__Original Research Article__

SLOPE STABILITY OF CANALS OUTER CURVE UNDER TRAFFIC LOAD

Abstract

Thestresses caused by the traffic loadembankments are investigated considering the loading action of the rolling material.Conventional methods of slope stability provide a constant value of safety factor for the slope, providing no information of slope displacements and possible variations of safety margins along the potential failure surface.The design model admits the idea of a homogeneous, isotropic, continuous and linear space that can be deformed. (Plaxis 2D) finite element program was applied to analyze the slope stability of canals outer curve under traffic load.In this study four different conditions were tested; Condition No 1: Dry condition, when there is no ground water in embankment and canal is running atfull supply level; Condition No 2: Dry condition, when there is no ground water in embankment and canal is running at lowest water level; Condition No 3: Wet condition, at fully ground water level in embankment and canal is running at full supply level; and Condition No 4: Wet condition, at full supply ground water level in embankment and canal is running at lowest water level.The embankment material tested for in-situ properties to clay and sand.And additional traffic load above embankment is considered to estimate the worst case.

Keywords: Slope stability; canals; factor of safety;traffic load.

INTRODUCTION

During recent years research on the stability of foundations and earthworks has been carried out by different investigators. A classification of the types of failure is necessary to engineers to enable them to distinguish and recognize the different phenomena for purposes of design and also to enable them to take the appropriate remedial or safety measures where necessary.The roads are subjected to loads originating in the weight of the moving rolling material.Landslide could have been caused by its own weight embankment, the slope embankment and the traffic loads over the road embankment.

Yiming. W. etal., (2019) studiedthe geotechnical analysis conducted to determine the factor of safety and probability of failure of the middle stack using limit equilibrium method under both drained and undrained conditions.

Huang. C. (2019) presented a case study on a well-monitored slope during a rainstorm showed that the measured slope displacement caused by an elevated groundwater table can be simulated using the proposed method along with hyperbolic soil parameters obtained in large-scale direct shear tests.

MacRobert. C. J. (2018) introduced a study that undertaken in which practitioners of geotechnical engineering were required to use judgment to assess the safety of a tailings dam, which they were unaware had failed. And reported on the varying degrees of confidence with which respondents solved the problem.

Liu. C.,et.al, (2018) investigated the disorders generated by breaking the slopes were usually spectacular, often destructive and sometimes murderers. Many methods of calculating stability have been proposed. These are differentiated by the assumptions accepted by their.

Salunkhe. D. P., etal.(2017) explored the stability by the balance of shear stress and shear strength.

If the forces available to resist movement were greater than the forces driving movement, the slope was considered stable. A factor of safety was calculated by dividing the forces resisting movement by the forces driving movement.

Harabinova. S. (2017) studied the assessment of slope stability on the road II/595 near the village Zlatno before and after the landslide caused by floods in 2010. For a comprehensive assessment and possible remedial action was necessary to know the geological conditions and choose the appropriate method for to assess slope stability.

Singh. D., et.al, (2017) explored the effort to find the effect of the forces on the stability of canal banks so that some precautionary measures were adopted during such critical period.

Su. K., et.al, (2016) studied the field variable was set as same as SRF along the solution processing, FOS can be directly determined as the corresponding value of field variable when the shear failure zone goes through.

Cheng. Y. M., etal. (2015) investigated a semi-analytical solution for the three-dimensional stability analysis of the ultimate uniform patched load on top of a slope was developed by the limit analysis using kinematically admissible failure mechanisms.

Zdankus. N. T. and Stelmokaitis. G. (2008) presented new idea about the possibilities to increase the reliability of clay slope stability computation method.

ASSESSMENT OF SLOPE STABILITY

Currently several methods of calculating slope stability based on the balance of forces, a factor of safety can be defined as the ratio of the forces resisting movement to those driving movement.

Calculation and assessment of slope stability on the road was performed using finite element model (Plaxis 2D).

