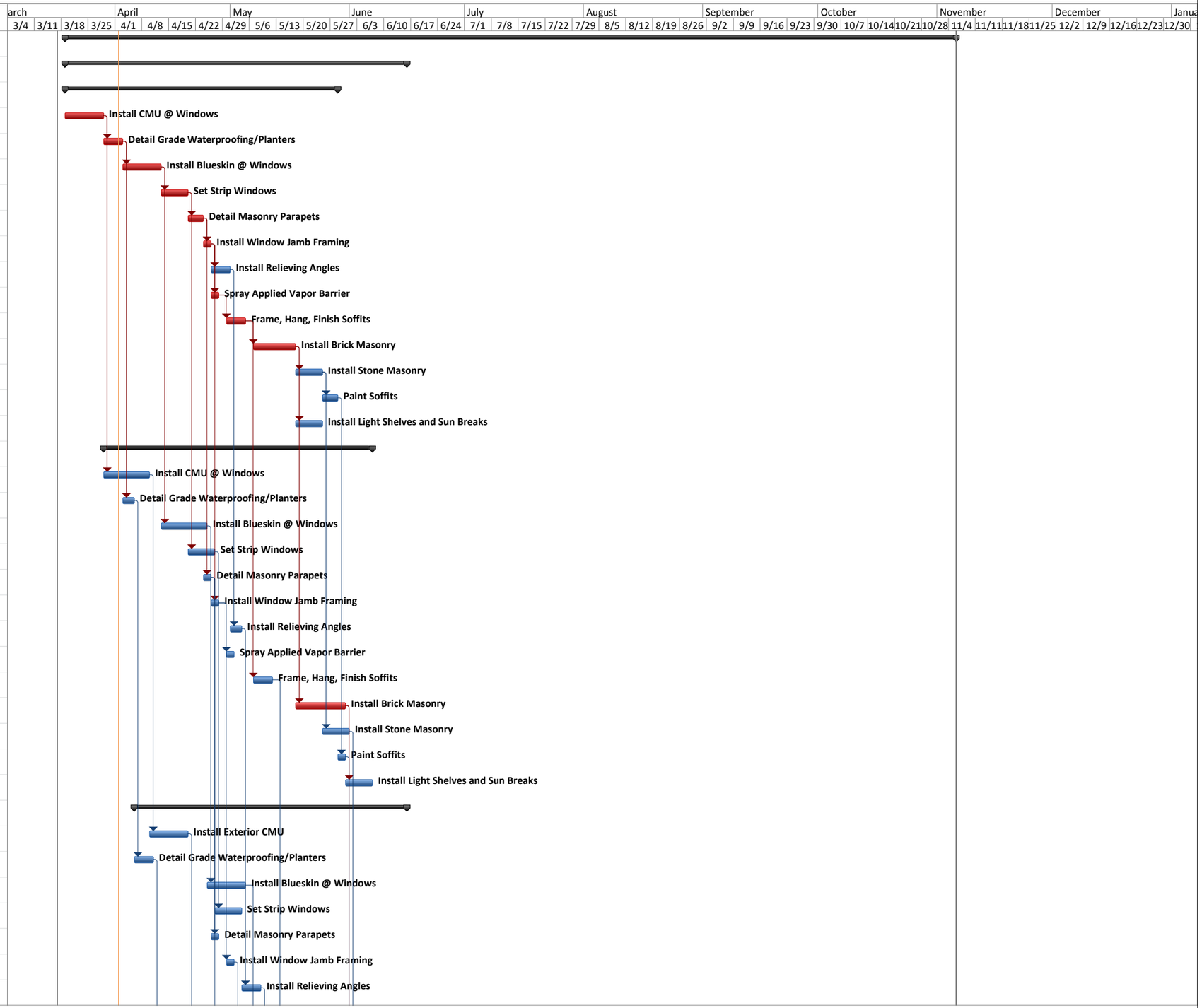
Updated Skin Schedule

ID	Task Name	Duration	Start	Finish
1	**Building 1 Skin**	**166 days**	**Mon 3/19/12**	**Mon 11/5/12**
2	**Childcare Center**	**65 days**	**Mon 3/19/12**	**Fri 6/15/12**
3	**North Elevation**	**51 days**	**Mon 3/19/12**	**Mon 5/28/12**
4	Install CMU @ Windows	8 days	Mon 3/19/12	Wed 3/28/12
5	Detail Grade Waterproofing/Planters	3 days	Thu 3/29/12	Mon 4/2/12
6	Install Blueskin @ Windows	8 days	Tue 4/3/12	Thu 4/12/12
7	Set Strip Windows	5 days	Fri 4/13/12	Thu 4/19/12
8	Detail Masonry Parapets	2 days	Fri 4/20/12	Mon 4/23/12
9	Install Window Jamb Framing	2 days	Tue 4/24/12	Wed 4/25/12
10	Install Relieving Angles	3 days	Thu 4/26/12	Mon 4/30/12
11	Spray Applied Vapor Barrier	2 days	Thu 4/26/12	Fri 4/27/12
12	Frame, Hang, Finish Soffits	5 days	Mon 4/30/12	Fri 5/4/12
13	Install Brick Masonry	9 days	Mon 5/7/12	Thu 5/17/12
14	Install Stone Masonry	5 days	Fri 5/18/12	Thu 5/24/12
15	Paint Soffits	2 days	Fri 5/25/12	Mon 5/28/12
16	Install Light Shelves and Sun Breaks	5 days	Fri 5/18/12	Thu 5/24/12
17	**East Elevation**	**50 days**	**Thu 3/29/12**	**Wed 6/6/12**
18	Install CMU @ Windows	8 days	Thu 3/29/12	Mon 4/9/12
19	Detail Grade Waterproofing/Planters	3 days	Tue 4/3/12	Thu 4/5/12
20	Install Blueskin @ Windows	8 days	Fri 4/13/12	Tue 4/24/12
21	Set Strip Windows	5 days	Fri 4/20/12	Thu 4/26/12
22	Detail Masonry Parapets	2 days	Tue 4/24/12	Wed 4/25/12
23	Install Window Jamb Framing	2 days	Thu 4/26/12	Fri 4/27/12
24	Install Relieving Angles	3 days	Tue 5/1/12	Thu 5/3/12
25	Spray Applied Vapor Barrier	2 days	Mon 4/30/12	Tue 5/1/12
26	Frame, Hang, Finish Soffits	5 days	Mon 5/7/12	Fri 5/11/12
27	Install Brick Masonry	9 days	Fri 5/18/12	Wed 5/30/12
28	Install Stone Masonry	5 days	Fri 5/25/12	Thu 5/31/12
29	Paint Soffits	2 days	Tue 5/29/12	Wed 5/30/12
30	Install Light Shelves and Sun Breaks	5 days	Thu 5/31/12	Wed 6/6/12
31	**West Elevation**	**51 days**	**Fri 4/6/12**	**Fri 6/15/12**
32	Install Exterior CMU	8 days	Tue 4/10/12	Thu 4/19/12
33	Detail Grade Waterproofing/Planters	3 days	Fri 4/6/12	Tue 4/10/12
34	Install Blueskin @ Windows	8 days	Wed 4/25/12	Fri 5/4/12
35	Set Strip Windows	5 days	Fri 4/27/12	Thu 5/3/12
36	Detail Masonry Parapets	2 days	Thu 4/26/12	Fri 4/27/12
37	Install Window Jamb Framing	2 days	Mon 4/30/12	Tue 5/1/12
38	Install Relieving Angles	3 days	Fri 5/4/12	Tue 5/8/12



