Trinity Plaza – Building 52

MID-ATLANTIC REGION, U.S.A.

2015

Technical Report 2

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Executive Summary

Breaking ground in October 2015, Trinity Plaza- Building 52 is an ongoing construction project located in the Mid-Atlantic Region of the United States. The purpose of this report is to analyze and reflect on a construction project from start until building turnover. This report will focus on in depth studies and analyzing the conditions under which the building is constructed as well as the preliminary scope of work. Throughout the entirety of the project, the AE Senior Capstone Thesis study will focus on a wide range of information including Project Acceleration scenarios, Site utilization plan, Building system estimated compared to their actual cost, and a LEED evaluation =.

Trinity Plaza-Building 52 is a 675,000 square foot commercial office building. It is the first ground-up building focused on the growth of the job marketplace. This building will be an impressive 264 ft, 16-story structure, becoming the tallest out of the 5 buildings located in this area. Located in an industrial center, the building will offer 525,000 SF of commercial use, 100,000 SF of retail space, and 50,000 SF of usable space. The building consists of high ceilings, large open spaces, eight-foot windows, state-of-the-art wiring and HVAC systems, tenant controlled A/C, Di-Boss building management system, and amenities like outdoor terraces, green roofs, basketball court, cafeteria, bike valet, roof conference center and health and wellness facilities.

For this large-scale project the site logistics, scheduling and budgeting will be a major concern to project completion. For this report these features will be studied by evaluating the phasing and sequencing related to the project's schedule. Next, the systems in the project will be estimated using Timberline and compared to the actual systems costs. The purpose of this estimation is to see how these systems will affect the project's budget and more importantly the schedule.

After analyzing the site logistics, systems break down and budget concerns it was found that each of these components will have its own effect on the project and its execution. There are a number of strategies that can be taken into account to accelerate the project's schedule to stay within budget and deliver the project on time. Estimating of the systems allows for a better understanding of budget issues as well as learning curves that can help accelerate the project in a positive manner. Lastly, site utilization will play a key factor in the site logistics planning for all phases of the project. Understanding where troublesome issues can appear prior to construction can help push to project completion time and save money for both parties such as the owner and general contractor.

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Production Plan

Structural System Scheduling

In this section, a detailed schedule for the structural system is provided. This structural schedule consists of the installation of beams, girders, columns and lateral bracing components. The framing for this structure was broken down into 4 phases. Two cranes are located in the center of the buildings structure and will be dedicated to serving the east and west sides of the building. Phase one consists of the first two floors which will be built simultaneously. Once the floors steel members are installed, the lateral bracing will be installed in between four sections of the columns. The braced framing members with span from column to column. Once this is complete 4-inch floor slabs will be poured on top of metal decking while phase 2 is constructed. Phase 2 consists of floors 3-8. The installation process will be identical the first phase of the building structure. Phase 3 will consist of floors 9-15. The last phase of the structure will be on floors 16 and 17. Throughout the entirety of this construction fireproofing will be applied to the steel structure from ground up. The schedule provided is broken down into 4 phases. The Structural Schedule summary for all four phases is shown below.

Table 1: Structural Schedule Summary

Project Phase	Start Date	Finish Date	Total Duration (Days)
Phase 1 (Floor 1-2)	05-November-2015	25-January-2016	82
Phase 2 (Floor 3-8)	30-November-2015	29-April-2016	142
.**Phase 3 (Floor 9-15)**	11-February-2016	29-June-2016	140
Phase 4 (Floor 16-17)	16-April-2016	29-July-2016	72

Phase 2 and 3 are similar in duration time due to the structure is erected most efficiently in the midsection of the structure. As for Phase 1, the structure is shown to take longer due to the ground level having a truss system, which takes longer to install compared to the typical steel construction above these floors. Although cost for the concrete decking is excluding in the decking it is important to show it is the system schedule to get a better understanding of how each phase works for the framing system. The schedule shows dates that start upcoming phases prior to completing past phases. This is due to metal decking, rebar installation and concrete pouring will take place. While this is happening the steel framing above can be installed to stay on the critical path of the overall project schedule.

Means and Methods

The Structural system is broken down into several components:

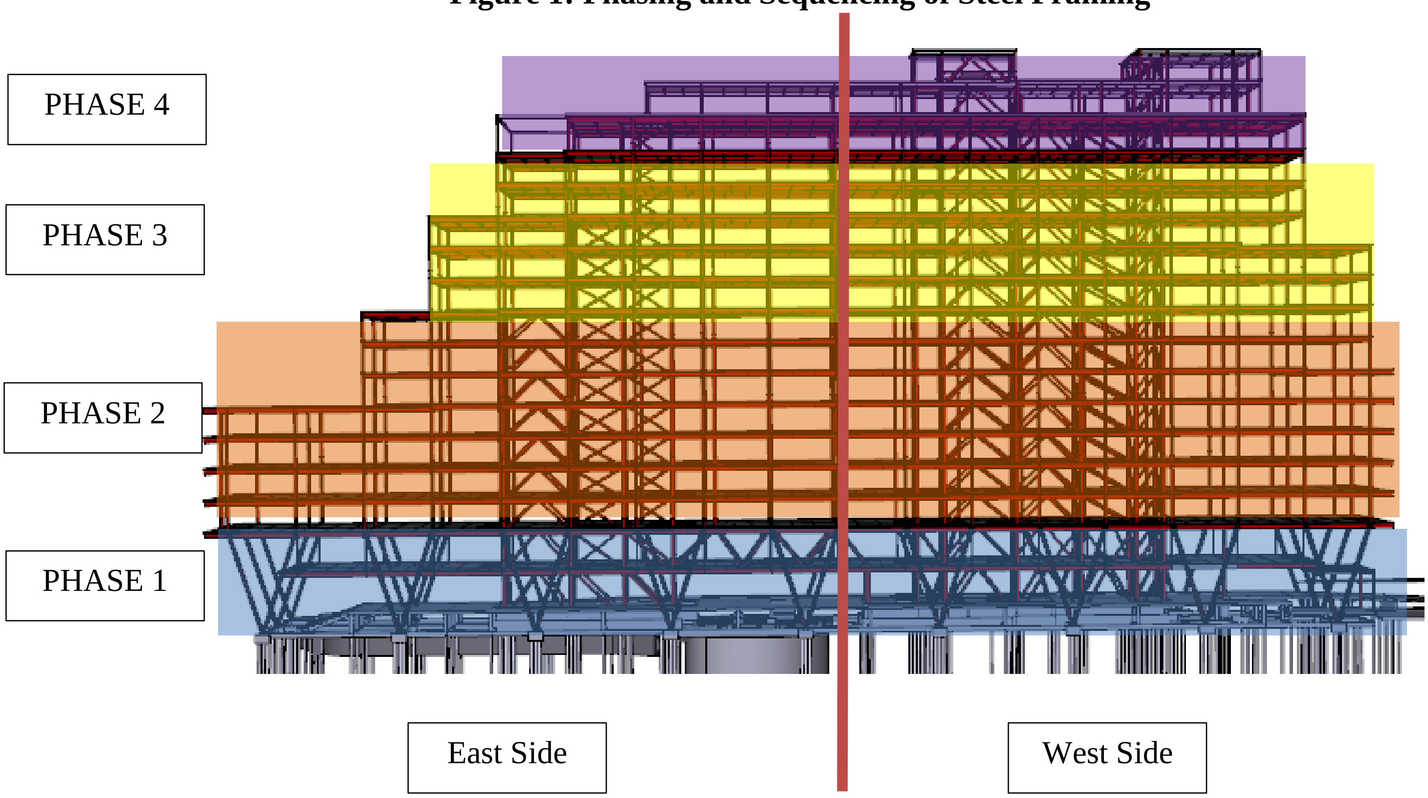
1. W 14 Columns
2. W24 Beams
3. W24 Girders
4. W18 Braced steel