Typically used in the analysis of the rotation of a slip plane in the embankment. Factor of safety values in the assumption are the ratio of resistance moment to a driving moment.

GEOMETRIC AND MATERIAL PARAMETERS

Forty-eight typical slopes were employed in this study (geometric parameters are listed inFig.1 and Table.1). While the material properties, including density, angle of internal friction ϕ, cohesion C, modules of elasticity E and poisons ratio μ are tabulated in Table.2

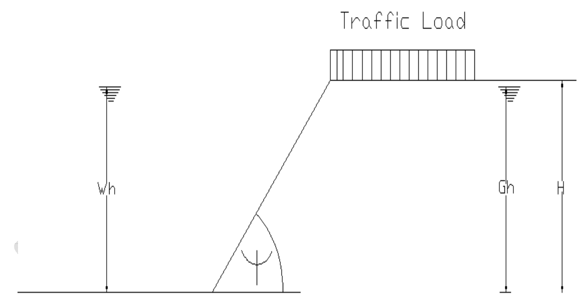


FIG.1Geometric parameters

Table.1. Range of considered parameters

Case No.	Ψ	Traffic Load (ton)	Gh (m)	Wh (m)
S_1	45°	30	2.00	3.00
S_2	45°	30	0.00	3.00
S_3	45°	30	2.00	2.00
S_4	45°	30	0.00	2.00
S_5	45°	60	2.00	3.00
S_6	45°	60	0.00	3.00
S_7	45°	60	2.00	2.00
S_8	45°	60	0.00	2.00
S_9	45°	30	2.00	3.00
S_{10}	45°	30	0.00	3.00
S_{11}	45°	30	2.00	2.00
S_{12}	45°	30	0.00	2.00

S_{13}	45^{o}	60	2.00	3.00
S_{14}	45^{o}	60	0.00	3.00
S_{15}	45^{o}	60	2.00	2.00
S_{16}	45^{o}	60	0.00	2.00
S_{17}	45^{o}	30	2.00	3.00
S_{18}	45^{o}	30	0.00	3.00
S_{19}	45^{o}	30	2.00	2.00
S_{20}	45^{o}	30	0.00	2.00
S_{21}	45^{o}	60	2.00	3.00
S_{22}	45^{o}	60	0.00	3.00
S_{23}	45^{o}	60	2.00	2.00
S_{24}	45^{o}	60	0.00	2.00
C_{25}	27^{o}	30	2.00	3.00
C_{26}	27^{o}	30	0.00	3.00
C_{27}	27^{o}	30	2.00	2.00
C_{28}	27^{o}	30	0.00	2.00
C_{29}	27^{o}	60	2.00	3.00
C_{30}	27^{o}	60	0.00	3.00
C_{31}	27^{o}	60	2.00	2.00
C_{32}	27^{o}	60	0.00	2.00
C_{33}	27^{o}	30	2.00	3.00
C_{34}	27^{o}	30	0.00	3.00
C_{35}	27^{o}	30	2.00	2.00
C_{36}	27^{o}	30	0.00	2.00
C_{37}	27^{o}	60	2.00	3.00
C_{38}	27^{o}	60	0.00	3.00
C_{39}	27^{o}	60	2.00	2.00
C_{40}	27^{o}	60	0.00	2.00
C_{41}	27^{o}	30	2.00	3.00
C_{42}	27^{o}	30	0.00	3.00
C_{43}	27^{o}	30	2.00	2.00
C_{44}	27^{o}	30	0.00	2.00
C_{45}	27^{o}	60	2.00	3.00
C_{46}	27^{o}	60	0.00	3.00
C_{47}	27^{o}	60	2.00	2.00
C_{48}	27^{o}	60	0.00	2.00

