ANALYSIS OF EMBEDDED RETAINING WALLS HAVING COMPACTED BACKFILLS NEAR BABU JAGJIWAN RAM MEMORIAL HOSPITAL AT JAHANGIR PURI, DELHI

MAJOR II REPORT ON

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS

FOR THE AWARD OF THE DEGREE

OF

MASTER OF TECHNOLOGY

IN

GEOTECHNICAL ENGINEERING

SUBMITTED BY:

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2K18/GTE/001

UNDER THE SUPERVISION OF

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DELHI TECHNOLOGICAL UNIVERSITY

NEW DELHI – 110042 JUNE-

2020

DELHI TECHNOLOGICAL UNIVERSITY, DELHI

CANDIDATE'S DECLARATION

I **, Abhimanyu Singh,** belonging to Master of Technology, Geotechnical Engineering, Delhi Technological University hereby certify that the work being presented in the minor entitled **"**ANALYSIS OF EMBEDDED RETAINING WALLS HAVING COMPACTED BACKFILLS NEAR BABU JAGJIWAN RAM MEMORIAL HOSPITAL AT JAHANGIR PURI, DELHI" in partial fulfillment for the award of degree of Master of Technology in the Geotechnical Engineering and submitted in the Department of Civil Engineering of Delhi Technological University, Delhi is an authentic record of my own work carried out under the supervision of Prof. Ashok Kumar Gupta, Department of Civil Engineering, Delhi Technological University, Delhi, India.

The matter presented in this minor has not been submitted by us for the award of any other degree in this or any other institution.

Abhimanyu

DATE: 30 JUNE 2020

ABHIMANYU SINGH (2K18/GTE/01)

This is to certify that the above statement made by the candidates is correct to the best of my knowledge and belief.

Supervisor

Prof. Ashok Kumar Gupta

Date: 30 JUNE 2020

CERTIFICATE

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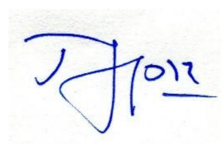
I hereby certify that the Project Dissertation titled **"**ANALYSIS OF EMBEDDED RETAINING WALLS HAVING COMPACTED BACKFILLS NEAR BABU JAGJIWAN RAM MEMORIAL HOSPITAL AT JAHANGIR PURI, DELHI"**,** belonging to Master of Technology, Geotechnical engineering, Civil Engineering Department, Delhi Technological University, Delhi in partial fulfillment of the requirement for the award of degree of Master of Technology, is a record of the project work carried out by the students under my supervision. To the best of my knowledge, this work has not been submitted in part or full for any Degree or Diploma to this University or elsewhere.



Place- Delhi **Prof. A.K Gupta**

Date: 30 JUNE 2020

ACKNOWLEDGEMENT

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We owe a debt of gratitude to my guide **Prof. AK Gupta** for incorporating in us the idea of a creative Minor Project, helping us in undertaking this project and for being there whenever we needed his assistance. We are immensely grateful to all those who have helped us in making this project better, by providing us their valuable comments and guidance.

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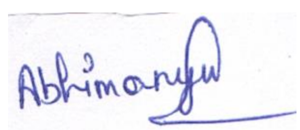

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ABSTRACT

Retaining walls have been widely constructed all over the world. In this study retaining walls behind the Babu Jagjiwan Ram Memorial hospital at Jahangir puri was considered under study. Properties of soil were assessed and classification was done. There were two retaining walls one behind the other separated by suitable distance. Influence of water table was also considered in the study. One retaining wall consisted of inclined backfill having a approximate slope angle of 30° and another retaining wall consisted of horizontal levelled levelled backfill. Surcharge load on the backfill was suitably considered by loads of different magnitudes on the upper and lower backfill.

It is being mentioned that the backfill in this study had already been compacted before the analysis. Plaxis 2D software is used for analysis considering 15 node strain criteria. Some of the material properties like cohesion value, angle of friction in case of sand were determined from soil testing in lab. Case history of the site and some other data like water table level, material properties was verified from respective Public Works Department Division, Division M-32, Sub division M-321. An attempt to analysis of retaining wall for stability for loading condition as on site using finite element analysis software PLAXIS 2D.

The analysis was carried out successfully and the results were found to be satisfactory and different distributions like deformations, stress , active pore pressure distribution are also plotted in this study to have a good insight into the analysis.

Chapter 1
INTRODUCTION

1.1 Retaining walls

Retaining walls are the earth retaining structures which are used to hold back a soil mass. Retaining walls, sheet pile walls, crib wall, sheetings in excavations, basement wall are examples of retaining structures. A retaining wall helps in maintaining the ground surface at different elevations on either side of it. Without such a structure, the soil at higher elevation would tend to move down till it acquires its natural stable configuration. Consequently, the soil that is retained at a slope steeper than it can sustain by virtue of its shearing strength, exerts a force called earth pressure. The Gravity earth retaining wall is the simplest type of retaining wall along with other types of retaining walls such as cantilever, and the counterfort walls.

Gravity retaining walls are made up of stone or concrete. Their stability depends on their own weight plus the weight of backfill it holds. Cantilever retaining walls are made of RCC and economical to a height of 8metres. Counterforts can be provided in cantilever retaing walls to reduce shear and bending moments which will then be called counterfort retaing walls. For design of retaining wall parameters like friction angle, unit weight, cohesion of soil must be known.

Walls of some retaining walls may be stabilized by reinforcing materials like bars, metal strips, geotextiles, mats and geogrids. These walls are flexible and can withstand substantial load without much damage. The design of structures like retaining wall requires the knowledge of the earth pressure acting on the backfill . This magnitude of earth pressure is itself a function of magnitude of absolute and relative movements of soil and the structure. Problems such as these, where a structure is in contact with the soil mass and the behavior of each one is influenced by that of the other, are classified as soil-structure interaction problems.

1.2 Stability of retaining walls

- Overturning about toe
- Sliding along base of wall
- Failure due to loss of bearing capacity
- Deep seated shear failure
- Exceeds allowable settlement

The Finite element method is an effective tool to describe the failure mechanism and deformation of reinforced soil with aditional advantage of good repeatability and low cost. Ling et al (1995) found out the performance of geosynthetic reinforced backfill using non linear elastic FEM and concluded the importance of geosynthetic layout and facing in reinforcement. Tatsuoka et al (1989) AND Tateyama (1980) made plane starins model fail by loading on wall crest**[12]**. They found that failure pattern of retaing walls was progressive with shear bands and peak footing loading was in direct proportion with the number of reinforcement layers. They also examined the effects of failure and deformation of reinforced retaining walls by the same results of FEM analyses.**[12]**. This shows that load deformation and strain fiels measured in model tests can be well simulated by FEM analysis.

1.3 Case History:

5% of tendered amount is deposited by the contractor in the favour of Executive Engineer. During the time of payments of bill this 5% money is held for a time period for atleast 2 years for Non- hydraulic stuctures and for atleast 5 years for hydrualic structures. Even in this case PG (performance guarantee) is to be held for a period of atleast 5 years.

1.4 Objective of this study:

Objective of the study is to carry the analysis of retaining wall by first assesing all the soil properties and other details . For this purpose finite element software will be used .

Performance Guarantee which is 5% of tender amount is held with the government so that structure should perform the intended function for the design period. In this study the retaining wall is analysed using finite element software PLAXIS 2D similar to actual site conditions to obtain defrmation pattern and failure pattern of retaining wall.

In this study the analysis is done by using a finite element analysis software, **PLAXIS 2D 8.6 Student Version** license.

1.5 Scope of this study:

With the boost in digital technology we don’t have to wait for the stipulated design period of the structure to check for stability. With the aid of finite element softwares we can analyse the structure even before the actual construction and loading on site. Software performs the intended iterations or similuations within the limits of boundary conditions fixed by the user. Stability of structures can be analysed by the user infinite number of times. With the help of stability analysis using finite element software we can analyse for stability in an instant in a number of clicks. This may give an opportunity to reduce the stipulated time for performance satisfaction to an extent.

Chapter 2

LITERATURE REVIEW

Different authors have carried out researches on th analysis of retaining walls of different types, material, different backfill, slopes and also the effect of vegetation roots on the slope stability. Various Numerical techniques have been used for analysis of retaining walls. Numerical techniques are used to find out deformation in retaining walls, generation of bending moments and carrying out slope stability with one click.

Sri Wulandr Paravita, Daniel Tjandra (2015) carried out the analysis of geotextile reinforced road embankments using a finite element software PLAXIS 2D. He founded out the optimum tensile strength of geotextile used as a reinforcement in road embankments with appropriate factor of safety and deformation. Three types of sequence modelling were done. First stability of road embankment without reinforcement. Second length of geotextile as a reinforcement. The last was to investigate tensile strength of geotextile reinforcement. The factor of safety increases with tensile strength of geotextile reinforcement.[14]

Ren Feifan et.al (2019) performed shaking table tests on reinforced soil retaining walls . this was a type of dynamic action on backfill of retaining walls. He considered combined effect os earthquake and rainfall to study the seismic performance . Five different cases were considered varying the degree of saturation for the model ground. Shaking table was shaken by a horizontal motion having a peak acceleartion of 0.5g. Some mechanical quantities like PWP, vertical and horizontal earth pressures, deformations, horizontal acceleration and reinforcement strain were monitered. RSRW (reinforced soil retaining wall) under unsaturated state had less deformations than those at saturated and dry phase. Also as water content increased horizontal displacement first increased then decreased.[9]

Zamiran Siavash et.al (2015) performed seismic analysis on the cantilever retaing walls with clayey backfills. A Mohr-Coulomb constitutive model was used study interaction between concrete wall and soil using elasto-plastic bilinear model. The results indicated upto 70% overestimation of lateral earth pressure for stem region. Walls having low value of friction angle had less lateral earth pressure comparable to pressure predicted by Mononabe Okabe's solution.[17]

Saran Swami, G. K Garg and R. K Bhandari (2015) analysed retaining wall with reinforced cohesionless backfill using limit equilibrium approach where reinforcements were in form of mats not jointed with wall. Stability was analysed considering a failure wedge and theoretical findings were verified with reinforced walls having bamboo and aluminium respectively as reinforcements.[13]

