Evaluation and comparison of classical earth pressure theories for cohesion-less (φ) backfill using professional softwares

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Abstract: Earth pressure related problems are one of the important topics of research in the area of geotechnical engineering to solve problems like retaining walls, ground anchors etc. Very often in the construction of building or bridges it is necessary to retain earth in a relatively vertical position whenever embankments are involved in the construction. The retaining material on the higher level exerts a force on retaining wall may causes its overturning, sliding, bearing etc. A retaining wall is massive structure so it is necessary to design and check stability of retaining wall analytically as well by software as per IS:456-2000. The calculation of wall dimension of particular earth retaining problem require several runs of analysis and thus computer application is desirable. The present research deals with evaluation of cantilever retaining wall by comparison of Excel worksheet & softwares Geo-5, RetainPro & RETWALL for single layered homogeneous φ soil backfill with and without ground water table. The MS-Excel Spreadsheet is to be prepared to carry out stability analysis. The analysis of Retaining wall can be done by using various static earth pressure theories such as Rankine, Coulomb's. Factory of safety against sliding, overturning and base pressure are satisfied without considering shear key & with provision of shear key.

Index Terms— **Cantilever retaining wall, Professional softwares, Single layered homogeneous φ soil backfill**

I. Introduction

Retaining walls are structures that are used to retain earth (or any other material) in a position where the ground level changes abruptly. They can be of many types such as gravity wall, cantilever wall, counterfort wall and buttress wall among others. The lateral force due to earth pressure is the main force that acts on the retaining wall which has the tendency to bend, slide and overturn it. The present research focuses on stability analysis of the cantilever type of wall for overturning, sliding and bearing. The main considerations are the external stability of the section with the help of codal provision i.e. IS: 456:2000 Satisfying the external stability criteria is primarily based on the section giving the required factor of safety. The ratio of resisting forces to the disturbing forces is the factor of safety, and this factor of safety should always be greater and equal to 1.55 for the structure to be safe against failure with respect to that particular criteria. Different modes of failure have different factors of safety. In this study stability check for a cantilever wall is obtained using a computer program that calculates various sections satisfying the stability criteria, according to the height and properties of earth that the wall is required to support.

Retaining walls are structures designed to restrain soil to unnatural slopes. They are used to bound soils between two different elevations often in areas of terrain possessing undesirable slopes or in areas where the landscape needs to be shaped severely and engineered for more specific purposes like hillside farming or roadway overpasses. It is a structure designed and constructed to resist the lateral pressure of soil when there is a desired change in ground elevation that exceeds the angle of repose of the soil.

In general, two classical methods of analysis have been proposed for evaluation of retaining wall.

1. Rankine earth pressure theory:
   Rankine earth pressure is a state of stress evaluation of soil behind a retaining structure that traditionally assumes a vertical wall and no fiction between the soil/wall interfaces. The orientation of the resultant earth pressure is parallel to the back slope surface.
2. Coulomb's earth pressure theory:
   In Coulomb theory Coulomb failure plane varies as a function of wall geometry and wall friction between soil/wall interfaces is taken into account.

Due to the rapid development of increasingly powerful computers, the solution of rather complex multi-phase problems encountered in widely different fields of engineering tasks is feasible nowadays. Nowadays, the numbers of software in the market is growing. Software is developed to help users in making their task easier. We can find different software for different business processes. In Geotechnical Engineering, there are few softwares which can be bought in the market. For example Geo-5, RetainPro, RETWALL, iCadRetaining wall Software and many more but in this study we are going to carryout evaluation of cantilever retaining wall by comparison by softwares Geo-5, RetainPro & RETWALL.

II. Objective of the Study

The aim of this study is to carry out evaluation and design of cantilever retaining wall by using EXCEL worksheet and professional softwares like Geo-5, Retrain pro and RETWALL .We are going to implement model to carry out stability analysis of retaining wall by considering static earth pressure.The factor of safety calculated with professional softwares alike Geo-5, RetainPro and RETWALL is validated or compared with traditional methods. A comparative parametric study is carried out between softwares/worksheet & traditional methods.

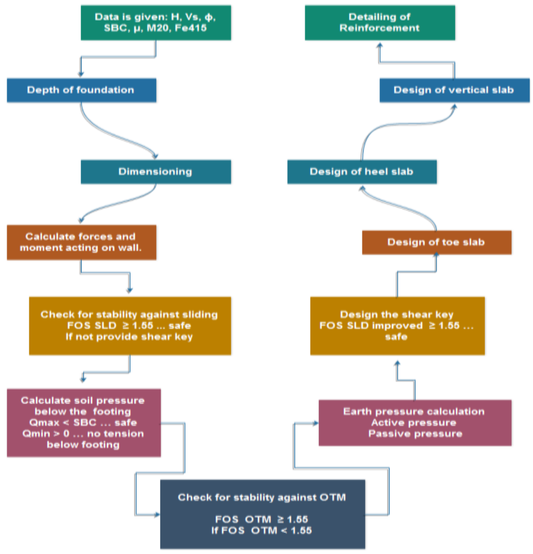
III. Scope of Work

Professional softwares like Geo-5, RetainPro and RETWALL & Excel Sheet evaluate the cantilever retaining wall of

- Homogeneous soil profile, with water table and without water table.
- With surcharge and without surcharge.
- With sloping and, without sloping backfill.

Also we will carry out evaluation and design of cantilever retaining wall using softwares Geo-5, RetainPro, RETWALL and Excel worksheet and will obtain results in terms of FOS against overturning (FOS OTM), FOS against sliding(FOS SLD), max and min base pressures. It gives detailed description of results based on Rankine, Coulomb's, Mazindrani, Muller-Breslau, Caquot-Kérisel, Absi earth pressure theories and also help in identifying limitations of softwares. Hence we can validate the results of worksheet and softwares Geo5, RetainPro and RETWALL.

IV. Flow Chart



V. Introduction to Cases

General

Professional softwares like Geo-5, RetainPro and RETWALL & Excel Sheet evaluate the cantilever retaining wall of different parameters that considered are as follows :

q = Uniform surcharge in kN/m^2
β = Backfill inclination with horizontal
Dw = GWT depth in meter
C, ϕ, C-ϕ single or double layered backfill

Table 1 Various Cases Considered

Modal no.	Description			
	q=Surcharge (kN/m^2)	β (degree)	GWT Dw (m)	Backfill
Validation modal HJ Shah	17	0	0	ϕ Single layer backfill
Modal 1	5	10	4.0	ϕ Single layer backfill
Modal 2	10	15	0.0	ϕ Single layer backfill

Validity of Softwares

It is necessary to validate the computer software by checking the output result of the computer software. Hence, it is important to validate the Geo-5, RetainPro, RETWALL software before we can really apply to solving problem. To validate the Geo-5, RETAIN – PRO, RETWALL, an example from known sources with an answer is used to analyze with the Geo-5, RetainPro, RETWALL. The importance of the process to validate the software is :

- To confirm and to know that the process of inputting data is correct.
- To ensure and be able to correctly interpret the computer data and understand enough the procedure of using the software.
- To satisfy that software will give the correct answer.

[1] Validation Problem

To validate the Geo-5, RetainPro, RETWALL software an example solved of a slope problem that had been chosen. The example problem selected is the Example 5.2 from the book "REINFORCED CONCRETE VOL – I" by Dr. H J SHAH. Below are the lists of the given data from the example:

Table 2 Data of Validation Model

Wall Height, Hc	4.00 m
Depth below GL, Df	1.00 m
Surcharge, q	17 kN/m^2
Backfill inclination, β	0 degree
GWT depth, Dw	0.0 m
Backfill	ϕ Single layer backfill
Unit weight, γ	17 kN/m^3
Cohesion, C	0 kN/m^2
Angle of internal friction, ϕ	30 deg
Angle of wall friction, δ	20 degree
SBC of soil	160 kN/m^2
Water density	10 kN/m^3
Coefficient of friction	0.55
Grade of Concrete	M20
Grade of Steel	Fe415

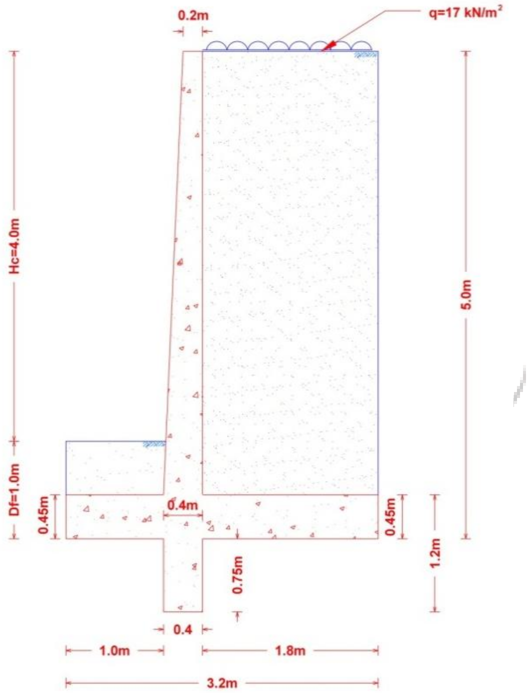


Fig 1 Geometry of Retaining Wall (Validation Model)

Table 3 Results of Validation Model Using Different Softwares

Methods	Ka	wt of soil	wt of conc.	PA	PH	PV	MR	MO	FOS OTM	FOS SLD	Pmax	Key Ht m
Geo-5 (Mazindrani)	0.333	139.23	77.62	126.26	126.26	0	499.68	191.38	2.61	1.6	99.31	0.75
Geo-5 (Coulomb)	0.297 0.297 0.297	139.23	77.62	113.25	100.25	50.4	646.07	150.22	4.3	2.71	93.08	0.75
Geo-5 (Muller Breslau)	0.297 0.297 0.297	139.23	77.62	113.25	100.25	50.4	646.07	150.22	4.3	2.71	93.08	0.75
Geo-5 (Caquot-Kérisel)	0.307 0.309 0.309	139.23	77.62	116.17	103.79	52.15	651.1	154.76	4.21	2.58	93.63	0.75
Geo-5 (Absi)	0.306 0.3 0.3	139.23	77.62	114.79	102.51	51.64	649.9	154.42	4.21	2.62	93.47	0.75
Classical (Rankine)	0.333	139.23	77.62	99.18	99.18	0	499.58	189.95	2.664	1.74	126.6	0.75

Classical (coulomb)	0.297	139.23	77.62	83.03	83.03	0	596.38	158.15	3.77	1.84	107.9	0.75
Excel worksheet (Rankine)	0.333	139.23	70.13	99.18	99.18	0	490.68	188.89	2.6	1.55	123.1	0
Excel worksheet (coulomb)	0.297	139.23	70.13	83.03	83.03	0	587.38	158.15	3.71	1.55	86.22	0
RetainPro (Rankine)	0.333	146.27	77.62	99.03	99.03	0	471.61	188.53	2.5	1.61	114.6	0.75
RetainPro (Coulomb)	0.297	146.27	77.62	86.5	86.5	0	471.61	164.67	2.86	1.85	100.6	0.75
RETWALL	-	-	-	99.18	99.18	0	494.14	188.9	2.61	1.67	125	0.75