TABLE2Material properties

Case No.	Density	Angle of internal friction (ϕ)	Cohesion (C) kN/m^2	Modulus of elasticity (E) kN/m^2	Poiss-on ratio (μ)
S_1	dense	38^{o}	------	100000	0.27
S_2	dense	38^{o}	------	100000	0.27
S_3	dense	38^{o}	------	100000	0.27
S_4	dense	38^{o}	------	100000	0.27
S_5	dense	38^{o}	------	100000	0.27
S_6	dense	38^{o}	------	100000	0.27
S_7	dense	38^{o}	------	100000	0.27
S_8	dense	38^{o}	------	100000	0.27
S_9	medium	34^{o}	------	50000	0.25
S_{10}	medium	34^{o}	------	50000	0.25
S_{11}	medium	34^{o}	------	50000	0.25
S_{12}	medium	34^{o}	------	50000	0.25
S_{13}	medium	34^{o}	------	50000	0.25
S_{14}	medium	34^{o}	------	50000	0.25
S_{15}	medium	34^{o}	------	50000	0.25
S_{16}	medium	34^{o}	------	50000	0.25
S_{17}	loose	31^{o}	------	20000	0.22
S_{18}	loose	31^{o}	------	20000	0.22
S_{19}	loose	31^{o}	------	20000	0.22
S_{20}	loose	31^{o}	------	20000	0.22
S_{21}	loose	31^{o}	------	20000	0.22
S_{22}	loose	31^{o}	------	20000	0.22
S_{23}	loose	31^{o}	------	20000	0.22
S_{24}	loose	31^{o}	------	20000	0.22
C_{25}	stiff	------	75.00	5000	0.35
C_{26}	stiff	------	75.00	5000	0.35
C_{27}	stiff	------	75.00	5000	0.35

C_{28}	stiff	------	75.00	5000	0.35
C_{29}	stiff	------	75.00	5000	0.35
C_{30}	stiff	------	75.00	5000	0.35
C_{31}	stiff	------	75.00	5000	0.35
C_{32}	stiff	------	75.00	5000	0.35
C_{33}	medium	------	37.00	3000	0.33
C_{34}	medium	------	37.00	3000	0.33
C_{35}	medium	------	37.00	3000	0.33
C_{36}	medium	------	37.00	3000	0.33
C_{37}	medium	------	37.00	3000	0.33
C_{38}	medium	------	37.00	3000	0.33
C_{39}	medium	------	37.00	3000	0.33
C_{40}	medium	------	37.00	3000	0.33
C_{41}	soft	------	20.00	1000	0.30
C_{42}	soft	------	20.00	1000	0.30
C_{43}	soft	------	20.00	1000	0.30
C_{44}	soft	------	20.00	1000	0.30
C_{45}	soft	------	20.00	1000	0.30
C_{46}	soft	------	20.00	1000	0.30
C_{47}	soft	------	20.00	1000	0.30
C_{48}	soft	------	20.00	1000	0.30

Condition 1: Dry condition, when there is no ground water in embankment and canal is running at full supply level.

Condition 2: Dry condition, when there is no ground water in embankment and canal is running at lowest water level.

Condition 3: Wet condition, at fully ground water level in embankment and canal is running at full supply level.

Condition 4: Wet condition, at full supply ground water level in embankment and canal is running at lowest water level.

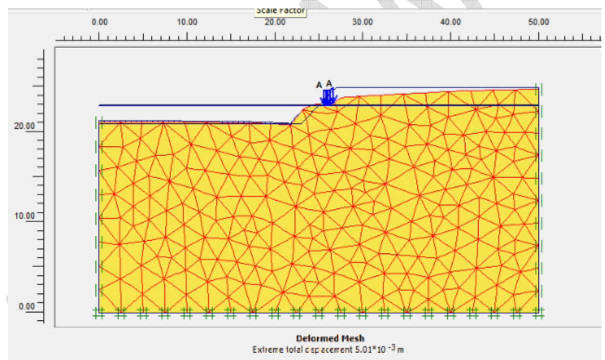
RESULTS AND DISCUSSION

Total displacement, effective mean stress and factor of safety were determined according to plaxis 2D finite element model data of studied cases.