S. Ichikawa, N. Suemasa, T. Katada and Y. Toyosawa (2006) performed analysis of retaining walls using sliding block method asumming ductile behavior. Deformation of wall was predicted using sliding block method given by NewMark's method. The numerical results showed that displacements with sliding block method were in good agreement with the experiments though somewhat smaller. [12]

Yan-Bo Cao and Fang-Le Peng (2011) performed numerical study on effects of the number of reinforcement layers for reinforced sand retaining wall by simulating results of laboratory test resullts by non linear FEM analyses. The result showed that load-settlement relation given by FEM agree with the phyical experiments.[15] Also peak footing load found to increase with increment in no. of reinforcement layers even though tensile stiffness being same and FEM simulation done found to be reasonably accurate giving good load settlement characteristics.[16]

Fang le Peng et.al (2011) Performed finite element modelling simulation of strength and deformation in a retaining wall reinforced with geogrid under the variation of loading rate. Geogrids reinforces sand exihibit effects due to loading rates due to properties of both polymer geogrid and sand . He concluded that variation of loading rate on retaining wall can well simulated by FEM.[15]

Ashok K Chud et.al (2016) actually gone into deep that how soil interacts with retaining wall. He concluded that order of placement of fill in back and front of wall, construction seqence, properties of soil used in foundation affects the development of active and passive earth pressure. Soil structure interaction affects the soil response and soil supporting structure to an external loading . He also assumed soil to be a continuum not discrete. [4]

A. A. S Correia, M.L Lopes, M. I. M Pinto (2011) concluded a design method for brick-faced reinforced retaining wall using modified approach of both Coulomb's and Rankine's approach with other methods in which failure surfaces seemed to be planar, circular and bilinear in shape. The design methodology which was based on bilinear failure surfaces was found to be most suitable for internal stability of brick faced designed retaining walls reinforced with geosynthetics constructed on rigid ground.[7]

Xiong Zhang (1999) carried out the slope stability based on the finite element method. He incorporated the use of numerical analyses technique to find out the insight into the limit equilibrium which are now widely used for slope stability, retaining walls stability, excavations and embankments for comparison with rigid finite element method to overcome backlogs into limit equilibrium method . He considered slope to be made of a number of slices with some arbitary polyhedral shape connected by elastoplastic surfaces using non linear programming. He also calculated interslice forces and moments and adjusted them using Mohr Coulomb criterion to satisfy the overall force in a way such that the solution is statically and kinematically admissible.[18]

J.R Greenwood, J.E Norrisand and J. Wint (2004) founded that vegetation cover works as a direct reinforcement available from the root of plants is found to be providing of the most significant contributions to slope stability. He developed techniques for measuring tensile forces in roots. He tried to find out the pullout resistance to account for the uncertainities in force distribution in roots with depth.[10]

M.G Andersen et al. (2003) carried out extensive research from the results of slope stability analysis by considering factor of safety as 1. He visualized all the slip surfaces to find out the extreme potential slope instability. [3]

Timothy Stark D et.al (1997) carried out slope stability analysis in stiff fissured clay based on the results of direct shear tests, triaxial compression tests, torsional ring tests. He implied that shear strength is stress dependent and depends also on the type of caly mineral, fraction and effective normal stress. He also said that fully softened shear strength is presented as a function of clay size fraction, effective normal stress and liquid limit. This relation was used to estimate a secant fully softened friction angle that attributed to average effective normal stress on the critical slip surface.[8]

D Twine et.al (2010) performed analysis on performance and design of retaing walls. Embedded retaing walls were cut for a length of 1.8 km and cover tunnels . Designs that assumed that walls of top down structures would not crack during construction were found to be unduly conservative. Modelling relaxation gave reductions in calculated Bending moments. [15]

Conclusion: After reviewing the above works it can be concluded that finite element analysis can be suitably used for analysis of retaining walls, slope stability. Finite element analysis can also be used to study analysis of retaining walls which are subjected to ground acceleration. We also found out that slope failures can be avoided by providing reinforced or anchored retaining walls. Retaining walls can be analysed with different approaches like finite element method, limit equilibrium method sliding block method. Out of these finite element method gives most suitable but overestimated results. Also load settlement and various other responses were found to be in good agreement with the physical test results.

Chapter 3

CONCLUSIVE EXPERIMENTAL PROGRAMME

3.1 Assessing soil properties.

Soil properties was determined in laboratory to determine the condition and physical properties of soil chosen. The soil sample was taken from the site after scraping off the top layer. The natural water content was determined first. Then unit weight of the sample was determined. Sieve analysis was also be carried out to classify the soil sample. Proctor compaction test was done to determine the optimum moisture content and maximum dry density of the sample.

3.1.1 Water content

Physical examination of soil was done and soil appeared to be clay -silty. Natural water content of soil was determined as

Water content (ω) = $(W_2-W_3)*100/(W_3-W_1)$

Where W_1= weight of container= 0.905 gm

W_2= weight of container with moist sample = 10.821 gm

W_3= weight of container with dried sample = 9.986 gm

Thus

ω = (10.821-9.986)*100/(9.986-.905) = 9.10 %

3.1.2 Sieve analysis

Total Weight of Soil=500 gm

Table 1 For grain size distribution analysis of given soil.

Sieve size(mm)	Retained weight (gm)	Percentage weight retained (%)	Cumulative Percentage weight retained	Percentage finer
4.75	37.3	7.46	7.46	92.54

2.36	7.2	1.44	8.9	91.1
1.18	26.4	5.28	14.18	85.82
.60	61	12.2	26.38	73.62
.30	78.5	15.7	42.08	57.92
.15	28.7	5.74	47.82	52.18
.075	94.3	18.86	66.68	33.32
PAN	166.6	33.32	100	0

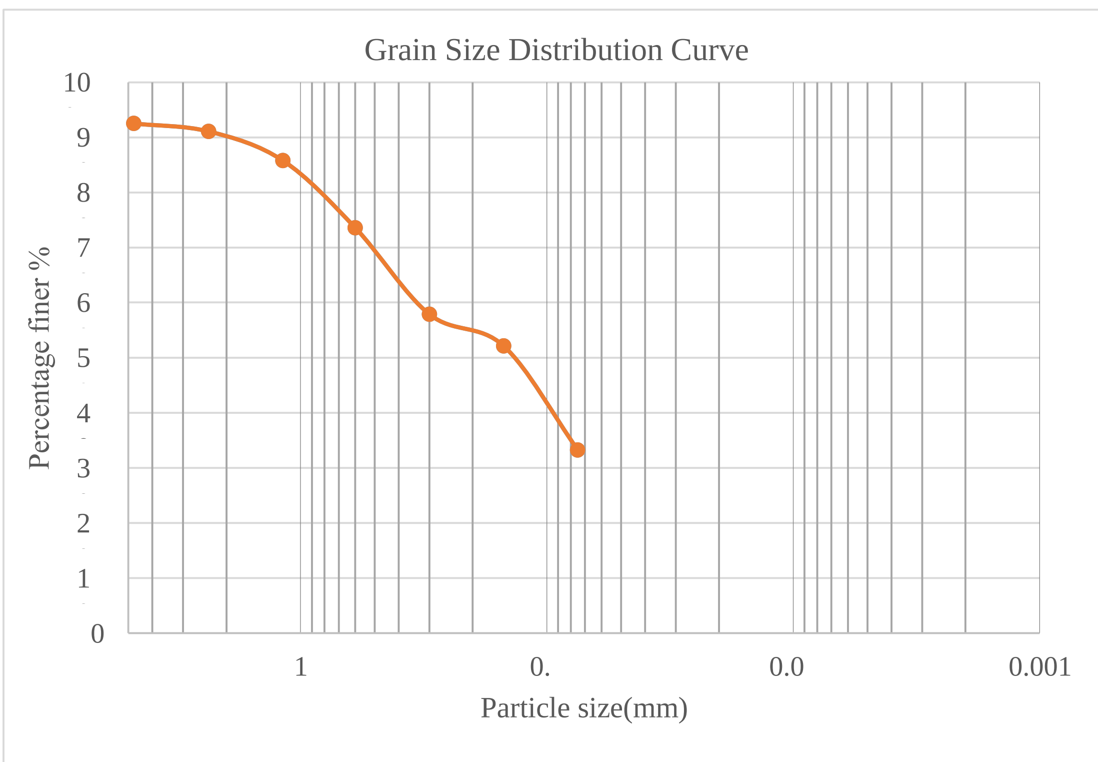

Fig 1: Grain size distribution curve

From the graph it is clear that it is not feasible to find D_{30} and D_{10} as most the particle size is below 75μ, So C_u and C_c couldn't be found.

3.1.3 Liquid Limit and Plastic Limit Test on soil sample:

Liquid limit test was done on the soil sample and water content corressponding to 25 number of blows on the casagrande apparatus at the rate of 2 revolutions per minute was noted.

Tabel 2 : For determination of liquid limit

S.NO	1	2	3	4	5
Moisture content	37.31	35	37	43	68.42
No Of blows	34	33	30	27	12

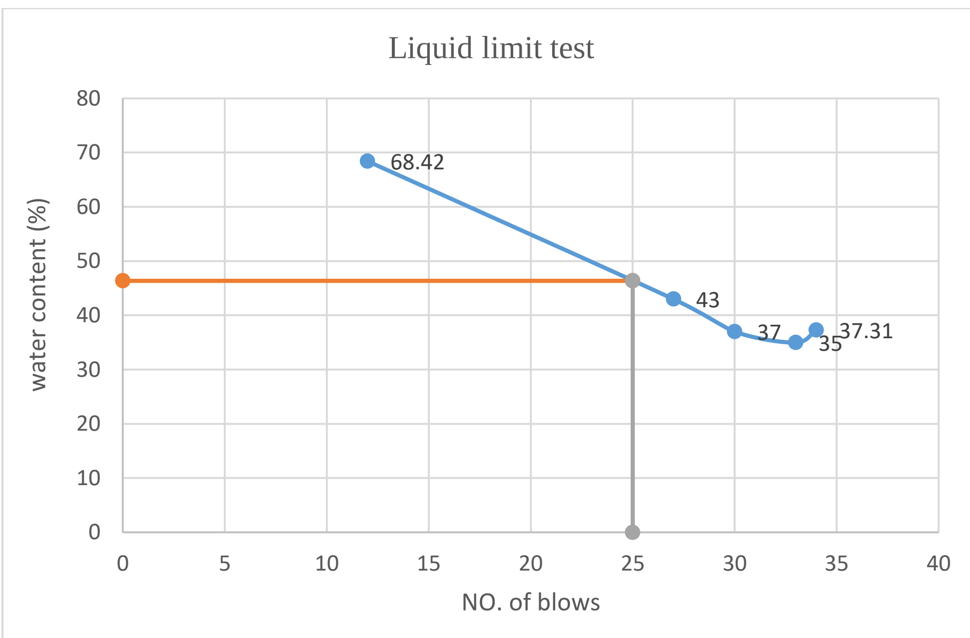

Fig 2: Liquid limit test

From the graph it is clear that the liquid limit of clay soil is 46.38 %

Plastic Limit of the soil was found to be 24% when 3mm thread of soil started crumbling.

