TO STUDY TYPE, BEHAVIOUR AND DESIGN OF RETAINING WALL STRUCTURE BY SOFTWARE ANALYSIS

A
THESIS

Submitted in partial fulfilment of the requirements for the award of the degree
of

MASTER OF TECHNOLOGY

IN

CIVIL ENGINEERING

With specialization in

STRUCTURAL ENGINEERING

Under the supervision

of

Mr. Chandra Pal Gautam
(Assistant Professor)

by

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to

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HIMACHAL PRADESH, INDIA
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STUDENT'S DECLARATION

I hereby declare that the work presented in the thesis entitled **"TO STUDY TYPE, BEHAVIOUR AND DESIGN OF RETAINING WALL STRUCTURE BY SOFTWARE ANALYSIS"** submitted for partial fulfilment of the requirements for the degree of Master of Technology in Civil Engineering (structural engineering) at **Jaypee University of Information Technology, Waknaghat** is an authentic record of my work carried out under the supervision of **Mr. Chandra Pal Gautam**. This work has not been submitted elsewhere for the reward of any other degree/diploma. I am fully responsible for the contents of my project report.

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25 May, 2022

CERTIFICATE

This is to certify that the work which is being presented in the thesis titled **"TO STUDY TYPE, BEHAVIOUR AND DESIGN OF RETAINING WALL STRUCTURE BY SOFTWARE ANALYSIS"** in partial fulfillment of the requirements for the award of the degree of Master of Technology in Civil Engineering (structural engineering) submitted to the Department of Civil Engineering, **Jaypee University of Information Technology, Waknaghat** is an authentic record of work carried out by **Nikita Raheja (202656)** during a period from 2021-22 under the supervision of **Mr. Chandra Pal Gautam**, Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat.

The above statement made is correct to the best of our knowledge.

Date…………………….

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Nikita Raheja

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ABSTRACT

Retaining wall is the structure that retains soil on the backside. Retaining wall are “rigid walls used for supporting soil laterally” so that it can be retainined at “different levels” on the “two sides”. Due to advancement in the technologies of highway construction, instability of the retaining wall to cause embankment land slide has become common. “In conventional approach of constructing the retaining walls, there are several disadvantages like more construction time, cost, manpower and environmental impacts makes these conventional methods ineffective and uneconomic”. For the accurate analysis, GEO5 is FEM based software that used in this work. By the Conventional and software approach (the retaining wall are designed and analyse for stability analysis in GEO5 software), differentiation shows whether a software analysis is best for a convention approach is good or not. Also software analysis stability check to be done at different heights of retaining wall. In GEO5 software we can check whether the wall of any material we are constructing is fulfilling the conditions or not . This software is very time saving when it comes to designing of the wall of different heights and material. For this study a cantilever reinforced retaining wall data has taken from the project named of FOUR LANING OF SOLAN –KAITHLIGHAT SECTION OF NH-22(NOW NH-5) FROM Km.106.00 TO KM. 129.050 ON EPC MODE IN THE STATE OF HIMACHAL PRADESH UNDER NHDP PHASE III. In this study, walls ranging from 2-10 meter height wall is designed on GEO5 of different material like reinforced retaining wall, stones masonry wall and stoncrete wall . These walls are then compared to each other on various factors and parameters to find out the best suited wall for different conditions.

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CHAPTER 1

INTRODUCTION

1.1 General

Retaining walls are that structure type which is used to retain or hold the soil backside. Retaining wall can be constructed with different kind of materials. Retaining wall tends to move down slope due to gravity and stresses acting within the soil. Walls are often used to achieve desired changes in ground elevation which exceeds the natural slope. “Stabilizing hillsides and control erosion are the main functions of retaining walls”. During “the roadway construction sometimes, it is necessary to construct these structures where there is over rugged terrain with steep slopes”. “These walls decrease the grades and land requirement alongside the roads. In some cases, there is a lack of land available besides the travel way then retaining walls become necessary to allow acceptable slope conditions and for safer construction”.

1.2 Types of retaining walls

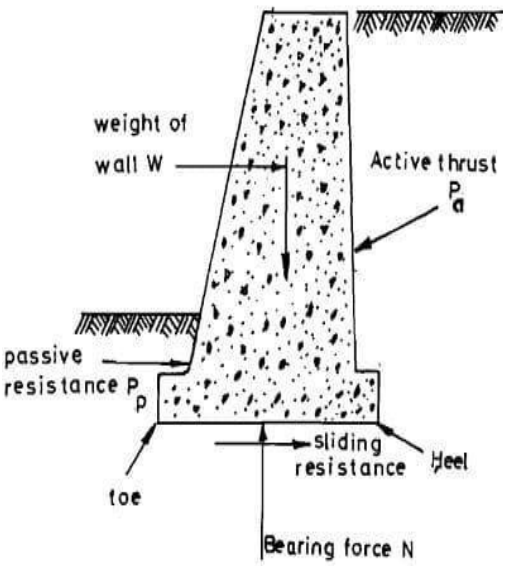
The different types of retaining walls, which are classified on the basis of their material and shape used which are as follows;

- Gravity retaining wall.
- Cantilever retaining wall.
- Buttress/ Counter-fort retaining wall.
- Pile retaining wall.
- Anchored retaining wall.
- Gabion retaining wall.
- Crib retaining wall.
- Soil nailing retaining wall.
- Mechanical soil stabilization earth retaining wall.
- Crib retaining wall.
- Sheet piled wall.

1.3 Gravity Retaining wall

"Gravity retaining wall depends on its self weight only to resist lateral earth pressure".

- Commonly, "Gravity retaining wall is massive because it requires significant gravity load to counter act soil pressure".
- "Sliding, overturning, and bearing forces shall be taken into consideration while this type of retaining wall structure is designed".
- "It is economical for a height up to 3m".
- "Material used concrete, stone etc".



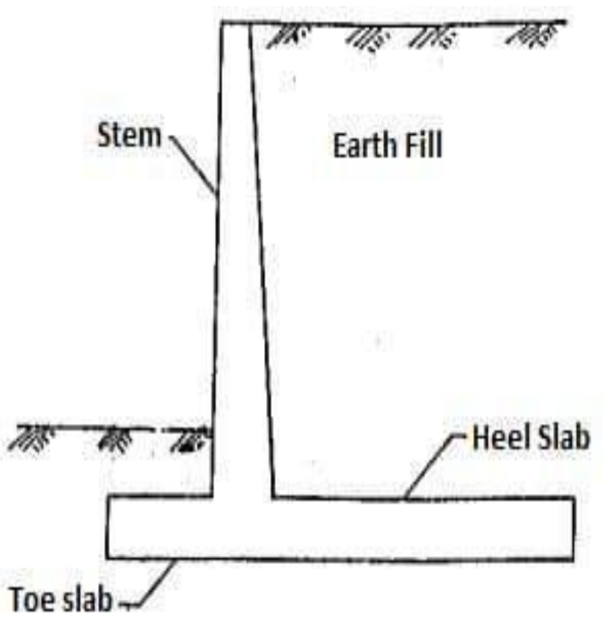
(a)

(b)

Fig 1.1 Gravity retaining wall (a) and (b)

1.4 Cantilever retaining wall

- "Cantilevered retaining walls are made from an internal stem of steel-reinforced,cast-in-place concrete or mortared masonry (often in the shape of an inverted T)".
- "These walls cantilever loads (like a beam) to a large, structural footing, converting horizontal pressures from behind the wall to vertical pressures on the ground below".
- "Cantilever retaining wall is economical up to height of 3-8m".

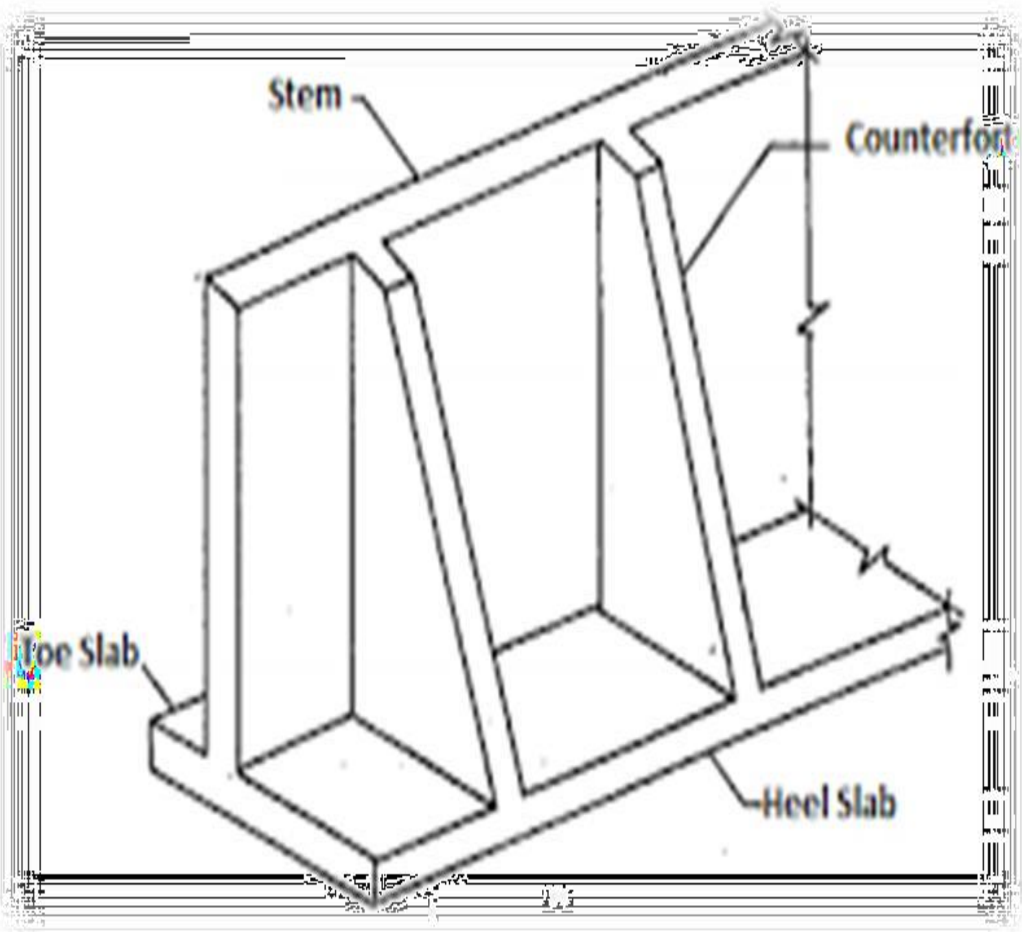


(a) (b)

Fig 1.2 Cantilever retaining wall (a) and (b)

1.5 Counter-fort/Buttress retaining wall

- "It is a cantilever retaining wall but strengthened with counter forts monolithic with the back of the wall slab and base slab".
- "Counter fort spacing is equal or slightly larger than half of the counter-fort height".
- "Counter-fort wall height ranges from 8-12m".



(a)

(b)

Fig 1.3 Counter-fort retaining wall (a) and (b)

1.6 Crib Retaining wall

- “Crib retaining wall are a form of gravity wall”.
- “They are constructed of interlocking individual boxes made from timber or pre-cast concrete”.
- “They are constructed of interlocking individual boxes made from timber or pre-cast concrete”.
- “It is suited to support planter areas, but it is not recommended for support of slopes or structures”.

(a)

(b)

Fig 1.4 Crib retaining wall (a) and (b)

1.7 Gabion Retaining Walls

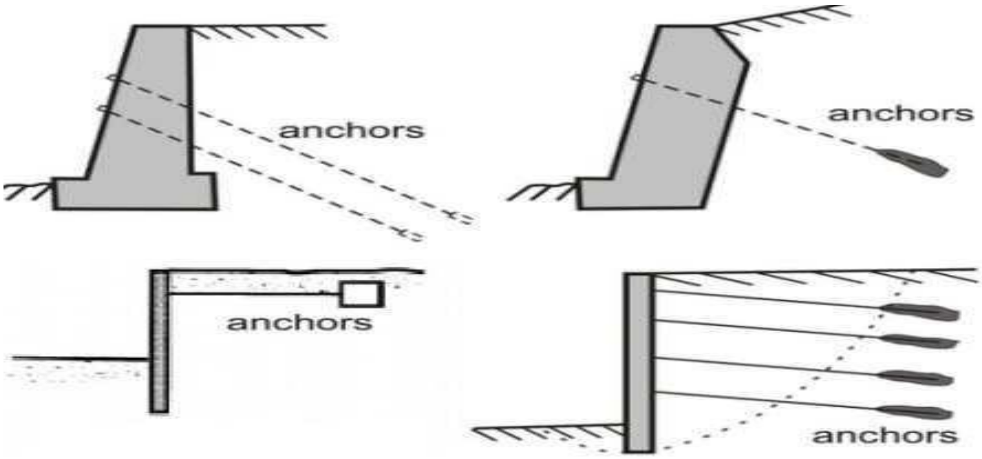
- "Gabion retaining wall walls are multi-celled, rectangular wire mesh boxes, which are filled with rocks or other suitable materials".
- "It is employed for construction of erosion control structures".
- "It is also used to stabilize steep slopes"

Fig 1.5 Gabion retaining wall

1.8 Anchored Retaining wall

- “This type of retaining wall is employed when the space is limited or thin retaining wall is required”.
- “Anchored retaining wall is suitable for loose soil over rocks”.
- “Considerably high retaining wall can be constructed using this type of retaining wall structure system”.

- "Deep cable rods or wires are driven deep sideways into the earth, then the ends are filled with concrete to provide anchor".
- "Anchors (tiebacks) acts against overturning and sliding pressure".



(a)

(b)

Fig 1.6 Anchored retaining wall (a) and (b)

1.9 Pile Retaining Wall

- “Pile retaining wall are constructed by driving reinforced concrete piles adjacent to each other”.
- “Piles are forced into a depth that is sufficient to counter the force which tries to push over the wall”.
- “It is employed in both temporary and permanent works”.

Fig 1.7 Pile retaining wall

1.10 Soil Nailing retaining wall

- "Piling is earth retention and excavation support technique that retains soil, victimization sheet sections with interlocking edges. Pile acts as a temporary certificate wall that has been driven into a slope or excavation to support the soft soils collapse from higher ground to lower ground. It provides high resistance to driving stresses and helps to lightweight".
- "Sheet piles will be reused on many comes and long service life above or below water with modest protection. Simple to adapt the pile length by either attachment or bolting and joints square measure less apt to deform throughout driving".

(a)

(b)

Fig 1.8 Soil nailing retaining wall (a) and (b)

1.11 Mechanical stabilization earth retaining wall

- “Mechanically stabilized earth (MSE) walls are walls that can tolerate some differential movement. The wall face is unfilled with granular soil whilst retaining the backfill soil”.
- “The advantage of MSE walls is the ease of construction, as they do not require formwork or curing. The use of soil nailing in MSE walls, involves introducing slender steel reinforcing bars to the soil, placed parallel to one another on a slight incline and grouted into place”.

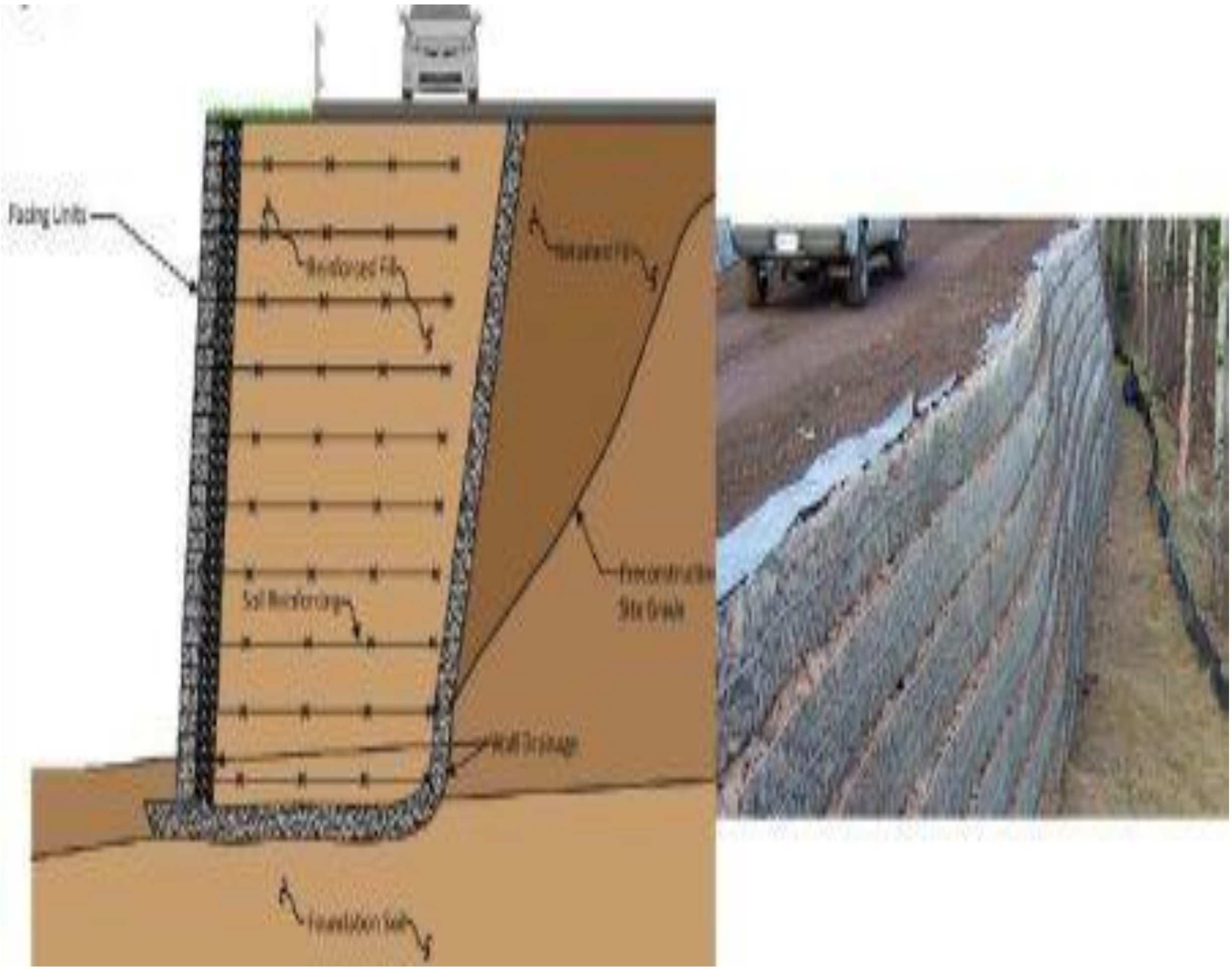


Fig 1.9 Mechanically stabilized retaining wall

1.12 Sheet pile retaining wall

- “Piling is earth retention and excavation support technique that retains soil, victimization sheet sections with interlocking edges. Pile acts as a temporary certificate wall that has beendriven into a slope or excavation to support the soft soils collapse from higher ground to lower ground. It provides high resistance to driving stresses and helps to lightweight. Sheet piles will be reused on many comes and long service life above or below water with modest protection. Simple to adapt the pile length by either attachment or bolting and joints square measure less apt to deform throughout driving”.