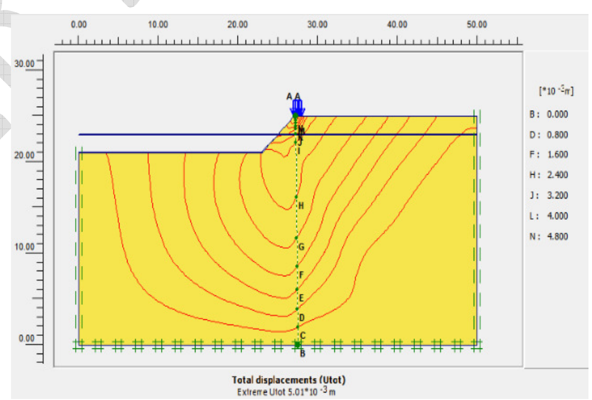
a. Total Displacement

The values of total displacement ranged between 0.264 and 0.1870 m and 0.145 and 7.60 m for sand and clay soil embankments, respectively.

Generally, the total displacement increases with increasing of applied traffic load and decreases with increasingthe cohesion for clay soil and angle of internal friction for sand soil, Fig. 2



Condition 2 for sand soil



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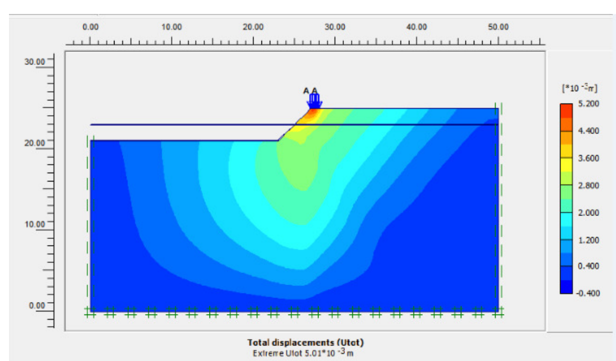

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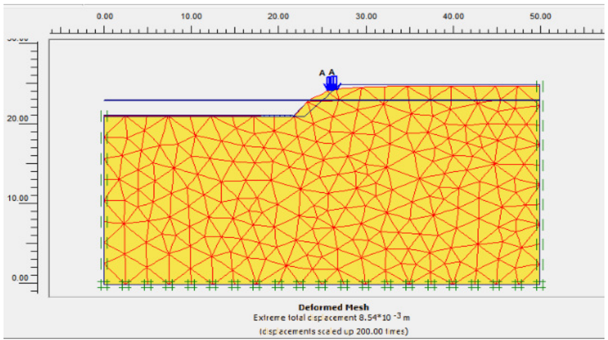

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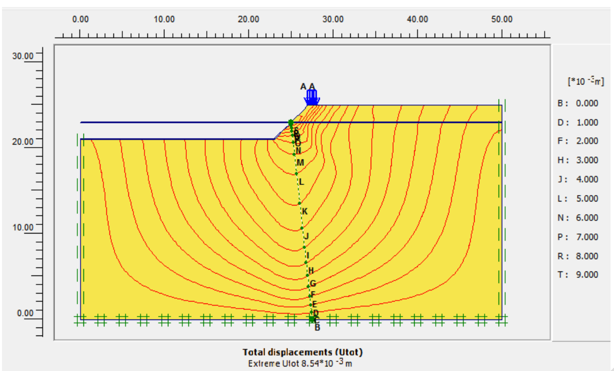