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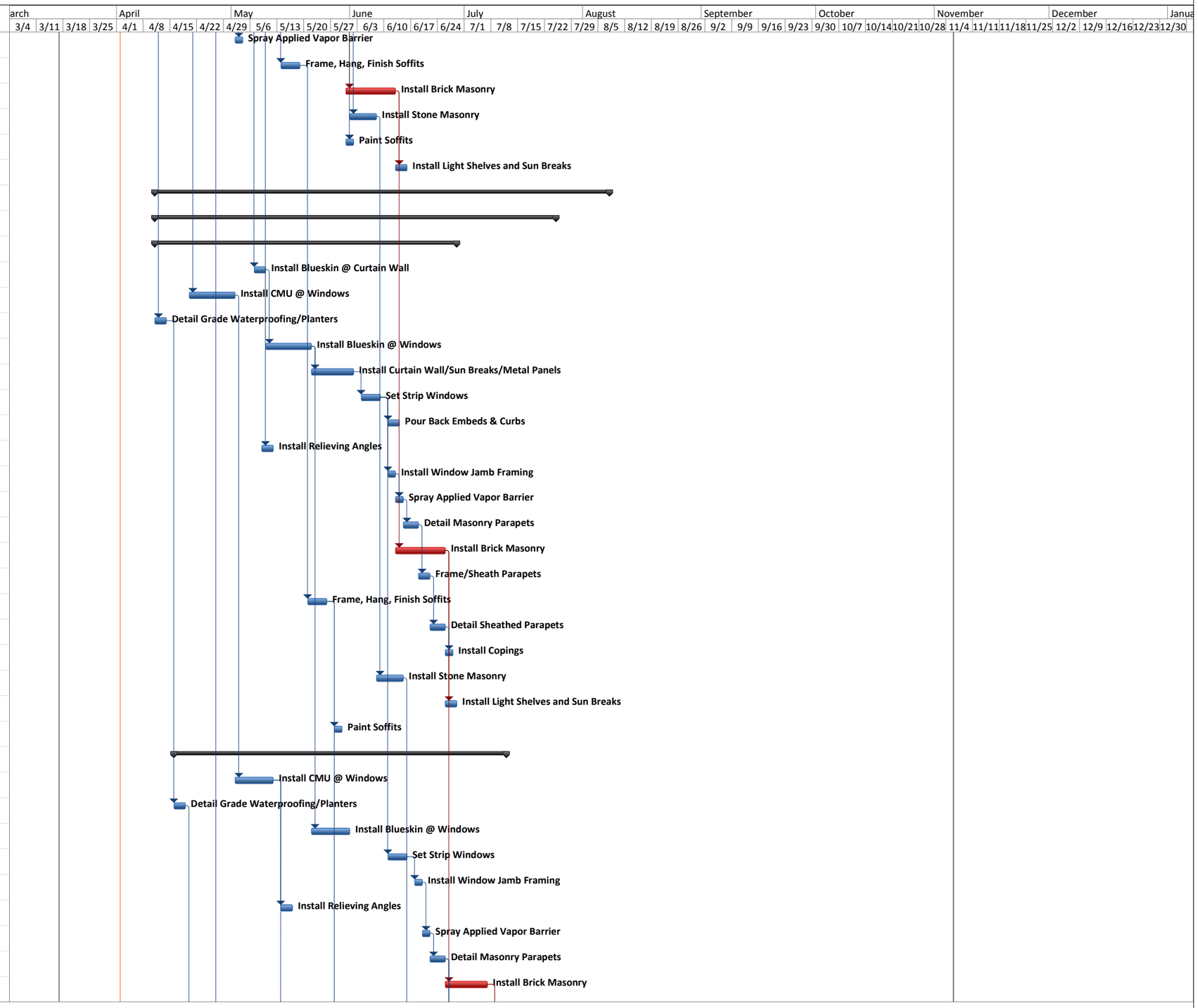
Updated Skin Schedule

ID	Task Name	Duration	Start	Finish
39	Spray Applied Vapor Barrier	2 days	Wed 5/2/12	Thu 5/3/12
40	Frame, Hang, Finish Soffits	5 days	Mon 5/14/12	Fri 5/18/12
41	Install Brick Masonry	9 days	Thu 5/31/12	Tue 6/12/12
42	Install Stone Masonry	5 days	Fri 6/1/12	Thu 6/7/12
43	Paint Soffits	2 days	Thu 5/31/12	Fri 6/1/12
44	Install Light Shelves and Sun Breaks	3 days	Wed 6/13/12	Fri 6/15/12
45	**Area A (Column Lines 1-12)**	**85 days**	**Wed 4/11/12**	**Tue 8/7/12**
46	**North Finger**	**75 days**	**Wed 4/11/12**	**Tue 7/24/12**
47	**North Elevation**	**57 days**	**Wed 4/11/12**	**Thu 6/28/12**
48	Install Blueskin @ Curtain Wall	3 days	Mon 5/7/12	Wed 5/9/12
49	Install CMU @ Windows	8 days	Fri 4/20/12	Tue 5/1/12
50	Detail Grade Waterproofing/Planters	3 days	Wed 4/11/12	Fri 4/13/12
51	Install Blueskin @ Windows	8 days	Thu 5/10/12	Mon 5/21/12
52	Install Curtain Wall/Sun Breaks/Metal Panels	9 days	Tue 5/22/12	Fri 6/1/12
53	Set Strip Windows	5 days	Mon 6/4/12	Fri 6/8/12
54	Pour Back Embeds & Curbs	3 days	Mon 6/11/12	Wed 6/13/12
55	Install Relieving Angles	3 days	Wed 5/9/12	Fri 5/11/12
56	Install Window Jamb Framing	2 days	Mon 6/11/12	Tue 6/12/12
57	Spray Applied Vapor Barrier	2 days	Wed 6/13/12	Thu 6/14/12
58	Detail Masonry Parapets	2 days	Fri 6/15/12	Mon 6/18/12
59	Install Brick Masonry	9 days	Wed 6/13/12	Mon 6/25/12
60	Frame/Sheath Parapets	3 days	Tue 6/19/12	Thu 6/21/12
61	Frame, Hang, Finish Soffits	5 days	Mon 5/21/12	Fri 5/25/12
62	Detail Sheathed Parapets	2 days	Fri 6/22/12	Mon 6/25/12
63	Install Copings	2 days	Tue 6/26/12	Wed 6/27/12
64	Install Stone Masonry	5 days	Fri 6/8/12	Thu 6/14/12
65	Install Light Shelves and Sun Breaks	3 days	Tue 6/26/12	Thu 6/28/12
66	Paint Soffits	2 days	Mon 5/28/12	Tue 5/29/12
67	**West Elevation**	**63 days**	**Mon 4/16/12**	**Wed 7/11/12**
68	Install CMU @ Windows	8 days	Wed 5/2/12	Fri 5/11/12
69	Detail Grade Waterproofing/Planters	3 days	Mon 4/16/12	Wed 4/18/12
70	Install Blueskin @ Windows	8 days	Tue 5/22/12	Thu 5/31/12
71	Set Strip Windows	5 days	Mon 6/11/12	Fri 6/15/12
72	Install Window Jamb Framing	2 days	Mon 6/18/12	Tue 6/19/12
73	Install Relieving Angles	3 days	Mon 5/14/12	Wed 5/16/12
74	Spray Applied Vapor Barrier	2 days	Wed 6/20/12	Thu 6/21/12
75	Detail Masonry Parapets	2 days	Fri 6/22/12	Mon 6/25/12
76	Install Brick Masonry	9 days	Tue 6/26/12	Fri 7/6/12



