NORTHERN ARIZONA UNIVERSITY
College of Engineering, Forestry & Natural Sciences

The International Pavilion Expansion

CENE 486C: Capstone Design

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Date: December 13, 2016

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Acknowledgements

This project would not be accomplished without the guidance of our two technical advisors, Dr. Robin Tuchscherer and Prof. Kai Kaoni for providing technical advice.

We would also like to thank to our clients, Mr. Kurt Kindermman and Mr. Nick Yuen from Meyer Borgman Johnson Engineering for the guidance and recommendations throughout the project.

The team would like to extend thanks to Prof. Alan Francis for providing architectural expertise needed for the project.

The team would additionally like to express our gratitude to Mr. Sam Heffelfinger of Peak Engineering in assisting the team with the site design process.

Finally, the team would like to thank our instructor, Dr. Bridget Bero for all the help throughout the project.

1.0 PROJECT DESCRIPTION

1.1 Project Purpose

The primary purpose of the project is to choose a site location for an expansion of the existing NAU International Pavilion and to design an additional building. The expansion is estimated to be 15,000 square feet. The space usage is listed below:

- 5000 square feet for classrooms
- 2000 square feet for offices
- 2500 square feet for student community space
- 3000 square feet for student study areas
- 400 square feet for the mechanical and electrical room
- 2000 square feet for miscellaneous use

Some of the building space may be dual purpose and allow for a reduced area.

1.2 Project Background

The existing NAU International Pavilion is located on central campus of Northern Arizona University (NAU). It is 10,000 square feet and it features student lounge space, a game area, and event space. The popularity of the existing facility has created a need for substantially more space. Therefore, Meyer Borgman Johnson Engineering requested Synergy Engineering to propose an expansion plan for an additional building at the vicinity of the existing building. The new location of the expansion would be either north, south, or west of the existing building. The east side of the building could be an option if the expansion spread over the pedestrian walkway. Figure 1.1 shows the location of International Pavilion in Flagstaff. Figure 1.2 shows the location of the International Pavilion and the surrounding buildings. Figure 1.3 shows the north elevation view of the building.

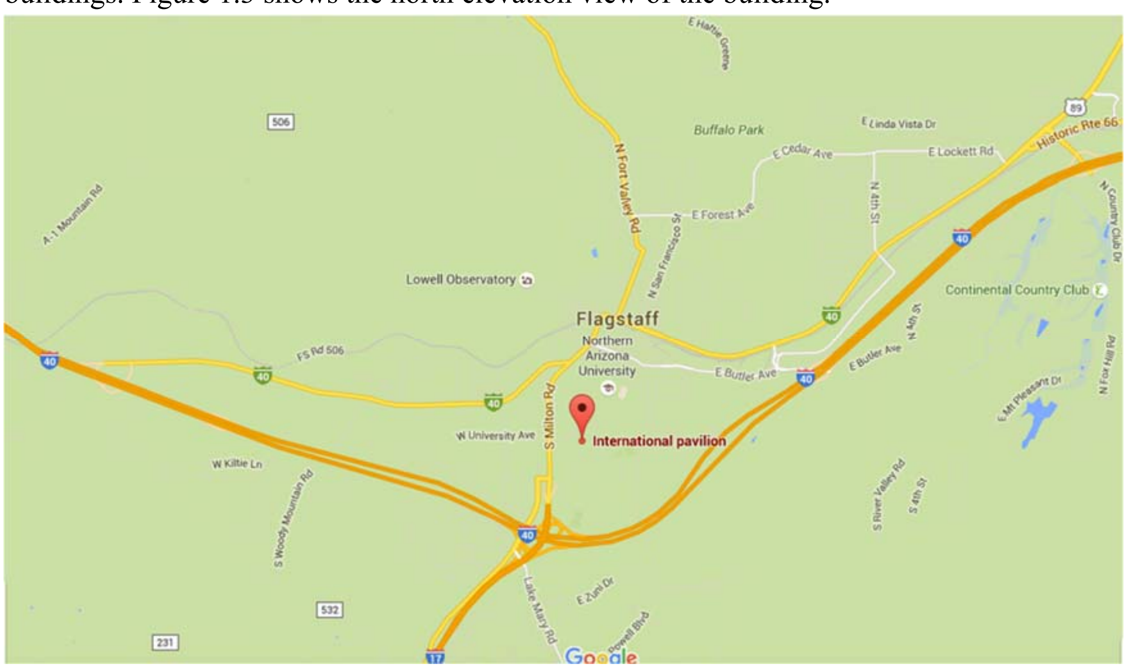

Figure 1.1 Location of International Pavilion building on Flagstaff map [1]

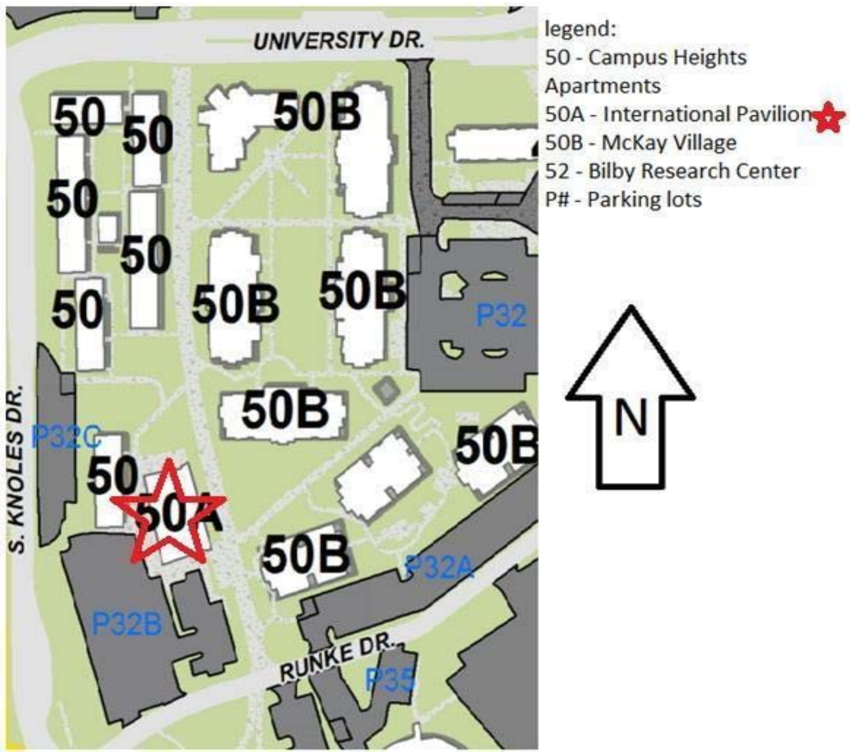

Figure 1.2 Location of International Pavilion building and the surrounding buildings [2]

Figure 1.3 North elevation view of the existing building (looking south)

2.0 SITE SELECTION

There are four potential site locations, which are in the south, east, north, and west of the existing International Pavilion (Building 50A) as shown in Figure 2.1. The four locations are indicated in the figure below but they are not drawn to scale.

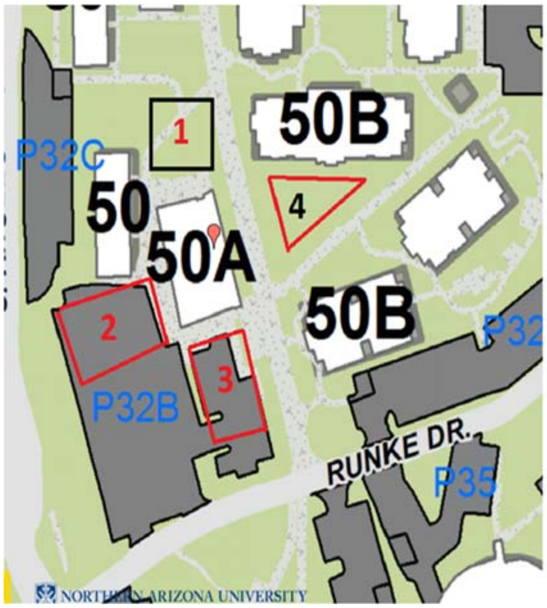

Figure 2.1 International Pavilion and four potential sites [2]

A total of seven items were considered for each site location in the decision making process. The items considered were: site elevation changes compared to the existing building, area of footprint, site utilities relocation, connection to existing building, relocation of sidewalk, removal of tress, and parking spaces lost. Table 2.1 below shows the detailed considerations for each site. EL stands for electrical line and WL stands for water line.

Table 2.1 Items considered for four sites

Items Considered	Considerations			
	Site 1	Site 2	Site 3	Site 4
Differential site elevation	-10 ft	-2 ft	+2 ft	-15 ft
Area of footprint available	10,520 sf	10,550 sf	9,020 sf	8,720-13,190 sf
Existing Utilities	Relocate detention basin, EL, 2WLs	Relocate EL and 2WLs	Relocated EL	Need no relocations
Connection to existing building	The existing pathway was considered to see if there is the potential to utilize it in the connection of the two buildings.			
Relocation of sidewalk	The existing sidewalk on the map was inspected to see if any relocation is needed. Site 4 requires a minor relocation of the sidewalk, and the other three sites requires some sorts of major sidewalk relocation.			
Removal of trees	11	0	10	9
Parking spaces taken	0	20	22	0

The following decision matrix, Table 2.2, was created to help select the best option based on the considerations explained above.

Table 2.2 Decision Matrix for site selection

Items considered	Weight	Site 1	Site 2	Site 3	Site 4
Site elevation relative to the International Pavilion	30%	6	8	8	5
Area of the footprint	30%	7	7	7	9
Site utilities	15%	4	5	8	10
Connection to existing building	10%	7	5	8	7
Relocation of sidewalk	5%	6	6	7	8
Removal of trees	5%	5	10	6	7
Parking Spaces Taken	5%	10	6	5	10
	100%	62.5%	68.5%	74.0%	76.5%

(Scale: 1-10, 1: Bad, 10: Good)

Bad	
Neutral	
Good	

As it can be seen in the table, Site 2 and Site 3 are the better choices. The team then discussed the decision matrix and the items considerations table with the client. The client chose Site 3 because of its relatively small elevation changes and least disruptive to existing residents in Campus Heights. Also, Site 3 has rectangular shape for a maximum use of space and it is close to the existing international building. Therefore, Site 3 was chosen for the new building. Based on the topography around Site 3, the team later decided to widen the building footprint, as can be seen in Figure 2.2. As part of the side walk relocation of sidewalk to Site 3, egress will be considered to link to the existing sidewalk.

3.0 SURVEYING

The team surveyed around the existing building to obtain the surrounding topography. 200 points were surveyed, which included the concrete boundary, gravels, utilities (water valves, reclaimed water valves, sewer, storm drains), fire hydrants and trees. The first control point used was the same as the point used from the existing pavilion survey. The team added another three control points in order to survey all the required points. After surveying, the team inputted the points into the Civil 3D and created a topographic map. The topographic map of the site can be found in Figure 3.1 below.