3.1.3 Standard Proctor Test:

Table 3: For determination of max. dry density and optimum moisture content for clay sample

Weight of mould + base plate (gm)	Weight of mould + base plate+soil (gm)	Weight of soil (gm)	Bulk Density(gm/cc) ɣ	Water Content(%) ω	Dry densities (gm/cc) $ɣ_d$
4210	5826	1616	1.616	4.5	1.546
4210	5843	1633	1.633	6.8	1.529
4210	5958	1748	1.748	8.4	1.612
4210	6047	1837	1.837	9.8	1.673
4210	5933	1723	1.723	10.9	1.553

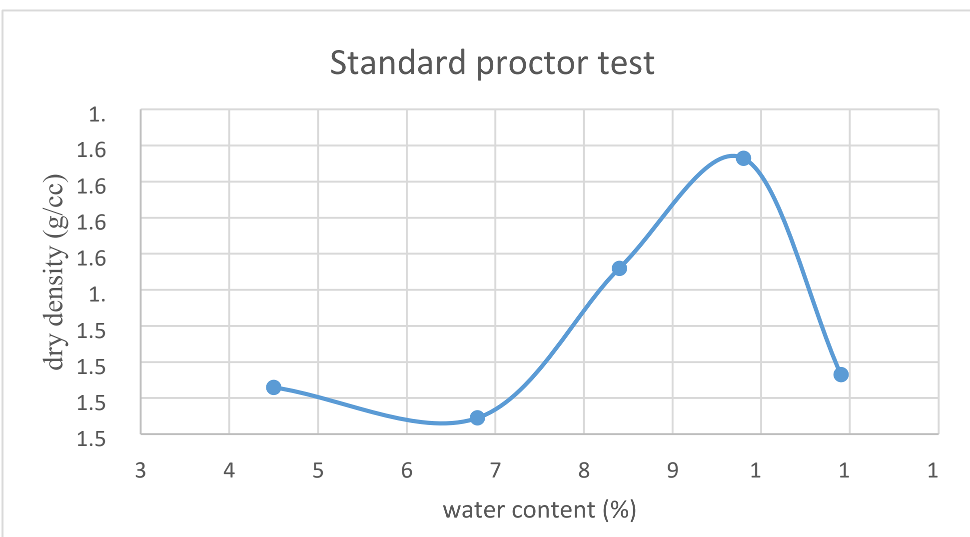

Fig 2: Compaction curve of given clay soil sample

3.1.4 Specific Gravity Test on soil:

Pycnometer was used to calculate specific gravity test on sand sample. Pycnometer ia approximately 900 ml capacity glass bottle provided with a conical top. A conical cap provided with a 6mm diameter hole at the top can be screwed on to glass bottle.

Specific gravity $G_s = (W_2-W_1) / ((W_2-W_1)-(W_3-W_4))$

W_1= weight of empty pycnometer= 685 gm

W_2= weight of pycnometer + soil sample =1068 gm

W_3 = weight of pycnometer+ soil + water= 1814 gm

W_4 = weight of pycnometer+ water only= 1580 gm

$$G_s = \frac{(1068-685)}{(1068-685)-(1814-1580)} = 2.57$$

3.1.5 Direct shear tests:

Direct shear test was done on soil sample to study the shear strength and shear strength parameters. Constant Normal load was changed for each trial of test. IS 2720 Part 13 was used for calculation of results

Table 4: Direct shear test on Clay sample

Normal stress (KN/m^2)	Displacement (cm)	Aj (cm^2) Effective area of shear	Load (N)	Shear Stress (KN/m^2) x 10^{-3}
50	0.383	35.54	0.0128	3.60
100	0.379	31.452	0.0188	5.977
150	0..327	32.076	0.0133	4.146

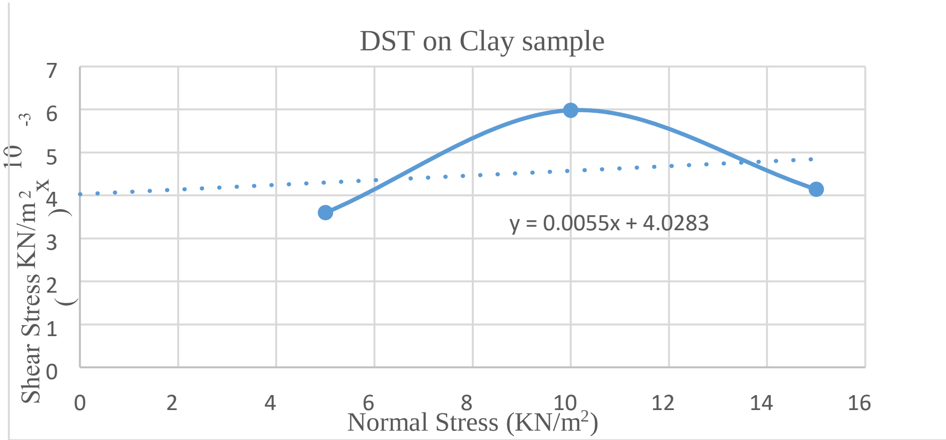

Fig 3: Direct shear test on clay sample

From graph $c_1 = 4.02$ KN/m^2 and $\varphi_1 = 4°$

Table 5: Direct shear test on sand sample

Normal stress (KN/m^2)	Displacement (cm)	Aj (cm^2) Effective area of shear	Load (N)	Shear Stress (KN/m^2) x 10^{-3}
50	0.304	32.352	0.0133	4.11
100	0.389	31.332	0.0300	9.57
150	0..277	32.676	0.0348	10.65

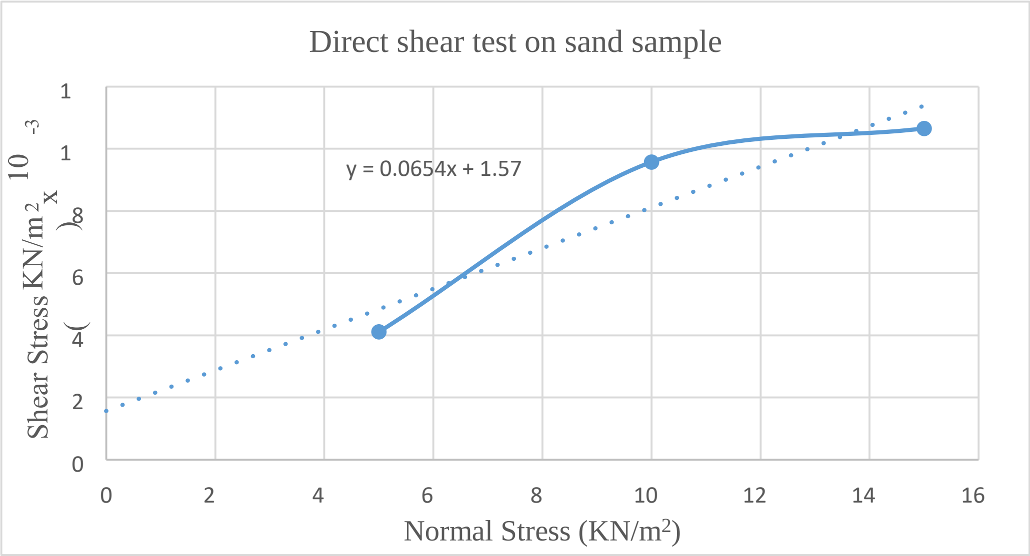

Fig 4: Direct shear test on sand

From graph c_2 = 1.57 KN/m^2 and φ_2 = 22°

3.1.6 Site Measurements

Actual site condition is shown below

Fig 5: Slope of backfill

Slope was measured on site using inch tapes in two directions

Fig 6: In horizontal direction **Fig 7: In Vertical Directions**

Tan θ= 6/10=0.6 θ ~ 30°

There existed two retaining walls back to back separated by suitable distance apart. Also height of front portion of retaining walls was measured by using a inch tape as shown in figure below.

Fig 8: Measurement of height of front wall

CHAPTER 4

Software Modelling and Results

4.1 Plaxis 2D Software

We will try to replicate the soil model on Plaxis 2D software and try to apply loading in sequential steps taking one element at a time and will use **φ/c** reduction technique till the stucture fails . The loading and other site conditions were verified from the site engineer. The φ/c value of soil will be lowered at each step. In this way the structure can be checked for stability for material failure, structure collapse etc.

For analysis of retaining wall Plaxis 2D software was used . Plaxis is a finite element package ntended for the two-dimensional analysis of deformation and stability in geotechnical engineering. Geotechnical applications require advanced constitutive models for the simulation of the non-linear time-dependent and anisotropic behavior of soils and/or rocks. In addition, since soil is a multi-phase material, special procedures are required to deal with hydrostatic and non-hydrostatic pore pressures in the soil. Although the modelling of the soil itself is an important issue, many tunnel projects involve the modelling of structures and the interaction between the structures and the soil. Plaxis is equipped with features to deal with various aspects of complex geotechnical structures.