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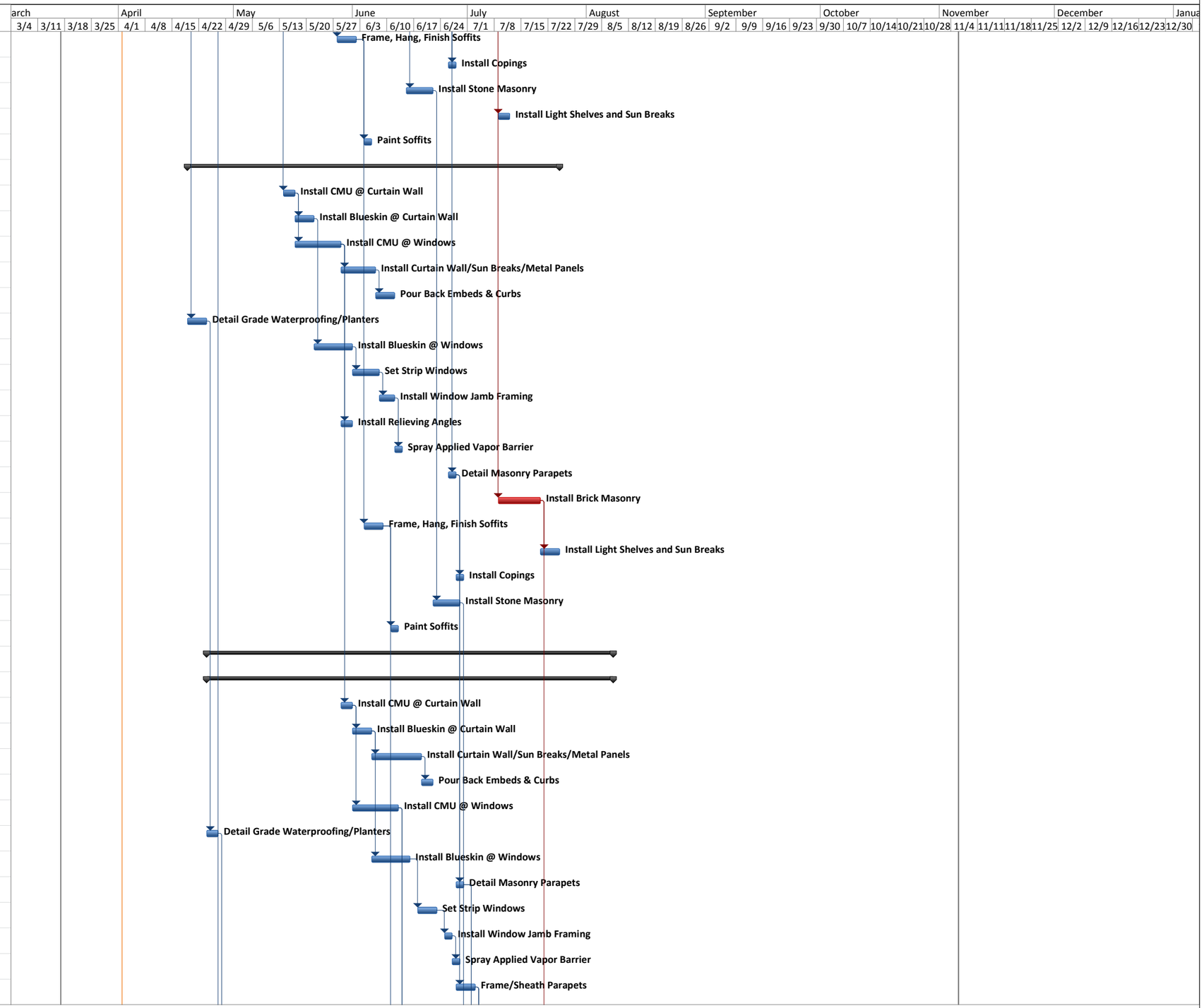
Updated Skin Schedule

ID	Task Name	Duration	Start	Finish
77	Frame, Hang, Finish Soffits	5 days	Mon 5/28/12	Fri 6/1/12
78	Install Copings	2 days	Tue 6/26/12	Wed 6/27/12
79	Install Stone Masonry	5 days	Fri 6/15/12	Thu 6/21/12
80	Install Light Shelves and Sun Breaks	3 days	Mon 7/9/12	Wed 7/11/12
81	Paint Soffits	2 days	Mon 6/4/12	Tue 6/5/12
82	**South Elevation**	**69 days**	**Thu 4/19/12**	**Tue 7/24/12**
83	Install CMU @ Curtain Wall	3 days	Mon 5/14/12	Wed 5/16/12
84	Install Blueskin @ Curtain Wall	3 days	Thu 5/17/12	Mon 5/21/12
85	Install CMU @ Windows	8 days	Thu 5/17/12	Mon 5/28/12
86	Install Curtain Wall/Sun Breaks/Metal Panels	7 days	Tue 5/29/12	Wed 6/6/12
87	Pour Back Embeds & Curbs	3 days	Thu 6/7/12	Mon 6/11/12
88	Detail Grade Waterproofing/Planters	3 days	Thu 4/19/12	Mon 4/23/12
89	Install Blueskin @ Windows	8 days	Tue 5/22/12	Thu 5/31/12
90	Set Strip Windows	5 days	Fri 6/1/12	Thu 6/7/12
91	Install Window Jamb Framing	2 days	Fri 6/8/12	Mon 6/11/12
92	Install Relieving Angles	3 days	Tue 5/29/12	Thu 5/31/12
93	Spray Applied Vapor Barrier	2 days	Tue 6/12/12	Wed 6/13/12
94	Detail Masonry Parapets	2 days	Tue 6/26/12	Wed 6/27/12
95	Install Brick Masonry	9 days	Mon 7/9/12	Thu 7/19/12
96	Frame, Hang, Finish Soffits	5 days	Mon 6/4/12	Fri 6/8/12
97	Install Light Shelves and Sun Breaks	3 days	Fri 7/20/12	Tue 7/24/12
98	Install Copings	2 days	Thu 6/28/12	Fri 6/29/12
99	Install Stone Masonry	5 days	Fri 6/22/12	Thu 6/28/12
100	Paint Soffits	2 days	Mon 6/11/12	Tue 6/12/12
101	**North Spine**	**76 days**	**Tue 4/24/12**	**Tue 8/7/12**
102	**West Elevation**	**76 days**	**Tue 4/24/12**	**Tue 8/7/12**
103	Install CMU @ Curtain Wall	3 days	Tue 5/29/12	Thu 5/31/12
104	Install Blueskin @ Curtain Wall	3 days	Fri 6/1/12	Tue 6/5/12
105	Install Curtain Wall/Sun Breaks/Metal Panels	9 days	Wed 6/6/12	Mon 6/18/12
106	Pour Back Embeds & Curbs	3 days	Tue 6/19/12	Thu 6/21/12
107	Install CMU @ Windows	8 days	Fri 6/1/12	Tue 6/12/12
108	Detail Grade Waterproofing/Planters	3 days	Tue 4/24/12	Thu 4/26/12
109	Install Blueskin @ Windows	8 days	Wed 6/6/12	Fri 6/15/12
110	Detail Masonry Parapets	2 days	Thu 6/28/12	Fri 6/29/12
111	Set Strip Windows	5 days	Mon 6/18/12	Fri 6/22/12
112	Install Window Jamb Framing	2 days	Mon 6/25/12	Tue 6/26/12
113	Spray Applied Vapor Barrier	2 days	Wed 6/27/12	Thu 6/28/12
114	Frame/Sheath Parapets	3 days	Thu 6/28/12	Mon 7/2/12