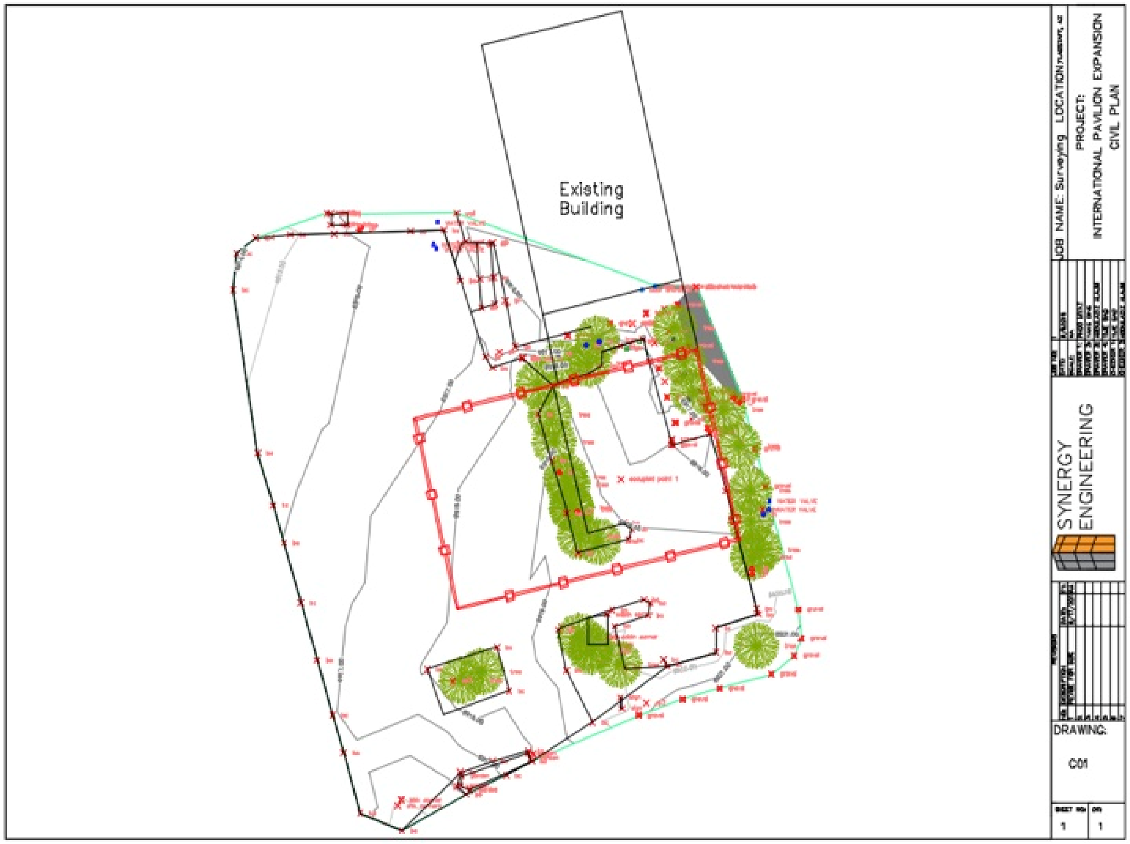

Figure 3.1 Topographic Map of the Site

3.1 Civil Site Plan

The civil site plan was developed based on the surveying file and according to Americans with Disabilities Act (ADA). Connection with the existing building is provided with a ramp without handrail and a set of stairs. Connection with the existing pathway is also provided with a ramp without handrail. The connection with the parking lot on the west side of the proposed building is achieved by a set of stairs. Ramp with handrails shall be designed between 5% -8.33% grade. Ramp without handrails shall be designed between 2%-5% slope. Ramps shall have level landings at the bottom and top of each run. Landing shall be designed at a maximum of 2% grade in all direction [10]. All of which are satisfied as shown in the site plan below. There is also a 10 ft apron surrounding the proposed building, providing a maximum of 2% slope. General parking is located on the west side of the proposed building. ADA parking is located on the south side of the proposed building.

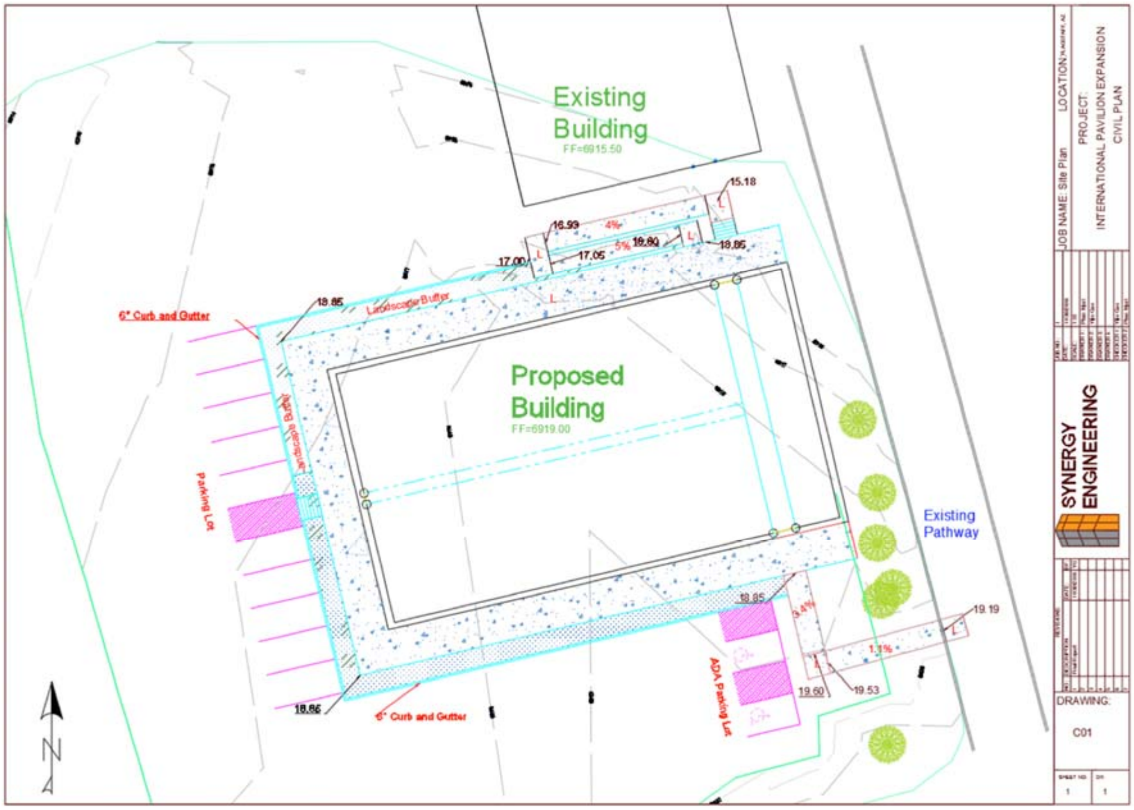

Figure 3.2 Civil Site Plan

4.0 DESIGN DOCUMENTS REVIEW

4.1 Geotechnical Reports Review

Speedie & Associates prepared the geotechnical reports for the vicinity of the International Pavilion in 2013 [3]. They did the soil borings and made recommendations for the International Pavilion. The team reviewed the existing soil report for the International Pavilion to obtain the information that is relevant to the expansion project. The soil profile for new building is as shown in the Figure 4.1. There is no groundwater present at the site. The area is located in a seismic zone that is considered to have low to moderate historical seismicity. The foundations may bear on properly compacted engineered fill at a minimum depth of 30 inches below finished exterior grade. The allowable bearing capacity of 3,500 psf can be utilized for design and the bearing capacity refers to the total of all loads, dead and live, and is a net pressure. It may be increased one-third for wind, seismic or other loads of short duration. As continuous wall footings and isolated rectangular footings within widths of 16 and 24 inches respectively are recommended in the soil report, the team will choose one and design the footing. Continuous footings and stem walls should be reinforced to distribute stresses arising from small differential movements, and long walls should be provided with control joints to accommodate these movements. Reinforcement and control joints are suggested to allow slight movement and prevent minor floor slab cracking. Lightly loaded interior partitions (less than 800 plf) may be supported on reinforced thickened slab sections (minimum 12 inches of bearing width). [3]

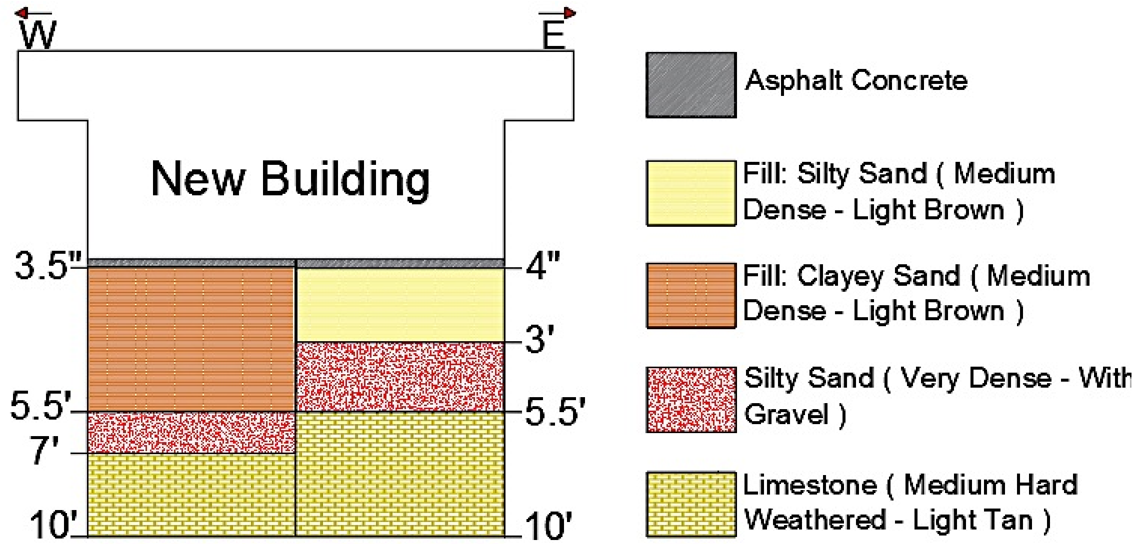

Figure 4.1 Soil Profile for new building

4.2 NAU Technical Standards Review

NAU Technical Standards is an internal document that applies to NAU properties only. The requests of building code variance, the functions of proposed building including building entrance, flood prevention, ramps and curb ramps are discussed in the NAU Technical Standard. Also, if any conflicts occur in the design guidelines or in the Technical Standards, the team shall follow the applicable building codes. Applicable sections are:

- *The requirements in this document do not supersede any applicable building codes. These requirements are in addition to all applicable codes, ordinances, statutes, regulations, and laws. If there is a conflict with any requirements in the design guidelines or in the Technical Standards, the applicable building codes take precedence* [4].
- *Requests for variance shall be evaluated by the NAU Fire Marshal (NAUFM) staff and NAU Building Official (NAUBO) staff, to ensure the proposed design, use, or operation satisfactorily complies with the intent of the IFC, IBC with related codes and NAU Technical Standards, as adopted by Northern Arizona University (Building Code Variance Requests)* [4].
- *The main entrance of a building shall be universally accessible via a single route. All building entrances shall be accessible - including employee entrances or entrances other than the main entrance (Section 2 - Accessible Routes- Building Entrances)* [4].

- *Where changes in elevation are encountered (including courtyards and open spaces) full consideration shall be given to university accessible design that addresses elevation change.*
- *Where grades/space allow, sloped sidewalks (slope 1:20 or flatter) shall be used to overcome changes in elevation.*
- *Ramps (defined as anything steeper than 1:20 slope) shall have a maximum of 1:16 slope (Section 2 – Accessible Routes- Ramps)* [4].
- *Curb ramp slopes shall be 1:12.*
- *Concrete aprons shall be provided at the bottom of the curb ramps.*
- *Curb ramps within sidewalks (parallel to the path of travel) shall be provided with a 1:16 slope.*
- *The University's standard for detectable warning surfaces is truncated domes in a contrasting color.*
- *The depth of detectable warning surface in the direction of travel shall not exceed 24 inches (Section 2 – Accessible Routes - Curb Ramps (curb cuts))* [4].
- *Proposed building ground floor elevations and any apertures into the building should be 1 feet or more above the 100-year floodplain. Sunken access ways or patios leading to building levels below the natural grade of the site are not permitted when adjacent to a 100-year floodplain, and discouraged in other areas. Soil should be graded so that water drains away from the building at a minimum of 2%, subject to other site criteria, such as accessibility. Elevations of underground utilities shall be considered in the grading layout (Section 6 - General Storm Water Guideline -Flood Prevention)* [4].