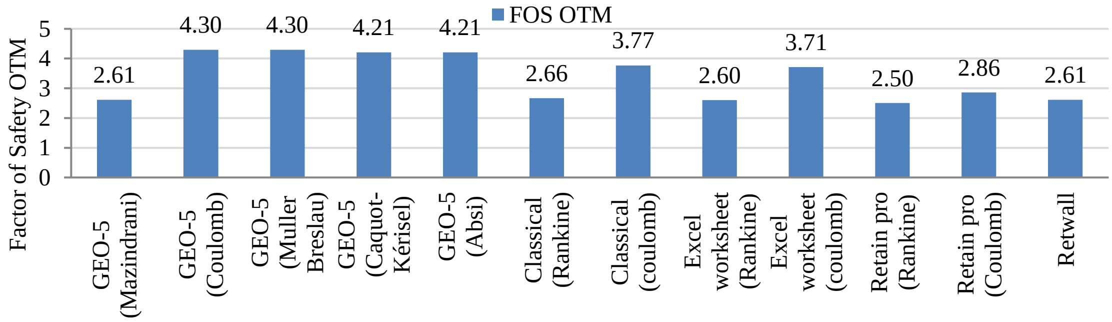


Fig 2 Graphical Representation of FOS OTM results by diff. Software (Val Model)

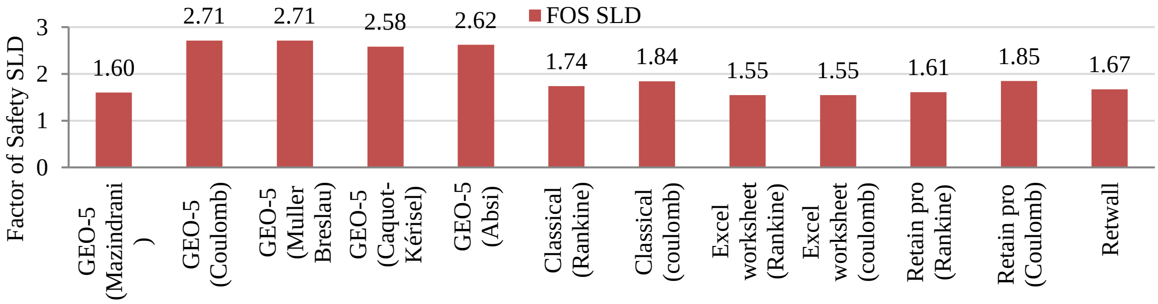


Fig 3 Graphical Representation of FOS SLD results by diff. Software (Val Model)

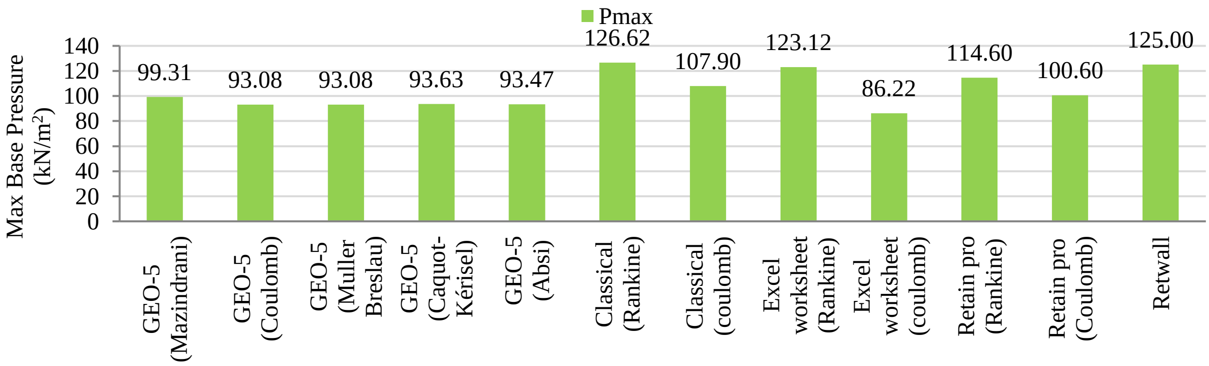


Fig V Graphical Representation of Max Base Pressure results by diff. Software (Val Model)

Model 1

Table 4 Data of Model 1

Wall Height, Hc	4.80 m
Depth below GL, Df	1.00 m
Surcharge, q	5 kN/m^2
Backfill inclination, β	10 degree
GWT depth, Dw	0.0 m
Backfill	ϕ Single layer backfill
Unit weight, γ	20 kN/m^3
Cohesion, C	0 kN/m^2
Angle of internal friction, ϕ	30 deg
Angle of wall friction, δ	20 degree
SBC of soil	200 kN/m^2
Water density	10 kN/m^3
Coefficient of friction	0.5
Grade of Concrete	M20
Grade of Steel	Fe415

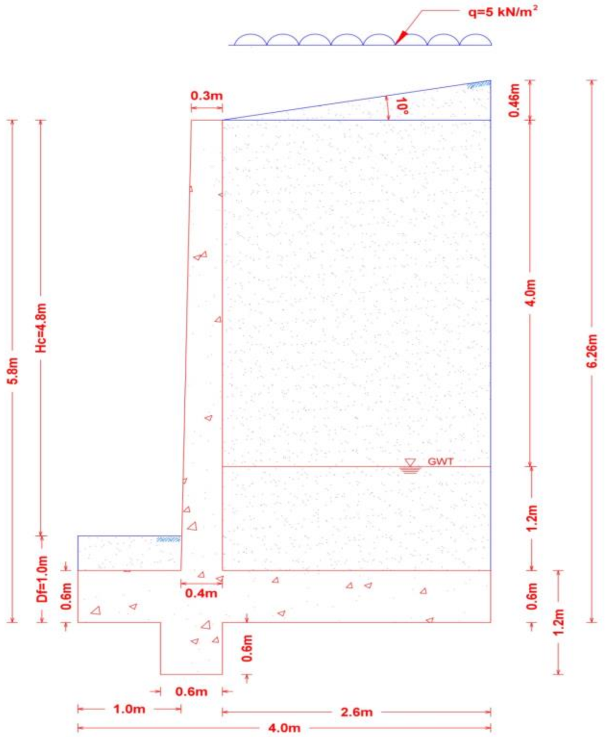


Fig 5 Geometry of Retaining wall (Model 1)

5.1 Design by Geo-5

5.1.1. Analysis by Mazindrani Theory

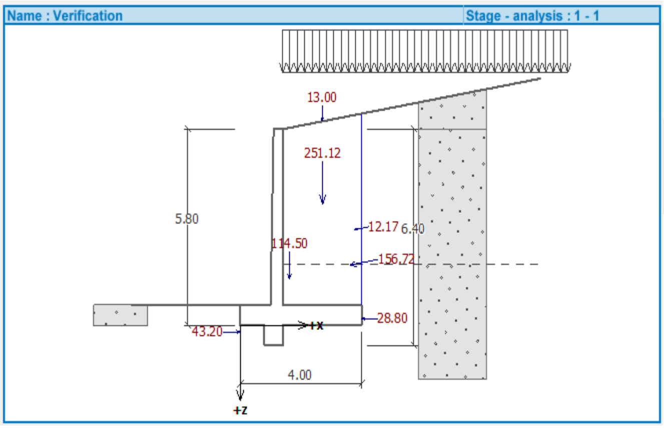


Fig 6 Verification of Model 1 by Mazindrani Theory

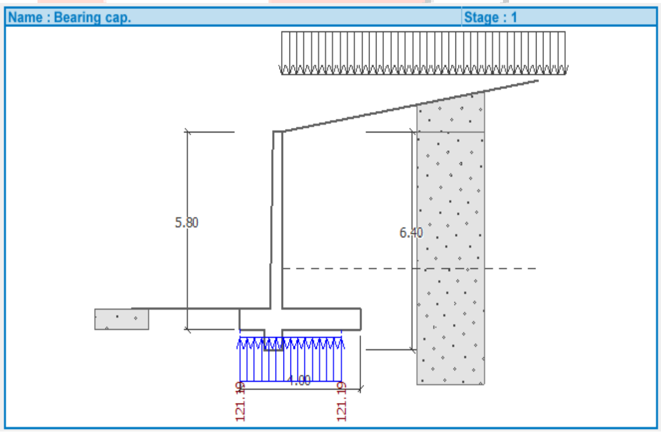


Fig 7 Bearing capacity of Model 1 by Mazindrani Theory

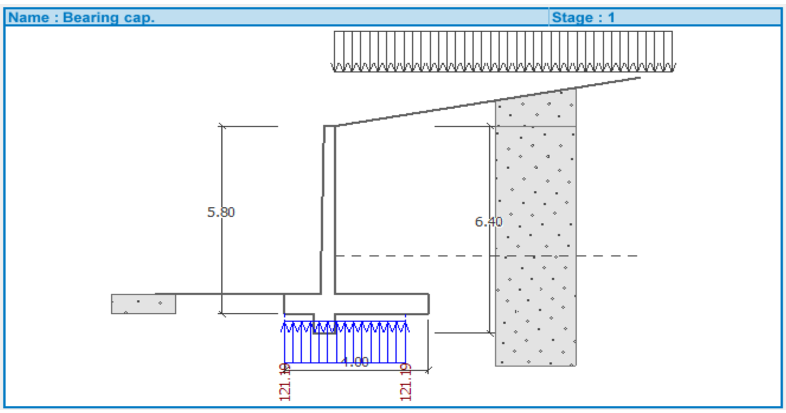


Fig 8 Dimensioning of Model 1 by Mazindrani Theory

Input data

Project

Date : 14-09-2015

Settings

(input for current task)

Materials and standards

Concrete structures : IS 456

Wall analysis

Active earth pressure calculation :	Mazindrani (Rankin)
Passive earth pressure calculation :	Mazindrani (Rankin)
Earthquake analysis :	Mononobe-Okabe
Shape of earth wedge :	Consider always vertical
Base key :	The base key is considered as inclined footing bottom
Allowable eccentricity :	0.333
Verification methodology :	Safety factors (ASD)

Safety factors			
Permanent design situation			
Safety factor for overturning :	SF_o =	1.55	[–]
Safety factor for sliding resistance :	SF_s =	1.55	[–]
Safety factor for bearing capacity :	SF_b =	1.55	[–]

Material of structure

Unit weight γ = 25.00 kN/m3
Analysis of concrete structures carried out according to the standard IS 456.

Concrete : M 20
Compressive strength f_{ck} = 20.00 MPa
Tensile strength f_{cr} = 3.13 MPa

Longitudinal steel : Fe 415
Tensile strength f_{yk} = 415.00 MPa

Terrain profile

Terrain behind construction has the slope 1: 5.67 (slope angle is 10.00 °).

Water influence

GWT behind the structure lies at a depth of 4.00 m
Uplift in foot. bottom due to different pressures is not considered.