Starting October 13th, 2015 two steel cranes will be assembled in the middle of the buildings footprint. One crane will serve the west side steel erection and the other crane will serve the east side steel erection. These cranes will work simultaneously in order to successfully complete each phase according to the steel erection schedule. As shown in figure 1 there are four phases to the steel erection process. The cranes are used to hoist the beams and columns into place. Once the columns are set in place for the first two floors, the beams will be installed. All of the members will be connected by several bolts on each side of the member to assure sustainability. Once the beams are installed the pre-fabricated bracing is installed. While the bracing is being installed, metal decking and 4'' concrete slabs will be poured as phase 2 begins. This will be repeated until all phases are complete. Fireproofing of all steel members will begin in mid-January, 2016 and completed at the end of August, 2016.

Floor-to-Floor Sequencing

The figure below shows the sequencing plan and how work is distributed over the entire building footprint. Since the building is broken down into two equal halves the structure will be erected from each end of the building and eventually meeting in the middle.

Figure 1: Phasing and Sequencing of Steel Framing



Structural System Cost Analysis

As stated in the previous technical report the structural system consists of many components. The foundation consists of 18” steel pipes that will be piled into the ground. 79”x79”x49” V-Column pile caps will be laid on top of the steel piles along with a 4’ square footing. Finally an 18” concrete slab will be poured to support the structure of the building. Overall the buildings structural system is supported by SOG foundation, grade beams, structural piles, and footings accompanied by a backfill of crushed concrete. The structure above grade will consist of W14 wide flanged columns that will span several stories. The columns range from W14x43 to W14x665. Between the spans of the columns are girders and wide flanged beams to support each floor and slab. These beams and girders vary in a range from W24-W76. The entire buildings structural system will be supported by a steel frame. The steel frame will consist of concentrically W12x65 braced frames that resist lateral loads through a vertical concentric truss system. The axes of these members will align at the joints of the structure. The system analyzed for this project was the structural steel system. The detailed estimate of the system consists of lateral bracing, steel columns, beams and girders.

Table 2: Detailed Structural Framing Estimate

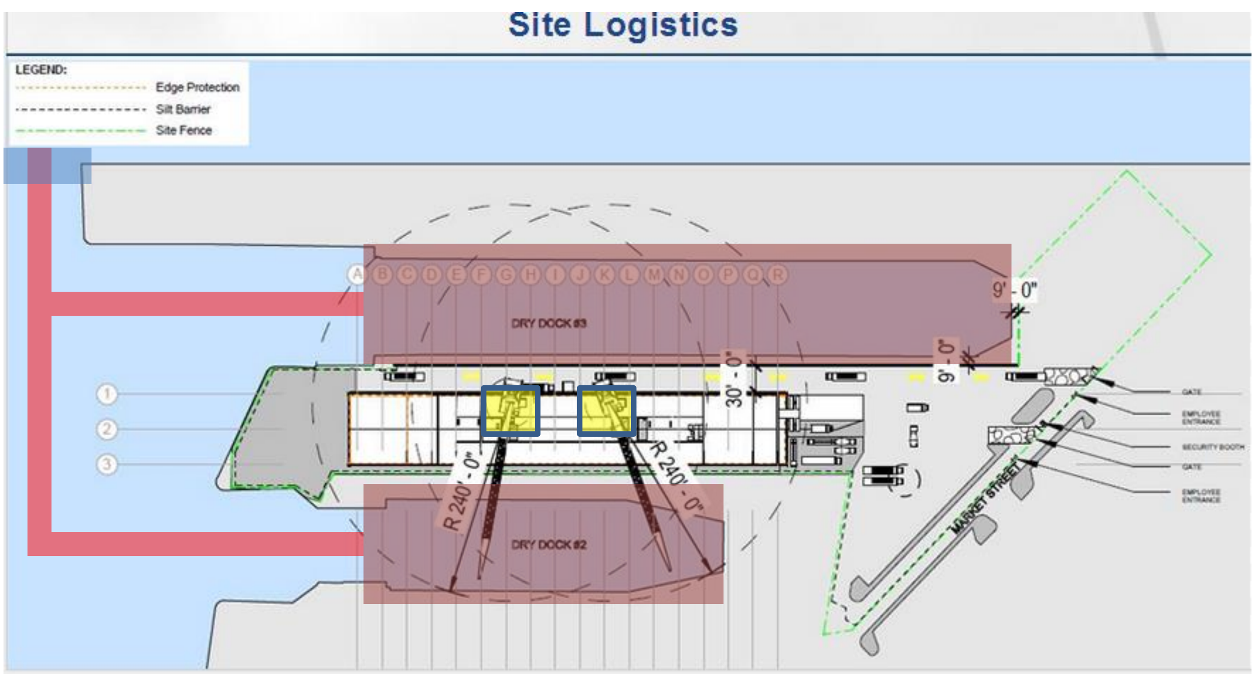
TOTAL: $20,000,000

Description	Takeoff Quantity	Labor Price	Labor Amount	Material Price	Material Amount	Total Amount
Beam W18 Weight	3,063,500 lb	$50.40/hr	43,238	3.47/lb	$10,630,345	$10,930,964
Beam W21 Weight	758,240 lb	$50.40/hr	8,648	3.47/lb	$2,631,093	$2,691,217
Lateral Bracing W21 Weight	540,000 lb	$50.40/hr	12,718	3.47/lb	$1,873,800	$1,962,218
Lateral Bracing W24 Weight	555,400 lb	$50.40/hr	7,020	3.47/lb	$1,927,238	$1,976,035
Girder W24 Weight	368,940 lb	$50.40/hr	1,964	3.47/lb	$1,280,222	$1,294,016
Column W14 Weight	272,656	$50.40/hr	11,090	3.47/lb	$946,116	$1,022,416
Column W14 Weight	27,200 lb	$50.40/hr	1,577	3.47/lb	$94,662	$105,626

