12.0 Appendices

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Appendix A: Building Frame Systems

Two of the most widely used construction materials for building frames are steel and concrete (Guggemos and Horvath 2005). Depending on which one of these materials is used, the design of a building can differ quite dramatically. There are many factors that determine the reasons for choosing one material over the other.

Reinforced Concrete Building Systems

Reinforced concrete is a composite material that is made up of Portland cement concrete and steel rebar. The compressive strength of the concrete usually can range anywhere from 3,000 to 10,000 psi, while the yield strength of steel is normally 60,000 psi. The tensile strength of concrete is approximately 10% of its compressive strength. To overcome this weakness steel is used to resist the tensile forces (Chen and Lui 2005).

The American Concrete Institute (ACI) is an organization which promotes "safe and efficient design and construction of concrete structures."(Shaeffer 1992) One of its commitees, specifically committee 318, publishes basic guidelines for design of concrete structures. These guidelines serve as the primary code for reinforced concrete structures and are incorporated into the International Building Code (IBC), as well as the design codes of the American Association of State Highway and Transportation Officials (AASHTO) (Chen and Lui 2005).

Reinforced concrete is a very versatile material because of the way structural members are cast, resulting in inherent continuity. This creates naturally occurring moment-resistant connections, which are not only visually appealing, but also can provide great design efficiency. The uniqueness of concrete allows for design and construction of a number of different building systems, such as flat plate, flat slab with shearheads, flat slab with beams, one-way slab, and waffle slab systems (Shaeffer 1992). These building systems will be discussed in the next few paragraphs.

One of the simplest concrete building systems is a flat plate system (Figure 1). This system is comprised of a flat concrete slab without any beams. It can be very economical due to the reduction in floor height (Chen and Lui 2005). It is primarily used in building with short column-to-column spans and light loads (Shaeffer 1992).

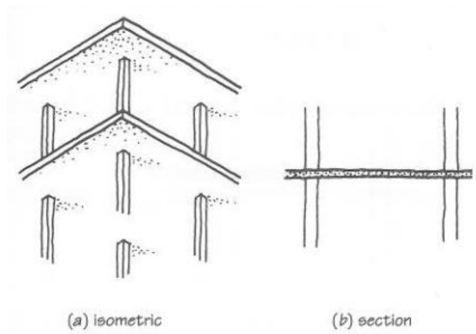


Figure 1 Flat Plate System

The thickness of the slab should not be less than 5 inches and increases with the increase in span length (Chen and Lui 2005). Slab thickness of flat plate systems for residential loads can be seen in Table 1.

Table 1 Flat Plate Thickness for Residential Loads

Span (ft)	Thickness (in)
12	5
15	6
18	7
20	8

In order to increase the load capacity of flat plates, shearheads can be introduced around the tops of columns that support flat slabs (Figure 2). These shearheads provide additional support again the punching shear forces (Chen and Lui 2005) and can be shaped as conical capitals or drop panels, depending on the shape of the column. Flat slab with sheadheads systems can be very effective and economical for office or industrial buildings (Shaeffer 1992).

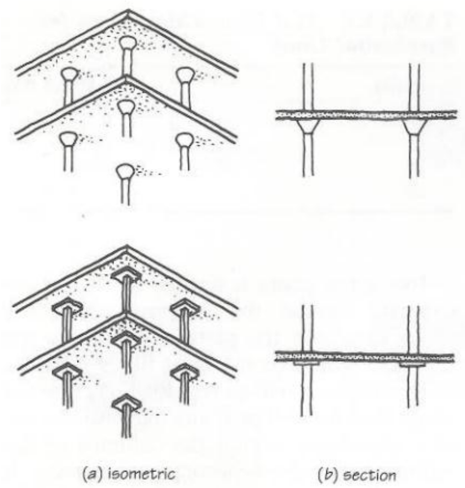


Figure 2 Flat Slab with Shearheads

Slab thickness of flat slab systems with shearheads should not be less than 4 inches (Chen and Lui 2005). Typical thicknesses of slabs and shearhead panels can be found in Table 2.

Table 2 Flat Slab with Drop Panel Thickness

Span (ft)	Thickness of Slab (in)	Total Thickness of Panel (in)
16	6	8
20	8	11
24	10	14
28	12	17

By introducing beams into a floor system, the requirement for the thickness of the slab can be greatly reduced because beams transfer the floor loads to the columns and thus there are no great punching shear forces on the slab (Figure 3). The beams also provide rigid moment connections to the columns which result in a building that can support much greater lateral loads. Overall flat slab with beam systems are much deeper than flat slab with shearheads system due to the depth of the beams and the fact that the service ducts have to be run under the beams (Shaeffer 1992).

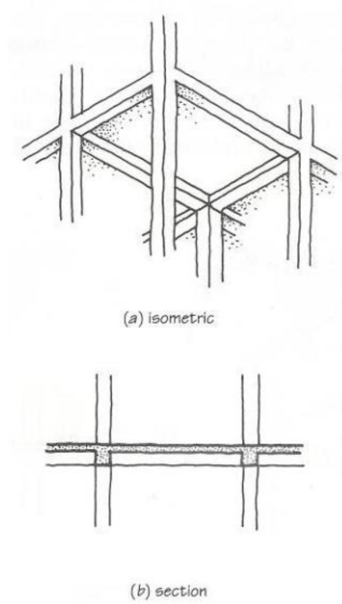


Figure 3 Flat Slab with Beams

Flat slab with beam systems can be used for spans ranging from 20 to 30 feet, but other systems are usually considered for spans more than 24 feet due to the great depth of the beams required along with their self-weight (Shaeffer 1992) (Table 3).

Table 3 Flat Slab with Beam Thickness

Span (ft)	Thickness of Slab (in)	Total Depth of Beams (in)
20	7	16
24	9	20
28	11	25
30	13	28

One-way slab system, which can be seen in Figure 4, is one of the most versatile and widely used concrete building systems (Shaeffer 1992). Even though the slab is supported on all four sides, if the ratio of the long to short span length is greater than 2, loads are considered to be transferred in one major direction (Chen and Lui 2005). Column span lengths of up to 36 feet in the long direction can be achieved with one-way slab systems (Shaeffer 1992).

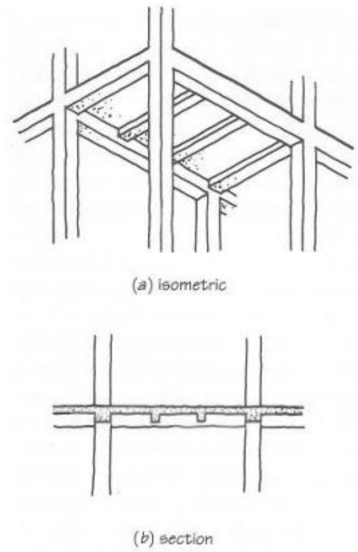


Figure 4 One-Way Slab System

Waffle Slab system can create the longest column-to-column spaces without the use of prestressed concrete (Shaeffer 1992). It can also support very heavy floor loads. (Chen and Lui 2005). Waffle slabs contains 2 to 3 foot ribs and can be designed in a number of ways to transfer the floor loads to columns. Figure 5 represents two types of waffle slabs, one that uses shearheads and another that uses beams to transfer loads to columns. Due to its aesthetic looks, waffles slab systems are usually left unenclosed (Shaeffer 1992). Waffle slab systems usually follow the same design procedures as flat slab systems (Chen and Lui 2005).

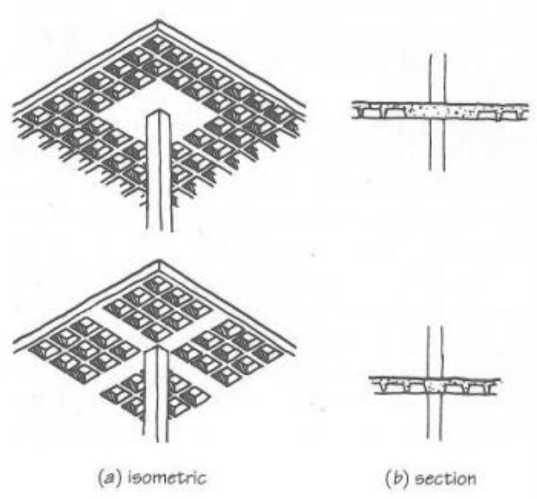


Figure 5 Waffle Slab

Waffle slab systems are generally designed for spans from 25 to 40 feet, but can reach up to 50 feet (Table 4) (Shaeffer 1992).

Table 4 Waffle Slab Thickness

Span (ft)	Slab Thickness (in)	Total Thickness (in)
25	3	12
30	3	15
35	4	19
40	5	24

Steel Building Systems

Structural steel possesses many qualities, such as strength, stiffness, toughness, and ductility, which make it very good for building construction. Strength of steel is usually expressed as yield strength F_y or ultimate strength F_u. There are many shapes of steel sections that are used in construction, such as wide flange (W), the American Standard beam (S), bearing pile (HP), American Standard channel (C), angles (L), tee (WT), and others. These sections can be formed by one of three primary methods: hot rolled, cold formed, and welded.

Structural steel sections can be connected to each other to create multistory frames. There are two main types of steel frames: moment frames and simple frames. A moment frames develops its stiffness from rigid joints between beams and columns. This results in a frame that can be designed to withstand forces with deformations that are well within allowable tolerances. Moment frames also perform better in earthquakes than other types of steel frames but are less economical due to the detailing of the rigid connections. Simple frames, unlike moment frames, can't withstand lateral forces. They have to be either connected to a moment frame or contain a bracing system. There is a number of advantages to consider the use of simple frames in steel frames:

1. Simple frames are easier and cheaper to fabricate and erect.
2. Connections can be bolted instead of welded.
3. Structural analysis of a building becomes much simpler because the building can be broken up into two systems: system that resists vertical loads and system that resists horizontal loads.

Choosing a floor system is another important consideration for steel frame building. The most widely used floor system is composite floor system. This system involves steel beams, girders, or trusses that support a concrete slab. The composite action of the beam comes from the shear studs that connect the concrete slab to the top flange of the steel beam. A cross section of a composite floor system can be seen in Figure 6.

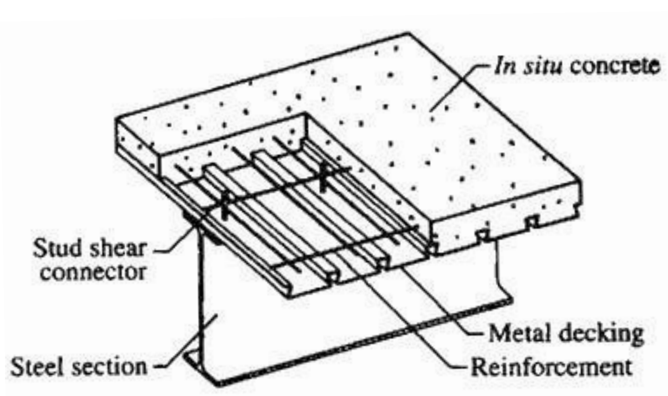


Figure 6 Composite beam system – Concrete slab on steel deck

In this figure the stress distribution diagram shows that the neutral axis is located relatively close to the top of the steel flange. This results in top flange and concrete slab to be in compression, while the bottom portion of the steel member to be in tension. One of the main factors that control the type of composite floor system to be chosen is the span length. A number of composite floor systems and their respective spans lengths can be seen in Figure 7 and will be discussed in the next few paragraphs.

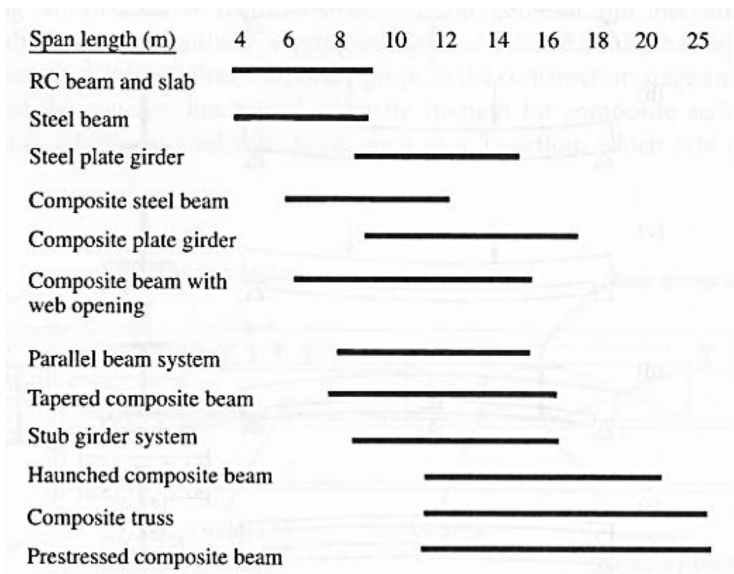


Figure 7 Comparison of Composite Floor Systems

One of the most commonly used composite floor systems is composite beam and girder. In it, horizontal steel members contain shear studs and support a metal decking. This metal decking is used as a form for the concrete slab (Figure 8).

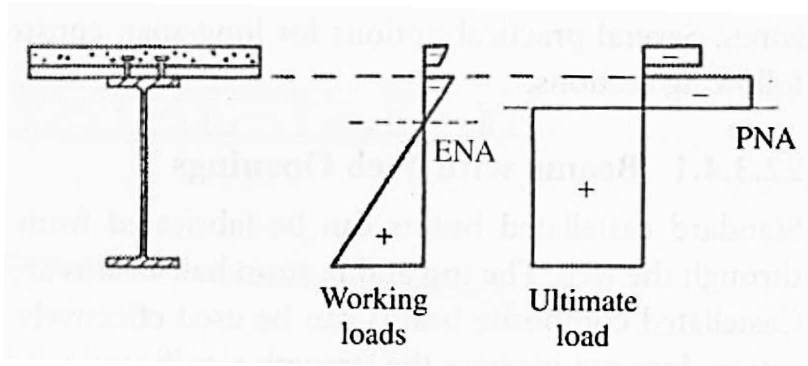


Figure 8 Stress Distribution in Composite Cross-Section

If a longer beam system is required and a deeper beam is chosen, openings inside of the beam webs can be made to allow for the passage of mechanical ducts and related services. Stiffeners are often added on top and bottom of the web openings to carry the shear forces, as can be seen in Figure 9.

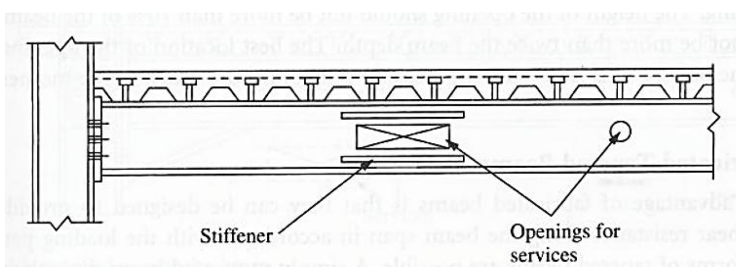


Figure 9 Web Opening with Horizontal Reinforcements

Custom fabricated beams can prove to be very economical, especially when they are made specifically to provide moment and shear resistance in accordance with the loading pattern. If a beam is simply supported then its maximum bending moment will be located near the center of the beam. To provide a more economical design, beams can be tapered at the ends. This will also allow for service ducts to be run next to tapered ends (Figure 10).

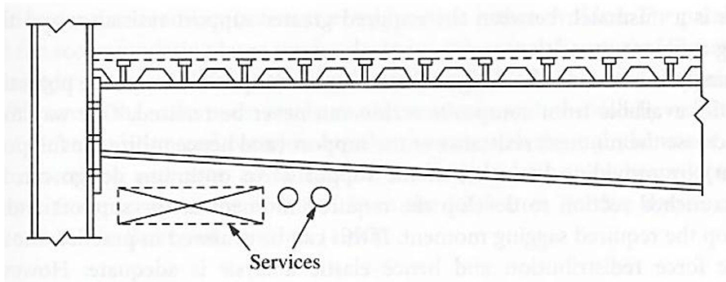


Figure 10 Tapered Composite Beam

Unlike simply supported beams that develop maximum bending moments at mid-span, beams with rigid connection can be designed to greatly reduce these moments and thus reduce the depth of the composite floor system by up to 30%. These beams are called haunched composite beams (Figure 11).

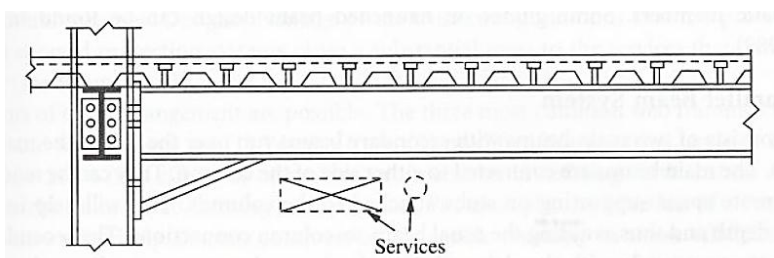


Figure 11 Haunched Composite Beam

The depth of the haunch can range from 5% to 15% of the span length, depending whether the frame is sway or non-sway. Haunched beam systems can resist lateral forces. Unfortunately, due to their difference in symmetry about the bending axis, haunched connections behave differently under negative and positive moments.

For buildings with long spans and large service ducts, parallel beam system can be the most cost effective composite floor system. This system uses one set of beams connected to each column, while also adding a second set of continuous beams that span 2 or 3 spans. The second beam system contains shear studs and becomes part of the composite system with concrete slab on top. This system can be seen in Figure 12.

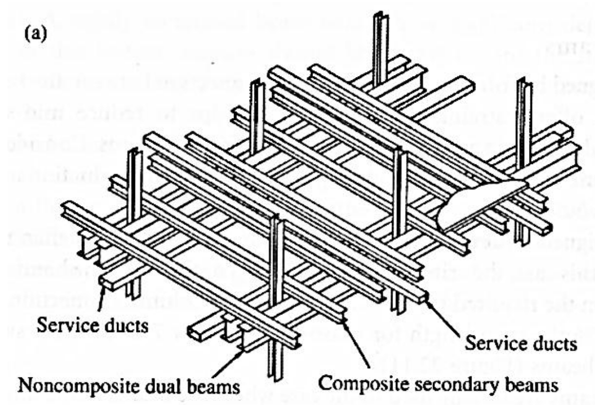


Figure 12 Parallel Composite Beam System

Instead of using regular W-section beams, trusses can be incorporated into a floor system to provide cost effective methods for long spans. Three common trusses used are Warren truss, modified Warren truss, and Pratt truss. Large openings in the truss can allow for service ducts to be run through. Two major setbacks with composite truss systems is the cost of fabrication and fire proofing, but when designed properly, this type of system can be very cost effective (Figure 13).

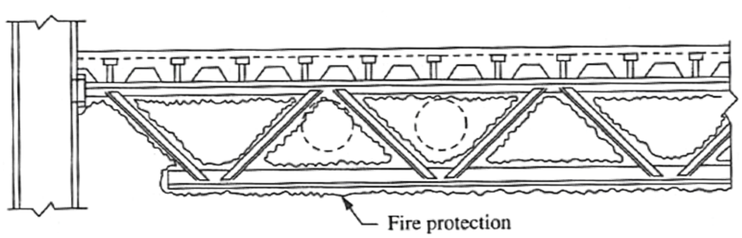


Figure 13 Composite Truss

Stub girder systems can achieve long spans anywhere between 12 and 15 meters. This type of system uses beam stubs that are attached to beams spanning from column to column (Figure 14).

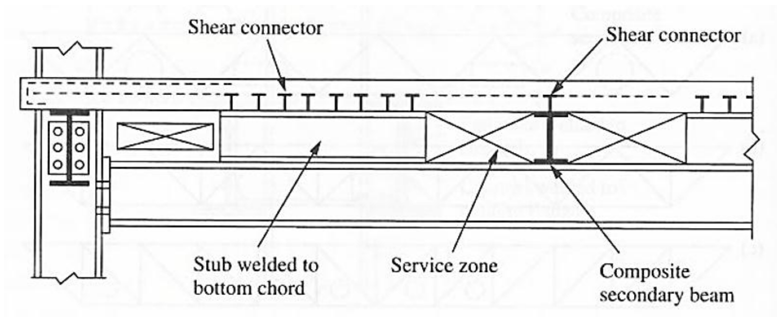


Figure 14 Stub Girder System

The stubs beams contain shear studs that provide composite action with concrete slab. This type of system can greatly reduce story-height and provide space for service ducts to be run in between stub beams. It can also prove to be costly due to temporary formwork required to support concrete floor during the curing process.

Prestressed composite beam systems can create spans that range anywhere from 12 to 25 meters. This system requires a number of steps (Figure 15) for construction which is usually performed off-site. A steel been has to first be precambered. Then the lower flange is encased in reinforced concrete. After the tension chord has been prestressed, shear studs are added to the top flange and the entire beam is encased in concrete. Concrete is fire resistant and thus no additional fire proofing is required for this type of system.

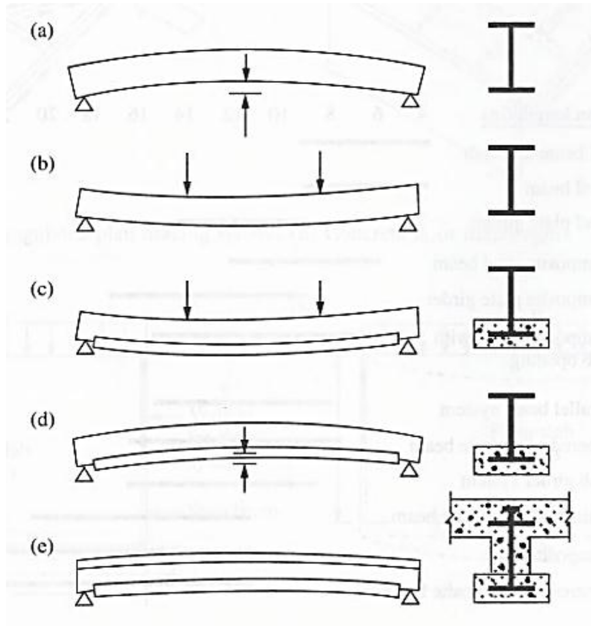
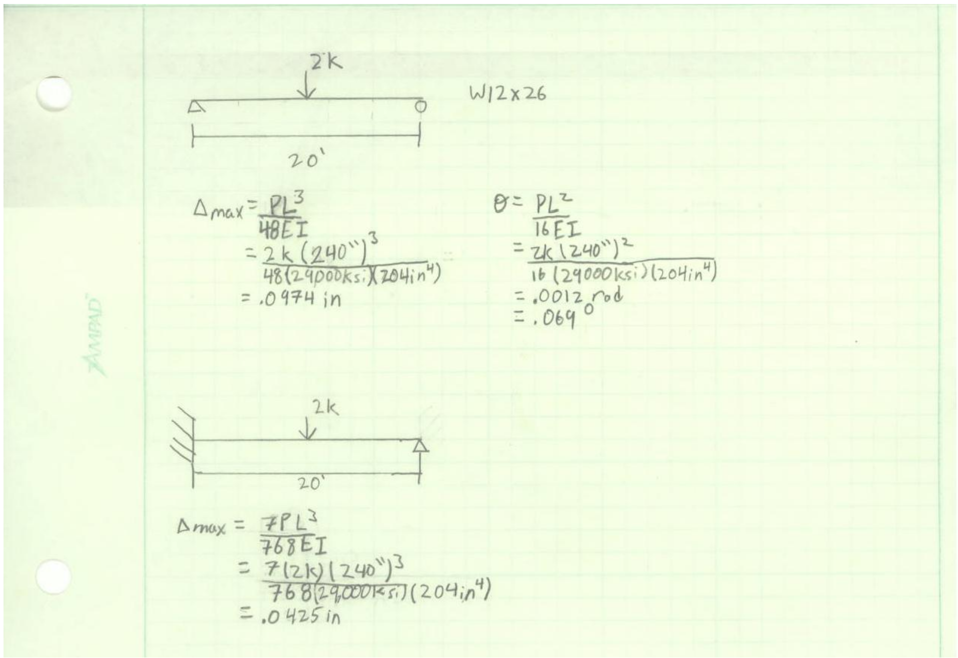


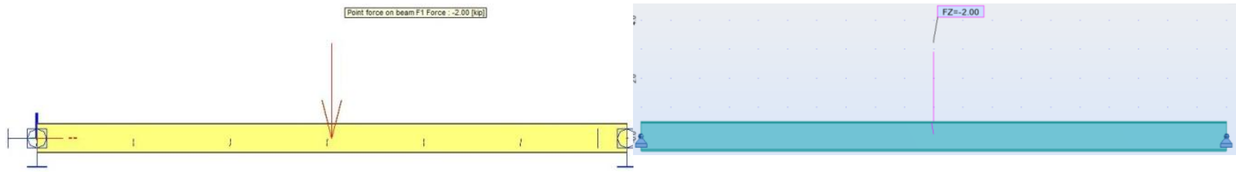
Figure 15 Process of Prestressing Using Precambering Techniques

Appendix B: Software and Hand Calculation Verification

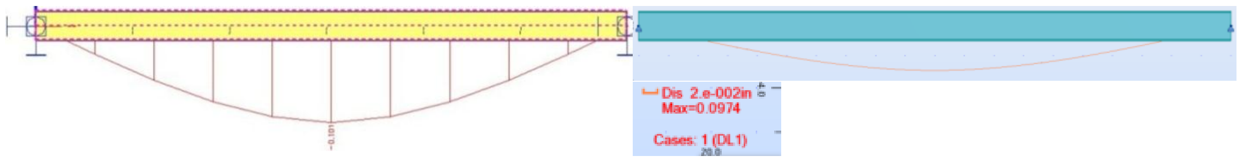
Simple Beam Hand Calculations:



Software Calculations:

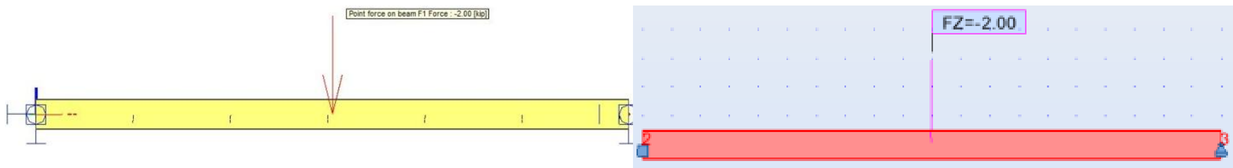


2 kip load is applied to a W12x26 beam. Beam is pinned on both sides.

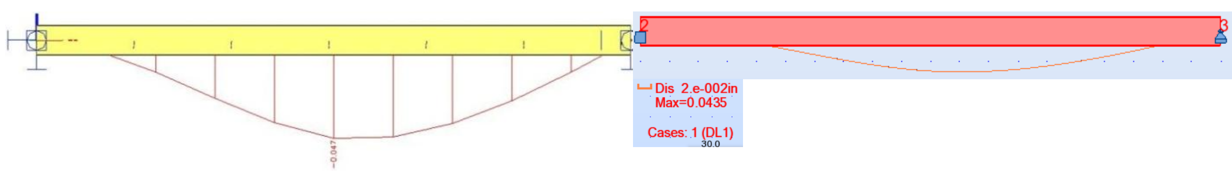


Deflection results:

- *Scia: -0.101in*
- *Robot: -0.0974in*
- *Hand Calculations: -0.0974in*

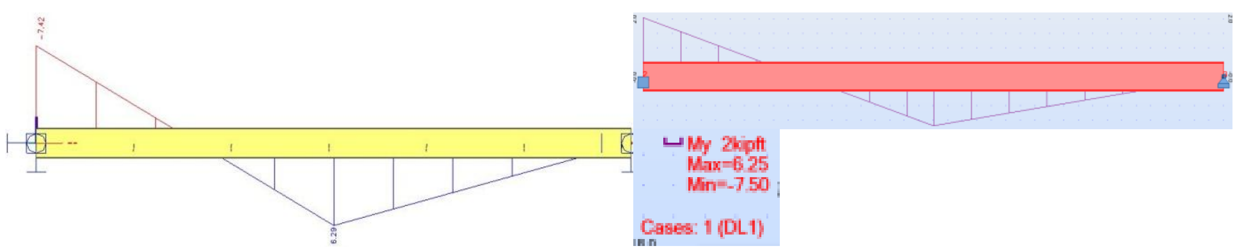


Left side of the beam is a moment connection while the right side of the beam is pinned.



Deflection Results:

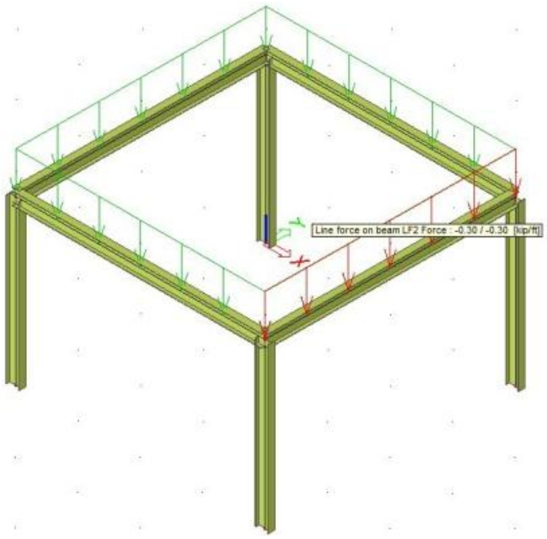
- *Scia: -0.047in*
- *Robot: -0.0435in*
- *Hand Calculations: -0.0425in*

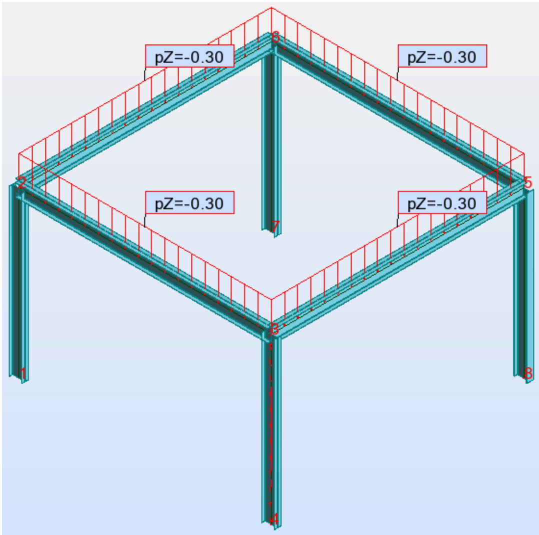


*Above are two moment diagrams for moment-pin connected beam (Units are in kip*ft)*

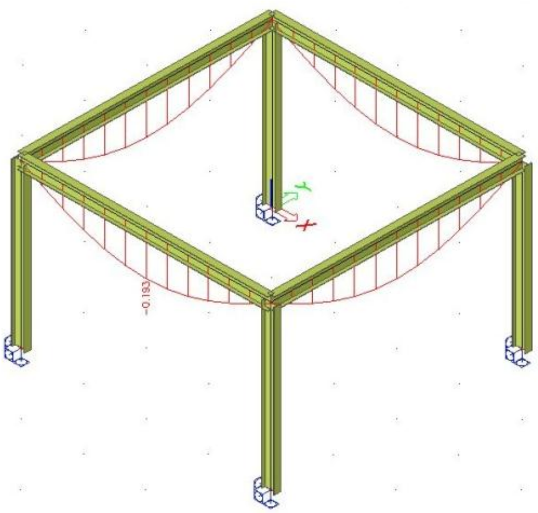
Results:

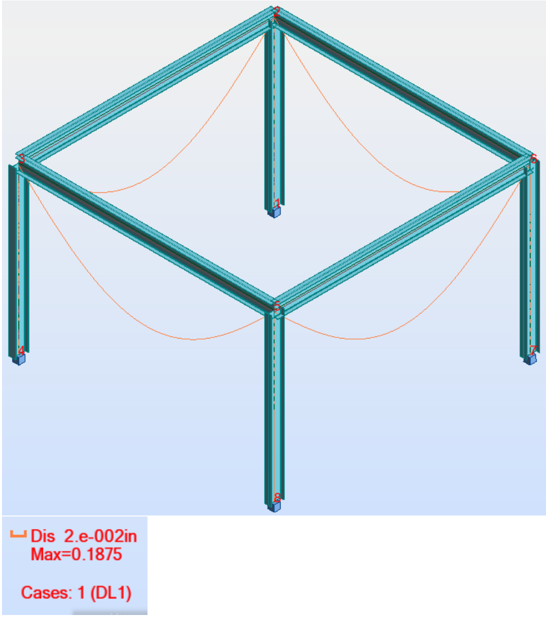
- *Scia:*
  - *Positive Moment: 6.29*
  - *Negative Moment: -7.42*
- *Robot:*
  - *Positive Moment: 6.25*
  - *Negative Moment: -7.50*





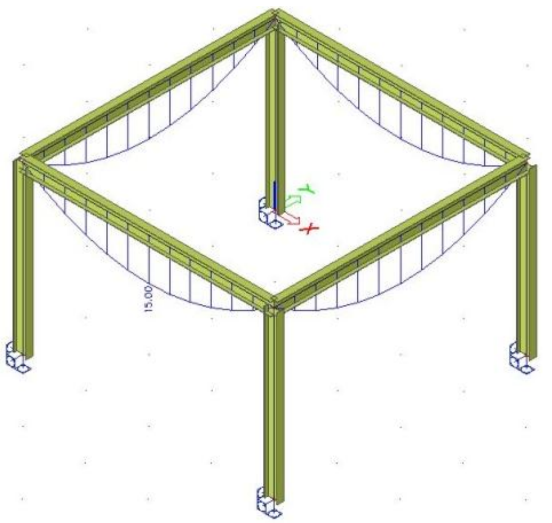
1-story frame comprised of W12x26 columns and beams. Columns are 13ft tall. All beams are 20ft long. 0.3 kip/ft load is distributed along the beams. All members are pin connected.

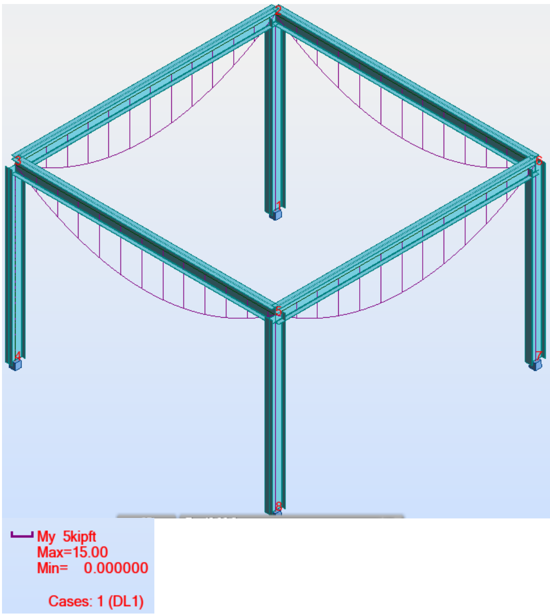




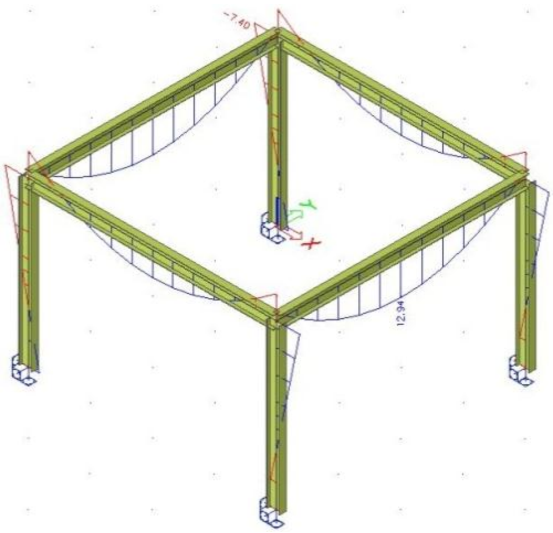
Deflection Results:

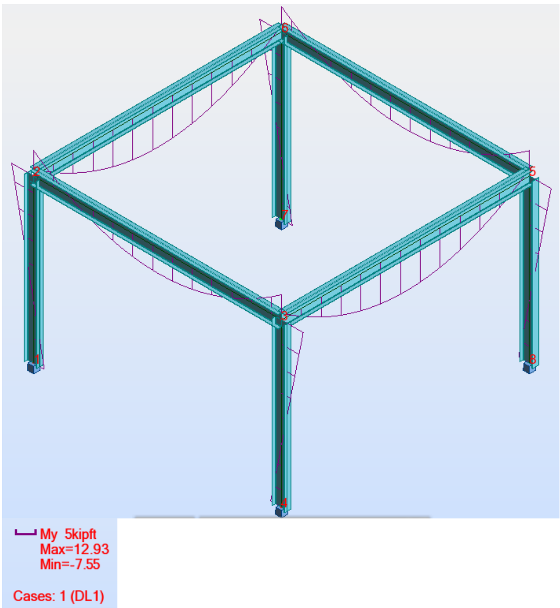
- *Scia: -0.193in*
- *Robot: -0.1875in*





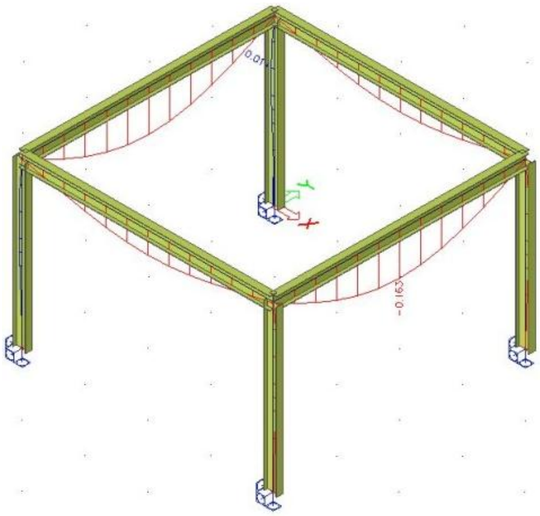
1-story frame comprised of W12x26 columns and beams. Columns are 13ft tall. All beams are 20ft long. 0.3 kip/ft load is distributed along the beams. All members have moment connections.

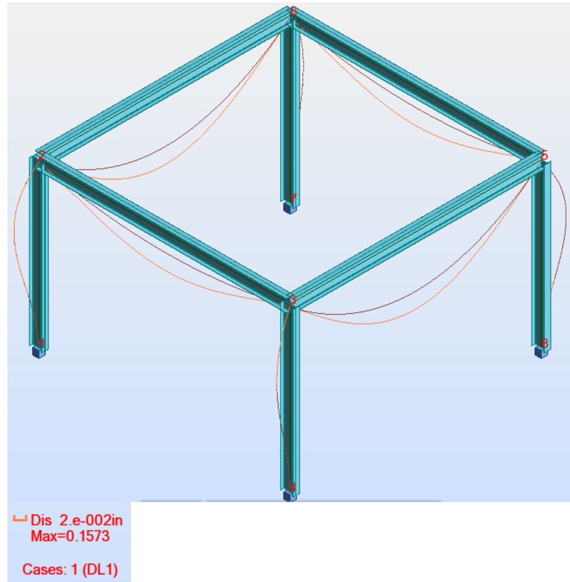




Moment Distribution Results:

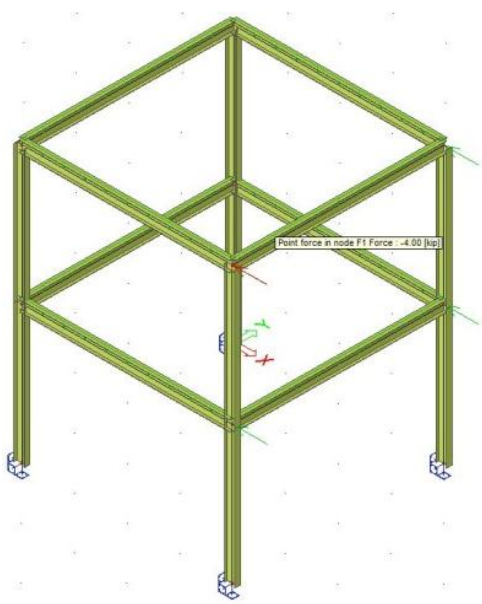
- *Scia: 12.94 kip*ft*
- *Robot: 12.93 kip*ft*

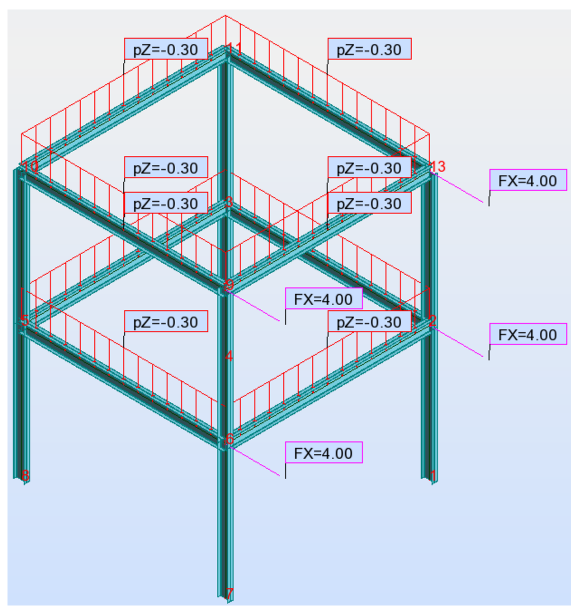




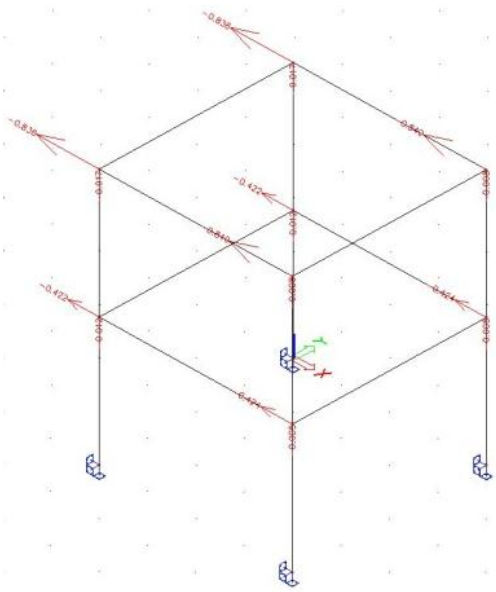
Deflection Results:

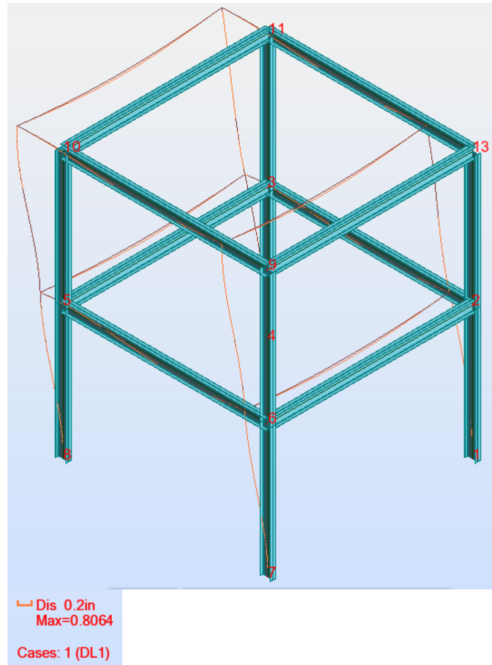
- *Scia: -0.165in*
- *Robot: -0.1573in*





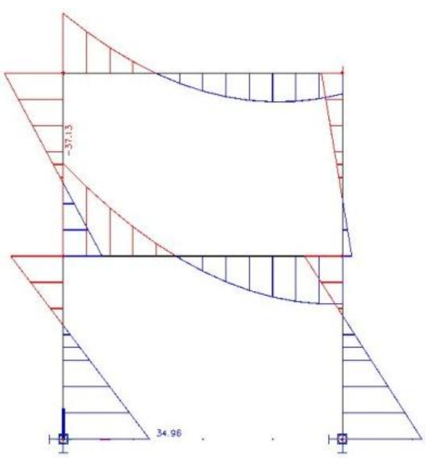
2 Story Frame made up of W12x26 columns and beams. Columns are 13ft tall. Beams are 20ft lon. -0.3k/ft distributed load is applied to all beams. 4kip point load applied to 4 nodes in one direction to represent a wind load.

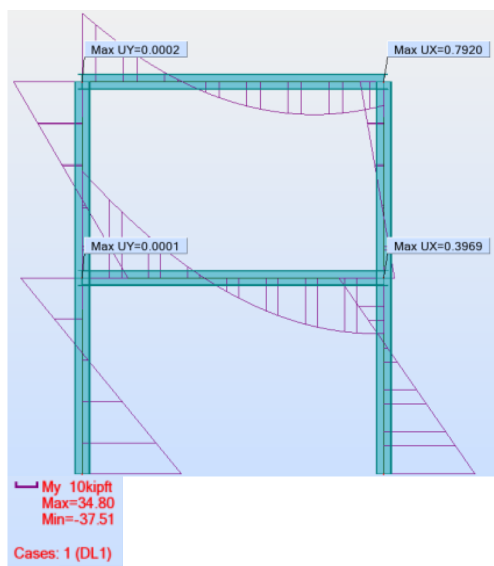




Deflection Results:

- *Scia max nodal displacement is 0.840 in*
- *Robot max nodal displacement is 0.8064 in*





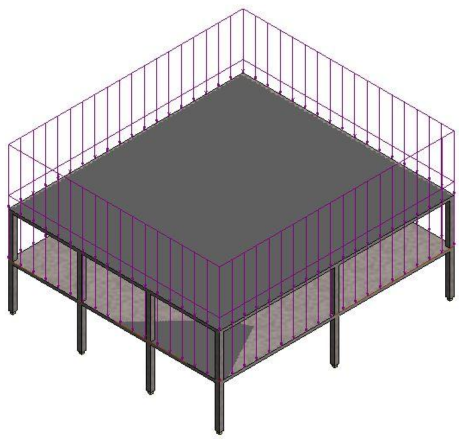
Moment Results are shown above

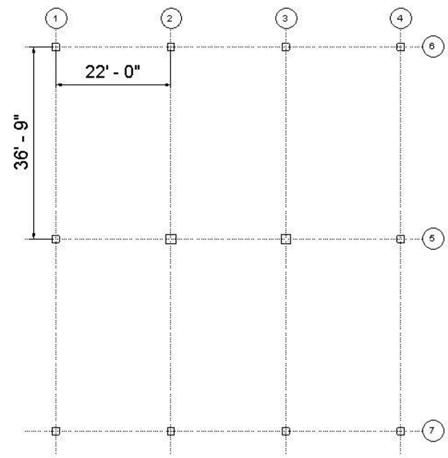
Conclusion:

Both Scia Engineer and Robot Structural Analysis have relatively same results when simply supported beams as well as simple 3D frames are analyzed. Some differences are due to differences in internal moments. This could point to both softwares treating joints with different rigidity. Overall, we are confident that we can use both these softwares to analyze the steel structure and be able to achieve similar results.

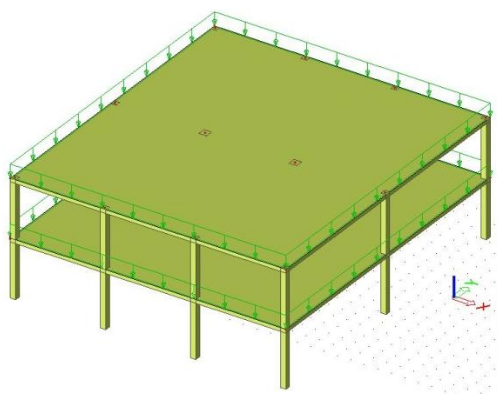
Export from Revit

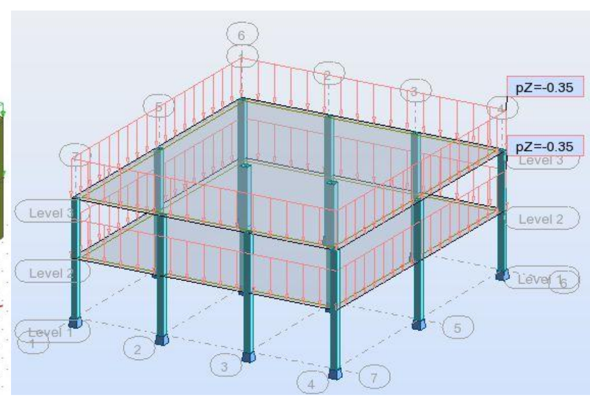
2 story concrete structure. 6 bays on each floor. Exterior columns are 16”x16”. Interior columns are 22”x22”. Story height is 14’. Slab is 10.5”. Dead load applied is 0.353 ksf onto slab. Self-weight of the structure is ignored to simplify the analysis and export. Fixed boundary conditions were added to the bottom of the columns on the first floor. The following is the Revit structure 3D view and plan view.





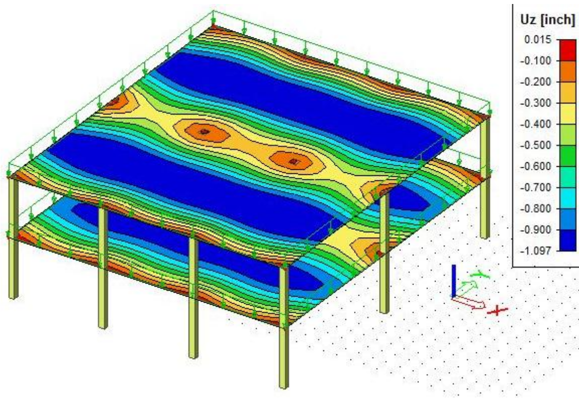
Model exported to Scia (left) and Robot (right)

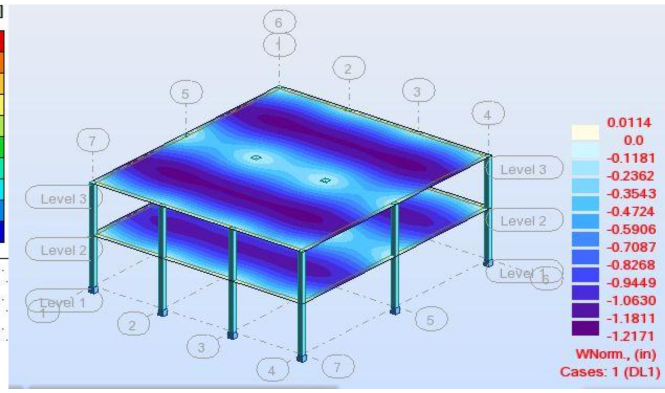




Deflection Results:

- Scia: -1.097 in
- Robot: -1.2171 in





Differences in deflections results can be attributed to differences in material properties in Scia and Robot. This issue is more closely looked at in Material Mapping section of Appendix H.

Appendix C: Floor-to-Floor Ceiling Height Determination

Table 5 Optimized Floor to Floor Height Calculations

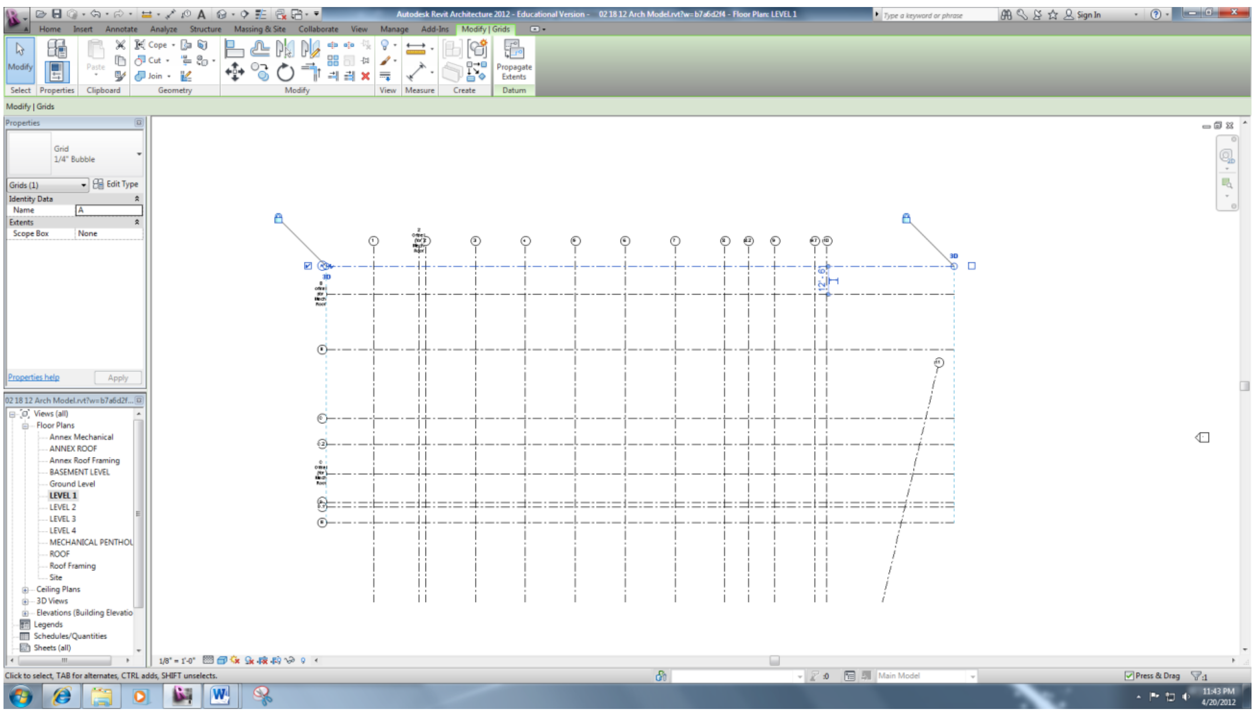
Floor Level	Room Number	AFF (ft)	Ceiling Thickness (in.)	Slab Thickness	Max. HVAC Duct (in.)	HVAC Insulation	Max. Piping (in.)	Piping Insulation (in.)	Space Required	F-F Required
Sub Lvl 1	1	X	X	X	X	2	X	2	X	X
	2	X	X	X	X	2	X	2	X	X
	3	X	X	X	X	2	X	2	X	X
	4	X	X	X	X	2	X	2	X	X
	004A	X	X	X	X	2	X	2	X	X
	5	X	X	X	X	2	X	2	X	X
	6	X	X	X	X	2	X	2	X	X
	006A	X	X	X	X	2	X	2	X	X
	7	X	X	X	X	2	X	2	X	X
	8	X	X	X	X	2	X	2	X	X
	9	X	X	X	X	2	X	2	X	X
	10	8	0.75	0.88	10	2	0.75	2	1.23	
	11	X	X	X	X	2	X	2	X	**X**
	12	X	X	X	X	2	X	2	X	X
Level 01	100	9.5	1.5	0.88	16	2	1	2	1.75	12.25
	100A	10.21	0.5	0.88	4.42	2	0	2	0.70	11.83
	100B	10.21	0.5	0.88	4.42	2	0	2	0.70	11.83
	101	8.5	0.5	0.88	22	4	0.75	2	2.40	11.81
	102	8.5	0.75	0.88	30	4	0	2	3.00	12.44
	103	8.5	0.75	0.88	30	4	0	2	3.00	12.44
	104	Jan. Closet	X	0.88	8	2	X	2	X	X
	105	8.5	0.75	0.88	6	2	0	2	0.83	10.27
	106	8.5	0..75	0.88	8	2	0	2	1.00	
	107	Stairs	X	0.88	X	2	X	2	X	X
	108	8.5	0.75	0.88	38	4	3	2	3.92	13.35
	109	Stairs	X	0.88	X	2	X	2	X	X
	110	X	X	0.88	X	2	X	2	X	X
	113	Annex	Annex	0.88	X	2	X	2	X	X
	111	X	X	0.88	X	2	X	2	X	X
	1200	8.5	0.75	0.88	14	2	2.5	4	1.88	11.31
	1201	9.17	0.75	0.88	8	2	2.5	4	1.38	11.48
	1202	9.17	0.75	0.88	14	2	0	2	1.50	11.61
	1203	9.5	0.75	0.88	14	4	0	2	1.67	12.10
	1204	9.17	0.75	0.88	16	2	2.5	2	1.88	11.98
	1205	9.5	0.75	0.88	14	2	2.5	4	1.88	12.31
	1206	X	X	0.88	X	2	X	2	X	X
	1207	9.5	0.75	0.88	12	2	0	2	1.33	11.77
	1208	9.5	0.75	0.88	12	2	0	2	1.33	11.77
	1209	9.5	0.75	0.88	14	2	2.5	4	1.88	12.31
	1210	9.5	0.75	0.88	14	2	4	4	2.00	12.44
	1211	9.5	0.75	0.88	14	2	5	4	2.08	12.52
	1212	9.5	0.75	0.88	14	2	5	4	2.08	12.52
	1213	9.5	0.75	0.88	16	2	5	4	2.25	12.69
	1214	9.5	0.75	0.88	16	2	5	4	2.25	12.69
	1215	9.5	0.75	0.88	14	2	1.5	4	1.79	12.23
	1216	9.5	0.75	0.88	12	2	0	2	1.33	11.77
	1217	9.5	0.75	0.88	16	2	6.5	8	2.71	13.15
	1218	9.5	0.75	0.88	24	4	5	4	3.08	13.52
	1219	OTS	0.75	0.88	38	4	X	2	X	X
	1220	9.5	0.75	0.88	10	2	12	4	2.33	12.77
	1221	9.5	0.75	0.88	10	2	12	4	2.33	12.77
	1222	OTS	OTS	0.88	8	2	12	4	2.17	
	1223	9.5	0.75	0.88	18	4	12	2	3.00	13.44
	1224	9.17	0.75	0.88	12	2	2.5	2	1.54	11.65
	1225	9.58	0.75	0.88	16	2	0	2	1.67	12.19
	1226	10	0.75	0.88	14	2	0	2	1.50	12.44
	1227	Annex	Annex	0.88	X	2	X	2	X	X
	1230	9.5	0.75	0.88	12	2	0	2	1.33	11.77
	1231	X	X	0.88	X	2	X	2	X	X

	1232	X	X	0.88	X	2	X	2	X	X
	1300	9.17	0.75	0.88	20	2	2.5	4	2.38	12.48
	1301	9	0.5	0.88	24	2	0	2	2.33	12.25
	1301A	9	0.5	0.88	16	2	0	2	1.67	11.58
	1302	9.5	0.75	0.88	10	2	0	2	1.17	11.60
	1303	9.5	0.75	0.88	12	2	0	2	1.33	11.77
	1304	9.5	0.75	0.88	20	2	1.5	4	2.29	12.73
	1305	9.5	0.75	0.88	12	2	2	4	1.67	12.10
	1306	9.5	0.75	0.88	12	2	2	4	1.67	12.10
	1307	9.5	0.75	0.88	8	2	X	2	X	X
	1308	9.5	0.75	0.88	12	2	2.5	2	1.54	11.98
	1309	9.5	0.75	0.88	8	2	0	2	1.00	11.44
	1310	9.5	0.75	0.88	8	2	0	2	1.00	11.44
	1311	9.5	0.75	0.88	8	2	0	2	1.00	11.44
	1312	9.5	0.75	0.88	12	2	2.5	4	1.71	12.15
	1313	9.5	0.75	0.88	8	2	0	2	1.00	11.44
	1314	9.5	0.75	0.88	8	2	0	2	1.00	11.44
	1315	9.5	0.75	0.88	12	2	0	2	1.33	11.77
	1316	9.5	0.75	0.88	12	2	3	4	1.75	12.19
	1317	9.5	0.75	0.88	12	2	3	4	1.75	12.19
	1318	9.5	0.75	0.88	12	2	0	2	1.33	11.77
	1319	9.5	0.75	0.88	8	2	3	4	1.42	11.85
	1320	9.5	0.75	0.88	8	2	0	2	1.00	11.44
	1321	9.5	0.75	0.88	8	2	0	2	1.00	11.44
	1322	9.5	0.75	0.88	X	2	0	2	X	X
	1323	9.5	0.5	0.88	6	2	0	2	0.83	11.25
	1324	9.5	0.75	0.88	10	2	4	4	1.67	12.10
	1325	9.5	0.75	0.88	8	2	4	2	1.33	11.77
	1326	9	0.5	0.88	12	2	3	2	1.58	11.50
	1327	9	0.5	0.88	8	2	0	2	1.00	10.92
	1328	9.5	0.75	0.88	8	2	0	2	1.00	11.44
	1329	9.5	0.75	0.88	8	2	0	2	1.00	11.44
	1330	9.17	0.75	0.88	16	2	0	2	1.67	11.77
	1331	9.5	0.75	0.88	8	2	0	2	1.00	11.44
	1332	9.5	0.75	0.88	8	2	0	2	1.00	11.44
	1333	9	0.5	0.88	10	2	2.5	4	1.54	11.46
	1334	9.5	0.75	0.88	10	2	0	2	1.17	11.60
	1335	9.5	0.75	0.88	8	2	0	2	1.00	11.44
	1336	9.5	0.75	0.88	10	2	0	2	1.17	11.60
	1337	9.5	0.75	0.88	10	2	0	2	1.17	11.60
	1338	9.5	0.75	0.88	10	2	2.5	4	1.54	11.98
	1339	9	0.5	0.88	20	2	2.5	2	2.21	12.13
Level 02	201	8.5	0.5	0.88	12	2	0	2	1.33	10.75
	202	8.5	0.75	0.88	34	4	0	2	3.33	12.77
	203	8.5	0.75	0.88	34	4	0	2	3.33	12.77
	204	X	X	0.88	8	2	X	2	X	X
	205	8.5	0.75	0.88	6	2	0	2	0.83	10.27
	206	8.5	0.75	0.88	8	2	0	2	1.00	10.44
	207	X	X	0.88	X	2	X	2	X	X
	208	8.5	0.75	0.88	22	2	5	4	2.75	12.19
	209	X	X	0.88	X	2	X	2	X	X
	2400	8.6	0.5	0.88	12	2	1	4	1.58	11.10
	2401	9	0.75	0.88	22	4	0	2	2.33	12.27
	2402	9.5	0.75	0.88	12	2	1.5	4	1.63	12.06
	2403	9.5	0.75	0.88	10	2	1.5	4	1.46	11.90
	2404	9	0.75	0.88	10	2	0	2	1.17	11.10
	2405	9.5	0.75	0.88	12	2	0	2	1.33	11.77
	2406	9.5	0.75	0.88	16	2	0	2	1.67	12.10
	2407	9	0.75	0.88	14	2	2	4	1.83	11.77
	2408	X	0.75	0.88	6	2	X	2	X	X
	2409	X	0.75	0.88	6	2	X	2	X	X
	2410	9.5	0.75	0.88	18	4	1.5	4	2.29	12.73
	2411	9.5	0.75	0.88	18	2	8.5	6	2.88	13.31
	2412	9.5	0.75	0.88	16	2	3	6	2.25	12.69
	2413	9.5	0.75	0.88	16	2	2	4	2.00	12.44
	2414	9.5	0.75	0.88	16	4	2	4	2.17	12.60
	2415	9.5	0.75	0.88	24	2	1.5	4	2.63	13.06

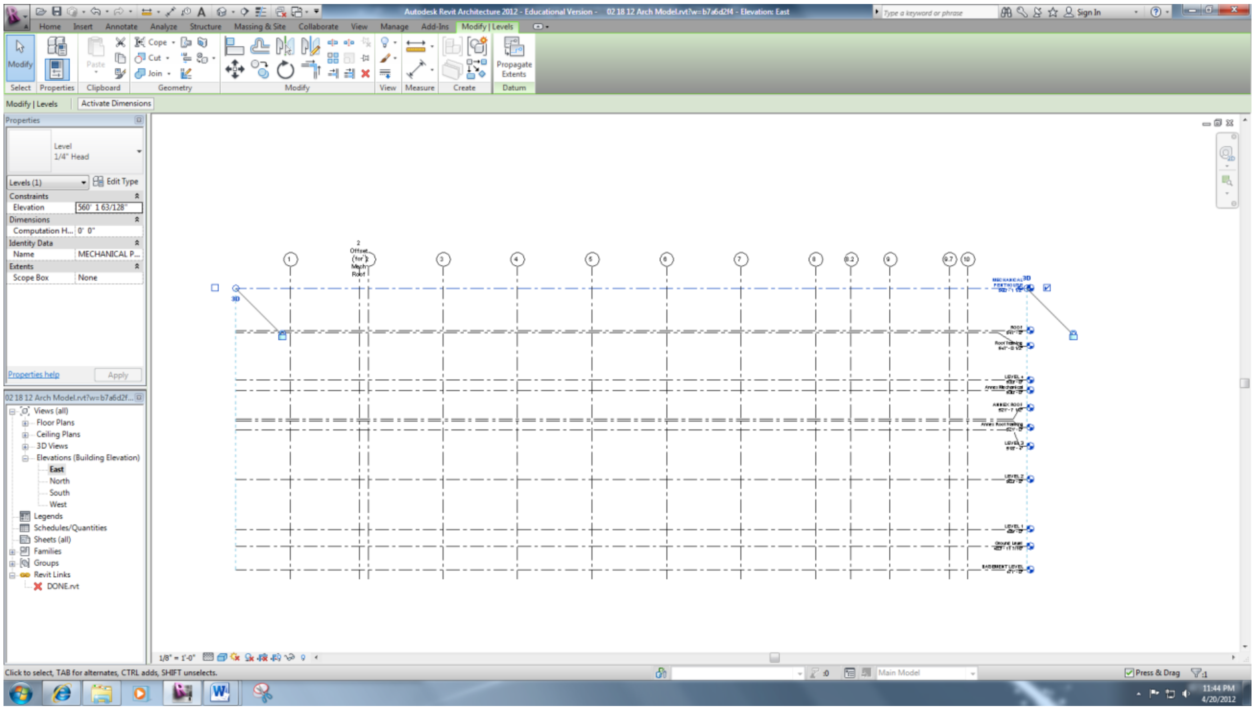
	2415A	X	0.75	0.88	22	2	5	8	3.08	X	
	2416	X	0.75	0.88	6	2	9	8	2.08	X	
	2417	9.5	0.75	0.88	18	2	0	2	1.83	12.27	
	2501	8.5	0.75	0.88	28	4	2	4	3.17	12.60	
	2501A	9	0.75	0.88	18	2	0	2	1.83	11.77	
	2501B	9.5	0.75	0.88	8	2	0	2	1.00	11.44	
	2501C	9.5	0.75	0.88	10	2	1.5	4	1.46	11.90	
	2501D	8.5	0.75	0.88	10	4	0	2	1.33	10.77	
	2502	9.5	0.75	0.88	18	4	2.5	4	2.38	12.81	
	2502A	9.5	0.75	0.88	8	2	0	2	1.00	11.44	
	2504	9.5	0.75	0.88	8	2	0	2	1.00	11.44	
	2505	9.5	0.75	0.88	6	2	0	2	0.83	11.27	
	2506	9.5	0.75	0.88	6	2	0	2	0.83	11.27	
	2507	9.5	0.75	0.88	6	2	0	2	0.83	11.27	
	2508	9.5	0.75	0.88	32	4	0	0	3.00	13.44	
	2509	9.5	0.75	0.88	6	2	0	2	0.83	11.27	
	2510	9.5	0.75	0.88	6	2	0	2	0.83	11.27	
	2511	9.5	0.75	0.88	6	2	0	2	0.83	11.27	
	2512	9.5	0.75	0.88	6	2	0	2	0.83	11.27	
	2513	9.5	0.75	0.88	6	2	0	2	0.83	11.27	
	2514	9.5	0.75	0.88	6	2	0	2	0.83	11.27	
	2515	9.5	0.75	0.88	6	2	0	2	0.83	11.27	
	2516	9.5	0.75	0.88	8	2	0	2	1.00	11.44	
	2517	9.5	0.75	0.88	10	2	0	2	1.17	11.60	
	2518	X	X	0.88	12	2	X	2	X	X	
	2519	9.5	0.75	0.88	14	2	1	4	1.75	12.19	
	2520	9.5	0.75	0.88	14	2	1	4	1.75	12.19	
	2521	9.5	0.75	0.88	16	2	0	2	1.67	12.10	
	2522	9.5	0.75	0.88	12	2	1	4	1.58	12.02	
	2523	9.5	0.75	0.88	14	2	7.5	6	2.46	12.90	
	2524	9.5	0.75	0.88	12	2	0	2	1.33	11.77	
	2500A	9	0.75	0.88	8	2	1.5	4	1.29	11.23	
	2500B	9	0.75	0.88	10	2	1.5	4	1.46	11.40	
	2500C	9	0.75	0.88	10	2	0	2	1.17	11.10	
	2500D	9	0.75	0.88	10	2	1.5	4	1.46	11.40	
	2500Z	9	0.75	0.88	16	2	2	4	2.00	11.94	
Level 03&04	301	8.5	0.5	0.88	12	2	0	2	1.33	10.75	
	302	8.5	0.75	0.88	30	4	0	2	3.00	12.44	
	303	8.5	0.75	0.88	30	4	0	2	3.00	12.44	
	304	X	X	0.88	X	2	X	2	X	X	
	305	8.5	0.75	0.88	6	2	0	2	0.83	10.27	
	306	8.5	0.75	0.88	6	2	0	2	0.83	10.27	
	307	X	X	0.88	X	2	X	2	X	X	
	308	8.5	0.75	0.88	20	2	6	6	2.83	12.27	
	309	X	X	0.88	X	2	X	2	X	X	
	401	8.5	0.5	0.88	12	2	0	2	1.33	10.75	
	402	8.5	0.75	0.88	30	4	0	2	3.00	12.44	
	403	8.5	0.75	0.88	30	4	0	2	3.00	12.44	
	404	X	X	0.88	X	2	X	2	X	X	
	405	8.5	0.75	0.88	6	2	0	2	0.83	10.27	
	406	8.5	0.75	0.88	6	2	0	2	0.83	10.27	
	407	X	X	0.88	X	2	X	2	X	X	
	408	8.5	0.75	0.88	20	2	10	2	2.83	12.27	
	409	X	X	X	X	2	X	2	X	X	
									Min Story Height	13.52	13' 7"

Appendix D: Architectural Model Development

In the development of the architectural model great caution and care was taken to implement the key architectural elements that included reference lines, the exterior façade, and interior components. The gridlines were created according to column locations and then pinned to prevent accidental shifting. Certain additional gridlines were created for key components of the architectural and structural model.