Basic soil parameters

No.	Name	Pattern	φ_{ef} [°]	c_{ef} [kPa]	γ [kN/m3]	γ_{su} [kN/m3]	δ [°]
1	b1		30.00	0.00	20.00	10.00	20.00

All soils are considered as cohesionless for at rest pressure analysis.

Soil parameters

b1

Unit weight :	γ = 20.00 kN/m3
Stress-state :	effective
Angle of internal friction :	φ_{ef} = 30.00 °
Cohesion of soil :	c_{ef} = 0.00 kPa
Angle of friction struc.-soil :	δ = 20.00 °
Soil :	cohesionless
Saturated unit weight :	γ_{sat} = 20.00 kN/m3

Geological profile and assigned soils

No.	Layer [m]	Assigned soil	Pattern
1	-	b1	

Input surface surcharges

No.	Surcharge		Action	Mag.1	Mag.2	Ord.x	Length	Depth
	new	change		[kN/m2]	[kN/m2]	x [m]	l [m]	z [m]
1	YES		permanent	5.00				on terrain

No.	Name
1	s1

Resistance on front face of the structure

Resistance on front face of the structure: passive
Soil on front face of the structure - b1
Angle of friction struc.-soil δ = 0.00 °
Soil thickness in front of structure h = 0.60 m
Terrain in front of structure is flat.

Settings of the stage of construction

Design situation : permanent
Active pressure acts on the wall and stem.

Verification No. 1

Forces acting on construction

Name	F_{hor} [kN/m]	App.Pt. z [m]	F_{vert} [kN/m]	App.Pt. x [m]	Design coefficient
Weight - wall	0.00	-1.36	114.50	1.62	1.000
FF resistance	-43.20	0.20	0.00	0.00	1.000
Weight - earth wedge	0.00	-3.58	251.12	2.72	1.000
Active pressure	154.34	-1.78	27.21	3.61	1.000
Water pressure	28.80	-0.20	0.00	4.00	1.000
Uplift pressure	0.00	-5.80	0.00	1.40	1.000
s1	11.99	-2.83	2.11	3.77	1.000
s1	0.00	-6.03	13.00	2.70	1.000

Verification of complete wall

Check for overturning stability

Resisting moment M_{res} = 1010.12 kNm/m

Overturning moment M_{ovr} = 323.52 kNm/m

Safety factor = 3.12 > 1.55

Wall for overturning is SATISFACTORY

Check for slip

Resisting horizontal force H_{res} = 235.53 kN/m

Active horizontal force H_{act} = 151.93 kN/m

Safety factor = 1.55 > 1.55

Wall for slip is SATISFACTORY

Overall check - WALL is SATISFACTORY

Bearing capacity of foundation soil

Design load acting at the center of footing bottom

No.	Moment [kNm/m]	Norm. force [kN/m]	Shear Force [kN/m]	Eccentricity [–]	Stress [kPa]
1	129.30	407.95	151.93	0.079	121.19

Service load acting at the center of footing bottom

No.	Moment [kNm/m]	Norm. force [kN/m]	Shear Force [kN/m]
1	129.30	407.95	151.93

Verification of foundation soil

Eccentricity verification

Max. eccentricity of normal force e = 0.079

Maximum allowable eccentricity e_{alw} = 0.333

Eccentricity of the normal force is SATISFACTORY

Verification of bearing capacity

Max. stress at footing bottom σ = 121.19 kPa

Bearing capacity of foundation soil R_d = 200.00 kPa

Safety factor = 1.65 > 1.55

Bearing capacity of foundation soil is SATISFACTORY

Overall verification - bearing capacity of found. soil is SATISFACTORY

Dimensioning No. 1

Forces acting on construction

Name	F_{hor} [kN/m]	App.Pt. z [m]	F_{vert} [kN/m]	App.Pt. x [m]	Design coefficient
Weight - wall	0.00	-2.48	45.49	0.22	1.000
Active pressure	91.95	-1.77	16.21	0.40	1.000
Water pressure	7.19	-0.40	0.00	0.40	1.000
Uplift pressure	0.00	-5.20	0.00	0.40	1.000
s1	9.09	-2.60	1.60	0.40	1.000

Wall stem check

Reinforcement and dimensions of the cross-section

Bar diameter = 20.0 mm

Number of bars = 5

Reinforcement cover = 30.0 mm

Cross-section width = 1.00 m

Cross-section depth = 0.40 m

Reinforcement ratio ρ = 0.44 % > 0.20 % = ρ_{min}

Position of neutral axis x = 0.08 m < 0.17 m = x_{max}

Ultimate shear force V_{rd} = 179.77 kN > 108.23 kN = V_u

Ultimate moment M_{rd} = 185.17 kNm > 184.54 kNm = M_u

Cross-section is SATISFACTORY.

5.1.2. Analysis by Coulomb and Muller Breslau Theory

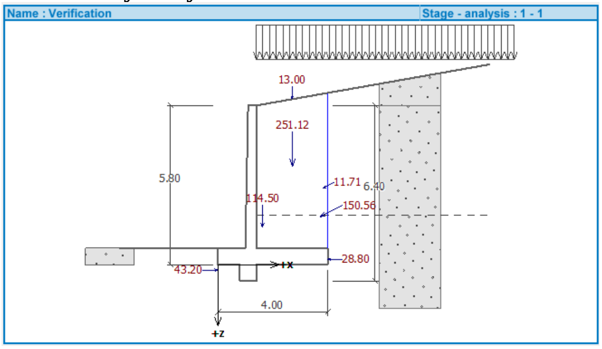


Fig 9 Verification of Model 1 by Coulomb and Muller Breslau Theory

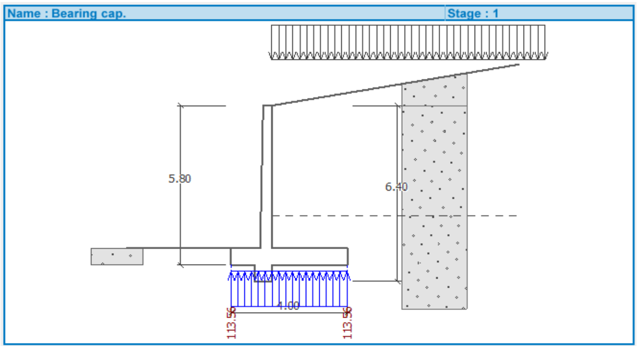


Fig 10 Bearing capacity of Model 1 by Coulomb and Muller Breslau Theory

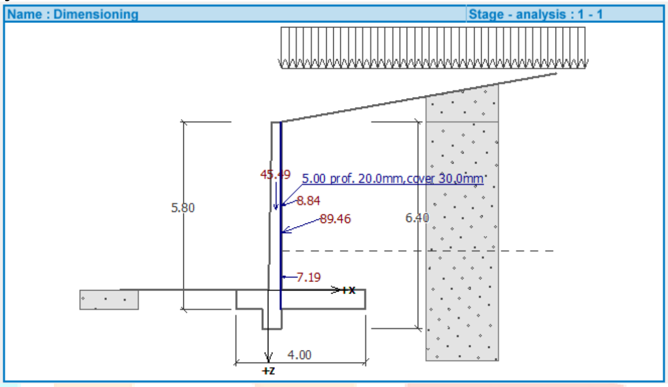


Fig 11 Dimensioning of Model 1 by Coulomb and Muller Breslau Theory

Cantilever wall analysis

Input data

Project

Date : 14-09-2015

Settings

(input for current task)

Materials and standards

Concrete structures : IS 456

Wall analysis

Active earth pressure calculation : Coulomb
Passive earth pressure calculation : Coulomb
Earthquake analysis : Mononobe-Okabe
Shape of earth wedge : Consider always vertical
Base key : The base key is considered as inclined footing bottom
Allowable eccentricity : 0.333
Verification methodology : Safety factors (ASD)

Safety factors			
Permanent design situation			
Safety factor for overturning :	SF_o =	1.55	[–]
Safety factor for sliding resistance :	SF_s =	1.55	[–]
Safety factor for bearing capacity :	SF_b =	1.55	[–]

Verification No. 1

Forces acting on construction

Name	F_{hor} [kN/m]	App.Pt. z [m]	F_{vert} [kN/m]	App.Pt. x [m]	Design coefficient
Weight - wall	0.00	-1.36	114.50	1.62	1.000
FF resistance	-43.20	0.20	0.00	0.00	1.000
Weight - earth wedge	0.00	-3.58	251.12	2.72	1.000
Active pressure	134.02	-1.74	68.61	3.71	1.000
Water pressure	28.80	-0.20	0.00	4.00	1.000
Uplift pressure	0.00	-5.80	0.00	1.40	1.000
s1	10.32	-2.79	5.55	3.84	1.000
s1	0.00	-6.03	13.00	2.70	1.000

Verification of complete wall

Check for overturning stability

Resisting moment M_{res} = 1179.61 kNm/m
Overturning moment M_{ovr} = 276.96 kNm/m

Safety factor = 4.26 > 1.55

Wall for overturning is SATISFACTORY

Check for slip

Resisting horizontal force H_{res} = 261.41 kN/m
Active horizontal force H_{act} = 129.94 kN/m

Safety factor = 2.01 > 1.55

Wall for slip is SATISFACTORY

Overall check - WALL is SATISFACTORY

Bearing capacity of foundation soil

Design load acting at the center of footing bottom

No.	Moment [kNm/m]	Norm. force [kN/m]	Shear Force [kN/m]	Eccentricity [–]	Stress [kPa]
1	2.90	452.78	129.94	0.002	113.56

Service load acting at the center of footing bottom

No.	Moment [kNm/m]	Norm. force [kN/m]	Shear Force [kN/m]
1	2.90	452.78	129.94

Verification of foundation soil

Eccentricity verification

Max. eccentricity of normal force $e = 0.002$

Maximum allowable eccentricity $e_{alw} = 0.333$

Eccentricity of the normal force is SATISFACTORY

Verification of bearing capacity

Max. stress at footing bottom $\sigma = 113.56$ kPa

Bearing capacity of foundation soil $R_d = 200.00$ kPa

Safety factor = 1.76 > 1.55

Bearing capacity of foundation soil is SATISFACTORY

Overall verification - bearing capacity of found. soil is SATISFACTORY

Dimensioning No. 1

Forces acting on construction

Name	F_{hor} [kN/m]	App.Pt. z [m]	F_{vert} [kN/m]	App.Pt. x [m]	Design coefficient
Weight - wall	0.00	-2.48	45.49	0.22	1.000
Active pressure	84.06	-1.77	30.60	0.40	1.000
Water pressure	7.19	-0.40	0.00	0.40	1.000
Uplift pressure	0.00	-5.20	0.00	0.40	1.000
s1	8.31	-2.60	3.02	0.40	1.000

Wall stem check

Reinforcement and dimensions of the cross-section

Bar diameter = 20.0 mm

Number of bars = 5

Reinforcement cover = 30.0 mm

Cross-section width = 1.00 m

Cross-section depth = 0.40 m

Reinforcement ratio ρ = 0.44 % > 0.20 % = ρ_{min}

Position of neutral axis x = 0.08 m < 0.17 m = x_{max}

Ultimate shear force V_{rd} = 179.77 kN > 99.55 kN = V_u

Ultimate moment M_{rd} = 185.17 kNm > 165.39 kNm = M_u

Cross-section is SATISFACTORY.

