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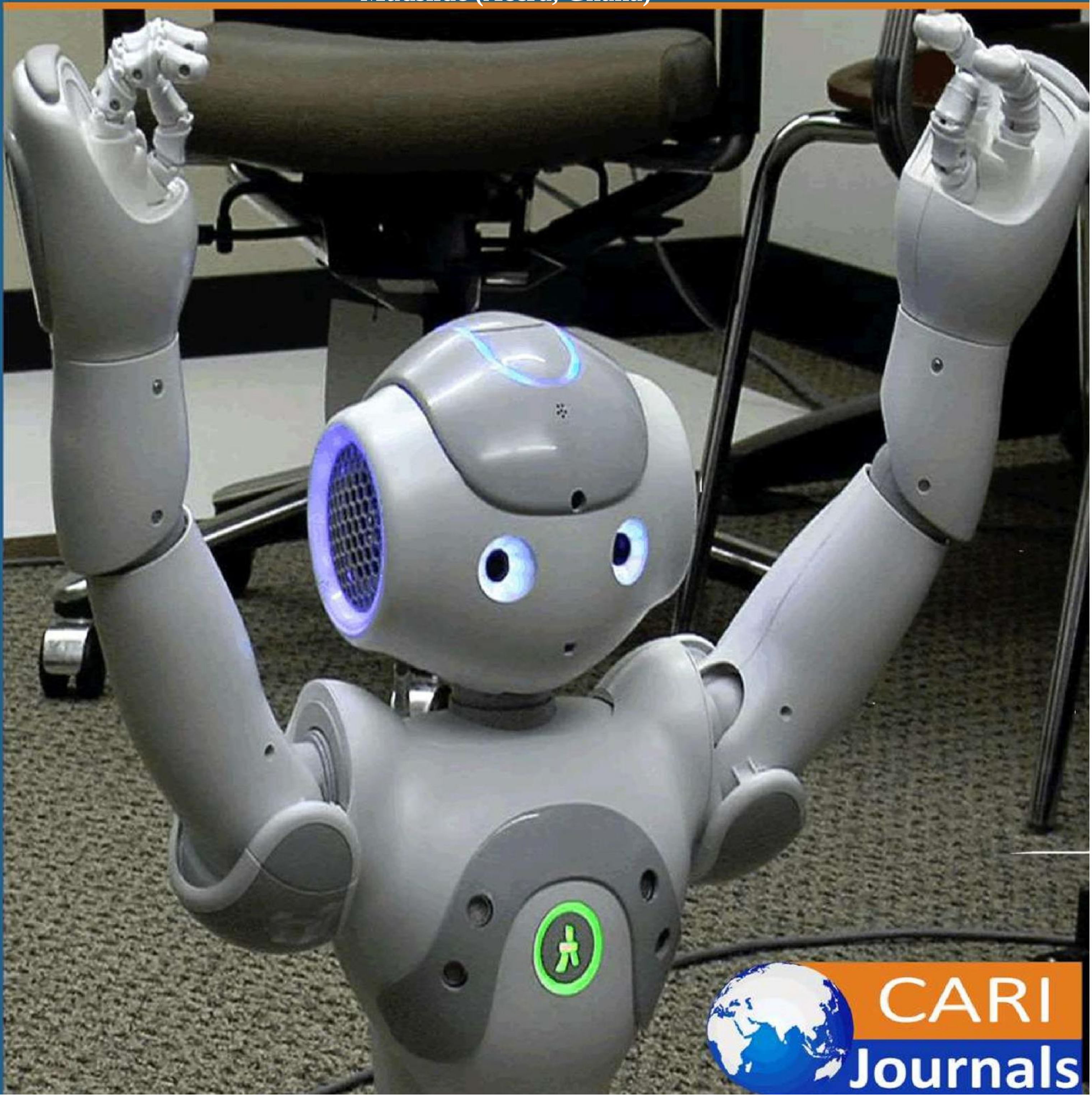

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Analysis of the Combination of the Soil Stability and the Slope Analysis Methods to Design a Retaining Wall on the Akoasa Mountain Mudslide (Accra, Ghana)

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Abstract

Purpose: The most unsafe geological chance in steep places is landslides. Landslides in Ghana have long been a most important source of worry, mainly during the rainy season. In some highland settlements, most of the buildings in Kasoa are impacted because the community is situated on a landslide terrain.