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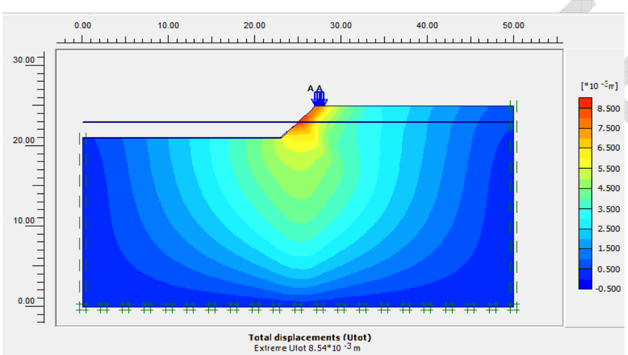

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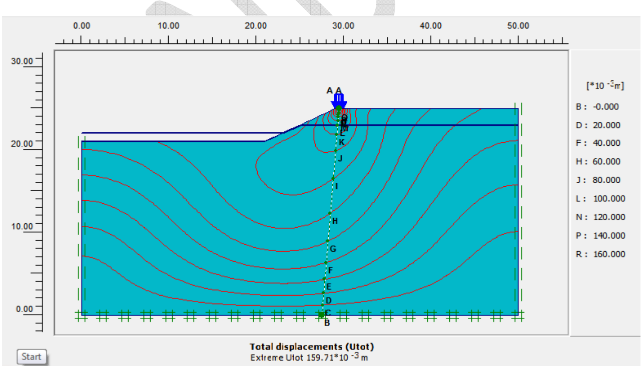
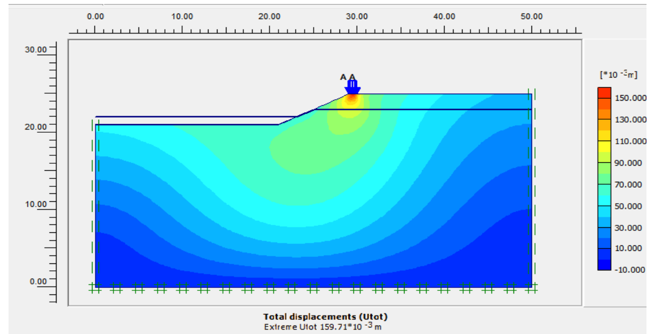


Condition 4 for clay soil



Condition 4 for clay soil

Fig.2

Deformed mesh and total displacement at variant cases

For condition No.(1), the values of total displacement in soft clay increased than another conditions by about seven times.

The total displacement in medium and dense clay soil in condition 1 and other conditions nearly closed.

According to the obtained results from applied traffic load equal 30 and 60 ton as shown in Figs. 3, 4 respectively.

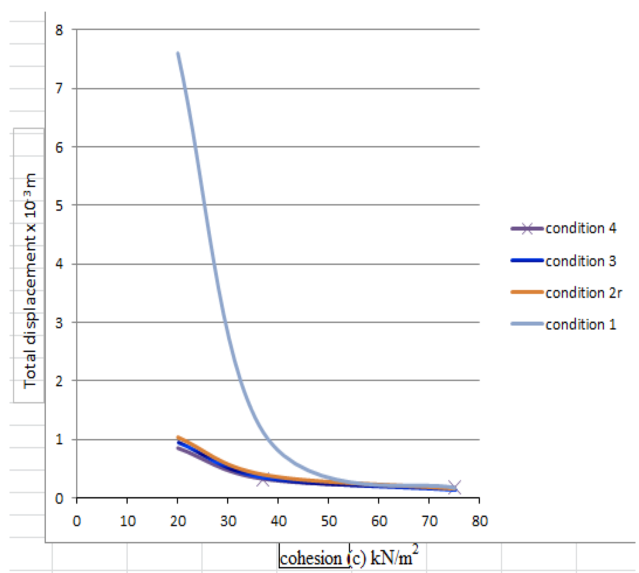


Fig.3.Relationship between cohesion and total displacement at traffic load = 30 t