5.1.3. Analysis by Caquot - Kérisel theory

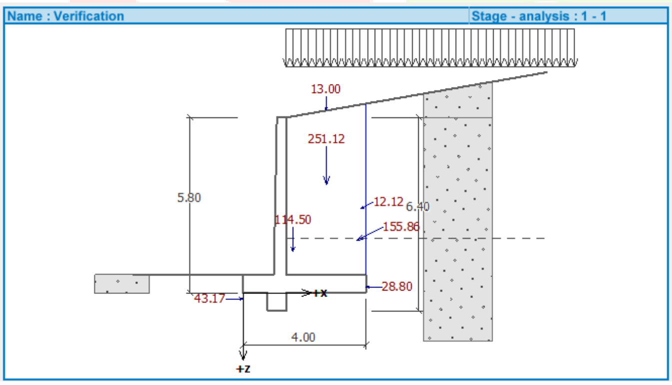


Fig12 Verification of Model 1 by Caquot - Kérisel theory

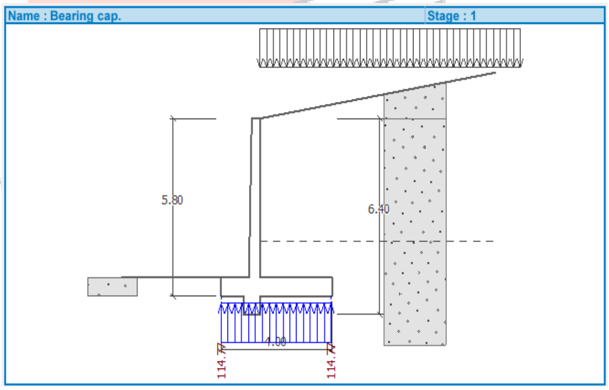


Fig 13 Bearing Capacity of Model 1 by Caquot - Kérisel theory

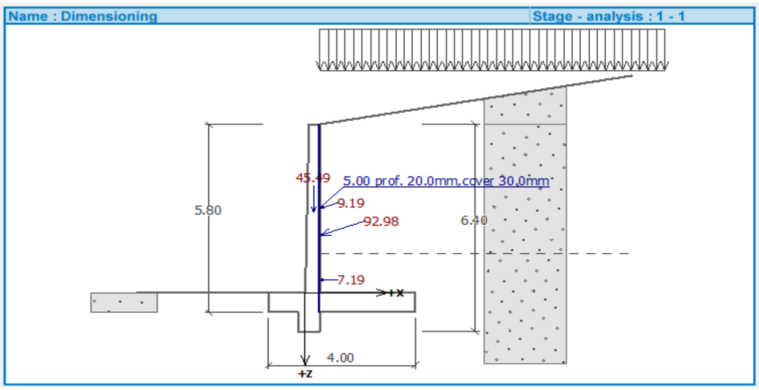


Fig 14 Dimensioning of Model 1 by Caquot - Kérisel theory

Cantilever wall analysis

Input data

Project

Date : 14-09-2015

Settings

(input for current task)

Materials and standards

Concrete structures : IS 456

Wall analysis

Active earth pressure calculation :	Caquot-Kerisel
Passive earth pressure calculation :	Caquot-Kerisel
Earthquake analysis :	Mononobe-Okabe
Shape of earth wedge :	Consider always vertical
Base key :	The base key is considered as inclined footing bottom
Allowable eccentricity :	0.333
Verification methodology :	Safety factors (ASD)

Safety factors			
Permanent design situation			
Safety factor for overturning :	SF_o =	1.55	[–]
Safety factor for sliding resistance :	SF_s =	1.55	[–]
Safety factor for bearing capacity :	SF_b =	1.55	[–]

Verification No. 1

Forces acting on construction

Name	F_{hor} [kN/m]	App.Pt. z [m]	F_{vert} [kN/m]	App.Pt. x [m]	Design coefficient
Weight - wall	0.00	-1.36	114.50	1.62	1.000
FF resistance	-43.17	0.20	0.00	0.00	1.000
Weight - earth wedge	0.00	-3.58	251.12	2.72	1.000
Active pressure	138.75	-1.74	70.99	3.71	1.000
Water pressure	28.80	-0.20	0.00	4.00	1.000
Uplift pressure	0.00	-5.80	0.00	1.40	1.000
s1	10.67	-2.79	5.74	3.84	1.000
s1	0.00	-6.03	13.00	2.70	1.000

Check for slip

Resisting horizontal force H_{res} = 262.90 kN/m

Active horizontal force H_{act} = 135.05 kN/m

Safety factor = 1.95 > 1.55

Wall for slip is SATISFACTORY

Overall check - WALL is SATISFACTORY

Bearing capacity of foundation soil

Design load acting at the center of footing bottom

No.	Moment [kNm/m]	Norm. force [kN/m]	Shear Force [kN/m]	Eccentricity [–]	Stress [kPa]
1	7.36	455.35	135.05	0.004	114.77

Service load acting at the center of footing bottom

No.	Moment [kNm/m]	Norm. force [kN/m]	Shear Force [kN/m]
1	7.36	455.35	135.05

Verification of foundation soil

Eccentricity verification

Max. eccentricity of normal force e = 0.004

Maximum allowable eccentricity e_{alw} = 0.333

Eccentricity of the normal force is SATISFACTORY

Verification of bearing capacity

Max. stress at footing bottom σ = 114.77 kPa

Bearing capacity of foundation soil R_d = 200.00 kPa

Safety factor = 1.74 > 1.55

Bearing capacity of foundation soil is SATISFACTORY

Overall verification - bearing capacity of found. soil is SATISFACTORY

Dimensioning No. 1

Forces acting on construction

Name	F_{hor} [kN/m]	App.Pt. z [m]	F_{vert} [kN/m]	App.Pt. x [m]	Design coefficient
Weight - wall	0.00	-2.48	45.49	0.22	1.000
Active pressure	87.37	-1.77	31.80	0.40	1.000
Water pressure	7.19	-0.40	0.00	0.40	1.000
Uplift pressure	0.00	-5.20	0.00	0.40	1.000
s1	8.63	-2.60	3.14	0.40	1.000

Wall stem check

Reinforcement and dimensions of the cross-section

Bar diameter = 20.0 mm

Number of bars = 5

Reinforcement cover = 30.0 mm

Cross-section width = 1.00 m

Cross-section depth = 0.40 m

Reinforcement ratio ρ = 0.44 % > 0.20 % = ρ_{min}

Position of neutral axis x = 0.08 m < 0.17 m = x_{max}

Ultimate shear force V_{rd} = 179.77 kN > 103.19 kN = V_u

Ultimate moment M_{rd} = 185.17 kNm > 171.83 kNm = M_u

Cross-section is SATISFACTORY.

5.1.4. Analysis by Absi Theory

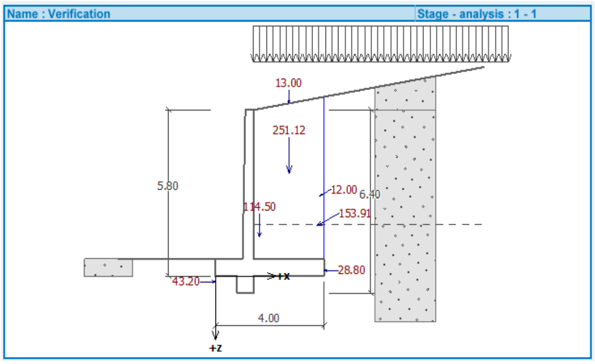


Fig 15 Verification of Model 1 by Absi Theory

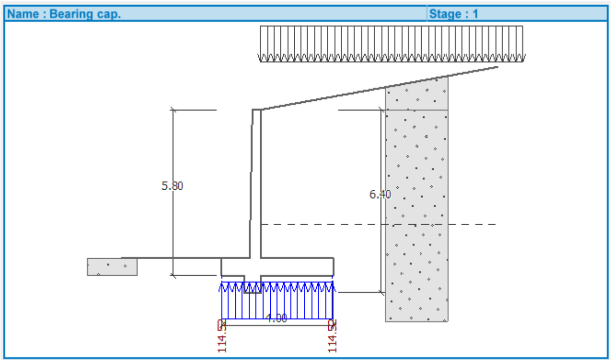


Fig 16 Bearing Capacity of Model 1 by Absi Theory

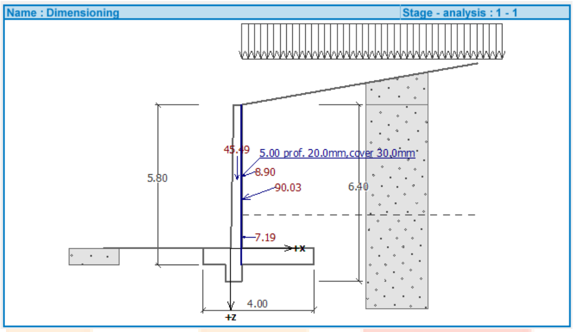


Fig 17 Dimensioning of Model 1 by Absi Theory

Cantilever wall analysis

Input data

Project

Date : 14-09-2015

Settings

(input for current task)

Materials and standards

Concrete structures : IS 456

Wall analysis

Active earth pressure calculation : Absi
Passive earth pressure calculation : Absi
Earthquake analysis : Mononobe-Okabe
Shape of earth wedge : Consider always vertical
Base key : The base key is considered as inclined footing bottom
Allowable eccentricity : 0.333
Verification methodology : Safety factors (ASD)

Safety factors Permanent design situation			
Safety factor for overturning :	SF_o =	1.55	[–]
Safety factor for sliding resistance :	SF_s =	1.55	[–]
Safety factor for bearing capacity :	SF_b =	1.55	[–]

Verification No. 1

Forces acting on construction

Name	F_{hor} [kN/m]	App.Pt. z [m]	F_{vert} [kN/m]	App.Pt. x [m]	Design coefficient
Weight - wall	0.00	-1.36	114.50	1.62	1.000
FF resistance	-43.20	0.20	0.00	0.00	1.000
Weight - earth wedge	0.00	-3.58	251.12	2.72	1.000
Active pressure	136.94	-1.76	70.24	3.71	1.000
Water pressure	28.80	-0.20	0.00	4.00	1.000
Uplift pressure	0.00	-5.80	0.00	1.40	1.000
s1	10.57	-2.80	5.69	3.84	1.000
s1	0.00	-6.03	13.00	2.70	1.000

Verification of complete wall

Check for overturning stability

Resisting moment M_{res} = 1186.57 kNm/m
Overturning moment M_{ovr} = 284.48 kNm/m

Safety factor = 4.17 > 1.55

Wall for overturning is SATISFACTORY

Check for slip

Resisting horizontal force H_{res} = 262.44 kN/m
Active horizontal force H_{act} = 133.11 kN/m