Methodology: In this project, cantilever and relieving platform retaining walls with varied heights of 3 to 10 meters and SBC 160 KN/m2 were analyzed and designed. Additionally, a comparative of factors like cost, efficiency, bending moment, stability against overturning, and sliding between the two retaining walls are shown. The cost comparison is done together with the comparative analysis, and the lowest or best estimate is selected.

Findings: This research also demonstrated that the relieving platform retaining wall is less expensive, more stable, and relieves the heel portion's bending moment

Unique Contributions to Theory, Policy and Practice: To reduce the risk of landslides on the road or in the town as a whole, we plan to construct or design a retaining wall model and, if possible, add a storm drainage system to the project.

Keywords: *Retaining Wall, Cantilever Retaining Wall, Relieving Platform Retaining Wall, Landslides, Mudslides, Stability Analysis Design, And Analysis.*

Background of the study

The definition of the phrase "landslide" is "the downward motion of good-sized quantities of earth or rock." They are capable of some of the most astounding floor movement damage. Mud flows, additionally regarded as mudslides, rock falls, earth slumps and a number of types of slope collapses are all viewed to be slides. Small or large, rapid or slow, wet or dry, reactivated or brand-new mudslides are all possible. In addition, they may additionally be shallow or deep. Rainfall, grading, pipeline breaks, irrigation for landscaping, inadequate surface drainage, earthquakes, erosion, and different natural and man-made phenomena are examples of triggers.

Debris floods and mud flows that move rapidly are particularly unsafe in wildfire burn sites. The tricky phenomenon recognized as slope instability, which also includes subtler procedures like soil creep, includes mudslides as one aspect of it. Mudslides are mainly common and unsafe herbal dangers that manifest worldwide, frequently causing extreme direct effects on human lives, public and personal properties, and lifelines (Klose, C. S., Flach). When the shear stress alongside a slope's geologic failure plane is increased than the material's shear strength, landslides (mudslide) is in all likelihood to occur. Geological forces, physical factors, morphological factors, and human-related things to do are the largest factors of landslides. These factors have a substantial influence on gravitational force, which tends to draw objects vertically downward. Landslides creep in or rush downhill like a slurry of wet concrete during periods of heavy rain. Landslides have the power to remove or wash away a significant quantity of debris from the cliff to the main road, making it difficult for cars to access the road. Additionally, slides can alter the path that water takes, which speeds up the devastation of the ground. In fact, landslides represent a risk to people's way of life and livelihood all over the nation, ranging from slight disturbance to social and financial catastrophe.

To prevent or lessen the potential damage, it is crucial to recognize the landslide-prone zones. When the shear tension is along a failure plane in the geologic materials, mudslides is bound to happen. To prevent or lessen the potential damage, it is crucial to recognize the landslide-prone zones. When the shear stress along a failure plane within the geologic materials of a slope is greater than the material's shear electricity, mudslides can result. Given a set of Geo-environmental variables, landslide susceptibility can be defined as the likelihood of spatial occurrence of slope failures (Guzzetti, F., Galli 2006). Small basins with steep slopes are typically thought to be landslide-prone.

Due to the gradual transformation of the once-beautiful mountaintop view into a cone form that ultimately caves in after any rainfall, the Akoasa mountain is not an uncommon landslide due to morphological reasons, physical causes, geological forces, and human-related activities. Following a rainstorm in June 2013, some parts of the loose mountain fell and blocked the Kasoa-Weija section of the highway, resulting in several hours long traffic jam. On June 14, 2015, a similar catastrophe happened, resulting in a huge mudslide that took days to clear up. (Gyesi, Z. K. 2017, November 18).