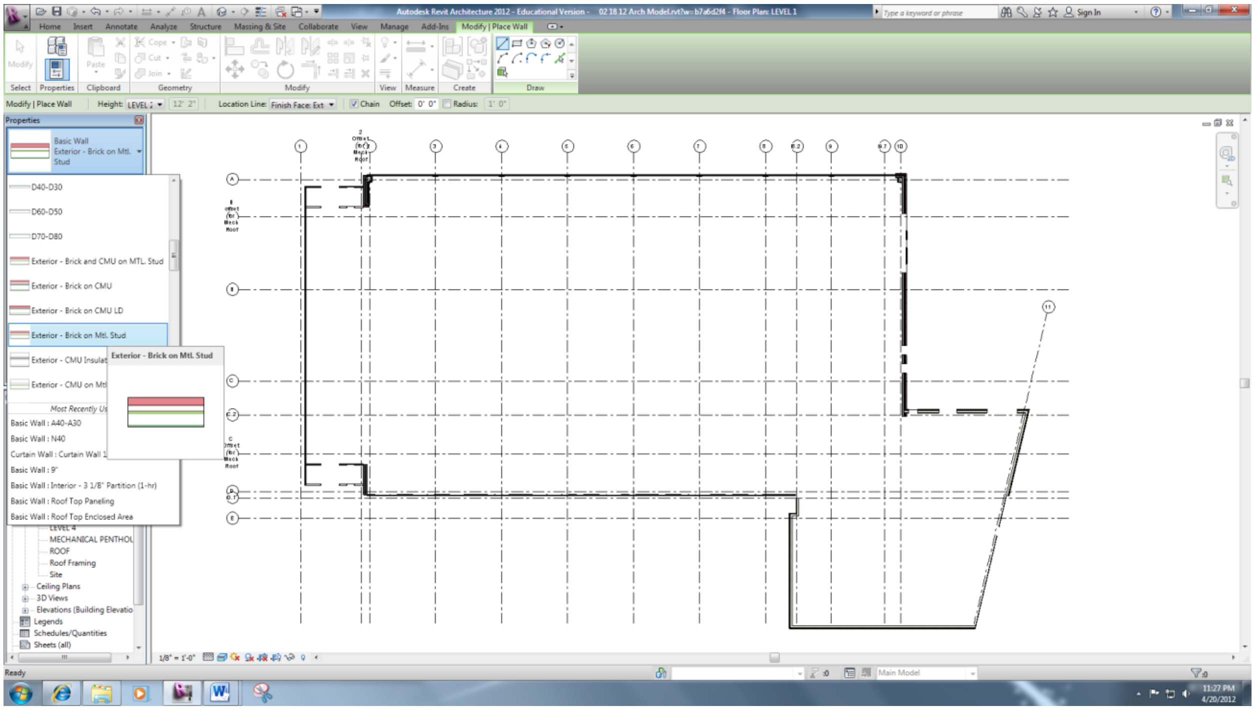


Twelve elevation levels were then created and pinned according to the finish elevations of each story. The architectural plan elevations were only given for the finish floor levels but additional elevations were placed in the structural model for the framing of each floor and the roof to eliminate the need of offsetting structural floor elements beneath the floor slabs. The elevations were also pinned to prevent accidental shifting.

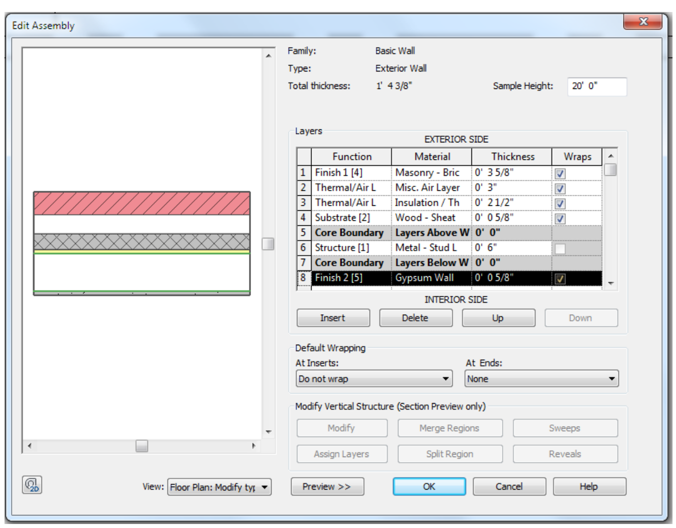


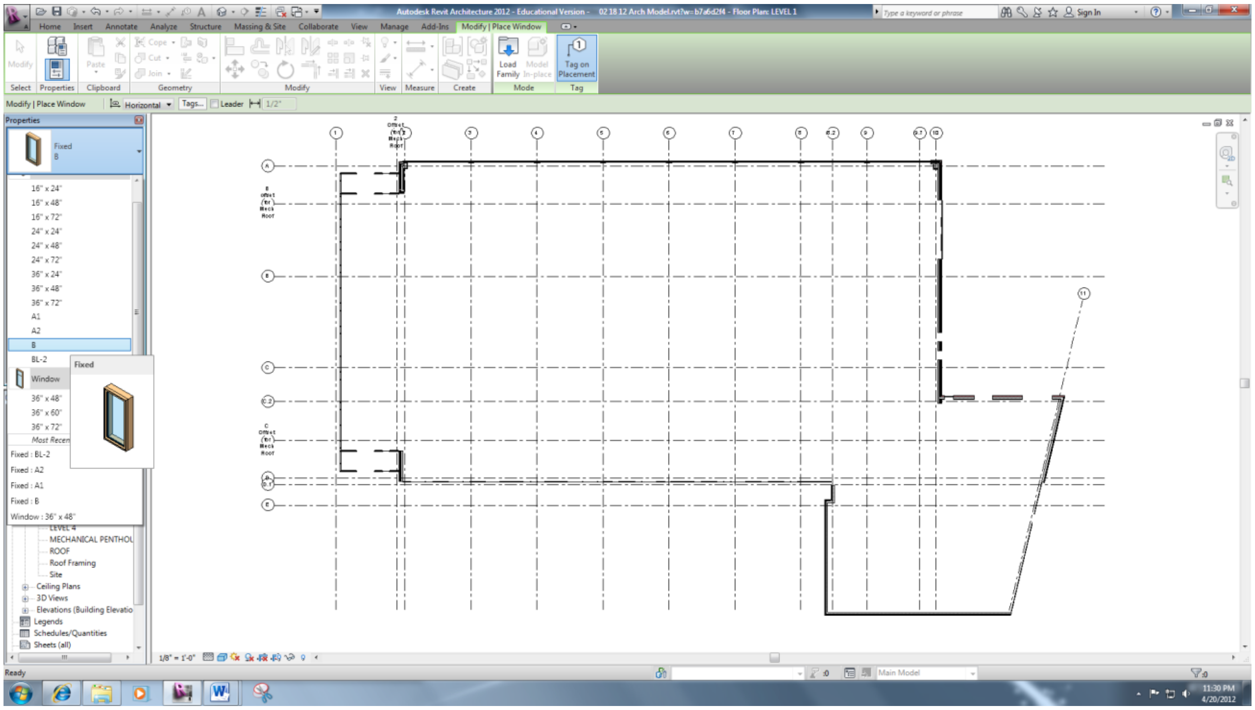
Exterior façade Modeling

The exterior façade were the next elements of focus and inputted in the model. The exterior comprised of exterior brick wall on metal studs, curtain walls, and windows. A modified family was created for the brick wall on metal studs to match the walls per the specifications. In the following figure, the materials and their respective thickness are shown for the exterior brick wall on metal studs.



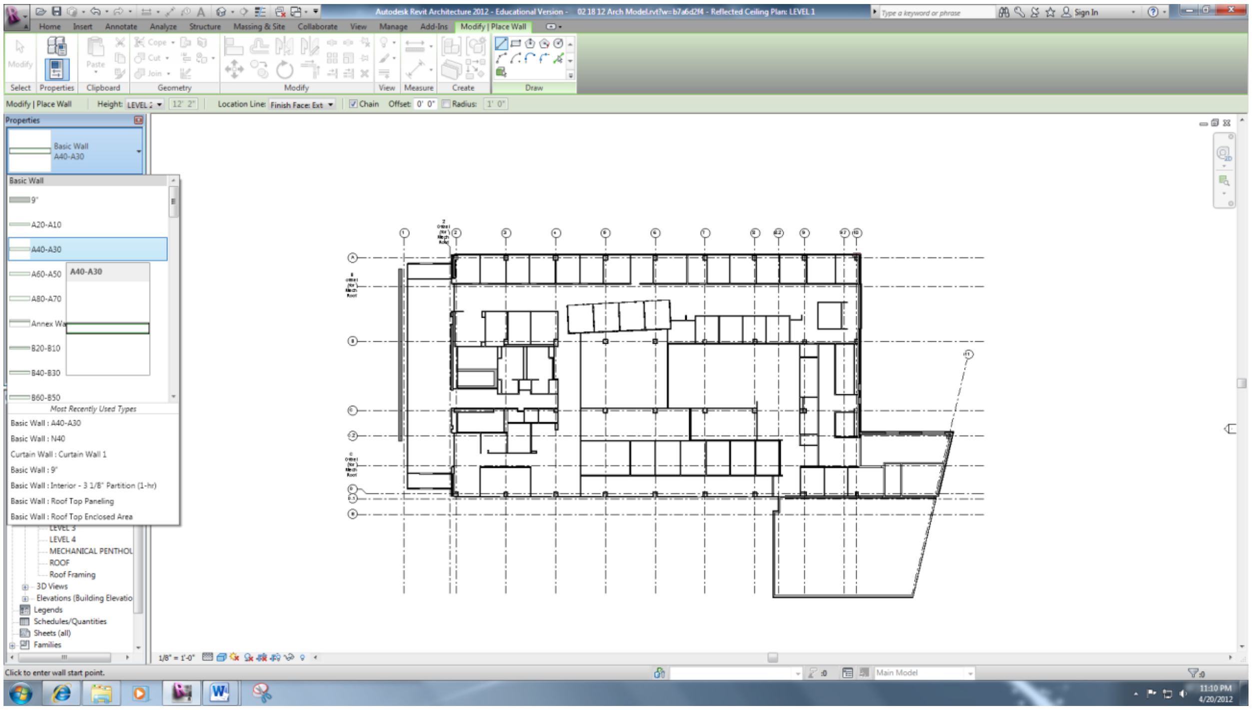
Once the column lines were established a new family was created for the exterior walls according to the specifications. The exterior walls were then placed along the building perimeter according to the finish face exterior. The architectural wraps for columns were also taken into account when modeling the spacing for the exterior façade. Once the basic wall type used was created the curtain walls were modeled. A single family type was created for the curtain wall while mullions were placed manually according to the drawings.



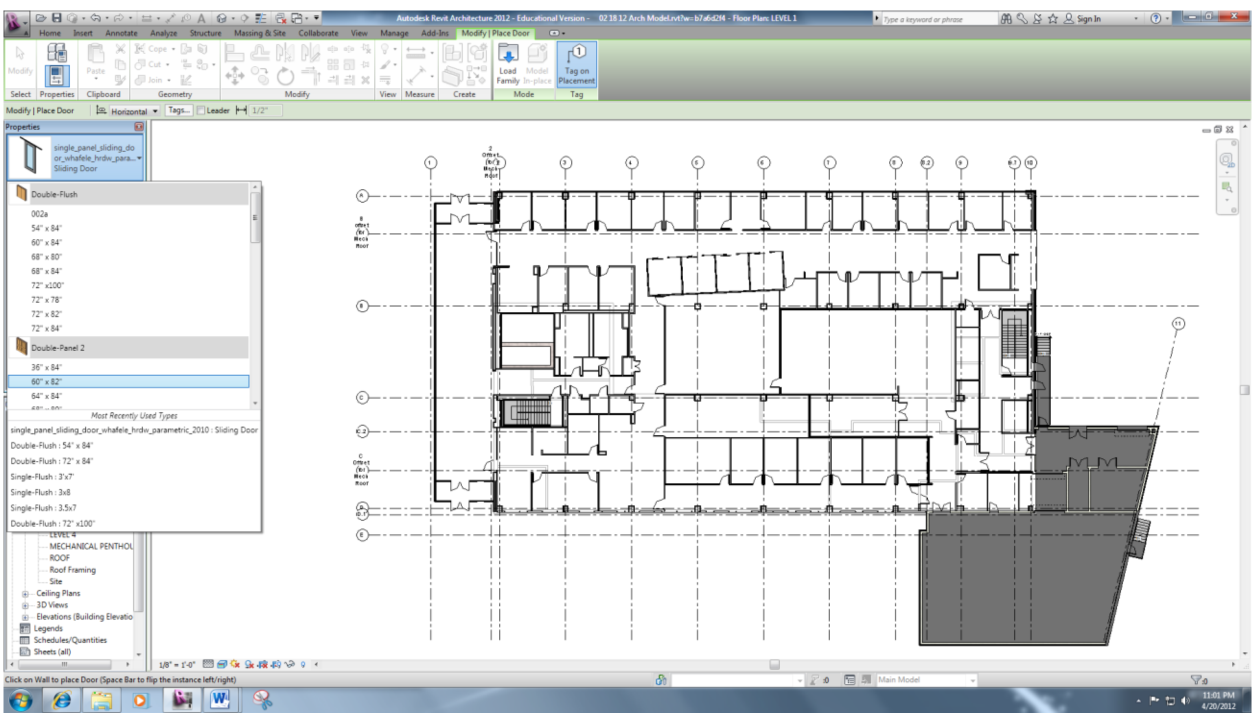


Interior Modeling

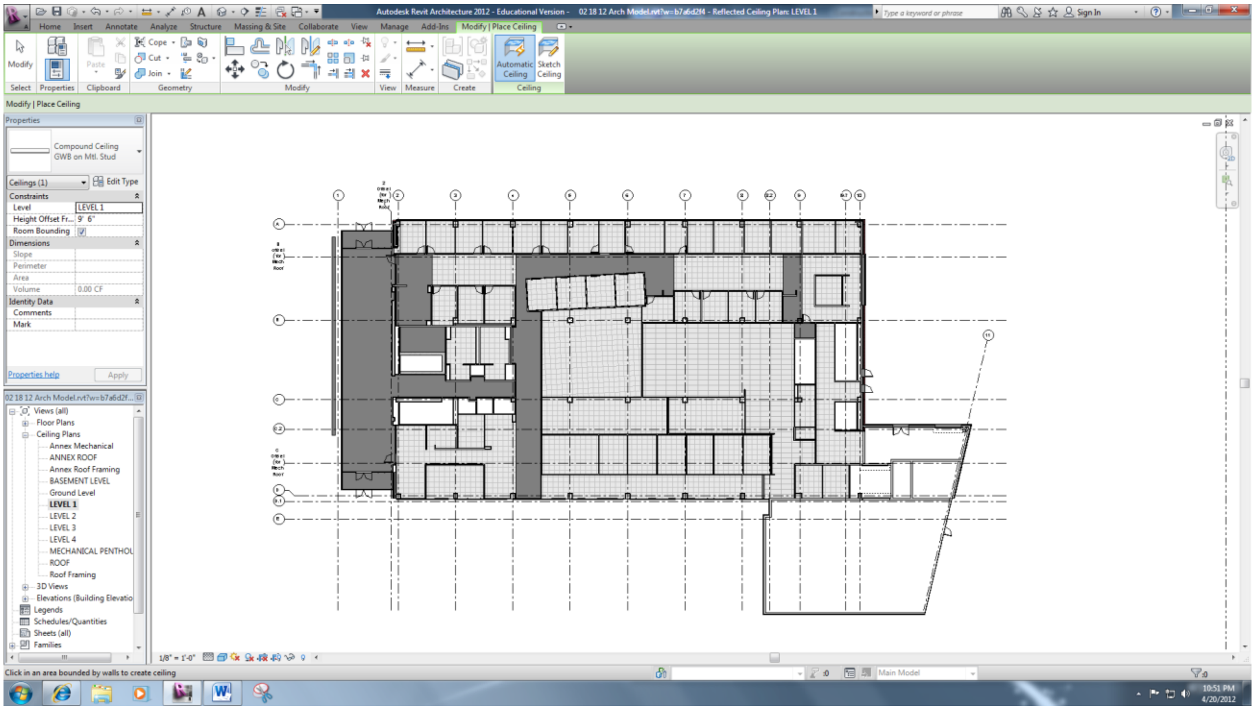
For the interior the elements inputted were the ceilings, doors, and partition walls as well as basic light fixtures for the purposes of an Architectural walkthrough. Throughout the building four types acoustic tiles were specified along with a metal stud with gypsum wall board. The rooms were modeled first to allow for simplified ceiling modeling.



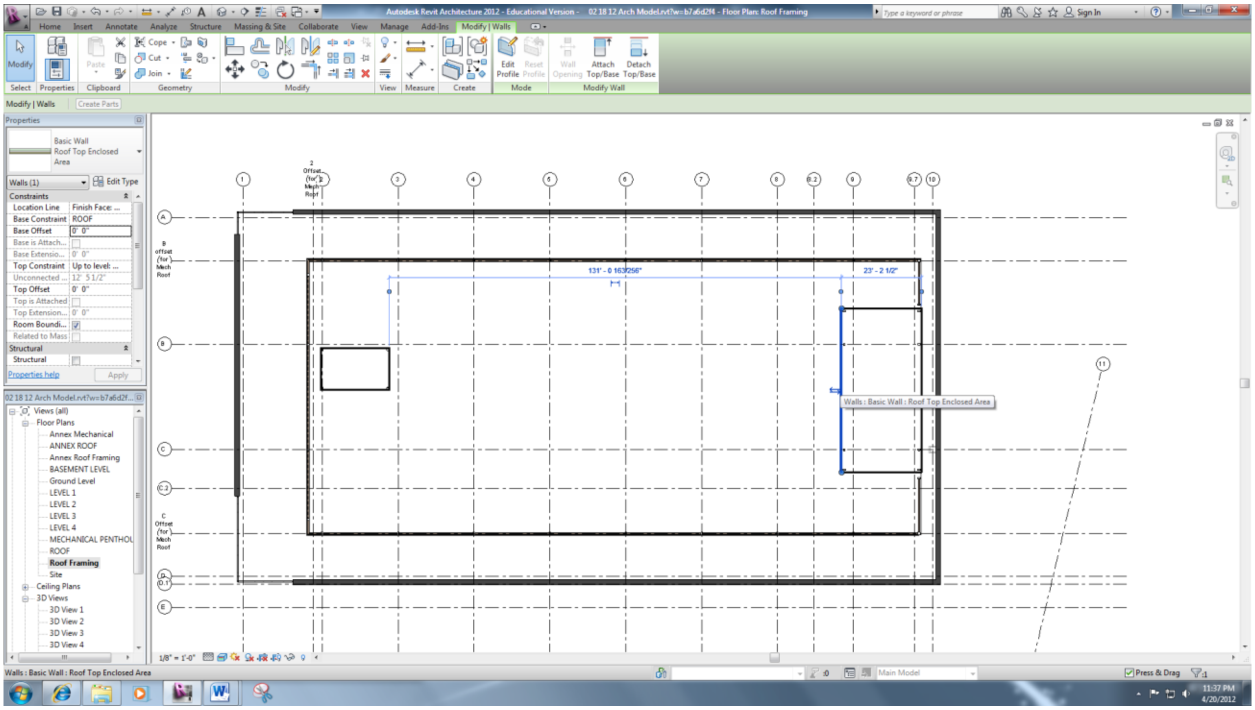
Once the rooms were completed families for the doors were created according to the door schedule provided. Doors were placed according to type and not room to avoid excessive switching between family types.



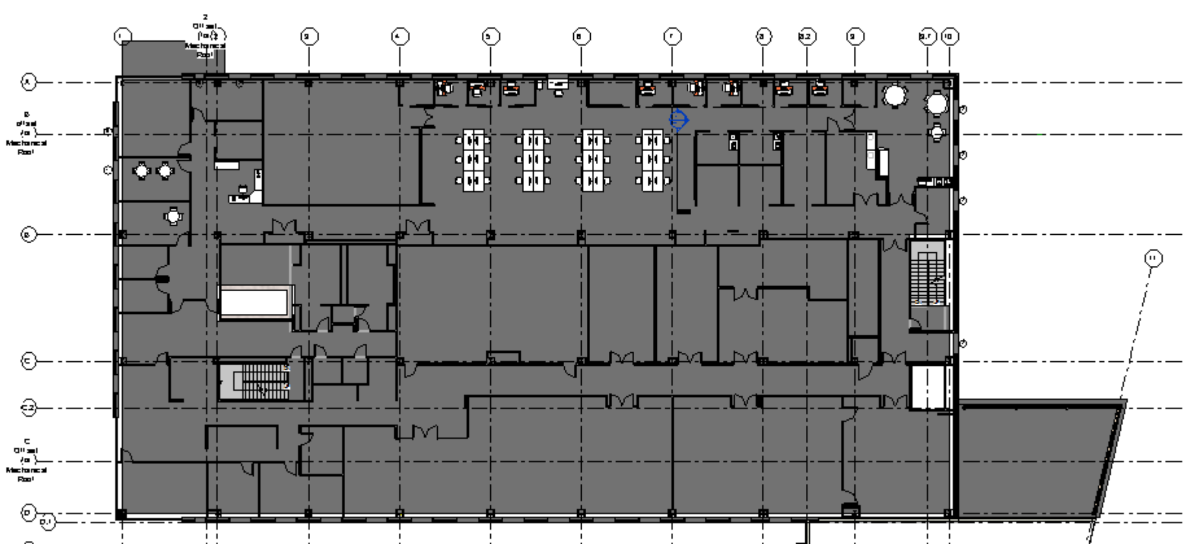
Once the rooms were finalized a reflected ceiling plan was created. Families for each of the four types of acoustical tiles specified were created. Ceilings were modeled according to room boundaries for rooms and manual sketch tool for the hallways. Ceiling heights were determined according to requirements for the floor to ceiling heights provided in the plans.



Since the annex was not part of the structural analysis certain portions of the model were created within the architectural model as opposed to the structural model, namely the roof. The roof was modeled using the manual sketch tool. There is also a roof screen framing which is constructed out of HSS sections. It was modeled in the Architectural model because it was not going to be analyzed. Additionally a mechanical penthouse as well as a staircase enclosure were placed on the roof.



Once the model was completed certain custom families were downloaded to furnish portions of the building for the purposes of a walkthrough. Since furnishings can vary widely the most popular items from Revit City were used. Also because of the level of detail required for furnishing even small portions of the building, only areas used in the walkthrough were furnished.

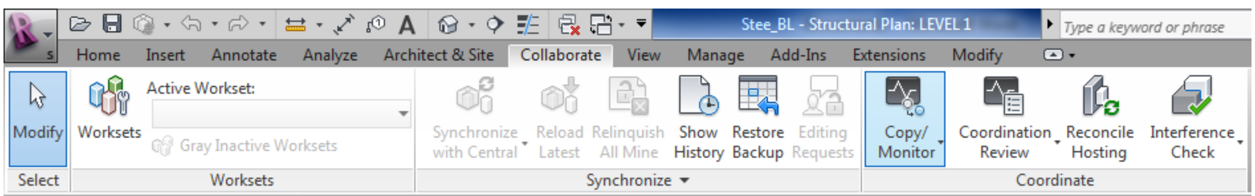


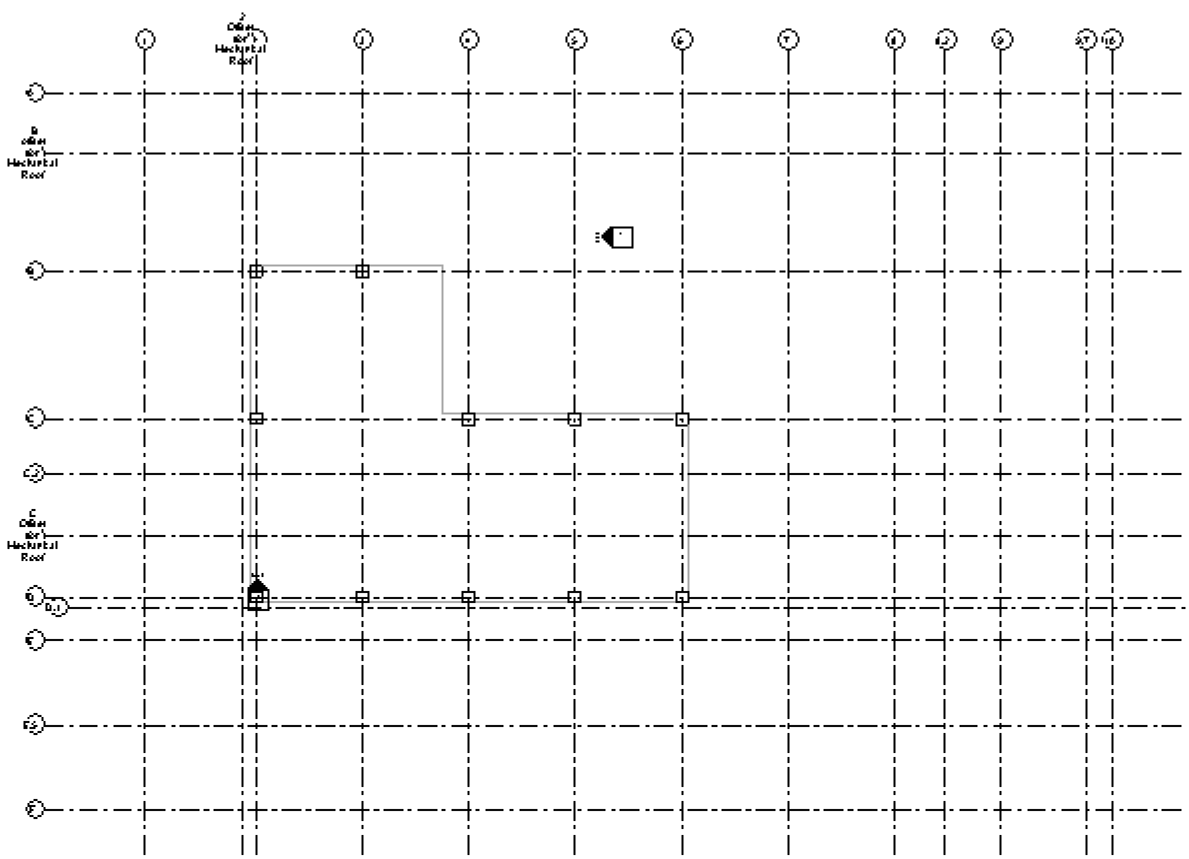
Once the model was finalized all items were pinned to prevent accidental alteration. Basic level sites were placed in the model for rendering and presentation.

Appendix E: Structural Model Development

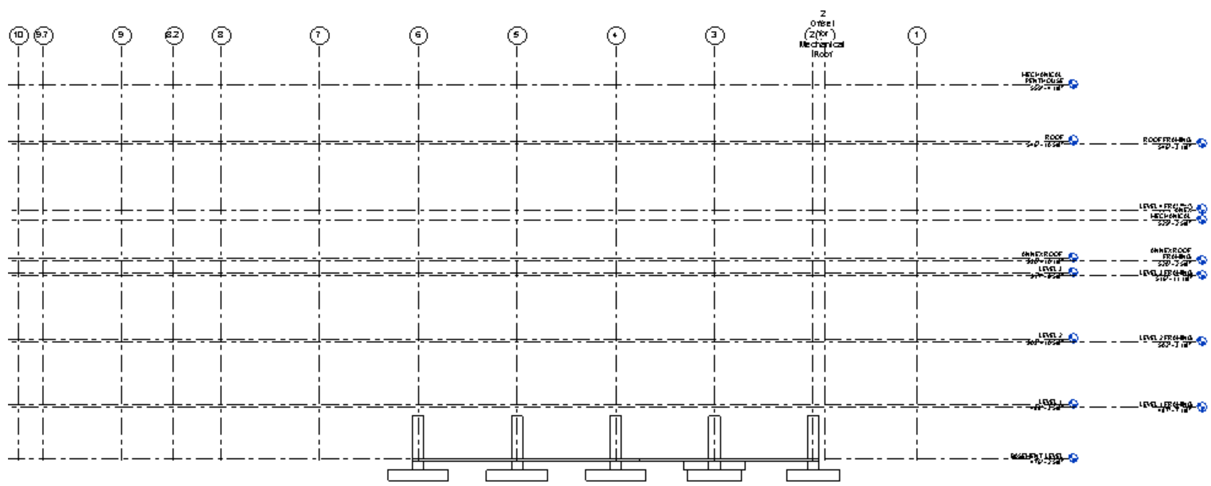
Once the major portions of the architectural model were completed it was linked into a new Revit Structures project. Due to problems which occurred during the initial analysis this section will document the creation of a model which can be fully exported and analyzed. To ensure consistency between multiple types of models everything was linked according to a common origin. The model was created in half story sections and analyzed immediately after creation.

The first step was to copy all gridlines created in the architectural model using the copy/monitor function. These gridlines were pinned immediately to ensure consistency between the two types of models. These gridlines would eventually determine the location of the columns so it was important that the architectural model gridline placement was accurate and final.

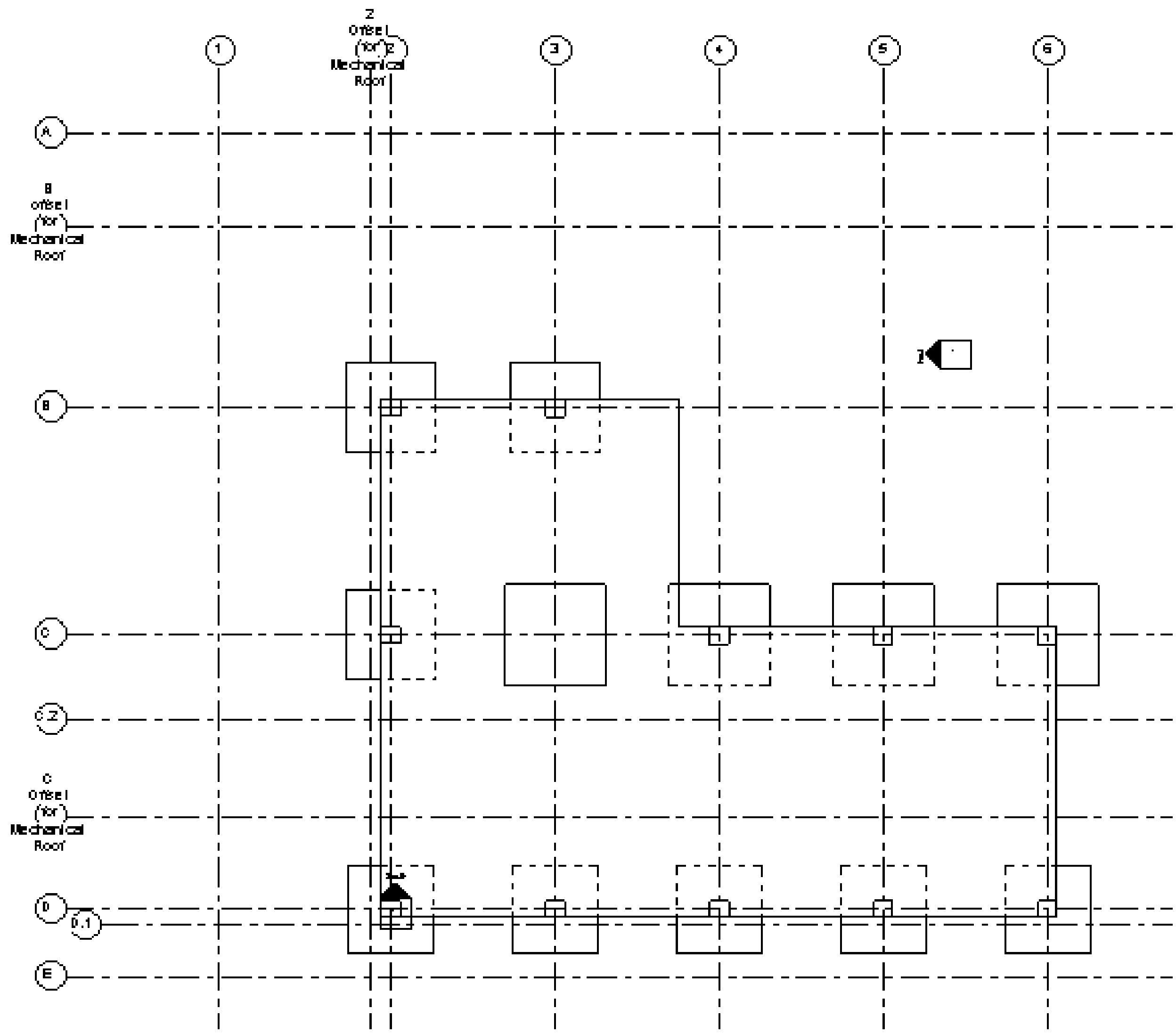




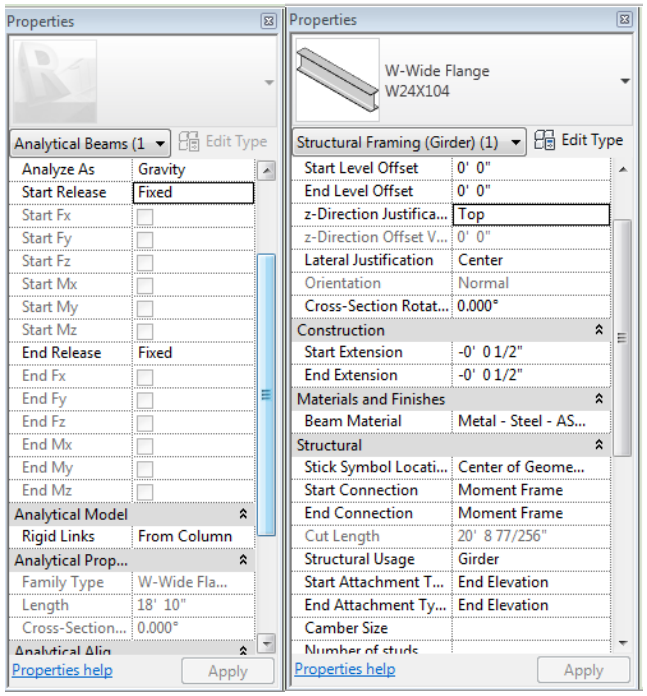
Once the gridlines were copied the process was repeated for the elevations created in the architectural model. These leves were then dupilcated and then offset by the depth of the slab to avoid offsetting each element of the framing plan. Plan views were then generated for the framing plan elevations while the finish floor plans did not have associated plan views. This allowed for a consolidated number of views while ensuring consistency between the two types of models.



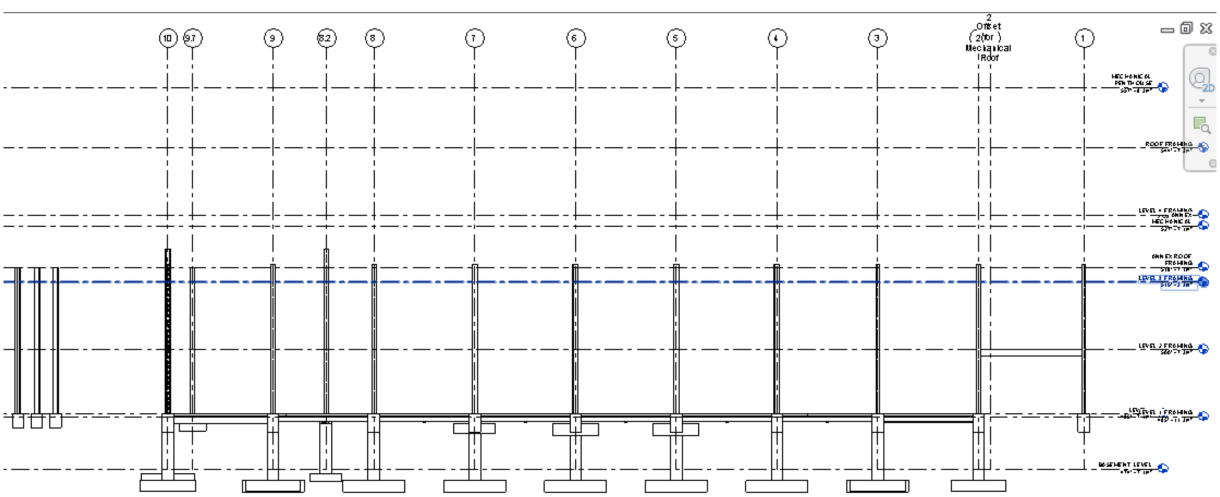
Creation of structural elements began with the placement of spread footings or foundation mats. These did not have a separate view created for them despite being offset from the typical framing elevation due to the relatively small quantity. Should there be an excessive number of footings it may be advantageous to create a separate view since the columns will also end on the footings. Once the foundations were placed the associated columns were placed in the views. Revit handles column placement differently than typical elements. A column placed in a view is actually the supporting the level as opposed to the placed. This means the basement columns were placed in the Level 1 View. Half of the slab for the level was placed along with any loads which would be applied after which the building was exported to be analyzed.



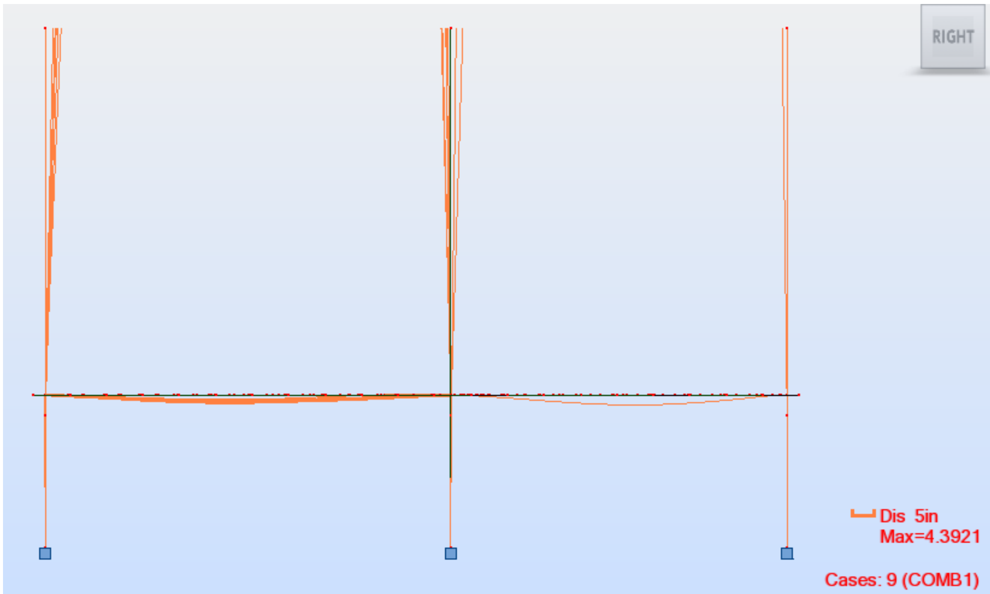
In the case of a structural steel building the columns were modeled according to when they were necessary since they often span multiple stories. The steel members supporting the floors were then input according to the specifications. It is important that the members also contain the proper connection type when modeled to ensure proper analysis as well as documentation. This means that the connections will have to be applied to the analytical model as well as the physical model. Applying member end connections after the entire section has been placed will allow for multiple beams and connection types to be selected.



Shear studs were input after the creation of half a floor to avoid the need to alter numerous elements of each beam upon placement. Any openings in the slab should be modeled as single openings, mostly due to the limitations of Robot Structural Analysis which cannot detect shafts at the moment. Once half the floor was created the building was again exported into the proper analysis program.



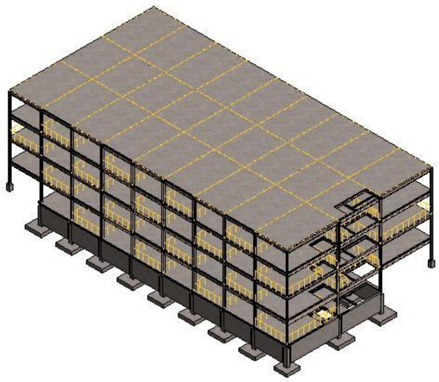
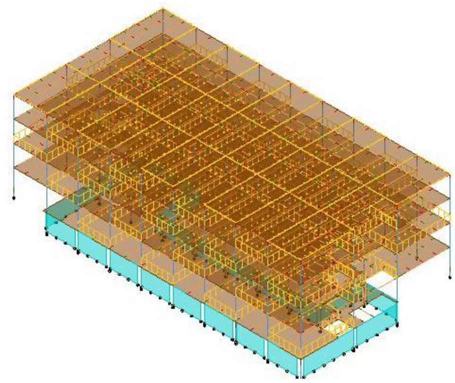
In some cases the columns may be shown to fail due to the lack of bracing which would normally be provided by the additional floors. There are a number of methods to counter this, either by adding beams temporarily as bracing, by shortening the column for the duration of the analysis or any other methods which would provide adequate stiffness to flexural members. Any steps taken should be undone upon completion of the analysis. A concrete system can be modeled the same way with the exception of the columns which should be added floor by floor for proper analysis.



The purpose of analyzing the half story sections is not to verify the structural integrity of the entire sections but rather to ensure that proper modeling techniques are being used. While structural instabilities may arise during the process a majority of them will be the result of the building being only partially modeled. Conversely the building passing the built in code checks should not be taken as an indication of structural validity until the entire building has been modeled and loaded with the appropriate cases and combinations.

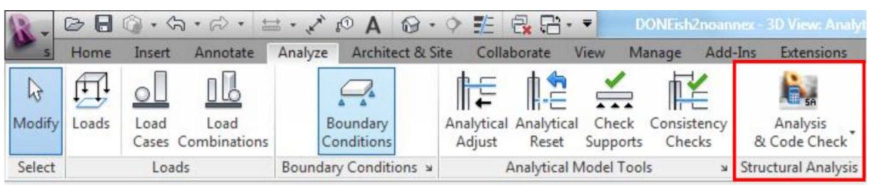
Appendix F: Robot Model Export and Preparation

The following model is exported from Revit Structure:

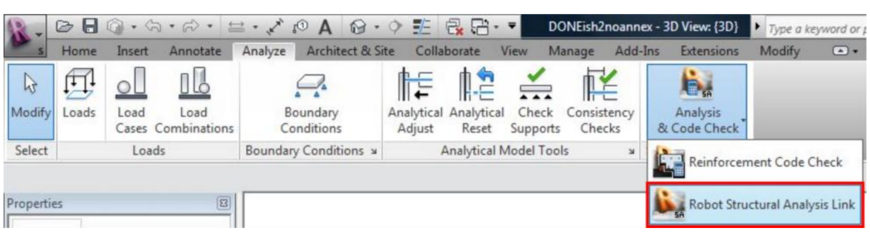



Step 1: use the ROBOT Revit link to export the analytical model

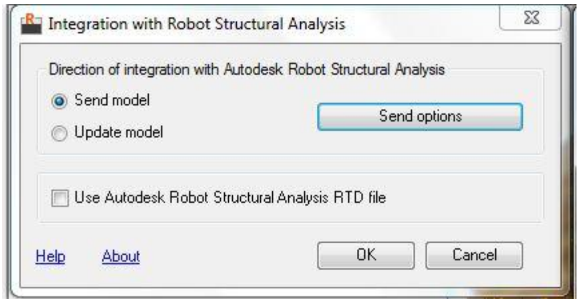
Link is located in the Analyze tab as Analysis and Code Check

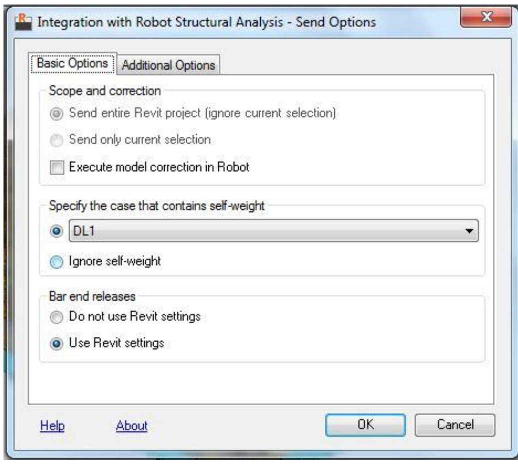


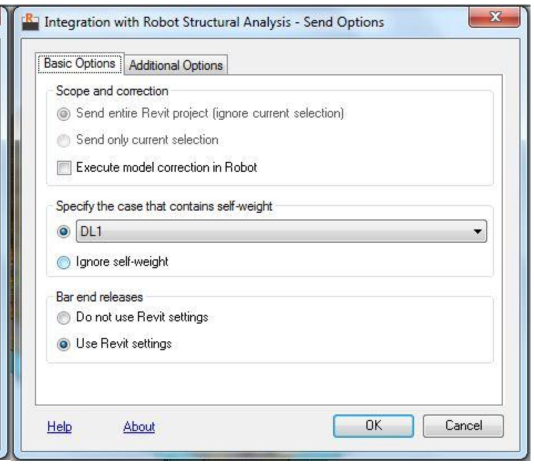
Step 2: Adjust the export options



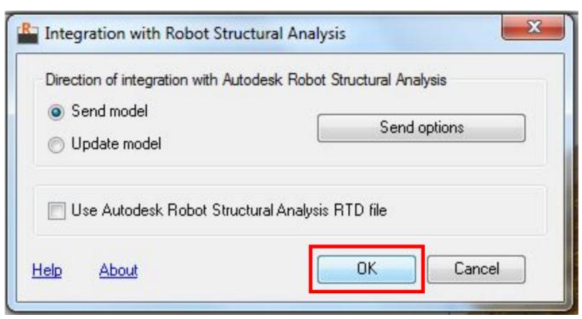
The following options were used for the export



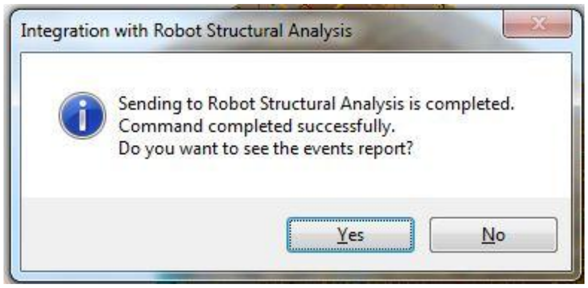


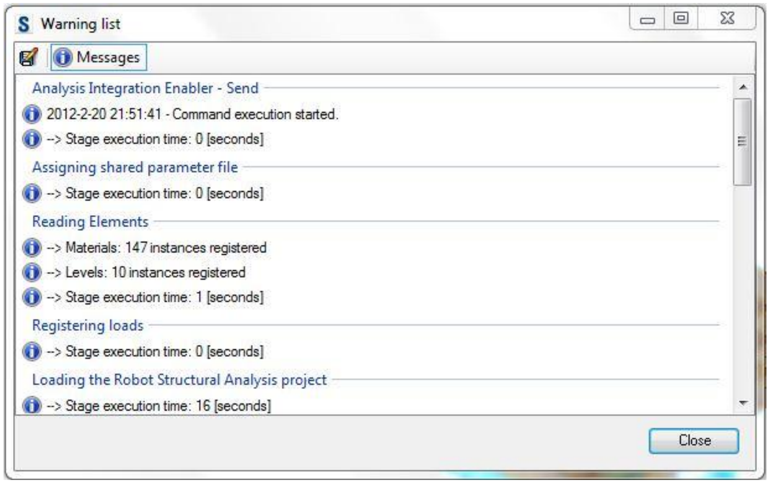


Step: 3 Click Ok to begin the export process



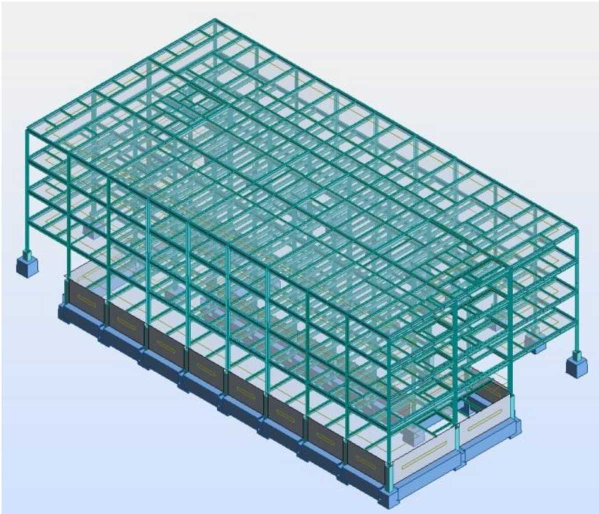
Step 5: After successfully exporting the model you will be prompted with a window asking if you would like to review the events report. This will give you a good overview as to potential errors or unsuccessfully exported elements



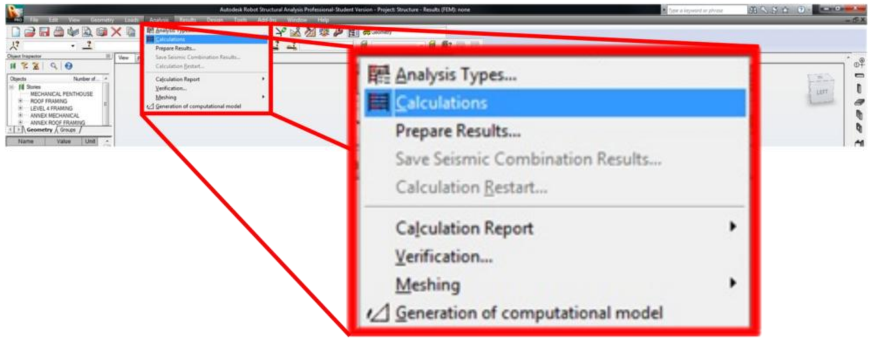


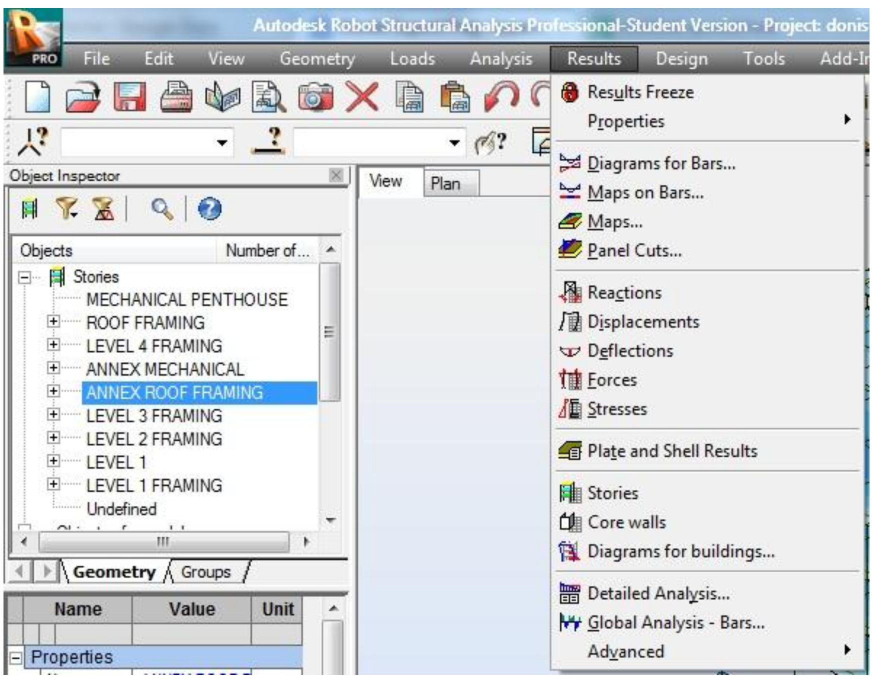
It is generally recommended to view the warning list to ensure everything has worked properly

Step 6: ROBOT will automatically be open to the exported model and should be ready for analysis if all the necessary steps were taken.

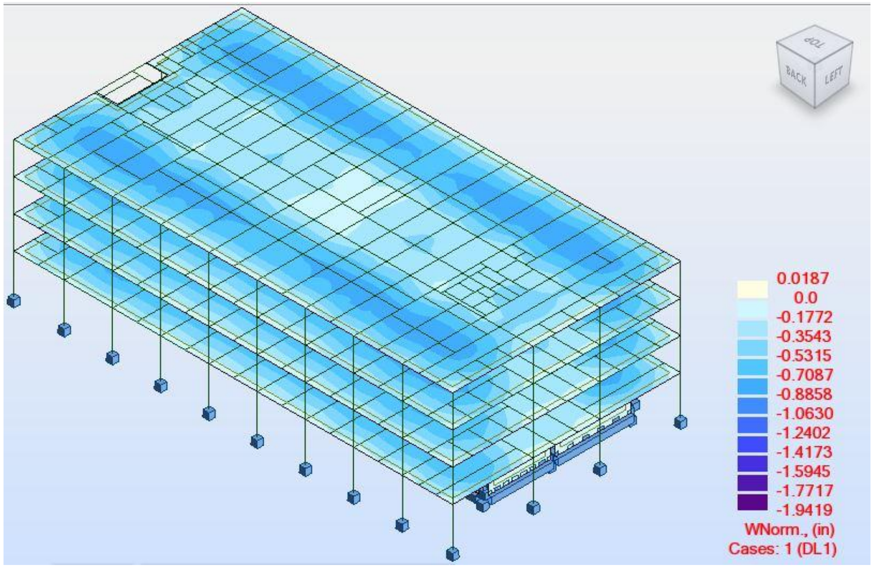


Step Something: Run the structural analysis, Calculations option in the Analysis tab. This will perform the actual structural analysis on the building and prepare FEM results.





For general overviews the maps and panel cuts option will display structural information for the building directly on the 3d model based on which load combination is selected.

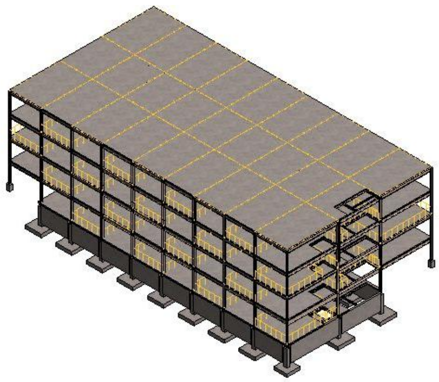


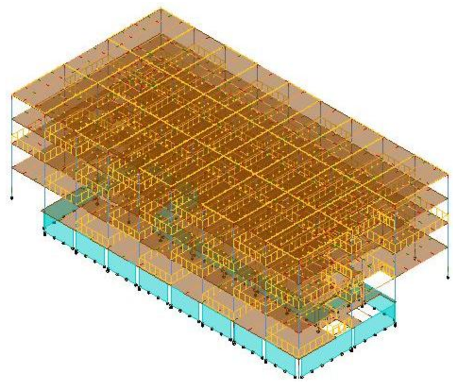
For individual member information deflections and displacements will display values for each member and loading combination. Values can be sorted according to bar number and ascending or descending values.

