CASE STUDY ON SLOPE STABILITY ANALYSIS OF RAILWAY EMBANKMENT

A DISSERTATION

SUBMITTED IN PARTIAL FULFILLMENT OF THE EQUIREMENTS
FOR THE AWARD OF DEGREE
OF

MASTER OF TECHNOLOGY
IN

[GEOTECHNICAL ENGINEERING]

Submitted By

[ANKIT SHARMA]

(Roll No. 2K20/GTE/03)

Under the supervision of

[PROF. A.K. GUPTA]

CIVIL ENGINEERING DEPARTMENT
DELHI TECHNOLOGICAL UNIVERSITY
(Formerly Delhi College of Engineering)

Bawana Road, Delhi-110042

JUNE, 2021

DELHI TECHNOLOGICAL UNIVERSITY
(Formerly Delhi College of Engineering)
Bawana Road, Delhi-110042

CANDIDATE'S DECLARATION

I, Ankit Sharma, Roll No. 2K20/GTE/03 of M.Tech. GEOTEHNICAL ENGINEERING, hereby declare that the project Dissertation titled **"CASE STUDY ON SLOPE STABILITY ANALYSIS OF RAILWAY EMBANKMENT"** which is submitted by me to the Department of Civil Engineering, Delhi Technological University, Delhi in partial fulfillment of the requirement for the award of the degree of Master of technology, is original and not copied from any source without proper citation. This work has not been used for the award of any Degree, Diploma Associateship, Fellowship or other similar title or recognition.

Place: Delhi, INDIA **(ANKIT SHARMA)**
Date:

DEPARTMENT OF CIVIL ENGINEERING

DELHI TECHNOLOGICAL UNIVERSITY

(Formerly Delhi College of Engineering)

Bawana Road, Delhi – 110042

CERTIFICATE

I hereby certify that the Project Dissertation titled "**CASE STUDY ON SLOPE STABILITY ANALYSIS OF RAILWAY EMBANKMENT**" which is submitted by Ankit Sharma, 2K20/GTE/03, Department of Civil Engineering, Delhi Technological University, Delhi in partial fulfilment of the requirement for the award of the degree of Master of Technology, is a record of the project work carried out by the 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
Date:

(PROF. A.K.GUPTA)
SUPERVISOR
Professor
Department of Civil Engineering
Delhi Technological University

ABSTRACT

In this case study, slope stability analysis of railway embankment of height 28 m was carried out by numerical modelling using finite element method. The Factor of safety was computed using PLAXIS 2D CE V20 with 32.5 tons axle loading. The soil for embankment was black cotton soil which is highly expansive in nature. Field test data were used for modelling of the railway embankment. Stiffness Parameters of different components of rail way track were studied in details. Staged Construction of the embankment was carried out and deformation and factor of safety result were presented.

Soil model for different parts of embankment were included in the analysis. Rail and Sleeper were Linear elastic and Subgrade was modeled Using Mohr coulomb model for soil.

The effective cohesion of black cotton soil had significant impact on the factor of safety. However it shows large deformation on failure for which blanket material was laid below ballasts. Further Stability was enhanced by providing turfing on side slopes. Step by Step modelling on PLAXIS 2D CE V20 was carried out in this study.

ACKNOWLEDGEMENT

I would wish to express my deepest sense of gratitude and thankfulness to my guide and inspiration Prof. A K Gupta, Professor, Department of Civil Engg., Delhi Technological University for his valuable guidance , supervision and kind support in all the processes from conceptualization to final realization of this project.

I wish to convey my sincere gratitude to the Head of Civil Engg. Deptt. Along with all the faculty member of our civil engineering department who have educated me during this course period, as successful completion of this major project depended on the knowledge accrued.

I am deeply thankful to Mr. Ankit Kitaha, Asst. Manager RITES Ltd. who have helped me in field geotechnical investigation.

I would always like to thank my parents for their informed and persistent support which has helped me to do better in all my works.

I am also thankful to all my classmates for the support and motivation during this work.

Last but not least, I specially thank all the prior researchers who are active in this field.

ANKIT SHARMA

ROLL NO.: 2K20/GTE/03

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATION

NTPC: National Thermal Power Corporation.

DFC: Dedicated Freight Corridor

UTS: Ultimate Tensile Strength

PSC: Pre Stress Concrete

FEM: Finite Element Method

RDSO: Railway Design

LEM: Limit Equilibrium Method

CBR: California bearing ratio

MDD: Maximum dry density

OMC: Optimum Moisture Content

FOS: Factor of Safety

BC SOIL: Black Cotton Soil

SPT: Standard Penetration Test

E_s : Young’s modulus

ν : Poisson’s ratio,

c’ : Effective cohesion,

ϕ’ : effective friction angle, and

Ψ : Dilatancy angle

Υ_{unsat} : Bulk Unit Weight

Υ_{sat} : Saturated Unit Weight

F_s = Factor of Safety

CHAPTER 1.
INTRODUCTION

1.1. Private Railway Siding

Railway freight services are built to connect their site with the railway system in order to reduce the cost of transporting raw materials. NTPC Ltd. sets up such railway sidings on a regular basis to import coal from mines and export fly ash to cement plants. NTPC had constructed a 37-kilometer railway line from Nimarkhedi Railway Station to the plant gate of the "Khargone Super Thermal Power Plant" Project in Madhya Pradesh's Khargone District.

The Railway formation for this track is laid on bridges and earth embankment. To aligned track with ruling gradient the embankment at some section of this railway siding are as high up to 28 m from ground level to formation level. This Railway track has been designed to meet the loading requirement of 32.5T DFC Axle loading with speed potential of 75 KMPH.

Track Gauge adopted is broad gauge (1676 mm) with rails of 60 Kg/m & 13.00m long 90 UTS Class-I rails at all locations.

Mono blocks PSC sleepers with density of 1660 nos. / Km are being used on a cushion of ballast depth 350 mm. 1000 mm depth Blanket material with negligible silt content is used just below ballast layer to cope with expansive soil.

1.2. Geometry

Formation width of 8.10 m for single track with side slopes of 2:1 in bank. For banks higher than 6m, a berm of 2m width will be provided on either side. Good soil will be used for making of formation. Blanketing – 60 cm on the top of the formation.

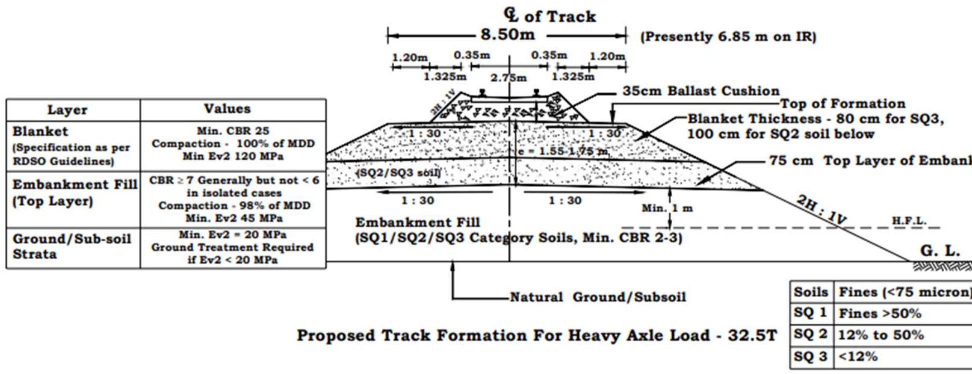

Fig. 1.1 General Arrangement of Formation top[1]

1.3. Geotechnical Conditions

The project's location is in Madhya Pradesh's Khargone District. Basalt rock is abundant in this area. Basalt weathering results in the production of residual soil that is quite expansive in nature. Locals name this Expansive Soil "Black Cotton Soil." Due to the presence of iron, the color of this soil is blackish. This soil is ideal for growing cotton and other crops due to its great moisture retention. However, because it contains a high amount of the clay mineral montmorillonite, it experiences significant volume changes due to swelling and shrinkage when the water content changes, resulting in low shear strength. Because of all of these disadvantages, it is unsuitable for infrastructure projects such as roads and railways.

1.4. Numerical Modelling

Slope Stability of the railway embankment prepared with black cotton soil is analyzed with numerical modelling based on finite element method. Here only the highest cross section is analyzed for preliminary assessment as it seems to be problematic. FEM is to be considered for detailed analysis of this selected cross-sections as possible failure surface on the basis of the result of calculations and further we can also check stability against rainfall infiltration. Deformation Analysis and Stability Enhancement with the aid of geotextiles can be also simulated with additional parameters.

Further for Stability, the staged construction of slopes is required in model, which takes input of time and strain dependent consolidation.

Finite element analysis can discretize the region into finite elements to study soil structure interaction. These discrete elements are assumed to be interconnected only at

[1] Guidelines and Specifications for Design of Formation for Heavy Axle Load, RDSO

the joints which are called nodes and they can be activated in different phases chronologically. The use of interpolating polynomials are used to describe the variation of a field variable within any element.

For analysis following conditions are to being satisfied at every node.

1- Equilibrium equations

2- Displacements compatibility.

3- Material Model Relationship.

1.5. Objectives:

By this case study our aim is to achieve the following result.

1. To Investigate the Factor of Safety With only Gravity Loading,
2. To Investigate the Factor of Safety With DFC 32.5 T Axle Loading,
3. To observe the rainfall infiltration simulation,
4. To Study Corresponding Deformation under each case.

CHAPTER 2. LITERATURE REVIEW

2.1. Introduction

On account of its expansive properties black cotton soil was considered as the most negative soil. In the recent years, usage of it as embankment material has rapidly. Numerical modelling of Slope Stability of Railway embankment can be now done efficiently and effectively with latest available FEMs Application Software.

The following sections are an attempt to encapsulate the experimental and numerical modelling studies carried out by various researchers to create a methodology for such analysis.

Literature on field experimentation result of Black Cotton Soil and Murrum Soil, Numerical Modelling by FEM, Stress Distribution of Load on Rail Section is reviewed in separate sections. A brief introduction about the use of PLAXIS 2D CE V20 FOR Fem analysis is also presented in this chapter.

2.2. Modelling of Railway Embankment

In this section, it is discussed how several researchers in the field of geotechnical and railway engineering carried out work to model the load distribution from wagon to rail and then to subsequent layers below.

(Chawla, et al., 2010) used MIDAS (GTS) (Management of information for design and analysis of systems geotechnical and tunneling software) to predict the displacement and the vertical stress along the track components. By creating the representation of nominal fixed track as given by RDSO, Elastic Modulus of Ballast Sub ballast and Sub grade were varied on applying train load of Stiffness was 243.75 kN. From the effect of modulus of various track components, it is clearly evident that the subgrade stiffness has the most significant impact on overall track response. It was shown that when subgrade elastic modulus decreases, the rail displacement increases dramatically, which indicates that the subgrade as a soft soil, then track maintenance would be the critical issue.

(Hammouri, et al., 2008) studied the Stability analysis of slopes using the finite element method and limiting equilibrium approach. In this study by varying the value of c/γh different model were compared. This Study also suggested that FEM and LEM gave an almost identical location and shape for slip circle in general cases. But in case of undrained clay slope when tension crack are there no such change is observe in fem analysis then LEM.

Sert et al. (2015) studied Stability and settlement problems of railway embankments in alluvial soils and suggested method to increase the FOS by preloading and removing upper soft soil with good soil.

Ciotlaus et al. (2016) studied for slope stability of railway embankment. It evaluates the mechanism of dynamic load distribution through the complex rail-sleeper-ballast-bed system.