Literature Review

Correct laboratory testing revealed the characteristics of soil, including its grain size distribution, shear strength, softness, plastic limit, and liquid limit. Additionally, because this method avoids disturbing samples during field examination, the in-place determination of soil strength and deformation properties was developed. Decomposition and crystallization are the two main processes that might involve minor physical and chemical modification. Moreover, colloids are present in soil organic matter and clay minerals. The colloids' small size and large area are also among their most important characteristics. The chemical processes that occur in soil and affect the movement and retention of contaminants, metals, and nutrients were found to be greatly influenced by the clay particle role. (Firoozi, A. A., Olgun, C. G., & Baghini, M. S. 2017)

The effect of stone mud on the characteristics of poor soil by adding stone dust improves the CBR and MDD of poor soils. Additionally, it was stated that the addition of stone mud will gradually improve the quality of soil used as road sub-grade material by decreasing the liquid limit, plastic limit, physical property index, and optimal wet content. (Bshara, A. S., Bind, Y. K., & Sinha, P. K. 2014)

It is well-known that crusher dust has a high shear strength and can be used in Geo-technical applications. In contrast to other materials like ash, which only has pozzolanic properties and no coarser soil particles, stone dust may contain both pozzolanic and coarser contents. Different researchers claim that mixing soil with stone dirt can significantly improve the properties of soil. In order to examine the effects of blending on the OMC, MDD, and CBR properties of soil, stone dirt was added to the soil in this study in amounts of 100%, 20%, 30%, 40%, and 50% by dry weight of soil (Onyelowe, K., Okafor, F. O., & Nwachukwu, D. 2012).

A uniform slope model with clay-sort soil was used to analyze a LEM module of the GEO5 software package. According to the study's findings, the issue of safety decreases for all Kv/Kh ratios as horizontal seismic constant Kh rises, taking into account all possible research avenues; conversely, the issue of safety rises for all Kv/Kh ratios as cohesion rises, taking into account all possible research avenues. For index properties, a simple check known as a classification check is always required. It was discovered that the check required to determine engineering properties was complex and time-consuming. Information on engineering characteristics like permeability, compressibility, and shear strength is provided to the index properties. It was definitely assumed subliminally that soils with similar index properties would have similar engineering properties (Mathur, U. 2017). It is possible to use the CRISP two-dimensional finite component code, it is also possible to calculate the pressure distribution across the globe behind a 20 m high wall. The application of line hundreds caused oscillations in the earth's pressure values, as evidenced by the results. It was discovered that these oscillations in the upper half of the wall grew with increasing load and shrank with decreasing load. The lateral earth pressure was almost linear in the bottom half of the wall, with the highest pressure (Salman, A., Ibrahim, F. I., Abdullah, M. Y. B., & Mahbob, M. H. 2011).

Methodology and Analysis

The investigations in the field and in the lab were conducted to attain the set goals. The process involved in the analysis of the stability of the retaining wall at Akoasa mountain:

Step 1: Investigation of the area.

The investigations of the site were conducted to help with future field investigation planning and evaluation of the required preliminary and in-depth investigations. Determining the scope of the work, the exploratory tactics to be used, the field tests to be conducted, and the administrative procedures required for the research were made easier as a result.

Step 2: Gathering the materials

The two main materials used for this project were soil and crusher dust. Polythene covers were used to collect the soil samples, which were afterward dried by air. The quarry where the crusher dust was gathered.

Step 3: Analyzing the characteristics of Soil and crusher dust Analyzing the features of Specific gravity, particle size distribution, free swell, and other measurements were used to identify the characteristics of the soil.

The Tests for California Bearing Ratio, Atterberg limits, light compaction, and unconfined compression, among others were conducted. The characteristics were assessed using the same tests on samples for crusher dust.

