DESIGN AND STABILITY STUDY OF CANTILEVER RETAINING WALL USING GEO-5 SOFTWARE

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IN

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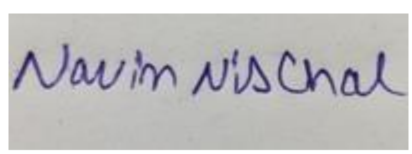
CANDIDATE'S DECLARATION

I, **Navin Nischal, Roll No. 2K18/GTE/10** student of M. Tech (Geotechnical Engineering), hereby declare that the report titled **"DESIGN AND STABILITY STUDY OF CANTILEVER RETAINING WALL USING GEO-5 SOFTWARE"** which is submitted by me to the Department of Civil Engineering, Delhi Technological University, Delhi in partial fulfillment of the requirement for the award of the degree of Master of Technology, is original and not copied from any source without proper citation. This work has not previously formed the basis for the award of any Degree, Diploma Associate ship, Fellowship or other similar title of recognition.



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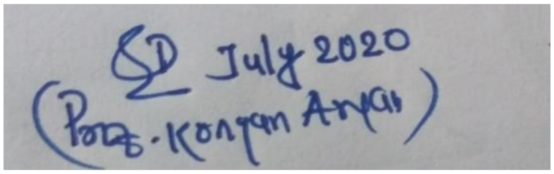
CERTIFICATE

I hereby certify that the report titled **“DESIGN AND STABILITY STUDY OF CANTILEVER RETAINING WALL USING GEO-5 SOFTWARE”** which is submitted by **NAVIN NISCHAL, 2K18/GTE/10**, Department of Civil Engineering, Delhi Technological University, Delhi in partial fulfilment of the requirement for the award of the degree of Master of Technology, is a record of the project work carried out by the student under my supervision. To the best of my knowledge this work has not been submitted in part or full for any Degree or Diploma to this University or elsewhere.



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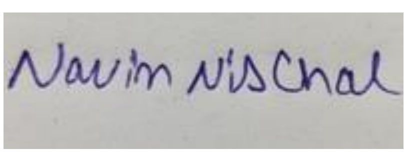

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ABSTRACT

Natural calamities are the most uncertain things which can happen round the globe and we geotechnical engineer are coping with this problem by solving the problems which occurs due to this natural hazards. One of the most common and dangerous hazards is landslides or in technical term slope stability. Analysis of the soundness of the earth retaining structures in such slopes and embankment could be a tough task for the geotechnical engineers. For this type of analysis which tough for onsite we take the help of software and we use GEO5 which permits geotechnical engineer to hold out the stability analysis of the retaining wall designed. This software consist of individual programs with unified and easy to use interface. We are dealing with the retaining walls that are accustomed to retain the earth in a position wherever the ground level changes suddenly. We are using ‘cantilever retaining wall’ which is most common variety retaining wall and is economical up to 10m. This research work deals with GEO5 slope stability software to evaluate stability of the retaining wall designed to hold more slope failure within the space. In order to improve the stability we will use some admixture at the backfill , cement kiln dust is waste product from Portland cement factory which is fine as fly ash as very economical to use as an filling and packing material.

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LIST OF ABBREVIATIONS

ASTM American Society for Testing and Materials

CBR California Bearing Ratio

C_U Coefficient of Uniformity

C_c Coefficient of Curvature.

OMC Optical Moisture Content.

MDD Maximum Dry Density

D_{10} Effective Particle size

D_{30} Diameter through which 30% of the total soil particles is passing

D_{60} Diameter through which 60% of the total soil particles is passing

NOTATIONS

A_o	Initial area of cross section
L_o	Initial length of sample
%	Percentage
Mm	Millimeter
m	Meter
W_s	Surcharge pressure on backfill
kN/m^2	Kilo newton per meter square
β	Slope of the backfill
γ	Unit weight of the soil
ϕ	Angle of internal friction
H	Overall Height
K_a	Active pressure co-efficient
K_p	Passive pressure co-efficient
l	Center to center distance between the counterforts
h	Height of the backfill
b	Base width
q_o	Safe bearing capacity
e	Eccentricity
Y_{min}	Depth of foundation
μ	Co-efficient of friction
A_{st}	Area of steel

M_u	Ultimate bending moment
d	Depth
θ	Angle
ϕ	Diameter
f_{ck}	Characteristic compressive strength
f_y	Characteristic yield strength
τ	Shear strength
δ	Soil wall interface friction
kPa	Kilopascal
$>$	Greater than
$<$	Less than
ρ	Reinforcement
w	Water content
G	Specific gravity
e	Axial strain
A	Area of cross section
q_u	Axial stress

CHAPTER 1

INTRODUCTION

Retaining walls has been designed for lateral earth pressure which supports the soil mass at the different levels and also soils with different sloped profiles, reinforced retaining walls where uses reinforcing steel to take care of the tension forces and stresses being developed in the concrete mass. Retaining walls are tremendous uses in many places, such as retaining a soil of high elevation (if we want to construct a building in lowest elevation) or retaining a soil to saves a highways from soil collapsing and for other applications. Retaining wall where divided into three parts- (stem, heel, and toe).

There are numbers of ways in which we construct a retaining wall:-

- Gravity walls: they are designed to resist pressure from back due to their own mass
- Piling walls: constructed from steel material, and usually used in tight spaces with soft soil having 2/3 of the wall under the ground
- Cantilever retaining walls: they have a large structural footing and convert horizontal pressure from behind the wall into vertical pressure on the ground below
- Counter fort walls: design values suitable and economical for retaining wall heights 8.0m to 10.0m.
- Anchored type of walls: which uses such as cables or other hold anchored in the rock or soil behind to increase resistance of the walls.

The type of wall we will examine is cantilever type of retaining wall. Cantilever type of retaining walls are constructed from reinforced Portland cement concrete. It is predominant type of rigid retaining walls used from about the 1920s to the 1970s. This type of wall displaced the traditional gravity wall are constructed of stone blocks or unreinforced cement concrete, which may prove to be not so economical for height above 3m, due to superior economics in the use of material and support backfill up to 7.5m high (Oyenuga, 2005) The present research work will focuses on the stability analysis and designing the cantilever retaining wall. The main discussions are the external stability of the section and the adherence to the recommendations of IS 456:2000.

STABILITY ANALYSIS

The stability analysis is done by graphs and using hands in older days. The conventional methods are been used for the analysis are Limit Equilibrium methods. Swedish circle method, Friction circle method and Bishop's method are the conventional methods which is used for designing the slopes. But nowadays this methods are been analysis through software. We will use GEO5 as an advanced software suitable for solving geotechnical problems based on traditional analytical method and Finite Element Method. GEO5 software is that type of software which offers various different methods of applying standards in the design, which drastically simplifies the work for the designer and at the same time, permit for consent with all required take aside. It is very accurate and easy to use tool in all geotechnical problems. GEO5 software gives output for the analysis is factor of safety, which explicate as the ratio of the shear strength. If the value of factor of safety is less than 1.5, the wall is unstable. For the safe standing of retaining wall, it is necessary to maintain the factor of safety. The factor of safety is determined for heights of wall with varying depths of soil and cement kiln dust as backfill material and also check for the different water table depth for analysis of the stability of the wall.

1.1 OBJECTIVE OF THE STUDY:-

The objectives for the study and designing in this thesis are.

1.1.1. To Determination of basic properties of foundation soil and fill material.

1.1.2. To analyze the stability of a retaining wall using GEO5 software at various depths.

1.1.3. To study the effect changes of additives on soil properties,in terms of the following parameters:

. Atterberg limits

. Maximum dry density(MDD), Optimum mostiure content(OMC)

. Califorina Bearing ratio(CBR)

1.1.4. It is more Economical both in terms of cost and energy.

CHAPTER 2

LITERATURE REVIEW

The literature review of the project consist of the title, research work parameter and result of different research papers of Design and analysis of retaining wall requires the determination of soil parameters and appropriate techniques for the analysis of stability. Different type of techniques adopted in the following literatures review to validate the soil properties, analyse its stability, design of the retaining wall to achieve stable the slope profile at accuracy, the developer needs to study characteristics of different methods and also determine the appropriate method for the situation before its usage in real application. The choice of the method is one of the important elements that have an influence the accuracy of analysis

Gunvant Solanki and Yash Chaliawala (2015) both done the work for comparative study of cantilever retaining wall and counter fort retaining wall. Priced against every optimum style of wall for explicit height was calculated by exploitation quantity of concrete and therefore the amount of steel. The result was found that Cantilever retaining walls are best in economically appropriate for all heights up to 6m and Counter fort walls are unit appropriate for retaining wall of height about eight meter to ten meter for the traditional conditions assumed.

Anissa Marron (2015) Research the form of slide surfaces which is form of gravity retaining walls constructed on sand by the small scale curved dynamic load tests. It had been ascertained that soils and structures receive the static load of the building made each within and on the surface and also dynamic loads. Laboratory modeling experiments were conducted to check the movement of soil grains and numerous dynamic hundreds were analyzed

Punde Gayatri Mehra (2007) made a Design of Retaining Wall, “Retaining walls are usually built to hold back soil mass to retain the soil which is unable to stand vertically by self-load. Nowadays retaining walls may be constructed for aesthetic landscaping purposes. The retaining walls are also provided to maintain the grounds at two different levels. Major important of that Retaining walls shall be designed to withstand lateral pressure which is exerted by earth and water pressures, the effects of surcharge loads, and the self-weight of the wall.

B.S.K Tahsildar (2008) investigated Stability of Retaining Wall under Seismic Load. A Review, A wall designed to maintain a difference in the elevations of the ground surfaces on either side of the wall is called a retaining wall. It is a very common civil engineering structure and is extensively used in railways, bridges, canals and other engineering works, Provision of a horizontal relief shelf projecting from the stem side of the retaining wall into backfill is known to reduce the total active earth pressure acting on the wall. This results will reduce in the overturning moment and more economical in the design of the stem and slab base. It is observed that the stability of retaining wall is a very crucial matter.

Raju (2000) in this research work researcher done work in stability of cantilever retaining wall. After going through his paper we see that he recommended some values for the stability of the cantilever retaining wall. Following recommended be like the Top width of the stem = 200 mm (min), base width, B = 0.5H to 0.6H for the wall without the surcharged loads on it. Then the 0.7H for the supporting walls with surcharge load but not state the effects of increasing surcharge load on stability of the retaining wall, Toe projection we will take as = B/3 , and the usually the thickness of the base slab = Thickness of stem and F.O.S should be against sliding to be greater than the 1.5 value.

Rameesha K and Chithira P. U (2009) in this research several design procedure has done for validate the slope on which they were examine, the slope which they study on a site of kuranchery which is a small village. Check all the soil parameter using various soil test in lab and then done the study work Landslides and natural hazards are major concern for the geotechnical engineer, so the software GEO5 use by them to work on the stability analysis of the retaining wall. Used most used retaining wall of 8m. Counterfort wall are appropriate for holding the wall height of 8.0m to 10.0m. The GEO5 use for the slope stability of the retaining wall against various parameter such as bend, slide and overturn. Use the filling material crusher dust for the enhance the stability of the backfill.

CHAPTER 3

MATERIAL AND METHODS

There are two type of material which are used in this experimental study, silty sandy Soil will collected from Delhi technological university, Rohini, New Delhi India, and another is cement industrial waste cement kiln dust. The type of soil is collected from the survey done by the New Comprehensive Soil Classification System based on National Bureau of Soil Survey and Land Use Planning (NBSS & LUP).

3.1.SOIL

3.1.1. Procurement of soil sample

The type of soil which we are using in this research in silt with handful amount of sand which is kind of problematic soil and present all over the north western Delhi areas. This type are susceptible to collapse when come in contact with water. These type of soils are coarse loamy in texture and brownish type of color. They are generally fertile in nature with high amount of moisture content.

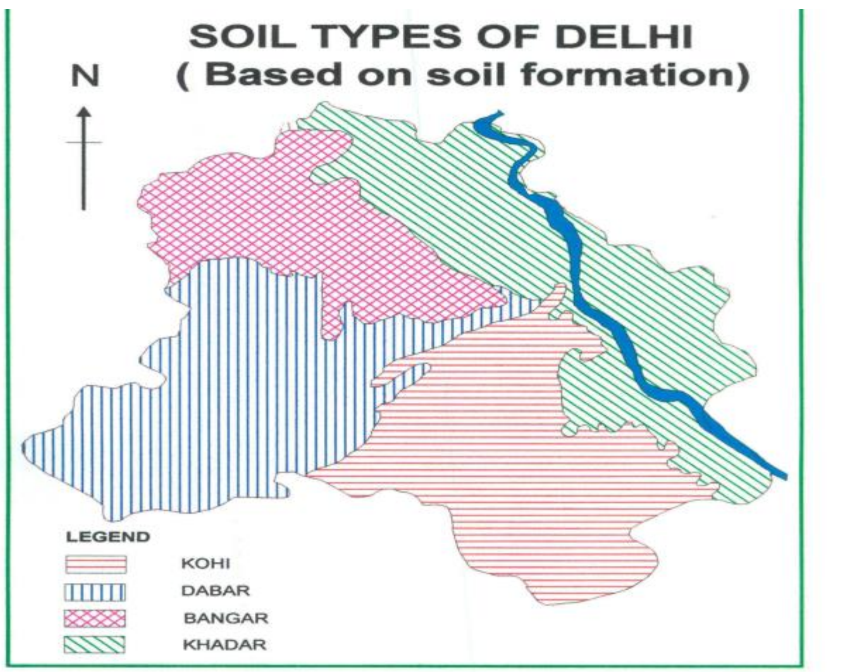


Figure 3.1.Different type of soil classification on area basis New Delhi, (NATIONAL BUREAU OF SOIL AND LAND USE PLANNING (NBSS & LUP).

3.1.2. **Properties of Representative Bangar soil (silty sand)**

Soils are classified into named Basic Soil Type groups according to size, and the groups further divided into coarse, medium and fine sub-groups: (British Standards Institution, 1990).

Table 3.1: soil classification basis of soil type

Very coarse soils	BOULDERS		> 200 mm
	COBBLES		60 - 200 mm
Coarse soils	**G** GRAVEL	coarse	20 - 60 mm
		medium	6 - 20 mm
		fine	2 - 6 mm
	S SAND	coarse	0.6 - 2.0 mm
		medium	0.2 - 0.6 mm
		fine	0.06 - 0.2 mm
Fine soils	**M** SILT	coarse	0.02 - 0.06 mm
		medium	0.006 - 0.02 mm
		fine	0.002 - 0.006 mm
	C CLAY		< 0.002 mm

3.2 SILTY SAND SOIL

3.2.1 Procurement

For this experimental study soil was taken from the concert ground, and soil is kept in the research laboratory of Delhi Technological University at the time of experiment and its properties were evaluated by performing different laboratory test. The soil sample was collected From a depth of 60 cm after removing the top surface soil from natural ground surface.

Figure.3.2.collecting soil sample for study.

3.3 CEMENT KILN DUST

Cement kiln dust (CKD) are the cement waste which is fined grained in texture and smooth in feel. This waste are removed from the cement kiln exhaust gas by air pollution control devices. Cement kiln dust are produced during the production of Portland cement plant. Cement kiln dust must be evaluated from the plant-by-plant basis since it varies in composition with respect to plant. When cement kiln dust is used alone may result in decreased of workability, setting times, and strength due to high alkali content. So it is advice cement kiln dust is used as admixture to stabilize the properties of the soil.

3.3.1 Some Advantages of cement kiln dust:-

Some of the following advantages are resulting from the research how cement kiln dust is usefull for stabilization process.

- Decreased initial and final setting times
- Increased strengths
- Pore Refinement

Cement kiln dust

Table 3.2: Typical Chemical Composition of Cement Kiln Dust.

Oxide	CaO	Al_2O_3	SiO_2	Fe_2O_3	Mn_2O_3	Na_2O	K_2O	Loss of Ignition
Concentration (%)	50.81	4.71	17.18	1.92	0.002	0.001	1.35	24.03

3.4 METHODOLOGY

The steps involved are various in stability of retaining wall.

Steps1: Determination of classification and properties of soil and cement kiln dust.

The soil and cement kiln dust are main constitute in this research. The soil characteristic were determine using Unconfined Compression Tests, California Bearing Ratio tests, Specific Gravity, Particle size distribution, Atterberg limits Same tests are conducted on the cement kiln dust samples, and the properties are determined.

Step 2: Designing of Retaining wall:

While designing the retaining wall there are various technical aspect while designing all important parameters and requirement are fulfilled and all possible solutions are generated. Following steps which are required in designing retaining wall.

- Designing the various parts of wall such as- stem, toe slab, heel slab, and counterfort wall.
- stability checks are been performed and find the maximum and minimum bearing pressure
- base width has been fixed and the other dimensions of the retaining wall

Step 3: Stability analysis using GEO5 software

GEO5 software can analysis different types of stability. Major three types of analysis we use are

- suitable height of retaining wall is selected
- select the height as constant, selection of suitable backfill mix
- At end we can find the stability analysis for various water table depths.

CHAPTER 4

EXPERIMENTAL STUDY

4.1 GENERAL

Basic properties of the soil sample were determined using laboratory tests by the Following laboratory tests have been conducted as per IS-2720-(1985) (Reaffirmed 1995).

- Moisture content determination test
- Specific gravity test
- Atterbergs limits as per IS-2720(Part V)
- CBR test as per IS-2720 (Part 16)

4.2 Dry Sieve Analysis

Sieve analysis is a method used to evaluate the grain size distribution of the granular material by allowing them to pass through a number of sieves of continuously smaller size and weighing the material that is retained on each sieve as a fraction of total mass of the material used.

Figure 4.1. Sieve analysis apparatus

4.3SPECIFIC GRAVITY

The specific gravity of solid particles (soil sample) is determined in a laboratory using density bottle fitted with a stopper having a hole. The density bottle (fig 7.1) of 50 milliliter unit capacity is employed. [IS: 2720 (part2) 1980]. The mass of the bottle, together with that of the stopper is taken. About (5-10) g of oven dry sample has been taken within the bottle and weighed. Water is additional till the bottle is full.

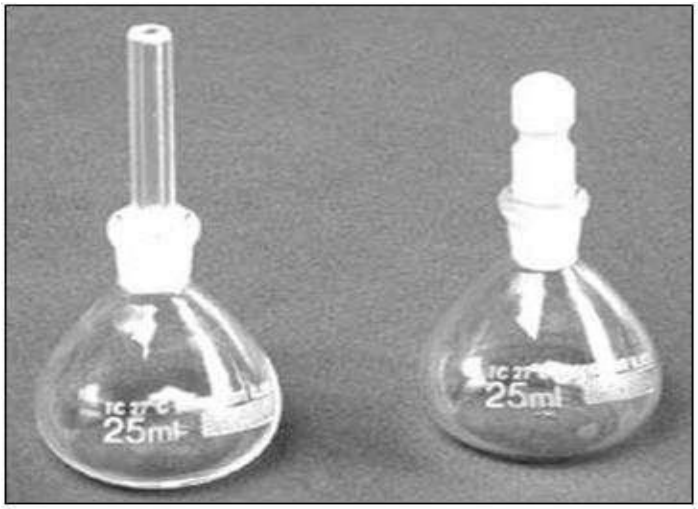


Figure 4.2 Density bottle

Additional water is added to the bottle to make it full. The stopper is inserted in the bottle and mass is taken. The bottle is empty, washed and so refilled with distilled water. The bottle should be crammed to the same mark as within the previous case.

Figure 4.3 pycnometer bottle

The mass of the bottle crammed with the water is taken. The specific gravity of crusher dust particles can be determined in a laboratory using pycnometer bottle by IS-2720-part-3-1980 decided mistreatment the relation:

$$G = \frac{(W_2 - W_1)}{(W_2 - W_1) - (W_3 - W_4)}$$

Where,
W_1 = Weight of dry pycnometer
W_2 = Weight of pycnometer and dry sample
W_3 = Weight of pycnometer, soil sample and water
W_4 = Weight of pycnometer and water

4.4 CONSISTENCY LIMITS OR ATTERBERG LIMITS

This is the basic measurement of the critical water content of fine grained soils. The atterberg limit test includes liquid limit test, plastic limit test, shrinkage limit test, which is given in the code book of ASTM D4943. These types of tests are principally used on clayey or silty soils since these are the soils that expand and shrink due to moisture content in the soils. Four states of soil varies like solid, semi-solid, plastic and liquid depending on the water content of the soil. In every stages the consistency and behaviour of a soil is completely different and therefore so are its engineering properties are changes according to. This tests are been evaluating various type of soils, which will ultimately have structure build upon that. Atterberg limit test are widely use in clayey or silty type of soil because this soil are most affected due to expansion and shrinkage varying moisture content. Thus this test are used mainly in the initial designing stages of structure ensuring that the soil will have the correct amount of parameters like shear strength, minimum volume change due difference in moisture content.

4.4.1 Liquid Limit

The liquid limit test, defined in ASTM Standard D4318,and was applied as per IS:2720, part 5-1985.It determines the water content at which the behavior of the clayey soil changes from plastic to liquid state. Liquid Limit can be determined using the tool Casagrande apparatus which is widely used in testing of liquid limit test. To determine the liquid limit the Flow curve is plot with variety of blows on x axis and water content on y axis. The twenty five blows is done to determined the liquid limit. In the below paragraph procedure how to do liquid limit test.

Soil sample is placed into the metal cup portion of the device and a groove is created down at one pace at centre with a homogenous tool of 13.5mm width. The cup is repeatedly dropped 10mm which the groove closes up step by step as a result of the impact. At end of test the number of blows for the groove is recorded, and thus last we calculate the liquid limit value using the graph, thus we can find the value of liquid limit value.

4.4.2 Plastic Limit

The method of doing plastic limit was as per IS: 2720, part 5-1985. The plastic limit (PL) is the water content of the soil varies between brittle and plastic behaviour of nature. The method we involves are to rolled out a thread of the fine portion of a soil on a flat, non-porous surface. A thread of soil is rolled out on a plan marble until its begins to crumble and rolled out to a diameter of 3mm of size. At this water content of soil loses its plasticity property and passes to the semi solid state.the plasticity index is that the size of the range of water contents wherever the soil exhibits its plastic property.

The PI is solve by the given equation- PI = LL-PL

Where, PI= Plasticity Index ,

LL= Liquid Limit,

PL= Plastic Limit

4.5 CALIFORNIA BEARING RATIO TEST (CBR)

The California bearing ratio abbreviated as (CBR) is a penetration test for testing of the mechanical strength of the road subgrades and base courses. CBR could be a check used to determine the bearing capacity of soil. For calculation of the CBR value the ratio of force per unit area need to penetrate a soil mass with a standard circular piston at the constant speed of standard circular plunger of 50 mm diameter at the rate of 1.25 mm/min. to that of required corresponding penetration of a regular material.

4.5.1 Preparation of Test Specimen-

- Soil sample is passed through 20mm size IS sieve and compacted dynamically at maximum dry density using high compaction method
- By removing the collar of mould trim the soil carefully using scraping tool, and weight the soil sample along with the mould and base plate.
- Weight of the surcharge is 2.5kg but not less than 5kg is to be placed on the top of the soil within the mould.
- Load is applied from the CBR machine while putting the mould on the loading machine by using penetration rate of 1.25 mm/min; use a seating load of 5 kilogram that isn't thought-about for the ultimate calculations.

- Record the load readings for numerous penetration values and also the chart is plotted. CBR values of two.5mm and 5mm penetration is calculated from their individual load values using CBR equation

Figure 4.5 Dry soil for CBR test mould

4.5.2 PREPRATION FOR CYLINDRICAL MOULD

Dimension of Inside mould is dia. 150mm and height 175mm with a detachable perforated base plate of 235mm dia. And 10mm thickness. Net capacity – 2250 ml; conforming to IS-9669:1980 (Reaffirmed-2016).

Figure 4.6 Prepared mould

4.5.3 PENETRATION TEST OF PREPARED SOIL SAMPLE MOULD

Unreinforced soil sample mould is placed with the surcharged put on the penetration test machine (CBR).placed the penetration piston at the centre of the specimen with the smallest possible load, so contact of piston and soil will made, make sure all nut and bolts thing should tight before starting machine. Set the penetration and loading dial gauge to zero. Apply the load on the piston so that the penetration rate is about 1.25 mm/min. Record the load readings at penetrations of 0.5, 1.0, 1.5,2.0, 2.5, 3.0, 4.0, 5.0, 7.5, 10 and 12.5 mm.Note the maximum load and corresponding penetration if it occurs for a penetration less than 12.5 mm.

Figure 4.7 Mould after unloading and taking penetration data

CHAPTER 5

DESIGN PROCEDURES OF RETAINING WALL

5.1 MODEL OF THE STRUCTURE

It cover design procedure for cantilever retaining walls and the calculation of the overturning moment and sliding forces, using numerical method and verify from GEO5 software.

5.2 DESIGN OF CANTILEVER RETAINING WALL

In the process of designing cantilever wall we use earth pressure co-efficient are calculated based on the theory of Rankine's and coulomb's backfill earth. We will assumed that a triangular pressure distribution is developed on the back of the wall due to the backfill earth. All earth pressure will be considered to act on a vertical plane, which pass through the rear end of the base slab.

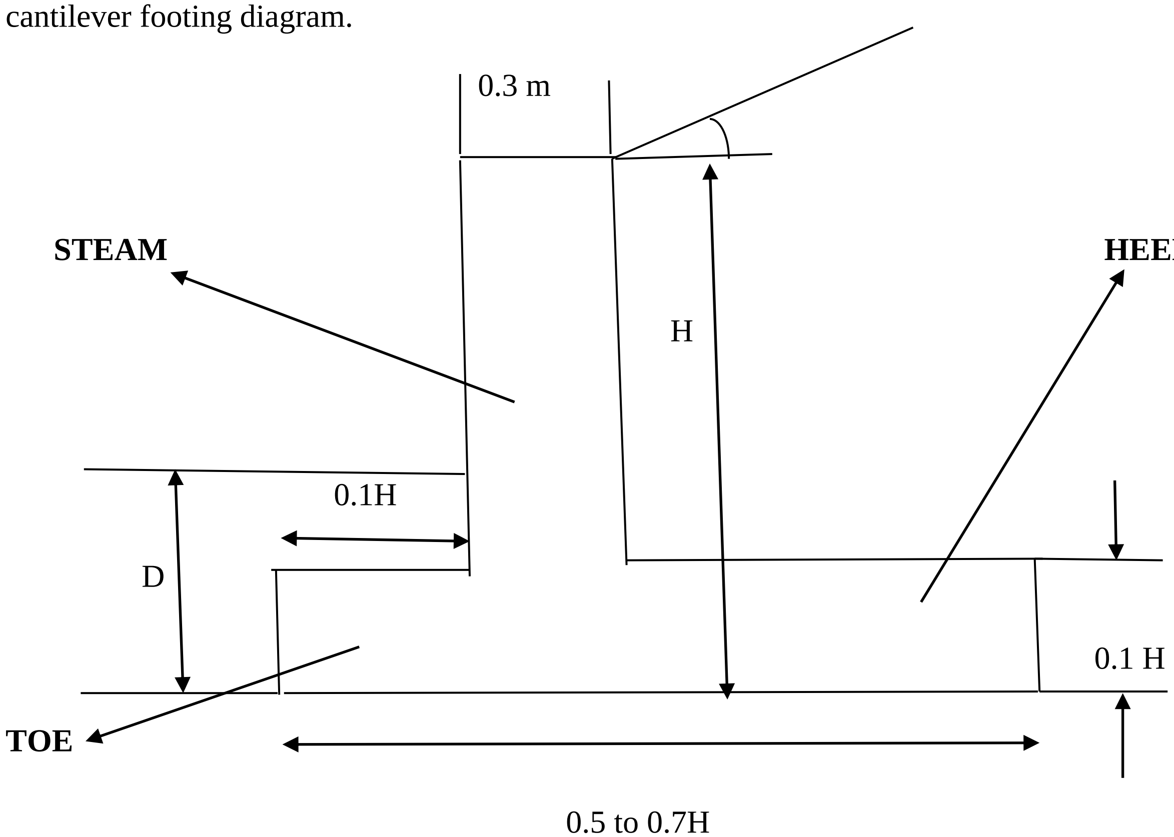
The design parameters for Stability Analysis:

- The height of the retaining wall was taken to be less than 10m for economical desgin and Width of the footing (B) was taken to be in the range of 0.5 to 1.0 of wall height, Wall thickness, b = B/6, toe width, c as 1/3 of B as suggested by Raju (2000) and width of heel, d was also used as 0.5B.
- In the process of designing the retaining walls, an design engineer must assume some of the dimensions for calculations called proportioning, such assumptions allow the engineer to check trial sections of the walls for stability, if stability check give undesirable result then section will be changed and then rechecked.
- Surcharge pressure on backfill, Ws (Kn/m^2), loads are not to be considered so zero is taken.
- Slope of backfill, β (^{0}) with the horizontal angle made by backfill soil with the horizontal.
- Unit weight of the soil (γ) –From the data collected, it is found to be 566.2 kN/m^2
- Concrete density varies between 23-25kN/m^2
- Bearing capacity of soil is taken as to the given depth of foundation for calculations.

- Depth of foundation is taken from the depth from surface of soil in front of the wall to the bottom of the base, for solving the designing.
- Base thickness in mm –the thickness of base slab is taken as 8-12% of total height (H) of wall.
- For initial design considerations, the length of heel slab is taken as $H\sqrt{K_a/3}$ (According to Pillai and Menon, Reinforced Concrete Design, 2011). The length of toe slab is in m.

5.3 Elements of Retaining Walls:

Retaining wall has been divided into three parts; stem, heel, and toe as shown for the following cantilever footing diagram.



In the above diagram the Approximate dimensions for various components of retaining wall for initial stability checks.

CHAPTER 6

SOFTWARE USED

6.1 GENERAL INFORMATION

The software which is used for the study is GEO5. It works on the combined principles of both analytical methods and Finite Element Method. GEO5 has a unique system of implementing standards and partial safety factors which are separate from structural input.

6.2 USEAGES OF GEO5

GEO5 is a geotechnical software package that is used to solve various geotechnical problems, such as slope stability, foundations, retaining walls, analysis of tunnels, building damage due to tunnelling or rock slope stability etc. The powerful programs in GEO5 suite is based on both analytical method as well as finite element method. The analytical method which are used in computation slope stability, sheeting design allow users to design in the software and also to check structures quickly and efficiently. The designed structure is transferred into the FEM where the finite element method is used for the overall general analysis of the structure. It saves designers time as well as compares two independent solutions, thus increasing the design safety. Each program analyses a different geotechnical task but all modules can communicate with each other and form an integrated package.

GEO5 software package that could be used for:

a. Analysis of stability

b. Design of excavation

c. Design of retaining wall

d. Design of foundation

e. Analysis of soil settlement

f. Model of digital terrain

g. Analysis of advanced finite element (F.E.)

6.3 SPECIFICATION OF GEO5 SOFTWARE-

The main features of GEO5 software are as follows-

1. **An essay to use tool**:

GEO5 computer code may be a terribly simpler and straightforward to use. The users principally don't require any intensive tutorial before victimization programs – they can work with confidence with it at intervals of some minutes. However you'll be able to use type of coaching and documentation resources whenever required

2. **Maintaining Standards of software**:

The basic methods that are enforced within the GEO5 programs are applicable everywhere the World. Many countries adapt their own standards and conventions.

3. **Availability of Localizations**:

GEO5 software is offered in fourteen different language versions, which user can work freely.

4. **A Low -cost modular system**:

The GEO5 programs area unit is cheap and it is possible to get a demo versions that the user can use and check how the software works, then they can buy and use as per user requirement.

5. **Simple and controlled data input:**

This is the most simple and user friendly software that geo5 offers. In most applications you'll be able to style and design check a structure among an hour without special training. Any modification if we do is straight away displayed on screen, providing you with absolute management of the method.

6. **Technical support:**

The service is on the market to Associate in nursing anyone for an annual fee, and enclosed square measure hotline phone support, skilled engineering help and unlimited access to computer code upgrades.

6.4 PARAMETERS FOR RETAINING WALL DESIGN PROGRAMS

GEO5 contains multiple programs for designing of retaining walls and supporting structures. Programs given in the software enables the analysis of the structure according to the given prescribe data. This software verify the wall material, analysis the stability of the natural manmade slopes and embankments, which is a difficult task for a geo-tech engineer. GEO 5 carried slope stability analysis at minimum chance of failure slopes and landslides.

6.5 SUMMARY

The Geo5 SOFTWARE is a modern tool for geotechnical engineers to solve various geotechnical problems. The package of this software includes the Stability analysis, Excavation design, Deep foundation, Settlement analysis, Tunnels and shaft, Walls and gabions and Shallow foundations. Working of the Geo5 software with the combination of Analytical method and Finite Element Method (FEM).It includes five methods of analysis namely Bishop, Janbu, Spencer, Fellenius and Morgenstern- Price Methods. It cooperates with all programs for finding and analysis of retaining wall design.

CHAPTER 7

EXPERIMENTAL RESULTS AND DISCUSSION

7.1 RESULTS OF TESTS PERFORMED ON SOIL SAMPLE

7.2 Dry sieve Analysis

Table.7.2 Sieve Analysis of soil

Seive size(mm)	WEIGHT RETAIND	Retaimed percentage %	cummulative Retained %	pass percenatge %
4.75	58.9	5.89	5.89	94.11
2.36	53.7	5.37	11.26	88.74
1.18	138.48	13.84	25.1	74.9
0.6	84.74	8.47	33.57	66.43
0.3	260.18	26.018	59.58	40.92
0.15	218.36	21.83	81.418	15.582
0.075	145.3	14.53	95.941	4.052
PAN	38.7	3.87	99.818	0.19

The % soil weight retained on the each sieve was noted on the reference with the total weight of soil taken during the test.Then cumulative % of the soil retained (which gives the %finer when minus from 100) on successive sieve is calculated. A log graph will plotted from the data from sieve analysis, the graph will plotted on log scale between the grain size on X-axis and percentage (%) finer on Y- axis. Diameter corresponding to 30%, 60% finer is obtained which can be evaluated as D_{30}, D_{60} respectively.

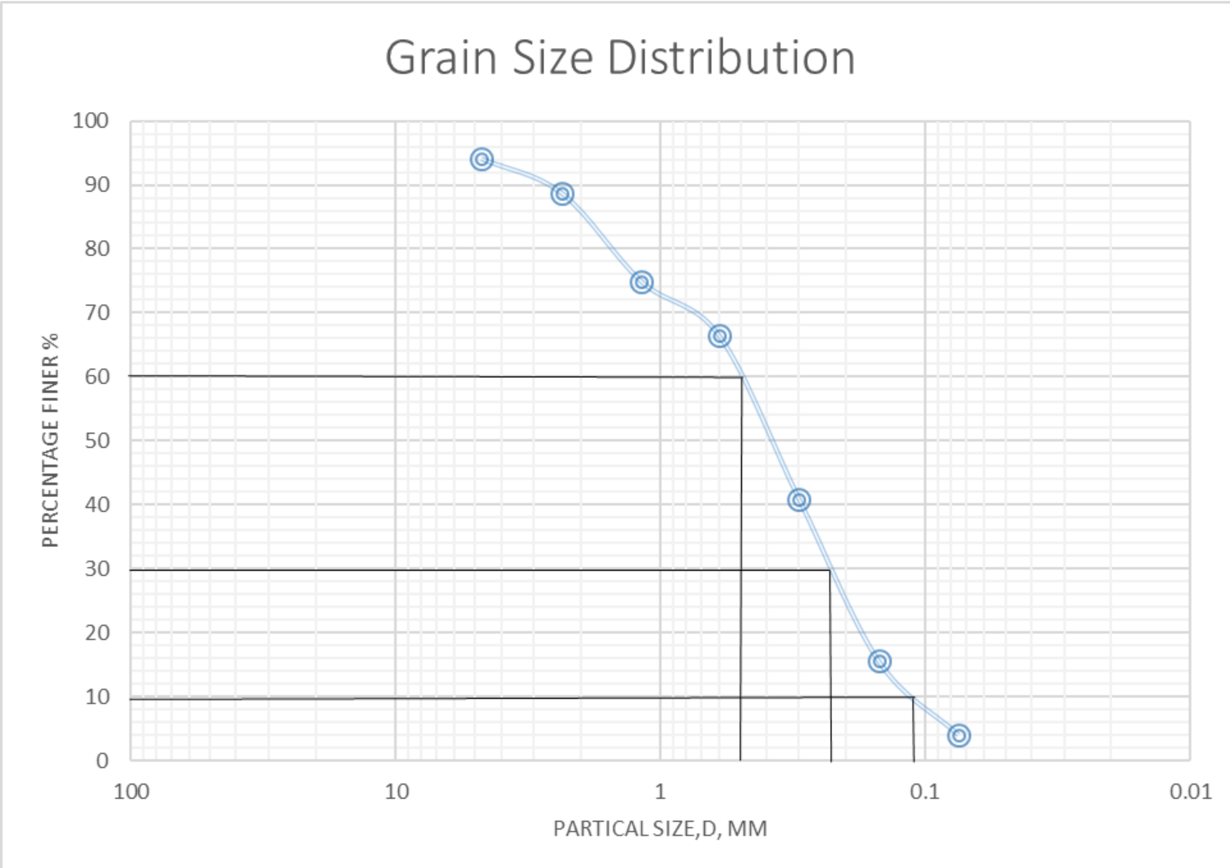


Figure.7.1.Particle size distribution of Silty Sand (SM) soil

D_{60} =0.6 mm, D_{30} =0.15mm, D_{10} =0.075

Uniformity Coefficient, C_u = 8

Coefficient of curvature, C_c = 0.5

For soil to be well graded, C_u > 5 and 1< C_c <3. So this is well graded soil.

7.3 Specific Gravity of Soil

As per IS: 2386-1963, Pycnometer test is formally used for determination of the Specific gravity of the soil sample which is used in the study.

Table 7.3. Specific Gravity of Soil

	Sample1	Sample2	Sample3
W_1 (gm.)(empty wt.)	687	688	689
W_2 (gm.)(wt. pycnometer with soil)	1115	1088	1107
W_3 (gm.) (wt. soil+water)	1840	1806	1823
W_4 (gm.) (only water)	1575	1580	1596
Specific Gravity, G	2.62	2.38	2.50

Average value of Specific Gravity is 2.5. Which is in normal range as per IS: 2386 (Part -3) – 1963 clause 2.4, for silty sand.

7.4 Liquid Limit

Table 7.3. Liquid Limit of soil

Number of Blows	W_1(Weight of wet soil Sample)	W_2 (Weight of Dry soil Sample)	Water Content (%)
28	15.73	12.45	26.34
24	17.71	14.80	19.66
21	13.26	11.21	18.28
20	18.31	15.75	16.25

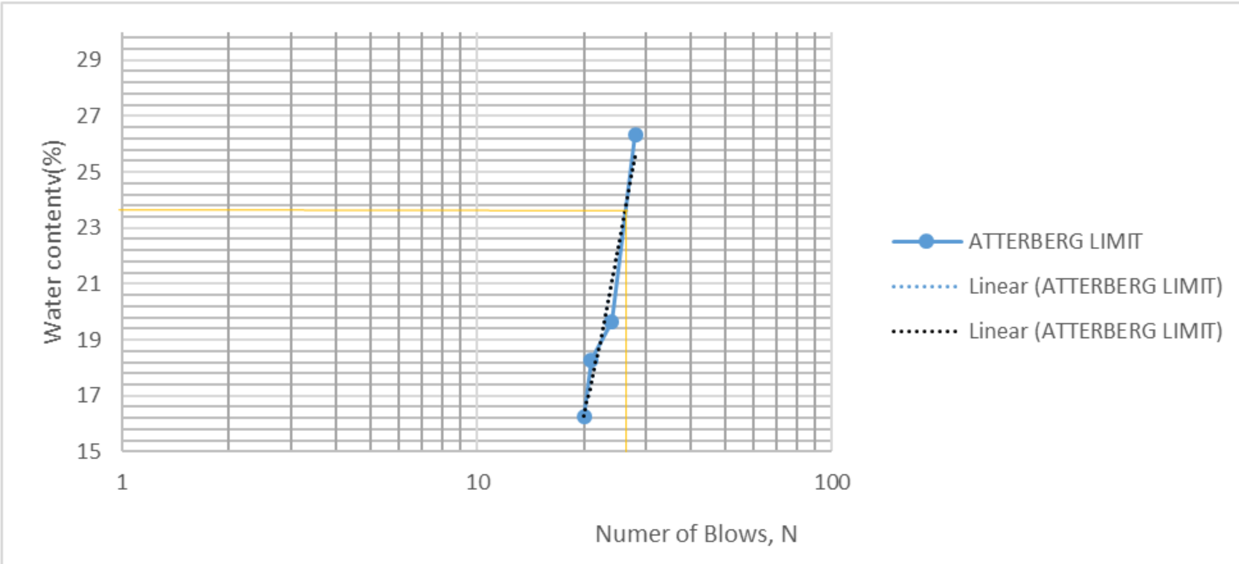


Figure.7.2. Liquid Limit Curve

From this Graph Liquid Limit of Soil is obtained was 23.95%. Code reference As per IS 2720 (part5)-1985.

7.5 Plastic Limit of Soil (W_P):

Table.7.4. Plastic Limit

Container Number	Weight of container, W_1 (gm.) (wet)	Weight of container W_2 (DRY)	Water content (%)
1	3.04	2.65	14.28
2	2.45	2.07	18.35
3	4.18	3.66	14.21

Plastic Limit (Mean Value, %) = 15.61%.code reference As per IS 2720 (part-5)-1985

7.6 Plasticity Index (I_P)

(I_P) = (W_L - W_P) = 23.95-15.61= 8.34%

Hence soil plasticity index is determined, this may be determined by the plasticity chart.

7.7 Liquidity Index (I_L)

(I_L) = (W-W_P)/(W_L -W_P)= (20-15.61)/8.34= 53%

7.8. <u>RESULTS OF TEST PERFORM ON CBR</u>.

Table 7.5. CBR test results of unreinforced soil sample.

As we takes out the data from the proving ring we have to multiply the calibrated forced measure from the data which proving ring gives, while performing the experimental study.

Table.7.5. CBR Test Data of Unreinforced Soil Sample

Penetration(mm)	Proving Ring reading (Mould1)	Proving Ring reading (Mould2)	Average
0	0	0	0
0.5	4	3	4
1	9	8	9
1.5	14	12	13
2	17	15	16
2.5	21	20	**20**
3	26	24	22
4	28	27	24
5	33	31	**27**
7.5	46	45	36
10	63	61	46
12.5	66	62	49

Figure. 4.1**.** CBR curve for soil sample with Unreinforced Soil

Calculate the load in kg for the penetration 0.5 mm, 1.0 mm, 1.5 mm, 2.0 mm, 2.5 mm, 3.0 mm, 4.0 mm, 5.0 mm, 7.5 mm, 10.0 mm, and 12.5 mm by multiplying by 1.239. (1.239 kg value we got from our load gauge calibration report)

The main important load value is what taken on 2.5 mm and 5.0 mm penetration.

- 2.5 mm penetration – 20
- 5.0 mm penetration – 27

So load value shall be on 2.5 mm penetration = 20 * 1.239 = 24.78kg

And for 5.0 mm penetration = 27 * 1.239= 33.45 kg

By this method we can calculate load value for each reading.

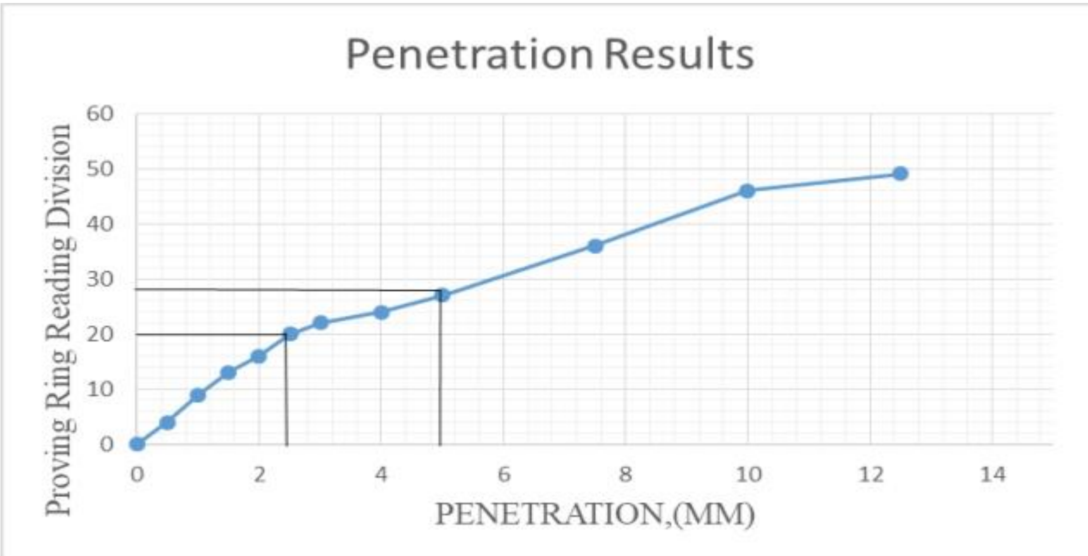


Figure 7.3 **CBR** curve for soil sample with Unreinforced Soil

Now we calculate the CBR value:

CBR value on 2.5 mm penetration = 24.78 / 1370 * 100 = 1.75%

CBR value on 5.0 mm penetration = 33.45 / 2055 * 100 = 1.62%

Important Note:

For each specimen we consider CBR value the higher value between 2.5 mm and 5.0 mm penetration.

So, our CBR value is 1.75%

7.9 PROPERTIES OF CEMENT KILN DUST

characteristics were determined using Specific Gravity test, Light compaction test, Unconfined Compression Tests, California Bearing Ratio test etc. The test results are shown.

Table 7.6 the test results are shown in

SL. NO	PROPERTIES	VALUES
1.	Liquid limit (%)	37.23
2.	Plastic limit (%)	19.12
3.	IS classification	sandy clay (CS)
4.	Specific Gravity	2.75
5.	Maximum Dry Density (g/cc)	1.88
6.	Optimum Moisture Content (%)	13.90
7.	Angle of internal friction (deg)	40^0

The various parameters has been required for the designing the retaining wall that has been obtained from the soil test results. In this research work presents the stability analysis of the retaining wall about 7m height with a single layer of walls. For the designing of wall we are using the Cantilever retaining wall. In the design process various assumptions value has been taken and after trial and error final wall has been design. Due to certain limitation we are not used the practical work rather the numerical design for the slope stability of wall and improvement of backfill is done by admixture of cement kiln dust, it is very cheap and easily available and improve the properties the backfill. The research work is confine with only numerical designing and slope stability of the cantilever retaining wall.

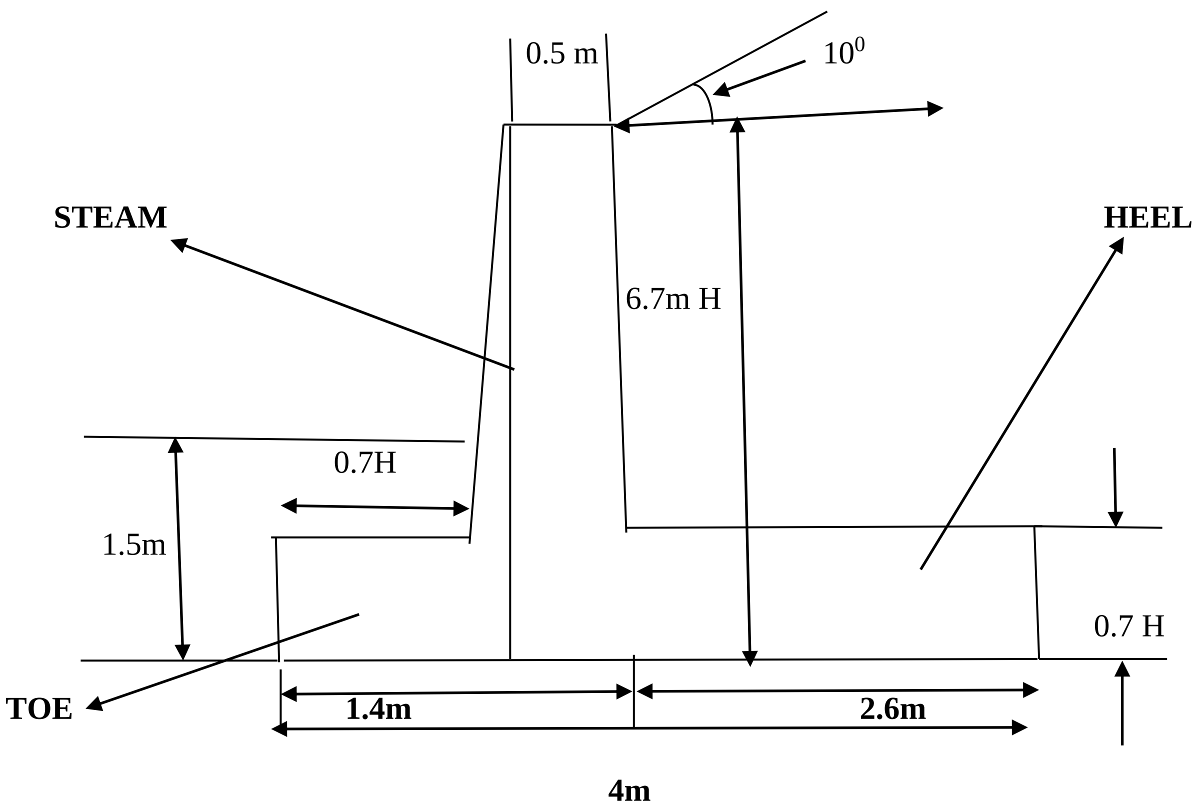
CHAPTER 8
RESULTS AND DISCUSSIONS
OF CANTILEVER RETAINING WALL

8.1 Design process:-

The detailed design for cantilever retaining wall having an embankment height of 6.7 m is given below. Safe bearing capacity of the soil (q_o) is 566.2 kN/m2. The unit weight of the soil is found to be 24 kN/m2. The angle of internal friction is 29. M25 grade concrete and Fe415 steel is adopted for design. The design is as per the guidelines of IS 456: 2000.

The cross section of the cantilever retaining wall shown below. Calculate the factor of safety with respect to overturning, sliding, and bearing capacity. γ_c = 24 kN/m3. Ahmed S. Al-Agha (2015).

Since it is not specified a method for solving the problem, directly we use Rankine theory. Now draw a vertical line starts from the right-down corner till reaching the backfill line.



Given data for designing the wall.

γ_1 = 18 kN/m^2

ϕ_1 = 29°
C_1 = 0.0

$\gamma 2$ = 19 kN/m^3
$\phi 2$ = 24°
C2 = 40kN/m^2

Co-efficient of active pressure, K_a=1−sinØ/1+sinØ = 1-sin (29^0)/1+sin (29^0) =0.346

Co-efficient of passive pressure, K_p =1/K_a = 1/0.346 = 2.890

P_a=1/2× γ_1 × H'^2 × K_a

Tan 10^0 = d/2.6 = 2.6 x tan 10^0 = 0.458m
$H^/$ = 6.7 + d = 6.7 + 0.458 = 7.158m

P_a=1/2× 18 × 7.158^2 × 0.3495 = 161.2 kN

Location of P_a =

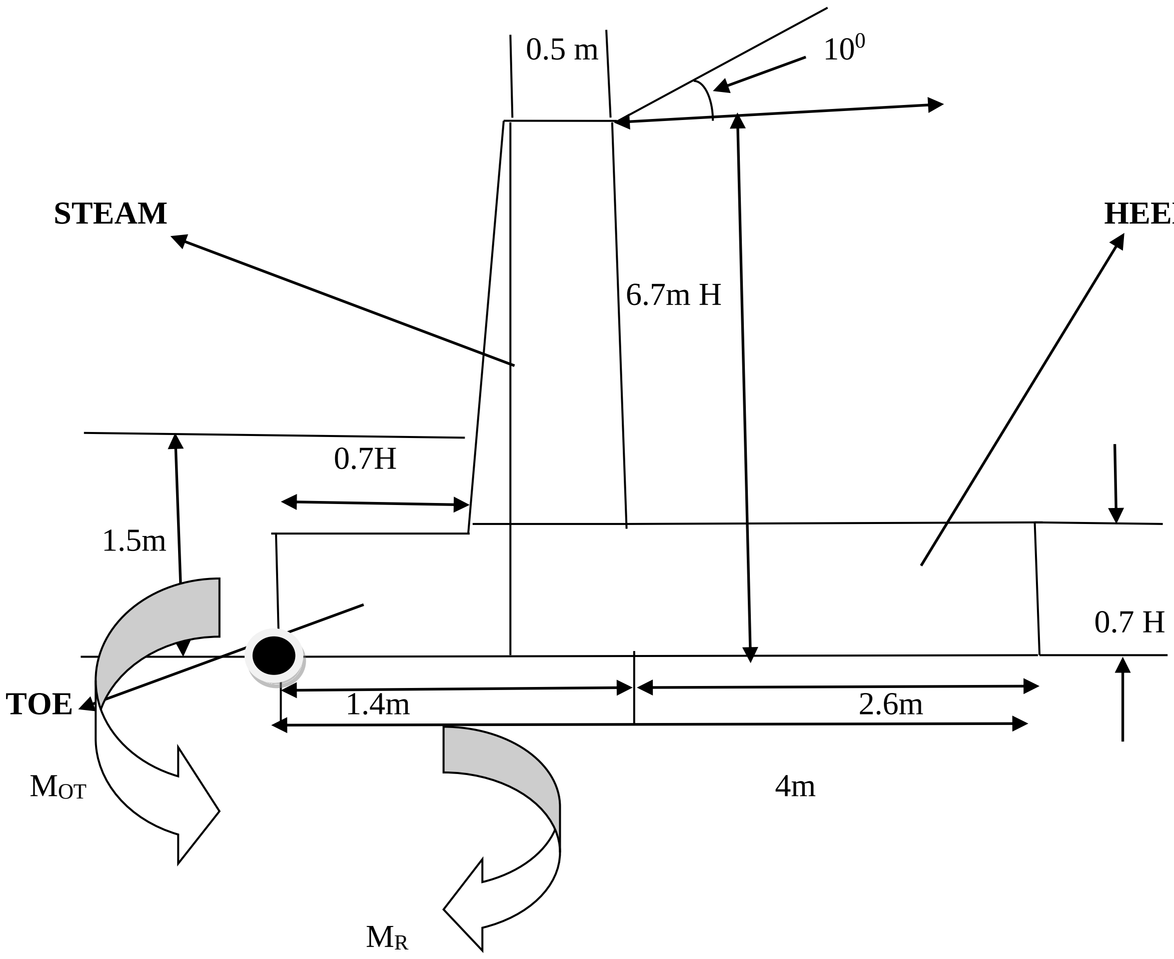
Location = $H^/$ /3 = 7.158/3 = 2.38

The total active force P_a is inclined with angle α = 10 with horizontal of that,

$P_{a,h}$ = 161.2 cos(10) = 158.75

$P_{a,v}$ = 161.2 sin (10) = 28.23

8.2 Check for overturning:



M_{OT} = 158.75x 2.38 = 337.8 KN.m

Now we have to calculate $M_{R,}$ so we have divided the soil and the concrete into rectangles and triangles to find the area easily (as shown above diagram) and to find the arm from the centre of each area to point **O** as prepared in the following table

Table 8.1: Stability check

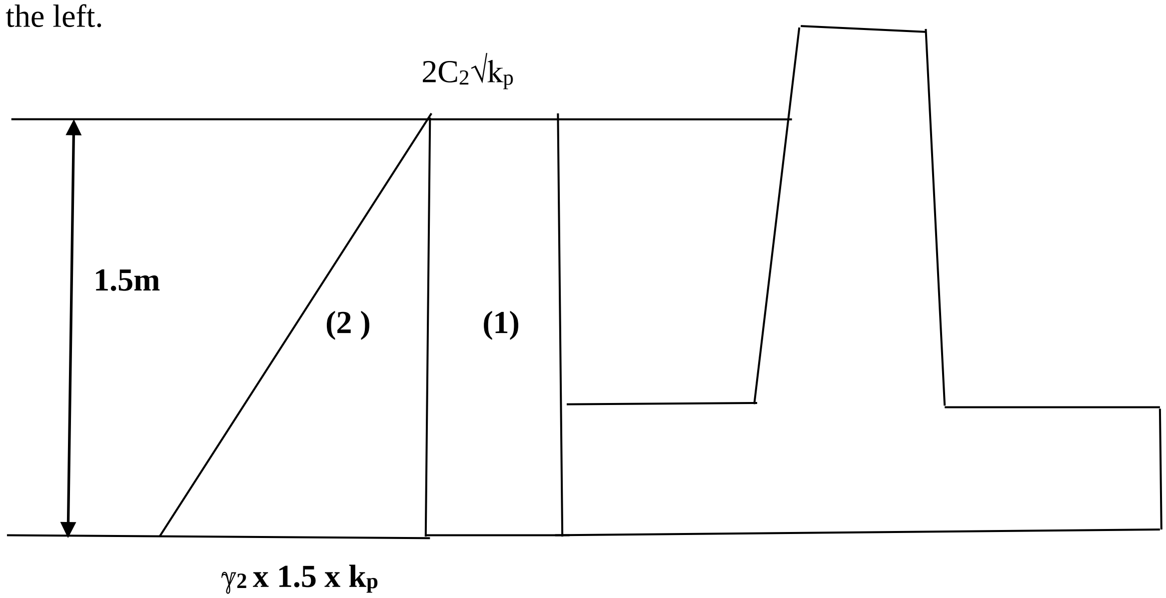
Section	**Area**	**Weight/unit length of the wall**	**Moment arm measured from O**	**Moment about O**
1	0.595	0.595 × 18 = 10.71	4 - 2.6/3 = 3.13	33.52
2	15.6	15.6 × 18 = 280.8	1.4 + 1.3 = 2.7	758.16
3	3	3 × 24 = 72	1.4 – 0.25 =1.15	82.8
4	0.6	0.6 × 24 = 14.4	0.9 – 0.2/3 = 0.83	12
5	2.8	2.8 × 24 = 67.2	4/2 =2	134.4
		$P_{a,v}$ = 28	B = 4	112
∑		∑v = 470.11		M_R = 1132.88

$FS_{OT} = M_R / M_{OT}$ = 1132.88/377.8 = 2.99 > 2 **OK**

8.3 Check for Sliding:

$FS_S = F_R / F_D \geq 2$,(if considered P_p in F_R)

For check in sliding condition we will take passive force, Applying rankine theory on the soil in the left.



k_p is been calculated for the soil using rankine theory without inclination of the wall because it is calculated for the soil below the base.

$K_p = \tan^2 (45 + \phi_2/2) = \tan^2 (45 + 20/2) = 2.04$

P_1 = (rectangle area) = $(2 \times 40 \times \sqrt{2.04}) \times 1.5 = 171.4$kN

P_2 = (triangle area) = $0.5 \times (19 \times 1.5 \times 2.04) \times 1.5 = 43.6$kN

$P_p = P_1 + P_2 = 171.4 + 43.6 = 215$ kN

$F_d = P_{a,h} = 158.75$kN

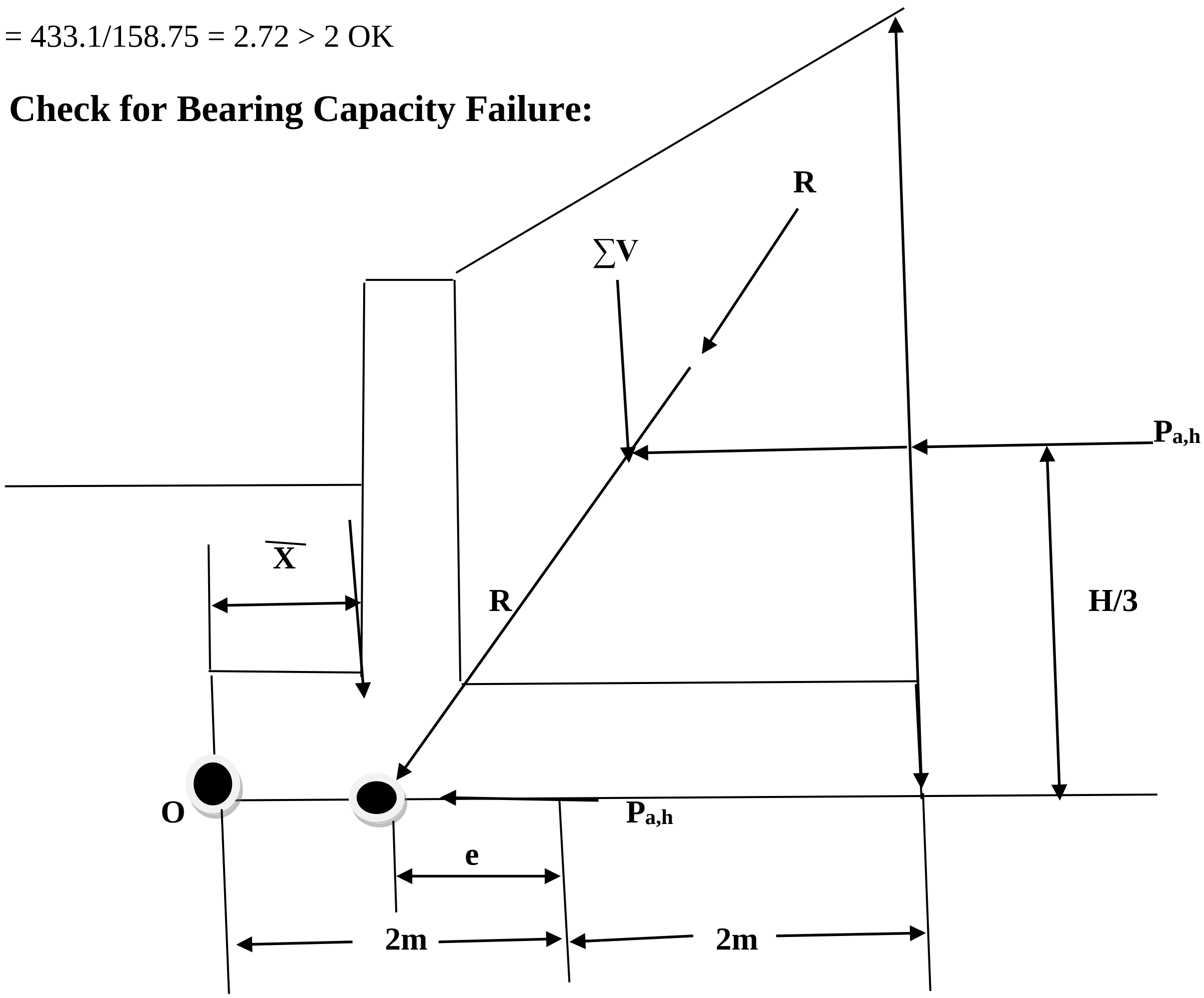
$F_R = \sum V \times \tan (K_1\ \phi_2) + K_2 c_2 B + P_p$

Taken $K_2 = K_2 = 2/3$ $\sum V = 470.11$ (from table number xyz).

$F_R = 470.11 \times \tan (2/3 \times 20) + 2/3 \times 40 \times 4 + 215 = 433.1$kN.

$FS_s = 433.1/158.75 = 2.72 > 2$ OK

8.4 Check for Bearing Capacity Failure:



$\overline{X}$ = $M_r - M_{ot} / \sum V$ = 1132.88 – 377.8/ 470.11 = 1.6m

e = (B/2 – $\overline{X}$) = (2- 1.6) = 0.4m

B/6 = 4/6 = 0667 -> e = 0.4 < B/6 ->->->

$Q_{max} = \sum V / B \times 1 (1 + 6e/B)$ = 470.11/4 x1(1+ 6 x 0.4/ 4) = 188.04kN/m2

$Q_{min} = \sum V / B \times 1 (1- 6e/B)$ = 470.11/ 4 x 1 (1- 6 x 0.4/4) = 47kN/m2.

8.5 Calculation of ultimate bearing capacity, q_u (for the soil below the base):

$q_u = cN_cF_{cs}F_{cd}F_{ci} + qN_qF_{qs}F_{qd}F_{qi} + 0.5B\gamma N_yF_{ys}F_{yd}F_{yi}$

c = 40, q = 1.5x19 = 28.5, γ = 19

B = B` = (B-2e) = 4-2 x (0.4) = 3.2m

Shape factor we will take = 1 (RW is considered as a strip footing)

For ϕ = 20 , N_c = 14.83, N_q = 6.4, N_γ = 5.39 (from table bm das book)

Depth factor: we will use B not B`

D/B = 1.5/4 = 0.375 < 1 and ϕ = 20> 0.0

$F_{qd} = 1+2 \tan \phi (1-\sin \phi)^2 (D_f / B)$

= 1+2tan20 $(1-\sin20)^2$ x (0.375) = 1.12

$F_{cd} = F_{qd} - (1- F_{qd}/ N_c \tan \phi)$ = 1.12 – 1 – 1.12/ 14.83 X tan20 = 1.15

$F_{\gamma d}$ = 1

Inclination factors:

$\beta = \Psi = \tan^{-1} (P_{a,h} / \sum V) = \tan^{-1}$ (158.75/470.11) = 19.3 (it is with vertical)

Fci = Fqi = $(1- \beta^0/90)^2$ X $(1- 18.6/90)^2$ = 0.64

$F_{\gamma i} = (1-\beta^0/ \phi^0)$ = (1- 18.6/20) = 0.07

q_u = 40 × 14.83 × 1.15 × 0.63 + 28.5 × 6.4 × 1.15 × 0.63 +0.5 × 3.2 × 19 × 5.39 × 1 × 0.07

q_u = 566.2 kN/m^2

$FS_{B.C} = q_u/q_{max}$ = 566.2/188.04 = 3.01> 3 **OK**

8.6 STABILITY ANALYSIS OF CANTILEVER RETAINING WALL USING GEO5 SOFTWARE:-

The stability analysis of the cantilever retaining wall has been performed as three separate cases as follows:

Case I: Stability analysis of selected height.

Case II: Trial for various backfill depths of cement kiln dust and backfill material.

Case III: Variation of effect in water table at different depth.

8.6.1Case I: Stability analysis of selected height

Analysis for stability of designed overall height of 6.7 m, considering the backfill to be of soil (Silty Sand soil) (SM) and the water table is not considered.

1. Analysis for overall height of 6.7m retaining wall

A. The first step to analysis is to open the software GEO5, cantilever wall design program. Click on the "project" option.

- Go to the frame section and then go to Project then click and insert Task, description, Author name, Part, Date, and Customer name, fill all the blank filled space the go to the next step
- Insert the unit in metrics
- After filling all the details then click on (Analysis methods) from the Frame sections and select proper codes and methods.

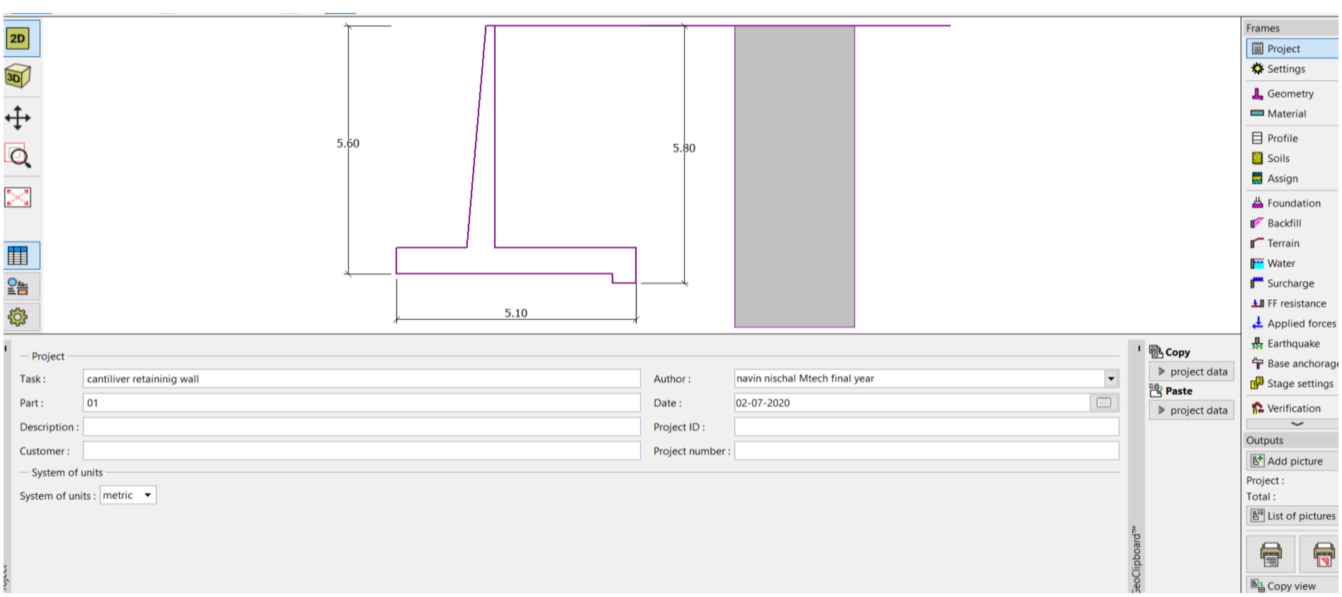


Fig 8.1: Project Frame

B. Click on the “settings” option

- Click on the edit option the proceed further
- After edit click on the Verification methodology – Classical way
- After verification method for classical way Choose analysis standard – IS 456
- Theory of analysis should be – Mononobe Okabe.

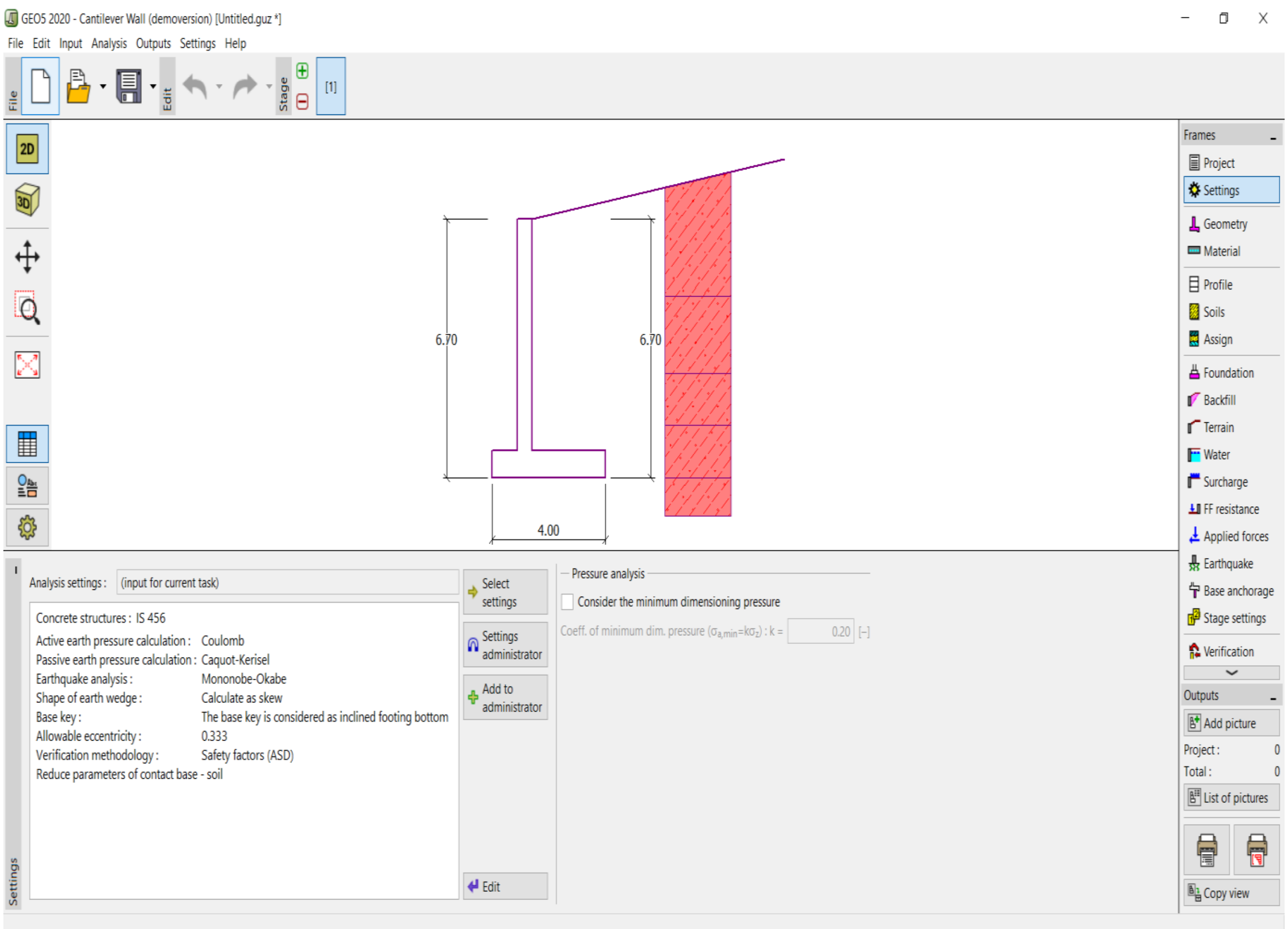


Fig 8.2 Settings frame

C. In the frame "Geometry", choose the wall shape and enter its dimensions.

- In the frame section go to the geometry for selection the type of the wall.
- Then select the shape, then fill the wall geometry dimensions.
- Insert dimensions as in chart of geometry.

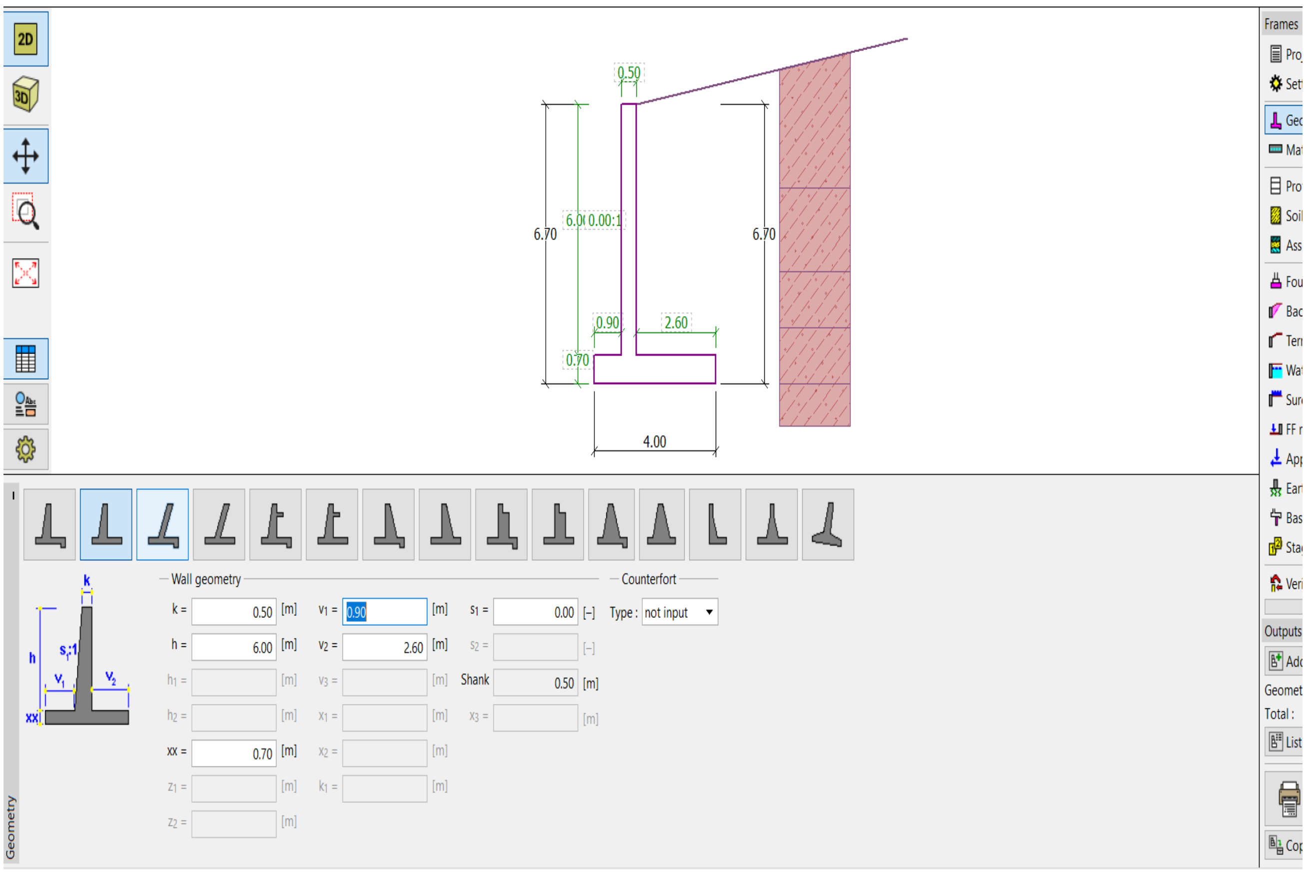


Fig 8.3 Geometry frame

D. In the frame section select the “material”, then enter the material of the wall as follows.

- In the first blank Enter the unit weight- 24 kN /m3
- Click on catalogue section and select characteristic strength of concrete f_{ck}=25 MPa
- Click on catalogue section and select longitudinal reinforcement-f_y=415 MPa

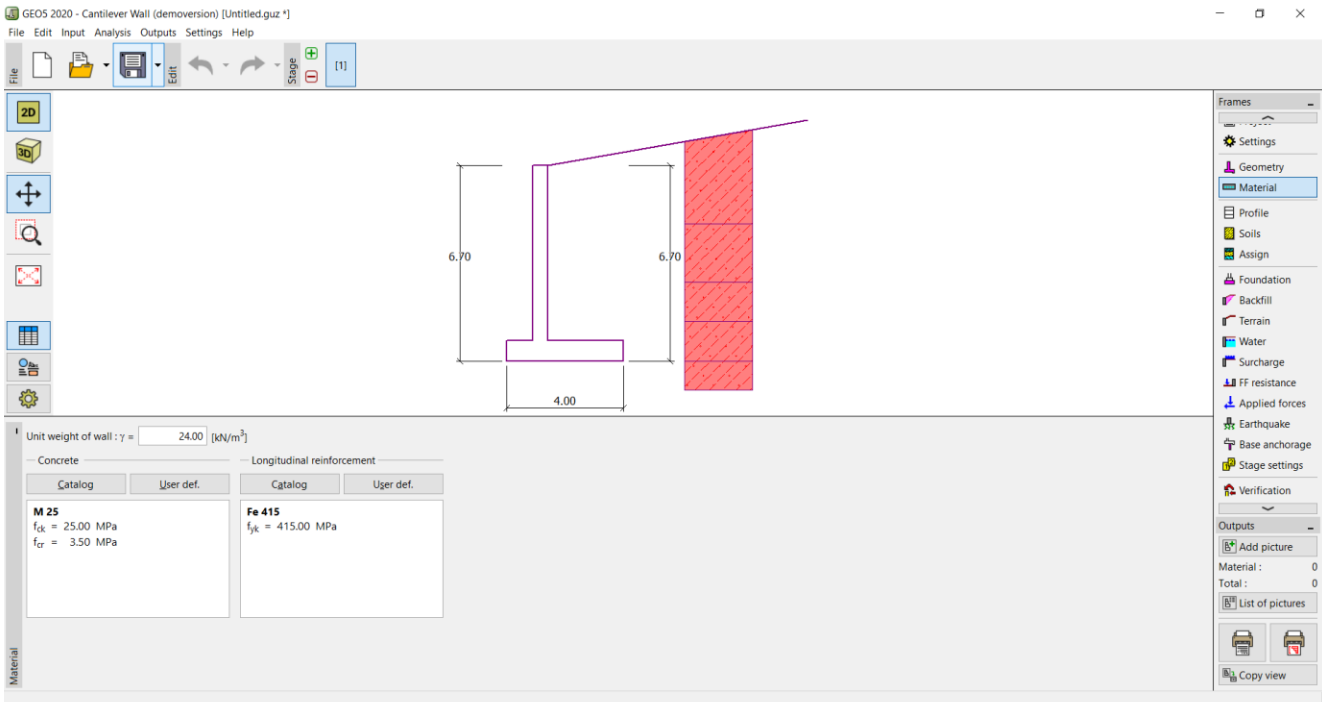


Fig 8.4 Material frame

E. Into the frame section select the “profile”, enter the depth of soil layers

- Click on the “add” section then fill the depth of top soil layer from top to the bottom.
- Then we have to divide the height into total size of the height of the wall.
- Check the details and values carefully.

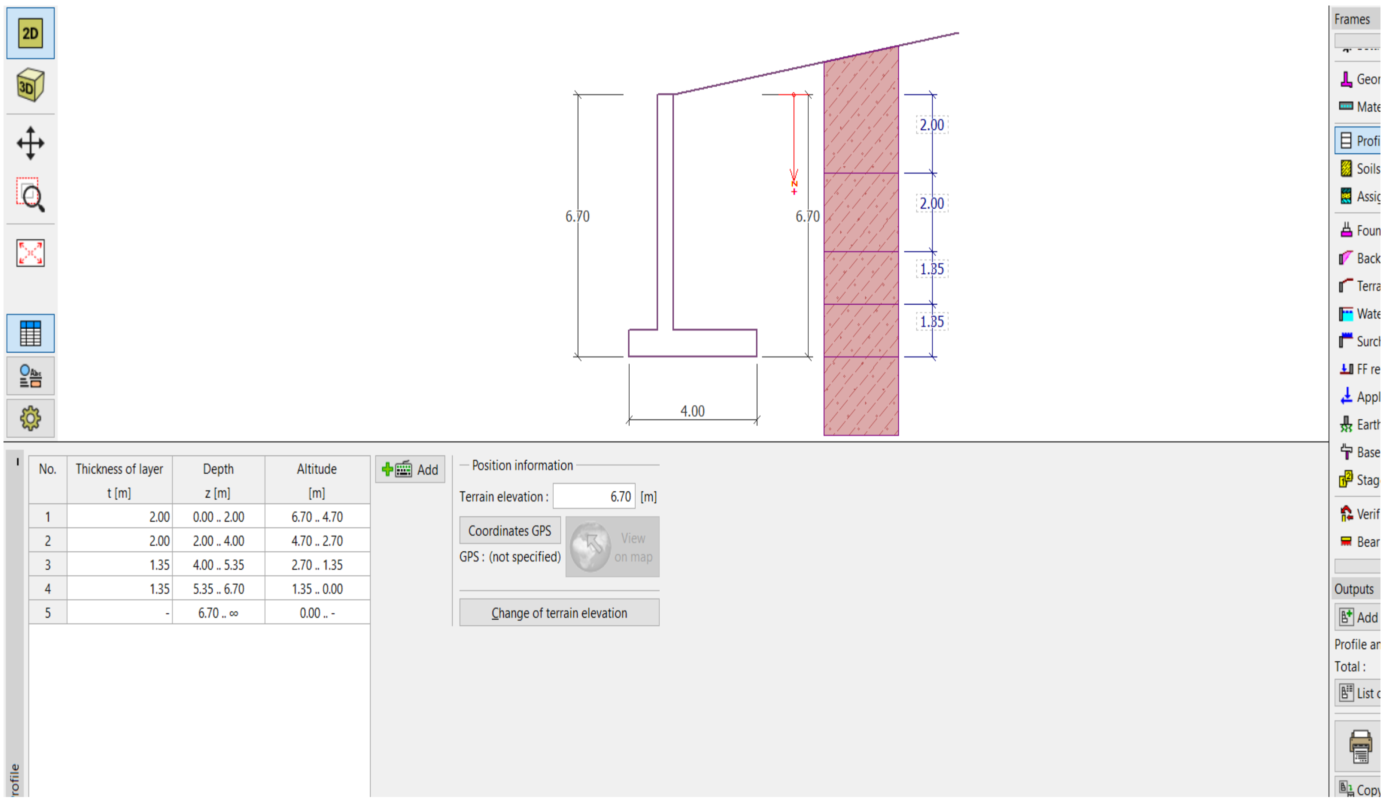


Fig 8.5 Profile frame

F. Into the frame section part select the “Soils”, define the parameters of soil

- click on “add”
- Enter the properties γ, c, ϕ and δ
- Wall stem is normally analysed for pressure at rest. For pressure at rest analysis, select “cohesion less” Soil
- Since our soil is cohesive less, select “cohesive less” soil
- Enter γsat= 25 kN /m3
- Enter name and choose Pattern of soil
- Otherwise from option “Classify” select type of soil as shown below and enter properties.
- The magnitude of active pressure depends also on the friction between the structure and soil

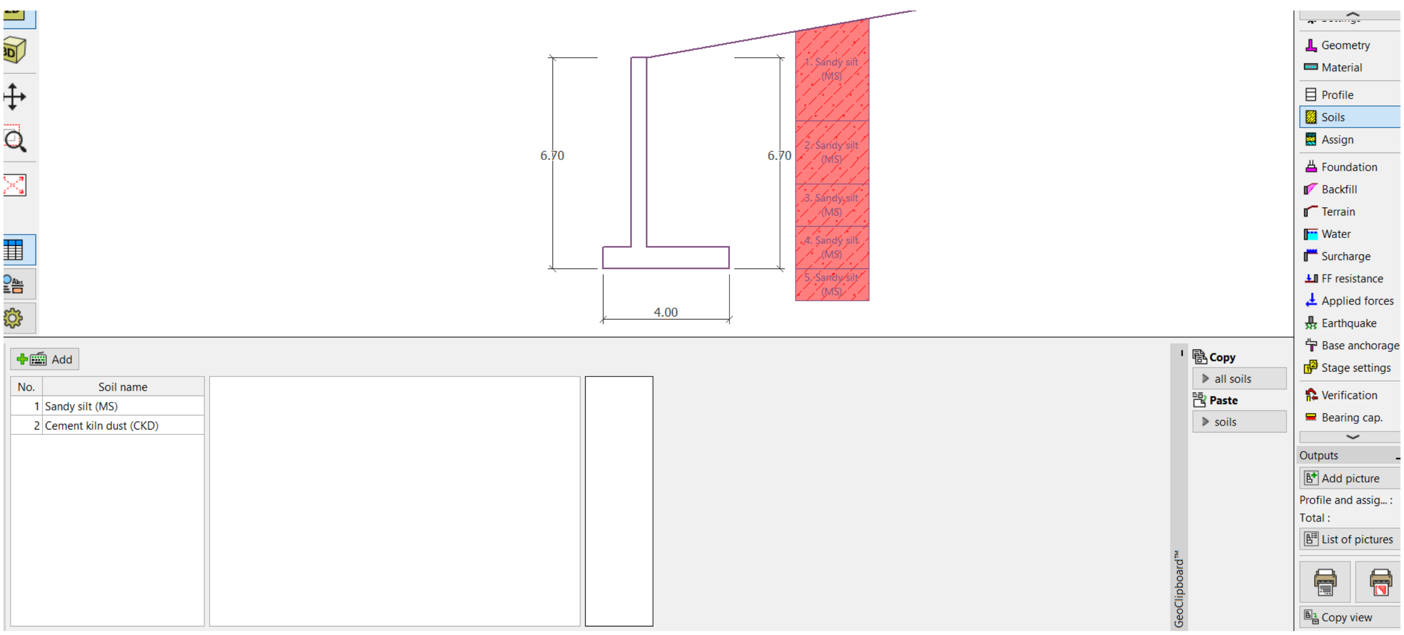


Fig 8.6 Soil frame

G. By clicking on the frame section assign the properties by clicking on the option “Assign”

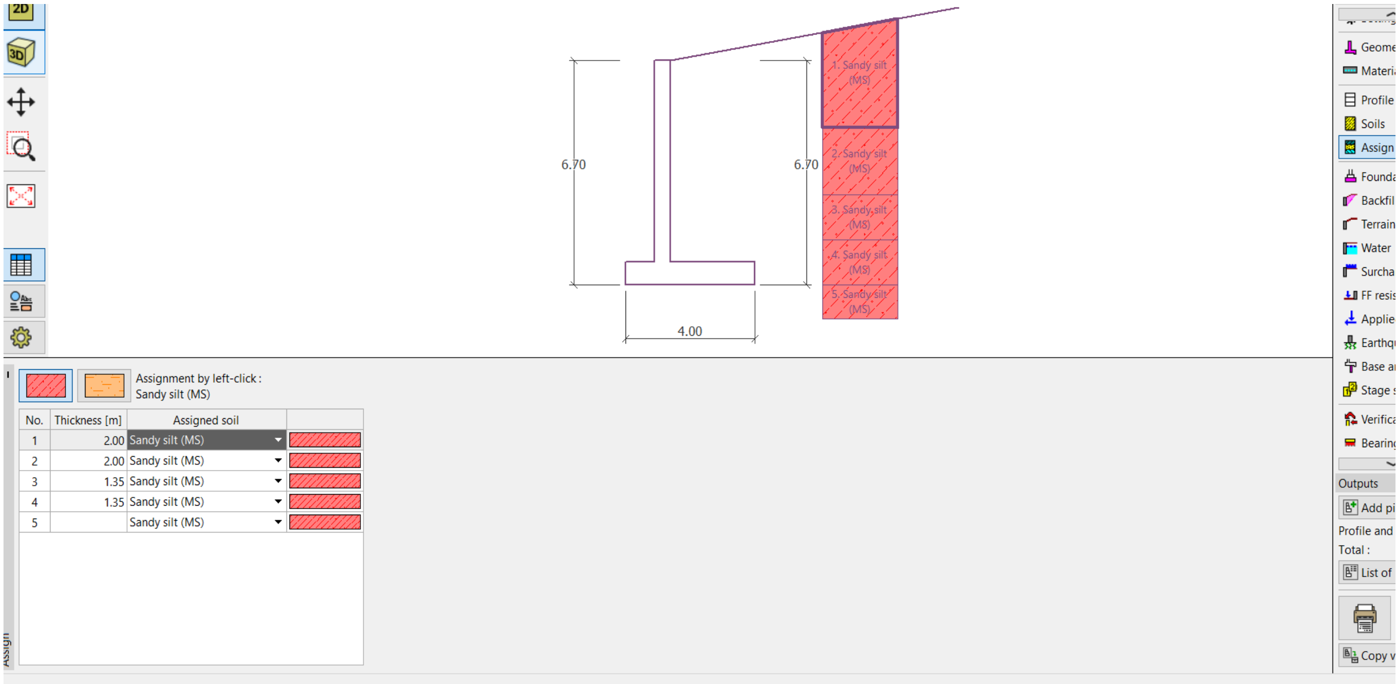


Fig 8.7 Assign frame

H. In the frame “Terrain” choose the horizontal terrain shape

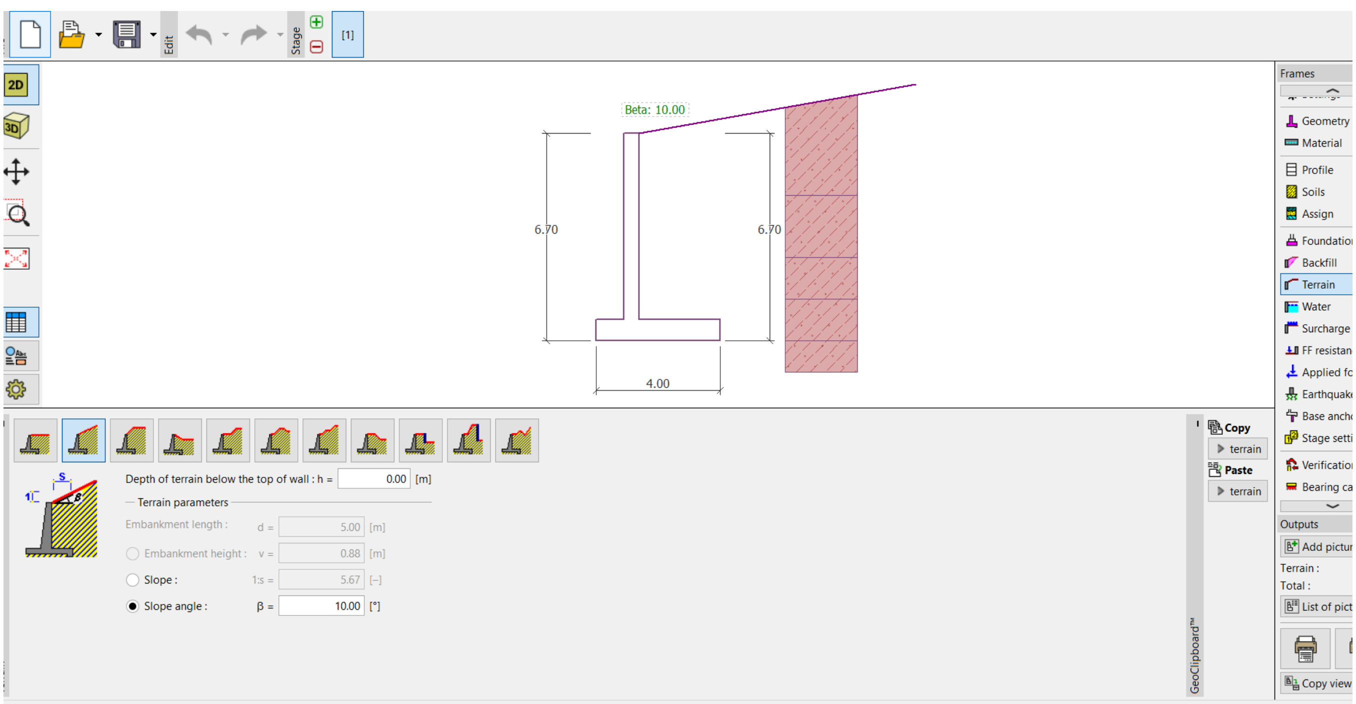


Fig 8.8 Terrain frame

I. In the frame “Water”, select the type of water close to the structure and its parameters

- Select position of Water table
- In the first case, water table is not considered, that is, the water table is assumed to be at infinite depth.

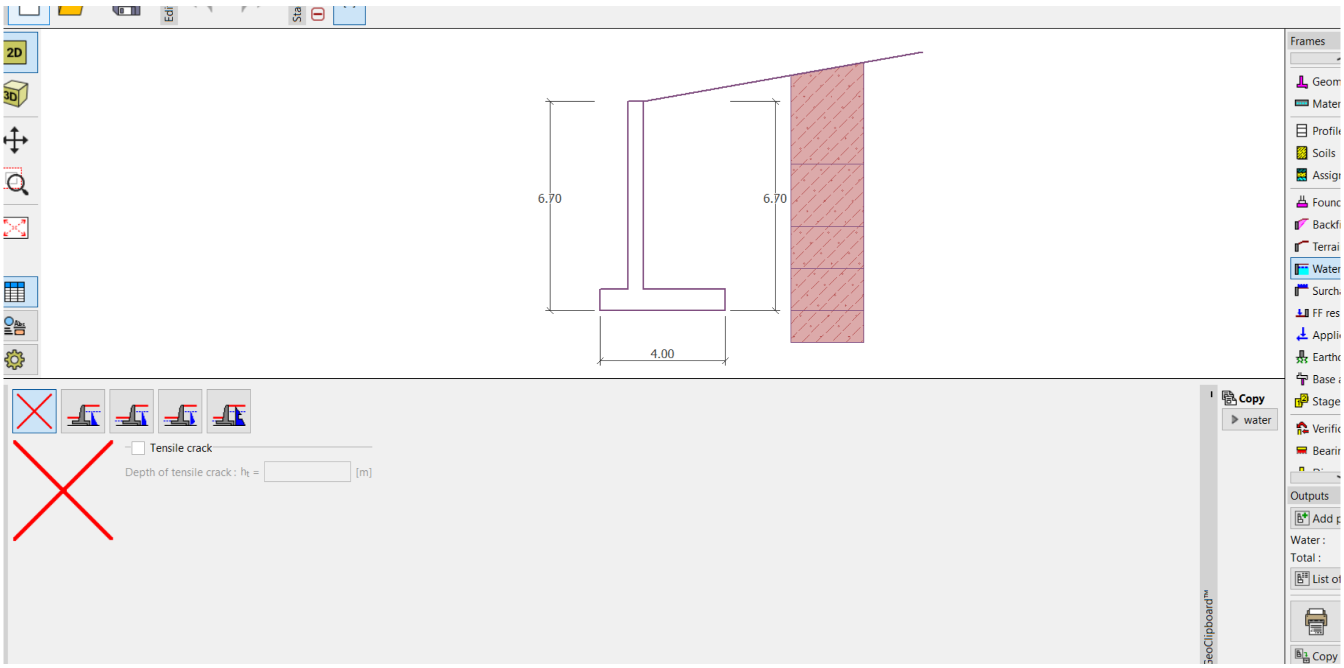


Fig 8.9 Water frame

J. Open up the frame column the go to the “Verification” and then analyse the results of overturning and slip of the cantilever wall, then check the result whether it is ok or not.

K.

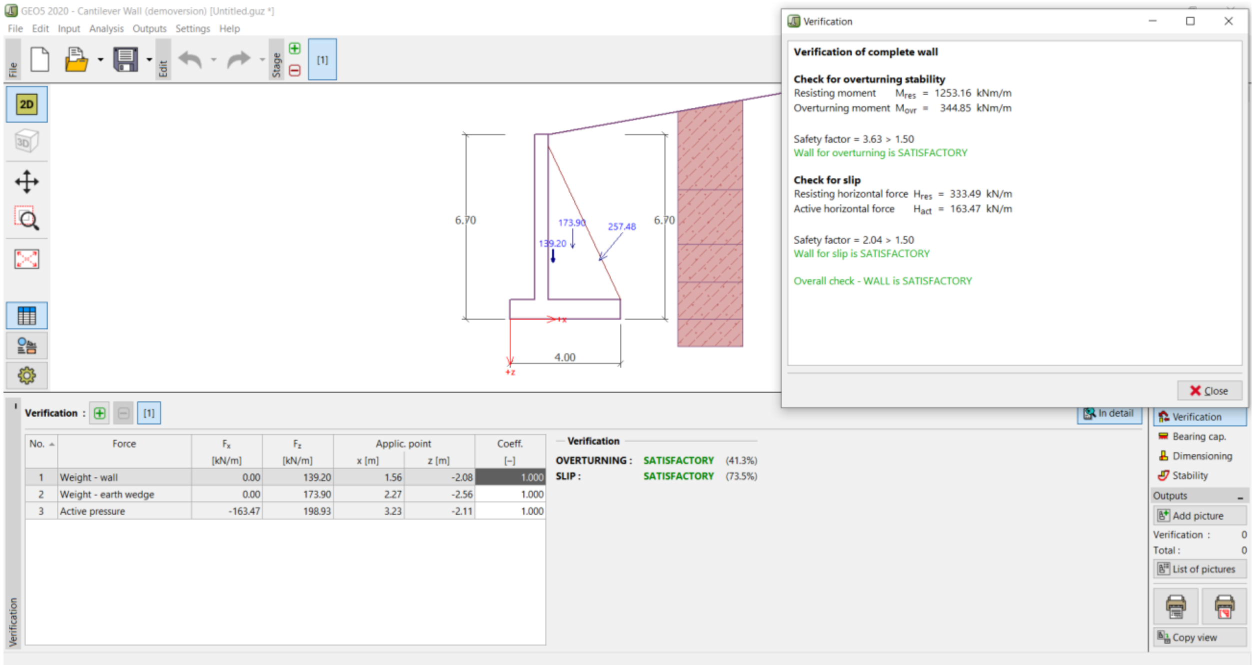


Fig 8.10 Verification frame

Point to be noted: In the section of that “In detail” in the right section of the screen, then opens a dialog window with detailed Information about the analysis results. Check the result of details information of the overturning and slip of the wall that are both satisfactory.

In the verification process if it is not satisfactory then of the slip is not satisfactory then we have to find the several possibilities how to improve the design. Take such as an example, possibilities are like we can use better type of soil behind the wall, anchor of the base, increase the friction by bowing the footing bottom or anchor the stem. Whatever changes we do in the designing process these changes would be economically and technologically the easiest alternative. Change of the design as per the requirement of design which refers to the change of the geometry of the wall.

L. In the frame column find the "Bearing capacity", then check the bearing capacity of the wall. Then perform an analysis for design bearing capacity of the foundation soil of 566.2 (kPa).

Point to be noted: In the 1st trial case, we analyse the bearing capacity of the foundation soil on an input value, which we can get from geological survey, respective from some standards. These values are normally conservative, so it is generally better to analyse the bearing capacity of the foundation soil in the program Spread footing that takes into account other factors like inclination of the load infused, depth of the foundation, geographical conditions.

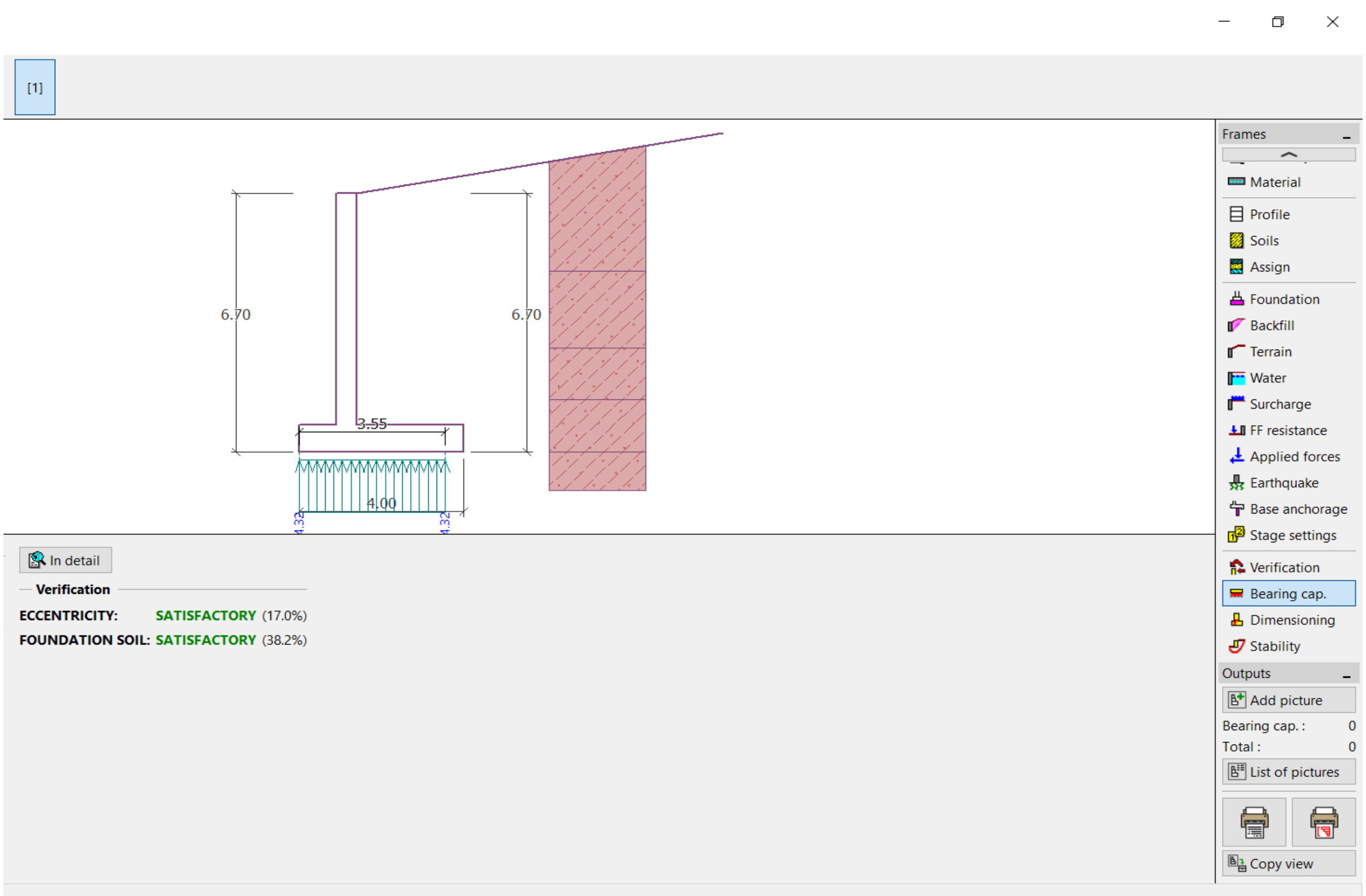


Fig 8.11 Bearing capacity frame

M. Open up the frame section the find the "Stability", and analyse the overall stability of the wall.

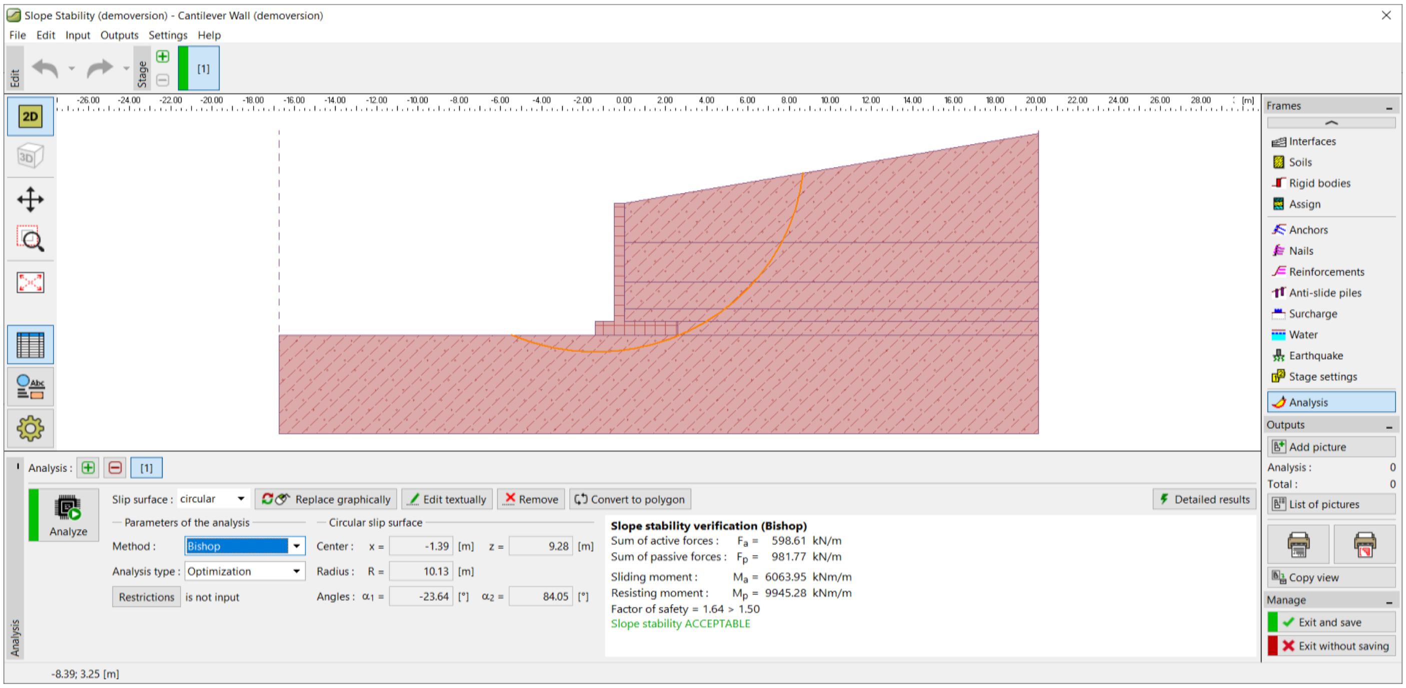


Fig 8.12 Assign frame

Results or pictures will be shown in the report of analysis in the program Cantilever retaining wall

N. Results of analysis

Overturning: 41.3 %; SATISFACTORY

Slip: 73.5 %; SATISFACTORY

Eccentricity: 17.0 %; SATISFACTORY

Foundation soil: 38.2 %; SATISFACTORY

Factor of Safety: 1.64 > 1.5; SATISFACTORY

Overall stability: This cantilever retaining wall is overall SATISFACTORY

8.6.2 Case II: Different Trials for various backfill depths of cement kiln dust and backfill material.

In this part of the trial, all steps are same as above that we design for the silty sand soil. Except in the frame section "assign", were different layers have to be assigned with the required type of fill. The slope stability results of various cases obtained are as follows:

Case 1: Backfill is completely with silty sand soil.

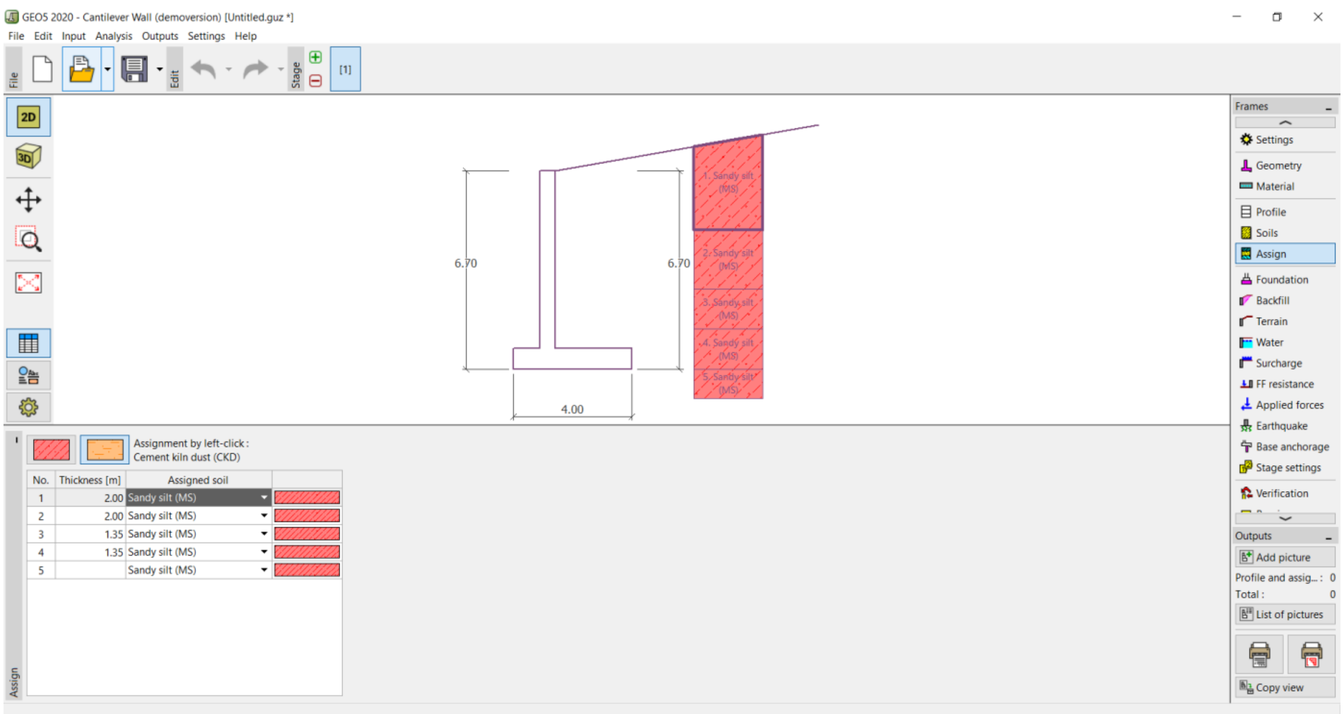


Fig 8.13 Assign frame

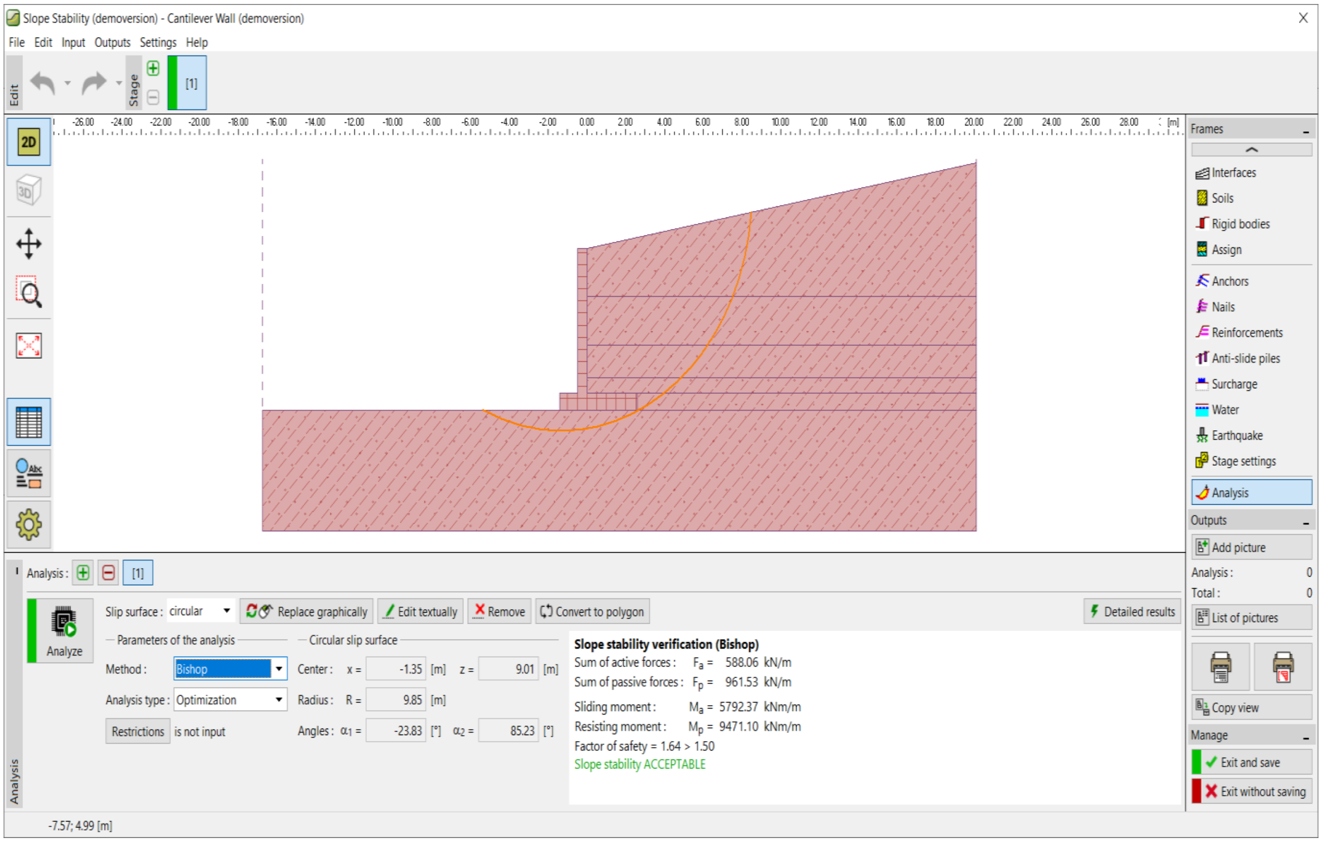


Fig 8.14 Stability frame

Factor of Safety = 1.64 > 1.50

Case 2: Backfill of 2m cement kiln dust from top and remaining with silty sand.

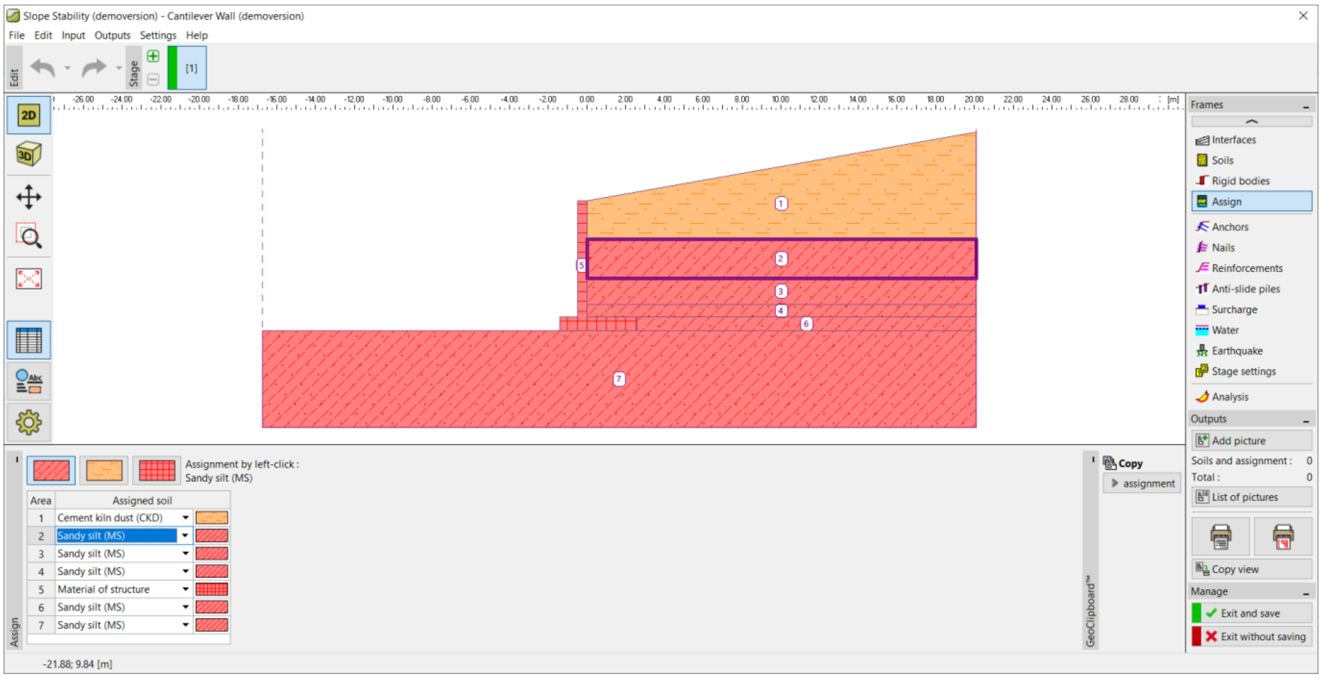


Fig 8.15 Assign frame

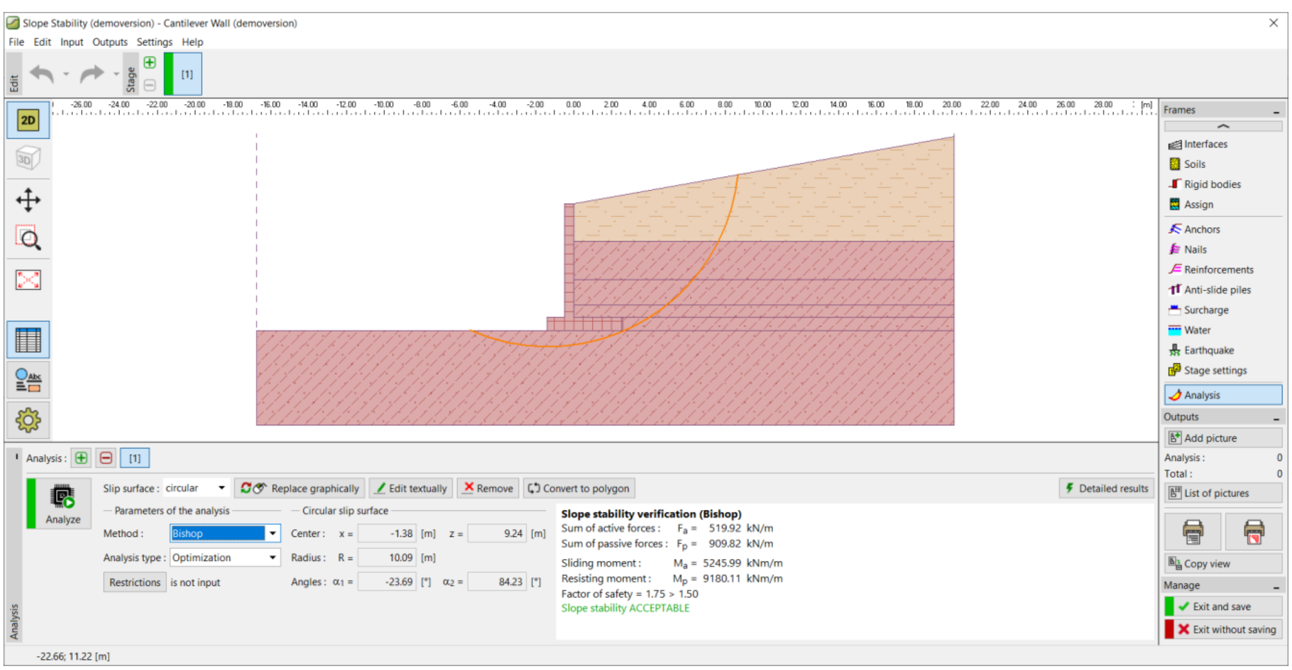


Fig 8.16 Stability frame

Factor of Safety = 1.75 > 1.50

Case 3: Backfill of 4m cement kiln dust from top and remaining with silty sand.

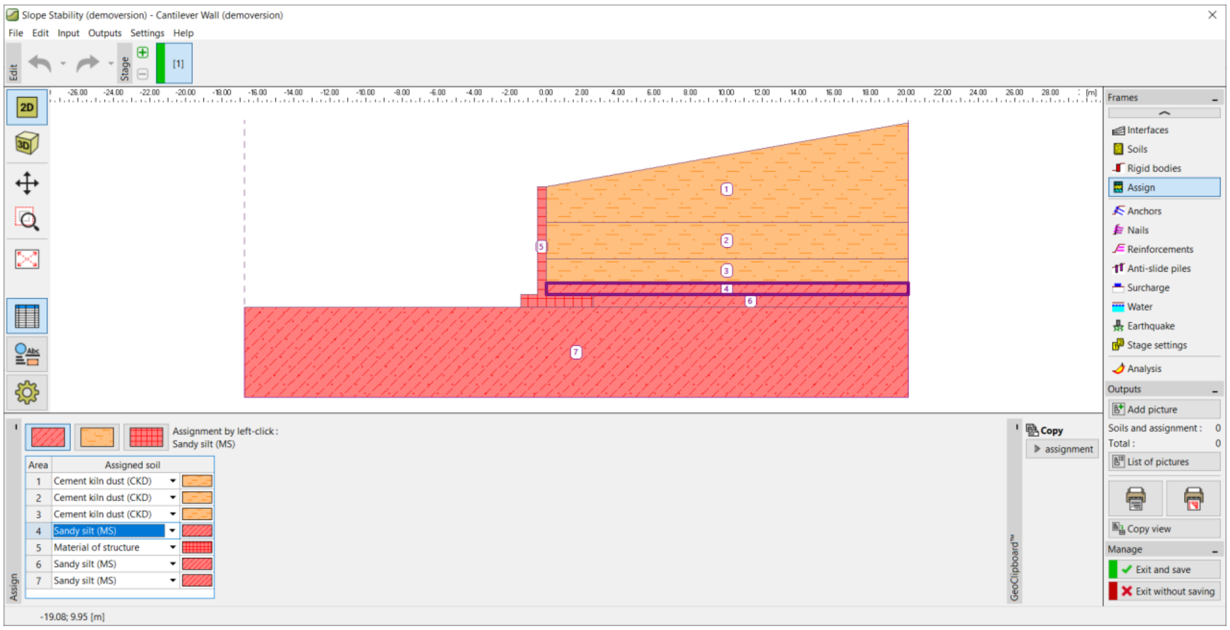


Fig 8.17 Assign frame

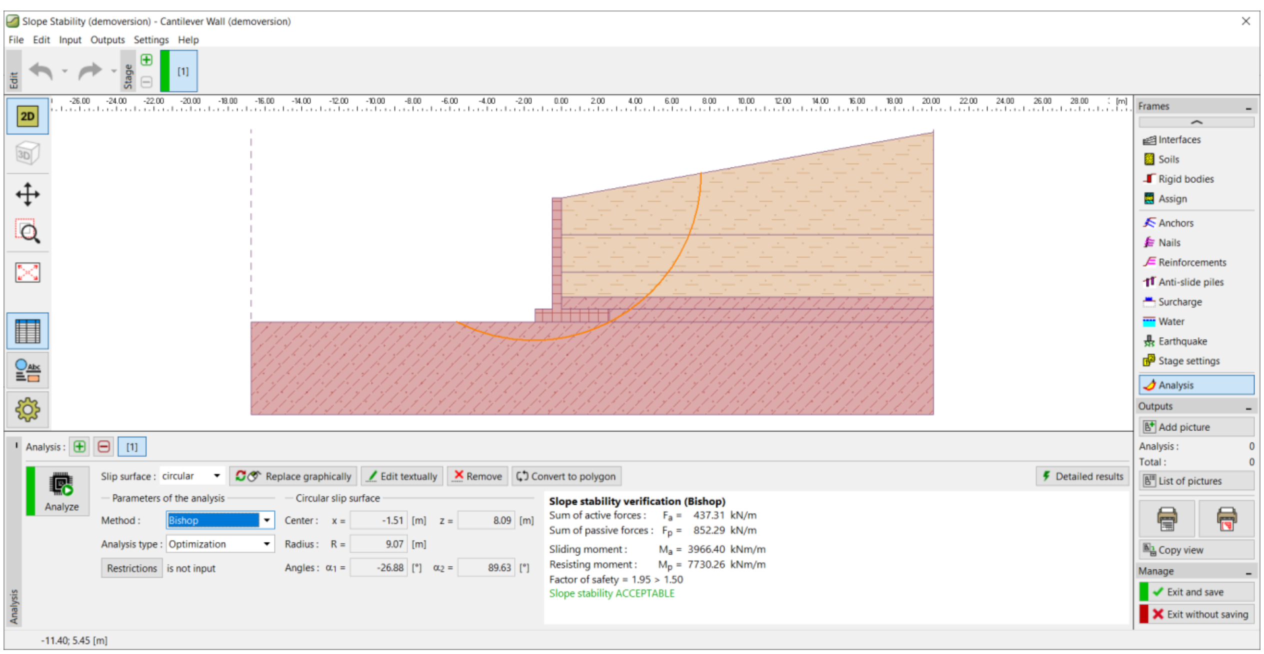


Fig 8.18 Stability frame

Factor of Safety = 1.95 > 1.50

Case 4: Backfill of 6.7 m cement kiln dust from top and remaining with silty sand

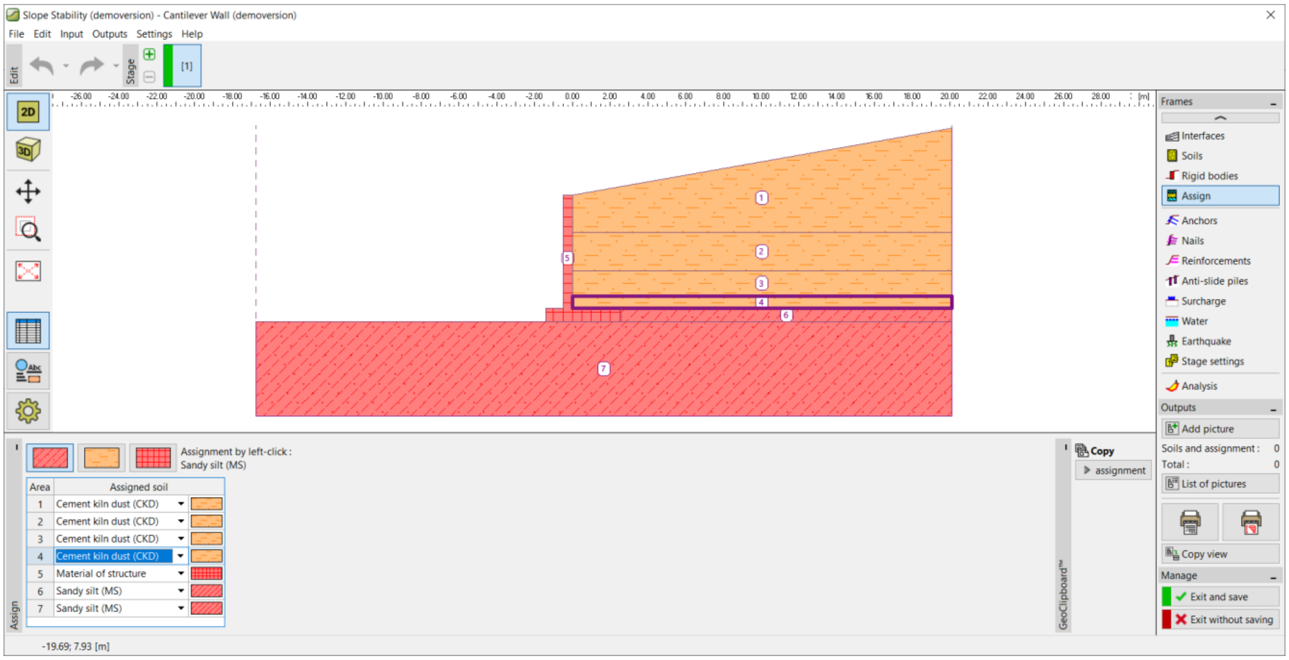


Fig 8.19 Assign frame

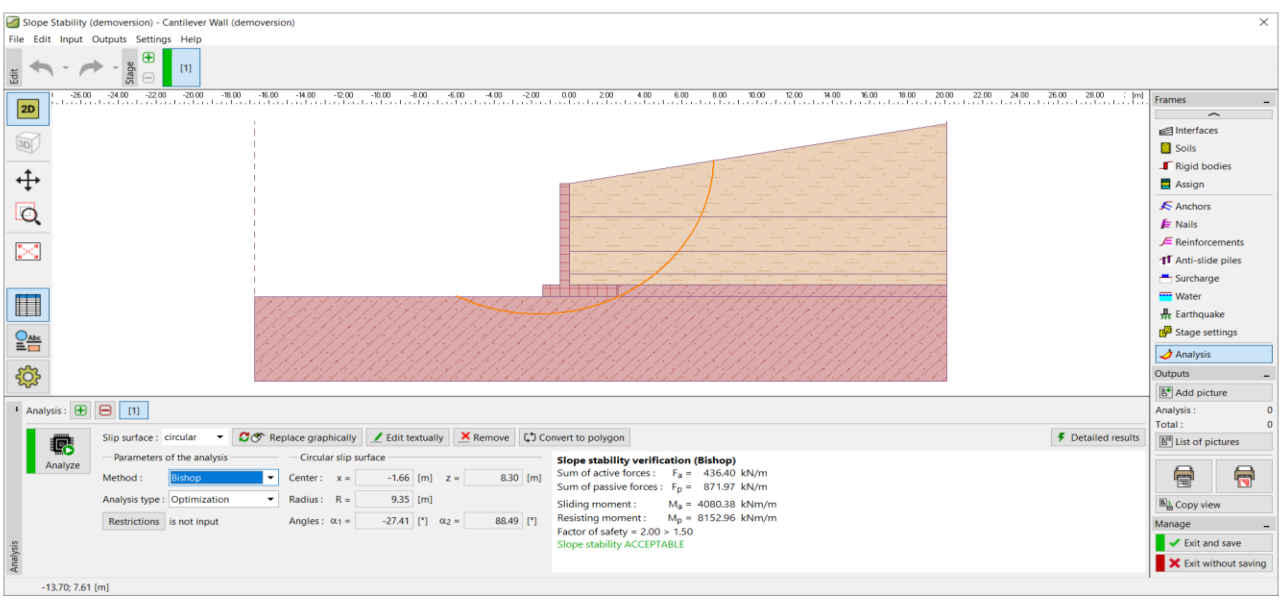


Fig 8.20 Stability frame

Factor of Safety = 2.00 > 1.50

Table 9.6: Variations in Factor of safety (backfill)

Case	Backfill criteria	Factor of Safety (should be > 1.5)
1	0m cement kiln dust	**1.64**
2	2m cement kiln dust	**1.75**
3	4m cement kiln dust	**1.95**
4	6.7m cement kiln dust	**2.00**

From the above results, it is observed that varying from different backfill criteria we can see the factor of safety is changes from low to high safety. With this observation we can check how cement kiln dust is improving the backfill. Thus Backfill with cement kiln dust fill up to 4m gives the maximum factor of safety and hence, this criterion is adopted for further analysis.

8.6.3 Case III: Check for the effect of water table for various heights

In this case we check the effect of water table for various depths below the ground level and has been analysed. The stability results of different depths for water table are as follows.

Case 1: Water table is at considered to be at the surface W=0.

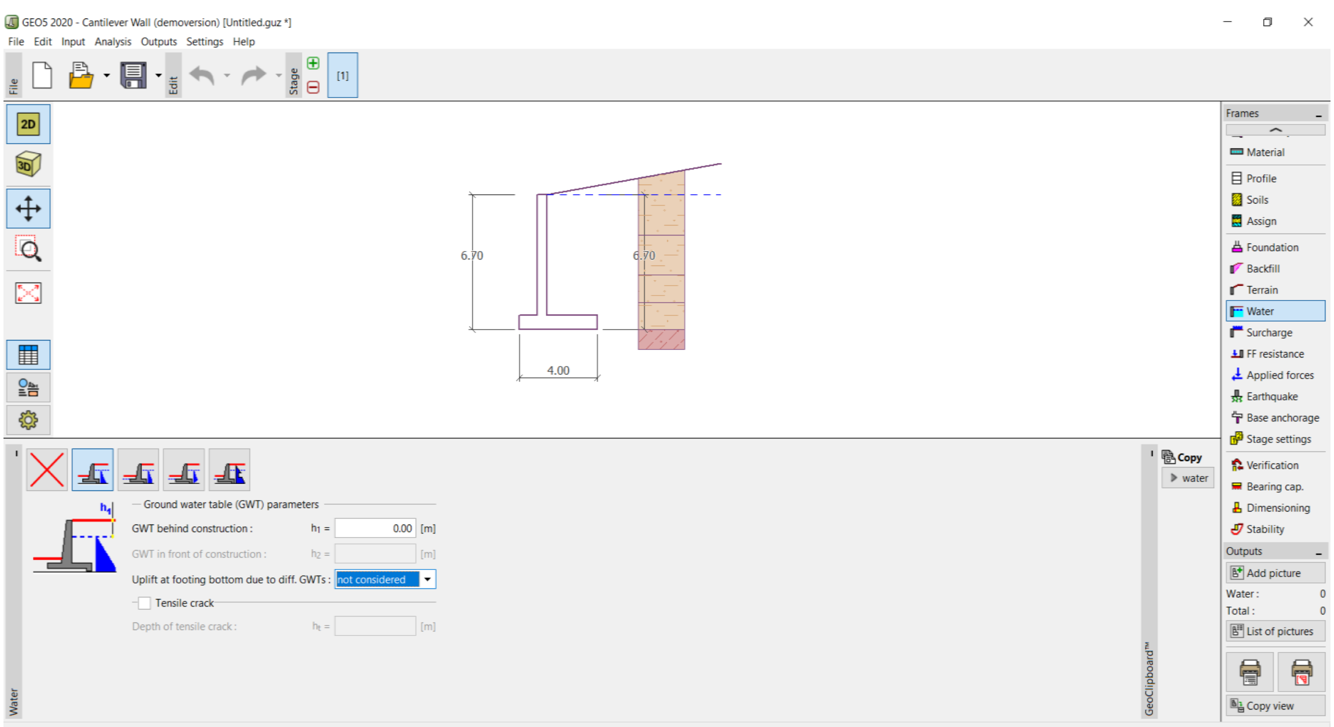


Fig 8.21 Water frame

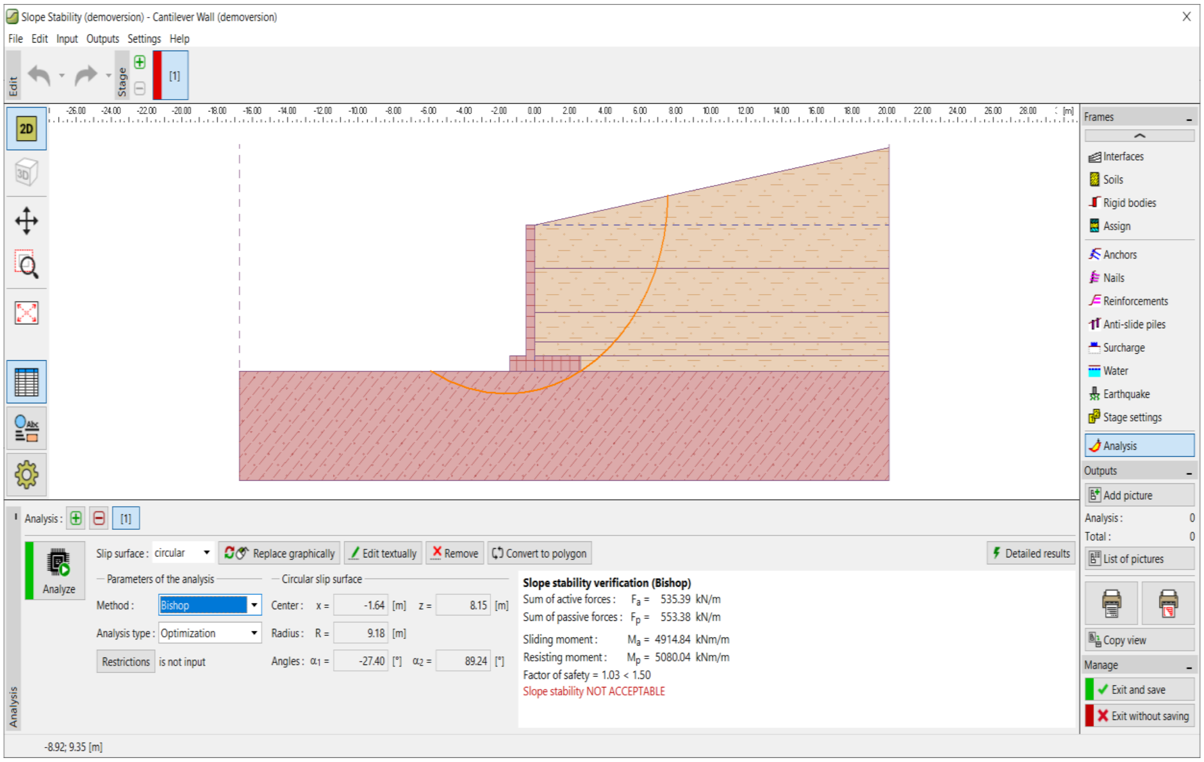


Fig 8.22 Stability frame

Factor of Safety = 1.03 < 1.50; NOT SATISFACTORY

Case 2: Water table is considered at a depth of 10m

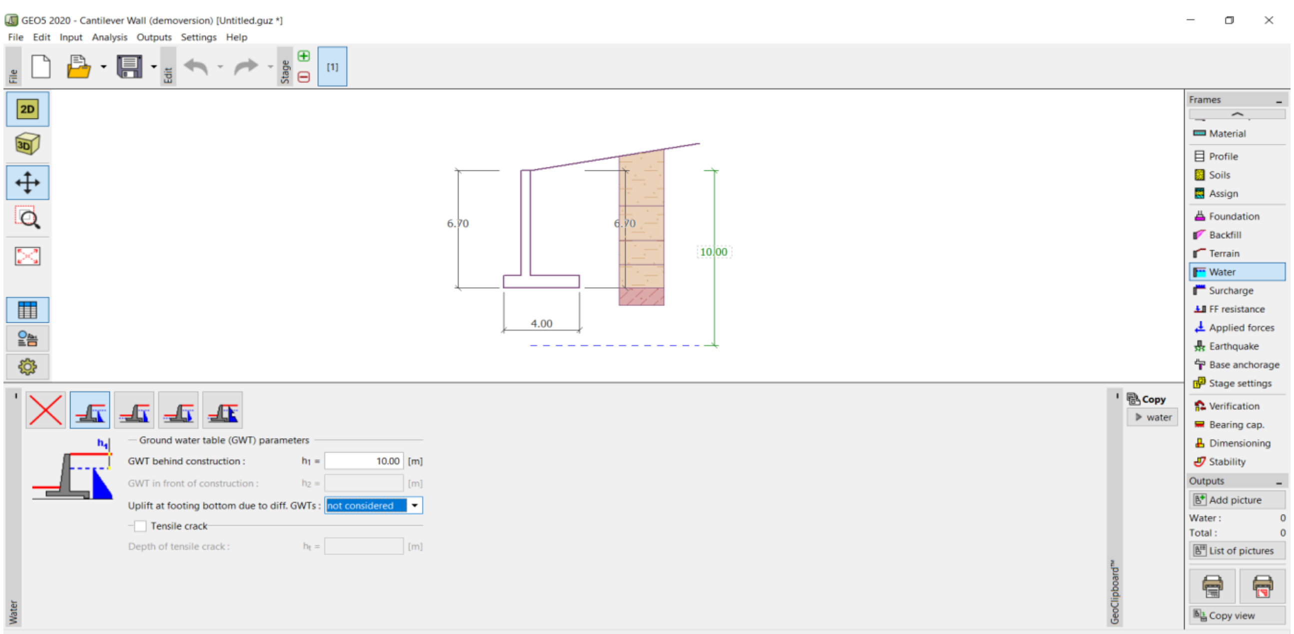


Fig 8.23 Water frame

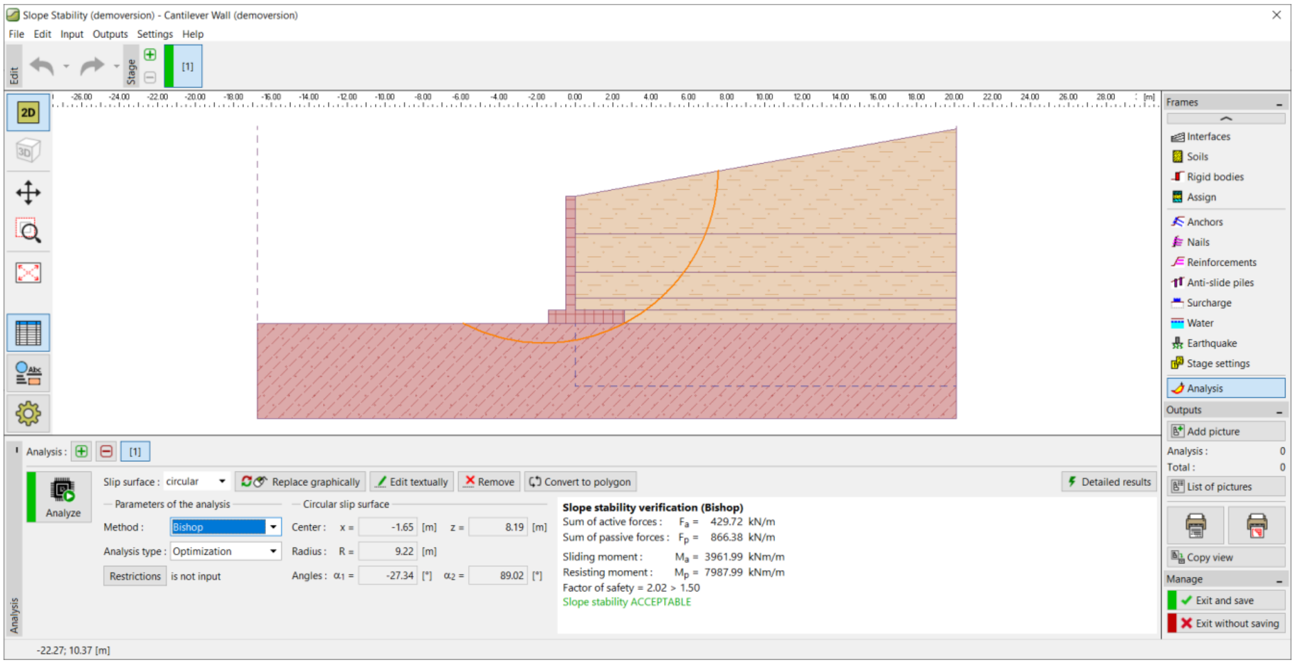


Fig 8.24 Stability frame

Factor of Safety = 2.02 < 1.50; NOT SATISFACTORY

Case 3: Water table is considered at a depth of 20m

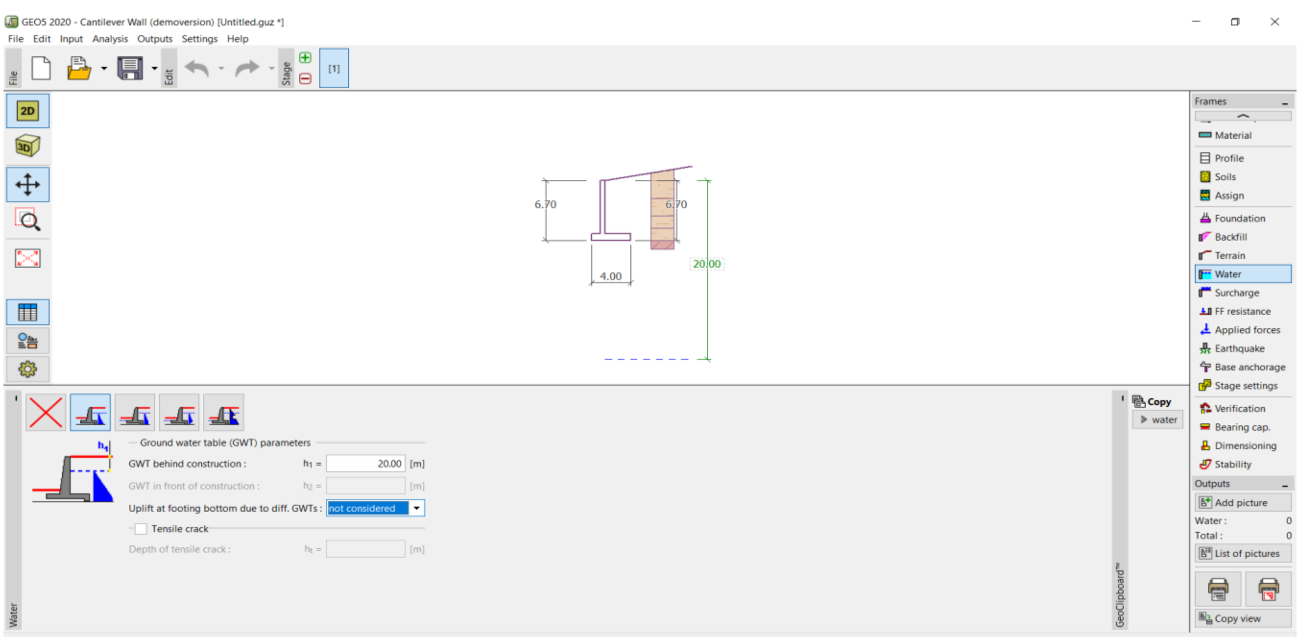


Fig 8.25 Water frame

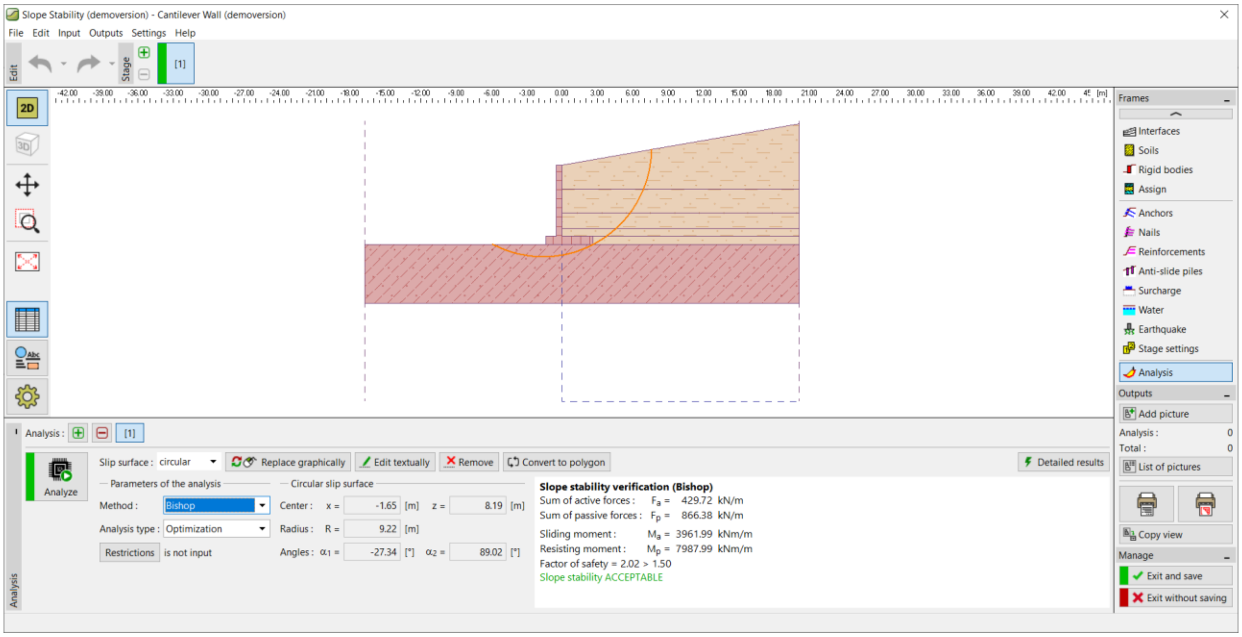


Fig 8.26 Stability frame

Factor of Safety = 2.02 > 1.50; SATISFACTORY

Case 4: Water table is considered at a depth of 40m

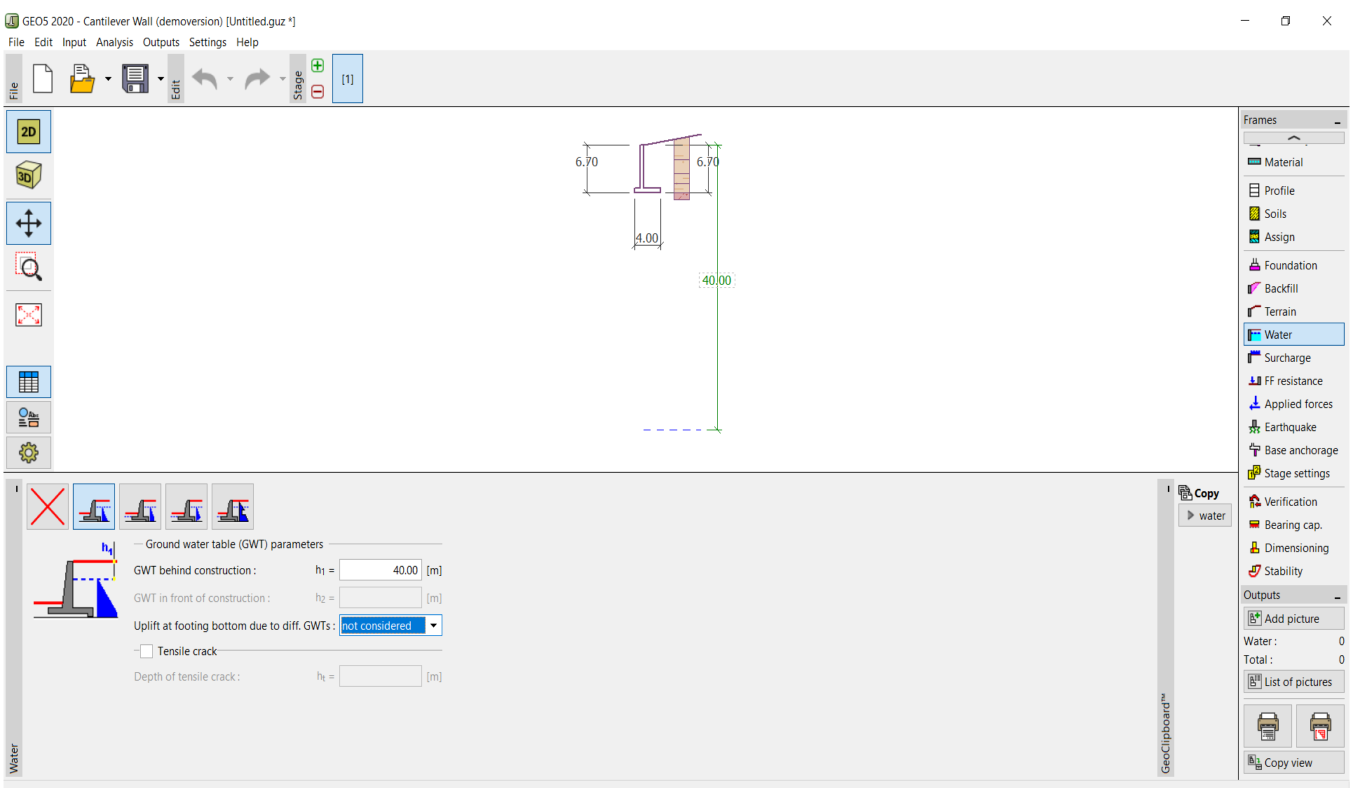


Fig 8.27 Water frame

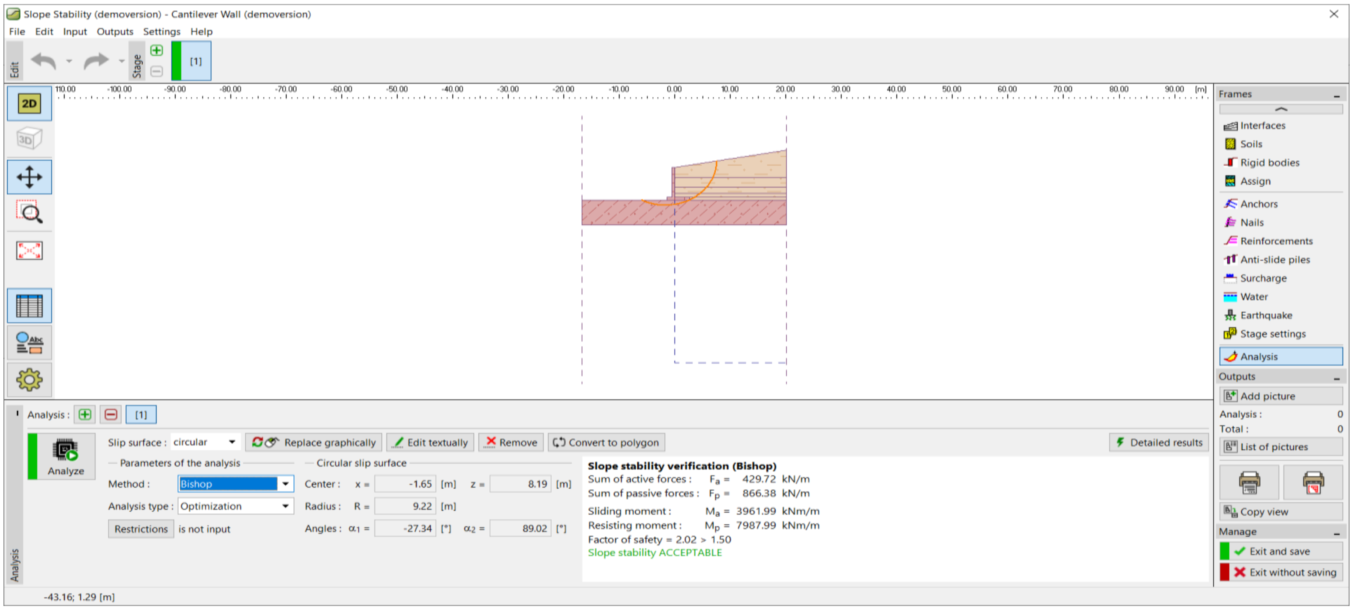


Fig 8.28 Stability frame

Factor of Safety = 1.70 > 1.50; SATISFACTORY

Case 5: Water table is considered at a depth of 60m

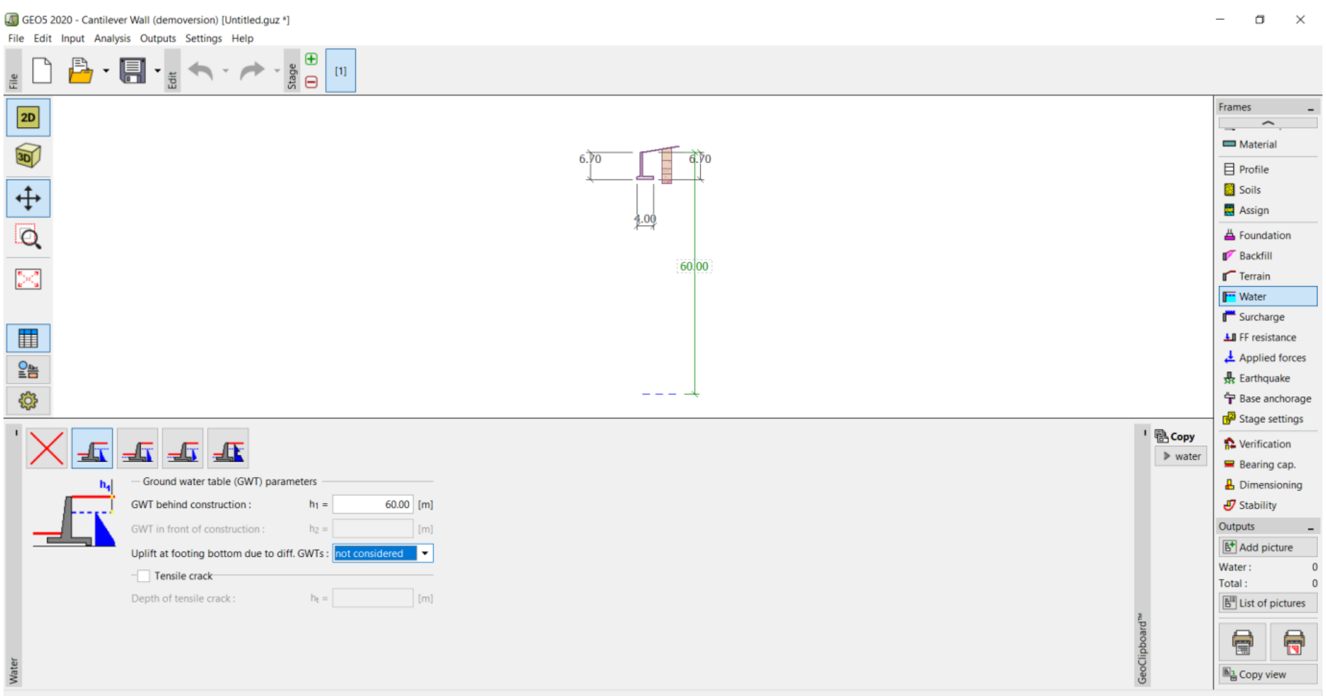


Fig 8.29 Water frame

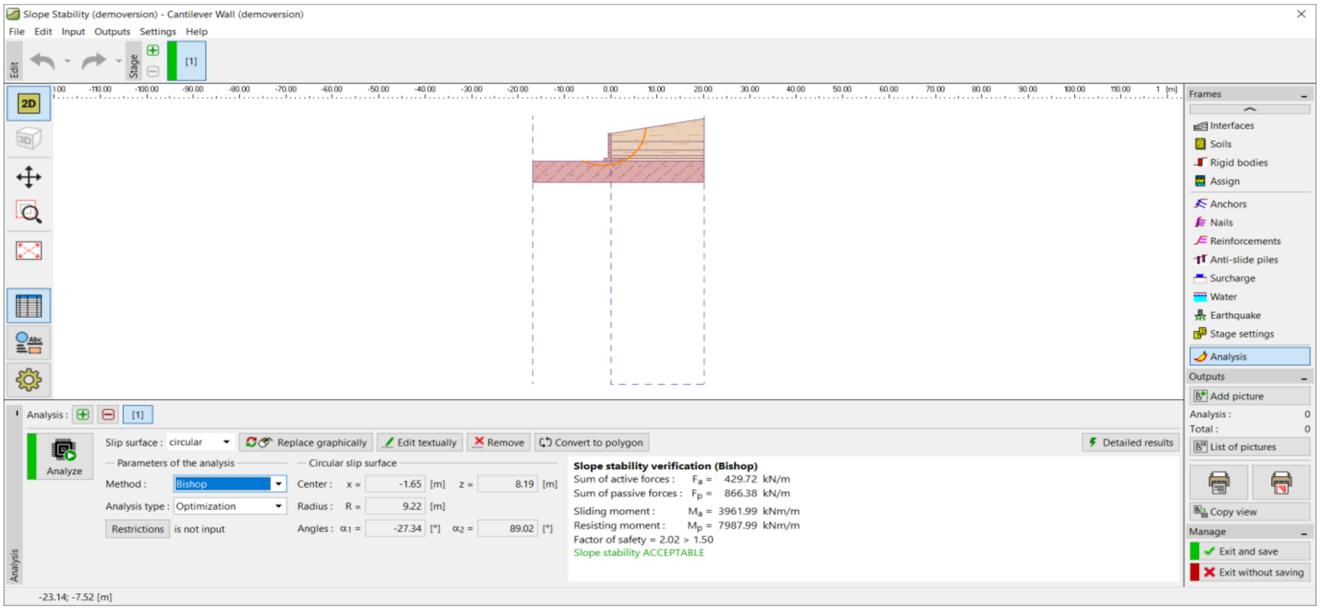


Fig 8.30 Stability frame

Factor of Safety = 1.70 > 1.50; SATISFACTORY

Table 9.7: Variations in Factor of Safety (water table)

Case	Depth of water table	Factor of safety (should be > 1.5)
1	At the surface	**1.03**
2	10 m below the surface	**2.02**
3	20 m below the surface	**2.02**
4	40 m below the surface	**2.02**
5	60 m below the surface	**2.02**

From the above results, it is observed that, as we increase the depth of the water table, there is no visible effect on the structure, thus we can design as according that further for stability of the retaining wall. As result that the data collected, is it found that the water table level of between 20m and 60m. The designed structure is thus observed to have the same effect in this depth.

8.7 CHECKS ON THE FINAL DESIGN OF COUNTERFORT RETAINING WALL – USING GEO5.

The cantilever retaining wall of overall depth of 6.7m and having a backfill consisting of cement kiln dust from the top and the remaining portion of soil, is finalized as the design for the thesis. Various checks have been performed using GEO5 are the results obtained are as follows:

8.7.1 Check for overturning and slip

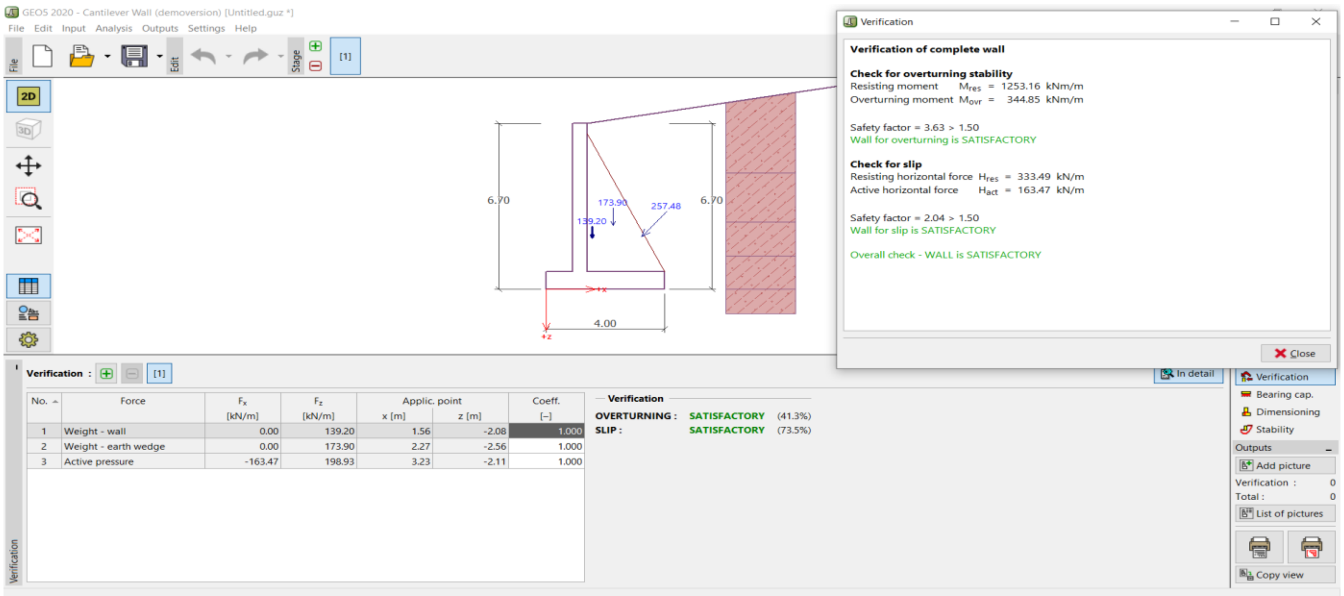


Fig 8.31 Verification frame

Overturning and slip are found to be satisfactory as the factor of safety obtained is greater than 1.5. The diagrammatic representation is shown in fig 9.41.