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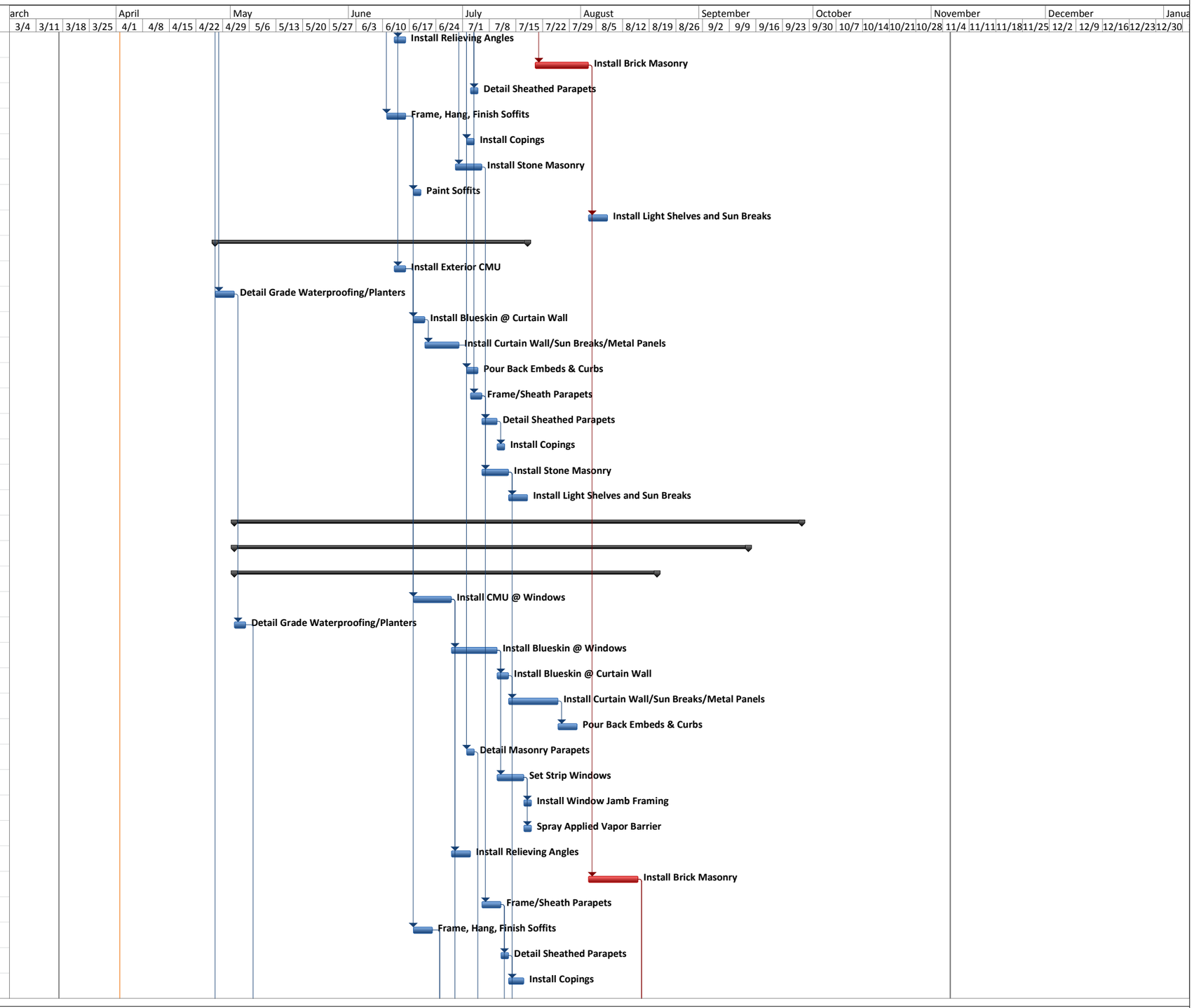
Updated Skin Schedule

ID	Task Name	Duration	Start	Finish
115	Install Relieving Angles	3 days	Wed 6/13/12	Fri 6/15/12
116	Install Brick Masonry	10 days	Fri 7/20/12	Thu 8/2/12
117	Detail Sheathed Parapets	2 days	Tue 7/3/12	Wed 7/4/12
118	Frame, Hang, Finish Soffits	5 days	Mon 6/11/12	Fri 6/15/12
119	Install Copings	2 days	Mon 7/2/12	Tue 7/3/12
120	Install Stone Masonry	5 days	Fri 6/29/12	Thu 7/5/12
121	Paint Soffits	2 days	Mon 6/18/12	Tue 6/19/12
122	Install Light Shelves and Sun Breaks	3 days	Fri 8/3/12	Tue 8/7/12
123	**East Elevation**	**58 days**	**Fri 4/27/12**	**Tue 7/17/12**
124	Install Exterior CMU	3 days	Wed 6/13/12	Fri 6/15/12
125	Detail Grade Waterproofing/Planters	3 days	Fri 4/27/12	Tue 5/1/12
126	Install Blueskin @ Curtain Wall	3 days	Mon 6/18/12	Wed 6/20/12
127	Install Curtain Wall/Sun Breaks/Metal Panels	7 days	Thu 6/21/12	Fri 6/29/12
128	Pour Back Embeds & Curbs	3 days	Mon 7/2/12	Wed 7/4/12
129	Frame/Sheath Parapets	3 days	Tue 7/3/12	Thu 7/5/12
130	Detail Sheathed Parapets	2 days	Fri 7/6/12	Mon 7/9/12
131	Install Copings	2 days	Tue 7/10/12	Wed 7/11/12
132	Install Stone Masonry	5 days	Fri 7/6/12	Thu 7/12/12
133	Install Light Shelves and Sun Breaks	3 days	Fri 7/13/12	Tue 7/17/12
134	**Area B (Column Lines 12-20)**	**107 days**	**Wed 5/2/12**	**Thu 9/27/12**
135	**Middle Finger**	**97 days**	**Wed 5/2/12**	**Thu 9/13/12**
136	**North Elevation**	**79 days**	**Wed 5/2/12**	**Mon 8/20/12**
137	Install CMU @ Windows	8 days	Mon 6/18/12	Wed 6/27/12
138	Detail Grade Waterproofing/Planters	3 days	Wed 5/2/12	Fri 5/4/12
139	Install Blueskin @ Windows	8 days	Thu 6/28/12	Mon 7/9/12
140	Install Blueskin @ Curtain Wall	3 days	Tue 7/10/12	Thu 7/12/12
141	Install Curtain Wall/Sun Breaks/Metal Panels	9 days	Fri 7/13/12	Wed 7/25/12
142	Pour Back Embeds & Curbs	3 days	Thu 7/26/12	Mon 7/30/12
143	Detail Masonry Parapets	2 days	Mon 7/2/12	Tue 7/3/12
144	Set Strip Windows	5 days	Tue 7/10/12	Mon 7/16/12
145	Install Window Jamb Framing	2 days	Tue 7/17/12	Wed 7/18/12
146	Spray Applied Vapor Barrier	2 days	Tue 7/17/12	Wed 7/18/12
147	Install Relieving Angles	3 days	Thu 6/28/12	Mon 7/2/12
148	Install Brick Masonry	9 days	Fri 8/3/12	Wed 8/15/12
149	Frame/Sheath Parapets	3 days	Fri 7/6/12	Tue 7/10/12
150	Frame, Hang, Finish Soffits	5 days	Mon 6/18/12	Fri 6/22/12
151	Detail Sheathed Parapets	2 days	Wed 7/11/12	Thu 7/12/12
152	Install Copings	2 days	Fri 7/13/12	Mon 7/16/12