Step 4: Design of Retaining Wall

All relevant factors and needs were taken into consideration, and all potential solutions were developed. The following steps are included in the design of a retaining wall: Fixation of the base width and other retaining wall dimensions calculating the maximum and minimum bearing pressure and conducting stability checks.

The design comprises of different components, such as the stem, toe slab, heel slab, and counter fort wall.

Step 5: GEO5 software's stability analysis

The evaluation made with GEO5 software consists of 3 different cases

- The selection of suitable height of retaining wall.
- The selected height as constant, and selection of suitable backfill mix.
- Finally, stability analysis for various water table depths.

1. **Experimental Study, Laboratory Works, and Procedures**

The basic properties of the collected sample were determined using laboratory tests. Laboratory tests

includes

- Particle size distribution

The procedures described in section 3.1.1 of this text were used to obtain and weigh a usable amount of soil. This procedure, known as quartering, involved pouring the soil gathered to represent the entire soil into two different weighing pans. The saturated soil was passed through a sieve with a mesh size of 75 microns to obtain the true or actual particle sizes before being dried in an oven for 24 hours. The soil was then weighed and divided into four categories: well-graded, evenly graded, gap-graded, and poorly graded. Figure 3.4 illustrates the grading process used on a sample of natural lateritic soil.

- Moisture content determination test

Water content is a ratio of how much water is contained in an object, expressed as a ratio between 0 and saturation porosity. Apparatus includes drying oven, measuring cups, Harmony, desiccator, test sieves, and scoop.

Test procedure

The most important details are that a single, spotless container with a lid is used, and the mass is measured in grams (m1) along with the container's identification number. The wet soil sample is broken up and put in the container, and the lid is removed and the lid and container are both placed in the oven. The sample is dried in a thermostatically controlled drying oven for 16 to 24 hours, and when the variations in successive weighing of the cooled soil at 4-hour intervals do not exceed 0.1% of the original mass, the soil is considered dry. An ideal drying temperature for gypsum-containing soil samples is 800C, and if a lid is present, it should be removed and the container, lid, or bottle and stopper should be placed in a desiccator and let to cool. Moisture content was determined as m3.

- Specific gravity test

The most important details are that a single, spotless container with a lid is used, and the mass is measured in grams (m1) along with the container's identification number. The wet soil sample is broken up and put in the container, the lid is removed and the lid and container are both placed in the oven. The sample is dried in a thermostatically controlled drying oven for 16 to 24 hours, and when the variations in the successive weighing of the cooled soil at 4-hour intervals do not exceed 0.1% of the original mass, the soil is considered dry. An ideal drying temperature for gypsum-containing soil samples is 800C, and if a lid is present, it should be removed and the container, lid, or bottle and stopper should be placed in a desiccator and let to cool. Moisture content was determined as m3.

- Atterbergs limits
- Hydrometer test

The hydrometer bulb's volume was calculated as the difference between the two readings, and the distance in cm between the cylinder's two graduations was measured to determine the area of cross-section (A). The height of the bulb was determined by measuring the distance (h) from the neck to its base. The effective depth (He) associated with each calibration mark (or hydrometer reading, Rh) was calculated by creating a calibration curve between He and Rh. The soil was rinsed with water before further processing because it was greater than 1%.

- Compaction test

The optimal moisture content (OMC) and maximum dry density (MDD) were determined and recorded at the peak of the curve by plotting the dry density against the compaction moisture content.

- Unconfined compression test

The soil sample was set up with the necessary water content and density and pressed into a sizable mold. A sample extractor and a knife were used to extrude the sample into the split mold. Vernier calipers were used to measure the specimen's length and diameter and the specimen was set on the compression machine's bottom plate. Axial strain resulted from the application of compression load and it was determined what angle the failure surface was at. The sample was then collected from the specimen's failure zone to gauge its water content.