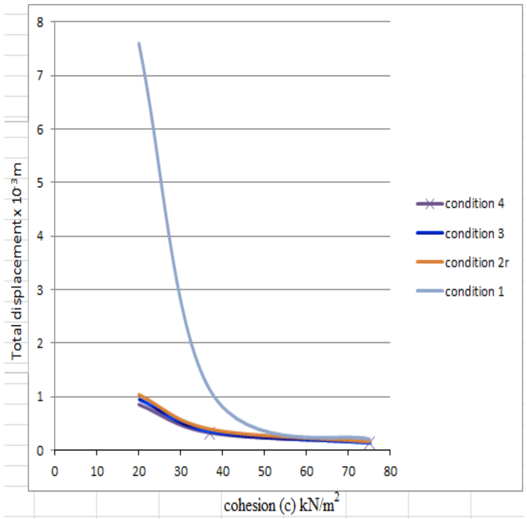


FIG.4. Relationship between the cohesion and the total displacement at a traffic load of 60 t

For condition No. (1), the values of total displacement increased than other conditions by about 20% in sand soil embankment.

The total displacements in condition 2, 3 and 4 in sand soil embankment were nearly closed.

According to the obtained results from applied traffic load of 30 and 60 ton as shown in Figs. 5 and 6 respectively.

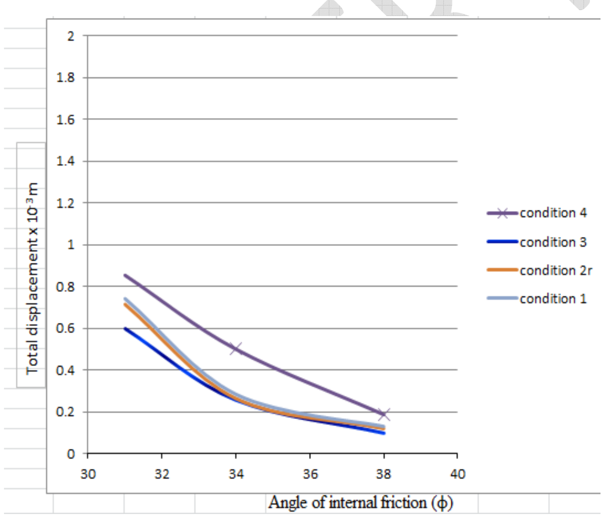


FIG.5Relationship between the angle of internal friction and the total displacement at a traffic load= 30 t