Safety factor = 1.97 > 1.55

Wall for slip is SATISFACTORY

Overall check - WALL is SATISFACTORY

Bearing capacity of foundation soil

Design load acting at the center of footing bottom

No.	Moment [kNm/m]	Norm. force [kN/m]	Shear Force [kN/m]	Eccentricity [–]	Stress [kPa]
1	7.01	454.55	133.11	0.004	114.52

Service load acting at the center of footing bottom

No.	Moment [kNm/m]	Norm. force [kN/m]	Shear Force [kN/m]
1	7.01	454.55	133.11

Verification of foundation soil

Eccentricity verification

Max. eccentricity of normal force e = 0.004

Maximum allowable eccentricity e_{alw} = 0.333

Eccentricity of the normal force is SATISFACTORY

Verification of bearing capacity

Max. stress at footing bottom σ = 114.52 kPa

Bearing capacity of foundation soil R_d = 200.00 kPa

Safety factor = 1.75 > 1.55

Bearing capacity of foundation soil is SATISFACTORY

Overall verification - bearing capacity of found. soil is SATISFACTORY

Dimensioning No. 1

Forces acting on construction

Name	F_{hor} [kN/m]	App.Pt. z [m]	F_{vert} [kN/m]	App.Pt. x [m]	Design coefficient
Weight - wall	0.00	-2.48	45.49	0.22	1.000
Active pressure	84.60	-1.77	30.79	0.40	1.000
Water pressure	7.19	-0.40	0.00	0.40	1.000
Uplift pressure	0.00	-5.20	0.00	0.40	1.000
s1	8.36	-2.60	3.04	0.40	1.000

Wall stem check

Reinforcement and dimensions of the cross-section

Bar diameter = 20.0 mm

Number of bars = 5

Reinforcement cover = 30.0 mm

Cross-section width = 1.00 m

Cross-section depth = 0.40 m

Reinforcement ratio ρ = 0.44 % > 0.20 % = ρ_{min}

Position of neutral axis x = 0.08 m < 0.17 m = x_{max}

Ultimate shear force V_{rd} = 179.77 kN > 100.15 kN = V_u

Ultimate moment M_{rd} = 185.17 kNm > 166.44 kNm = M_u

Cross-section is SATISFACTORY.

5.1.5. Slope stability

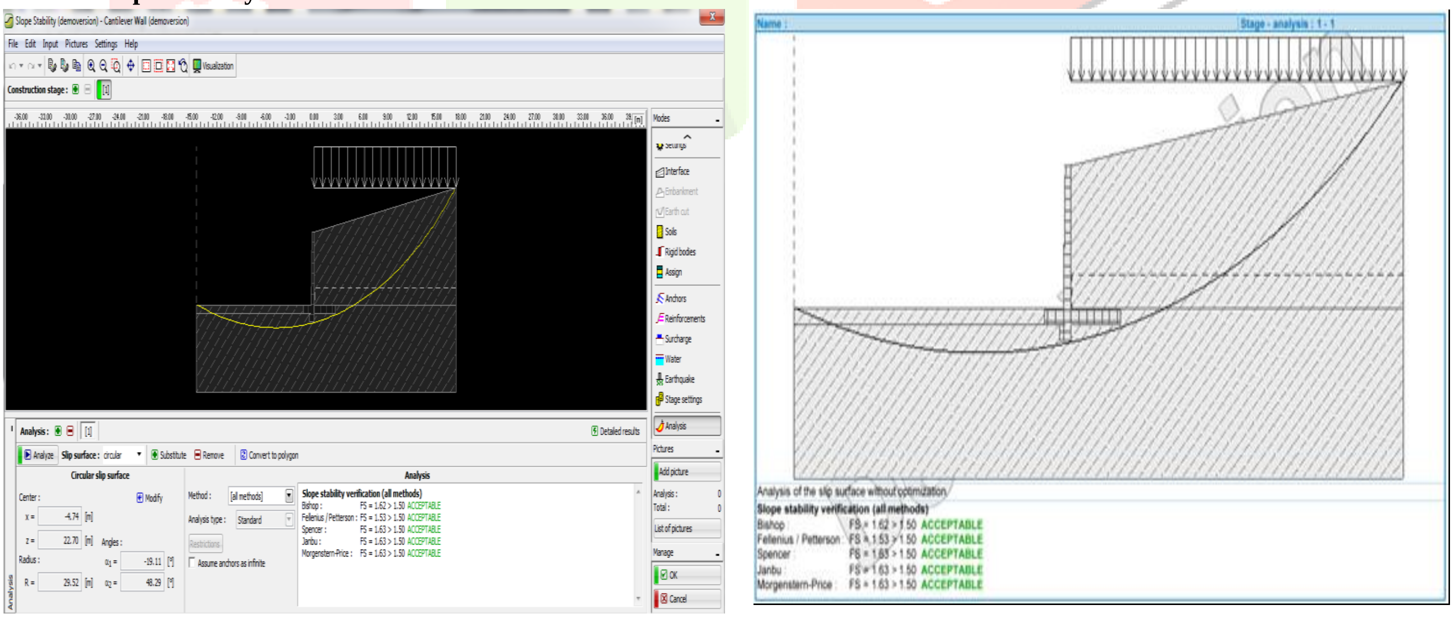


Fig 18 Slope stability of Model 1

Results (Stage of construction 1)

Analysis 1

Slope stability verification (all methods)