- CBR test

The Optimum Moisture Content (OMC) from the compaction test was used to determine the consistency of the CBR test results. The soil was combined with the OMC after the OMC-producing molds and two more molds were weighed and recorded. The expected weight was 50% of the weight of the mold and moist soil, and the road was submerged in water for 96 hours. The plunger penetration was shown against a graph of the load ring dial.

- pH

The sample was dried by air, sieved with a No. 10 sieve, and then 10 ml of distilled or deionized water was added. The pH meter's temperature dial was set to Celsius, and the electrode was inserted into the sample suspension.

Table 1 shows the summary of the results of soil calculated

% gravel	26.18	D60(mm)	2.89	Cu(D60/D10)	14.37

% sand	73.42	D30(mm)	0.70	Cc(D30^2/D10*D60)	0.85
%fines	0.4	D10(mm)	0.20		

The percentage of the sample passing sieve number #200 was less than 50% which makes the sample coarse-grained soil. The percentage of sample passing sieve # 200 was < 5%. The percentage of sample passing sieve #200 falls within 0-5%. Cu (coefficient of uniformity)>6 and 1<Cc<3. Based on our results from ASTM D 2487 chat shows the soil is well-graded gravel with sand since the % of sand is >15%

2. Direct Shear Test Results

A direct shear test was also conducted to determine the shear strength properties of the soil including the bearing capacity of the soil. This test helped in providing the angle of internal friction and cohesion of the soil.

Table 2: Shows the summary results of the normal stress and maximum shear stress acting on the Direct Shear Box.

Test	Normal load(N)	Shear force at failure(N)	(σ)Normal stress (KPa)	(τ)Shear stress (KPa)
1	70	54	28	21.60
2	135	83.11	54	33.24
4	270	134.29	108	53.72
5	315	190.1	126	76.04
6	450	285.2	180	114.08

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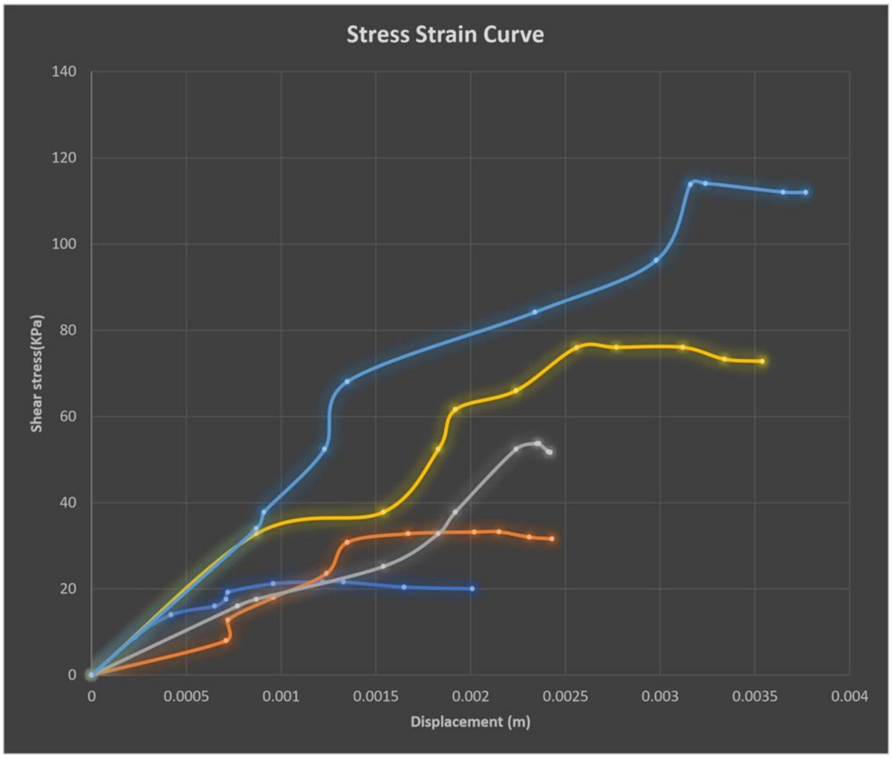
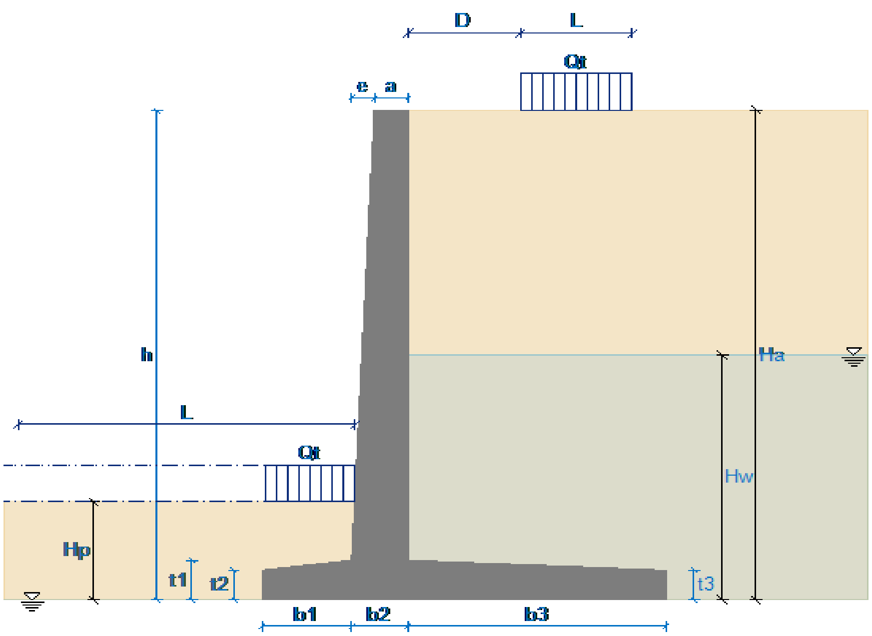