Kaushal et al. (2015) conducted experimental studies on black cotton soil to find relationships of plasticity index (PI) with angle of friction. This study suggested that plasticity index is inversely related to friction angle. Hence with regression to obtain the parameters in similar scenarios.

Kshatriya et al.(2022) analyzed the behavior of Re wall in black cotton soil. The Stiffness parameter suggested for Black Cotton Soil to be used in plaxis 2D were discussed here to be used to model the black cotton soil.

Koganti et al. (2016) Presented a study of the strength properties of propellant soil and muram using quarry dust. Experiments have shown that swelling is controlled by adding quarry dust into it. Also, as MDD increases, CBR increases and OMC decreases.

Praveen et al. (2021) For the reinforced soil construction, significant direct shear tests were undertaken to examine the interaction behaviour of Murrum soil and geosynthetics, and geogrid exhibited a greater value of shear stress.

Watanabe et al. (2021) Construction and field measurement were the subjects of a technical report. "Black Cotton Soil," an Indian expansive soil, was used to build a high-speed railway test embankment. The deformation of the embankment with and without geosynthetics was compared in this study. The results reveal that using non-swelling cohesive soil as a replacement has no effect on the soil's swelling and shrinking behaviour. However, when cement mixed soil was used, shrinkage and swelling were limited to the train embankment. With geosynthetics, it was possible to counteract deformation to the point where the permissible settlement was severely regulated to roughly 10 mm over a ten-year period.

Kundagol et al. (2021) conducted a dynamic slope stability analysis of black cotton soil stabilised with ground granulated blast furnace slag and lime in an experimental setting. By altering the ggbs and lime composition, qualities such as the mdd omc free swell index and unconfined compressive strength test were obtained. It was discovered that stabilising Black cotton soil with ground granulated blast furnace slag boosts MDD, lowers OMC, and lowers the Free swell index. The dynamic shear modulus of Black Cotton Soil enhanced when it was mixed with GGBS and Lime.

Indraratna et al.(2013) studied Stress-strain degradation response of railway ballast stabilized with geosynthetics. The Study Represent the result of cyclic drained tests conducted on railroad ballast bed. It suggests that use of geosynthetics reduced the particle deformation of ballasts. The study also showed by finite element simulation by incorporating various type of soil models. Hardening Soil Model was adopted for ballast. It is based on isotropic hardening plasticity by cyclic loading on ballast. For the blanket and prepared subgrade the model adopted is Mohr coulomb all other material are modelled as linear elastic only.
The FEM analysis showed that reduction of the vertical and lateral displacements of ballast under cyclic loading by application of geosynthetics.

Raj et al. (2014) Rain-induced slope failure of the railway embankment at Malda, India was investigated. For embankment soil, a link between soil–water content and matric suction is developed. The numerical results demonstrate that when the intensity and length of rainfall increases, the factor of safety of the railway embankment decreases significantly.

Andrea Benedetto (2010) studied about the integration of Vegetation ROLE in computer simulation for slope stability. It demonstrate the FOS increment by contribution of vegetation.

Maula et al. (2011) Plaxis 2D and Geo Studio 07 were used to calculate the factor of safety acquired by studying the same slope using two FEM software, and it was found that Plaxis 2D gives greater FOS than Studio 2007. FOS appears to grow with friction angle, according to the study.

CHAPTER 3. EXPERIMENTAL INVESTIGATION

3.1. INTRODUCTION

This chapter includes the materials properties from the field. Undisturbed sample and SPT test samples were tested for various soil properties. Input Parameters of Modelling of Railway Track under axial loading are also discussed. The Effect of this on the stability analysis is explained in terms of Displacement and factor of safety.

3.2. SUB STRATA PROFILE

From the bore logs field and laboratory investigation, it is concluded that the sub soil essentially is followed by B.C. Soil up to 0.60 m and Brownish Clayey Silt is having SPT N Value is 36 & 37 up to 6.50 m and Brownish Hard Clayey silt with sand is having SPT N value is 50 up to 8.00 m.

Table 3.1 Bore log, Sub Soil profile and Laboratory Test Results

DEPTH BELOW GL(M)		TYPE OF SAMPLES	SPT N- VALUE	INSITU BULK UNIT T(g/cm^3)	DRY UNIT WT (g/cm^3)	INSITU WATER CONTENT (%)	LIQUID LIMIT %	PLATIC LIMIT %	PLASTICTCY INDEX, IP	IS CLASIFICATION	SHEAR PARAMETERS			SPECIFIC GRAVITY
FROM	TO										TYPE OF TEST	C (Kg/cm^2)	PHI,Φ [°]	
1	2	3	4	5	6	7	14	15	16	17	18	19	20	21
0.00	0.60	DS												
0.60	1.50	UDS		1.87	1.48	26.31				CH	UU	0.78	13	2.63
1.50	1.55	SPT	36		1.69		48.11	29.34	18.77	CH		1.67	19	2.62
1.55	3.00	UDS		1.92	1.5	28.12				CH	UU	0.81	15	2.64
3.00	4.50	SPT	37		1.71		49.16	30.11	19.05	CH		1.69	21	2.61
4.50	6.00	UDS		1.89	1.5	25.87					UU	0.97	18	2.65
6.00	7.50	SPT	50		1.89		35	19	16	CH		1.85	24	2.63
7.50	9.00	UDS												
UPTO 20.5 m WEATHERED ROCK														

3.3. SUB-GRADE (EMBANKMENT SOIL)

Murrum Soil is used for construction of embankment which was procured from lachora, badgao & Malwa region of Madhya Pradesh. Soil Experiment were performed on field and laboratory on the soil specimen. Result are Summarized below.

Table 3.2 Experimental Test Result on Sub- Grade

S. N.	PROPERTIES	TEST METHOD	TEST RESULTS
1	**Sieve Analysis**	IS:2720 Part 4	
	• Cobble*(75+ to 300 mm size)*		0%
	• Gravel*(4.75+ to 75 mm size)*		66.32%
	• Sand*(0.075+ to 4.75 mm size)*		26.78%
	• Silt & Clay*(Below 0.075 mm size)*		6.90%
2	Coefficient of Uniformity C_u		42.85
3	Coefficient of Curvature C_c		4.75
4	**Modified Compaction**	IS:2720 Part 8	
	• Optimum Moisture Content		9%
	• Maximum Dry Density		2.185 g/cm^3
5	Plasticity Characteristics	IS:2720 Part 5	
	• Liquid Limit		36.10%
	• Plastic Limit		21.30%
	• Plasticity Index		14.90%
6	Laboratory Soaked CBR	IS:2720 Part 16	41.30%
7	Engineering Classification	IS:1498	GW-GM(Well Graded Silty Gravel)

It follows Mohr-coulomb criterion. The MC model involves five key parameters (i.e., Young's modulus Es, Poisson's ratio ν, effective cohesion c', effective friction angle ϕ', and dilatancy angle Ψ.)The Parameters for Embankments are presented below.

Table 3.3 Key Parameters for Sub-Grade of Embankments

Properties	Top Soil	Bottom Soil
Bulk Unit Weight, Υ_{unsat}	18.54 kN/m^3	21.13
Saturated Unit Weight Υ_{sat}	19.79 kN/m^3	22.51
Young's Modulus (E_s) kN/m^2	65250	67000
Poisson' Ratio, ν	0.25	0.25
Drainage Condition	Drained	Drained
Effective cohesion, c' kN/m^2	95.12	95.1182
Friction angle, ϕ'	18	18

3.4. RAILS

In this study rails of Specification 60 Kg/m & 13.00 m long 90 UTS Class-I are used for rolling loads on the railway track. Rails are modeled as elastic material. The Rail section has been assumed rectangular having same EI value as of that of an I –section.

Table 3.4 Key parameters for Rail Section

Height	172 mm
Base Width	150 mm
Base Area, A	76.86 cm^2
Young's Modulus (E_s)	$2x10^8$ kN/m^2
Poisson's Ratio (ν)	0.30
Moment of Inertia, MOI	3055 (cm^4)
Weight	60.34 Kg

3.5. SLEEPER

60 kg mono blocks PSC sleepers with density of 1660 nos. / Km were laid on the track. Sleepers are modelled as Soil and Interface elements with Linear Elasticity. The Sleepers are assumed as Non-Porous.

Table 3.5 Key Parameters obtained for Sleeper in Linear Elastic Model

Height	210 mm
Top & Base Width	150 mm , 250 mm
Length	2.75 m
Base Area, A	76.86 cm^2
Young's Modulus (E_s)	$3x10^7$ kN/m^2
Poisson's Ratio (ν)	0.20
Moment of Inertia, MOI	15290 (cm^4)
Weight	285.4 Kg
Spacing	60 cm
Unit Weight	24 kN/m^3

3.6. Ballast

The Ballast are assumed to have linear elasticity and non-porosity The Linear Elastic model involves input parameters (i.e., Young's Modulus E, Poisson's ratio n, unit weight).

Table 3.6 Gradation of Ballast

S.N.	Sieve Size (mm)	Wt. Retained (gm)	Cum. Wt. Retained	% Retained	Spec. Limited
1	65	0	0	-	0-5
2	40	28780	28780	67.48	40-60
3	20	13690	42470	99.59	98-100
4	Pan				

Table 3.7 Key Parameters involved for Ballast cushion modelling

Depth	350 mm
Unit Weight	15.6 k N/m2
Young's Modulus (E_s)	130×10^3 k N/m2
Poisson' Ratio ν	0.37

3.7. Blanket Layer

As the Embankment soil is of poor quality, and traffic density is high. A Blanket Layer of Soil is provided below ballast to prevent swelling or heaving of formation. The Blanket Layer is free from silt content. Result of Modified Proctor Test performed on Blanket top is presented below.

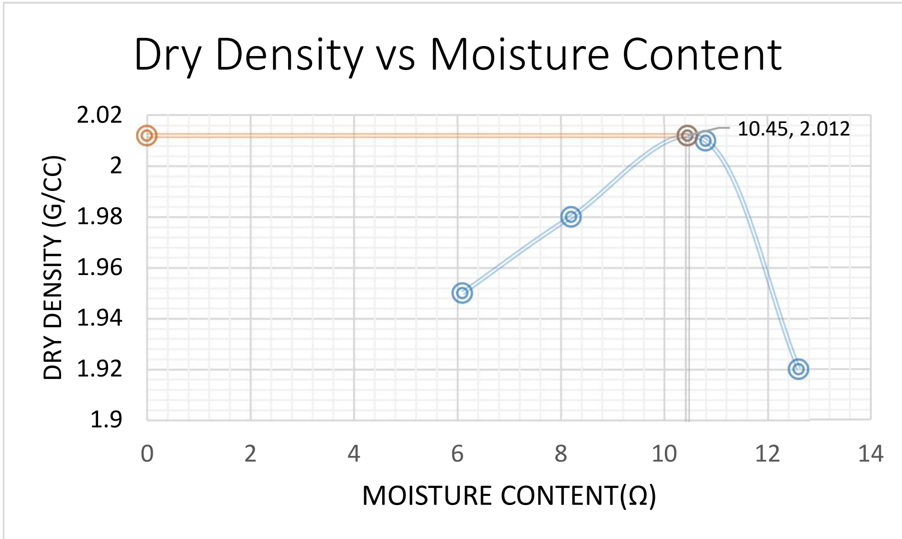

Fig. 3.1 Relationship Between dry density and Moisture content-Modified Proctor Test

These result shows that a higher MDD is required for Blanket Layer.