4.3 The City of Flagstaff Engineering Standards Review

The City of Flagstaff Engineering Standards covers the items in the soil report, mapping requirements, easement requirements, fire access requirements, and context sensitive design requirements. However, it is not mandatory for NAU to follow the City of Flagstaff Standards because NAU is a state property. The team reviewed the city standards to check for its discrepancies with the NAU Technical Standards and the International Building Code. Also, it serves as a guideline for things to be aware of in the design process. Applicable sections are:

- *The soils engineer shall address the following problems: shrink-swell potential, ground water, wetness, depth of rock, erosion, flood hazard, allowable velocity in earth drainage channels, bearing capacity, corrosion potential, organic layers, ease of excavation, and other pertinent issues. Correlated "R-values" that are used in the pavement structural section design should be determined from soil samples containing the highest amount of clay (PI values).*
- *If higher PI values are reported but not considered in the determination of the correlated R-values, the engineer shall provide recommendations for removal of these materials, including specific areas of removals that must be reflected on the approval civil plans.*

- *If cut and fill slopes are proposed which exceed those allowed by City standards and/or Flagstaff City Code Title 4, Building Code, a slope stability analysis establishing maximum stable slope grades must be included (Section 13-05-001-0002 Soils Report) [5].*
- *A complete boundary survey based upon fieldwork shall be performed prior to submittal of the preliminary plat, and documentation of said survey shall be included with that submittal.*
- *Mapping (including contours) of the site and adjacent areas shall be sufficient to show clearly the influence of surrounding conditions (topography) as well as the influence of the proposed development on surrounding conditions.*
- *Contour interval shall be one foot or two feet, depending on the slope of the ground and the judgment of the Engineer or Land Surveyor (Section 13-02-001-0001 Mapping) [5].*
- *The City of Flagstaff Utilities Division requires safe and quick access to all city water and sewer mains at all times in order to repair main breaks, install taps, and perform preventive maintenance. For this reason, City of Flagstaff water and sewer mains shall be constructed in streets within the public right-of-way. Where possible, water shall be 10 ft. north or east of centerline and sewer on the centerline. Water mains in easements create access problems and will not be permitted except under the following special circumstances.*
- *When a water or sewer main is located adjacent to a building, the main shall be offset a minimum of ten (10) feet from the building in a minimum twenty (20) foot easement (Section 13-09-001-0008 Utility Alignment and Easement Requirements) [5].*
- *A fire access drive 20 feet in width minimum, with 13 feet 6 inches of overhead clearance will be required within 150 feet of all buildings. 1. Fire access drives 26 feet in width minimum (measured from the eave or flat roof parapet) will be required for structures 20 feet high or greater. 2. Access for up to two single-family dwelling units may be supplied by a 10-foot wide driveway meeting all Fire Department requirements.*
- *If the access drive exceeds 150 feet in length and is not looped, an approved turn-around shall be supplied. (Section 13-13-004-0001 Fire Access) [5].*
- *Baseline Design Theme Preservation of, and compatibility with, Flagstaff's natural environment is the baseline design theme. Landscape designs shall maximize the amount of land retained in its natural state. Projects shall be designed to preserve and protect native vegetation, particularly existing trees and attractive natural features. New landscaping for rights-of-ways shall seek the restoration of the natural environment disturbed by construction. The baseline theme may vary depending on location and use. (13-18-002-0003.1 Context Sensitive Design) [5].*

4.4 International Building Code (IBC) 2012 Review

The team used the International Building Code 2012 as a backbone for the structural design portion of the proposed building. Applicable sections are:

- *The proposed building height was classified as type I or II (Chapter 5 General building heights and areas: Table 503 in Section 602) [6].*
- *The building occupancy was classified as Businesses Group B. (Chapter 5 General building heights and areas: Section 302) [6]*
- *Building element shall have fire-resisting material as shown below:*
- *Primary structure frame 2 hours*
- *Bearing wall 2 hours*
- *Non-bearing wall is separated by distance, then fire resisting shall need to restrain 1 hour*
- *Interior 0 hour*
- *Floor 2 hours*
- *Roof 2 hours*
- *If building is: Type I: h=160 ft, A=Unlimited, 11 stories*
  Type II: h=55 ft, A=23,000 ft2, 3 stories (h=height, a=area)
  (Chapter 5 General building heights and areas: Section 602)
- *Yards and other spaces for any system that belongs to the buildings shall be included in building perimeter. (Chapter 5 General building heights and areas: Section 5.7) [6].*
- *Table 1604.3 of the Structural design chapter illustrates the deflection limit in members, which should not be exceed in designing. The table demonstrates the limits for roof members, floor members, and exterior walls and interior portions. This table also provides the limits due to snow, wind, live, and dead loads [6].*
- *The risk category, which requires in the structural elements design, was classified as category III based on the occupancy. the category was chosen based on the listed criteria:"Building and other structures containing adult education facilities, such as colleges and universities, with an occupant load greater than 500" (Chapter 16 Structural Design: Table 1604.5).*
- *Load Combinations formulas will be used in the required load calculations. These formulas include dead, live, snow or rain, and wind loads. (Chapter 16 Structural Design: Table 1605.2) [6].*
- *Minimum live loads and the reduction factors can be found in Table 1607.10.1 and Table 1607.10.1. The reductions factors can be used to reduce loads that structural members have to support.*
- *Due to the weather of flagstaff, snow load has to be considered. Section 1608 will provide the minimum snow load that shall be consider in the design.*
- *The structural design portion will be based on the formulas and tables from ASCE 7-10. (Chapter 16 Structural Design) [6].*
- *Chapter 18 Soil and foundations, is a guidance of what kind of foundation to select, along with any necessary additions to the foundation [6].*

The building design took into account all of the items discussed in this section.

5.0 STRUCTURAL DESIGN

5.1 Building Layout Options

In order to start the design process, a building shell needed to be established. After a building shell is selected, a framing plan of the building can be determined. For this task, the team designed four different shell models with a purpose of fulfilling the requirements as requested by the client:

- Classroom – 5000 sf (800-1000 sf)
- Office – 2000 sf
- Student community space – 2500 sf
- Student study area – 3000 sf
- Mechanical / electrical – 400 sf
- Misc – 2000 sf
- Building height of 40 ft.
- Distance between the existing and proposed building is minimum 30'.

The first building shell is as shown in Figure 5.1. It was inspired by an Egyptian pyramid shape and its stability throughout the thousands of years. [7].

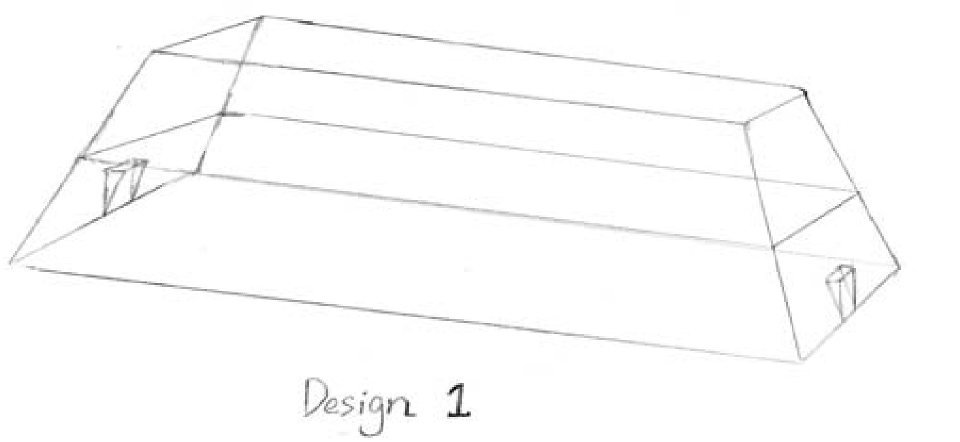

Figure 5.1 Building Shell Option 1

Figure 5.2 below shows the second proposed building shell. The shell basically mirrors the rectangular shape of the existing pavilion, but with an added open area on the second floor. This design provides more natural light to the space and more space for people to socialize. In addition, the shape of the shell will maximize the wind energy and solar energy potential. For example, windmills can be installed on top of the left side building, and solar panels can be mounted on the windows of the building.

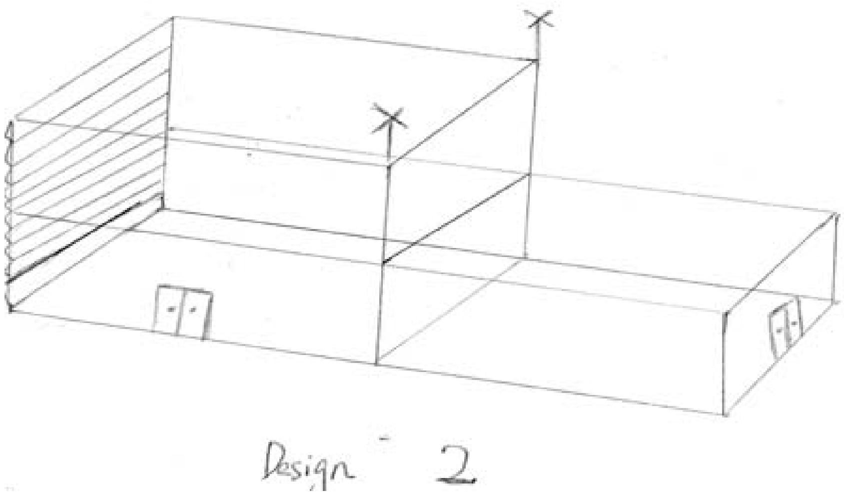

Figure 5.2 Building Shell Option 2

The concept for third building shell was based on a tradition Chinese dwelling, the Fujian Tulou, to incorporate the cultural exchange idea, to attract attention, and to make it easier to be recognized among the neighboring buildings. The Fujian Tulou are Chinese rural dwellings unique to the Hakka in the mountainous areas in southeastern China [8]. They were mostly built between the 12th and the 20th centuries. It is usually a large, enclosed and fortified earth building, most commonly rectangular or circular in configuration, it can house up to 800 people. Smaller interior buildings are often enclosed by these huge peripheral walls which can contain halls, storehouses, wells and living areas, the whole structure resembling a small fortified city [8]. The below figure shows the design of the building based on the idea of the Fujian Tulou.

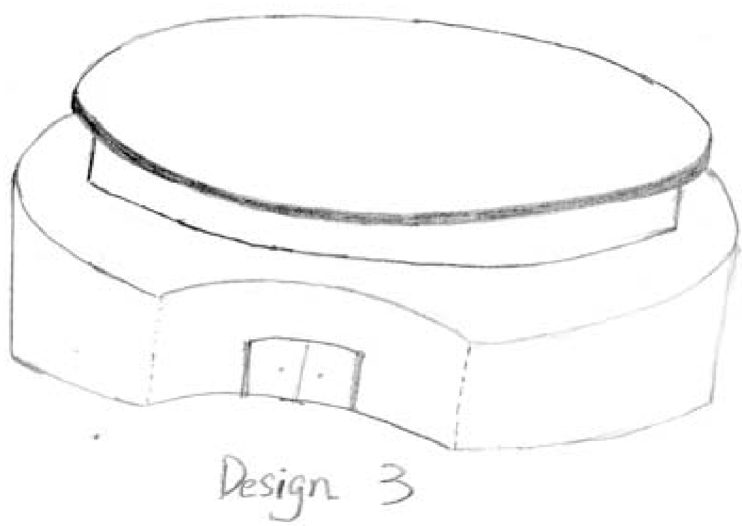

Figure 5.3 Building Shell Option 3

The fourth proposed building shell shown in Figure 5.4 and Figure 5.5 was designed after the team discussed with Professor Francis. It utilizes the simple rectangular shape and a sloped curtain wall on the south side of the building. It has a simple shape, which makes it easier to incorporate energy-saving, and environmental ideas.

