Project Understanding

Retaining Wall Redesign

Grand Canyon High School
Grand Canyon Village, AZ

CENE 476
Due: 2/15/2018

By:

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1.0 Project Purpose

The purpose of this capstone project is to redesign a failing retaining wall for Grand Canyon High School located in Grand Canyon Village. A re-design is needed due to the current retaining wall, made with railroad ties, being pushed out of place by the pressure exerted by the soil. The testing and analysis of this project will determine the proper wall material and design functions needed to comply with any necessary standards for retaining wall design. Using the necessary engineering knowledge and design methods, a new retaining wall will be designed to replace the existing wall that will provide sufficient accessibility in structural, geotechnical, and drainage areas. The new retaining wall design will also meet all codes, engineering and construction, and provide serviceability for many years to come.

2.0 Project Background

2.1 Project Description

The current status of the retaining wall is that it is failing due to overturning from the soil being retained. It is also believed that poor drainage in the current retaining wall has contributed to the failure. The wall is protruding over a walkway at the base of the retaining wall with a playground that sits on the soil above the structure, and it is constructed out of railroad ties. There has been no site visit or contact with the client at this time, although contact through means of emailing is currently in progress. The technical advisor for this project is Dr. Chun-Hsing Ho, and the technical advisor agreement can be found in appendix A. More will be known about the project once a site visit and client meeting are conducted.

2.2 Project Location

The project is located at Grand Canyon High School in Grand Canyon Village, AZ. The high school is part of a k-12 school that serves the South Rim of the Grand Canyon [3]. Grand Canyon Village is at an elevation of 6,804 feet above sea level and has a population of 2,004 people [3]. The enrollment at Grand Canyon High School is about 80 students [4]. Both Grand Canyon High School and the town of Grand Canyon Village are located within the boundaries of the Grand Canyon National Park. Figure 1 below shows the general location of Grand Canyon High School in Northern Arizona [14].

Figure 1: Grand Canyon High School Location [14]

3.0 Technical Considerations

To begin the technical work and analysis of the project, a site visit will be needed to understand the current conditions of the wall and the topography associated with it.

3.1 Surveying

Land surveying is used to gain an understanding of the topography around the failing retaining wall. Surveying will require equipment such as a total station, prism and rod, data collector, and possibly a GPS unit. The points surveyed will be used to create a topographic map of the site around the wall. The topographic map created from the survey will give the elevations of the surrounding land. Knowing the surrounding topography will aid in analyzing the direction water may flow. Determining how steep the slopes in the area of the retaining wall will help to analyze the surrounding land's stability. The topographic map created will also be available in the construction plans for the final designed retaining wall.

3.2 Geotechnical Analysis

3.2.1 Geotechnical Principles

The three main geotechnical principles needed for retaining wall design are the concepts of active earth pressure, passive earth pressure, and bearing capacity. Active earth pressure is the lateral earth pressure on a retaining wall from the soil being retained [10]. Retaining walls must be designed to resist the driving moment and lateral force that active earth pressure exerts on a wall. Passive earth pressure is the pressure that the soil in front of the retaining wall pushes the wall back into the soil being retained [10]. In retaining wall design, the magnitude of passive earth pressure, along with friction between the soil and foundation base, must be strong enough to resist the active earth pressure forces. The bearing capacity is essentially how much weight in the form of vertical loading a soil can support [10]. If a soil has an insufficient bearing capacity, it will collapse under the weight of a vertical stress increase. For retaining wall design, the soil under the wall must have a large enough bearing capacity to support the weight of the wall and soil above it. Section 1.3.2.3 below contains more details regarding the geotechnical stability design of retaining walls.

3.2.2 Soil Testing

Geotechnical tests and analysis are used to understand the properties of the existing soils and how they will influence the design of the new retaining wall. Certain soil properties are needed for designing a retaining wall such as the unit weight, friction angle, void ratio, moisture content, and cohesion if there is clay in the soil [10]. In addition to this, soil behind the retaining wall and at the base needs to be classified based on particle size. The particle sizes in a soil dictate how much sand and clay are contained in the soil [10]. To determine the size distribution of the current soil in the area samples will need to be collected for sieve analysis as well. Knowing the content of clay in the soil at the retaining wall site is critical for determining how drainage conditions will be behind the wall as clay swells with the addition of water [10]. More information on drainage can be found in section 1.3.4 of this report. All soil properties will be found using lab tests at the Northern Arizona University soil lab.