Table 3.8 Key Parameters involved for Blanket Layer

Depth	600 mm
Bulk Unit Weight, Υ_{unsat}	21.39 kN/m^3
Saturated Unit Weight Υ_{sat}	22.52 kN/m^3
Young's Modulus (E_s)	140×10^3 kN/m^2
Poisson' Ratio ν	0.37
Drainage Condition	Drained

CHAPTER 4.
SLOPE STABILITY USING FINITE ELEMENT METHOD

4.1. Introduction

Stability of Slopes is characterized by the balance of shear stress and shear strength. It can be done either with limit equilibrium approach or the FEM method.

4.2. Limit Equilibrium Method (LEM)

In Limit equilibrium approach analytical method analytical methods are adopted to find the stability of slopes. Some of the Most Commonly used are overviewed here:

1. Ordinary Method of Slices: Also referred as Swedish method considered only moment equilibrium. In this Inter slice forces are neglected.

$$F_m = \frac{\Sigma(c'l + (W cos\alpha - ul) tan\phi'}{\Sigma W sin} \qquad 4\text{-}1$$

2. Swedish slip circle method: In this friction angle is adopted as zero. Hence shear strength is directly proportional to cohesiveness. FOS is obtained by

$$F_s = \frac{cL_a + tan\phi \Sigma N}{\Sigma T} \qquad 4\text{-}2$$

3. Modified Bishop's method of analysis-In this normal interaction forces between adjacent slices are assumed to be collinear and the resultant inter slice shear force is zero.

$$F_s = \frac{\Sigma \left\{ \frac{mc' + \left[\left(\frac{W}{b} \right) - u \quad \right] tan\phi}{\psi} \right\}}{\Sigma [\left(\frac{W}{b} \right) sin\,\alpha} \qquad 4\text{-}3$$

$$\psi = cos\,\alpha + \frac{sin\alpha tan\phi'}{F_s} \qquad 4.4$$

$$F_s = \frac{\Sigma\left\{\frac{ms_u}{\cos\alpha}\right\}}{\Sigma[\left(\frac{W}{b}\right)] \sin\alpha} \qquad 4.5$$

4. Spencer Method: In this inter slices forces are assumed to be parallel.

$$FS = \frac{Shear\ Strength\ available}{Shear\ Strengt\ \ Mobilized} \qquad 4.6$$

$$f_s = \frac{\tan\phi\prime}{\tan\phi_m} \qquad 4.7$$

5. Taylor's Stability Number :

Here Stability of slopes is easily calculated with the help of pre calculated Taylor stability number from Taylor's stability chart.

By Comparing cohesion c, friction angle ϕ and depth factor we can find S_n.

$$S_n = \frac{c}{\gamma . f_s . h} \qquad 4.8$$

Drawbacks of Limit Equilibrium Method:

1. Although the LEM methods are relatively very simple. One of the major hurdle is to locate the critical slip surface at which failure will occur.

4.3. Finite Element Method

It is a numerical method technique to calculate boundary value problems. By this technique we can use progressive failure theory.

We can perform elastic stress analysis for initial phase due to self-weight. Elastoplastic finite element slope stability is analyzed, by mesh generation. In this method stability is obtained by decreasing phi c. In this c and phi are related by

$$c_f = \frac{c\prime}{F}\ ;\ \phi_{f=}\ \tan^{-1}\left\{\tan\left(\frac{\phi\prime}{F}\right)\right\} \qquad 4.9$$

By Continuous iteration, F (factor of safety) keeps on decreasing till the ultimate state of the system is achieved, that will be the F_s(factor of safety) of that slope.

Calculations is completed when the non-linear equation starts to converges. Or there is large displacement is recorded.

Now by plotting the output based on shear stress & shear strain result we can determine the failure surface by its contours.

Thus it can be used tin complex calculations as we have to take no assumption about the inter slices forces.

However the disadvantage related to this is having as failure surface is spread no clear distinction can be pointed out here.

CHAPTER 5.
NUMERICAL MODELLING

5.1. Geometry of Embankment

1. Geometric Model is selected as Plain Strain with 15-Noded Elements.
2. Formation Width is 8.1 m. Rails are modelled as plate of length 150 mm. Wheel Load 'W' as point load is applied on center of plate.
3. Rail are placed with spacing of broad gauge distance 1676 mm on Sleeper of Length 2750 mm.
4. Sleeper are resting on ballast cushion of 350 mm having slide slope of 2H:1V.
5. To prevent formation from swelling and shrinkage the blanket layer of depth 600 mm under ballast is laid with the slope of 1:30.
6. Further below embankment is made up of prepared subgrade.
7. The Embankment height from Ground Level to formation top is 28 m.
8. The side slope provided is 1V:2H. The Bed of Embankment is 120m. For banks higher than 6m, a berm of 2m width will be provided on either side. Thus it had four berms.

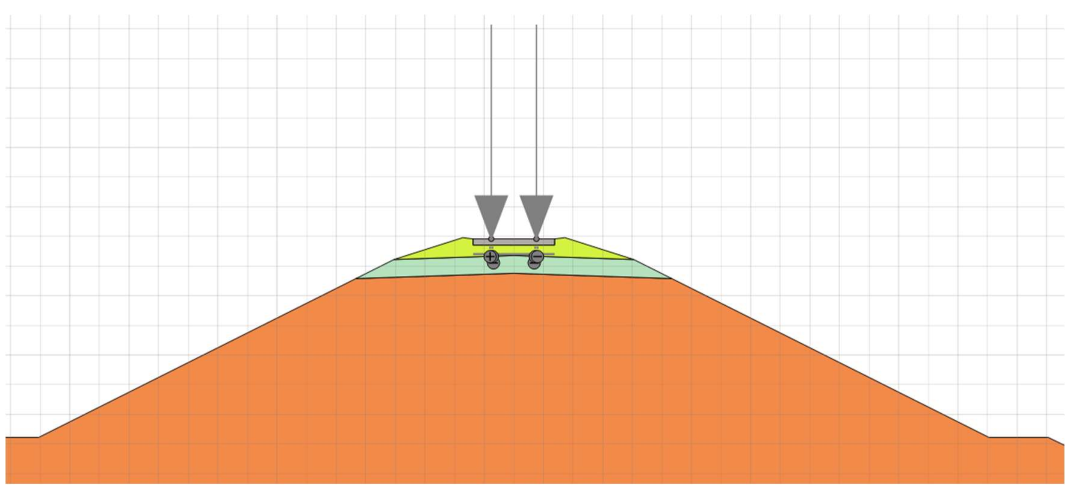

Fig. 5.1 Cross Section of Embankment top.

5.2. Determination of Pressure on Rails

The axle loads, as calculated, are applied to the rail rolling surface's surface. The sleeper is only loaded by a portion of the vertical force. It is possible to calculate the vertical loads S that are applied to the sleeper.

Loading Calculations,

DFC Axle Loading = 32.5 T

Dynamic Augment Factor = 1.5

Augmented Dynamic Loading = 48.75 T

Wheel Loads on each rail = 24.375 T or 243.75 kN.

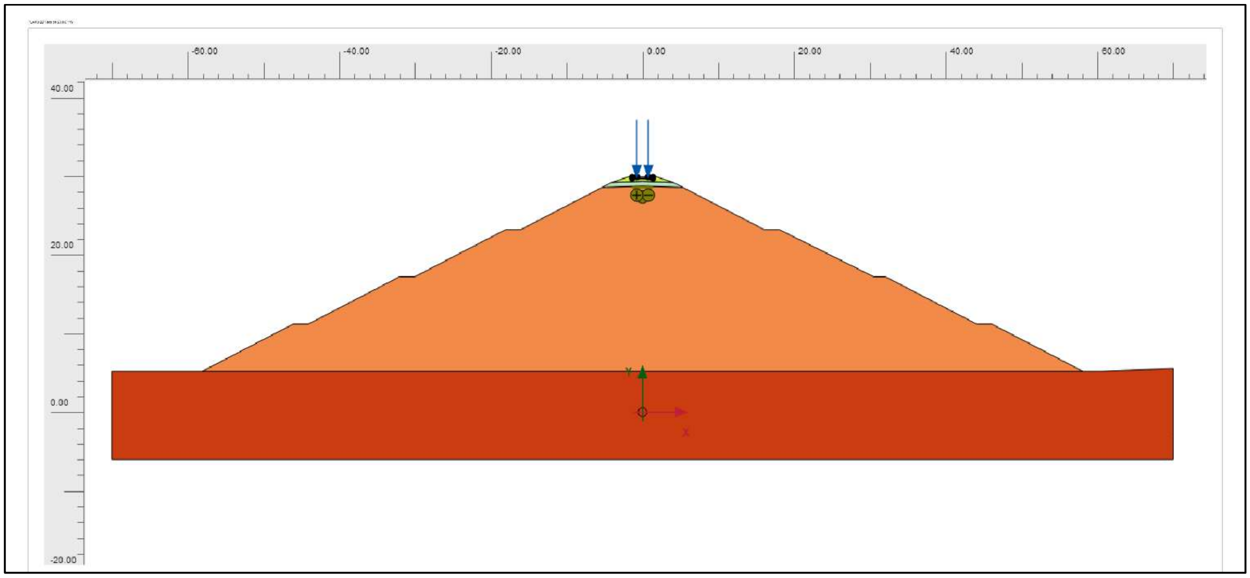

Fig. 5.2 Cross section of embankment with bottom soil

This Load is applied as point load on rail then subsequently transferred to ballast and then to subgrade through blanket.

<u>Railway Track Embankment Model in PLAXIS 2D CE V20</u>

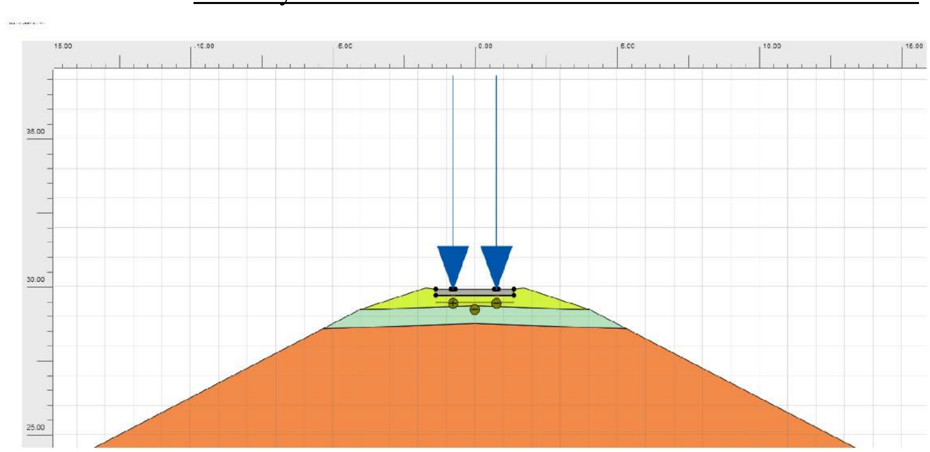

Fig. 5.3 Geometrical arrangement of Wheel load on Sleeper Ballast Blank Assembly.