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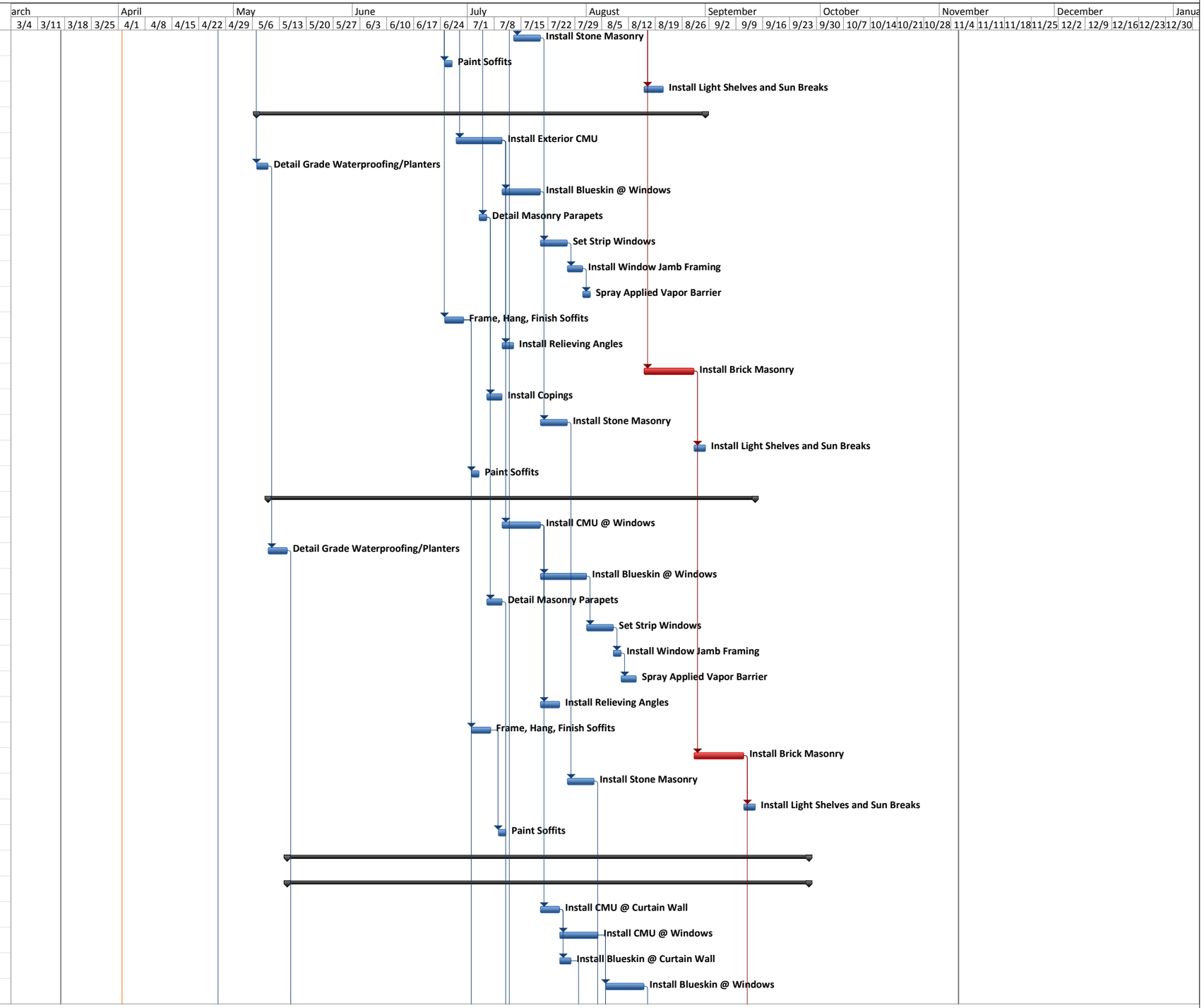
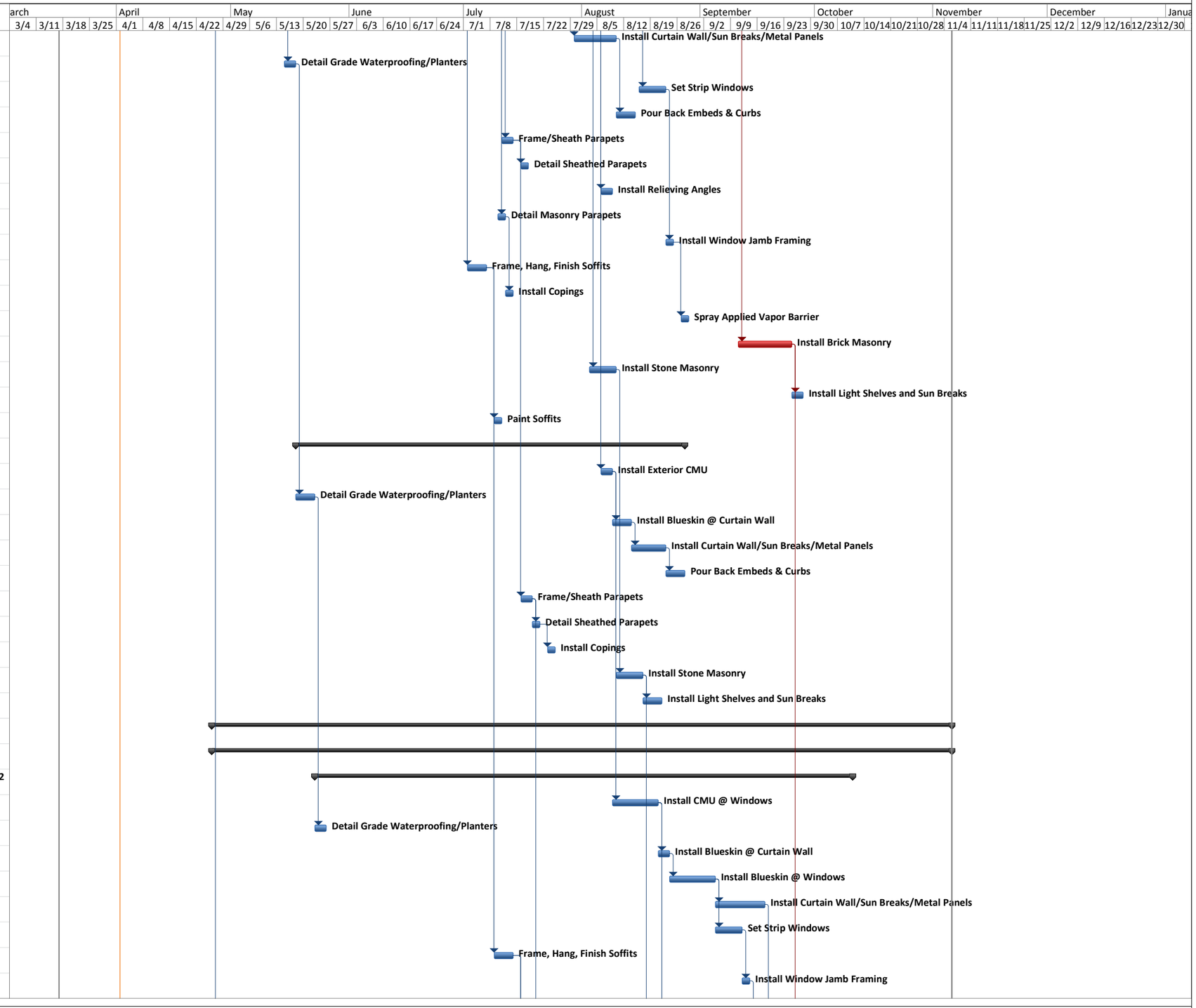
Updated Skin Schedule