3.2.3 Retaining Wall Geotechnical Stability

The geotechnical design of the retaining wall will address the three main types of retaining wall failures. The three checks for geotechnical stability are the overturning check, sliding check, and bearing capacity check [10]. Overturning is when the wall is pushed outward and rotates about the toe of its foundation [10]. The overturning check makes sure there is an adequate resisting moment to prevent the retaining wall from rotating. Sliding is when the wall is pushed along the base by active earth pressure forces [10]. The sliding check makes sure that passive earth pressure resisting forces and friction along the base of the wall foundation are strong enough to prevent the wall from sliding. The bearing capacity check makes sure that the soil underneath the foundation of the retaining wall is the strong to support the weight of the wall and soil above [10]. If the underlying soil does not have a large enough bearing capacity, the retaining wall will sink down ultimately failing. Figure 2 below shows the retaining wall failures of overturning about the toe, sliding, and bearing capacity [13].

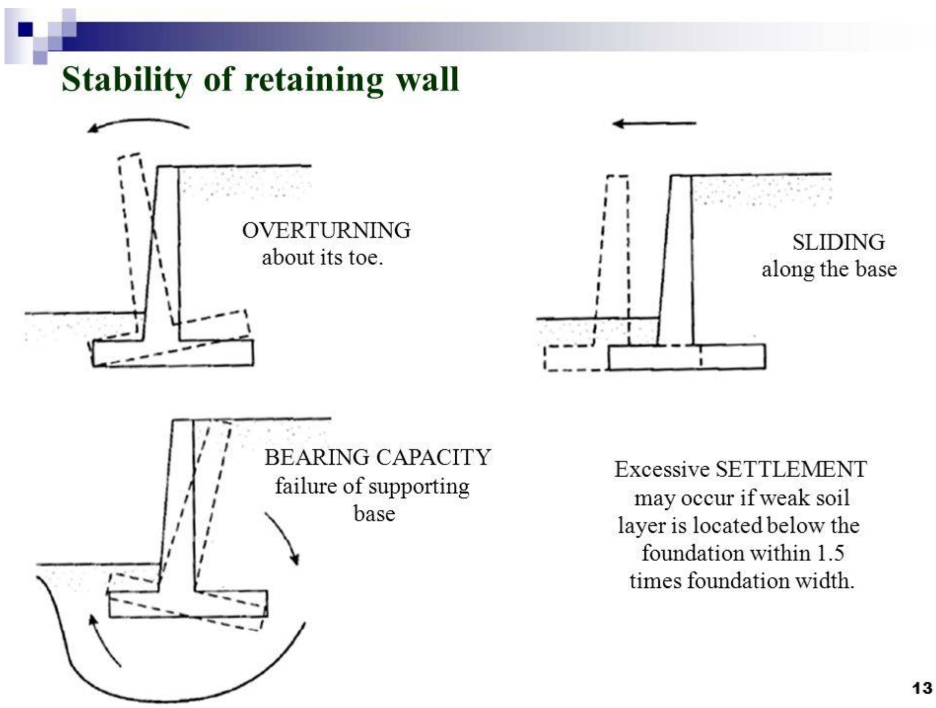

Figure 2: Types of Retaining Wall Failures [13]

3.3 Structural Analysis

Structural analysis of the retaining wall has many components associated with it. Mechanics of materials will need to be performed on the retaining wall to determine the strengths of the materials used to construct it. This includes but is not limited to bending moments and shear stresses acting upon the materials. Depending on the type of retaining wall being constructed, analysis would be performed on the footing and on the vertical wall itself which can include materials such as concrete, masonry block, rebar, wood, and steel. This will help to determine if the sizing of the material used is adequate or if its properties meets the requirements needed to be met. Dimensions would be a large part of structural analysis in that the correct dimensions can be cost efficient to the client while also providing a factor of safety that would meet regulations and standards. Analysis of the overall structure would be used to determine max bending moments and max shear stresses to ensure that the retaining wall is capable of holding back the required loading. Analysis for this can be done by constructing moment and shear diagrams to determine where the wall will be most vulnerable. This analysis would determine the type of reinforcement the wall would need to properly be designed.