Bishop : FS = 1.62 > 1.50 ACCEPTABLE

Fellenius / Petterson : FS = 1.53 > 1.50 ACCEPTABLE

Spencer : FS = 1.63 > 1.50 ACCEPTABLE

Janbu : FS = 1.63 > 1.50 ACCEPTABLE

Morgenstern-Price : FS = 1.63 > 1.50 ACCEPTABLE

5.2 Design by RetainPro

5.2.1. Analysis by Rankine Theory

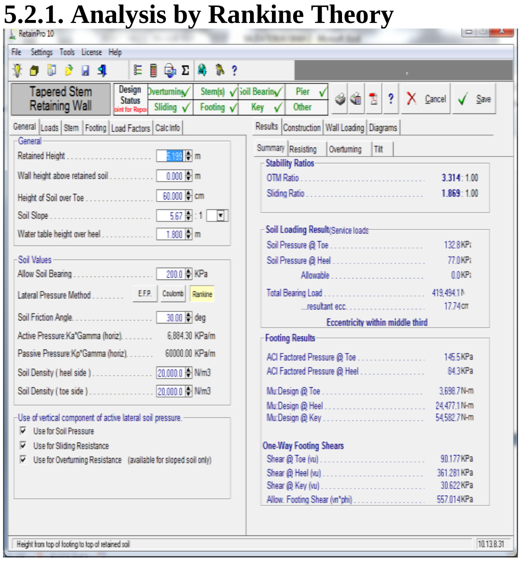


Fig 19 Wall construction of Model 1 by Rankine Theory

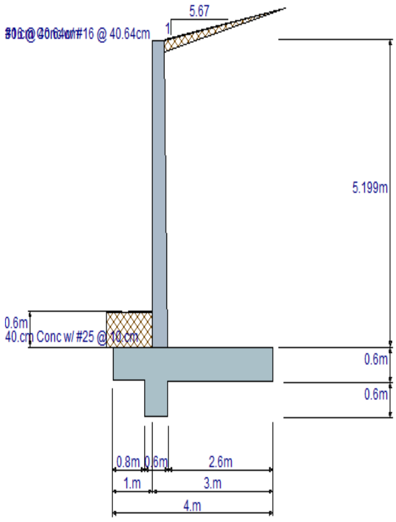


Fig 20 Wall construction of Model 1 by Rankine Theory

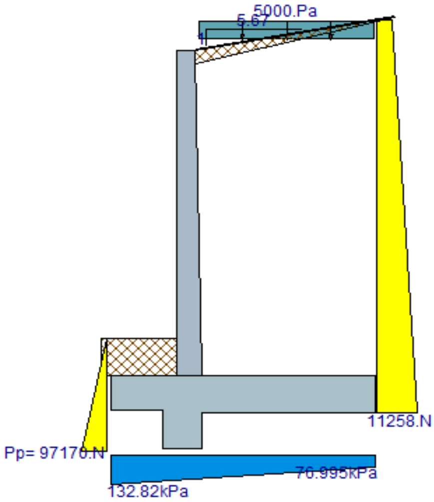


Fig 21 Wall Loading of Model 1 by Rankine Theory

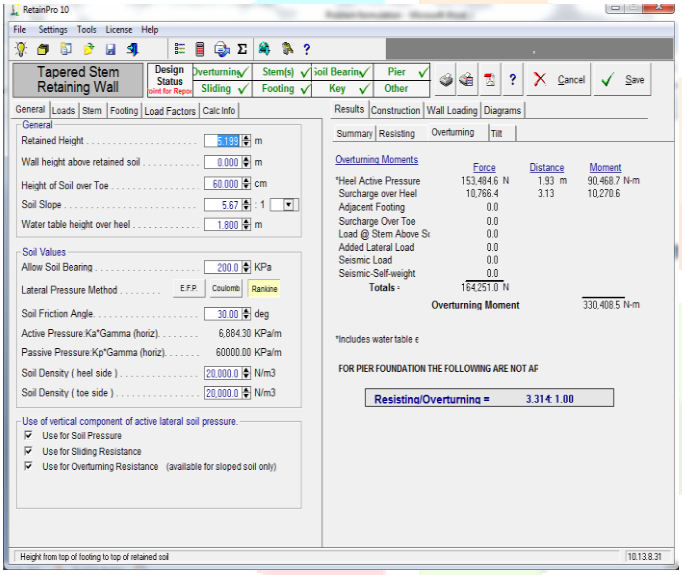


Fig 22 Overturning Moment calculations by Rankine Theory

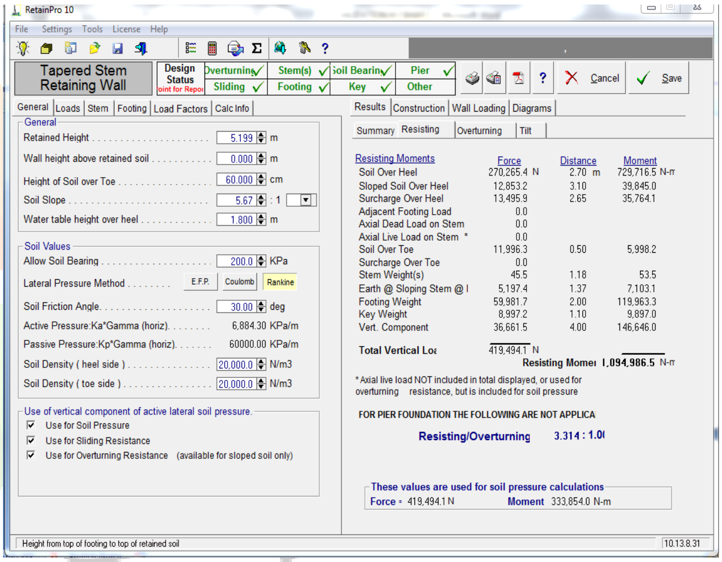


Fig 23 Resisting Moment calculations by Rankine Theory

5.2.2. Analysis by Coulomb Theory

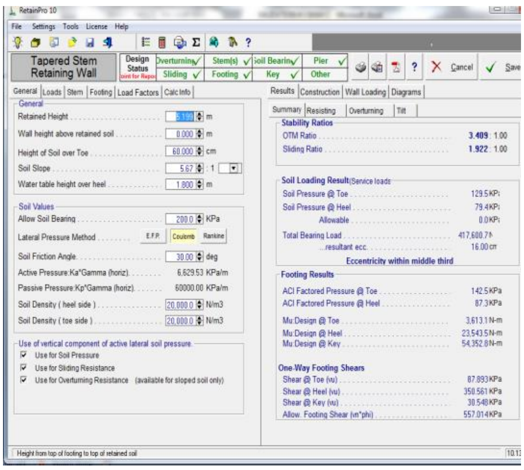


Fig 24 Wall construction of Model 1 by Coulomb Theory

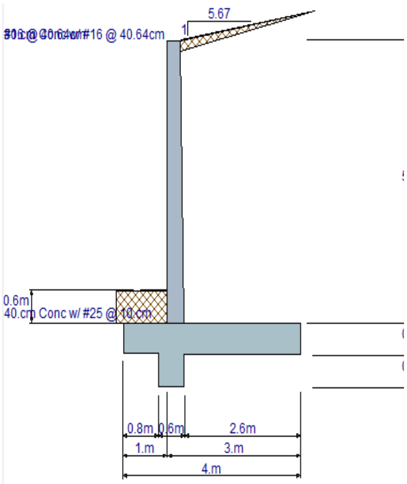


Fig 25 Wall construction of Model 1 by Coulomb Theory

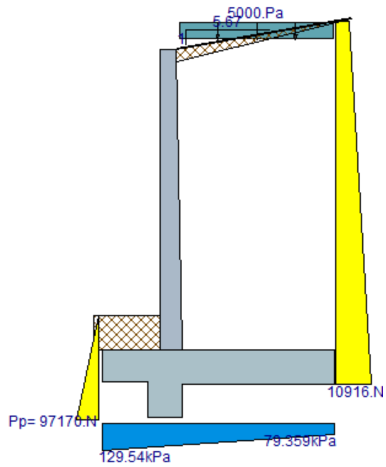


Fig 26 Wall Loading of Model 1 by Coulomb Theory

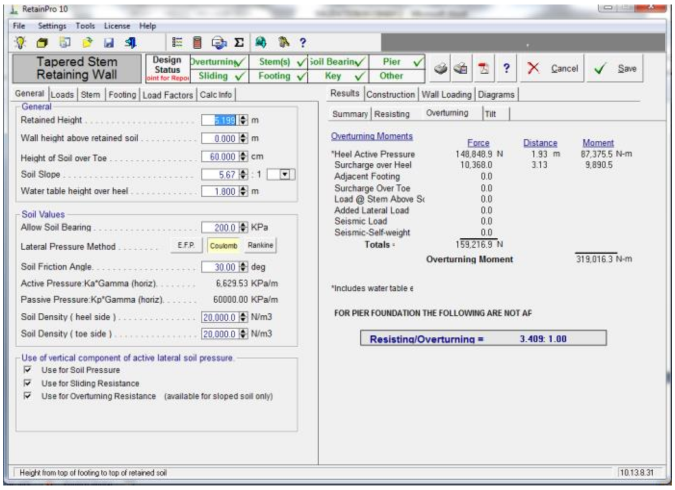


Fig 22 Overturning Moment calculations by Coloumb Theory

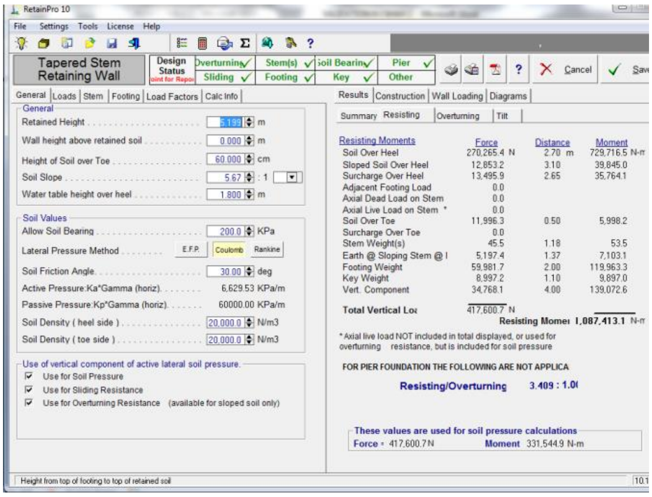


Fig 23 Resisting Moment calculations by Coloumb Theory

5.3 Design by Excel workshee

CANTILEVER RETAINING WALL			
DATA:			
		Type of layer	Without layer
WALL HT. Above LOWER GL, Hc (m) =	4.80	INT FRICTION ANGLE Heel, Φh (°) =	30.0
FDn. Depth below LOWER GL, Df (m) =	1.00	INT FRICTION ANGLE Toe, ΦT (°) =	30.0
MIN. FoS : OVERTURNING =	1.55	ANGLE OF WALL FRICTION, δ (°) =	20.0
MIN. FoS : SLIDING =	1.55	Rankine/Coulomb's Theory	Rankine's The
SBC, qa (kN/m²) =	200	GWT from WALL TOP, Dw (m) =	4.00
FRICTION COEFF. @ Wall base, μ =	0.50	SOIL @ HEEL γsat (kN/m³) =	20.00
SURCHARGE ANGLE, β (°) =	10.00	SOIL @ HEEL: γb (kN/m³) =	20.00
SURCHARGE (Plan Area), q ((kN/m²)=	5.00	SOIL ABOVE TOE : γb (kN/m³) =	20.00
Provide Key for Control of Sliding	Yes	UNIT WT. OF WATER, γw (kN/m³) =	10.00
SUBMERGEED UNIT WT., γ ' (kN/m³) =	10.00	UNIT WT. OF CONC, γCONC (kN/m³) =	25.00

EQ AccCoef, Ah =	0.000	STEP-2	SELECT, Bf,TOE	OPTIMAL
BwTOP, (mm) =	300	Bf,TOE, (m) =	1.00	1.00
Bwtoe, (mm) =	100	Bf, (m) =	4.00	6.67
DTmin (mm) =	600	BwBOT, (mm) =	400	
DHmin (mm) =	600	Overall Thkness of Base, D (mm) =	600	
Neglect Toe Fill for Stablility Chk	Yes	Bf, HEEL (m) =	2.60	
		STEP-1		
DEPTH of KEY, (m) =	0.00			

TOTAL WALL HT. ABOVE FDn. BOT., H (m) =	5.80	FoS, Overturning =	3.39
CLEAR STEM HT., Hc (m) =	5.20	FoS, SLIDING =	1.55
TOTAL HT. ABOVE FDn. BOT.AT HEEL, Hh (m) =	6.26	p, max =	141.28
ANGLE OF INNER WALL FACE W / HORI. α' (°) =	90.00	p, min =	57.07
ANGLE OF INNER WALL FACE W / VERT. θ (°) =	0.00		
Ka', BACK FILL,STATIC =	0.350	Kp' FOR SOIL, TOE FILL =	3.00
Coulomb's Theory incl. Wall Inclination & Wall Friction used for Active Earth Pr.			

DYNAMIC EARTH PRESSURE		Above GWT		Below GWT	
		λ1 =	0.00	λ1 =	0.00
EQ Acc, Av =	0.000	λ2 =	0.00	λ2 =	0.00
		Ka,1 =	0.340	Ka,1 =	0.340
		Ka,2 =	0.340	Ka,2 =	0.340
		Ka,dyn =	0.340	Ka,dyn =	0.340

EARTH PR. CALCULATIONS	LEVEL FROM TOE (m)	EARTH PR. INT. Total Dyn. (kN/m2)	EARTH PR. INT. Static. (kN/m2)	EARTH PR. INT. Dyn. (kN/m2)
TOP OF SOIL ABOVE HEEL	6.26	0.00	1.75	0.00
GWT IN BACK FILL, IF ANY	1.80	30.32	32.91	-2.60
BOT. OF HEEL	0.00	57.21	57.21	0.000

COMPONENT	STATIC EARTH Pr, (kN)	Vert. DIST. FROM TOE (m)	Overturning Mmt @ TOE, (kN.m)	Dyn EARTH Pr, (kN)	Overturning Mmt @ TOE-Dyn(kN.m)
Earth Pr-1	76.09	3.36	255.76	-5.79	
Earth Pr-2	79.88	0.82	65.43	-2.34	
T O T A L,	155.97		321.19	-8.12	-25.42

COMPONENT	Wt. (kN)	DIST. FROM TOE (m)	MMT @ TOE, (kN.m)
WALL - STEM, W1 =	45.50	1.22	55.68
BASE, W2 =	60.00	2.00	120.00
SOIL ABOVE TOE, W3 =	0.00	0.00	0.00
SOIL @ HEEL (ABOVE GWT), W4 =	219.92	2.72	598.95
SOIL @ HEEL (BELOW GWT), W5 =	31.20	2.70	84.24

Layered soil profile

WALL HT. Above LOWER GL, Hc (m) =	4.80
FDn. Depth below LOWER GL, Df (m) =	1.00

level	Ka*y*Z	TOTAL E P	moment
z1	1.75	6.04	27.37
z2	25.92	41.81	165.25
z3	25.92	72.59	101.62
z4	45.50	27.40	25.58
		147.84	319.82
z01 0 zo2 0.00	EARTH PRESSURE Ph	145.59	314.96
	Z	2.163	
	EARTH PRESSURE Pv	25.67	102.69

ht	Ka*y*Z	TOTAL E P	moment
z1	1.75	6.04	27.37
z2	29.71	40.78	162.56
z3	27.82	0.51	1.34
z4	27.82	77.89	109.04
z5	37.60	13.70	12.79
z6	55.60	16.20	9.72
		155.12	322.83
	EARTH PRESSURE WITH WATER TABLE Ph	152.77	317.93
	Z	2.081	
	EARTH PRESSURE WITH WATER TABLE Pv	26.94	107.75

Earth pressure for flexure

ht	Ka*y*Z	TOTAL E P	moment
z1	1.75	5.24	19.40
z2	22.72	36.26	116.04
z3	22.72	57.03	62.73
z4	38.10	21.53	15.79
		120.07	213.97
	EARTH PRESSURE Ph	118.24	210.72
	Z	1.782	
	EARTH PRESSURE Pv	20.85	83.40

ht	Ka*y*Z	TOTAL E P	moment
z1	1.75	5.24	19.40
z2	29.71	27.96	94.14
z3	26.21	1.75	3.26
z4	26.21	57.67	63.44
z5	33.90	8.46	6.20
z6	51.90	16.20	9.72
		117.28	196.16
	EARTH PRESSURE WITH WATER TABLE Ph	115.50	193.18
	Z	1.673	
	EARTH PRESSURE WITH WATER TABLE Pv	20.37	81.46