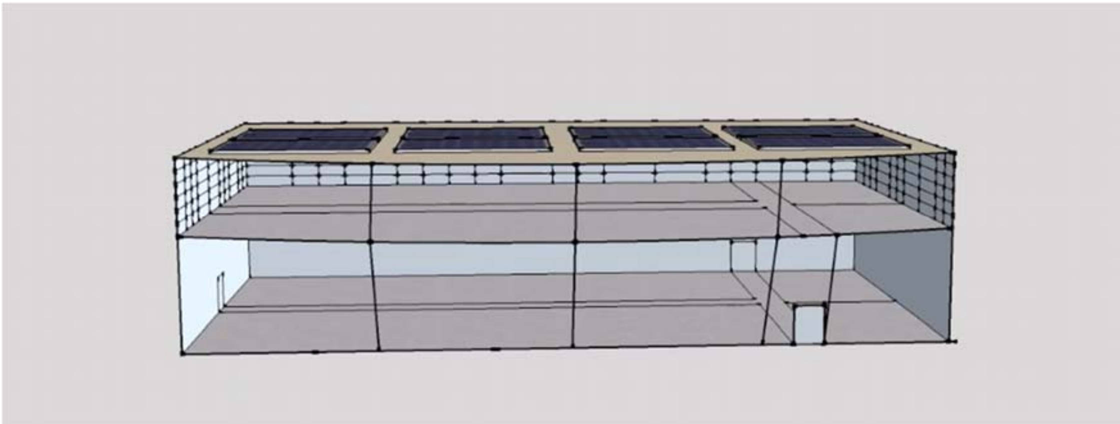

Figure 5.4 Building Shell Option 4 (front view)

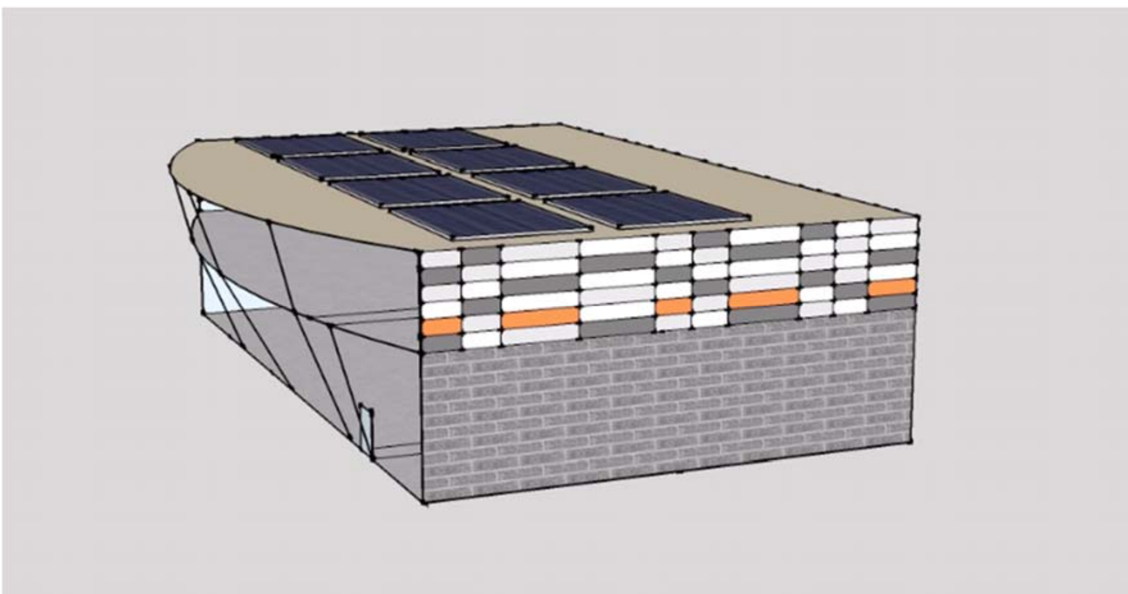

Figure 5.5 Building Shell Option 4 (side view)

The team did not make a decision matrix in selecting and refining the final building layout due to the objective of coming up with a basic building layout design and the time constraint. The five design principles that were used in establishing the final design were:

- Culture Exchange
  - As International Pavilion is a dynamic event destination for all the students in NAU, it allows different people from different parts of the world to gather, interact with each other, and exchange their cultures.

- Energy Saving building
    - The building will need to provide alternative green energy solutions along with providing an efficient heating and cooling systems.
- Connection with the existing building
    - As the new building is the expansion of the existing International Pavilion, the two buildings need to connect in some ways.
- Have all the necessary spaces
    - This means that the required spaces should all fit in the proposed design.
- Central innovation side of Campus as indicated in NAU Master Plan
    - This principle focus on the design and it should be creative and modern as the NAU ambition towards the future of this section of the campus.

In Option 4, the first and fourth principle was achieved as shown in the floor plan in Figure 5.6. It provides an adequate space for the socializing and meetings. In order to be an energy-saving building, the team will design the structural frame to carry the solar panels loads on the roof. Also, one of the reasons to choose angled curtain wall is to provide passive heating in the wintertime and to prevent excessive heat entering during the summer days. Due to the distance between the existing building and the proposed one, the team would recommend a covered sidewalk between them to provide open air social areas during the summer days, and prevent the accumulation of excessive snow during winter. Finally, the building shell is an innovative design and requires structural cantilever to complete the design, which satisfy the challenges set forth in the NAU Master Plan.

After establishing Option 4 as the final design, the floor plan was created according to the space usage provided by the client. The floor plan can be seen below in Figure 5.6.

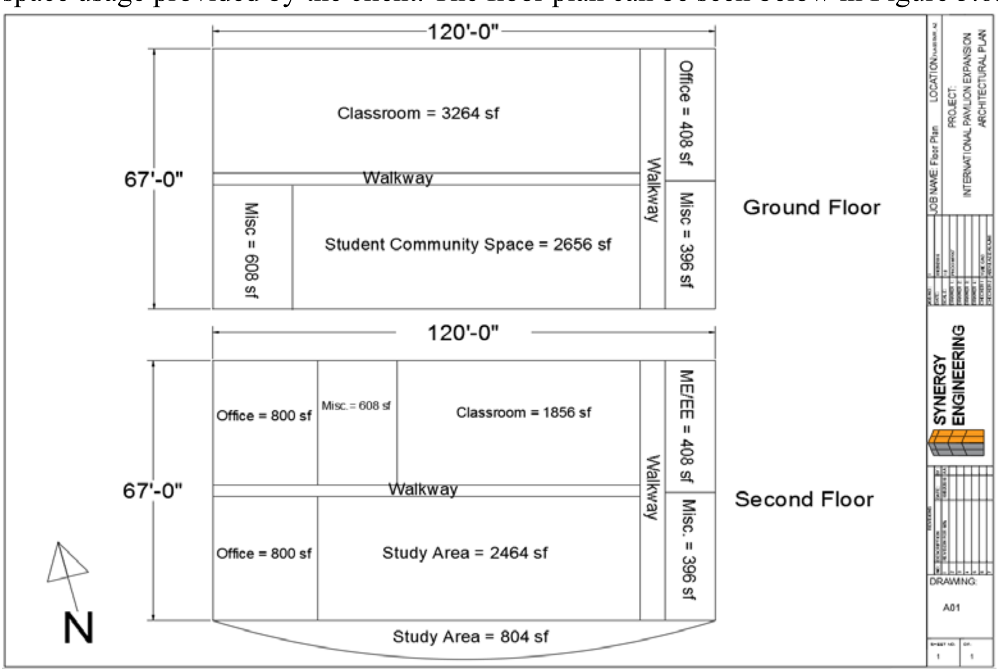

Figure 5.6 Floor Plan

The proposed building elevation views can be seen in Figure 5.7. There are entrances on the north, south, and west side of the building. There are also windows on the north and east side.

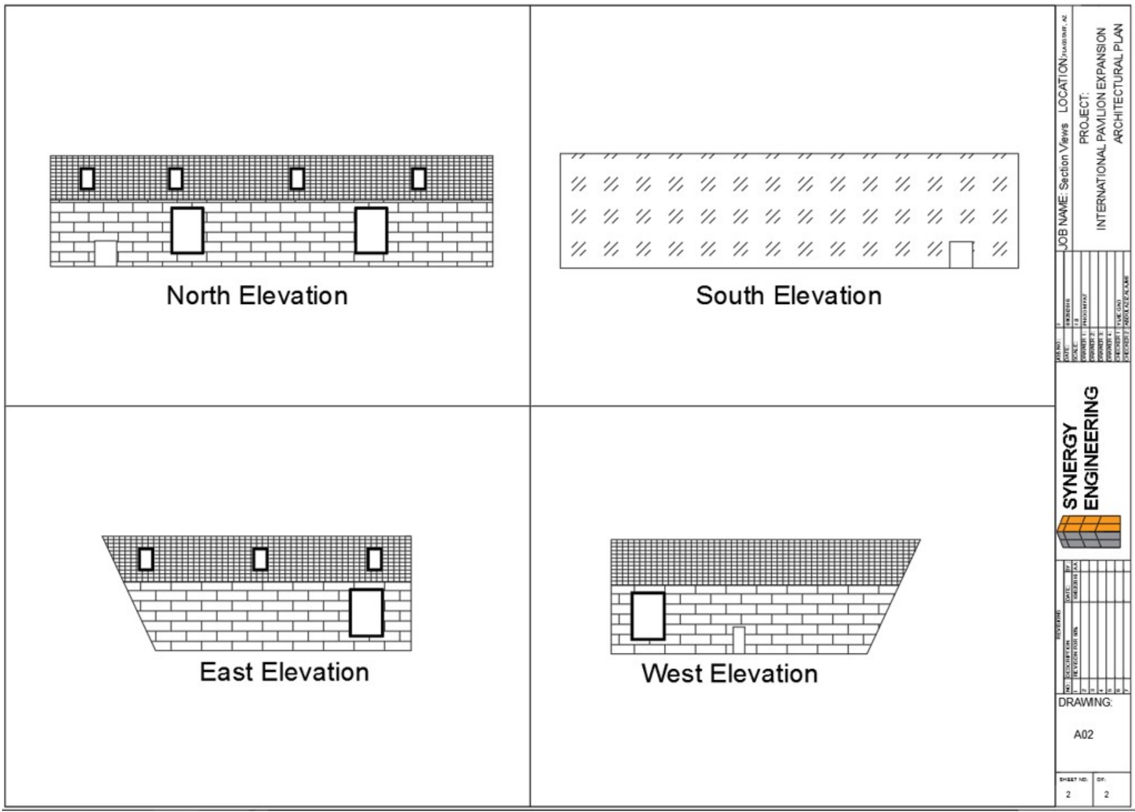

Figure 5.7 Building Elevations

5.2 Framing Plan

This section will illustrate the building's framing plan based on the chosen building shell.

5.2.1 Design Loads

The following loads have been calculated so that the team can complete the framing portion of the design process.

- *Live Loads*
  The live load is calculated from ASCE 7-10 based on the space usage of the proposed building [9]. The calculation can be found in Appendix 8.1. The design live load was chosen to be 100 psf to allow for reduction and construction easement.
- *Dead Loads*
  First, the superimposed dead load for the roof and the floor was assumed in order for the design of the structural components. Dead loads include self-weight of structural members, superimposed dead load, and other dead loads (mechanical system). After designing all the structural members, the total dead load was calculated to be 200 psf.
- *Snow Loads*
  The snow loads are calculated based on the roof slope, shape, thermal properties, and the percentage of ground snow loads. ASCE 7-10 was used to determine the ground snow load, and the various factors [9]. The snow load was calculated to be 38.5 psf. The detailed calculation can be seen in Appendix 8.3.
- *Seismic Loads*
  The seismic loads are calculated by using ASCE 7-10 Seismic Procedure. The total seismic load calculated is 199.6 kip and it is greater than wind loads. Therefore, when designing for the lateral system, the seismic load is used instead of wind load. The detailed calculation can be found in Appendix 8.4.
- *Wind Loads*
  The wind loads are calculated based on the basic wind speed, occupancy category, importance factor, exposure category, gust effect, and internal pressure coefficient. ASCE 7-10 was used to determine the basic wind speed, and the different factors [9]. The wind load was calculated to be 26 psf for the roof, 23psf in the windward direction and 9 psf in the leeward direction. The total lateral wind load is calculated by adding the loads in both leeward and windward directions and it is 32 psf (115.2 kip). The detailed calculation can be seen in Appendix 8.5.

5.2.2 Framing Plans

Figure 5.7 illustrates the framing plan for the ground floor of the building. There are three types of foundations (F) and columns (C) depending on the amount of tributary area they need to support. Further details about foundation calculation will be explained in Section 5.4. The ground floor uses a 5-in thick slab-on-grade system. There are three lateral load frames to resist the lateral force and the loads for those frames were checked by using Skyciv software.