ID	Task Name	Duration	Start	Finish
153	Install Stone Masonry	5 days	Fri 7/13/12	Thu 7/19/12
154	Paint Soffits	2 days	Mon 6/25/12	Tue 6/26/12
155	Install Light Shelves and Sun Breaks	3 days	Thu 8/16/12	Mon 8/20/12
156	**West Elevation**	**85 days**	**Mon 5/7/12**	**Fri 8/31/12**
157	Install Exterior CMU	8 days	Thu 6/28/12	Mon 7/9/12
158	Detail Grade Waterproofing/Planters	3 days	Mon 5/7/12	Wed 5/9/12
159	Install Blueskin @ Windows	8 days	Tue 7/10/12	Thu 7/19/12
160	Detail Masonry Parapets	2 days	Wed 7/4/12	Thu 7/5/12
161	Set Strip Windows	5 days	Fri 7/20/12	Thu 7/26/12
162	Install Window Jamb Framing	2 days	Fri 7/27/12	Mon 7/30/12
163	Spray Applied Vapor Barrier	2 days	Tue 7/31/12	Wed 8/1/12
164	Frame, Hang, Finish Soffits	5 days	Mon 6/25/12	Fri 6/29/12
165	Install Relieving Angles	3 days	Tue 7/10/12	Thu 7/12/12
166	Install Brick Masonry	9 days	Thu 8/16/12	Tue 8/28/12
167	Install Copings	2 days	Fri 7/6/12	Mon 7/9/12
168	Install Stone Masonry	5 days	Fri 7/20/12	Thu 7/26/12
169	Install Light Shelves and Sun Breaks	3 days	Wed 8/29/12	Fri 8/31/12
170	Paint Soffits	2 days	Mon 7/2/12	Tue 7/3/12
171	**South Elevation**	**91 days**	**Thu 5/10/12**	**Thu 9/13/12**
172	Install CMU @ Windows	8 days	Tue 7/10/12	Thu 7/19/12
173	Detail Grade Waterproofing/Planters	3 days	Thu 5/10/12	Mon 5/14/12
174	Install Blueskin @ Windows	8 days	Fri 7/20/12	Tue 7/31/12
175	Detail Masonry Parapets	2 days	Fri 7/6/12	Mon 7/9/12
176	Set Strip Windows	5 days	Wed 8/1/12	Tue 8/7/12
177	Install Window Jamb Framing	2 days	Wed 8/8/12	Thu 8/9/12
178	Spray Applied Vapor Barrier	2 days	Fri 8/10/12	Mon 8/13/12
179	Install Relieving Angles	3 days	Fri 7/20/12	Tue 7/24/12
180	Frame, Hang, Finish Soffits	5 days	Mon 7/2/12	Fri 7/6/12
181	Install Brick Masonry	9 days	Wed 8/29/12	Mon 9/10/12
182	Install Stone Masonry	5 days	Fri 7/27/12	Thu 8/2/12
183	Install Light Shelves and Sun Breaks	3 days	Tue 9/11/12	Thu 9/13/12
184	Paint Soffits	2 days	Mon 7/9/12	Tue 7/10/12
185	**South Spine**	**98 days**	**Tue 5/15/12**	**Thu 9/27/12**
186	**West Elevation**	**98 days**	**Tue 5/15/12**	**Thu 9/27/12**
187	Install CMU @ Curtain Wall	3 days	Fri 7/20/12	Tue 7/24/12
188	Install CMU @ Windows	8 days	Wed 7/25/12	Fri 8/3/12
189	Install Blueskin @ Curtain Wall	3 days	Wed 7/25/12	Fri 7/27/12
190	Install Blueskin @ Windows	8 days	Mon 8/6/12	Wed 8/15/12



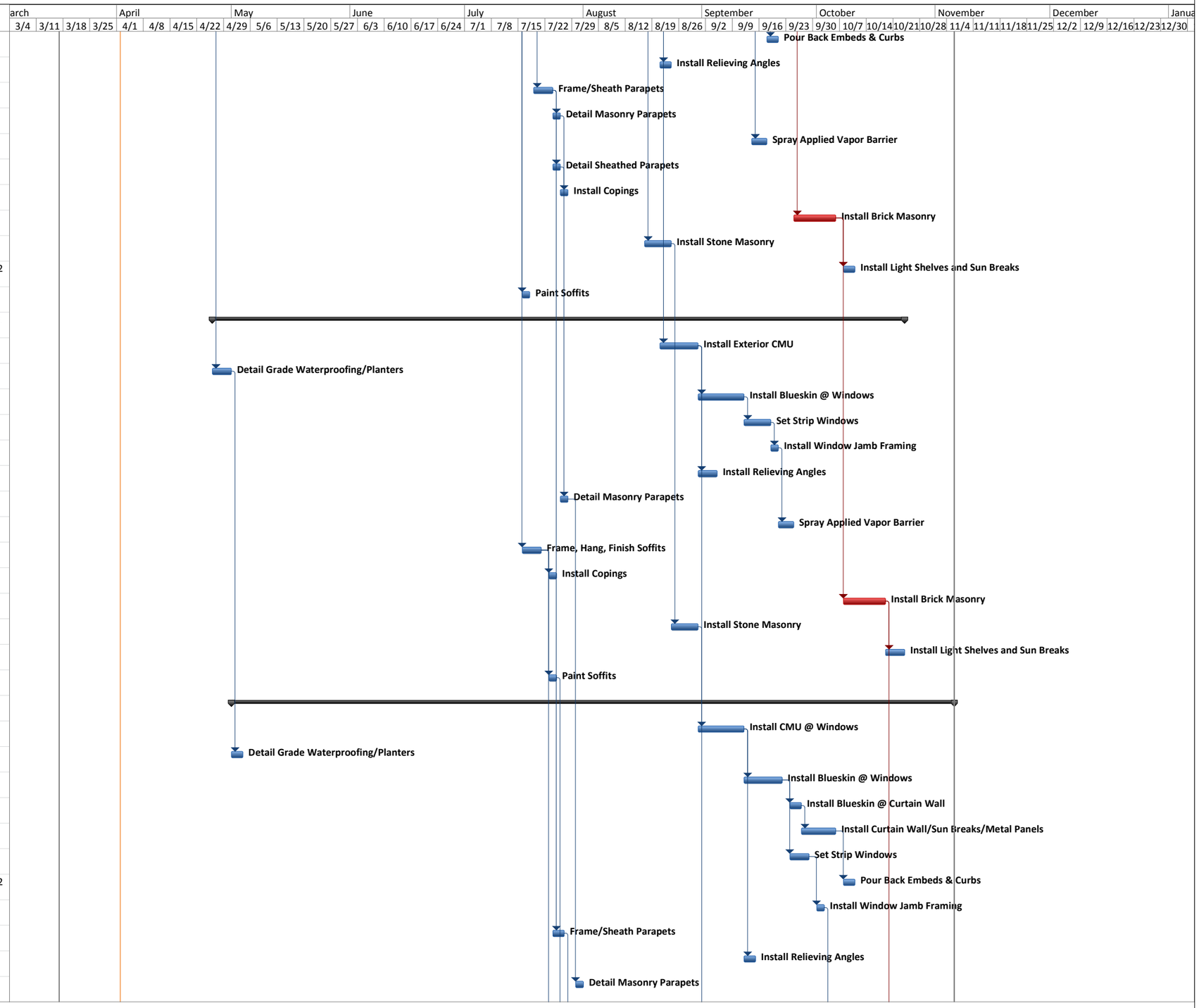
Patrick Laninger - Senior Thesis
Updated Skin Schedule

ID	Task Name	Duration	Start	Finish
191	Install Curtain Wall/Sun Breaks/Metal Panels	9 days	Mon 7/30/12	Thu 8/9/12
192	Detail Grade Waterproofing/Planters	3 days	Tue 5/15/12	Thu 5/17/12
193	Set Strip Windows	5 days	Thu 8/16/12	Wed 8/22/12
194	Pour Back Embeds & Curbs	3 days	Fri 8/10/12	Tue 8/14/12
195	Frame/Sheath Parapets	3 days	Wed 7/11/12	Fri 7/13/12
196	Detail Sheathed Parapets	2 days	Mon 7/16/12	Tue 7/17/12
197	Install Relieving Angles	3 days	Mon 8/6/12	Wed 8/8/12
198	Detail Masonry Parapets	2 days	Tue 7/10/12	Wed 7/11/12
199	Install Window Jamb Framing	2 days	Thu 8/23/12	Fri 8/24/12
200	Frame, Hang, Finish Soffits	5 days	Mon 7/2/12	Fri 7/6/12
201	Install Copings	2 days	Thu 7/12/12	Fri 7/13/12
202	Spray Applied Vapor Barrier	2 days	Mon 8/27/12	Tue 8/28/12
203	Install Brick Masonry	10 days	Tue 9/11/12	Mon 9/24/12
204	Install Stone Masonry	5 days	Fri 8/3/12	Thu 8/9/12
205	Install Light Shelves and Sun Breaks	3 days	Tue 9/25/12	Thu 9/27/12
206	Paint Soffits	2 days	Mon 7/9/12	Tue 7/10/12
207	**East Elevation**	**72 days**	**Fri 5/18/12**	**Mon 8/27/12**
208	Install Exterior CMU	3 days	Mon 8/6/12	Wed 8/8/12
209	Detail Grade Waterproofing/Planters	3 days	Fri 5/18/12	Tue 5/22/12
210	Install Blueskin @ Curtain Wall	3 days	Thu 8/9/12	Mon 8/13/12
211	Install Curtain Wall/Sun Breaks/Metal Panels	7 days	Tue 8/14/12	Wed 8/22/12
212	Pour Back Embeds & Curbs	3 days	Thu 8/23/12	Mon 8/27/12
213	Frame/Sheath Parapets	3 days	Mon 7/16/12	Wed 7/18/12
214	Detail Sheathed Parapets	2 days	Thu 7/19/12	Fri 7/20/12
215	Install Copings	2 days	Mon 7/23/12	Tue 7/24/12
216	Install Stone Masonry	5 days	Fri 8/10/12	Thu 8/16/12
217	Install Light Shelves and Sun Breaks	3 days	Fri 8/17/12	Tue 8/21/12
218	**Area C (Column Lines 20+)**	**138 days**	**Thu 4/26/12**	**Mon 11/5/12**
219	**South Finger**	**138 days**	**Thu 4/26/12**	**Mon 11/5/12**
220	**North Elevation**	**101 days**	**Wed 5/23/12**	**Wed 10/10/12**
221	Install CMU @ Windows	8 days	Thu 8/9/12	Mon 8/20/12
222	Detail Grade Waterproofing/Planters	3 days	Wed 5/23/12	Fri 5/25/12
223	Install Blueskin @ Curtain Wall	3 days	Tue 8/21/12	Thu 8/23/12
224	Install Blueskin @ Windows	8 days	Fri 8/24/12	Tue 9/4/12
225	Install Curtain Wall/Sun Breaks/Metal Panels	9 days	Wed 9/5/12	Mon 9/17/12
226	Set Strip Windows	5 days	Wed 9/5/12	Tue 9/11/12
227	Frame, Hang, Finish Soffits	5 days	Mon 7/9/12	Fri 7/13/12
228	Install Window Jamb Framing	2 days	Wed 9/12/12	Thu 9/13/12



