victoria interval

MTOB[pennsylvania]

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12 october 2012

MTOB

alternative floor systems [II]

contents

executive summary

Technical report 2 analyzes and discusses the existing floor system and three alternatives. The original floor system is composed of composite beams and deck. The three alternatives chosen were composite cellular beams (SmartBEAMS), non-composite steel joists, and one-way concrete slab on beams. These systems were chosen to provide variety in materials and construction, and are analyzed in this report based on depth, weight, cost, and several other factors.

The original system is found to be the least expensive at $17.30 per square foot, yet average in depth and weight. Its overall depth is 29.5” and it weighs approximately 64 PSF. It is thought that this system was chosen for its inexpensive price.

System 2 (SmartBEAMS) is the deepest system at 38.5” but it takes advantage of its long span capacity, increasing the bay size to 60’ in length. It weighs 65 PSF and costs $17.31 per square foot, only 1 PSF and $0.31 more than the existing system. This is could be a viable alternative if the architect wanted to take advantage of its aesthetic appeal and MEP integrating potential. SmartBEAMS also remove a significant number of columns, opening up the floor plan even more.

The third system analyzed in this report is the non-composite steel joists system. This system is found to be the lightest at 61.4 PSF, and in the middle in all categories. It costs $18.89 per square foot and is 32.5” deep. Steel joists are quick to construct and is viable, but this system does not have enough advantages to be preferable to the existing.

A one-way slab system is analyzed to provide a concrete comparison to the three steel options. The concrete system has the smallest depth at only 20”, but also costs the most at $21.58 per square foot. As a massive system, the concrete has excellent deflection characteristics (deflecting less than half an inch in total load deflection). This alternative would be good if the overall building height needed to be reduced. Otherwise, it costs more and can be more laborious to construct.

Included in the appendices are all hand, computer program [RAM] and excel calculations for each of the floor systems analyzed as well as some drawings that may be useful in understanding the building.

building introduction

The Multi-Tenant Office Building is currently being constructed in Pennsylvania and is expected to be done in July 2013. MTOB is designed as a 5-story, 152,000 square foot office building to be leased into different office spaces for multiple tenants. It is designed to hold high-end office spaces and sits in a luxury office park created by a developer. The architecture plays off of the existing buildings in the office park, which is mostly new construction. Over-sized windows allow natural light to penetrate deep into the spaces without being uncomfortable or distracting. It is expected to have full tenant lease agreements before the completion of the building, which will ensure a successful venture.

structural overview

MTOB is a 5-story steel structure with eccentrically braced frames sitting on drilled concrete caissons. The floors are concrete slab on grade and concrete slab on deck. All calculations are based on Occupancy Category II, for office buildings [ASCE7-10].

included in this section:

building materials
foundation system
framing system
floor system
lateral system
roof system

building materials

Although the building exterior has some brick masonry work, the steel frame, CMU walls, and concrete floors and foundations are the only structural aspects of this building. The materials used in this building can be found in Figures 1-3. These were found on AES's sheet S001.

steel	
shape/type	**grade**
structural W shape	ASTM A992
structural M, S, C, MC, L	ASTM A36
HSS steel tube	ASTM A500, grade B
round HSS steel pipe	ASTM A500, grade B
plates and bars	ASTM A36

Figure 1: *(left)*

Structural steel shapes and standards for the project

masonry	
shape/type	**strength [psi]**
8" CMU wall	1500
12" CMU wall	1500
18" CMU wall	1500

Figure 2: *(left)*

Masonry wall sizes and standards for the project

concrete		
Usage	**weight [pcf]**	**strength [psi]**
footings, grade beams, caisson caps	> 144	3000
caissons [drilled piers]	> 144	4000
Walls	> 144	4000
slabs on grade	> 144	4000
elevated floor slabs	> 144	4000
balconies, with 2 ½ gallons of corrosion inhibitor per CY	> 144	5000

Figure 3: *(above)*
Concrete usage and standards for the project

foundation system

The foundation system of MTOB was designed by AES after reviewing the recommendations of the geotechnical reports from the geotechnical engineer, Professional Service Industries, Inc.

preliminary geotechnical recommendation

Professional Service Industries, Inc. (PSI) submitted a preliminary geotechnical recommendation report in December, 2011 based on geotechnical information from existing geotechnical reports and drawings from various geotechnical firms. From the existing reports, PSI noted 14 boring logs of interest to the project. From these borings, it was interpolated that rock can be expected between the approximate elevations of 1020-1030 ft, NGVD. PSI agreed with AES's proposed foundation system of drilled piers with grade beams. Initial design values were given as follows:

25ksf net end bearing pressure
2ksf preliminary slide friction

geotechnical report

A new geotechnical survey was conducted by PSI in February, 2012. The geotechnical engineering firm executed a total of 12 additional borings: 6 in the proposed footprint of the building and 6 in the parking lot areas surrounding the building footprint (see Figure 4). From borings B-1 through B-6, PSI recommends the drilled pier foundations extend to the limestone/sandstone bedrock (found between 9 and 27 feet below the finished floor elevation).

For adequate ground water control, sump pumps shall be used to keep water a minimum of two feet below the subgrade elevation.

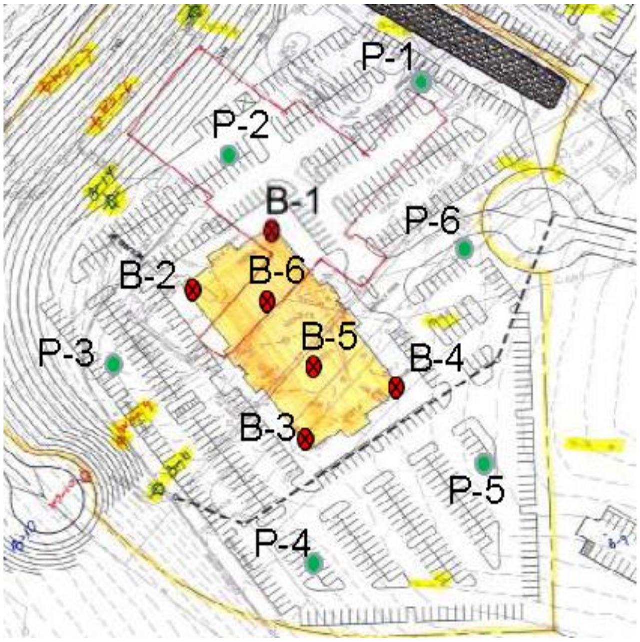


Figure 4: *(above)*
Locations of PSI test borings. Image taken from PSI geotechnical report

foundation design

The MTOB foundation is designed as drilled piers and grade beams along the exterior walls. The concrete grade beams range in sizes from 12”-24” wide and 36”-68” deep. Reinforcement varies, but generally the grade beams are reinforced with #7 bars on top and bottom and #5 bars on the sides. The caissons are designed as 30” diameter concrete with reinforcing and caisson caps depending on the corresponding framing. A plan of the caissons and grade beams can be seen in Figure 5. Note that the grade beams have been highlighted in green and the caissons in pink.

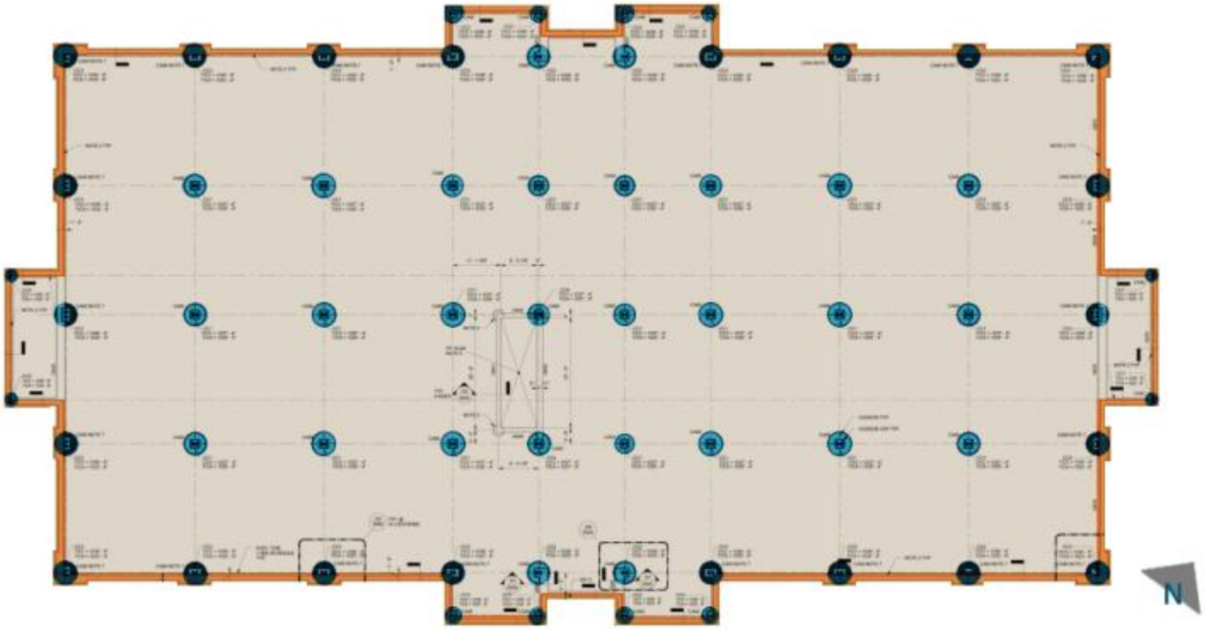


Figure 5: *(above)*
Modified AES foundation plan with caissons highlighted in blue and grade beams highlighted in orange.

framing system

MTOB framing consists of five stories of steel columns. Column splices occur on level four at varying heights so that stability is not jeopardized. The majority of columns range from W12x40 to W12x78, but they reach W12x152 in the areas supporting heavier loads under the mechanical penthouse.

floor system

The rectangular building shape is mirrored with regularly spaced bay sizes. Figure 7 shows a typical floor plan with the two typical bay sizes.

Level 1 floor is a typical slab on grade, and levels 2-5 floors are slab on composite deck. Specifically, 3 ½" normal weight concrete on 2" 20 gauge deck for a total thickness of 5 ½". Because of the building's regularity, this is the only type of floor system. See Figure 6 to see the typical floor system on beams.

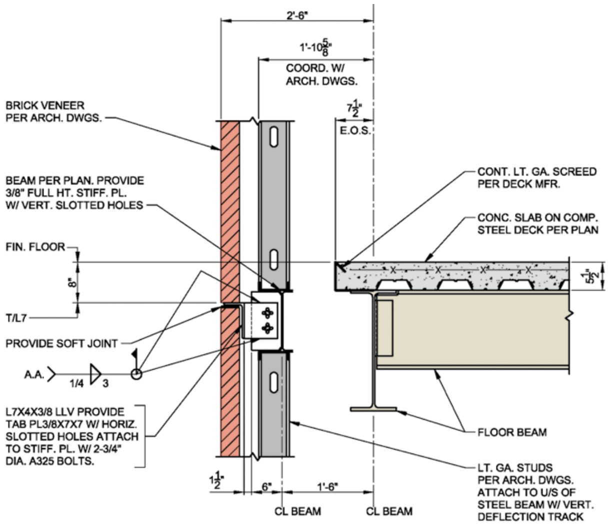
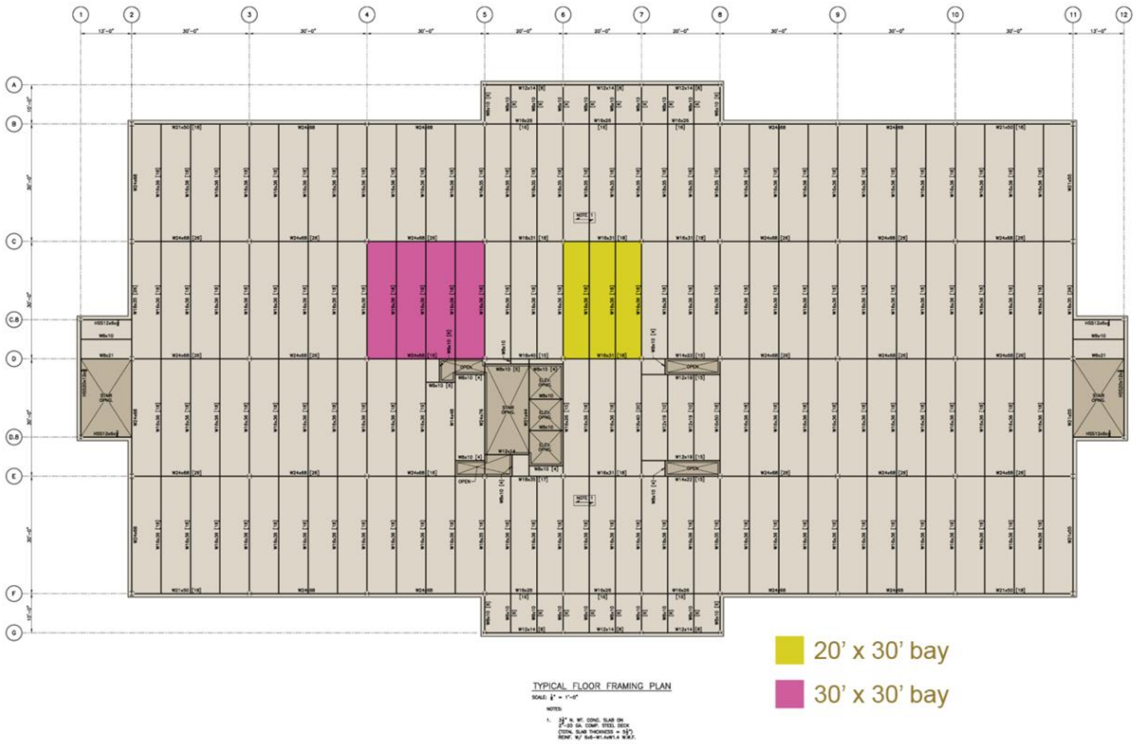


Figure 6: *(above)*
Modified AES section 201 showing a typical floor and exterior wall section.

Figure 7: *(below)*
Typical floor plan with typical bay sizes called out



lateral system

Braced frames resist lateral loads in the MTOB. There are a total of 8 braced frames throughout the building, with three different (though all eccentric) configurations. The frames are eccentric so that none of the bracing crosses behind the large windows that line the exterior walls at every level. See Figure 8 for the typical elevation of MTOB's braced frames. The layout of the braced frames is spaced so that the lateral forces will be adequately acknowledged no matter which direction they approach from. Figure 9 shows the location of each of the 8 braced frames in the building. A components and cladding check has not been included with this technical report, but will be explored in a later report to check that the lateral forces are adequately reaching the braced frames.

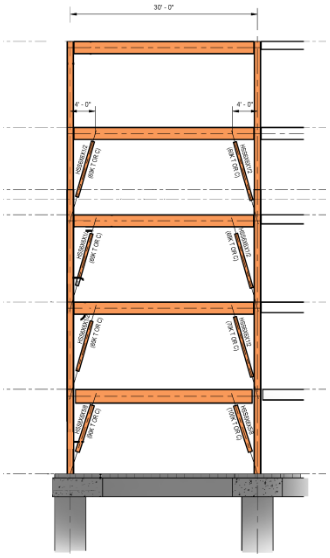
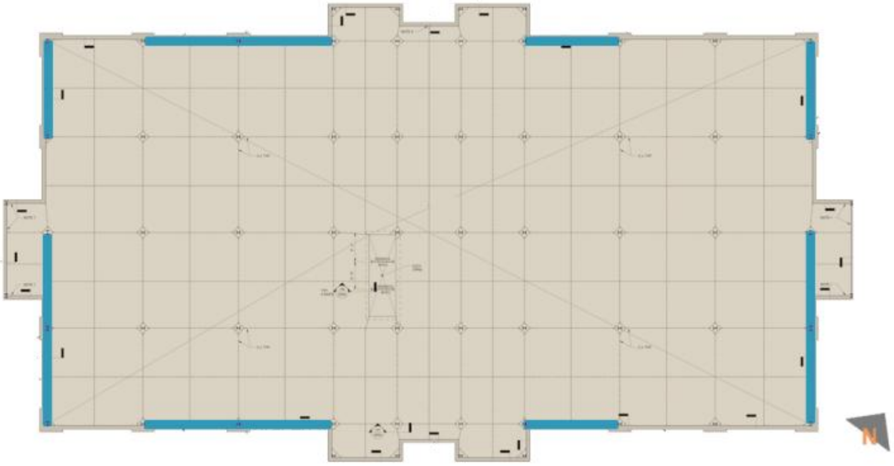


Figure 8: *(above)*
Modified AES braced frame elevation

Figure 9: *(left)*
Modified AES floor plan with locations of braced frames highlighted in pink



As lateral forces are applied to the building exterior (specifically the components and cladding), bearing connections transfer the loads to the composite floor system. The load travels parallel to the original force. From there, the loads then travel perpendicularly to the braced frames at that particular level through the beams or girders. A lateral load path can be seen in Figure 10.

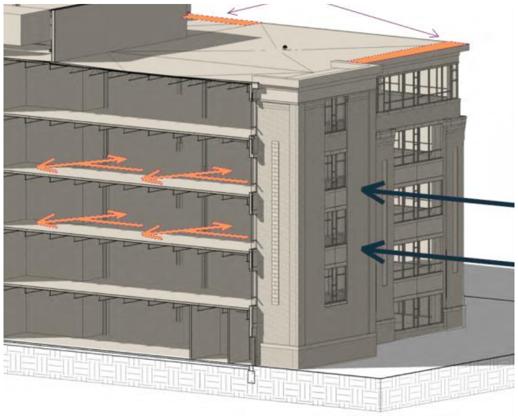


Figure 10: *(above)*
Modified Kernick Architecture building section showing lateral load path

roof system

The roof of MTOB is an unassuming, simple structure because it does not play an architectural role for the building. The structure consists of 1 ½" galvanized roof deck on supporting beams. Like most steel construction buildings with concrete slabs on deck floor systems, the roof deck does not have any concrete because it is not structurally necessary and the extra weight would cause inefficiencies in the structure. The roof is finished with white TPO Membrane Roof (fully adhered) as the weather resistant covering on top of sloped structure and tapered 20CI insulation. White roofing is becoming more and more popular because of its reflective properties that allow it to minimize heat gain. In an office building, people are often a large contributor to mechanical load and so they have to be cooled most of the year, even in cooler climates like Pennsylvania.

design codes

original codes MTOB was designed using:

- 2009 International Building Code (IBC 2009)
- Minimum Design Loads for Buildings and Other Structures (ASCE 7-05)
- Building Code Requirements for Structural Concrete (ACI 318-08)
- AISC Manual of Steel Construction, Allowable Stress Design (ASD)

codes used to complete the analysis in this technical report:

- 2009 International Building Code (IBC 2009)
- Minimum Design Loads for Buildings and Other Structures (ASCE 7-10)
- Building Code Requirements for Structural Concrete (ACI 318-11)
- AISC Manual of Steel Construction, Load Resistance Factor Design (LRFD)

load summary

Gravity loads for live, dead, flat roof snow, and drift snow are found using ASCE 7-10 code and estimations. Tables are included tabulating the values of the load in each corresponding category. Lateral loads are also calculated using ASCE 7-10.

included in this section:
dead load
live load
snow load
gravity spot checks
wind load
seismic load

dead load

superimposed dead loads	
description	**load**
level 1 ceiling + misc. mechanical	10 [psf]
levels 2-5 ceiling + misc. mechanical	15 [psf]
roofing	20 [psf]
mechanical spaces	80 [psf]
brick veneer (4” thick)	60 [psf]

Figure 11: *(above)*
Dead loads used in design and in technical report

live load

The design live loads of the building are found using ASCE 7-05. In comparing these with ASCE 7-10, the loads are found to be the same. The mechanical floor allowance is not higher because no expansion is expected for MTOB.

live loads		
description	**design load ASCE 7-05 [psf]**	**ASCE 7-10 [psf]**
public areas	100	100
office lobbies	100	100
office first floor corridors	100	100
office corridors above first floor	80	80
offices	50	50
partitions	15	15
mechanical	100	100
stairs	100	100

Figure 12: *(above)*
Live loads used in design and in technical report

snow load

Flat roof snow load was calculated using ASCE 7-10. A summary of the factors used and the results can be found in Figure 13 below. Although the maps from ASCE 7-10 chapter 7 (Figure 7-1) indicate a design ground snow load of 25 psf, local code governs with a 30 psf design limit for the area.

flat roof snow load	
description	**value**
exposure factor, C_e	1.0
temperature factor, C_t	1.0
importance factor, I_s	1.0
ground snow load, p_g [psf]	30
flat roof snow load, p_f [psf]	21

Figure 13: *(above)*
Dead loads used in design and in technical report

There were two types of areas on the roof that can cause snow drift. Since the mechanical penthouse stands 14' higher than the main roof, snow drift may accumulate around its walls. The penthouse is centered on the roof and is in the same rectangular shape of the MTOB footprint. Also, along the South and North facing facades, a small portion of the roof has a tall parapet as an architectural feature. See Figure 14, highlighting the areas that will cause snow drift.

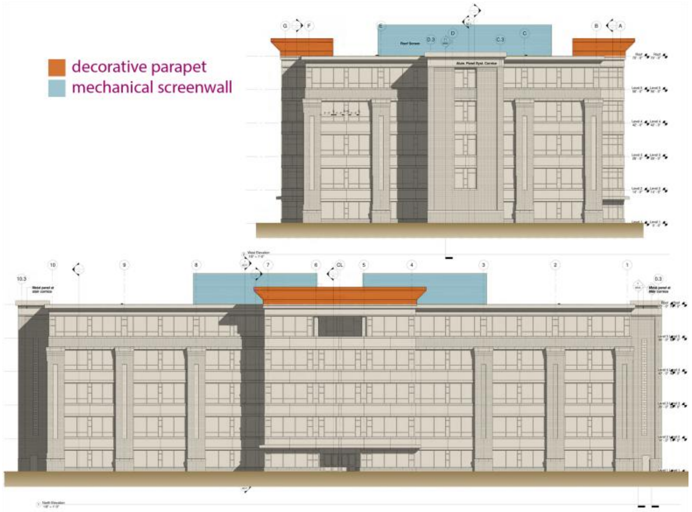


Figure 14: *(above)*
Modified Kernick Architecture elevations showing the parapet and screenwall that cause snow drift

To simplify drift load, the worst case drift was calculated (using the longer rectangle dimension of the mechanical screenwall) for use along the exterior perimeter of the mechanical penthouse and along the decorative parapet. Figure 15 shows a summary sketch of the results. Full snow load/drift load calculations can be found in Appendix A.

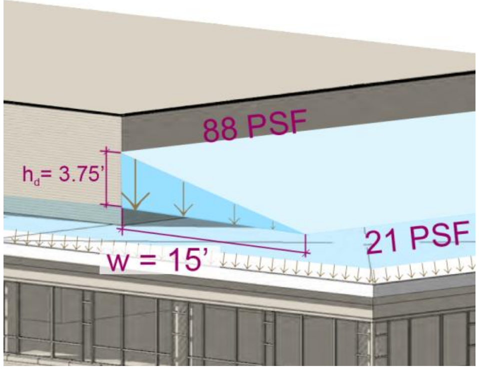


Figure 15: *(above)*
Drift load sketch

wind load

While the original MTOB design pressures were found using ASCE 7-05, the pressures in this technical report were calculated using the updated code, ASCE 7-10. All hand calculations following chapter 26 and 27 of ASCE 7-10 can be found in Appendix B. The design criterion for these calculations matches the design criteria of the original design, except for the main wind velocity. As part of the ASCE 7-10 update, the maps found in chapter 26 contain slightly higher values than the previous maps found in ASCE 7-05, chapter 6. With the changes in both procedure and criteria values, the pressures calculated in this report are slightly higher than the design values on the drawings.