3.4 Drainage Analysis

3.4.1 Retaining Wall Drainage Design

Analysis of drainage can be done by taking the following into consideration: Types of soils, drainage of the surrounding area, and surface of runoff for the area. Soil types need to be analyzed to make sure that moisture will not be sitting behind the retaining wall for prolonged periods. If soil is comprised of fine materials such as clay and silt, then replacing the soil behind the wall would need to be taken into consideration. The soil would need to be replaced with a more well-graded type of material that can not only compact well but that can also drain well. From performing surveying and figuring out elevations and slopes, analysis can be done in determining where to direct the water to ensure no puddling happens up top or down below the retaining wall. Based on the varying heights of the wall, length of the retaining wall, and the type of material used for construction will the location of the drains behind the wall be determined. Based on the amount of moisture that the area receives will the size of the pipe be determined as well as the slope of the pipe [8][9].

3.4.2 Hydrology

In order to determine how drainage will be implemented for the retaining wall, the following research and data collection will need to be done. Storm runoff data can be determined from precipitation data of the area located on websites such as the U.S. Climate Data with combination of hydrology analysis [11]. Effective precipitation will be part of the hydrological analysis which entails the difference of storm runoff and the infiltration rate of the soil [12]. This data will determine how much storm water will affect the project and how the soils and drainage pipe in the retaining wall will be designed.

4.0 Potential Challenges

Challenges can arise from many aspects. Performing fieldwork is challenged by traveling, safety, and weather conditions. There may be challenges conducting field work when school or other school related activities are in session as well. Other technical challenges will include any regulations or standards pertaining to the design of the retaining wall.

4.1 Fieldwork Challenges

A potential challenge that can be faced during the course of this project can be weather conditions as extreme amounts of snow can prevent traveling between sites. This can be mitigated by continuously checking forecasts prior to site visits. This would also ensure that fieldwork is not hampered by weather such as surveying and collecting soil samples. Another potential challenge can be safety around the retaining wall. This can mitigated if the team looks after one another and themselves, especially when in close proximity to the edge of the retaining wall.

4.2 Standards and Regulations

Arizona School and Facilities Board Title 7 states that school building must be in compliance with federal, state and local building codes [5]. The federal government, the state of Arizona, and Coconino county all follow the International Building Codes (IBC). Coconino county however has adopted the 2012 IBC as of 2014 as the others still use older IBC's [6]. But since the Grand Canyon Village is located within the National Park Service (NPC), it will use the NPC adopted codes and standards which are the IBC 2015, American Society of Civil Engineers (ASCE) 7-10, American Concrete Institute (ACI) numbers 530-13, 301-10, and 318-14, and the

2015 National Design Standards (NDS) [7]. These standards and regulations constrain the design of the retaining wall in every aspect. They determine the standards and regulations for the geotechnical design, structural design, and drainage design.

5.0 Stakeholders

A stakeholder is someone who is involved by the outcome of an action or are affected by the course of that action [1]. One way to break this down is the triple bottom line method which looks at the economic impact, environmental impact, and social impacts that an action has [2]. Referring to the triple bottom line, the following stakeholders can be determined:

1. Economical
    a. The client, Ivan Landry, is a stakeholder being that he is in charge of the budget of the project.
    b. Taxpayers (state and federal) have a stake in this as the Grand Canyon Unified District is funded by both. Even though the taxpayers might not fully know where their tax money is going to, some of it will be allocated to improving the infrastructure of a public school which is always a boost for the economy.
2. Environmental
    a. The students of Grand Canyon High School are affected by the environmental impacts of a new retaining wall because the retaining wall will improve drainage conditions around the wall area and can reduce puddling.
3. Social
    a. Students are stakeholders in the social aspect due to the fact that there is a playground located directly above the location of the retaining wall. With a newly designed retaining wall, students will be able to have more safety while using the playground.
    b. The sidewalk that will be located below the retaining wall will allow safe travel for those using it. The stakeholders would then be faculty as well as students of the Grand Canyon High School.

