Stability Analysis of Cellular Retaining Structure by PLAXIS Finite Element Code

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Abstract

In this study, analysis of retaining structure by using the software PLAXIS is adopted and the deformation that occurs in the body of the retaining structure after applied the failure load detected; the failure loads are obtained from the series of laboratory tests. Then, the cofferdam is modelled by using finite element code PLAXIS.

The laboratory tests have been carried out two diaphragm cells of different width to depth ratios, and used three different soil materials (subbase, sand passing No.4, river sand, and clay). The analysis includes studying the effect of height, width, and embedment depth. The input data of soils that are used in this software are getting from these laboratory tests. The comparison is done between the deformation that is obtained from the actual experimental and the software PLAXIS. It can be seen that the displacement for the retaining structure place on ground surface in the laboratory test equal to 0.00322m and the displacement that obtain from PLAXIS equal to 0.00372m, and the displacement for retaining structure with embedment depth in laboratory test equal to 0.00321m and the displacement from software PLAXIS equal to 0.00263m Thus, the results from these two studies have been found closed to each other.

1: Introduction

The program will be analyzed the construction by finite element method to obtain the deformation that accrued into retaining structure and so beneath of the structure and calculated the effective stress, shear stress and horizontal displacements. The study include two case, in the first case the structure placed on the ground surface and the second case the body of structure has driven into soil.

2: Creating Geometry Model

In order to carry out a finite element analysis, a geometry model of soil layer is required. For drawing the full geometry contour it is preferred to form a table including the x and y coordinates of each point as the accuracy is higher than that drawing by mouse directly. Consequently lines and clusters are generated geometry contour is completed for each stage. The geometry models created for the structure placed on the ground surface and the body of structure has driven into soil are presented in figures (1) and (2) **(Bowles, 1997).**

2.1: Loads and Boundary Conditions

To set up the boundary condition, the standard fixities option is used. As a result a full fixity at the base and free condition at the horizontal side of geometry are generated. It is worth mentioned that the point loads are take in state failure of retaining structure in the laboratory tests**(Al-Taee,1990),**, the point loads in two figures (1) and (2) are 0.57 KN and 0.76KN are applied on structure.