Site Plan and Logistics

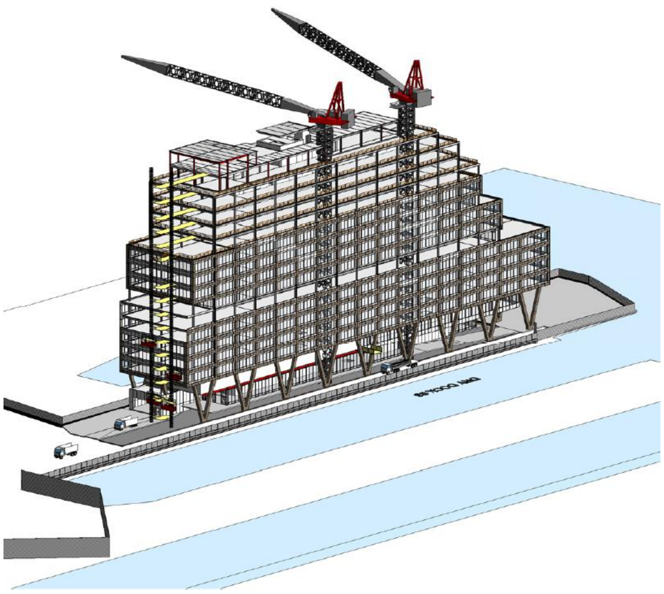
For the production sequencing of the steel construction the logistics plan shows the crane locations, steel staging layouts and material delivery roadways. Delivery of materials for this project is quite different than many other projects. Due to the building waterfront location materials such as prefabricated steel members are delivered on a barge. The barge is simply a boat that can hold heavy loads and drive these materials to the site by traveling on the water. If the materials cant be delivered due to cold weather conditions then materials will be delivered on a flat bed truck and enter through the east side of the site. The two cranes will first be used to hoist all the materials off the barge and onto the two docks that run parallel to the buildings site. There are two steel staging areas (one for each dock) that the cranes can hoist these materials efficiently onto the jobsite. The main reason for the two cranes is not only due to the large span of the building footprint, but also to accompany the steel staging areas to construct the building at a faster pace. Each of the dock spaces will be dedicated to one crane. Therefore, the cranes can pick up the materials independently and won't interfere with one another. This is important because the time is reduced to construct the steel frame due to the cranes having the ability to work simultaneously with one another. Throughout all four phases of the steel construction the logistics plan will not be changed. Each crane will be used until the building is watertight.

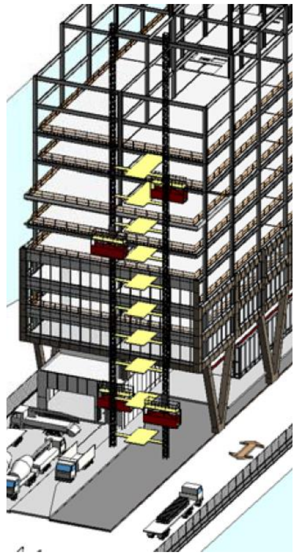
Figure 2: Site Logistics Plan for Steel Construction



Steel Staging
Hoist
Site Fencing
Site Access Roads
Gate Entrance

Figure 3: Hoist Location and Sequencing of Assemblies





Some of the key changes in workflow revolve around phase 2 and phase 3. Steel will be assembled at a faster rate due the structure having a simplistic method of bolting beams, columns and girders. Therefore, these floors are similar and many of the items that will be installed have prefabricated sections that need to be bolted and secured safely. Workflow will be at its peak during phase 2 and 3 due to the amount of steel that will be installed throughout floors 3-15. This process will be repeated until all floors are complete. As each piece of steel is brought on to the jobsite two laborers will be located in the steel staging area and attach straps to each side of the steel before being hoisted. To hoist the steel, structural ironworkers use cables connected to the crane to lift the beams onto the steel columns. A rope called a tagline is attached to the beams so an ironworker can control the beams if necessary. The crane hoists steel into place, and the ironworker's position the beams in place with spud wrenches to align bolt holes. Then, the beams can be bolted to the steel columns. Workers will be located where the steel needs to be place so that guidance for this beam can be safe and efficient. 60 ironworkers will be used throughout the entirety of the steel construction. Crews will be divided by installation of beams, girders, columns and bracing. As the project is progressing manpower will beak during phases two and 3. The bulk of the manpower will be dedicated to the installment of beams. Those crews will be larger than the crews for columns and lateral bracing. This method will be repeated until all steel members are properly installed.

In both the tension and shear joint design cases for bolt installation, some level of tension preload in the bolt and resulting compression preload in the clamped components is essential to the joint integrity. The preload target can be achieved by applying a measured torque to the bolt, measuring bolt extension, heating to expand the bolt then turning the nut down. These methods will be used to assure sustainable joint integrity when each steel member is installed.

Production Analysis

The schedule related to crews, resources, site constraints and similar schedule activities is shown to be efficient for each phase. The manpower-loaded schedule (Refer to Appendix B) was quite accurate confirming that manpower will be at its peak during phase 2 and 3 that starts halfway through the entirety of construction (Refer to Appendix A). This is due to the majority of the work will be taken place during these two phases. The issue analyzed in the scheduling is the way the phases work. Since the installation of the braced system is labor intensive causes the phases to overlap one another (Refer to Figure 4). For example, when bracing is installed the columns are getting ready to be hoisted to the next phase. The phase's start earlier than they end because at the end of each phase the installation of metal decking and concrete pouring can start while another phase is being constructed. This is important because it makes the project more efficient and does not put crew members at a standstill. Since the project is quite big the concrete trucks are located at the east and west ends of building and do not interfere with the cranes that are hoisting steel. This process enables work to be successfully completed at an expedited pace.

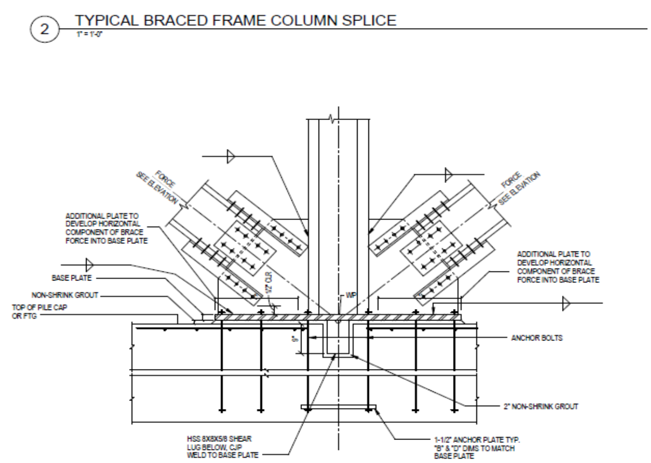
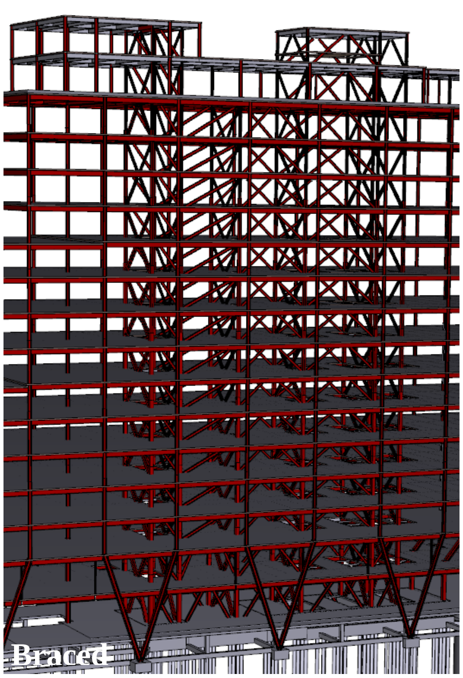