The actual site dimensions was modelled in Plaxis as shown in figure

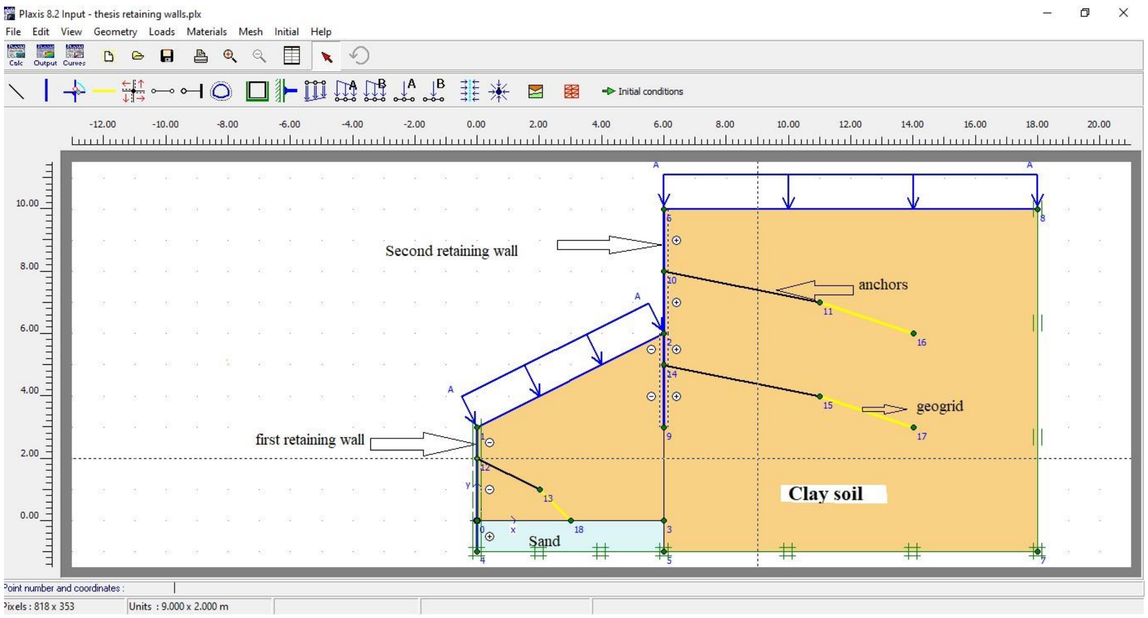

Fig 9:Model showing actual site conditions

Water table was approximately 1m below the front retaining wall as shown

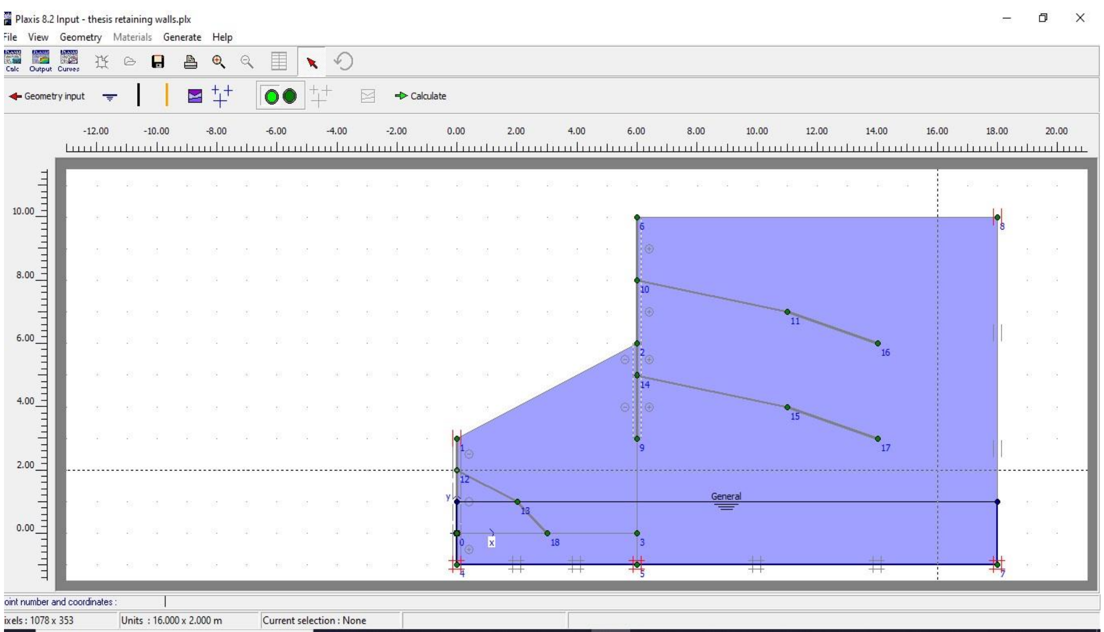

Fig 10: Water table level in the model

15 node analysis is used in this study

The effective stresses mesh generated is shown below

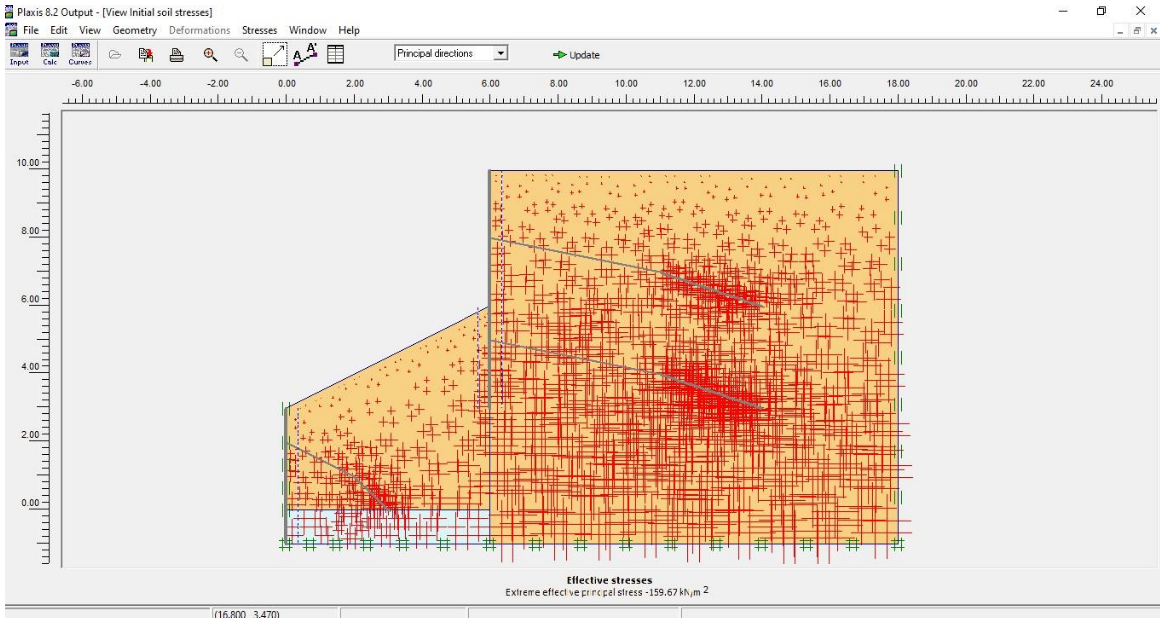

Fig 11: Showing effective stresses distributions before analysis

4.2 Output of Analysis

The output of the analysis for different parameters are shown below

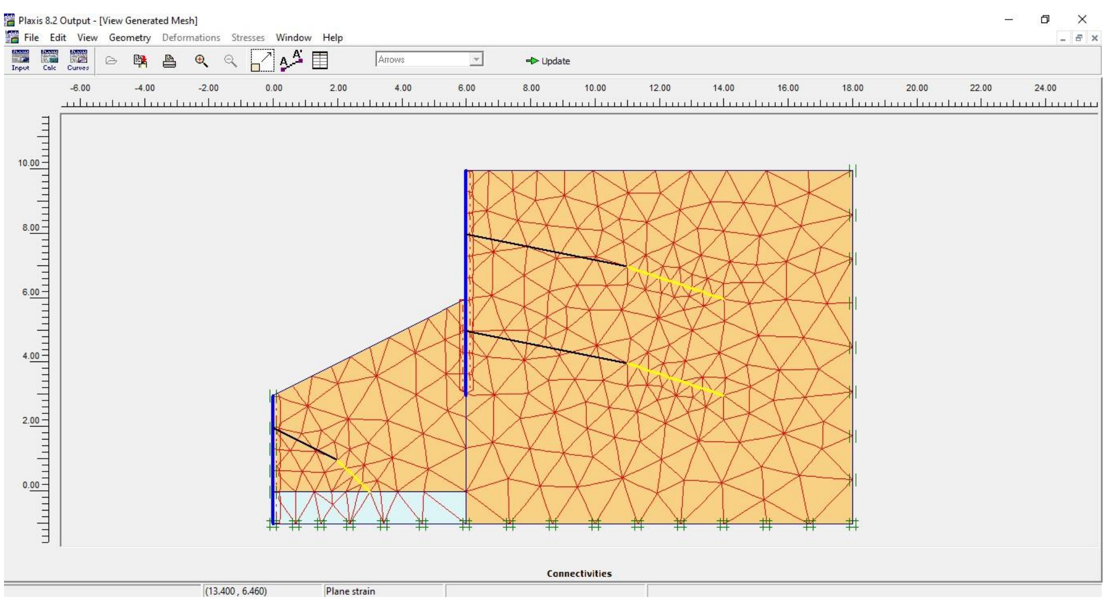

Fig 12: Mesh genearated before analysis

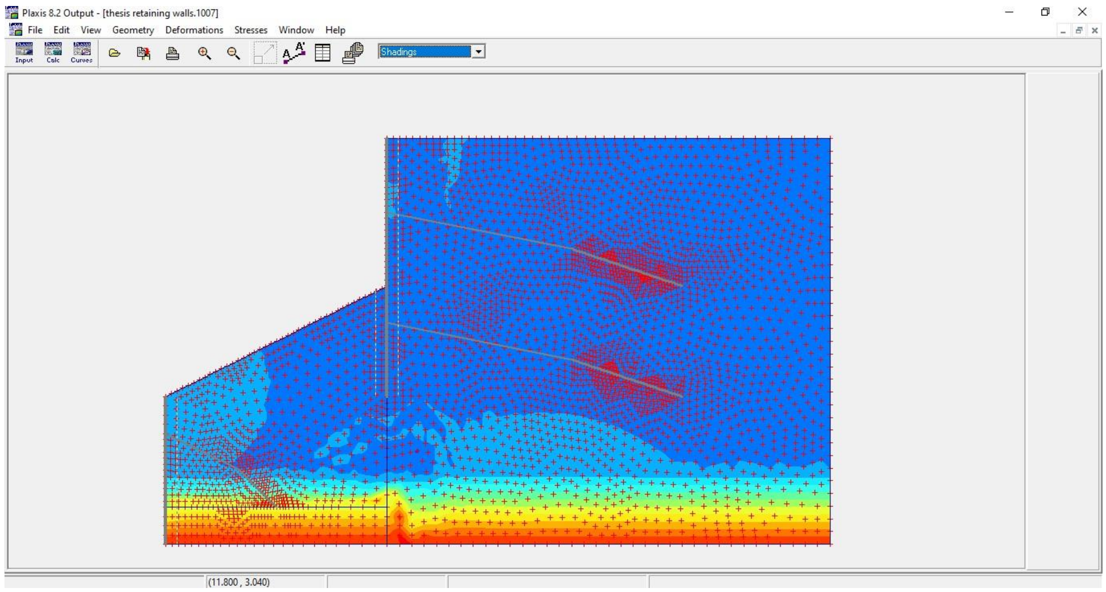

Fig 13: Active Pore pressure distribution after analysis