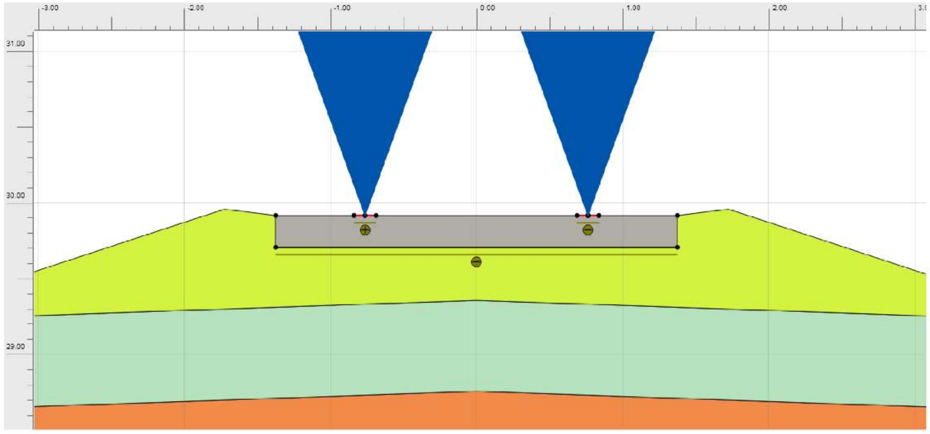

Fig. 5.4 Application of Wheel Load as point Load on Rail Model as Linear plate element.

5.3. Material Properties:

The Various key Input Parameters required for corresponding model obtained from experimental and literature study are used.

Mohr Coulomb model for Bottom Layer Soil.

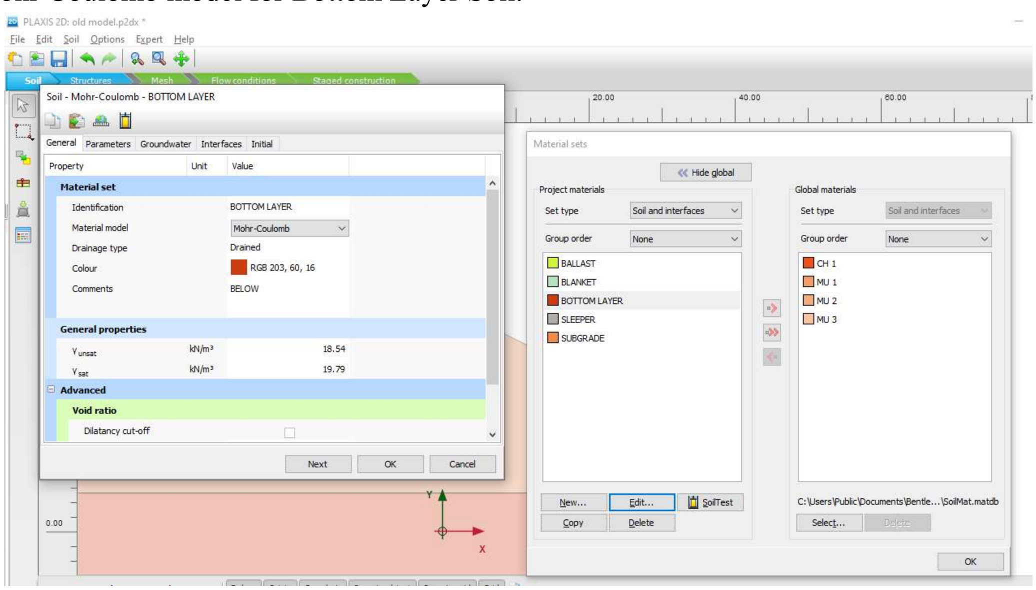

Fig. 5.5Material database for soil and interface

Properties for rails entered as plate material with linear elastic model.

Stiffness Parameters E_s and Poisson's Ratio ν

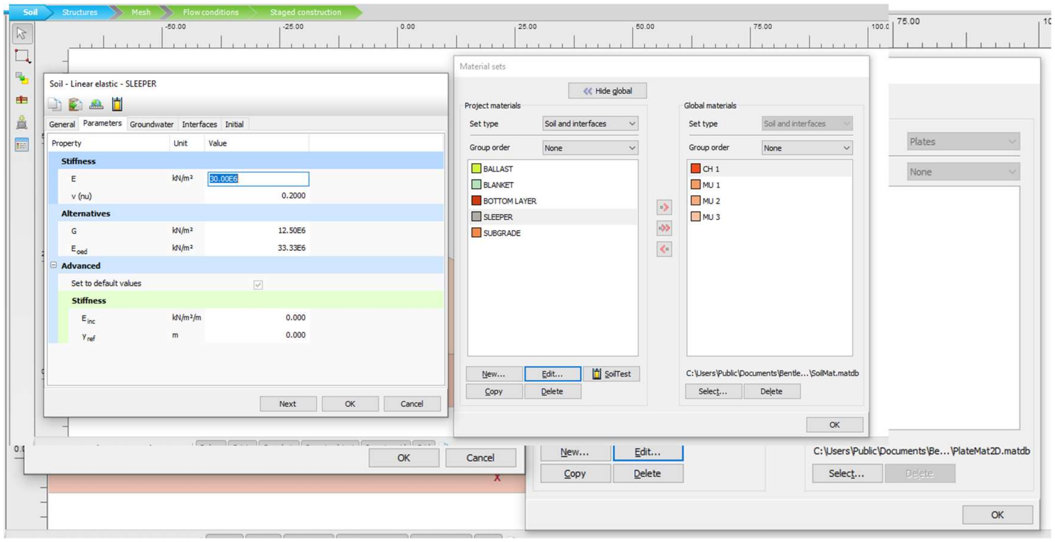

Fig. 5.6 material database for plate elements

5.4. Mesh Generation-

Finite elements 16- Nodded Mesh fine Mesh results in more accurate analysis but is time taking.

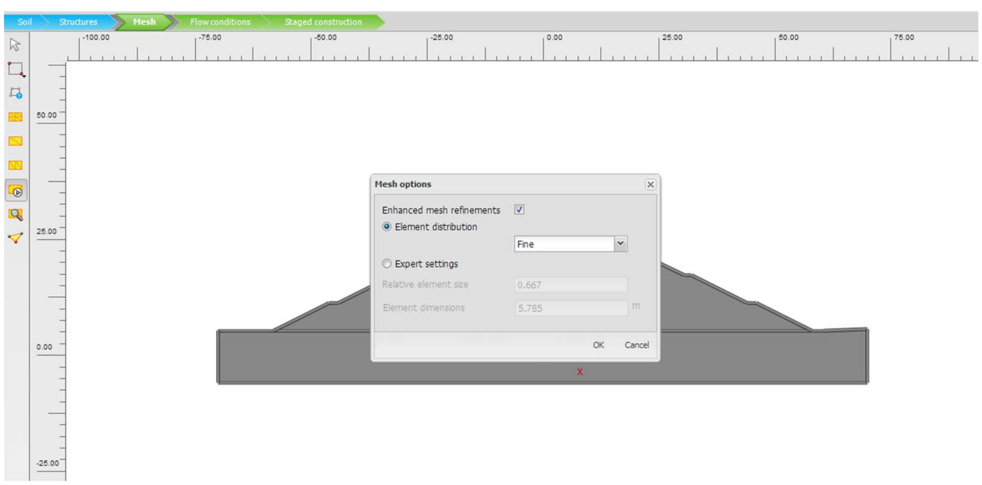

Fig. 5.7 Creation of fine mesh

Interfaces are provided to avoid development of point stress between two different models.