Figure 4: Braced Frame

Cost Analysis

After completing the detailed estimate for the steel frame the overall price for the system was $20,000,000(Table 2). This was $2 million dollars lower than the actual construction cost of the system. This observation is assumed to be due to the custom structural bracing system and the prefabricated steel members that where brought on site. The lateral bracing system is assumed to take more time to install as well as to fabricate.



Also, the lateral bracing system has many trusses that where prefabricated prior to installation on site, which could increase the cost of delivery as well as material cost. Some of these members are prefabricated because installation is labor intensive and challenging. This could affect the critical path of the project schedule and is an efficient way to eliminate schedule risks. As shown in figure 4, gusset plates, splice plates, stiffener plates and slotted plates where all used in each angle connection. This could be one of the many reasons that the structural detailed estimate was lower than the actual cost for the steel frame. Figure 5 shows the braced framed system and all the members that could have been lost in the estimate due to its custom design. Overall, the cost estimate is quite close to the original budget of $401.94/Sq.Ft from R.S Means.

Logistical Analysis

Although the projects logistics are quite efficient, there are always alternatives to maximize production. For this specific project the cranes are located in the middle of the building footprint. Due to the lack of space and assembly of the cranes can cause the project to be in danger. One alternative that could solve this issue is to locate the cranes on barges, which could free up some area for other materials to be laid out. Taking the cranes off the site is going to be a challenge due to the space limitations on each side of the building. If two cranes were located on two separate barges they would not interfere with the project site and can be hauled away more efficiently. This will allow for other trades to get onto the site faster and continue performing work at an earlier time. As for the methods of construction, it would be ideal to take advantage of the building being located on the water. Deliveries are key to a successful project and having more prefabricated systems brought onto sight can accelerate the project completion date. This would be interesting to see if larger prefabricated systems could be brought to this project and immediately installed. Space is always an issue in construction and using this sites open space can allow for other scopes of work to be completed earlier. This method could not only expedite the schedule but also lower the amount of manpower needed, which ultimately reduces costs.

Schedule Acceleration

In order for the project schedule to be a success each of the systems schedules sequence of activities must be completed in an orderly fashion to follow the critical path method. Each of the systems activities must be completed on time to follow the critical path of the project schedule. For the steel framing, all activities such as the installation of columns, must be completed prior to the start of the next activity. The structural system is broken down into four phases. Each of the phases will consist of the installation of steel beams, columns, girders and lateral bracing. All of these activities where completed within the system schedule and meet the credentials of pursuing the critical path of the project schedule. Some of the biggest risks of the project's completion date are poor weather conditions, delayed material deliveries, lack of space on a jobsite, and minimal manpower. There are also many methods that can accelerate the system schedule. Some key ways to accelerate the framing system schedule is by prefabricating steel systems. The prefabrication of steel systems will reduce the amount of headaches on the jobsite and eliminate the installation of complex members such as the lateral bracing. If the bracing is completed in sections rather then bolting each individual member on site, it can open opportunities accelerate the system schedule. Once the prefabricated system is brought on to the jobsite it can be installed with less manpower and more efficiently. The issue with prefabricating systems is the cost. These systems can cost double the amount of a typical steel assembly but can reduce the schedule. If the reduction in manpower and duration days of system completion is an option, it may be beneficial to take this option into consideration. The prefabricated steel systems sequencing for floor-to-floor construction will be the same as the original sequencing. The only difference is that the duration time could be cut in half by prefabricating the east and west side structural systems and delivering them to the job site to be installed.

Constructability and Logistical Issues

For the structural framing system the constructability challenges will be the installation of the braced frame system. The challenging part about this construction is getting the proper angle prior to bolting it to the structure. Each angle has to be precise so the other braced members can fit tight with no air gaps at the connections. It is also important that these members are installed immediately due to their interior location where a crane may not be able to reach if beams are installed. (Refer to Figure 4,5&6)

The team's solution to this issue is to prefabricate these braces on site and then hoist them up and install them. It is much more efficient to construct a braced system on the ground compared to limited space on the structure. The braced systems are then installed along with the columns.

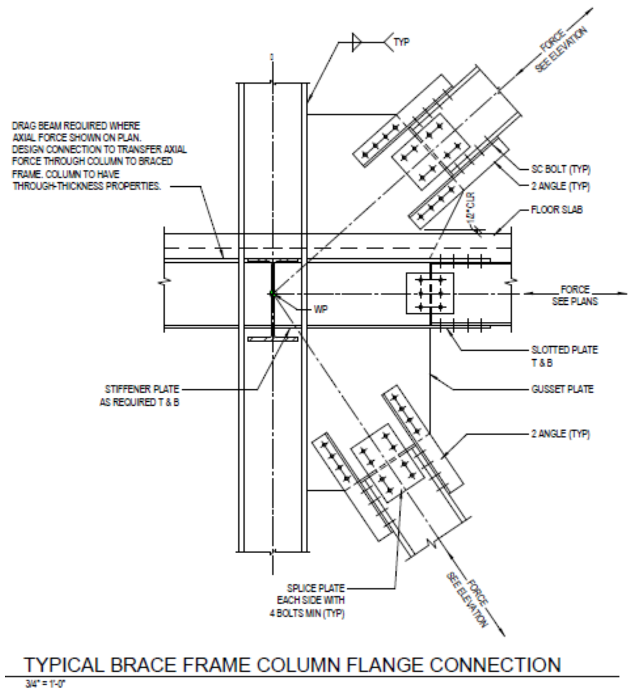


Figure 6: Brace Frame Detail

The superintendent believes if the structure were to be built again that prefabrication of angled members are always a more efficient option because it reduces the amount of time needed to place and install the members properly. Due to the site logistics, these lateral braces could be prefabricated as four members and brought on to site with a barge. This would not only reduce the amount of coordination issues on site but also accelerate the project schedule.

APPENDIX A

Field Supervisor interview

Question: How does the limited amount of site space effect the overall production of the Project?

Answer: Although the building footprint is located on a thin strip of land, two empty docks located on the north and south sides of the building surround the site. This will be used for material layouts. If the case was that the land could not be used for this project we would have to use the lot located by the delivery entrance. The entrance would have to be moved as well as the delivery route.