8.7.2 Check for eccentricity and foundation soil

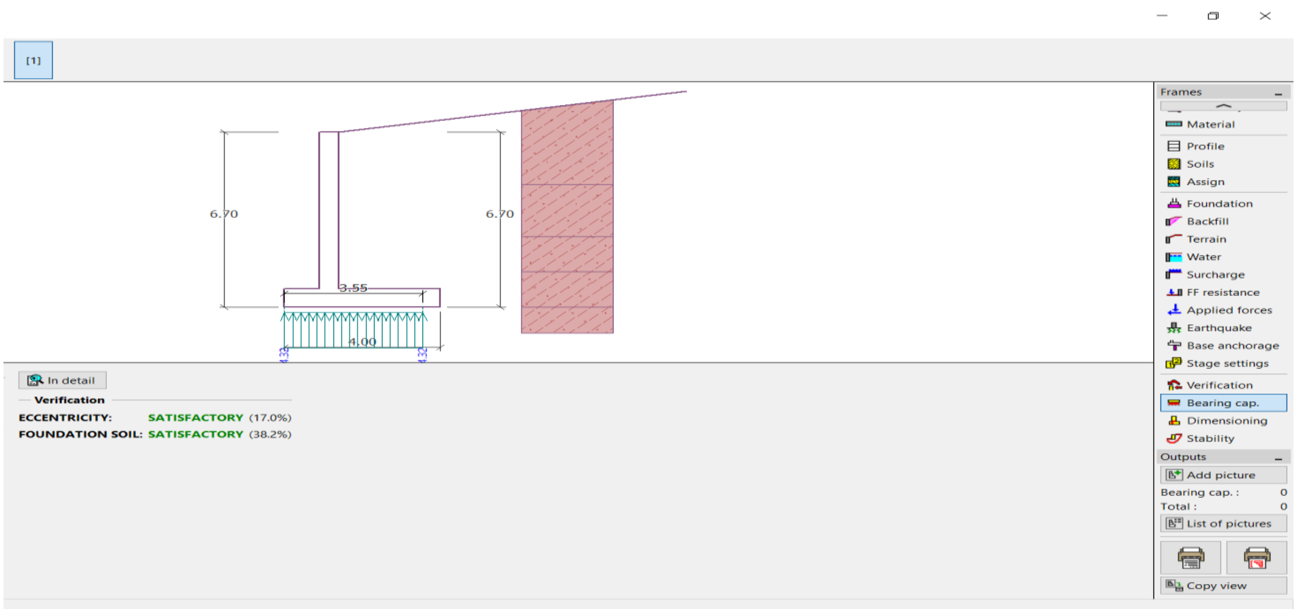


Fig 8.32 Diagrammatic representation of bearing capacity

Eccentricity and foundation soil are found to be satisfactory as the factor of safety obtained is greater than 1.5.

8.7.3 Wall stem check

Wall -stem check - front vertical reinforcement – Vu

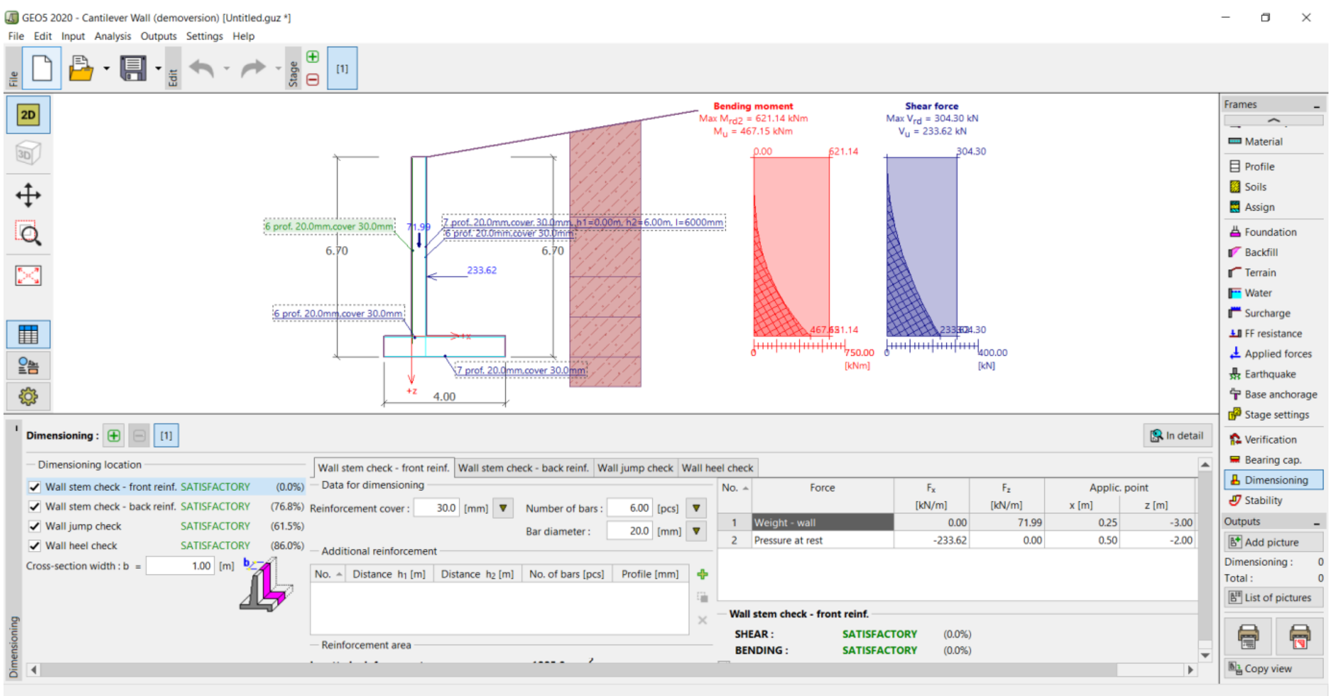


Fig 8.33 Diagrammatic representation of wall steam check-front

Cross-section is SATISFACTORY

Wall stem check - back vertical reinforcement

Fig 8.34 Diagrammatic representation of wall steam check-back

Cross-section is SATISFACTORY

8.7.4 Wall jump check

Provisions for the satisfactory wall jump check are as follows

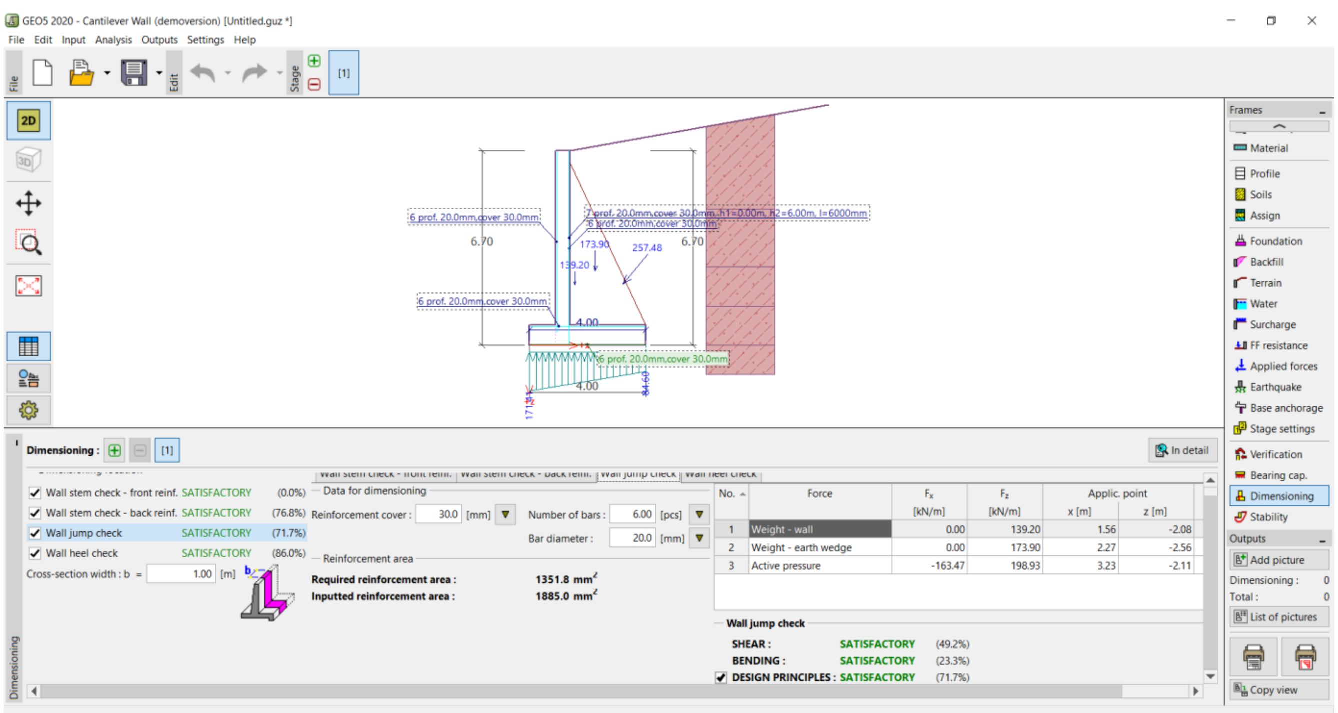


Fig 8.35 Dimensioning- wall jump check

8.7.5 Wall heel check

Satisfactory provisions for the wall heel check are as follows:-

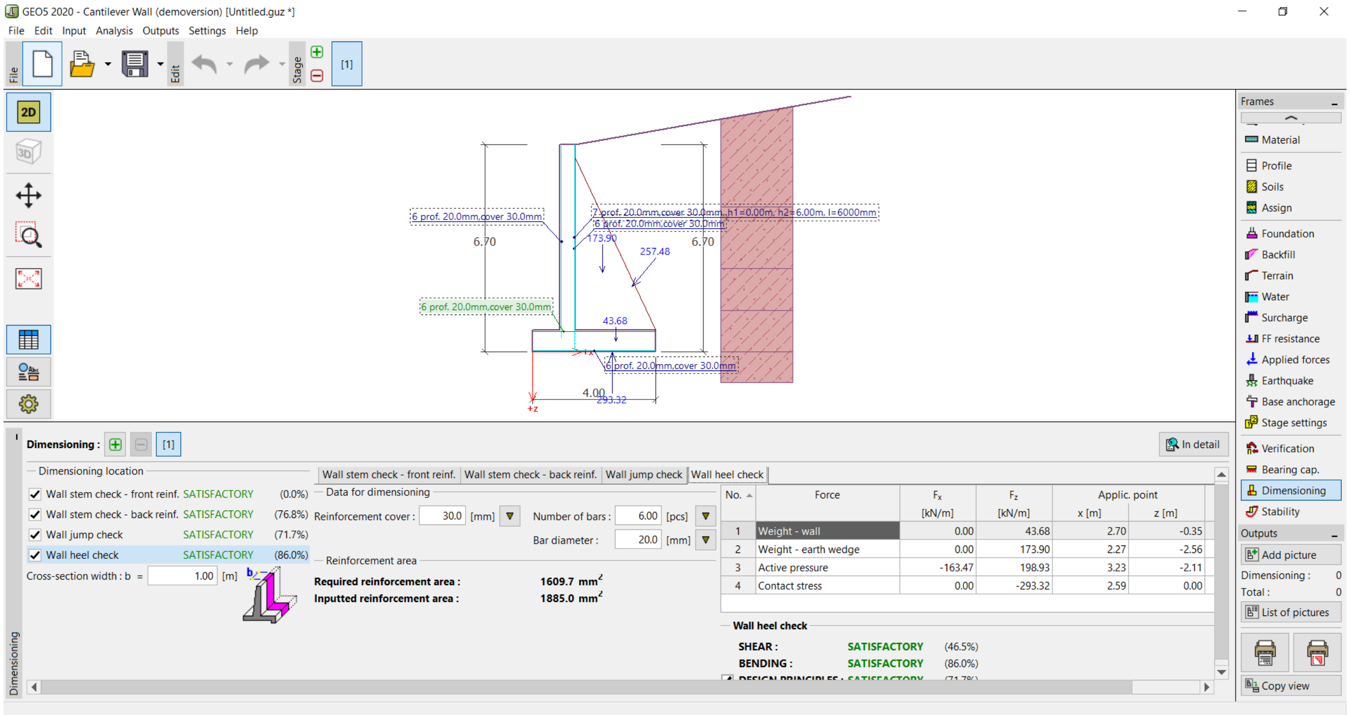


Fig 8.36 Dimensioning- wall check check

Wall stem check - front vertical reinforcement – Mu

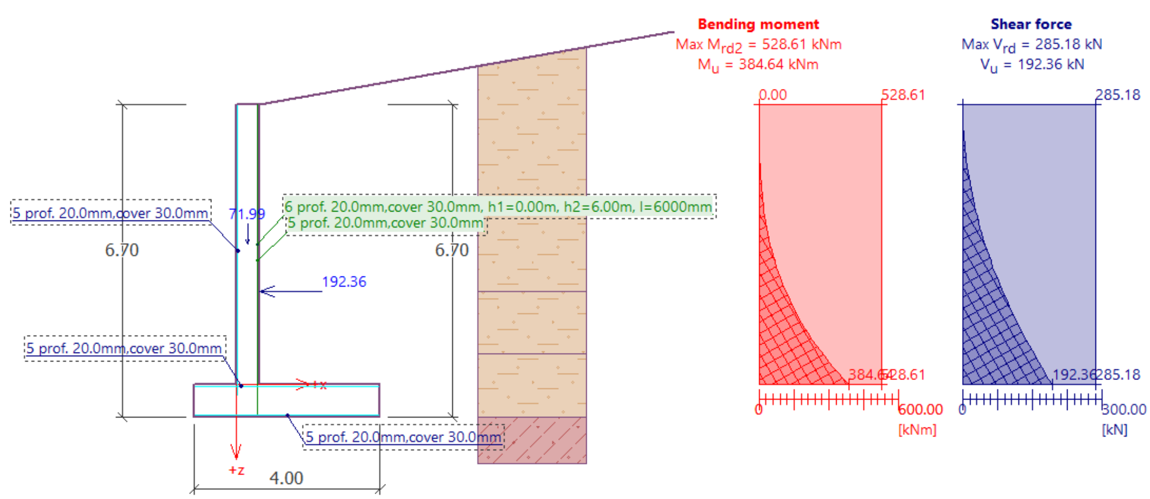


Fig 8.37 Diagram for- wall stem check

8.7.6 The three dimensional view of the finalized design are shown in fig 9.48 and fig 9.49

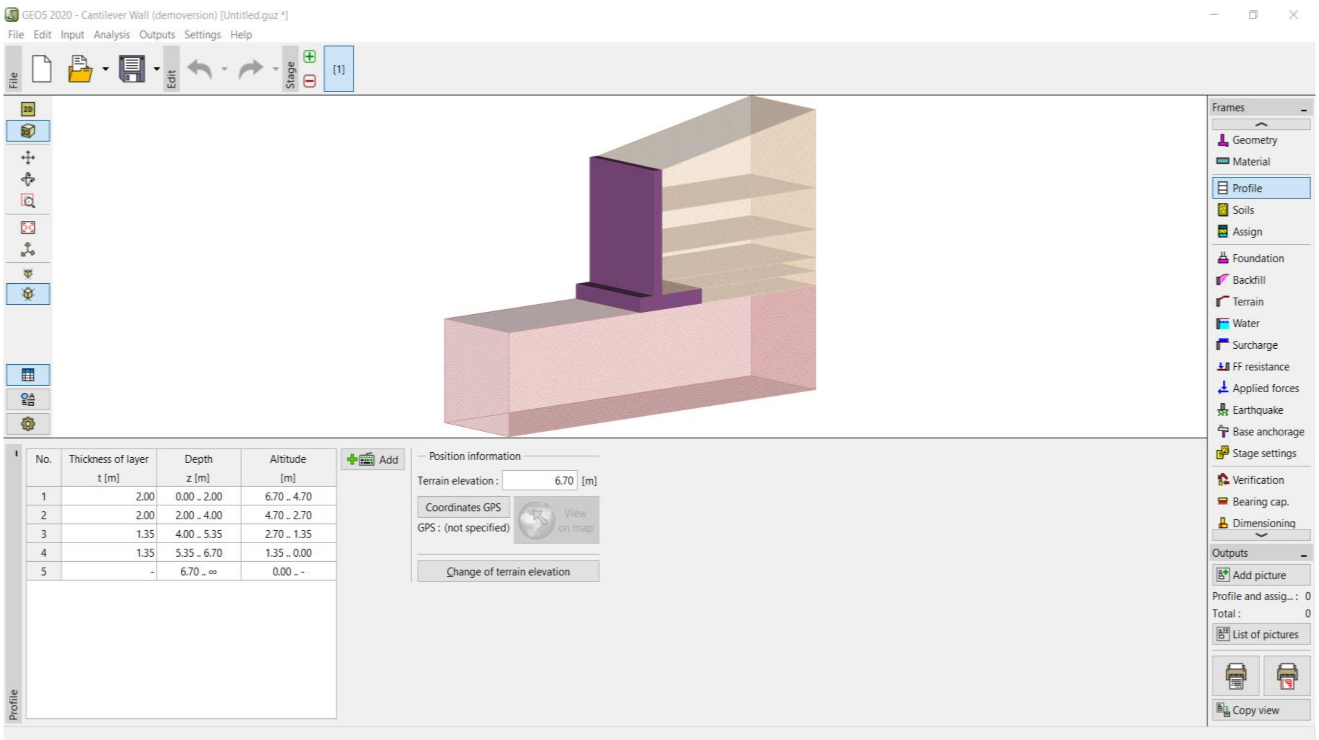


Fig 8.38 3-D view (a)

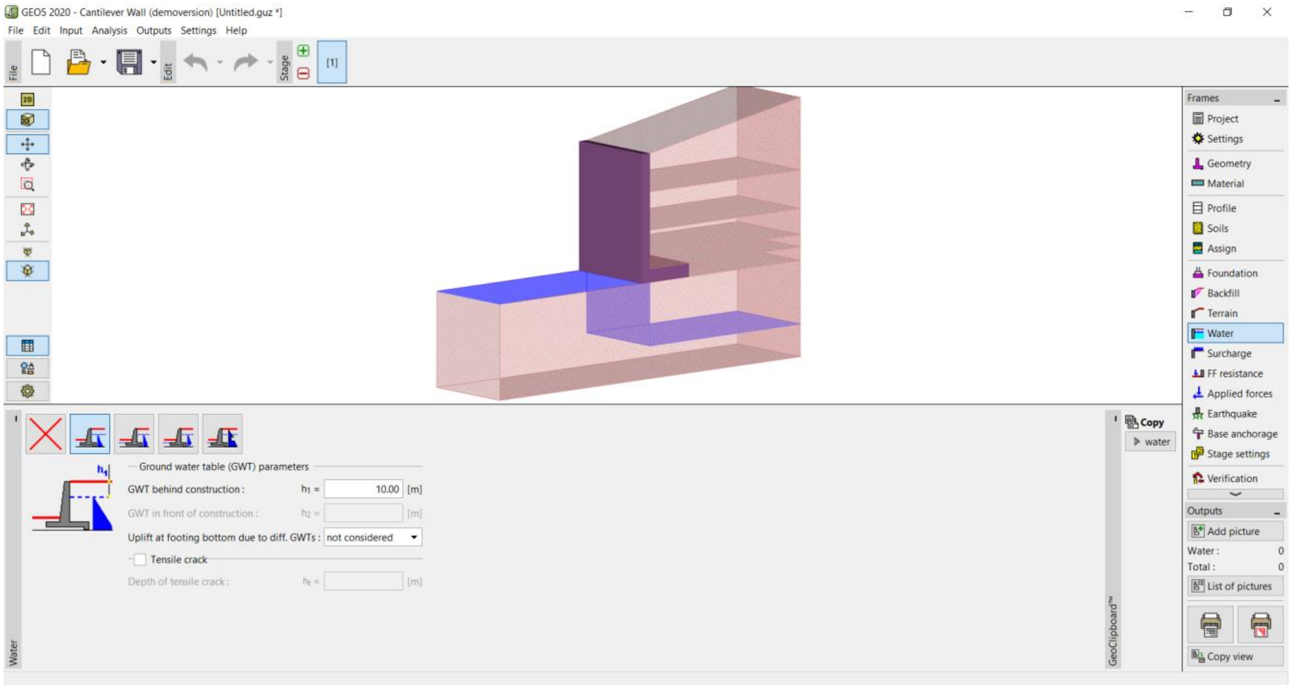


Fig 8.39 3-D view (b)

CHAPTER 9

CONCLUSIONS

The stability analysis of the cantilever retaining wall for define designed is carried out with the GEO5 software. Performa of the stability of whole wall under the service loads, which include overturning, sliding and bearing failure modes, have been checked and performed successful. The soil parameters which required for the designing of the retaining wall are been obtained from the different geotechnical test conducted on the soil sample which is collected from the DTU campus. By testing the soil sample in the lab the soil shows that it is silty sand in texture and safe bearing capacity and unit weight has been calculated in the results. Generally cantilever retaining wall have been designed for the support the slope from failure and safe and economical. Primarily retaining wall are designed for the different height. But from the results that we performed is that the stability is altered as the height of the wall increases and thus the retaining wall and the structure becomes not so economical for construction. Thus we can concluded that above the height 6m and below the 8m the retaining wall become most economical.

The designed and analysis for the cantilever retaining wall are as per recommendations of the IS 456: 2000. The stability of the backfill is improved by the admixture of the cement kiln dust which is waste from the Portland cement factory. We check the properties of the cement kiln dust in the lab for different parameters that are given in the results, some values are assumed or refereed from the research paper, and trial and error method has been used in designing the wall because it is theoretical type of designing. Due to limitations the practical work is not done for the retaining wall. The angle of internal friction for cement kiln dust is (40^0) is more than silty sand that is collected from the DTU ground (29^0). The addition of cement kiln dust decreases the OMC and increases the MDD of the soil, it also decreases the cohesion and increases the angle of internal friction. As the angle of internal friction increase the factor of safety increases for an admixture and thus the structure become stable and safe. The GEO5 software is very useful in analysis, it is observed that the factor of safety increases with the increases in depth of cement kiln dust as a fill material. The stability analysis to check the effect of water table level on the structure was made and it is observed that as the depth of water table increases, it has least effect on the structure.

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