Bar/Case	UX (in)	UY (in)	UZ (in)
227/ 9 (C)	-0.0001	-0.0001	-1.5829
362/ 9 (C)	0.0001	0.0001	-1.4854
320/ 9 (C)	0.0001	-0.0001	-1.4204
614/ 9 (C)	0.0001	-0.0001	-1.4050
593/ 9 (C)	-0.0000	0.0001	-1.4017
383/ 9 (C)	0.0001	-0.0003	-1.3833
366/ 9 (C)	-0.0001	0.0002	-1.3698
587/ 9 (C)	-0.0000	0.0000	-1.3606
173/ 9 (C)	0.0001	-0.0000	-1.3482
174/ 9 (C)	-0.0001	-0.0001	-1.3160
537/ 9 (C)	-0.0001	0.0000	-1.2821
304/ 9 (C)	-0.0000	0.0000	-1.2799
306/ 9 (C)	-0.0000	-0.0000	-1.2767
127/ 9 (C)	-0.0001	-0.0000	-1.2762
318/ 9 (C)	0.0000	0.0000	-1.2675
374/ 9 (C)	-0.0000	-0.0000	-1.2627
547/ 9 (C)	-0.0000	-0.0000	-1.2604
311/ 9 (C)	-0.0000	-0.0000	-1.2415
540/ 9 (C)	-0.0000	-0.0000	-1.2335
319/ 9 (C)	0.0000	0.0000	-1.2328

Appendix G: Scia Model Export and Preparation

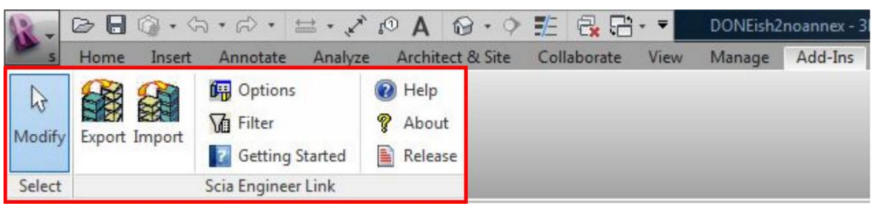
The following model is exported from Revit Structure:



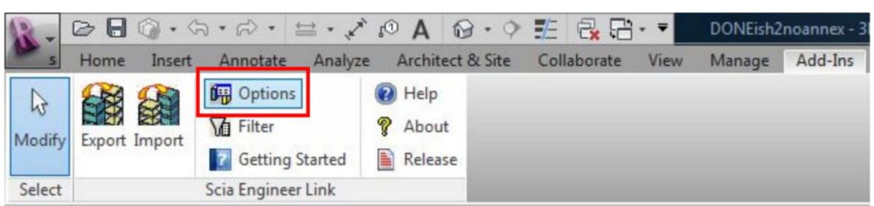


Step 1: is to use the Scia-Revit Link to export the model

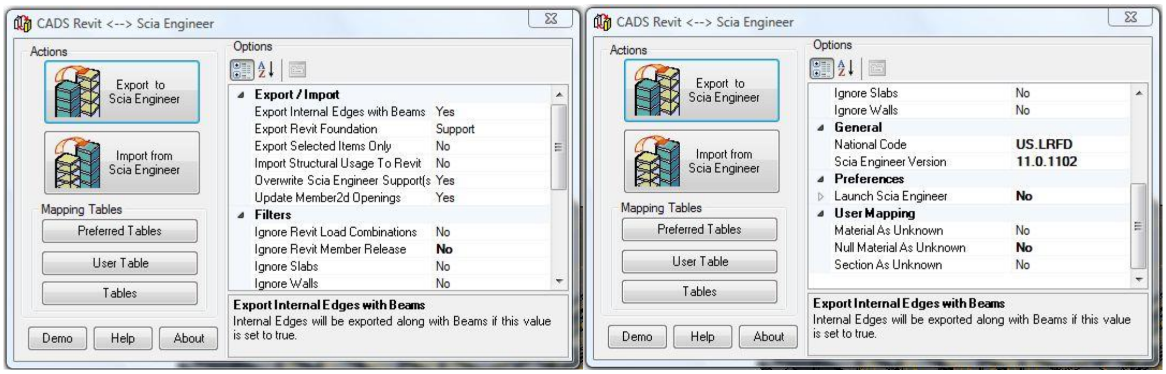
The link is installed under Add-Ins tab



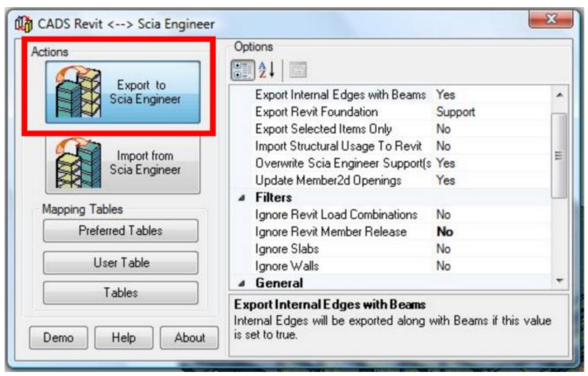
Step 2: Adjust the export options



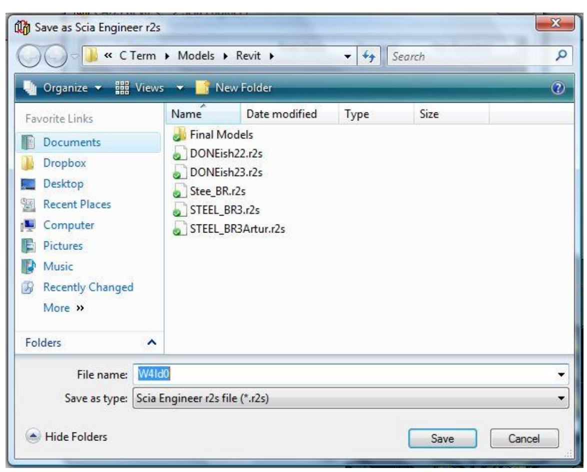
The following Options were used for the export of the model:



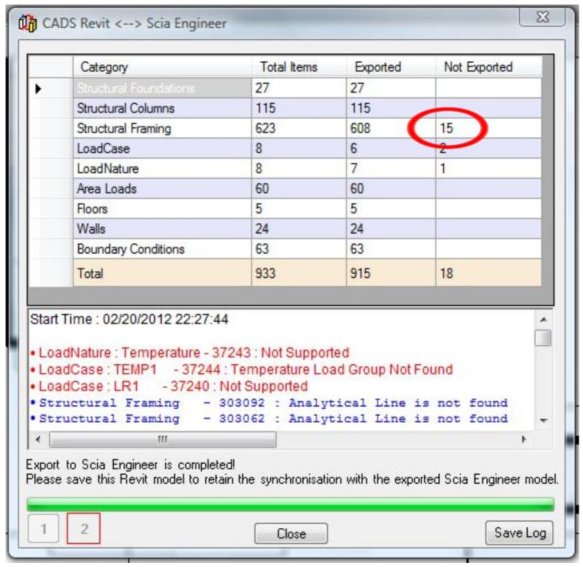
Step 3: Click on “Export to Scia Engineer”



Step 4: Save the new export file. After clicking on “Export to Scia Engineer,” you will be prompted with a pop-up which will require to determine the path for the exported model as well as the name for the model:



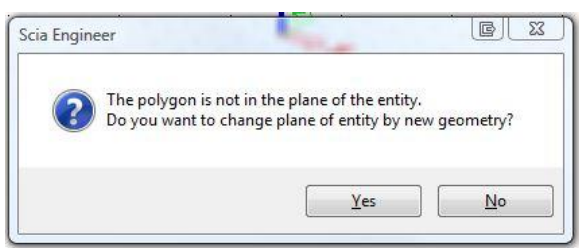
Step 5: Review the export log:



In the current log it can be seen that 15 Structural Framing members have not been exported. This is because some structural members were not going to be analyzed and thus the analytical model for those 15 members was turned off in Revit.

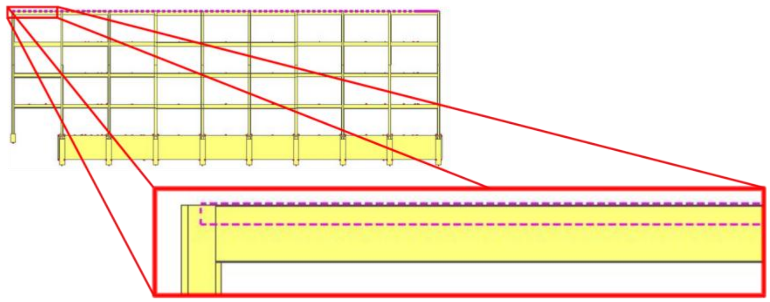
Step 6: Open structural model in Scia Engineer

If you have applied free loads to the structure, you will see a pop-up for every free load applied:

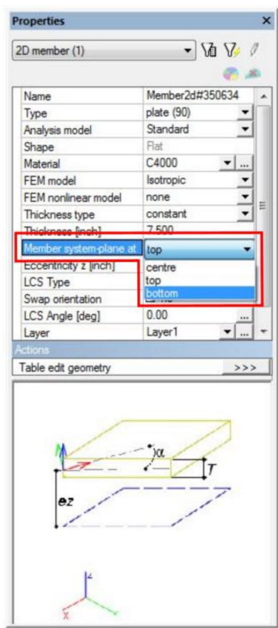


Hit "Yes" as many times as needed. This message appears when area loads are exported from Revit Structure to Scia Engineer. There should be no other error messages and the model should load:

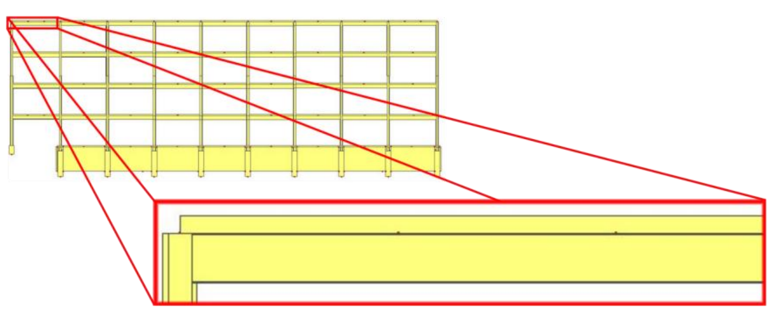
Step 7: Adjust Slabs



It can be seen from the previous screen shot that the both the top of flange and top of the slab are projected at the same elevation. In our model, the slab on metal deck should be resting on top of the metal decking. In order to adjust it, select the slab and in the Properties window change the “Member system-plane at” from “top” to “bottom”



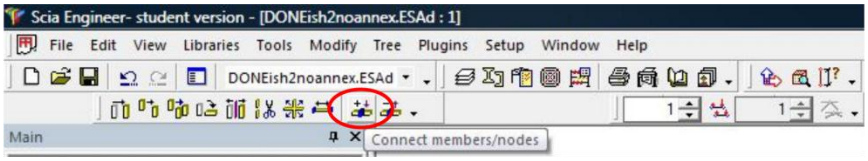
After all slabs have been adjusted the model will look as follows



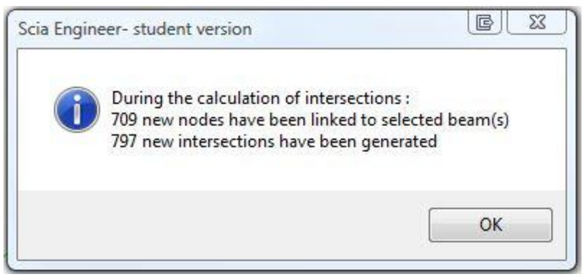
Step 8: Automatically Adjust the Model

The next step is to automatically adjust the model. This is done in order to delete duplicate nodes and to connect all members to one another.

"Connect member/nodes" tool is used for this operation which can be located on the top of the menu screen:

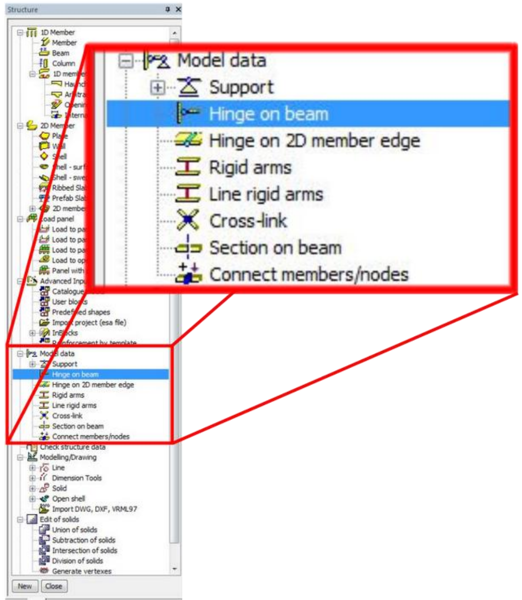


After the command has been run, you will see a pop-up which will display how many intersections have been updated and also how many nodes have been adjuster or created:



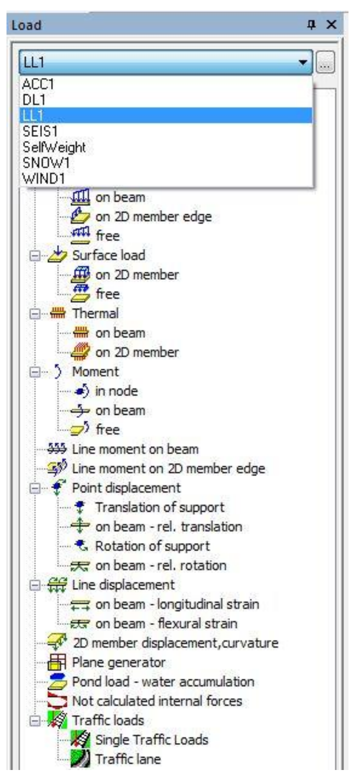
Step 9: Adjust Steel Connections

Scia Engineer automatically exports all steel member connections as moment connections. Structural steel members in the building used for this project are mostly pin connected and some members, which are part of the moment frame, are moment connected. In order to adjust the model the "Hinge on beam" tool, which is located in the "structure" menu, should be used to change moment connections to pin connections:

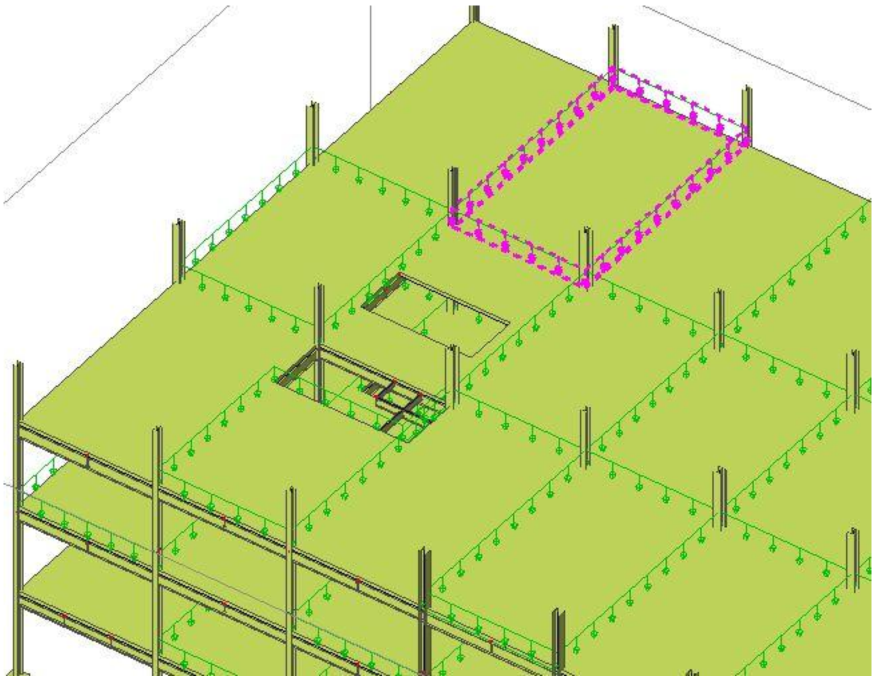


Step 10: Apply Revit's Area Loads to 2D surfaces.

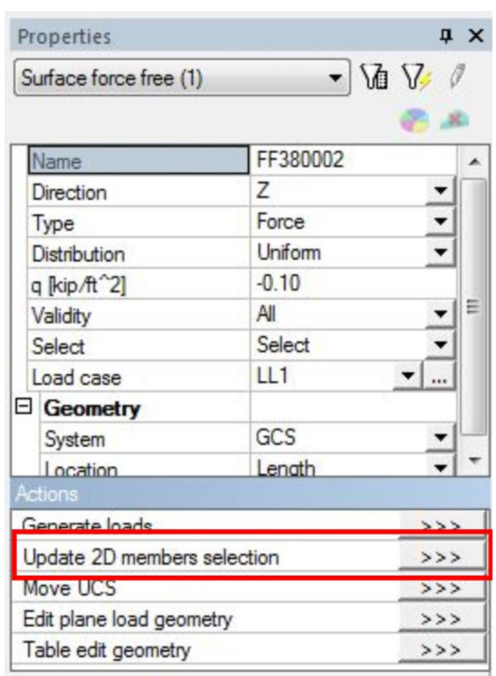
Unlike Hosted Area Loads, regular Area Loads which have been applied to the structure in Revit Structure will not be applied directly to structural elements. If they are left without being assigned then they will not be considered in the analysis process. In order to assign Area Loads to 2D structural elements, first select which load type you are adjusting in the load's menu:



After a particular load type has been selected, area loads will appear on the structure



In order to assign an area load to a 2D member, first highlight the area load, then click on "Update 2D members selection" in the Properties window:

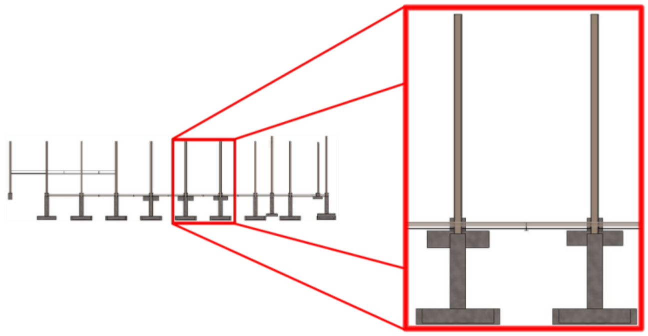


Next step is to select the 2D member (slab) which the load should be applied to.

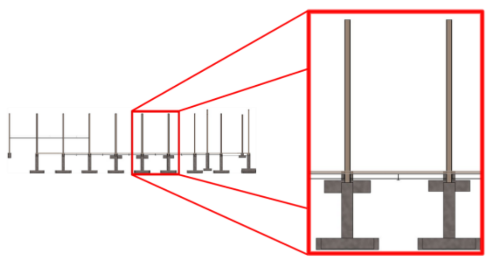
Appendix H: Interoperability Issues

Revit

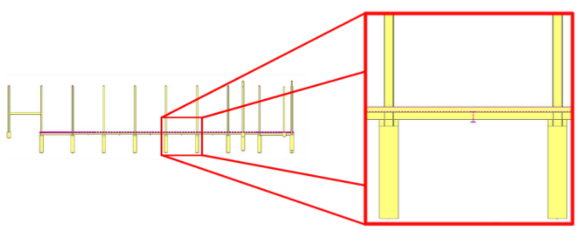
After drawing beams which support floor slabs, and putting the slab on the same level, we realized that the slab does not rest on top of beams, Instead, top portions of the beams and girders are in cased in the slab:



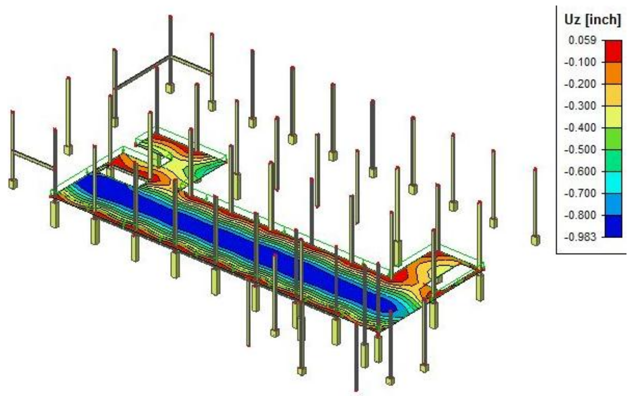
In order to fix this we offset the floors up by the thickness of the slab so that the slab would rest on top of the beams.



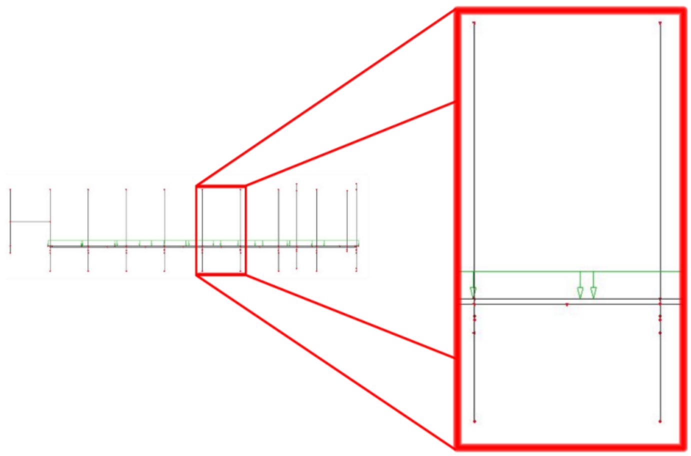
By offsetting the slab, we fixed the issue with the structural model. We then exported the structure to Scia for primary error analysis.



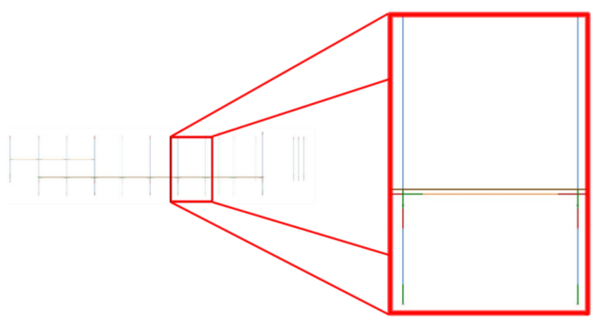
After using Scia to calculate deflections in the slab we noticed that the deflections of -0.983in were too high.



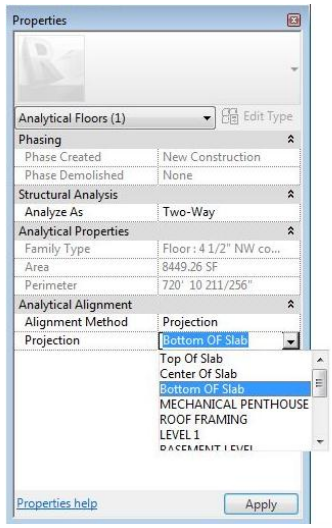
We then looked at the analytical model in Scia:



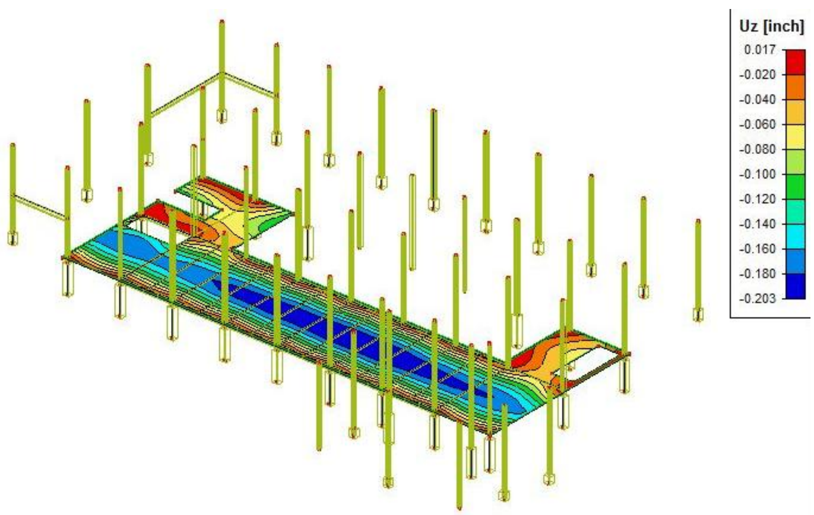
We realized that the analytical element of the slab was not resting on the beams and thus beams only supported their self weights and not the slab.

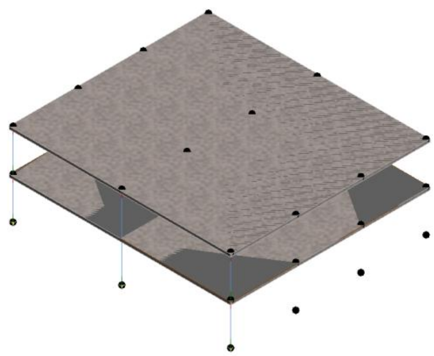


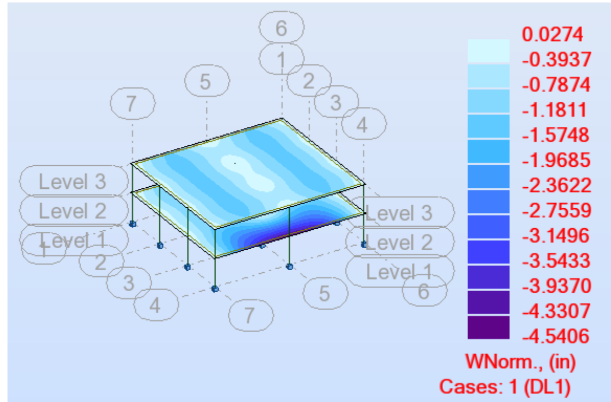
Our model had the same issue in Revit. We then adjusted the alignment of the analytical model of the slab to be projected to the bottom of the slab in the element property window:



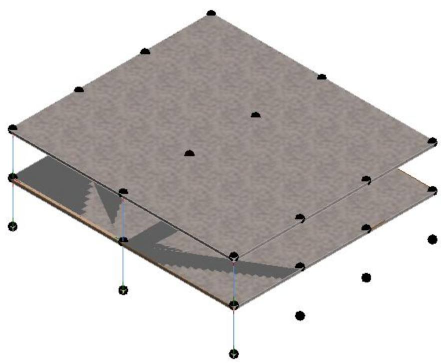
After the analytical model has been adjusted, the results are more in line with what is expected (-0.203 in max deflection)

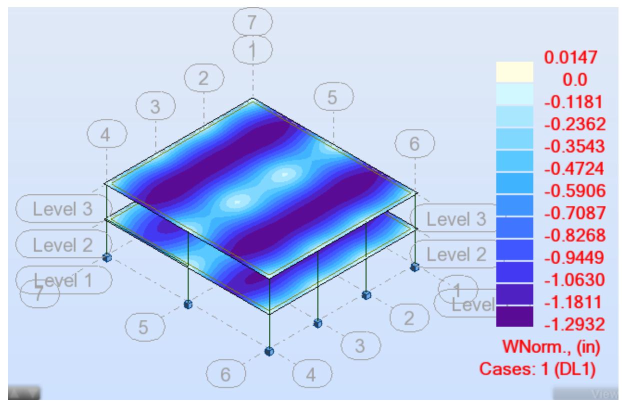






Revit does not place a node in the middle of a column slab intersection. Robot does not add the node

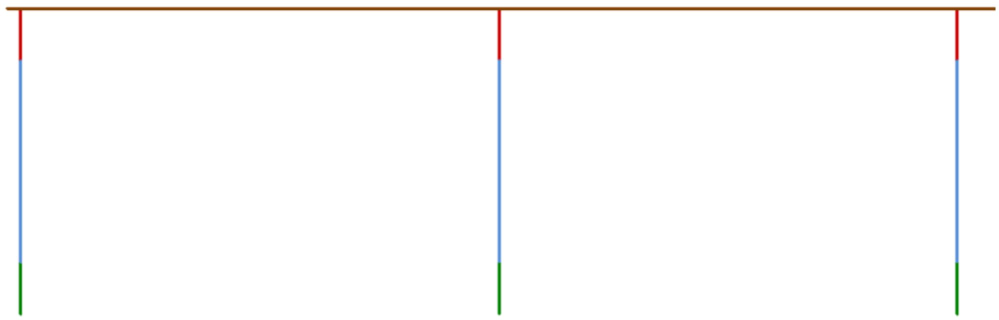




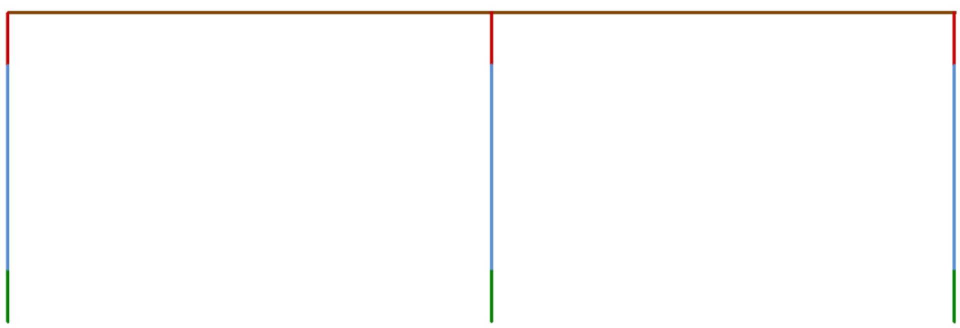
Adding another structural element to the point will fix it. This is a rather unique problem arising out of foundations extending below slab-on-grade with no other structural support.

Horizontal Slab Projection:

Revit automatically creates the analytical model to the same extents of the physical model so our typical method was to model the slab to the column center-line with the steel model. Originally the projections would extend beyond the columns which would create an excessive moments within the cantilevered portion of the slab.

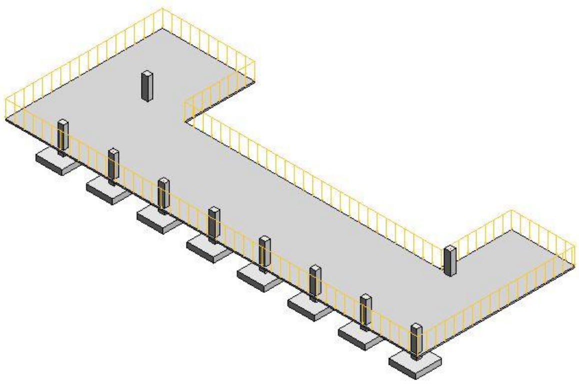


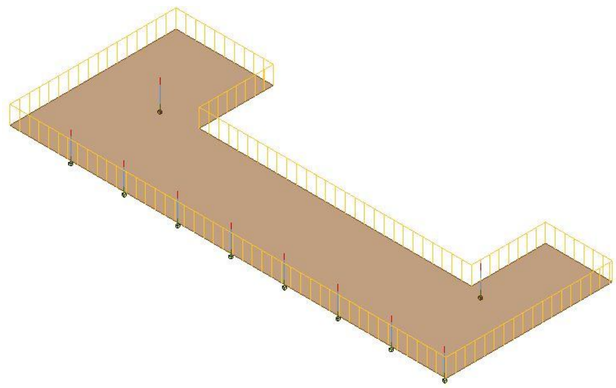
However with the concrete model we decided to look into altering the horizontal projections of the floor system due to the punching stress requirements placed on exterior columns. This lead us to using the auto-detect settings that were disabled for the vertical projections. The results are shown below.

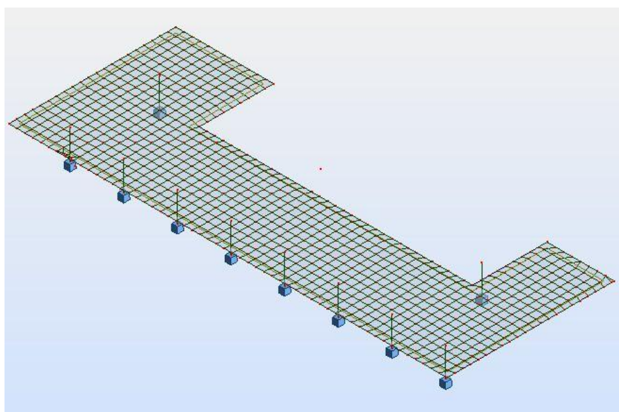


Robot

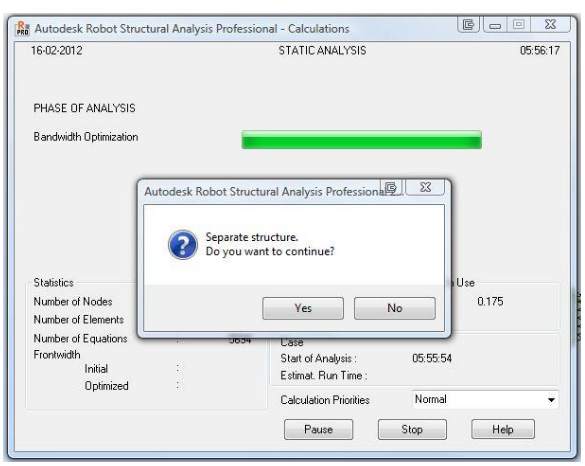
When exporting the basement floor into ROBOT our slab on grade in the basement was not attached to any of the columns. ROBOT reads only the nodes that were placed in Revit and will not perform an analytical adjust to attach the slab and column intersections the way Scia does. This was an issue when modeling any slab on grade or slabs that do not end on analytical elements. Since Scia does not support area boundary conditions we decided to not treat the slab on grade as a boundary condition.

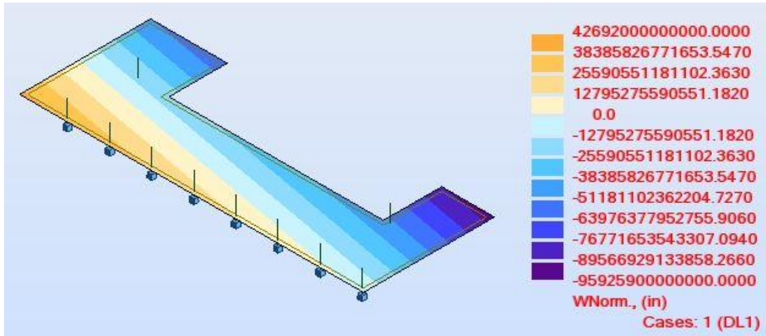




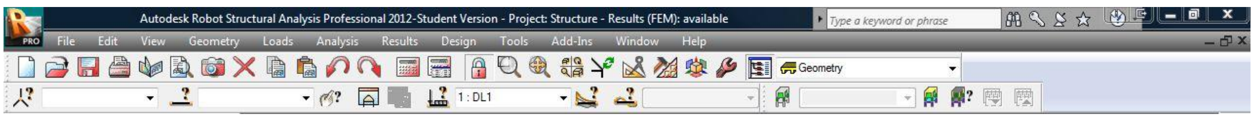


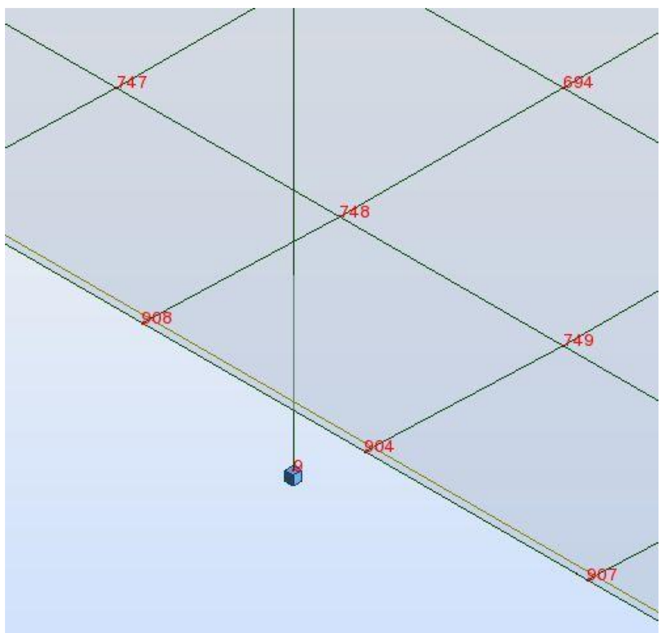
Attempting to analyze this model would bring up a separate structure warning and would result in extremely large deflections.



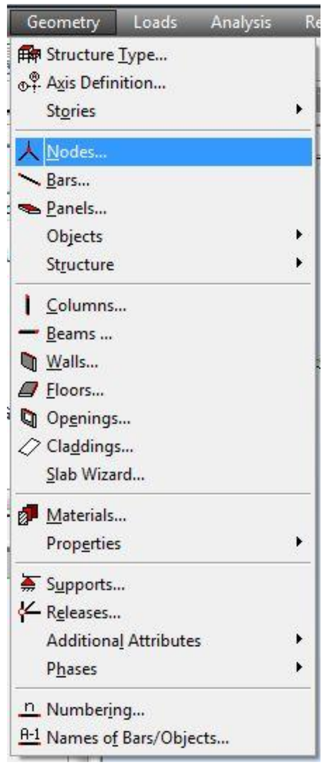


This was a similar problem to the one encountered above but this is a problem with the way Robot reads files. Attaching a structural element or analytical node to the bottom of the slab will correct the issue but does not correctly model the slab on grade behavior

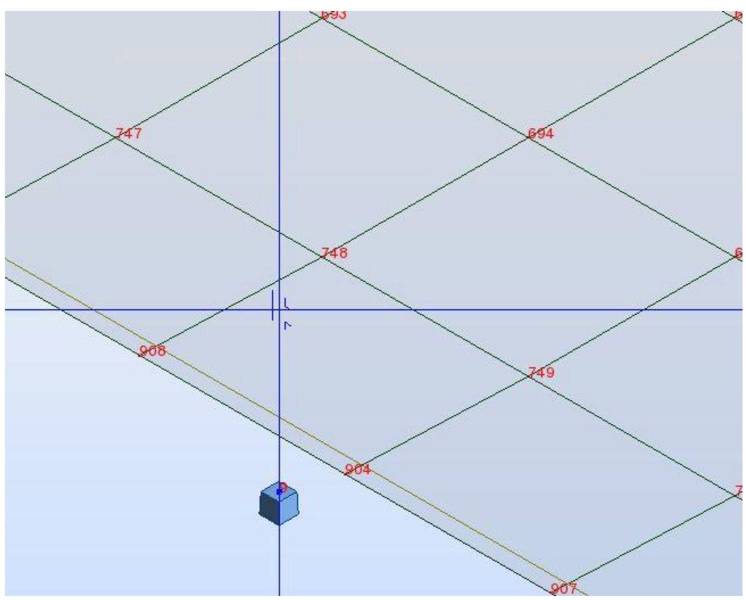


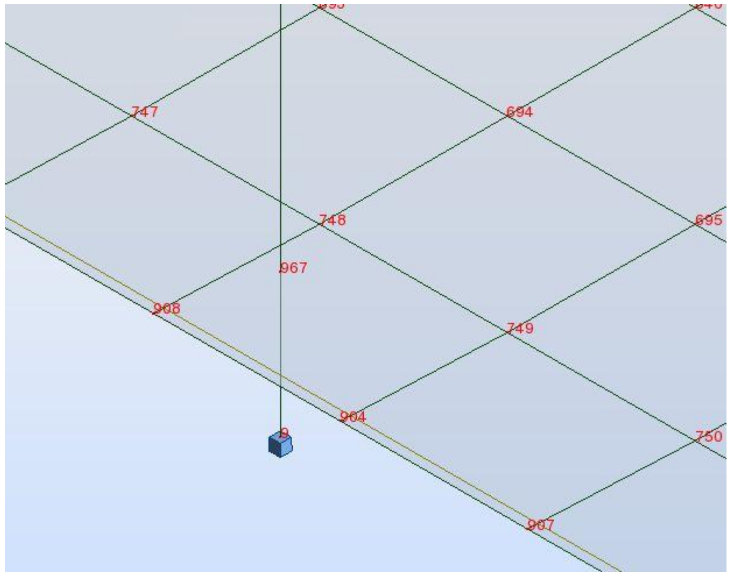


The figure above shows that a node which connects the column and the slab is missing. We found that this issue could be fixed by going into “Nodes” menu under the “Geometry” tab.

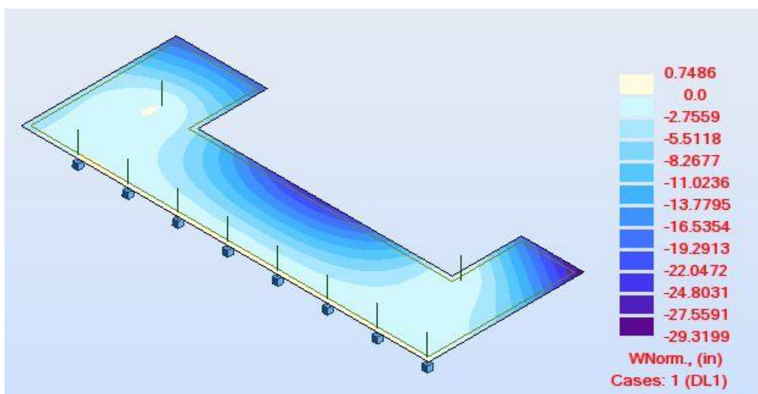


While in the “Nodes” menu, the cursor will automatically snap to the intersection between the column and the slab and left-clicking the mouse will add the missing node.





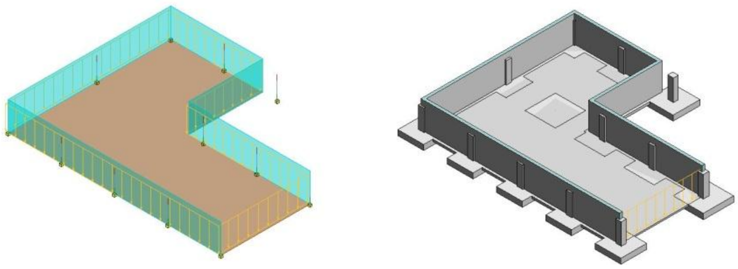
In the figure above, it can be seen that a new node “967” was created.



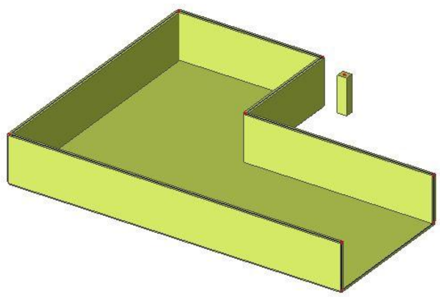
The figure above shows the analysis after columns have been attached to the slabs. It can be seen that almost zero deflections are achieved near the supporting columns while the ends of the slab have high deflections because they are not supported by anything.

Scia

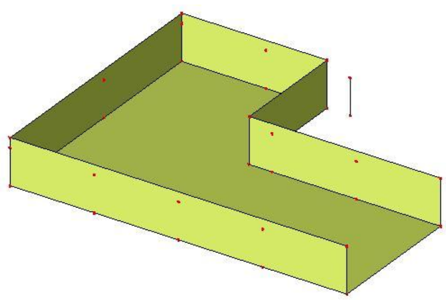
Concrete Column Export Issues



When we created left side of the basement in Revit (you can see structural model and analytical models and tried to export it to Scia this is what we got.

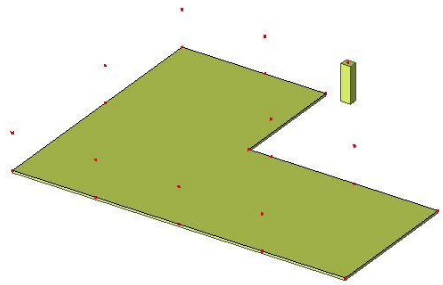


Concrete columns inside the basement are missing completely



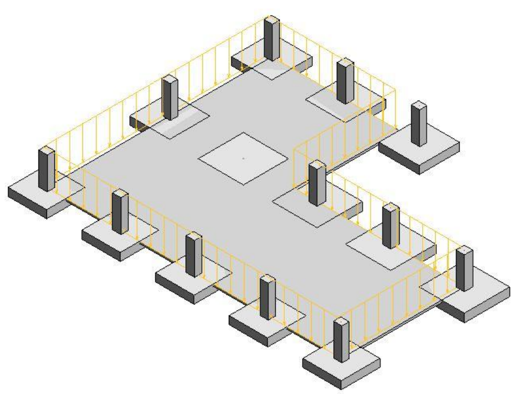
If you look at the analytical model you can see that Nodes have been created for the columns but the columns themselves were are exported.

Now we try export the same model but ignore the walls (via export options). There following model gets exported:

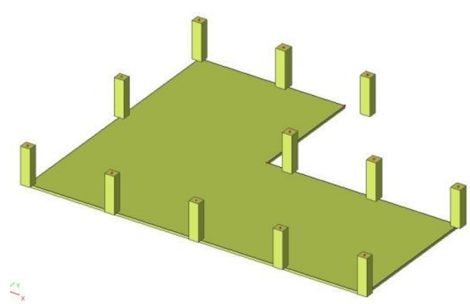


Result - Columns are still missing.

Next attempt is to delete the foundation walls and export the model to Scia. The revit model after removing foundation walls in Revit (prior to deleting the foundation walls completely we also attempted to turn off the analytical model for the walls and export the model, results were the same → model did not have walls nor columns but had column nodes):

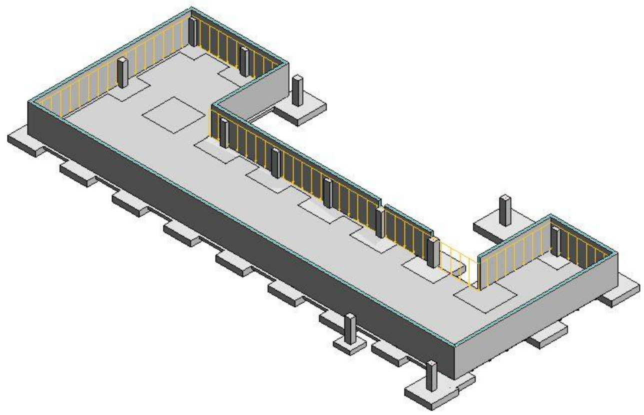


Export to Scia of the model:

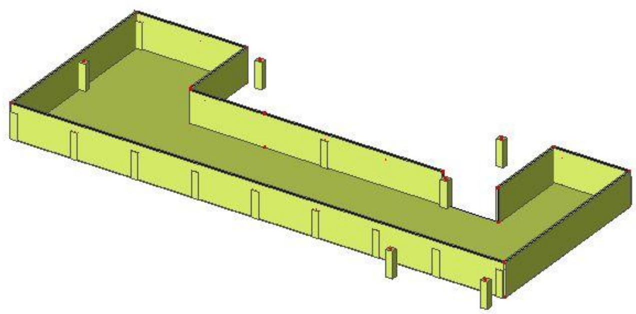


The issue has been solved but foundation walls are not exported at all.

We then wanted to see exactly why the concrete columns were missing during export. We finished the entire basement floor in Revit:

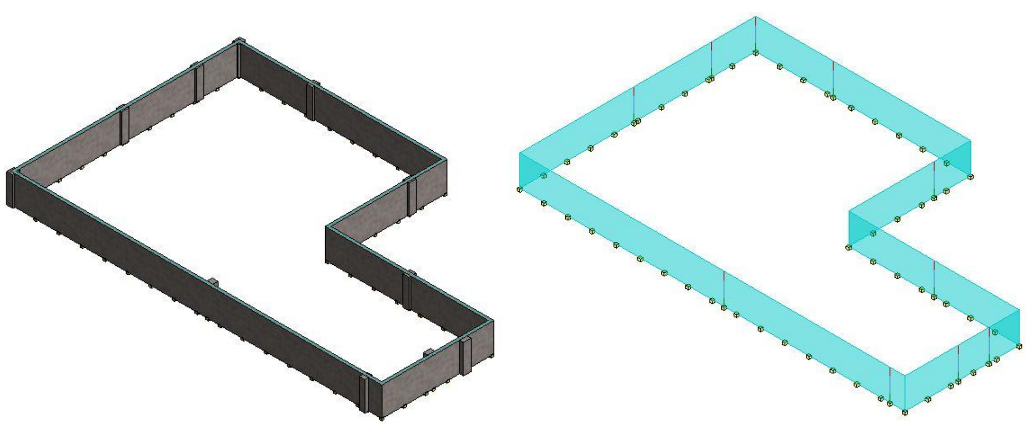


and then exported it to Scia again

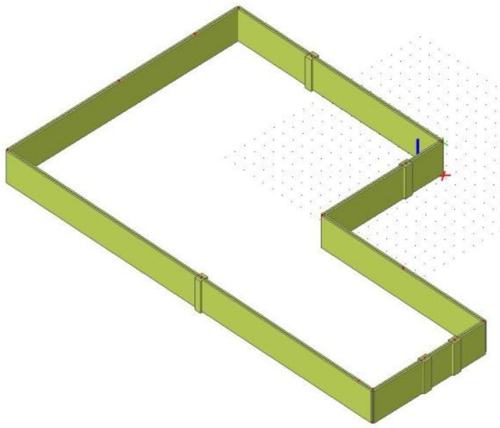


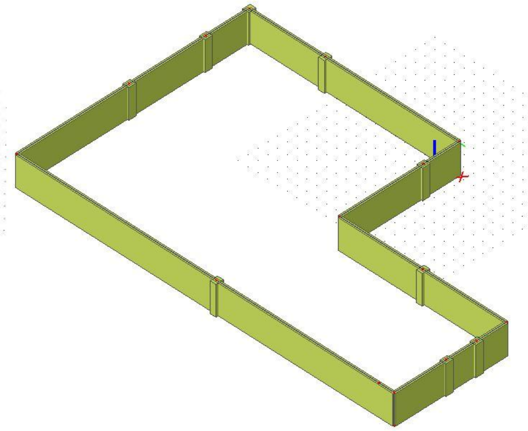
Instead of all columns inside the walls missing, only some are. We then tried to fix the issue by redrawing foundation walls, spread footings, columns, and turning off foundation wall analytical models. Every time different columns would appear and disappear.

Revisiting missing column issue:

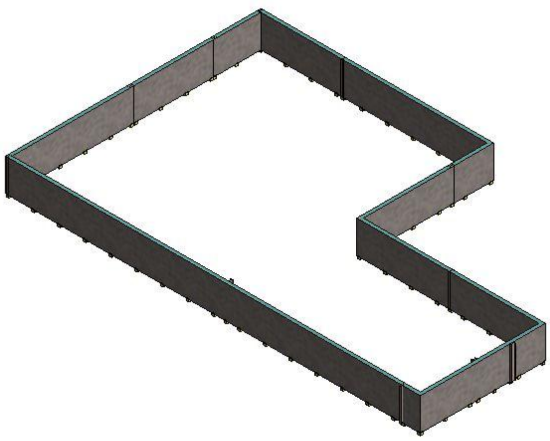


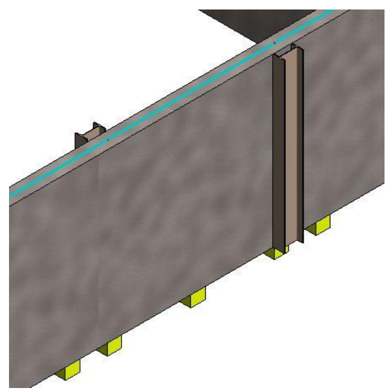
In the figures above you can see a Revit Structural model as well as Revit Analytical Model. These models were exported into Scia and different columns became missing during the export process.



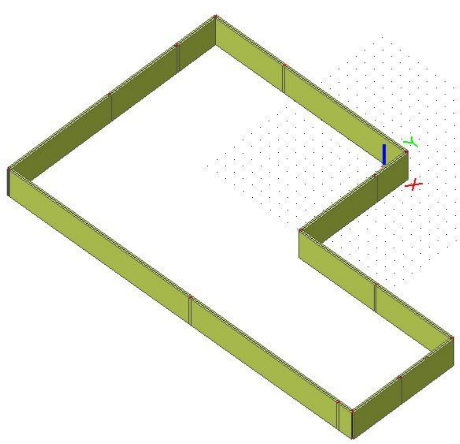


Next attempt was to replace concrete columns with steel W-shape Columns:

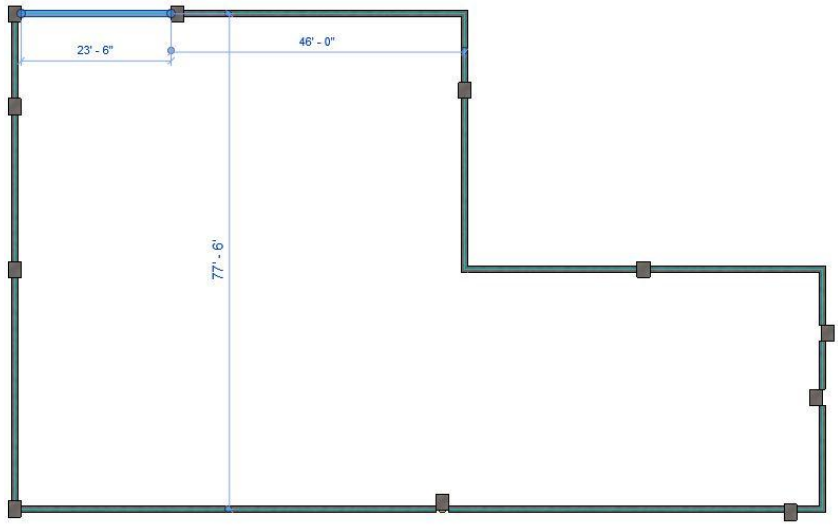




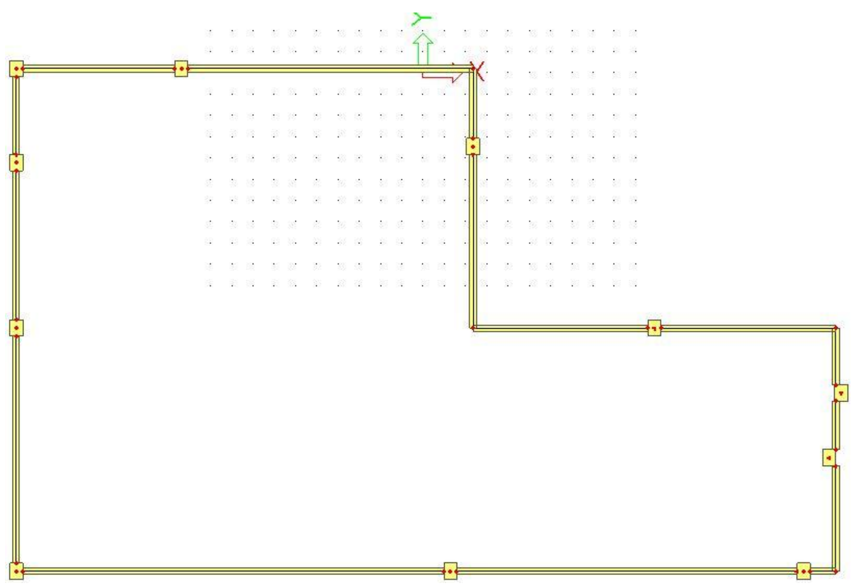
They exported into Scia with no issues:



Our next attempt to solve the issue was to create foundation walls that do not overlap with concrete columns:



Successful export into Scia:

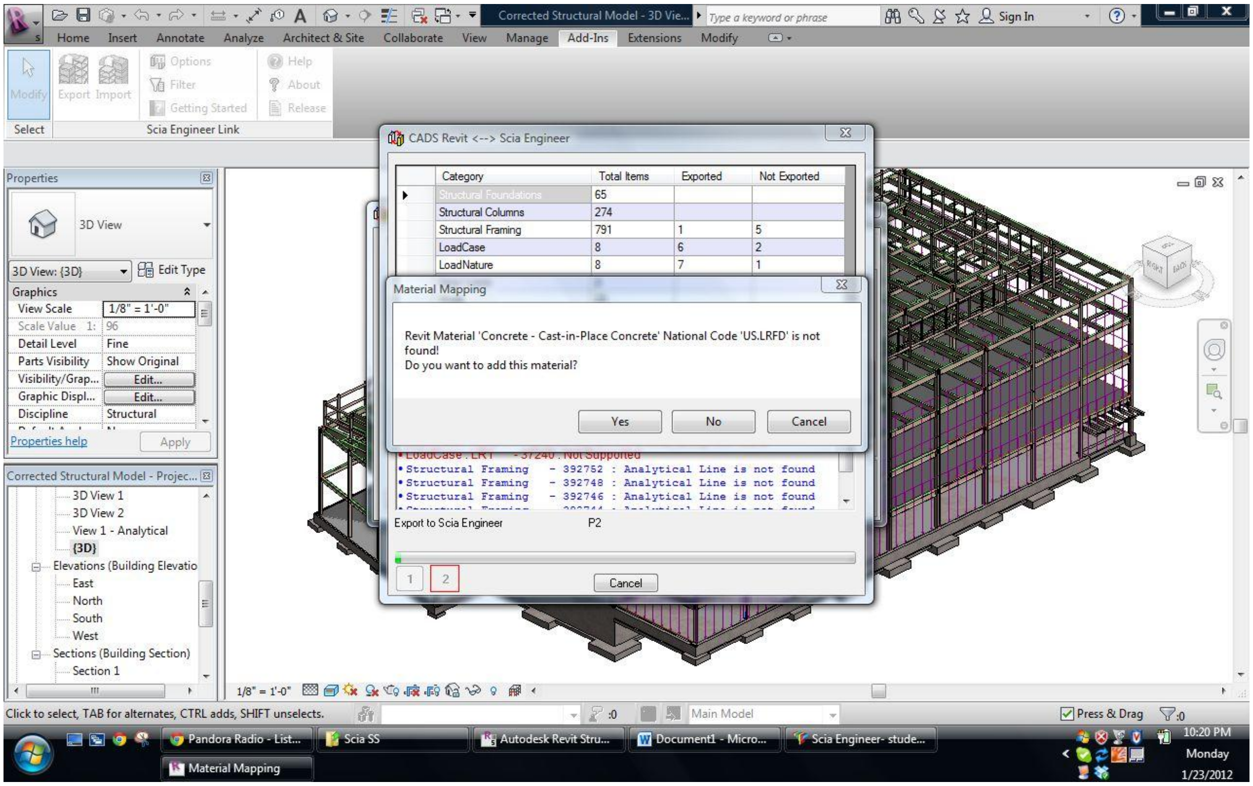


Conclusion with disappearing columns:

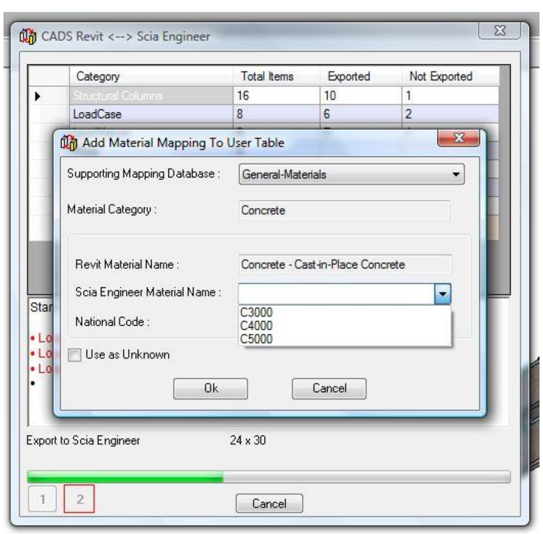
If foundation walls and columns are made out of same material and overlap in the Revit model, during export, some columns may disappear. To fix the issue, foundation walls and columns should not overlap.

Material Mapping Issues

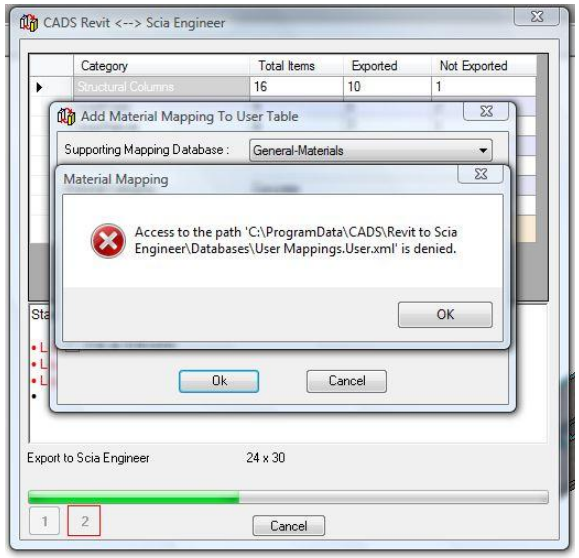
When trying to export a material (or cross-section) which is either not mapped by default or which is mapped as "null", you will get a pop-up similar to the following:



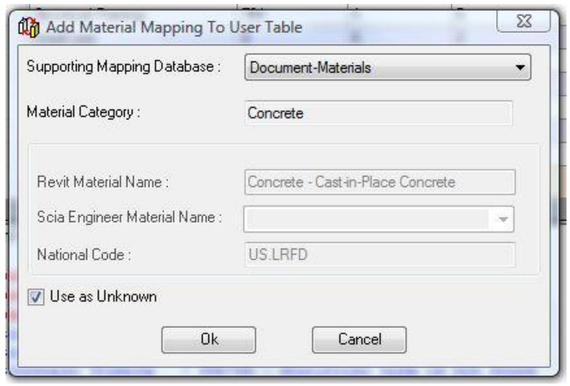
In the pop-up shown above, the user is asked whether he or she wants to manually add this material (or cross section). After clicking "Yes", the user is prompted with a new pop-up requesting for user's selection of the material, which can be seen in the following screen shot:



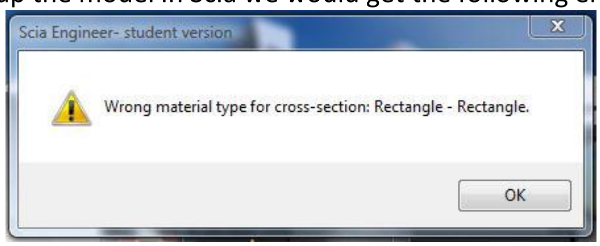
In this example, the user can select material properties for “Concrete - Cast-in-Place Concrete.” After selecting C5000 for 5KSI concrete, and clicking “OK”, we got the following error:

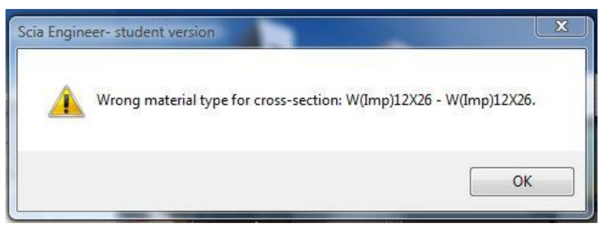


This error was persistent on two different personal computers. First computer ran Windows Vista x32 while the second computer ran Windows Vista x64. Due to this error and in order to continue exporting the model, we had to map materials and cross sections as “unknown,” which can be seen in the following screen shots:

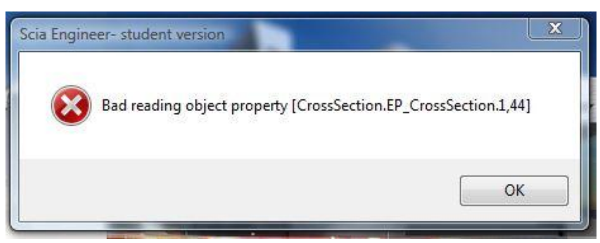


After doing this, some members would be missing and some members lacked material properties. When attempting to open up the model in Scia we would get the following error messages:

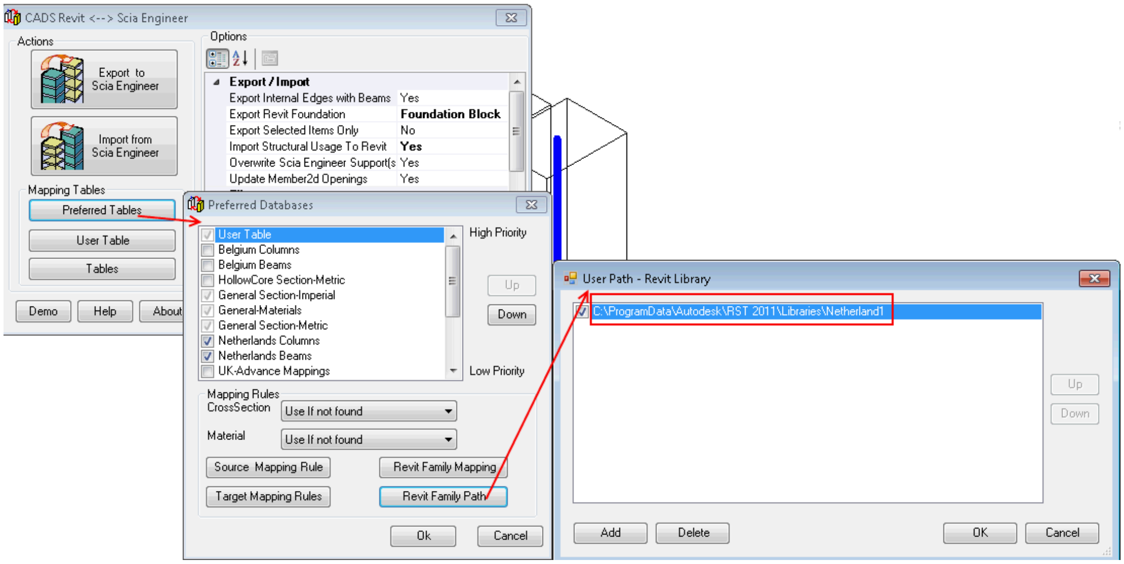




At one point, after exporting the model, we were not able to open in in Scia and had the following error message while attempting to open up the file:

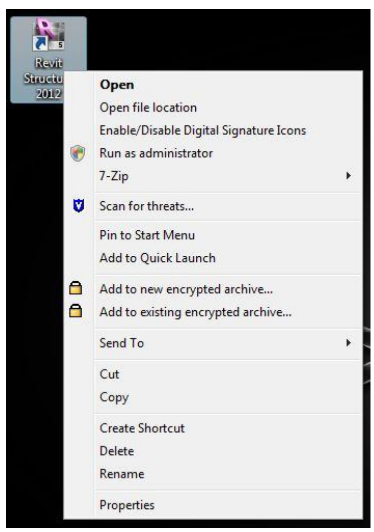


To fix the issue with the model, we had to find a way to correctly map materials and cross-sections. Scia Online Support Staff suggested that we do not have the administrative privileges to access the mapping database and presented us with a solution to update the Revit Family Path. They also provided us with a screen shot on how to perform this operation:



Unfortunately, this solution did not help.