6.0 References

[1] "Definition of STAKEHOLDER", Merriam-webster.com, 2018. [Online]. Available: https://www.merriam-webster.com/dictionary/stakeholder. [Accessed: 13- Feb- 2018].

[2] A. Fontinelle, "Triple Bottom Line (TBL)", Investopedia, 2018. [Online]. Available: https://www.investopedia.com/terms/t/triple-bottom-line.asp. [Accessed: 13- Feb- 2018].

[3] "South Rim Historic Village | Grand Canyon National Park Lodges", Grandcanyonlodges.com, 2018. [Online]. Available: http://www.grandcanyonlodges.com/Grand-Canyon-South-Rim-Historic-District. [Accessed: 13- Feb- 2018].

[4] "Grand Canyon High School in Grand Canyon, Arizona", Public-schools.startclass.com, 2018. [Online]. Available: http://public-schools.startclass.com/l/3231/Grand-Canyon-High-School-in-Arizona. [Accessed: 13- Feb- 2018].

[5] Arizona School Facilities Board, "Title 7. Education", 2006.

[6] Coconino County Arizona Community Development, "Design Criteria Building Division", Flagstaff, AZ, 2014.

[7] "Structural Engineering Standards - (U.S. National Park Service)", Nps.gov, 2018. [Online]. Available: https://www.nps.gov/dscw/ds-structural.htm#bcis. [Accessed: 15- Feb- 2018].

[8] Allan Block, "http://www.allanblock.com/," [Online]. Available: http://www.allanblock.com/retaining-walls/landscape-water-management.aspx. [Accessed 30 1 2018].

[9] Allan Block, "http://www.allanblock.com/," [Online]. Available: http://www.allanblock.com/specifications/water-management-specs.aspx. [Accessed 30 1 2018].

[10] B. M. Das, Principles of Foundation Engineering (8th Edition). Cengage Learning, 2014

[11] U. Data, "Climate Grand Canyon - Arizona and Weather averages Grand Canyon", Usclimatedata.com, 2018. [Online]. Available: https://www.usclimatedata.com/climate/grand-canyon/arizona/united-states/usaz0088. [Accessed: 15- Feb- 2018].

[12] S. E.Serrano, Hydrology for Engineers, Geologists, and Environmental Professionals, Ambler, PA: HydroScience, Inc., 2010.

[13] M. Tanah, "Retaining Wall Design", Slideplayer.com, 2018. [Online]. Available: http://slideplayer.com/slide/5832372/. [Accessed: 14- Feb- 2018].

[14] "Google Earth – Google Earth", Google Earth, 2017. [Online]. Available: https://www.google.com/earth/. [Accessed: 13- Feb- 2018].

Appendix A
Technical Advisor Contract

CENE 476 Technical Advising Contract

General information for TA communication and interaction (to be filled out by technical advisor):

- Provide your contact information: chun-hsing.ho@nau.edu
  928-523-5309
- Preferred means of contact: email
- Minimum number of days needed to have a meeting scheduled: biweekly
- Preferred meeting location: 325-C
- Preferred meeting days and/or timeframe: Thursday or Tuesday 3-4 PM
- Are you willing to be contacted via phone (YES or NO) and/or email (YES or NO) for quick questions from individual team members YES YES
- Are you willing to meet more the identified minimum of four times (YES or NO)
- Any other comments: ______

The foregoing CONTRACT with its identified **Terms and Conditions** has been has been read, is understood, and is hereby accepted.

EXECUTED BY:

[signature] Technical Advisor Signature	Chun-Hsing Ho Technical Advisor Typed or Printed Name	2/1/18 Date
[signature] Student Signature	Spencer Floyd Student Typed or Printed Name	1/30/18 Date
[signature] Student Signature	Emory Chamberlain Student Typed or Printed Name	1/30/18 Date
[signature] Student Signature	Josh Madrigal Student Typed or Printed Name	1/30/18 Date
[signature] Student Signature	Kurtis Chivens Student Typed or Printed Name	1/30/18 Date
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