Question: What items from the steel frame schedule do you think would impact the project from staying on the critical path of the project schedule?

Answer: The most important item in the beginning of steel construction is installation of the columns. Although the foundation is the most important item when talking about sustainability, the columns are the backbone to the entire structure, especially the columns connecting to the foundation. If these activities are not completed on time and properly this can cause workflow to decrease and put construction to a halt. Improper installation of members can cause the entire project schedule to be delayed.

Question: Are there any permits needed to get items delivered by boat?

Answer: Yes, you need approval and there is a maximum requirement allowed to be delivered. If our team breaks those rules we can be in danger of the project shutting down and/or getting fined.

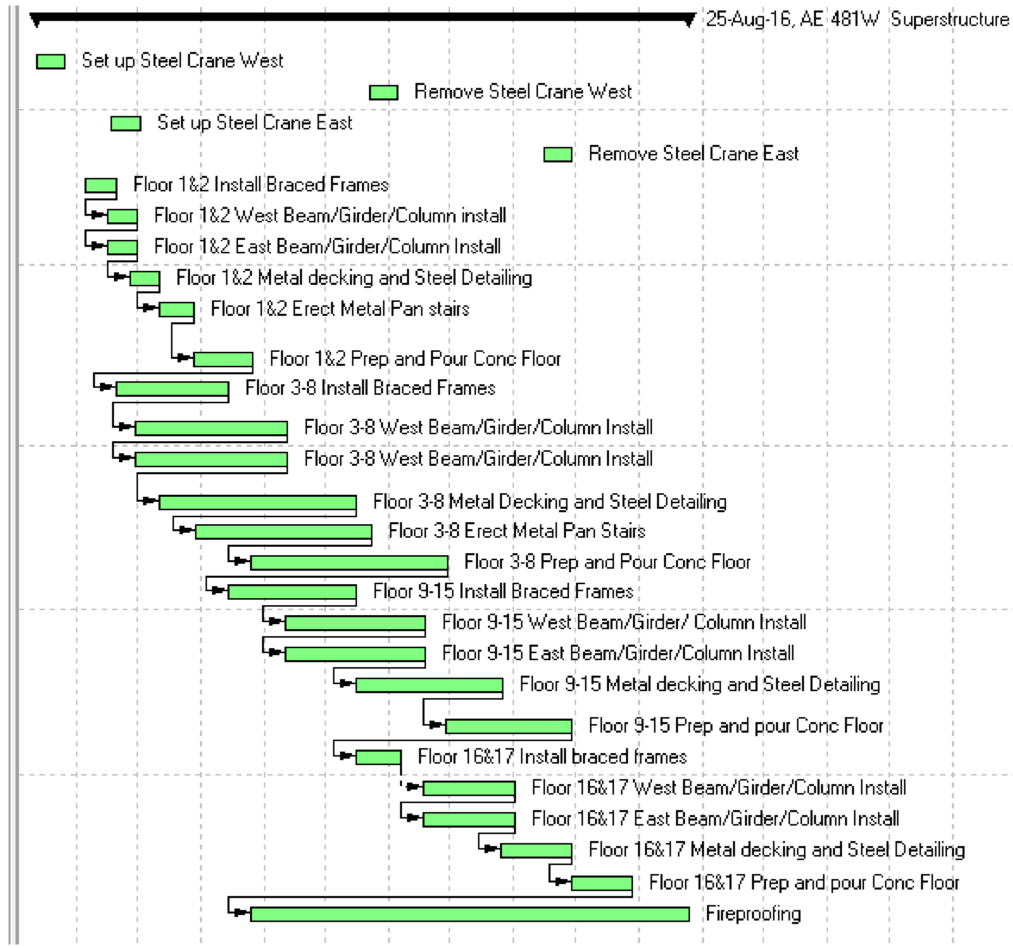
Question: Do you believe that the lateral bracing could have been prefabricated into bigger members, and then brought on site?

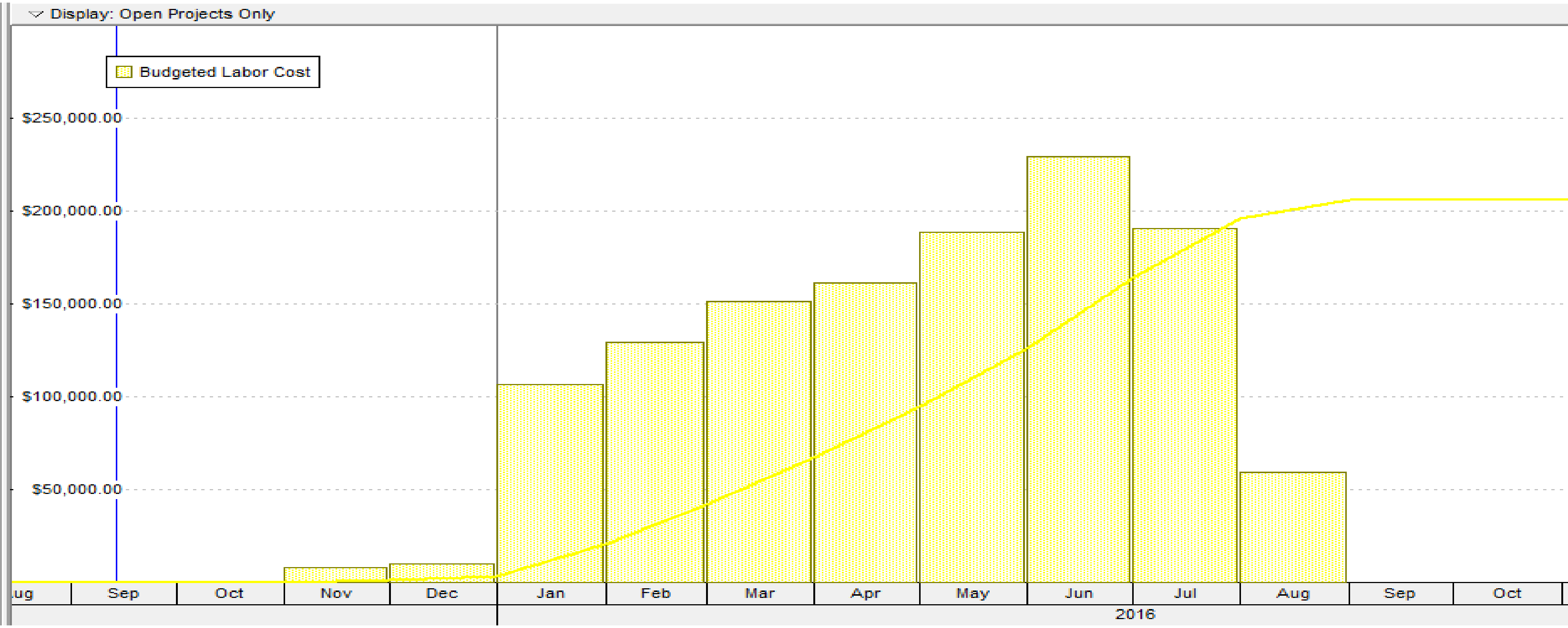
Answer: Due to the site logistics these lateral braces could be prefabricated as four members and brought on to site with a barge. This would not only reduce the amount of coordination issues on site but also accelerate the project schedule.