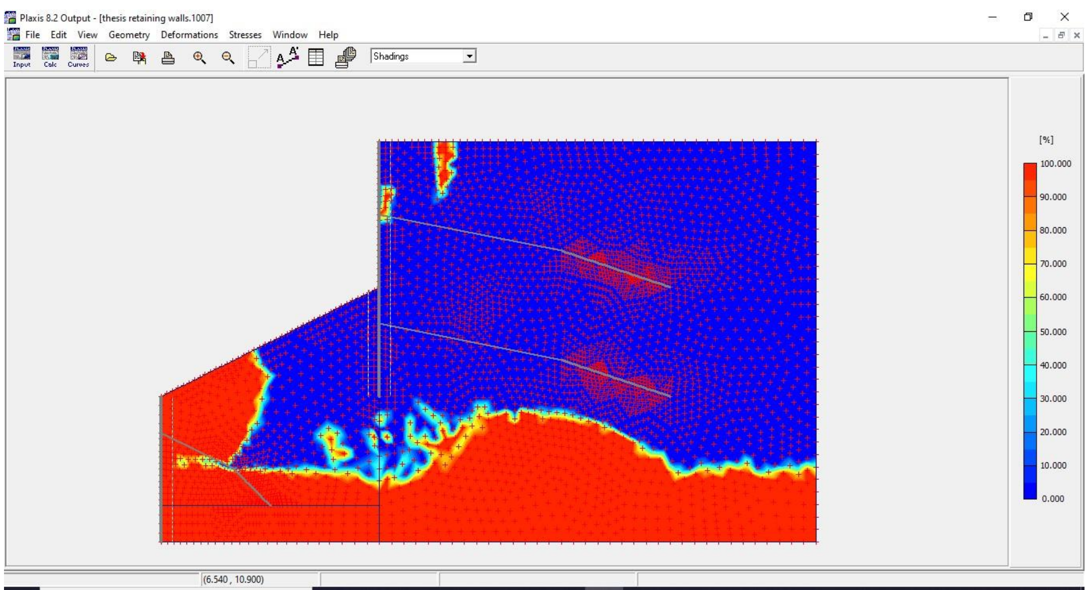

Fig 14: Degree of saturation distribution after analysis

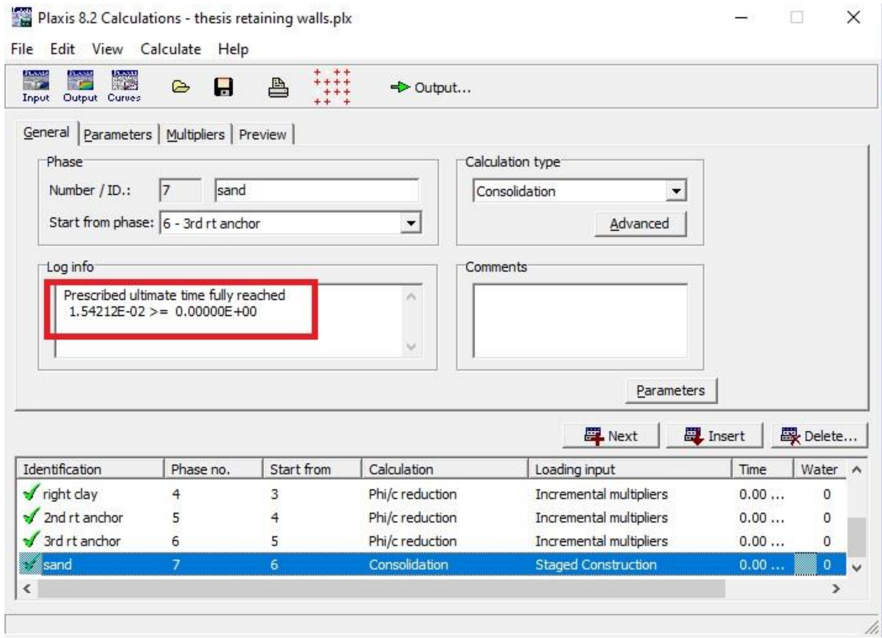

Fig 15: Showing stability results after analysis

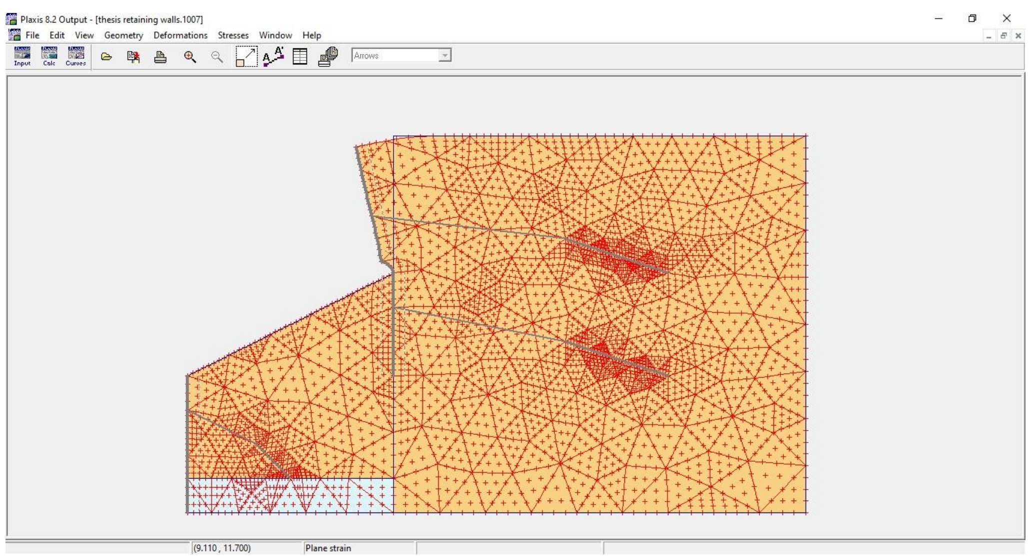

Fig 16: Deformed mesh after analysis

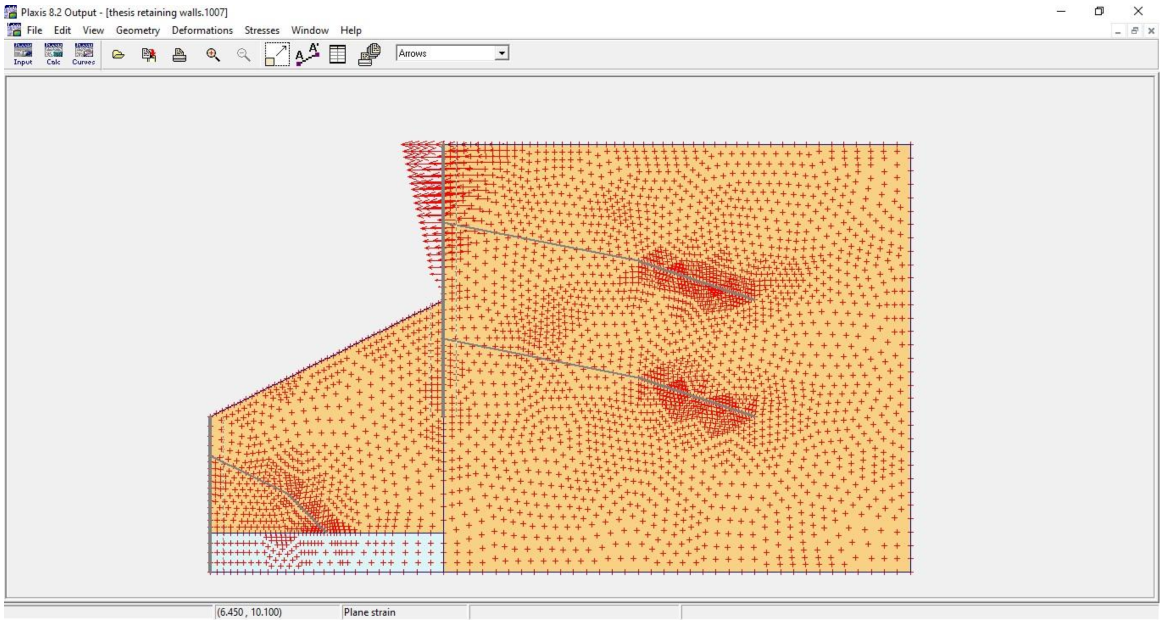

Fig 17: Horizontal displacements after analysis

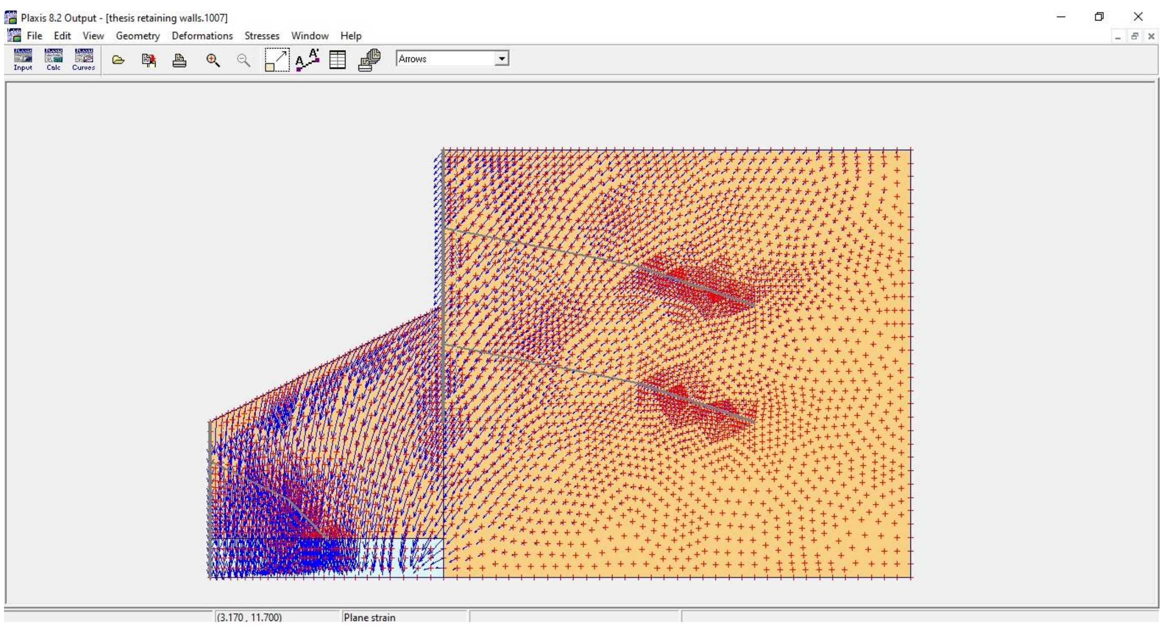

Fig 18: Phase displacemens

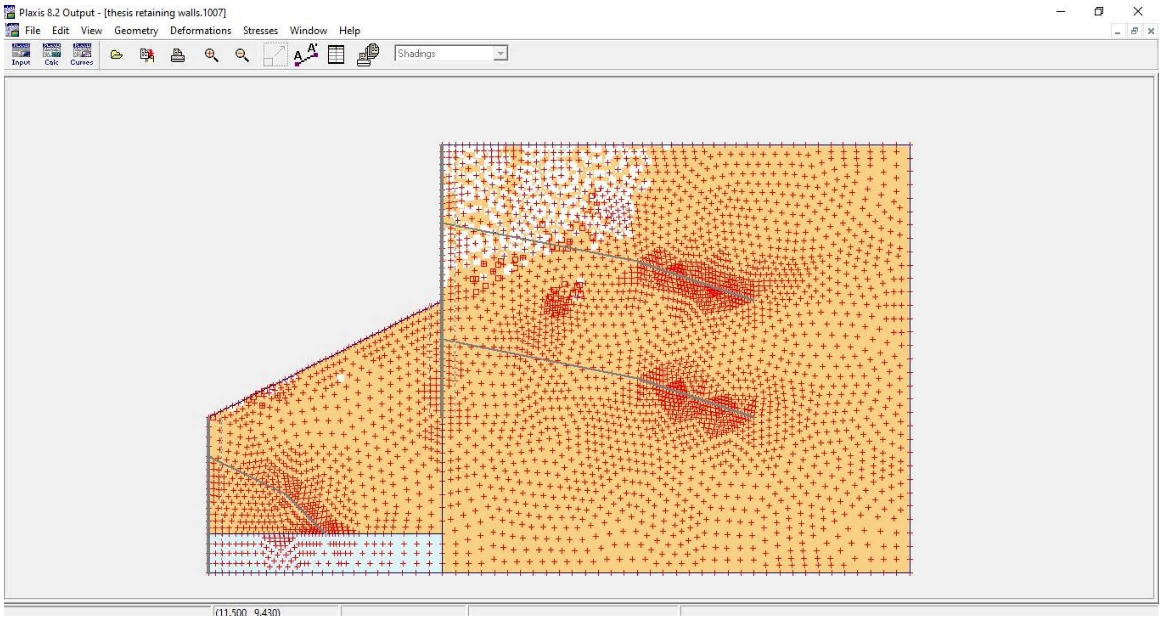

Fig 19: Plastic points distribution

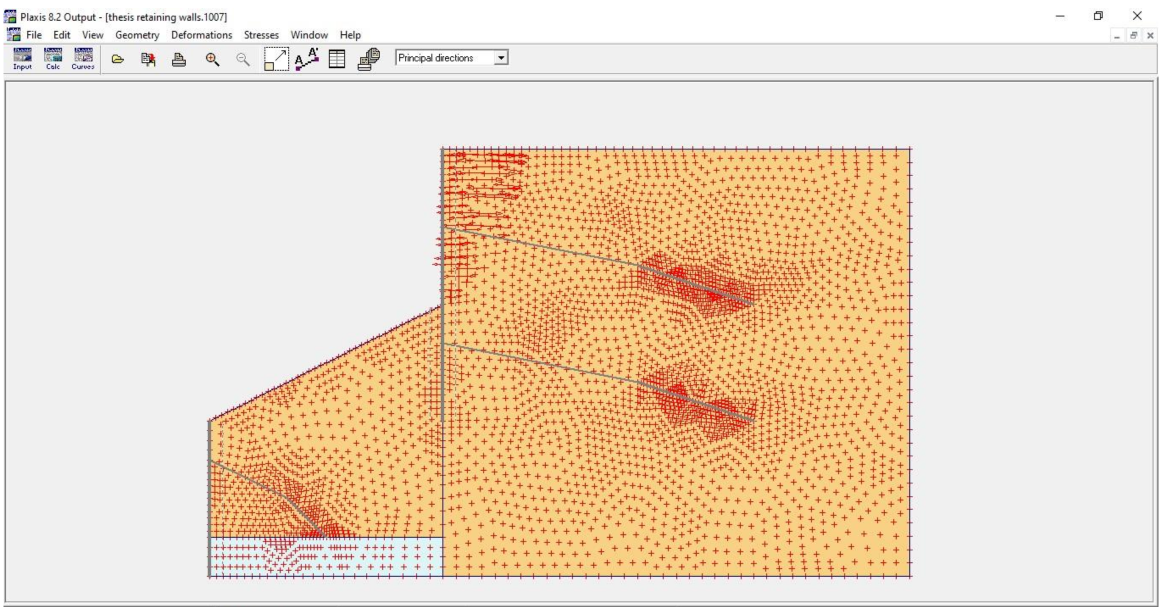

Fig 20 :Total strains after analysis

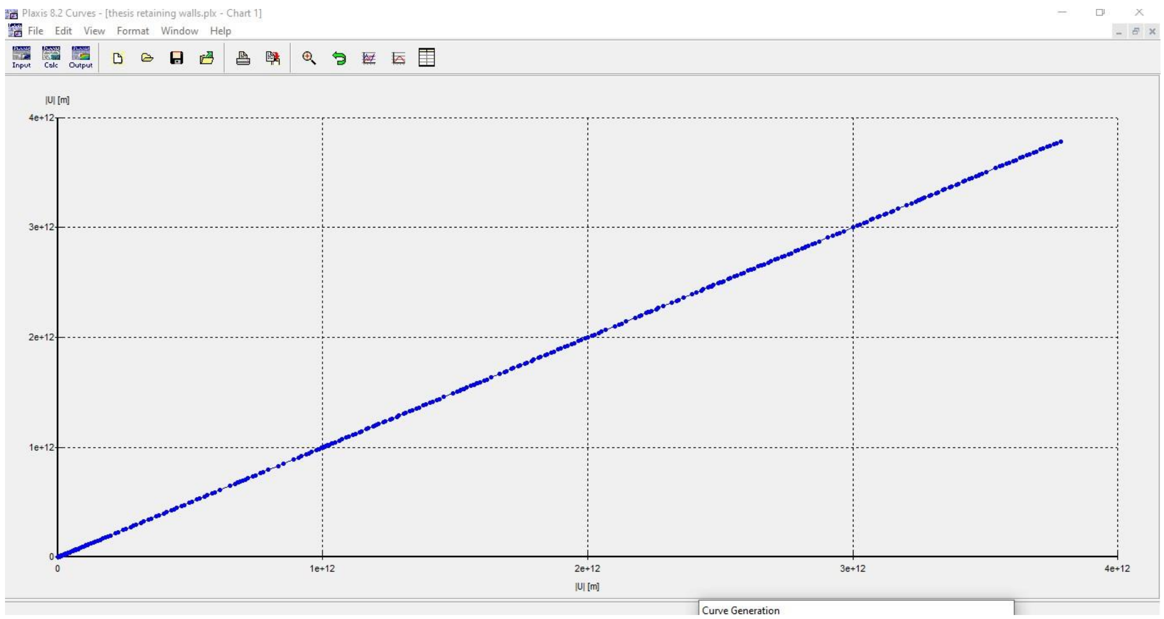

Fig 21 Curve of Displacements in Y directions vs displacements in X direction

4.3 Software Analysis Report

4.3.1. General Information