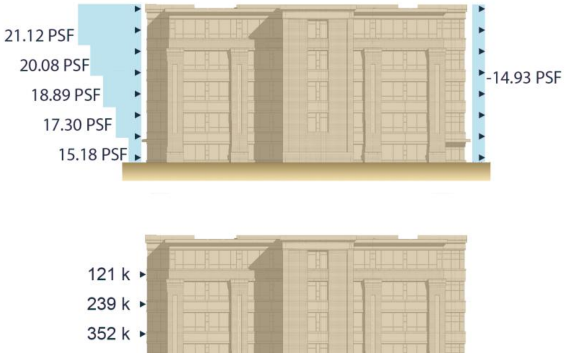
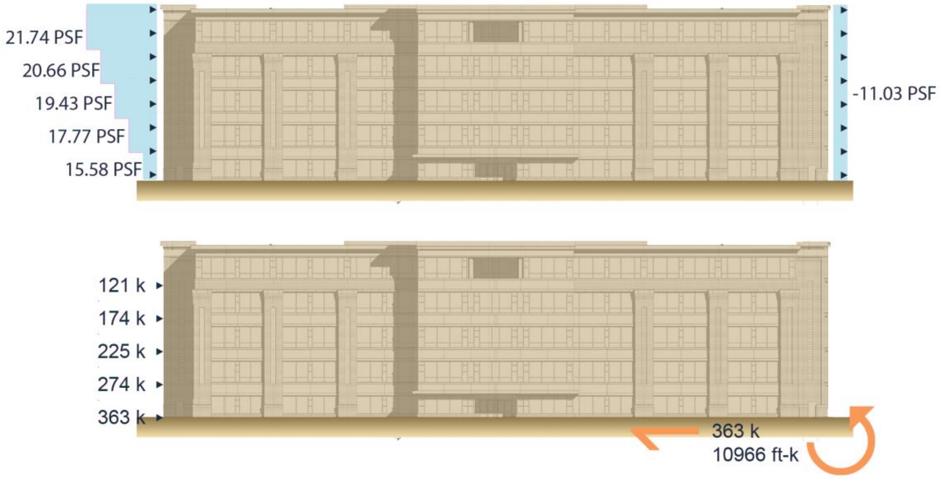


Figure 16: *(above)*
North-South wind load pressures, story shears, base shear, and overturning moment

The building is considered rigid since its fundamental frequency is less than 1 hz (see Appendix B for calculations). Using this, the gust factor was calculated for both the N|S and E|W wind directions. Since this is an office building, it is not necessary to withstand more than the basic code recommended values for wind velocity. For the purpose of simplifying, the roofline was assumed straight at 70'. The footprint of MTOB is already mostly rectangular in nature, so no extreme simplifications were necessary for calculations.

The wind pressures, story shear, base shear, and overturning moments can be seen in Figures 17 and 18 for the N|S and E|W wind directions, respectively. The excel spreadsheet calculations of these values can be found in appendix C with the hand calculations.

Figure 17: *(below)*
East-West wind load pressures, story shears, base shear, and overturning moment



seismic load

The area MTOB is located is not high in seismic activity. From the comparison between the base shear and overturning moment contributed by seismic forces vs. those contributed by wind forces, it is only about a quarter of the magnitude. The summary of seismic findings is tabulated in Figure 19, and full hand calculations can be found in appendix D.

seismic						
level	**h_x [ft]**	**h_x^k**	**w_x [k]**	**c_{vx}**	**F_v [k]**	**overturning moment [ft-k]**
1	0	0	1849	0.0	0.0	0
2	14	18.86429	2603.5	0.0779	10.424	146
3	28	40.80251	2603.5	0.1684	22.547	631
4	42	64.07321	2603.5	0.2645	35.406	1487
5	56	88.25377	2603.5	0.3643	48.767	2731
roof	70	113.1343	697	0.1250	16.736	1172
		$\Sigma w_i h_i^k$:	**630780.4**		**base shear [k]:**	**134**
			total overturning moment [ft-k]:			**6167**

Figure 18: *(above)*
Summary of seismic forces

analysis of floor systems

Four systems are analyzed and discussed in the following section of this technical report. System 1 [existing] is composite beams and deck. The alternative three systems are [2] composite cellular beams, [3] non-composite steel joists, and [4] one-way slab on beams.

These systems are analyzed in weight, depth, cost, and other factors. They will be compared in the next section.

Included in this section:
system 1: composite beams and deck
system 2: composite cellular beams
system 3: non-composite steel joists
system 4: one-way slab on beams

system 1: [existing] composite beams+deck

The existing MTOB floor system consists of composite slab/decking on composite beams and girders. This system was analyzed for the purpose of comparing it with three selected possible alternative floor systems. A series of gravity spot checks of the typical bay's beams, girders, and columns are found adequate for the building loads. The bay size is 30'x30'. See Appendix D for system 1 calculations.

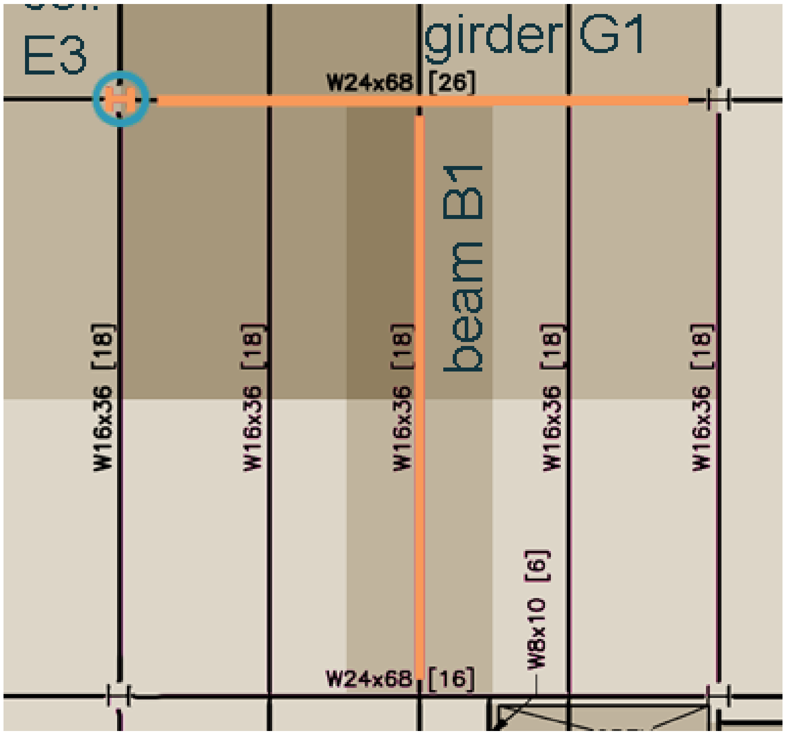


Figure 19: *(above)*
30'x30' bay of System 1

analysis

The existing system in MTOB was found to have an overall depth of 29.5" and a weight of 64.1 PSF. Deflections are minimal because of the cambering: 0.65". Using this system allowed for braced frames in the lateral system, which is much lighter than shear walls.

The overall cost was found to be approximately $17.30 per square foot. This is the least expensive, although all of the systems were very close in price. This may be one of the reasons for choosing this type of system in MTOB.

advantages

Composite systems are often chosen for their efficiency with member section. Composite vs. non-composite will turn up lighter sections because of its capability to use the slab for compressive purposes while handling the tension in the steel. This method uses each material efficiently, so members are often lighter and shallower than they would be in non-composite construction.

disadvantages

The main disadvantage of composite system is in constructability. Each shear stud must be welded to the beam, which is a laborious and time consuming process. Fireproofing must also be sprayed to the beams, girders, and deck to meet the fire rating.

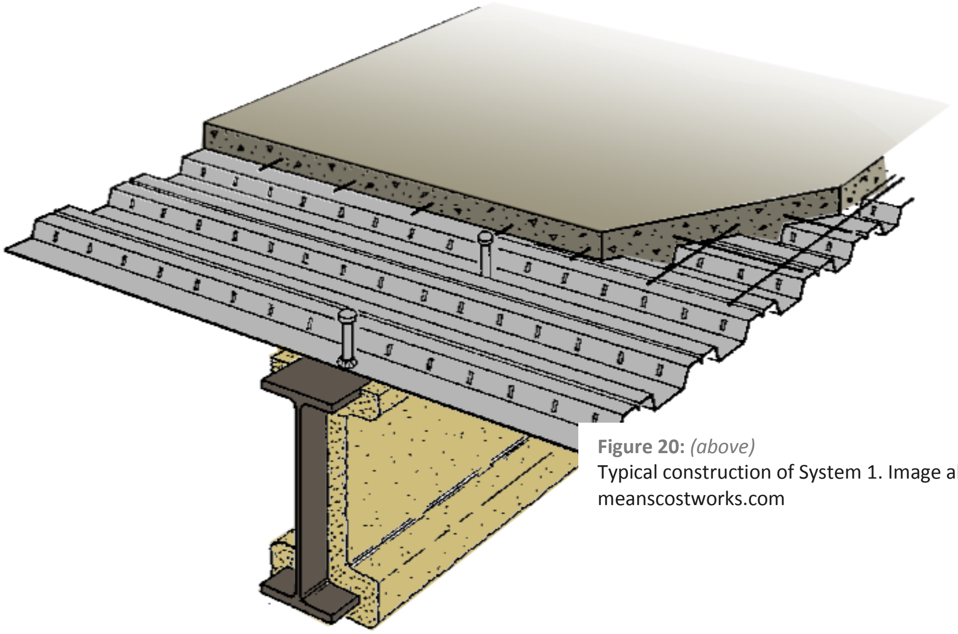


Figure 20: *(above)*
Typical construction of System 1. Image altered from meanscostworks.com

system 2: composite cellular beams

Smartbeams (a composite castellated beam system) resting on steel girders was chosen as the third alternative floor system. Castellated beams are most economical when using longer spans (40+ feet). Because of this, the bay size was doubled in length to 30'x60'. This system was chosen because of its potential to reduce the number of columns and integration capabilities with MEP systems. See figure 21 below for the layout plan. Note that the left girder and bottom beam were designed as edge members, with no other loads framing in. All other member are for an interior typical bay. Calculations for this system can be found in Appendix E.

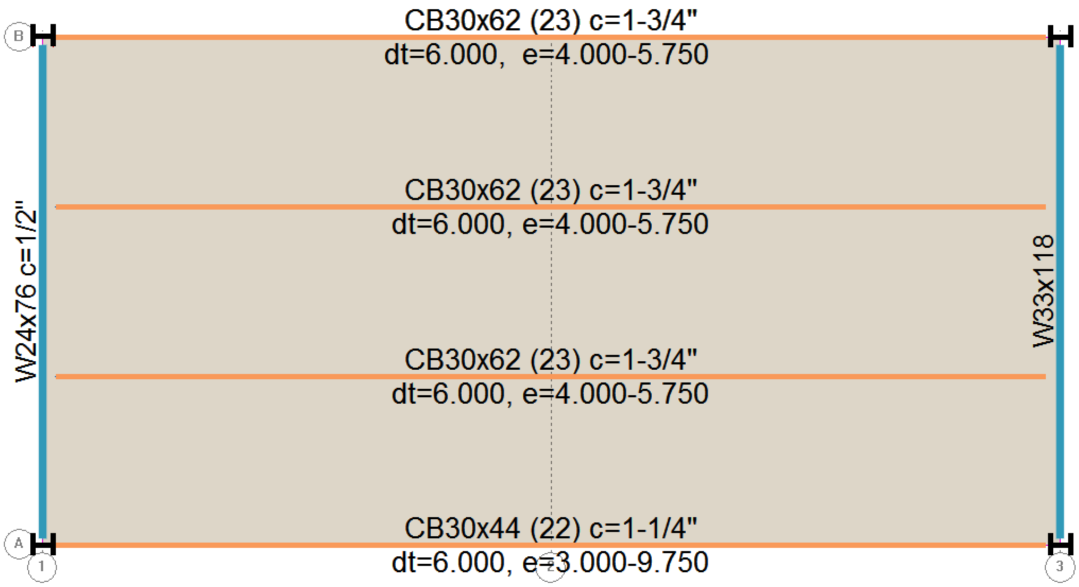


Figure 21: *(above)*
60'x30' typical bay layout for System 2

analysis

The use of Smartbeams is average in weight at 65.2 PSF, but it is much deeper than the others at 38.5". Smartbeams tend to be deeper than traditional steel beams because of the way they are fabricated. However, with the design-build approach to the MEP systems, the openings could easily be taken advantage of in the ceiling space by running smaller duct feeds and conduits through the beams. Because of this, the overall building height may not increase at all even though this system adds an additional 9" to the existing system structural depth.

The spacing between the beams is 10 feet, which is allowable for the unshored 3+ span condition of Vulcraft 2VLI 19 gauge composite deck (which allows 10'-9" max spacing).

The cost for cellular beams was estimated at about $0.31 per square foot extra than its counterpart W-shape system. This puts it in second place for inexpensive systems. However, the bay size has been doubled so if the decrease in number of columns is taken into account, the true difference in price between the two may be a null issue.

advantages

There are many advantages of cellular beams, especially when compared to traditional W-shape beams. First, longer spans are ideal. The sections of a cellular beam are much taller, which increases its section properties (giving it more strength capacity). The web openings also greatly decrease the weight of the beam, allowing its strength properties to be used for other building loads besides self-weight. Second, MEP systems can be run directly through the structure, which can save ceiling space and thus make up for the additional depth required by these long span members. Third, since each beam is cut and welded back together, camber can be added at no additional cost.

disadvantages

Because the members span such a long distance, the deflection of this system is the highest at 2.184”. It also costs a bit more and has a longer lead time than the traditional W-shapes, since each one must be cut (typically using either a water stream or a laser) apart and welded back together.

system 3: non-composite steel joists

The third system analyzed was non-composite steel joists. This system was chosen for its simplicity and its ease of construction. With the bay size of 30'x30' (kept as existing) and a spacing at 5' chosen, the loads exceeded typical K series joists. LH joists were used in place. See figure 22 below for the layout plan. Note that the left girder and bottom joist were designed as edge members, with no other loads framing in. All other member are for an interior typical bay. Calculations for this system can be found in Appendix F.

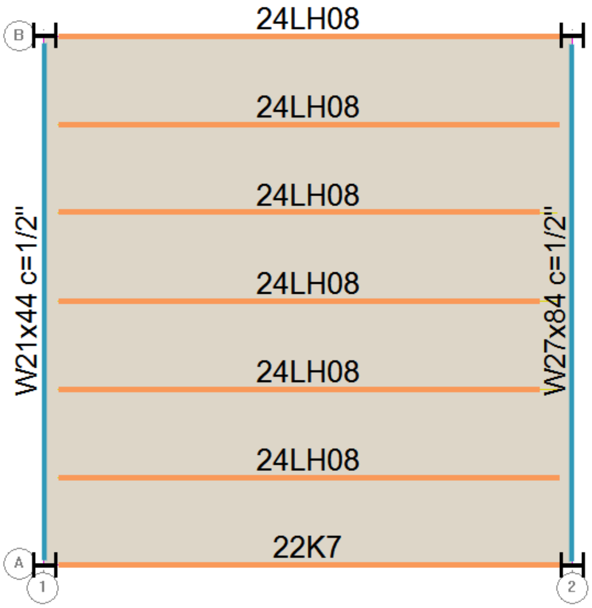


Figure 22: *(above)*
30'x30' typical bay layout for System 3

analysis

System 3 comes out as the lightest system at only 61.4 PSF. Its depth is 32.5" and costs $18.89 per square foot, which is on the upper end. This system has fast construction time, but it does not have excessive benefits when compared to the existing system. Its lightweight construction makes it susceptible to vibrations (especially in an office setting), and it deflects 1.256". Even though it is viable, this system is not specifically suggested as an alternative to the existing system.

advantages

This system has a very simple design. Joists are easy and fast to erect. It is also very light.

disadvantages

Because of the lightweight floor system, steel joist construction can often exhibit bad vibration qualities. It also has a much larger deflection than some of the other systems, and it is the second deepest system investigated.

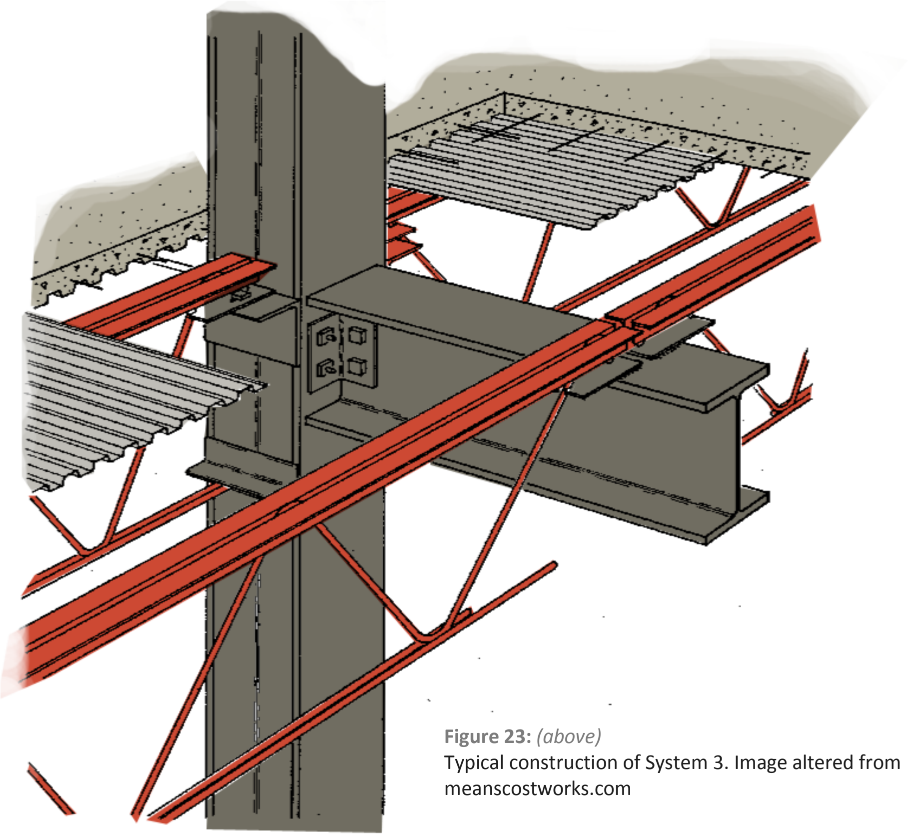


Figure 23: *(above)*
Typical construction of System 3. Image altered from meanscostworks.com

system 4: one-way slab on beams

The final floor system that was investigated was a one-way slab on beams. The bay size was kept at 30’x30’ with an intermediate beam centered in the bay. This alternative was chosen to examine the use of a concrete system for MTOB, which has some advantages and disadvantages in comparison to the other three steel-based systems. Calculations can be found in Appendix G.

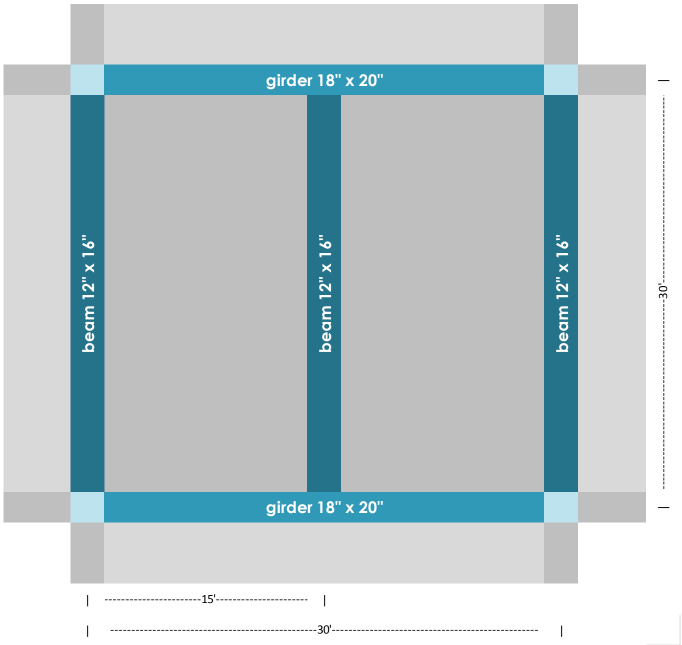


Figure 24: *(above)*
30’x30’ typical bay layout for System 4

analysis

The total depth of the 1-way slab system was found to be only 20”. This was the shallowest of the alternative systems, at only about 2/3 the depth of the existing system (which is 29.5” deep). In contrast, it is also the heaviest system at 82 PSF. This was expected, since concrete tends to create much more massive and heavier buildings than steel.

Its cost was estimated at $21.58 per square foot. This was the most expensive option, but not by very much. The extra cost can be attributed to the formwork and extra labor required to install a concrete beam and floor system.

advantages

A concrete system has several advantages over its steel peers. For one, concrete systems tend to be shallower, which can decrease the overall building height. This is advantageous in areas with strict zoning height restrictions and also in buildings with expensive façade materials. A concrete floor has inherent fire proofing properties. In addition, its heavy mass provides excellent vibration performance, especially when compared to some of the very light weight framing options (like steel joists).

disadvantages

Concrete systems can bring many problems to a building, since the material itself is so variable. Creep and shrinkage are typical problems, as well as excessive cracking and spalling when moisture conditions are poorly cared for. Concrete can be laborious to place, since forms, reinforcing steel, and rebar chairs must all be used in addition to concrete finishing after it is placed.

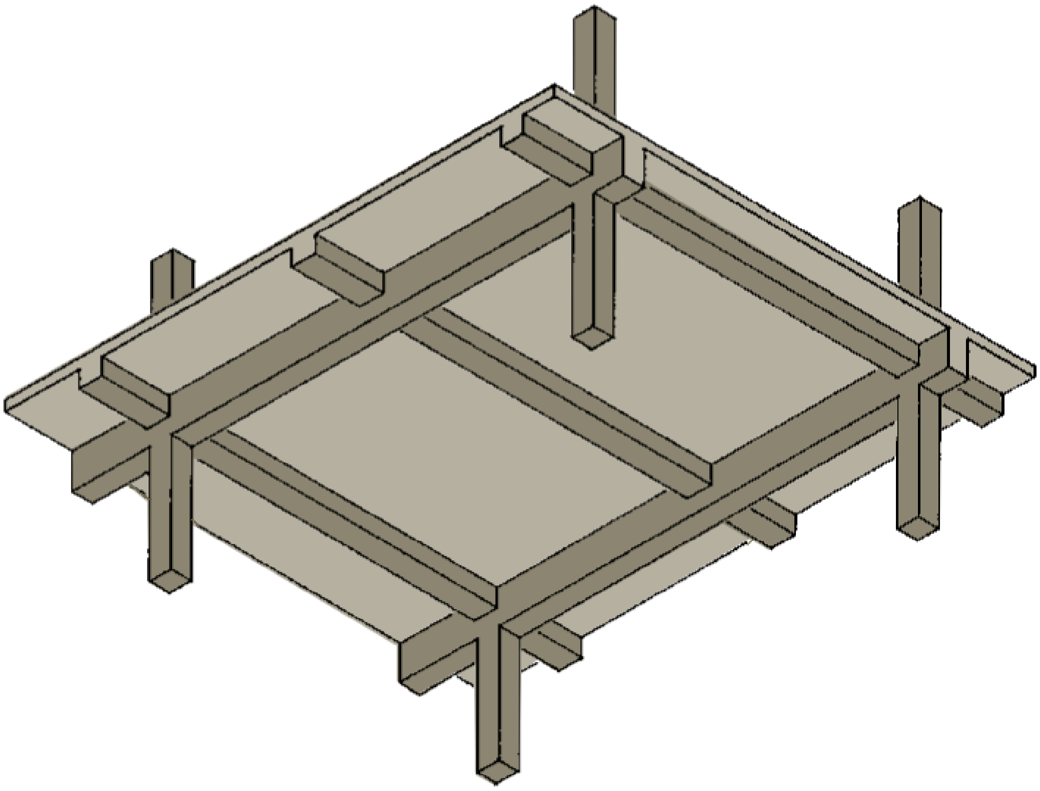


Figure 25: *(above)*
Typical construction of System 4 Image altered from meanscostworks.com

comparison of floor systems

Each of the floor system alternatives were analyzed and compared. A summary of the findings can be found in figure 26 below.

criterion	**system [1]** composite beams	**system [2]** Smartbeams	**system [3]** steel joist	**system[4]** 1-way slab
weight [psf]	64.1	65.2	61.4	82.01
depth [in]	29.5	38.5	32.5	20
cost [psf]	$17.30	$17.61	$18.89	$21.58
total load deflection [in]	0.65	2.184 [60' span]	1.256	0.331
bay size	30' x 30'	30' x 60'	30' x 30'	30' x 30'
fire protection	spray-on	depends on architectural preferences: spray-on if enclosed	enclosure	inherent
forms required	N	N	N	Y
foundation impact	[none]	[none]	[none]	possbile increase
lateral impact	[none]	[none]	[none]	need shear walls
constructability	moderate	moderate	easy	moderate
lead time	long	long	moderate	moderate
viable?	Y	Y	Y	Y

Figure 26: *(above)*
Comparison chart of Systems 1 through 4

conclusion

This technical report investigated the existing floor system of MTOB as well as three alternative systems. The existing system of composite steel beams and deck has been compared with composite cellular steel beams, non-composite steel joists, and one-way concrete slab on beams. These systems are compared in the preceding reports based on several factors, including overall depth, weight, and cost.