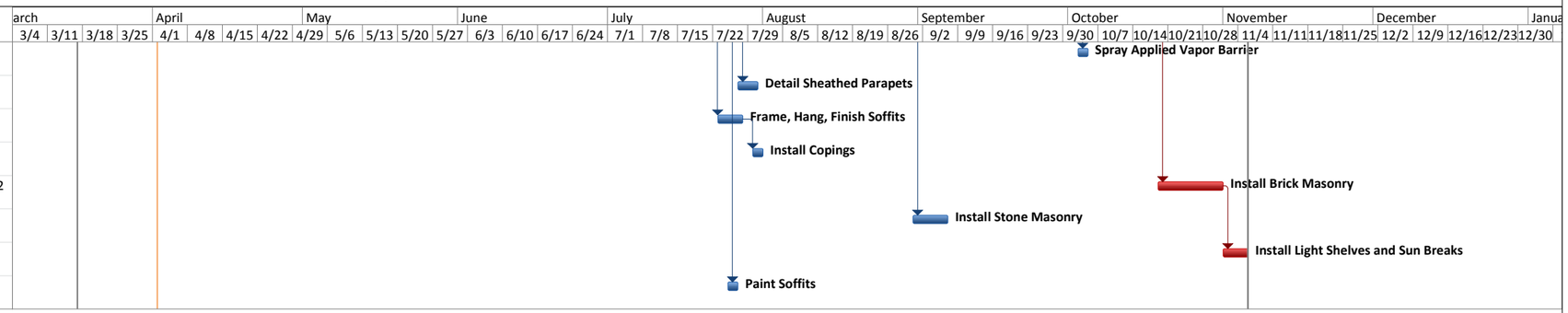
Patrick Laninger - Senior Thesis
Updated Skin Schedule

ID	Task Name	Duration	Start	Finish
229	Pour Back Embeds & Curbs	3 days	Tue 9/18/12	Thu 9/20/12
230	Install Relieving Angles	3 days	Tue 8/21/12	Thu 8/23/12
231	Frame/Sheath Parapets	3 days	Thu 7/19/12	Mon 7/23/12
232	Detail Masonry Parapets	2 days	Tue 7/24/12	Wed 7/25/12
233	Spray Applied Vapor Barrier	2 days	Fri 9/14/12	Mon 9/17/12
234	Detail Sheathed Parapets	2 days	Tue 7/24/12	Wed 7/25/12
235	Install Copings	2 days	Thu 7/26/12	Fri 7/27/12
236	Install Brick Masonry	9 days	Tue 9/25/12	Fri 10/5/12
237	Install Stone Masonry	5 days	Fri 8/17/12	Thu 8/23/12
238	Install Light Shelves and Sun Breaks	3 days	Mon 10/8/12	Wed 10/10/12
239	Paint Soffits	2 days	Mon 7/16/12	Tue 7/17/12
240	**West Elevation**	**129 days**	**Thu 4/26/12**	**Tue 10/23/12**
241	Install Exterior CMU	8 days	Tue 8/21/12	Thu 8/30/12
242	Detail Grade Waterproofing/Planters	3 days	Thu 4/26/12	Mon 4/30/12
243	Install Blueskin @ Windows	8 days	Fri 8/31/12	Tue 9/11/12
244	Set Strip Windows	5 days	Wed 9/12/12	Tue 9/18/12
245	Install Window Jamb Framing	2 days	Wed 9/19/12	Thu 9/20/12
246	Install Relieving Angles	3 days	Fri 8/31/12	Tue 9/4/12
247	Detail Masonry Parapets	2 days	Thu 7/26/12	Fri 7/27/12
248	Spray Applied Vapor Barrier	2 days	Fri 9/21/12	Mon 9/24/12
249	Frame, Hang, Finish Soffits	5 days	Mon 7/16/12	Fri 7/20/12
250	Install Copings	2 days	Mon 7/23/12	Tue 7/24/12
251	Install Brick Masonry	9 days	Mon 10/8/12	Thu 10/18/12
252	Install Stone Masonry	5 days	Fri 8/24/12	Thu 8/30/12
253	Install Light Shelves and Sun Breaks	3 days	Fri 10/19/12	Tue 10/23/12
254	Paint Soffits	2 days	Mon 7/23/12	Tue 7/24/12
255	**South Elevation**	**135 days**	**Tue 5/1/12**	**Mon 11/5/12**
256	Install CMU @ Windows	8 days	Fri 8/31/12	Tue 9/11/12
257	Detail Grade Waterproofing/Planters	3 days	Tue 5/1/12	Thu 5/3/12
258	Install Blueskin @ Windows	8 days	Wed 9/12/12	Fri 9/21/12
259	Install Blueskin @ Curtain Wall	3 days	Mon 9/24/12	Wed 9/26/12
260	Install Curtain Wall/Sun Breaks/Metal Panels	7 days	Thu 9/27/12	Fri 10/5/12
261	Set Strip Windows	5 days	Mon 9/24/12	Fri 9/28/12
262	Pour Back Embeds & Curbs	3 days	Mon 10/8/12	Wed 10/10/12
263	Install Window Jamb Framing	2 days	Mon 10/1/12	Tue 10/2/12
264	Frame/Sheath Parapets	3 days	Tue 7/24/12	Thu 7/26/12
265	Install Relieving Angles	3 days	Wed 9/12/12	Fri 9/14/12
266	Detail Masonry Parapets	2 days	Mon 7/30/12	Tue 7/31/12



Patrick Laninger - Senior Thesis
Updated Skin Schedule

ID	Task Name	Duration	Start	Finish
267	Spray Applied Vapor Barrier	2 days	Wed 10/3/12	Thu 10/4/12
268	Detail Sheathed Parapets	2 days	Fri 7/27/12	Mon 7/30/12
269	Frame, Hang, Finish Soffits	5 days	Mon 7/23/12	Fri 7/27/12
270	Install Copings	2 days	Mon 7/30/12	Tue 7/31/12
271	Install Brick Masonry	9 days	Fri 10/19/12	Wed 10/31/12
272	Install Stone Masonry	5 days	Fri 8/31/12	Thu 9/6/12
273	Install Light Shelves and Sun Breaks	3 days	Thu 11/1/12	Mon 11/5/12
274	Paint Soffits	2 days	Wed 7/25/12	Thu 7/26/12



APPENDIX H – DESIGN BUILD TEAM DYNAMIC TRADE SURVEYS

Design-Build Team Dynamic Survey
The purpose of this survey is to determine common characteristics of subcontractor organizations and individuals who successfully embraced the mindset of the design-build project delivery method.