Figure 1: Shows the results of the stress strain curve



3. Design of The Retaining Wall

Figure 2: Cantilever Retaining wall dimension

Table 3: The dimensions of the retaining wall

Wall Height	(h): 5200.00 mm
Base Plate Front Length	(b1): 800.00 mm
Stem Bottom Width	(b2): 500.00 mm
Base Plate Back Length	(b3): 2300.00 mm
Stem Top Width (From Left)	(a): 300.00 mm
Eccentricity from Left	(e): 200.00 mm
Base Plate Height	(t1): 400.00 mm
Base Plate Front Height	(t2): 300.00 mm
Base Plate Back Height	(t3): 300.00 mm

Table 4: Total Failure Analysis Results

No	X (mm)	Y (mm)	R (mm)	Safety Factor	No	X (mm)	Y (mm)	R (mm)	Safety Factor
1	300.00	9000.00	9700.00	1.85	25	1800.00	9000.00	9300.00	2.05
2	300.00	8500.00	9300.00	1.86	26	1800.00	8500.00	8800.00	2.08
3	300.00	8000.00	8800.00	1.80	27	1800.00	8000.00	8300.00	2.04
4	300.00	7500.00	8300.00	1.75	28	1800.00	7500.00	7900.00	1.95
5	300.00	7000.00	7900.00	1.77	29	1800.00	7000.00	7400.00	2.00
6	300.00	6500.00	7400.00	1.72	30	1800.00	6500.00	6900.00	1.97
7	300.00	6000.00	7000.00	1.69	31	1800.00	6000.00	6400.00	1.89
8	300.00	5500.00	6600.00	1.72	32	1800.00	5500.00	5900.00	1.85