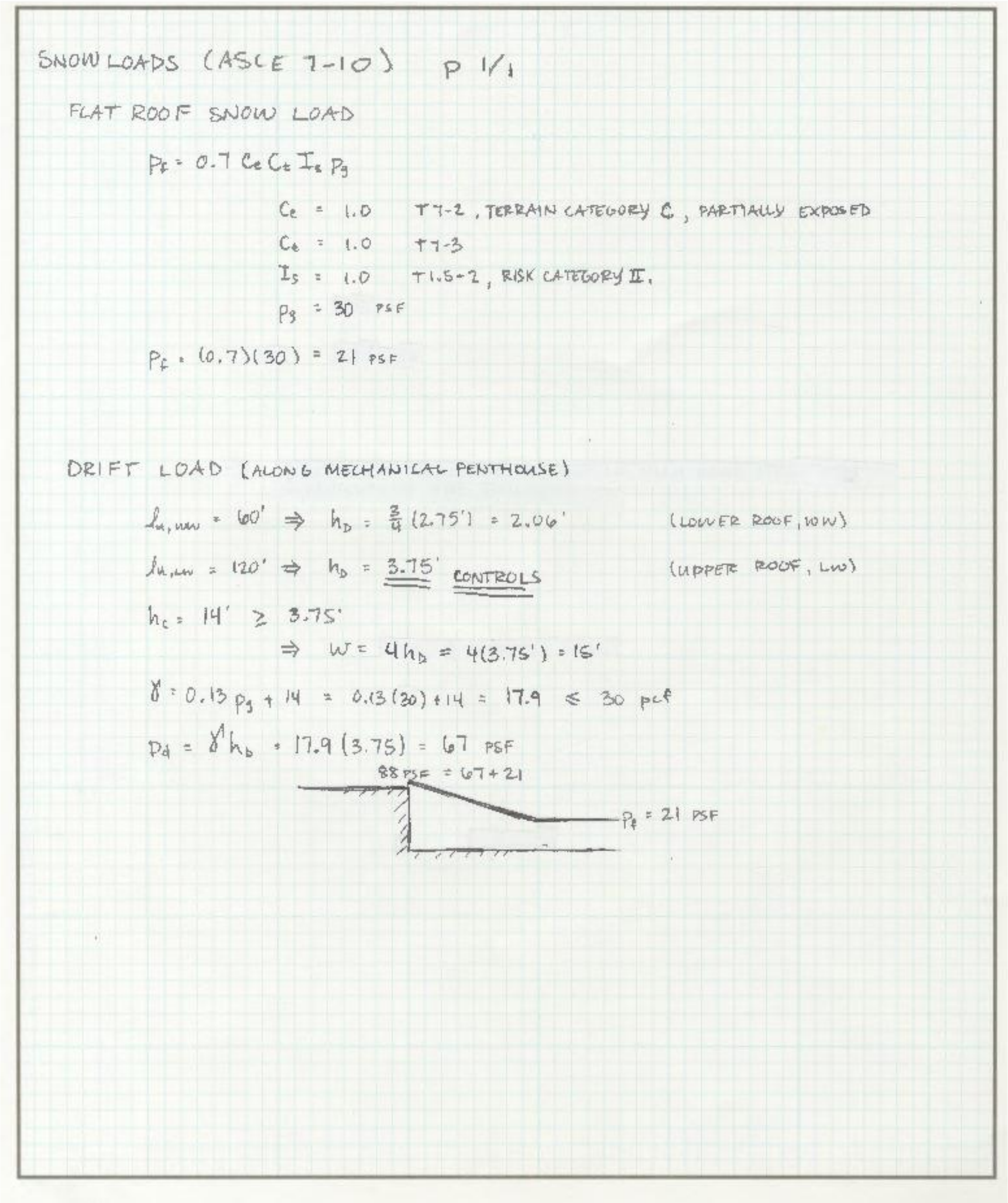
It is found that all three of the alternatives are feasible, but the steel joist system is the least preferable. Between system 2 (cellular beams) and system 4 (one-way slab), these can both be selected as the “best” alternative system for different reasons. The concrete system is the shallowest, which would lower the overall building height. The cellular beams allow for much longer spans, which double the bay size and create a more open floor plan. Since the concrete system costs significantly more than the cellular beam system, it is concluded here that the cellular beams are the best alternative to the existing system.

In future technical reports, these systems may be investigated further to better understand their impacts on other building systems, such as the foundation system and lateral system.

appendices

included in this section:

appendix A: snow load calculations



SNOW LOADS (ASCE 7-10) P 1/1

FLAT ROOF SNOW LOAD

$P_f = 0.7\ C_e C_t I_s P_g$

$C_e = 1.0$ T7-2, TERRAIN CATEGORY C, PARTIALLY EXPOSED

$C_t = 1.0$ T7-3

$I_s = 1.0$ T1.5-2, RISK CATEGORY II.

$P_g = 30$ PSF

$P_f = (0.7)(30) = 21$ PSF

DRIFT LOAD (ALONG MECHANICAL PENTHOUSE)

$l_{u,ww} = 60' \Rightarrow h_D = \frac{3}{4}(2.75') = 2.06'$ (LOWER ROOF, WW)

$l_{u,lw} = 120' \Rightarrow h_D = \underline{\underline{3.75'}}$ $\underline{\underline{\text{CONTROLS}}}$ (UPPER ROOF, LW)

$h_c = 14' \geq 3.75'$

$\Rightarrow w = 4h_D = 4(3.75') = 15'$

$\gamma = 0.13\, p_g + 14 = 0.13(30) + 14 = 17.9 \leq 30$ pcf

$P_d = \gamma h_D = 17.9(3.75) = 67$ PSF

88 PSF = 67 + 21

$P_f = 21$ PSF

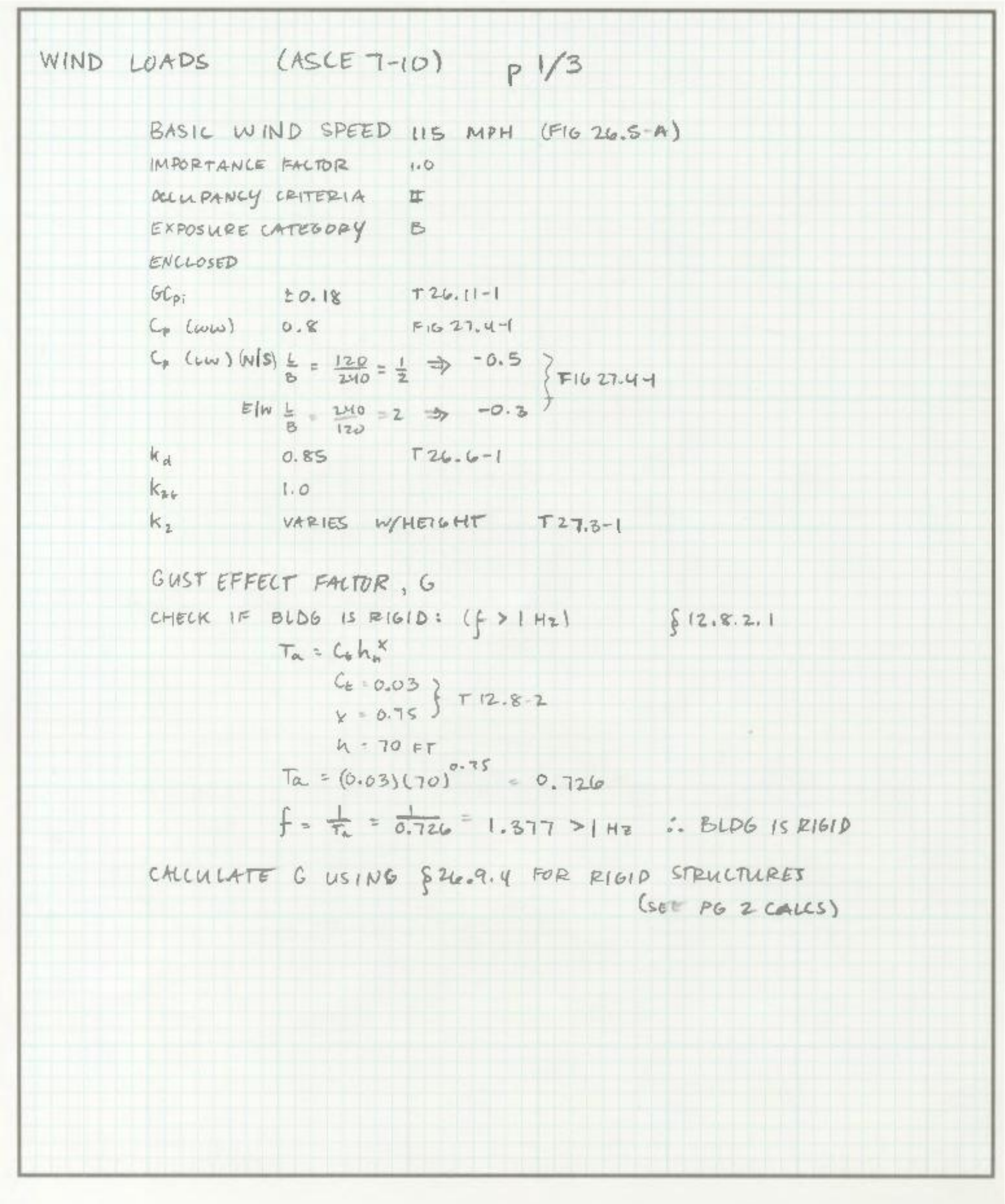
appendix B: wind calculations

wind pressures [N|S direction]

level	q_h [psf]	z	k_z	q_z [psf]	windward [psf]	leeward [psf]	trib area [sf]	force [k]	story shear [k]	overturning moment [ft-k]
1	25.61	0	0.57	16.40	15.18	-14.93	3360	101	663	0
2	25.61	14	0.57	16.40	15.18	-14.93	3360	101	562	1417
3	25.61	28	0.684	19.68	17.30	-14.93	3360	108	461	3032
4	25.61	42	0.77	22.16	18.89	-14.93	3360	114	352	4773
5	25.61	56	0.834	24.00	20.08	-14.93	3360	118	239	6588
roof	25.61	70	0.89	25.61	21.12	-14.93	3360	121	121	8479
									base shear [k]:	**663**
									total overturning moment [ft-k]:	**24288**

wind pressures [E|W direction]

level	q_h [psf]	z	k_z	q_z [psf]	windward [psf]	leeward [psf]	trib area [sf]	force [k]	story shear [k]	overturning moment [ft-k]
1	25.61	0	0.57	16.40	15.58	-11.03	1680	45	363	0
2	25.61	14	0.57	16.40	15.58	-11.03	1680	45	319	626
3	25.61	28	0.684	19.68	17.77	-11.03	1680	48	274	1355
4	25.61	42	0.77	22.16	19.43	-11.03	1680	51	225	2149
5	25.61	56	0.834	24.00	20.66	-11.03	1680	53	174	2982
roof	25.61	70	0.89	25.61	21.74	-11.03	1680	55	121	3854
									base shear [k]:	**363**
									total overturning moment [ft-k]:	**10966**



WIND LOADS (ASCE 7-10) p 1/3

BASIC WIND SPEED 115 MPH (FIG 26.5-A)

IMPORTANCE FACTOR 1.0

OCCUPANCY CRITERIA II

EXPOSURE CATEGORY B

ENCLOSED

GC_{pi} ± 0.18 T 26.11-1

C_p (WW) 0.8 FIG 27.4-1

C_p (LW) (N/S) $\frac{L}{B} = \frac{120}{240} = \frac{1}{2} \Rightarrow -0.5$

E/W $\frac{L}{B} = \frac{240}{120} = 2 \Rightarrow -0.3$

} FIG 27.4-1

k_d 0.85 T 26.6-1

k_{zt} 1.0

k_z VARIES W/HEIGHT T 27.3-1

GUST EFFECT FACTOR, G

CHECK IF BLDG IS RIGID: ($f > 1$ Hz) § 12.8.2.1

$$T_a = C_t h_n^x$$

$C_t = 0.03$

$x = 0.75$

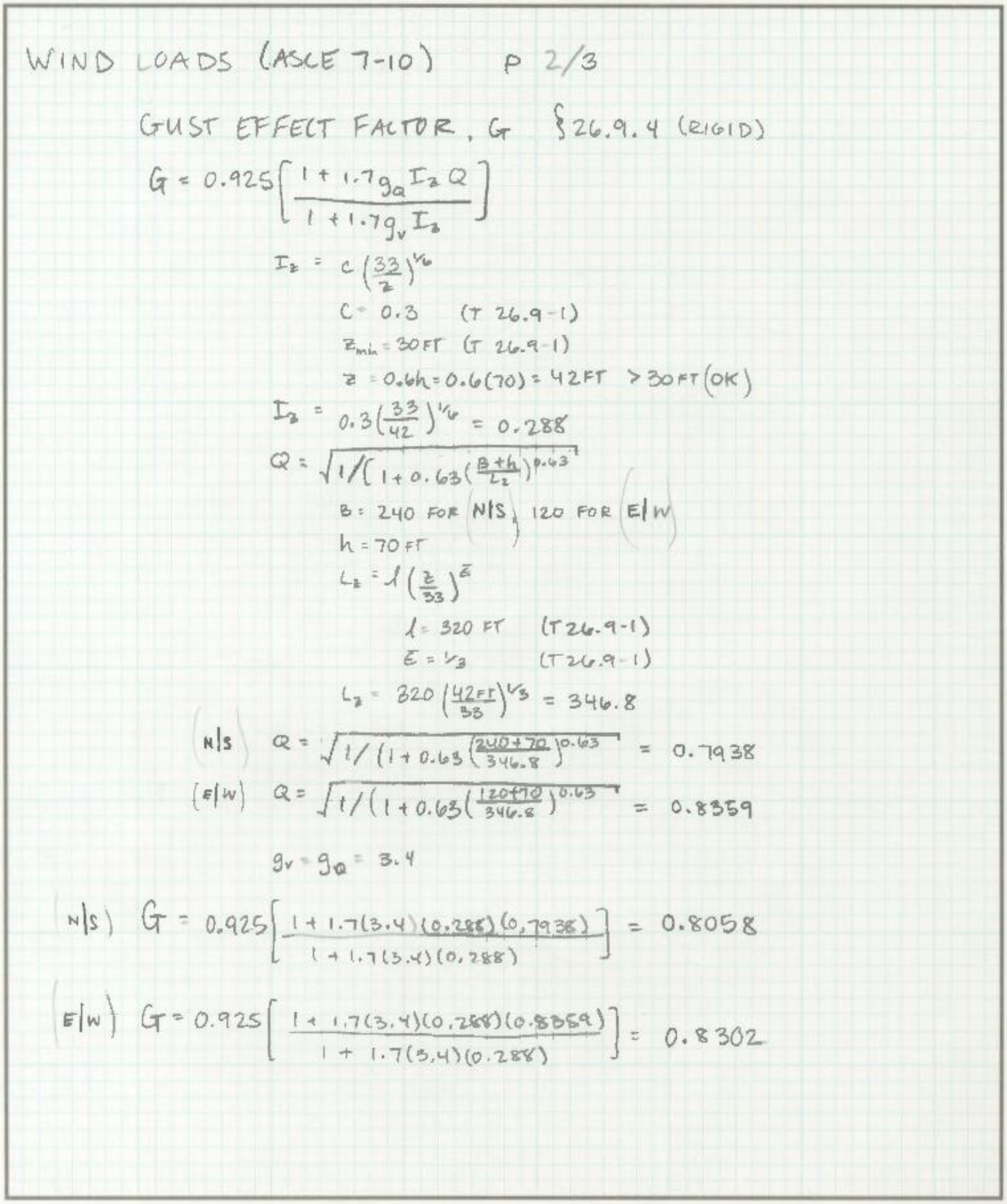
} T 12.8-2

$h = 70$ FT

$$T_a = (0.03)(70)^{0.75} = 0.726$$

$$f = \frac{1}{T_a} = \frac{1}{0.726} = 1.377 > 1 \text{ Hz}$$ ∴ BLDG IS RIGID

CALCULATE G USING § 26.9.4 FOR RIGID STRUCTURES (SEE PG 2 CALCS)



WIND LOADS (ASCE 7-10) P 2/3

GUST EFFECT FACTOR, G §26.9.4 (RIGID)

$$G = 0.925\left[\frac{1+1.7g_Q I_z Q}{1+1.7g_v I_z}\right]$$

$$I_z = c\left(\frac{33}{z}\right)^{1/6}$$

$c = 0.3$ (T 26.9-1)

$z_{min} = 30\text{FT}$ (T 26.9-1)

$z = 0.6h = 0.6(70) = 42\text{FT} > 30\text{FT}$ (OK)

$$I_z = 0.3\left(\frac{33}{42}\right)^{1/6} = 0.288$$

$$Q = \sqrt{1/\left(1+0.63\left(\frac{B+h}{L_z}\right)^{0.63}\right.}$$

$B = 240$ FOR (N/S), 120 FOR (E/W)

$h = 70$ FT

$$L_z = \ell\left(\frac{z}{33}\right)^{\bar{\epsilon}}$$

$\ell = 320$ FT (T 26.9-1)

$\bar{\epsilon} = 1/3$ (T 26.9-1)

$$L_z = 320\left(\frac{42\text{FT}}{33}\right)^{1/3} = 346.8$$

(N/S) $Q = \sqrt{1/\left(1+0.63\left(\frac{240+70}{346.8}\right)^{0.63}\right.} = 0.7938$

(E/W) $Q = \sqrt{1/\left(1+0.63\left(\frac{120+70}{346.8}\right)^{0.63}\right.} = 0.8359$

$g_v = g_Q = 3.4$

(N/S) $G = 0.925\left[\frac{1+1.7(3.4)(0.288)(0.7938)}{1+1.7(3.4)(0.288)}\right] = 0.8058$

(E/W) $G = 0.925\left[\frac{1+1.7(3.4)(0.288)(0.8359)}{1+1.7(3.4)(0.288)}\right] = 0.8302$

WIND LOADS (ASCE 7-10) P 3/3

$$q_h = 0.00256 K_z K_{zt} K_d V^2 I$$
$$= 0.00256(0.89)(1.0)(0.85)(115)^2(1.0)$$
$$= 25.61 \text{ PSF}$$

$$p = q\,GC_p - q_i(GC_{pi})$$

$$P_{WW} = q_z GC_p - q_i(GC_{pi}) = q_z(\overset{(N|S)}{0.8058})(0.8) - q_i(\pm 0.18)$$

$$P_{LW} = q_h GC_p - q_i(GC_{pi}) = 25.61(\overset{(E|W)}{0.8359})(\overset{(E|W)}{-0.3}) - q_i(\pm 0.18)$$

* ALL PRESSURES CALCULATED IN EXCEL SPREADSHEET

appendix C: seismic calculations

SEISMIC LOAD (ASCE 7-10) 1/2

BLDG OCCUPANCY CATEGORY	II
IMPORTANCE FACTOR	1.0
SITE CLASS	C
S_s	0.108 g
S_1	0.053 g
S_{MS}	0.129 g
S_{M1}	0.090 g
S_{DS}	0.086 g
S_{D1}	0.060 g

geohazards.usgs.gov/designmaps/us

$T = C_t h_n^x = 0.726\,s$ (SEE WIND CALCS, p.1)

CHECK SPECTRAL RESPONSE ACCELERATION PARAMETERS

$S_{MS} = F_a S_s$ EQN 11.4-1

$F_a = 1.2$ T 11.4-1

$S_s = 0.108\,g < 0.25$

$= 1.2(0.108) = 0.1296 \sim 0.129$ OK

$S_{M1} = F_v S_1$ EQN 11.4-2

$F_v = 1.7$ T11.4-2

$S_1 = 0.053\,g$

$= (1.7)(0.053) = 0.0901 \sim 0.090$ OK

$S_{DS} = 2/3\, S_{MS} = 0.0864$ OK EQN 11.4-3

$S_{D1} = 2/3\, S_{M1} = 0.06007$ OK EQN 11.4-4

WILL USE USGS VALUES

$T_L = 12\,s$ FIG 22-12

$T_0 = 0.2 \dfrac{S_{D1}}{S_{DS}} = 0.1395$

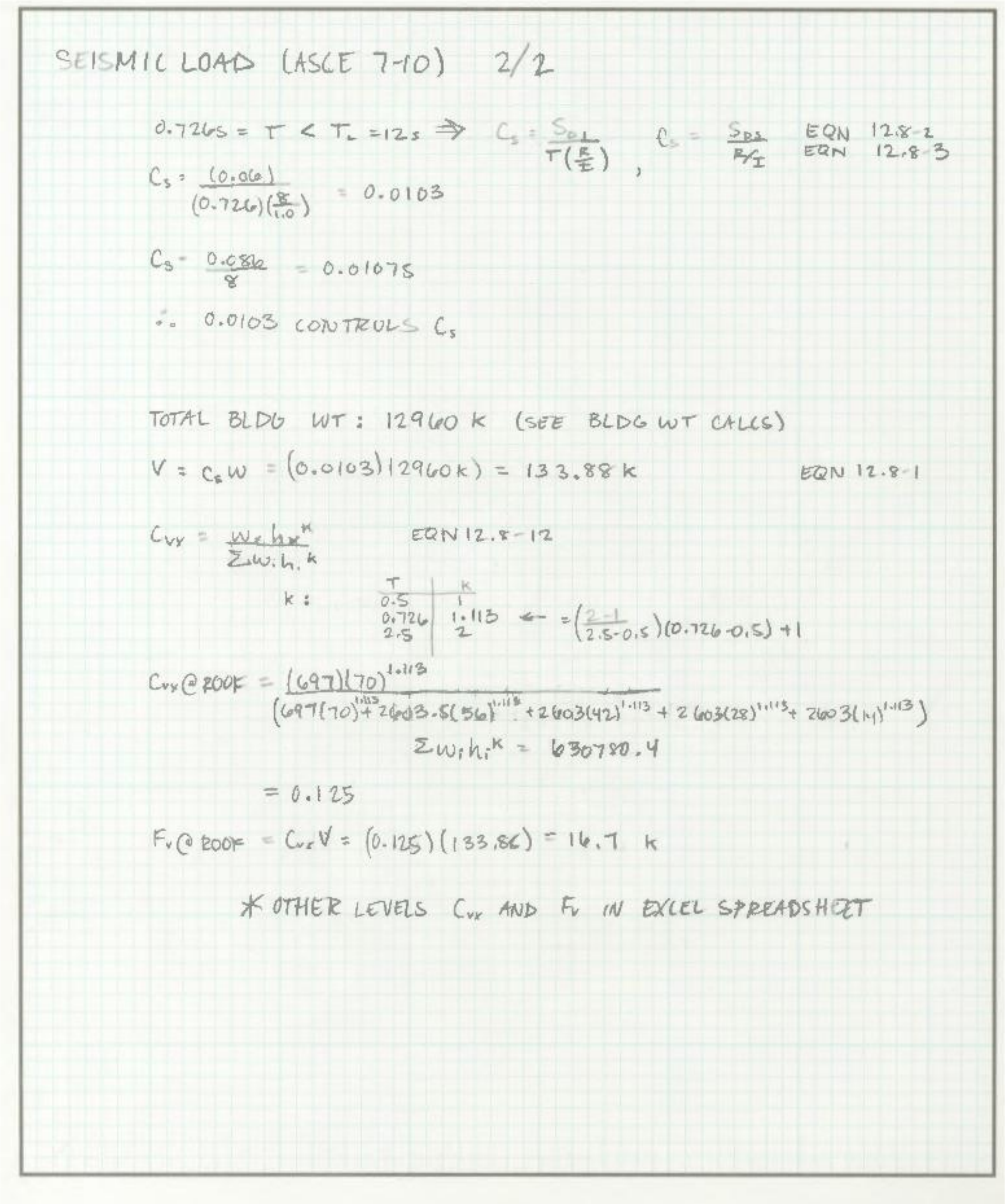
$T_s = \dfrac{S_{D1}}{S_{DS}} = 0.698$

$\rho = 1.0$

$\Omega = 2$ T12.2-1

$C_d = 4$ T12.2-1

$R = 8$ T12.2-1



SEISMIC LOAD (ASCE 7-10) 2/2

$0.726s = T < T_L = 12s \Rightarrow C_s = \frac{S_{D1}}{T(\frac{R}{I})}$, $C_s = \frac{S_{DS}}{R/I}$ EQN 12.8-2 EQN 12.8-3