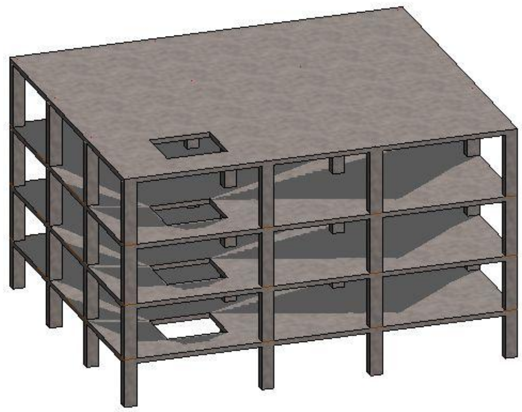
After changing numerous properties and options for model export, we tried running Revit Structure 2012 as administrators by right clicking on Revit Structure 2012 icon, as selection “Run as Administrator.” This can be seen in the following screen shot:



After we ran Revit Structure as “administrators” all issues were gone. We were able to add materials and cross-sections into user-mapping tables and export materials such as “Concrete - Cast-in-Place Concrete” into Scia as different types of concrete.

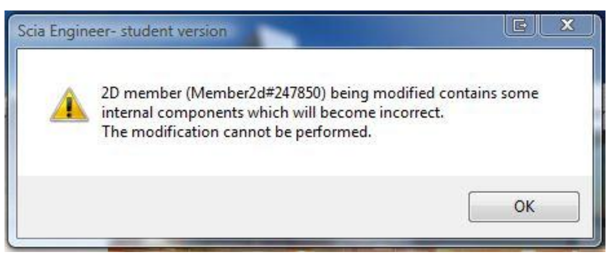
Slab Opening Issues

The following Revit Structures Model with slab openings on each floor was exported into Scia

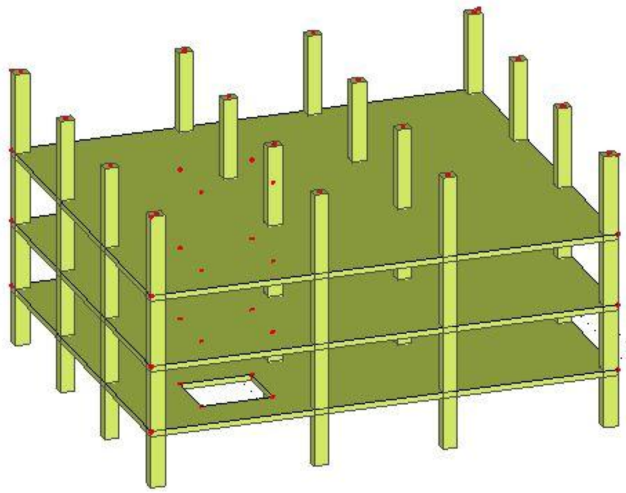


The first three slabs were created by manually creating each slab as well as opening. The top slab was created by copying one of those slabs and copying it to the top level.

After exporting the structure and opening it in Scia Engineer, the following message appears:

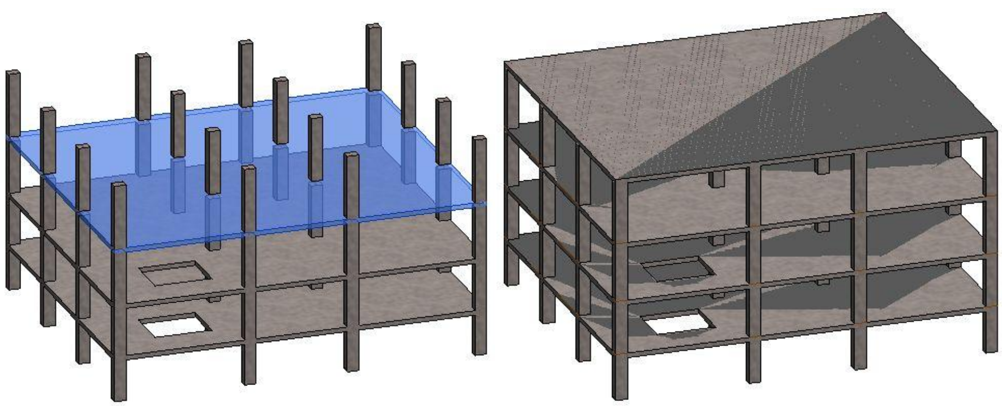


After clicking "OK," the model opens up in Scia Engineer

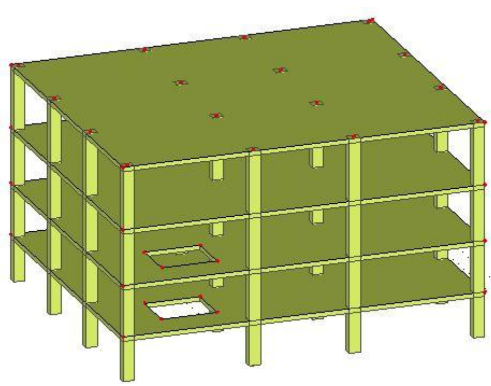


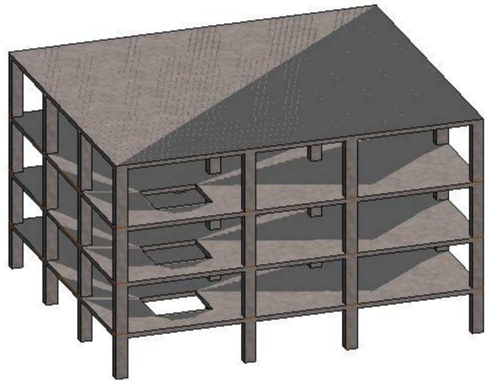
The Scia model above is missing the copied slab. Some of the openings are also missing, but the nodes for the openings were exported.

If a slab without openings, seen highlighted in the following screen shot, is copied onto the top floor

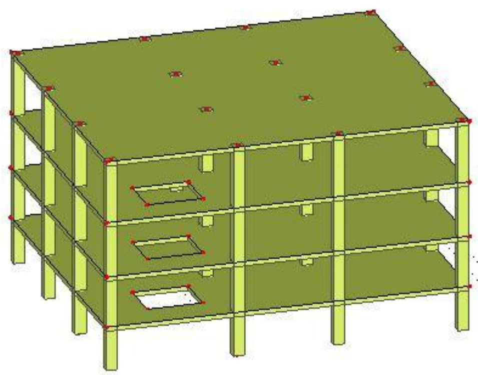


The model gets exported to Scia with no issues, as can be seen in the following screen shot:





Creating a concrete structure. 5ksi concrete. 24”x30” columns at random grid lines. Three openings created in the floor slab. Top slab is left unedited. All slabs and slab openings were created separately. None of the items were copied.



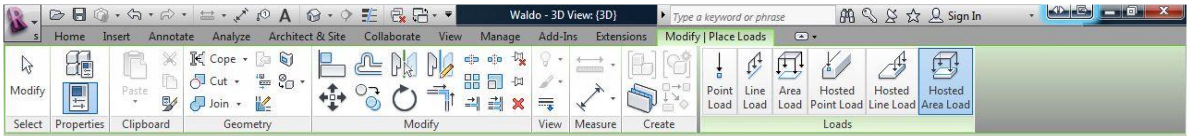
The exported model has exported without an error. All slab openings were exported as well as slabs

Conclusion:

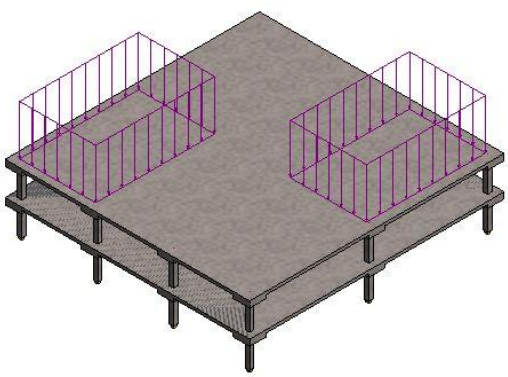
If slab openings are created, they have to be created separately in Revit for each slab. To avoid other issues slabs should not be copied from level to level, even if they are identical. Instead they have to be manually created.

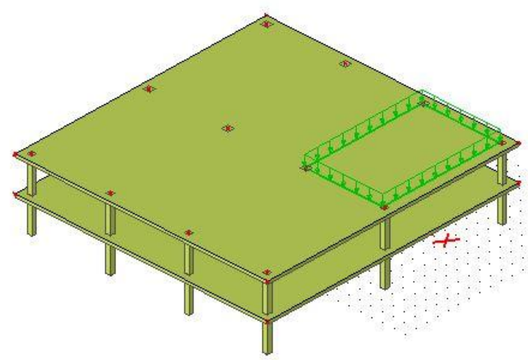
Export of Area Loads

In order to correctly analyze a structure in analytical software and to achieve maximum possible moments inside of beams and slabs, live loads should be applied to alternate bays. Hosted Area Loads cannot be used for this purpose because they automatically apply the load to the entire slab. Instead, regular Area Loads should be used.

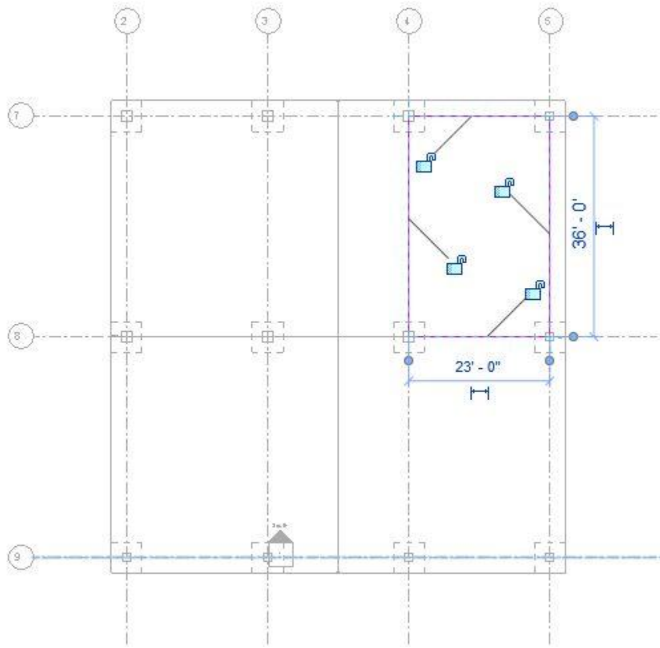


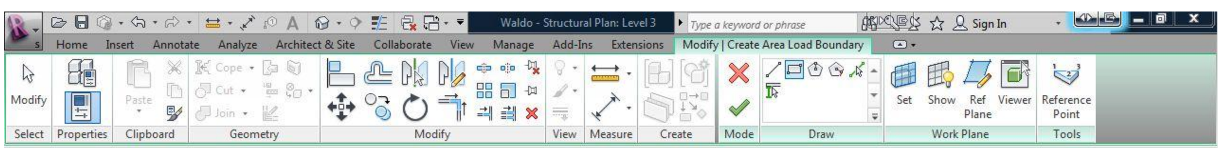
If you place multiple free Area Loads onto a structure, hit "accept" free loads and attempt to export the structure you, only the first free load that you drew would be exported. This can be seen in the following screen shots:



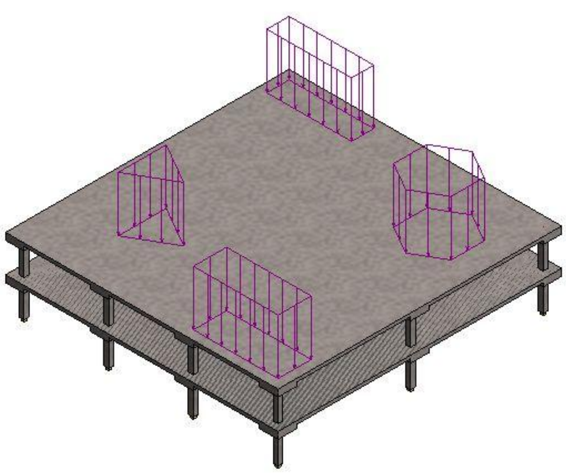


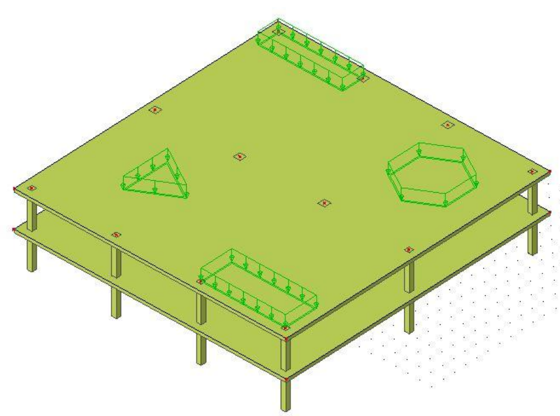
In order to successfully export all instances of applied live loads to alternate bay, after placing one fully enclosed live load (which can be seen in the following screen shot), you have you accept the load by hitting the check mark button.





After accepting the load you will have to click on “Area Load” command again and draw the area load. These two steps would have to be repeated for each instance of free live load placement in order for successful export to Scia Engineer.



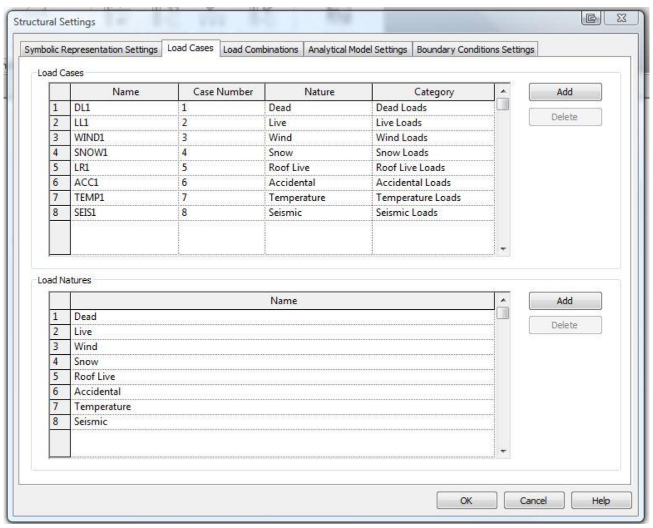


Appendix I: 5 Interoperability Categories

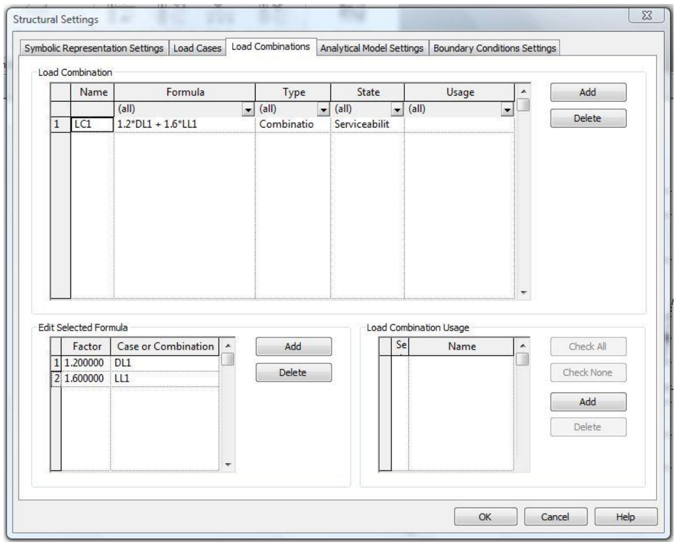
The following appendix contains information about 5 types of criteria that we thought were important for export from Revit Structure to Scia Engineer and Robot Structural Analysis packages. The current appendix is broken up into 5 distinct parts. Each portion briefly introduces the option and tools under study in Revit. Each section is then divided further into two parts: Scia Engineer and Robot Structural Analysis, in which the options and tools are exported into their respective structural package.

Loads

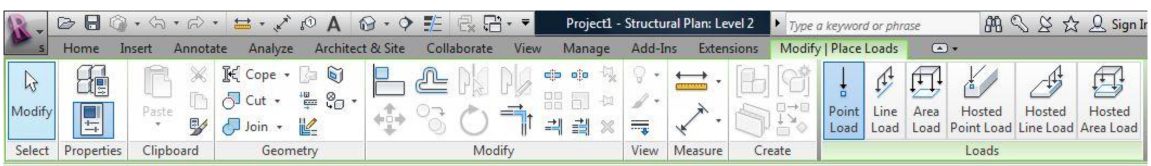
When a new project is created in Revit, eight Load Cases are automatically generated: Dead Loads, Live Loads, Wind Loads, Snow Loads, Roof Live Loads, Accidental Loads, Temperature Loads, and Seismic Loads. The following screen shot shows the default Load Cases which are automatically generated when creating a new project in Revit Structure:



In Revit, Load Cases can be combined to generate Load Combinations which can be seen in the following screen shot:

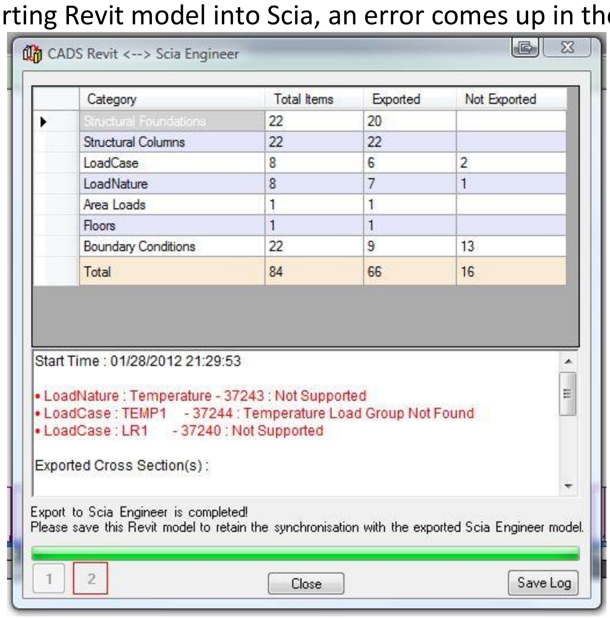


Overall, there are six types of loads that can be applied to a structure in Revit Structure. These loads include: Point Load, Line Load, Area Load, Hosted point Load, Hosted Line Load, and Hosted Area Load.

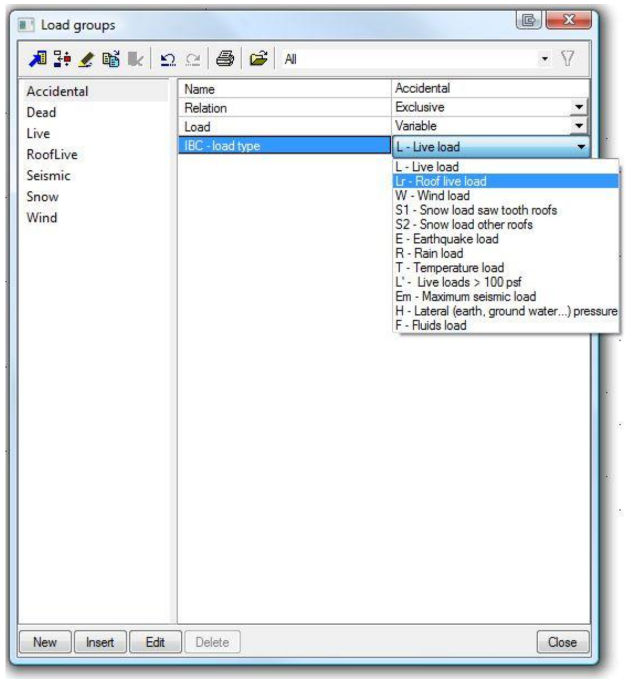


Loads in Scia Engineer:

When exporting Revit model into Scia, an error comes up in the export log



From the above screen shot we can see that Temperature and Roof Live Loads do not get exported from Revit into Scia. This can be one of the limitations of the Scia-Revit link because Scia supports both Temperature and Roof Live Loads which can be seen in the following screen shot:

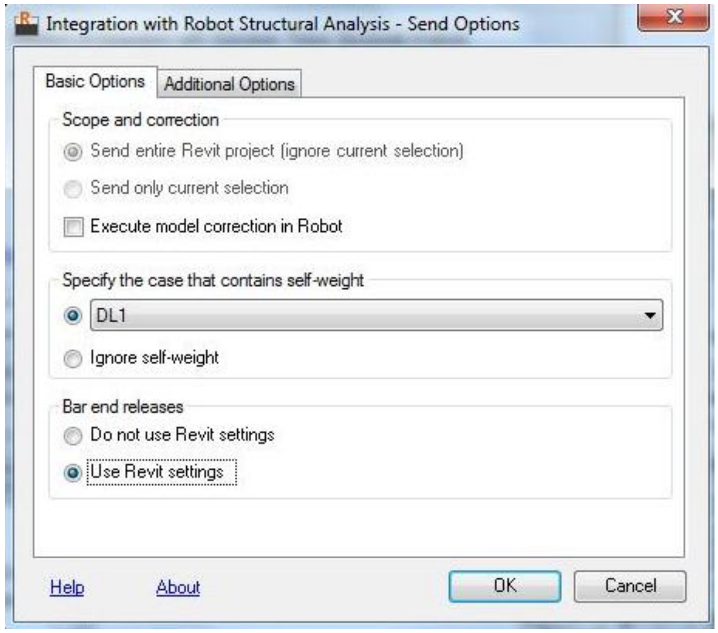


Scia Online Support has been contacted but were unable to find a solution for this issue.

Overall, Basic Loads and Load Combinations are exported from Revit to Scia. These include both free loads and hosted loads. This makes the analysis process much more fluent as necessary loads can be applied to a model directly in Revit and then easily exported to Scia.

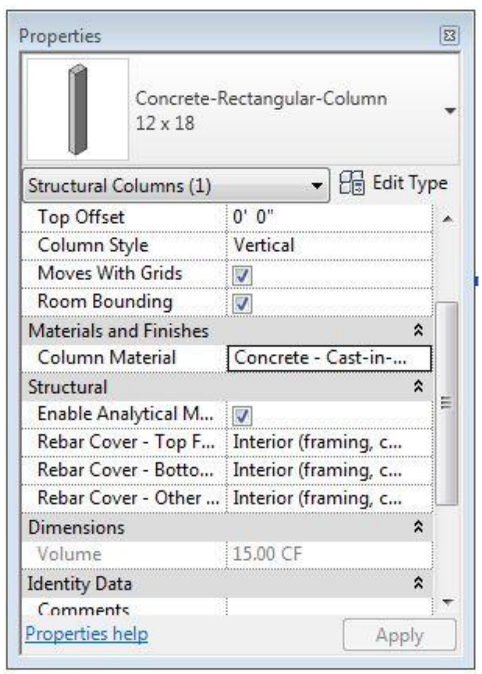
Loads in Robot:

Loads placed in Revit will automatically be applied in ROBOT. The export process works seamlessly and allows for all types of loads to be exported as either basic free loads or hosted loads. Robot does include the option to specify which load case contains the self weight or to ignore the self weight of the building as seen in figure below. The loads can also be exported as combinations or can be combined within Robot depending on what type of design is being used.

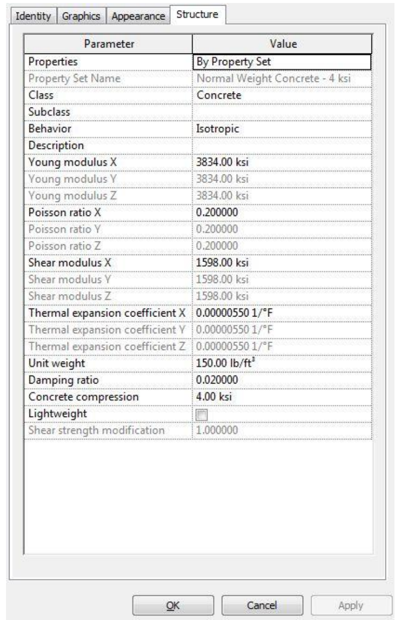


Materials

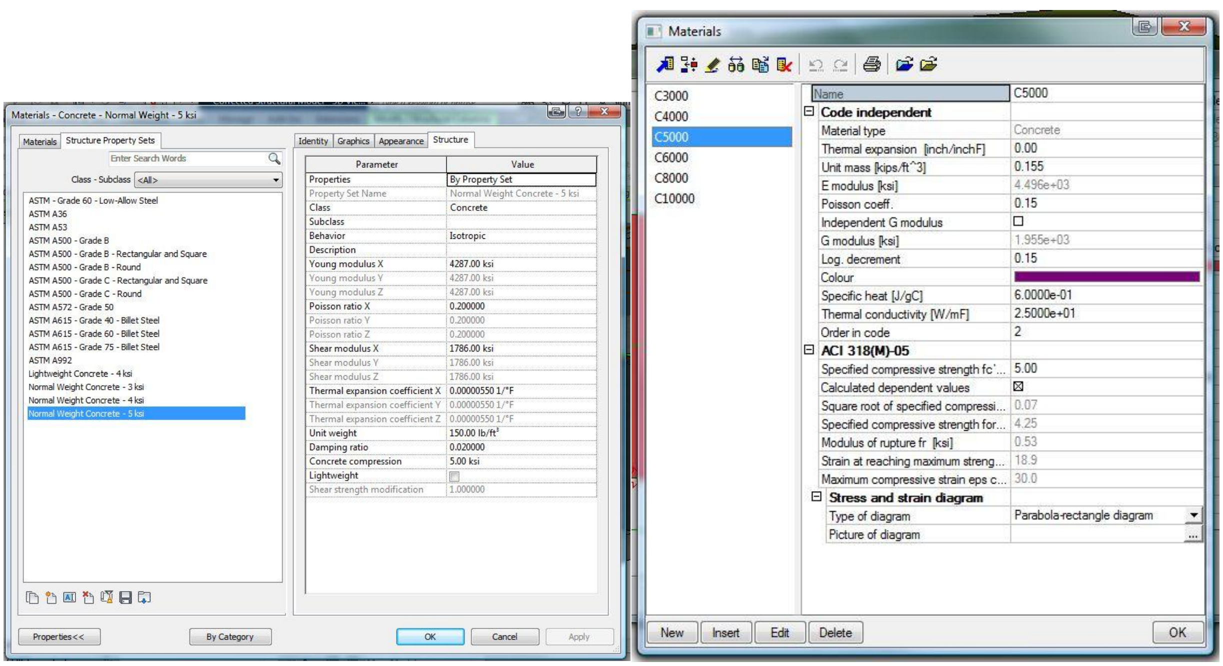
In Revit Structure, different materials can be assigned to different elements:



Some of these materials contain structural properties which can be seen in the following screen shot:



Each material in Revit has structural properties. The following shows the properties for Revit's "Normal Weight Concrete - 5 ksi," and Scia's "C5000 Concrete":

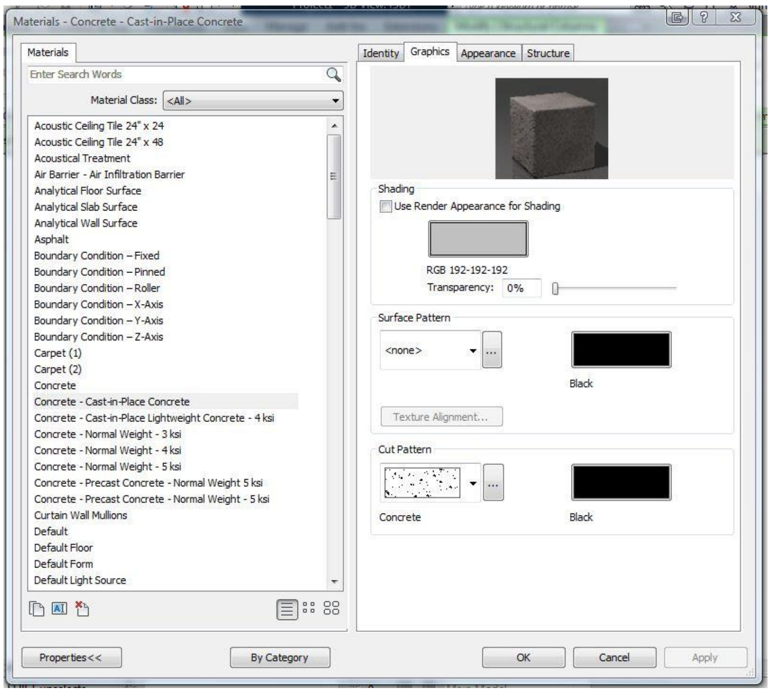


These structural material properties slightly vary between Revit and Scia and thus one must be aware of these slight variations when working with different materials.

Most common materials are already mapped though and thus this is not an issue unless you use some special elements (C shapes, HSS memeberts, etc). Scia support has been contacted to see what the error is. Waiting for response.

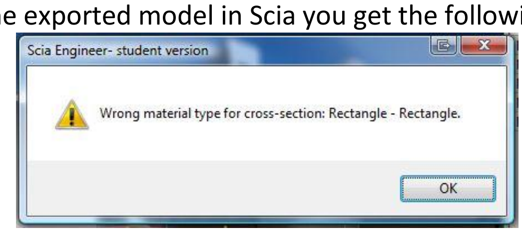
Scia:

When you create a concrete column or a generic concrete slab the basic concrete material is called "Concrete - Cast-in-Place Concrete".

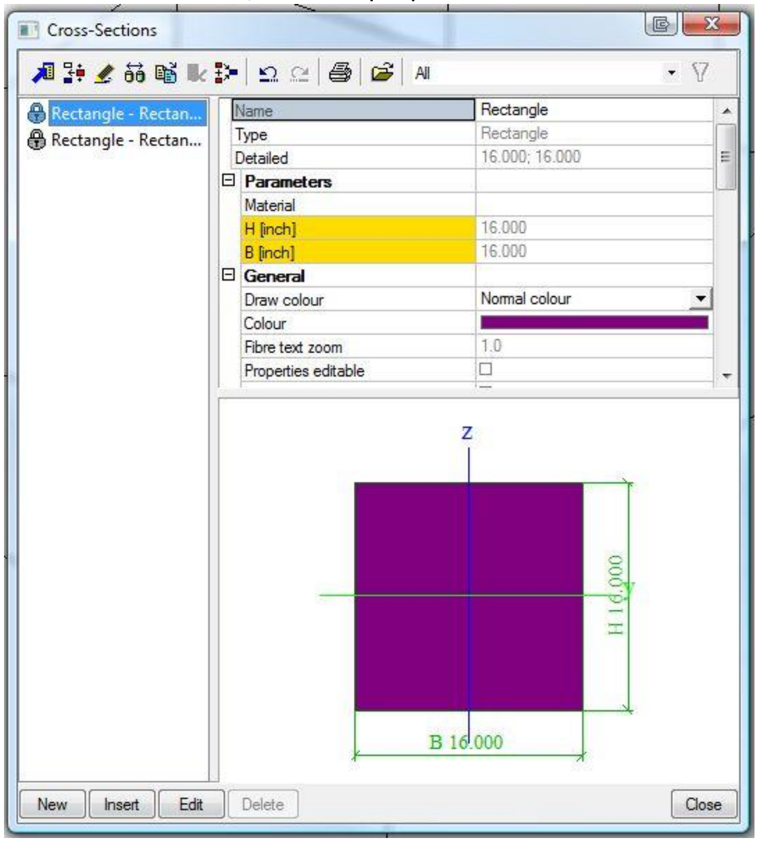


When exporting the structure which is primarily made up of cast-in-place from Revit to Scia, you get an error message in the report log saying: "Revit Material :"Concrete - Cast-in-Place Concrete" is mapped as "Unknown" based on user mapping." This means that it would seem that all elements which are made up of concrete in the project would have unknown material properties.

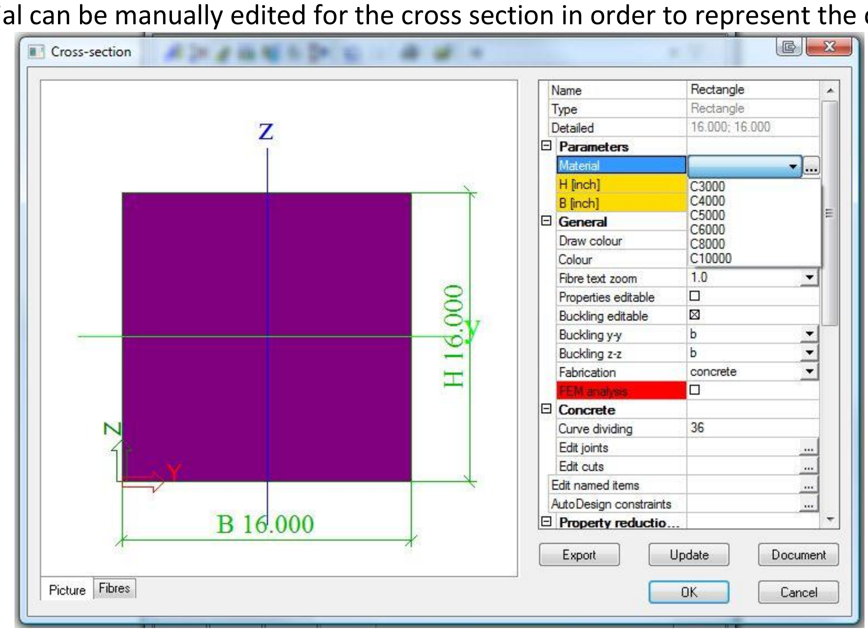
When opening the exported model in Scia you get the following error message:



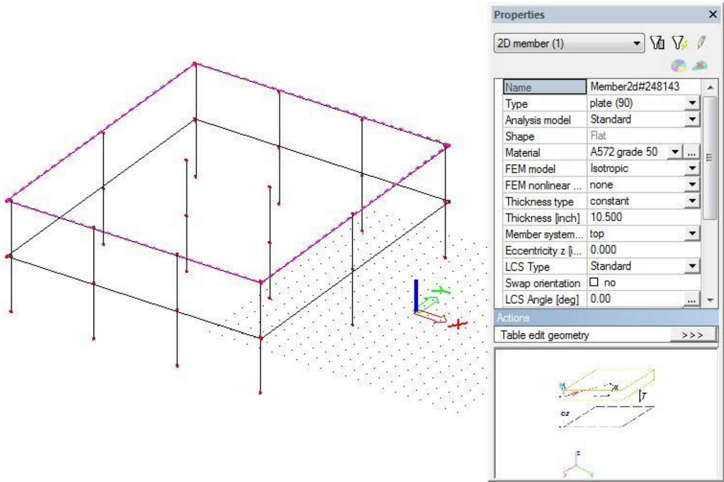
After clicking "OK", you will be able to interact with the model. Prior to performing structural analysis on model, all elements should have material properties assigned to them. Because Concrete Cast-in-Place has been mapped as Unknown in Scia, material properties can be seen to be missing for columns:



The material can be manually edited for the cross section in order to represent the correct one:

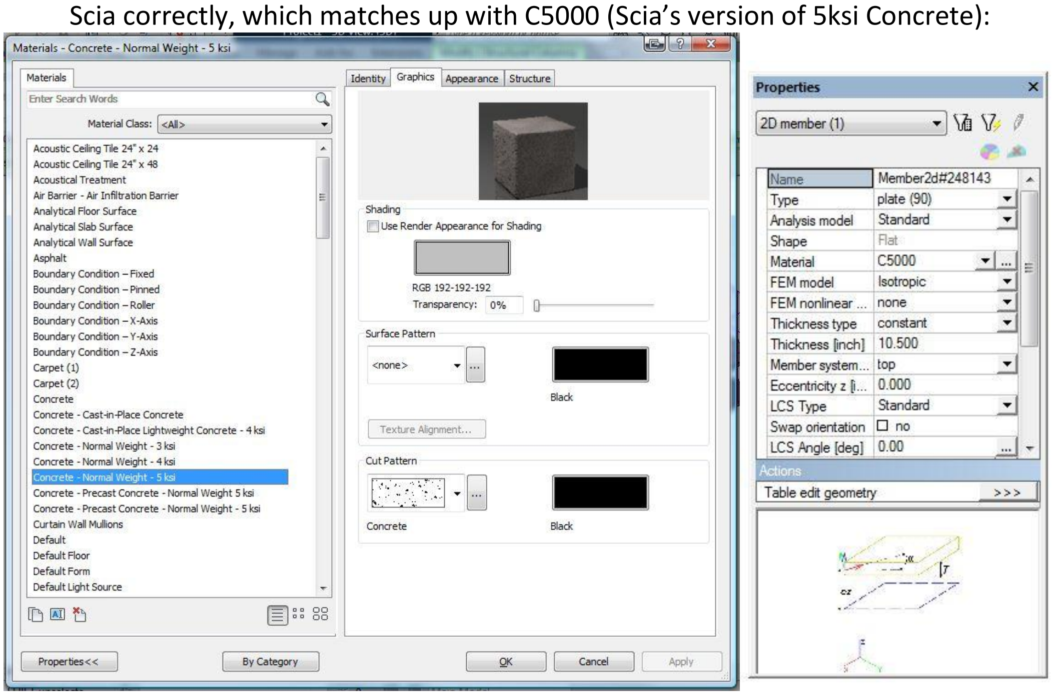


After columns have been checked and correct material has been decided, we checked the slab. We found that wrong material has been assigned to the slab:



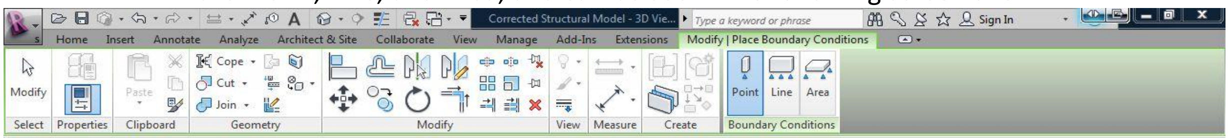
Instead of assigning a different type of concrete or not assigning material at all, Scia exported the cast-in-place concrete as A572 grade 50 Steel. This is a serious error because steel is a completely different type of material and errors like this can greatly compromise the structural integrity of the structure.

When you change the material in Revit to “Concrete - Normal Weight - 5 ksi”, the material is mapped in Scia correctly, which matches up with C5000 (Scia’s version of 5ksi Concrete):



Boundary Conditions

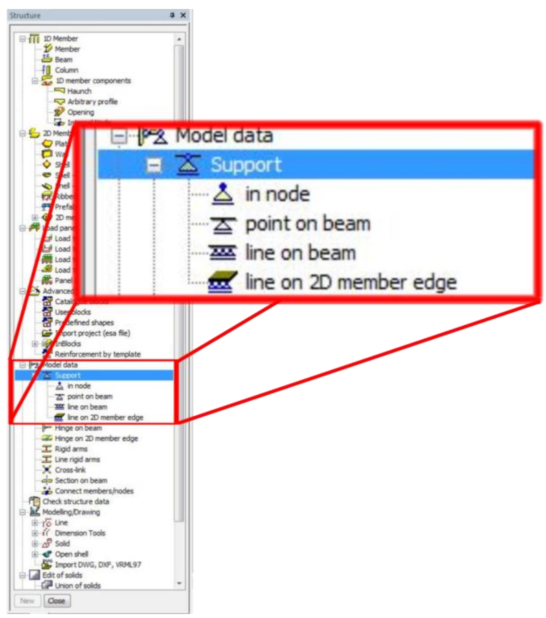
In Revit, three types of Boundary Conditions can be set for different types of members. These conditions are: Point, Line, and Area, and can be see in the following screen shot.



Point boundary conditions are used primarily for column supports. Line boundary conditions are used for foundation and retaining walls. Area boundary conditions are used for slabs on grade.

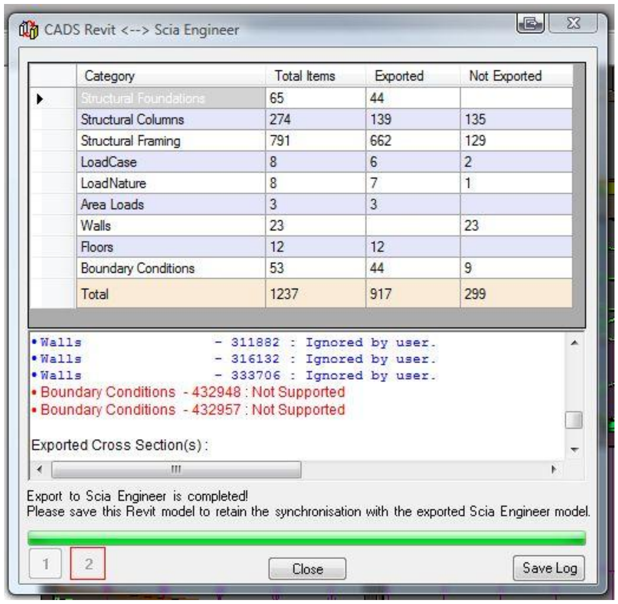
Boundary Conditions in Scia:

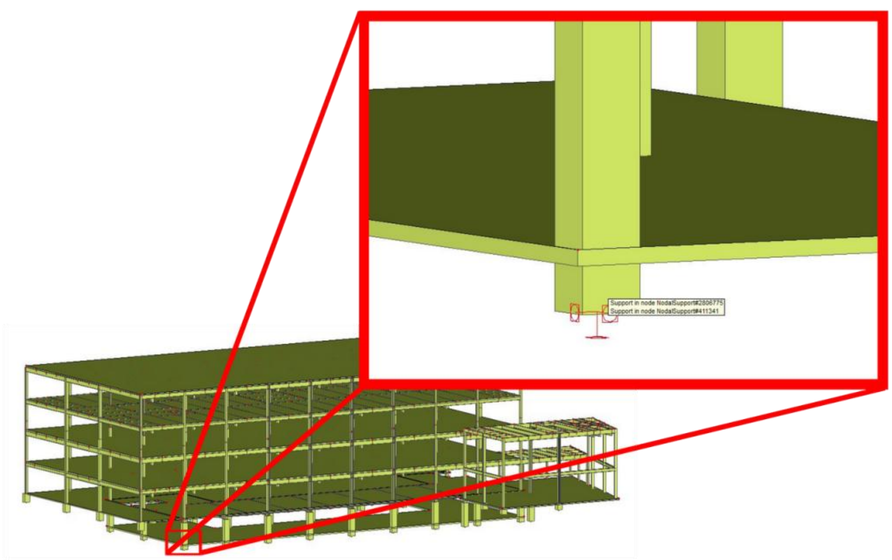
In Scia, boundary conditions are called "supports." If you look at Scia's structural menu (pictured below), you can see there there are 4 types of supports.



Robot Boundary Condition	Scia Support
Point	In node
N/A	Point on beam
Line	Line on beam Line on 2D member edge
Area	N/A

From this table we can see that exporting Point and Line loads from Revit to Scia would work, but If you Export a slab that is supported by an Area boundary condition, it will not be recognized in Scia, and thus the slab will not be supported at all (if it isn't connected to any other member), or it will be supported by the columns that it is attached to. During the export of a structure with an area boundary condition, you will recieve the following error in the export log:

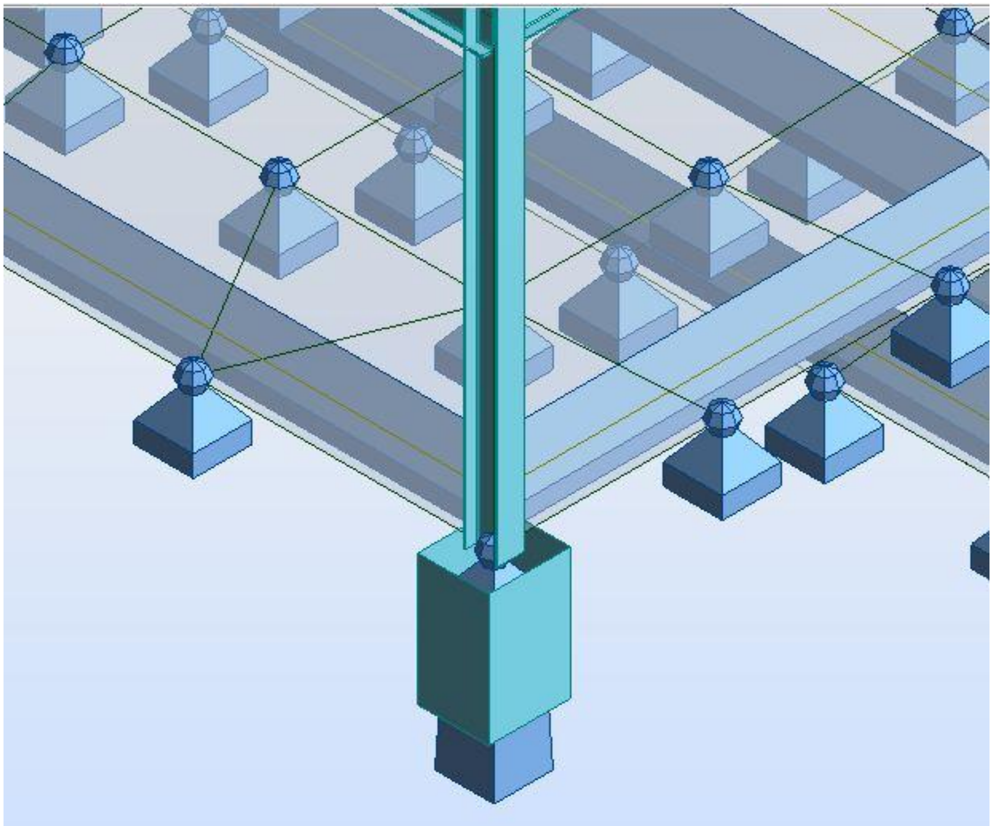




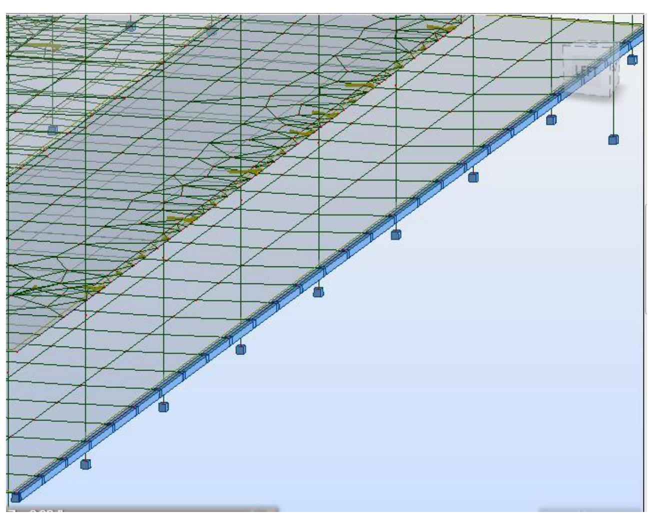
When you export a structure from Revit to Scia, Scia automatically replaces the foundation blocks with Rigid Support types.

Boundary Conditions in Robot:

Robot will model different boundary conditions depending on what is assigned in Revit. The screenshot below shows a fixed point boundary condition, modeled as a box, as well as an area boundary condition, modeled as a set of pin supports beneath the applied surface.

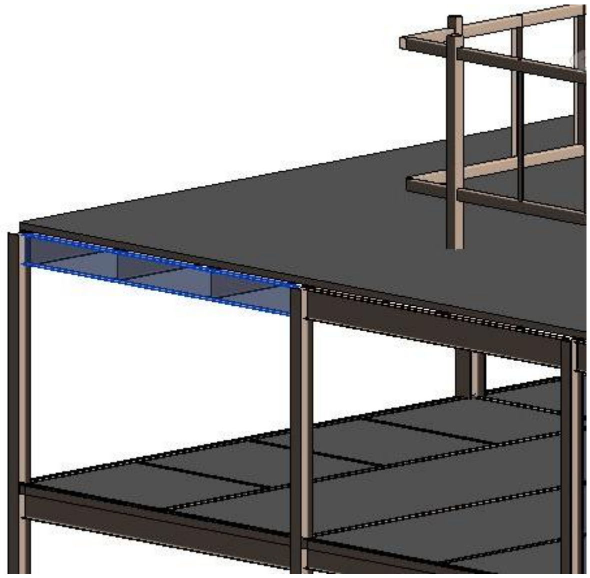


Linear boundary conditions will be set as a set of point boundary conditions applied along the length of a member as shown in the figure below.



Steel Connection Types

Overall in Revit you can set member beam and girder connections, which include none (pinned), cantilever moment and moment frame. Different connection type can be set to each different endpoint of the beam, ie. one side can be pinned while the ether side is connected with a moment connection.



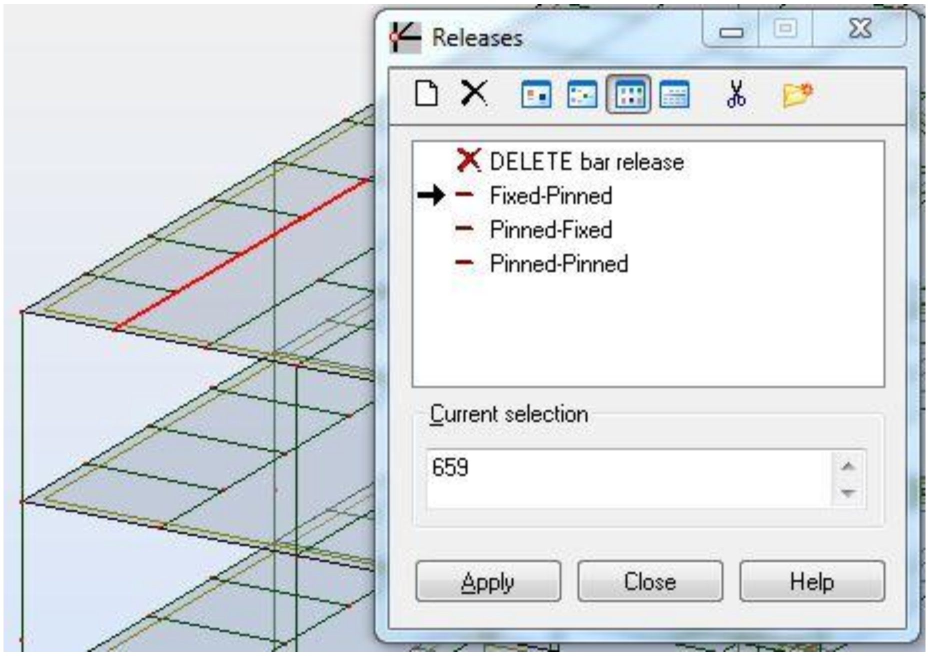
Steel Connections in Scia:

When exporting this structure to Scia, all connections turn into moment connection by default. No matter what type of connection is exported from Revit to Scia, Scia automatically treats them as moment connections. In order to create a pinned connection, a “hinge” must be places at the end of the beam.

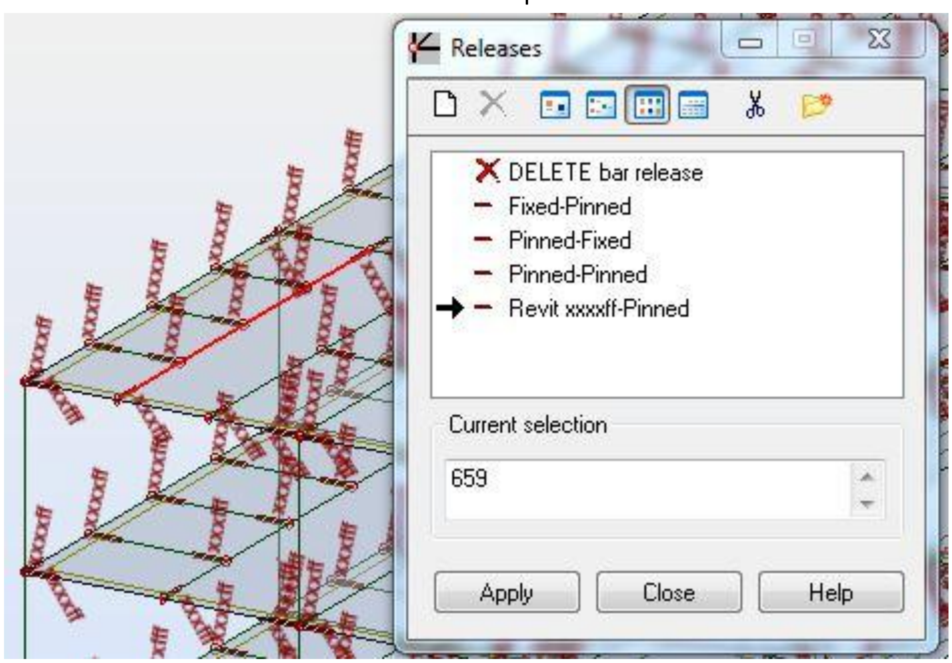
Scia support has been contacted to clarify whether or not steel connection types are available for export from Revit to Scia. The reply stated: “The import of connections from Revit to Scia Engineer is not supported.”

Steel Connections in Robot:

When exporting steel connections into Robot there are two different options, the connections can either be ignored if they were not previously set or may be exported as the values applied in Revit. In the send options of the export window there will be an option to export bar end releases as modeled in Revit or to ignore the releases. Ignoring releases will automatically export each member as a fixed pinned member as shown in in figure below.



Exported bar end releases will be displayed as Revit xxxxff-Pinned as shown in figure below regardless of the type of connection but will have different values for pinned and fixed connections.



Reinforcement

Scia does not support steel reinforcement to be exported from Revit. Overall, if you start a project in Scia and you use International Building Code as the primary code for the project, you will not be able to manually add reinforcement at all.

Robot supports steel reinforcement. It was used for the design of the cast-in-place concrete structure. Details about steel reinforcement in Robot can be in Appendix K.

Appendix J: Cast-in-Place Concrete Structure Hand Calculation

Table 6 Slab Design

150	pcf concrete
5000	psi concrete
60	ksi steel

Dead Load	161.25	psf
Live Load	100	psf
Reduced Live Load	53	psf
wu	353.5	psf
Mu	614	ft*kips

Clear Span	31.625	ft
Thickness	9.4875	in
Story Height	13.58	ft

Moments					
End Spans				Interior	
Slab Moments	Exterior Negative	Positive	Interior Negative	Positive	Negative
Total Moment	159.72	319.43	430.01	215.00	399.29
Column Strip	159.72	190.43	325.58	129.00	301.01
Middle Strip	0.00	129.00	104.43	86.00	98.29

Reinforcing								
Span Location		Mu	b (in)	d	As	As min	Bars No 4	No 5 bars
End Span								
Column Strip	Ext. Negative	159.72	66.00	9.25	4.32	1.39	22	14
	Ext. Positive	190.43	66.00	9.25	5.15	1.39	26	17
	Int. Negative	325.58	66.00	9.25	8.80	1.39	44	29
Middle Strip	Ext. Negative	0.00	132.00	9.25	0.00	2.77	14	9
	Ext. Positive	129.00	132.00	9.25	3.49	2.77	18	12
	Int. Negative	104.43	132.00	9.25	2.82	2.77	15	10
Interior Span								
Column Strip	Positive	129.00	132.00	9.25	3.49	2.49	18	12
Middle Strip	Positive	86.00	132.00	9.25	2.32	2.49	13	9

Table 7 Column Design

Interior Column Properties		
Size	22.5	in
2hr fire cover	0.75	in
lu	166.5	in
klu/h	8.325	
ϕPn	1607	k

Exterior Column Properties		
Size	16	in
2hr fire cover	0.75	in
lu	166.5	in
klu/h	8.33	
ϕPn	714.19	k

Interior Colum Design																							
Floor	DL	LL	AT	Reduced LL	Cumulative DL (kips)	Cumulative LL	Cumulative Factored Load	Cumulative Unfactored Load	Moment	Lateral Moment	kl/r	Eq9-2		Eq9-3		Eq9-4		Eq9-6		Ast	Pg	Bars	Number
												Pu	Mu	Pu	Mu	Pu	Mu	Pu	Mu				
5	120	20	739.75	10.52	96.27146	7.78	127.97	104.05	45.57	10.31	30.25	134.25	45.57	134.25	81.16	121.21	39.28	86.46	16.50	2.88	0.5%	6	7
4	179.31	100	739.75	52.58	236.42	46.67	358.37	283.09	45.57	21		397.17	45.57	397.17	89.71	318.91	56.38	212.50	33.60	2.88	0.5%	5	7
3	179.31	100	739.75	52.58	376.56	85.56	588.77	462.12	45.57	30		660.09	45.57	660.09	96.91	516.60	70.78	338.54	48.00	3.72	0.6%	6	8
2	179.31	100	739.75	52.58	516.71	124.46	819.18	641.16	68.35	44		923.01	68.35	923.01	144.56	714.30	104.58	464.58	70.40	5.18	0.9%	8	8
1	179.31	150	739.75	150	656.85	235.42	1164.89	892.27	68.35	44		1268.60	68.35	1268.60	144.56	937.84	104.58	590.62	70.40	10.16	1.8%	8	10

Exterior Column Design																							
Floor	DL	LL	AT	Reduced LL	Cumulative DL (kips)	Cumulative LL	Cumulative Factored Load	Cumulative Unfactored Load	Moment	Lateral Moment	kl/r	Eq9-2		Eq9-3		Eq9-4		Eq9-6					Number
												Pu	Mu	Pu	Mu	Pu	Mu	Pu	Mu	Ast	Pg	Bars	5
5	120	20	369.88	20	48.07388	7.3975	69.52466667	55.47138889	45.5686	5.41	45.4	69.52	45.57	69.52	77.24	61.39	31.44	43.27	8.66	1.28	0.5%	4	5
4	170.4	100	369.88	100	114.7711	44.385	208.7414313	159.1561927	45.5686	14.25		208.74	45.57	208.74	84.31	159.92	45.58	103.29	22.80	1.28	0.5%	4	8
3	170.4	100	369.88	100	181.4684	81.3725	347.9581959	262.8409966	45.5686	18		347.96	45.57	347.96	87.31	258.45	51.58	163.32	28.80	1.55	0.6%	4	10
2	170.4	100	369.88	100	248.1658	118.36	487.1749605	366.5258004	68.3529	39		487.17	68.35	487.17	140.56	356.98	96.58	223.35	62.40	3.66	1.4%	4	11
1	170.4	150	369.88	150	314.8631	173.84125	655.9817251	488.7043542	68.3529	39		655.98	68.35	655.98	140.56	464.76	96.58	283.38	62.40	6.24	2.4%	4	

Pg	0.02	
As	0.529795	in^2
Bars	8	No. 10

Table 8 Foundation Design

Basement Design							
4 Feet deep							
Soil Capacity	3.5	ksf					
interior Column Load	892.27	k		Exterior Column Load	446.51	kips	
Areq	254.93	sq feet		Areq	127.57	sq feet	
Footing Size	22	feet		Footing Size	13	ft	
	15	Feet					
Depth	3	feet		Depth	2.5	ft	
Area	330	Sq feet		Area	169	sq feet	
Allowable Load	1155	kips		Allowable Load	591.5	sq feet	
Total Load	1040.77	kips		Total Load	509.88	Kips	
Foundation Size	15 Foot wide mat			Foundation Size	13 Foot Spread Footing		

First Floor Design							
4 Feet deep							
Soil Capacity	6	ksf					
interior Column Load	641.16	k		Exterior Column Load	324.25	kips	
Areq	106.86	sq feet		Areq	54.04	sq feet	
Footing Size	11.5	feet		Footing Size	8.5	ft	
	11.5	Feet					
Depth	3	feet		Depth	2	ft	
Area	132.25	Sq feet		Area	72.25	sq feet	
Allowable Load	793.5	kips		Allowable Load	433.5	sq feet	
Total Load	700.67	kips		Total Load	345.93	Kips	
Foundation Size	11.5 foot spread footing			Foundation Size	8.5 Spread Footing		

1.5 Feet Deep							
Soil Capacity	3	ksf					
interior Column Load	892.27	k		Exterior Column Load	446.51	kips	
Areq	297.42	sq feet		Areq	148.84	sq feet	
Footing Size	22	feet		Footing Size	14	ft	
	17.5	Feet					
Depth	3	feet		Depth	2.5	ft	
Area	385	Sq feet		Area	196	sq feet	
Allowable Load	1155	kips		Allowable Load	588	sq feet	
Total Load	1065.52	kips		Total Load	520.01	Kips	
Foundation Size	17.5 foot mat			Foundation Size	14 ft spread footing		

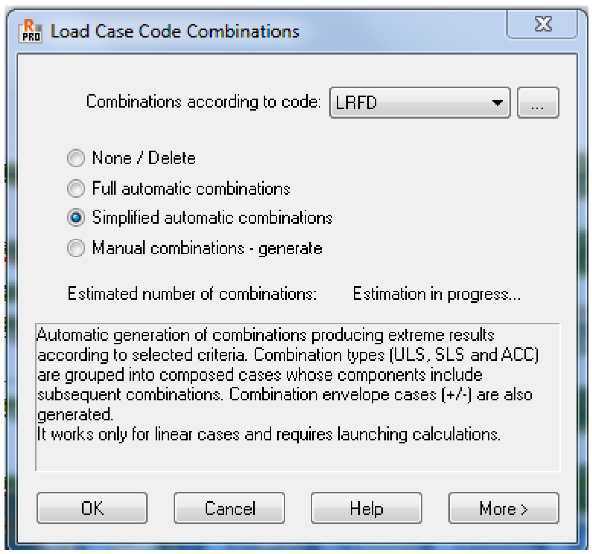
1.5 feet deep							
Soil Capacity	4	ksf					
interior Column Load	641.16	k		Exterior Column Load	324.25	kips	
Areq	160.29	sq feet		Areq	81.06	sq feet	
Footing Size	14.50	feet		Footing Size	10	ft	
	14.50	Feet					
Depth	3.00	feet		Depth	2	ft	
Area	210.25	Sq feet		Area	100	sq feet	
Allowable Load	841.00	kips		Allowable Load	400	sq feet	
Total Load	735.77	kips		Total Load	354.25	Kips	
Foundation Size	14.5 foot spread footing			Foundation Size	8.5 Spread Footing		

Table 9 Exterior Beam Design

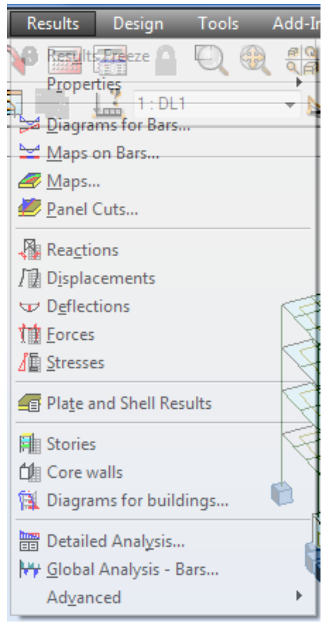
Beam	16	in square										
Floor	DL	LL	AT	Reduced LL	Factored DL (plf)	Factored LL (plf)	Wu (klf)	L	Mu (k ft)	Vu Center	Vu Support	Vu at d
5	120.00	20.00	350.75	16.33	1656.00	300.41	1.96	36.75	330.2823	35.94909	32.03627	33.34054
4	179.31	100.00	350.75	81.63	3126.45	1502.07	4.63	36.75	781.3878	85.04901	75.79198	78.87766
3	179.31	100.00	350.75	81.63	3126.45	1502.07	4.63	36.75	781.3878	85.04901	75.79198	78.87766
2	179.31	100.00	350.75	81.63	3126.45	1502.07	4.63	36.75	781.3878	85.04901	75.79198	78.87766
1	179.31	150.00	350.75	150.00	3126.45	2760.00	5.89	36.75	993.7526	108.1636	96.39065	100.3149

Appendix K: Cast-in-Place Concrete Structural Analysis

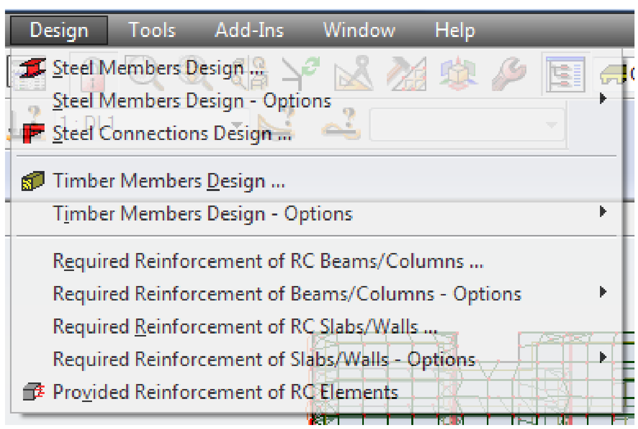
Assuming that proper modeling and export guidelines have been followed the structural analysis and design should begin with a fully exported structural model with boundary conditions and loads applied. If loading conditions were created in the Revit model as well they will have already been loaded into the analysis project. If they were not created new load combinations will have to be created. If major load cases have already been identified they may be input into the project manually, and if not the automatic combinations option has a simplified automatic combinations option which will generate a list of combinations which will produce the most extreme results. The figure below shows the different types of combinations that Robot Structural Analysis can create.