Fig 1.10 Sheet pile retaining wall

1.13 Purpose of retaining wall

- “This wall prevents the soil or other material at places with sudden elevation changes”

- “Earth retaining structures are used to hold back the earth and maintain the difference in the ground surface height”.
- “Retaining structures are designed to withstand the grounds or backfill; other externally exerted loads transmit these forces safely to a foundation”.
- “Retaining walls serve as a functional product to prevent sinkholes from destroying your landscape structure”. “They are used to stabilize the sloping landscapes and provides level surfaces on slopes”.
- “If your property is not prevented from infiltrating, then rainwater runoff can completely damage your land. This can protect your landscape design, also prevent floods from inflowing the area”.
- “Retaining walls additionally give your landscape an aesthetically pleasing design”.

1.14 Application of retaining wall

- “Construction of basement below ground level in buildings”.
- “In the bridge, work consists of the wing walls and abutment”.
- “To maintain slopes in hilly areas”.
- “As side walls of bridge approach roads”.
- “Providing lateral support to the embankment”.
- “Protect soil from erosion”.

CHAPTER 2

LITERATURE REVIEW

2.1 Literature survey

Ankit C. Mahure and Prof. M. N. Umare[6] in their research they conclude dynamic behavior of the retaining wall at their different heights. "The major problem of instability of walls" is mainly depends on "earth pressure distribution on the wall and the response of wall against the earth pressure, especially, under dynamic/seismic loading condition". So they take a problem and analysis the behavior, stability and strength as well on the different "height of the retaining wall" structure. The study basically helps that what kind of retaining wall is suitable at what height. The main conclusions they got by their research

- Difference in steel increases with increase in heights, the reason behind that the required A_{st} will increases with increase in height.
- Maximum steel required for "L shape retaining wall" than the "cantilever retaining wall". Due to The "thickness" of steam in "L shape retaining wall" is "more" than the "cantilever retaining wall".
- Difference in concrete increases with increase in height, The reason behind that the "L shape retaining wal"l having greater wall thickness than the "cantilever retaining wall".
- "L Shape retaining wall" "consumes more concrete" than the "cantilever retaining wall".

Hua Wen, Jiu-jiang Wu, Jiao-li Zou, Xin Luo,Min Zhang, and Chengzhuang Gu[7] in their research they use GEOBAGS filled with construction waste (demolished concrete waste) and prepare a model in proportion of a prototype. There "retaining walls constructed from geobags filled with construction waste are a new flexible supporting structure characterized by easy construction, low costs, and good supporting effects and facilitate the recycling of construction waste". They took this concept from ancient Egypt time. They conduct this model test on different slopes and length of the Geobags (Q1, Q2, Q3, Q4 and Q5). Accordingly they find mode of failure of retaining wall, load carrying capacity, mode of failure of the slopes. By their study provides helps to use waste construction material effectively,

Su Yang, Amin Chegnizadeh, Hamid Nikraz[8] in this they conclude how the retaining walls behave under the seismic conditions. They elaborate the actual condition of the retaining wall unde earthquake they mainly focus two analytical theories one of coulombs wedge failure theory and one sub-method of this is elasticity analysis method. Also analyse MO (Mononobe and okabe) method. And describe the limitation of MO method.

Ganesh C. Chikute, Ishwar P. Sonar[9] the main aim of their case study was how best the gabion wall among the other as the suggest itself "Techno-Economical Analysis of Gabion Retaining Wall Against Conventional Retaining Walls". They describe the material needed and work methodology for the gabion walls while taking a actual case study of Bank erosion at Ordinance factory, Kirki, Pune. They make a proper comparative of gabion wall with other conventional retaining wall in term of cost of construction, speed of construction, material quantity needed which is very helpful in future. According to them The construction cost of Gabion Wall as compare to Rubble Masonry, RCC Cantilever, RCC Counter-fort, Gravity retaining wall are 0.3%, 54.12%, 10.72% , 9.56% less respectively. Gabion Wall is ideally suited for remote area where skill labour, advance machinery, material is difficult to arrange.

Karthik Babu C and Keerthi Gowda B S [10] the study is basically on "counter fort retaining walls" with and without "pressure relief shelf" using soft computing techniques (SAP200). They gives a brief about this SAP200 software. They conclude a design of counter fort wall with conventional method as well as SAP200 software with and without pressure relieve wall and make comparative that which one is good In the present study comparison of conventional "counter-fort earth retaining wall" with "pressure relief shelf" attached counter-fort earth retaining wall is studied. "counter-fort earth retaining wall" with "pressure relief shelf" at 2H/3 positions is very well suited to design the "counter-fort earth retaining wall". Performing analysis of "counter-fort earth retaining wall" by using SAP-2000 is very much advantageous compared to manual techniques. It saves time; repeated iterative analysis could be done with effortlessly. A less experienced (new) design engineers can be successfully use SAP-2000 for analysis of counter-fort earth retaining wall Hence counter-fort earth retaining wall with pressure relief shelf at 2h/3 positions is very well suited to design the counter-fort earth retaining wall. Performing analysis of counter-fort earth retaining wall by using SAP-2000 is very much advantageous compared to manual techniques. It saves time; repeated iterative analysis could be done.

HAN Shang Yu, LI Kai Ren and Qiu Fang[11] their study is on "Construction Technique about The Reinforced Concrete Retaining Wall's Lateral Displacement Repairing". This repairing technique is very useful and their study is also very help full in construction world because describe the method that how to repair retaining wall when got laterally displaced. In this they describe all material required for this repairing and work procedure for the repairing as well. They also ensure and mentioned "Construction Quality Control Points" and "Quality Assurance Measures" taken before during and after the repairing.

Jyoti P. Bhusari and Rajashri S. Ghodke[12]: in this they study "the structural behavior of cantilever retaining wall with pressure relieving shelves". By this we knew about how these pressure relieving wall helps in decreasing the net effect of lateral earth pressure and Bending moment as well. But in this they also try to find the ideal location of the pressure relieving walls in the cantilever r/wall so that maximum amount of net forces can be reduces**.** The deflection also gets reduced about 95 percent if we provide shelf of 3.5m at height of 0.5h. Overall they conclude that, “retaining wall with shelves can be considered as an effective solution of the high retaining walls according to the study”.

Suk -Min Kong, Dong-Wook Oh, So-Yeon Lee, Hyuk-Sang Jung and Yong-Joo Lee[14] in their study they analyze reinforced retaining wall failure based on reinforced length. They did numerical 3D analysis i.e. modeling by using PLAXIS 3D (It widely used fem program for 3D geotechnical engineering). In this they plotted a graph b/w height of retaining wall vs horizontal displacement for straight retaining wall vs. curved retaining wall and this way the find out the role of retaining wall (length wise) in budging and settlement.

K. Jagadeesh, K.suresh and Dr. K. uday[15] in this they analyze the multi tier retaining wall. In this they analyze the stability of retaining wall external as well as internal. They took well graded as well as poorly graded soil for the study and they same study is carried out by GEO5 Software and form the finding it have been conclude that “intensity of surcharge” of the “upper tier to the lower tier” has “calculated by GEO5 Software, as per the results it is seen that to increase in the pull out resistance there would be minimum length of reinforcement”. The stability of the retaining wall depends upon shape or geometry of retaining wall.

Anjali Diwalkar[16]: in this they design and study the outcomes of retaining wall And the conclude that Various systems are implemented to support laterally the soil. Retaining walls might face failure because of sliding, overturning, and bending. Gross pressure and its point of application plays vital role in its failure. “Coulomb’s theory method and Rankine theory method used to evaluate the lateral earth pressure on retaining wall for static condition”. The “retaining wall with relieving platform is safer against overturning and sliding as compared to cantilever retaining wall”. In the gravity type of walls the sequence of construction is a also a important factor to be considered in the design.

Dr. Dhamdhere, Dr. V. R. Rathi and Dr. P. K. Kolase[17] they study about the design criteria of the cantilever and counter fort retaining wall with pressure relieving wall. Also study the results of stability of retaining walls, cost optimization and their behavior of bending moments at different heights so it is helpful in designing the cantilever and counter fort at adequate heights accordingly all the data has been described by help of graphs which is very helpful for construction and selection purposes. “The bending moment in toe and heel is less for retaining wall with relieving platform than cantilever retaining wall”. “The area of steel for toe and heel is less for retaining wall with relieving platform than cantilever retaining wall”.

2.2 Research objective

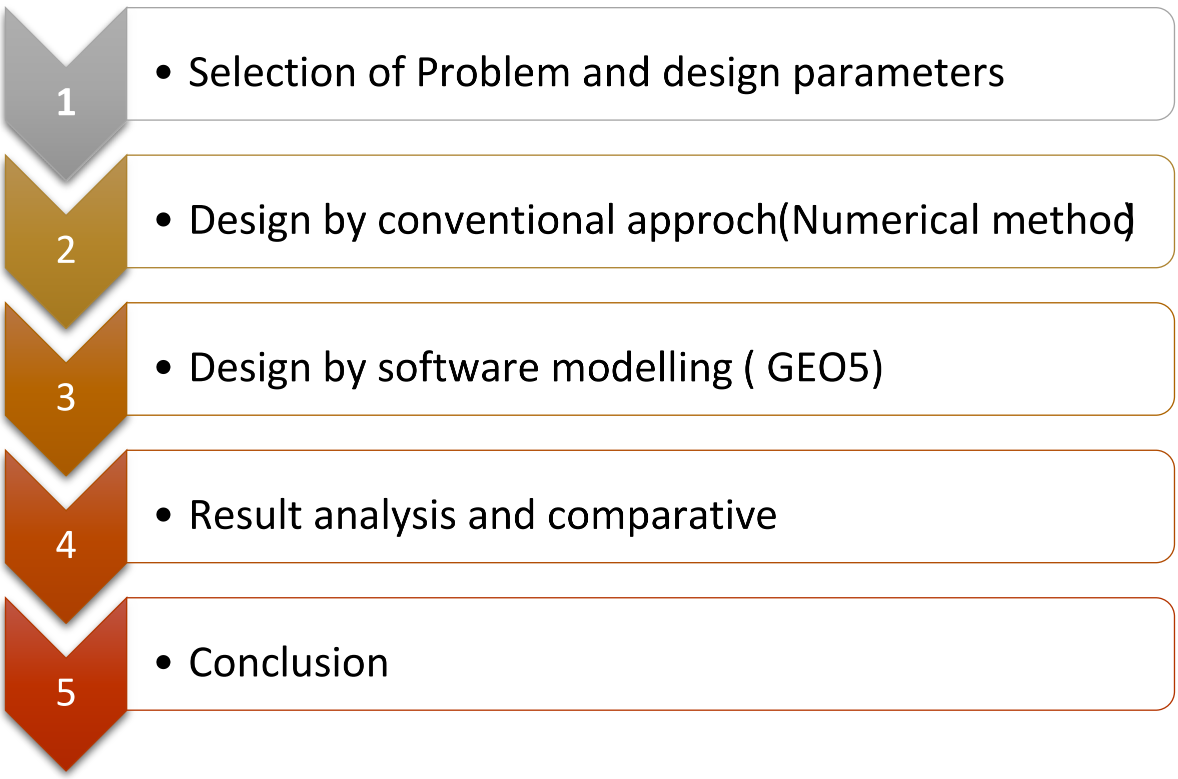
- Designing of the retaining wall and analysis its behaviour and stability
- GEO5 models
- Comparative between the result out comes with other type of retaining wall

CHAPTER 3

METHODOLOGY

3.1 Procedure to be followed

After the study , about the retaining wall, its type, application and its purposes. In this case study a numerical problem to be taken for the analysis of the conventional design approach and the same problem has to be analyzing by the software i.e. GEO5. The design process goes with the “selection of geometry”, “according to the specifications given in various codes” and “then their overall stability is calculated when backfill load acts on them” at different heights but same loading condition. After all the outcomes/ results by both approaches we have to prepare a comparative and check weather which approach is best for the designing of the retaining walls.



CHAPTER 4

DESIGN BY CONVENTIONAL METHOD

4.1 General

The design of "reinforced cantilever retaining wall" is as follows;

(a) Preliminary structural data

Deck level	8.0	m
Depth of foundation	2	m
Stem thickness at top	0.3	m
Stem thickness at base	1.5	m
Toe length	3.2	m
Heel length	4.0	m
Thickness of base at toe and stem junction	1.5	m
Thickness of toe slab at edge	0.75	m
Thickness of heel slab at edge	0.75	m
Total Height (H)	10.0	m
Base Width (B)	9.2	m

(b)Material Data

Grade of concrete	30	N/mm^2
Grade of reinforcement	500	N/mm^2

(c)Material unit weight Data

Unit weight of RCC	25.0	kN/m^3
Unit weight of dry soil	20	kN/m^3

(d)Calculation units

KN, m, KN-m, Mpa, mm

(e) Soil Data

Table 4.1 Soil data

Description	Units	Value
Cohesion of soil	-	0.0
Angle of internal friction;	deg.	30.0
	Rad.	0.52
Safe bearing capacity of soil;	kN/m^2	225
Net safe bearing capacity of soil	kN/m^2	

(f) Other Data

Table 4.2 Other data

	Units	Symbol	Value
Surcharge angle =$TAN^{-1}(1/2)$	degree	β	0
	rad.	β	0.000
Active earth pressure coefficient	-	K_a	0.318
Coefficient of friction b/w concrete and soil	-	µ	0.577
IRC:78-2014			

"Partial Safety Factor for Verification of Structural Strength".

Table 4.3 Partial safety factor for structural strength

Load	ULS	Rare Combination.	Frequent Combination	Quasi-permanent Combination.
DL	1.35	1	1	1
EP	1.5	1	1	1
LSC	1.2	0.8	0	0

Vertical force (kN)

Table 4.4 Vertical forces

Description	Units	Vertical forces
Weight of stem / unit length of wall	kN	191.25
Weight of Base slab / unit length of wall	kN	258.75
Weight of backfill soil	kN	812.00
Weight of soil above toe	kN	56.00
Force due to active pressure /unit length of wall (P_v)	kN	0.00
Net vertical force	kN	1318.00

Table 4.5 Uls and Sls

ULS	SLS		
Basic Comb.	Rare Comb.	FrequentComb.	Quasi-permanentComb.
258.19	191.25	191.25	191.25
349.31	258.75	258.75	258.75
1096.20	812.00	812.00	812.00
75.60	56.00	56.00	56.00
0.00	0.00	0.00	0.00
1779.30	1318.00	1318.00	1318.00

Horizontal force (kN)

Table 4.6 Horizontal forces

			ULS	SLS		
Description	Units	Vertical forces	Basic Comb.	Rare Comb.	Frequent Comb.	Quasi-permanent Comb.
Force due to active pressure /unitlength of wall (P_h)	kN	317.75	476.62	317.75	317.75	317.75
Live Load Surcharge	kN	76.26	91.51	61.01	0.00	0.00
Net Horizontal force	kN	394.00	568.13	378.75	317.75	317.75

4.2 Check for Over Turning

Restoring Moment (Per Unit)

Table 4.7 Restoring moment

Section	Area	Weight (kN/m)	l. arm (m)	ULS	SLS			
				Basic Comb.	Rare Comb.	Frequent Comb.	Quasi-permanent Comb.	Moment about Toe (kN-m)
1	2.55	63.75	3.35	86.06	63.75	63.75	63.75	288.31
2	5.10	127.50	3.90	172.13	127.50	127.50	127.50	671.29
3	39.10	782.00	6.39	1055.70	782.00	782.00	782.00	6742.71
4	6.53	163.13	4.35	220.22	163.13	163.13	163.13	957.95
5	1.60	32.00	1.60	43.20	32.00	32.00	32.00	69.12
6	1.50	37.50	6.03	50.63	37.50	37.50	37.50	305.44
7	1.50	30.00	7.37	40.50	30.00	30.00	30.00	298.35
8	1.20	30.00	2.13	40.50	30.00	30.00	30.00	86.40
9	1.20	24.00	1.07	32.40	24.00	24.00	24.00	34.56
10	1.13	28.13	3.95	37.97	28.13	28.13	28.13	149.98
11	0.00	0.00	6.97	0.00	0.00	0.00	0.00	0.00
P_v		0.00	9.20	0.00	0.00	0.00	0.00	0.00

Total Restoring Moment (Mr) 9604.1

Overturning Moment (kN-m) Mo 2459.35

Factor of Safety against Overturning (F.O.S) 3.91

Criteria Safe > 1.5

4.3 Check for Sliding

Sliding Force 568.13

Resisting Force 1027.28

Factor of Safety against Sliding (F.O.S) 1.81

Criteria Safe > 1.5

4.4 Base Pressure Check

"Partial Safety Factor for Verification of Serviceability Limit State"

Table 4.8 Partial safety factor for limit state

Load	Comb.(1)	Comb.(2)	Accidental Comb.
DL	1.35	1.00	1.00
EP	1.50	1.30	0.00
LSC	1.20	1.00	0.20

Vertical force (kN)

Table 4.9 Vertical forces

Description	Units	Vertical forces	Comb.(1)	Comb.(2)	Accidental Comb.
Weight of stem / unit length of wall	kN	191.25	258.19	191.25	191.25
Weight of Base slab / unit length of	kN	258.75	349.31	258.75	258.75
Weight of backfill soil	kN	812.00	1096.20	812.00	812.00
Weight of soil above toe	kN	56.00	75.60	56.00	56.00
Net vertical force	kN	1318.00	1779.30	1318.00	1318.00

Horizontal force

Table 4.10 Horizontal forces

Force due to active pressure /unit length of wall (P_h)	kN	317.75	476.62	413.07	0.00
Live Load Surcharge	kN	76.26	91.51	76.26	15.25
Net Horizontal force	kN	394.00	568.13	489.33	15.25

Restoring Moment (Per Unit)