$C_s = \frac{(0.06)}{(0.726)(\frac{8}{1.0})} = 0.0103$

$C_s = \frac{0.086}{8} = 0.01075$

$\therefore$ 0.0103 CONTROLS C_s

TOTAL BLDG WT : 12960 k (SEE BLDG WT CALCS)

$V = C_s W = (0.0103)(12960k) = 133.88\,k$ EQN 12.8-1

$C_{vx} = \frac{w_x h_x^k}{\Sigma w_i h_i^k}$ EQN 12.8-12

k :

T	K
0.5	1
0.726	1.113
2.5	2

$\leftarrow = \left(\frac{2-1}{2.5-0.5}\right)(0.726-0.5)+1$

$$C_{vx}@\text{ROOF} = \frac{(697)(70)^{1.113}}{(697(70)^{1.113} + 2603.5(56)^{1.113} + 2603(42)^{1.113} + 2603(28)^{1.113} + 2603(14)^{1.113})}$$

$\Sigma w_i h_i^k = 630780.4$

$= 0.125$

$F_v @\text{ROOF} = C_{vx} V = (0.125)(133.86) = 16.7\ k$

* OTHER LEVELS C_{vx} AND F_v IN EXCEL SPREADSHEET

FLOOR WEIGHTS (ASD) 1/2

TYP FLOOR SELF WT:

CONC ON DECK —— [57 PSF (VULCRAFT, P 52)

STEEL BEAMS —— [5.4 PLF

$30'/4 = 7.5'$

$20'/3 = 6.67$ ← CONTROLS SPACING TO STAY CONSERVATIVE

W16×36 @ 6.67'

$\Rightarrow \frac{36\ PLF}{6.67'} = 5.4\ PLF$

STEEL GIRDERS —— [2.27 PSF

30' SPACES

W24×68

$\Rightarrow \frac{68\ PLF}{30'} = 2.27\ PSF$

EXT WALL —— [1209.6 k (TOTAL FOR ENTIRE BLDG)

ASSUME ~40% EXT

$(120)(70)(2) + (240)(70)(2) = 50400$ SF SURFACE AREA

$50400SF(0.4) \times 60\ PSF = 1209.6\ K/_{5\ FLOORS} = 241.9k$ PER FLOOR

STEEL COLUMNS —— [2.4 PSF

ASSUME W12×79 AS TYP MIDDLE SIZE

~62 COL/FLOOR

14' HEIGHT

$79 \times 14 \times 62 = \frac{68572}{120 \times 240}$ # PER FLOOR $= 2.4\ PSF$

▶ TOTAL SELF WT PER TYP FLOOR:

$57 + 5.4 + 2.27 + 2.4 = 67$ PSF SELF WT

FLOOR WTS 2/2

- ROOF

20 PSF ROOFING × 240×120 = 576 k

1/2 HEIGHT EXT WALL = 241.9/2 = 120.96 K

696.96 K

- FLOORS 2-5

$(67 \text{ PSF} + 15 \overset{\text{mech+misc}}{\text{PSF}})(120)(240) + \overset{\text{EXT WALL}}{241.9} = 2603.5 \text{ K}$

- FLOOR 1

SOG 4" NWC

$150 \text{ PCF} \times \frac{4''}{12} = 50 \text{ PSF}$

$(50 \text{ PSF} + \underset{\text{misc}}{10} \text{ PSF})(240)(120) = 1728 \text{ K} + \frac{241.9}{2} = 1849 \text{ k}$

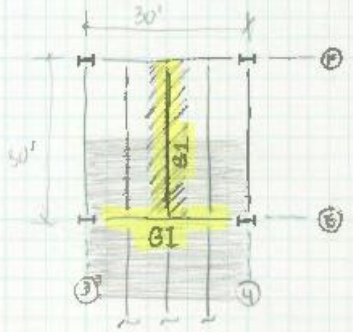
TOTAL BLDG WT:

ROOF + 1st + (2 to 5)

697 + 1849 + (4)(2603.5) = 12960 K

appendix D: system 1

GRAVITY SPOT CHECKS 1/5



#STUDS

B1 : W16×36 [18]

G1 : W24×68 [26]

- TYP LOADING:

SLAB	57PSF
SDL	15 PSF
SELF WT	5 PSF
LL	80 PSF

- ASD LOAD COMBO § 2.4

D

$D + L$

$D + (L_R \text{ OR } S \text{ OR } R)$

$D + 0.75L + 0.75(L_R \text{ OR } S \text{ OR } R)$

SINCE NOT ON ROOF, S AND L_R NOT APPLICABLE. D + L CONTROLS

LATERAL ANALYSIS NOT INCLUDED

$D + (0.6W \text{ OR } 0.7E)$

$D + 0.75L + 0.75(0.6W) + 0.75(L_R \text{ OR } S \text{ OR } R)$

$D + 0.75L + 0.75(0.7E) + 0.75S$

$0.6D + 0.6W$

$0.6D + 0.7E$

GRAVITY SPOT CHECKS 2/5

- BEAM B1

LL REDUCTION (ASCE 7-10, CH 4)

$A_T = (30/4)(30) = 225$ SF

$K_{LL} = 2$ T4-2, INT BEAM

$LL = 80\left[0.25 + \frac{15}{\sqrt{(7.5)(2)}}\right] = 77$ PSF

$W = D + L = (57 + 15 + 5) + (77) = 154$ PSF

154 PSF × 7.5' = 1155 PLF

= 1.155 KLF

$M = \frac{wl^2}{8} = \frac{(1.155)(30)^2}{8} = 129.94$ K·FT

(COMPOSITE BEAM)

$b_{eff} = \min \left| \begin{array}{l} \text{span}/8 \\ 1/2\ d \text{ to adj BEAM} \end{array} \right. + \min \left| \begin{array}{l} \text{span}/8 \\ 1/2\ d \text{ to adj BM} \end{array} \right.$

$= \min \left| \begin{array}{l} 30'/8 = 3.75 \\ 1/2(7.5) = 3.75 \end{array} \right. + 3.75$

$= 7.5' = 90"$

ASSUME $a = 1.0$, $Y_2 = 6.5 - \frac{1.0}{2} = 6"$

$Q_n: \min \left| \begin{array}{ll} 0.5 A_{sc} \sqrt{f'_c E_c} & = 26.1 \text{ K} \\ R_g R_p A_{sc} F_u & = 17.2 \text{ K} \end{array} \right.$ (ONE STUD)

$A_{sc} = 3/4\ \phi = \pi(\frac{3}{8})^2 = 0.4418$

$F_u = 65$ ksi

$R_p = 0.6$

$R_g = 1$ FOR 1 STUD

$f'_c = 4000$ PSI

$E_c = 145^{1.5}\sqrt{4} = 3.492$ ksi

CHECK W16×36 [18] M = 238

$\Sigma Q_n = 133$

133/17.2 = 7.7 ≈ 8 ⇒ 16 STUDS

GRAVITY SPOT CHECKS 3/5

- BEAM B1 (CONT)

CHECK $a = \frac{\Sigma Q_n}{0.85 f'_c b_{eff}} = \frac{133}{0.85(4)(90'')} = 0.435 < 1.0$ GOOD

- check LL DEFL

$I_{LB} = 862 \text{ in}^4$

$w_{LL} = 77 \text{ PSF } (7.5') = 577.5 \text{ PLF}$

$y_2 = 6''$

$\Sigma Q_n = 133 \text{ k}$

$$\Delta_{LL} = \frac{5(0.5775)(30)^4(12^3)}{384(29000)(862)} = 0.421''$$

$$\Delta_{LL\,max} = \frac{L}{360} = \frac{30'}{360} = 1'' > 0.421'' \text{ GOOD}$$

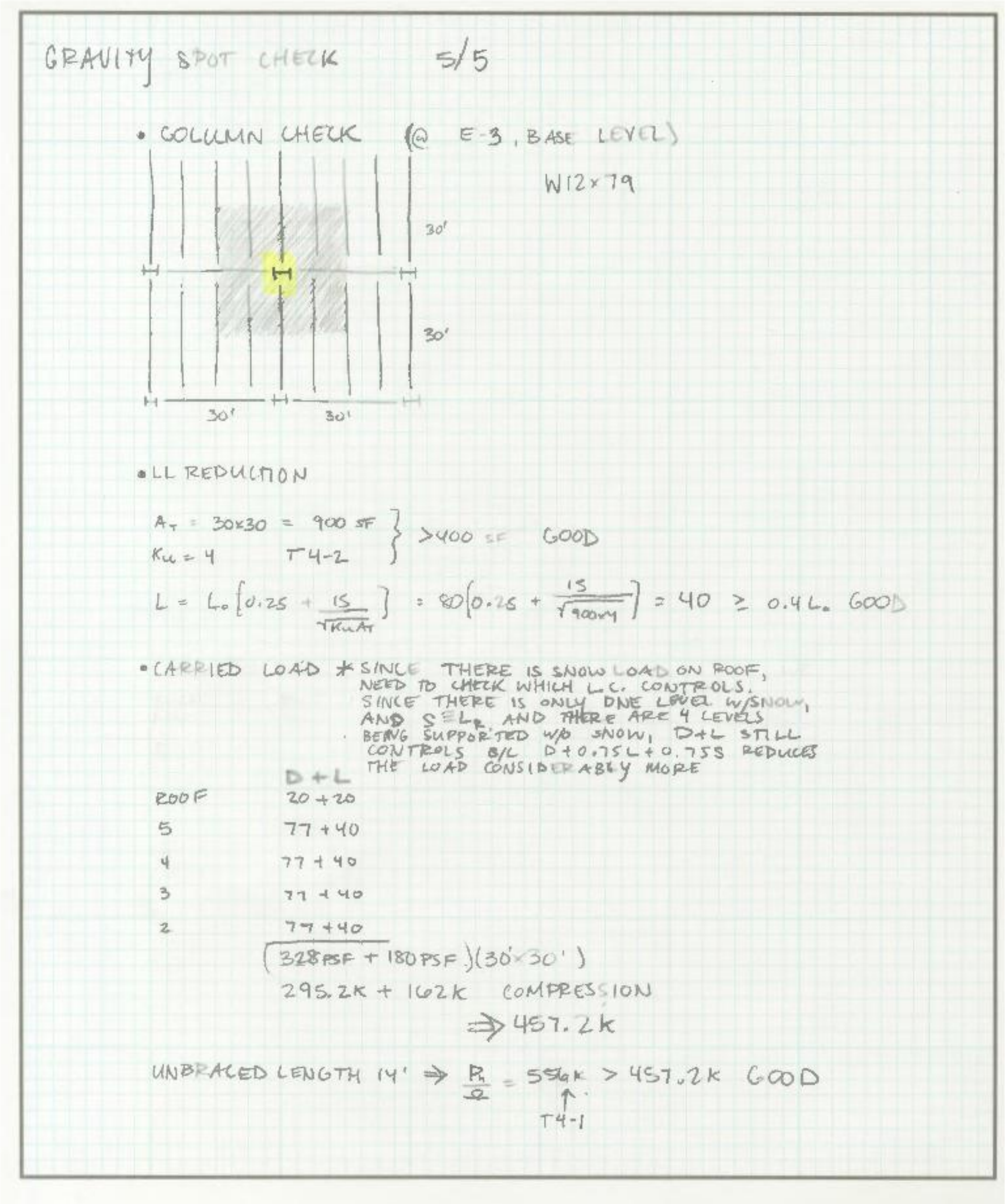
- CHECK TOTAL LOAD DEFLECTION

$w_{TL} = 1.155 \text{ KLF (P.2)}$

$$\Delta_{TL} = \frac{5(1.155)(30)^4 \times 12^3}{384(29000)(862)} = 0.842''$$

$$\Delta_{TL\,MAX} = \frac{L}{240} = \frac{30'}{240} = 1.5'' > 0.842'' \text{ GOOD}$$

$\therefore$ W16×36 w/16 STUDS OK ⇒ W16×36 w/18 STUDS OK



GRAVITY SPOT CHECK 5/5

- COLUMN CHECK (@ E-3, BASE LEVEL)

W12×79

- LL REDUCTION

$A_T = 30 \times 30 = 900$ SF
$K_{LL} = 4$ T4-2
} >400 SF GOOD

$L = L_o \left[0.25 + \frac{15}{\sqrt{K_{LL} A_T}}\right] = 80\left[0.25 + \frac{15}{\sqrt{900 \times 4}}\right] = 40 \geq 0.4 L_o$ GOOD

- CARRIED LOAD * SINCE THERE IS SNOW LOAD ON ROOF, NEED TO CHECK WHICH L.C. CONTROLS. SINCE THERE IS ONLY ONE LEVEL W/SNOW, AND $S \leq L_R$ AND THERE ARE 4 LEVELS BEING SUPPORTED W/O SNOW, D+L STILL CONTROLS B/C D+0.75L+0.75S REDUCES THE LOAD CONSIDERABLY MORE

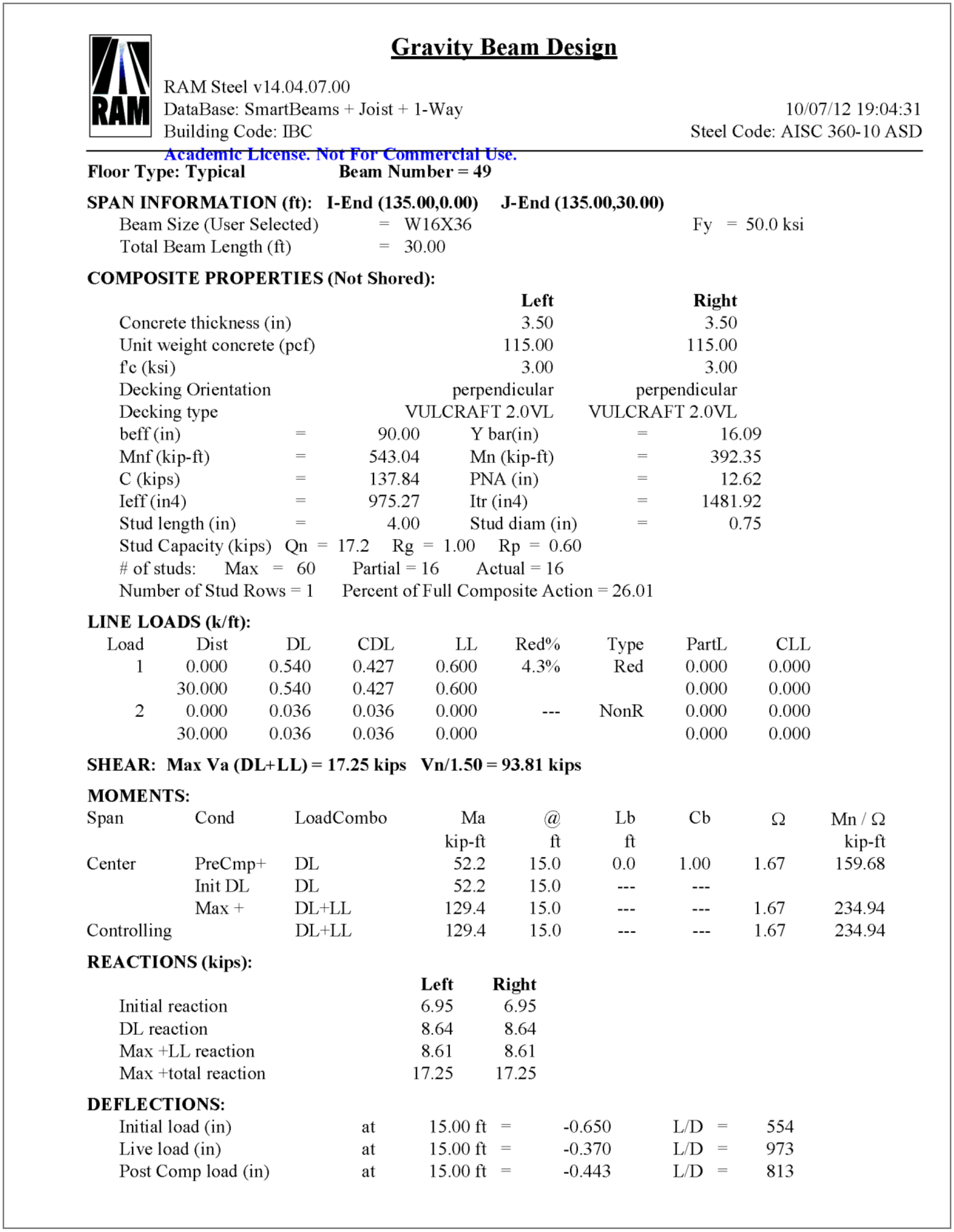
	D + L
ROOF	20 + 20
5	77 + 40
4	77 + 40
3	77 + 40
2	77 + 40

(328 PSF + 180 PSF)(30'×30')
295.2K + 162K COMPRESSION
⇒ 457.2K

UNBRACED LENGTH 14' ⇒ $\frac{P_n}{\Omega} = 556$K > 457.2K GOOD
↑
T4-1

appendices

system 1: RAM beam analysis



Gravity Beam Design

RAM Steel v14.04.07.00
DataBase: SmartBeams + Joist + 1-Way
Building Code: IBC

10/07/12 19:04:31
Steel Code: AISC 360-10 ASD

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Floor Type: Typical **Beam Number = 49**

SPAN INFORMATION (ft): I-End (135.00,0.00) J-End (135.00,30.00)

Beam Size (User Selected) = W16X36 Fy = 50.0 ksi
Total Beam Length (ft) = 30.00

COMPOSITE PROPERTIES (Not Shored):

	Left	Right
Concrete thickness (in)	3.50	3.50
Unit weight concrete (pcf)	115.00	115.00
f'c (ksi)	3.00	3.00
Decking Orientation	perpendicular	perpendicular
Decking type	VULCRAFT 2.0VL	VULCRAFT 2.0VL

beff (in) = 90.00 Y bar(in) = 16.09
Mnf (kip-ft) = 543.04 Mn (kip-ft) = 392.35
C (kips) = 137.84 PNA (in) = 12.62
Ieff (in4) = 975.27 Itr (in4) = 1481.92
Stud length (in) = 4.00 Stud diam (in) = 0.75
Stud Capacity (kips) Qn = 17.2 Rg = 1.00 Rp = 0.60
# of studs: Max = 60 Partial = 16 Actual = 16
Number of Stud Rows = 1 Percent of Full Composite Action = 26.01

LINE LOADS (k/ft):

Load	Dist	DL	CDL	LL	Red%	Type	PartL	CLL
1	0.000	0.540	0.427	0.600	4.3%	Red	0.000	0.000
	30.000	0.540	0.427	0.600			0.000	0.000
2	0.000	0.036	0.036	0.000	---	NonR	0.000	0.000
	30.000	0.036	0.036	0.000			0.000	0.000

SHEAR: Max Va (DL+LL) = 17.25 kips Vn/1.50 = 93.81 kips

MOMENTS:

Span	Cond	LoadCombo	Ma kip-ft	@ ft	Lb ft	Cb	Ω	Mn / Ω kip-ft
Center	PreCmp+	DL	52.2	15.0	0.0	1.00	1.67	159.68
	Init DL	DL	52.2	15.0	---	---		
	Max +	DL+LL	129.4	15.0	---	---	1.67	234.94
Controlling		DL+LL	129.4	15.0	---	---	1.67	234.94

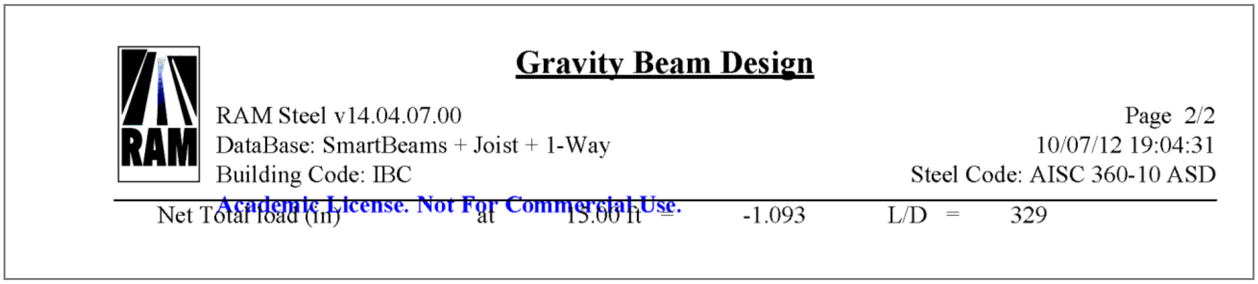
REACTIONS (kips):

	Left	Right
Initial reaction	6.95	6.95
DL reaction	8.64	8.64
Max +LL reaction	8.61	8.61
Max +total reaction	17.25	17.25

DEFLECTIONS:

Initial load (in) at 15.00 ft = -0.650 L/D = 554
Live load (in) at 15.00 ft = -0.370 L/D = 973
Post Comp load (in) at 15.00 ft = -0.443 L/D = 813

system 1: RAM beam analysis



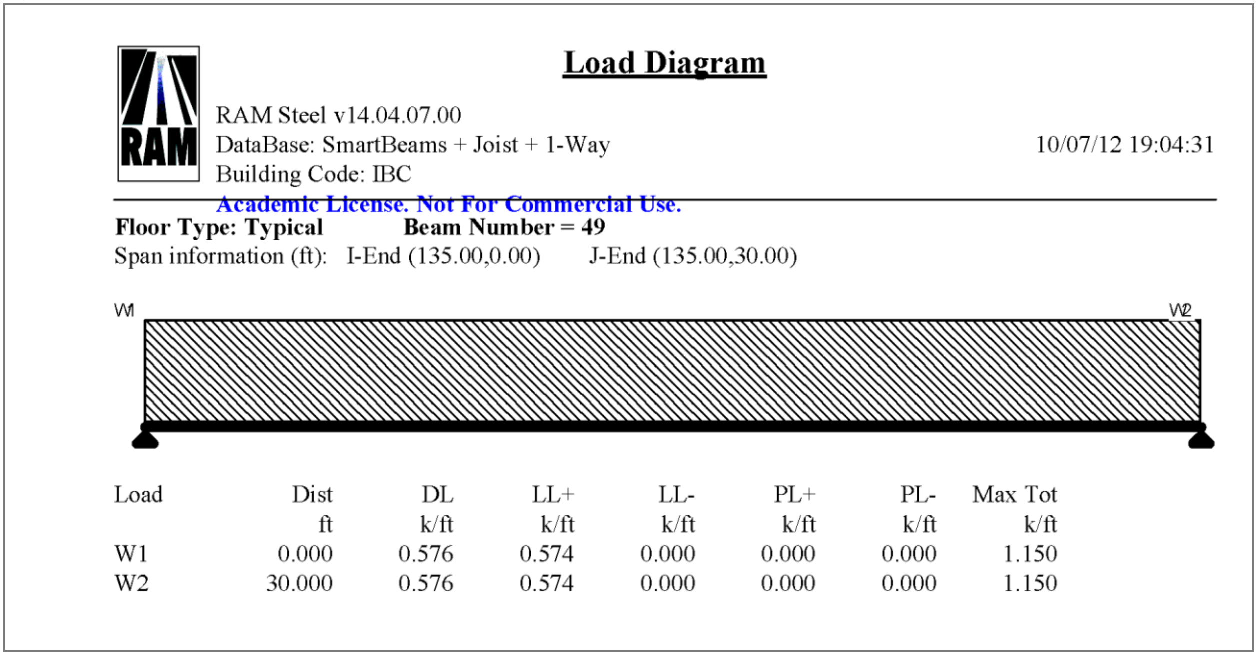
Gravity Beam Design

RAM Steel v14.04.07.00
DataBase: SmartBeams + Joist + 1-Way
Building Code: IBC

Page 2/2
10/07/12 19:04:31
Steel Code: AISC 360-10 ASD

Net Total load (in) at 15.00 ft = -1.093 L/D = 329

system 1: RAM beam loads



Load Diagram

RAM Steel v14.04.07.00
DataBase: SmartBeams + Joist + 1-Way
Building Code: IBC

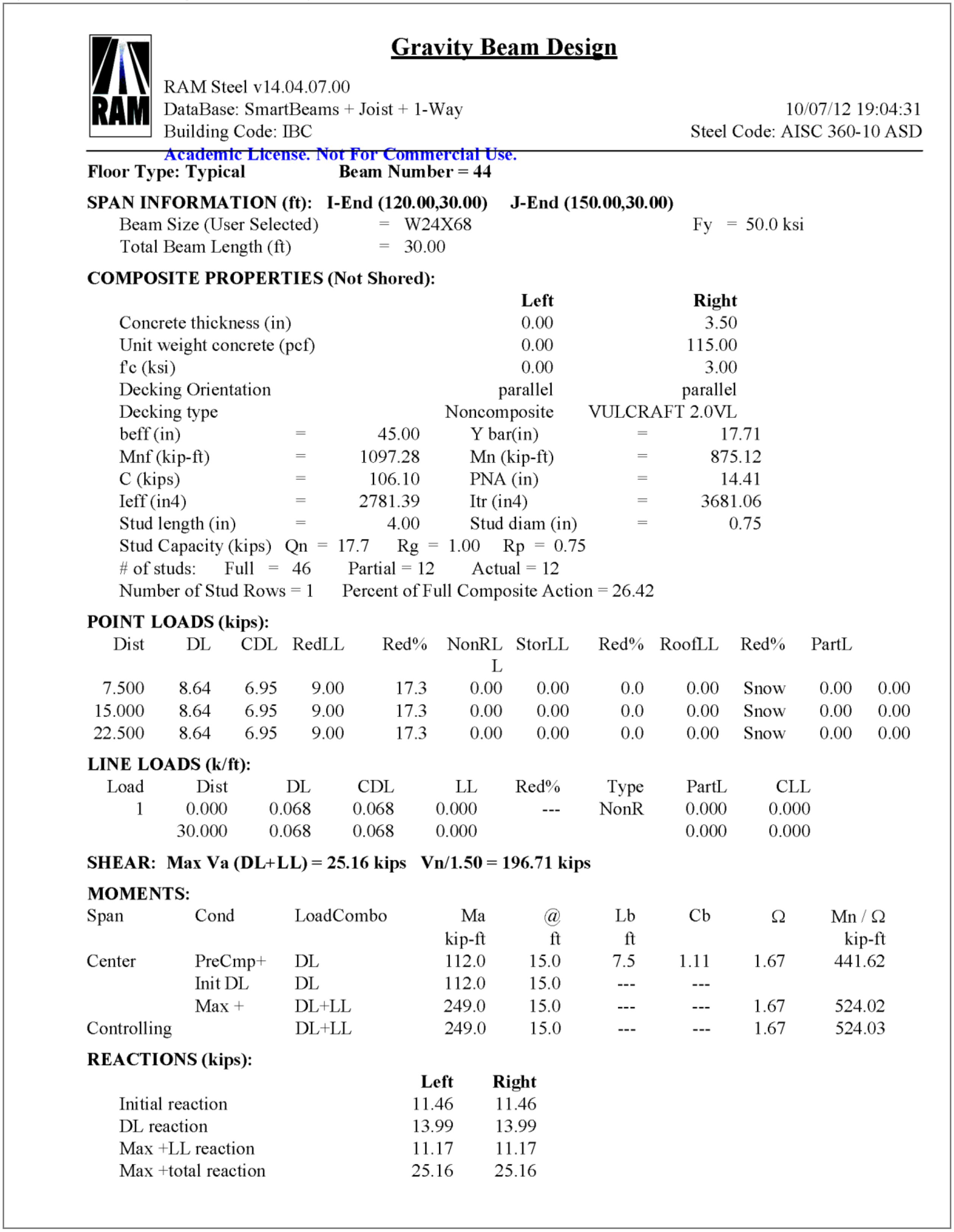
10/07/12 19:04:31

Floor Type: Typical **Beam Number = 49**

Span information (ft): I-End (135.00,0.00) J-End (135.00,30.00)

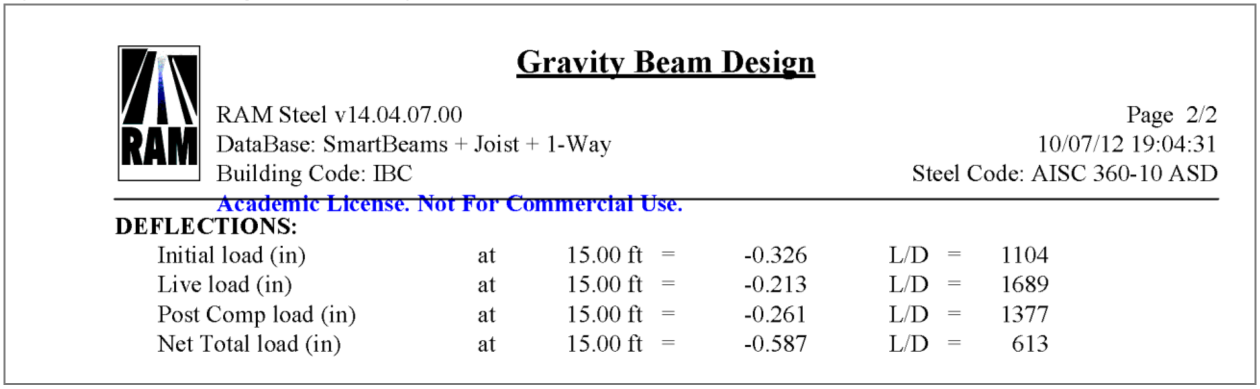
Load	Dist ft	DL k/ft	LL+ k/ft	LL- k/ft	PL+ k/ft	PL- k/ft	Max Tot k/ft
W1	0.000	0.576	0.574	0.000	0.000	0.000	1.150
W2	30.000	0.576	0.574	0.000	0.000	0.000	1.150

system 1: RAM girder analysis



```
                                Gravity Beam Design
RAM   RAM Steel v14.04.07.00
      DataBase: SmartBeams + Joist + 1-Way                             10/07/12 19:04:31
      Building Code: IBC                                       Steel Code: AISC 360-10 ASD
      Academic License. Not For Commercial Use.
Floor Type: Typical                Beam Number = 44

SPAN INFORMATION (ft):  I-End (120.00,30.00)   J-End (150.00,30.00)
   Beam Size (User Selected)      =  W24X68                        Fy  = 50.0 ksi
   Total Beam Length (ft)         =  30.00

COMPOSITE PROPERTIES (Not Shored):
                                                  Left              Right
   Concrete thickness (in)                        0.00               3.50
   Unit weight concrete (pcf)                     0.00             115.00
   f'c (ksi)                                      0.00               3.00
   Decking Orientation                        parallel           parallel
   Decking type                            Noncomposite    VULCRAFT 2.0VL
   beff (in)              =       45.00    Y bar(in)        =        17.71
   Mnf (kip-ft)           =     1097.28    Mn (kip-ft)      =       875.12
   C (kips)               =      106.10    PNA (in)         =        14.41
   Ieff (in4)             =     2781.39    Itr (in4)        =      3681.06
   Stud length (in)       =        4.00    Stud diam (in)   =         0.75
   Stud Capacity (kips)  Qn  = 17.7    Rg  = 1.00    Rp  = 0.75
   # of studs:     Full   =  46      Partial = 12      Actual = 12
   Number of Stud Rows = 1     Percent of Full Composite Action = 26.42

POINT LOADS (kips):
   Dist      DL     CDL   RedLL     Red%   NonRL  StorLL    Red%  RoofLL    Red%     PartL
                                              L
  7.500    8.64    6.95    9.00     17.3    0.00    0.00     0.0    0.00    Snow     0.00    0.00
 15.000    8.64    6.95    9.00     17.3    0.00    0.00     0.0    0.00    Snow     0.00    0.00
 22.500    8.64    6.95    9.00     17.3    0.00    0.00     0.0    0.00    Snow     0.00    0.00

LINE LOADS (k/ft):
  Load       Dist        DL       CDL        LL      Red%      Type     PartL       CLL
     1      0.000     0.068     0.068     0.000       ---      NonR     0.000     0.000
           30.000     0.068     0.068     0.000                         0.000     0.000

SHEAR:  Max Va (DL+LL) = 25.16 kips   Vn/1.50 = 196.71 kips

MOMENTS:
Span         Cond        LoadCombo          Ma       @       Lb       Cb        Ω     Mn / Ω
                                         kip-ft     ft       ft                       kip-ft
Center       PreCmp+     DL               112.0   15.0      7.5     1.11      1.67    441.62
             Init DL     DL               112.0   15.0      ---      ---
             Max +       DL+LL            249.0   15.0      ---      ---      1.67    524.02
Controlling              DL+LL            249.0   15.0      ---      ---      1.67    524.03

REACTIONS (kips):
                                        Left      Right
   Initial reaction                    11.46      11.46
   DL reaction                         13.99      13.99
   Max +LL reaction                    11.17      11.17
   Max +total reaction                 25.16      25.16
```

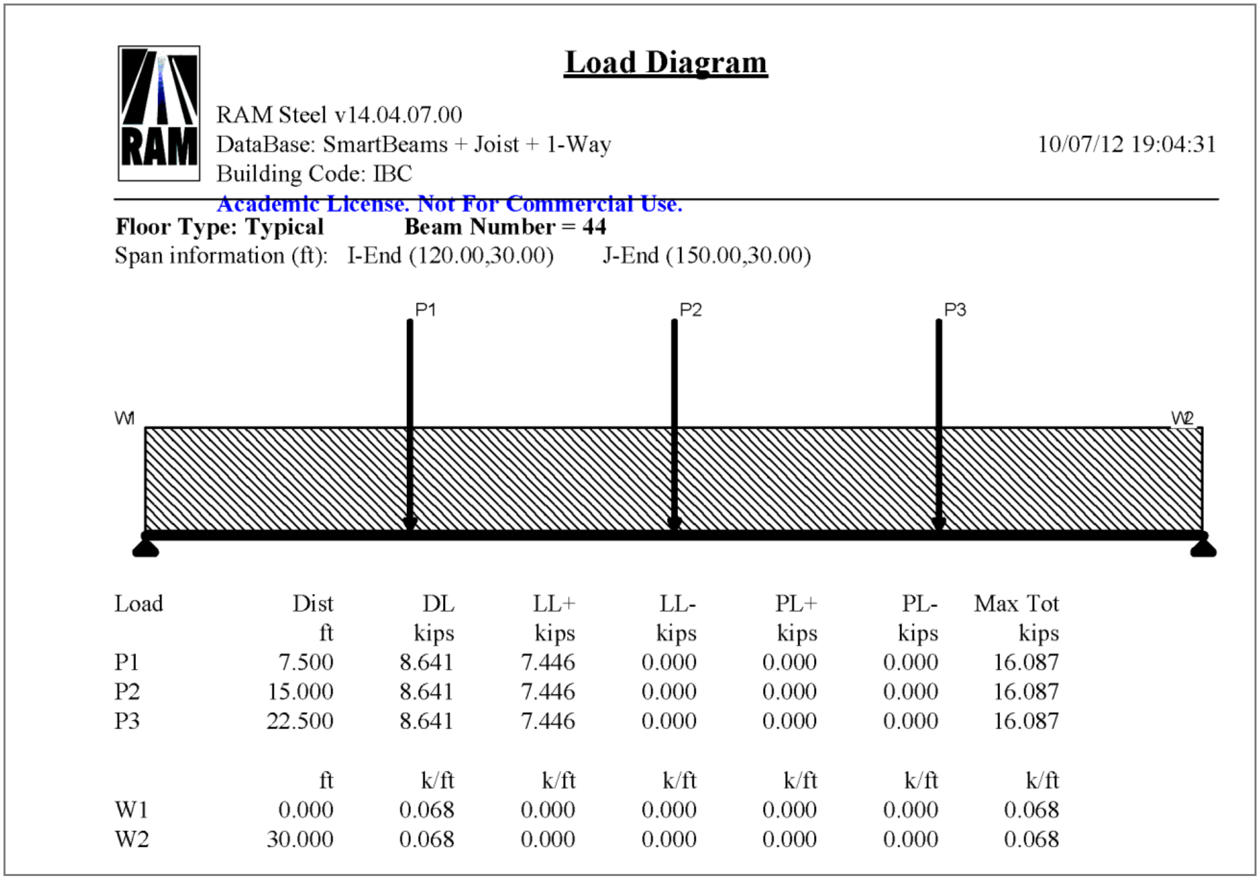
system 1: RAM girder analysis



Gravity Beam Design

```
RAM Steel v14.04.07.00                                    Page  2/2
DataBase: SmartBeams + Joist + 1-Way               10/07/12 19:04:31
Building Code: IBC                              Steel Code: AISC 360-10 ASD
Academic License. Not For Commercial Use.
DEFLECTIONS:
   Initial load (in)      at    15.00 ft  =   -0.326    L/D  =   1104
   Live load (in)         at    15.00 ft  =   -0.213    L/D  =   1689
   Post Comp load (in)    at    15.00 ft  =   -0.261    L/D  =   1377
   Net Total load (in)    at    15.00 ft  =   -0.587    L/D  =    613
```

system 1: RAM girder loads

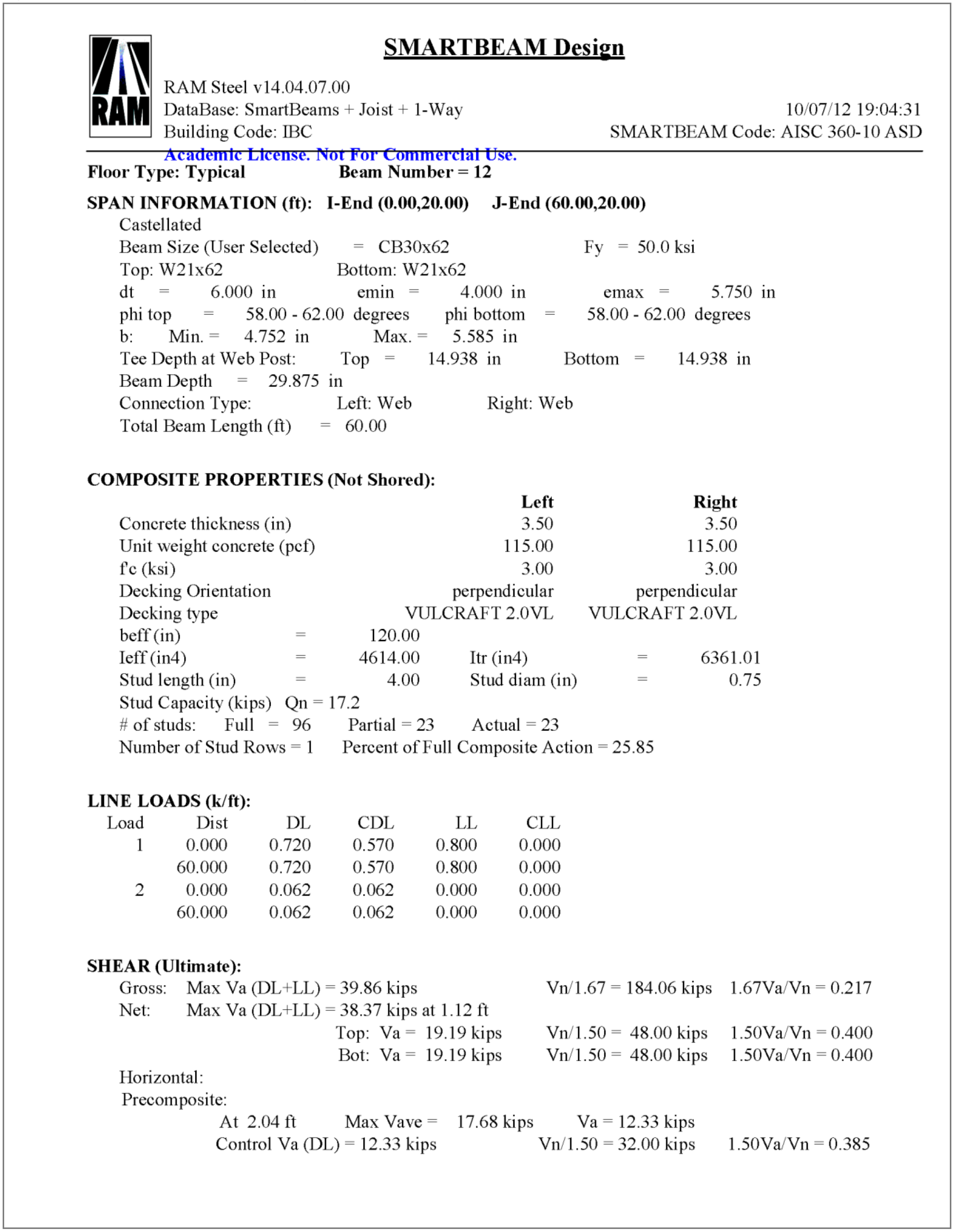


Load Diagram

```
RAM Steel v14.04.07.00
DataBase: SmartBeams + Joist + 1-Way               10/07/12 19:04:31
Building Code: IBC
Academic License. Not For Commercial Use.
Floor Type: Typical          Beam Number = 44
Span information (ft):   I-End (120.00,30.00)     J-End (150.00,30.00)

Load        Dist      DL      LL+      LL-      PL+      PL-    Max Tot
              ft    kips     kips     kips     kips     kips       kips
P1         7.500   8.641    7.446    0.000    0.000    0.000     16.087
P2        15.000   8.641    7.446    0.000    0.000    0.000     16.087
P3        22.500   8.641    7.446    0.000    0.000    0.000     16.087

              ft     k/ft     k/ft     k/ft     k/ft     k/ft      k/ft
W1         0.000   0.068    0.000    0.000    0.000    0.000      0.068
W2        30.000   0.068    0.000    0.000    0.000    0.000      0.068
```

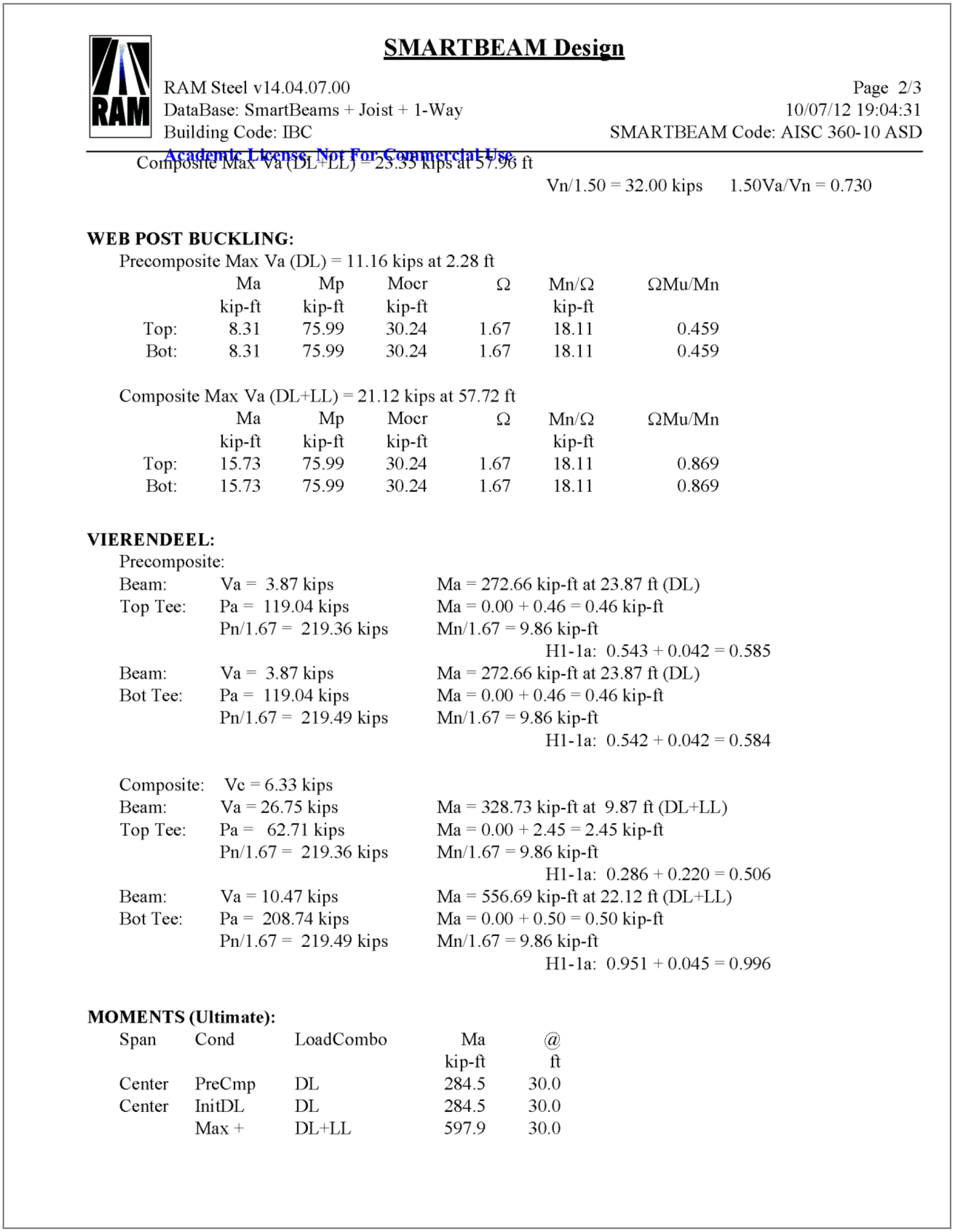
appendix E: system 2

system 2: RAM beam analysis



```
                         SMARTBEAM Design
RAM Steel v14.04.07.00
DataBase: SmartBeams + Joist + 1-Way                          10/07/12 19:04:31
Building Code: IBC                              SMARTBEAM Code: AISC 360-10 ASD
Academic License. Not For Commercial Use.
Floor Type: Typical          Beam Number = 12

SPAN INFORMATION (ft):   I-End (0.00,20.00)    J-End (60.00,20.00)
   Castellated
   Beam Size (User Selected)    =  CB30x62                  Fy   =  50.0 ksi
   Top: W21x62                  Bottom: W21x62
   dt    =      6.000  in          emin   =     4.000  in          emax   =     5.750  in
   phi top     =     58.00 - 62.00  degrees     phi bottom    =   58.00 - 62.00  degrees
   b:     Min. =    4.752  in          Max. =    5.585  in
   Tee Depth at Web Post:        Top   =     14.938  in          Bottom   =     14.938  in
   Beam Depth     =    29.875  in
   Connection Type:             Left: Web             Right: Web
   Total Beam Length (ft)      =    60.00

COMPOSITE PROPERTIES (Not Shored):
                                                    Left                  Right
   Concrete thickness (in)                          3.50                   3.50
   Unit weight concrete (pcf)                     115.00                 115.00
   f'c (ksi)                                        3.00                   3.00
   Decking Orientation                     perpendicular          perpendicular
   Decking type                          VULCRAFT 2.0VL         VULCRAFT 2.0VL
   beff (in)              =          120.00
   Ieff (in4)             =         4614.00       Itr (in4)              =          6361.01
   Stud length (in)       =            4.00       Stud diam (in)         =             0.75
   Stud Capacity (kips)   Qn = 17.2
   # of studs:      Full   =   96      Partial = 23       Actual = 23
   Number of Stud Rows = 1     Percent of Full Composite Action = 25.85

LINE LOADS (k/ft):
  Load       Dist        DL       CDL        LL        CLL
     1      0.000     0.720     0.570     0.800     0.000
           60.000     0.720     0.570     0.800     0.000
     2      0.000     0.062     0.062     0.000     0.000
           60.000     0.062     0.062     0.000     0.000

SHEAR (Ultimate):
   Gross:    Max Va (DL+LL) = 39.86 kips                   Vn/1.67 = 184.06 kips    1.67Va/Vn = 0.217
   Net:      Max Va (DL+LL) = 38.37 kips at 1.12 ft
                                  Top:  Va =  19.19 kips    Vn/1.50 =  48.00 kips    1.50Va/Vn = 0.400
                                  Bot:  Va =  19.19 kips    Vn/1.50 =  48.00 kips    1.50Va/Vn = 0.400
   Horizontal:
    Precomposite:
                   At  2.04 ft        Max Vave =    17.68 kips        Va = 12.33 kips
                  Control  Va (DL) = 12.33 kips             Vn/1.50 = 32.00 kips     1.50Va/Vn = 0.385
```