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9	800.00	9000.00	9600.00	1.94	33	2300.00	9000.00	9400.00	2.31
10	800.00	8500.00	9100.00	1.86	34	2300.00	8500.00	9000.00	2.24
11	800.00	8000.00	8600.00	1.85	35	2300.00	8000.00	8500.00	2.18
12	800.00	7500.00	8200.00	1.81	36	2300.00	7500.00	8000.00	2.24
13	800.00	7000.00	7700.00	1.76	37	2300.00	7000.00	7500.00	2.21
14	800.00	6500.00	7200.00	1.76	38	2300.00	6500.00	7000.00	2.12
15	800.00	6000.00	6800.00	1.75	39	2300.00	6000.00	6600.00	2.20
16	***800.00***	***5500.00***	***6300.00***	***1.69 (Critical)***	40	2300.00	5500.00	6100.00	2.20
17	1300.00	9000.00	9400.00	2.00	41	2800.00	9000.00	9600.00	2.53
18	1300.00	8500.00	9000.00	1.95	42	2800.00	8500.00	9100.00	2.42
19	1300.00	8000.00	8500.00	1.89	43	2800.00	8000.00	8600.00	2.49
20	1300.00	7500.00	8000.00	1.91	44	2800.00	7500.00	8200.00	2.41
21	1300.00	7000.00	7500.00	1.87	45	2800.00	7000.00	7700.00	2.37
22	1300.00	6500.00	7000.00	1.79	46	2800.00	6500.00	7200.00	2.47
23	1300.00	6000.00	6600.00	1.82	47	2800.00	6000.00	6800.00	2.49
24	1300.00	5500.00	6100.00	1.79	48	2800.00	5500.00	6300.00	2.42

Table 5: Total Failure Critical Diameter Results

Slice	**b (mm)**	**W (kN/m)**	**α (°)**	**Sinα**	**Cosα**	**W·Sinα**	**W·Cosα**	**c·L**
1	500.00	12.65	73	0.96	0.29	12.11	3.66	0.00

2	500.00	24.02	61	0.88	0.48	21.09	11.51	0.00
3	500.00	31.07	53	0.80	0.60	24.81	18.71	0.00
4	500.00	36.36	46	0.72	0.69	26.14	25.27	0.00
5	500.00	40.55	40	0.64	0.77	25.94	31.17	0.00
6	500.00	43.94	34	0.56	0.83	24.62	36.39	0.00
7	500.00	46.73	29	0.48	0.88	22.48	40.97	0.00
8	500.00	50.00	24	0.40	0.92	20.08	45.79	0.00
9	500.00	51.83	19	0.32	0.95	16.70	49.06	0.00
10	500.00	53.23	14	0.24	0.97	12.93	51.64	0.00
11	500.00	54.24	9	0.16	0.99	8.87	53.51	0.00
12	280.13	17.53	6	0.10	0.99	1.78	17.44	0.00
13	473.91	59.56	2	0.04	1.00	2.49	59.51	0.00
14	500.00	19.01	-2	-0.04	1.00	-0.68	18.99	0.00
15	500.00	18.04	-7	-0.11	0.99	-2.07	17.92	0.00
16	500.00	16.60	-11	-0.19	0.98	-3.23	16.29	0.00
17	500.00	15.52	-16	-0.27	0.96	-4.25	14.93	0.00
18	500.00	14.03	-21	-0.35	0.94	-4.95	13.13	0.00
19	500.00	12.11	-26	-0.43	0.90	-5.23	10.92	0.00
20	500.00	9.69	-31	-0.51	0.86	-4.96	8.33	0.00
21	500.00	6.71	-36	-0.59	0.81	-3.96	5.41	0.00
22	435.17	2.87	-42	-0.67	0.75	-1.91	2.15	0.00
					Total	***188.78***	***319.08***	***0.00***

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Total Failure Critical Diameter Results: 1.69>1.50 ✔

Table 6: Force Moments at different sections (kN.m/m)

Position	1.4G+1.6Q	0.9G+1.6H	1.4G+1.6Q+1.6H	G+Q+H+E	0.9G+H+E
The Stem Base	0.0	185.3	185.3	226.0	226.0
The Front Side of the Base Plate	28.2	19.9	24.0	20.5	21.2
The Back Side of the Base Plate	246.2	144.8	139.1	177.0	176.6