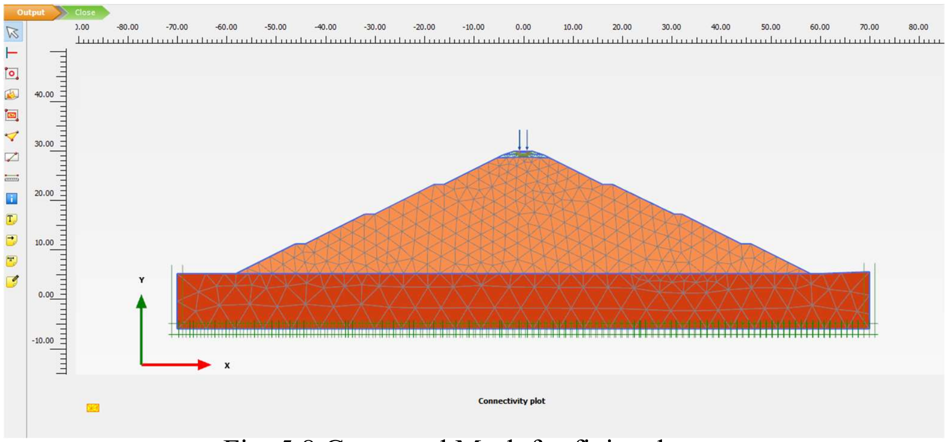

Fig. 5.8 Generated Mesh for finite elements

5.5. Flow Conditions against Rain Infiltration of as 0.001 m day.

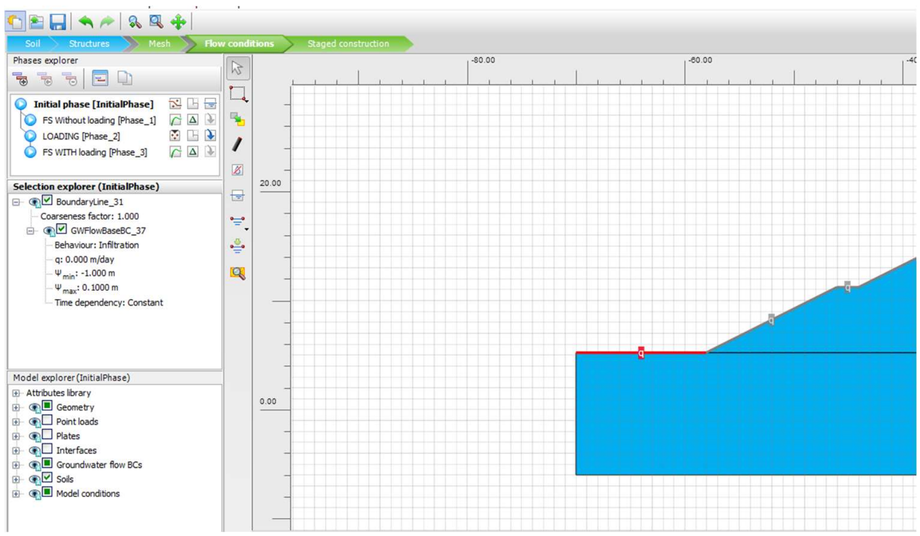

Fig. 5.9 Selection for water boundary in flow condition

5.6. Staged Constructions:

1. Initial Phase: This is to generate initial stresses in the soil.

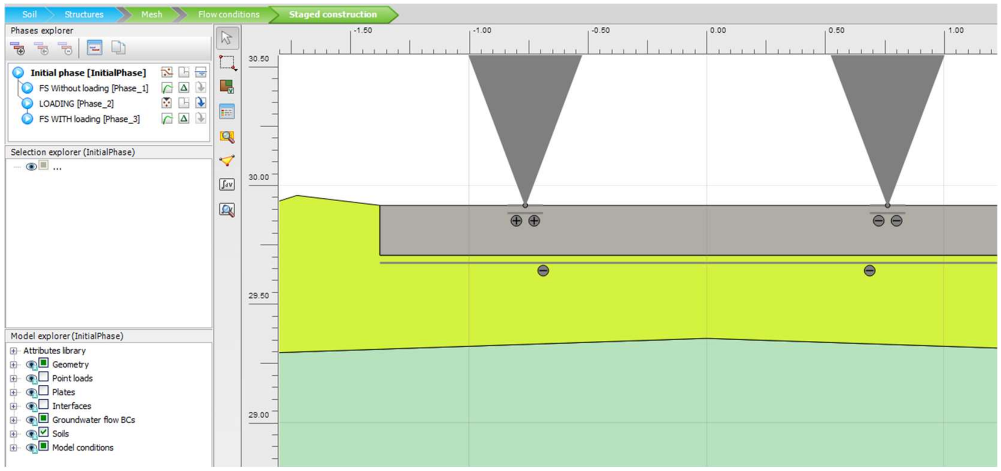

Fig. 5.10 Initial phase

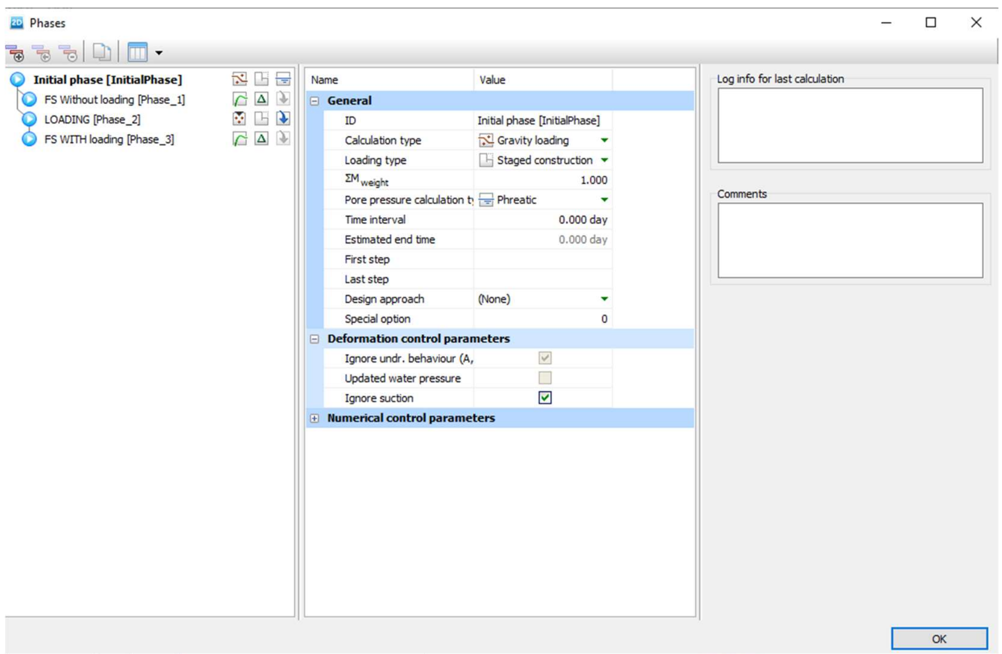

Fig. 5.11 Calculations input for initial phase

2. Initially Stresses are generated due to self-weight or gravity loading only.

3. Factor of Safety is computed when initial stress have been generated. Now Calculation type would become safety only. It will start as soon as the initial stresses are generated.

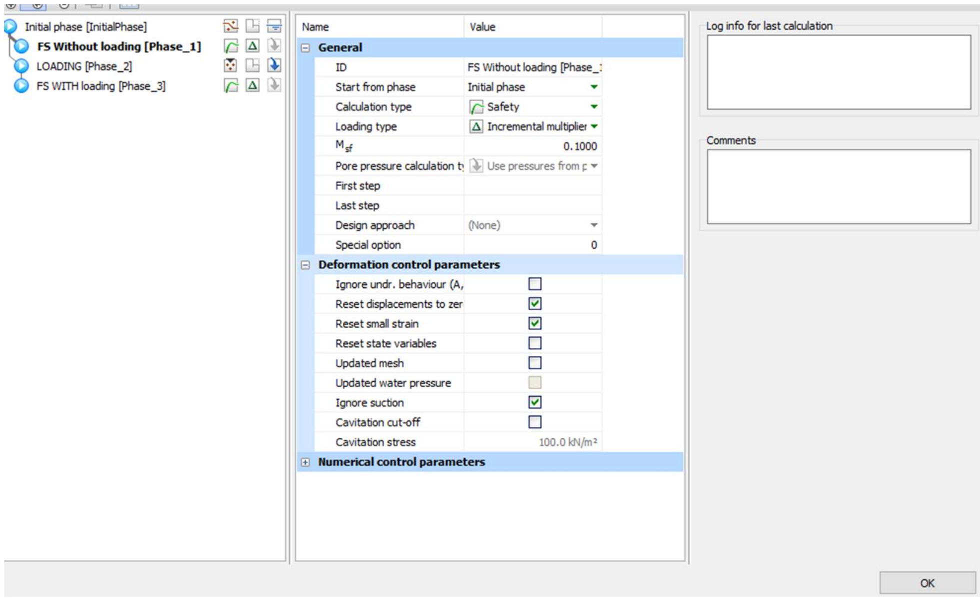

Fig. 5.12 Factor of Safety without loading.

4. Third Stage will be to activate the point wheel load on rails plates. As the deformation in soil are of permanent in nature. We have to calculate plastic in calculation type.