system 2: RAM beam analysis

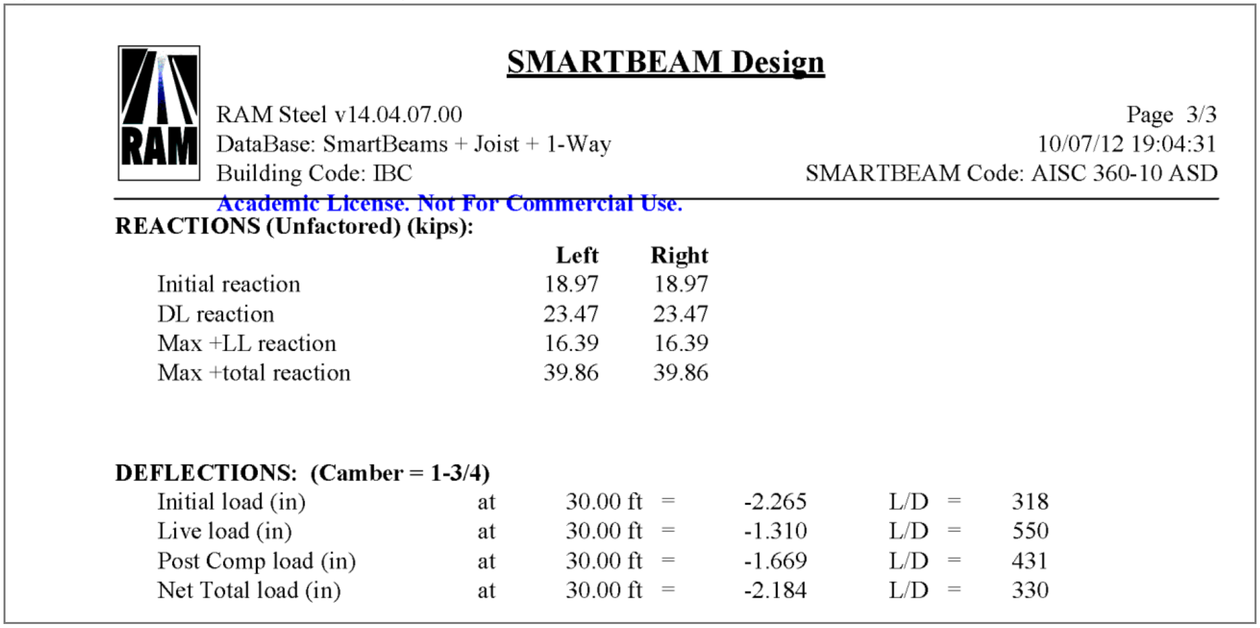


SMARTBEAM Design

```
RAM Steel v14.04.07.00                                          Page  2/3
DataBase: SmartBeams + Joist + 1-Way                   10/07/12 19:04:31
Building Code: IBC                        SMARTBEAM Code: AISC 360-10 ASD
```

```
    Composite Max Va (DL+LL) = 23.35 kips at 57.96 ft
                                      Vn/1.50 = 32.00 kips    1.50Va/Vn = 0.730

WEB POST BUCKLING:
    Precomposite Max Va (DL) = 11.16 kips at 2.28 ft
                 Ma        Mp       Mocr        Ω      Mn/Ω      ΩMu/Mn
             kip-ft    kip-ft     kip-ft             kip-ft
      Top:     8.31     75.99      30.24     1.67     18.11       0.459
      Bot:     8.31     75.99      30.24     1.67     18.11       0.459

    Composite Max Va (DL+LL) = 21.12 kips at 57.72 ft
                 Ma        Mp       Mocr        Ω      Mn/Ω      ΩMu/Mn
             kip-ft    kip-ft     kip-ft             kip-ft
      Top:    15.73     75.99      30.24     1.67     18.11       0.869
      Bot:    15.73     75.99      30.24     1.67     18.11       0.869

VIERENDEEL:
    Precomposite:
    Beam:       Va =  3.87 kips          Ma = 272.66 kip-ft at 23.87 ft (DL)
    Top Tee:    Pa =  119.04 kips        Ma = 0.00 + 0.46 = 0.46 kip-ft
                Pn/1.67 =  219.36 kips   Mn/1.67 = 9.86 kip-ft
                                                    H1-1a:  0.543 + 0.042 = 0.585
    Beam:       Va =  3.87 kips          Ma = 272.66 kip-ft at 23.87 ft (DL)
    Bot Tee:    Pa =  119.04 kips        Ma = 0.00 + 0.46 = 0.46 kip-ft
                Pn/1.67 =  219.49 kips   Mn/1.67 = 9.86 kip-ft
                                                    H1-1a:  0.542 + 0.042 = 0.584

    Composite:   Vc = 6.33 kips
    Beam:       Va = 26.75 kips          Ma = 328.73 kip-ft at  9.87 ft (DL+LL)
    Top Tee:    Pa =   62.71 kips        Ma = 0.00 + 2.45 = 2.45 kip-ft
                Pn/1.67 =  219.36 kips   Mn/1.67 = 9.86 kip-ft
                                                    H1-1a:  0.286 + 0.220 = 0.506
    Beam:       Va = 10.47 kips          Ma = 556.69 kip-ft at 22.12 ft (DL+LL)
    Bot Tee:    Pa =  208.74 kips        Ma = 0.00 + 0.50 = 0.50 kip-ft
                Pn/1.67 =  219.49 kips   Mn/1.67 = 9.86 kip-ft
                                                    H1-1a:  0.951 + 0.045 = 0.996

MOMENTS (Ultimate):
    Span      Cond         LoadCombo          Ma        @
                                          kip-ft       ft
    Center    PreCmp       DL              284.5     30.0
    Center    InitDL       DL              284.5     30.0
              Max +        DL+LL           597.9     30.0
```

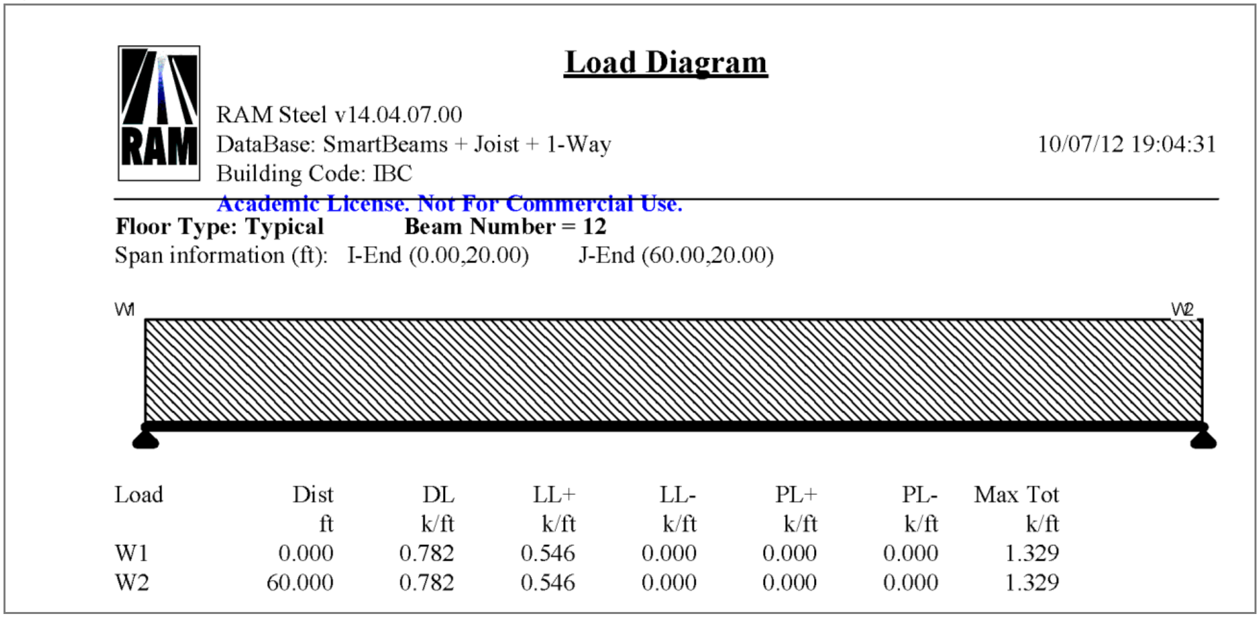
system 2: RAM beam analysis



SMARTBEAM Design

```
RAM Steel v14.04.07.00                                              Page  3/3
DataBase: SmartBeams + Joist + 1-Way                       10/07/12 19:04:31
Building Code: IBC                          SMARTBEAM Code: AISC 360-10 ASD
Academic License. Not For Commercial Use.
REACTIONS (Unfactored) (kips):
                                      Left      Right
   Initial reaction                   18.97     18.97
   DL reaction                        23.47     23.47
   Max +LL reaction                   16.39     16.39
   Max +total reaction                39.86     39.86


DEFLECTIONS:  (Camber = 1-3/4)
   Initial load (in)        at     30.00 ft  =    -2.265     L/D  =   318
   Live load (in)           at     30.00 ft  =    -1.310     L/D  =   550
   Post Comp load (in)      at     30.00 ft  =    -1.669     L/D  =   431
   Net Total load (in)      at     30.00 ft  =    -2.184     L/D  =   330
```

system 2: RAM beam loads

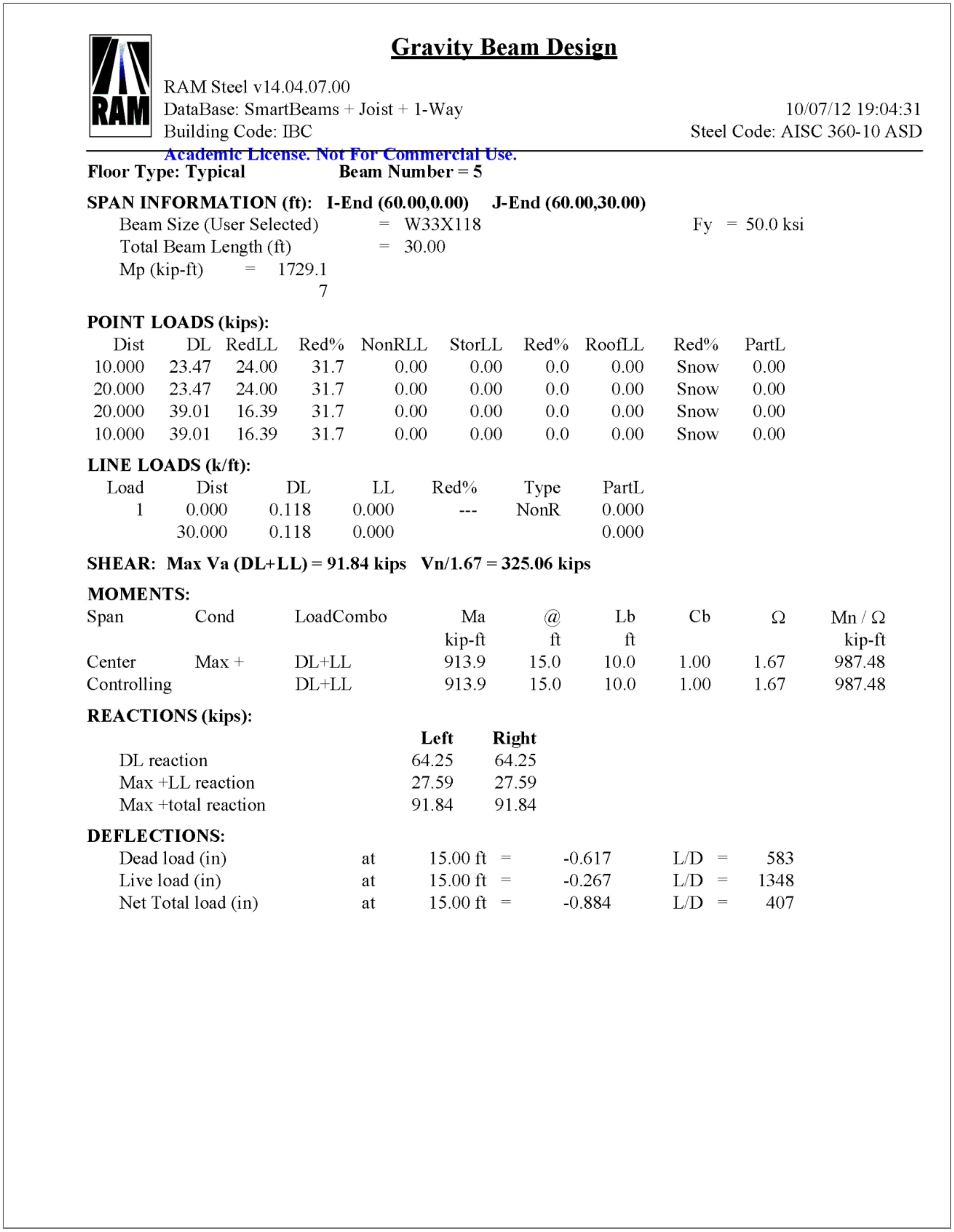


Load Diagram

```
RAM Steel v14.04.07.00
DataBase: SmartBeams + Joist + 1-Way                       10/07/12 19:04:31
Building Code: IBC
Academic License. Not For Commercial Use.
Floor Type: Typical          Beam Number = 12
Span information (ft):  I-End (0.00,20.00)     J-End (60.00,20.00)
```

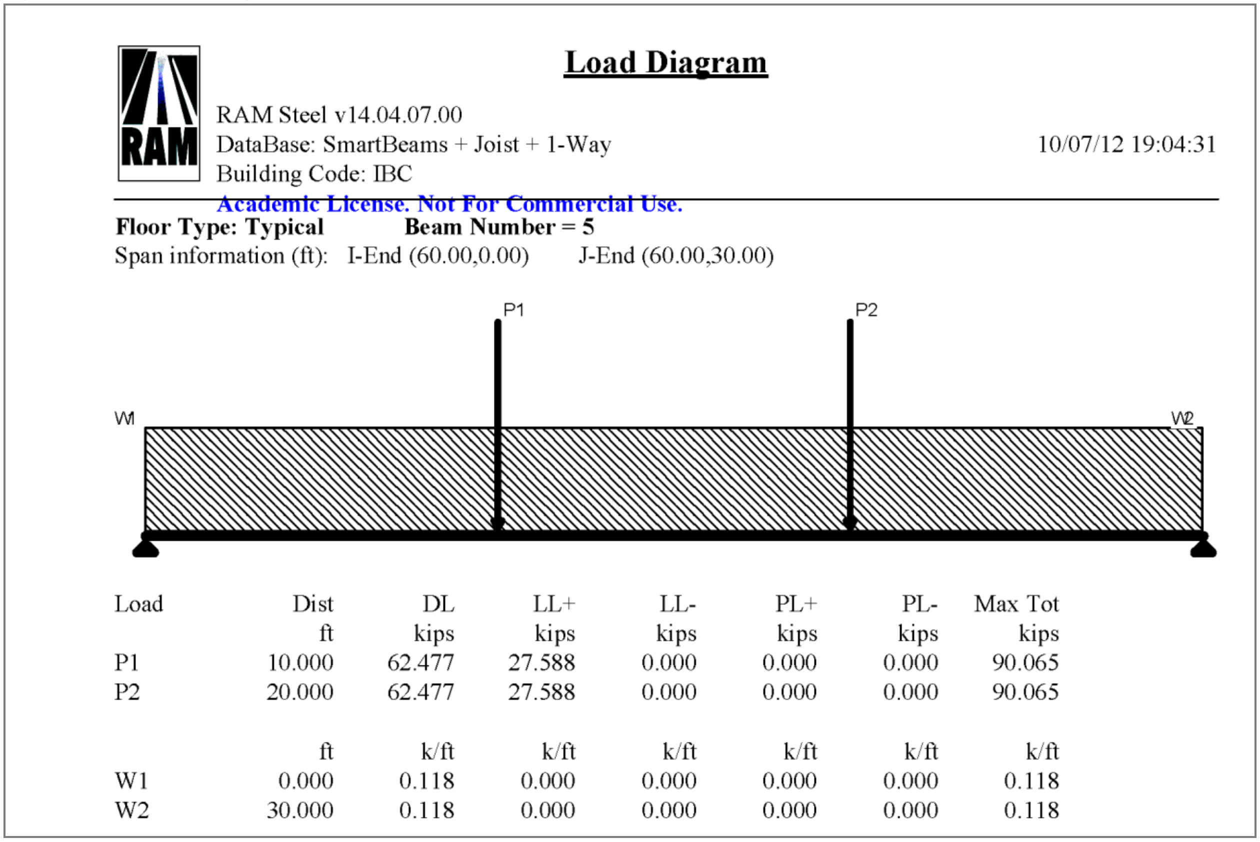
```
Load        Dist      DL      LL+      LL-      PL+      PL-   Max Tot
              ft    k/ft     k/ft     k/ft     k/ft     k/ft      k/ft
W1         0.000   0.782    0.546    0.000    0.000    0.000     1.329
W2        60.000   0.782    0.546    0.000    0.000    0.000     1.329
```

system 2: RAM girder analysis



```
                              Gravity Beam Design

RAM Steel v14.04.07.00
DataBase: SmartBeams + Joist + 1-Way                          10/07/12 19:04:31
Building Code: IBC                                     Steel Code: AISC 360-10 ASD
Academic License. Not For Commercial Use.
Floor Type: Typical               Beam Number = 5

SPAN INFORMATION (ft):  I-End (60.00,0.00)    J-End (60.00,30.00)
   Beam Size (User Selected)        =  W33X118                    Fy  = 50.0 ksi
   Total Beam Length (ft)           =  30.00
   Mp (kip-ft)         =     1729.1
                                   7

POINT LOADS (kips):
   Dist      DL   RedLL    Red%   NonRLL    StorLL   Red%   RoofLL    Red%    PartL
 10.000   23.47   24.00    31.7     0.00      0.00    0.0     0.00    Snow     0.00
 20.000   23.47   24.00    31.7     0.00      0.00    0.0     0.00    Snow     0.00
 20.000   39.01   16.39    31.7     0.00      0.00    0.0     0.00    Snow     0.00
 10.000   39.01   16.39    31.7     0.00      0.00    0.0     0.00    Snow     0.00

LINE LOADS (k/ft):
  Load       Dist       DL        LL      Red%     Type     PartL
     1      0.000    0.118     0.000     ---      NonR     0.000
           30.000    0.118     0.000                       0.000

SHEAR:  Max Va (DL+LL) = 91.84 kips   Vn/1.67 = 325.06 kips

MOMENTS:
Span          Cond        LoadCombo         Ma        @       Lb       Cb       Ω      Mn / Ω
                                          kip-ft      ft       ft                        kip-ft
Center        Max +       DL+LL            913.9     15.0     10.0     1.00     1.67    987.48
Controlling               DL+LL            913.9     15.0     10.0     1.00     1.67    987.48

REACTIONS (kips):
                                          Left     Right
   DL reaction                           64.25     64.25
   Max +LL reaction                      27.59     27.59
   Max +total reaction                   91.84     91.84

DEFLECTIONS:
   Dead load (in)                at     15.00 ft  =      -0.617      L/D  =    583
   Live load (in)                at     15.00 ft  =      -0.267      L/D  =   1348
   Net Total load (in)           at     15.00 ft  =      -0.884      L/D  =    407
```

system 2: RAM girder loads



Load Diagram

RAM Steel v14.04.07.00
DataBase: SmartBeams + Joist + 1-Way
Building Code: IBC

10/07/12 19:04:31

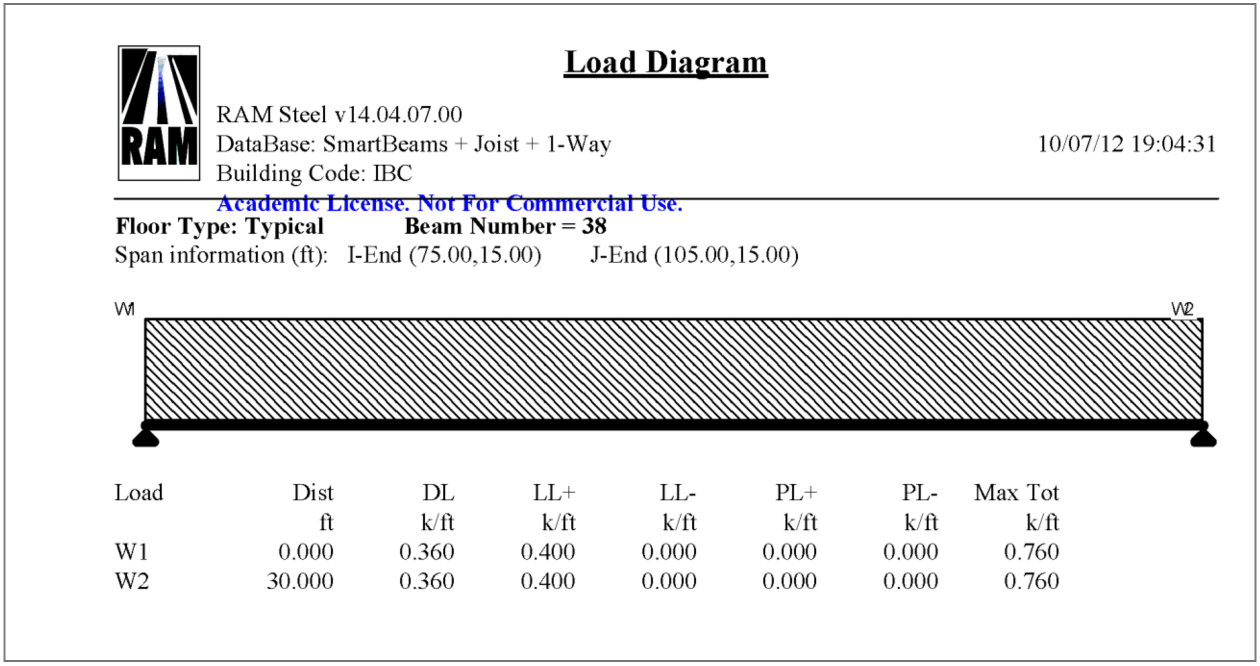
Academic License. Not For Commercial Use.