Surcharge, W6 =	13.00	2.70	35.10
Earth Pr.-Vert. Comp = Pa,v	27.08	4.00	108.34
TOTAL WT.	396.70	M-Resist, kN.m =	1002.31
Overturning Moment, kN.m =			295.76
CG OF LOADS FROM TOE, m			1.72
ECC. OF THE LOADS, m			0.28
Passive Earth Pressure =			0.00

Earth pressure for shear

ht	Ka*y*Z	TOTAL E P	moment
z1	1.75	5.24	17.54
z2	22.72	36.26	103.17
z3	22.72	47.83	44.12
z4	35.62	18.06	11.10
		107.39	175.93
	Z	1.638	
	EARTH PRESSURE Pv	18.65	74.59

ht	Ka*y*Z	TOTAL E P	moment
z1	1.75	5.24	17.54
z2	29.71	27.96	84.21
3.00	26.21	1.75	2.64
z4	26.21	48.36	44.62
z5	32.66	5.95	3.66
z6	50.66	16.20	9.72
		105.47	162.39
	EARTH PRESSURE WITH WATER TABLE Ph	103.86	159.92
	Z	1.540	
	EARTH PRESSURE WITH WATER TABLE Pv	18.31	73.26

RCC DESIGN OF STEM

EARTH PR. FOR FLEXURE

EARTH PR. CALCULATIONS	LEVEL FROM TOE (m)	EARTH PR. INT. (kN/m2)
TOP OF SOIL at STEM	5.80	1.75
GWT IN BACK FILL, IF ANY	1.80	29.71
BOT. OF STEM	0.60	45.90

COMPONENT	EARTH Pr, (kN)	Vert. DIST. FROM STEM BOT. (m)	Bending Mmt @ STEM BOT., Mmax (kN.m)
Earth Pr-1	61.96	2.61	161.55
Earth Pr-2	44.68	0.56	24.89
TOTAL,	106.64		186.44
*Ast design X-dir (mm2/m) =	2487		
Ld, reqd. (mm)	Bar Dia. / Spacing (mm)		Provide Spacing
900	20	126	110

fck (MPa) =	25
d' x (mm) =	55
DESIGN FOR FLEXURE	
Mx (kN.m)=	186.44
D,critical(mm)=	335
D,k=1.5, (mm)=	487
D,k=1.2,(mm)=	538
SELECT, D(mm)=	410
d, (mm)=	355
`k'=	2.22
p %=	0.700
Ast mm2/m=	2487
As,min(mm2/m)	492
*Ast provided(mm2/m) =	2856

EARTH PR. FOR SHEAR

EARTH PR. CALCULATIONS	LEVEL FROM TOE (m)	EARTH PR. INT. (kN/m2)
TOP OF SOIL at STEM	5.80	1.75
GWT IN BACK FILL, IF ANY	1.80	29.71
At Critical Section for Shear	0.96	41.11

COMPONENT	EARTH Pr, (kN)	Vert. DIST. FROM STEM BOT. (m)	Bending Mmt @ STEM BOT., Mmax (kN.m)
Earth Pr-1	61.96	2.25	139.55
Earth Pr-2	29.47	0.40	11.60
Vu,c (kN) =	91.43	Mu,c (kN.m)=	151.16

CHECK FOR SHEAR

ds (mm) =	347
p% (crit.sec) =	0.82
BETA-x =	3.53
BETA,USE=	3.53
Tc, (MPa) =	0.60
Tv, (MPa) =	0.36

RCC DESIGN OF TOE

	@ FACE OF WALL	@ FREE END
BASE PR. (kPa)	120.23	141.28
SOIL PR. (kPa)	-8.00	-8.00
SELF WT.(kPa)	-15.00	-15.00
Net (kPa)	97.23	118.28
SELECT ` D '(mm) =		400
*Ast design X-dir (mm2/m) =		728
Ld, reqd. (mm)	Bar Dia. / Spacing (mm)	
900	20	431
Provide Spacing		220
*Ast provided(mm2/m) =		1428

Eff. Cover,(mm)	60
DESIGN FOR FLEXURE	
Mx (kN.m)=	55.63
D,critical(mm)=	220
D,k=1.5, (mm)=	296
D,k=1.2,(mm)=	324
d, (mm)=	340
`k'=	0.72
p %=	0.214
Ast mm2/m=	728
As,min(mm2/m)	480

Neglect Toe fill for Wt. Calc.: No

CHECK FOR SHEAR

Shear Span, Ls=	0.66	ds (mm) =	408
pc,shear (kPa) =	104.39	p% (crit.sec) =	0.35
Vu,c (kN) =	73.48	BETA-x =	8.29
Mu,c (kN.m) =	24.75	BETA,USE=	8.29
Tv, (MPa) =	0.315	Tc, (MPa) =	0.4214

DESIGN OUT PUT FOR DEPTH OF STEM & BASE

BwBOT, (mm) =	410	FINAL DSN DIM.
Overall Thkness of Base, D (mm) =	450	

RCC DESIGN OF Heel

	@ FACE OF WALL	@ FREE END
BASE PR. (kPa)	111.81	57.07
SOIL PR. (kPa)	-92.00	-101.17
SELF WT.(kPa)	-15.00	-15.00
Net (kPa)	4.81	-59.10
SELECT ` D '(mm) =		450
*Ast design X-dir (mm2/m) =		1919
Ld, reqd. (mm)	Bar Dia. / Spacing (mm)	
720	16	105
Provide Spacing		130
*Ast provided(mm2/m) =		1547

DESIGN FOR FLEXURE	
Eff. Cover,(mm)	60
Mx (kN.m)=	-163.46
D,critical(mm)=	330
D,k=1.5, (mm)=	464
D,k=1.2,(mm)=	512
d, (mm)=	390
`k'=	1.61
p %=	0.492
Ast mm2/m=	1919
As,min(mm2/m)	540

Neglect vert. componet of Pa for Heel Dsn: No

CHECK FOR SHEAR

Shear Span, Ls=	2.40	ds (mm) =	413
pc,shear (kPa) =	0.00	p% (crit.sec) =	0.37
Vu,c (kN) =	-94.07	BETA-x =	7.74
Mu,c (kN.m) =	-113.89	BETA,USE=	7.74
Tv, (MPa) =	0.40	Tc, (MPa) =	0.43

Fig 24 Design of model 1 by Excel worksheet

Table 5 Results of Model 1 Using Different Softwares

Methods	Ka	wt of soil	wt of conc.	PA	PH	PV	MR	MO	FOS OTM	FOS SLD	Pmax	Key Ht.
Geo-5 (Mazindrani	0.355	251.12	114.5	168.89 28.8	166.33 28.8	29.32	1010.1	323.52	3.12	1.55	121.19	0.6
Geo-5 (Coulomb)	0.343 0.343 0.34 0.34	251.12	114.5	162.27 28.8	144.34 28.8	74.61	1179.6	276.96	4.26	2.01	113.56	0.6
Geo-5 (Muller Breslau)	0.343 0.343 0.34 0.34	251.12	114.5	162.27 28.8	129.94 28.8	74.61	1179.6	276.96	4.26	2.01	113.56	0.6
Geo-5 (Caquot-Kérisel)	0.354 0.354 0.353 0.353	251.12	114.5	167.98 28.8	149.42 28.8	76.73	1189.1	285.74	4.16	1.95	114.17	0.6
Geo-5 (Absi)	0.353 0.353 0.342 0.342	251.12	114.5	165.91 28.8	147.51 28.8	75.93	1186.5	284.48	4.17	1.97	114.52	0.6
Classical (Rankine)	0.35	251.12	114.5	158.64	156.22	27.54	1011.3	321.75	3.14	1.58	147.55	0.6
Classical (coulomb)	0.34	251.12	114.5	154.57	145.24	52.83	1112.5	298.49	3.72	1.78	126.19	0.6
Excel worksheet (Rankine)	0.35	251.12	105.5	158.38	155.97	27.5	1003.9	321.19	3.39	1.55	141.08	0.1
Excel worksheet (coulomb)	0.34	251.12	105.5	154.5	145.18	52.84	1105.3	298.38	3.92	1.55	119.85	0.0
RetainPro (Rankine)	0.35	300	114.5	166.82	164.29	36.67	1095.1	330.55	3.31	1.86	132.9	0.6
RetainPro (Coulomb)	0.34	300	114.5	161.71	159.26	34.77	1087.6	319.15	3.4	1.92	129.5	0.6

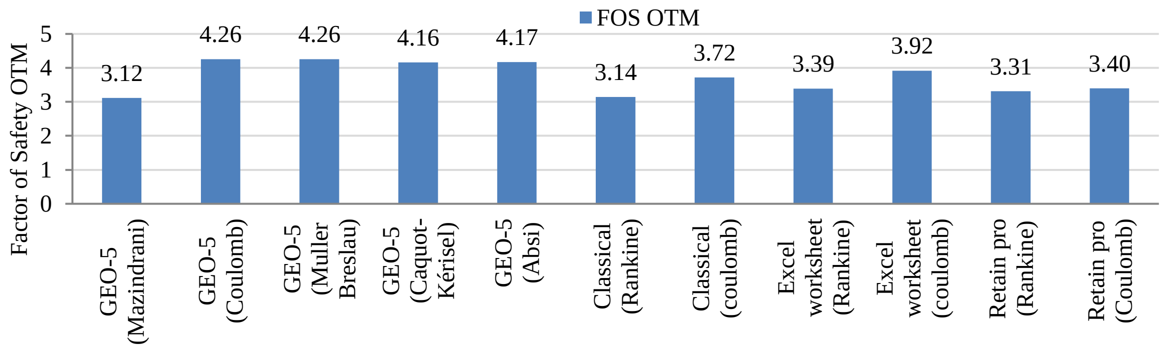


Fig 25 Graphical Representation of FOS OTM results by diff. Software (Model 1)

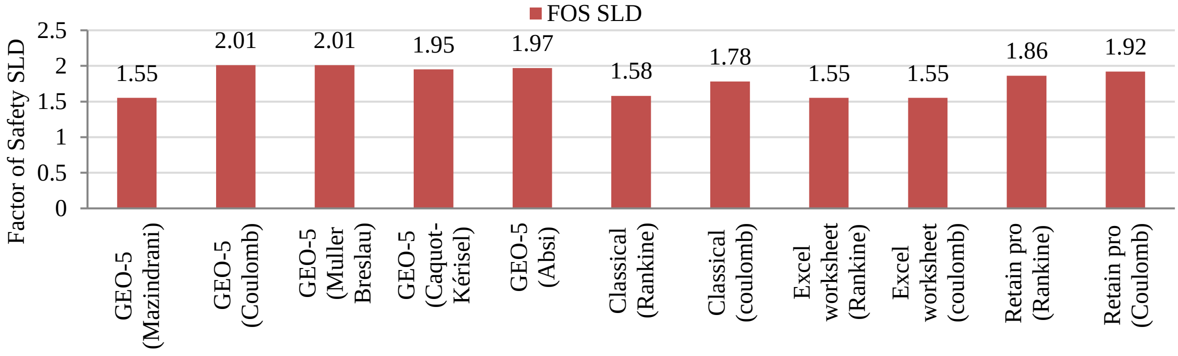


Fig 26 Graphical Representation of FOS SLD results by diff. Software (Model 1)