Table 4.11 Restoring moment

Section	Area	Weight (kN/m)	l. arm (m)	Combination(1)	Combination(2)	Accidental Combination	Moment
1	2.55	63.75	3.35	86.06	63.75	63.75	288.31
2	5.10	127.50	3.90	172.13	127.50	127.50	671.29
3	39.10	782.00	6.39	1055.70	782.00	782.00	6742.71
4	6.53	163.13	4.35	220.22	163.13	163.13	957.95
5	1.60	32.00	1.60	43.20	32.00	32.00	69.12
6	1.50	37.50	6.03	50.63	37.50	37.50	305.44
7	1.50	30.00	7.37	40.50	30.00	30.00	298.35
8	1.20	30.00	2.13	40.50	30.00	30.00	86.40
9	1.20	24.00	1.07	32.40	24.00	24.00	34.56
10	1.13	28.13	3.95	37.97	28.13	28.13	149.98
11	0.00	0.00	2.23	0.0	0.0	0.0	0.00

Total Restoring Moment(Mr) 9604.1

Overturning Moment (kN-m)(Mo) 2459.35

Eccentricity (e)	e	0.58
	B/6	1.53
	Criteria	e < B/6
		No tension
Minimum Pressure (kN/m^2)	P_{min}	119.68
Maximum Pressure (kN/m^2)	P_{max}	267.13

4.5 DESIGN OF STEM, TOE & HEEL

Design BM & SF - Heel Slab

Table 4.12 Design of bending moment for heel slab

Description	units	Symbol	Value
1) Downward Pr. due to weight of soil	kN/m^2		258.30
2) Pr. due to weight of heel slab	kN/m^2		50.63
4) Upward Pressure -			
a) At edge of heel	kN/m^2		119.68
b) Below junction of stem and heel	kN/m^2		183.79
5) Net downward pressure -			
a) At edge of heel	kN/m^2		189.25
b) Below junction of stem and heel	kN/m^2		125.14
Ultimate Moment	kN-m	Mu	1343.03

Table 4.13 Design of shear force for heel slab

Description	units	Symbol	Value
1) Downward Pr. due to weight of soil	kN/m^2		258.30
2) Pr. due to weight of heel slab	kN/m^2		50.63
4) Upward Pressure -			
a) At edge of heel	kN/m^2		119.68
b) At d from stem	kN/m^2		204.57
5) Net downward pressure -			
a) At edge of heel	kN/m^2		189.25
b) At d from stem	kN/m^2		104.35
Ultimate shear	kN	Vu	587.21

Table 4.14 BM & SF for toe slab

Description	units	Symbol	Value
1) Downward Pr. due to weight of soil	kN/m^2		0.00
2) Pr. due to weight of toe slab	kN/m^2		37.97
3) Upward Pressure -			
a) At edge of toe slab	kN/m^2		267.13
b) At the face of Stem	kN/m^2		207.83
4) Net downward pressure -			
a) At edge of toe slab	kN/m^2		229.16
b) At the face of Stem	kN/m^2		169.86
Ultimate Moment	kN-m	Mu	1072.09
Ultimate shear	kN	Vu	349.14

Design BM & SF –Stem

Table 4.15 BM & SF for stem

Description	units	Symbol	Stem @ Base	Stem @ 0.5*(H-D)
Thickness of heel slab	m	ts	1.50	1.50
Revised height of stem	m	H_1	8.50	4.25
Ultimate Moment	kN-m	Mu	1559.94	236.31
Ultimate Shear	kN	Vu	422.14	124.98

4.6 Reinforcement Calculation

Flexure Reinforcement

Table 4.16 Reinforcement calculations

Description	Units	Stem @ Base	Stem @ 0.5*(H -D)	Toe	Heel
Main reinforcement					
Design bending moment	kN-m	1560	236	1072	1343
Reqd effective depth	mm	614	239	509	570
Dia. of bars	mm	25	16	25	25
Dia. of bars (In 2nd Layer)	mm	25	0	0	25
Cover	mm	75	75	75	75
Prov. avg depth	mm	900	600	1125	1125
Prov. effective depth	mm	813	517	1038	1038
Reqd. area of reinf.	mm^2	4908	1089	2474	3134
min. area of reinf.	mm^2	1080	720	2454	2454
prov. area of reinf.	mm^2	9817	1340	4909	9817
prov. spacing of reinf.	mm	100	150	100	100
Check		ok	ok	ok	ok
Distribution reinforcement					
dia. of bar	mm	12	12	12	12
min. area of reinf.	mm^2	982	218	495	627
Min. area on earth face	mm^2	654	145	330	418
Min. area on exposed face	mm^2	327	73	165	209
Spacing on earth face	mm	150	150	200	200
Spacing of exposed face	mm	150	150	200	200
prov. area of reinf. each face	mm^2	1508	1508	1131	1131
Check		ok	ok	ok	ok

4.7 Check for shear

Table 4.17 Check for shear

Description	Units	Stem @ Base	Stem @ 0.5*(H-D)	Toe	Heel
effective depth	mm	812.5	517	1037.5	1037.5
k		1.50	1.62	1.44	1.44
b_w	mm	1000	1000	1000	1000
ρ_1		1.21E-02	2.59E-03	4.73E-03	9.46E-03
σ_{cp}		0	0	0	0
$V_{Rd.c(calc.)}$	kN	443.16	183.96	399.45	502.11
$V_{Rd.c\ min.}$	kN	252.47	181.33	304.11	304.11
V_{Ed}	kN	422.14	124.98	349.14	587.21
Shear Reinf. Requirement		No	No	No	No

4.8 Seismic Data

Seismic Zone Zone IV

Horizontal seismic coefficient (αh) is given by :

$$\alpha_h = \frac{Z}{2}\frac{I}{R}\frac{S_a}{g}$$

where,

Zone factor	Z	0.24
Importance factor	I	1.20
Response reduction factor	R	3.00
Spectral coefficient in x-direction	(Sa/g)x	2.50
Spectral coefficient in z-direction	(Sa/g)z	2.50
Spectral coefficient in y-direction	(Sa/g)y	2.50
Seismic coefficient in x-direction	(αh)x	0.120
Seismic coefficient in z-direction	(αh)z	0.120

4.9 Calculation of earth pressure coefficients

"Calculation of earth pressure coefficients in normal and seismic

Ca	horizontal dynamic active earth pressure coefficient
Cp	horizontal dynamic passive earth pressure coefficient
Ka	horizontal static active earth pressure coefficient
Kp	horizontal static passive earth pressure coefficient

$$C_a = \frac{(1 \pm A_v)\cos^2(\varphi - \lambda - \alpha)}{\cos\lambda \cos^2\alpha \cos(\delta + \alpha + \lambda)} \times \left[\frac{1}{1 + \left\{ \frac{\sin(\varphi + \delta)\sin(\varphi - \beta - \lambda)}{\cos(\alpha - \beta)\sin(\delta + \alpha + \lambda)} \right\}^{1/2}} \right]^2$$

$$C_P = \frac{(1 \pm A_V)\cos^2(\varphi - \lambda - \alpha)}{\cos\lambda \cos^2\alpha \cos(\delta + \alpha + \lambda)} \times \left[\frac{1}{1 - \left\{ \frac{\sin(\varphi + \delta)\sin(\varphi + \beta - \lambda)}{\cos(\alpha - \beta)\sin(\delta - \alpha + \lambda)} \right\}^{1/2}} \right]^2$$

" where,

Φ	angle of internal friction of soil
α	angle which earth face of the wall makes with the vertical
β	slope of earthfill
δ	angle of friction between the wall and earthfill should be equal to 2/3 of Φ subject to maximum of 22.5°

Ah horizontal seismic coefficient
Av vertical seismic coefficient"

Here

$$\lambda = \tan^{-1} \frac{A_h}{1 \pm A_v}$$

Ah 0.12

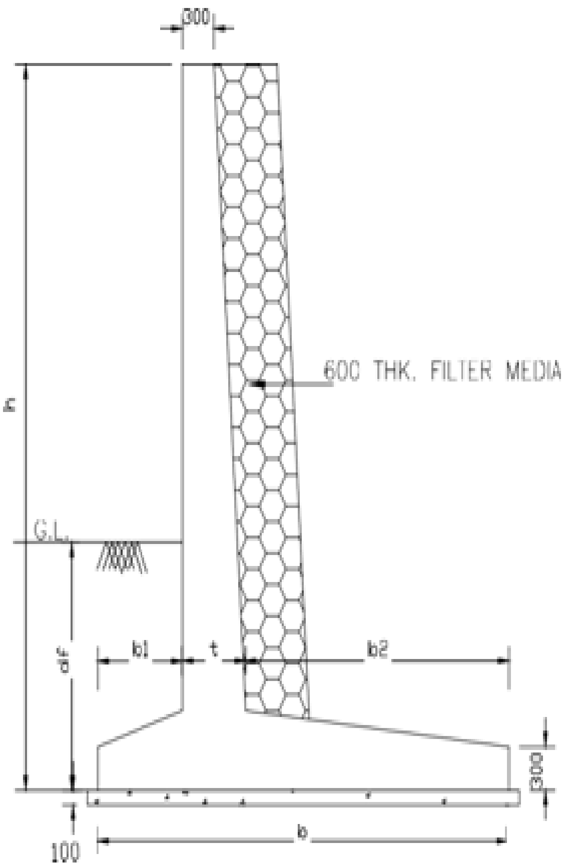
Av 0.08

Table 4.18 Different parameters

Φ	30.0 degree	0.52 rad
α	0.14 degree	0.00 rad
β	0 degree	0.00 rad
δ	20 degree	0.35 rad
λmax	7.43 degree	0.13 rad
λmin	6.34 degree	0.11 rad

Table 4.19 Design coefficients

Design Coefficient	max	min	Design dynamic coefficient	static coefficient	dynamic change
Ca	0.33	0.25	0.33	0.32	0.01



TYPICAL CROSS SECTION OF RETAINING WALL

(SCALE 1:50)

NOTES

1. ALL DIMENSIONS ARE IN MM, & LEVELS ARE IN METRES UNLESS OTHERWISE SPECIFIED.
2. DIMENSIONS ARE NOT TO BE SCALED. ONLY WRITTEN DIMENSIONS SHALL BE FOLLOWED.
3. THIS DRG. SHALL BE READ IN CONJUNCTION WITH OTHER RELEVANT DRGS.
4. GRADE OF CONCRETE IN R.C.C. WING/ RETAINING WALLS SHALL BE OF M35 MIX.
5. ALL REINFORCING STEEL SHALL BE HIGH YIELD STRENGTH DEFORMED (TMT) BARS AND (GRADE-Fe 500). CONFORMING TO IS:1786.
6. WHEREVER THERE IS VARIATION IN DEPTH OF FOUNDATION A CONSTRUCTION JOINT SHALL BE PROVDED IN FOUNDATION.
7. CLEAR COVER TO REINFORCEMENT SHALL BE AS FOLLOWS.

   (a) FOR FOUNDATION AND WALL ON EARTH RETAINING SIDE-75mm.

FIG 4.1 Typical cross section of retaining wall

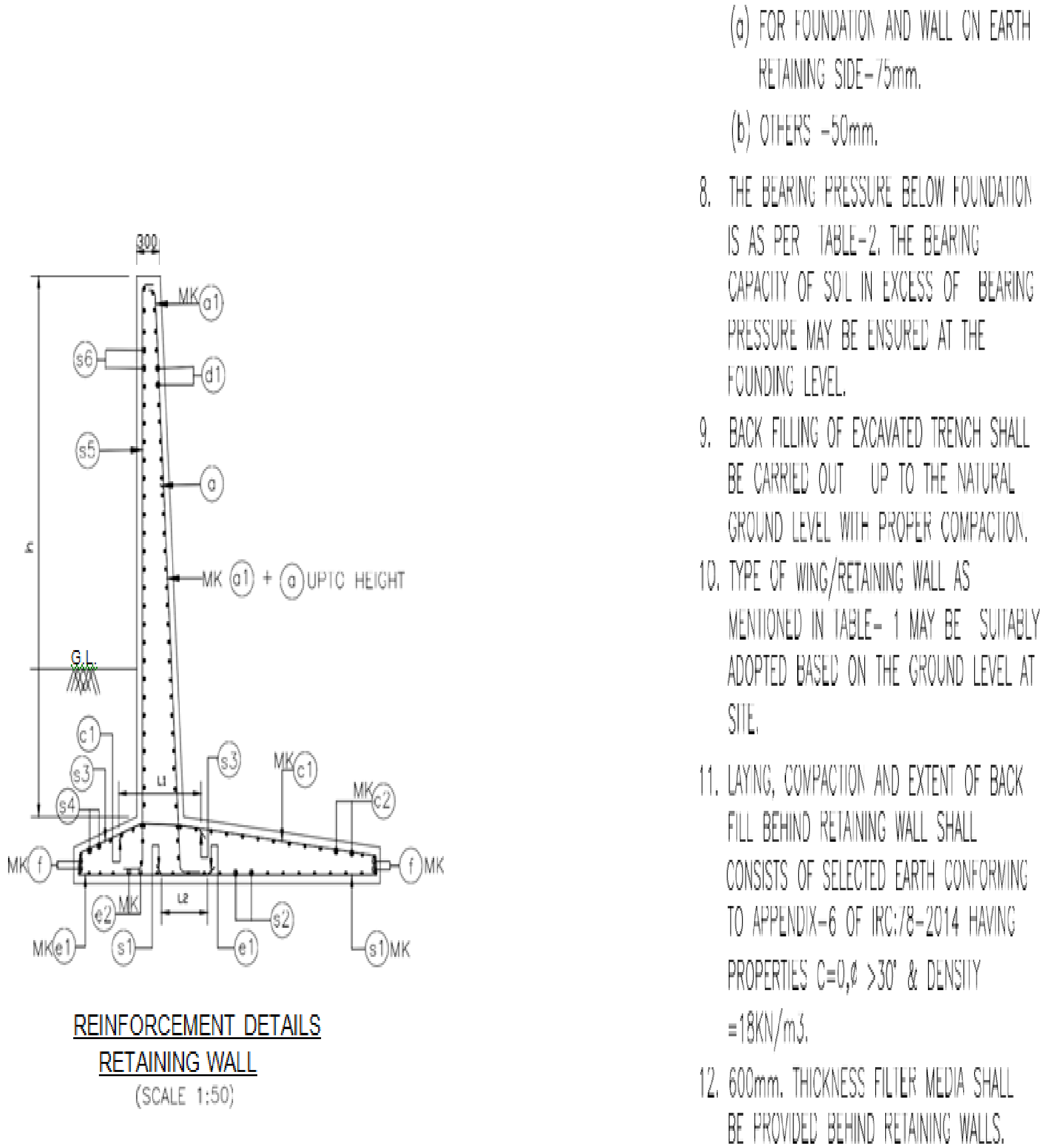


FIG 4.2 Reinforcement detail of retaining wall

4.10Schedule of retaining wall

SCHEDULE OF RETAINING/TOE WALL

			HEIGHT (H) 2M		HEIGHT (H) 4M		HEIGHT (H) 5M		HEIGHT (H) 6M		HEIGHT (H) 7M		HEIGHT (H) 8M		HEIGHT (H) 9M		HEIGHT (H) 10M	
SR.NO	TYPES OF BAR	SHAPE OF (NOT TO SCALE)	DIA OF BARS (mm)	SPACING/ NO OF BARS(mm)	DIA OF BARS (mm)	SPACING/ NO OF BARS(mm)	DIA OF BARS (mm)	SPACING/ NO OF BARS(mm)	DIA OF BARS (mm)	SPACING/ NO OF BARS(mm)	DIA OF BARS (mm)	SPACING/ NO OF BARS(mm)	DIA OF BARS (mm)	SPACING/ NO OF BARS(mm)	DIA OF BARS (mm)	SPACING/ NO OF BARS(mm)	DIA OF BARS (mm)	SPACING/ NO OF BARS(mm)
1	a		10	150	12	150	12	75	16	120	20	150	20	75	25	75	25 2 layer	100
2	a1		10	150	12	150	12	150	16	150	16	150	16	150	16	150	16	150
3	c1		10	150	12	150	12	150	16	150	16	150	16	100	20	100	20	120
4	c2		8	200	8	200	8	200	8	200	8	200	10	200	12	200	12	200
5	d1		8	150	8	150	8	150	8	150	8	150	10	150	12	150	12	150
6	e1		10	150	12	100	12	75	16	100	20	100	25	100	25 2 layer	100	25 2 layer	100
7	e2		8	200	8	200	8	200	8	200	8	200	10	200	12	200	12	200
8	f		10	4 NOS	10	4 NOS	10	4 NOS	10	4 NOS	10	4 NOS	10	4 NOS	10	4 NOS	10	4 NOS
9	s1		10	300	10	300	10	300	10	300	10	300	10	300	10	300	10	300
10	s2		8	200	8	200	8	200	8	200	8	200	10	200	12	200	12	200
11	s3		10	300	10	300	10	300	10	300	10	300	10	300	10	300	10	300
12	s4		8	200	8	200	8	200	8	200	8	200	10	200	12	200	12	200
13	s5		12	200	12	200	12	200	12	200	12	200	12	200	12	200	12	200
14	s6		8	150	8	150	8	150	8	200	8	200	10	200	12	200	12	200

Fig 4.3 Schedule of retaining wall

4.11 Parameters of retaining wall

TABLE SHOWING VARIOUS PARAMETERS OF RCC RETAINING WALL									
	PARAMETERS								
SR.NO	HIGHT (mm)	2-3M	4-5M	5-6M	6-7M	7-M	8M	9M	10M
1	B	2.3	3.4	4.2	5.0	5.9	6.8	7.1	7.7
2	b1	0.8	1.3	1.4	1.8	2.0	2.6	3	3.2
3	b2	1	1.6	2.0	2.2	2.6	2.9	3.6	4
4	t	0.5	0.8	1.0	1.1	1.2	1.3	1.4	1.5
5	t1	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.4
6	t2	0.5	0.6	0.8	1	1.3	1.3	1.4	1.5
7	L1	0.85	0.85	1.05	1.05	1.05	1.05	1.05	1.05
8	L2	0.85	0.85	0.85	0.85	1.05	1.05	1.05	1.05
9	L3	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55
10	Df	1.5	1.5	1.5	2.0	2.0	2.0	2.0	2.0
11	maximum hose pressure kN/m^2	64.00	150.00	176.00	189.23	224.36	224.0	225.00	260.00

Fig 4.4 Parameters of retaining wall

CHAPTER 5

ANALYSIS BY SOFTWARE

5.1 GENERAL

The GEO 5 “software” is used for this study. GEO 5 is used for both Finite Element Method and analytical methods. GEO5 acquire a isolated way of execute “standards and partial safety factors which are distinct from structural input”.