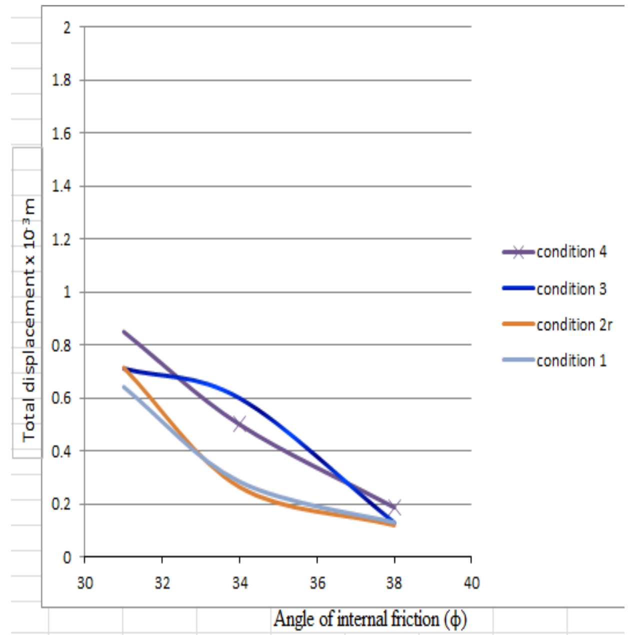


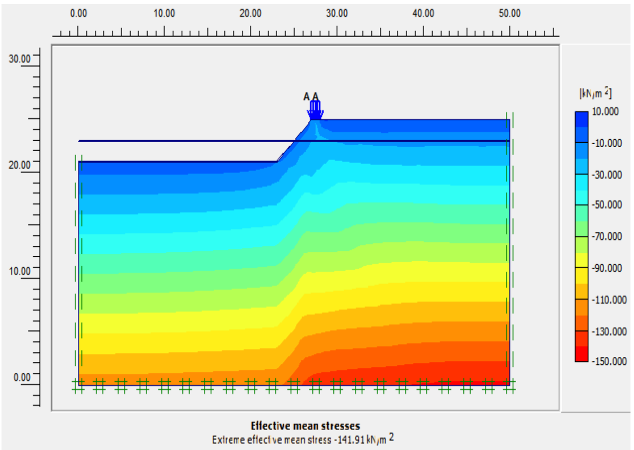
FIG.6.Relationship between the angle of internal friction and the total displacement at a traffic load of 60 t

b. Effective mean stress

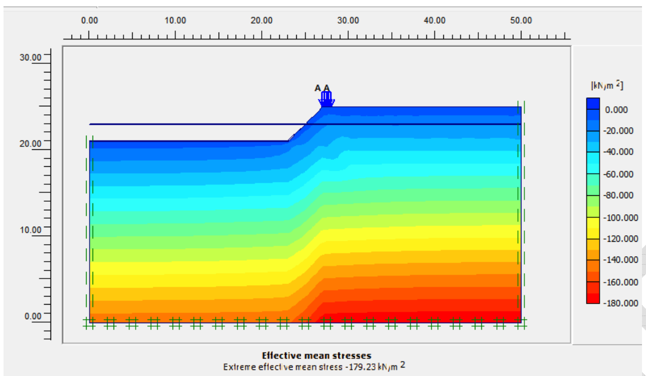
The values of effective mean stresses ranged between (-134.58 and 179.46) kN/m^2 and (-174.94 and -185.05) kN/m^2 for sand and clay soil embankments, respectively.

Generally, the effective stress increased with the increasing of applied traffic load and decreased with the increasing of cohesion for clay soil and angle of internal friction for sandy soil.

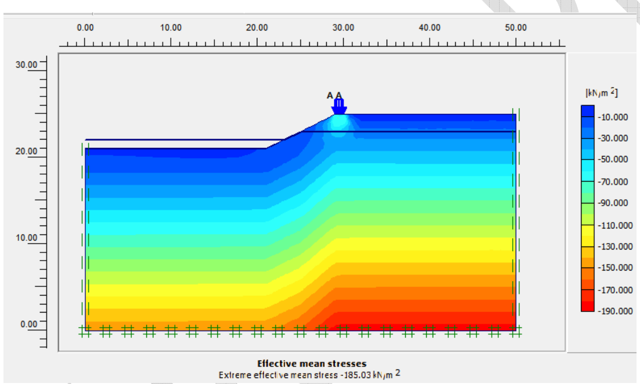
For conditions 1 and 3 the values of the effective mean stresses are less than of condition 2 and 4, respectively in both sand and clay embankments, as shown by Fig. 7.



Condition 2 for sand soil



Condition 2 for clay soil



Condition 4 for clay soil

FIG.7. Effective mean stresses at different soil cases

c. Factor of safety (F.S)

Thefactor of safety depended upon the balance of the forces resisting movement to the driving movement.According to the values of sand and clay soil embankment results of the relationship between factor of safety with the angle of internal friction and cohesion it can be noted that:

1- At sandy soil embankment the values of (F.S) is ranged between 0.99 and 1.12 with an average value of 1.05 and increased with increasing and at the angle of internal friction as shown in Fig. 8
2- At clay soil embankment the values of (F.S) is ranged between 1.80 and 10.25 with an average value of about 6.02 and increased with increasing the cohesion, Fig. 9.