Table 5: Units

Type	**Unit**
Length	m
Force	kN day
Time	

Table 6: Model dimensions

	min.	max.
X	0.000	18.000
Y	-1.000	10.000

Table 7: Model

Model	Plane strain
Element	15-Noded

4.3.2. Geometry

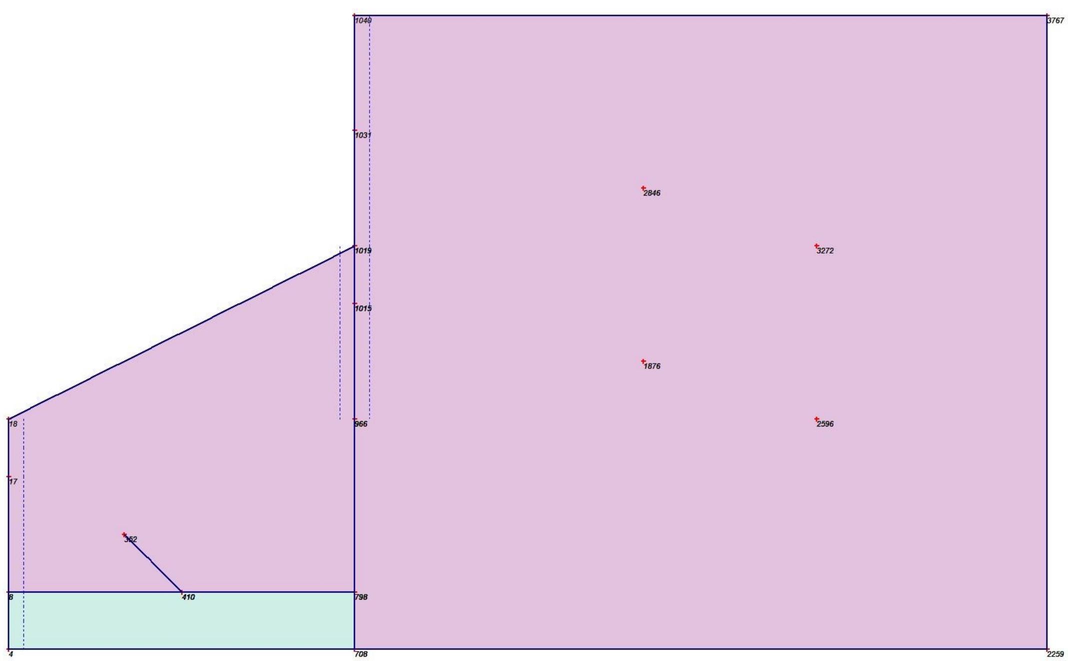

Fig. 22: Plot of geometry model with significant nodes

Table 8: Table of significant nodes

Node no.	x-coord.	y-coord.	Node no.	x-coord.	y-coord.
8	0.000	0.000	1031	6.000	8.000
18	0.000	3.000	2846	11.000	7.000
1019	6.000	6.000	17	0.000	2.000
798	6.000	0.000	352	2.000	1.000
4	0.000	-1.000	1015	6.000	5.000
708	6.000	-1.000	1876	11.000	4.000
1040	6.000	10.000	3272	14.000	6.000
Node no.	**x-coord.**	**y-coord.**	**Node no.**	**x-coord.**	**y-coord.**
2259	18.000	-1.000	2596	14.000	3.000
3767	18.000	10.000	410	3.000	0.000
966	6.000	3.000			