5.2 APPLICATIONS OF GEO5

“GEO5 is a geotechnical software that is used to solve various geotechnical problems”. Apart from “geotechnical engineering task (slope stability, foundations, retaining walls)”, it also involves the “applications for the analysis of tunnels, building damage due to tunneling or rock slope stability”. GEO5 is “based” on both “analytical method” and “finite element method”. The “analytical method” i.e “slope stability, sheeting design allow users to design and also to check structures quickly and efficiently”. “The designed structure is transferred into the FEM which is used for the overall analysis of the structure”. “It saves designers time as well as compares two independent solutions, thus increasing the design safety”. “It is a powerful and easy to use package which consists of individual programs having a consistent graphical interface”.

GEO5 is used for the;

a. Stability analysis.
b. Excavation.
c. Retaining wall design.
d. Foundation design.
e. Soil settlement analysis.
f. Digital terrain design model.
g. Finite element analysis (advanced).

5.3 DESIGN STEPS OF CANTILEVER REATINING WALL USING GEO5

The design steps are as follows;

- Start the Geo5 program, click on cantilever retaining wall plan . Click on the "project" option. Fill the details like date, project name, description etc .

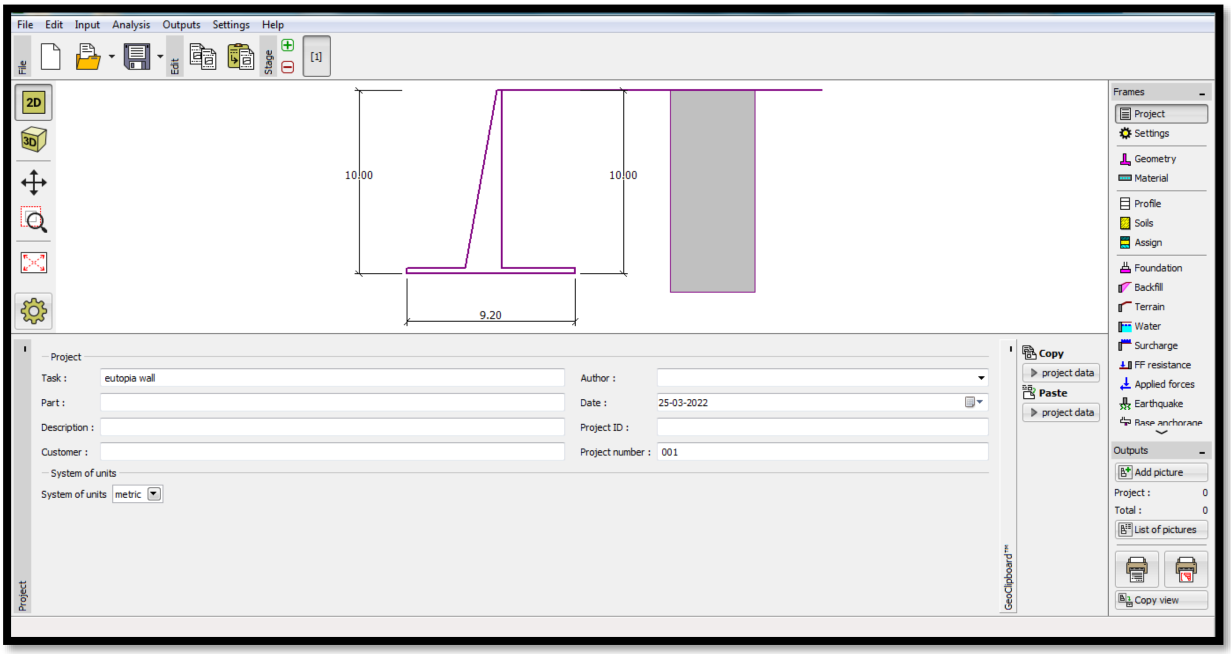


Fig 5.1 Project frame

- Next step is "setting" click on setting and select the code which is appropriate for the design of wall.

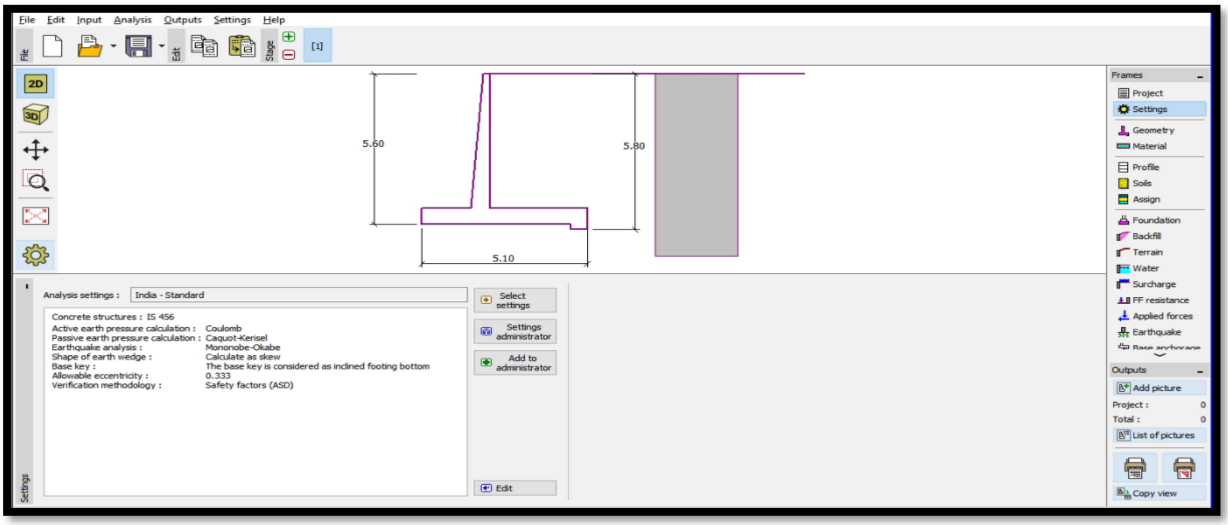


Fig5.2 Setting frame

➢ Now go for the “Geometry ’’, select the shape and fill the dimensions

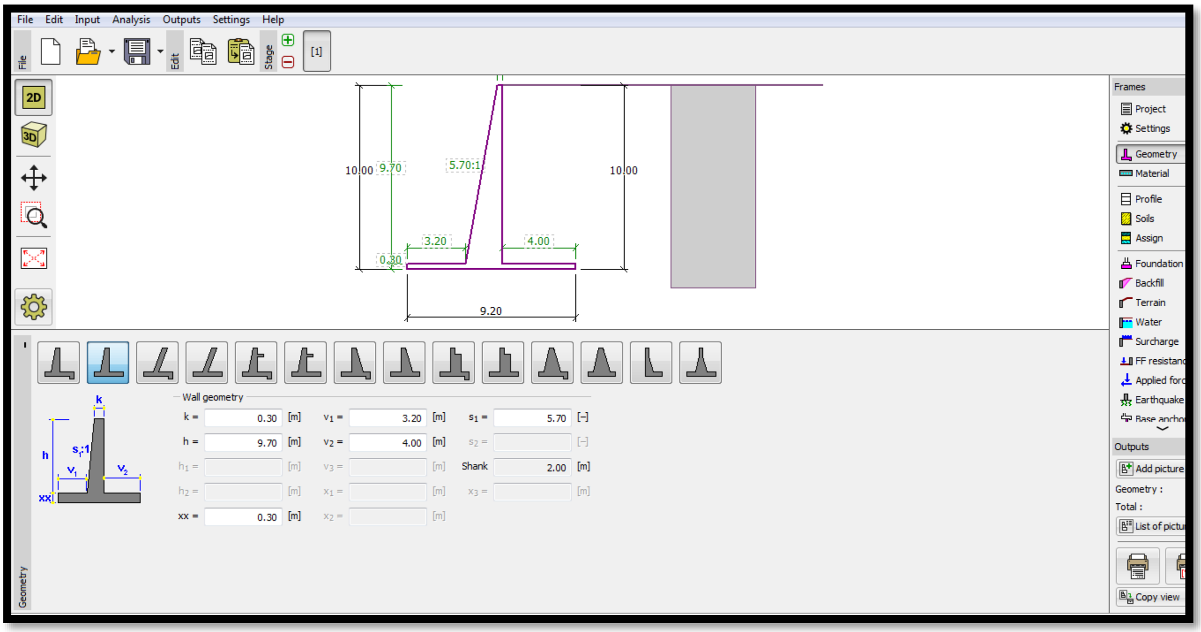


Fig5.3 Geometry frame

➢ Next one is “material”, select the properties of the wall . Fill the units weight of the wall. Select from list of type of steel used cement used.

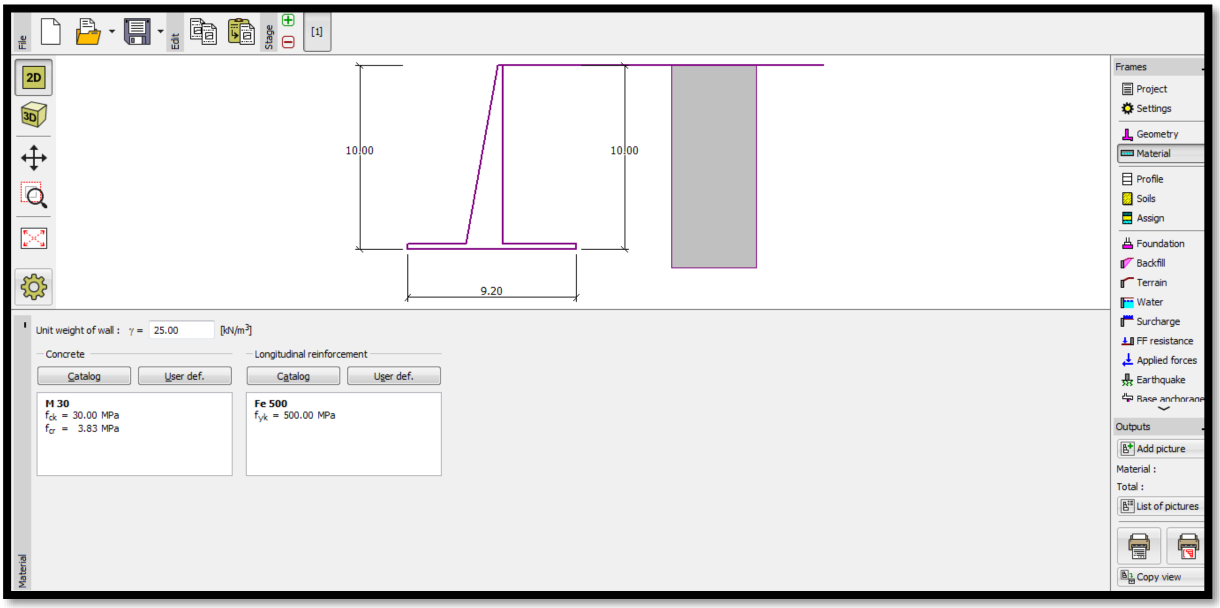


Fig5.4 Material frame

➢ Next frame is “profile”, enter the depth of soil layers present click on “add” to add the depth of top soil layer from top

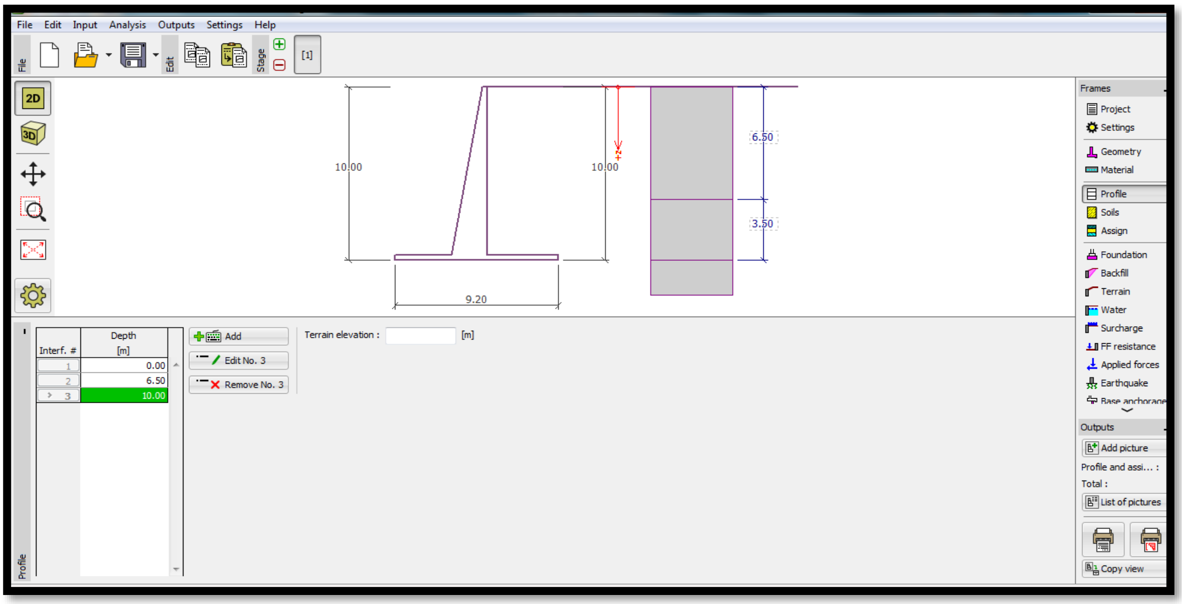
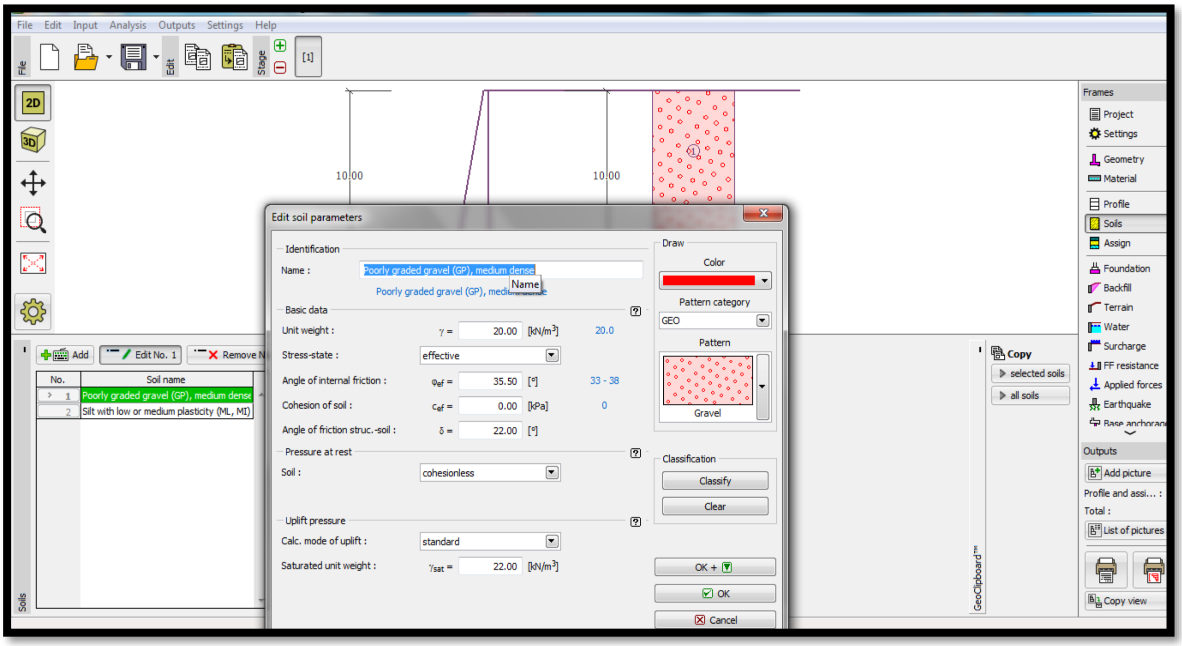
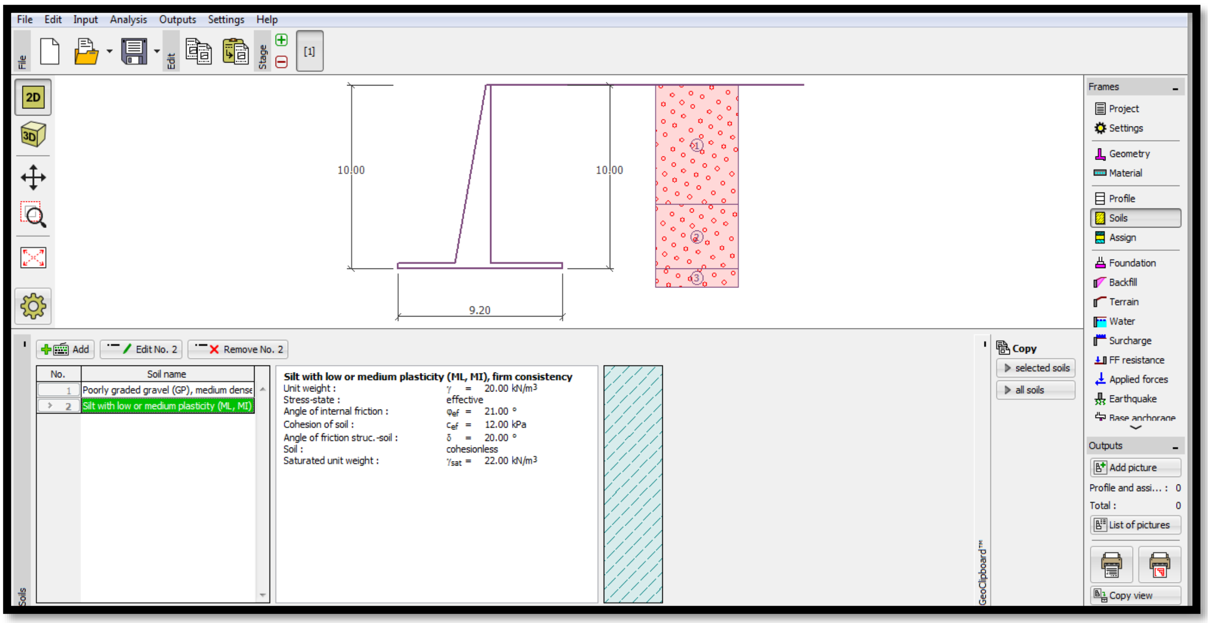