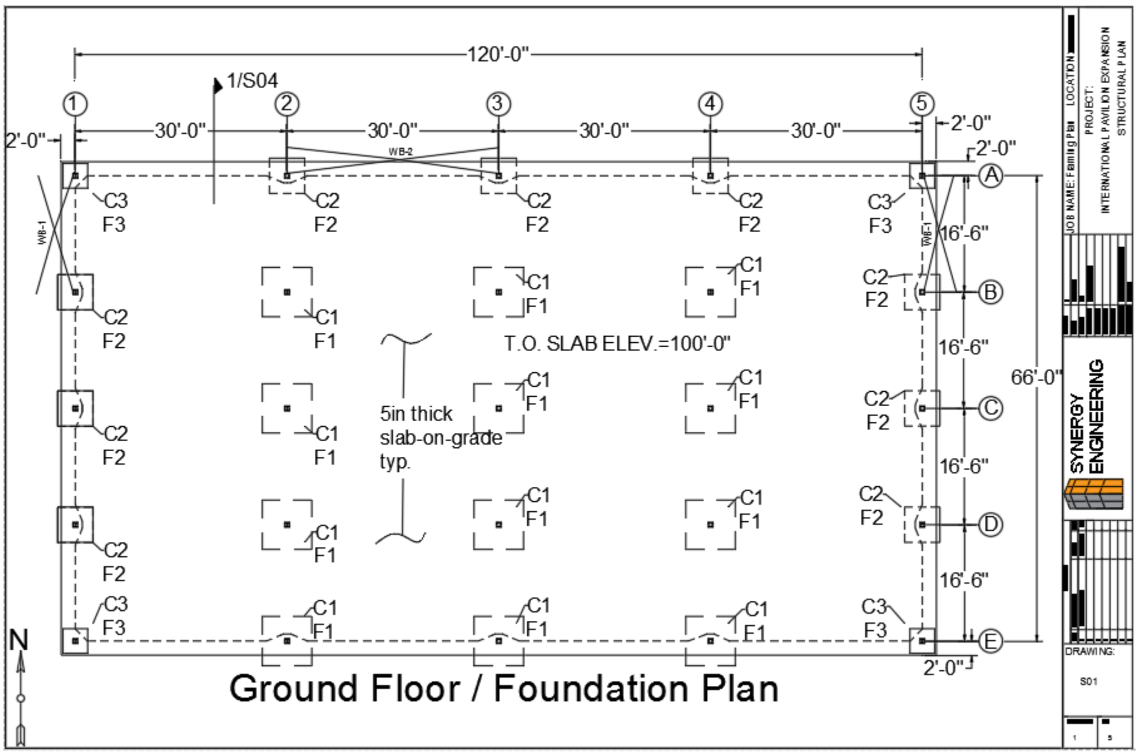

Figure 5.8 Framing Plan (Ground Floor)

For the second floor framing plan in Figure 5.8, a concrete slab-based floor on wide flange steel beam was utilized to reduce the vibration of the steel frame chosen. The second floor uses the composite floor system. The metal deck is chosen from the vulcraft deck catalog. The floor girders, joists, and beams were calculated with serviceability and strength designs and the size of the girders, joist, and beams were chosen from the Steel Code. All the detailed calculations can be found in Appendix 8.6.1.

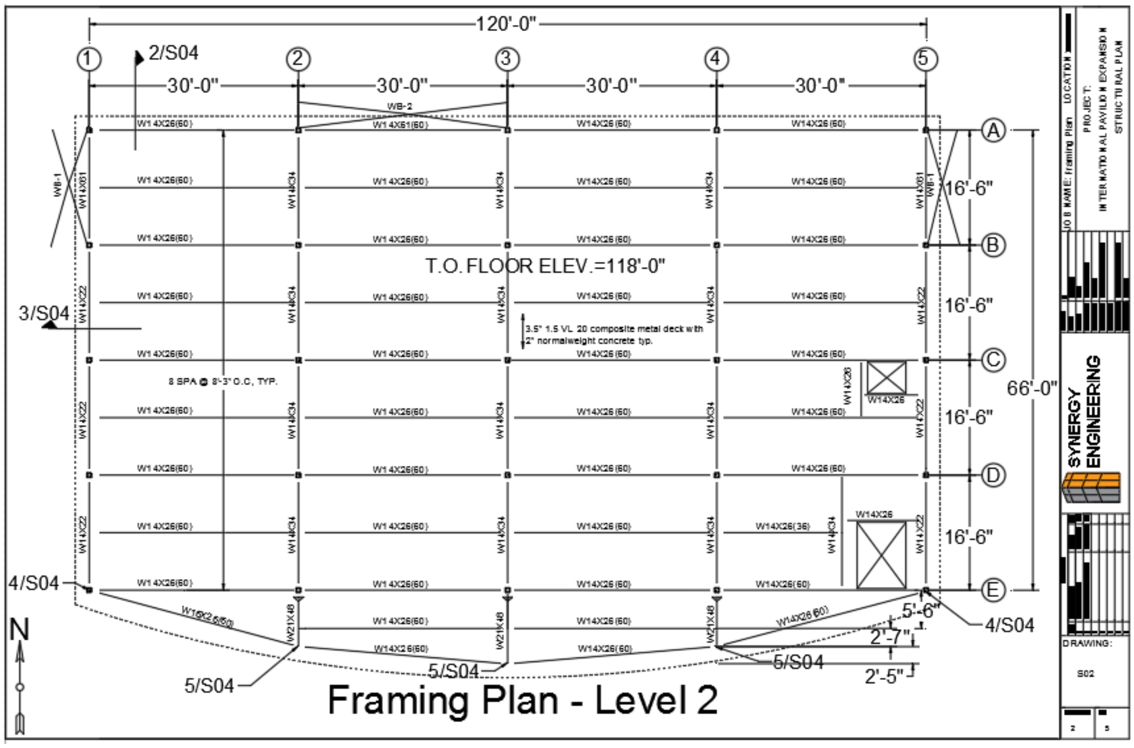

Figure 5.9 Framing Plan (Second Floor)

For the roof framing plan in Figure 5.9, the floor system is a joist-based system because there will not as much vibration as the second floor. The joists are 6 feet apart from each other. There is brace on top of column as there is no connection between column and joist to resist the lateral movement. The sizes of roof interior joists and exterior joists are found by using Vulcraft catalog by using superimposed dead load. The exterior and interior girders calculations can be found in Appendix 8.6.2.

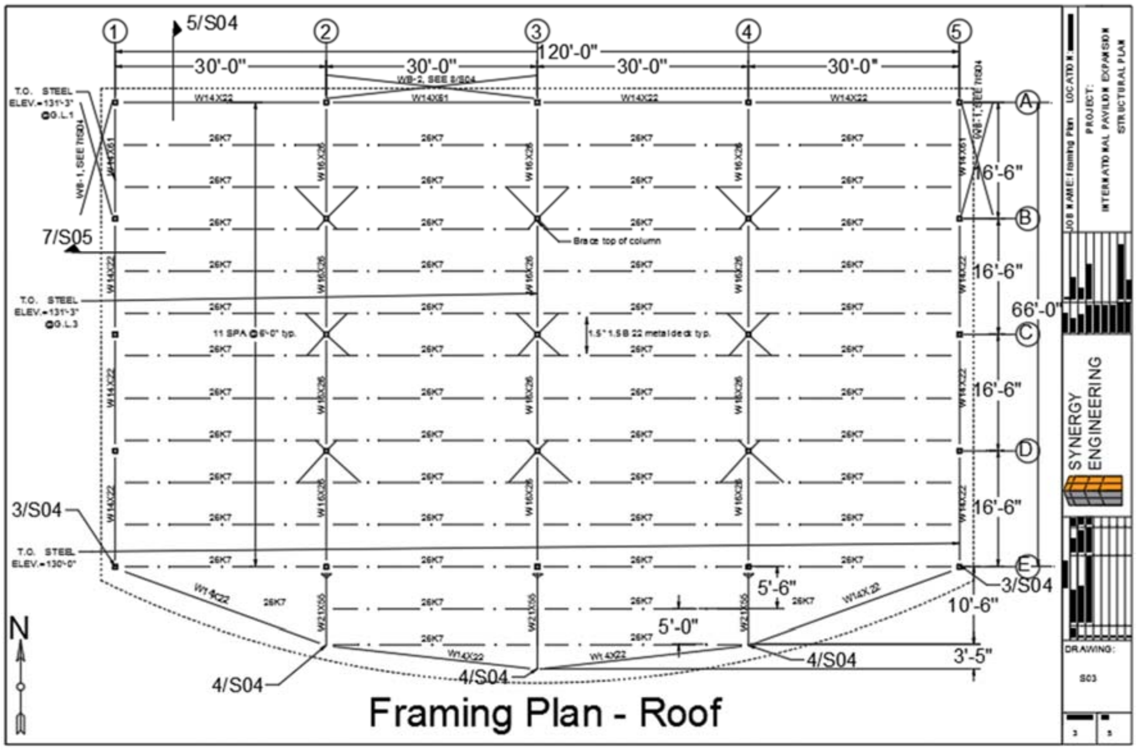

Figure 5.10 Framing Plan (Roof)

5.4 Foundation Plan

For the foundation plan, steel columns, concrete footings, and grade beam were designed. The steel columns were designed to support the gravity loads from the second floor and the roof. The concrete footings were designed based on the different tributary areas. The grade beam is designed to support the exterior columns and walls. The calculation for column design can be seen in Appendix 8.7, Appendix 8.8 and Appendix 8.9.

5.5 Framing and Foundation Details

As requested by the client, some of the basic connection details and schedule are provided in Figure 5.10. The cross-bracing size and details are shown in Figure 5.11.