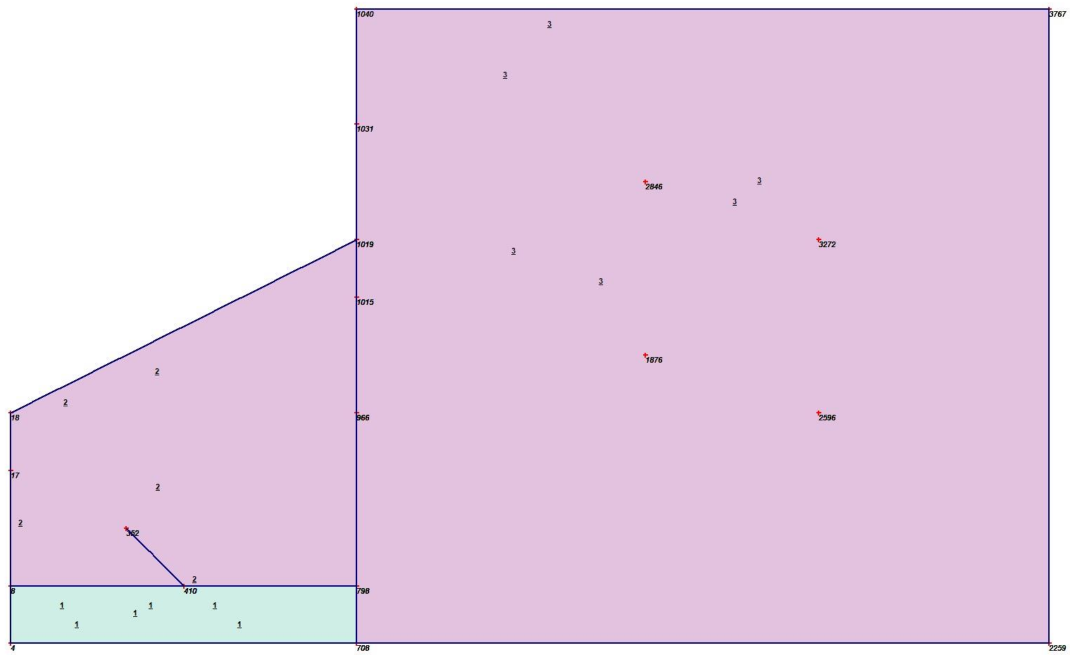

Fig. 23 Plot of geometry model with cluster numbers

Table 9: Table of clusters

Cluster no.	Nodes
1	8, 798, 4, 708, 410.
Cluster no.	**Nodes**
2	8, 18, 1019, 798, 966, 17, 352, 1015, 410.
3	1019, 798, 708, 1040, 2259, 3767, 966, 1031, 2846, 1015, 1876, 3272, 2596.

3. Structures

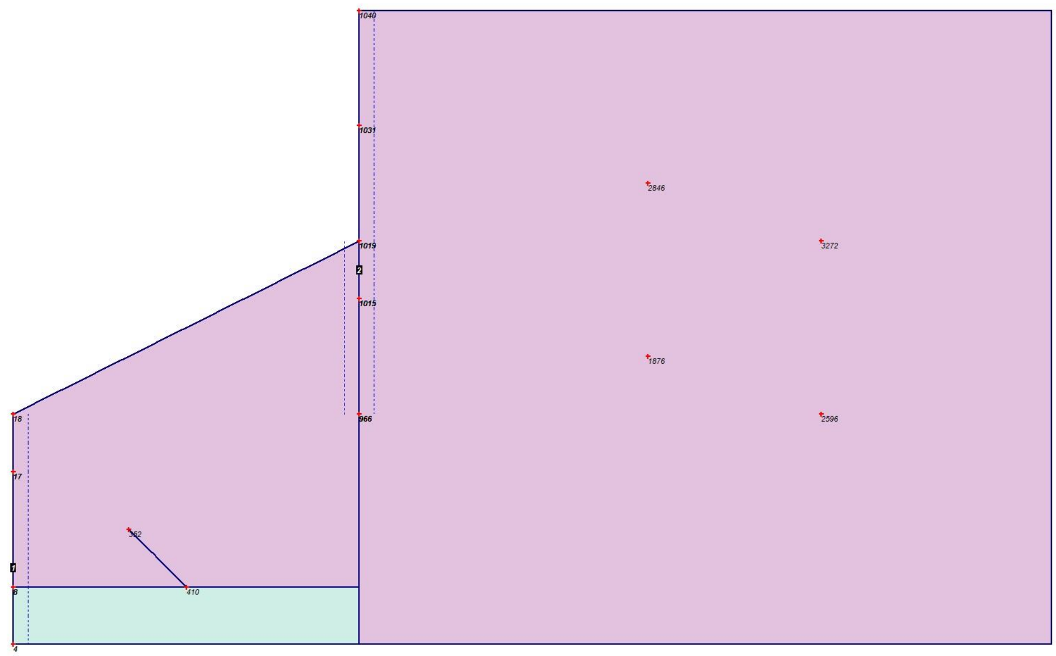

Fig. 24: Plot of geometry model with structures

Table 10: Beams

Plate no.	Data set	Length [m]	Nodes
1	Lesson 2 - Diaphragm wall	4.000	8, 8, 17, 18.
Plate no.	**Data set**	**Length [m]**	**Nodes**

2	Lesson 2 - Diaphragm wall	7.000	1015, 1019, 1031, 1040,

Table 11: Geotextiles

Geotextiles no.	Data set	Length [m]	Nodes
1	Lesson 4 - Grout body	3.162	2846, 3272.
2	Lesson 4 - Grout body	3.162	1876, 2596.
3	Lesson 4 - Grout body	1.414	352, 410.

Table 12: Interfaces

Interface no.	Data set	Nodes
1	Lesson 1 - Sand	8, 4.
	Lesson 2 - Clay	17, 8, 18, 17.
2	Lesson 2 - Clay	1015, 1019, 966, 1015.
	Lesson 2 - Clay	1040, 1031, 1031, 1019, 1019, 1015, 1015, 966.

Table 13: Node-to-node anchors

Anchor no.	Data set	Length [m]	First node	Last node
1	Lesson 4 - Anchor rod	5.099	1031	2846
2	Lesson 4 - Anchor rod	5.099	1015	1876
3	Lesson 4 - Anchor rod	2.236	17	352

4.3.4. Loads & boundary conditions

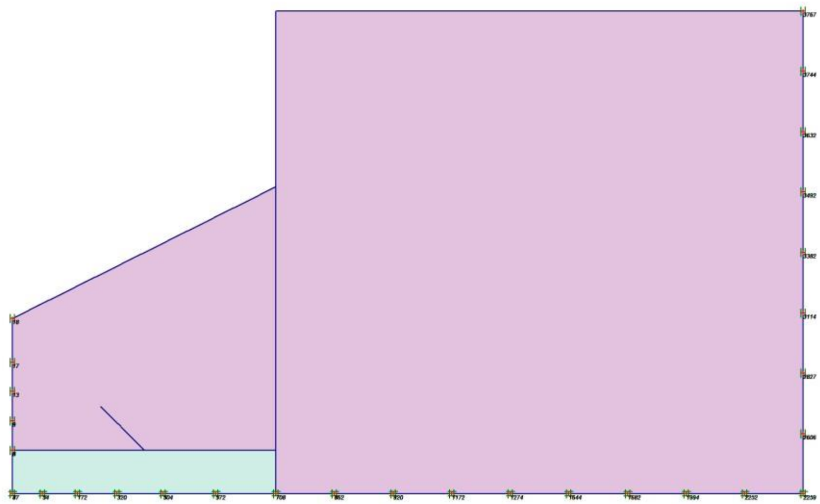

Fig. 25 Plot of geometry with loads & boundary conditions

Table 14: Node fixities

Node no.	Sign	Horizontal	Vertical	Node no.	Sign	Horizontal	Vertical
4	#	Fixed	Fixed	1994	#	Fixed	Fixed
708	#	Fixed	Fixed	2252	#	Fixed	Fixed
2259	#	Fixed	Fixed	8	||	Fixed	Free
37	#	Fixed	Fixed	18	||	Fixed	Free
54	#	Fixed	Fixed	3767	||	Fixed	Free
172	#	Fixed	Fixed	9	||	Fixed	Free
320	#	Fixed	Fixed	13	||	Fixed	Free
504	#	Fixed	Fixed	17	||	Fixed	Free

572	#	Fixed	Fixed	2606	||	Fixed	Free
862	#	Fixed	Fixed	2827	||	Fixed	Free
920	#	Fixed	Fixed	3114	||	Fixed	Free
1172	#	Fixed	Fixed	3382	||	Fixed	Free
Node no.	**Sign**	**Horizontal**	**Vertical**	**Node no.**	**Sign**	**Horizontal**	**Vertical**
1274	#	Fixed	Fixed	3492	||	Fixed	Free
1644	#	Fixed	Fixed	3632	||	Fixed	Free
1682	#	Fixed	Fixed	3744	||	Fixed	Free