Floor Type: Typical **Beam Number = 5**
Span information (ft): I-End (60.00,0.00) J-End (60.00,30.00)

Load	Dist	DL	LL+	LL-	PL+	PL-	Max Tot
	ft	kips	kips	kips	kips	kips	kips
P1	10.000	62.477	27.588	0.000	0.000	0.000	90.065
P2	20.000	62.477	27.588	0.000	0.000	0.000	90.065
	ft	k/ft	k/ft	k/ft	k/ft	k/ft	k/ft
W1	0.000	0.118	0.000	0.000	0.000	0.000	0.118
W2	30.000	0.118	0.000	0.000	0.000	0.000	0.118

appendix F: system 3

system 3: RAM joist loads



Load Diagram

RAM Steel v14.04.07.00
DataBase: SmartBeams + Joist + 1-Way
Building Code: IBC

10/07/12 19:04:31

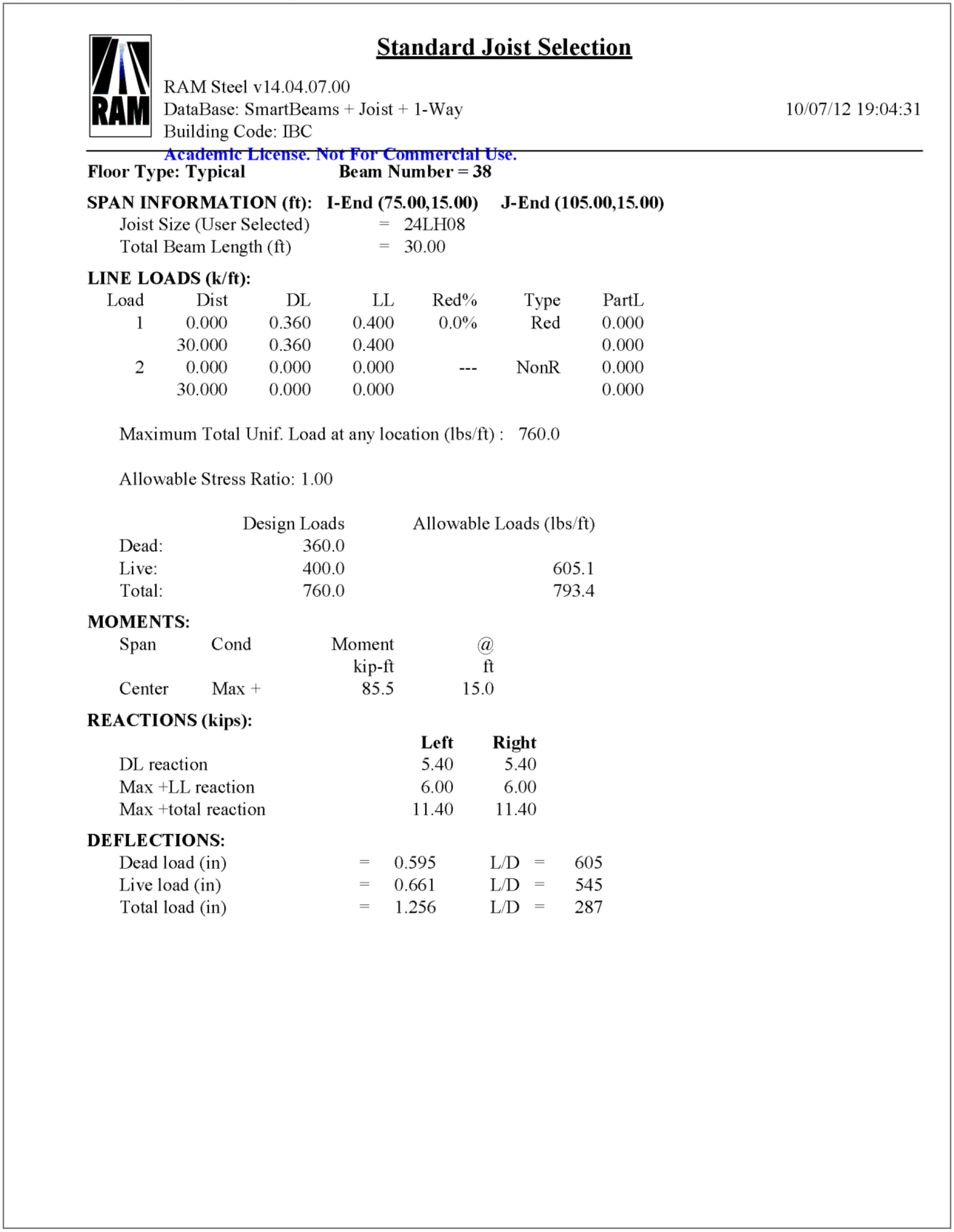
Academic License. Not For Commercial Use.

Floor Type: Typical **Beam Number = 38**

Span information (ft): I-End (75.00,15.00) J-End (105.00,15.00)

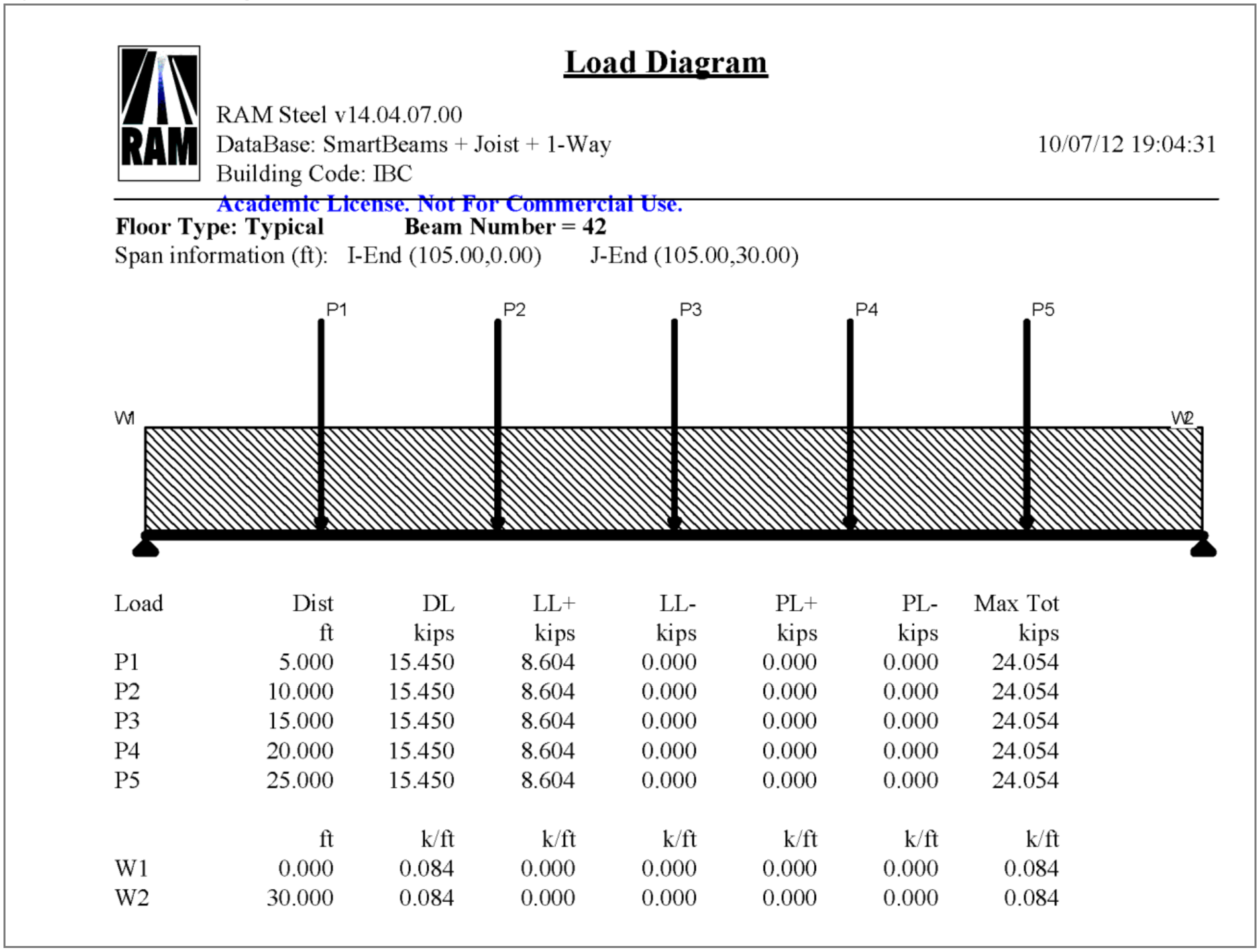
Load	Dist ft	DL k/ft	LL+ k/ft	LL- k/ft	PL+ k/ft	PL- k/ft	Max Tot k/ft
W1	0.000	0.360	0.400	0.000	0.000	0.000	0.760
W2	30.000	0.360	0.400	0.000	0.000	0.000	0.760

system 3: RAM joist analysis



```
                              Standard Joist Selection

RAM Steel v14.04.07.00
DataBase: SmartBeams + Joist + 1-Way                                  10/07/12 19:04:31
Building Code: IBC
Academic License. Not For Commercial Use.
Floor Type: Typical                 Beam Number = 38

SPAN INFORMATION (ft):  I-End (75.00,15.00)   J-End (105.00,15.00)
   Joist Size (User Selected)         =   24LH08
   Total Beam Length (ft)             =   30.00

LINE LOADS (k/ft):
  Load      Dist       DL        LL      Red%       Type      PartL
    1       0.000     0.360     0.400    0.0%       Red       0.000
           30.000     0.360     0.400                         0.000
    2       0.000     0.000     0.000     ---       NonR      0.000
           30.000     0.000     0.000                         0.000

   Maximum Total Unif. Load at any location (lbs/ft) :   760.0

   Allowable Stress Ratio: 1.00

                  Design Loads        Allowable Loads (lbs/ft)
   Dead:                360.0
   Live:                400.0                        605.1
   Total:               760.0                        793.4

MOMENTS:
   Span       Cond            Moment          @
                              kip-ft          ft
   Center     Max +            85.5         15.0

REACTIONS (kips):
                                        Left      Right
   DL reaction                          5.40       5.40
   Max +LL reaction                     6.00       6.00
   Max +total reaction                 11.40      11.40

DEFLECTIONS:
   Dead load (in)              =    0.595      L/D   =    605
   Live load (in)              =    0.661      L/D   =    545
   Total load (in)             =    1.256      L/D   =    287
```

system 3: RAM girder loads



Load Diagram

RAM Steel v14.04.07.00
DataBase: SmartBeams + Joist + 1-Way 10/07/12 19:04:31
Building Code: IBC

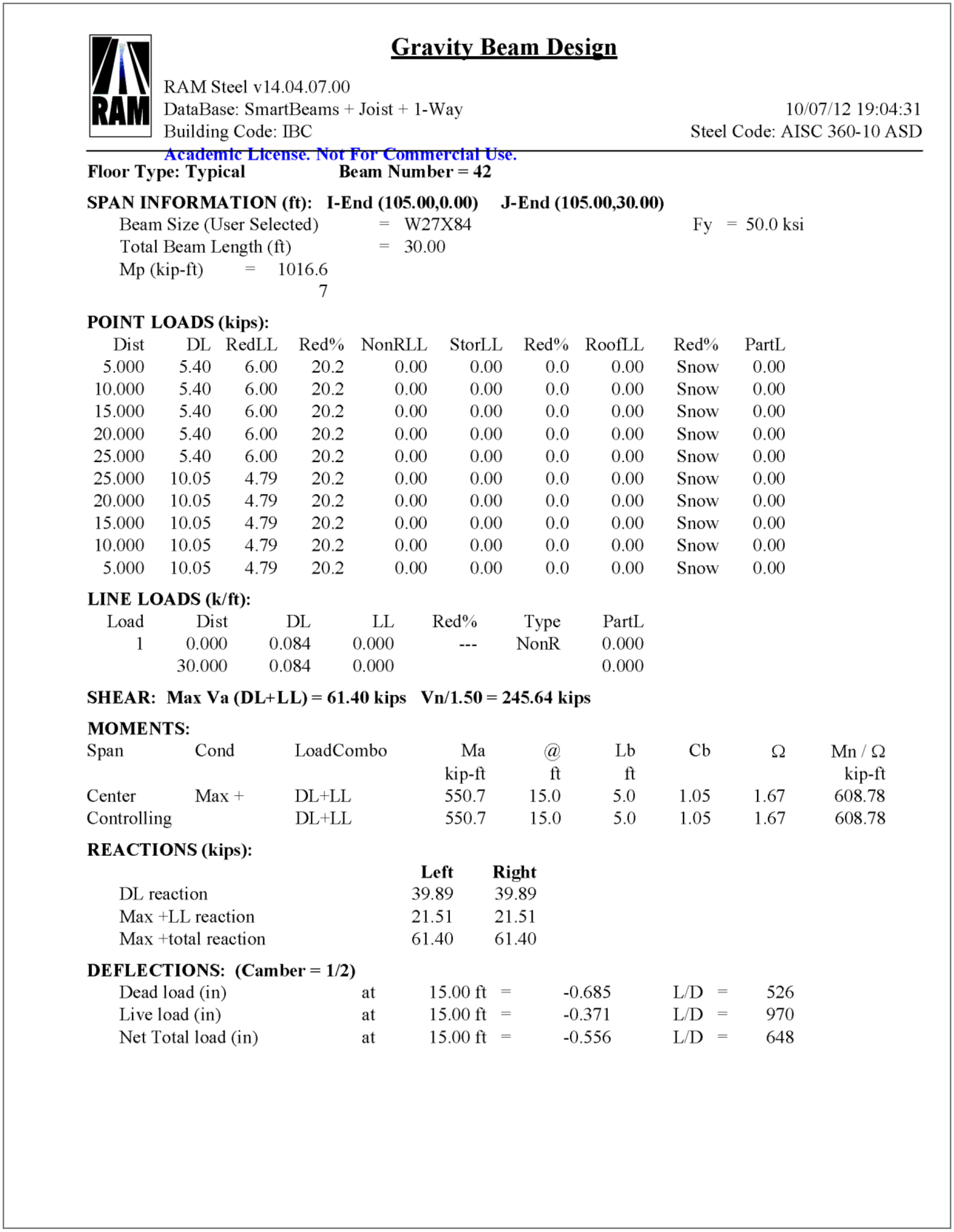
Academic License. Not For Commercial Use.

Floor Type: Typical **Beam Number = 42**

Span information (ft): I-End (105.00,0.00) J-End (105.00,30.00)

Load	Dist	DL	LL+	LL-	PL+	PL-	Max Tot
	ft	kips	kips	kips	kips	kips	kips
P1	5.000	15.450	8.604	0.000	0.000	0.000	24.054
P2	10.000	15.450	8.604	0.000	0.000	0.000	24.054
P3	15.000	15.450	8.604	0.000	0.000	0.000	24.054
P4	20.000	15.450	8.604	0.000	0.000	0.000	24.054
P5	25.000	15.450	8.604	0.000	0.000	0.000	24.054
	ft	k/ft	k/ft	k/ft	k/ft	k/ft	k/ft
W1	0.000	0.084	0.000	0.000	0.000	0.000	0.084
W2	30.000	0.084	0.000	0.000	0.000	0.000	0.084

system 3: RAM girder analysis



```
                                   Gravity Beam Design

RAM Steel v14.04.07.00
DataBase: SmartBeams + Joist + 1-Way                              10/07/12 19:04:31
Building Code: IBC                                        Steel Code: AISC 360-10 ASD
Academic License. Not For Commercial Use.
Floor Type: Typical             Beam Number = 42

SPAN INFORMATION (ft):  I-End (105.00,0.00)    J-End (105.00,30.00)
   Beam Size (User Selected)        =   W27X84                        Fy   =  50.0 ksi
   Total Beam Length (ft)           =   30.00
   Mp (kip-ft)         =      1016.6
                                  7

POINT LOADS (kips):
    Dist      DL   RedLL   Red%   NonRLL    StorLL   Red%   RoofLL    Red%    PartL
   5.000    5.40    6.00   20.2     0.00      0.00    0.0     0.00    Snow     0.00
  10.000    5.40    6.00   20.2     0.00      0.00    0.0     0.00    Snow     0.00
  15.000    5.40    6.00   20.2     0.00      0.00    0.0     0.00    Snow     0.00
  20.000    5.40    6.00   20.2     0.00      0.00    0.0     0.00    Snow     0.00
  25.000    5.40    6.00   20.2     0.00      0.00    0.0     0.00    Snow     0.00
  25.000   10.05    4.79   20.2     0.00      0.00    0.0     0.00    Snow     0.00
  20.000   10.05    4.79   20.2     0.00      0.00    0.0     0.00    Snow     0.00
  15.000   10.05    4.79   20.2     0.00      0.00    0.0     0.00    Snow     0.00
  10.000   10.05    4.79   20.2     0.00      0.00    0.0     0.00    Snow     0.00
   5.000   10.05    4.79   20.2     0.00      0.00    0.0     0.00    Snow     0.00

LINE LOADS (k/ft):
  Load       Dist        DL         LL       Red%       Type      PartL
     1      0.000     0.084      0.000       ---        NonR      0.000
           30.000     0.084      0.000                            0.000

SHEAR:  Max Va (DL+LL) = 61.40 kips   Vn/1.50 = 245.64 kips

MOMENTS:
Span          Cond         LoadCombo         Ma        @        Lb        Cb        Ω      Mn / Ω
                                          kip-ft       ft       ft                          kip-ft
Center        Max +        DL+LL           550.7     15.0      5.0      1.05      1.67     608.78
Controlling                DL+LL           550.7     15.0      5.0      1.05      1.67     608.78

REACTIONS (kips):
                                              Left      Right
   DL reaction                               39.89      39.89
   Max +LL reaction                          21.51      21.51
   Max +total reaction                       61.40      61.40

DEFLECTIONS:  (Camber = 1/2)
   Dead load (in)                 at      15.00 ft  =       -0.685        L/D  =     526
   Live load (in)                 at      15.00 ft  =       -0.371        L/D  =     970
   Net Total load (in)            at      15.00 ft  =       -0.556        L/D  =     648
```

appendix G: system 4

SYSTEM 4 : ONE-WAY SLAB ON BEAMS 1/4

FIRE RATING 2HR ⇒ 5" SLAB (MIN)
COVER 3/4 " (MIN)
$f'_c = 4000$ PSI (FROM SPECS)
$f_y = 60000$ PSI (FROM SPECS)
LET COL = 18" × 18"

LOADS:

LL	80 PSF
DL (MISC)	15 PSF
PARTITION	15 PSF
SELF WT	82 PSF

$W_u = 1.2(97) + 1.6(95) = 268.4$ PSF
(INCLUDING SLAB SELF WT)

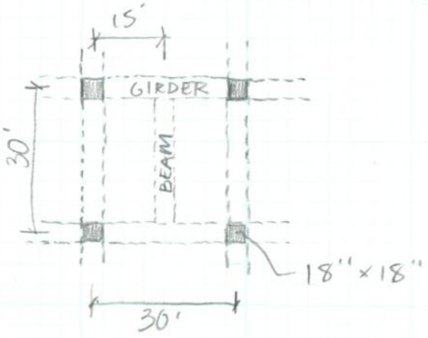


TABLE 9.5a (ACI 318-11)
→ INTERIOR PANEL

$$h_{min} = \frac{l}{28} = \frac{15'}{28} = 6.42" \Rightarrow 6.5"$$

$6.5" \times 150$ PCF = $\underline{\underline{82 \text{ PSF}}}$

SLAB DESIGN

$h = 6.5"$

(ASSUMING # 5 BAR)

$d = 6.5" - 3/4"$ clearcover $- \frac{0.625}{2} = 4.44" = 5"$

1 FOOT WIDE BEAM:

$W_u = 270$ PSF $= 200$ PSF × 1FT WIDTH SLAB $= 200$ PLF

$$M_u = \frac{(270)(15\text{FT} - 18")^2}{8} = 6.15 \text{ KFT}$$

$$A_s \cong \frac{M(\text{KFT})}{4d(\text{in})} = \frac{6.15}{4(5)} = 0.3075 \text{ in}^2/\text{FT}$$

∴ USE #5 @ 12" O.C.
#4 @ 18" O.C. TRANSVERSE

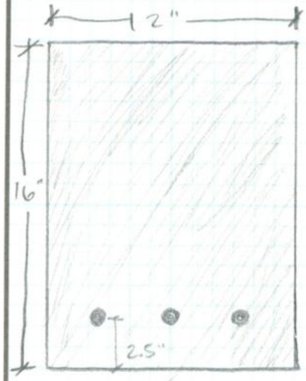
SYSTEM 4: 1-WAY SLAB 2/4

BEAM DESIGN ASSUME 12" × 16"

$w_u = 270(15') + 1.2(12'' \times 16'' \times 150\,\text{PCF})$

$= 4050 + 240$

$= 4.29$ KLF



$M_u = \dfrac{4.29\,(13.5)^2}{8} = 97.73$ KFT

$A_s = \dfrac{M_u}{4d} = \dfrac{97.73}{4(16-2.5)} = 1.8\ \text{in}^2$

$\Downarrow$

$\therefore$ USE (3) #8 $= 2.37\ \text{in}^2$

$a = \dfrac{A_s f_y}{0.85 f'_c b} = \dfrac{(2.37)(60)}{(0.85)(4)(12)} = 3.49''$

$c = a/\beta_1 = \dfrac{3.49}{0.85} = 4.1$ in

$\varepsilon_s = \varepsilon_u\left(\dfrac{d-c}{c}\right) = 0.003\left(\dfrac{13.5-4.1}{4.1}\right) = 0.00688 > 0.00207$
GOOD

SINCE $\varepsilon_t > 0.005 \Rightarrow \phi = 0.9$

$M_n = A_s f_y\,(d - a/2)$

$= (2.37)(60)(13.5 - 3.49/2)$

$= 1671.56$ k·in

$= 139.3$ KFT

$97.73 = M_u \leq \phi M_n = 125.37$ GOOD

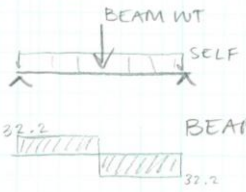
CHECK $A_{s,min} = \dfrac{200}{f_y}\,bd = \dfrac{200}{60000}(12)(16) = 0.64 < 2.37$
GOOD

CHECK $\rho = \dfrac{A_s}{bd} = \dfrac{2.37}{(12)(13.5)} = 0.0146$

$\rho_{max} = 0.85\beta_1 \dfrac{f'_c}{f_y}\,\dfrac{\varepsilon_u}{\varepsilon_u + 0.005} = 0.0181 > 0.0146$
GOOD