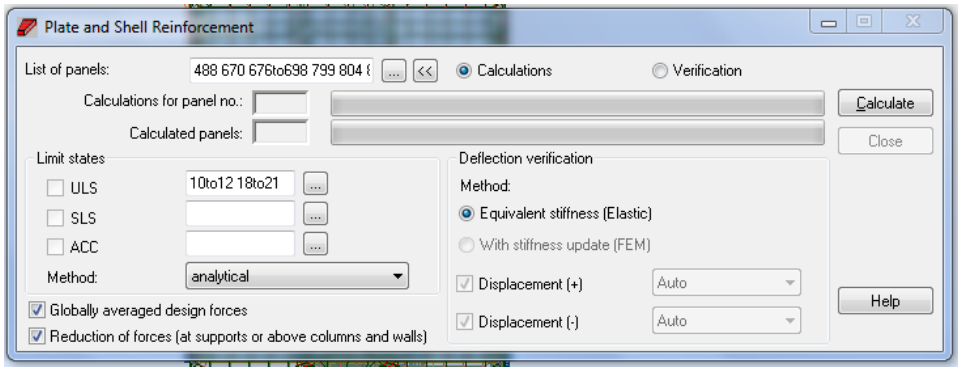
Once the load combinations have been created the structure can be analyzed for internal forces and deflections. Different results can be viewed by the selecting the results option from the main menu, shown in the figure below. One of the most useful, single glance overviews available is the maps option. Any areas with large deflections will appear so any areas with errors in modeling or design can be viewed.



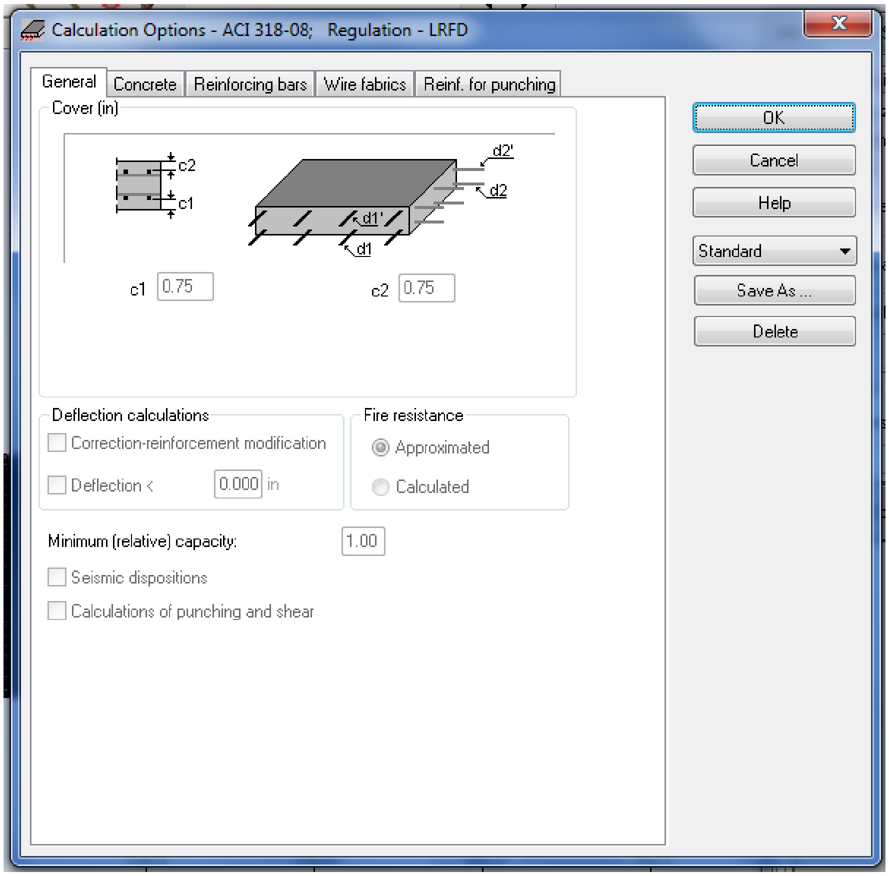
Once the structure has been analyzed the project may be loaded into the concrete design module which is split between RC Beams/Columns and RC Slabs/Walls, as show below.



In general RC Slabs/Walls should be completed first to ensure proper punching capacity which could require resizing columns. The main component for the RC Slabs/Walls module will be the Plate and Shell Reinforcement pane shown below. Any elements of interest, or the entire building, may be analyzed in the List of Panels area. Members may be chosen based on groupings made, family type, or by member number. One key option that must be selected is the reduction of forces (at supports or above columns and walls). This option will reduce the number of finite elements around columns to avoid the extremely high forces which would typically be a result of the column being analyzed as a point.



The results of the plate and shell reinforcement will be stored as a required reinforcement and will be used in the Provided Reinforcement of RC Elements module. The RC design requires that each element to be designed be selected in the main view of Robot. Once in the Provided Reinforcement module several parameters for design may be selected. The calculations option under the analysis tab will allow for different design parameters to be selected. One possible set of values can be seen below. Once all parameters have been set the calculations can be started, also located in the analysis tab. This will also provide the option of generating a set of drawings for the calculated elements which will show general plans, reinforcement patterns and schedule of required reinforcing bars and the corresponding lengths.



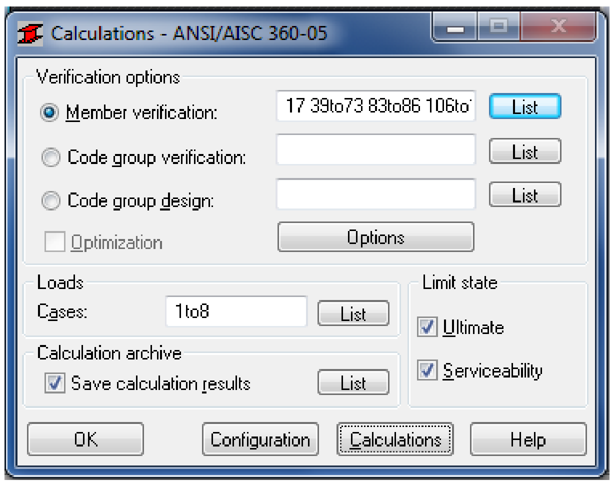
The design module for RC Beams/Columns will be very similar to the RC Slabs/Walls module with the exception of a required reinforcement summary pane. This pane will be blank until the calculations are run for each member at which point it will give a summary of the required reinforcement. One example can be seen below.

Bar	Required reinforcement along b (in2)	Reinforcement along b - distribution	Required reinforcement along h (in2)	Reinforcement along h - distribution	Transversal reinforcement - type/distribution
490	0.80	2#8	0.48	2#8	2#4 30@7.00
498	0.80	2#8	0.48	2#8	2#4 30@7.00
499	0.80	2#8	0.48	2#8	2#4 30@7.00
500	0.80	2#8	0.48	2#8	2#4 30@7.00
501	0.80	2#8	0.48	2#8	2#4 30@7.00
508	0.80	2#8	0.48	2#8	2#4 19@7.00
509	0.80	2#8	0.48	2#8	2#4 19@7.00
510	0.80	2#8	0.48	2#8	2#4 19@7.00
511	1.14	2#8	0.14	2#8	2#4 19@7.00
512	0.12	2#8	1.16	2#8	2#4 19@7.00
513	1.27	2#8	1.61	3#8	2#4 16@11.00
514	1.80	3#8	1.08	2#8	2#4 19@11.00
515	1.80	3#8	1.08	2#8	2#4 19@11.00
516	1.80	3#8	1.08	2#8	2#4 19@11.00
517	1.80	3#8	1.08	2#8	2#4 19@11.00
518	1.80	3#8	1.08	2#8	2#4 19@11.00
519	2.78	4#8	0.10	2#8	2#4 16@11.00
520	0.46	2#8	2.42	4#8	2#4 16@11.00
521	1.80	3#8	1.08	2#8	2#4 16@11.00
522	1.80	3#8	1.08	2#8	2#4 16@11.00
523	1.80	3#8	1.08	2#8	2#4 16@11.00

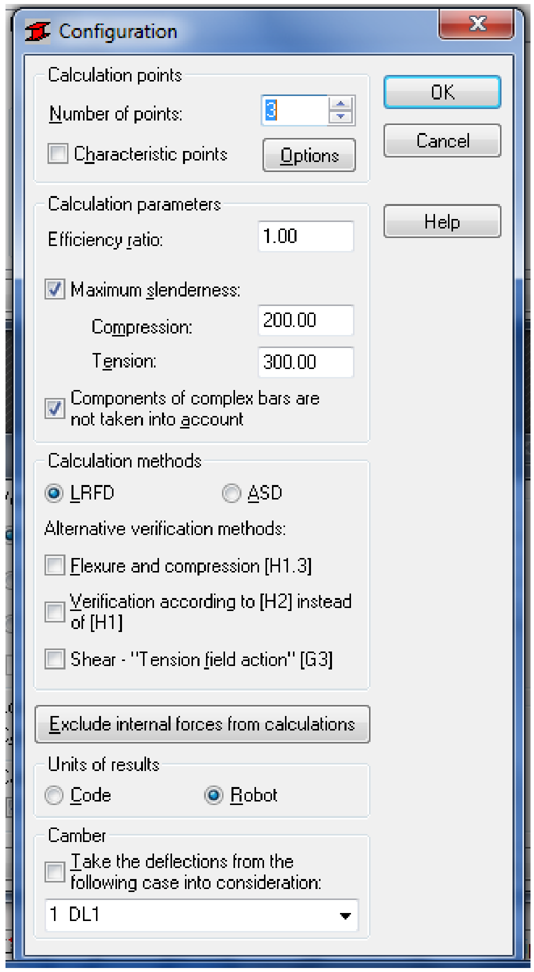
After this point the beams and column provided reinforcement will be identical to the slab provided reinforcement, even using the same design module.

Appendix L: Steel Building Structural Analysis

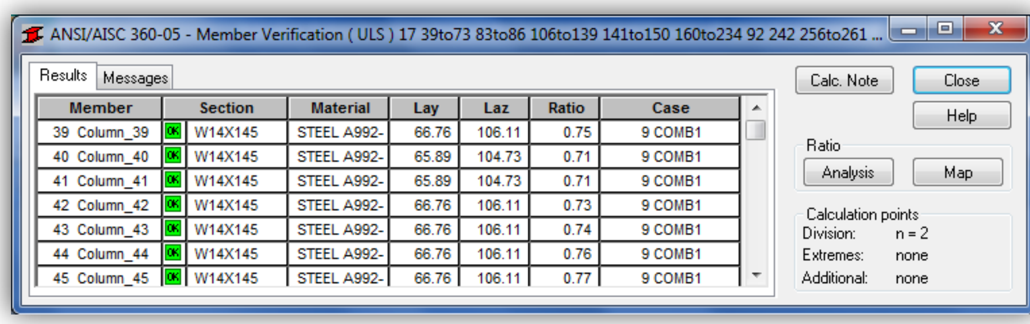
The steel analysis process can be completed in the same manner as the concrete analysis. Refer to Appendix K for the analysis process. After the analysis has been completed the structure should go through the steel members design module available under the design tab. The design module will bring up a number of different options however the main one used will be the calculations pane, shown below. If there are certain areas of interest or members which need to be verified individual members can be verified as opposed to running verifications on the entire building.



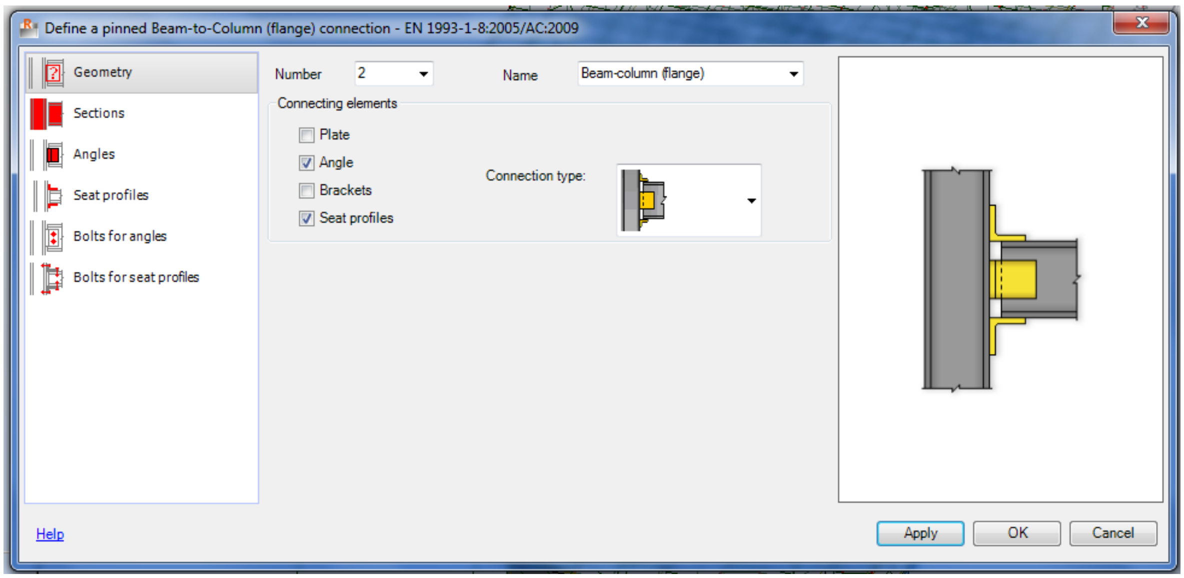
Certain configurations can be set for the member verification from the configurations option in the calculations tab. The different options will allow for various settings to be adjusted such as number of points for analysis, efficiency ratios, calculation methods and alternative verification methods, show in the figure below.



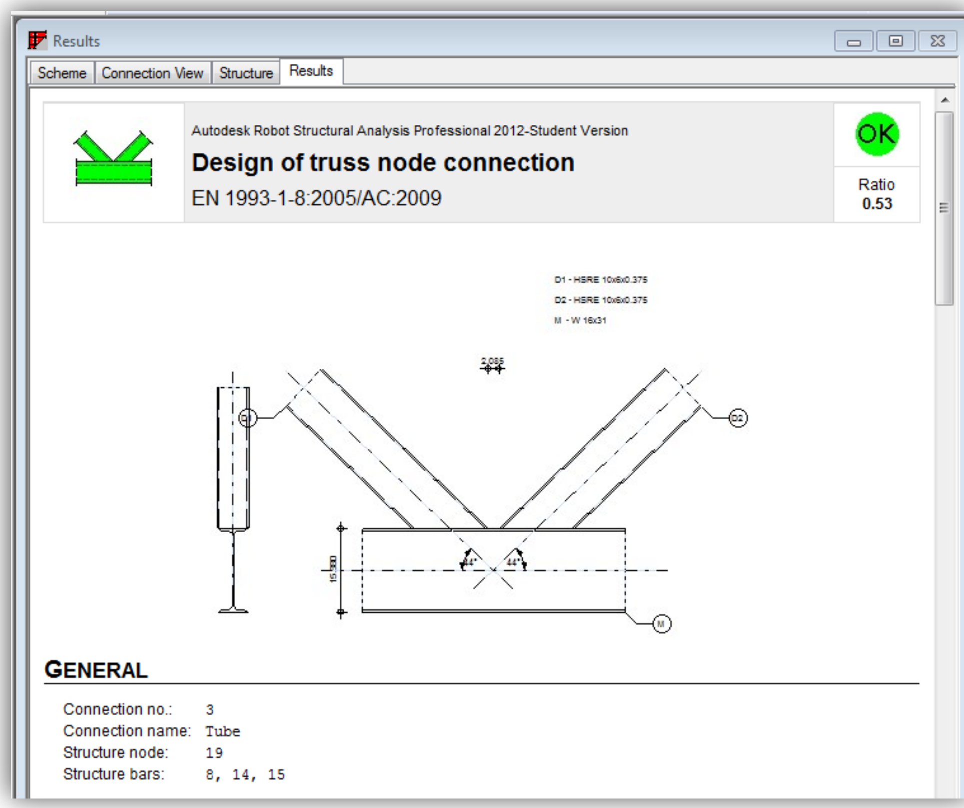
The results from the member verification are presented in tabular form and give an overview of the members including section, material, applicable ratios, and most extreme loading cases. One example is shown below. Any members which fail the member verification will appear without the check marks and can be opened for further details.



After all the members have been verified the design can be input into the steel connection design module to create and detail connections. The connection design module can automatically select the type of connection to design based on members selected in the structure tab of the design module. For a standard beam to column connection the members may be attached using either angle irons or plates and then fixed using brackets or seat profiles, a screen shot is provided below. Different properties for the connections used may be set such as angle sections and number of bolts required.



Once the connection has been fully designed Robot will provide a sample drawing providing member properties, connection geometry, and bolt/weld verifications. These will be automatically applied to the building. A sample connection note can be seen below.


Results

Scheme | Connection View | Structure | Results

Autodesk Robot Structural Analysis Professional 2012-Student Version

Design of truss node connection

EN 1993-1-8:2005/AC:2009

OK

Ratio
0.53

GENERAL

Connection no.: 3
Connection name: Tube
Structure node: 19
Structure bars: 8, 14, 15

Appendix M: Moment Connections (Welds & Web Stiffeners)

Table 10 Required Field Welds and Web Stiffeners

Connection Number	Girder	Girder Flange Width (in)	Girder Flange Thickness (in)	Column	Column Flange Width (in)	Column Flange Thickness (in)	Column Web Thickness (in)	Column Web Height (in)	Connection Method	Area of Web Stiffener (in^2)	Thickness of Web Stiffener (in)	Length of Welds for Stiffener (in)	Depth of Welds for Stiffener (in)	Length of Beam Welds (in)	Thickness of Beam Welds (in)	Length of Welds for backing bar (in)	Thickness of welds for backing bar (in)
1	W24X104	12.8	0.75	W14x132	14.7	1.03	0.645	10	B to F	281.1	0.75	192.44	0.375	25.6	0.75	51.2	0.3125
2	W24X104	12.8	0.75	W14x132	14.7	1.03	0.645	10	B to F	281.1	0.75	192.44	0.375	25.6	0.75	51.2	0.3125
3	W24X104	12.8	0.75	W14x132	14.7	1.03	0.645	10	B to F	281.1	0.75	192.44	0.375	25.6	0.75	51.2	0.3125
4	W24X104	12.8	0.75	W14x132	14.7	1.03	0.645	10	B to F	281.1	0.75	192.44	0.375	25.6	0.75	51.2	0.3125
5	W24X104	12.8	0.75	W14x132	14.7	1.03	0.645	10	B to F	281.1	0.75	192.44	0.375	25.6	0.75	51.2	0.3125
6	W24X104	12.8	0.75	W14x132	14.7	1.03	0.645	10	B to F	281.1	0.75	192.44	0.375	25.6	0.75	51.2	0.3125
7	W24X104	12.8	0.75	W14x132	14.7	1.03	0.645	10	B to F	281.1	0.75	192.44	0.375	25.6	0.75	51.2	0.3125
8	W24X104	12.8	0.75	W14x132	14.7	1.03	0.645	10	B to F	281.1	0.75	192.44	0.375	25.6	0.75	51.2	0.3125
9	W24x84	9.02	0.77	W14x109	14.6	0.86	0.525	10	B to F	281.5	0.77	192.6	0.385	18.04	0.77	36.08	0.3125
10	W24x84	9.02	0.77	W14x109	14.6	0.86	0.525	10	B to F	281.5	0.77	192.6	0.385	18.04	0.77	36.08	0.3125
11	W24x84	9.02	0.77	W14x109	14.6	0.86	0.525	10	B to F	281.5	0.77	192.6	0.385	18.04	0.77	36.08	0.3125
12	W24x84	9.02	0.77	W14x109	14.6	0.86	0.525	10	B to F	281.5	0.77	192.6	0.385	18.04	0.77	36.08	0.3125
13	W24x84	9.02	0.77	W14x109	14.6	0.86	0.525	10	B to F	281.5	0.77	192.6	0.385	18.04	0.77	36.08	0.3125
14	W24x84	9.02	0.77	W14x109	14.6	0.86	0.525	10	B to F	281.5	0.77	192.6	0.385	18.04	0.77	36.08	0.3125
15	W24x84	9.02	0.77	W14x109	14.6	0.86	0.525	10	B to F	281.5	0.77	192.6	0.385	18.04	0.77	36.08	0.3125
16	W24x84	9.02	0.77	W14x109	14.6	0.86	0.525	10	B to F	281.5	0.77	192.6	0.385	18.04	0.77	36.08	0.3125
17	W24X104	12.8	0.75	W14x132	14.7	1.03	0.645	10	B to F	281.1	0.75	192.44	0.375	25.6	0.75	51.2	0.3125
18	W24X104	12.8	0.75	W14x132	14.7	1.03	0.645	10	B to F	281.1	0.75	192.44	0.375	25.6	0.75	51.2	0.3125
19	W24X104	12.8	0.75	W14x132	14.7	1.03	0.645	10	B to F	281.1	0.75	192.44	0.375	25.6	0.75	51.2	0.3125
20	W24X104	12.8	0.75	W14x132	14.7	1.03	0.645	10	B to F	281.1	0.75	192.44	0.375	25.6	0.75	51.2	0.3125
21	W24X104	12.8	0.75	W14x132	14.7	1.03	0.645	10	B to F	281.1	0.75	192.44	0.375	25.6	0.75	51.2	0.3125
22	W24X104	12.8	0.75	W14x132	14.7	1.03	0.645	10	B to F	281.1	0.75	192.44	0.375	25.6	0.75	51.2	0.3125
23	W24X104	12.8	0.75	W14x132	14.7	1.03	0.645	10	B to F	281.1	0.75	192.44	0.375	25.6	0.75	51.2	0.3125
24	W24X104	12.8	0.75	W14x132	14.7	1.03	0.645	10	B to F	281.1	0.75	192.44	0.375	25.6	0.75	51.2	0.3125
25	W24x84	9.02	0.77	W14x109	14.6	0.86	0.525	10	B to F	281.5	0.77	192.6	0.385	18.04	0.77	36.08	0.3125
26	W24x84	9.02	0.77	W14x109	14.6	0.86	0.525	10	B to F	281.5	0.77	192.6	0.385	18.04	0.77	36.08	0.3125
27	W24x84	9.02	0.77	W14x109	14.6	0.86	0.525	10	B to F	281.5	0.77	192.6	0.385	18.04	0.77	36.08	0.3125
28	W24x84	9.02	0.77	W14x109	14.6	0.86	0.525	10	B to F	281.5	0.77	192.6	0.385	18.04	0.77	36.08	0.3125
29	W24x84	9.02	0.77	W14x109	14.6	0.86	0.525	10	B to F	281.5	0.77	192.6	0.385	18.04	0.77	36.08	0.3125
30	W24x84	9.02	0.77	W14x109	14.6	0.86	0.525	10	B to F	281.5	0.77	192.6	0.385	18.04	0.77	36.08	0.3125
31	W24x84	9.02	0.77	W14x109	14.6	0.86	0.525	10	B to F	281.5	0.77	192.6	0.385	18.04	0.77	36.08	0.3125
32	W24x84	9.02	0.77	W14x109	14.6	0.86	0.525	10	B to F	281.5	0.77	192.6	0.385	18.04	0.77	36.08	0.3125
33	W21X166	12.4	1.36	W14x145	15.5	1.09	0.68	10	B to F	296.4	1.36	198.56	0.68	24.8	1.36	49.6	0.3125
34	W21X166	12.4	1.36	W14x145	15.5	1.09	0.68	10	B to F	296.4	1.36	198.56	0.68	24.8	1.36	49.6	0.3125
35	W24X131	12.9	0.96	W14x145	15.5	1.09	0.68	10	B to F	296.4	0.96	198.56	0.48	25.8	0.96	51.6	0.3125
36	W24X131	12.9	0.96	W14x145	15.5	1.09	0.68	10	B to F	296.4	0.96	198.56	0.48	25.8	0.96	51.6	0.3125

37	W24X94	9.07	0.875	W14x109	14.6	0.86	0.525	10	B to F	281.5	0.875	192.6	0.4375	18.14	0.875	36.28	0.3125
38	W24X94	9.07	0.875	W14x109	14.6	0.86	0.525	10	B to F	281.5	0.875	192.6	0.4375	18.14	0.875	36.28	0.3125
39	W24X94	9.07	0.875	W14x109	14.6	0.86	0.525	10	B to F	281.5	0.875	192.6	0.4375	18.14	0.875	36.28	0.3125
40	W24X94	9.07	0.875	W14x109	14.6	0.86	0.525	10	B to F	281.5	0.875	192.6	0.4375	18.14	0.875	36.28	0.3125
41	W24X131	12.9	0.96	W14x145	15.5	1.09	0.68	10	B to F	296.4	0.96	198.56	0.48	25.8	0.96	51.6	0.3125
42	W24X131	12.9	0.96	W14x145	15.5	1.09	0.68	10	B to F	296.4	0.96	198.56	0.48	25.8	0.96	51.6	0.3125
43	W24X131	12.9	0.96	W14x145	15.5	1.09	0.68	10	B to F	296.4	0.96	198.56	0.48	25.8	0.96	51.6	0.3125
44	W24X131	12.9	0.96	W14x145	15.5	1.09	0.68	10	B to F	296.4	0.96	198.56	0.48	25.8	0.96	51.6	0.3125
45	W24X94	9.07	0.875	W14x109	14.6	0.86	0.525	10	B to F	281.5	0.875	192.6	0.4375	18.14	0.875	36.28	0.3125
46	W24X94	9.07	0.875	W14x109	14.6	0.86	0.525	10	B to F	281.5	0.875	192.6	0.4375	18.14	0.875	36.28	0.3125
47	W24X94	9.07	0.875	W14x109	14.6	0.86	0.525	10	B to F	281.5	0.875	192.6	0.4375	18.14	0.875	36.28	0.3125
48	W24X94	9.07	0.875	W14x109	14.6	0.86	0.525	10	B to F	281.5	0.875	192.6	0.4375	18.14	0.875	36.28	0.3125
49	W18X60	7.56	0.695	W14x145	15.5	1.09	0.68	10	B to F	296.4	0.695	198.56	0.3475	15.12	0.695	30.24	0.3125
50	W18X60	7.56	0.695	W14x145	15.5	1.09	0.68	10	B to F	296.4	0.695	198.56	0.3475	15.12	0.695	30.24	0.3125
51	W30X132	10.5	1	W14x145	15.5	1.09	0.68	10	B to F	296.4	1	198.56	0.5	21	1	42	0.3125
52	W30X132	10.5	1	W14x145	15.5	1.09	0.68	10	B to F	296.4	1	198.56	0.5	21	1	42	0.3125
53	W30X132	10.5	1	W14x145	15.5	1.09	0.68	10	B to F	296.4	1	198.56	0.5	21	1	42	0.3125
54	W30X132	10.5	1	W14x145	15.5	1.09	0.68	10	B to F	296.4	1	198.56	0.5	21	1	42	0.3125
55	W30X99	10.5	0.67	W14x109	14.6	0.86	0.525	10	B to F	281.5	0.67	192.6	0.335	21	0.67	42	0.3125
56	W30X99	10.5	0.67	W14x109	14.6	0.86	0.525	10	B to F	281.5	0.67	192.6	0.335	21	0.67	42	0.3125
57	W30X99	10.5	0.67	W14x109	14.6	0.86	0.525	10	B to F	281.5	0.67	192.6	0.335	21	0.67	42	0.3125
58	W30X99	10.5	0.67	W14x109	14.6	0.86	0.525	10	B to F	281.5	0.67	192.6	0.335	21	0.67	42	0.3125
59	W30X132	10.5	1	W14x145	15.5	1.09	0.68	10	B to F	296.4	1	198.56	0.5	21	1	42	0.3125
60	W30X132	10.5	1	W14x145	15.5	1.09	0.68	10	B to F	296.4	1	198.56	0.5	21	1	42	0.3125
61	W30X132	10.5	1	W14x145	15.5	1.09	0.68	10	B to F	296.4	1	198.56	0.5	21	1	42	0.3125
62	W30X132	10.5	1	W14x145	15.5	1.09	0.68	10	B to F	296.4	1	198.56	0.5	21	1	42	0.3125
63	W30X99	10.5	0.67	W14x109	14.6	0.86	0.525	10	B to F	281.5	0.67	192.6	0.335	21	0.67	42	0.3125
64	W30X99	10.5	0.67	W14x109	14.6	0.86	0.525	10	B to F	281.5	0.67	192.6	0.335	21	0.67	42	0.3125
65	W30X99	10.5	0.67	W14x109	14.6	0.86	0.525	10	B to F	281.5	0.67	192.6	0.335	21	0.67	42	0.3125
66	W30X99	10.5	0.67	W14x109	14.6	0.86	0.525	10	B to F	281.5	0.67	192.6	0.335	21	0.67	42	0.3125
67	W30X132	10.5	1	W14x145	15.5	1.09	0.68	10	B to F	296.4	1	198.56	0.5	21	1	42	0.3125
68	W30X132	10.5	1	W14x145	15.5	1.09	0.68	10	B to F	296.4	1	198.56	0.5	21	1	42	0.3125
69	W30X132	10.5	1	W14x145	15.5	1.09	0.68	10	B to F	296.4	1	198.56	0.5	21	1	42	0.3125
70	W30X132	10.5	1	W14x145	15.5	1.09	0.68	10	B to F	296.4	1	198.56	0.5	21	1	42	0.3125
71	W30X99	10.5	0.67	W14x109	14.6	0.86	0.525	10	B to F	281.5	0.67	192.6	0.335	21	0.67	42	0.3125
72	W30X99	10.5	0.67	W14x109	14.6	0.86	0.525	10	B to F	281.5	0.67	192.6	0.335	21	0.67	42	0.3125
73	W30X99	10.5	0.67	W14x109	14.6	0.86	0.525	10	B to F	281.5	0.67	192.6	0.335	21	0.67	42	0.3125
74	W30X99	10.5	0.67	W14x109	14.6	0.86	0.525	10	B to F	281.5	0.67	192.6	0.335	21	0.67	42	0.3125
75	W30X132	10.5	1	W14x145	15.5	1.09	0.68	10	B to F	296.4	1	198.56	0.5	21	1	42	0.3125
76	W30X132	10.5	1	W14x145	15.5	1.09	0.68	10	B to F	296.4	1	198.56	0.5	21	1	42	0.3125
77	W30X132	10.5	1	W14x145	15.5	1.09	0.68	10	B to F	296.4	1	198.56	0.5	21	1	42	0.3125
78	W30X132	10.5	1	W14x145	15.5	1.09	0.68	10	B to F	296.4	1	198.56	0.5	21	1	42	0.3125
79	W30X99	10.5	0.67	W14x109	14.6	0.86	0.525	10	B to F	281.5	0.67	192.6	0.335	21	0.67	42	0.3125

80	W30X99	10.5	0.67	W14x109	14.6	0.86	0.525	10	B to F	281.5	0.67	192.6	0.335	21	0.67	42	0.3125
81	W30X99	10.5	0.67	W14x109	14.6	0.86	0.525	10	B to F	281.5	0.67	192.6	0.335	21	0.67	42	0.3125
82	W30X99	10.5	0.67	W14x109	14.6	0.86	0.525	10	B to F	281.5	0.67	192.6	0.335	21	0.67	42	0.3125
83	W24X76	8.99	0.68	W12X79	12.1	0.735	0.47	9.125	B to W	230.4975	0.68	166.04	0.34	17.98	0.68	35.96	0.3125
84	W24X76	8.99	0.68	W12X106	12.2	0.99	0.61	9.125	B to F	211.5175	0.68	165.72	0.34	17.98	0.68	35.96	0.3125
85	W24X76	8.99	0.68	W12X106	12.2	0.99	0.61	9.125	B to F	211.5175	0.68	165.72	0.34	17.98	0.68	35.96	0.3125
86	W24X76	8.99	0.68	W12X87	12.1	0.81	0.515	9.125	B to W	229.67625	0.68	165.68	0.34	17.98	0.68	35.96	0.3125
87	W16X67	10.2	0.665	W12X79	12.1	0.735	0.47	9.125	B to W	230.4975	0.665	166.04	0.3325	20.4	0.665	40.8	0.3125
88	W16X67	10.2	0.665	W12X106	12.2	0.99	0.61	9.125	B to F	211.5175	0.665	165.72	0.3325	20.4	0.665	40.8	0.3125
89	W16X67	10.2	0.665	W12X106	12.2	0.99	0.61	9.125	B to F	211.5175	0.665	165.72	0.3325	20.4	0.665	40.8	0.3125
90	W16X67	10.2	0.665	W12X79	12.1	0.735	0.47	9.125	B to W	230.4975	0.665	166.04	0.3325	20.4	0.665	40.8	0.3125
91	W24X76	8.99	0.68	W12X79	12.1	0.735	0.47	9.125	B to W	230.4975	0.68	166.04	0.34	17.98	0.68	35.96	0.3125
92	W24X76	8.99	0.68	W12X106	12.2	0.99	0.61	9.125	B to F	211.5175	0.68	165.72	0.34	17.98	0.68	35.96	0.3125
93	W24X76	8.99	0.68	W12X106	12.2	0.99	0.61	9.125	B to F	211.5175	0.68	165.72	0.34	17.98	0.68	35.96	0.3125
94	W24X76	8.99	0.68	W12X79	12.1	0.735	0.47	9.125	B to W	230.4975	0.68	166.04	0.34	17.98	0.68	35.96	0.3125
95	W16X67	10.2	0.665	W12X79	12.1	0.735	0.47	9.125	B to F	212.2475	0.665	166.04	0.3325	20.4	0.665	40.8	0.3125
96	W16X67	10.2	0.665	W12X79	12.1	0.735	0.47	9.125	B to F	212.2475	0.665	166.04	0.3325	20.4	0.665	40.8	0.3125
97	W16X67	10.2	0.665	W12X79	12.1	0.735	0.47	9.125	B to F	212.2475	0.665	166.04	0.3325	20.4	0.665	40.8	0.3125
98	W16X67	10.2	0.665	W12X79	12.1	0.735	0.47	9.125	B to F	212.2475	0.665	166.04	0.3325	20.4	0.665	40.8	0.3125
99	W18X50	7.5	0.57	W12X79	12.1	0.735	0.47	9.125	B to F	212.2475	0.57	166.04	0.285	15	0.57	30	0.3125
100	W18X50	7.5	0.57	W12X79	12.1	0.735	0.47	9.125	B to F	212.2475	0.57	166.04	0.285	15	0.57	30	0.3125
101	W18X50	7.5	0.57	W12X79	12.1	0.735	0.47	9.125	B to F	212.2475	0.57	166.04	0.285	15	0.57	30	0.3125
102	W18X50	7.5	0.57	W12X79	12.1	0.735	0.47	9.125	B to F	212.2475	0.57	166.04	0.285	15	0.57	30	0.3125
103	W16X67	10.2	0.665	W12X79	12.1	0.735	0.47	9.125	B to F	212.2475	0.665	166.04	0.3325	20.4	0.665	40.8	0.3125
104	W16X67	10.2	0.665	W12X79	12.1	0.735	0.47	9.125	B to F	212.2475	0.665	166.04	0.3325	20.4	0.665	40.8	0.3125
105	W16X67	10.2	0.665	W12X79	12.1	0.735	0.47	9.125	B to F	212.2475	0.665	166.04	0.3325	20.4	0.665	40.8	0.3125
106	W16X67	10.2	0.665	W12X79	12.1	0.735	0.47	9.125	B to F	212.2475	0.665	166.04	0.3325	20.4	0.665	40.8	0.3125
107	W18X50	7.5	0.57	W12X79	12.1	0.735	0.47	9.125	B to F	212.2475	0.57	166.04	0.285	15	0.57	30	0.3125
108	W18X50	7.5	0.57	W12X79	12.1	0.735	0.47	9.125	B to F	212.2475	0.57	166.04	0.285	15	0.57	30	0.3125
109	W18X50	7.5	0.57	W12X79	12.1	0.735	0.47	9.125	B to F	212.2475	0.57	166.04	0.285	15	0.57	30	0.3125
110	W18X50	7.5	0.57	W12X79	12.1	0.735	0.47	9.125	B to F	212.2475	0.57	166.04	0.285	15	0.57	30	0.3125

Table 11 Summary of Field Welds

Depth of Weld (in)	Length of Weld (ft)
0.285	110.69
0.3125	376.44
0.3325	165.99
0.335	256.80
0.34	110.56
0.3475	33.09
0.375	256.59
0.385	256.80
0.4375	128.40
0.48	99.28
0.5	264.75
0.57	10.00
0.665	20.40
0.67	28.00
0.68	45.08
0.695	2.52
0.75	34.13
0.77	24.05
0.875	12.09
0.96	12.87
1	28.00
1.36	4.13

Table 12 Summary of Web Stiffeners

Thickness (in)	Plate Area (ft^2)
0.57	11.79
0.665	17.93
0.67	31.28
0.68	12.27
0.695	4.12
0.75	31.23
0.77	31.28
0.875	15.64
0.96	12.35
1	32.93
1.36	4.12

Appendix N: Existing Steel Structure Estimate

Table 13 Existing Steel Structure Estimate

CostWorks 2011 - Gateway Phase II (Steel)

Qty	Description	Crew	Daily Output	Labor Hours	Unit	Bare Mat.	Bare Labor	Bare Equip.	Total	Total Incl. O&P
0.67	Column, structural tubing, 8" x 8" x 3/8" x 14'-0", incl shop primer, cap & base plate, bolts	E2	50	1.12	Ea.	$ 370.74	$ 44.76	$ 21.71	$ 437.21	$ 507.68
66.04	Column, structural, 2-tier, W12x106, A992 steel, incl shop primer, splice plates, bolts	E2	984.00	0.057	L.F.	$ 7,340.35	$ 227.84	$ 110.95	$ 7,679.13	$ 8,536.13
481.33	Column, structural, 2-tier, W12x53, A992 steel, incl shop primer, splice plates, bolts	E2	984.00	0.057	L.F.	$ 26,771.57	$ 1,569.14	$ 760.50	$ 29,101.21	$ 32,624.87
405.00	Column, structural, 2-tier, W12x58, A992 steel, incl shop primer, splice plates, bolts	E2	984.00	0.057	L.F.	$ 24,632.10	$ 1,328.40	$ 643.95	$ 26,604.45	$ 29,784.30
246.00	Column, structural, 2-tier, W12x65, A992 steel, incl shop primer, splice plates, bolts	E2	984.00	0.057	L.F.	$ 16,755.06	$ 814.26	$ 393.60	$ 17,962.92	$ 20,077.59
209.25	Column, structural, 2-tier, W12x79, A992 steel, incl shop primer, splice plates, bolts	E2	984.00	0.057	L.F.	$ 17,300.79	$ 705.17	$ 341.08	$ 18,347.04	$ 20,457.47
32.00	Column, structural, 2-tier, W12x87, A992 steel, incl shop primer, splice plates, bolts	E2	984	0.057	L.F.	$ 2,912.00	$ 109.12	$ 52.80	$ 3,073.92	$ 3,424.00
481.33	Column, structural, 2-tier, W14x109, A992 steel, incl shop primer, splice plates, bolts	E2	984.00	0.057	L.F.	$ 55,006.39	$ 1,665.40	$ 813.45	$ 57,485.24	$ 63,884.94
271.67	Column, structural, 2-tier, W14x132, A992 steel, incl shop primer, splice plates, bolts	E2	984.00	0.057	L.F.	$ 37,607.28	$ 956.28	$ 467.27	$ 39,030.83	$ 43,307.82
479.25	Column, structural, 2-tier, W14x145, A992 steel, incl shop primer, splice plates, bolts	E2	984.00	0.057	L.F.	$ 72,793.28	$ 1,706.13	$ 833.90	$ 75,333.31	$ 83,533.74
93,202.00	Metal floor decking, steel, non-cellular, composite, galvanized, 1-1/2" D, 18 gauge	E4	3,650	0.009	S.F.	$ 190,132.08	$ 47,533.02	$ 2,796.06	$ 240,461.16	$ 296,382.36
75,262.74	Sprayed cementitious fireproofing, sprayed mineral fiber or cementitious for fireproofing, beams, 1 hour rated, 1-3/8" thick, excl. tamping or canvas protection	G2	1,500	0.016	S.F.	$ 37,631.37	$ 69,994.35	$ 6,021.02	$ 113,646.74	$ 152,783.36
17,485.32	Sprayed cementitious fireproofing, sprayed mineral fiber or cementitious for fireproofing, columns, 1-1/8" thick, excl. tamping or canvas protection	G2	1,100	0.022	S.F.	$ 9,791.78	$ 22,031.50	$ 1,923.38	$ 33,746.66	$ 46,161.23
11.79	Steel plate, structural, for connections & stiffeners, 0.57" T, shop fabricated, incl shop primer				S.F.	$ 261.03			$ 261.03	$ 287.13
17.93	Steel plate, structural, for connections & stiffeners, 0.665" T, shop fabricated, incl shop primer				S.F.	$ 463.31			$ 463.31	$ 509.64
31.28	Steel plate, structural, for connections & stiffeners, 0.67" T, shop fabricated, incl shop primer				S.F.	$ 814.22			$ 814.22	$ 895.64
12.27	Steel plate, structural, for connections & stiffeners, 0.68" T, shop fabricated, incl shop primer				S.F.	$ 324.17			$ 324.17	$ 356.59
4.12	Steel plate, structural, for connections & stiffeners, 0.695" T, shop fabricated, incl shop primer				S.F.	$ 111.24			$ 111.24	$ 122.36
31.28	Steel plate, structural, for connections & stiffeners, 0.77" T, shop fabricated, incl shop primer				S.F.	$ 936.21			$ 936.21	$ 1,029.83
15.64	Steel plate, structural, for connections & stiffeners, 0.875" T, shop fabricated, incl shop primer				S.F.	$ 532.07			$ 532.07	$ 585.28
12.35	Steel plate, structural, for connections & stiffeners, 0.96" T, shop fabricated, incl shop primer				S.F.	$ 461.03			$ 461.03	$ 507.13
32.93	Steel plate, structural, for connections & stiffeners, 1" T, shop fabricated, incl shop primer				S.F.	$ 1,284.27			$ 1,284.27	$ 1,412.70
4.12	Steel plate, structural, for connections & stiffeners, 1.36" T, shop fabricated, incl shop primer				S.F.	$ 217.99			$ 217.99	$ 239.79
31.23	Steel plate, structural, for connections & stiffeners, 3/4" T, shop fabricated, incl shop primer				S.F.	$ 905.67			$ 905.67	$ 996.24

74.01	Structural concrete, in place, column (4000 psi), square, avg reinforcing, 36" x 36", includes forms(4 uses), reinforcing steel, concrete, placing and finishing	C14A	23.32	8.576	C.Y.	$ 23,313.15	$ 39,965.40	$ 2,442.33	$ 65,720.88	$ 90,677.05
365.46	Structural concrete, in place, spread footing (3000 psi), over 5 C.Y., includes forms, reinforcing steel, concrete, placing and finishing	C14C	75	1.493	C.Y.	$ 57,377.22	$ 32,708.67	$ 113.29	$ 90,199.18	$ 113,285.29
1,561.60	Structural concrete, placing, elevated slab, pumped, less than 6" thick, includes strike off & consolidation, excludes material	C20	140	0.457	C.Y.	$ -	$ 38,259.20	$ 8,744.96	$ 47,004.16	$ 67,164.42
1,561.60	Structural concrete, ready mix, normal weight, 4000 PSI, includes local aggregate, sand, Portland cement and water, delivered, excludes all additives and treatments				C.Y.	$ 147,571.20	$ -	$ -	$ 147,571.20	$ 162,328.32
64.69	Structural steel member, 100-ton project, 1 to 2 story building, W10x12, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	600	0.093	L.F.	$ 808.63	$ 362.26	$ 175.31	$ 1,346.20	$ 1,681.94
297.67	Structural steel member, 100-ton project, 1 to 2 story building, W10x15, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	600	0.093	L.F.	$ 4,658.54	$ 1,666.95	$ 806.69	$ 7,132.17	$ 8,781.27
30.68	Structural steel member, 100-ton project, 1 to 2 story building, W10x19, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	600.00	0.093	L.F.	$ 609.00	$ 171.81	$ 80.07	$ 860.88	$ 1,043.35
86.24	Structural steel member, 100-ton project, 1 to 2 story building, W10x22, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	600	0.093	L.F.	$ 1,983.52	$ 482.94	$ 233.71	$ 2,700.17	$ 3,277.12
98.58	Structural steel member, 100-ton project, 1 to 2 story building, W12x16, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	880	0.064	L.F.	$ 1,646.29	$ 374.60	$ 182.37	$ 2,203.26	$ 2,661.66
1,466.59	Structural steel member, 100-ton project, 1 to 2 story building, W12x19, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	880.00	0.064	L.F.	$ 29,111.81	$ 5,573.04	$ 2,713.19	$ 37,398.05	$ 44,682.30
22.00	Structural steel member, 100-ton project, 1 to 2 story building, W12x26, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	880	0.064	L.F.	$ 594.00	$ 83.60	$ 40.70	$ 718.30	$ 847.00
150.75	Structural steel member, 100-ton project, 1 to 2 story building, W12x40, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	880.00	0.064	L.F.	$ 6,305.87	$ 639.18	$ 310.55	$ 7,255.60	$ 8,415.80
49.70	Structural steel member, 100-ton project, 1 to 2 story building, W12x58, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	750	0.075	L.F.	$ 3,006.85	$ 222.16	$ 107.85	$ 3,336.86	$ 3,802.05
711.53	Structural steel member, 100-ton project, 1 to 2 story building, W14x22, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	750.00	0.075	L.F.	$ 16,365.19	$ 2,163.05	$ 1,045.95	$ 19,574.19	$ 22,812.14
333.49	Structural steel member, 100-ton project, 1 to 2 story building, W16x26, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	1,000	0.056	L.F.	$ 9,004.23	$ 1,113.86	$ 540.25	$ 10,658.34	$ 12,505.88
597.47	Structural steel member, 100-ton project, 1 to 2 story building, W16x31, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	900	0.062	L.F.	$ 19,417.78	$ 2,222.59	$ 1,081.42	$ 22,721.78	$ 26,288.68
61.00	Structural steel member, 100-ton project, 1 to 2 story building, W16x36, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	900.00	0.062	L.F.	$ 2,287.50	$ 242.78	$ 118.34	$ 2,648.62	$ 3,055.02
487.09	Structural steel member, 100-ton project, 1 to 2 story building, W16x50, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	800	0.07	L.F.	$ 25,572.23	$ 2,040.91	$ 993.66	$ 28,606.80	$ 32,635.03
111.42	Structural steel member, 100-ton project, 1 to 2 story building, W16x57, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	800.00	0.070	L.F.	$ 6,652.89	$ 476.88	$ 231.75	$ 7,361.52	$ 8,370.45
166.88	Structural steel member, 100-ton project, 1 to 2 story building, W16x67, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	760	0.074	L.F.	$ 11,681.60	$ 734.27	$ 357.12	$ 12,773.00	$ 14,435.12
773.47	Structural steel member, 100-ton project, 1 to 2 story building, W18x35, A992 steel, shop fabricated, incl shop primer, bolted connections	E5	960	0.083	L.F.	$ 28,231.66	$ 3,906.02	$ 1,399.98	$ 33,537.66	$ 39,060.24
73.50	Structural steel member, 100-ton project, 1 to 2 story building, W18x46, A992 steel, shop fabricated, incl shop primer, bolted connections	E5	960	0.083	L.F.	$ 3,528.00	$ 371.18	$ 133.04	$ 4,032.21	$ 4,630.50
182.42	Structural steel member, 100-ton project, 1 to 2 story building, W18x50, A992 steel, shop fabricated, incl shop primer, bolted connections	E5	912	0.088	L.F.	$ 9,577.05	$ 966.83	$ 348.42	$ 10,892.30	$ 12,495.77
30.50	Structural steel member, 100-ton project, 1 to 2 story building, W18x60, A992 steel, shop fabricated, incl shop primer, bolted connections	E5	900.00	0.089	L.F.	$ 1,913.88	$ 163.18	$ 58.56	$ 2,135.61	$ 2,443.98

23.00	Structural steel member, 100-ton project, 1 to 2 story building, W18x65, A992 steel, shop fabricated, incl shop primer, bolted connections	E5	900	0.089	L.F.	$ 1,564.00	$ 124.20	$ 44.39	$ 1,732.59	$ 1,978.00
30.50	Structural steel member, 100-ton project, 1 to 2 story building, W21x166, A992 steel, shop fabricated, incl shop primer, bolted connections	E5	1,000.00	0.080	L.F.	$ 5,279.55	$ 147.32	$ 53.07	$ 5,479.94	$ 6,121.62
7,015.75	Structural steel member, 100-ton project, 1 to 2 story building, W21x44, A992 steel, shop fabricated, incl shop primer, bolted connections	E5	1,064	0.075	L.F.	$ 322,724.50	$ 31,851.51	$ 11,435.67	$ 366,011.68	$ 420,945.00
404.25	Structural steel member, 100-ton project, 1 to 2 story building, W21x50, A992 steel, shop fabricated, incl shop primer, bolted connections	E5	1,064	0.075	L.F.	$ 21,223.13	$ 1,835.30	$ 658.93	$ 23,717.35	$ 27,084.75
36.75	Structural steel member, 100-ton project, 1 to 2 story building, W21x93, A992 steel, shop fabricated, incl shop primer, bolted connections	E5	1,000	0.08	L.F.	$ 3,564.75	$ 177.50	$ 63.95	$ 3,806.20	$ 4,299.75
308.00	Structural steel member, 100-ton project, 1 to 2 story building, W24x104, A992 steel, shop fabricated, incl shop primer, bolted connections	E5	1,050	0.076	L.F.	$ 33,572.00	$ 1,419.88	$ 508.20	$ 35,500.08	$ 40,040.00
91.50	Structural steel member, 100-ton project, 1 to 2 story building, W24x131, A992 steel, shop fabricated, incl shop primer, bolted connections	E5	1,050.00	0.076	L.F.	$ 12,532.76	$ 421.82	$ 150.98	$ 13,105.55	$ 14,710.10
287.98	Structural steel member, 100-ton project, 1 to 2 story building, W24x55, A992 steel, shop fabricated, incl shop primer, bolted connections	E5	1,110	0.072	L.F.	$ 16,558.85	$ 1,252.71	$ 449.25	$ 18,260.81	$ 20,734.56
79.85	Structural steel member, 100-ton project, 1 to 2 story building, W24x68, A992 steel, shop fabricated, incl shop primer, bolted connections	E5	1,110	0.072	L.F.	$ 5,669.35	$ 347.35	$ 124.57	$ 6,141.26	$ 6,946.95
258.54	Structural steel member, 100-ton project, 1 to 2 story building, W24x76, A992 steel, shop fabricated, incl shop primer, bolted connections	E5	1,110	0.072	L.F.	$ 20,424.66	$ 1,124.65	$ 403.32	$ 21,952.63	$ 24,819.84
304.85	Structural steel member, 100-ton project, 1 to 2 story building, W24x84, A992 steel, shop fabricated, incl shop primer, bolted connections	E5	1,080	0.074	L.F.	$ 26,674.38	$ 1,365.73	$ 487.76	$ 28,527.86	$ 32,009.25
292.00	Structural steel member, 100-ton project, 1 to 2 story building, W24x94, A992 steel, shop fabricated, incl shop primer, bolted connections	E5	1,080	0.074	L.F.	$ 28,616.00	$ 1,308.16	$ 467.20	$ 30,391.36	$ 34,164.00
335.50	Structural steel member, 100-ton project, 1 to 2 story building, W30x132, A992 steel, shop fabricated, incl shop primer, bolted connections	E5	1,160	0.069	L.F.	$ 45,963.50	$ 1,402.39	$ 499.90	$ 47,865.79	$ 54,015.50
122.00	Structural steel member, 100-ton project, 1 to 2 story building, W30x99, A992 steel, shop fabricated, incl shop primer, bolted connections	E5	1,200	0.067	L.F.	$ 12,688.00	$ 491.66	$ 175.68	$ 13,355.34	$ 15,006.00
62.92	Structural steel member, 100-ton project, 1 to 2 story building, W33x118, A992 steel, shop fabricated, incl shop primer, bolted connections	E5	1,176	0.068	L.F.	$ 7,739.16	$ 258.60	$ 92.49	$ 8,090.25	$ 9,123.40
128.73	Structural steel member, 100-ton project, 1 to 2 story building, W36x160, A992 steel, shop fabricated, incl shop primer, bolted connections	E5	1,160.00	0.069	L.F.	$ 21,497.91	$ 536.80	$ 193.10	$ 22,227.81	$ 24,972.36
36.75	Structural steel member, 100-ton project, 1 to 2 story building, W8x10, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	600	0.093	L.F.	$ 384.04	$ 205.80	$ 99.59	$ 689.43	$ 882.00
19.00	Structural steel member, 100-ton project, 1 to 2 story building, W8x28, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	550	0.102	L.F.	$ 551.00	$ 115.90	$ 56.24	$ 723.14	$ 864.50
9,218.00	Weld shear connector, 3/4" dia x 5" L	E10	920.00	0.017		$ 6,176.06	$ 9,586.72	$ 3,226.30	$ 18,989.08	$ 27,378.20
932.02	Welded wire fabric, sheets, 6 x 6 - W2.9 x W2.9 (6 x 6) 42 lb. per C.S.F., A185	2 Rodm	29	0.552	C.S.F.	$ 21,436.46	$ 36,348.78	$ -	$ 57,785.24	$ 81,561.07
165.99	Welding structural steel in field, 3 passes, 0.5 Lb/LF, 0.3325" thick, continuous fillet, type 6011	E14	30.00	0.267	L.F.	$ 132.79	$ 2,360.38	$ 484.69	$ 2,977.86	$ 4,878.34
256.80	Welding structural steel in field, 3 passes, 0.5 Lb/LF, 0.335" thick, continuous fillet, type 6011	E14	30.00	0.267	L.F.	$ 208.01	$ 3,679.94	$ 757.56	$ 4,645.51	$ 7,608.75
110.56	Welding structural steel in field, 3 passes, 0.5 Lb/LF, 0.34" thick, continuous fillet, type 6011	E14	30.00	0.267	L.F.	$ 90.66	$ 1,609.75	$ 330.57	$ 2,030.99	$ 3,327.11
256.80	Welding structural steel in field, 3 passes, 0.5 Lb/LF, 0.385" thick, continuous fillet, type 6011	E14	30.00	0.267	L.F.	$ 251.66	$ 4,255.18	$ 880.82	$ 5,387.66	$ 8,815.69
99.28	Welding structural steel in field, 3 passes, 0.5 Lb/LF, 0.48" thick, continuous fillet, type 6011	E14	30.00	0.267	L.F.	$ 136.01	$ 2,085.87	$ 447.75	$ 2,669.64	$ 4,352.91
128.40	Welding structural steel in field, 3 passes, 0.5 Lb/LF, 04375" thick, continuous fillet, type 6011	E14	30.00	0.267	L.F.	$ 151.51	$ 2,434.46	$ 513.60	$ 3,099.58	$ 5,062.53
33.09	Welding structural steel in field, 3 passes, 0.5 Lb/LF, 3.475" thick,	E14	30.00	0.267	L.F.	$ 28.13	$ 492.71	$ 101.26	$ 622.09	$ 1,018.85

	continuous fillet, type 6011									
256.59	Welding structural steel in field, 3 passes, 0.5 Lb/LF, 3/8" thick, continuous fillet, type 6011	E14	30	0.267	L.F.	$ 266.85	$ 4,233.74	$ 933.99	$ 5,434.58	$ 8,852.36
264.75	Welding structural steel in field, 4 passes, 0.7 Lb/LF, 1/2" thick, continuous fillet, type 6011	E14	22	0.364	L.F.	$ 386.54	$ 5,956.88	$ 1,315.81	$ 7,659.22	$ 12,445.90
34.13	Welding structural steel in field, 5 - 6 passes, 1.3 Lb/LF, 3/4" thick, continuous fillet, type 6011	E14	12	0.667	L.F.	$ 92.15	$ 1,399.33	$ 312.29	$ 1,803.77	$ 2,935.86
28.00	Welding structural steel in field, 8 - 11 passes, 2.4 Lb/LF, 1" thick, continuous fillet, type 6011	E14	6	1.333	L.F.	$ 139.44	$ 2,310.00	$ 509.60	$ 2,959.04	$ 4,816.56
110.69	Welding structural steel in field, single pass, 0.4 Lb/LF, 0.285" thick, continuous fillet, type 6011	E14	38.00	0.211	L.F.	$ 73.06	$ 1,331.60	$ 276.73	$ 1,681.38	$ 2,723.05
10.00	Welding structural steel in field, single pass, 0.4 Lb/LF, 0.57" thick, continuous fillet, type 6011	E14	38.00	0.211	L.F.	$ 18.10	$ 260.80	$ 58.00	$ 336.90	$ 541.67
20.40	Welding structural steel in field, single pass, 0.4 Lb/LF, 0.665" thick, continuous fillet, type 6011	E14	38.00	0.211	L.F.	$ 47.94	$ 674.42	$ 153.61	$ 875.98	$ 1,406.00
28.00	Welding structural steel in field, single pass, 0.4 Lb/LF, 0.67" thick, continuous fillet, type 6011	E14	38.00	0.211	L.F.	$ 66.64	$ 937.44	$ 213.64	$ 1,217.72	$ 1,954.45
45.08	Welding structural steel in field, single pass, 0.4 Lb/LF, 0.68" thick, continuous fillet, type 6011	E14	38.00	0.211	L.F.	$ 110.00	$ 1,548.95	$ 353.43	$ 2,012.37	$ 3,229.72
2.52	Welding structural steel in field, single pass, 0.4 Lb/LF, 0.695" thick, continuous fillet, type 6011	E14	38.00	0.211	L.F.	$ 6.40	$ 90.04	$ 20.59	$ 117.03	$ 187.80
24.05	Welding structural steel in field, single pass, 0.4 Lb/LF, 0.77" thick, continuous fillet, type 6011	E14	38.00	0.211	L.F.	$ 73.11	$ 1,049.78	$ 240.50	$ 1,363.39	$ 2,188.39
12.09	Welding structural steel in field, single pass, 0.4 Lb/LF, 0.875" thick, continuous fillet, type 6011	E14	38.00	0.211	L.F.	$ 46.30	$ 704.48	$ 159.35	$ 910.14	$ 1,463.29
12.87	Welding structural steel in field, single pass, 0.4 Lb/LF, 0.96" thick, continuous fillet, type 6011	E14	38.00	0.211	L.F.	$ 58.43	$ 949.68	$ 210.81	$ 1,218.92	$ 1,963.80
4.13	Welding structural steel in field, single pass, 0.4 Lb/LF, 1.36" thick, continuous fillet, type 6011	E14	38.00	0.211	Ea.	$ 36.01	$ 860.20	$ 169.08	$ 1,065.29	$ 1,736.11
376.44	Welding structural steel in field, single pass, 0.4 Lb/LF, 5/16" thick, continuous fillet, type 6011	E14	38	0.211	L.F.	$ 312.45	$ 4,912.54	$ 1,084.15	$ 6,309.13	$ 10,163.88
	Totals					**$1,534,146.29**	**$418,057.65**	**$ 66,157.58**	**$2,018,361.53**	**$ 2,435,118.04**

Appendix O: Laterally Braced System Estimate

Table 14 Laterally Braced Steel System Estimate

CostWorks 2011 - Gateway Phase II (Steel)

Qty	Description	Crew	Daily Output	Labor Hours	Unit	Bare Mat.	Bare Labor	Bare Equip.	Total	Total Incl. O&P
26.760	Column, structural tubing, 10" x 6" x 3/8" x 14'-0", incl shop primer, cap & base plate, bolts	E2	50	1.12	Ea.	$ 14,851.80	$ 1,792.92	$ 869.70	$ 17,514.42	$ 20,337.60
0.67	Column, structural tubing, 8" x 8" x 3/8" x 14'-0", incl shop primer, cap & base plate, bolts	E2	50	1.12	Ea.	$ 370.74	$ 44.76	$ 21.71	$ 437.21	$ 507.68
66.04	Column, structural, 2-tier, W12x106, A992 steel, incl shop primer, splice plates, bolts	E2	984.00	0.057	L.F.	$ 7,340.35	$ 227.84	$ 110.95	$ 7,679.13	$ 8,536.13
1,013.33	Column, structural, 2-tier, W12x53, A992 steel, incl shop primer, splice plates, bolts	E2	984.00	0.057	L.F.	$ 56,361.41	$ 3,303.46	$ 1,601.06	$ 61,265.93	$ 68,684.18
14.04	Column, structural, 2-tier, W12x58, A992 steel, incl shop primer, splice plates, bolts	E2	984.00	0.057	L.F.	$ 853.91	$ 46.05	$ 22.32	$ 922.29	$ 1,032.52
1,304.04	Column, structural, 2-tier, W12x65, A992 steel, incl shop primer, splice plates, bolts	E2	984.00	0.057	L.F.	$ 88,818.16	$ 4,316.37	$ 2,086.46	$ 95,221.00	$ 106,430.80
162.04	Column, structural, 2-tier, W12x79, A992 steel, incl shop primer, splice plates, bolts	E2	984.00	0.057	L.F.	$ 13,397.47	$ 546.07	$ 264.13	$ 14,207.67	$ 15,841.95
32.00	Column, structural, 2-tier, W12x87, A992 steel, incl shop primer, splice plates, bolts	E2	984	0.057	L.F.	$ 2,912.00	$ 109.12	$ 52.80	$ 3,073.92	$ 3,424.00
0.00	Column, structural, 2-tier, W14x109, A992 steel, incl shop primer, splice plates, bolts	E2	984.00	0.057	L.F.	$ -	$ -	$ -	$ -	$ -
94.42	Column, structural, 2-tier, W14x132, A992 steel, incl shop primer, splice plates, bolts	E2	984.00	0.057	L.F.	$ 13,070.56	$ 332.36	$ 162.40	$ 13,565.32	$ 15,051.81
93,202.00	Metal floor decking, steel, non-cellular, composite, galvanized, 1-1/2" D, 18 gauge	E4	3,650	0.009	S.F.	$ 190,132.08	$ 47,533.02	$ 2,796.06	$ 240,461.16	$ 296,382.36
73,162.88	Sprayed cementitious fireproofing, sprayed mineral fiber or cementitious for fireproofing, beams, 1 hour rated, 1-3/8" thick, excl. tamping or canvas protection	G2	1,500	0.016	S.F.	$ 36,581.44	$ 68,041.48	$ 5,853.03	$ 110,475.95	$ 148,520.65
15,562.93	Sprayed cementitious fireproofing, sprayed mineral fiber or cementitious for fireproofing, columns, 1-1/8" thick, excl. tamping or canvas protection	G2	1,100	0.022	S.F.	$ 8,715.24	$ 19,609.29	$ 1,711.92	$ 30,036.45	$ 41,086.14
11.79	Steel plate, structural, for connections & stiffeners, 0.57" T, shop fabricated, incl shop primer				S.F.	$ 261.03			$ 261.03	$ 287.13
17.93	Steel plate, structural, for connections & stiffeners, 0.665" T, shop fabricated, incl shop primer				S.F.	$ 463.31			$ 463.31	$ 509.64
12.27	Steel plate, structural, for connections & stiffeners, 0.68" T, shop fabricated, incl shop primer				S.F.	$ 324.17			$ 324.17	$ 356.59
74.01	Structural concrete, in place, column (4000 psi), square, avg reinforcing, 36" x 36", includes forms(4 uses), reinforcing steel, concrete, placing and finishing	C14A	23.32	8.576	C.Y.	$ 23,313.15	$ 39,965.40	$ 2,442.33	$ 65,720.88	$ 90,677.05
365.46	Structural concrete, in place, spread footing (3000 psi), over 5 C.Y., includes forms, reinforcing steel, concrete, placing and finishing	C14C	75	1.493	C.Y.	$ 57,377.22	$ 32,708.67	$ 113.29	$ 90,199.18	$ 113,285.29
1,561.60	Structural concrete, placing, elevated slab, pumped, less than 6" thick, includes strike off & consolidation, excludes material	C20	140	0.457	C.Y.	$ -	$ 38,259.20	$ 8,744.96	$ 47,004.16	$ 67,164.42
1,561.60	Structural concrete, ready mix, normal weight, 4000 PSI, includes local aggregate, sand, Portland cement and water, delivered, excludes all additives and treatments				C.Y.	$ 147,571.20	$ -	$ -	$ 147,571.20	$ 162,328.32
53.48	Structural steel member, 100-ton project, 1 to 2 story building, W10x12, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	600	0.093	L.F.	$ 668.50	$ 299.49	$ 144.93	$ 1,112.92	$ 1,390.48
297.67	Structural steel member, 100-ton project, 1 to 2 story building, W10x15, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	600	0.093	L.F.	$ 4,658.54	$ 1,666.95	$ 806.69	$ 7,132.17	$ 8,781.27