APPENDIX B

Steel Framing System Schedule & Manpower loaded Schedule

	AE 481W Superstructure Estimate	228	228	0%	13-Oct-15	25-Aug-16
SS-300	Set up Steel Crane West	10	10	0%	13-Oct-15	26-Oct-15
SS-310	Remove Steel Crane West	10	10	0%	23-Mar-16*	05-Apr-16
SS-320	Set up Steel Crane East	11	11	0%	18-Nov-15*	02-Dec-15
SS-330	Remove Steel Crane East	10	10	0%	16-Jun-16*	29-Jun-16
SS-360	Floor 1&2 Install Braced Frames	12	12	0%	05-Nov-15*	20-Nov-15
SS-370	Floor 1&2 West Beam/Girder/Column install	11	11	0%	16-Nov-15*	30-Nov-15
SS-380	Floor 1&2 East Beam/Girder/Column Install	11	11	0%	16-Nov-15*	30-Nov-15
SS-390	Floor 1&2 Metal decking and Steel Detailing	11	11	0%	27-Nov-15*	11-Dec-15
SS-400	Floor 1&2 Erect Metal Pan stairs	12	12	0%	11-Dec-15*	28-Dec-15
SS-410	Floor 1&2 Prep and Pour Conc Floor	21	21	0%	28-Dec-15*	25-Jan-16
SS-420	Floor 3-8 Install Braced Frames	40	40	0%	20-Nov-15*	14-Jan-16
SS-430	Floor 3-8 West Beam/Girder/Column Install	54	54	0%	30-Nov-15*	11-Feb-16
SS-440	Floor 3-8 West Beam/Girder/Column Install	54	54	0%	30-Nov-15*	11-Feb-16
SS-450	Floor 3-8 Metal Decking and Steel Detailing	69	69	0%	11-Dec-15*	16-Mar-16
SS-460	Floor 3-8 Erect Metal Pan Stairs	62	62	0%	29-Dec-15*	23-Mar-16
SS-470	Floor 3-8 Prep and Pour Conc Floor	70	70	0%	25-Jan-16*	29-Apr-16
SS-480	Floor 9-15 Install Braced Frames	45	45	0%	14-Jan-16*	16-Mar-16
SS-490	Floor 9-15 West Beam/Girder/ Column Install	48	48	0%	11-Feb-16*	18-Apr-16
SS-500	Floor 9-15 East Beam/Girder/Column Install	48	48	0%	11-Feb-16*	18-Apr-16
SS-510	Floor 9-15 Metal decking and Steel Detailing	52	52	0%	16-Mar-16*	26-May-16
SS-520	Floor 9-15 Prep and pour Conc Floor	44	44	0%	29-Apr-16*	29-Jun-16
SS-530	Floor 16&17 Install braced frames	17	17	0%	16-Mar-16*	07-Apr-16
SS-540	Floor 16&17 West Beam/Girder/Column Install	33	33	0%	18-Apr-16*	01-Jun-16
SS-550	Floor 16&17 East Beam/Girder/Column Install	33	33	0%	18-Apr-16*	01-Jun-16
SS-560	Floor 16&17 Metal decking and Steel Detailing	25	25	0%	26-May-16*	29-Jun-16
SS-570	Floor 16&17 Prep and pour Conc Floor	22	22	0%	29-Jun-16*	28-Jul-16
SS-580	Fireproofing	154	154	0%	25-Jan-16*	25-Aug-16