Fig5.5 Profile frame

➢ Next is “Soils”, fill the specifications of soil click on “add” to classify the type of soil and fill the properties γ, δ, c and ϕ

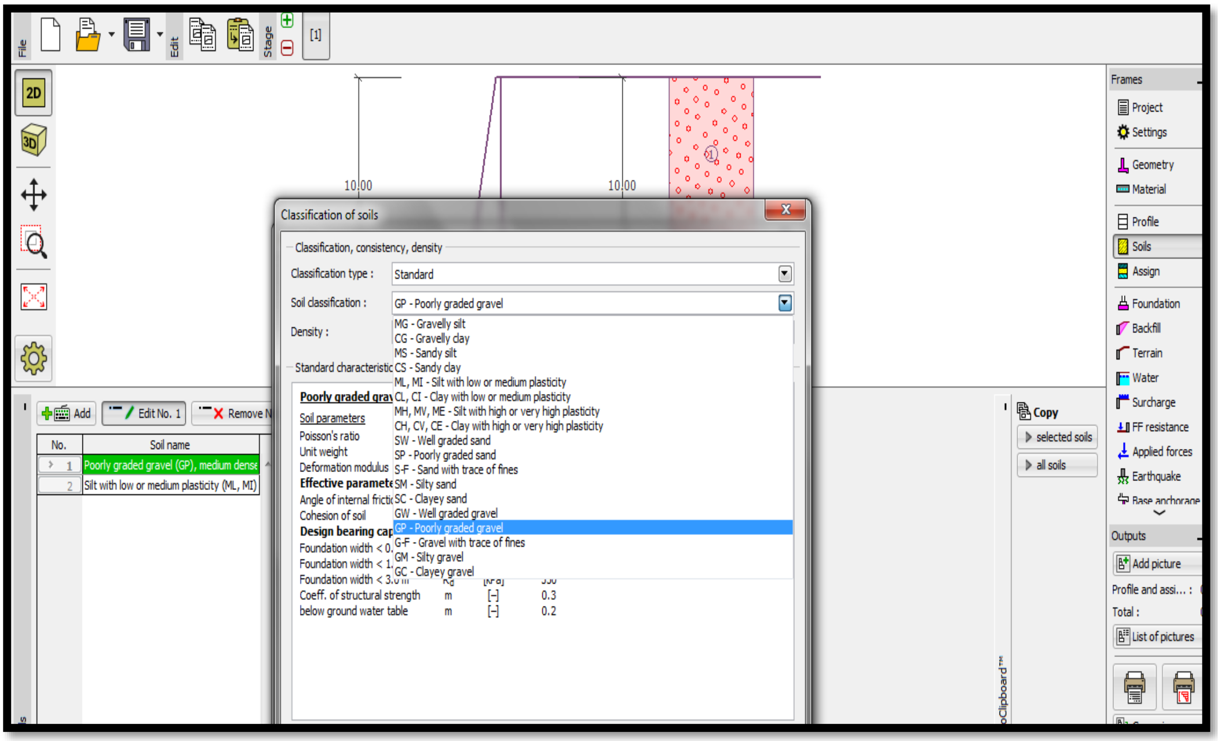


(a)



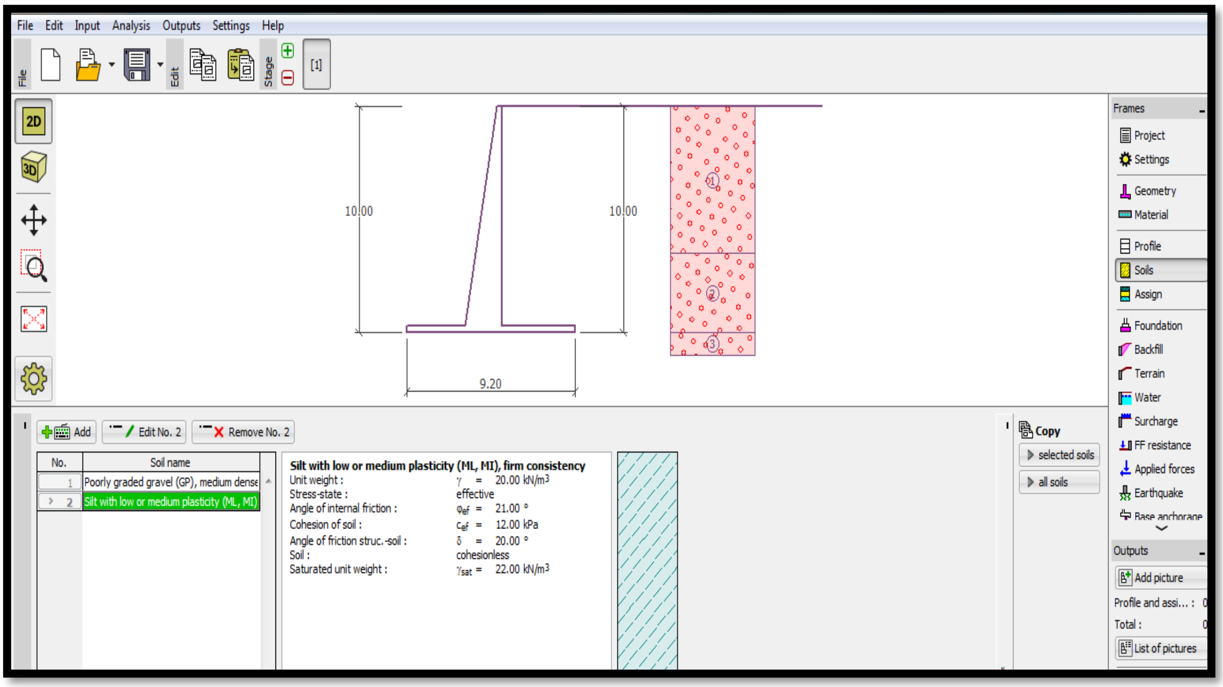
File Edit Input Analysis Outputs Settings Help
10.00
10.00
9.20
Add
Edit No. 2
Remove No. 2
No.
Soil name
Poorly graded gravel (GP), medium dense
Silt with low or medium plasticity (ML, MI)
Silt with low or medium plasticity (ML, MI), firm consistency
Unit weight : γ = 20.00 kN/m3
Stress-state : effective
Angle of internal friction : φef = 21.00 °
Cohesion of soil : cef = 12.00 kPa
Angle of friction struc.-soil : δ = 20.00 °
Soil : cohesionless
Saturated unit weight : γsat = 22.00 kN/m3
Copy
selected soils
all soils
Frames
Project
Settings
Geometry
Material
Profile
Soils
Assign
Foundation
Backfill
Terrain
Water
Surcharge
FF resistance
Applied forces
Earthquake
Outputs
Add picture
Total :
List of pictures
Copy view

(b)



Classification of soils
Classification, consistency, density
Classification type : Standard
Soil classification : GP - Poorly graded gravel
Density :
MG - Gravelly silt
CG - Gravelly clay
MS - Sandy silt
CS - Sandy clay
ML, MI - Silt with low or medium plasticity
CL, CI - Clay with low or medium plasticity
MH, MV, ME - Silt with high or very high plasticity
CH, CV, CE - Clay with high or very high plasticity
SW - Well graded sand
SP - Poorly graded sand
S-F - Sand with trace of fines
SM - Silty sand
SC - Clayey sand
GW - Well graded gravel
GP - Poorly graded gravel
G-F - Gravel with trace of fines
GM - Silty gravel
GC - Clayey gravel
Soil parameters
Poisson's ratio
Unit weight
Deformation modulus
Coeff. of structural strength
below ground water table
Add
Edit No. 1
No.
Soil name
Poorly graded gravel (GP), medium dense
Silt with low or medium plasticity (ML, MI)
Copy
selected soils
all soils
Frames
Project
Settings
Geometry
Material
Profile
Soils
Assign
Foundation
Backfill
Terrain
Water
Surcharge
FF resistance
Applied forces
Earthquake
Outputs
Add picture
Total :
List of pictures

(c)



(d)

Fig5.6 Soil frame of different soils (a)(b) (c) & (d)

➢ Input the parameters of soil by "Assign" command.

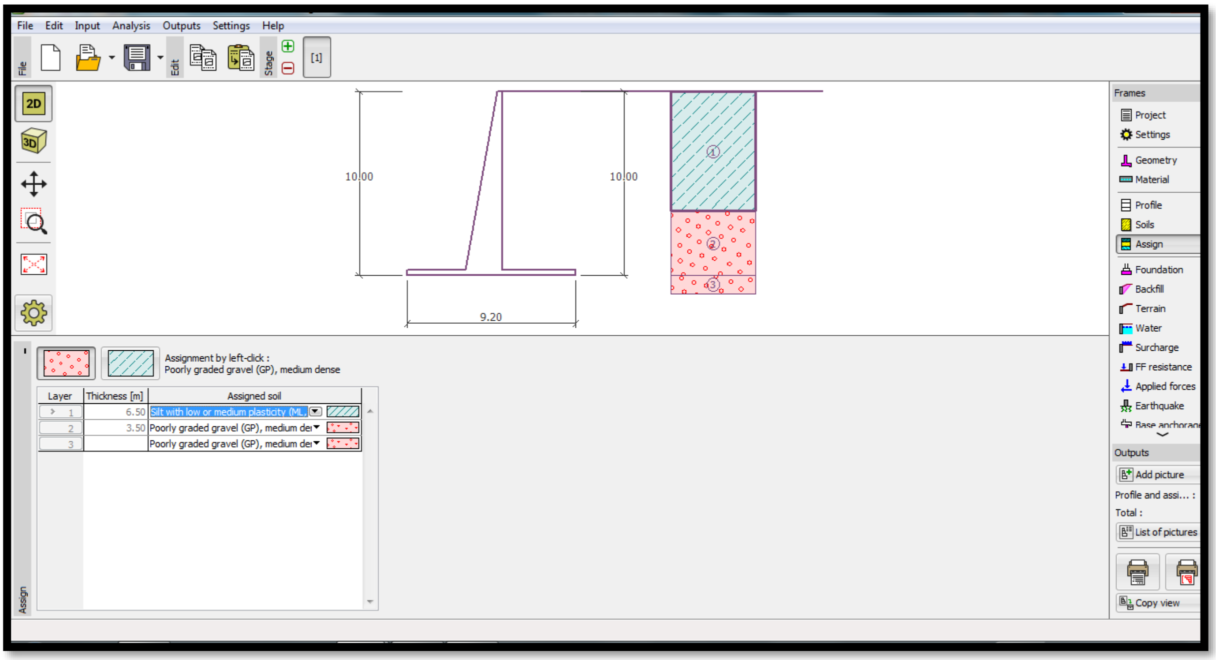


Fig5.7 Assign frame

➢ Click on "foundation " and prefer the appropriate type of foundation

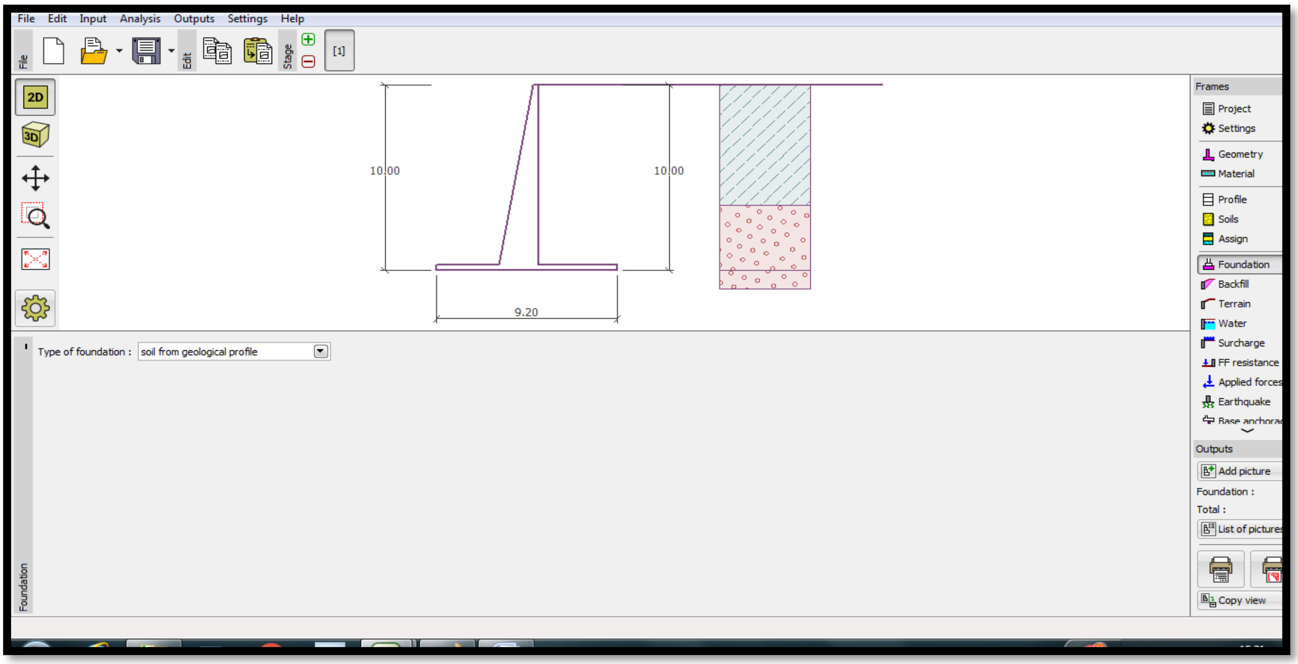


Fig5.8 Foundation frame

➢ Next step is "Backfill" select the suitable backfill shape and type of soil requied for backfill

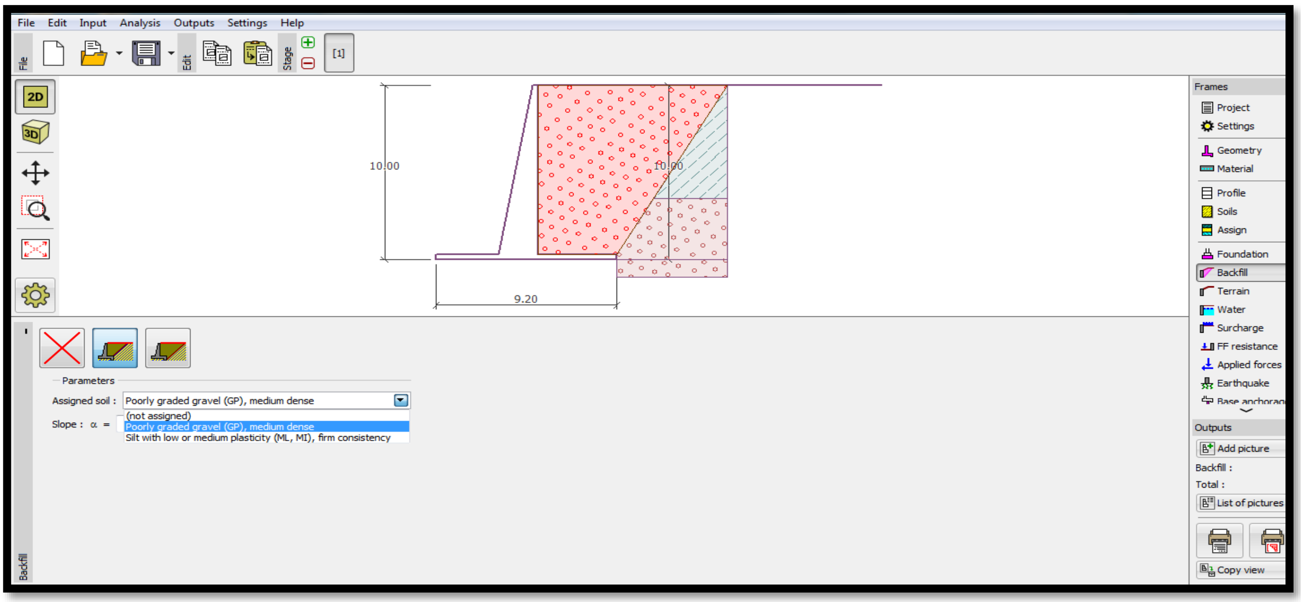


Fig5.9 Backfill frame

➢ Next is “Terrain” select shape of the terrain type.

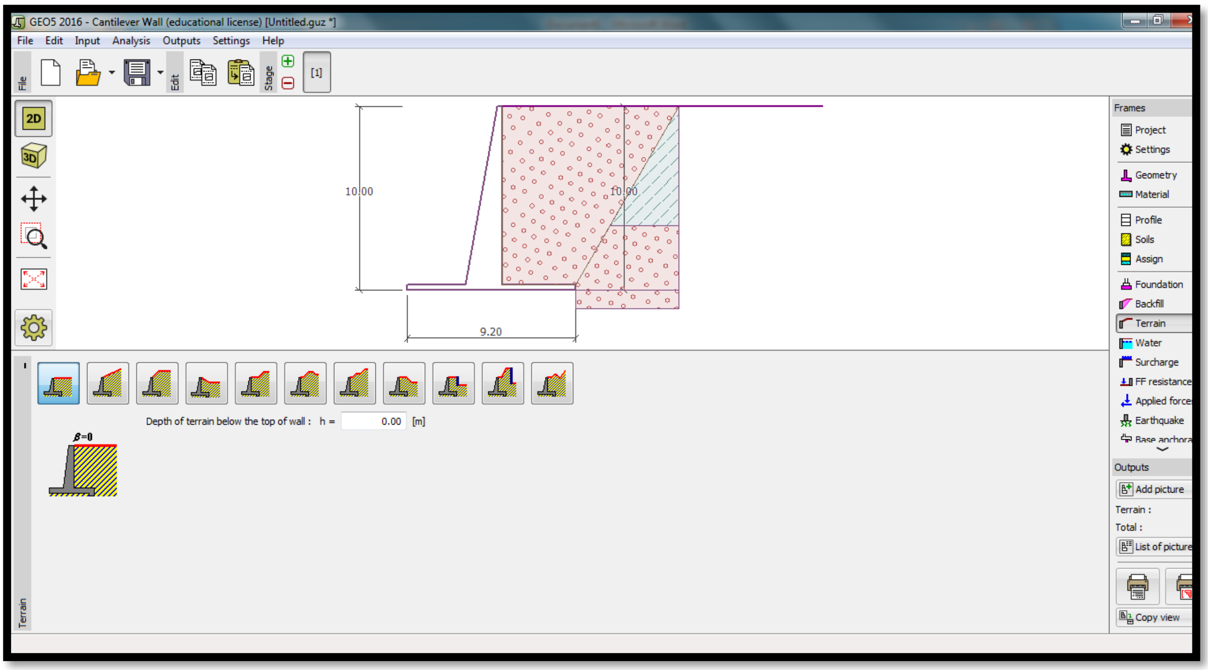


Fig 5.10 Terrain frame

➢ Next parameter is “Water”, select the position of water table.