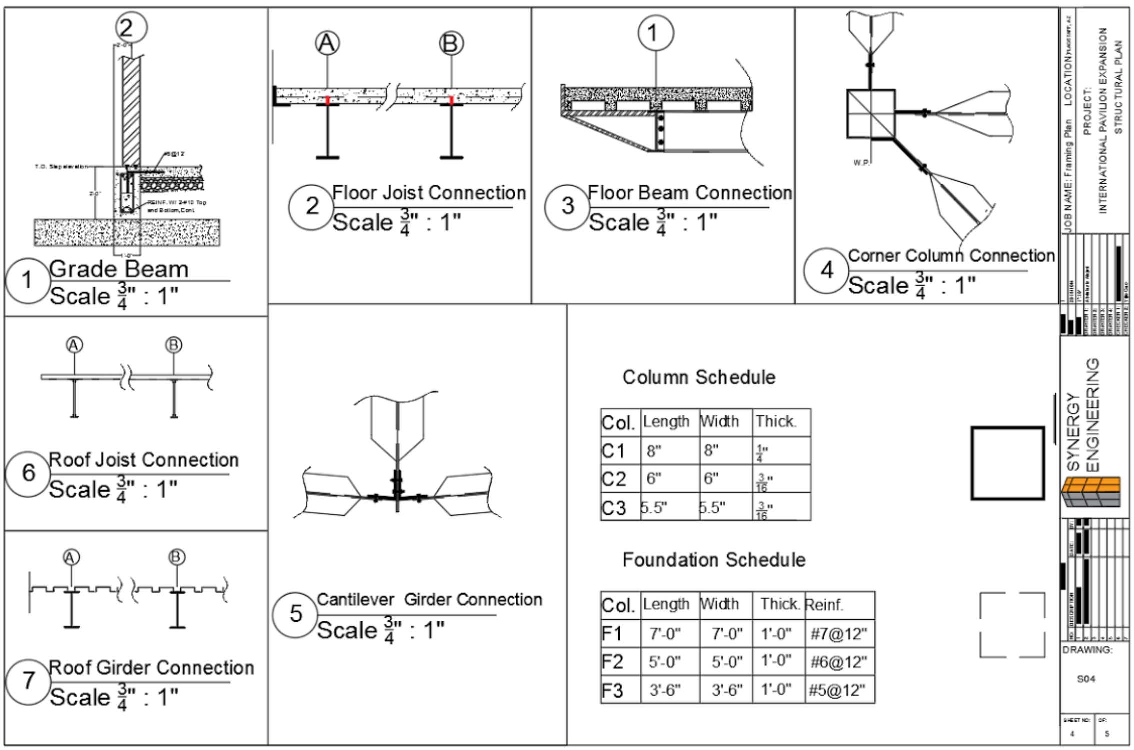

Figure 5.10 Structural Details

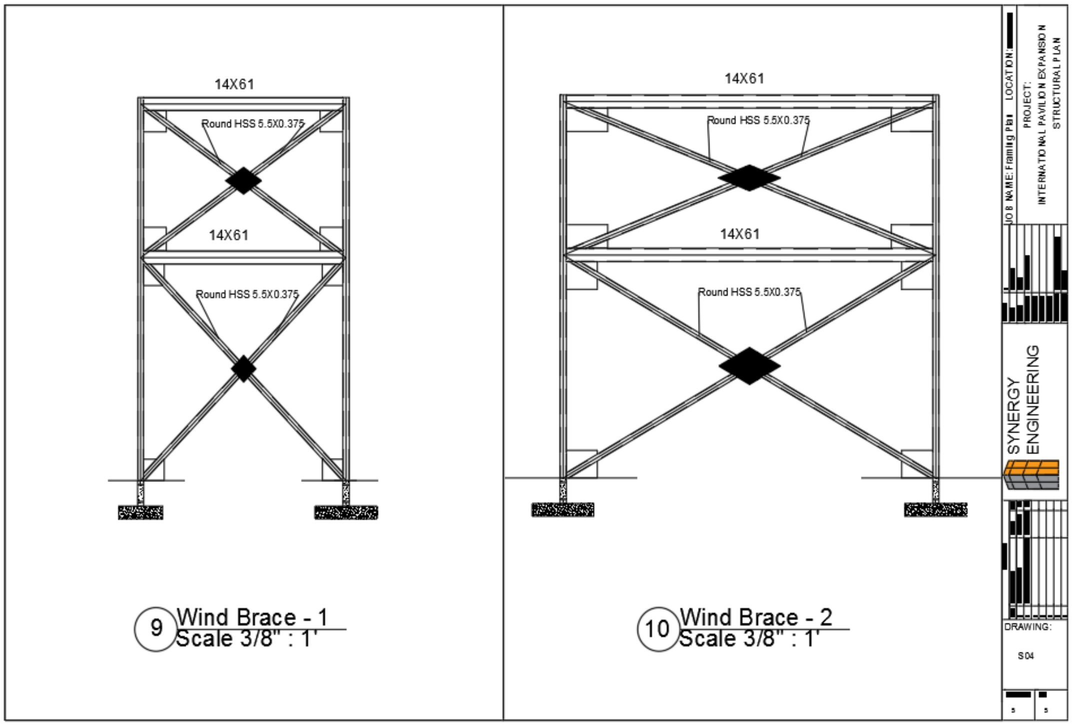

Figure 5.12 Cross-bracing Detail

6.0 CONSTRUCTION COST ESTIMATE

The team came up with the construction cost estimate by diving them into 12 types of divisions that are relevant to the project. The gap between Division 10 and Division 14, Division 14 and Division 21 are due to some irrelevant division to the project. The 12 types of divisions were referred from the divisions of construction information, defined as the Construction Specification Institute (CSI)'s Master Format. It included the cost of requirements, site work, construction materials and other miscellaneous items. Based on Table 6.1, the total hard cost is $3,325,869.

Table 6.1: Total construction cost

	Total Cost
Division 1: General Requirements	$150,000
Division 2, 31-33: Demolition and Site Work	$285,215
Division 3: Concrete	$193,262
Division 4: Masonry	$123,050
Division 5: Metals	$389,395
Division 6: Wood and Plastics	$16,400
Division 7: Thermal and Moisture Protection	$183,354
Division 8: Doors and Windows	$276,400
Division 9: Finishes	$356,426
Division 10: Specialties	$20,000
Division 14: Conveying Systems	$65,000
Division 21-26: Mechanical and Electrical	$1,267,366
Total:	$3,325,869

Based on the total hard cost, the team calculate the total square feet cost of the project. As shown in Table 6.2, the cost of 15% contingency, which takes into account the uncertainties of the current designs and sites, the cost of general conditions, which is for project management, the markup (profit), tax, insurance and bond were list respectively and the total cost was calculated as $4,887,523. Divided by 15,000 square feet (area of the proposed building), the square feet cost was determined to be $289.

Table 6.2: Square feet cost

	Total Cost
Total Construction Cost	$3,325,869
Contingency (15%)	$498,880
General Conditions	$475,220
Mark up, Tax, Insurance, and Bond	$587,554
Total Cost	$4,887,523
Square Feet Cost	$289

7.0 COST OF ENGINEERING SERVICES

For the total cost of engineering services, Table 6.3 showed the comparison between the estimated hours and cost and the actual hours and cost. The difference exists only on personnel and travel services. For personnel part the estimated hour is 682 hours with a cost of is $82,160, the actual hour is 576 and cost is $82,333, which is similar to the previous estimate. It is noted that the actual hours are less than estimated hours but the cost is still similar to the estimated one. That is because the team members have different roles and different roles have different cost rate. In the team's situation, the project manager and project engineer, which has higher pay rate than other roles, spent more hours than estimated. For the travel cost, the team was planning on a meeting with our client in Phoenix, but actually the team had the meeting with our client in Flagstaff. Therefore, there is not any travelling cost. For the cost of survey equipment rental and standards purchase, the team met the estimated cost. Summing up all the above items discussed, the actual total cost came up to $83,133, which is similar with the estimated total cost of $83,104.

Table 7.1: Cost of Engineering Services

Total Cost of Engineering Services				
Service	Estimated	Actual	Estimated Cost	Actual Cost
1.0 Personnel	682 Hours	576 Hours	$82,160	$82,333
2.0 Surveying Equipment Rental	10 Hours	10 Hours	$200	$200
3.0 Travel	288 Miles at $0.5/mile	0	$144	0
4.0 Code and Standards Purchase			$600	$600
		Total Cost	$83,104	$83,133
		Cost Difference	0.0085%	

Table 7.2 Actual Hours vs. Estimated Hours

	Actual Hours	Estimated Hours
Aziz	191.5	174
Phoo	172	168
Yang	166	160
Yijie	183	172

The total actual hours for this project is 714 hours, which exceed the estimated hours, 682 hours. This is due to the unexpected challenges of the framing plan. The actual total hours for each person all exceed the estimated total hours. Overall, the team has approximately 30 hours more than estimated.

8.0 IMPACTS

The project has three main impacts: environmental, societal, and social impacts. For the environmental impact, the positive impact is that the proposed building will utilize renewable energy, including solar energy and wind energy. The negative impact is that the construction of the new pavilion may cause a potential tree removal. For the economic impact, the construction will provide more jobs for students and general public. Also, the new international pavilion will attract more international students to apply for NAU. For the societal impact, the proposed building will attract students from different countries and promote the culture exchange between students. Also, it can provide more event spaces for the university.

9.0 REFERENCES

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[10] "ADA ramp code", 2016. [Online]. Available: http://www.guldmann.net/Files/Billeder/GuldmannProdukter/Stepless/Transportable%20ramper/Shared%20files/US/ADA%20Ramp%20Codes_US.pdf.

10.0 APPENDICES

10.1 Live Loads Calculation

Roof (Reducible): 20psf
Hanging Catwalks: 40psf

Floors:
Classrooms: 40psf
Student community space: 100psf
Student study area: 60psf

Offices: 80psf
Office Concentrated Load: 2000lbs
Partition: 0 psf (not required where the minimum specified live load >80psf)

Light Storage: 125 psf
Partition: 0 psf

Lobbies and first floor corridor: 100psf
Corridor above first floor: 80psf

Stair: 100psf
Stair Tread Concentrated Load: 300lbs
Catwalks: 75psf

Mechanical Rooms: 125psf

(All of these are selected from ASCE 7-10 design live load)

10.2 Dead Loads Calculation

Superimposed dead load on roof: 35 psf (assumed)

Superimposed dead load on floor: 90 psf (assumed)

Total dead loads of the entire building structural system: 200 psf (calculated from the weight of all structural members from the framing plan)

10.3 Snow Loads Calculation

Ground snow load (P_g) = 50 psf
Exposure factor (C_e) = 1.0 (partially exposed)
Thermal factor (C_t) = 1.0

Importance factor (I) = 1.1 (category III)
Warm roof slope factor (C_s) = 1.0
Flat roof snow load (P_f) = $0.7 C_e C_t C_e \mathrm{I} P_g$= 38.5 psf

10.4 Seismic Loads Calculation

Occupancy = III
Importance factor (I) = 1.1
Site Class = B
S_s= 0.357
S_1= 0.102
S_{DS}= 0.238
S_{D1}= 0.068
R = 3
$C_s = \frac{S_{DS}}{\left(\frac{R}{I}\right)}$ = 0.099167
$V = C_s W$ = 0.099167 * DL

$$DL = 200\, psf = 200 * 120 * 84 = 2016\, kip$$

V=0.099167*2016 kip = 199.6 kip

10.5 Wind Loads Calculation

Basic wind speed = 120 mph
Occupancy category = III
Importance factor (I) = 1.1
Exposure category = C
Gust effect factor = 0.85 (rigid building)
Internal pressure coefficient (G_{cpi}) = +/- 0.18 (enclosed building)
K_z= 0.98, K_{zt}= 1, K_d= 0.85

$$q_z = 0.00256 K_z K_{zt} K_d V^2 = 34\, psf$$

Windward:

C_p= 0.8
Windward = $q_z G C_p$= 34 * 0.85 * 0.8 = 23 psf

Leeward:

C_p= -0.3
Leeward = 34 * 0.85 * 0.3 = 9 psf

Roof:

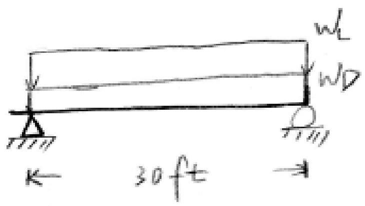
C_p= -0.9
Roof = 34 * 0.85 * 0.9 = 26 psf (upward)

Wind Lateral Load=32 psf*120 ft* 30 ft =115.2 kip

10.6 Joist, beam and girder design

10.6.1 Floor design

Floor Joist (interior)



D + L: $\Delta allow = \frac{30'' * \frac{12''}{1'}}{240} = 1.5''$

L: $\Delta allow = \frac{30'' * \frac{12''}{1'}}{360} = 1.0''$

$w_L = 100\, psf * \left(8' + \frac{3''}{12''}\right) = 825\, plf$

$w_D = 50\, psf * \left(8' + \frac{3''}{12''}\right) = 413\, plf$

D + L:

$$I_{req} \geq \frac{5(w_D + w_L)L^4}{384E\Delta \text{allow}} = \frac{5\left[\frac{413plf+825plf}{12''}\right](30' * 12'')^4}{384*29000*1000*1.5} = 518.6\, in^4$$

L:

$$I_{req} \geq \frac{5w_L L^4}{384E\Delta \text{allow}} = \frac{5\left[\frac{825plf}{12''}\right](30' * 12'')^4}{384*29000*1000*1.0} = 518.4\, in^4 \quad -> \quad \text{W18*40}$$

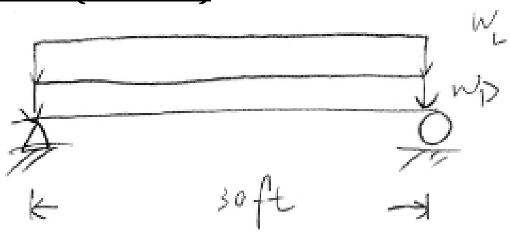
(I = 612 in^4)

$M = \frac{(W_L + W_D)*L^2}{8} = \frac{(413+825)(30ft)^2}{8} = 139275 \text{ lb} - \text{ft} = 139.3 \text{ kip} - \text{ft}$