Table 7: Reinforced Concrete Design

Materials

Concrete Grade: C16/20	**Fcd = 13.33 N/mm2**	**Fctd = 1.05 N/mm2**	**Unit Weight = 24.000 kN/m3**
Rebar Grade: Grade 410 (Type 2)	**Fyd = 356.52 N/mm^2**		**Unit Weight = 78.000 kN/m^3**
Link Grade: Grade 410 (Type 2)	**Fyd = 356.52 N/mm2**		**Unit Weight = 78.000 kN/m3**

Shear Capacity Calculation

At the Stem Base : Vd = 120.4 < Vcr (299.3) kN/m

The Front Side of the Base Plate : Vd = 117.9 < Vcr (231.2) kN/m At the Back Side of the Base Plate : Vd = 155.6 < Vcr (231.3) kN

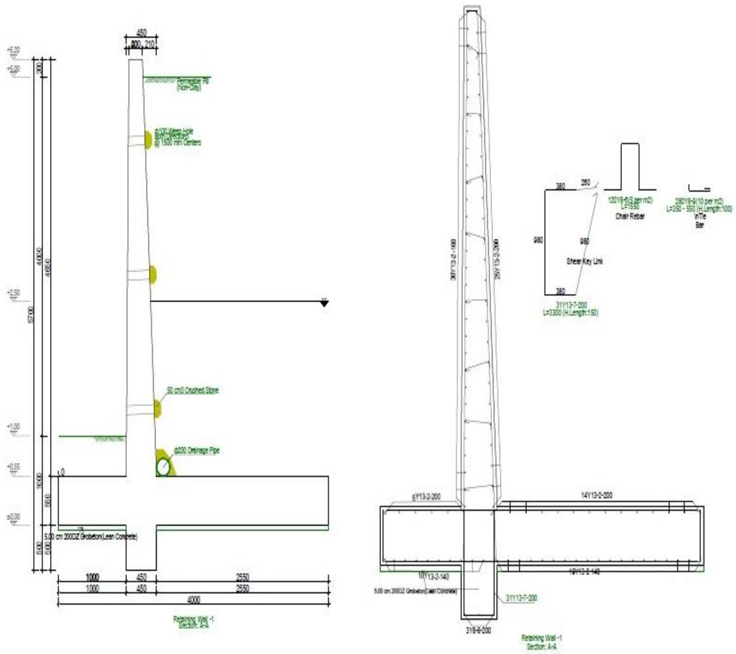

Figure 3 shows the details of the sustaining wall given by the software Prota structure

Conclusion

The Prota Structure Software contributed massively in the successful analysis of the stability of the retaining wall at Akoasa Mountain. The Geo-technical test on the soil sample taken from Akoasa Mountain yielded the soil parameters needed for the design of the retaining wall. According to the test results, the soil has a well-graded sand texture and a safe bearing capacity of 496kN/m2, with a unit weight of 23.14kN/m3. At the beginning, a 3 meters high cantilever retaining wall was designed. The result received from the analysis under those parameters shows that the stability was successfully achieved at an effective cost,. In conclusion, the retaining wall was suitable and able to stabilize the soil and avoid overturning and sliding of the building. The prota structure software was used to produce the manual design checks for overturning and sliding. Some holes were created in the cantilever retaining wall to release the additional pressure created by accumulated water and help in stabilizing the retaining wall. This ensures that the retaining will not collapse due to the fast flow of water on the hill.

Recommendations

The study of the combination of the soil stability and slope analysis to design the retaining wall was made at an height 0f 3 meters and 5.2 meters it is advised to design and analyze soil nailing for heights above the heights used in order to ensure additional stability. In order, to avoid flood for nearby properties, it is advised to install sub soil drainage systems behind all the designed retaining walls.

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