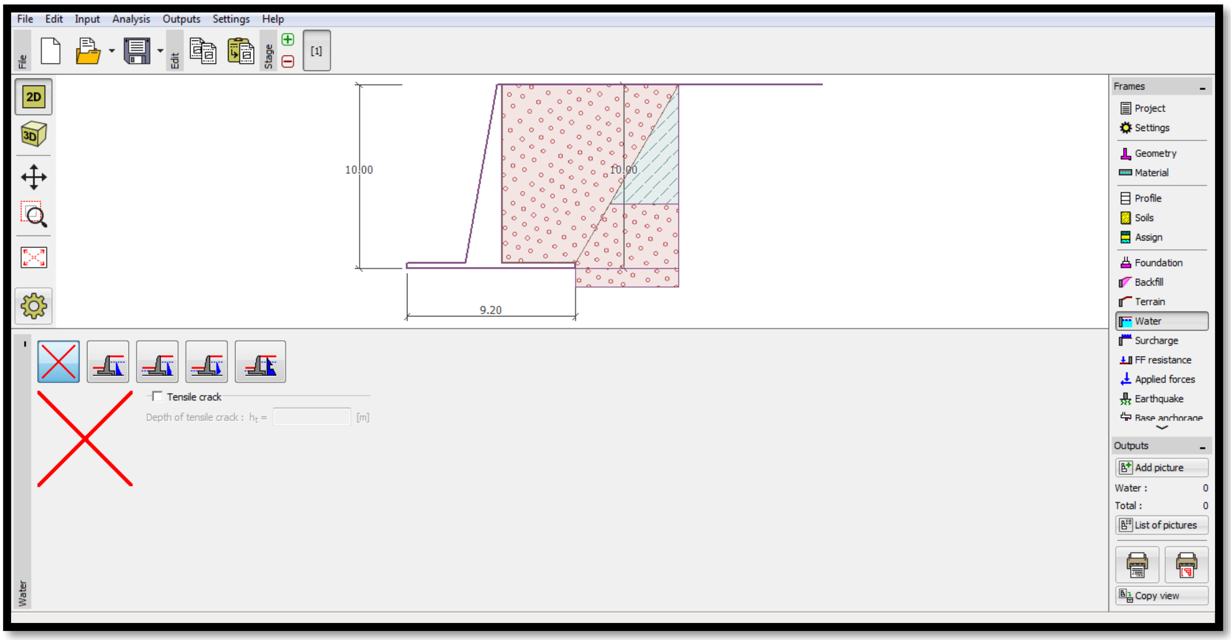
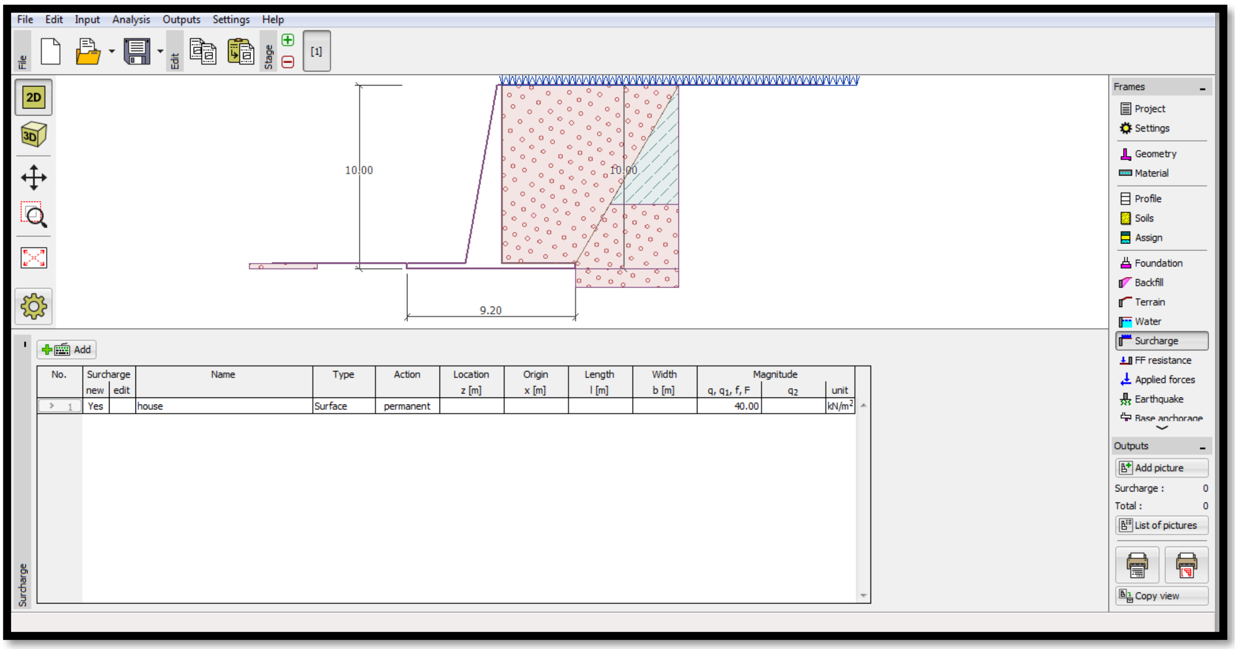
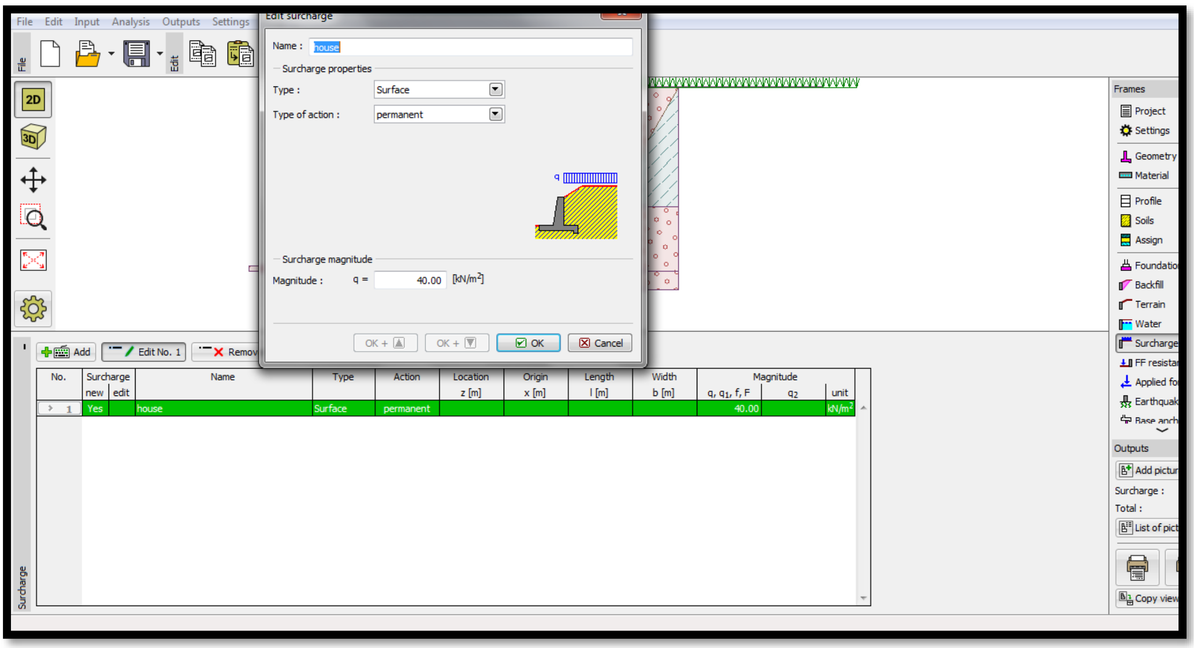


Fig5.11 Water frame

- ➢ Next is “Surcharge”, by clicking on add select the suitable surcharge condition according to the the present situation of the area



(a)



(b)

Fig5.12 Surcharge frame (a) and (b)

➢ Next is “Front Face Resistance”, select the type of suitable height and type of soil.

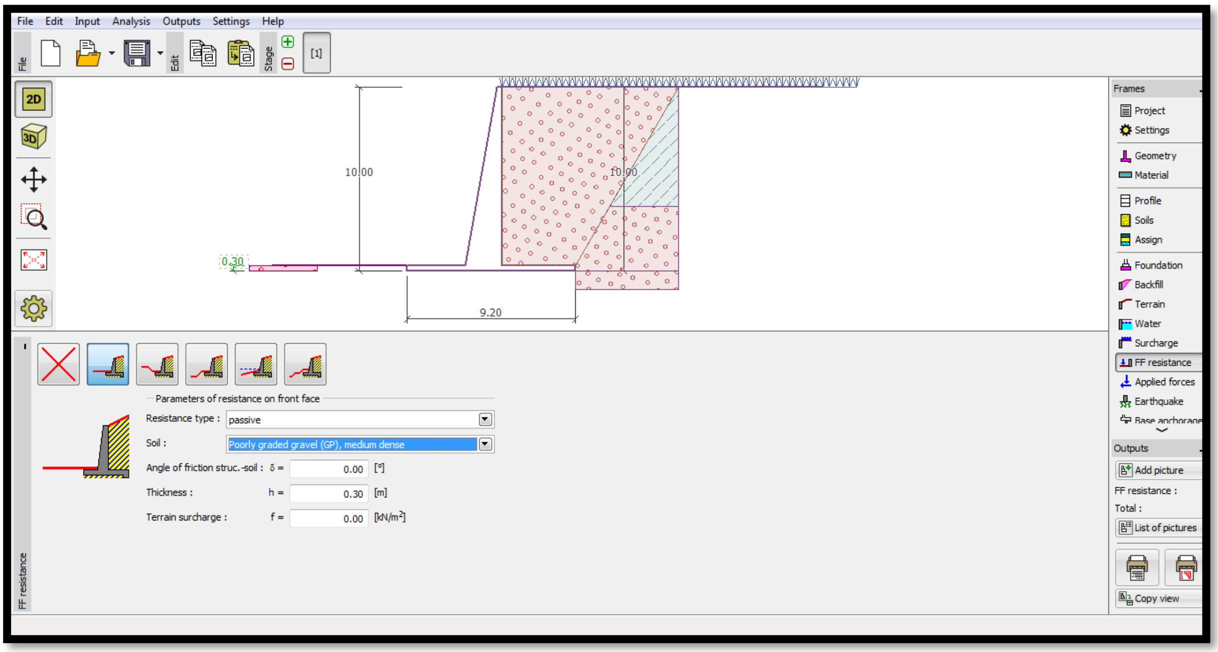


Fig5.13 Front face resistance frame

➢ Next is “Applied force”, by clicking on add fill the forces acting on the wall or soil

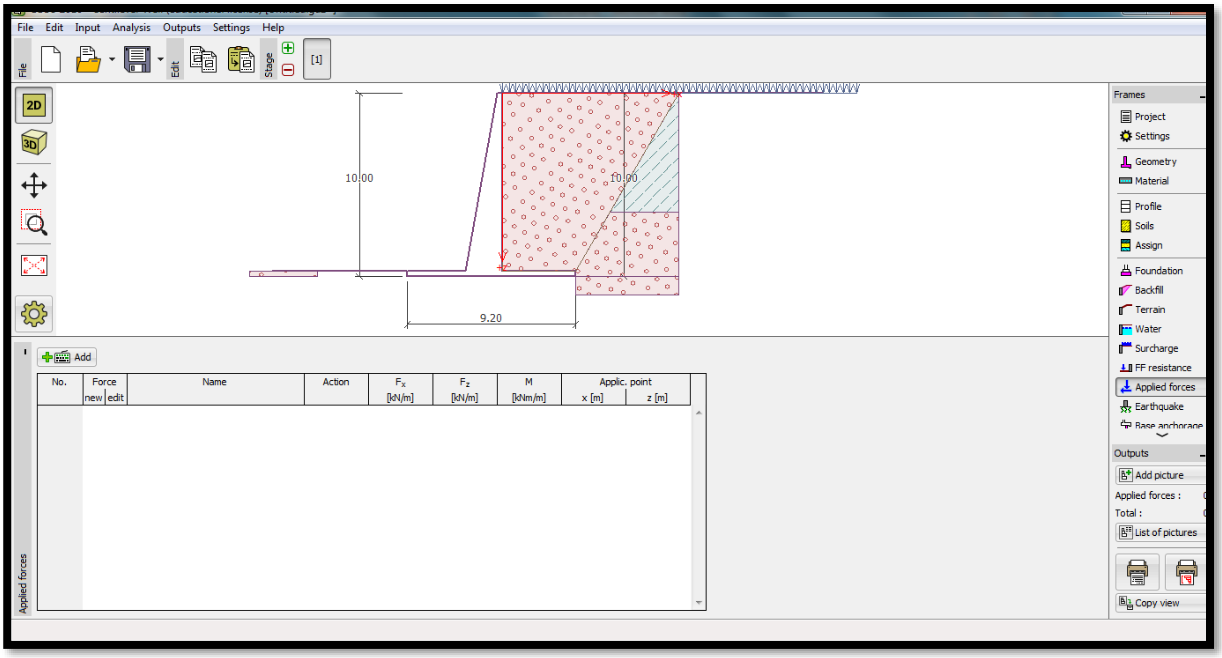


Fig 5.14 Applied forces frame

➢ Next frame is “Earthquake”, select the suitable condition and analyse the earthquake condition