30.68	Structural steel member, 100-ton project, 1 to 2 story building, W10x19, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	600.00	0.093	L.F.	$ 609.00	$ 171.81	$ 80.07	$ 860.88	$ 1,043.35
40.22	Structural steel member, 100-ton project, 1 to 2 story building, W10x22, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	600	0.093	L.F.	$ 925.06	$ 225.23	$ 109.00	$ 1,259.29	$ 1,528.36
98.58	Structural steel member, 100-ton project, 1 to 2 story building, W12x16, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	880	0.064	L.F.	$ 1,646.29	$ 374.60	$ 182.37	$ 2,203.26	$ 2,661.66
1,466.59	Structural steel member, 100-ton project, 1 to 2 story building, W12x19, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	880.00	0.064	L.F.	$ 29,111.81	$ 5,573.04	$ 2,713.19	$ 37,398.05	$ 44,682.30
22.00	Structural steel member, 100-ton project, 1 to 2 story building, W12x26, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	880	0.064	L.F.	$ 594.00	$ 83.60	$ 40.70	$ 718.30	$ 847.00
150.75	Structural steel member, 100-ton project, 1 to 2 story building, W12x40, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	880.00	0.064	L.F.	$ 6,305.87	$ 639.18	$ 310.55	$ 7,255.60	$ 8,415.80
711.53	Structural steel member, 100-ton project, 1 to 2 story building, W14x22, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	750.00	0.075	L.F.	$ 16,365.19	$ 2,163.05	$ 1,045.95	$ 19,574.19	$ 22,812.14
333.49	Structural steel member, 100-ton project, 1 to 2 story building, W16x26, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	1,000	0.056	L.F.	$ 9,004.23	$ 1,113.86	$ 540.25	$ 10,658.34	$ 12,505.88
1,054.97	Structural steel member, 100-ton project, 1 to 2 story building, W16x31, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	900	0.062	L.F.	$ 34,286.53	$ 3,924.49	$ 1,909.50	$ 40,120.51	$ 46,418.68
61.00	Structural steel member, 100-ton project, 1 to 2 story building, W16x36, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	900.00	0.062	L.F.	$ 2,287.50	$ 242.78	$ 118.34	$ 2,648.62	$ 3,055.02
523.84	Structural steel member, 100-ton project, 1 to 2 story building, W16x50, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	800	0.07	L.F.	$ 27,501.60	$ 2,194.89	$ 1,068.63	$ 30,765.12	$ 35,097.28
74.67	Structural steel member, 100-ton project, 1 to 2 story building, W16x57, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	800.00	0.070	L.F.	$ 4,458.55	$ 319.59	$ 155.31	$ 4,933.45	$ 5,609.60
166.88	Structural steel member, 100-ton project, 1 to 2 story building, W16x67, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	760	0.074	L.F.	$ 11,681.60	$ 734.27	$ 357.12	$ 12,773.00	$ 14,435.12
902.97	Structural steel member, 100-ton project, 1 to 2 story building, W18x35, A992 steel, shop fabricated, incl shop primer, bolted connections	E5	960	0.083	L.F.	$ 32,958.41	$ 4,560.00	$ 1,634.38	$ 39,152.78	$ 45,599.99
73.50	Structural steel member, 100-ton project, 1 to 2 story building, W18x46, A992 steel, shop fabricated, incl shop primer, bolted connections	E5	960	0.083	L.F.	$ 3,528.00	$ 371.18	$ 133.04	$ 4,032.21	$ 4,630.50
182.42	Structural steel member, 100-ton project, 1 to 2 story building, W18x50, A992 steel, shop fabricated, incl shop primer, bolted connections	E5	912	0.088	L.F.	$ 9,577.05	$ 966.83	$ 348.42	$ 10,892.30	$ 12,495.77
30.50	Structural steel member, 100-ton project, 1 to 2 story building, W18x60, A992 steel, shop fabricated, incl shop primer, bolted connections	E5	900.00	0.089	L.F.	$ 1,913.88	$ 163.18	$ 58.56	$ 2,135.61	$ 2,443.98
23.00	Structural steel member, 100-ton project, 1 to 2 story building, W18x65, A992 steel, shop fabricated, incl shop primer, bolted connections	E5	900	0.089	L.F.	$ 1,564.00	$ 124.20	$ 44.39	$ 1,732.59	$ 1,978.00
7,627.00	Structural steel member, 100-ton project, 1 to 2 story building, W21x44, A992 steel, shop fabricated, incl shop primer, bolted connections	E5	1,064	0.075	L.F.	$ 350,842.00	$ 34,626.58	$ 12,432.01	$ 397,900.59	$ 457,620.00
330.75	Structural steel member, 100-ton project, 1 to 2 story building, W21x50, A992 steel, shop fabricated, incl shop primer, bolted connections	E5	1,064	0.075	L.F.	$ 17,364.38	$ 1,501.61	$ 539.12	$ 19,405.10	$ 22,160.25
36.75	Structural steel member, 100-ton project, 1 to 2 story building, W21x93, A992 steel, shop fabricated, incl shop primer, bolted connections	E5	1,000	0.08	L.F.	$ 3,564.75	$ 177.50	$ 63.95	$ 3,806.20	$ 4,299.75
132.00	Structural steel member, 100-ton project, 1 to 2 story building, W24x104, A992 steel, shop fabricated, incl shop primer, bolted connections	E5	1,050	0.076	L.F.	$ 14,388.00	$ 608.52	$ 217.80	$ 15,214.32	$ 17,160.00
349.98	Structural steel member, 100-ton project, 1 to 2 story building, W24x55, A992 steel, shop fabricated, incl shop primer, bolted connections	E5	1,110	0.072	L.F.	$ 20,123.85	$ 1,522.41	$ 545.97	$ 22,192.23	$ 25,198.56
79.85	Structural steel member, 100-ton project, 1 to 2 story building, W24x68, A992 steel, shop fabricated, incl shop primer, bolted connections	E5	1,110	0.072	L.F.	$ 5,669.35	$ 347.35	$ 124.57	$ 6,141.26	$ 6,946.95
221.79	Structural steel member, 100-ton project, 1 to 2 story building, W24x76, A992 steel, shop fabricated, incl shop primer, bolted connections	E5	1,110	0.072	L.F.	$ 17,521.41	$ 964.79	$ 345.99	$ 18,832.19	$ 21,291.84

106.82	Structural steel member, 100-ton project, 1 to 2 story building, W24x84, A992 steel, shop fabricated, incl shop primer, bolted connections	E5	1,080	0.074	L.F.	$	9,346.75	$	478.55	$	170.91	$	9,996.22	$	11,216.10
73.50	Structural steel member, 100-ton project, 1 to 2 story building, W24x94, A992 steel, shop fabricated, incl shop primer, bolted connections	E5	1,080	0.074	L.F.	$	7,203.00	$	329.28	$	117.60	$	7,649.88	$	8,599.50
62.92	Structural steel member, 100-ton project, 1 to 2 story building, W33x118, A992 steel, shop fabricated, incl shop primer, bolted connections	E5	1,176	0.068	L.F.	$	7,739.16	$	258.60	$	92.49	$	8,090.25	$	9,123.40
128.73	Structural steel member, 100-ton project, 1 to 2 story building, W36x160, A992 steel, shop fabricated, incl shop primer, bolted connections	E5	1,160.00	0.069	L.F.	$	21,497.91	$	536.80	$	193.10	$	22,227.81	$	24,972.36
36.75	Structural steel member, 100-ton project, 1 to 2 story building, W8x10, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	600	0.093	L.F.	$	384.04	$	205.80	$	99.59	$	689.43	$	882.00
19.00	Structural steel member, 100-ton project, 1 to 2 story building, W8x28, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	550	0.102	L.F.	$	551.00	$	115.90	$	56.24	$	723.14	$	864.50
9,218.00	Weld shear connector, 3/4" dia x 5" L	E10	920.00	0.017		$	6,176.06	$	9,586.72	$	3,226.30	$	18,989.08	$	27,378.20
932.02	Welded wire fabric, sheets, 6 x 6 - W2.9 x W2.9 (6 x 6) 42 lb. per C.S.F., A185	2 Rodm	29	0.552	C.S.F.	$	21,436.46	$	36,348.78	$	-	$	57,785.24	$	81,561.07
165.99	Welding structural steel in field, 3 passes, 0.5 Lb/LF, 0.3325" thick, continuous fillet, type 6011	E14	30.00	0.267	L.F.	$	132.79	$	2,360.38	$	484.69	$	2,977.86	$	4,878.34
110.56	Welding structural steel in field, 3 passes, 0.5 Lb/LF, 0.34" thick, continuous fillet, type 6011	E14	30.00	0.267	L.F.	$	90.66	$	1,609.75	$	330.57	$	2,030.99	$	3,327.11
105.00	Welding structural steel in field, 3 passes, 0.5 Lb/LF, 3/8" thick, continuous fillet, type 6011	E14	30	0.267	L.F.	$	109.20	$	1,732.50	$	382.20	$	2,223.90	$	3,622.50
110.69	Welding structural steel in field, single pass, 0.4 Lb/LF, 0.285" thick, continuous fillet, type 6011	E14	38.00	0.211	L.F.	$	73.06	$	1,331.60	$	276.73	$	1,681.38	$	2,723.05
10.00	Welding structural steel in field, single pass, 0.4 Lb/LF, 0.57" thick, continuous fillet, type 6011	E14	38.00	0.211	L.F.	$	18.10	$	260.80	$	58.00	$	336.90	$	541.67
20.40	Welding structural steel in field, single pass, 0.4 Lb/LF, 0.665" thick, continuous fillet, type 6011	E14	38.00	0.211	L.F.	$	47.94	$	674.42	$	153.61	$	875.98	$	1,406.00
0.00	Welding structural steel in field, single pass, 0.4 Lb/LF, 0.67" thick, continuous fillet, type 6011	E14	38.00	0.211	L.F.	$	-	$	-	$	-	$	-	$	-
11.99	Welding structural steel in field, single pass, 0.4 Lb/LF, 0.68" thick, continuous fillet, type 6011	E14	38.00	0.211	L.F.	$	29.26	$	411.98	$	94.00	$	535.23	$	859.01
84.77	Welding structural steel in field, single pass, 0.4 Lb/LF, 5/16" thick, continuous fillet, type 6011	E14	38	0.211	L.F.	$	70.36	$	1,106.25	$	244.14	$	1,420.75	$	2,288.79
	Totals						**$1,366,740.31**		**$379,845.09**	**$**	**58,904.10**		**$1,805,489.49**	**$**	**2,175,797.37**

Appendix P: Cast-in-Place Concrete Estimate

Table 15 Cast-in Place Concrete Estimate

CostWorks 2011 - Gateway Phase II (Concrete)

Qty	Description	Crew	Daily Output	Labor Hours	Unit	Bare Mat.	Bare Labor	Bare Equip.	Total	Total Incl. O&P
7,404.300	C.I.P. concrete forms, column, square, steel framed plywood, 16" x 16", based on 50 uses of purchased forms, 4 uses of bracing lumber, includes erecting, bracing, stripping and cleaning	C1	400	0.08	SFCA	$ 7,552.39	$ 30,209.54	$ -	$ 37,761.93	$ 4,421.61
8,434.240	C.I.P. concrete forms, column, square, steel framed plywood, 24" x 24", based on 50 uses of purchased forms, 4 uses of bracing lumber, includes erecting, bracing, stripping and cleaning	C1	440	0.073	SFCA	$ 5,482.26	$ 31,206.69	$ -	$ 36,688.94	$ 53,979.14
3,040.000	C.I.P. concrete forms, elevated slab, edge forms, to 6" high, 4 use, includes shoring, erecting, bracing, stripping and cleaning	C1	500	0.064	L.F.	$ 486.40	$ 9,940.80	$ -	$ 10,427.20	$ 15,808.00
70,650.000	C.I.P. concrete forms, elevated slab, flat slab with drop panels, to 15' high, 4 use, includes shoring, erecting, bracing, stripping and cleaning	C2	544	0.088	S.F.	$ 79,834.50	$ 325,696.50	$ -	$ 405,531.00	$ 589,927.50
1,858.000	C.I.P. concrete forms, elevated slab, floor, with 1-way joist pans, 1 use, includes shoring, erecting, bracing, stripping and cleaning	C2	415	0.116	S.F.	$ 9,661.60	$ 11,240.90	$ -	$ 20,902.50	$ 27,870.00
8.07	Column, structural tubing, 8" x 8" x 3/8" x 14'-0", incl shop primer, cap & base plate, bolts	E2	50	1.12	Ea.	$ 4,478.85	$ 540.69	$ 262.28	$ 5,281.82	$ 6,133.20
68.08	Column, structural, 2-tier, W12x106, A992 steel, incl shop primer, splice plates, bolts	E2	984.00	0.057	L.F.	$ 7,567.09	$ 234.88	$ 114.37	$ 7,916.34	$ 8,799.81
170.21	Column, structural, 2-tier, W12x79, A992 steel, incl shop primer, splice plates, bolts	E2	984.00	0.057	L.F.	$ 14,072.96	$ 573.61	$ 277.44	$ 14,924.01	$ 16,640.69
34.04	Column, structural, 2-tier, W12x87, A992 steel, incl shop primer, splice plates, bolts	E2	984	0.057	L.F.	$ 3,097.64	$ 116.08	$ 56.17	$ 3,269.88	$ 3,642.28
7,426.00	Metal floor decking, steel, non-cellular, composite, galvanized, 1-1/2" D, 18 gauge	E4	3,650	0.009	S.F.	$ 15,149.04	$ 3,787.26	$ 222.78	$ 19,159.08	$ 23,614.68
37.600	Reinforcing Steel, in place, columns, #3 to #7, A615, grade 60, incl labor for accessories, excl material for accessories	4 Rodm	1.5	21.333	Ton	$ 36,660.00	$ 56,400.00	$ -	$ 93,060.00	$ 131,600.00
200.000	Reinforcing Steel, in place, elevated slabs, #4 to #7, A615, grade 60, incl labor for accessories, excl material for accessories	4 Rodm	2.9	11.034	Ton	$ 205,000.00	$ 157,000.00	$ -	$ 362,000.00	$ 75,000.00
2,486.32	Sprayed cementitious fireproofing, sprayed mineral fiber or cementitious for fireproofing, beams, 1 hour rated, 1-3/8" thick, excl. tamping or canvas protection	G2	1,500	0.016	S.F.	$ 1,243.16	$ 2,312.28	$ 198.91	$ 3,754.34	$ 5,047.23
1,527.40	Sprayed cementitious fireproofing, sprayed mineral fiber or cementitious for fireproofing, columns, 1-1/8" thick, excl. tamping or canvas protection	G2	1,100	0.022	S.F.	$ 855.34	$ 1,924.52	$ 168.01	$ 2,947.88	$ 4,032.34
11.79	Steel plate, structural, for connections & stiffeners, 0.57" T, shop fabricated, incl shop primer				S.F.	$ 261.03			$ 261.03	$ 287.13
17.93	Steel plate, structural, for connections & stiffeners, 0.665" T, shop fabricated, incl shop primer				S.F.	$ 463.31			$ 463.31	$ 509.64
12.27	Steel plate, structural, for connections & stiffeners, 0.68" T, shop fabricated, incl shop primer				S.F.	$ 324.17			$ 324.17	$ 356.59
17.60	Structural concrete, in place, column (4000 psi), square, avg reinforcing, 36" x 36", includes forms(4 uses), reinforcing steel, concrete, placing and finishing	C14A	23.32	8.576	C.Y.	$ 5,544.00	$ 9,504.00	$ 580.80	$ 15,628.80	$ 21,563.52
457.890	Structural concrete, in place, foundation mat (3000 psi), over 20 C.Y., includes forms(4 uses), reinforcing steel, concrete, placing and finishing	C14C	56.4	1.986	C.Y.	$ 70,972.95	$ 54,488.91	$ 192.31	$ 125,654.17	$ 162,550.95
342.110	Structural concrete, in place, spread footing (3000 psi), over 5 C.Y., includes forms, reinforcing steel, concrete, placing and finishing	C14C	75	1.493	C.Y.	$ 3,711.27	$ 30,618.85	$ 06.05	$ 84,436.17	$ 106,054.10
140.420	Structural concrete, placing, column, square or round, pumped, 18" thick, includes strike off & consolidation, excludes material	C20	90	0.711	C.Y.	$ -	$ 5,335.96	$,235.70	$ 6,571.66	$ 9,408.14
225.190	Structural concrete, placing, column, square or round, pumped, 24" thick, includes strike off & consolidation, excludes material	C20	92	0.696	C.Y.	$ -	$ 8,332.03	$ 1,936.63	$ 10,268.66	$ 14,862.54
124.42	Structural concrete, placing, elevated slab, pumped, less than 6" thick,	C20	140	0.457	C.Y.	$ -	$ 3,048.29	$ 696.75	$ 3,745.04	$ 5,351.30

	includes strike off & consolidation, excludes material									
2,906.460	Structural concrete, placing, elevated slab, pumped, over 10" thick, includes strike off & consolidation, excludes material	C20	180	0.356	C.Y.	$ -	55,368.06	$ 2,730.29	$ 68,098.36	$ 98,819.64
124.42	Structural concrete, ready mix, normal weight, 4000 PSI, includes local aggregate, sand, Portland cement and water, delivered, excludes all additives and treatments				C.Y.	$ 11,757.69	$ -	$ -	$ 11,757.69	$ 12,933.46
3,155.300	Structural concrete, ready mix, normal weight, 5000 psi, includes local aggregate, sand, Portland cement and water, delivered, excludes all additives and treatments				C.Y.	$ 321,840.60	$ -	$ -	$ 321,840.60	$ 353,393.60
298.60	Structural steel member, 100-ton project, 1 to 2 story building, W12x19, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	880.00	0.064	L.F.	$ 5,927.21	$ 1,134.68	$ 552.41	$ 7,614.30	$ 9,097.39
59.07	Structural steel member, 100-ton project, 1 to 2 story building, W12x40, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	880.00	0.064	L.F.	$ 2,470.90	$ 250.46	$ 121.68	$ 2,843.04	$ 3,297.65
18.42	Structural steel member, 100-ton project, 1 to 2 story building, W14x22, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	750.00	0.075	L.F.	$ 423.66	$ 56.00	$ 27.08	$ 506.73	$ 590.56
139.97	Structural steel member, 100-ton project, 1 to 2 story building, W16x31, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	900	0.062	L.F.	$ 4,549.03	$ 520.69	$ 253.35	$ 5,323.06	$ 6,158.68
130.13	Structural steel member, 100-ton project, 1 to 2 story building, W16x67, A992 steel, shop fabricated, incl shop primer, bolted connections	E2	760	0.074	L.F.	$ 9,109.10	$ 572.57	$ 278.48	$ 9,960.15	$ 11,256.25
78.32	Structural steel member, 100-ton project, 1 to 2 story building, W18x35, A992 steel, shop fabricated, incl shop primer, bolted connections	E5	960	0.083	L.F.	$ 2,858.68	$ 395.52	$ 141.76	$ 3,395.96	$ 3,955.16
105.92	Structural steel member, 100-ton project, 1 to 2 story building, W18x50, A992 steel, shop fabricated, incl shop primer, bolted connections	E5	912	0.088	L.F.	$ 5,560.80	$ 561.38	$ 202.31	$ 6,324.48	$ 7,255.52
71.98	Structural steel member, 100-ton project, 1 to 2 story building, W24x55, A992 steel, shop fabricated, incl shop primer, bolted connections	E5	1,110	0.072	L.F.	$ 4,138.85	$ 313.11	$ 112.29	$ 4,564.25	$ 5,182.56
34.85	Structural steel member, 100-ton project, 1 to 2 story building, W24x68, A992 steel, shop fabricated, incl shop primer, bolted connections	E5	1,110	0.072	L.F.	$ 2,474.35	$ 151.60	$ 54.37	$ 2,680.31	$ 3,031.95
126.29	Structural steel member, 100-ton project, 1 to 2 story building, W24x76, A992 steel, shop fabricated, incl shop primer, bolted connections	E5	1,110	0.072	L.F.	$ 9,976.91	$ 549.36	$ 197.01	$ 10,723.28	$ 12,123.84
40.85	Structural steel member, 100-ton project, 1 to 2 story building, W24x84, A992 steel, shop fabricated, incl shop primer, bolted connections	E5	1,080	0.074	L.F.	$ 3,574.38	$ 183.01	$ 65.36	$ 3,822.74	$ 4,289.25
26.17	Structural steel member, 100-ton project, 1 to 2 story building, W33x118, A992 steel, shop fabricated, incl shop primer, bolted connections	E5	1,176	0.068	L.F.	$ 3,218.91	$ 107.56	$ 38.47	$ 3,364.94	$ 3,794.65
128.73	Structural steel member, 100-ton project, 1 to 2 story building, W36x160, A992 steel, shop fabricated, incl shop primer, bolted connections	E5	1,160.00	0.069	L.F.	$ 21,497.91	$ 536.80	$ 193.10	$ 22,227.81	$ 24,972.36
867.00	Weld shear connector, 3/4" dia x 5" L	E10	920.00	0.017		$ 580.89	$ 901.68	$ 303.45	$ 1,786.02	$ 2,575.06
74.26	Welded wire fabric, sheets, 6 x 6 - W2.9 x W2.9 (6 x 6) 42 lb. per C.S.F., A185	2 Rodm	29	0.552	C.S.F.	$ 1,707.98	$ 2,896.14	$ -	$ 4,604.12	$ 6,498.49
165.99	Welding structural steel in field, 3 passes, 0.5 Lb/LF, 0.3325" thick, continuous fillet, type 6011	E14	30.00	0.267	L.F.	$ 132.79	$ 2,360.38	$ 484.69	$ 2,977.86	$ 4,878.34
110.56	Welding structural steel in field, 3 passes, 0.5 Lb/LF, 0.34" thick, continuous fillet, type 6011	E14	30.00	0.267	L.F.	$ 90.66	$ 1,609.75	$ 330.57	$ 2,030.99	$ 3,327.11
110.69	Welding structural steel in field, single pass, 0.4 Lb/LF, 0.285" thick, continuous fillet, type 6011	E14	38.00	0.211	L.F.	$ 73.06	$ 1,331.60	$ 276.73	$ 1,681.38	$ 2,723.05
10.00	Welding structural steel in field, single pass, 0.4 Lb/LF, 0.57" thick, continuous fillet, type 6011	E14	38.00	0.211	L.F.	$ 18.10	$ 260.80	$ 58.00	$ 336.90	$ 541.67
20.40	Welding structural steel in field, single pass, 0.4 Lb/LF, 0.665" thick, continuous fillet, type 6011	E14	38.00	0.211	L.F.	$ 47.94	$ 674.42	$ 153.61	$ 875.98	$ 1,406.00
11.99	Welding structural steel in field, single pass, 0.4 Lb/LF, 0.68" thick, continuous fillet, type 6011	E14	38.00	0.211	L.F.	$ 29.26	$ 411.98	$ 94.00	$ 535.23	$ 859.01
84.77	Welding structural steel in field, single pass, 0.4 Lb/LF, 5/16" thick, continuous fillet, type 6011	E14	38	0.211	L.F.	$ 70.36	$ 1,106.25	$ 244.14	$ 1,420.75	$ 2,288.79
	Totals					**$934,547.97**	**$814,765.57**	**$22,961.35**	**$1,772,274.88**	**$2,322,710.44**

Appendix Q: Schedule

The formwork process is completely integrated and interrelated with the construction schedule of concrete structures. Formwork systems are defined as "the total system of support for freshly placed concrete including the mold or sheathing which contacts the concrete as well as supporting members, hardware, and necessary bracing" (Peurifoy and Oberlender 2010, P 14). Figure 16 displays the integrated process where after the erection of the chosen formwork system, the construction sequence of placing of rebar, pouring concrete, and curing returns to the formwork cycle activities of stripping and re-shoring.

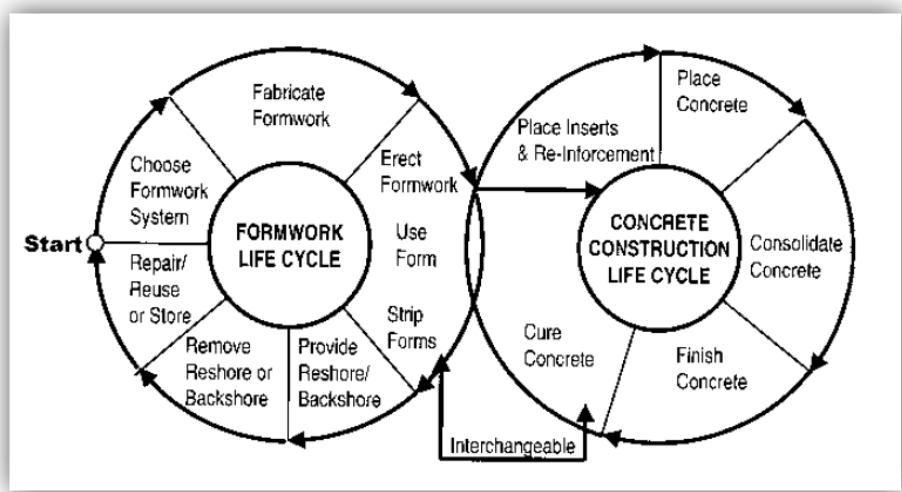


Figure 16 Integrated Concrete Formwork Life Cycle

(Hanna 1999)

Formwork accounts for a significant portion of the cost for a concrete structure. It can range "from one-third to one-half of the total installed cost" of the building (Peurifoy and Oberlender 2010, P 8). Therefore, substantial benefits can be obtained if an emphasis is placed on the constructability and formwork scheduling of the structure. Formwork efficiencies improve safety, reduce probability of errors, and accelerate the rate of construction (Peurifoy and Oberlender 2010, P 7). As a result the overall construction schedule was? reduced and allow economic savings to be obtained. Focusing on these elements can reduce the total associated direct and indirect frame costs as greatly as 25% (Peurifoy and Oberlender 2010, P 7).

To develop a detailed and competitive construction schedule for the redesigned concrete building great consideration was placed on the selected formwork system and construction floor cycle. There are several available formwork systems in the construction industry for concrete structures and they are wood, metal, flying truss, column mounted, and the tunnel system. To choose an appropriate formwork system various factors must be considered such as building geometry, available capital, and local conditions. The selected formwork system for the redesigned GWP II building was guided by Figure 17. From the figure a conventional wood or metal system would be appropriate since the building square footage is very close to 100,000 square feet and the building story heights are close to 14 foot high stories.

Influence factor			Formwork system: Conventional wood system	Conventional metal system	Flying truss system	Column-mounted shoring system	Tunnel form
Building design	Slab type	Slab type	All slab systems Most suited for two-way slab supported by beams or one-way slab, beam, girder		Two-way: flat plate and flat slab One-way: slab supported by beams or walls and joist slab (standard or skip-joist)		One-way slab supported by walls Less than 12-in. thickness
Building design	Lateral support	Compatibility with lateral load supporting system	Compatible with all lateral load supporting systems		Generally not suitable for framed tube and tube in tube because of the close distance between columns which characterize the tube systems		Bearing wall
Building design	Building shape	Horizontal uniformity / irregularity	Can handle variations in beam size and location Can handle variations in cantilever shape, size, and location Avoid cross beams		Beams should be of the same size and location or within 20% difference from floor to floor Cantilever should be of the same size and location or within 20% difference from floor to floor		Beams should be of the same size and location Cantilever balconies should be of the same size and location
Building design	Building shape	Vertical uniformity / irregularity	Can handle variations of column/wall size and location. Can handle variations in story height within one floor or from floor to floor.		Column/wall should be of the same size and location or within 20% difference from floor to floor Can handle limited variation (20%) in story height		Walls should be of the same size, location, and height from floor to floor
Building design	Building shape	High stories (higher than 14 ft)	Not suitable for high stories	More suitable for high stories (light alum. wt.)	Limited by truss depth (up to 20 ft)	Height independent system	Limited height system (between 7.5 and 10 ft)
Building design	Miscellaneous	Openings	System can handle variation in opening size and location		Can handle limited variation (20%) in opening size and location		
Building design	Miscellaneous	Slopes and cambers	Slopes and cambers can be accommodated at additional cost	System must be designed to accommodate slopes and cambers	Slopes and camber must be identical from floor to floor		
Building design	Miscellaneous	HVAC	Can accommodate extensive HVAC	Cannot accommodate extensive HVAC	HVAC should be minimal and identical from floor to floor		
Building design	Miscellaneous	Dimension Limitations	Used for small building size (less than 100,000 ft^2)	Used for medium building size (between 100,000 and 200,000 ft^2)	Used for large size buildings (more than 200,000 ft^2)		

Figure 17 Factors Affecting the Selection of Horizontal Framing System

(Hanna 1999, P 221)

The tables below display the major building elements categorized from the RS Means estimates. Then the Item Description column shows the corresponding activity per building element. In the following column the daily output values were taken from RS means and represent the output for 1 crew. The Total Quantity values are the summarized from the estimates. Next the Crews column shows the number of crews allocated in the schedule for the item descriptions. Lastly, the Duration column shows the values input into the Primavera scheduling. The durations were calculated by dividing the total quantity column values by the daily output column values that were first multiplied by the number in the Crews column.

Table 16 Concrete System Schedule

Floor	Building Element	Activity	Daily Output	Total Quantity	Units	Crews	
LVL 0	Ftgs.	Formwork, Rein. Steel Installation, Pouring, Finishing	75	11.5	C.Y	1	0.2
	Mat	Formwork, Rein. Steel Installation, Pouring, Finishing	56.4	457	C.Y	3	2.7
	Columns, 0-1	Rein. Steel Installation	1.5	3.3	Tons	1	2.2
		Formwork, 24 x 24	440	1353	SFCA	2	1.5
		Formwork, 16 x 16	400	834	SFCA	2	1.0
		Pour, 18"	90	13	C.Y	1	0.1
		Pour, 24"	92	25	C.Y	1	0.3
	Fdn. Walls	15" thick, 12' high, incl. forms, reinf. steel, pouring	51.26	253	C.Y	3	1.6
	Slab on Grade	3500 PSI, 6" thick incl. forms, rein. steel, pouring	92	316	C.Y	3	1.1
LVL 1	Columns, 1-2	Rein. Steel Installation	1.5	6.7	Tons	3	1.5
		Formwork, 24 x 24	440	1873	SFCA	3	1.4
		Formwork, 16 x 16	400	2519	SFCA	3	2.1
		Pour, 18"	90	39	C.Y	1	0.4
		Pour, 24"	92	35	C.Y	1	0.4
	Elevated Slab, 1	Formwork, flat slab	544	8151	S.F	3	5.0
		Reshoring	1400	8151	S.F	5	1.2
		Rein. Steel Installation	2.9	30	Tons	5	2.1
		Pour, over 10" thick	180	264	C.Y	2	0.7
	Slab on Grade, 1	3500 PSI, 6" thick incl. forms, rein. steel, pouring	92	483	C.Y	3	1.8
LVL 2	Columns, 2-3	Rein. Steel Installation	1.5	6.7	Tons	3	1.5
		Formwork, 24 x 24	440	1738	SFCA	3	1.3
		Formwork, 16 x 16	400	2172	SFCA	3	1.8
		Pour, 18"	90	34	C.Y	1	0.4
		Pour, 24"	92	32	C.Y	1	0.3
	Elevated Slab, 2	Formwork, flat slab	544	20165	S.F	6	6.2
		Reshoring	1400	20165	S.F	7	2.1
		Rein. Steel Installation	2.9	50	Tons	8	2.2
		Pour, over 10" thick	180	653	C.Y	3	1.2
LVL 3	Columns, 3-4	Rein. Steel Installation	1.5	6.7	Tons	3	1.5
		Formwork, 24 x 24	440	1731	SFCA	3	1.3
		Formwork, 16 x 16	400	2172	SFCA	3	1.8
		Pour, 18"	90	34	C.Y	1	0.4
		Pour, 24"	92	32	C.Y	1	0.3
	Elevated Slab, 3	Formwork, flat slab	544	20165	S.F	6	6.2
		Reshoring	1400	20165	S.F	7	2.1
		Rein. Steel Installation	2.9	50	Tons	8	2.2
		Pour, over 10" thick	180	653	C.Y	3	1.2
LVL 4	Columns, 4-5	Rein. Steel Installation	1.5	7	Tons	3	1.6
		Formwork, 24 x 24	440	1738	SFCA	3	1.3
		Formwork, 16 x 16	400	2172	SFCA	3	1.8
		Pour, 18"	90	34	C.Y	1	0.4
		Pour, 24"	92	32	C.Y	1	0.3
	Elevated Slab, 4	Formwork, flat slab	544	20167	S.F	6	6.2
		Reshoring	1400	20167	S.F	7	2.1
		Rein. Steel Installation	2.9	50	Tons	8	2.2
		Pour, over 10" thick	180	653	C.Y	3	1.2
LVL 5	Roof Elevated Slab, 5	Formwork, flat slab	544	21037	S.F	6	6.4
		Reshoring	1400	21037	S.F	7	2.1
		Rein. Steel Installation	2.9	20	Tons	8	0.9
		Pour, over 10" thick	180	681	C.Y	3	1.3

Table 17 Existing Steel Schedule

	Building Element	Item Description	Daily Output	Crew	Quantity	Units	Duration
		P1,P2,P3	23.32		316	LF	13.5506
		W12x79	984	1	47	LF	0.047764
	Columns	W14x145	984	1	47	LF	0.047764
	FDN Walls		51	3	253	CY	2
	FTGS		11.5	1	11.5	CY	1
LVL 0	Slab on Grade		92	3	316	CY	1
		W12x58	984	1	405.02	LF	0.411606
		W12x65	984	1	246.01	LF	0.25001
		W14x132	984	1	271.68	LF	0.276098
	Columns	W14x145	984	1	381.39	LF	0.387591
		W14X22	750	1	22	LF	0.029333
		W16X50	800	1	413.59	LF	0.516988
		W16X57	800	1	36.75	LF	0.045938
		W16X67	760	1	36.75	LF	0.048355
		W18X65	900	1	23	LF	0.025556
		C-Channel: C12X20.7		1	10.1	LF	0
		W10X15	600	1	11.67	LF	0.01945
		W12X16	880	1	21.72	LF	0.024682
		W12X19	880	1	116.05	LF	0.131875
		W14X22	750	1	20.5	LF	0.027333
		W16X26	1000	1	97.19	LF	0.09719
		W16X36	900	1	61	LF	0.067778
		W16X57	800	1	37.92	LF	0.0474
	Horizontal Framing	W18X60	900	1	30.5	LF	0.033889
		Metal Decking	3650	1	8313	SF	2.277534
		Shear Studs	920	1	938	CT	1.019565
		WWF	29000	1	8313	SF	0.286655
LVL 1	Slabs	Concrete Pour	140	4	653	CY	4.664286
		W8X10	600	1	36.75	LF	0.06125
		W12X16	880	1	22.2	LF	0.025227
		W12X19	880	1	125.71	LF	0.142852
		W14X22	750	1	202.87	LF	0.270493
		W16X31	900	1	183	LF	0.203333
		W16X50	800	1	73.5	LF	0.091875
		W16X57	800	1	36.75	LF	0.045938
		W18X35	960	1	170.65	LF	0.17776
		W18X46	960	1	73.5	LF	0.076563
		W18X50	912	1	46	LF	0.050439
		W21X44	1064	1	1641.75	LF	1.542998
		W21X50	1064	1	36.75	LF	0.034539
		W21X93	1000	1	36.75	LF	0.03675
		W21X166	1000	1	30.5	LF	0.0305
		W24X68	1110	1	45	LF	0.040541
		W24X76	1110	1	36.75	LF	0.033108
		W24X104	1050	1	132	LF	0.125714
		W24X131	1050	1	30.5	LF	0.029048
		W30X132	1160	1	91.5	LF	0.078879
	Horizontal Framing	W33X118	1176	1	36.75	LF	0.03125
		Metal Decking	3650	1	19777	SF	5.418356
		Shear Studs	920	1	2887	CT	3.138043
		WWF	29000	1	19777	SF	0.681966
LVL 2	Slab	Concrete Pour	140	4	653	CY	4.664286
		W12x53	984	1	481	LF	0.488821
		W14x109	984	1	481	LF	0.488821
	Columns	W14x145	984	1	51	LF	0.051829
		W12X16	880	1	21.2	LF	0.024091
		W12X19	880	1	210.61	LF	0.23933
		W14X22	750	1	172.37	LF	0.229827
		W16X26	1000	1	26.65	LF	0.02665
		W16X31	900	1	183	LF	0.203333
		W18X35	960	1	144	LF	0.15
		W21X44	1064	1	1790.75	LF	1.683036
		W21X50	1064	1	73.5	LF	0.069079
		W24X55	1110	1	23	LF	0.020721
		W24X94	1080	1	96.5	LF	0.089352
		W24X104	1050	1	176	LF	0.167619
		W24X131	1050	1	61	LF	0.058095
	Horizontal Framing	W30X132	1160	1	122	LF	0.105172
		Metal Decking	3650	1	19759	SF	5.413425
		Shear Studs	920	1	2118	CT	2.302174
		WWF	29000	1	19759	SF	0.681345
LVL 3	Slab	Concrete Pour	140	4	653	CY	4.664286
		W12X16	880	1	21.2	LF	0.024091
		W12X19	880	1	200.3	LF	0.227614
		W14X22	750	1	275	LF	0.366667
		W16X26	1000	1	26.65	LF	0.02665
		W16X31	900	1	91.5	LF	0.101667
		W18X35	960	1	144	LF	0.15
		W21X44	1064	1	1519	LF	1.427632
		W21X50	1064	1	294	LF	0.276316
		W24X55	1110	1	46	LF	0.041441
		W24X76	1110	1	95	LF	0.085586
		W24X84	1080	1	132	LF	0.122222
		W24X94	1080	1	134	LF	0.124074
	Horizontal Framing	W30X132	1160	1	122	LF	0.105172
		Metal Decking	3650	1	19771	SF	5.416712
		Shear Studs	920	1	2641	CT	2.870652
		WWF	29000	1	19771	SF	0.681759
LVL 4	Slab	Concrete Pour	140	1	653	CY	4.664286
		HSS-Hollow Structural Section: HSS16X4X3/8	70	1	17	LF	0.242857
		W8X28	550	1	19	LF	0.034545
		W10X12	600	1	53.48	LF	0.089133
		W10X15	600	1	286	LF	0.476667
		W10X19	600	1	30.68	LF	0.051133
		W10X22	600	1	40.22	LF	0.067033
		W12X16	880	1	12.26	LF	0.013932
		W12X19	880	1	516	LF	0.586364
		W12X26	880	1	22	LF	0.025
LVL 5	Horizontal Framing	W12X40	880	1	91.68	LF	0.104182

		W16X26	1000	1	183	LF	0.183
		W18X35	960	1	213.5	LF	0.222396
		W18X50	912	1	30.5	LF	0.033443
		W21X44	1064	1	2064.5	LF	1.94032
		W24X55	1110	1	147	LF	0.132432
		W24X84	1080	1	132	LF	0.122222
		W24X94	1080	1	61	LF	0.056481
		W30X99	1200	1	122	LF	0.101667
	Slab	Metal Decking	3650	1	20683	SF	5.666575
		Shear Studs	920	1	0	CT	0
		WWF	29000	1	20683	SF	0.713207
		Concrete Pour	140	1	981	CY	7.007143
All Levels	BM	Fire proofing	1500	2	75262	SF	25.08733
	CL		1100	2	17561	SF	7.982273

Table 18 Laterally Braced System Schedule

Floor	Building Element	Item Description	Daily outpout	Crew	Quantity	Units	Duration
Lvl 0	Footings		11.5	1	11.5	CY	1
	Columns	P1,P2,P3	23.32	1	316	LF	13.5506003
		W14X132	984	1	94.42	LF	0.09595528
	Fdn Walls		51	3	253	CY	2
	Slab On Grade		92	3	316	CY	1
	Columns	W12X65	984	1	1304.04	LF	1.3252439
Lvl 1	Framing	W-Wide Flange: W14X22	750	1	43	LF	0.05733333
		W-Wide Flange: W16X50	800	1	414	LF	0.5175
		W-Wide Flange: W16X57	800	1	75	LF	0.09375
		W-Wide Flange: W16X67	760	1	36.75	LF	0.04835526
		W-Wide Flange: W18X65	900	1	23	LF	0.02555556
		W-Wide Flange: W10X15	600	1	11.67	LF	0.01945
		W-Wide Flange: W12X16	880	1	22	LF	0.025
		W-Wide Flange: W12X19	880	1	116	LF	0.13181818
		W-Wide Flange: W16X26	1000	1	98	LF	0.098
		W-Wide Flange: W16X36	900	1	61	LF	0.06777778
		W-Wide Flange: W18X60	900	1	30.5	LF	0.03388889
	Slabs	Metal Deck	3650	1	8313	SF	2.27753425
		Shear Studs	920	1	938	CT	1.01956522
		WWF	29000	1	8313	SF	0.28665517
		Concrete Pour	140	4	653	CY	4.66428571
Lvl 2	Framing	W-Wide Flange: W8X10	600	1	36.75	LF	0.06125
		W-Wide Flange: W12X16	880	1	22	LF	0.025
		W-Wide Flange: W12X19	880	1	126	LF	0.14318182
		W-Wide Flange: W14X22	750	1	203	LF	0.27066667
		W-Wide Flange: W16X31	900	1	336	LF	0.37333333
		W-Wide Flange: W16X50	800	1	111	LF	0.13875
		W-Wide Flange: W18X35	960	1	171	LF	0.178125
		W-Wide Flange: W18X46	960	1	74	LF	0.07708333
		W-Wide Flange: W18X50	912	1	46	LF	0.0504386
		W-Wide Flange: W21X44	1064	1	1671	LF	1.57048872
		W-Wide Flange: W21X44	1064	1	36.75	LF	0.03453947
		W-Wide Flange: W21X50	1064	1	36.75	LF	0.03453947
		W-Wide Flange: W21X93	1000	1	36.75	LF	0.03675
		W-Wide Flange: W24X68	1110	1	45	LF	0.04054054
		W-Wide Flange: W24X76	1110	1	36.75	LF	0.03310811
		W-Wide Flange: W24X104	1050	1	66	LF	0.06285714
		W-Wide Flange: W33X118	1176	1	36.75	LF	0.03125
	Slabs	Metal Deck	3650	1	19777	SF	5.41835616
		Shear Studs	920	1	2887	CT	3.13804348
		WWF	29000	1	19777	SF	0.68196552
		Concrete Pour	140	4	653	CY	4.66428571
Lvl 3	Columns	W12X53	984	1	1013.33	LF	1.02980691
	Framing	W-Wide Flange: W12X16	880	1	21	LF	0.02386364
		W-Wide Flange: W12X19	880	1	211	LF	0.23977273
		W-Wide Flange: W14X22	750	1	172	LF	0.22933333
		W-Wide Flange: W16X26	1000	1	26.65	LF	0.02665
		W-Wide Flange: W16X31	900	1	366	LF	0.40666667
		W-Wide Flange: W18X35	960	1	144	LF	0.15
		W-Wide Flange: W21X44	1064	1	2071	LF	1.94642857
		W-Wide Flange: W24X55	1110	1	23	LF	0.02072072
		W-Wide Flange: W24X104	1050	1	66	LF	0.06285714
	Slabs	Metal Deck	3650	1	19759	SF	5.41342466
		Shear Studs	920	1	2118	CT	2.30217391
		WWF	29000	1	19759	SF	0.68134483
		Concrete Pour	140	4	653	CY	4.66428571
Lvl 4	Framing	W-Wide Flange: W12X16	880	1	21	LF	0.02386364
		W-Wide Flange: W12X19	880	1	201	LF	0.22840909
		W-Wide Flange: W14X22	750	1	254	LF	0.33866667
		W-Wide Flange: W16X26	1000	1	26.65	LF	0.02665
		W-Wide Flange: W16X31	900	1	214	LF	0.23777778
		W-Wide Flange: W18X35	960	1	175	LF	0.18229167
		W-Wide Flange: W21X44	1064	1	1682	LF	1.58082707
		W-Wide Flange: W21X44	1064	1	36.75	LF	0.03453947
		W-Wide Flange: W21X50	1064	1	294	LF	0.27631579
		W-Wide Flange: W24X55	1110	1	46	LF	0.04144144
		W-Wide Flange: W24X76	1110	1	59	LF	0.05315315
		W-Wide Flange: W24X94	1080	1	74	LF	0.06851852
	Slabs	Metal Deck	3650	1	19771	SF	5.41671233
		Shear Studs	920	1	2641	CT	2.87065217
		WWF	29000	1	19771	SF	0.68175862
		Concrete Pour	140	1	653	CY	4.66428571
Lvl 5	Framing	W-Wide Flange: W8X28	550	1	19	LF	0.03454545
		W-Wide Flange: W10X12	600	1	54	LF	0.09
		W-Wide Flange: W10X15	600	1	286	LF	0.47666667
		W-Wide Flange: W10X19	600	1	31	LF	0.05166667
		W-Wide Flange: W10X22	600	1	41	LF	0.06833333
		W-Wide Flange: W12X16	880	1	13	LF	0.01477273
		W-Wide Flange: W12X19	880	1	516	LF	0.58636364
		W-Wide Flange: W12X26	880	1	22	LF	0.025
		W-Wide Flange: W12X40	880	1	92	LF	0.10454545
		W-Wide Flange: W16X26	1000	1	183	LF	0.183
		W-Wide Flange: W18X35	960	1	336	LF	0.35
		W-Wide Flange: W18X50	912	1	30.5	LF	0.03344298
		W-Wide Flange: W21X44	1064	1	2131	LF	2.00281955
		W-Wide Flange: W24X55	1110	1	208	LF	0.18738739
		W-Wide Flange: W24X84	1080	1	69	LF	0.06388889
	Slabs	Metal Deck	3650	1	20683	SF	5.66657534
		Shear Studs	920	1	0	CT	0
		WWF	29000	1	20683	SF	0.7132069
		Concrete Pour	140	1	981	CY	7.00714286
All Levels	BM	Fire proofing	1500	2	73162	SF	24.3873333
	CL		1100	2	15562	SF	7.07363636

Appendix R: Laterally Braced Frame System Structural Drawings

GENERAL NOTES:

1.– All work shall conform to the requirements of the State Building Code of the Commonwealth of Massachusetts, Eighth edition.

2.– The Contractor shall verify all dimensions and conditions in the field prior to commencing work. Where dimensions and elevations of existing construction could affect the new construction, it is the Contractor's responsibility to make field measurements in time for their incorporation in the Shop Drawings. The Architect and Engineer shall be notified of any discrepancies that may exist.

3.– See architectural drawings for floor elevations, slopes, locations of depressed floor areas, and floor openings. The Contractor shall compare the structural drawings with the architectural drawings and report any discrepancy to the Architect and Engineer prior to construction.

4.– Principal openings through the framing are shown on these drawings. The General Contractor shall examine the structural, architectural and mechanical drawings for the required openings and shall verify size and location of all openings with the Mechanical Contractor. Providing all openings required by the Mechanical, Electrical, or Plumbing trades shall be a part of the General Contract, whether or not shown in the structural drawings. Any deviation from the openings shown on the structural drawings shall be brought to the Engineer's attention for review.

5.– Furnish and place all supports, temporary and permanent, whether shoring, bracing, needling, underpinning, or sheet piling, necessary to brace existing walls or framing to remain, so that no horizontal or vertical settlement occurs to the existing structures. Temporary supports shall be maintained in place until permanent supports are installed. Design of these supports shall be by a registered Structural Engineer in the project state in the employ of the Contractor.

6.– Alternate connection details may be approved if such details are submitted to the Engineer for review and acceptance is granted. However, the Engineer shall be the sole judge of acceptability and the Contractor's bid shall anticipate the use of those specific details shown on the drawings. The Contractor shall retain a registered Structural Engineer to be responsible for the design of any alternate details which he proposes.

7.– Work not indicated on a part of the drawings but reasonably implied to be similar to that shown at corresponding places, shall be included in the Contractor's work.

8.– The Contractor shall be completely responsible for the safety of adjacent structures, property, his workmen, and the public, as affected by the construction of this project.

9.– All Contractors are required to examine the drawings and specifications carefully, visit the site and fully inform themselves as to all existing conditions and limitations, prior to agreeing to perform the work. Failure to visit the site and familiarize themselves with the existing conditions and limitations will in no way relieve the Contractor from furnishing any materials or performing any work in accordance with drawings and specifications without additional cost to the Owner.

10.– Structural drawings may represent construction with a reference scale. Due to the inherent process of drawing development and presentation not all work may be shown "exact" in that scale. Do not "scale" drawings to obtain any missing information or to interpret any information not specifically dimensioned for "exact" detailing or construction purposes.

FOUNDATIONS:

1.– The foundation design is based on recommendations contained in the Geotechnical Report by Maguire Group Inc. dated November 2009. This report is available to bidding Contractors for their information, however their attention is directed to the limitations of the report described therein.

2.– All footings shall be carried down to soil having minimum bearing capacity of 3.0 tons per square foot at street level and 1.5 tons per square foot at basement level. Elevations if given, are the bottom of the footings, are minimum depths, and are not to be construed as limiting in any way the depth of excavation required to reach good bearing.

3.– In general, exterior construction shall be carried down to a minimum of 4 feet below finished exterior grade or the lowest slab level.

4.– No foundations shall be placed in water or on frozen ground.

5.– All footing excavations are to be finished by hand, unless otherwise directed by the Geotechnical Engineer.

6.– All finished foundation excavations shall be inspected and approved by the Architect or his designate before any concrete is placed.

7.– Unless otherwise noted, all footings and pilasters shall be centered under supported members.

8.– Dowels from foundations into piers, columns, buttresses, or walls above shall be the same size and number as vertical reinforcement in piers, columns, buttresses, or walls above, except as otherwise shown on the drawings.

9.– Carefully follow the requirements of the specifications for back fill under or adjacent to any portion of the building.

10.– Where foundation elements are to have fill on both sides, each side shall be filled simultaneously, maintaining a common elevation.

11.– Coordinate under floor drain requirements with architectural and mechanical drawings and the requirements of the Geotechnical Engineer.

12.– Contractor shall provide continuous control of surface and underground water as required during construction such that the work is done in the dry. However, the Contractor shall insure that ground water levels under adjacent structures are not lowered by his construction techniques. Additionally, if so directed by notes in the plans, the Contractor will continue to maintain a condition of no hydrostatic pressure until sufficient building weight is in place to prevent flotation of any part of the structure.

13.– Building walls retaining earth rely on the completed floor slabs for lateral support. If required by the construction sequence, the Contractor shall temporarily brace all building walls against which back fill is to be placed until all floor slabs supporting the walls are in place and have attained at least 75% of their specified design strength. Design of temporary braces shall be by a registered structural engineer in the employ of the Contractor.

CONCRETE:

1.– All concrete work shall conform to the 2002 edition of the ACI Building Code Requirements for Reinforced Concrete (ACI 318) and the Commonwealth of Massachusetts State Building Code. In case of conflict, the State Building Code shall govern.

2.– All concrete shall be controlled concrete, mixed and placed under the supervision of an approved concrete testing agency.

3.– For locations listed below, concrete shall be normal weight concrete with sand and gravel aggregate, Type I or Type II Portland Cement and a minimum compressive strength (f'c) in 28 days as follows:

Footings and piers . . . . .4000 psi
Foundation tie beams . . . . .4000 psi
Walls . . . . .4000 psi
Slabs on grade . . . . .4000 psi
All other foundation concrete . . . . .3000 psi
Fill concrete .3000 psi
Mud mats . . . . .2000 psi
Steel member encasement . . . . .3000 psi
Slabs on metal deck . . . . .See note 5

4.– All concrete exposed to the weather or possible freeze/thaw action shall contain an air entrainment admixture. See specifications for air content.

5.– Concrete floor slabs on metal deck shall have normal weight or lightweight coarse aggregate, Type I or Type II Portland Cement and 4000 psi Compressive strength (f'c) in 28 days.

6.– The steel framing has been designed as unshored construction, and the plans may show cambering of some structural members to counteract some of the system deflection under the weight of concrete as it is placed. Due consideration should be given to camber tolerance and erection tolerance in providing for the thickness of concrete necessary to obtain the specified finish floor elevations. The final slab thickness shall not be less than called for on plans. Contractor is to provide the additional concrete required to compensate for deflection of unshored beams and deck and to produce a slab level within tolerance and with a slab thickness at least the thickness specified in all locations.

7.– All concrete shall be placed without horizontal construction joints, except where specifically noted. Vertical construction joints and stops in shored concrete work shall be made at midspan. Horizontal reinforcement shall be continuous through vertical construction joints.

8.– Construction joint locations other than shown on the drawings are permitted subject to prior approval of the Engineer. Expansion joint and control joint locations are mandatory as shown. Contractor shall submit drawings showing intended placing sequences and locations of construction joints to the Engineer for approval. At poured in place walls, Construction joints shall be located so as to provide a 60'–0" maximum horizontal length of concrete placement in any direction.

9.– Unless otherwise shown on drawings, slabs on grade shall be cast in alternating strips, one (1) column bay wide. Adjacent sections shall be placed no sooner than three days apart. Alternatively, slab on grade areas may be poured in as large an area as can be handled provided that saw cut joints are cut as soon as the concrete will support a man's weight without permanent deformation and the joint process does not dislodge aggregates.

10.– Grout under column base plates and under other bearing plates shall be non-shrink, nonmetallic grout with a minimum compressive strength of 5000 psi at 3 days.

11.– Pipes or conduits placed in slabs on grade shall not be placed closer than 3 diameters on centers and shall have an outside diameter less than 1/3 of the slab thickness and be positioned so that they do not interfere with slab reinforcement. Aluminum conduits shall not be placed in concrete. No conduits or pipes shall be placed in composite slabs on metal deck.

12.– All keys shall be 2" x 4" (nominal) unless otherwise shown on the drawings.

13.– Concrete cast on sloped surfaces shall begin at the lowest elevation and continue monolithically toward the higher elevations until the intended pour is completed.

14.– No concrete shall be cast before review and approval of the reinforcing and embedded items have been obtained from the Architect, or his designated representative.

15.– All exposed edges of concrete members shall be chamfered 3/4" unless shown otherwise on architectural drawings.

16.– Concrete must reach the following percentages of its 28–day compressive strength (f'c) before forms or shores may be removed:

Walls and beam sides. 20%
Floor systems. 85%

17.– Refer to architectural drawings for concrete finishes. Where finish is not specified, conform to requirements of ACI 301 – "Specifications for Structural Concrete for Buildings."

18.– See architectural drawings for door and window openings, drips, washes, reglets, concrete finishes, masonry anchors, and for miscellaneous embedded plates, bolts, anchors, angles, etc.

19.– The placement of sleeves, outlet boxes, box–outs, anchors, etc., for the mechanical, electrical and plumbing trades is the responsibility of the trade involved. However, any box–outs not covered by typical details in the structural drawings shall be submitted for approval.

20. At sawcutting of existing concrete, including slabs on grade, no overcut at corners is allowed. All corners shall have a core hole of sufficient diameter made prior to cutting at adjacent sides to prevent cut beyond the required dimension.

REINFORCING:

1.– All concrete reinforcing bars less than #11 shall conform to ASTM A615, Grade 60, except where noted. All concrete reinforcing bars #11 and greater shall conform to ASTM A615, Grade 75. All reinforcing bars to be welded shall conform to ASTM A706. Reinforcing bars may not be welded without prior approval of the Structural Engineer.

2.– All welded wire fabric (W.W.F.) shall conform to ASTM 185.(Fy=65 KSI min.) W.W.F. shall be provided in flat sheets. The following W.W.F. shall be used for areas specified below unless otherwise shown on the drawings. ie: W.W.F. designations where shown on the plans supersede these shown below:

Slab on grade: . . . . .6x6 – W2.9 x W2.9

Slab on metal deck: . . . . . .6x6 – W2.1 x W2.1

Around structural members encased in concrete: . . .4x4 – W1.4 x W1.4, plus 1–#5 spacer bar each corner

In middle of concrete fill for stairs: . . . . . .2x2 – W1.4 x W1.4

Note: Fibermesh at 1 1/2#/cu. yd. may be substituted for WWF in stairs.

3.– Reinforcement shall be continuous through all construction joints unless otherwise noted on drawings.

4.– Detailing of concrete reinforcement and accessories shall be in accordance with ACI 315 – "Manual of Standard Practice for Detailing Reinforced Concrete Structures," latest edition.

5.– Provide and schedule with the shop drawings, all necessary accessories to hold reinforcing securely in position.
Minimum requirements shall be:

High chairs. . . . . .4'–0" on center
Slab bolsters. . . . . .4'–0" on center
Support bars for high chairs No. 5

6.– All continuous reinforcement shall have a minimum lap as required for a Class B splice (AC1 318) unless noted otherwise.

7.– All laps in W.W.F. shall be one mesh plus two inches at splices.

8.– Concrete protection for reinforcement including W.W.F. shall be provided as follows unless otherwise shown on the drawings:

a. Surfaces cast against earth. . . .3 inches

b. Formed surfaces exposed to earth or weather
#6 through #18 bars. . . . . .2 inches
#5 bars and smaller. . . . . .1 1/2 inches

c. Formed surfaces not exposed to earth or weather
Slabs, walls, joists
#11 bar and smaller. . . . . .3/4 inch
#14 and #18 bar . . . . . . .1 1/2 inches

Beams, columns. . . . . . . .1 1/2 inches

d. Slabs on grade
(from top of slab). . . . . . .1 1/2 inches

e. Slabs on metal deck
Top. . . . . .3/4 inch
Bottom. . . . . .3/4 inch

Maximum deviation from these requirements shall be ±1/4 inch for sections 10 inches thick or less; and ±1/2 inch for sections over 10 inches thick. See ACI 318–95, section 7.7.1 for conditions not listed.

9.– All hooks shown on drawings shall be standard hooks unless noted otherwise.

10.– Where continuous bars are called for, they shall run continuously around corners and be lapped at necessary splices, or hooked at discontinuous ends. Lap lengths shall be as given in the splice and development table. Lap beam top bars at mid–span and beam bottom bars at supports, unless otherwise noted.

11.– Provide additional reinforcing at the sides and corners of all openings in concrete in accordance with the typical details. Minimum additional reinforcing shall be as follows:

(2) – #5 top and bottom in slabs

(2) – #5 each face in walls

(2) – #5 x 4'–0" long diagonally each corner of opening

Extend bars a minimum of 2'–0" beyond opening, hook where extension is not possible.

12.– In beams, where stirrups are not specified for the whole beam length, or for any part thereof, provide #3 spaced at (beam depth –2")/2, or 24" maximum.

13.– Provide for a minimum of 1–#5 stirrup support bar at each stirrup bend where primary bars do not exist.

14.– In beams over 18" deep provide continuous #4 bars on the side faces with a spacing of not more than 12" on center.

15.– Primary top & bottom horizontal reinforcing in beams and girders shall be detailed to be placed in one layer unless shown or noted otherwise on the drawings.

16.– All beam "stirrups" or "ties" shall be continuous closed type unless otherwise noted on the drawings.

REINFORCED MASONRY:

1.– All masonry work shall conform to the "Building Code Requirements of Masonry Structures" (ACI 530–05/ASCE 5–02) And (ACI 530.1–05/ASCE 6–02).

2.– The compressive strength of the masonry, f'm, shall be at least 1500 psi. Unless otherwise approved by the Structural Engineer on the basis of prism testing the components of the masonry shall have compressive strengths as given below:

3.– All concrete masonry units (CMU) shall conform to ASTM C90, grade N–1, with an individual compressive strength of 2400 psi

4.– Mortar for block wall construction shall be Type M or S conforming to ASTM C270.

5.– Grout for piers and block walls shall conform to ASTM C476 with a minimum compressive strength of 2000 psi determined in accordance with the provisions of ASTM C1019.

6.– Reinforcing bars shall conform to ASTM A615, Grade 60, except bars to be welded shall conform to ASTM A706.

7.– Wire for joint reinforcing shall conform to ASTM A82, yield point = 70 ksi (min.).

8.– Unless noted otherwise provide the following minimum reinforcing:

VERTICAL

6" and 8" CMU

<8' High	8'–12' High	>12' High
#4@24"	#4@32"	#5@48"

10" and 12" CMU

<8' High	8'–12' High	>12' High
#4@24"	#5@32"	#6@32"

HORIZONTAL

6" and 8" CMU
#9 Dur–o–wal Ladur (2–W1.7 wires)
@16" o.c.

10" and 12" CMU
3/16" Dur–o–wal Ladur (2–W1.7 wires)
@16" o.c.

9.– Provide bond beams with 2–#5 continuous, at [the top of foundation walls and] the top of parapets, at each floor level, and where shown on the drawings.

10.– Unless noted otherwise on plans, provide the following additional vertical reinforcement in the cell immediately adjacent to each side of a masonry opening and in the cell of discontinuous walls. These bars are to extend full height of the wall or in the case of masonry openings at multi–story walls, from story to level above to story level below the opening.
6" and 8" CMU Walls – 2–#5
10" and 12" CMU Walls – 2–#6

11.– Extend additional reinforcement a minimum of 36 bar diameters beyond the opening.

12.– The minimum length of lap for reinforcing bars embedded in grout is 48 bar diameters, unless shown otherwise on the drawings.

13.– Place reinforcing bars before grouting. Place grout in lifts not exceeding 5 feet. Consolidate each lift by mechanical vibration. The next lift of the pour may be made after the initial water loss and reconsolidation of the prior lift, while it is still plastic.

14.– Properly secure reinforcing bars to maintain the positions indicated on the drawings. Bars to be located in center of cells unless otherwise noted.

15.– All CMU shall be braced during construction for the governing code lateral design loads until permanent restraints have been installed.

16.– The following steps are to be followed when laying masonry in the temperatures stated below:

40° – 32° F (mean daily air temperature)

Heat mixing water or aggregate to 70° F.
Protect masonry from rain or snow for 24 hours.

32° – 20° F, mean daily air temperature

Heat mixing water and aggregate to 70° F.
Provide wind breaks for wind velocity in excess of 15 m.p.h.
Cover masonry with insulating blankets for 24 hours and provide heat sources on both sides of masonry construction.

Below 20° F, mean daily air temperature

Heat mixing water and aggregate to 70° F.
Provide enclosures and heat to maintain 40° minimum temperature.
Temperature of masonry units must be 40° F minimum when laid.
Maintain masonry above 40° F for 24 hours by enclosures and supplemental heat.

STRUCTURAL STEEL:

1.– Structural steel design conforms to "Load and Resistance Factor Design Specification for Structural Steel Buildings" (AISC, Third Edition).

2.– Structural steel rolled shapes, plates, and bars shall conform to the following ASTM designations:

ASTM A–572, Grade 50 or A992 . . . . . All W shapes, unless noted otherwise

ASTM A–36. . . . . All other rolled shapes, plates and bars unless noted unless noted otherwise

ASTM A–500, Grade B. . . . . . HSS sections (square, rectangular)

ASTM A–500, Grade C. . . . . . HSS sections (round)

ASTM A–53, Grade B. . . . . . Pipe

ASTM A–325, Type SC or N. . . All bolts for connecting structural members

ASTM F–1554. . . . . All anchor bolts, unless noted otherwise

3.– Shop painting of structural steel is not required unless otherwise noted. Add/Alternate: Provide 1 coat of standard shop primer to all interior steel except at beam flanges receiving shear studs and steel receiving spray fireproofing around stairs, shafts, elevators, and in the annex.

4.– Filler beams shall be spaced equally between established dimensions, unless noted otherwise.

5.– The concrete slabs and/or non–composite steel decks are part of the stability system for a completed structure. The Contractor shall provide temporary erection bracing to maintain structural steel in proper position until permanently secured. Remove temporary bracing and their connections only after erection of permanent members is complete and all concrete slabs have been placed and cured and non–composite steel decks are properly fastened. A completed structure has its boundary's defined by the building exterior and/or interior expansion joints where they exist between building segments.

6.– Shear connectors shall be 3/4" diameter headed studs, field applied, with a nominal shear strength of 26.1 kips per connector. The number of shear connectors is indicated in brackets by each beam. More than one number in a bracket indicates groups of shear connectors to be placed between connection points of intersecting beams. Substitution of shear connectors with nominal strength less than given above, or a placement which results in a reduction factor by formulas I3–1 or I3–2, AISC manual (Third Edition) if approved, will require an adjustment in the number of shear connectors to maintain the same total shear transfer capacity and will be at the Contractor's expense.

7.– All composite beams, using concrete slab as compression flange, are designed for strength assuming unshored construction, unless otherwise noted.

8.– Provide an upward beam camber at the mid span between supports where indicated thus: +c= 1 1/2", if specified on drawings. Camber is to be provided by mill rolling or shop fabrication, or a combination of each. Contractor is to note that the structural steel beams have been cambered in an effort to limit extra concrete placement due to the deflection of the structural steel beams and girders. However, the amount of actual camber for each structural steel member may vary due to mill or shop tolerance and beams with computed initial deflections of no more than 3/4" are not cambered at all. Therefore, the Contractor may not assume that the cambers indicated eliminate the need for extra concrete placement.

9.– Shop connections unless otherwise noted, shall be made by welding, or by using snug tight 3/4"ø high strength bolts, minimum.

10.– All shop and field welds shall be made by certified welders, and shall conform to "Structural Welding Code – Steel" (AWS D1.1 2000).

11.– Electrodes for all field and shop welding shall conform to AWS E–70 Series.

12.– Bolted field connections shall be made with 3/4" diameter A325 bolts, minimum, unless otherwise noted.

13.– A325 bolts installed with the bolt tension (pre–tensioned) specified in Table J3.1 of the AISC LRFD Third Edition Specification, shall be used for the following connections.

a. Column splices
b. Connections of beams and girders to columns
c. Bolted moment connections
d. Bracing members
e. Hangers
f. Connections noted as Type SC on the design drawings
g. Connections of beams and girders to columns in brace frames
h. Connections c, d, e, f, and g shall be designed as "slip critical" connections.

* All other A325 bolts may be pre–tensioned as defined by AISC.

* All other A325 bolts shall not be pre–tensioned but shall be installed to the snug tight condition as defined by AISC.

14.– Connections shown on these drawings are generally schematic. They are intended to define the spatial relationship of the framed members and show a feasible method of making the connection. Any connection that is not shown or is not completely detailed on the structural drawings shall be designed by a registered professional Engineer, retained by the fabricator. Details and connections may be designed to conform to AISC Manuals Third Edition – LRFD or Ninth Edition – ASD. Completely detailed means the following information is shown on the shop detail drawings:

a. All plate dimensions and grade.

b. All weld sizes, lengths, pitches and returns.

c. All hole sizes and spacings.

d. Number and type of bolts: where bolts are shown but no number is given, the connection has not been completely detailed.

e. Where partial information is given, it shall be the minimum requirement for the connection.

f. Method of design.

15.– All rectangular hss members to be orientated long side vertical u.n.o.

16.– Details and connections completely detailed in the Contract Drawings may not be altered without written approval by the Engineer. Where approved, altered connections shall be completely detailed by the fabricator's engineer clearly on the shop drawings.

17.– Alterations of schematic connection details may impact architectural concept and shall not be made without prior written approval of the Engineer.

18.– Minimum connection plate thickness shall be 3/8", unless otherwise indicated in the Contract Drawings.

19.– Unless otherwise noted, beam to beam connections and beam to column connections shall be double angle (t=5/16") framed beam connections shop welded per Table 10–2, AISC Manual Third Edition – LRFD) using weld A, or shop bolted using Table 10–1 and using 3/4" diameter A325–N bolts in standard or horizontally slotted holes for the field connection. The number of rows of bolts, n, shall be in accordance with the following table. Table applies to composite and non–composite beams.

Beam Size	n	Shear Design Strength (kips)
W8x10, W10x12	2	18.5
W8x13, 15, W10x15	2	24.0
W8x18, 21, 24, W10x17, 19, 22, 26	2	26.9
W8 ≥ 28, W10 ≥ 30	2	34.8
W12x14, 16	3	33.0
W14 ≤ 30, W12x19, 22, 26, 30	3	40.2
W12x35, 40, 45 W14x34, 38, 43, 48	3	52.1
W12 ≥ 50 W14 ≥ 53	3	63.0
W16x26, 31	4	60.0
W16x36, 40 W18x35, W18x40	4	71.9
W16 ≥ 45, W18x46, 50, 55	4	84.2
W18 ≥ 60, W21 ≤ 62, W24x55	5	106.7
W21 ≥ 68, W24x62, 68, 76	5	126.5
W24 ≥ 84, W27x84	6	151.8
W27 ≥ 94, W30x90, 99	7	195.0
W30 ≥ 108	8	230.0
W33	9	260.0
W36	10	290.0
W40	11	319.0

Where the Fabricator proposes an alternate connection, it shall have at least the shear capacity indicated in the above table. Where reactions are indicated in the drawings (example: R=85k) they supersede the table above and the Fabricator shall provide a connection with a capacity at least equal to the reaction indicated. Seated beam connections will not be allowed unless the seat is used for erection purposes only. For other beam shapes (S, C, MC) provide a two bolt connection unless otherwise shown on the drawings. Where reactions are posted, they have been factored per State Building Code of Commonwealth of Massachusetts, Seventh Edition. "Load and Resistance Factor Design Specifications for Steel Hollow Structural Sections" (2000).

20.– Unless otherwise noted, all connections at HSS sections shall be designed and detailed in accordance with the AISC "Load and Resistance factor design specifications for steel hollow structural sections" (2000).
Moment connection details on the drawings must be consistent with Note 21. Typical moment connection details allow for 3 options:

21.– Beam to column moment connections that are part of the lateral force resisting system shall be designated for $1.1R_yM_p = 1.1R_yF_yZ$. Connection shall be detailed in accordance with chapter 11 Ordinary Moment Frames of AISC 341–02]. The connection shear strength shall meet or exceed values shown on structural steel note 19, unless noted otherwise.

22.– The connection at the ends of tension or compression members shall develop the force due to the design load, but not less than 100% of the tension strength of the member where no design load is posted. Design forces, if posted, have been factored in accordance with the Governing Building Code and no stress increase is permitted. Tension strength of member = 0.9Fy x Ag, except for braces that are of the seismic load resisting system. These brace connections shall be designed for the expected tensile strength = RyFyAg. When design force is based on tension capacity of member, load is to be applied as a tension or compression force.

23.– Splicing of structural members where not detailed on the drawings is prohibited without prior approval of the Structural Engineer.

24.– Provide welded stiffener plates on both sides of the web of beams at points of concentrated loads including beams supporting columns or running over the tops of columns or other beams. Minimum stiffener plate thickness shall be 5/8" or flange thickness of column above or below, whichever is greater.

25.– Screed plates, pour stops and slab supports at slab openings, at slab edges and supports for metal deck around columns shall be furnished by the contractor as required to complete the work.

26.– Cuts, holes, coping, etc. required for work of other trades shall be shown on the shop drawings and made in the shop. Cuts or burning of holes in structural steel members in the field will not be permitted, unless specifically approved in each case by the Structural Engineer.

27.– Unless otherwise detailed in the drawings, provide galvanized loose steel angle lintels over all openings in masonry walls, as follows. Lintels shall have a minimum of 8" bearing on each side of opening. Steel angles in pairs shall be plug welded or bolted at 2'–0" o.c. or stitch welded top and bottom at 1'–0" o.c.

For each 4" of wall thickness

L4 x 3 1/2 x 5/16 for spans less than 5'–0"
L5 x 3 1/2 x 5/16 for spans greater than 5'–0" to 7'–0"
L6 x 3 1/2 x 3/8 for spans greater than 7'–0" to 9'–0"
L6 x 3 1/2 x 1/2 for spans greater than 9'–0" to 12'–0"

For each 6" of wall thickness

L6 x 6 x 5/16 for spans to 7'–0"
L6 x 6 x 3/8 for spans greater than 7'–0" to 9'–0"
L6 x 6 x 1/2 for spans greater than 9'–0" to 12'–0"

28.– All structural steel directly supporting a concrete floor slab shall have shear studs spaced longitudinally at no more than 24" o.c. unless otherwise noted.

29.– All HSS shapes except diagonal bracing members (round, square rectangular, etc.) are to have a 1/4" cap plate at all exposed ends. Cap plates to be seal welded all around, u.n.o.

30.– All weld sizes not shown in details herein shall be the minimum required size based on thickness of thicker part as per AISC, Tables J2.3 & J2.4. Exception: At member splices, welds or bolts shall develop full strength of the member or components being connected.

31.– All around welds indicated herein shall be discontinuous at the flange tips of open sections.

32.– All structural steel, including baseplates and tops of anchor bolts, to be encased in concrete are to be coated with with an approved coal tar epoxy. 16 mils minimum thickness.

33.– Any alteration made by the detailer on the structural steel shop drawings to schematic or completely detailed connections shown on the contract drawings must be clearly identified by clouding or by direct note on the shop drawing by the detailer prior to submission to the engineer.

34.– Any member sizes shown on the plans, and currently listed in the AISC Manual of Steel Construction, Latest Edition, which are not currently available must be brought to the Architect and Structural Engineers attention prior to award of steel contract. No claim for additional cost will be accepted after the award, for member/built up member substitutions for these sizes.

35.– The submerged arc welding process may be substituted for welding together plate girder sections. Fabricator to submit equivalent weld sizes to be used in lieu of the requirements specified herein.

COMPOSITE METAL FLOOR DECK

1.– Design of composite metal floor deck shall be governed by the "Specifications for the Design of Cold Formed Steel Structural Members," by the American Iron and Steel Institute (AISI) and conform to the design and loading requirements of the Steel Deck Institute (SDI).

2.– Metal deck shall be manufactured from galvanized steel conforming to ASTM A653, grade 33 or higher. Galvanizing shall conform to the requirements of ASTM A653, coating class G30.

3.– 3" composite metal floor deck shall have a minimum ratio of width to depth (W/H) of 2.0. The metal deck shall be adequate to support the dead load of the concrete slabs indicated on the drawings and 20 lbs/sq. ft. of construction live load without shoring. The deflection of the deck for concrete weight shall not be greater than 1/180th of the span or 3/4", whichever is smaller. The composite floor deck supplied shall be capable of supporting the design loads given in these drawings, and have section properties per foot of width of approximately:

3 inch x 20 gauge deck (0.0358")

I. .0.953 $inches^4$
S (Positive). . . . . .0.548 $inches^3$
S (Negative). . . . . .0.577 $inches^3$

3 inch x 18 gauge deck (0.0474")

I. .1.261 $inches^4$
S (Positive). . . . . .0.793 $inches^3$
S (Negative). . . . . .0.790 $inches^3$

4.– Fasten metal floor deck by prequalified methods at all supports with 3/4" diameter fusion welds or welded stud shear connectors spaced not more than 12" o.c. Fasten side laps @ 3'–0" on–center or mid–span, whichever is less.

5.– Fabricate deck units in lengths to span three or more support spacings, where possible.

6.– Coordinate size and location of floor openings with architectural and mechanical drawings. See typical details for supplemental framing.

METAL ROOF DECK:

1.– Design of metal roof deck and accessories shall be governed by the "Specifications for the Design of Cold Formed Steel Structural Members," by the American Iron and Steel Institute (AISI) and conform to the design and loading requirements of the "Steel Deck Institute" (SDI).

2.– Metal roof deck shall be rolled of steel sheet, galvanized and conforming to ASTM A653 Grade 33 or higher, coating class G60 [or painted and conforming to ASTM A1008]. The metal roof deck supplied shall be capable of supporting the design loads given in these drawings and have section properties per foot of width of approximately:

3 inch Type N x 20 gauge deck (0.0358")
I. . . . . .0.790 $inches^4$
S (Positive). . . . . .0.470 $inches^3$
S (Negative). . . . . .0.510 $inches^3$

3 inch Type N x 18 gauge deck (0.0474")
I. . . . . .1.140 $inches^4$
S (Positive). . . . . .0.650 $inches^3$
S (Negative). . . . . .0.700 $inches^3$

1 1/2 inch Type B x 20 gauge deck (0.0358")
I. . . . . .0.200 $inches^4$
S (Positive). . . . . .0.230 $inches^3$
S (Negative). . . . . .0.230 $inches^3$

1 1/2 inch Type B x 18 gauge deck (0.0474")
I. . . . . .0.290 $inches^4$
S (Positive). . . . . .0.320 $inches^3$
S (Negative). . . . . .0.320 $inches^3$

3.– Unless otherwise shown on the drawings, fasten metal roof deck by prequalified methods at all supports with 5/8" diameter fusion welds in every rib at end laps, every other rib at intermediate supports and at every rib or 6" o.c. at all supports within 15'–0" of building periphery, braces, openings. Fasten side laps at 2'–6" maximum o.c. or mid–span, whichever is less.

4.– Fabricate deck units in lengths to span three or more support spacings, where possible.

5.– Fabricate roof deck to lap ends a minimum 2 inches.

6.– Coordinate size and location of roof openings with architectural and mechanical drawings. See typical details for supplemental framing.

7.– Do not suspend pipes, ducts, or conduit from roof deck.

LIGHT GAGE STEEL FRAMING

1.– Light gage steel framing is to be supplied with engineering and detailing by the supplier. See specification Section 05400.

2.– Information in these drawings regarding light gage steel framing is only to set conditions important to the appearance of the finished building, to identify where structural loadings from the light gage steel framing will be delivered to the building structure, or to specify the structural interaction between the light gage steel framing and the building structure.

DESIGN LOADS:

1.– Uniformly Distributed Floor Live Loads:

Offices/Lab. . . . . .100 psf
Corridors above 1st floor. . . . . .100 psf
First Floor. . . . . .150 psf
Slab on grade. . . . . .150 psf
Storage (light). . . . . .125 psf
Storage (heavy). . . . . .250 psf
Stairs. .100 psf
Mechanical areas. . . . . .150 psf*
Elevator machine room. . . . . .150 psf*
Sidewalks (intentional or accidental. vehicular traffic) . . . . .250 psf

* or actual equipment weights where greater

2.– Roof Live Load:

Minimum roof live load=20 psf

3.– Roof Snow Load:

Ground snow load, pg=55 psf
Flat roof snow load, $p_f = 0.7C_e C_t I_s p_g = 38.5$psf
Snow exposure factor, C_e=1.0.
Thermal factor, C_t =1.0.
Snow load importance factor, I_s=1.0
Snow drift conditions in accordance with Section 1608.0

4.– Concentrated Live Loads:

Floors have been designed to support the uniformly distributed live loads prescribed in (1) above, or the following concentrated loads, whichever produces the greater stress.

Location	Concentrated Load
Elevator machine room gratings (on 2.0 inches square)	300 lbs.
Floor areas and roofs with concrete (on 30 inches square)	2000 lbs.
Hatches, skylight ribs, and accessible ceilings (on 1.0 inch square)	200 lbs.
Stair treads (on 2.0 inches square)	300 lbs.
Roofs w/o concrete (on 6 inches square)	200 lbs.

All concentrated loads above have been assumed to be non–concurrent with uniform live loads.

5.– Live Load Reduction:

For design live loads of 100 psf or less: Except for places of public assembly, floors of passenger car garages, and roofs, a structural member having a tributary area of $K_{LL} A_T$ that is greater than 400 square feet, may be designated for a reduced live load, L, as follows.

$L = L_o(0.25+15/\sqrt{K_{LL} A_T})$, where
L_o= basic design live load
A_T= loaded area tributary to the member, square feet.
K_{LL}= live load element factor as follows:
K_{LL}= 4 for interior columns and exterior columns without cantilever slabs
K_{LL}= 3 for edge columns with cantilever slabs
K_{LL}= 2 for corner columns with cantilever slabs, edge beams without cantilever slabs, and interior beams
K_{LL}= 1 for all others

L shall not be less than 0.50L for members supporting one floor and not less than $0.40L_o$ for members supporting two or more floors.

Places of public assembly, passenger car garages, and design live loads greater than 100 psf: for members supporting load from more than one floor may be designed for a reduced live load equal to $0.80L_o$ but shall not be less than L as calculated above.

6.– Wind Loads:

Basic Wind Speed (3–Second gust) = 100 mph.
Wind Importance factor, I_w = 1.0
Wind Exposure = B
Design wind pressures for main wind force resisting in accordance with ASCE–02 Section 6.5.12.2
Design wind pressures on components and cladding in accordance with ASCE–02 Section 6.5.12.4

7.– Earthquake Loads:

Seismic importance factor, I_E = 1.0
Seismic Use Group = I.
Spectral response acceleration at short periods, S_s = 0.24
Spectral response acceleration at 1–second period, S_1 = 0.067
Site class D.
Design spectral response acceleration at short periods, Sds = 0.256
Design spectral response acceleration at 1–second period, Sd_1 = 0.107
Seismic design category = B.
Basic Seismic force resisting system = Steel braced frames not specifically detailed for seismic resistance – (X–direction)
= Steel moment frames not specifically detailed for seismic resistance – (Y–direction)

Seismic Base Shear = 422k (X–direction)
= 282k (Y–direction)

Seismic response coefficient, C_s = 0.0500 (X–direction)
= 0.0333 (Y–direction)

Response Modification Coefficient = 3.0 (X direction)
= 3.0 (Y direction)

Analysis procedure = Equivalent Lateral force.

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Drawing Issue	Date
Permit & Construction Documents	Mar 25, 2011
Pricing set	Mar 18, 2011
Steel and Foundation Package	Feb 14, 2011

Revisions

NO	ISSUE	DATE

Sheet Information

Date	03.18.2011
Job Number	29067.00
Drawn	R.J.M
Checked	M.F.A
Approved	-

Title

GENERAL NOTES

Sheet

S-001

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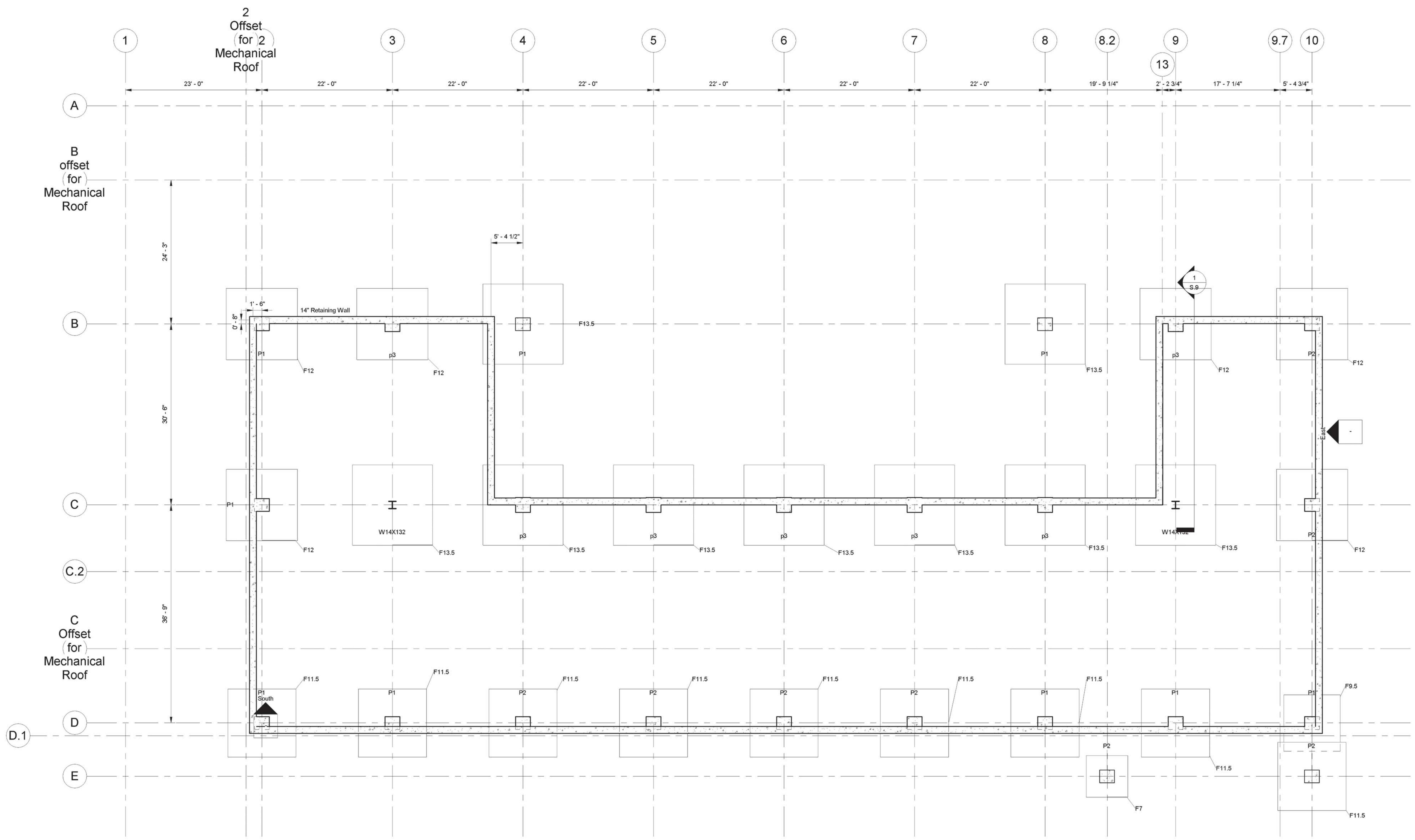

1 BASEMENT LEVEL
1/8" = 1'-0"

Basement Structural Foundation Schedule		
Family and Type	Level	Elevation at Bottom
Footing-Rectangular: F7	BASEMENT LEVEL	474' - 4"
Footing-Rectangular: F9.5	BASEMENT LEVEL	472' - 6"
Footing-Rectangular: F11.5	BASEMENT LEVEL	472' - 2"
Footing-Rectangular: F11.5	BASEMENT LEVEL	472' - 2"
Footing-Rectangular: F11.5	BASEMENT LEVEL	472' - 2"
Footing-Rectangular: F11.5	BASEMENT LEVEL	472' - 2"
Footing-Rectangular: F11.5	BASEMENT LEVEL	472' - 2"
Footing-Rectangular: F11.5	BASEMENT LEVEL	472' - 2"
Footing-Rectangular: F11.5	BASEMENT LEVEL	472' - 2"
Footing-Rectangular: F11.5	BASEMENT LEVEL	472' - 2"
Footing-Rectangular: F11.5	BASEMENT LEVEL	473' - 8"
Footing-Rectangular: F12	BASEMENT LEVEL	472' - 2"
Footing-Rectangular: F12	BASEMENT LEVEL	472' - 2"
Footing-Rectangular: F12	BASEMENT LEVEL	472' - 2"
Footing-Rectangular: F12	BASEMENT LEVEL	472' - 2"
Footing-Rectangular: F12	BASEMENT LEVEL	472' - 2"
Footing-Rectangular: F12	BASEMENT LEVEL	472' - 2"
Footing-Rectangular: F13.5	BASEMENT LEVEL	472' - 0"
Footing-Rectangular: F13.5	BASEMENT LEVEL	472' - 0"
Footing-Rectangular: F13.5	BASEMENT LEVEL	472' - 0"
Footing-Rectangular: F13.5	BASEMENT LEVEL	472' - 0"
Footing-Rectangular: F13.5	BASEMENT LEVEL	472' - 0"
Footing-Rectangular: F13.5	BASEMENT LEVEL	472' - 0"
Footing-Rectangular: F13.5	BASEMENT LEVEL	472' - 0"
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Footing-Rectangular: F13.5	BASEMENT LEVEL	472' - 0"

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Basement Framing Plan

Project Number	Project Number
Date	Issue Date
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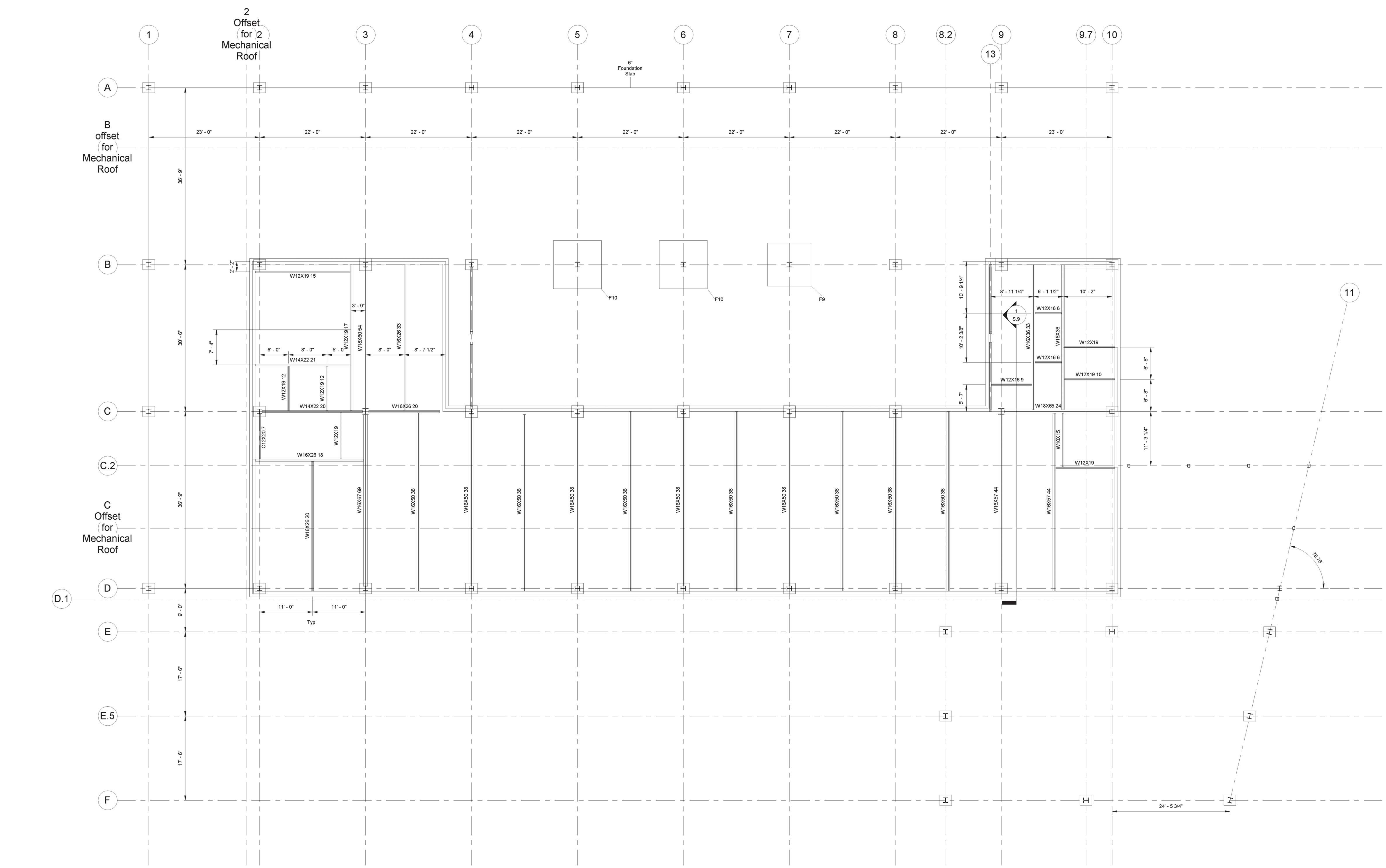

1 Dependent on LEVEL 1 FRAMING
1/8" = 1'-0"

Lvl 1 Structural Foundation Schedule		
Family and Type	Level	Elevation at Bottom
Footing-Rectangular: F9	LEVEL 1	484' - 7 1/2"
Footing-Rectangular: F10	LEVEL 1	484' - 3 1/2"
Footing-Rectangular: F10	LEVEL 1	484' - 3 1/2"
Foundation Slab: 6" Foundation Slab	LEVEL 1 FRAMING	487' - 10 1/2"

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Level 1 Framing Plan

Project Number	Project Number
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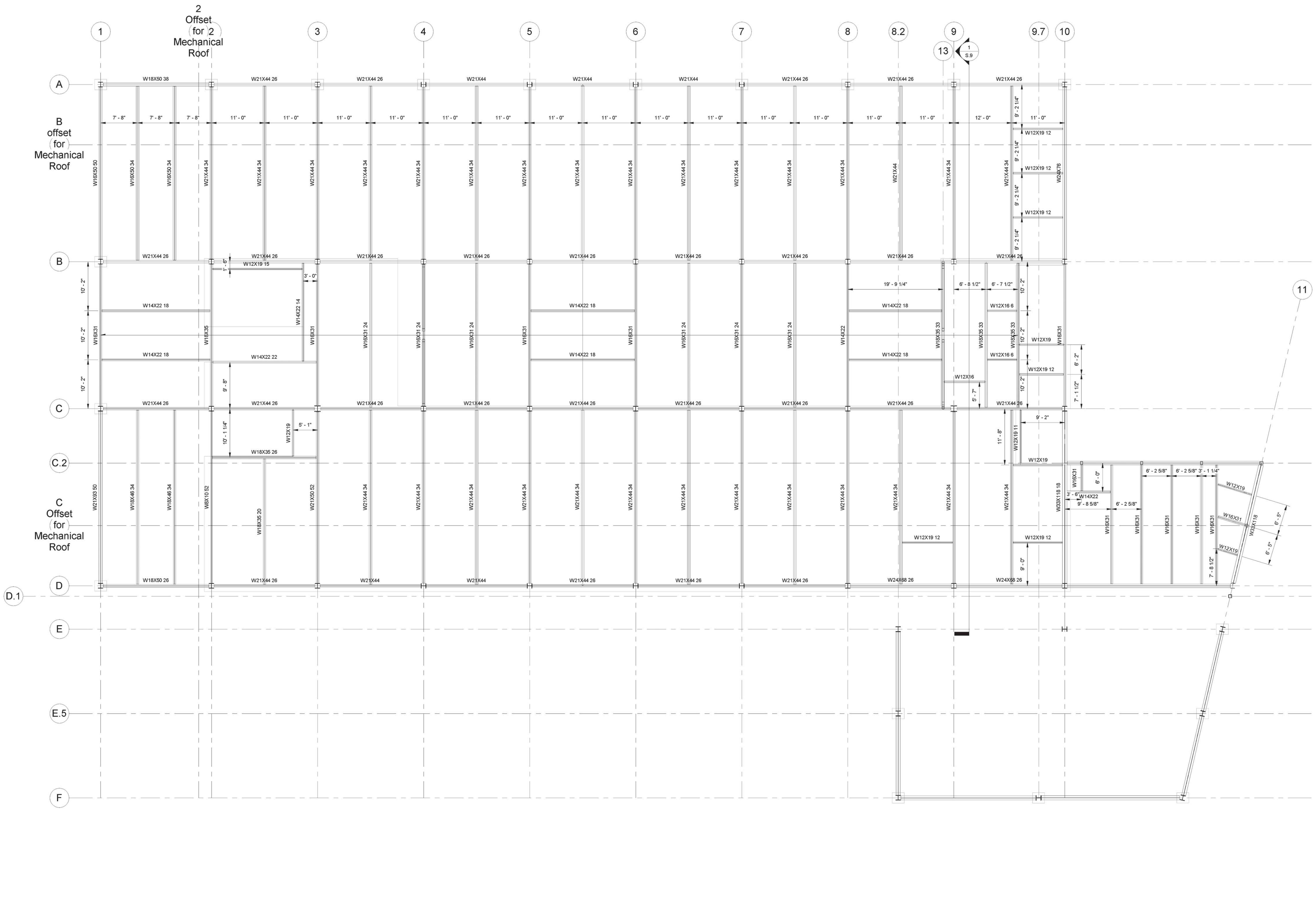

1 LEVEL 2 FRAMING
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Level 2 Framing Plan

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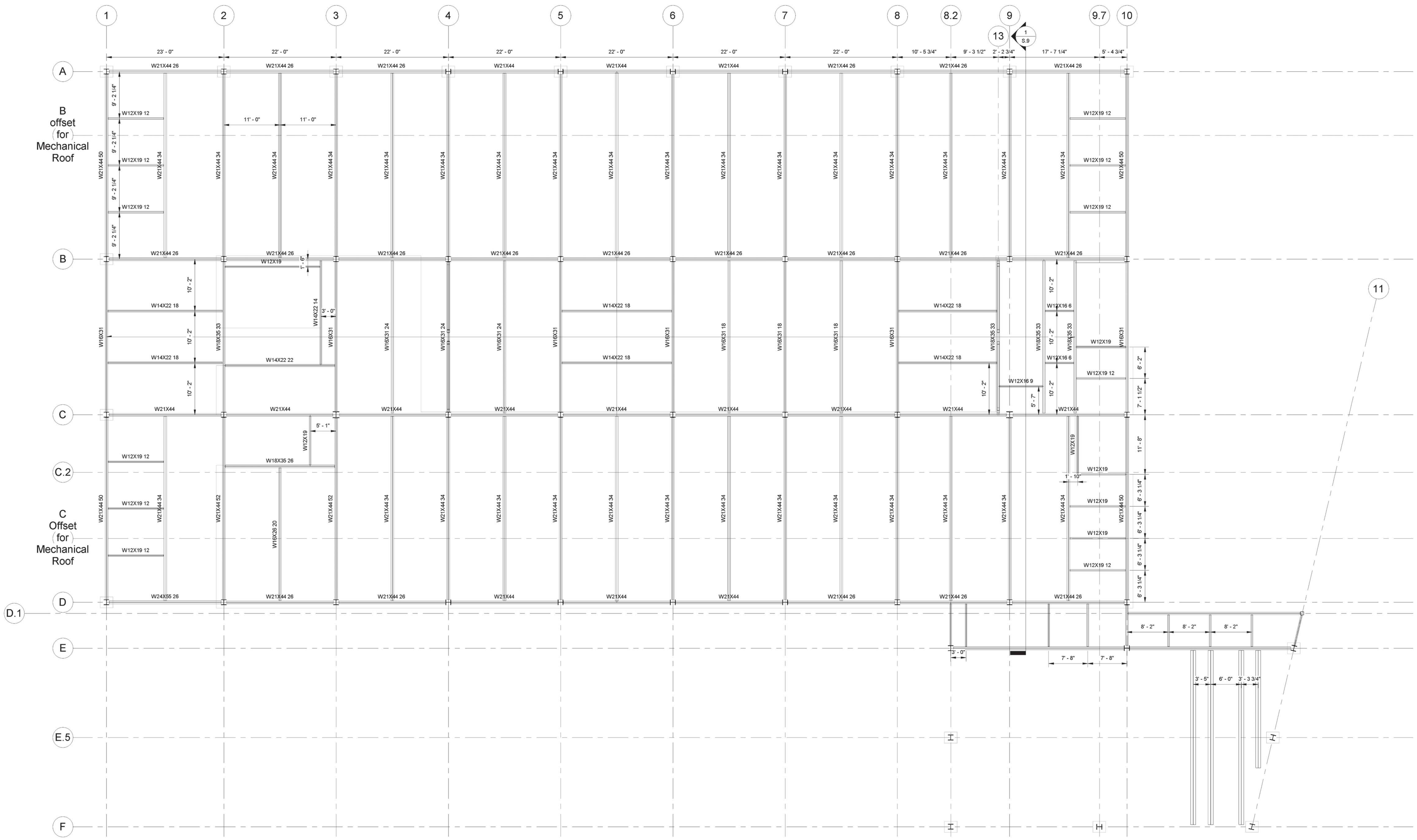

1 LEVEL 3 FRAMING
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Level 3 Framing Plan

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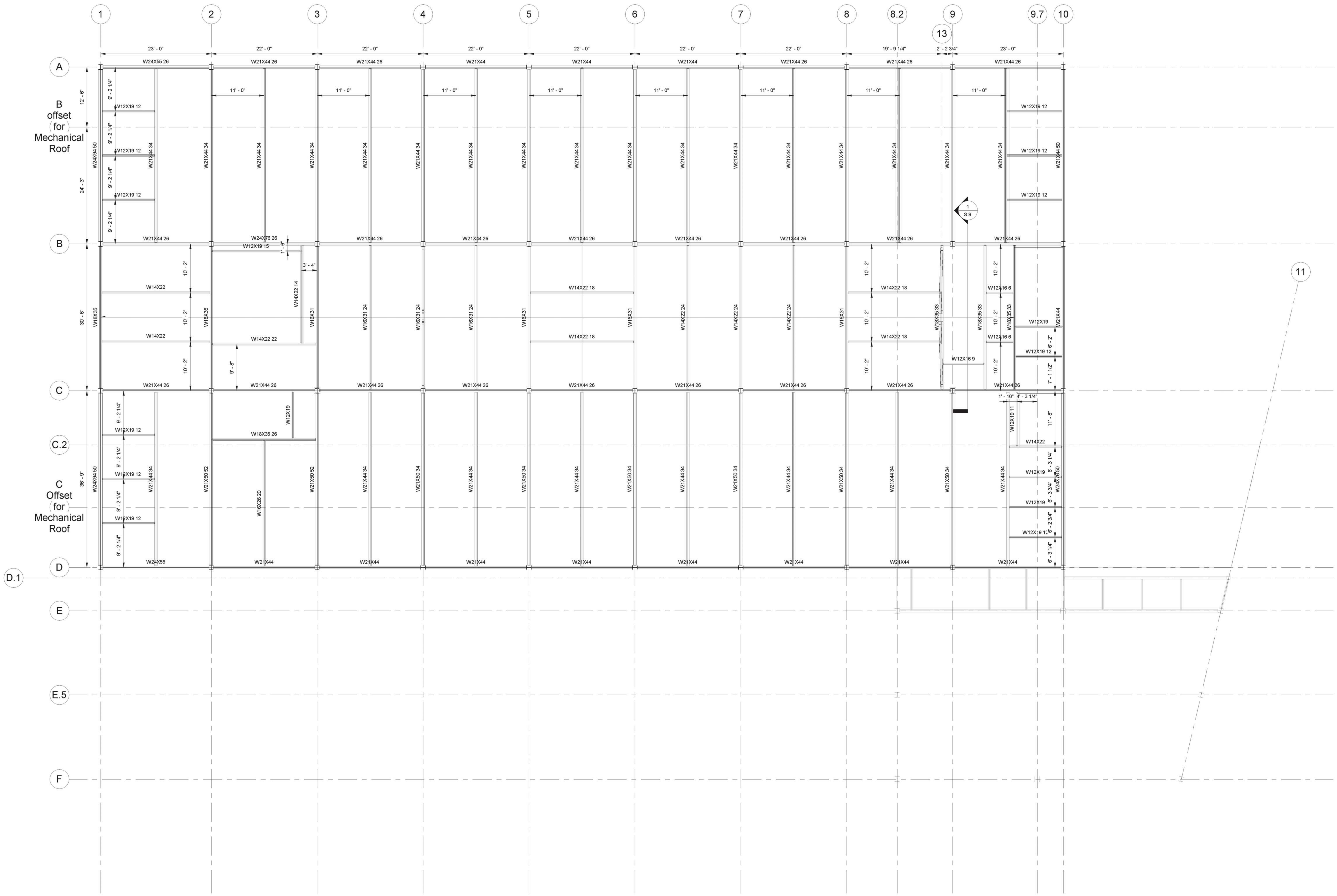

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Level 4 Framing Plan

Project Number	Project Number
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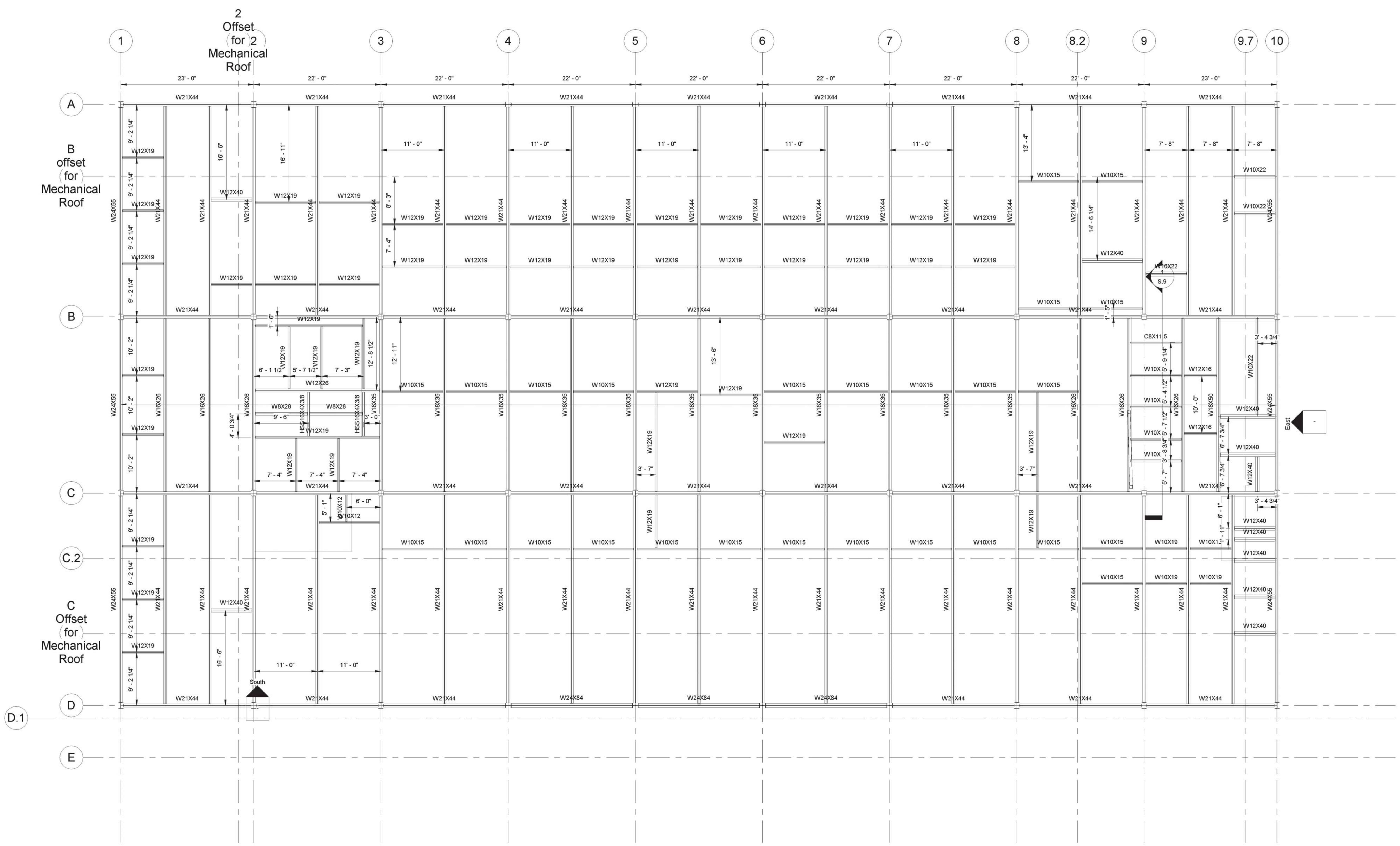

1 ROOF FRAMING
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Roof Framing Plan

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Date	Issue Date
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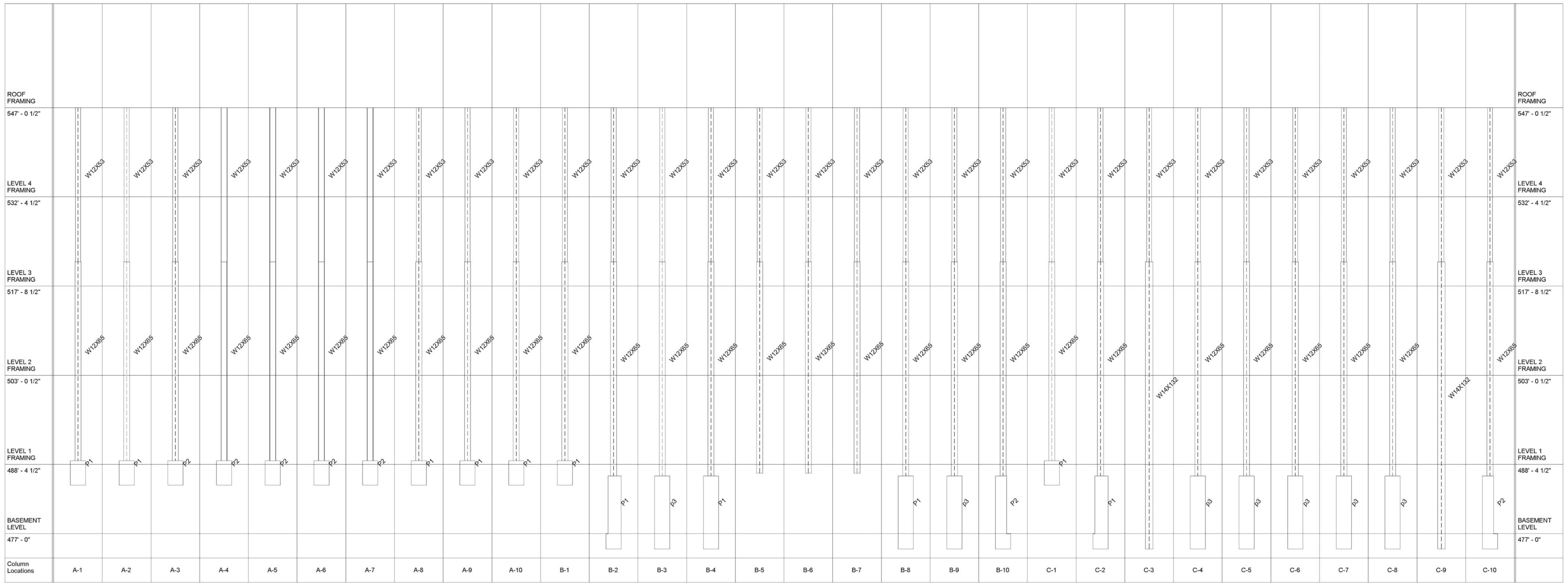

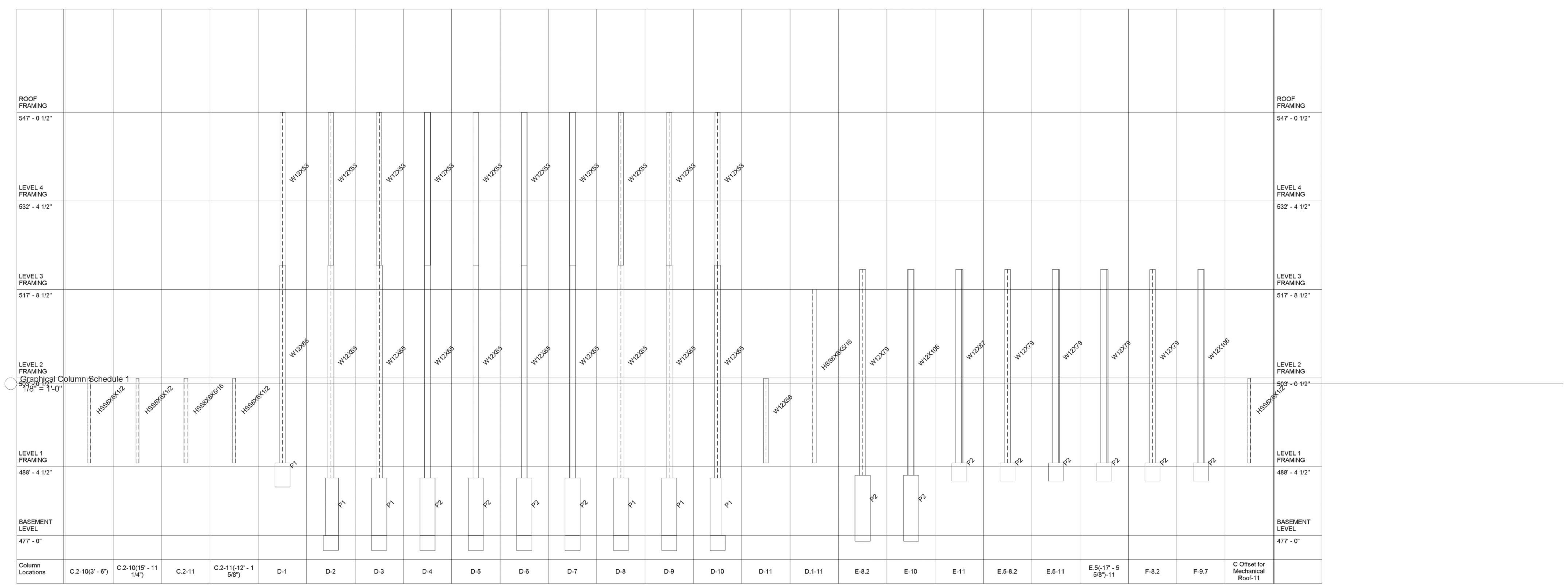

Graphical Column Schedule 1
1/8" = 1'-0"

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Column Schedule

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Date	Issue Date
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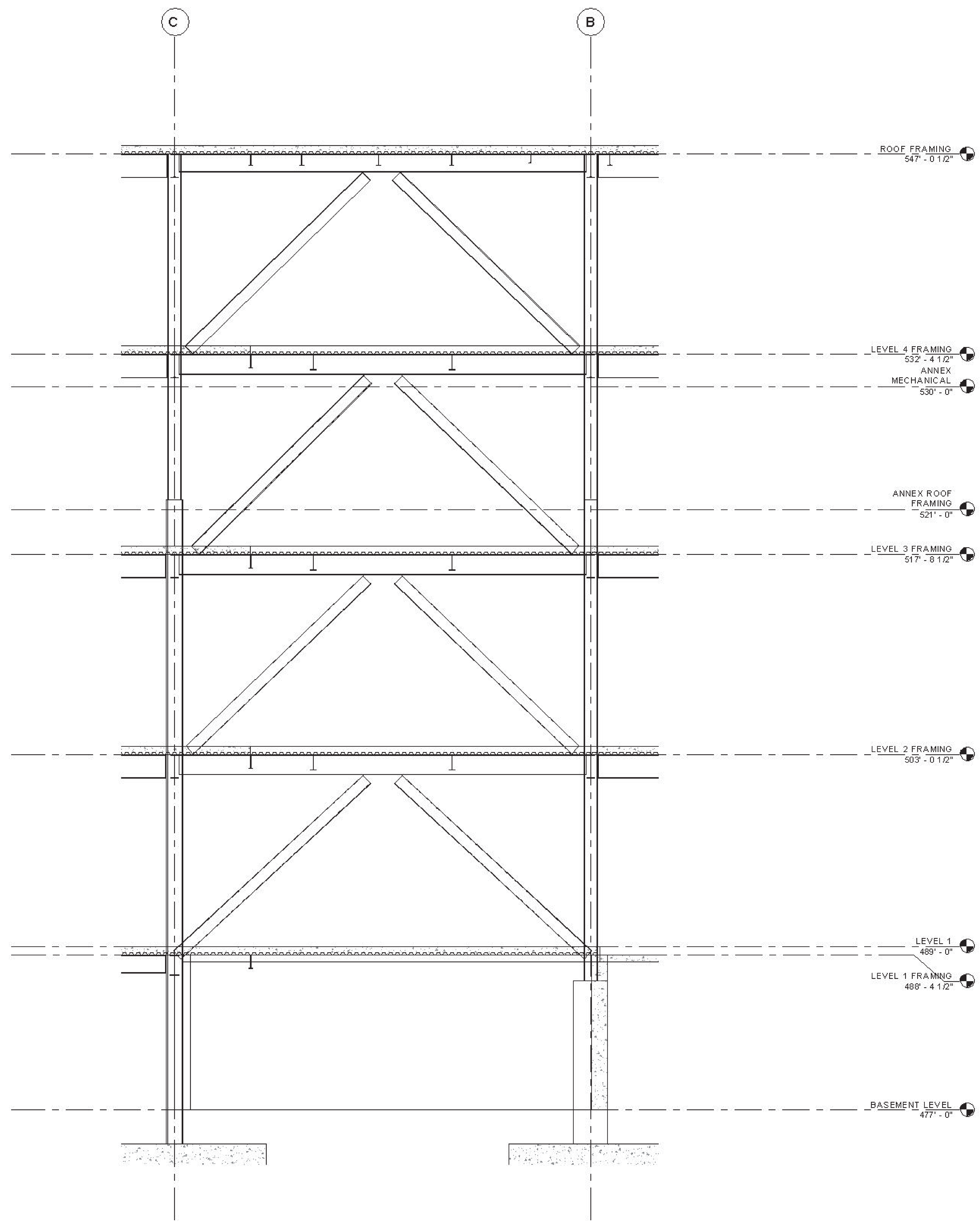

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No.	Description	Date

Gateway Buidling 2012

Lateral Braced Section

Project Number	Project Number
Date	Issue Date
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Appendix S: Cast-in-Place Concrete Structural Drawings

GENERAL NOTES:

1.– All work shall conform to the requirements of the State Building Code of the Commonwealth of Massachusetts, Eighth edition.

2.– The Contractor shall verify all dimensions and conditions in the field prior to commencing work. Where dimensions and elevations of existing construction could affect the new construction, it is the Contractor's responsibility to make field measurements in time for their incorporation in the Shop Drawings. The Architect and Engineer shall be notified of any discrepancies that may exist.

3.– See architectural drawings for floor elevations, slopes, locations of depressed floor areas, and floor openings. The Contractor shall compare the structural drawings with the architectural drawings and report any discrepancy to the Architect and Engineer prior to construction.

4.– Principal openings through the framing are shown on these drawings. The General Contractor shall examine the structural, architectural and mechanical drawings for the required openings and shall verify size and location of all openings with the Mechanical Contractor. Providing all openings required by the Mechanical, Electrical, or Plumbing trades shall be a part of the General Contract, whether or not shown in the structural drawings. Any deviation from the openings shown on the structural drawings shall be brought to the Engineer's attention for review.

5.– Furnish and place all supports, temporary and permanent, whether shoring, bracing, needling, underpinning, or sheet piling, necessary to brace existing walls or framing to remain, so that no horizontal or vertical settlement occurs to the existing structures. Temporary supports shall be maintained in place until permanent supports are installed. Design of these supports shall be by a registered Structural Engineer in the project state in the employ of the Contractor.

6.– Alternate connection details may be approved if such details are submitted to the Engineer for review and acceptance is granted. However, the Engineer shall be the sole judge of acceptability and the Contractor's bid shall anticipate the use of those specific details shown on the drawings. The Contractor shall retain a registered Structural Engineer to be responsible for the design of any alternate details which he proposes.

7.– Work not indicated on a part of the drawings but reasonably implied to be similar to that shown at corresponding places, shall be included in the Contractor's work.

8.– The Contractor shall be completely responsible for the safety of adjacent structures, property, his workmen, and the public, as affected by the construction of this project.

9.– All Contractors are required to examine the drawings and specifications carefully, visit the site and fully inform themselves as to all existing conditions and limitations, prior to agreeing to perform the work. Failure to visit the site and familiarize themselves with the existing conditions and limitations will in no way relieve the Contractor from furnishing any materials or performing any work in accordance with drawings and specifications without additional cost to the Owner.

10.– Structural drawings may represent construction with a reference scale. Due to the inherent process of drawing development and presentation not all work may be shown "exact" in that scale. Do not "scale" drawings to obtain any missing information or to interpret any information not specifically dimensioned for "exact" detailing or construction purposes.

FOUNDATIONS:

1.– The foundation design is based on recommendations contained in the Geotechnical Report by Maguire Group Inc. dated November 2009. This report is available to bidding Contractors for their information, however their attention is directed to the limitations of the report described therein.

2.– All footings shall be carried down to soil having minimum bearing capacity of 3.0 tons per square foot at street level and 1.5 tons per square foot at basement level. Elevations if given, are the bottom of the footings, are minimum depths, and are not to be construed as limiting in any way the depth of excavation required to reach good bearing.

3.– In general, exterior construction shall be carried down to a minimum of 4 feet below finished exterior grade or the lowest slab level.

4.– No foundations shall be placed in water or on frozen ground.

5.– All footing excavations are to be finished by hand, unless otherwise directed by the Geotechnical Engineer.

6.– All finished foundation excavations shall be inspected and approved by the Architect or his designate before any concrete is placed.

7.– Unless otherwise noted, all footings and pilasters shall be centered under supported members.

8.– Dowels from foundations into piers, columns, buttresses, or walls above shall be the same size and number as vertical reinforcement in piers, columns, buttresses, or walls above, except as otherwise shown on the drawings.

9.– Carefully follow the requirements of the specifications for back fill under or adjacent to any portion of the building.

10.– Where foundation elements are to have fill on both sides, each side shall be filled simultaneously, maintaining a common elevation.

11.– Coordinate under floor drain requirements with architectural and mechanical drawings and the requirements of the Geotechnical Engineer.

12.– Contractor shall provide continuous control of surface and underground water as required during construction such that the work is done in the dry. However, the Contractor shall insure that ground water levels under adjacent structures are not lowered by his construction techniques. Additionally, if so directed by notes in the plans, the Contractor will continue to maintain a condition of no hydrostatic pressure until sufficient building weight is in place to prevent flotation of any part of the structure.

13.– Building walls retaining earth rely on the completed floor slabs for lateral support. If required by the construction sequence, the Contractor shall temporarily brace all building walls against which back fill is to be placed until all floor slabs supporting the walls are in place and have attained at least 75% of their specified design strength. Design of temporary braces shall be by a registered structural engineer in the employ of the Contractor.

CONCRETE:

1.– All concrete work shall conform to the 2002 edition of the ACI Building Code Requirements for Reinforced Concrete (ACI 318) and the Commonwealth of Massachusetts State Building Code. In case of conflict, the State Building Code shall govern.

2.– All concrete shall be controlled concrete, mixed and placed under the super–vision of an approved concrete testing agency.

3.– For locations listed below, concrete shall be normal weight concrete with sand and gravel aggregate, Type I or Type II Portland Cement and a minimum compressive strength (f'c) in 28 days as follows:

Footings and piers. . . . . .4000 psi
Foundation tie beams. . . . . .4000 psi
Walls. . . . . .4000 psi
Slabs on grade. . . . . .4000 psi
All other foundation concrete. . . . . .3000 psi
Fill concrete. . . . . .3000 psi
Mud mats. . . . . .2000 psi
Steel member encasement. . . . . .3000 psi
Slabs on metal deck . . . . .See note 5

4.– All concrete exposed to the weather or possible freeze/thaw action shall contain an air entrainment admixture. See specifications for air content.

5.– Concrete floor slabs on metal deck shall have normal weight or lightweight coarse aggregate, Type I or Type II Portland Cement and 4000 psi Compressive strength (f'c) in 28 days.

6.– The steel framing has been designed as unshored construction, and the plans may show cambering of some structural members to counteract some of the system deflection under the weight of concrete as it is placed. Due consideration should be given to camber tolerance and erection tolerance in providing for the thickness of concrete necessary to obtain the specified finish floor elevations. The final slab thickness shall not be less than called for on plans. Contractor is to provide the additional concrete required to compensate for deflection of unshored beams and deck and to produce a slab level within tolerance and with a slab thickness at least the thickness specified in all locations.

7.– All concrete shall be placed without horizontal construction joints, except where specifically noted. Vertical construction joints and stops in shored concrete work shall be made at midspan. Horizontal reinforcement shall be continuous through vertical construction joints.

8.– Construction joint locations other than shown on the drawings are permitted subject to prior approval of the Engineer. Expansion joint and control joint locations are mandatory as shown. Contractor shall submit drawings showing intended placing sequences and locations of construction joints to the Engineer for approval. At poured in place walls, Construction joints shall be located so as to provide a 60'–0" maximum horizontal length of concrete placement in any direction.

9.– Unless otherwise shown on drawings, slabs on grade shall be cast in alternating strips, one (1) column bay wide. Adjacent sections shall be placed no sooner than three days apart. Alternatively, slab on grade areas may be poured in as large an area as can be handled provided that saw cut joints are cut as soon as the concrete will support a man's weight without permanent deformation and the joint process does not dislodge aggregates.

10.– Grout under column base plates and under other bearing plates shall be non–shrink, nonmetallic grout with a minimum compressive strength of 5000 psi at 3 days.

11.– Pipes or conduits placed in slabs on grade shall not be placed closer than 3 diameters on centers and shall have an outside diameter less than 1/3 of the slab thickness and be positioned so that they do not interfere with slab reinforcement. Aluminum conduits shall not be placed in concrete. No conduits or pipes shall be placed in composite slabs on metal deck.

12.– All keys shall be 2" x 4" (nominal) unless otherwise shown on the drawings.

13.– Concrete cast on sloped surfaces shall begin at the lowest elevation and continue monolithically toward the higher elevations until the intended pour is completed.

14.– No concrete shall be cast before review and approval of the reinforcing and embedded items have been obtained from the Architect, or his designated representative.

15.– All exposed edges of concrete members shall be chamfered 3/4" unless shown otherwise on architectural drawings.

16.– Concrete must reach the following percentages of its 28–day compressive strength (f'c) before forms or shores may be removed:

Walls and beam sides. 20%
Floor systems. 85%

17.– Refer to architectural drawings for concrete finishes. Where finish is not specified, conform to requirements of ACI 301 – "Specifications for Structural Concrete for Buildings."

18.– See architectural drawings for door and window openings, drips, washes, reglets, concrete finishes, masonry anchors, and for miscellaneous embedded plates, bolts, anchors, angles, etc.