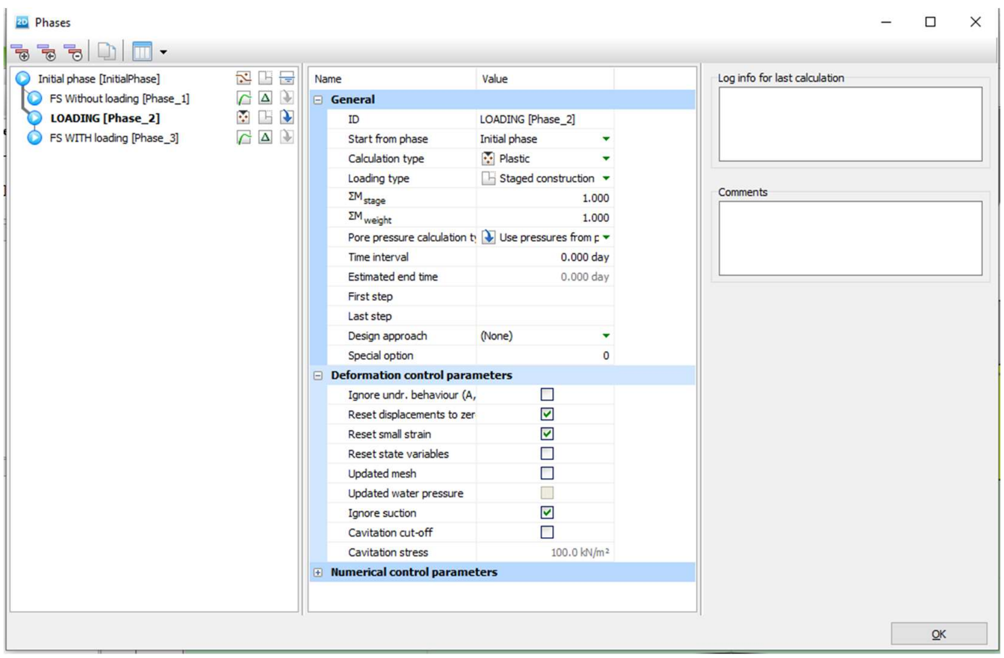

Fig. 5.13 Calculation input for phase 2 : loading

5. Finally the Factor of Safety is calculated with loading applied.

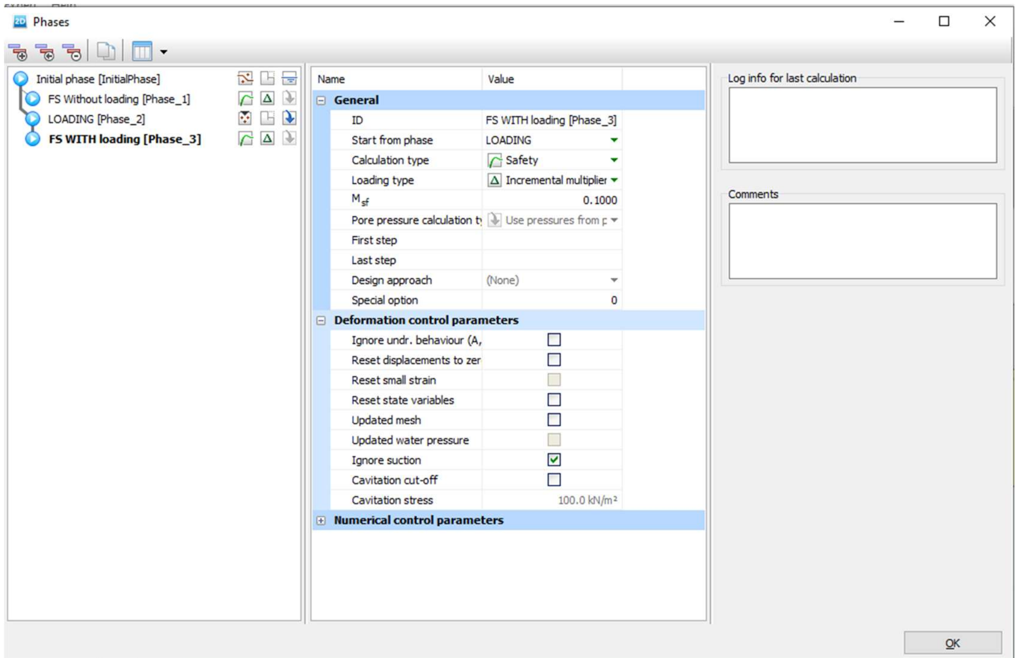

Fig. 5.14 Factor of safety with loading

6. Initial phase doesn't include loading. It is deactivated which is indicated by grey color.

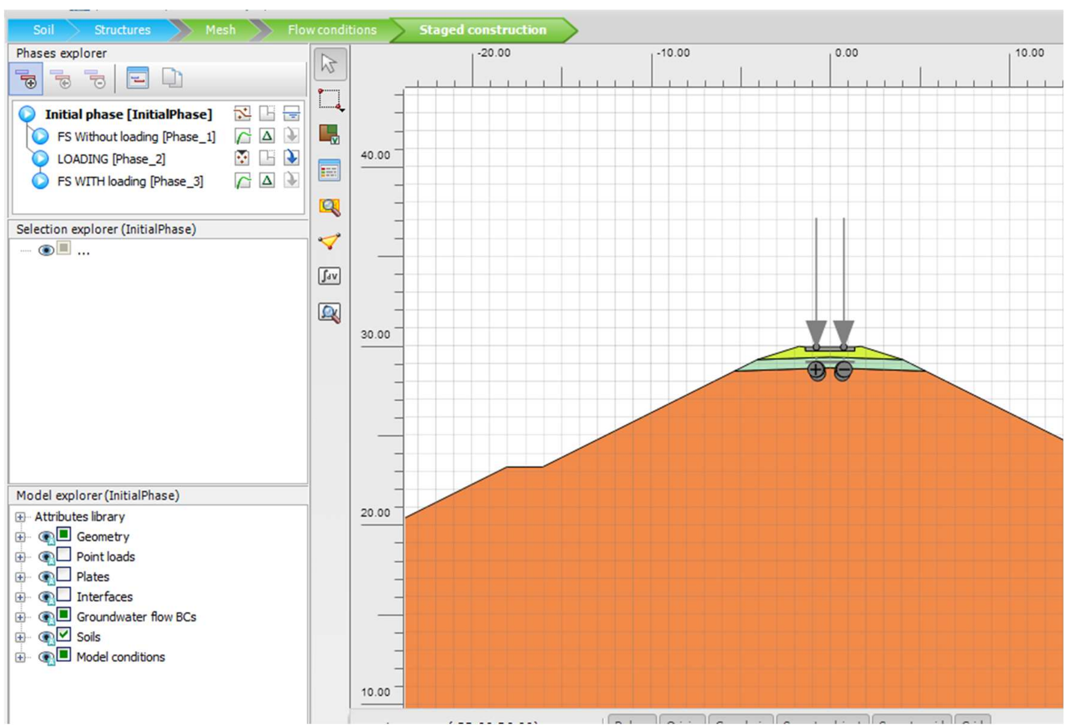

Fig. 5.15 Activation in Initial phase self-weight only

7. Loading phase i.e. phase 2 doesn't include loading. It is can be activated which is indicated by blue color.

Fig. 5.16 Activation of Load in Phase 2

8. After everything is in order Calculation can be started from initial phase.

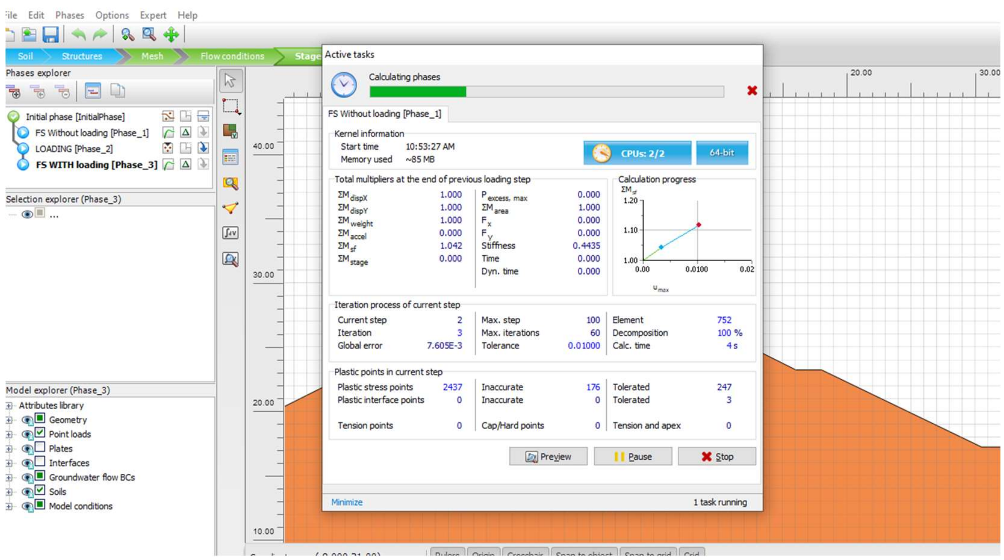

Fig. 5.17 Computing the Results

CHAPTER 6.
RESULTS AND DISCUSSION

6.1. Introduction

The Deformed mesh, total deformation, contour of shear stress shear strain and factor of safety are presented as output with and without loading to study the location and slip surfaces.

6.2. Deformation in Mess

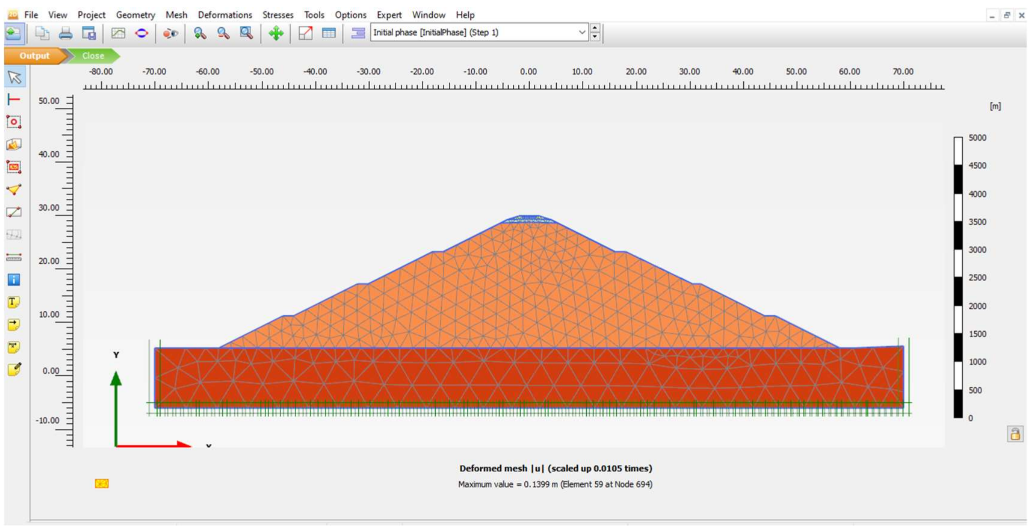

Fig. 6.1 Deformed Mesh due to initial stress only..

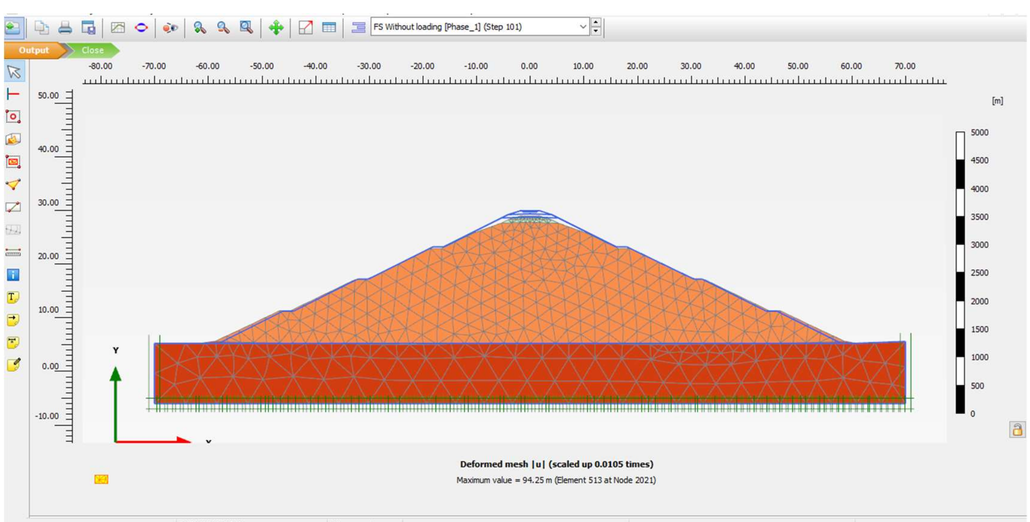

Fig. 6.2 Deformed mesh after failure due to self-weight.

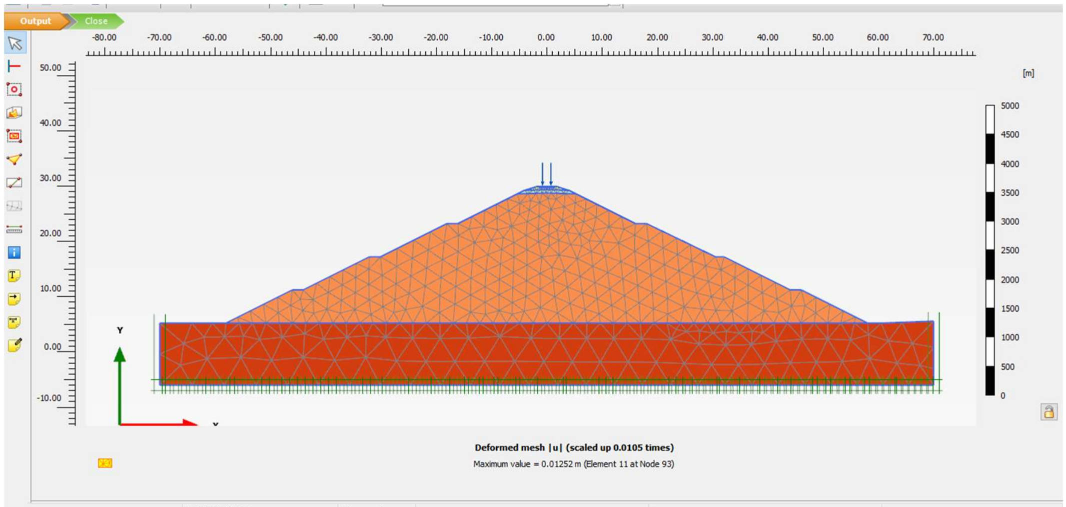

Fig. 6.3 Deformed mesh due to loading.

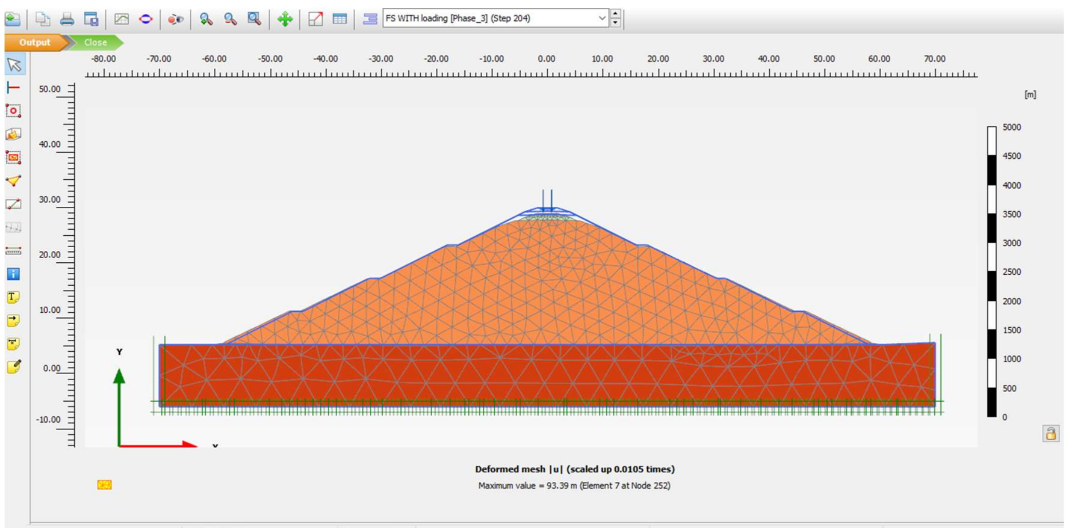

Fig. 6.4 Deformed mesh after failure with loading.

6.3. Total Displacements

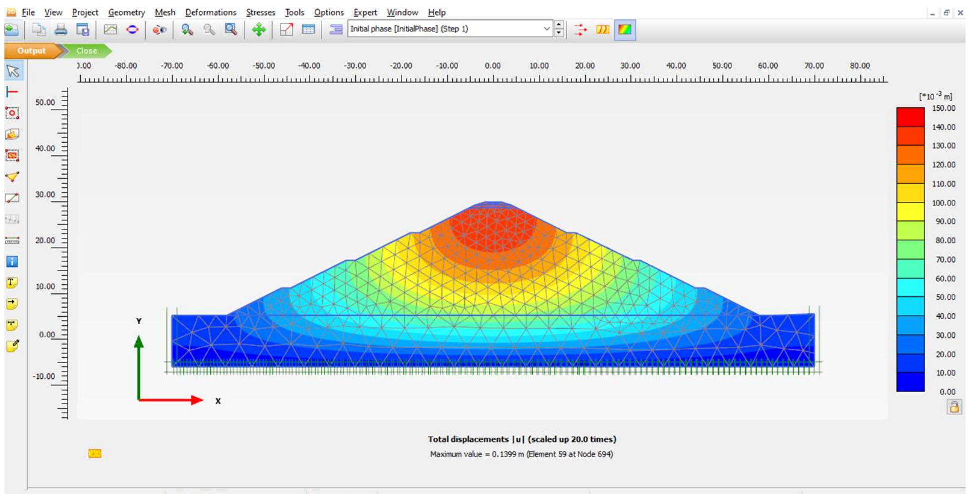

Fig. 6.5 Total Displacement at initial phase due to self-weight.

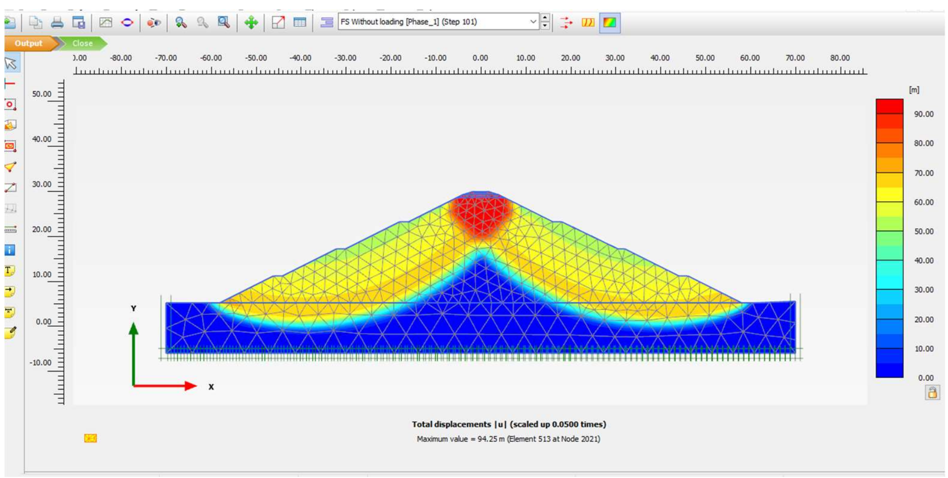

Fig. 6.6 Total Displacement after failure for FOS without any loading.

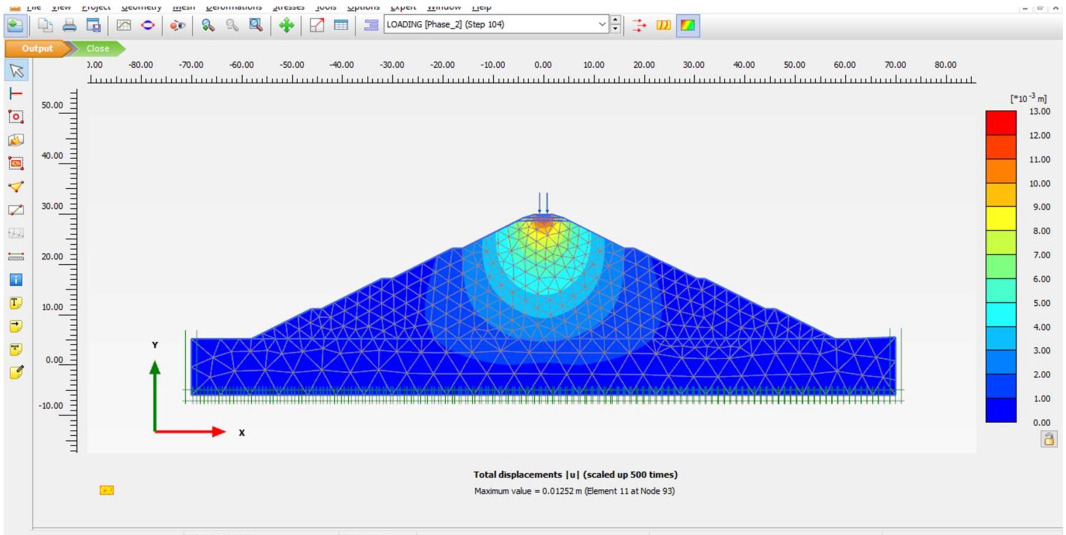

Fig. 6.7 Total Displacement after loading.

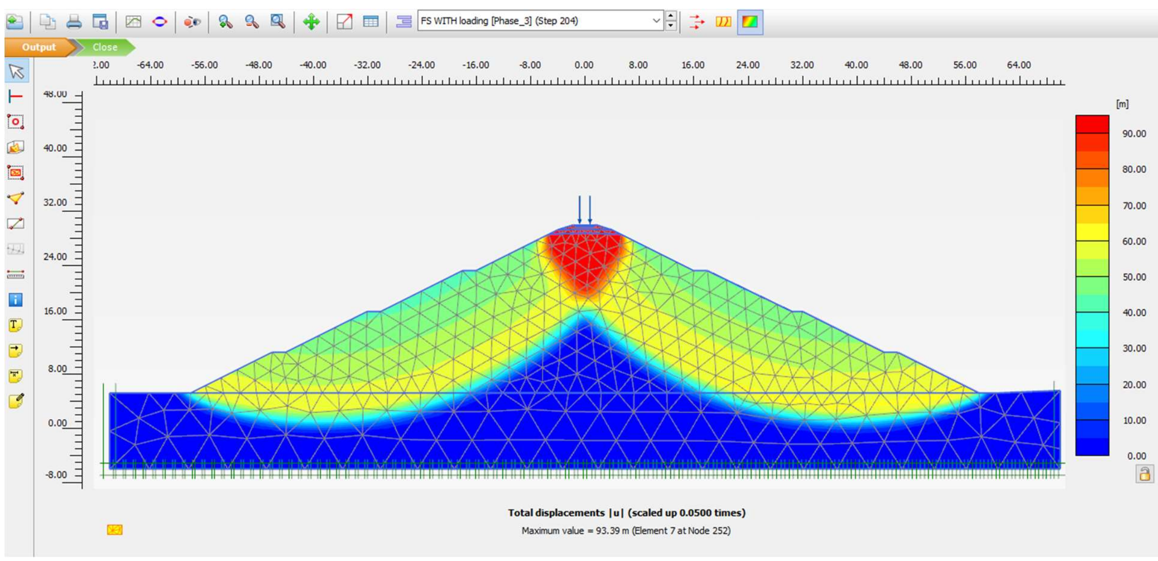

Fig. 6.8 Total Displacement after failure for FOS with loading.

6.4. Analysis for Factor of Safety

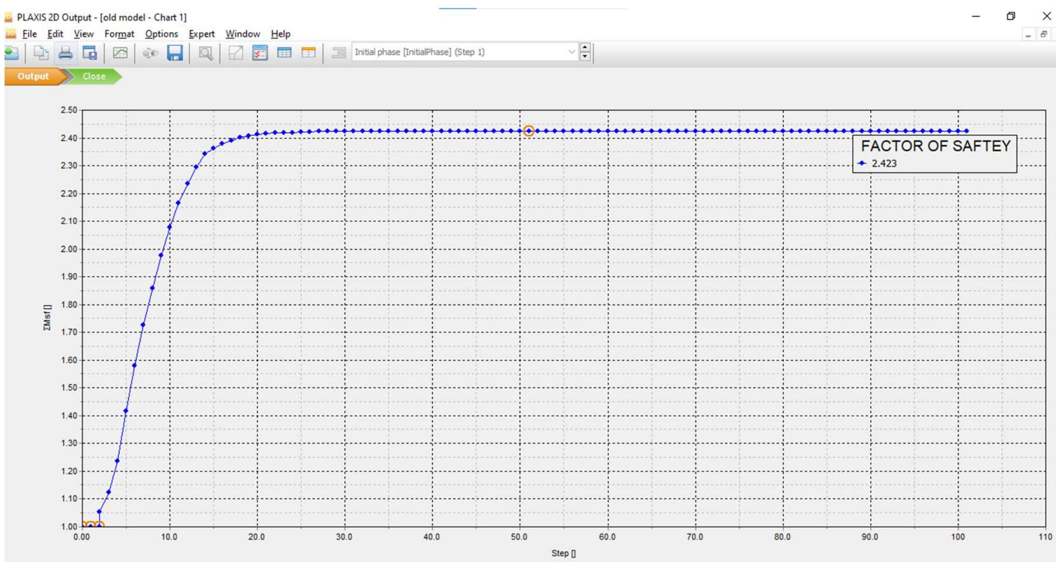

Fig. 6.9 FOS in case of Self Weight.

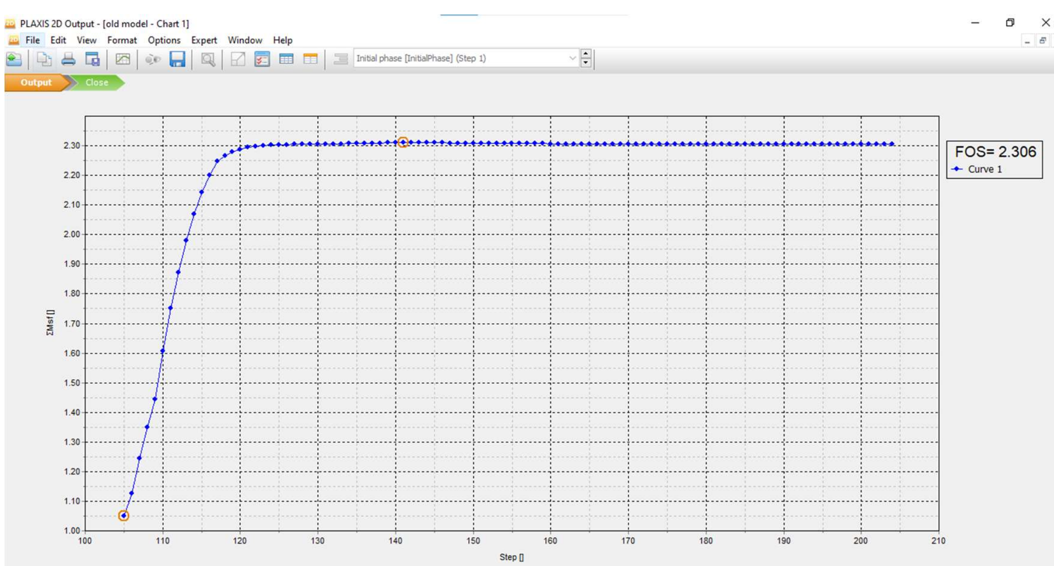

Fig. 6.10 FOS in case of 32.5 T loading.

6.5. Contour Lines of Shear Stress -Strain

.

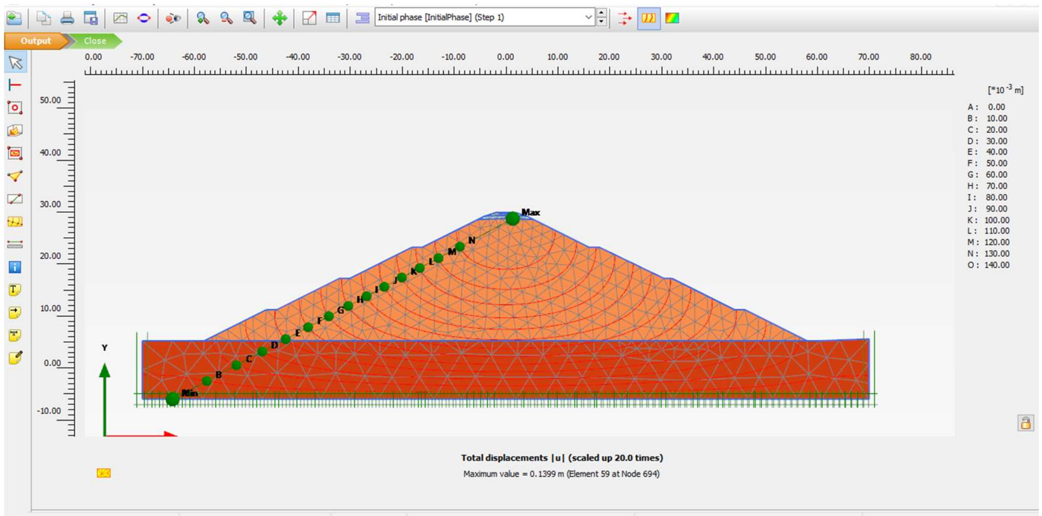

Fig. 6.11 Contour Line of Shear Stress-Strain due to initial stress

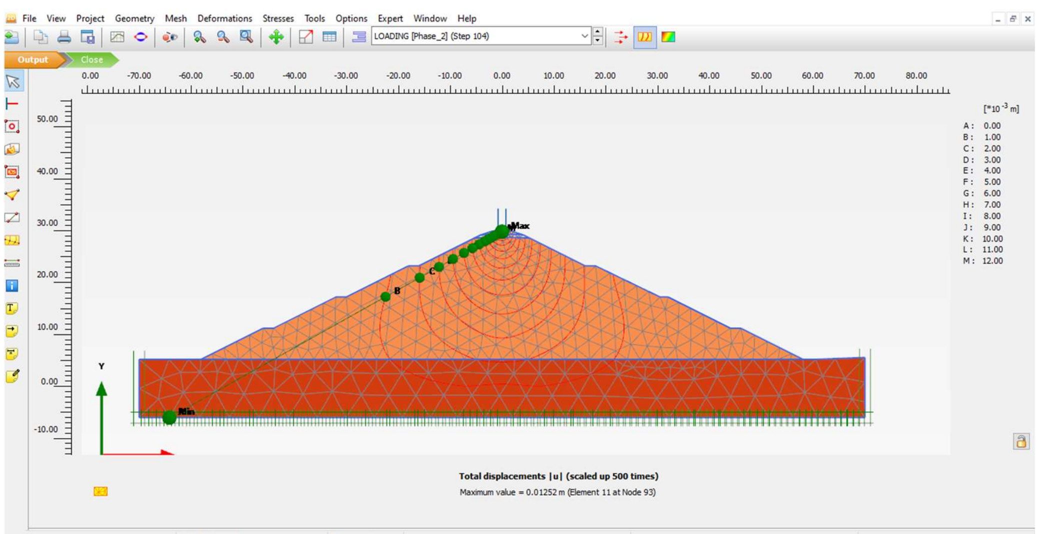

Fig. 6.12 Contour Line of Shear Stress-Strain due to loading

6.6. CONTOUR OF SLIP SURFACE

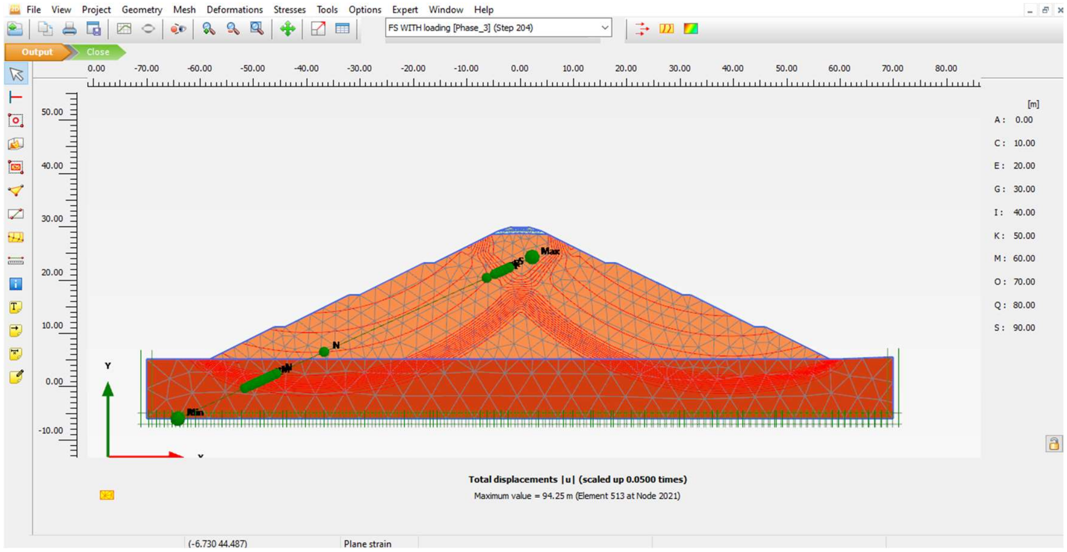

Fig. 6.13. CONTOUR OF SLIP SURFACE due to initial stress

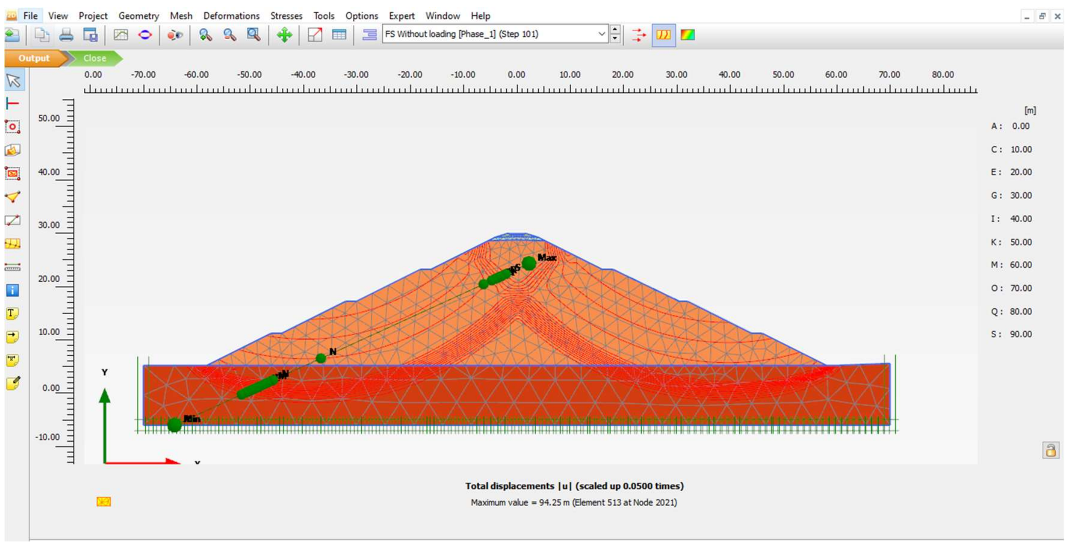

Fig. 6.14 CONTOUR OF SLIP SURFACE due to loading

6.7. Effect of Loading

Table 6.1 Variation in Parameters

PARMETERS	INITIAL PHASE	WITH LOADING
FACTOR OF SAFETY	2.423	2.306
EXTREME TOTAL DISPLACEMENTS (M)	0.1399	0.01252

CHAPTER 7.
CONCLUSIONS AND RECOMMENDATION FOR FUTURE WORK

Case study on the analysis of slope stability of the railway embankment was carried out in PLAXIS 2D CE V20. The deformation and Factor of safety was analyzed with and without 32.5 T DFC axle loading in black cotton soil railway formation. Although Factor of safety was coming in tune of 2.306 however deformation and settlement of railway track was more than the general guidelines by Indian railway. As per RDSO railway settlement should be 10 mm/10year .The result suggested the higher factor of safety was due to high cohesiveness of the BC soil in formation.

Further scope of study is to study the stability analysis against rainfall infiltration.

As the result table show that settlement is exceeding the prescribe allowable limit further counter measures such as geosynthetics have to be studied next.

REFERENCES

[1] B.H. Maula, L. Zhang, Assessment of Embankment Factor Safety Using Two Commercially Available Programs in Slope Stability Analysis,Procedia Engineering,Volume14, 2011,Pages 559-566, ISSN 1877-7058, https://doi.org/10.1016/j.proeng.2011.07.070. (https://www.sciencedirect.com/science/article/pii/S1877705811011477)

[2] Chawla, Sowmiya. (2010). Sowmiya, L.S., Shahu, J.T. and Gupta, K.K. (2010). "Three Dimensional Finite Element Analysis of Railway Track", Proceedings of Indian Geotechnical Conference-2010, GEOtrendz, IIT Bombay, Vol. II, pp. 909-912.

[3] Hammouri, Nezar & Husein Malkawi, Abdallah & Yamin, Mohammad. (2008). Stability analysis of slopes using the finite element method and limiting equilibrium approach. Bulletin of Engineering Geology and the Environment. 67. 471-478. 10.1007/s10064-008-0156-z.

[4] Indraratna, B. & Nimbalkar, Sanjay. (2013). Stress-Strain Degradation Response of Railway Ballast Stabilized with Geosynthetics. Journal of Geotechnical and Geoenvironmental Engineering. 139. 684-700. 10.1061/(ASCE)GT.1943-5606.0000758.

[5] G.V. Praveen, Pandu Kurre,Large direct shear testing to evaluate the interaction behaviour of murrum soil and geosynthetics for the reinforced soil construction,Materials Today: Proceedings,Volume 39, Part 1,2021,Pages 500-503, ISSN 22147853, https://doi.org/10.1016/j.matpr.2020.08.229. (https://www.sciencedirect.com/science/article/pii/S2214785320360995)

[6] Kenji Watanabe, Susumu Nakajima, Torajiro Fujiwara, Kyoichiro Yoshii, G. Venkatappa Rao,Construction and field measurement of high-speed railway test embankment built on Indian expansive soil "Black Cotton Soil",Soils and Foundations,Volume 61, Issue1, 2021, Pages 218-238,ISSN 0038-0806, https://doi.org/10.1016/j.sandf.2020.08.008. (https://www.sciencedirect.com/science/article/pii/S0038080620337422)

[7] Koganti, Shyam & Hanumantha, Rao & Chappidi, Hanumantharao. (2016). Strength Characteristics of Expansive Soil and Murrum Using Quarry Dust. Electronic Journal of Geotechnical Engineering. 21. 1799-1808.

[8] Kshatriya, R., Sathe, P. and Kankarej, P., 2022. Analysis and Behavior of Retaining Wall on Black Cotton Soil by Using Software 'PLAXIS 2D'. Available at SSRN 4043255.

[9] Kaushal, Vinayak & Guleria, S... (2015). Geotechnical Investigation of Black Cotton Soils. International Journal of Advances in Engineering Sciences. 5.

[10] Madalina Ciotlaus, Gavril Kollo, Dorin Moldovan, Lavinia Muntean, Slope Stability of Railway Embankments, Procedia Engineering, Volume 181, 2017, Pages 52-59,ISSN 18777058, https://doi.org/10.1016/j.proeng.2017.02.362.
(https://www.sciencedirect.com/science/article/pii/S1877705817309451)

[11] Chandan Kumar Behera , Satyapriya Senapati, 2021, Soil Stabilization by Industrial Waste (GGBS and Stone Dust), INTERNATIONAL JOURNAL OF ENGINEERING RESEARCH & TECHNOLOGY (IJERT) Volume 10, Issue 09 (September 2021),

[12] Raj, M., Sengupta, A. Rain-triggered slope failure of the railway embankment at Malda, India. Acta Geotech. 9, 789–798 (2014). https://doi.org/10.1007/s11440-014-0345-9

[13] Sert, S., Ozocak, A., & Bol, E. (2015). Stability and settlement problems of railway embankments in alluvial soils.

[14] Andrea Benedetto, Integrating Vegetation Role in Computer Simulation for Slope Stability: The Case Study of a Railway Embankment Andrea Benedetto Geo-environmental Engineering and Geotechnics: Progress in Modeling and Applications. GSP 204. 2010