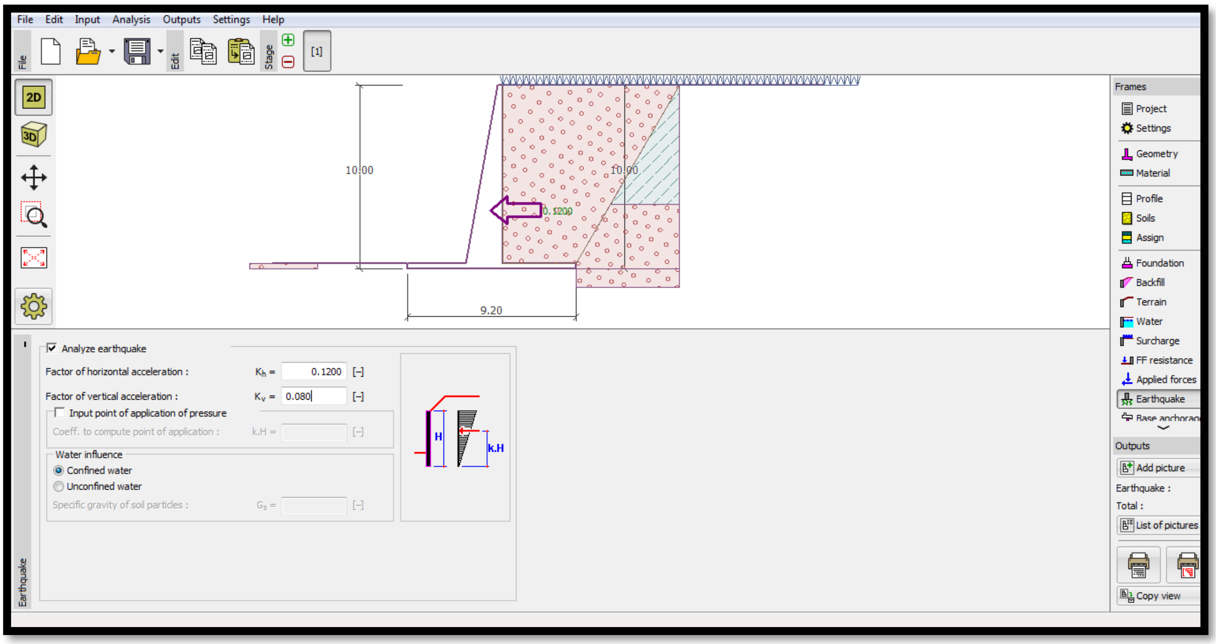


Fig5.15 Earthquake frame

➢ Next step is “Base anchorage” select the icon if any need

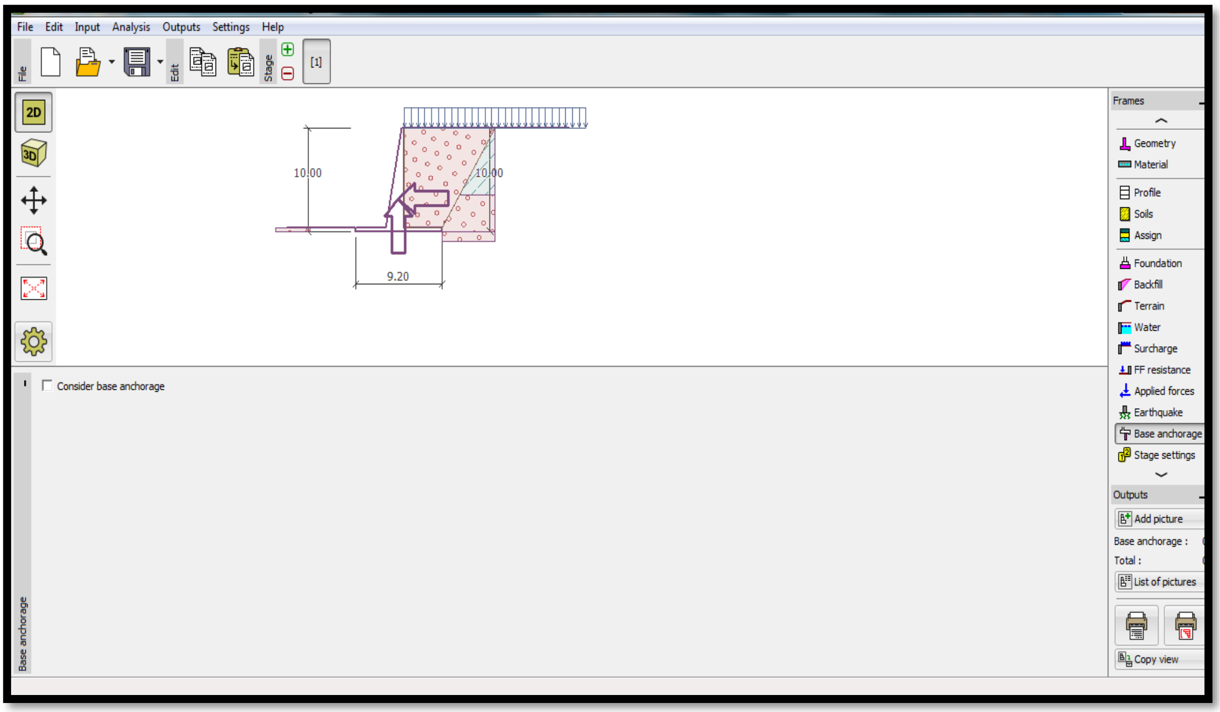


Fig 5.16 Base anchorage frame

➢ Next one is "Stage setting" select the stages according to the given condition

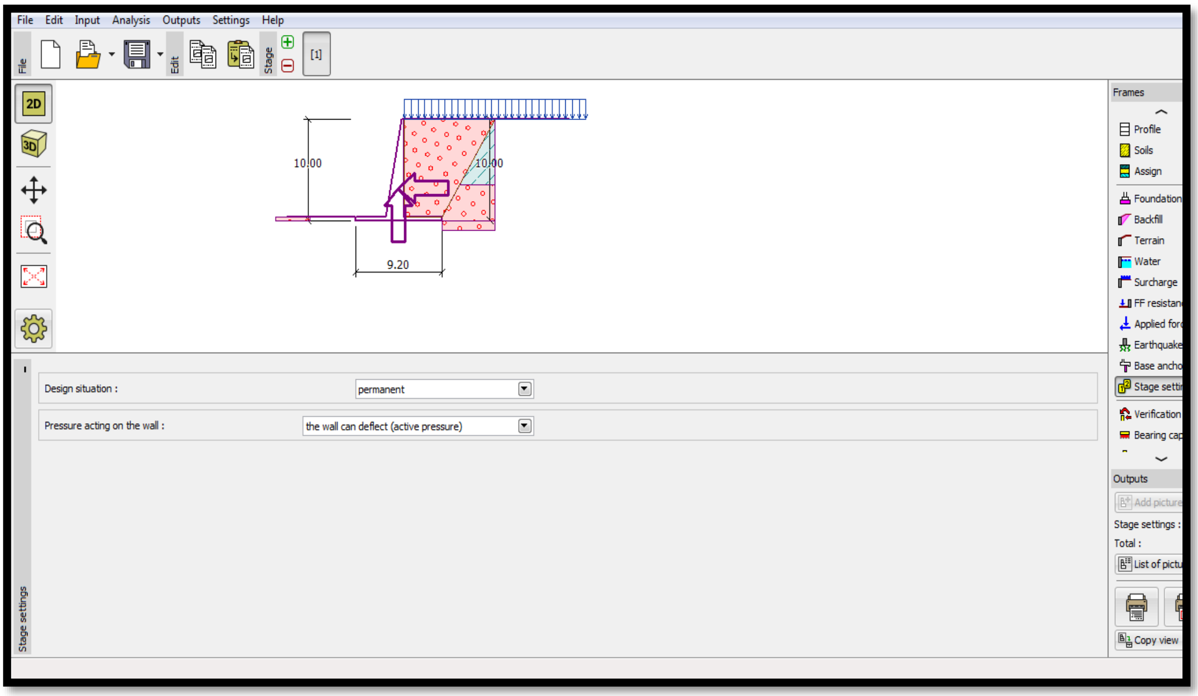
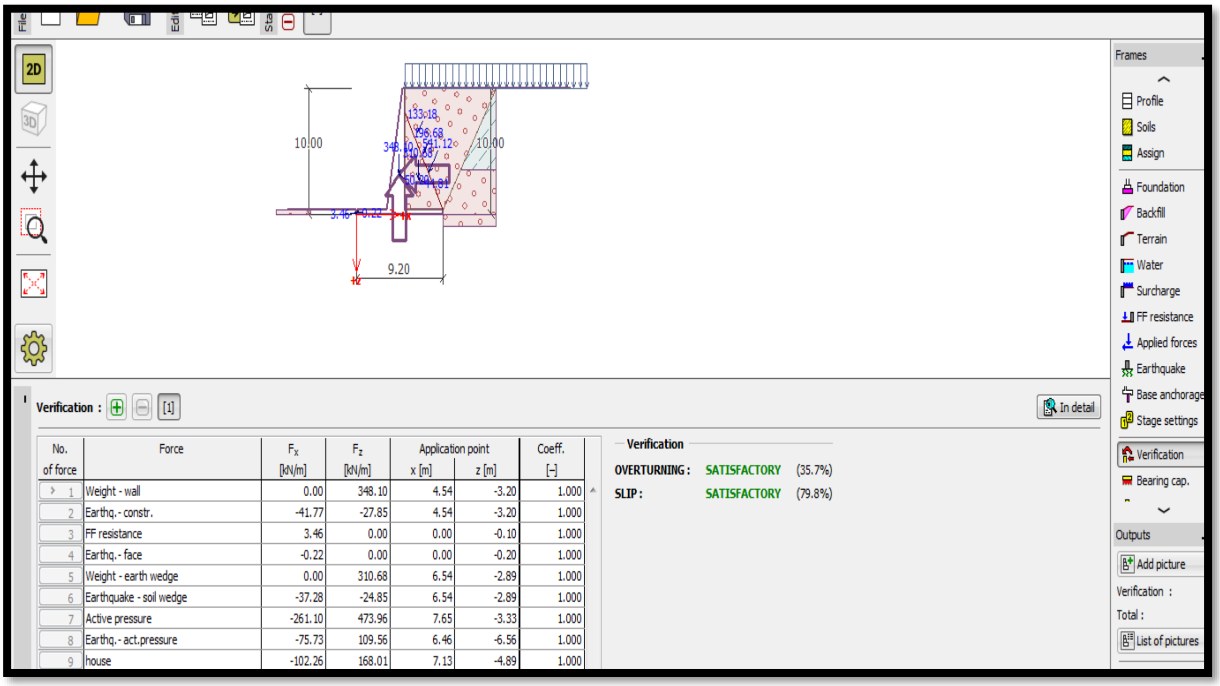


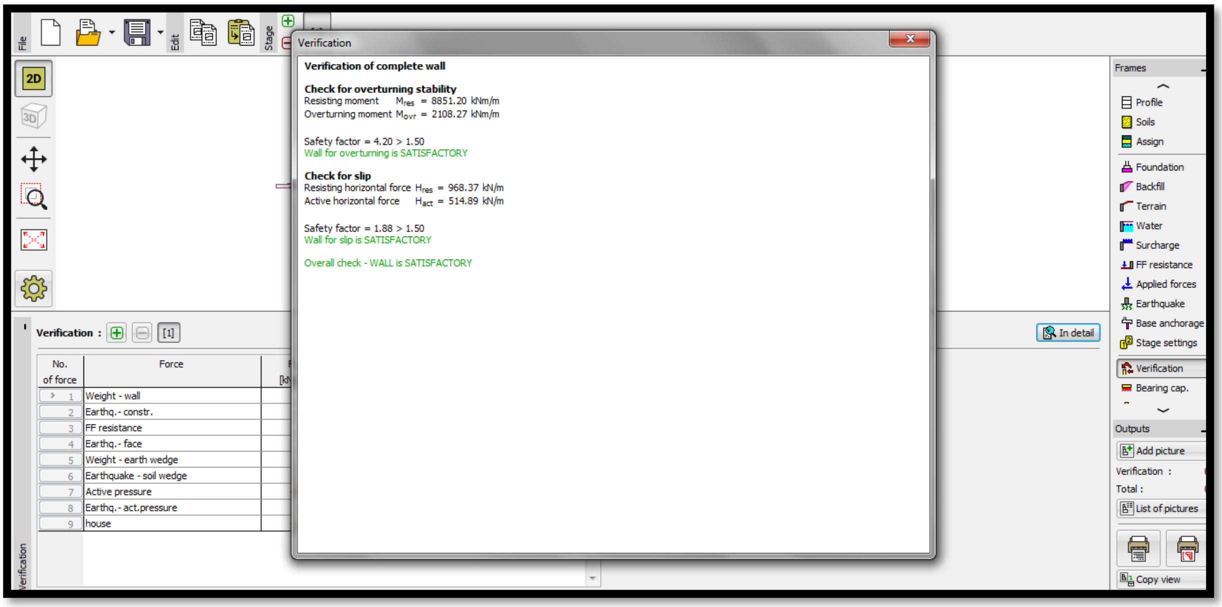
Fig 5.17 Stage setting frame

➢ Now click on the "Verification" and examine the "result" of slip and overturning of the "reinforced cantilever wall"



(a)

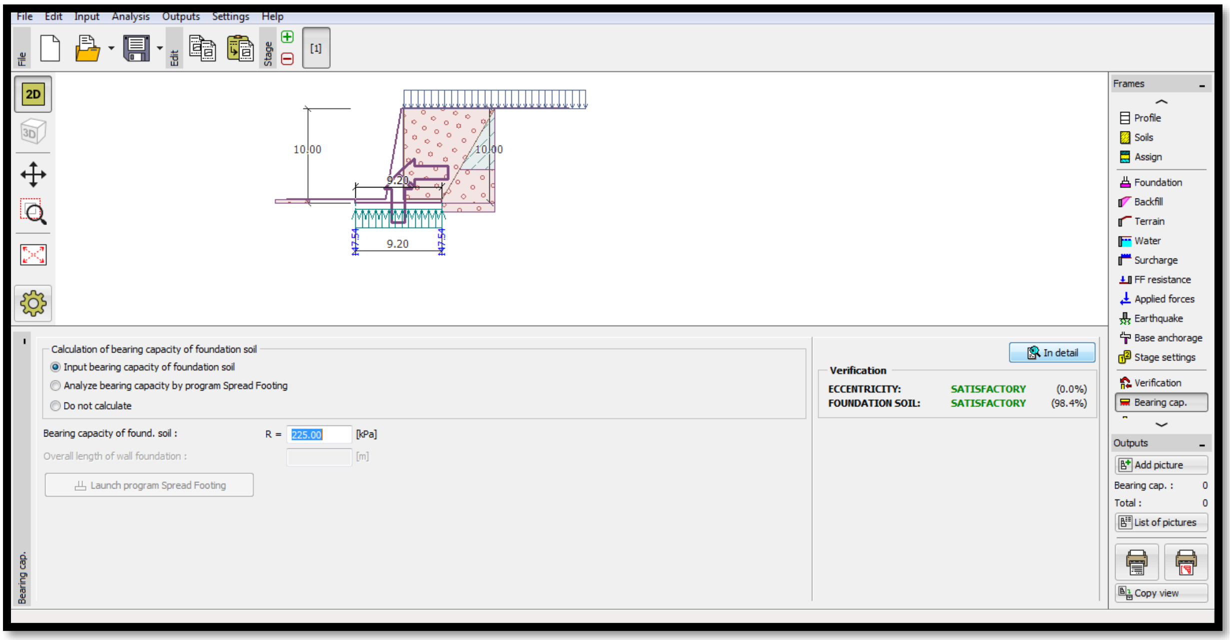
➢ Click on in detail to go for the detailed results



(b)

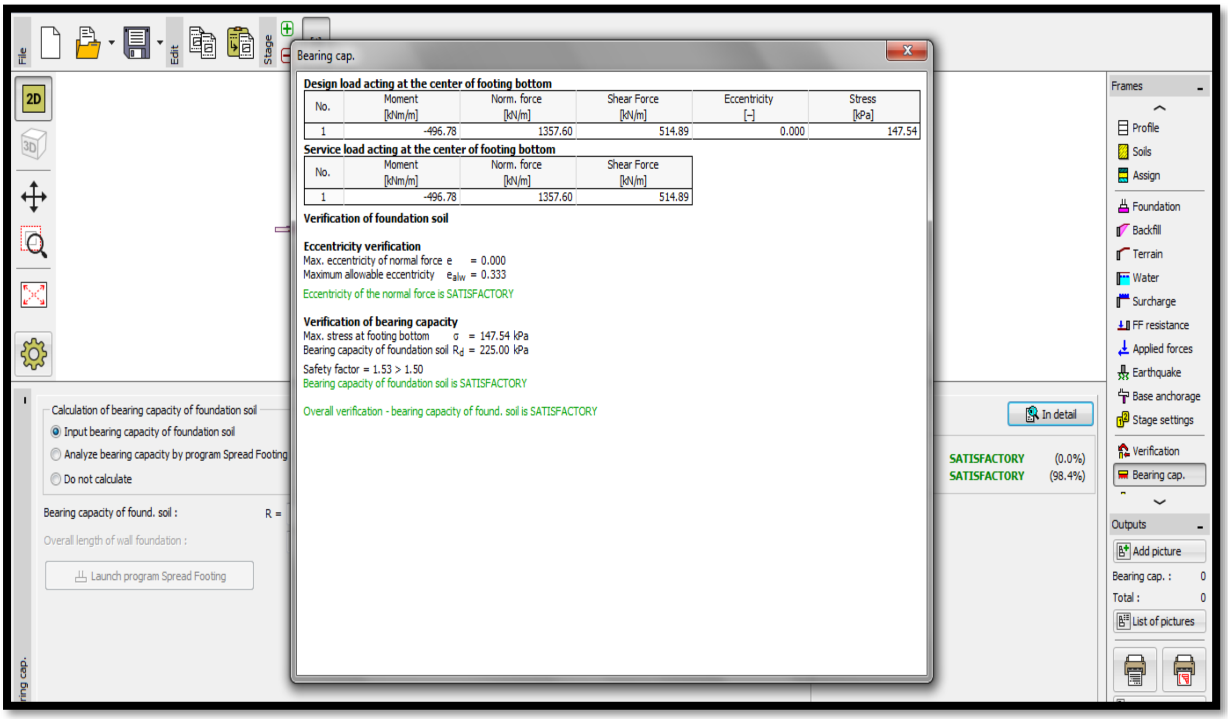
Fig 5.18 Verification frame (a) and (b)

➢ Now go for “Bearing capacity”, “perform an analysis for design bearing capacity of the “foundation soil” having bearing capacity of 225 kPa



(a)

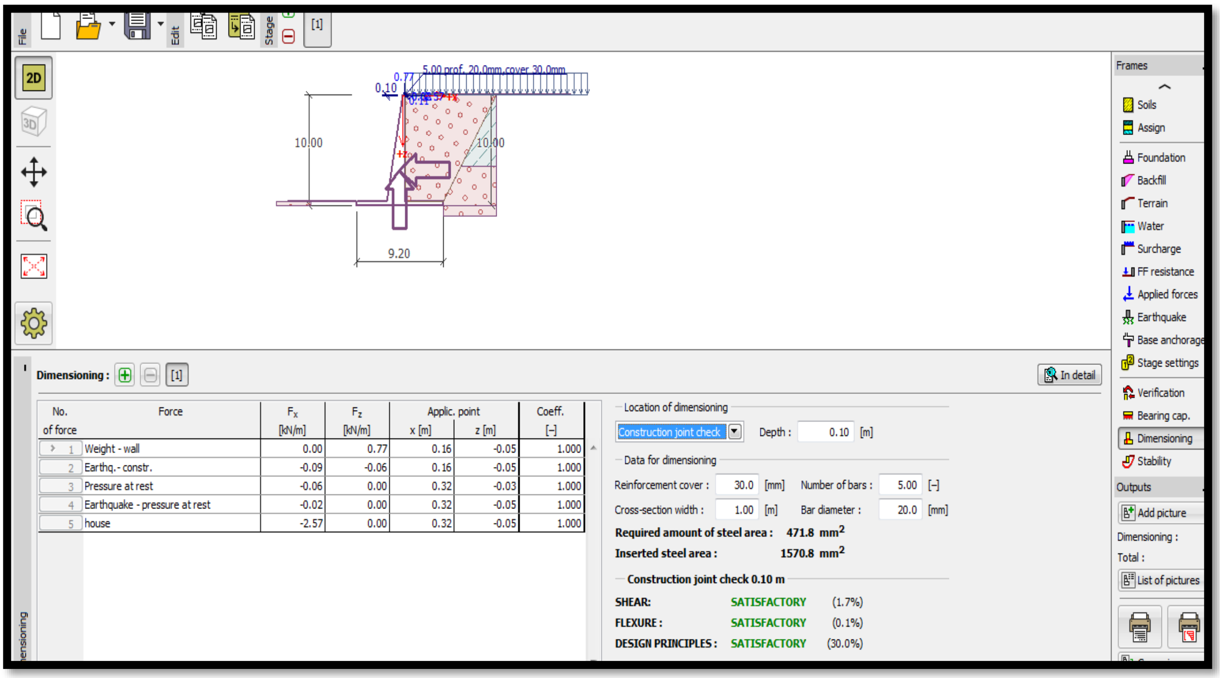
➢ Note: For detailed results click on in detail.