$Unbraced\ length\ = 2\ ft$

W16*36	W18*35	W14*43	W16*40	W21*44
I = 448 in^4	I = 510 in^4	I = 518 in^4	I = 428 in^4	I = 843 in^4

Floor beam (exterior)



D + L: $\Delta allow = \frac{30'' * \frac{12''}{1'}}{240} = 1.5''$

L: $\Delta allow = \frac{30'' * \frac{12''}{1'}}{360} = 1.0''$

$w_L = 100\, psf * \left(8' + \frac{3''}{24''}\right) = 413\, plf$

$w_D = 50\, psf * \left(8' + \frac{3''}{24''}\right) = 207\, plf$

D + L:

$$I_{req} \geq \frac{5(w_D + w_L)L^4}{384E\Delta \text{allow}} = \frac{5\left[\frac{413plf + 207plf}{12''}\right](30' * 12'')^4}{384 * 29000 * 1000 * 1.5} = 259.7\, in^4$$

L:

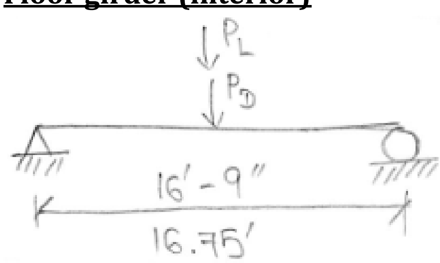
$$I_{req} \geq \frac{5w_L L^4}{384E\Delta \text{allow}} = \frac{5\left[\frac{413plf}{12''}\right](30' * 12'')^4}{384 * 29000 * 1000 * 1.0} = 259.5\, in^4$$

$M = \frac{(W_L + W_D) * L^2}{8} = 74101.12 \text{ lb} - \text{ft} = 74.101 \text{ kip} - \text{ft}$

$Unbraced\ length = 2\, ft$

W10*26	W16*26	W12*26

Floor girder (interior)



$P_L = 825\, plf * 30ft = 24750\, lb = 24.75\, kip$

$P_D = 50\, psf * 30ft * 1ft = 1500\, lb = 1.5kip$

$P_L + P_D = 24.75\, kip + 1.5\, kip = 26.25\, kip = 26250\, lb$

D + L: $\Delta allow = \frac{16.75'' * \frac{12''}{1'}}{240} = 0.8375''$

L: $\Delta allow = \frac{16.75'' * \frac{12''}{1'}}{360} = 0.5583''$

D + L:

$$I_{req} \geq \frac{(P_L+P_D)L^3}{48E\Delta allow} = \frac{26250\ lb*(16.75'*12'')^3}{48*29000*1000*0.8375} = 182.9\ in^4$$

L:

$$I_{req} \geq \frac{P_L L^3}{48E\Delta allow} = \frac{24750\ lb*(16.75'*12'')^3}{48*29000*1000*0.5583} = 258.6\ in^4$$

$M = M_L + M_D = \frac{P_L*L}{4} + \frac{P_D*L}{4} = \frac{1500\ lb*16.75ft}{4} + \frac{24750\ lb*16.75ft}{4} = 109922lb - ft =$
$109.92\ kip - ft$

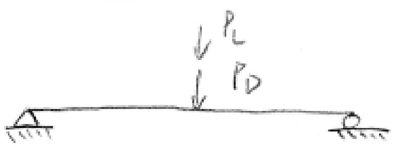
$Unbraced\ length\ =\ 8.25\ ft$

$I =\ 301\ in^4$

From table 3-127,

W14*34	W18*35	W16*36
I = 340 in^4	I = 510 in^4	I = 448 in^4

Floor girder (exterior)



$P_L = 825\ plf * 15ft = 12375\ lb = 12.38\ kip$

$P_D = 50\ psf * 15ft * 1ft = 750\ lb = 0.75kip$

$P_L + P_D = 12.38\ kip + 0.75\ kip = 13.13\ kip = 13130\ lb$

D + L: $\Delta allow\ = \frac{16.75''*\frac{12''}{1'}}{240} = 0.8375''$

L: $\Delta allow\ = \frac{16.75''*\frac{12''}{1'}}{360} = 0.5583''$

D + L:

$$I_{req} \geq \frac{(P_L+P_D)L^3}{48E\Delta allow} = \frac{13130\ lb*(16.75'*12'')^3}{48*29000*1000*0.8375} = 91.5\ in^4$$

L:

$$I_{req} \geq \frac{P_L L^3}{48E\Delta allow} = \frac{12380\ lb*(16.75'*12'')^3}{48*29000*1000*0.5583} = 129.36\ in^4$$ —> W12*19 (I = 130 in^4)

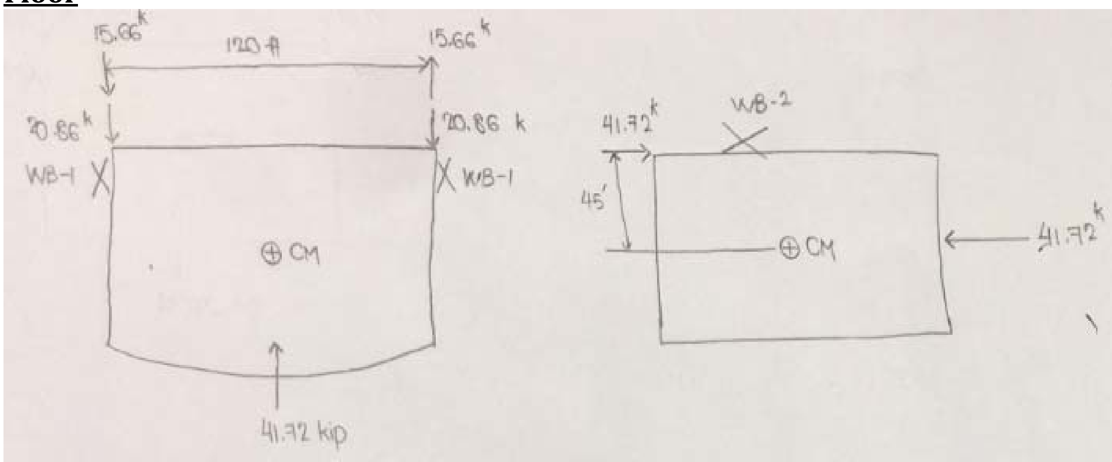
$M = M_L + M_D = \frac{P_L*L}{4} + \frac{P_D*L}{4} = \frac{750\ lb*16.75ft}{4} + \frac{12380\ lb*16.75ft}{4} = 54981.88lb - ft =$
$54.982\ kip - ft$

$Unbraced\ length\ =\ 8.25\ ft$

From table 3-127,

W14*22	W10*26	W12*26
I = 199 in^4	I = 144 in^4	I = 204 in^4

Floor



$M = 41.72^K(45) = 1878.75k - ft$

$\frac{1878.75k-ft}{120ft} = 15.66kip$

WB-1 @ Roof =36.52 kip

WB-2 @ Roof = 41.72 kip

10.6.2 Roof design

Roof girder (interior)

D + S: $\Delta allow = \frac{16.5'' * \frac{12''}{1'}}{240} = 0.825''$

S: $\Delta allow = \frac{16.5'' * \frac{12''}{1'}}{360} = 0.55''$

$w_S = 40\ psf * 30\ ft = 1200\ plf$

$w_D = 35\ psf * 30\ ft = 1050\ plf$

D + S:

$$I_{req} \geq \frac{5(w_D + w_S)L^4}{384E\Delta allow} = \frac{5\left[\frac{2250plf}{12''}\right](16.5' * 12'')^4}{384*29000*1000*0.825} = 156.8\ in^4 \quad -> \text{W14*22}$$

(I = 199 in^4)

S:

$$I_{req} \geq \frac{5w_S L^4}{384E\Delta allow} = \frac{5\left[\frac{1200plf}{12''}\right](16.5' * 12'')^4}{384*29000*1000*0.55} = 125.47\ in^4$$

For strength:

$M = \frac{(W_L + W_D)*L^2}{8} = \frac{(2250\ plf)(16.5ft)^2}{8} = 76570.31\ \text{lb} - \text{ft} = 76.6\ \text{kip} - \text{ft}$

$Unbraced\ length = 6\ ft$

W16*26	W12*26
I = 301 in^4	I = 204 in^4

Roof girder (exterior)

D + S: $\Delta allow = \frac{16.5'' * \frac{12''}{1'}}{240} = 0.825''$

S: $\Delta allow = \frac{16.5'' * \frac{12''}{1'}}{360} = 0.55''$

$w_S = 40\ psf * 15\ ft = 525\ plf$

$w_D = 35\ psf * 15\ ft = 600\ plf$

D + S:

$I_{req} \geq \frac{5(w_D + w_S)L^4}{384E\Delta \text{allow}} = \frac{5\left[\frac{1125plf}{12''}\right](16.5' * 12'')^4}{384 * 29000 * 1000 * 0.825} = 78.4\ in^4$ −> W12*14 (I = 88.6 in^4)

S:

$I_{req} \geq \frac{5w_S L^4}{384E\Delta \text{allow}} = \frac{5\left[\frac{600plf}{12''}\right](16.5' * 12'')^4}{384 * 29000 * 1000 * 0.55} = 62.74\ in^4$

For strength:

$M = \frac{(W_L + W_D) * L^2}{8} = \frac{(1125\ plf)(16.5ft)^2}{8} = 38285.16 \text{ lb} - \text{ft} = 38.3 \text{ kip} - \text{ft}$

$Unbraced\ length = 6\ ft$

W10*19	W12*19	W8*21
I = 96.3 in^4	I = 130 in^4	I = 155 in^4

Composite floor beam

$W_{concrete} = 33\ PSF\ (8.25\ FT.) = 272.25\ PLF$

$\Delta a < \frac{L}{360} = 1in$

$I \geq \frac{5W_{concrete}L^4}{384E} = \frac{5 * 272.25 * \frac{1}{12} * \left(30 * \frac{12}{1}\right)^4}{384 * 29000 * 1000} = 171.01 in^4$

D + L: $\Delta allow = \frac{30'' * \frac{12''}{1'}}{240} = 1.5''$

L: $\Delta allow = \frac{30'' * \frac{12''}{1'}}{360} = 1.0''$

$w_L = 100\ psf * \left(8' + \frac{3''}{12''}\right) = 825\ plf$

$w_D = 50\ psf * \left(8' + \frac{3''}{12''}\right) = 413\ plf$

b Selection:

1) $\frac{1}{8} * 30 * 12 = 45''$ ------> CONTROL

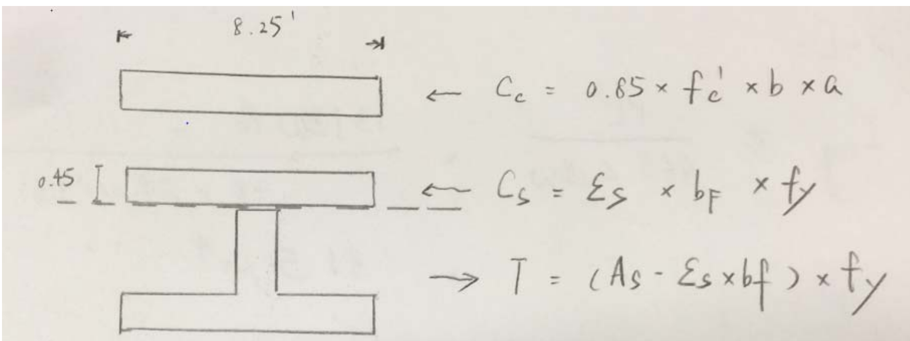
2) $\frac{1}{2} * 8.3 * 12 = 49.8''$

3) $4.125 * 12 = 49.5''$

By using the equation below:

$$\sum Q_n = F_y A_s$$

Beam Size	12*26	12*30	14*26
$\sum Q_n$	382.5 Kip	439.5 Kip	382.5 Kip



$C_s = 1428.87\ kip$ $C_c = 146.25 kip$ $T = 503.75 kip$

So $C_s + C_c > T$ ------> assume PNA@BFL ------> Conservative

D + L:

$$I_{req} \geq \frac{5(w_D+w_L)L^4}{384E\Delta\text{allow}} = \frac{5\left[\frac{413plf+825plf}{12''}\right](30'*12'')^4}{384*29000*1000*1.5} = 518.6\ in^4$$