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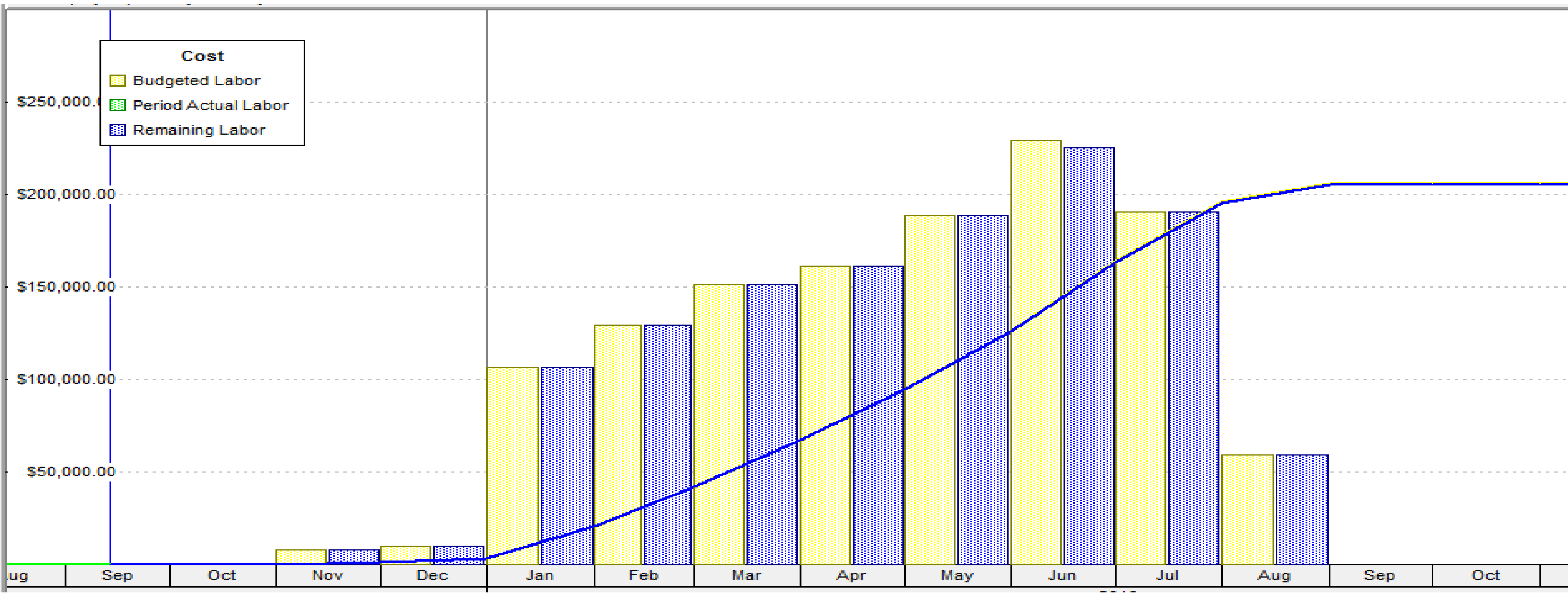
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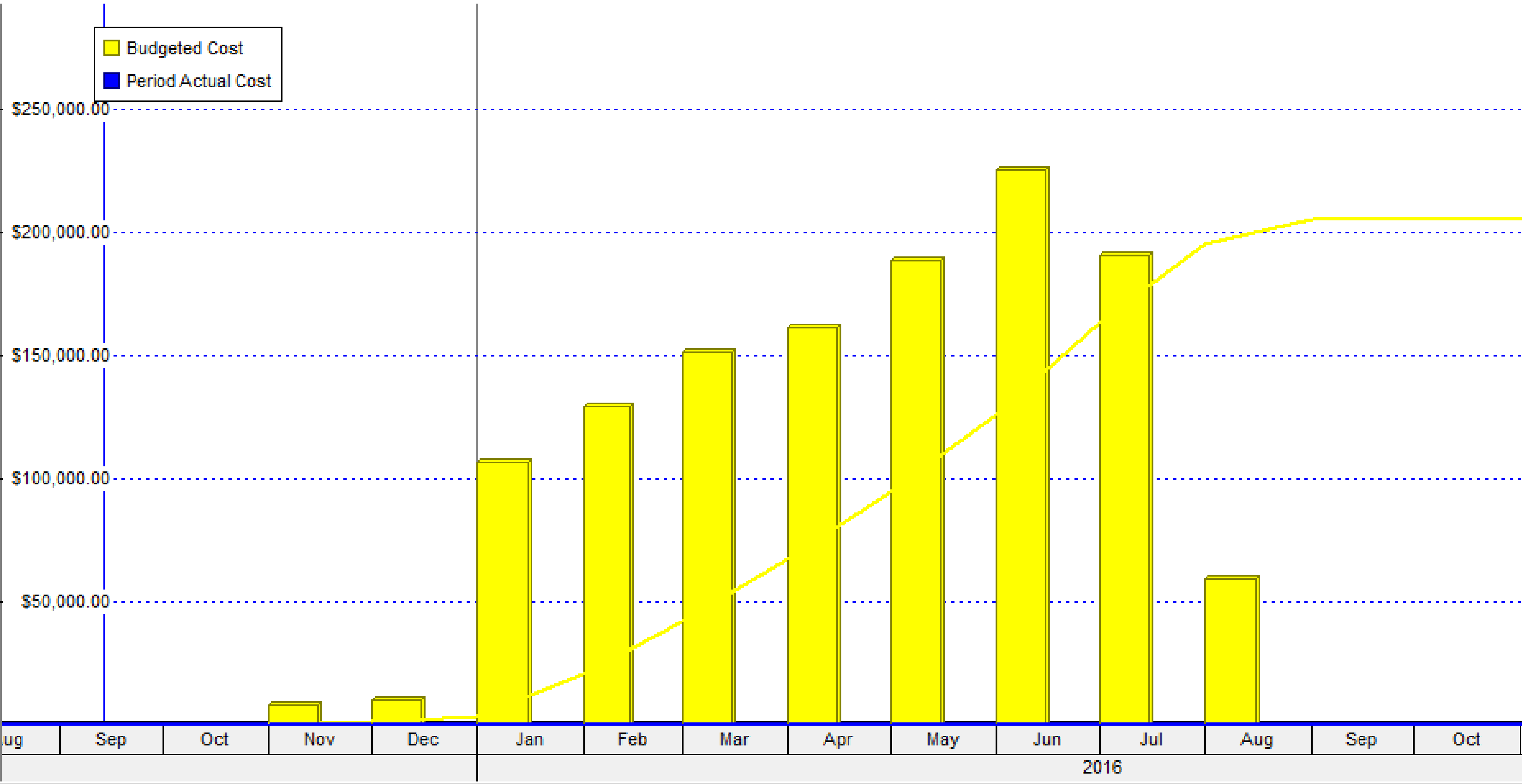
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APPENDIX C

Timberline Detailed Structural Framing Estimate

Nicholas Boccia AE 481W Building 52 Structural Estimate

Assembly	Phase	Description	Takeoff Quantity	Labor Cost/Unit	Labor Price	Labor Amount	Material Price	Material Amount	Vendor Name	Sub Amount	Sub Name	Equip Price	Equip Amount	Other Price	Other Amount	Total Cost/Unit	Total Amount
0509-		Beam - W Shape 18"															
	5900.170	Weight lbs	3,063,500.00 lbs	-	-	-	3.47 / lbs	10,630,345		-		-	-	-	-	3.47 / lbs	10,630,345
	5150.570	Quantity handling	1,700.00 each	21.84 /each	33.60 /hour	37,128	-	-		-		200.00 /hour	221,000	-	-	151.84 /each	258,128
	5150.570	Saw Cut Ends	3,400.00 each	1.80 /each	16.80 /hour	6,112	-	-		-		100.00 /hour	36,380	-	-	12.50 /each	42,492
0510-		Beam - W Shape 21"															
	5900.170	Weight lbs	758,240.00 lbs	-	-	-	3.47 /lbs	2,631,093		-		-	-	-	-	3.47 /lbs	2,631,093
	5150.800	Quantity handling	340.00 each	21.84 /each	33.60 /hour	7,426	-	-		-		200.00 /hour	44,200	-	-	151.84 /each	51,626
	5150.800	Saw Cut Ends	680.00 each	1.80 /each	16.80 /hour	1,222	-	-		-		100.00 /hour	7,276	-	-	12.50 /each	8,498
0510-		Beam - W Shape 21"															
	5900.170	Weight lbs	540,000.00 lbs	-	-	-	3.47 /lbs	1,873,800		-		-	-	-	-	3.47 /lbs	1,873,800
	5150.800	Quantity handling	500.00 each	21.84 /each	33.60 /hour	10,920	-	-		-		200.00 /hour	65,000	-	-	151.84 /each	75,920
	5150.800	Saw Cut Ends	1,000.00 each	1.80 /each	16.80 /hour	1,798	-	-		-		100.00 /hour	10,700	-	-	12.50 /each	12,498
0511-		Beam - W Shape 24"															
	5900.170	Weight lbs	555,400.00 lbs	-	-	-	3.47 /lbs	1,927,238		-		-	-	-	-	3.47 /lbs	1,927,238
	5175.100	Quantity handling	276.00 each	21.84 /each	33.60 /hour	6,028	-	-		-		200.00 /hour	35,880	-	-	151.84 /each	41,908
	5175.100	Saw Cut Ends	552.00 each	1.80 /each	16.80 /hour	992	- /each	-		-		100.00 /hour	5,906	-	-	12.50 /each	6,899
0511-		Beam - W Shape 24"															
	5900.170	Weight lbs	368,940.00 lbs	-	-	-	3.47 /lbs	1,280,222		-		-	-	-	-	3.47 /lbs	1,280,222
	5175.100	Quantity handling	78.00 each	21.84 /each	33.60 /hour	1,704	-	-		-		200.00 /hour	10,140	-	-	151.84 /each	11,844
	5175.100	Saw Cut Ends	156.00 each	1.80 /each	16.80 /hour	280	-	-		-		100.00 /hour	1,669	-	-	12.50 /each	1,950
0577-		Column - W Shape 14"															
	5900.170	Weight lbs	272,656.00 lbs	-	-	-	3.47 /lbs	946,116		-		-	-	-	-	3.47 /lbs	946,116
	5150.100	Quantity handling	436.00 each	21.84 /each	33.60 /hour	9,522	-	-		-		200.00 /hour	56,680	-	-	151.84 /each	66,202
	5150.100	Saw Cut Ends	872.00 each	1.80 /each	16.80 /hour	1,568	-	-		-		100.00 /hour	9,330	-	-	12.50 /each	10,898
0577-		Column - W Shape 14"															
	5900.170	Weight lbs	27,280.00 lbs	-	-	-	3.47 /lbs	94,662		-		-	-	-	-	3.47 /lbs	94,662
	5150.100	Quantity handling	62.00 each	21.84 /each	33.60 /hour	1,354	-	-		-		200.00 /hour	8,060	-	-	151.84 /each	9,414
	5150.100	Saw Cut Ends	124.00 each	1.80 /each	16.80 /hour	223	-	-		-		100.00 /hour	1,327	-	-	12.50 /each	1,550

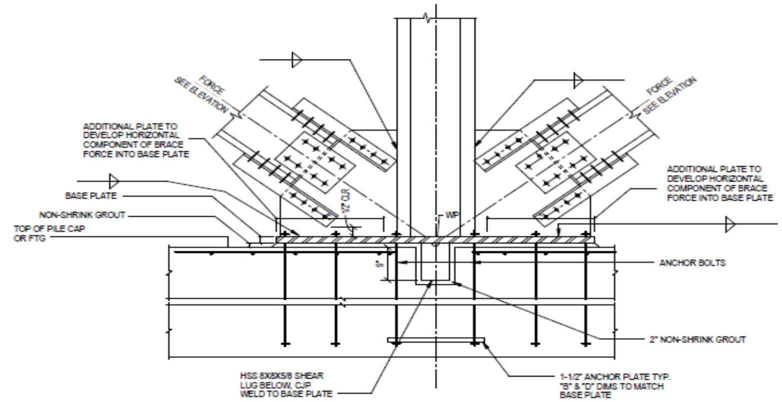
Help, press F1 Grand Total: 19,983,301 10/13/2015

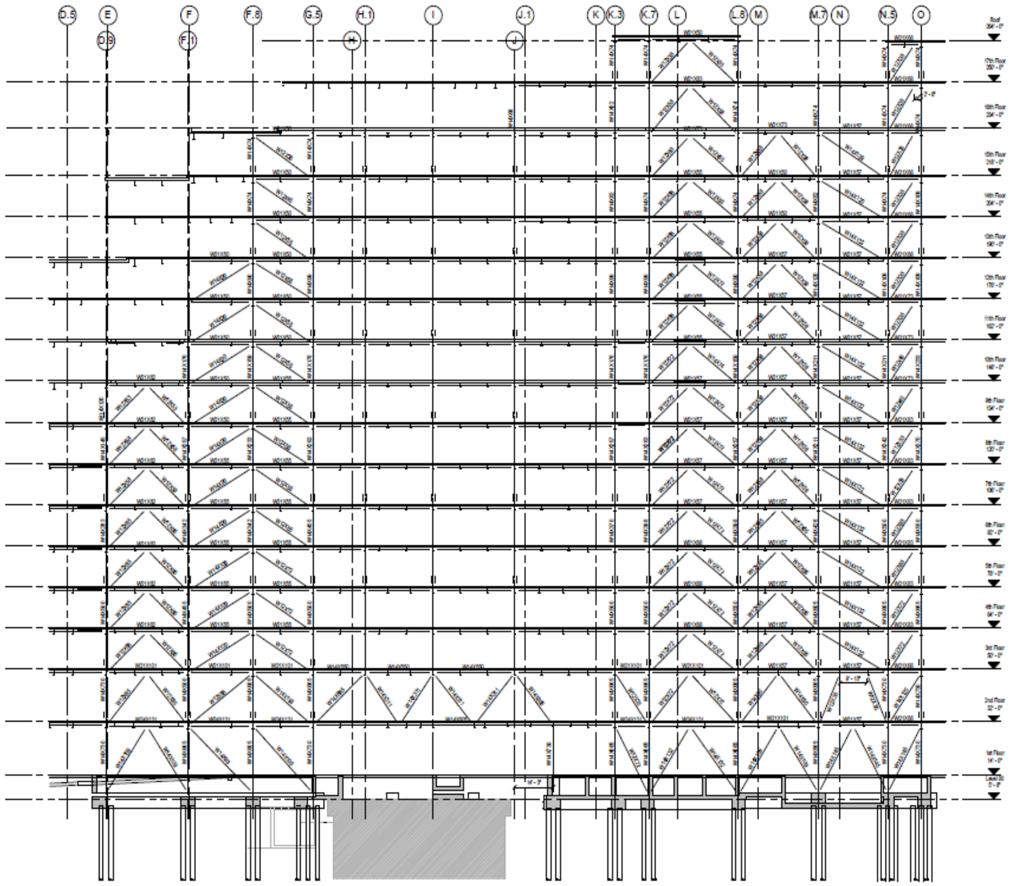
APPENDIX D

Braced System & Detailed Connection

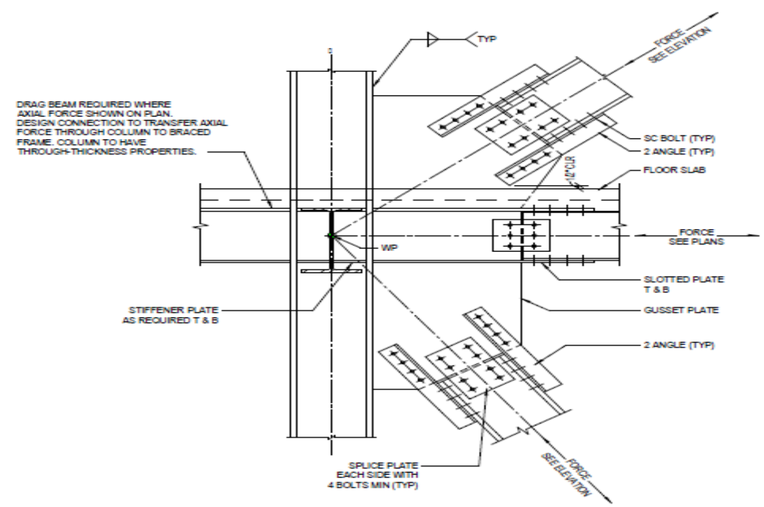
2 TYPICAL BRACED FRAME COLUMN SPLICE

1" = 1'-0"





1 BRACED FRAMES IN GRID 1.5



TYPICAL BRACE FRAME COLUMN FLANGE CONNECTION

3/4" = 1'-0"

3D Model of Steel Construction