(b)

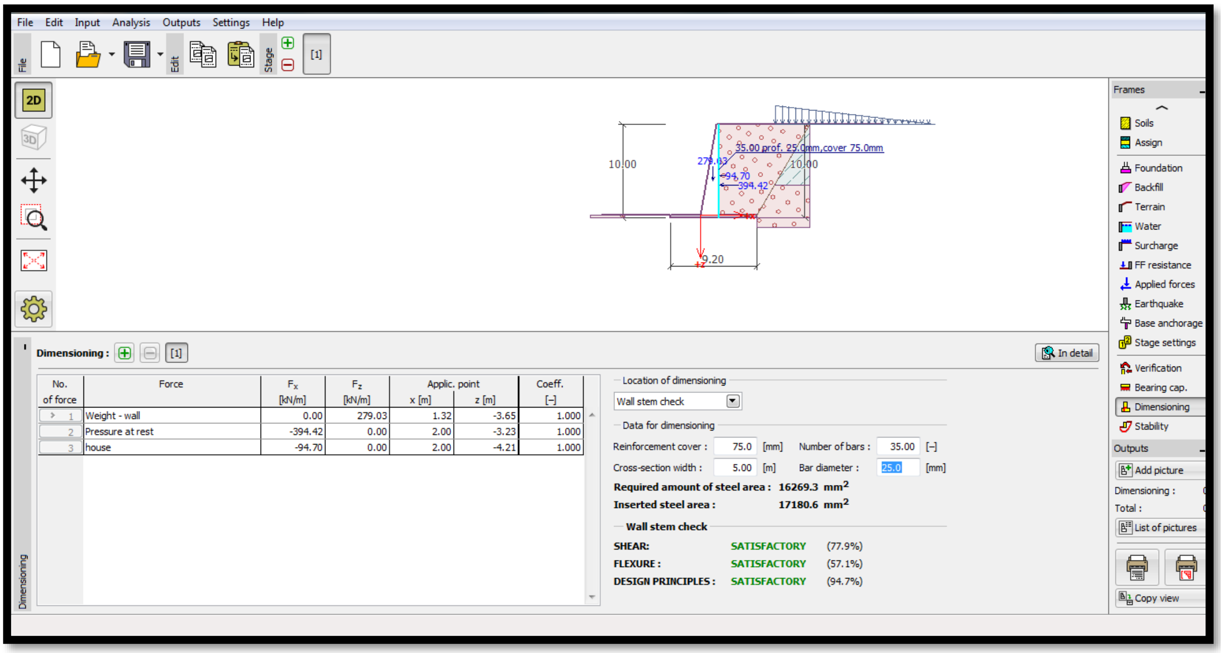
Fig 5.19 Bearing capacity frame (a) & (b)

➢ Next parameter is "Dimensioning", analyze dimensions and steel used of the wall



(a)

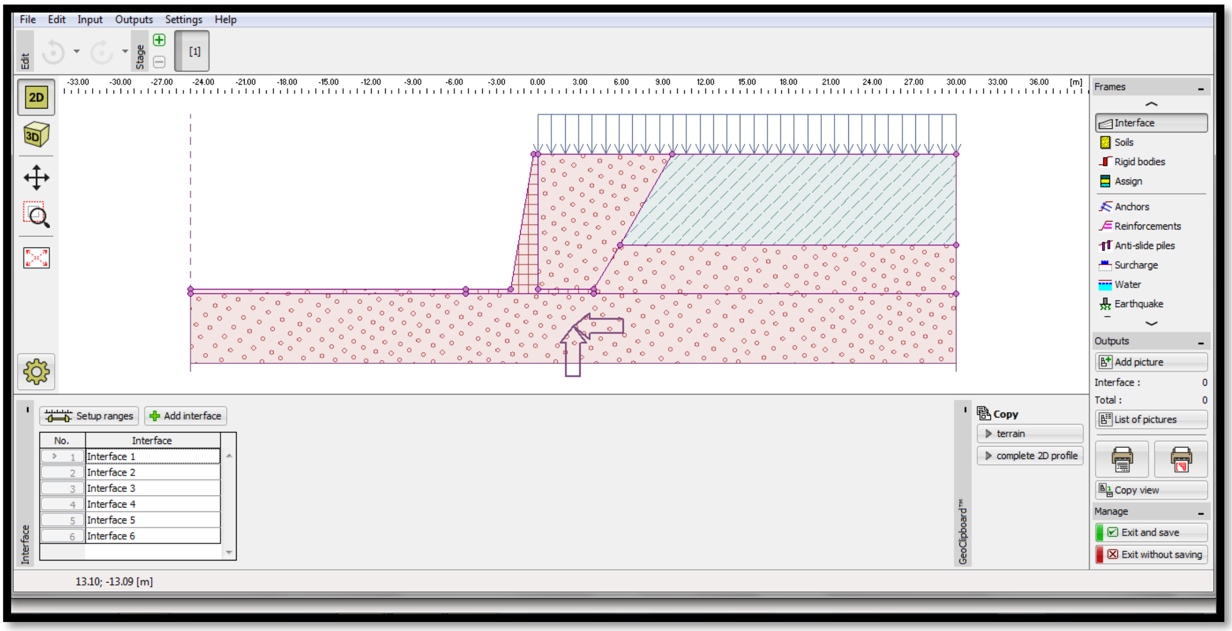
➢ Wall jump check



(b)

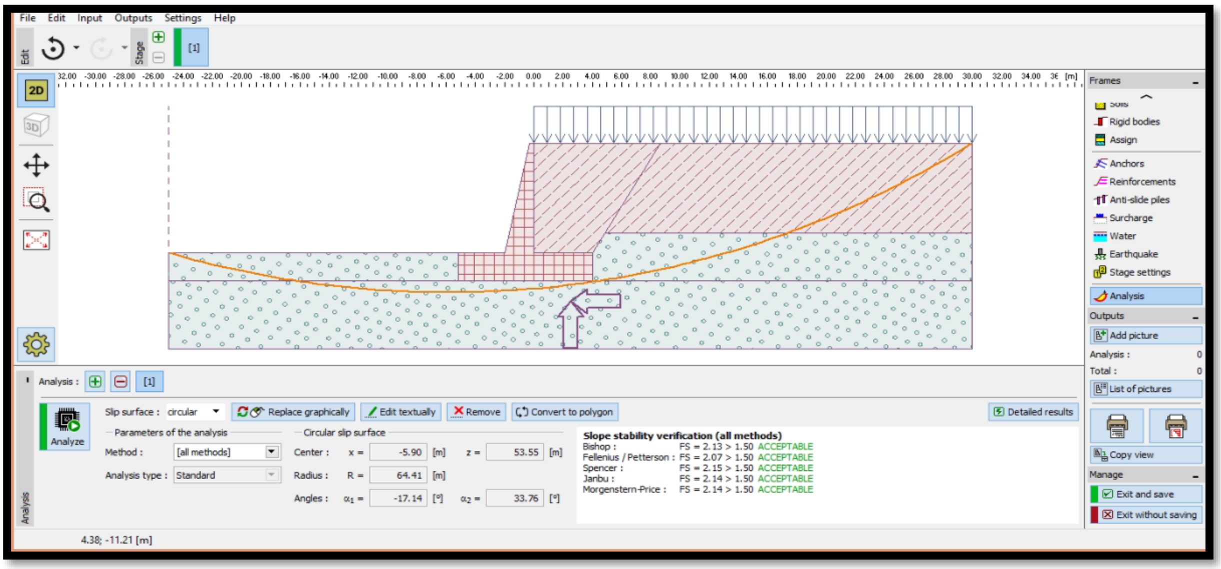
Fig 5.20 Dimesioning frame (a) & (b)

➢ Next is "Stability", and examine the stability of the wall by different methods



(a)

➢ Analyze it with all methods



(b)

Fig 5.21 Stability frame (a) & (b)

5.4 Results of analysis

Overturning	:43.8 % ; SATISFACTORY
Slip	:97.4 % ; SATISFACTORY
Eccentricity	:0.00 % ; SATISFACTORY
Foundation soil	:94.80 % ; SATISFACTORY
Factor of Safety	:3.42 > 1.5 ; SATISFACTORY
Overall stability	: The cantilever wall is overall acceptable.

CHAPTER 6

DISCUSSION AND RESULTS

6.1 RESULTS BY SOFTWARE

" For retaining walls of different height the overturning factor is as shown in the table between Retaining wall , stone wall and stoncrete wall"

Table 6.1 Results for the overturning with factor 1.5

SR NO	HEIGHT OF RETAINING WALL (M)	REINFORCED CANTILEVER RETAINING WALL	STONE MASONARY RETAINING WALL	STONECRETE RETAINING WALL
1	2	6.23	6.19	6.17
2	4	3.77	4.01	3.98
3	6	2.95	2.96	2.92
4	8	3.60	3.58	3.59
5	10	3.42	3.83	3.75

"In this table the various values of overturning is shown for different kinds of wall having different wall height". "In this the wall of different kinds having different heights is modeled on Geo5 software to check the overturning factor and from this we come to know about which material and height wall is more safe in overturning".

Table 6.2 Values for shear of wall

SR NO	HEIGHT OF RETAINING WALL (M)	REINFORCED CANTILEVER RETAINING WALL(%)	STONE MASONARY RETAINING WALL (%)	STONECRETE RETAINING WALL (%)
1	2	3.60	7.0	7.2
2	4	18.3	2.6	2.4
3	6	44.3	14.5	12.9
4	8	27.0	7.2	6.7
5	10	47.3	12.2	11.5

"In this table the different values of different heights and material wall is calculated by software and shown in tabular form for easy understanding". "By this we are able to understand which wall is more safe in shear If the shear is more than the shape of the wall can deflect in direction parallel to their planes". "If shear is more in the wall then we can provide a shear key which holds the wall in position and resist to have the change in the shape of the wall"

Table 6.3 Values of flexure and flexure + pressure

SR NO	HEIGHT OF RETAINING WALL (M)	REINFORCED CANTILEVER RETAINING WALL (%)	STONE MASONARY RETAINING WALL (%)	STONECRETE RETAINING WALL (%)
1	2	1.0	27.1	25.2
2	4	10.9	10.2	10.1
3	6	34.1	16.4	15.7
4	8	10.9	0.5	0.2
5	10	20.6	0.9	0.7

"In this table the different values of flexure and flexure + pressure is find out on software to make the wall more safe". "If the bending moments required for the equilibrium exceeds the flexural strength of the wall , flexural failure may occur". "The structural ductility of the wall itself may influence the level of deformation produced by flexural failure". "If the flexure is more than the wall is not safe"

Table 6.4 Values for slip

SR NO	HEIGHT OF RETAINING WALL (M)	REINFORCED CANTILEVER RETAINING WALL	STONE MASONARY RETAINING WALL	STONECRETE RETAINING WALL
1	2	2.59	2.66	2.52
2	4	2.06	2.34	2.08
3	6	1.51	1.66	1.45
4	8	1.93	1.99	1.65
5	10	1.54	1.98	1.72

“In the above table the value of slip is given by software analysis for different heights and materials. The wall will slide if the lateral thrust exceeds the frictional resistance developed between the base of the wall and soil. All the lateral forces try to slide the wall. The resistance against sliding is mainly provided by the friction between the base slab and the soil below it”.

Table 6.5 Results for slope stability of RCC wall

SR NO	HEIGHT OF RCC WALL	BISHOPS	FELLENIUS/ PETTERSON	SPENCER	JANBU	MOGENSTERN-PRINCE
1	2	2.95	2.91	2.95	2.95	2.95
2	4	2.11	2.05	2.12	2.12	2.12
3	6	2.07	2.03	2.08	2.08	2.08
4	8	2.10	2.06	2.12	2.11	2.11
5	10	1.68	1.68	1.63	1.62	1.62

Table 6.6 Results for slope stability of stone wall

SR NO	HEIGHT OF STONE WALL (M)	BISHOPS	FELLENIUS/ PETTERSON	SPENCER	JANBU	MOGENSTERN-PRINCE
1	2	2.77	2.44	2.77	2.77	2.77
2	4	2.14	2.08	2.15	2.15	2.15
3	6	2.08	2.03	2.08	2.08	2.08
4	8	2.12	2.07	2.13	2.12	2.12
5	10	2.01	1.96	2.02	2.01	2.01

"In the above table of 6.5& 6.6 slope stability the walls are analyzed by five different methods to check the overall stability of the walls by software". "Slope stability analysis is performed to assess the safe design of a man-made or natural slopes and the equilibrium conditions". "Slope is the resistance of inclined surface to failure by sliding or collapsing". "In this the stone walls and the rcc wall are designed and analysed on the geo5 software to give the better results about the slope stability anaylsis of the wall".

6.2 BAR CHARTS AND DISCUSSIONS

"In this we will discuss about the amount of steel portion used in the reinforced cantilever wall". "In this we compare the amount of steel used at different heights of the retaining wall". "When a reinforced retaining wall is made it is very important to find out the exact amount of steel required foe stem , toe and heel of the wall".

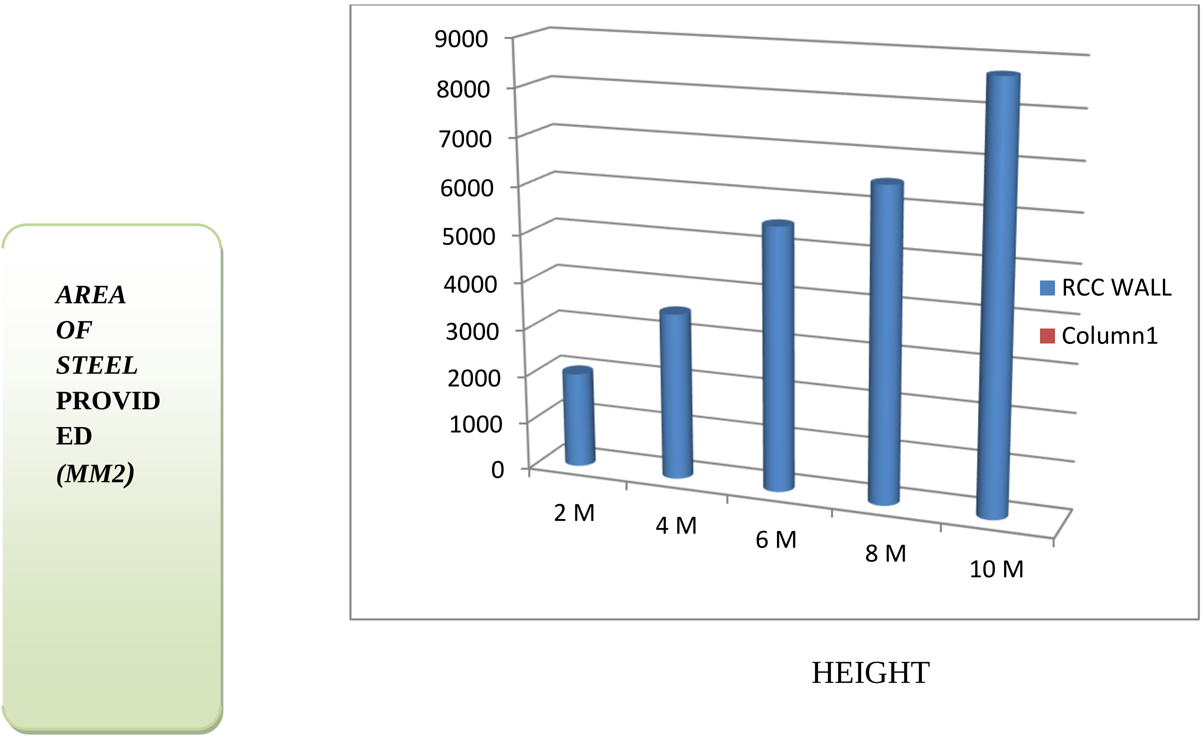


Fig 6.1 Reinforcement details of walls

Bar chart for slope stability of different wall

In this bar chart we are going to discuss about the slope stability of different material and different heights. In thus we take a reinforced retaining wall , stne masonary wall and stonecrete wall. These are tested on different heights on geo5 software to get the detailied or accurate results of slope stability.

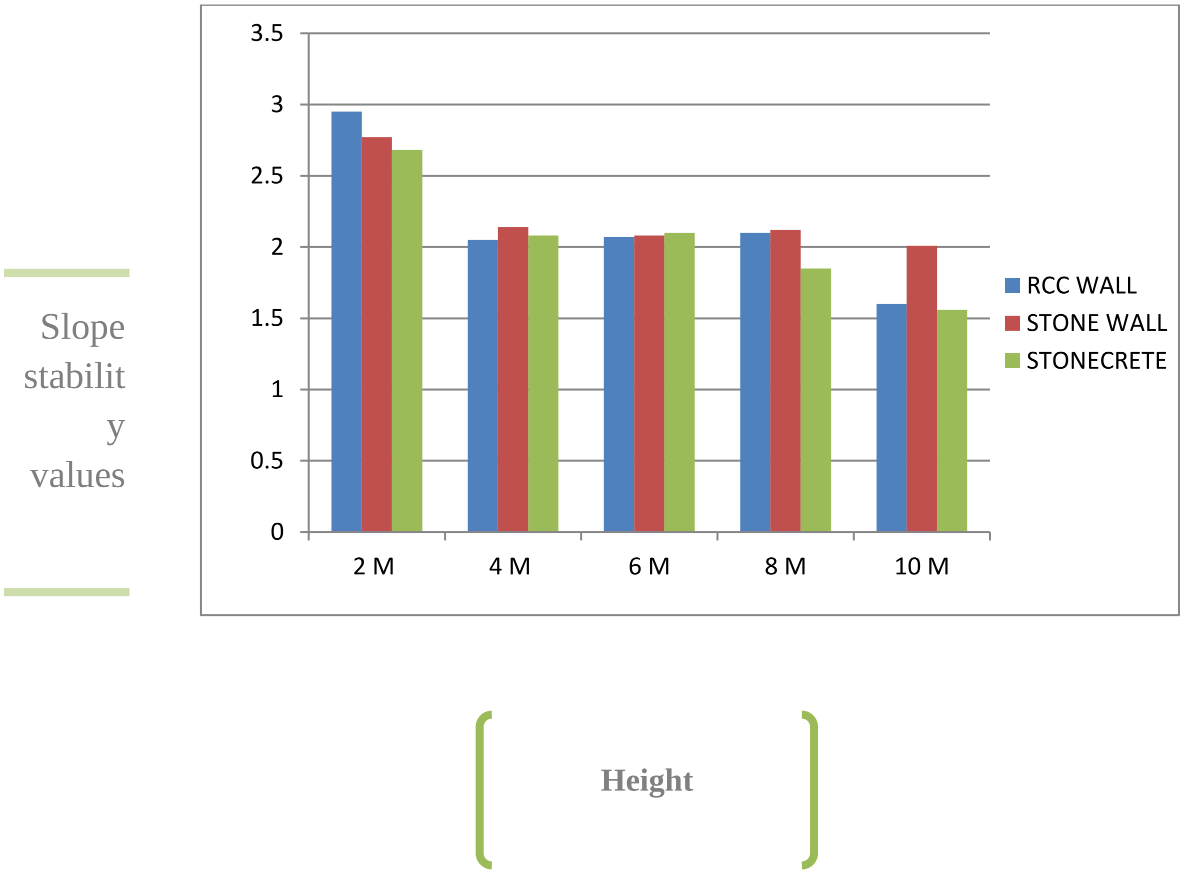


Fig 6.2 Slope stability of different walls

CHAPTER 7

CONCLUSION

7.1 Conclusion

“In this project work I decided to work on the stability, design and behavior of retaining walls of different height having different construction material for same parameters and for same loading conditions. By designing the wall using software and by manual calculations I concluded that”

- “The overturning factor of reinforced retaining wall ,stone masonry wall and stoncrete wall is nearly equal to each other. All the walls are safe in overturning”.
- “The shear factor of reinforced retaining wall, stone masonry wall and stoncrete wall , retaining wall has the maximum shear among them and stone masonry have the least values for shear”.
- “When we consider the factor cost then reinforced retaining wall is more costly than the other two walls. For example if we are constructing a 10 m wall than it will cost around 2.5 lacs for reinforced retaining wall and 1.05 lacs for stone masonry wall”.
- “The slope stability of retaining wall and stone wall is nearly equal to each other and both wall are overall stable”.
- “For 8 -25 m height of retaining wall generally reinforced wall is preferred or best , below 8 m height stone wall is more economical and preferred”.

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