SYSTEM 4: 1-WAY SLAB 3/4

GIRDER DESIGN



BEAM LOAD: $\frac{4.29 \text{ KLF} \times 15'}{2} \times 2$ BEAMS FRAMING INTO GIRDER $= 64.35 \text{ k}$

SELF WT: ASSUME $B = 18''$ (SAME WIDTH AS COL)

SELF WT ALLOWANCE

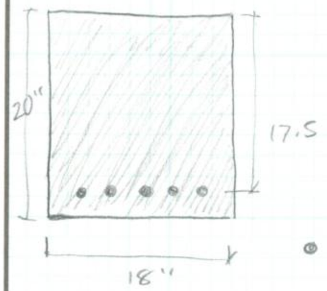
$M_u \approx 1.1 \times 32.2 \times 7.5' = 265.65 \text{ kFT}$

$bd^2 \approx 20 M_u$

$18'' d^2 \approx 20(265.65)$

$d \approx 17.2 = 17.5'' \Rightarrow h = 2.5 + 17.5 = 20''$

$18'' \times 20'' \times 150 \text{ PCF} = 187.5 \text{ PLF}$



- $M_u = 32.2 \times 7.5' + \left(\frac{0.1875}{8}\right) 13.5^2 = 245.8 < 265$ GOOD
  k-FT

$A_s = \frac{M_u}{4d} = \frac{245.8}{4(17.5)} = 3.51 \text{ in}^2$

$\Downarrow$

use (5) #8 $= 3.95 \text{ in}^2$

$a = \frac{A_s f_y}{0.85 f'_c b} = \frac{3.95(60)}{0.85(4)(18)} = 3.87 \text{ in}$

$c = a/\beta_1 = 4.56 \text{ in}$

$\varepsilon_s = 0.003\left(\frac{17.5 - 4.56}{4.56}\right) = 0.00851$ > 0.00207 GOOD
$> 0.005 \Rightarrow \phi = 0.9$

- $M_n = A_s f_y (d - a/2)$
  $= (3.95)(60)(17.5 - 3.87/2)$
  $= 3689 \text{ kin} = 307 \text{ kFT}$

$245.8 \text{ kFT} = M_u \le \phi M_n = 276.67 \text{ kFT}$ GOOD

- CHECKS

$A_{s\,min} = \frac{200}{f_y} bd = \frac{200}{60000}(18)(17.5) = 1.05 < 3.95$ GOOD

$\rho = \frac{A_s}{bd} = \frac{3.95}{(18)(17.5)} = 0.013$

$\rho_{max} = 0.85\beta_1 \frac{f'_c}{f_y} \frac{\varepsilon_u}{\varepsilon_u + 0.005} = 0.0181 > 0.013$ GOOD

SYSTEM : 1-WAY SLAB 4/4

DEFLECTION CHECKS

- BEAM

$$W_{TL} = 4.29 \text{ kLF}$$

$$E = 57000\sqrt{4000} = 3605 \text{ ksi}$$

$$I = \frac{bh^3}{12} = \frac{(12)(16)^3}{12} = 4096 \text{ in}^4$$

$$\Delta_{TL} = \frac{5 w_{TL} \ell^4}{384\, EI}$$

$$= \frac{5(4.29)\text{kLF})(15\text{FT})^4}{384(4096)(3605)} \times 12^3$$

$$= 0.331 \text{ in}$$

$$\Delta_{TL,allow} = \frac{L}{240} = \underline{0.75 \text{ in} > 0.331 \text{ in}} \text{ GOOD}$$

- GIRDER

$$W_{equiv} = \frac{M \times 8}{\ell^2} = \frac{(246)(8)}{15^2} = 8.75 \text{ kLF}$$

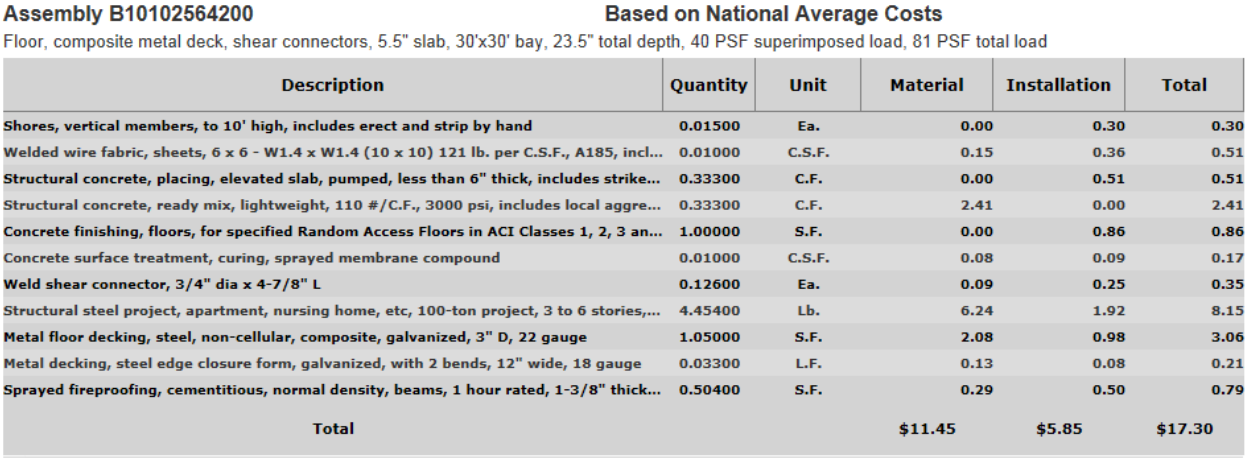
$$I = \frac{(18)(20)^3}{12} = 12000 \text{ in}^4$$

$$\Delta_{TL} = \frac{5(8.75)(15)^4}{384(12000)(3605)} \times 12^3$$

$$= \underline{0,230 \text{ in} < 0,75 \text{ in}} \text{ GOOD}$$

appendix H: comparison calculations

cost analysis: system 1 [meanscostworks.com]



Assembly B10102564200 **Based on National Average Costs**

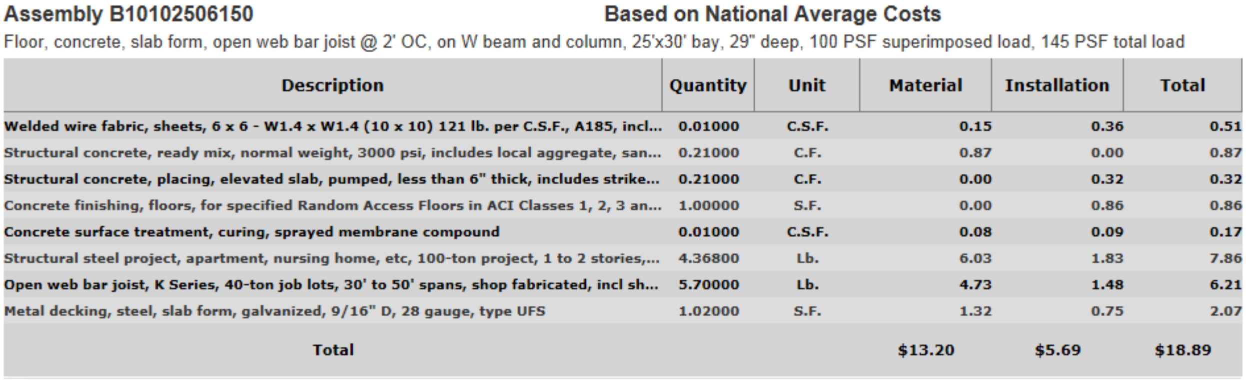
Floor, composite metal deck, shear connectors, 5.5" slab, 30'x30' bay, 23.5" total depth, 40 PSF superimposed load, 81 PSF total load

Description	Quantity	Unit	Material	Installation	Total
Shores, vertical members, to 10' high, includes erect and strip by hand	0.01500	Ea.	0.00	0.30	0.30
Welded wire fabric, sheets, 6 x 6 - W1.4 x W1.4 (10 x 10) 121 lb. per C.S.F., A185, incl...	0.01000	C.S.F.	0.15	0.36	0.51
Structural concrete, placing, elevated slab, pumped, less than 6" thick, includes strike...	0.33300	C.F.	0.00	0.51	0.51
Structural concrete, ready mix, lightweight, 110 #/C.F., 3000 psi, includes local aggre...	0.33300	C.F.	2.41	0.00	2.41
Concrete finishing, floors, for specified Random Access Floors in ACI Classes 1, 2, 3 an...	1.00000	S.F.	0.00	0.86	0.86
Concrete surface treatment, curing, sprayed membrane compound	0.01000	C.S.F.	0.08	0.09	0.17
Weld shear connector, 3/4" dia x 4-7/8" L	0.12600	Ea.	0.09	0.25	0.35
Structural steel project, apartment, nursing home, etc, 100-ton project, 3 to 6 stories,...	4.45400	Lb.	6.24	1.92	8.15
Metal floor decking, steel, non-cellular, composite, galvanized, 3" D, 22 gauge	1.05000	S.F.	2.08	0.98	3.06
Metal decking, steel edge closure form, galvanized, with 2 bends, 12" wide, 18 gauge	0.03300	L.F.	0.13	0.08	0.21
Sprayed fireproofing, cementitious, normal density, beams, 1 hour rated, 1-3/8" thick...	0.50400	S.F.	0.29	0.50	0.79
Total			$11.45	$5.85	$17.30

cost analysis: system 2 [see next page]

Total: $17.61

cost analysis: system 3 [meanscostworks.com]

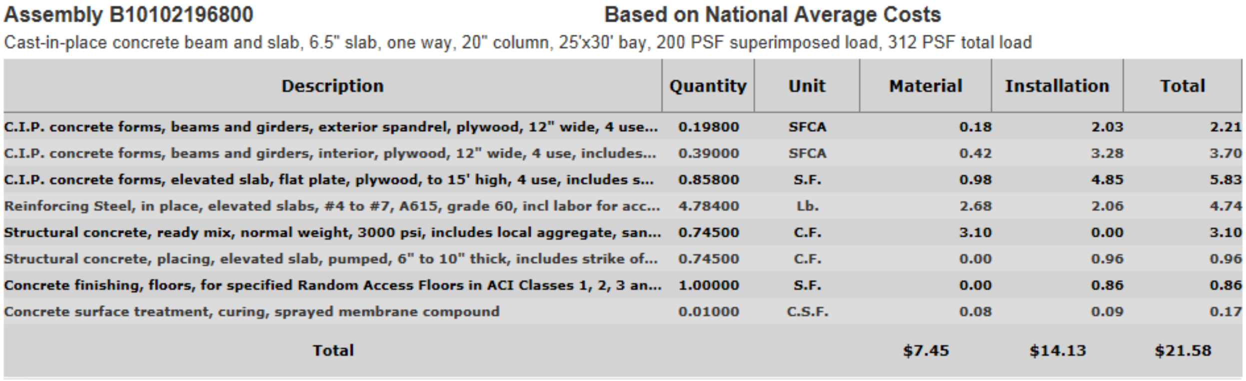


Assembly B10102506150 **Based on National Average Costs**

Floor, concrete, slab form, open web bar joist @ 2' OC, on W beam and column, 25'x30' bay, 29" deep, 100 PSF superimposed load, 145 PSF total load

Description	Quantity	Unit	Material	Installation	Total
Welded wire fabric, sheets, 6 x 6 - W1.4 x W1.4 (10 x 10) 121 lb. per C.S.F., A185, incl...	0.01000	C.S.F.	0.15	0.36	0.51
Structural concrete, ready mix, normal weight, 3000 psi, includes local aggregate, san...	0.21000	C.F.	0.87	0.00	0.87
Structural concrete, placing, elevated slab, pumped, less than 6" thick, includes strike...	0.21000	C.F.	0.00	0.32	0.32
Concrete finishing, floors, for specified Random Access Floors in ACI Classes 1, 2, 3 an...	1.00000	S.F.	0.00	0.86	0.86
Concrete surface treatment, curing, sprayed membrane compound	0.01000	C.S.F.	0.08	0.09	0.17
Structural steel project, apartment, nursing home, etc, 100-ton project, 1 to 2 stories,...	4.36800	Lb.	6.03	1.83	7.86
Open web bar joist, K Series, 40-ton job lots, 30' to 50' spans, shop fabricated, incl sh...	5.70000	Lb.	4.73	1.48	6.21
Metal decking, steel, slab form, galvanized, 9/16" D, 28 gauge, type UFS	1.02000	S.F.	1.32	0.75	2.07
Total			$13.20	$5.69	$18.89

cost analysis: system 4 [meanscostworks.com]



Assembly B10102196800 **Based on National Average Costs**

Cast-in-place concrete beam and slab, 6.5" slab, one way, 20" column, 25'x30' bay, 200 PSF superimposed load, 312 PSF total load

Description	Quantity	Unit	Material	Installation	Total
C.I.P. concrete forms, beams and girders, exterior spandrel, plywood, 12" wide, 4 use...	0.19800	SFCA	0.18	2.03	2.21
C.I.P. concrete forms, beams and girders, interior, plywood, 12" wide, 4 use, includes...	0.39000	SFCA	0.42	3.28	3.70
C.I.P. concrete forms, elevated slab, flat plate, plywood, to 15' high, 4 use, includes s...	0.85800	S.F.	0.98	4.85	5.83
Reinforcing Steel, in place, elevated slabs, #4 to #7, A615, grade 60, incl labor for acc...	4.78400	Lb.	2.68	2.06	4.74
Structural concrete, ready mix, normal weight, 3000 psi, includes local aggregate, san...	0.74500	C.F.	3.10	0.00	3.10
Structural concrete, placing, elevated slab, pumped, 6" to 10" thick, includes strike of...	0.74500	C.F.	0.00	0.96	0.96
Concrete finishing, floors, for specified Random Access Floors in ACI Classes 1, 2, 3 an...	1.00000	S.F.	0.00	0.86	0.86
Concrete surface treatment, curing, sprayed membrane compound	0.01000	C.S.F.	0.08	0.09	0.17
Total			$7.45	$14.13	$21.58

cost analysis: system 2 [cont.]

information is based on a phone call to Steve Redman (CMC Steel, Northeast, 10.09.2012) and meanscostworks.com

From Mr. Redman:

@ 60' span, expect SmartBEAM to cost **$100/ton** more than traditional W-shape

From meanscostworks.com:

30'x30' composite beam and slab system = **$17.30**

Calculations:

CB30x62 typical beam size

3 beams per 30'x60' bay

62PLF x 60' x 3bms = 11,160# = 5.58 tons

Since the bay size is double the typical bay (30'x30'), divide tonnage by two

= 2.79 tons per 30'x30'

2.79 tons x $100/ton = $279 extra per 30'x30' bay
$279/(900 SF) = **+$0.31 per SF**
(NOTE: $0.31 x 152,000 SF = $47,120 additional cost for entire building over traditional W-shape beams)

$17.30 + $0.31 = **$17.61 Total Cost**

depth analysis

system 1: composite beam/slab

slab 5.5”

beam 16”

girder 24”

depth = 5.5” + 24” = **29.5”**

system 2: castellated composite beams

slab 5.5”

cast. beam 30”

girder 33”

depth = 5.5” + 33” = **38.5”**

system 3: steel joist on beams

slab 5.5”

joist 24”

girder 27”

depth = 5.5” + 27” = **32.5”**

system 4: 1-way slab

slab 6.5”

beam 16” (including slab)

girder 20” (including slab)

depth = **20”**

weight analysis

system 1: composite beam/slab

slab/deck 57 PSF

beam 36 PLF x 4 beams

girder 68 PLF

w = 57 + 4 x 36/30 + 68/30 = **64.1 PSF**

system 2: castellated composite beams

slab 57 PSF

cast. beam 62 PLF x 3 beams

girder 118 PLF x ½ beams since bay is 2x as large

w = 57 + 3 x 62/30 + ½ x 118/30 = **65.2 PSF**

system 3: steel joist on beams

slab 57 PSF

joist 8 PLF x 6 joists

girder 84 PLF

w = 57 + 6 x 8/30 + 84/30 = **61.4 PSF**

system 4: 1-way slab

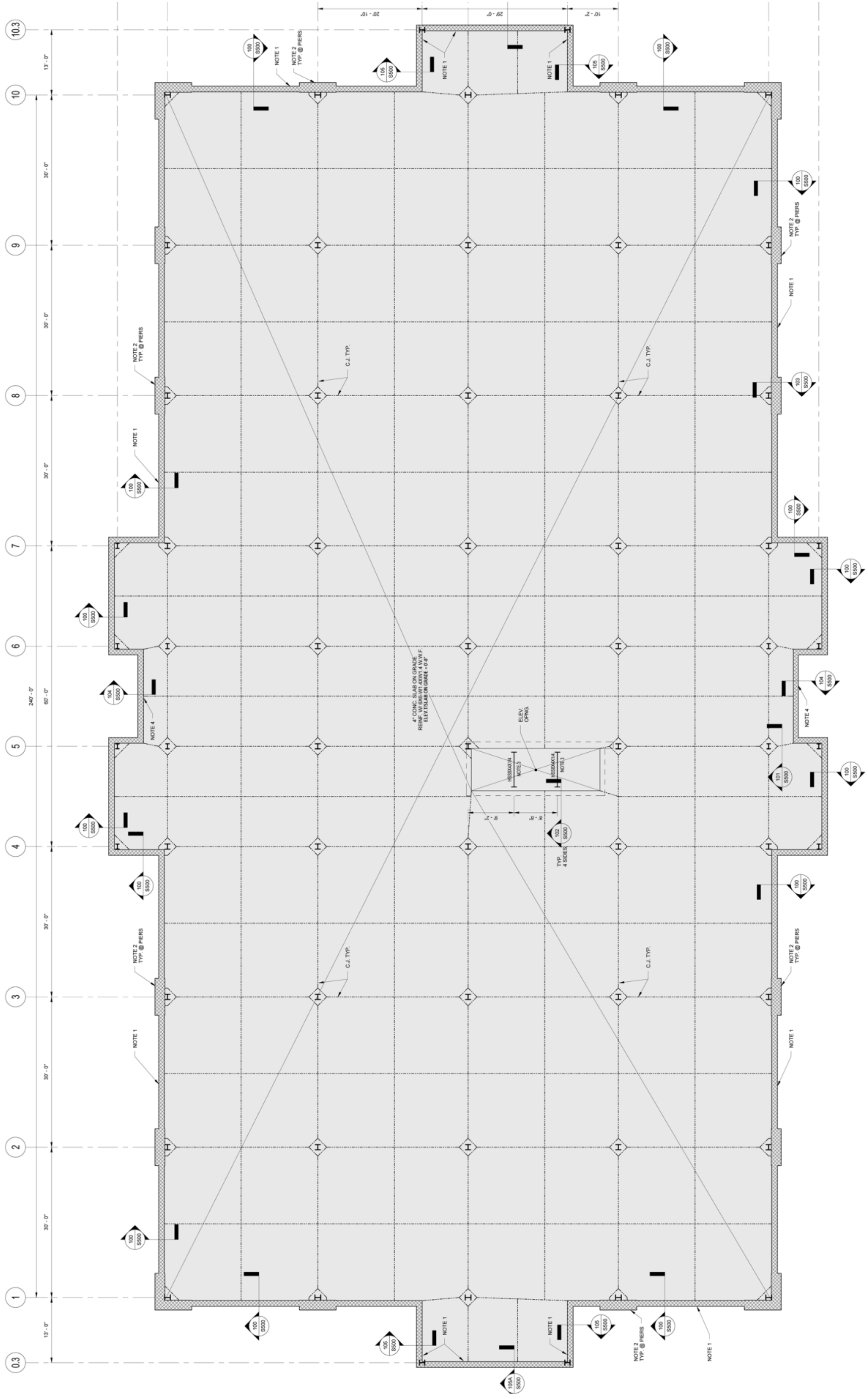
slab 150 PCF x 6.5” = 82 PSF

beam 150 PCF x (16” – 6.5”)/12 x 12” x 15’ x 2beams = 3.56 k per bay

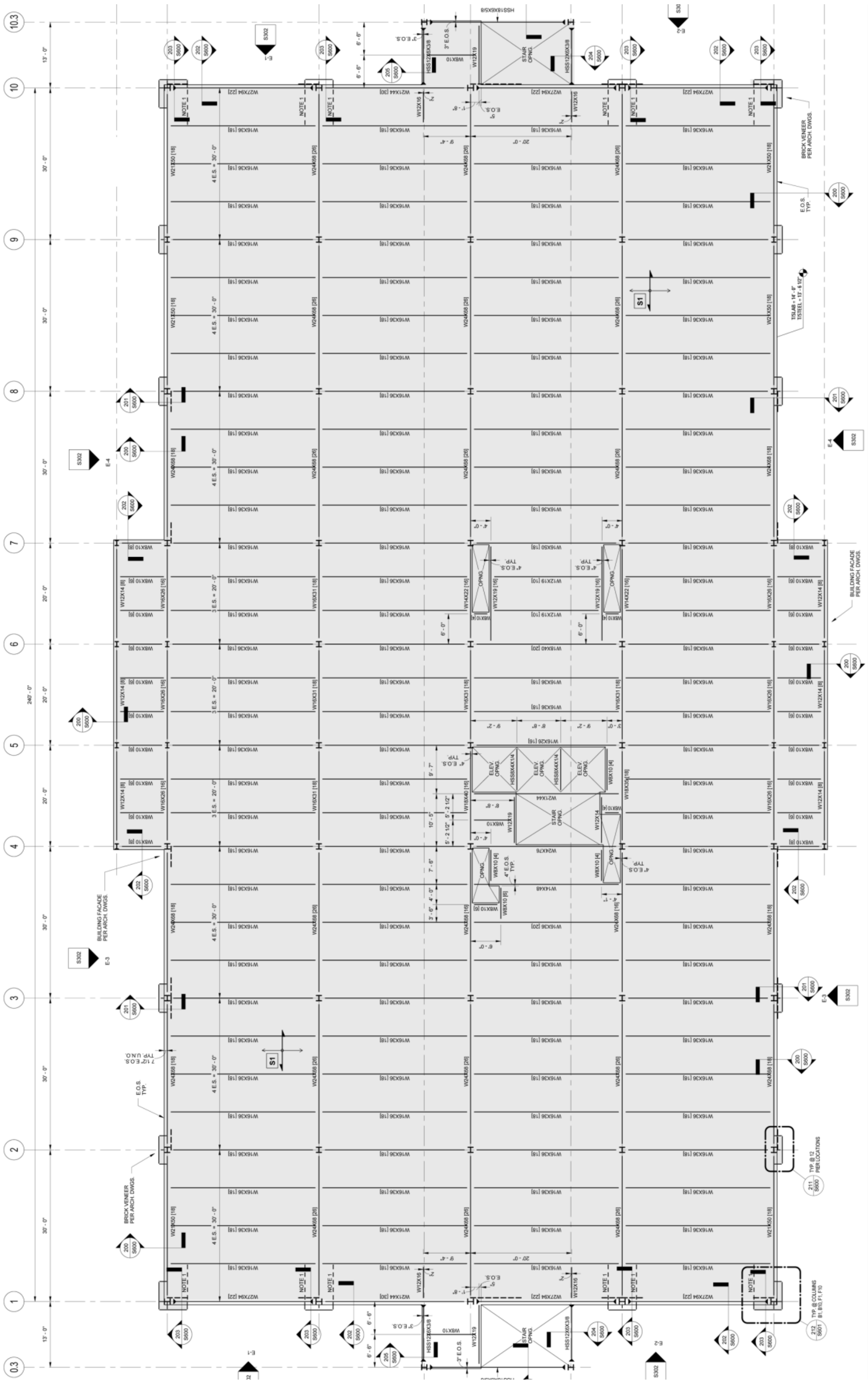
girder 150 PCF x (20” – 6.5”)/12 x 18” x 15’ = 3.8 k

depth = 82 + 3.56/900 + 3.8/900 = **82.01 PSF**

appendix I: additional drawings



slab on grade plan (S101)



typical floor plan for floors 2-5 (S200)