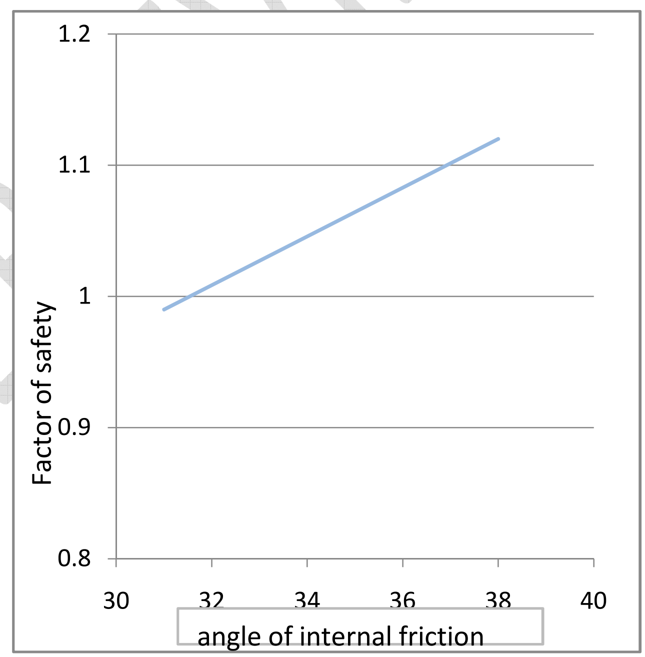


FIG.8. Relationship between Factor of Safety and the angle of internal friction

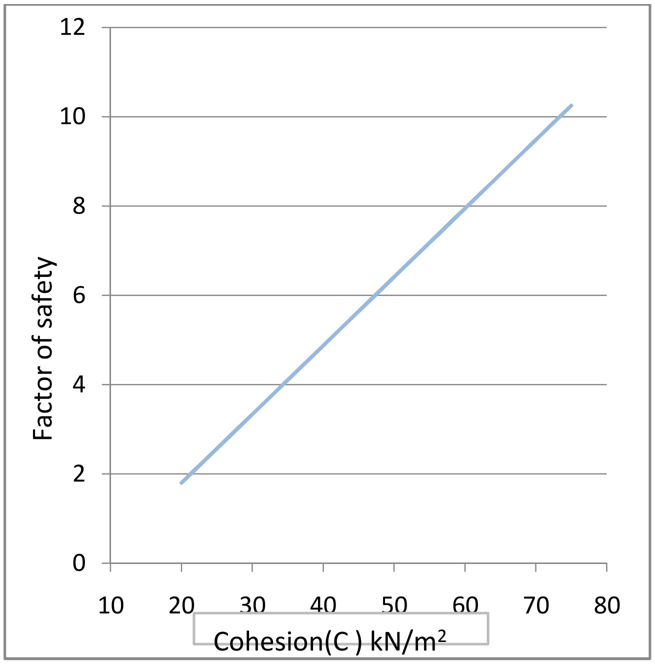


Fig.9, Relationship between F.S and cohesion

Conclusions

The following conclusions can be drawn:

1- The total displacement increases with the increasing of applied traffic load and decreases with the increasing of cohesion for clay soil and angle of internal friction for sand soil.
2- For dry condition, when there is no ground water in theembankment and thecanal is running at full supply level, the total displacements in soft clay increase more than inother conditions by about seven-times.
3- The total displacements in medium and dense clay soil in dry and other conditions are nearly similar.
4- For condition1 described above, the values of the total displacement increase more than in other conditions by about 20% of that in sand soil embankment.
5- The total displacements in condition 2, 3 and 4 in sand soil embankment were nearly similar.
6- For condition No. (1) and (3) the values of effective mean stresses less than the condition No. (2) and (4) respectively in sand and clay soil embankment.
7- At sand soil embankment the values of (F.S) is ranged between 0.99 and 1.12 with average value about 1.05 and increased with increasing the angle of internal friction.
8- At clay soil embankment the values of (F.S) is ranged between 1.80 and10.25 with average value about 6.02 and increased with increasing the cohesion.

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