19.– The placement of sleeves, outlet boxes, box–outs, anchors, etc., for the mechanical, electrical and plumbing trades is the responsibility of the trade involved. However, any box–outs not covered by typical details in the structural drawings shall be submitted for approval.

20. At sawcutting of existing concrete, including slabs on grade, no overcut at corners is allowed. All corners shall have a core hole of sufficient diameter made prior to cutting at adjacent sides to prevent cut beyond the required dimension.

REINFORCING:

1.– All concrete reinforcing bars less than #11 shall conform to ASTM A615, Grade 60, except where noted. All concrete reinforcing bars #11 and greater shall conform to ASTM A615, Grade 75. All reinforcing bars to be welded shall conform to ASTM A706. Reinforcing bars may not be welded without prior approval of the Structural Engineer.

2.– All welded wire fabric (W.W.F.) shall conform to ASTM 185.(Fy=65 KSI min.) W.W.F. shall be provided in flat sheets. The following W.W.F. shall be used for areas specified below unless otherwise shown on the drawings. ie: W.W.F. designations where shown on the plans supersede these shown below:

Slab on grade:. . . . . .6x6 – W2.9 x W2.9

Slab on metal deck:. . . . . . .6x6 – W2.1 x W2.1

Around structural members encased in concrete: . . .4x4 – W1.4 x W1.4, plus 1–#5 spacer bar each corner

In middle of concrete fill for stairs: . . . . . .2x2 – W1.4 x W1.4

Note: Fibermesh at 1 1/2#/cu. yd. may be substituted for WWF in stairs.

3.– Reinforcement shall be continuous through all construction joints unless otherwise noted on drawings.

4.– Detailing of concrete reinforcement and accessories shall be in accordance with ACI 315 – "Manual of Standard Practice for Detailing Reinforced Concrete Structures," latest edition.

5.– Provide and schedule with the shop drawings, all necessary accessories to hold reinforcing securely in position.
Minimum requirements shall be:

High chairs. . . . . .4'–0" on center
Slab bolsters. . . . . .4'–0" on center
Support bars for high chairs No. 5

6.– All continuous reinforcement shall have a minimum lap as required for a Class B splice (AC1 318) unless noted otherwise.

7.– All laps in W.W.F. shall be one mesh plus two inches at splices.

8.– Concrete protection for reinforcement including W.W.F. shall be provided as follows unless otherwise shown on the drawings:

a. Surfaces cast against earth. . . .3 inches

b. Formed surfaces exposed to earth or weather
#6 through #18 bars. . . . . .2 inches
#5 bars and smaller. . . . . .1 1/2 inches

c. Formed surfaces not exposed to earth or weather
Slabs, walls, joists
#11 bar and smaller. . . . . .3/4 inch
#14 and #18 bar . . . . . . .1 1/2 inches

Beams, columns. . . . . . . .1 1/2 inches

d. Slabs on grade
(from top of slab). . . . . . .1 1/2 inches

e. Slabs on metal deck
Top. . . . . .3/4 inch
Bottom. . . . . .3/4 inch

Maximum deviation from these requirements shall be ±1/4 inch for sections 10 inches thick or less; and ±1/2 inch for sections over 10 inches thick. See ACI 318–95, section 7.7.1 for conditions not listed.

9.– All hooks shown on drawings shall be standard hooks unless noted otherwise.

10.– Where continuous bars are called for, they shall run continuously around corners and be lapped at necessary splices, or hooked at discontinuous ends. Lap lengths shall be as given in the splice and development table. Lap beam top bars at mid–span and beam bottom bars at supports, unless otherwise noted.

11.– Provide additional reinforcing at the sides and corners of all openings in concrete in accordance with the typical details. Minimum additional reinforcing shall be as follows:

(2) – #5 top and bottom in slabs

(2) – #5 each face in walls

(2) – #5 x 4'–0" long diagonally each corner of opening

Extend bars a minimum of 2'–0" beyond opening, hook where extension is not possible.

12.– In beams, where stirrups are not specified for the whole beam length, or for any part thereof, provide #3 spaced at (beam depth –2")/2, or 24" maximum.

13.– Provide for a minimum of 1–#5 stirrup support bar at each stirrup bend where primary bars do not exist.

14.– In beams over 18" deep provide continuous #4 bars on the side faces with a spacing of not more than 12" on center.

15.– Primary top & bottom horizontal reinforcing in beams and girders shall be detailed to be placed in one layer unless shown or noted otherwise on the drawings.

16.– All beam "stirrups" or "ties" shall be continuous closed type unless otherwise noted on the drawings.

REINFORCED MASONRY:

1.– All masonry work shall conform to the "Building Code Requirements of Masonry Structures" (ACI 530–05/ASCE 5–02) And (ACI 530.1–05/ASCE 6–02).

2.– The compressive strength of the masonry, f'm, shall be at least 1500 psi. Unless otherwise approved by the Structural Engineer on the basis of prism testing the components of the masonry shall have compressive strengths as given below:

3.– All concrete masonry units (CMU) shall conform to ASTM C90, grade N–1, with an individual compressive strength of 2400 psi

4.– Mortar for block wall construction shall be Type M or S conforming to ASTM C270.

5.– Grout for piers and block walls shall conform to ASTM C476 with a minimum compressive strength of 2000 psi determined in accordance with the provisions of ASTM C1019.

6.– Reinforcing bars shall conform to ASTM A615, Grade 60, except bars to be welded shall conform to ASTM A706.

7.– Wire for joint reinforcing shall conform to ASTM A82, yield point = 70 ksi (min.).

8.– Unless noted otherwise provide the following minimum reinforcing:

VERTICAL
6" and 8" CMU

<8' High	8'–12' High	>12' High
#4@24"	#4@32"	#5@48"

10" and 12" CMU

<8' High	8'–12' High	>12' High
#4@24"	#5@32"	#6@32"

HORIZONTAL
6" and 8" CMU
#9 Dur–o–wal Ladur (2–W1.7 wires)
@16"o.c.

10" and 12" CMU
3/16" Dur–o–wal Ladur (2–W1.7 wires)
@16"o.c.

9.– Provide bond beams with 2–#5 continuous, at [the top of foundation walls and] the top of parapets, at each floor level, and where shown on the drawings.

10.– Unless noted otherwise on plans, provide the following additional vertical reinforcement in the cell immediately adjacent to each side of a masonry opening and in the cell of discontinuous walls. These bars are to extend full height of the wall or in the case of masonry openings at multi–story walls, from story to level above to story level below the opening.
6" and 8" CMU Walls – 2–#5
10" and 12" CMU Walls – 2–#6

11.– Extend additional reinforcement a minimum of 36 bar diameters beyond the opening.

12.– The minimum length of lap for reinforcing bars embedded in grout is 48 bar diameters, unless shown otherwise on the drawings.

13.– Place reinforcing bars before grouting. Place grout in lifts not exceeding 5 feet. Consolidate each lift by mechanical vibration. The next lift of the pour may be made after the initial water loss and reconsolidation of the prior lift, while it is still plastic.

14.– Properly secure reinforcing bars to maintain the positions indicated on the drawings. Bars to be located in center of cells unless otherwise noted.

15.– All CMU shall be braced during construction for the governing code lateral design loads until permanent restraints have been installed.

16.– The following steps are to be followed when laying masonry in the temperatures stated below:

40° – 32° F (mean daily air temperature)

Heat mixing water or aggregate to 70° F.
Protect masonry from rain or snow for 24 hours.

32° – 20° F, mean daily air temperature

Heat mixing water and aggregate to 70° F.
Provide wind breaks for wind velocity in excess of 15 m.p.h.
Cover masonry with insulating blankets for 24 hours and provide heat sources on both sides of masonry construction.

Below 20° F, mean daily air temperature

Heat mixing water and aggregate to 70° F.
Provide enclosures and heat to maintain 40° minimum temperature.
Temperature of masonry units must be 40° F minimum when laid.
Maintain masonry above 40° F for 24 hours by enclosures and supplemental heat.

STRUCTURAL STEEL:

1.– Structural steel design conforms to "Load and Resistance Factor Design Specification for Structural Steel Buildings" (AISC, Third Edition).

2.– Structural steel rolled shapes, plates, and bars shall conform to the following ASTM designations:

ASTM A–572, Grade 50 or A992 . . . . .All W shapes, unless noted otherwise

ASTM A–36. . . . . .All other rolled shapes, plates and bars unless noted unless noted otherwise

ASTM A–500, Grade B. . . . . .HSS sections (square, rectangular)

ASTM A–500, Grade C. . . . . .HSS sections (round)

ASTM A–53, Grade B. . . . . .Pipe

ASTM A–325, Type SC or N. . .All bolts for connecting structural members

ASTM F–1554. . . . . .All anchor bolts, unless noted otherwise

3.– Shop painting of structural steel is not required unless otherwise noted. Add/Alternate: Provide 1 coat of standard shop primer to all interior steel except at beam flanges receiving shear studs and steel receiving spray fireproofing around stairs, shafts, elevators, and in the annex.

4.– Filler beams shall be spaced equally between established dimensions, unless noted otherwise.

5.– The concrete slabs and/or non–composite steel decks are part of the stability system for a completed structure. The Contractor shall provide temporary erection bracing to maintain structural steel in proper position until permanently secured. Remove temporary bracing and their connections only after erection of permanent members is complete and all concrete slabs have been placed and cured and non–composite steel decks are properly fastened. A completed structure has its boundary's defined by the building exterior and/or interior expansion joints where they exist between building segments.

6.– Shear connectors shall be 3/4" diameter headed studs, field applied, with a nominal shear strength of 26.1 kips per connector. The number of shear connectors is indicated in brackets by each beam. More than one number in a bracket indicates groups of shear connectors to be placed between connection points of intersecting beams. Substitution of shear connectors with nominal strength less than given above, or a placement which results in a reduction factor by formulas I3–1 or I3–2, AISC manual (Third Edition) if approved, will require an adjustment in the number of shear connectors to maintain the same total shear transfer capacity and will be at the Contractor's expense.

7.– All composite beams, using concrete slab as compression flange, are designed for strength assuming unshored construction, unless otherwise noted.

8.– Provide an upward beam camber at the mid span between supports where indicated thus: +c= 1 1/2", if specified on drawings. Camber is to be provided by mill rolling or shop fabrication, or a combination of each. Contractor is to note that the structural steel beams have been cambered in an effort to limit extra concrete placement due to the deflection of the structural steel beams and girders. However, the amount of actual camber for each structural steel member may vary due to mill or shop tolerance and beams with computed initial deflections of no more than 3/4" are not cambered at all. Therefore, the Contractor may not assume that the cambers indicated eliminate the need for extra concrete placement.

9.– Shop connections unless otherwise noted, shall be made by welding, or by using snug tight 3/4"ø high strength bolts, minimum.

10.– All shop and field welds shall be made by certified welders, and shall conform to "Structural Welding Code – Steel" (AWS D1.1 2000).

11.– Electrodes for all field and shop welding shall conform to AWS E–70 Series.

12.– Bolted field connections shall be made with 3/4" diameter A325 bolts, minimum, unless otherwise noted.

13.– A325 bolts installed with the bolt tension (pre–tensioned) specified in Table J3.1 of the AISC LRFD Third Edition Specification, shall be used for the following connections.

a. Column splices
b. Connections of beams and girders to columns
c. Bolted moment connections
d. Bracing members
e. Hangers
f. Connections noted as Type SC on the design drawings
g. Connections of beams and girders to columns in brace frames
h. Connections c, d, e, f, and g shall be designed as "slip critical" connections.

* All other A325 bolts may be pre–tensioned as defined by AISC.

* All other A325 bolts shall not be pre–tensioned but shall be installed to the snug tight condition as defined by AISC.

14.– Connections shown on these drawings are generally schematic. They are intended to define the spatial relationship of the framed members and show a feasible method of making the connection. Any connection that is not shown or is not completely detailed on the structural drawings shall be designed by a registered professional Engineer, retained by the fabricator. Details and connections may be designed to conform to AISC Manuals Third Edition – LRFD or Ninth Edition – ASD. Completely detailed means the following information is shown on the shop detail drawings:

a. All plate dimensions and grade.

b. All weld sizes, lengths, pitches and returns.

c. All hole sizes and spacings.

d. Number and type of bolts: where bolts are shown but no number is given, the connection has not been completely detailed.

e. Where partial information is given, it shall be the minimum requirement for the connection.

f. Method of design.

15.– All rectangular hss members to be orientated long side vertical u.n.o.

16.– Details and connections completely detailed in the Contract Drawings may not be altered without written approval by the Engineer. Where approved, altered connections shall be completely detailed by the fabricator's engineer clearly on the shop drawings.

17.– Alterations of schematic connection details may impact architectural concept and shall not be made without prior written approval of the Engineer.

18.– Minimum connection plate thickness shall be 3/8", unless otherwise indicated in the Contract Drawings.

19.– Unless otherwise noted, beam to beam connections and beam to column connections shall be double angle (t=5/16") framed beam connections shop welded per Table 10–2, AISC Manual Third Edition – LRFD) using weld A, or shop bolted using Table 10–1 and using 3/4" diameter A325–N bolts in standard or horizontally slotted holes for the field connection. The number of rows of bolts, n, shall be in accordance with the following table. Table applies to composite and non–composite beams.

Beam Size	n	Shear Design Strength (kips)
W8x10, W10x12	2	18.5
W8x13, 15, W10x15	2	24.0
W8x18, 21, 24, W10x17, 19, 22, 26	2	26.9
W8 ≥ 28, W10 ≥ 30	2	34.8
W12x14, 16	3	33.0
W14 ≤ 30, W12x19, 22, 26, 30	3	40.2
W12x35, 40, 45 W14x34, 38, 43, 48	3	52.1
W12 ≥ 50 W14 ≥ 53	3	63.0
W16x26, 31	4	60.0
W16x36, 40 W18x35, W18x40	4	71.9
W16 ≥ 45, W18x46, 50, 55	4	84.2
W18 ≥ 60, W21 ≤ 62, W24x55	5	106.7
W21 ≥ 68, W24x62, 68, 76	5	126.5
W24 ≥ 84, W27x84	6	151.8
W27 ≥ 94, W30x90, 99	7	195.0
W30 ≥ 108	8	230.0
W33	9	260.0
W36	10	290.0
W40	11	319.0

Where the Fabricator proposes an alternate connection, it shall have at least the shear capacity indicated in the above table. Where reactions are indicated in the drawings (example: R=85k) they supersede the table above and the Fabricator shall provide a connection with a capacity at least equal to the reaction indicated. Seated beam connections will not be allowed unless the seat is used for erection purposes only. For other beam shapes (S, C, MC) provide a two bolt connection unless otherwise shown on the drawings. Where reactions are posted, they have been factored per State Building Code of Commonwealth of Massachusetts, Seventh Edition. "Load and Resistance Factor Design Specifications for Steel Hollow Structural Sections" (2000).

20.– Unless otherwise noted, all connections at HSS sections shall be designed and detailed in accordance with the AISC "Load and Resistance factor design specifications for steel hollow structural sections" (2000).
Moment connection details on the drawings must be consistent with Note 21. Typical moment connection details allow for 3 options:

21.– Beam to column moment connections that are part of the lateral force resisting system shall be designated for $1.1R_yM_p = 1.1R_yF_yZ$. Connection shall be detailed in accordance with chapter 11 Ordinary Moment Frames of AISC 341–02]. The connection shear strength shall meet or exceed values shown on structural steel note 19, unless noted otherwise.

22.– The connection at the ends of tension or compression members shall develop the force due to the design load, but not less than 100% of the tension strength of the member where no design load is posted. Design forces, if posted, have been factored in accordance with the Governing Building Code and no stress increase is permitted. Tension strength of member = 0.9Fy x Ag, except for braces that are of the seismic load resisting system. These brace connections shall be designed for the expected tensile strength = RyFyAg. When design force is based on tension capacity of member, load is to be applied as a tension or compression force.

23.– Splicing of structural members where not detailed on the drawings is prohibited without prior approval of the Structural Engineer.

24.– Provide welded stiffener plates on both sides of the web of beams at points of concentrated loads including beams supporting columns or running over the tops of columns or other beams. Minimum stiffener plate thickness shall be 5/8" or flange thickness of column above or below, whichever is greater.

25.– Screed plates, pour stops and slab supports at slab openings, at slab edges and supports for metal deck around columns shall be furnished by the contractor as required to complete the work.

26.– Cuts, holes, coping, etc. required for work of other trades shall be shown on the shop drawings and made in the shop. Cuts or burning of holes in structural steel members in the field will not be permitted, unless specifically approved in each case by the Structural Engineer.

27.– Unless otherwise detailed in the drawings, provide galvanized loose steel angle lintels over all openings in masonry walls, as follows. Lintels shall have a minimum of 8" bearing on each side of opening. Steel angles in pairs shall be plug welded or bolted at 2'–0" o.c. or stitch welded top and bottom at 1'–0" o.c.

For each 4" of wall thickness

L4 x 3 1/2 x 5/16 for spans less than 5'–0"
L5 x 3 1/2 x 5/16 for spans greater than 5'–0" to 7'–0"
L6 x 3 1/2 x 3/8 for spans greater than 7'–0" to 9'–0"
L6 x 3 1/2 x 1/2 for spans greater than 9'–0" to 12'–0"

For each 6" of wall thickness

L6 x 6 x 5/16 for spans to 7'–0"
L6 x 6 x 3/8 for spans greater than 7'–0" to 9'–0"
L6 x 6 x 1/2 for spans greater than 9'–0" to 12'–0"

28.– All structural steel directly supporting a concrete floor slab shall have shear studs spaced longitudinally at no more than 24"o.c. unless otherwise noted.

29.– All HSS shapes except diagonal bracing members (round, square rectangular, etc.) are to have a 1/4" cap plate at all exposed ends. Cap plates to be seal welded all around, u.n.o.

30.– All weld sizes not shown in details herein shall be the minimum required size based on thickness of thicker part as per AISC, Tables J2.3 & J2.4. Exception: At member splices, welds or bolts shall develop full strength of the member or components being connected.

31.– All around welds indicated herein shall be discontinuous at the flange tips of open sections.

32.– All structural steel, including baseplates and tops of anchor bolts, to be encased in concrete are to be coated with with an approved coal tar epoxy. 16 mils minimum thickness.

33.– Any alteration made by the detailer on the structural steel shop drawings to schematic or completely detailed connections shown on the contract drawings must be clearly identified by clouding or by direct note on the shop drawing by the detailer prior to submission to the engineer.

34.– Any member sizes shown on the plans, and currently listed in the AISC Manual of Steel Construction, Latest Edition, which are not currently available must be brought to the Architect and Structural Engineers attention prior to award of steel contract. No claim for additional cost will be accepted after the award, for member/built up member substitutions for these sizes.

35.– The submerged arc welding process may be substituted for welding together plate girder sections. Fabricator to submit equivalent weld sizes to be used in lieu of the requirements specified herein.

COMPOSITE METAL FLOOR DECK

1.– Design of composite metal floor deck shall be governed by the "Specifications for the Design of Cold Formed Steel Structural Members," by the American Iron and Steel Institute (AISI) and conform to the design and loading requirements of the Steel Deck Institute (SDI).

2.– Metal deck shall be manufactured from galvanized steel conforming to ASTM A653, grade 33 or higher. Galvanizing shall conform to the requirements of ASTM A653, coating class G30.

3.– 3" composite metal floor deck shall have a minimum ratio of width to depth (W/H) of 2.0. The metal deck shall be adequate to support the dead load of the concrete slabs indicated on the drawings and 20 lbs/sq. ft. of construction live load without shoring. The deflection of the deck for concrete weight shall not be greater than 1/180th of the span or 3/4", whichever is smaller. The composite floor deck supplied shall be capable of supporting the design loads given in these drawings, and have section properties per foot of width of approximately:

3 inch x 20 gauge deck (0.0358")

I. .0.953 $inches^4$
S (Positive). . . . . .0.548 $inches^3$
S (Negative). . . . . .0.577 $inches^3$

3 inch x 18 gauge deck (0.0474")

I. .1.261 $inches^4$
S (Positive). . . . . .0.793 $inches^3$
S (Negative). . . . . .0.790 $inches^3$

4.– Fasten metal floor deck by prequalified methods at all supports with 3/4" diameter fusion welds or welded stud shear connectors spaced not more than 12" o.c. Fasten side laps @ 3'–0" on–center or mid–span, whichever is less.

5.– Fabricate deck units in lengths to span three or more support spacings, where possible.

6.– Coordinate size and location of floor openings with architectural and mechanical drawings. See typical details for supplemental framing.

METAL ROOF DECK:

1.– Design of metal roof deck and accessories shall be governed by the "Specifications for the Design of Cold Formed Steel Structural Members," by the American Iron and Steel Institute (AISI) and conform to the design and loading requirements of the "Steel Deck Institute" (SDI).

2.– Metal roof deck shall be rolled of steel sheet, galvanized and conforming to ASTM A653 Grade 33 or higher, coating class G60 [or painted and conforming to ASTM A1008]. The metal roof deck supplied shall be capable of supporting the design loads given in these drawings and have section properties per foot of width of approximately:

3 inch Type N x 20 gauge deck (0.0358")
I. .0.790 $inches^4$
S (Positive). . . . . .0.470 $inches^3$
S (Negative). . . . . .0.510 $inches^3$

3 inch Type N x 18 gauge deck (0.0474")
I. .1.140 $inches^4$
S (Positive). . . . . .0.650 $inches^3$
S (Negative). . . . . .0.700 $inches^3$

1 1/2 inch Type B x 20 gauge deck (0.0358")
I. .0.200 $inches^4$
S (Positive). . . . . .0.230 $inches^3$
S (Negative). . . . . .0.230 $inches^3$

1 1/2 inch Type B x 18 gauge deck (0.0474")
I. .0.290 $inches^4$
S (Positive). . . . . .0.320 $inches^3$
S (Negative). . . . . .0.320 $inches^3$

3.– Unless otherwise shown on the drawings, fasten metal roof deck by prequalified methods at all supports with 5/8" diameter fusion welds in every rib at end laps, every other rib at intermediate supports and at every rib or 6" o.c. at all supports within 15'–0" of building periphery, braces, openings. Fasten side laps at 2'–6" maximum o.c. or mid–span, whichever is less.

4.– Fabricate deck units in lengths to span three or more support spacings, where possible.

5.– Fabricate roof deck to lap ends a minimum 2 inches.

6.– Coordinate size and location of roof openings with architectural and mechanical drawings. See typical details for supplemental framing.

7.– Do not suspend pipes, ducts, or conduit from roof deck.

LIGHT GAGE STEEL FRAMING

1.– Light gage steel framing is to be supplied with engineering and detailing by the supplier. See specification Section 05400.

2.– Information in these drawings regarding light gage steel framing is only to set conditions important to the appearance of the finished building, to identify where structural loadings from the light gage steel framing will be delivered to the building structure, or to specify the structural interaction between the light gage steel framing and the building structure.

DESIGN LOADS:

1.– Uniformly Distributed Floor Live Loads:

Offices/Lab. . . . . .100 psf
Corridors above 1st floor. . . . . .100 psf
First Floor. . . . . .150 psf
Slab on grade. . . . . .150 psf
Storage (light). . . . . .125 psf
Storage (heavy). . . . . .250 psf
Stairs. .100 psf
Mechanical areas. . . . . .150 psf*
Elevator machine room. . . . . .150 psf*
Sidewalks (intentional or accidental vehicular traffic). . . . .250 psf

* or actual equipment weights where greater

2.– Roof Live Load:

Minimum roof live load=20 psf

3.– Roof Snow Load:

Ground snow load, pg=55 psf
Flat roof snow load, $p_f = 0.7C_eC_tI_sp_g$ =38.5psf
Snow exposure factor, C_e=1.0.
Thermal factor, C_t =1.0.
Snow load importance factor, I_s=1.0
Snow drift conditions in accordance with Section 1608.0

4.– Concentrated Live Loads:

Floors have been designed to support the uniformly distributed live loads prescribed in (1) above, or the following concentrated loads, whichever produces the greater stress.

Location	Concentrated Load
Elevator machine room gratings (on 2.0 inches square)	300 lbs.
Floor areas and roofs with concrete (on 30 inches square)	2000 lbs.
Hatches, skylight ribs, and accessible ceilings (on 1.0 inch square)	200 lbs.
Stair treads (on 2.0 inches square)	300 lbs.
Roofs w/o concrete (on 6 inches square)	200 lbs.

All concentrated loads above have been assumed to be non–concurrent with uniform live loads.

5.– Live Load Reduction:

For design live loads of 100 psf or less: Except for places of public assembly, floors of passenger car garages, and roofs, a structural member having a tributary area of $K_{LL}A_T$ that is greater than 400 square feet, may be designated for a reduced live load, L, as follows.

$L = L_o(0.25+15/\sqrt{K_{LL}A_T})$, where
L_o= basic design live load
A_T= loaded area tributary to the member, square feet.
K_{LL}= live load element factor as follows:
K_{LL}= 4 for interior columns and exterior columns without cantilever slabs
K_{LL}= 3 for edge columns with cantilever slabs
K_{LL}= 2 for corner columns with cantilever slabs, edge beams without cantilever slabs, and interior beams
K_{LL}= 1 for all others

L shall not be less than 0.50L for members supporting one floor and not less than $0.40L_o$ for members supporting two or more floors.

Places of public assembly, passenger car garages, and design live loads greater than 100 psf: for members supporting load from more than one floor may be designed for a reduced live load equal to $0.80L_o$ but shall not be less than L as calculated above.

6.– Wind Loads:

Basic Wind Speed (3–Second gust) = 100 mph.
Wind Importance factor, I_w = 1.0
Wind Exposure = B
Design wind pressures for main wind force resisting in accordance with ASCE–02 Section 6.5.12.2
Design wind pressures on components and cladding in accordance with ASCE–02 Section 6.5.12.4

7.– Earthquake Loads:

Seismic importance factor, I_E = 1.0
Seismic Use Group = I.
Spectral response acceleration at short periods, S_s = 0.24
Spectral response acceleration at 1–second period, S_1 = 0.067
Site class D.
Design spectral response acceleration at short periods, Sds = 0.256
Design spectral response acceleration at 1–second period, Sd_1 = 0.107
Seismic design category = B.
Basic Seismic force resisting system = Steel braced frames not specifically detailed for seismic resistance – (X–direction)
= Steel moment frames not specifically detailed for seismic resistance – (Y–direction)

Seismic Base Shear = 422k (X–direction)
= 282k (Y–direction)

Seismic response coefficient, C_s = 0.0500 (X–direction)
= 0.0333 (Y–direction)

Response Modification Coefficient = 3.0 (X direction)
= 3.0 (Y direction)

Analysis procedure = Equivalent Lateral force.

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Drawing Issue	Date
Permit & Construction Documents	Mar 25, 2011
Pricing set	Mar 18, 2011
Steel and Foundation Package	Feb 14, 2011

Revisions

NO	ISSUE	DATE

Sheet Information

Date	03.18.2011
Job Number	29067.00
Drawn	R.J.M
Checked	M.F.A
Approved	-

Title

GENERAL NOTES

Sheet

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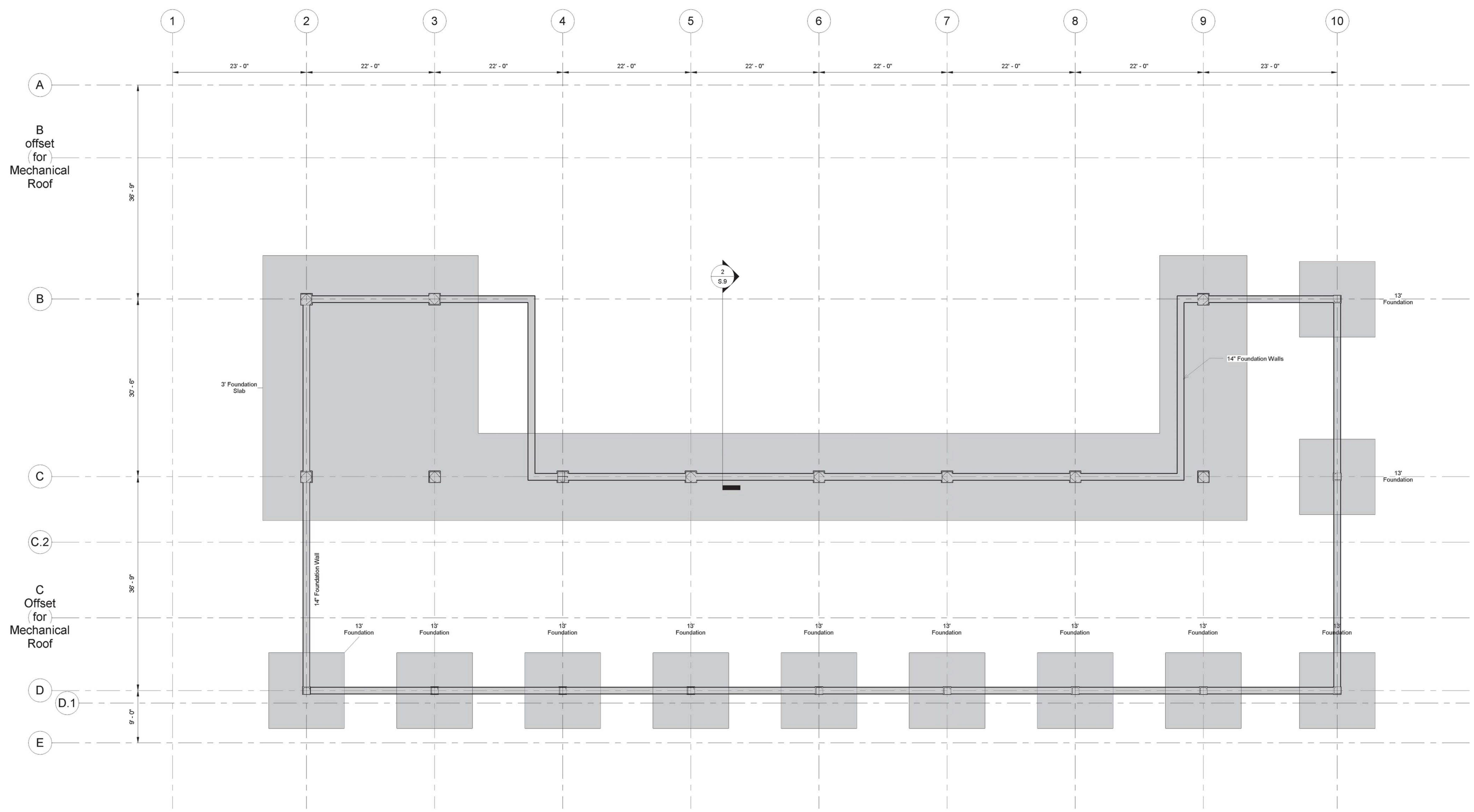

1 BASEMENT LEVEL
1/8" = 1'-0"

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Basement Framing

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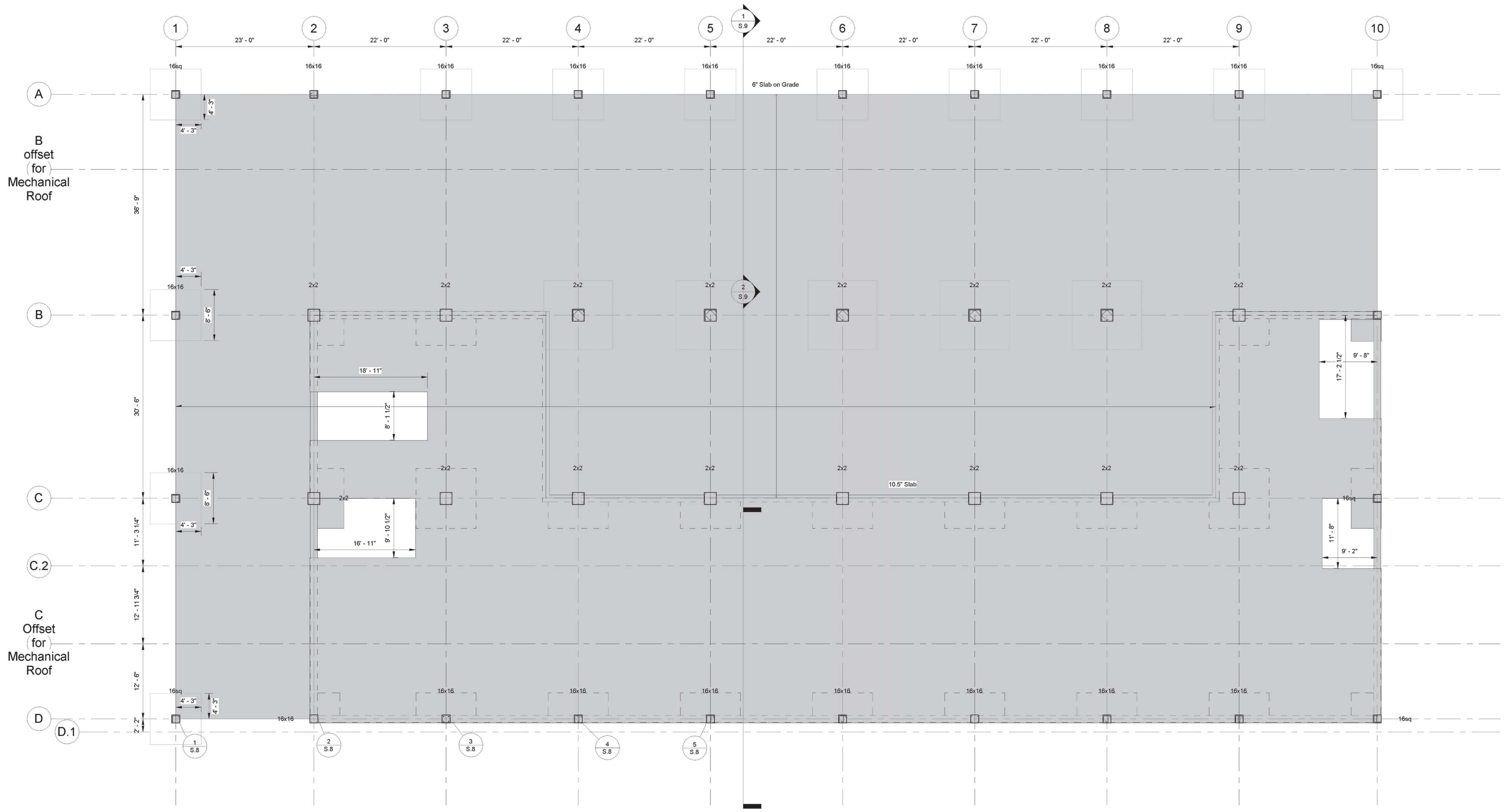

1 LEVEL 1 FRAMING
1/8" = 1'-0"

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Level 1 Framing

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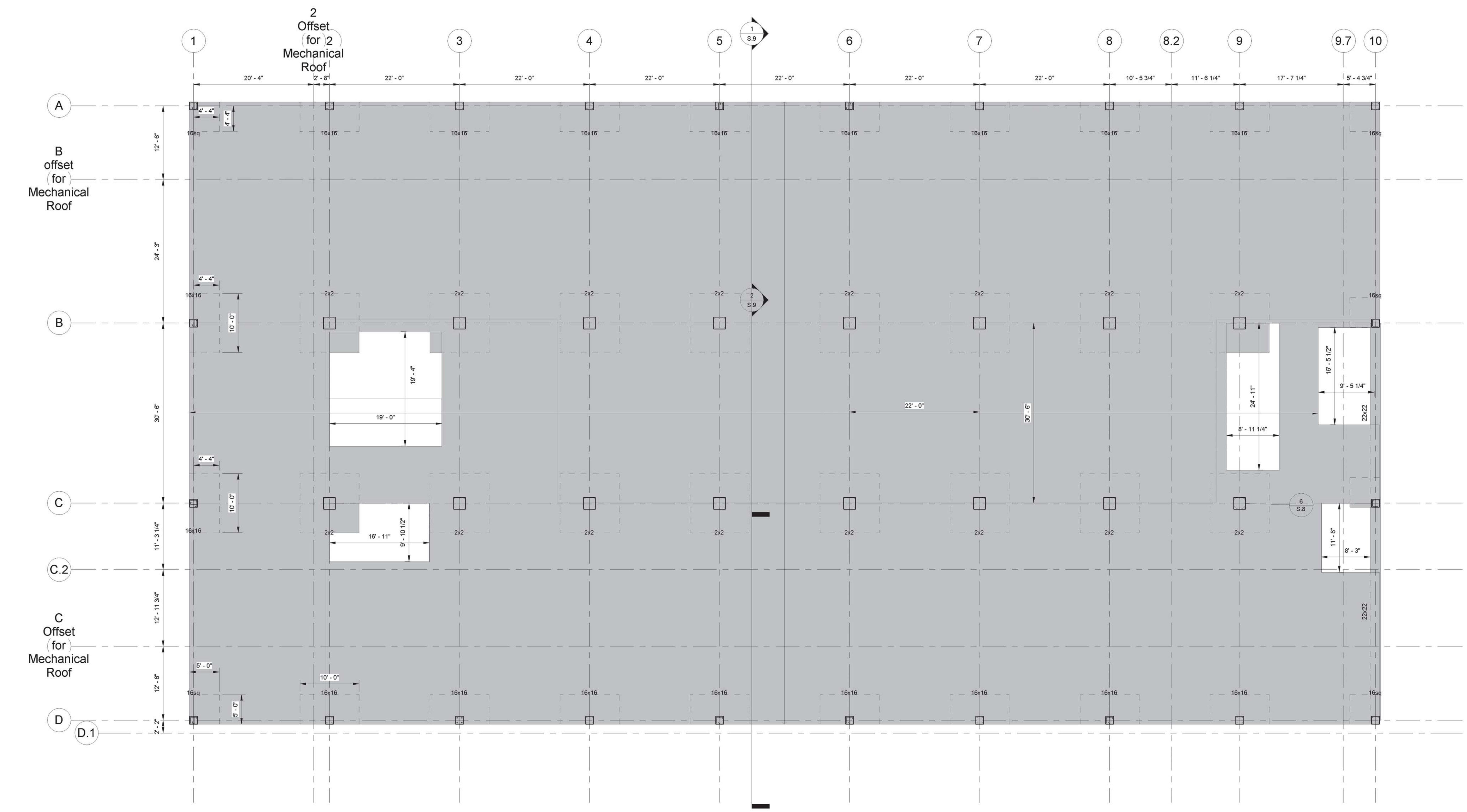

1 LEVEL 2 FRAMING
1/8" = 1'-0"

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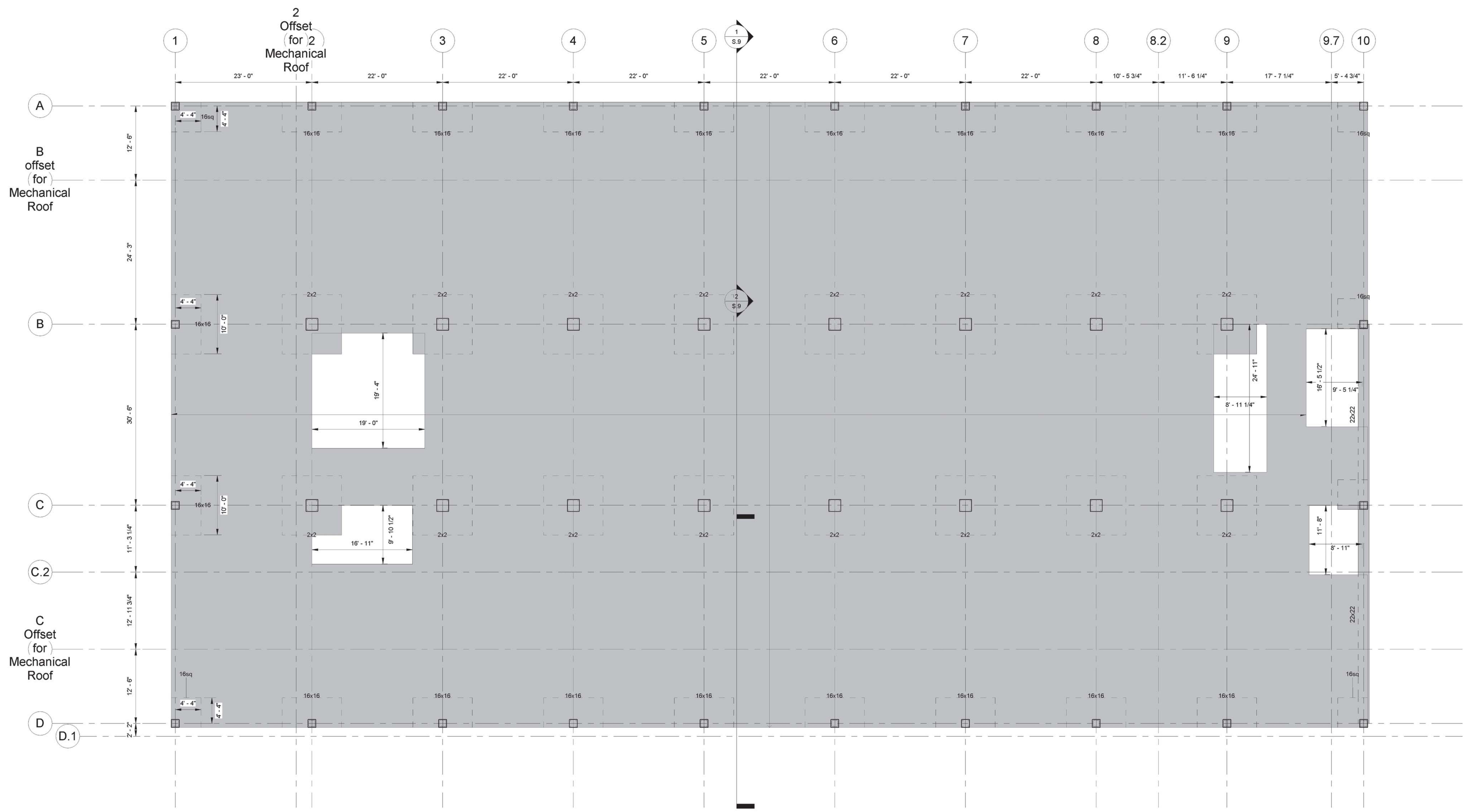

1 LEVEL 3 FRAMING
1/8" = 1'-0"

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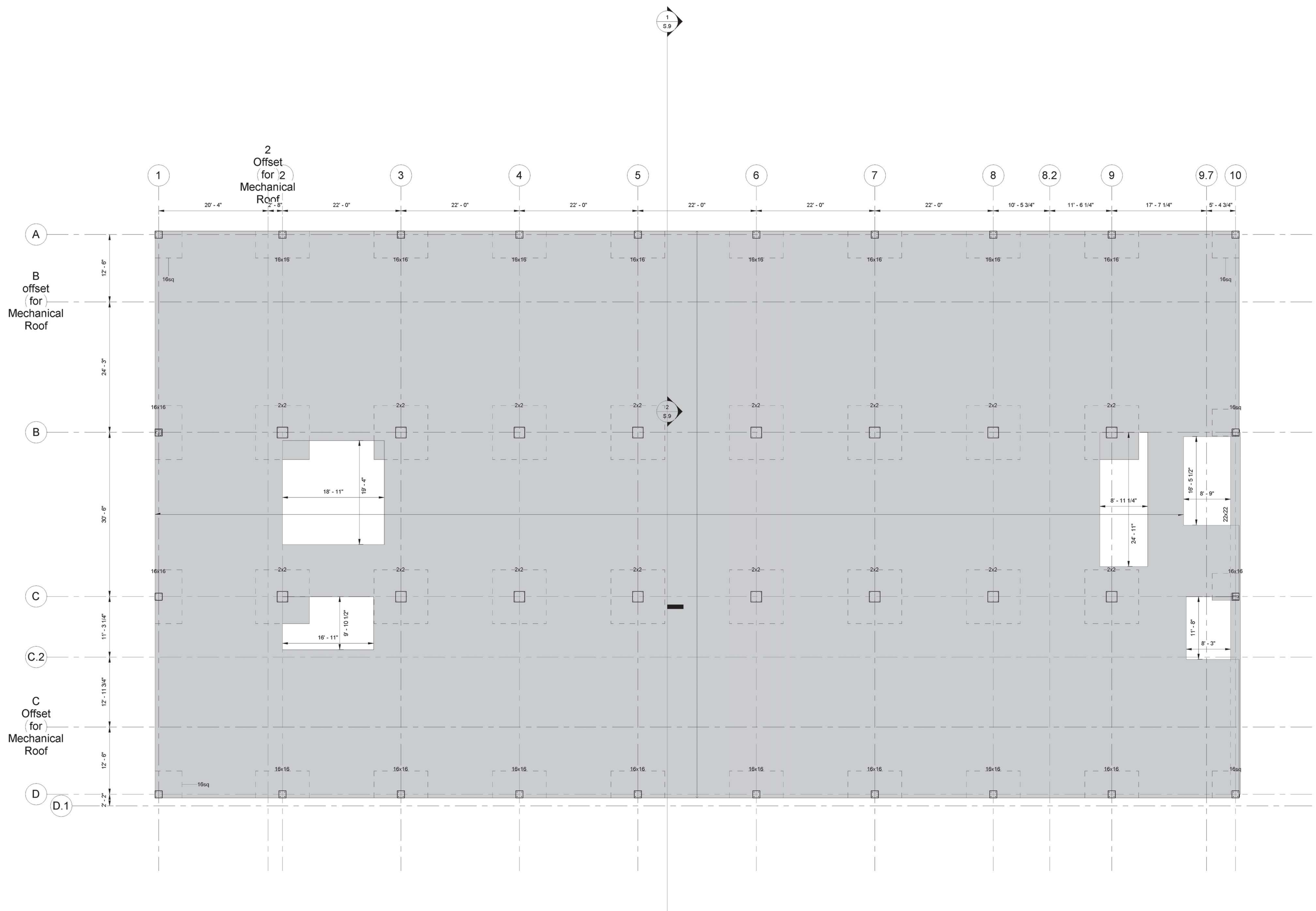

1 LEVEL 4 FRAMING
1/8" = 1'-0"

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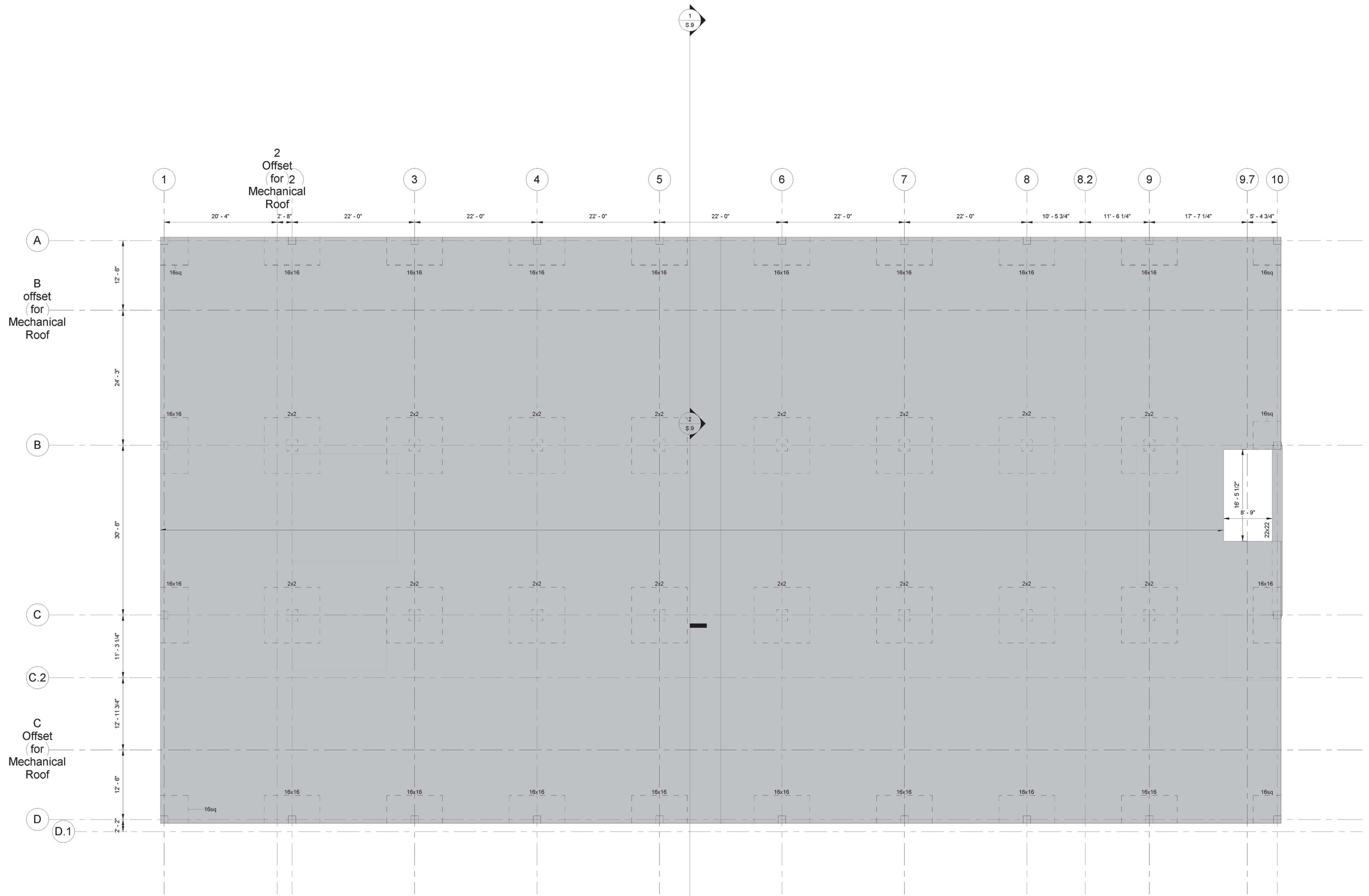

1 ROOF FRAMING
1/8" = 1'-0"

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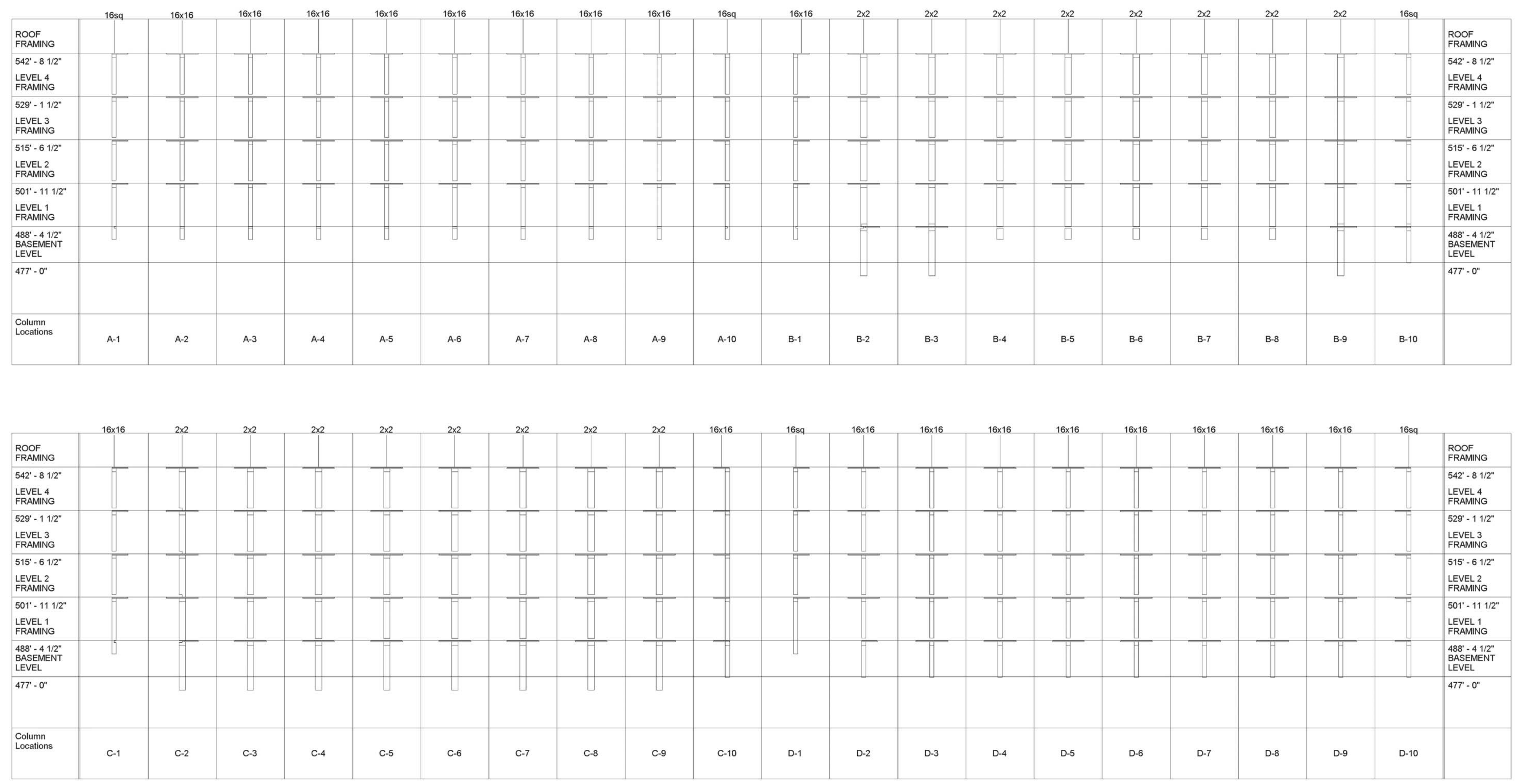
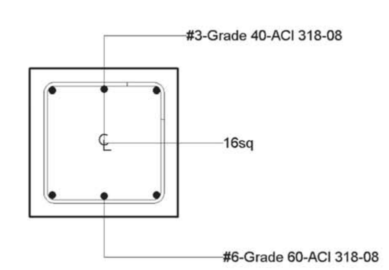
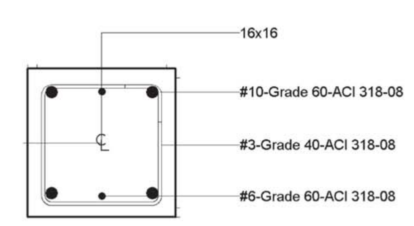


Graphical Column Schedule 1
3/64" = 1'-0"



1 Typical Column Detail A
1" = 1'-0"



2 Typical Column Detail B
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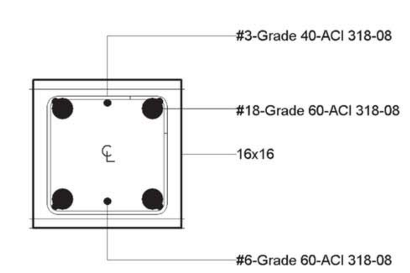
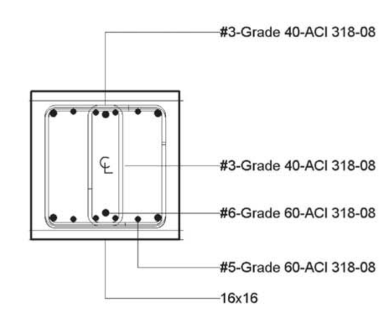


3 Typical Column Detail C
1" = 1'-0"



4 Typical Column Detail D
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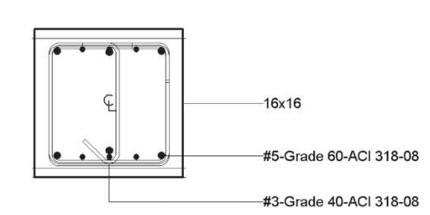

5 Typical Column Detail E
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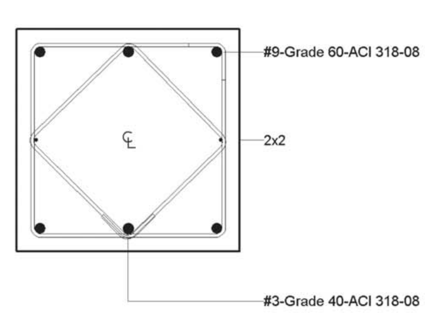

6 Typical Column Detail F
1" = 1'-0"

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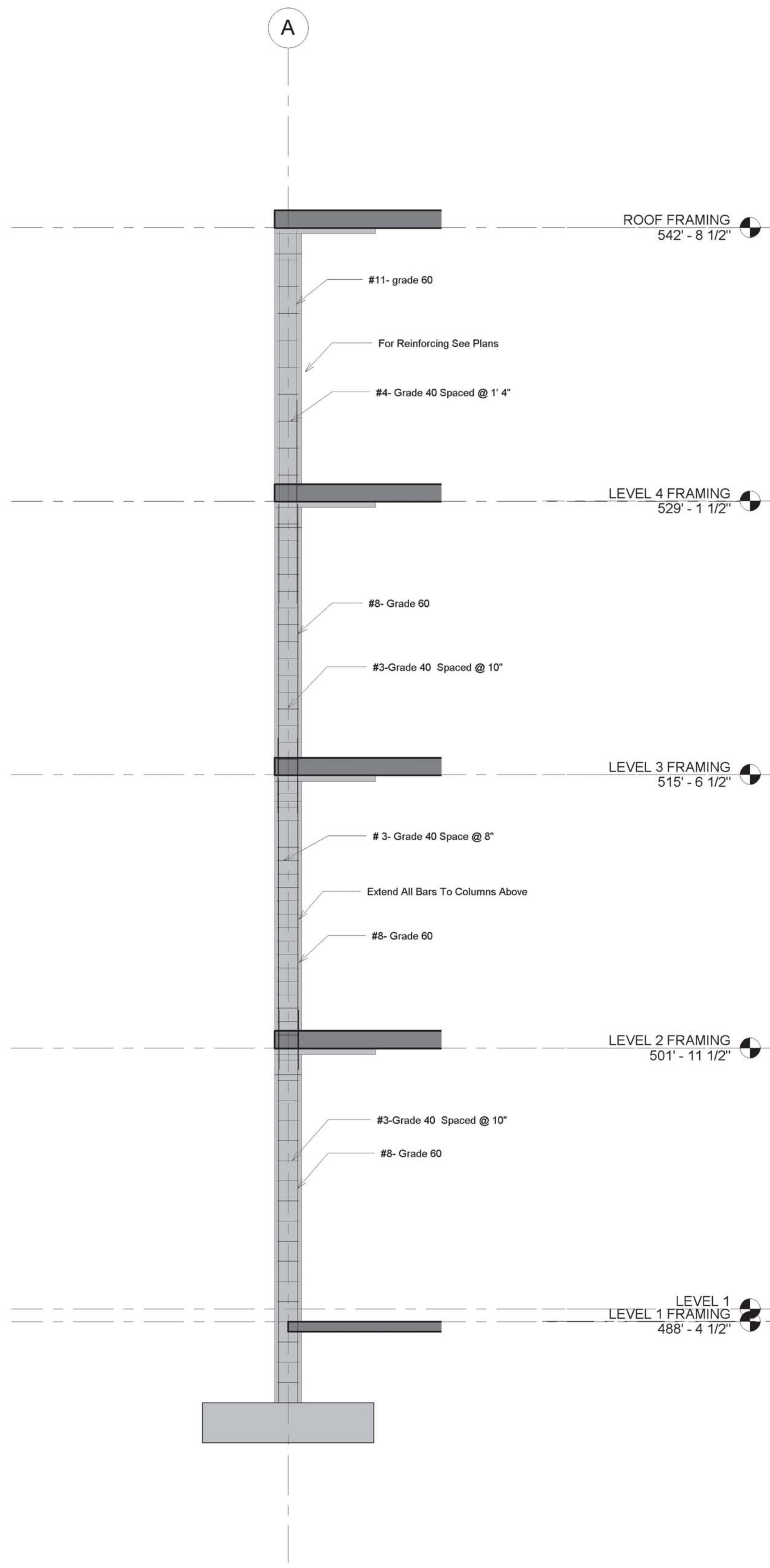
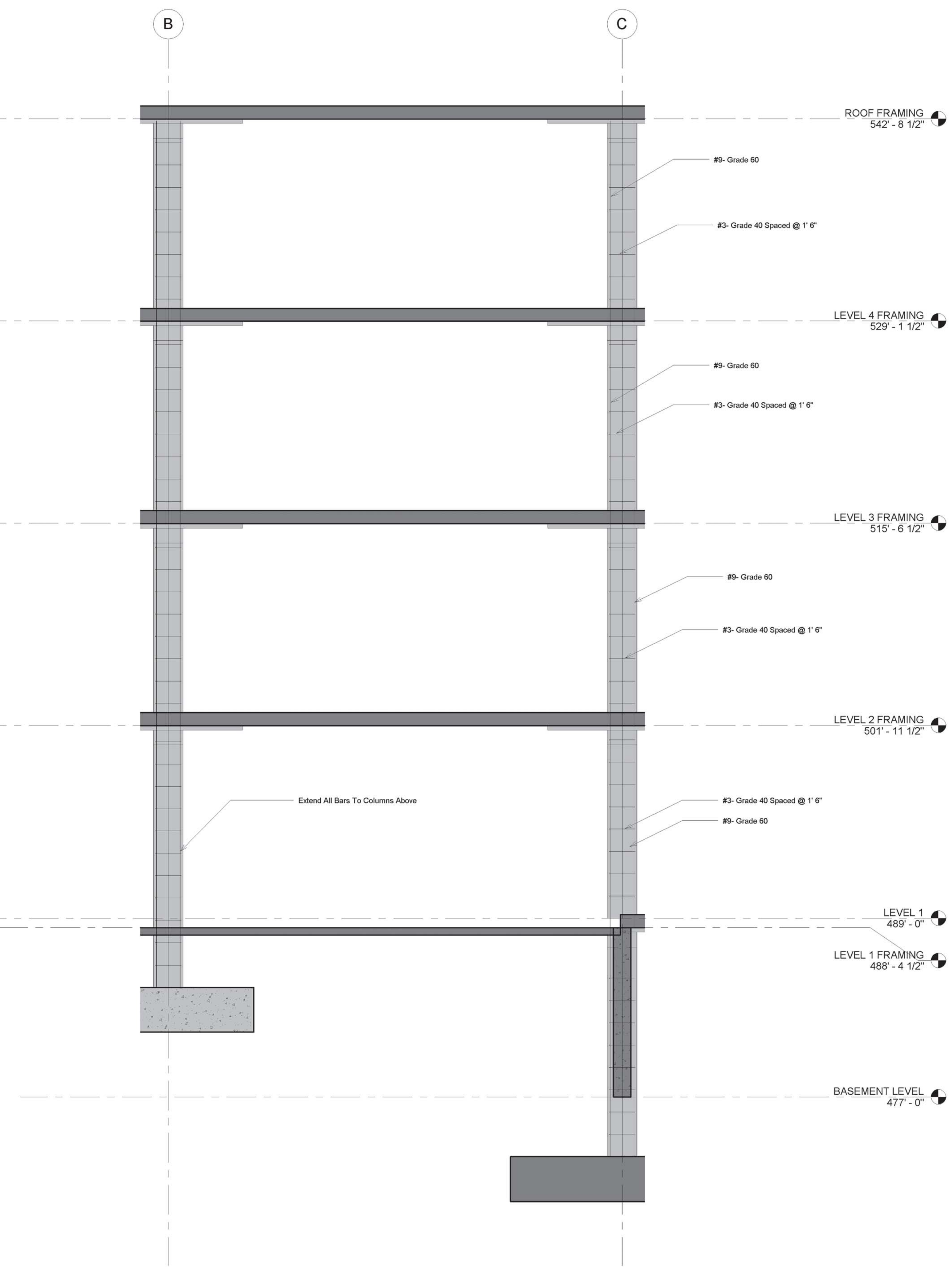


1 Typical Exterior Column Elevation
1/4" = 1'-0"



2 Typical Interior Column Elevation
1/4" = 1'-0"

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