Name: Barry L. Fahnestock
Company: The Farfield Company

Name: Glenn Feldstein
Company: Telligent Masonry

Name: Jeff Sandeen
Company: Hensel Phelps

Name: Nick Umosella
Company: Barton Malow
Note: Nick's responses were assembled from information provided during a telephone interview on 2/13/12.

Q: Do you have experience with teams or individuals who have successfully embraced a design-build project approach? If so, what trade were they associated with and what was the extent of their involvement in the project?

Barry Fahnestock: I've had experience on a number of projects, including all trades, which were successful in executing design-build projects. However, this is the first project on which I have participated that is being accomplished as a design assist basis.

Glenn Feldstein: We have been involved in several design-build projects as masonry subcontractors.

Jeff Sandeen: Yes – I have worked with multiple MEP contractors, precast contractors, security contractors and sprinkler contractors on D/B projects. They were all contracted as design/build partners and were responsible for their own design, coordination and RFP compliance. Obviously their involvement doesn't replace the architect/designer of record.

Nick Umosella – I am currently working on the Pennsylvania State University South Halls Renovation project, a design build project with multiple design assist subcontractors.

Q: What aspects of the way they handled themselves defined their level of success?

Barry Fahnestock: The projects I was involved with were comprised, from the outset, of a team which was made up by the owner, design professional, and primary trade contractors which understood the partnering, cooperation and full disclosure which made these projects a success.

Glenn Feldstein: With design-build your input is value and your expertise in your trade is called upon frequently to problem solve for the benefit of all parties involved. If all parties involved (subs, GC, Owner, Architect, Engineers) are not willing to work quickly to resolve issues the project will be delayed. This is due to incomplete drawings, specs, etc.

Jeff Sandeen: Their understanding of the RFP, code compliance and their ability to coordinate with the other trades/designs and most importantly their team approach.

Nick Umosella – Subcontractors who walked the team through their estimates provided a lot of confidence. They filled in scope gaps and showed the designers what they forgot and what they'd need as well as described the ins and outs of each system and what components are responsible for each function of the system.

Q: What characteristics made these groups or individuals more successful than others?

Barry Fahnestock: While not every project was comprised of partners which were experienced with this approach, they were all trusted participants (from previous experience) which (generally) did not come solely from a "hard dollar bid" contracting environment.

Glenn Feldstein: If any of the parties are not willing to be an active part of the project, the problems will out-weigh the solutions and result in costly delays and issues.

Jeff Sandeen: Their knowledge and understanding of the systems they were contracted to design. They knew how to design the best system, while meeting the intent of the RFP and while maintaining their own budgets. No understanding of how something operates can result in a significant financial loss.

Nick Umosella – The subcontractors who broke out all of their line items and general conditions in their estimates showed the team that they had the ability to fill out detailed pricing sheets as well as understand every component that was going to be necessary for the success of the project. The subcontractors who recognize the importance of preconstruction efforts on design-build projects are usually the most successful additions to the team.

Q: Was there anything special about the contractual arrangement between your firm and the organization that effectively embraced the design-build approach? If so, what contractual provisions fostered the design-build relationship?

Barry Fahnestock: The structure of the design-build projects which I was experienced with included a knowledgeable owner with a need to fill and a preliminary idea of how much they were willing to invest, a design-build General Contractor , an A/E which was retained by the GC and typical major trade Contractors (typically including Mechanical, Plumbing, Electrical and Fire Protection subcontractors). Other consultants were also retained, with the approval of the owner, by the General Contractor which typically included site/civil engineering, geotechnical and interior design firms. The General Contractor served as the primary point of contact, and held the entire contract with the owner, and acted as the PM/CM for the entire project. More importantly than the legal aspects of the contract, the success of this type of relationship was based upon experience, trust and integrity.

Glenn Feldstein: The only contractual difference would be budget amounts for special shapes, colors, etc. and a line item or two that remind the signing party that they are expected to actively participate to problem solve.

Jeff Sandeen: Below is some of the language we incorporate into our subcontract agreements for design/build partners:
"This is a design build project and the Subcontractor will be viewed by all project team members as the Design Build Subcontractor for (enter scope) and is responsible for the proper interpretation of the RFP and Bridging requirements. Subcontract is a lump sum contract arrangement. It is this subcontractor's responsibility to monitor the design development of this contract in its entirety, and to maintain overall cost within the pre-established budget of this subcontract. Change orders will be issued only for owner requested changes."

Nick Umosella – Approximately $300,000 was allotted for preconstruction services. There are also "360 Evaluations" that evaluate team member during the preconstruction and construction process.

Q: Have you noticed an increase or reduction in the number of RFI's/Change-Orders on successfully executed design-build projects when compared to traditionally delivered projects? If so, could you please estimate the number less/more of RFI's and Change Orders on a successfully approached design-build job?

Barry Fahnestock: In the type of "design-build" relationships I have been involved with, there were very few change orders in relation to traditionally delivered projects. However, this was only possible with an owner that knew what they wanted, how much they were willing to spend and weren't afraid to make "final" decisions. In other words, this required an owner (or owner's representative) who was authorized to evaluate suggestions, design development, and sign off on the final design product prior to the commencement of construction.

Glenn Feldstein: There is typically an increase in both RFIs and Cos when compared to traditionally delivered projects. Depending on the type of the project we have experienced up to 200% more change orders which resulted in 50% of the final contract being from change orders.

Jeff Sandeen: I have not seen much of a reduction in the number of RFI's but I have seen a significant reduction in change orders. I would say that CO's are about half of what they used to be for all trades.

Nick Umosella – While the number of RFI's will most likely be similar to other jobs, the number of change orders will likely decrease due to the number of project aspects that are being addressed during the preconstruction stage that WOULD have become change orders later in the process. To date, a number of unforeseen conditions have been detected by the subcontractors, allowing the team to address these issues now, rather than later when their remediation would be more expensive. More specifically, the existing utility drawings are not 100% accurate, the details of which were documented by exploring utility tunnels and duct banks. The required design changes can be incorporated immediately in the building's design, rather than later on in the project.

Q: Do you have experience with teams or individuals who had trouble embracing a design-build project approach?

Barry Fahnestock: Those owners and/or institutions which do not have a trusted person to represent their best interests, or those who want to retain traditional competitive bidding under a design-build format will have issues with taking full advantage of a true design-build approach.

Glenn Feldstein: As a sub we typically only deal with the GC and my firm has never had an issue with a GC embracing design-build.

Nick Umosella – Some subs require additional motivation to perform the required tasks. Project managers are sometimes stretched thin on other projects and do not divert a large amount of their time to preconstruction efforts while they are busy on other (active) projects. The process is also very new to the Architect/Engineer firm, but they are remaining very open and taking a lot of Barton Malow's advice.

Q: What aspects of the way they handled themselves defined their struggles?

Barry Fahnestock: Respect, collaboration and cooperation worked. Anything less did not.

Glenn Feldstein: N/A based on above response.

Nick Umosella – Some subcontractors required an explanation of how/why their time to redesign preliminary systems will save money in the long run. A lot of their input is required in refreshing the project documents, which is sometimes hard to get from them.

Q: What characteristics made these groups or individuals less successful than others?

Barry Fahnestock: Too many strong egos.

Glenn Feldstein: N/A based on above response.

Nick Umosella – In general, it's hard to get project managers to focus on a project in preconstruction phase. Also hard to get the A/E designers to constantly update drawings with new input from the team/owner. One other hurdle is the administrative hierarchy of the owner. There are a lot of players that each think they have an input in the design details. It's sometimes difficult to determine who has the final say, or how to compromise between the desires of the different stakeholders.

APPENDIX I - BIBLIOGRAPHY

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