L:

$$I_{req} \geq \frac{5w_L L^4}{384E\Delta\text{allow}} = \frac{5\left[\frac{825plf}{12''}\right](30'*12'')^4}{384*29000*1000*1.0} = 518.4\ in^4$$

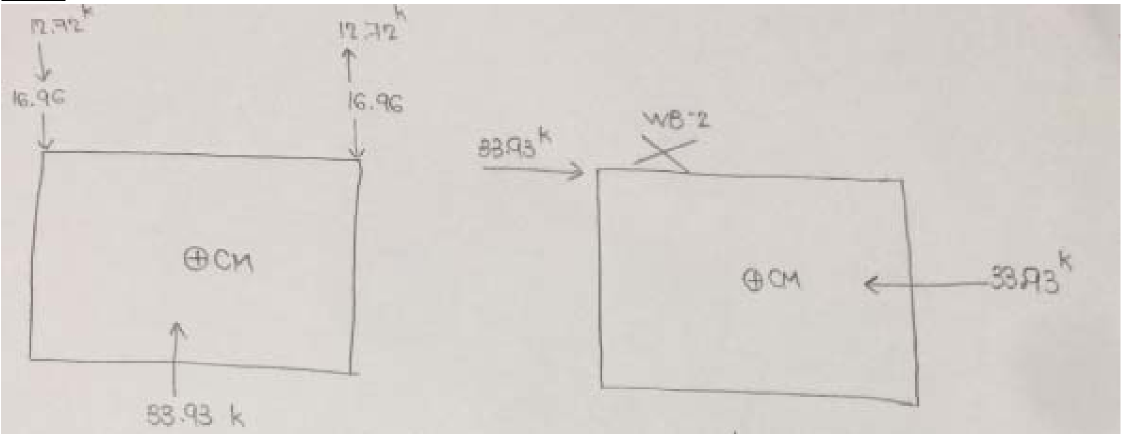
From T 3-20 ---> I = 556 in^4 ---> So both are less than 556 in^4

$M_{allowable} = \frac{(W_L+W_D)*L^2}{8} = \frac{(413+825)(30ft)^2}{8} = 139275 \text{ lb} - \text{ft} = 139.3 \text{ kip} - \text{ft}$

M_s from T 3-19 = 162 Kip-ft

So $M_s > M_{allowable}$

Roof



$M = 33.93^K(45) = 1526.85k - ft$

$\frac{1526.85k-ft}{120ft} = 12.72kip$

WB-1 @ Roof = 29.68 kip

WB-2 @ Roof = 33.93 kip

10.7 Column design

Columns:

$$Roof = D + 0.75L + 0.75S = 35 + (0.75 * 20) + (0.75 * 40) = 80\ PSF$$

Roof joist exterior	Roof joist interior	Roof girder
22 PLF	8.9 PLF	26 PLF

$$Floor = D + L = 50\ PSF + 100\ PSF = 150\ PSF$$

Roof joist exterior	Roof joist interior	Roof girder
26 PLF	26 PLF	34 PLF

Interior Column:

$\sum Load = [(80 + 150)\ PSF * 30\ ft.* 18.5\ ft.] + [(22\ PLF * 32\ ft.) + (8.9\ PLF * 4 * 30\ ft.) + (26\ PLF * 23\ ft.)] + [(26\ PLF * 32\ ft.) + (26PLF * 3 * 30\ ft.) + (34\ PLF * 18.25\ ft.)]$

$= 133812.5\ lb = 133.8\ kip$

Column type	$HSS\ 6 * 6 * \frac{1}{2}$	$HSS\ 7 * 7 * \frac{5}{16}$	$HSS\ 8 * 8 * \frac{1}{4}$	$HSS\ 9 * 9 * \frac{1}{4}$
Self-Weight (plf)	35.1	27.5	25.8	29.2

Exterior Column:

$\sum Load = [(80 + 150)\ PSF * 15\ ft.* 16.5\ ft.] + [(8.9\ PLF * 3 * 15\ ft.) + (26\ PLF * 16.5\ ft.) + [(26\ PLF * 3 * 15\ ft.) + (34\ PLF * 16.5\ ft.)]$

$= 59525.5\ lb = 59.5\ kip$

Column type	Column type	$HSS\ 6*6*\frac{3}{16}$	$HSS\ 5\frac{1}{2}*5\frac{1}{2}*\frac{1}{4}$	$HSS\ 5*5*\frac{5}{6}$	$HSS\ 7*7*\frac{3}{16}$
Self-Weight (plf)	Self-Weight (plf)	14.5	17.3	19	17.1

Corner:

$\sum Load = [(80+150)\ PSF * 15\ ft.* 8.25\ ft.] + [(22\ PLF * 15\ ft.) + (8.9\ PLF * 15\ ft.) + (26\ PLF * 8.25\ ft.)] + [(26\ PLF * 15\ ft.) + (26\ PLF * 15\ ft.) + (34\ PLF * 8.25\ ft.)] = 30126\ lb = 30.2\ kip$

Column type	$HSS\ 4*4*\frac{3}{8}$	$HSS\ 4\frac{1}{2}*4\frac{1}{2}*\frac{1}{4}$	$HSS\ 5*5*\frac{3}{16}$	$HSS\ 5\frac{1}{2}*5\frac{1}{2}*\frac{1}{8}c$	$HSS\ 5\frac{1}{2}*5\frac{1}{2}*\frac{1}{8}c$
Self-Weight (plf)	17.2	13.9	12	9	9.85

10.8 Footing design

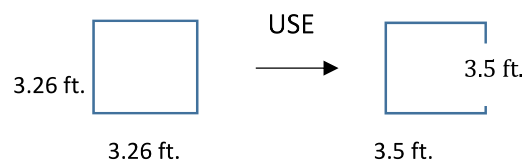
Corner footing (4) * C3

$Load = 300\ psf * 15\ ft * 8.26\ ft = 37125\ lb$

$Allowable\ bearing\ capacity = 3500\ psf$

---> $A_s = \frac{Load}{3500psf} = \frac{37125lb}{3500psf} = 10.61ft^2$

---> $W = L = \sqrt{10.61ft^2} = 3.26ft$



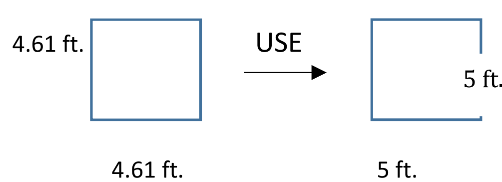
Exterior footing (12) * C2

$Load = 300\ psf * 16.5\ ft * 15\ ft = 74250\ lb$

$Allowable\ bearing\ capacity = 3500\ psf$

---> $A_s = \frac{Load}{3500psf} = \frac{74250lb}{3500psf} = 21.21ft^2$

---> $W = L = \sqrt{21.21ft^2} = 4.61ft$

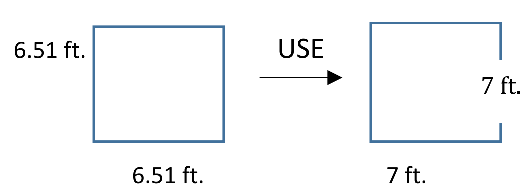


Interior footing (9) * C1

$Load = 300\ psf * 16.5\ ft * 30\ ft = 148500\ lb$

$Allowable\ bearing\ capacity = 3500\ psf$

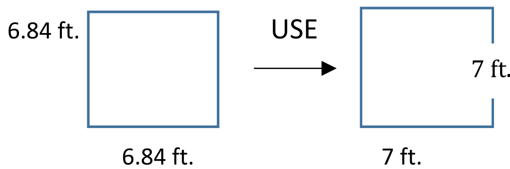
---> $A_s = \frac{Load}{3500psf} = \frac{148500lb}{3500psf} = 42.43ft^2$



---> $W = L = \sqrt{42.43ft^2} = 6.51ft$

Check for Cantilever footing

From AutoCAD, the area is 546.19 ft^2



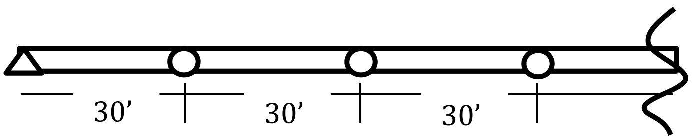
---> $Load = 300\ psf * 546.19ft^2 = 163857\ lb$

$Allowable\ bearing\ capacity = 3500\ psf$

---> $A_s = \frac{Load}{3500psf} = \frac{1638570lb}{3500psf} = 46.82ft^2$

---> $W = L = \sqrt{46.82\ ft^2} = 6.84\ ft$

10.9 Grade beam design



Factored Moment:

1) Live Load:

$LL = 100\ psf * 3\ ft = 300\ plf$

2) Dead Load:

$DL = First\ Floor\ Wall + self - weight + slab\ weight$

1. Assume CMU = 55 psf

---> $First\ Floor\ Wall = 55\ psf * 18\ ft = 990\ plf$

2. Assume self-weight = 300 plf
3. $Slab\ weight = 150\ pcf * 3\ ft * 0.5\ ft = 225\ plf$

$DL_{total} = 990plf + 300plf + 225plf = 1515plf$

$W_u = 1.2D + 1.6L = 1.2 * 1515plf + 1.6 * 300plf = 1996.2plf$

$M_u(+) = \frac{W_u Ln^2}{14} = \frac{1996.2plf*(30ft)^2}{14} = 128.3k - ft$

$M_u(-) = -\frac{W_u Ln^2}{10} = -\frac{1996.2plf*(30ft)^2}{10} = -179.7k - ft$

Minimum Depth:

$h_{min} = \frac{l}{18.5} = \frac{30ft}{18.5} = 1.62ft = 19.5in$

Determine Dimensions:

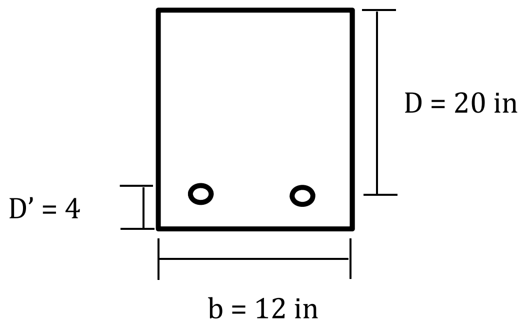
For doubly reinforcement & Assume $f'_c = 4ksi, f_y = 60ksi, R = 1.0ksi$

$$bd^2 = \frac{M_u}{\Phi R}$$

Assume that $b = \frac{d}{2}$,

$\frac{d^3}{2} = \frac{M_u}{\Phi R} = \frac{179.7k-ft*\frac{12in}{1ft}}{0.9*1ksi}$

---> $d \geq 16.9in$ (< 19.5 min depth so that using 19.5 in)
Use b = 12 in for clear cover purposes & d = 20 in and H = 24 in
Check S_w:
$S_w = 150 \frac{lb}{ft^3} * 12in * 24in * \frac{1ft^2}{144in^2} = 300plf <$ Assume $300\ plf$



Find A_s, req:
$A_s, req \geq \frac{M_u}{\Phi * f_y * j * d} = \frac{179.7k = ft * \frac{12in}{1ft}}{0.9*60ksi*0.9*20in} = 2.22in^2$
2#10 ($2.54\ in^2$) $b_w = 2 * 3in + 1.5in + 2 * 1.127in + 1.127in = 10.88in < 12in$
CheckA_s, min:
$A_s, \min \geq \frac{200}{f_y} * b * d = \frac{200}{60*10^3 psi} * 12in * 20in = 0.8in^2$
Check E_s:
$E_s = 0.011 > 0.005$ (From the excel sheet)
Check ΦM_n:
$\Phi M_n = 206k = ft > 179.7k - ft$

Final Design: