UNIVERSITY OF TEXAS AT EL PASO

CIVIL ENGINEERING DEPARTMEN

CE 4288

SENIOR DESIGN II

CLASS 2011

STRUCTURAL DESIGN TEAM

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Introduction

The City of Vinton, Texas has inquired about building a Multipurpose Center in the lot of the old Border Steel Inc. building. The size of the lot is approximately 10.5 acres. The City of Vinton has supplied us with a list of requirements for the Multipurpose Center. These include an indoor basketball court, two classrooms, entertainment room, banquet room, fitness center, administrative offices and a police station. Being the structural design team, we decided to design two separate buildings. One building will be the Police Station and the other will be the Multipurpose Center. Our final design will consist of member designs, column designs, structural analysis, and a physical scale model. This design process will also incorporate a Passive Solar design because we want our design to be energy efficient and cost effective.

Passive Solar

We want to integrate a passive solar approach in our design. A Passive Solar design requires a combination of features that will reduce or eliminate the need of mechanical cooling and heating, as well as artificial lighting. These features consist of the orientation of the building, increasing south facing windows for direct gain in the winter shading and shading or overhang design for the summer. These features are cost-effective because they require little or no first costs and require minimal maintenance throughout the life of the buildings.

The orientation of the buildings is a design feature used in Passive Solar Design. To maximize direct sunlight in the winter we want to optimize the orientation of the buildings. One of the concepts that we incorporated into our design is a rectangular floor plan with the elongated axis running from east to west. Figure 1 shows the layout of the lot and the positioning of the buildings according to the passive solar design techniques. The long axis is oriented east to west so that large south facing windows are exposed to the sun in all seasons.

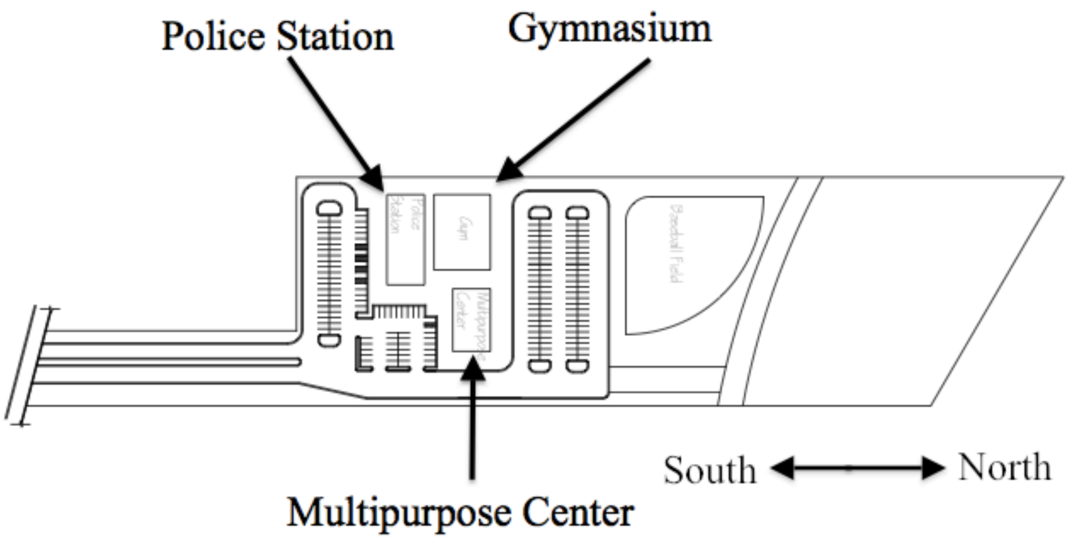


Figure 1- Building Layout for Passive Solar

Window sizing is another factor that contributes to a Passive Solar Design. Large south facing windows is a key component to decreasing the use of mechanical heating. The area of the south facing windows should be between 5% and 7% of the total floor area. The total window area of a building should not exceed 12% of the total floor area. If the window area were to exceed 12% then overheating would occur and increase the cost for mechanical cooling. The total window area for the main building came out to be 1260 ft^2, which does not exceed the 12 % window area of 1440 ft^2. The total window area came out to be 972 ft^2, which also does not exceed the 12 % window area of 1140 ft^2.

Table 1: Window Parameters for Main Building

	Number of Windows	Size (ft by ft)	Area (ft^2)
South	10	9 x 7	630
West	6	9 x 5	270
East	6	9 x 5	270
North	2	9 x 5	90
Total			1260

Table 2: Window Parameters for Police Station

	Number of Windows	Size (ft by ft)	Area (ft^2)
South	10	9 x 6	540
West	3	9 x 6	162
East	3	9 x 6	162
North	2	9 x 6	108
Total			972

The overhang design is an important component of a passive solar design. Overhangs are an effective option to optimize the solar heat gain and shading. Properly sized overhangs will provide shade to the windows from the summer sun; and in the winter when the sun is lower in the sky, allow sunlight pass through the window to warm the interior. Since Vinton, Texas lies in a warm climate region, we want to maximize our shading to the south facing windows of the buildings. The following table depicts how the maximum sunlight percentage occurs during the winter months and minimum sunlight percentage occurs during summer months.

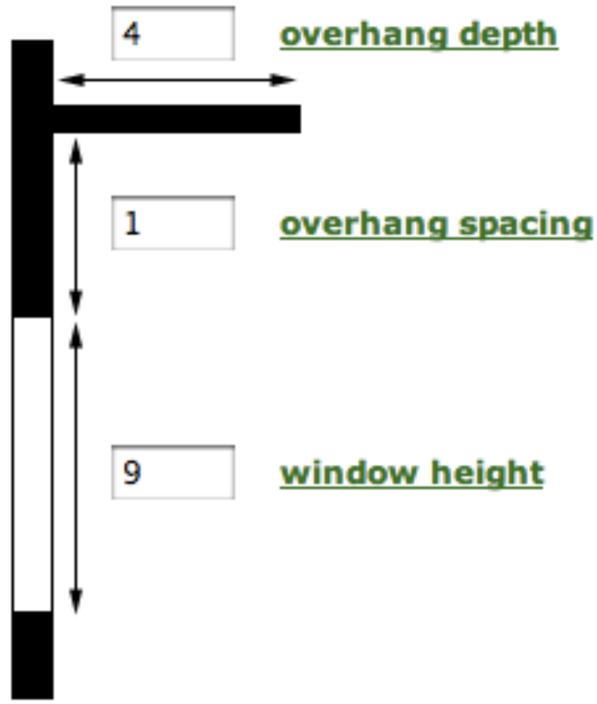


Figure 2 - Overhang Design in Feet

	MORNING									AFTERNOON								
	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	
Jan				100%	95%	86%	81%	79%	78%	79%	81%	86%	95%	100%				Jan
Feb				98%	82%	73%	69%	67%	66%	67%	69%	73%	81%	97%				Feb
Mar				59%	51%	48%	46%	46%	46%	46%	46%	48%	50%	58%				Mar
Apr					0%	0%	0%	1%	2%	0%	0%	0%	0%					Apr
May						0%	0%	0%	0%	0%	0%	0%						May
Jun						0%	0%	0%	0%	0%	0%	0%						Jun
Jul						0%	0%	0%	0%	0%	0%	0%						Jul
Aug					0%	0%	0%	0%	0%	0%	0%	0%	0%					Aug
Sep				0%	19%	26%	29%	30%	31%	30%	29%	26%	20%	0%				Sep
Oct				87%	72%	65%	61%	59%	59%	60%	61%	65%	72%	88%				Oct
Nov				100%	91%	82%	78%	75%	74%	75%	78%	83%	91%	100%				Nov
Dec					97%	89%	84%	81%	80%	81%	84%	89%	97%					Dec
	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	
	MORNING									AFTERNOON								

Figure 3 - Sunlight Percentage Entering Southern Facing Windows

Police Station

The first requirements for this building were to design a police station with at least three offices and three holding cells. Our second meeting with the council of Vinton provided us a specific design for the police station. Figure 4

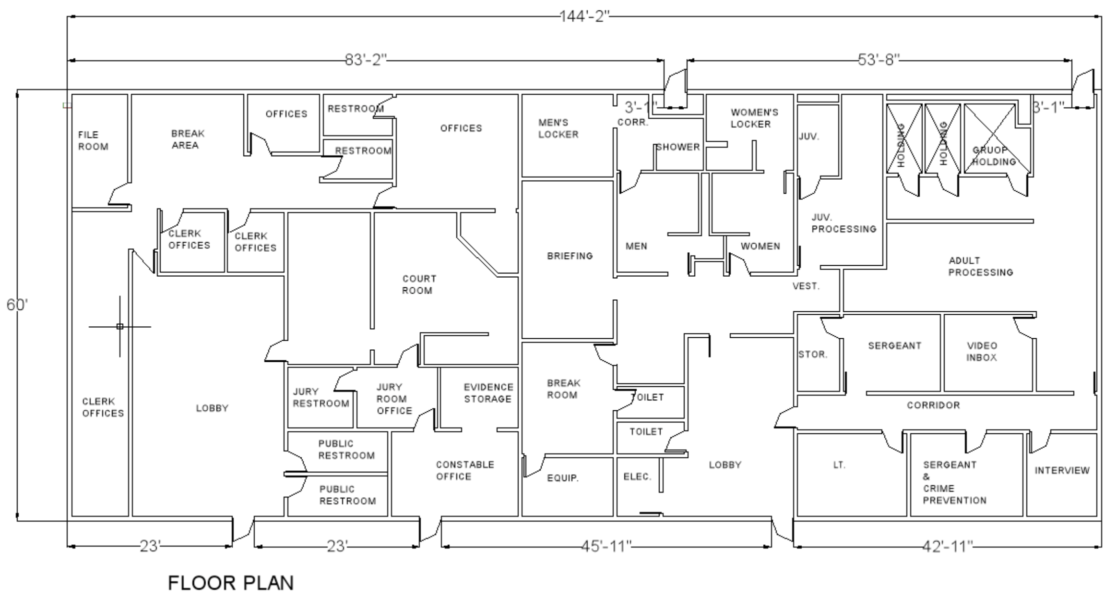


Figure 4 - Vinton Police Station Floor Plan

In this floor plan developed the distribution of the space for the police station. After analyzing the floor plan and the purpose for the building we came up with different ideas for the design of this complex.

Our primary thinking regarding the project was the architectural design and the type of structure. Having the dimensions, we created a 3D render. During the course of the semester we came up with some changes for a better design and to provide a better working environment for the police of Vinton. The complex will be constructed with CMU (concrete masonry units) for the perimeter walls. The interior walls will be constructed with drywall.

Figure 5 - ARCHICAD 3D Rendering

On the following figure we have the structural design. As we have a width of 60 ft we came up with the necessity to build a supporting frame in the middle of the building. The blue lines represent the joist and will have a length of 30 ft. The frame will support those joists. The red lines represent the supporting frame that will carry the load of the joist. In this frame we have six beams with a total length of 144 ft.

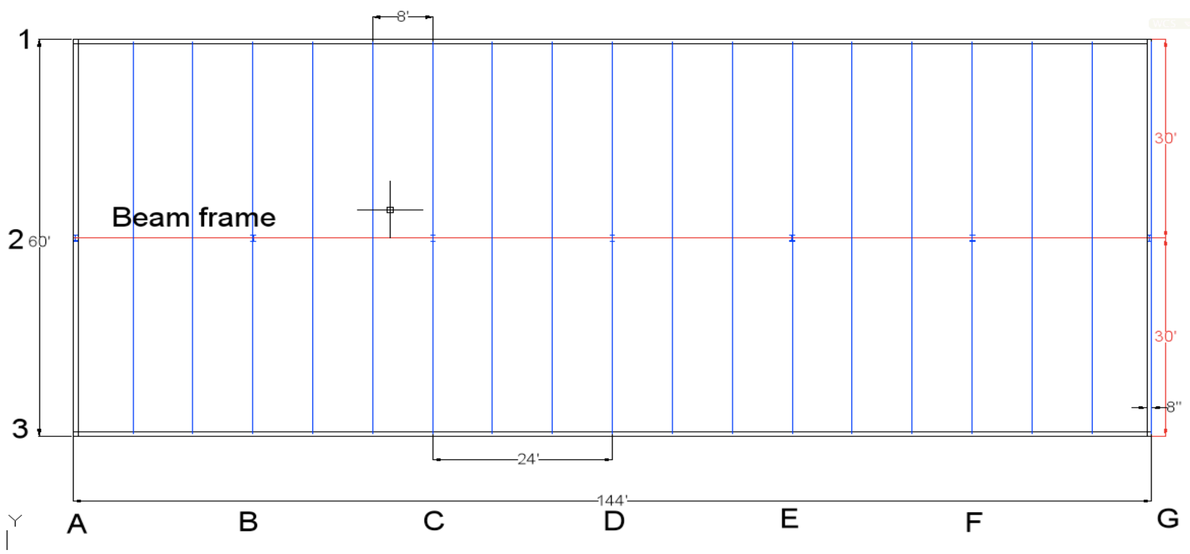


Figure 6 - Structural Frame

CMU Properties

Moreover, CMU needs a lot more reinforcement in the vertical direction and the horizontal direction. In Figure 7, we have a section for the reinforcing of the CMU in the vertical direction.

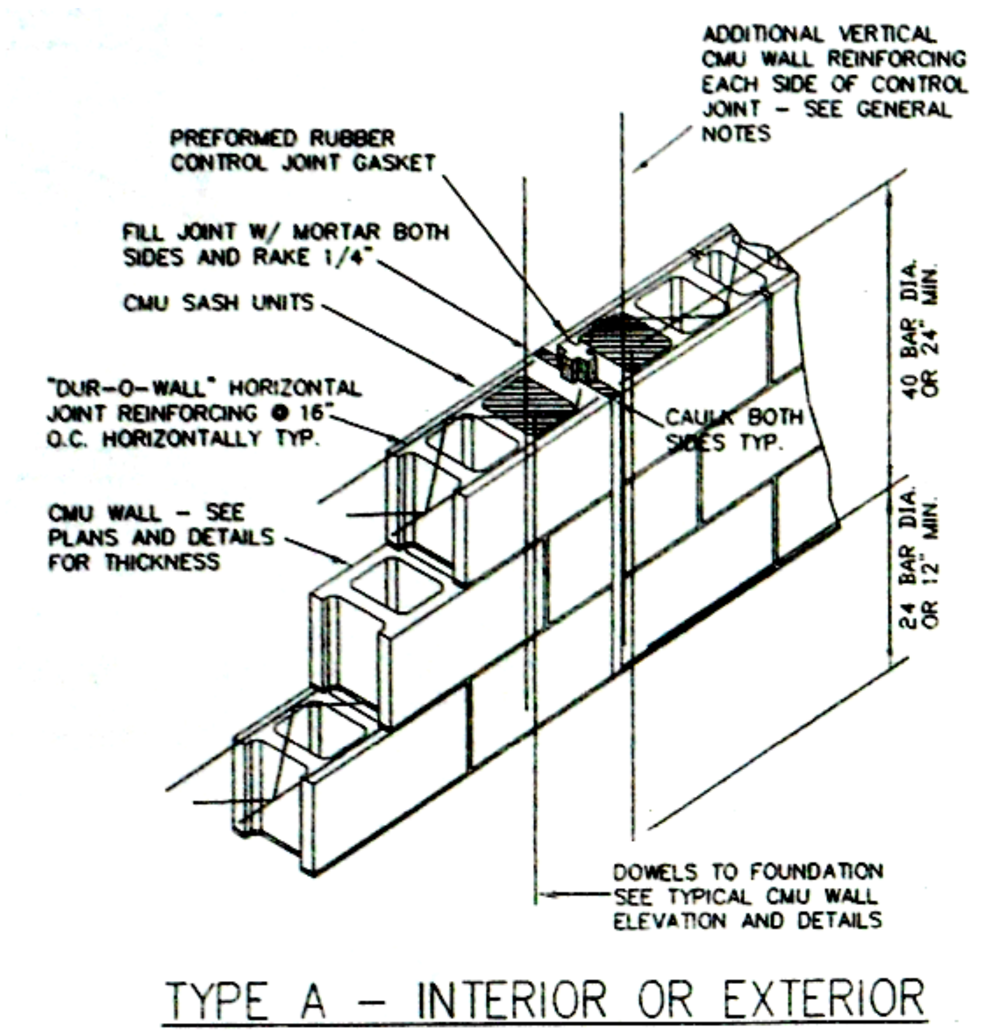


Figure 7 - Reinforced CMU

For vertical reinforced wall. At every 4 ft we need a reinforced bar to support the tension and compressive forces.

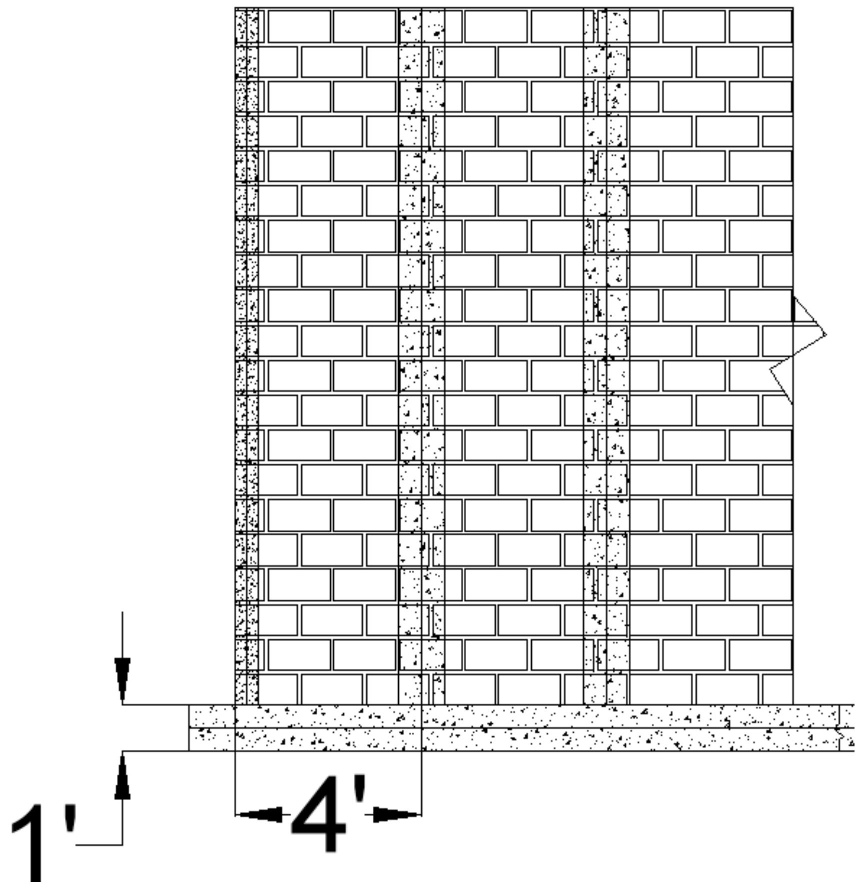


Figure 8 - Vertical Reinforced Wall

For the corner of the building we also have some details in Figure 9.

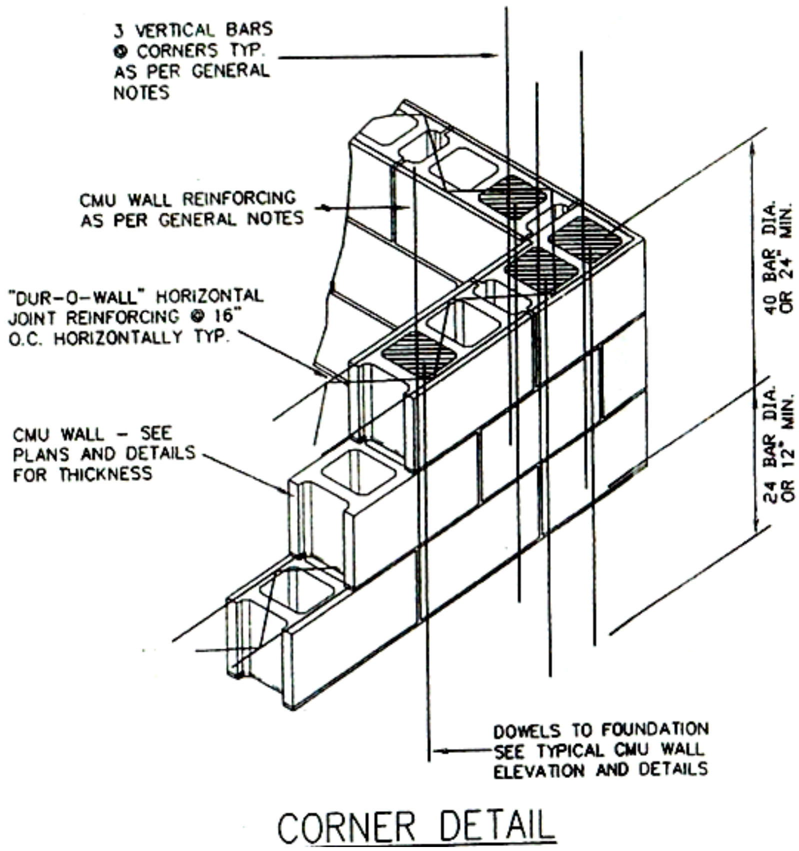


Figure 9 - Reinforced Corner

Roof Design- Police Station

For the roof of this building we were working on a flat roof with a parapet structure, but since we need slope for the runoff, we designed a 2% slope.

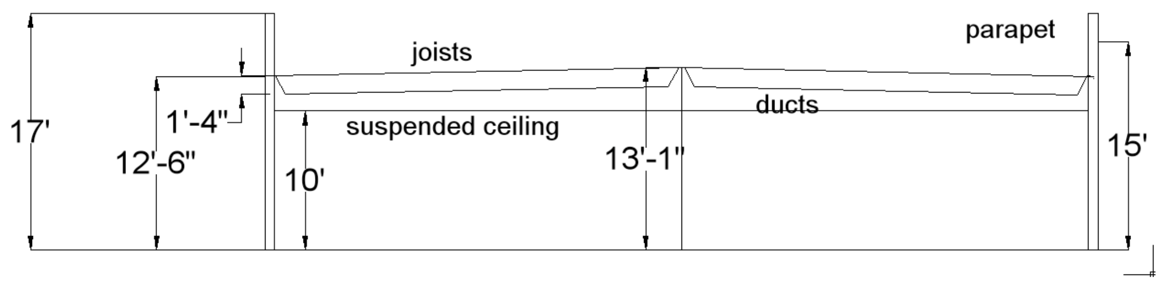


Figure 10 - Roof Design for Police Station

The roof in this complex will be a conventional roof with the following materials:

A. Wall protection cap

B. Dense deck

C. Parapet wall framing

D. Exterior finish

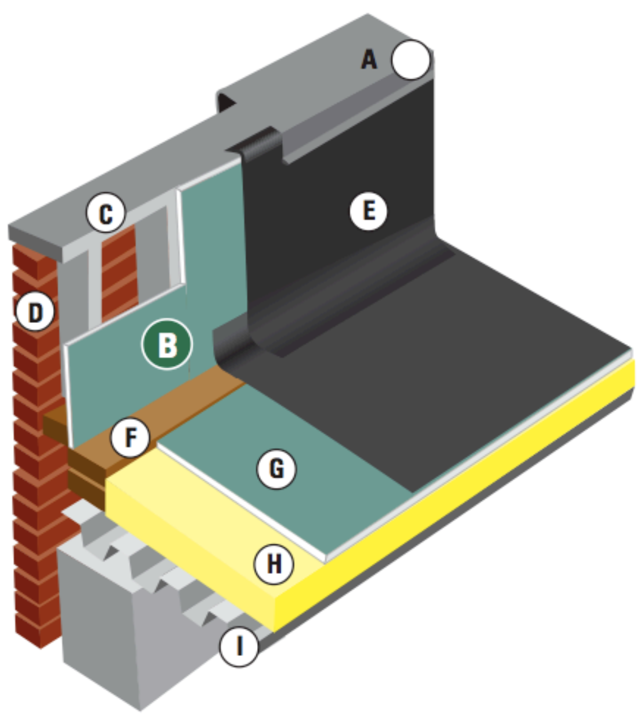
E. Membrane and three ply felt tar and gravel

F. Nailer

G. Dense deck.

H. Insulation.

I. Metal deck.



Structural Design – Police Station

Table 3: Roof Dead Loads and Live Loads

LOAD COMBINATIONS		
DEAD LOAD		
ROOF	**THREE PLY FELT TAR AND GRAVEL**	**5.5 (psf)**
	DENSE DECK	**3(psf)**
	INSULATION	**2.5(psf)**
	METAL DECK	**3(psf)**
TOTAL		**14(psf)**
LIVE LOAD		
TOTAL		**20(psf)**

Table 4: Wind load

WIND LOAD			
VARIABLE	TERM	VALUE	UNITS
STATIC WIND PRESSURE	q_s	0.256	lb/ft^2
VELOCITY	V	100	mph
VELOCITY WIND PRESSURE	q_z	22.52	lb/ft^2
IMPORTANCE FACTOR	I	1.15	
EXPOSSURE COEFFICIENT	K_Z ©	2.4	
TOPOGRAFIC FACTOR	K_{ZT}	1	
WIND DIRECTIONALITY FAC	K_d	0.85	
DESIGN WIND PRESSURE	p	15.31	lb/ft^2
GUST FACTOR	G	0.85	
EXTERNAL PRESSURE COEF	C_P	0.8	
L/B		2.4	
CP_W	C_P	0.8	
CP_L		-0.3	
CP_S		-0.7	
Leeward	p_l	-5.4	lb/ft^2
Windward	p_s	-12.61	lb/ft^2

Load combinations

After calculating all the loads applied to our building we use a combination of loads provided on the IBC (International Building Codes) and in the ASCE 7 manual. Moreover, since we are just using roof live load, dead load and wind load, we used equation 1 for the combination of loads:

$$1.2(D)+1.6(W)+(L)+0.5(L_r) \qquad \textbf{Eq (1)}$$

Girder design

For the girder design we use the Joist Steel Institute manual considering the following parameters the length (span), the dead load and live load and at the end we get the name of the section, which is 16K9.

LRFD

STANDARD LOAD TABLE FOR OPEN WEB STEEL JOISTS, K-SERIES
Based on a 50 ksi Maximum Yield Strength - Loads Shown in Pounds per Linear Foot (plf)

Joist Designation	8K1	10K1	12K1	12K3	12K5	14K1	14K3	14K4	14K6	16K2	16K3	16K4	16K5	16K6	16K7	16K9
Depth (in.)	8	10	12	12	12	14	14	14	14	16	16	16	16	16	16	16
Approx. Wt (lbs./ft.)	5.1	5.0	5.0	5.7	7.1	5.2	6.0	6.7	7.7	5.5	6.3	7.0	7.5	8.1	8.6	10.0
Span (ft.) ↓ 8	825 550															

Figure 11 - Steel Joist Manual

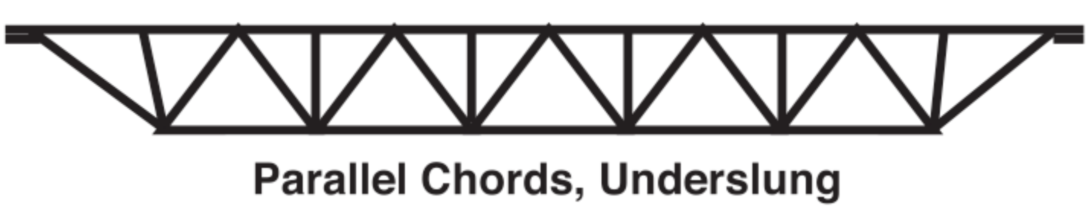


Figure 12 - Girder

The second thing to design is the supporting frame that we have in the middle of the structure. For its design we use two methods. The first method helped us designing the beams that support the girders. What we use here is a spread sheet that came up with an I beam after introduced some parameters like dead load, live load, length and tributary width.

Table 5: Beam Design Spreadsheet

BEAM DESIGN						
DEAD (PSF)=	14	14	14	14	14	14
LIVE (PSF)=	20	20	20	20	20	20
LENGTH (FT)=	24	24	24	24	24	24
T.WIDTH (ft)=	30	30	30	30	30	30
Ix (in4)=	375	375	375	375	375	375
FACTORED LOAD (kips)=	1.464	1.464	1.464	1.464	1.464	1.464
Mu (k ft)=	105.408	105.408	105.408	105.408	105.408	105.408
DEFLECTION=	0.7	0.7	0.7	0.7	0.7	0.7
ALLOWED DEFELCTION	0.8	0.8	0.8	0.8	0.8	0.8
SELECTED MEMBER	**W16x31**	**W16x31**	**W16x31**	**W16x31**	**W16x31**	**W16x31**

In the following figure we have the analysis from the RISA software where we designed according to the suggested shapes that the spreadsheet gives.

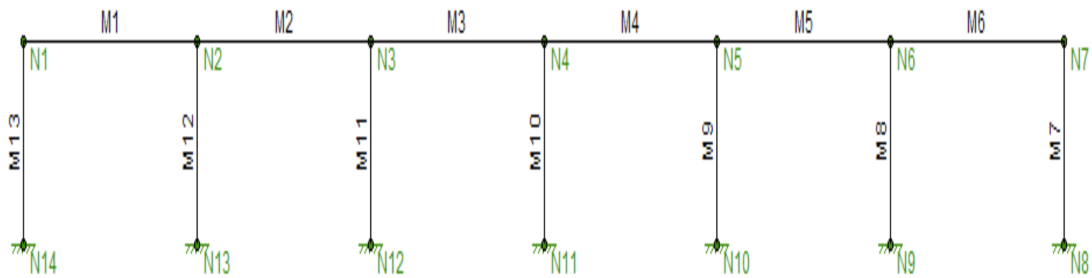


Figure 13 - Supporting Frame RISA

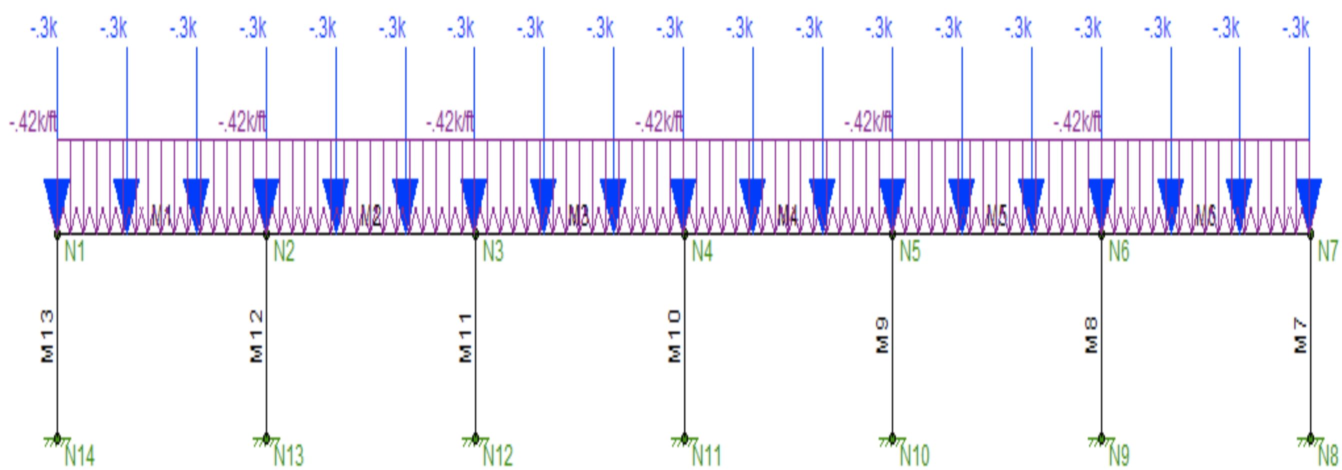


Figure 14 - Dead Load

The main purpose of the analysis for our structure is that RISA is able to check the columns and see if the structure will be stable and remain with allowed deformation on all members.

Table 6: Member Forces

MEMBER FORCES			
MEMBER	AXIAL (K)	Y SHEAR (K)	Z-MOMENT (K-ft)
M1	2.839	9.176	26.016
	2.839	4.352	-14.566
	2.839	-0.832	-24.764
	2.839	-6.016	-4.579
	2.839	-10.84	45.991
M2	2.374	10.096	42.107
	2.374	5.272	-3.999
	2.374	0.088	-19.721
	2.374	-5.096	-5.059
	2.374	-9.92	39.987
M3	2.39	9.993	40.236
	2.39	5.169	-5.247
	2.39	-0.015	-20.347
	2.39	-5.199	-5.063
	2.39	-10.023	40.606
M4	2.416	10.036	40.753
	2.416	5.212	-4.989
	2.416	0.028	-20.347
	2.416	-5.156	-5.32
	2.416	-9.98	40.09
M5	2.453	9.933	40.143
	2.453	5.109	-4.984
	2.453	-0.075	-19.726
	2.453	-5.259	-4.084
	2.453	-10.083	41.942
M6	2.97	10.848	46.109

	2.97	6.024	-4.504
	2.97	0.84	-24.734
	2.97	-4.344	-14.58
	2.97	-9.168	25.958
M7	9.528	-2.97	-25.958
	9.528	-2.865	-16.404
	9.528	-2.76	-7.194
	9.528	-2.655	1.674
	9.528	-2.55	10.198
M8	21.291	0.517	4.168
	21.291	0.517	2.475
	21.291	0.517	0.782
	21.291	0.517	-0.911
	21.291	0.517	-2.605
M9	20.273	0.037	0.053
	20.273	0.037	-0.068
	20.273	0.037	-0.189
	20.273	0.037	-0.311
	20.273	0.037	-0.432
M10	20.419	0.026	0.147
	20.419	0.026	0.062
	20.419	0.026	-0.023
	20.419	0.026	-0.108
	20.419	0.026	-0.194
M11	20.272	0.016	0.249
	20.272	0.016	0.196
	20.272	0.016	0.143
	20.272	0.016	0.091
	20.272	0.016	0.038

M12	21.297	-0.465	-3.884
	21.297	-0.465	-2.361
	21.297	-0.465	-0.837
	21.297	-0.465	0.686
	21.297	-0.465	2.21
M13	9.536	2.839	26.016
	9.536	2.839	16.719
	9.536	2.839	7.422
	9.536	2.839	-1.875
	9.536	2.839	-11.171

Table 7: Member Deflections

DEFLECTION		
MEMBER	X(in)	Y(in)
M1	0.007	-0.006
	0.006	-0.126
	0.006	-0.177
	0.005	-0.101
	0.004	-0.013
M2	0.004	-0.013
	0.003	-0.072
	0.003	-0.123
	0.002	-0.075
	0.001	-0.012
M3	0.001	-0.012
	0	-0.079
	0	-0.13
	0	-0.078
	-0.001	-0.012
M4	-0.001	-0.012
	-0.002	-0.078
	-0.002	-0.13
	-0.003	-0.079
	-0.004	-0.012
M5	-0.004	-0.012
	-0.004	-0.074
	-0.005	-0.123
	-0.006	-0.072
	-0.006	-0.013
M6	-0.006	-0.013

	-0.007	-0.1
	-0.008	-0.177
	-0.009	-0.126
	-0.01	-0.006
M7	0.006	0.01
	0.004	-0.019
	0.003	-0.02
	0.001	-0.009
	0	0
M8	0.013	0.006
	0.009	0.008
	0.006	0.006
	0.003	0.002
	0	0
M9	0.012	0.004
	0.009	0.002
	0.006	0.001
	0.003	0
	0	0
M10	0.012	0.001
	0.009	0
	0.006	0
	0.003	0
	0	0
M11	0.012	-0.001
	0.009	0
	0.006	0
	0.003	0
	0	0

M12	0.013	-0.004
	0.009	-0.006
	0.006	-0.005
	0.003	-0.002
	0	0
M13	0.006	-0.007
	0.004	0.022
	0.003	0.022
	0.001	0.009
	0	0

Multipurpose Center

For the multipurpose center we designed for the following spaces:

1. Offices
2. Fitness Center
3. Classrooms
4. Banquet Room
5. Entertainment Room

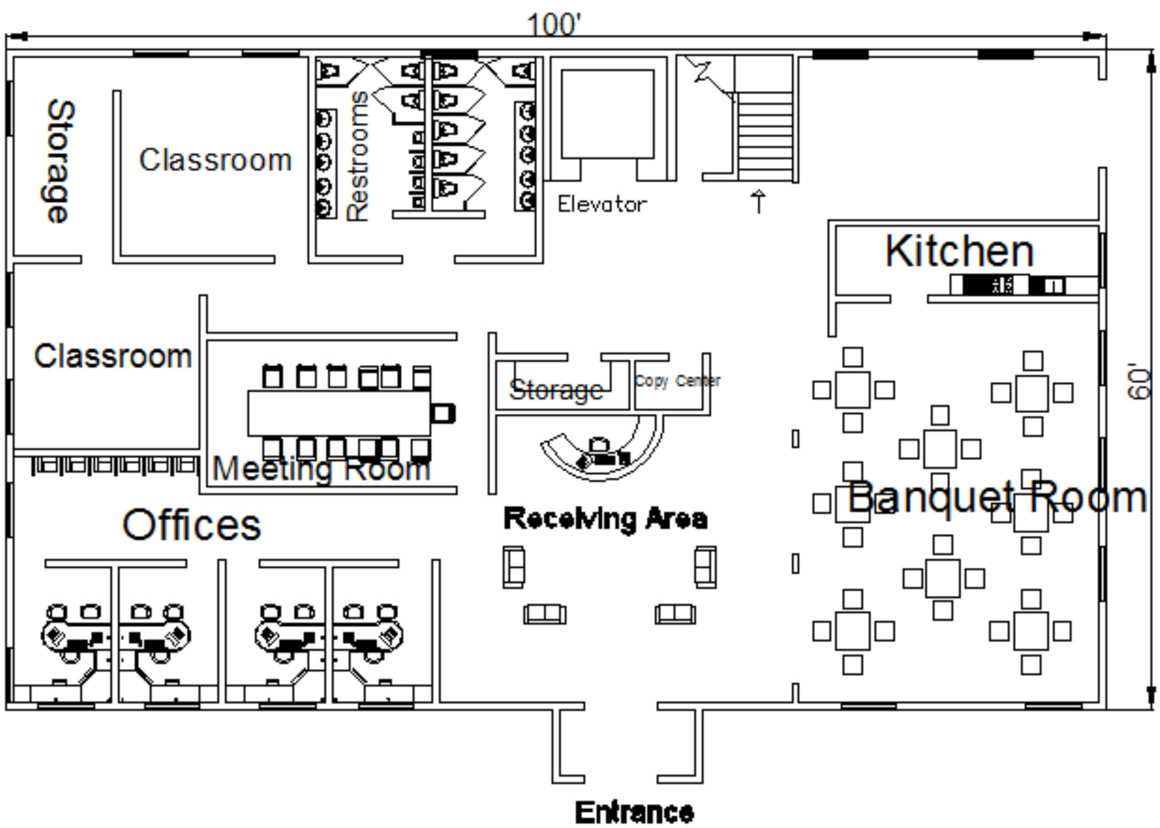


Figure 15 - 1st floor

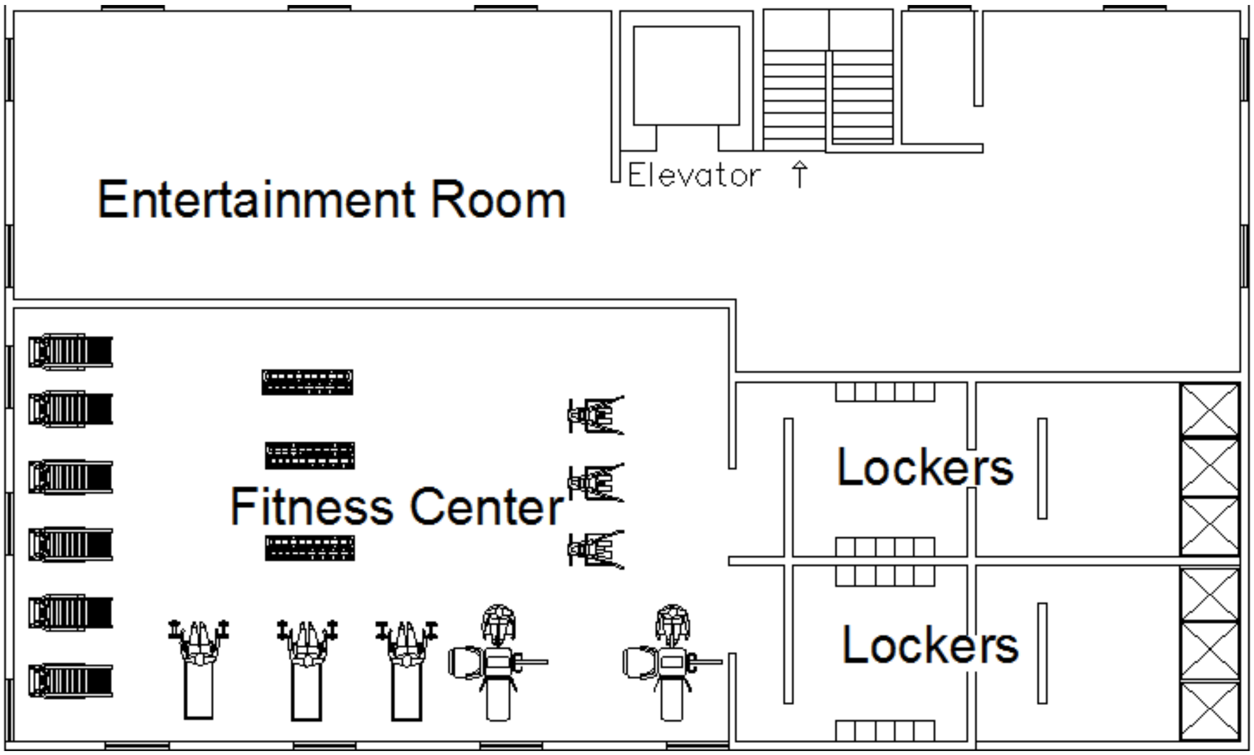


Figure 16 - 2nd floor

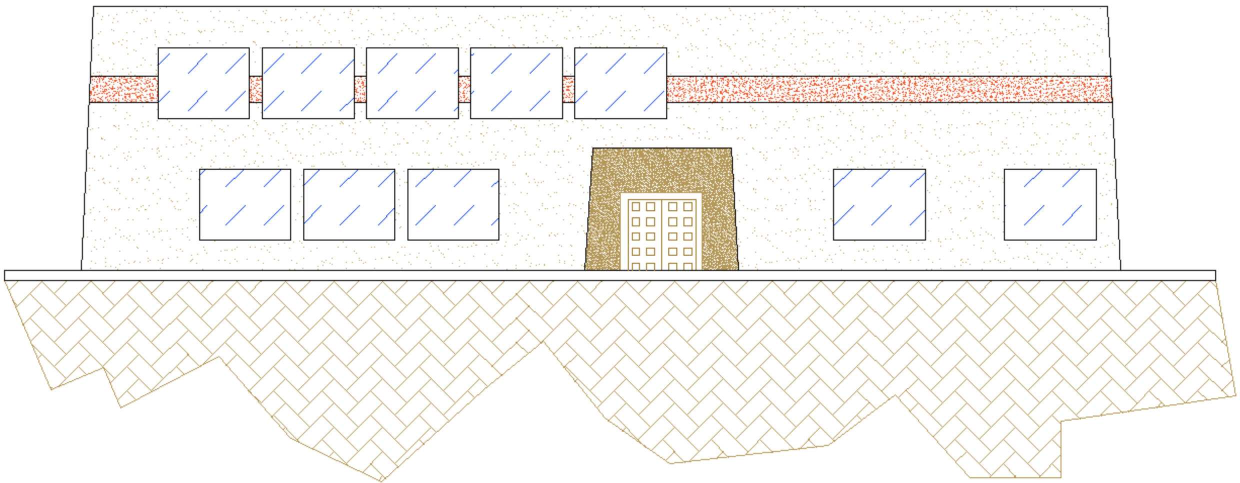
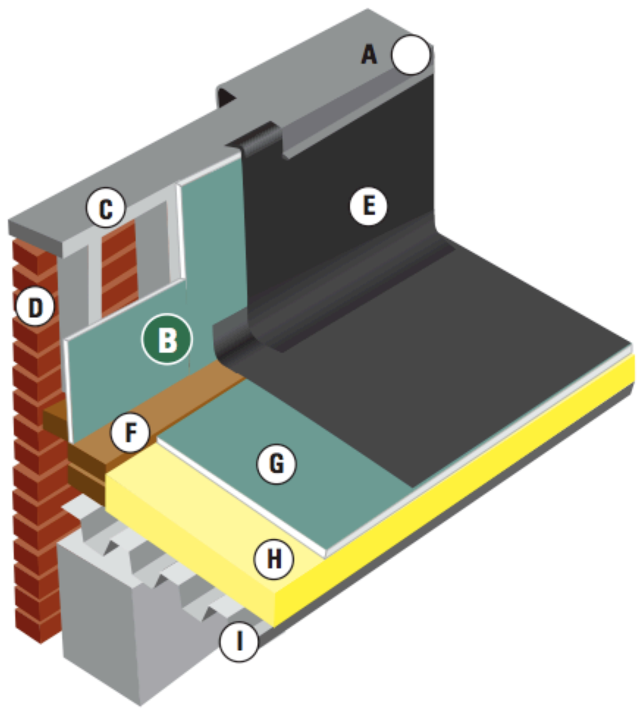


Figure 17 - Front View (AUTOCAD)

Figure 18 - ARCHICAD 3D Rendering

Roof design



A. Wall protection cap

B. Dense deck

C. Parapet wall framing

D. Exterior finish

E. Membrane and three ply felt tar

F. Nailer

G. Dense deck

H. Insulation

I. Metal deck

Walls

The construction of the main building will use different material. The exterior walls will use metal stud for partitions and insulated sheets, an impermeable layer to avoid water coming into the building and in the top of it we will have the finish layer made of stucco. The materials used for the construction of the interior walls are metal studs and the conventional dry wall or sheet rock. The second level Floor needs a 5 in concrete slab and will be supported by I beams and a metal deck strong enough to avoid its deformation while placing the concrete.

Structural Design – Multipurpose Center

The structure of this building is based on a steel structure made with I beams of different sizes. For its design we use different methods to choose the beams. The symmetrical roof allows for an effective design.

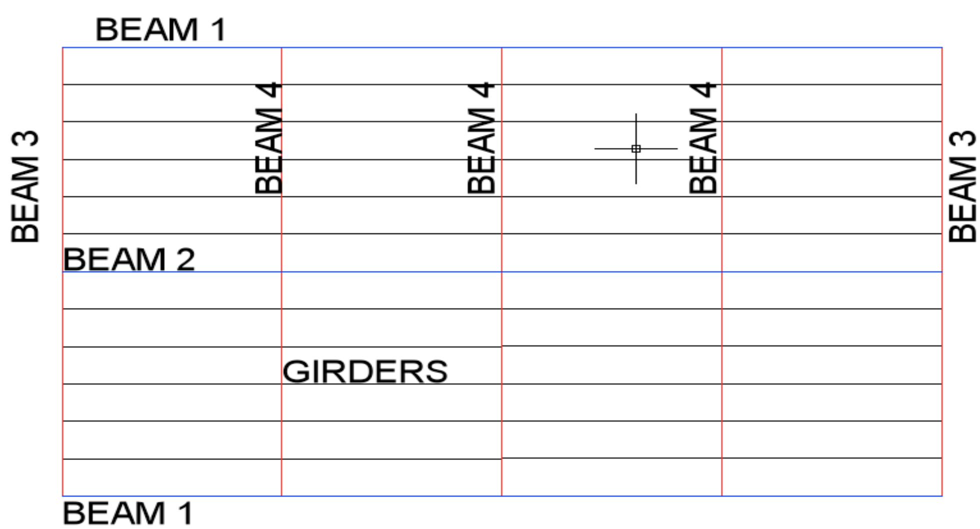


Figure 17- Roof structure

The following table is a excel template used to design the beams on the previous figure using the parameters listed in the table. Table 8 also, displays the results for the moment, deflection, allowed deflection and the factored load. The last row is the final result that the spreadsheet gives us and is the name of the section that we have to use.

Table 8: Beam Design

ROOF BEAM DESIGN				
	BEAMS			
VARIABLES	1	2	3	4
DEAD (PSF)=	14	14	14	14
LIVE (PSF)=	20	20	20	20
LENGTH (FT)=	25	25	30	30
T.WIDTH (ft)=	15	30	12.5	25
Ix (in4)=	199	375	291	612
FACTORED LOAD (kips)=	0.732	1.464	0.61	1.22
Mu (k ft)=	57.1875	114.375	68.625	137.25
DEFLECTION=	0.78	0.82	0.92	0.87
ALLOWED DEFELCTION	0.83	0.83	1	1
SELECTED MEMBER	W14x22	W16x31	W14x30	**W18x40**

As seen in Table 8 the sections are different for each case that we are analyzing but since working with a big project it is better to avoid mistakes and confusion at the job site, using just one section instead of different section. The final design for the roof design structure is the section W18X40 because is the one that will be carry more load and if using it for less load it won’t fail.

Table 9: Girder Design

GIRDERS DESIGN	
VARIABLES	1
DEAD (PSF)=	14
LIVE (PSF)=	20
LENGTH (FT)=	25
T.WIDTH (ft)=	5
Ix (in^4)=	103
FACTORED LOAD (kips)=	0.244
Mu (kips-ft)=	19.0625
DEFLECTION (in)=	0.5
ALLOWED DEFELCTION	0.83
SELECTED MEMBER	**W12x16**

The following figure is the layout used for the analysis of the 2nd floor that will support a concrete slab with a unit weight of 150lb/ft^3.

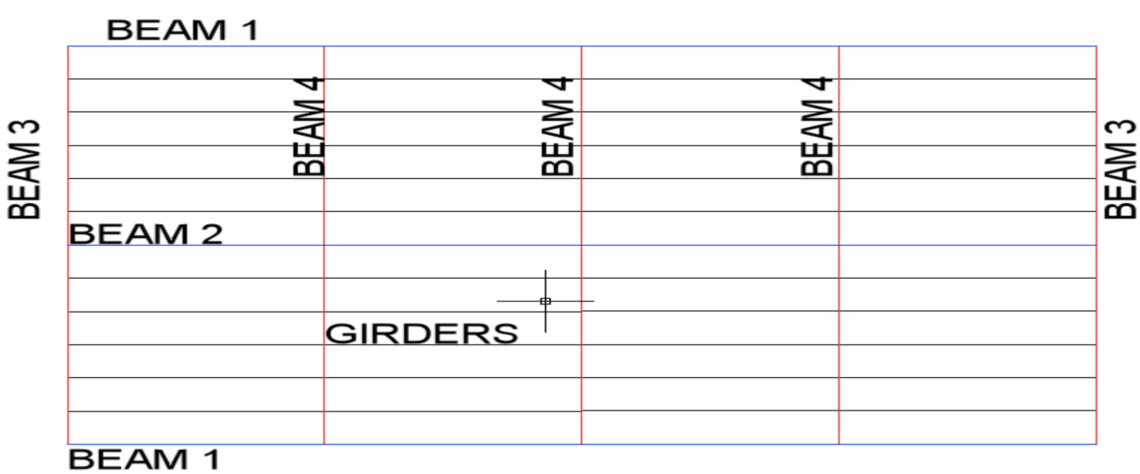


Figure 18 - Floor Structure

Table 10: Beam Design

FLOOR BEAM DESIGN				
	BEAMS			
VARIABLES	1	2	3	4
DEAD (PSF)=	62.5	62.5	62.5	62.5
LIVE (PSF)=	100	100	100	100
LENGTH (FT)=	25	25	30	30
T.WIDTH (ft)=	15	30	12.5	25
Ix (in4)=	984	1830	1330	2850
FACTORED LOAD (kips)=	3.525	7.05	2.9375	5.875
Mu=	275.390625	550.78125	330.46875	660.9375
DEFLECTION=	0.75	0.81	0.96	0.9
ALLOWED DEFELCTION	0.83	0.83	1	1
SELECTED MEMBER	**W21x50**	**W24x68**	**W21x62**	**W27x84**

Table 11: Girder Design

GIRDER DESIGN	
VARIABLES	1
DEAD (PSF)=	62.5
LIVE (PSF)=	100
LENGTH (FT)=	25
T.WIDTH (ft)=	5
Ix (in4)=	375
FACTORED LOAD (kips)=	1.175
Mu (k ft)=	91.79
DEFLECTION=	0.66
ALLOWED DEFELCTION	0.83
SELECTED MEMBER	W16x31