Table 15: Distributed loads A

Loads no.	First node	qx [kN/m/m]	qy [kN/m/m]	Last node	qx [kN/m/m]	qy [kN/m/m]
1						
2	3767	0.000	0.000			

4.3.5. Mesh data

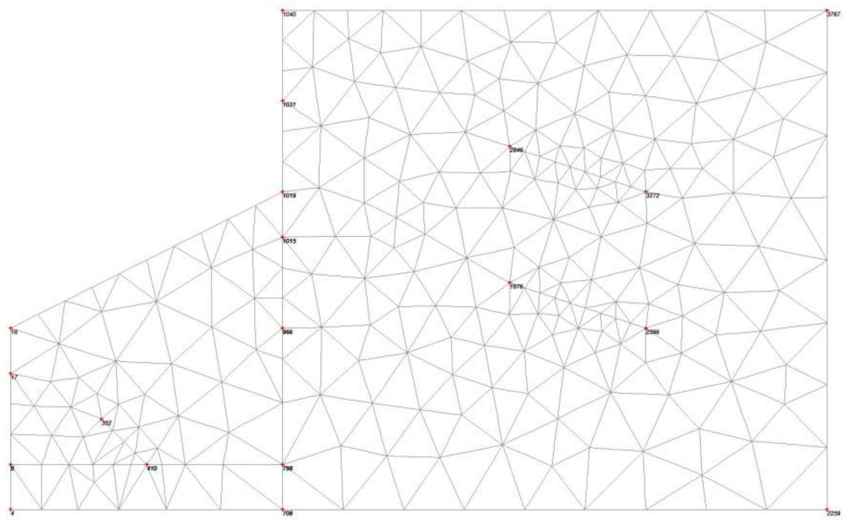

Fig. 26: Plot of the mesh with significant nodes

Table 16: Numbers, type of elements, integrations

Type	Type of element	Type of integration	Total no.
Soil	15-noded	12-point Gauss	450
Plate	5-node line	4-point Gauss	15
Geogrid	5-node line	4-point Newton-Cotes	22
Interface	5-node line	4-point Newton-Cotes	19

4.3.6. Material data

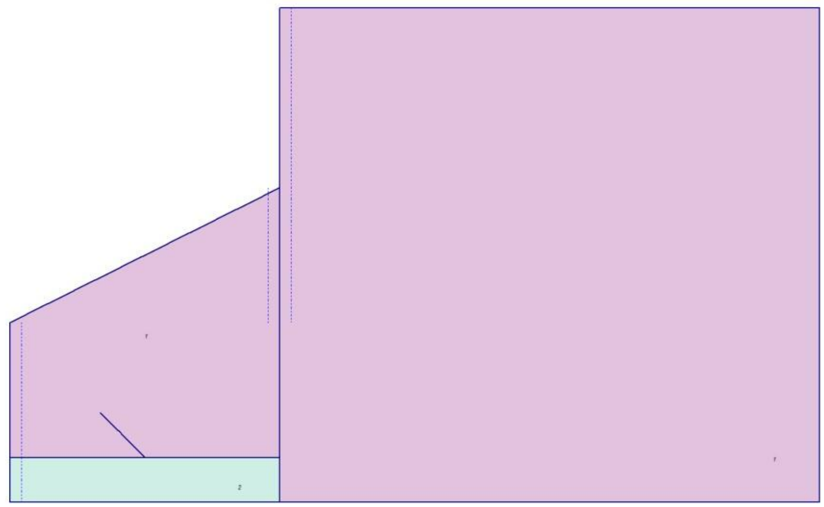

Fig. 27 Plot of geometry with material data sets

Table 17: Soil data sets parameters

Mohr-Coulomb		**1** **Lesson 2 - Clay**	**2** **Lesson 1 - Sand**
Type		Drained	Undrained
g_{unsat}	[kN/m³]	16.00	17.00
g_{sat}	[kN/m³]	18.00	20.00
k_x	[m/day]	0.001	1.000
k_y	[m/day]	0.001	1.000
e_{init}	[-]	1.000	1.000
c_k	[-]	1E15	1E15
E_{ref}	[kN/m²]	10000.000	13000.000
n	[-]	0.350	0.300
G_{ref}	[kN/m²]	3703.704	5000.000

Mohr-Coulomb		1 Lesson 2 - Clay	2 Lesson 1 - Sand
E_{oed}	[kN/m²]	16049.383	17500.000
c_{ref}	[kN/m²]	4.02	1.57
j	[°]	4.00	22.00
y	[°]	0.00	0.00
E_{inc}	[kN/m²/m]	0.00	0.00
y_{ref}	[m]	0.000	0.000
$c_{increment}$	[kN/m²/m]	0.00	0.00
$T_{str.}$	[kN/m²]	0.00	0.00
$R_{inter.}$	[-]	0.50	1.00
Interface permeability		Neutral	Neutral

;

Table 18: Beam data sets parameters

No.	Identification	EA [kN/m]	EI [kNm²/m]	w [kN/m/m]	n [-]	Mp [kNm/m]	Np [kN/m]
1	Lesson 2 - Diaphragm wall	7.5E6	1E6	10.00	0.00	1E15	1E15

Table 19: Geotextile data sets parameters

No.	Identification	EA [kN/m]	n [-]
1	Lesson 4 - Grout body	100000.00	0.00

Table 20: Anchor data sets parameters

No.	Identification	EA [kN]	|Fmax,comp| [kN]	|Fmax,tens| [kN]	L spacing [m]
1	Lesson 4 - Anchor rod	200000.00	1E15	1E15	2.50

4.3.7. Calculation phases

Table 21 List of phases

Phase	Ph-No.	Start phase	Calculation type	Load input	First step	Last step
initial phase	0	-1	Plastic	-	0	0
walls and loads	1	0	Phi/c reduction	Incremental multipliers	1	100
left clay	2	1	Phi/c reduction	Incremental multipliers	101	200
1st anchor	3	2	Phi/c reduction	Incremental multipliers	201	300
right clay	4	3	Phi/c reduction	Incremental multipliers	301	400
2nd rt anchor	5	4	Phi/c reduction	Incremental multipliers	401	500
3rd rt anchor	6	5	Phi/c reduction	Incremental multipliers	501	600
sand	7	6	Consolidation	Staged Construction	601	1007

Table 22: Staged construction info

Ph-No.	Active clusters	Inactive clusters	Active beams	Active geotextiles	Active anchors
0	1, 2, 3.				

Table 23: Control parameters 1

Ph-No.	Additional steps	Reset displacements to zero	Ignore undrained behaviour	Delete intermediate steps
1	100	No	No	No
2	100	No	No	No
3	100	No	No	No
4	100	No	No	No
5	100	No	No	No
6	100	No	No	No
7	100	No	No	No

Table 24: Control parameters 2

Ph-No.	Iterative procedure	Tolerated error	Over relaxation	Max. iterations	Desired min.	Desired max.	Arc-Length control

1	Standard	0.010	1.200	60	6	15	Yes
2	Standard	0.010	1.200	60	6	15	Yes
3	Standard	0.010	1.200	60	6	15	Yes
4	Standard	0.010	1.200	60	6	15	Yes
5	Standard	0.010	1.200	60	6	15	Yes
6	Standard	0.010	1.200	60	6	15	Yes
7	Standard	0.010	1.200	60	6	15	Yes
							Yes

Table 25: Incremental multipliers (input values)

Ph-No.	Displ.	Load A	Load B	Weight	Accel	Time	s-f
0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1000
1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1000
2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1000
3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1000
4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1000
5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1000
6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1000
7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table 26: Total multipliers - input values

Ph-No.	Displ.	Load A	Load B	Weight	Accel	Time	s-f

0	1.0000	1.0000	1.0000	1.0000	0.0000	0.0000	1.0000
1	1.0000	1.0000	1.0000	1.0000	0.0000	0.0000	0.2146
2	1.0000	1.0000	1.0000	1.0000	0.0000	0.0000	0.2208
3	1.0000	1.0000	1.0000	1.0000	0.0000	0.0000	0.2163
4	1.0000	1.0000	1.0000	1.0000	0.0000	0.0000	0.2165
5	1.0000	1.0000	1.0000	1.0000	0.0000	0.0000	0.2158
6	1.0000	1.0000	1.0000	1.0000	0.0000	0.0000	0.2160
7	1.0000	1.0000	1.0000	1.0000	0.0000	0.0000	0.2160

Table 27: Total multipliers - reached values

Ph-No.	Displ.	Load A	Load B	Weight	Accel	Time	s-f
0	1.0000	1.0000	1.0000	1.0000	0.0000	0.0000	1.0000
Ph-No.	**Displ.**	**Load A**	**Load B**	**Weight**	**Accel**	**Time**	**s-f**
1	1.0000	1.0000	1.0000	1.0000	0.0000	0.0000	0.2146
2	1.0000	1.0000	1.0000	1.0000	0.0000	0.0000	0.2208
3	1.0000	1.0000	1.0000	1.0000	0.0000	0.0000	0.2163
4	1.0000	1.0000	1.0000	1.0000	0.0000	0.0000	0.2165
5	1.0000	1.0000	1.0000	1.0000	0.0000	0.0000	0.2158
6	1.0000	1.0000	1.0000	1.0000	0.0000	0.0000	0.2160
7	1.0000	1.0000	1.0000	1.0000	0.0000	0.0154	0.2200

CHAPTER 5

Conclusions

Within the limits of experimental errors we have successfully carried out the analysis of retaining walls. Errors may have occurred due to some unknown insufficient data, lack of practice of proper modelling. Proper modeling is required to get the best out of numerical analysis as it depends on the intelligence of user who is using it. We have carried out the stability analysis of the structure and the structure was found to be stable. Thus these types of analysis can be done on structures even before the structure is actually loaded .

The accuracy at which reality is approximated depends highly on the expertise of the user regarding the modelling of problem, understanding of soil models and their limitations, the selection of model parameters, and ability to judge the reliability of the computational results. The user must be aware of his or her responsibility regarding the computational results for geotechnical design purpose.

The results of analysis were found to be satisfactory and the retaining wall is performing well it's intended function and the analysis justified the whole scenario of analysis.

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