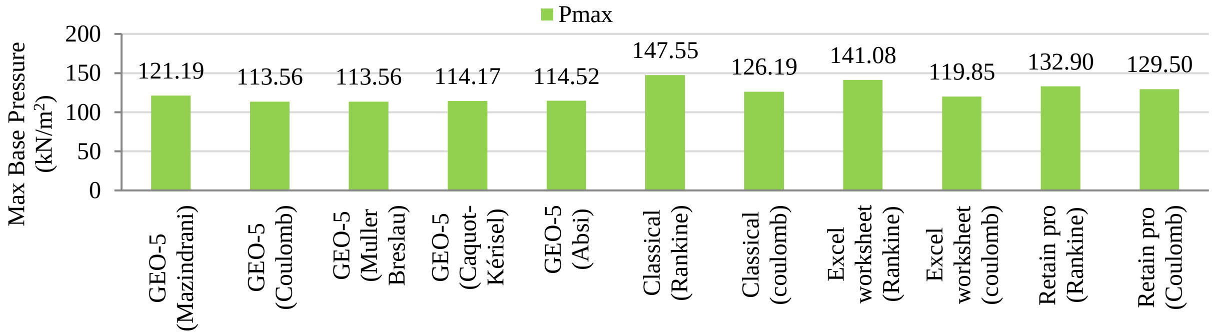


Fig 27 Graphical Representation of Max Base Pressure results by diff. Software (Model 1)

Model 2

Table 6 Data of Model 2

Wall Height, Hc	5.00 m
Depth below G, Df	1.00 m
Surcharge, q	10 kN/m^2
Backfill inclination, β	15 degree
GWT depth, Dw	0.0 m
Backfill	ϕ Single layer backfill
Unit weight, γ	18 kN/m^3
Cohesion, C	0 kN/m^2
Angle of internal friction, ϕ	30 deg
Angle of wall friction, δ	20 degree
SBC of soil	220 kN/m^2
Water density	10 kN/m^3
Coefficient of friction	0.5
Grade of Concrete	M20
Grade of Steel	Fe415

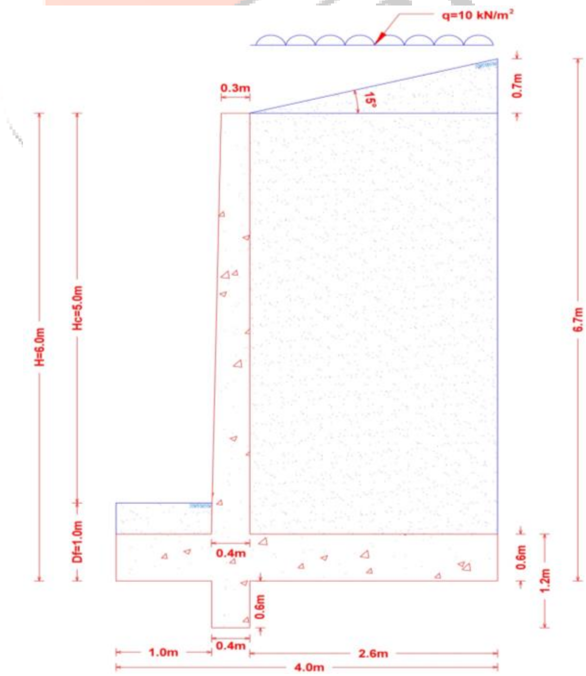


Fig 28 Geometry of Retaining wall (Model 2)

Table7 Results of Model 2 Using Different Softwares

Methods	Ka	wt of soil	wt of conc.	PA	PH	PV	MR	MO	FOS OTM	FOS SLD	Pmax	Key Ht.
Geo-5 (Mazindrani)	0.386	269.02	113.57	213.18	205.92	55.17	1190.2	418.17	2.85	1.6	139.29	0.6
Geo-5 (Coulomb)	0.376 0.371 0.371	269.02	113.57	206.14	183.34	94.21	1340.8	366.03	3.66	2.01	129.67	0.6
Geo-5 (Muller Breslau)	0.376 0.371 0.371	269.02	113.57	206.14	183.34	94.21	1340.8	366.03	3.66	2.01	129.67	0.6
Geo-5 (Caquot-Kérisel)	0.388 0.385 0.385	269.02	113.57	213.25	189.69	97.42	1352.6	377.78	3.58	1.94	131.33	0.6
Geo-5 (Absi)	0.386 0.374 0.374	269.02	113.57	210.57	187.22	96.35	1349.1	375.57	3.59	1.97	130.94	0.6
Classical (Rankine)	0.373	269.02	113.57	175.5	169.51	45.42	1170.3	405.33	2.88	1.56	166.8	0.6
Classical (coulomb)	0.371	269.02	113.57	174.58	164.05	59.7	1227.5	392.26	3.13	1.66	154.7	0.6
Excel worksheet (Rankine)	0.373	269.02	107.25	175.5	169.51	45.42	1163.1	405.33	2.87	1.55	163.52	0.2
Excel worksheet (coulomb)	0.371	269.02	107.25	174.58	164.05	59.7	1220.3	392.26	3.11	1.55	151.47	0.02
Reatain pro (Rankin)	0.373	275	113.5	176.44	170.43	40.27	1107.8	408.37	2.71	1.74	156.7	0.6
Reatain pro (coulomb)	0.371	275	113.5	176.45	170.44	38.89	1102.3	408.39	2.69	1.73	157.4	0.6
RETWALL	-	275	113.5	159.81	154.37	41.36	990.4	332.8	2.97	1.68	160	0.6

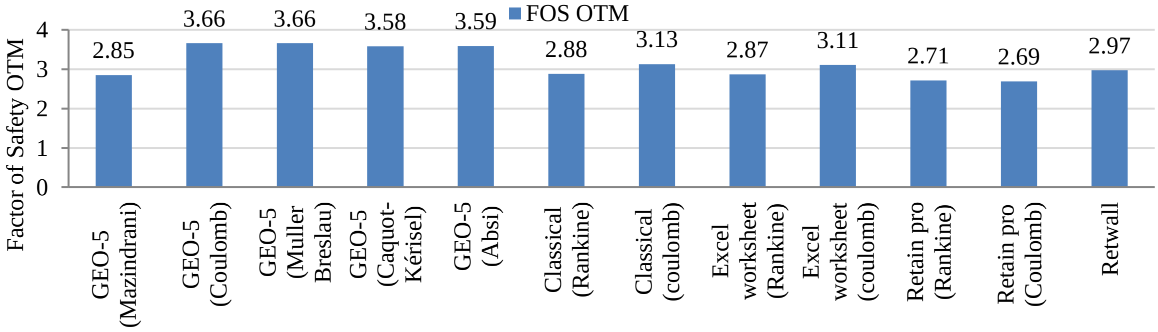


Fig 29 Graphical Representation of FOS OTM results by diff. Software (Model 2)

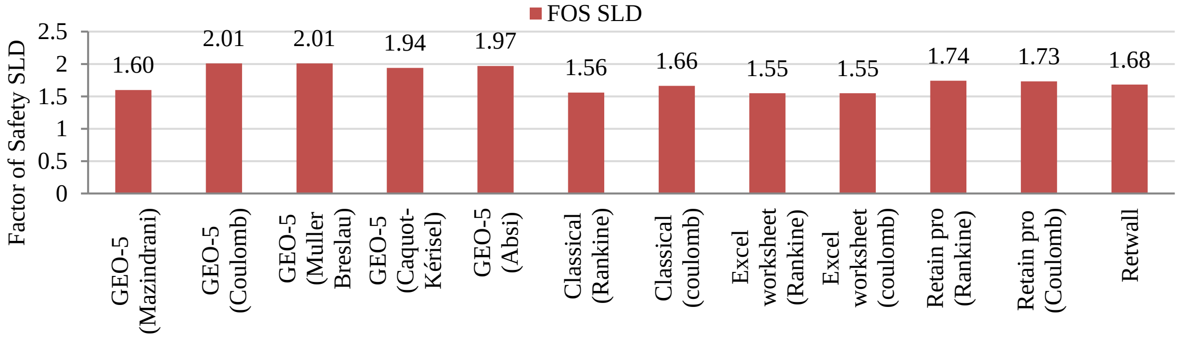


Fig 30 Graphical Representation of FOS SLD results by diff. Software (Model 2)

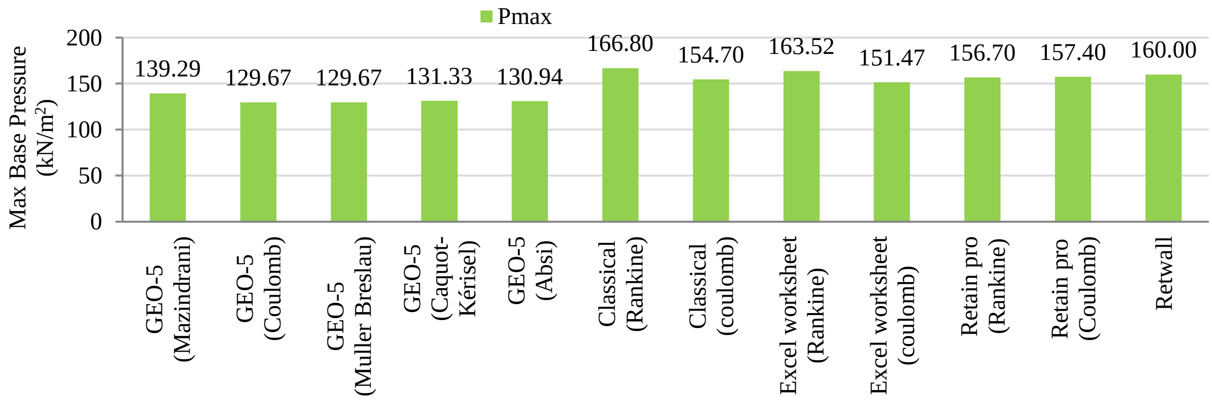


Fig 31 Graphical Representation of Max Base Pressure results by diff. Soft (Model 2)

VI. RESULT AND DISCUSSION

For Model 1 result among all earth pressure theories of Geo-5, Coulomb's and Muller Breslau theory gives higher FOS for overturning moment is 4.26 ≥1.55 and Mazindrani theory gives lesser FOS for sliding 1.55 ≥1.55. Among all softwares and their respective earth pressure theories, the most conservative maximum base pressure is 113.56 kN/m^2 which is obtained by Geo-5 software using Coulomb and Muller Breslau's earth pressure theory. For model 2 result among all earth pressure theories of Geo-5, Coulomb's and Muller Breslau theory gives higher FOS for overturning moment is 3.66 ≥1.55 and Mazindrani theory gives lesser FOS for sliding 1.6 ≥1.55. Among all softwares and their respective earth pressure theories, the most conservative maximum base pressure is 129.67 kN/m^2 which is obtained by Geo-5 software using Coulomb and Muller Breslau's earth pressure theory. So by using Mazindrani earth pressure theory the results obtained are as satisfactory as classical earth pressure theories.

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