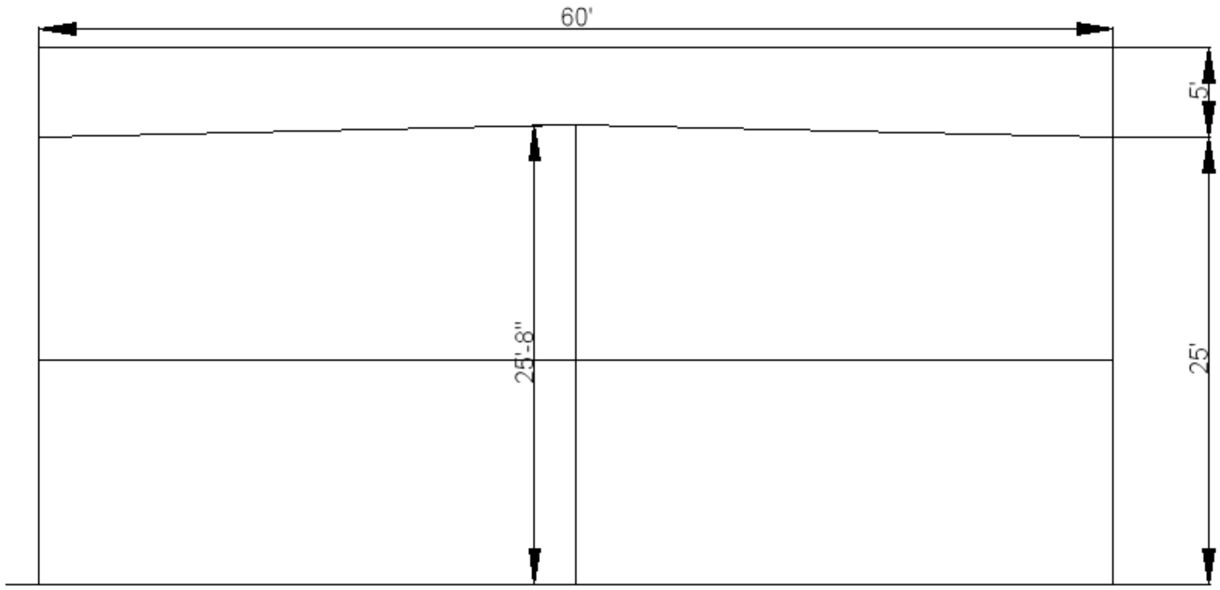


Figure 18- Heights

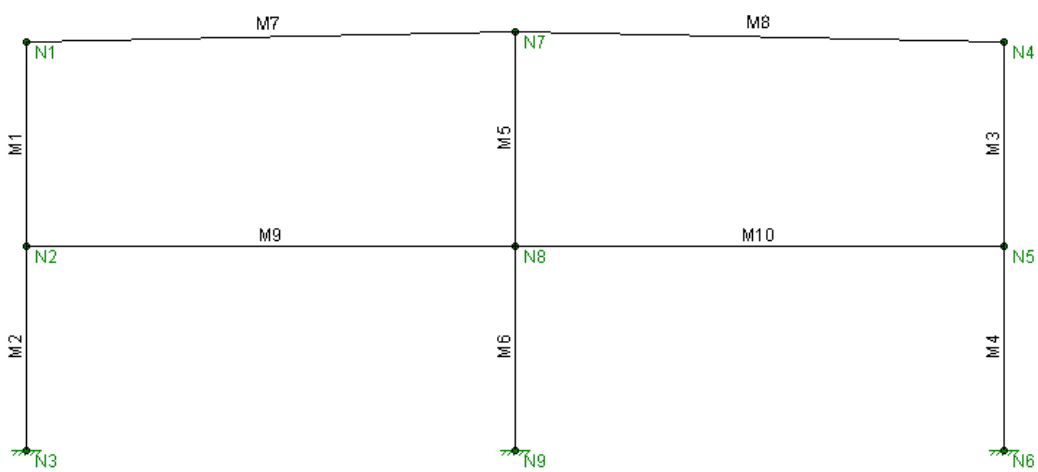


Figure 19- RISA model

The previous figure is related to a 2D model on RISA and we can set up the loads and the members that we already design in the previous sections. RISA analyze all the members and also suggest the members that are best for the load cases. In table 12 we have the current shapes that we are using and the ones suggested for RISA.

Table 12-Suggested shapes

SUGGESTED SHAPES		
MEMBER	CURRENT	SUGGESTED
M1	W14X68	W10X39
M2	W14X82	W14X43
M3	W14X68	W10X33
M4	W14X82	W12X40
M5	W14X68	W8X24
M6	W14X82	W8X35
M7	W18X40	W10X49
M8	W18X40	W10X49
M9	W27X84	W14X99
M10	W27X84	W24X104

The process to analyze the structures with RISA is easy and consist only of introducing the loads and combinations, the type of structure and the sections at the end RISA evaluates the members and displays the results as the member forces, stresses and deflections.

Gymnasium

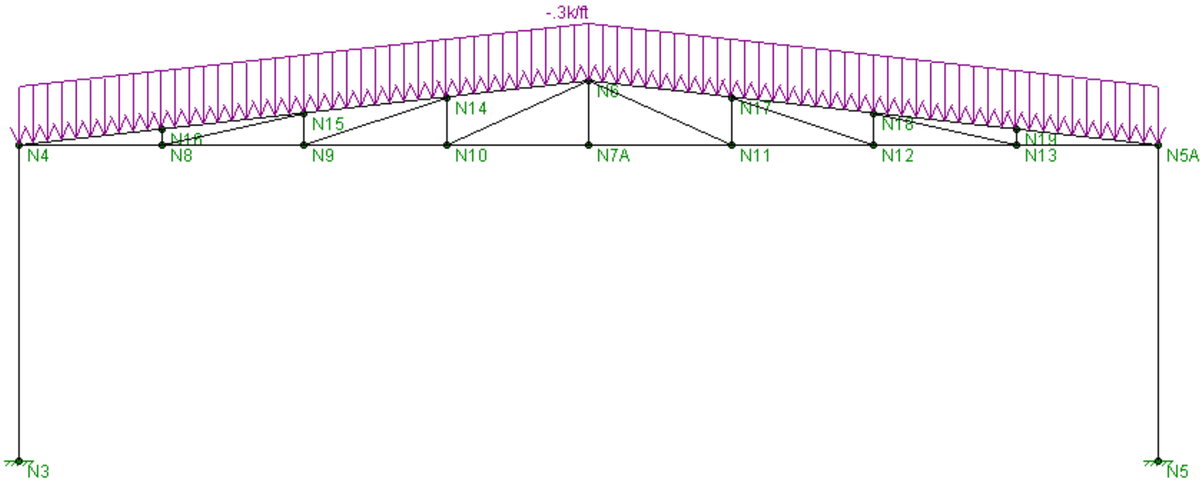


Figure 20-RISA model

Table 13-Suggested shapes

SUGGESTED SHAPES		
MEMBER	CURRENT	SUGGESTED
M1	W14X68	W10X49
M2	W14X68	W10X49

Building Occupancy

To calculate the occupant loads for each building, the code states to use a factor of 15 ft squared per occupant for assembly rooms with no fixed seats and a factor of 20 to 40 ft squared for assembly rooms like, educational rooms, courtrooms, etc. Calculating the occupant load using the total area of the buildings:

Gymnasium - 120'x90' = 10800 ft^2 / 15 ft^2 per occupant = 720 persons

Multipurpose - 100'x60' = 6000 ft^2 / 20 ft^2 per occupant= 300 persons

Police Station - 144'x60' = 8640 ft sq^2 / 40 ft^2 per occupant = 216 persons

Cost Analysis

The cost analysis for the entire project was obtained from the RS Means Residential Square Foot Cost Manual, in which base cost tables are prepared as costs per square foot of constructed area. The total cost for the buildings came out to be 5.7 million dollars.

Table 12: Unit Cost

BUILDING	AREA	UNITS	UNIT COST	TOTAL
POLICE STATION	8700	S.F	183.00	$ 1,600,000.00
MULTIPURPOSE CENTER	12000	S.F	212.00	$ 2,600,000.00
GYMNASIUM	10800	S.F	138.00	$1,500,000.00
			TOTAL	$5,700,000.00

Work Cited

U.S. DOE Energy Efficiency and Renewable Energy (EERE) Home Page. Web. 04 May, 2011. <http://apps1.eere.energy.gov>.

"Passive Solar Heating | Whole Building Design Guide." *WBDG - The Whole Building Design Guide*. Web. 04 May 2011. <http://www.wbdg.org/resources/psheating.php>.

"Passive Solar Building Design." *Wikipedia, the Free Encyclopedia*. Web. 04 May 2011. <http://en.wikipedia.org/wiki/Passive_solar>.

Steel Joist Institute - Home. Web. 04 May 2011. <http://steeljoist.org/>.

"Georgia-Pacific Building Products Home Page, Building Materials, Building Products, Building Materials Manufacturer, Residential Building Materials, Building Materials for Commercial Construction." *Georgia-Pacific Home*. Web. 04 May 2011. <http://www.gp.com/build/>.

Leet, Kenneth, Chia-Ming Uang, and Anne M. Gilbert. *Fundamentals of Structural Analysis*. Boston: McGraw-Hill Higher Education, 2008. Print.

Steel Construction Manual. Chicago, IL: American Institute ofSteel Construction, 2007. Print.

Contractor's Pricing Guide: Residential Square Foot Costs. R S Means, 2009. Print.

Patterson, Terry L. *Illustrated Building Code Handbook*. McGraw-Hill Professional, 2009. Print.