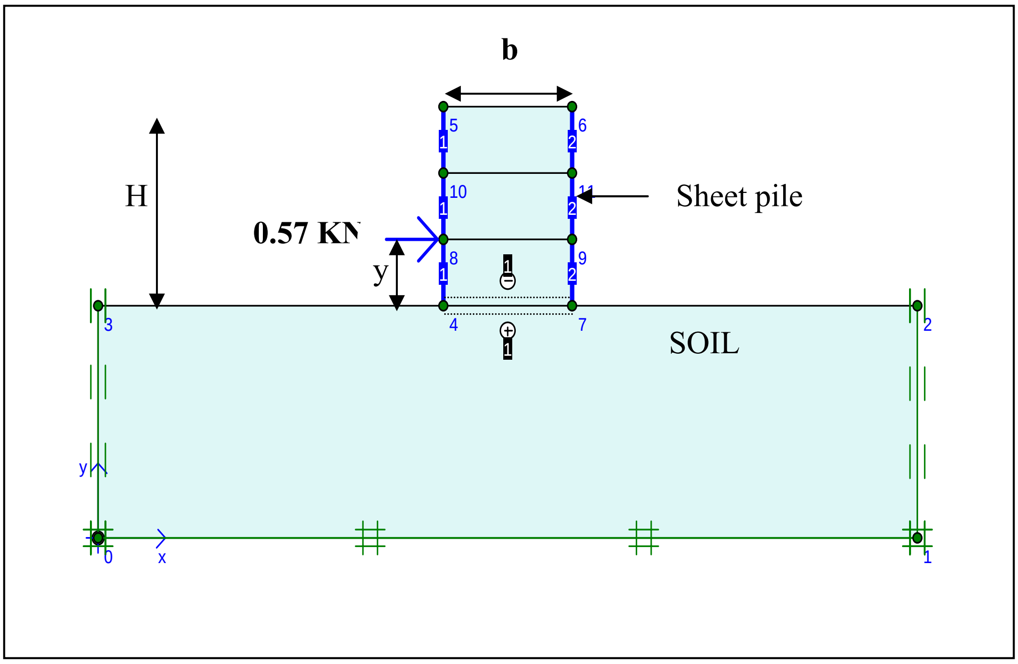

Fig (1): Geometry of Model for Cell Filled with Subbase, y=100mm

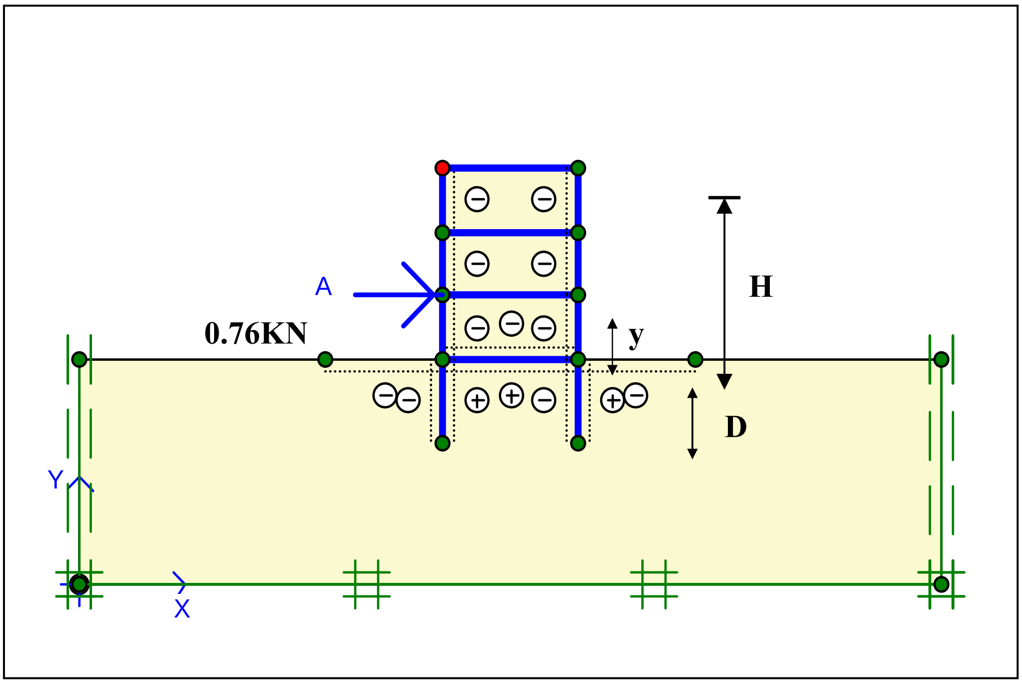

Fig (2) Geometry of model for cell filled with subbase, $\frac{b}{H}$ =0.75, y=100mm, D=0.135mm

2.2 Setting Material Data Base

Soil properties are stored in material data base. For fill, subbase, sand passing sieve No.4, clay and sand river unit's different material data sets have been created and the material properties are given in Table (1) **(TVA,2003)**.

In order to modeling the PLAXIS requires the soil parameters obtained from laboratorial tests. In the analysis elastic-plastic Mohr-Coulomb model is used as material model. It involves five parameters namely, Young's Modulus (E) and poison's ratio (ν) for soil elasticity, friction angle (ϕ) and cohesion (c) for soil plasticity (**Abadjiev, 1994**).

2.3 Mesh Generation and Calculations

After assigning the material properties to the related layer, the geometry model required to carry out a finite element analysis has been completed. The second step for the performance of finite element calculations is the division of the geometry into elements. Finite element mesh, which is a composition of the finite elements, is generated fully automatic in PLAXIS **(Brinkgreve, 2008)**. The mesh generated for the retaining structure as shown in figures (3) and (4).

Table (1): Material Properties.

Parameter	Name	Subbase	Sand passing sieve No.4	River sand	Clay	Unit
Material model	Model	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	-
Material of behavior	Drained	Drained	Drained	Drained	Drained	-
Soil unit weight	**γdry**	17.5	16.5	15.3	14.5	KN/m^3
Soil unit weight	**γsat**	18.4	17.2	16.5	15.7	KN/m^3
Young's modules	**E**	10000	7000	7000	4000	KN/m^2
Poison's ratio	**ν**	0.15	0.15	0.15	0.15	°
Cohesion	**c**	1	3	3	7	KN/m^2
Angle of friction	**ϕ**	38	34	32	22	°

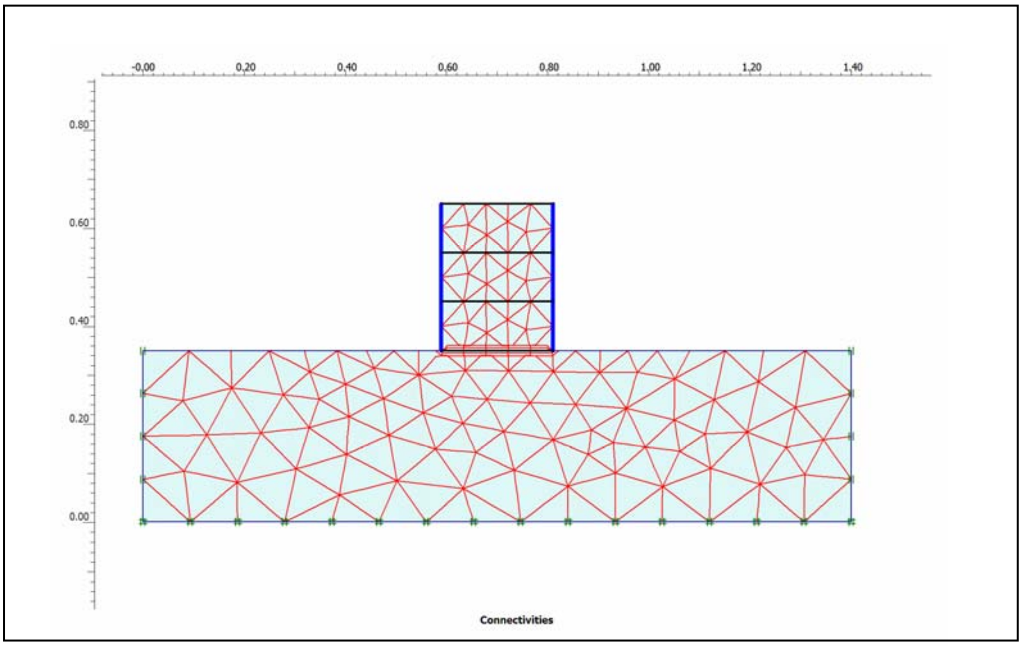

Fig. 3. Generated Finite Element Mesh for Retaining Structure Place on ground surface

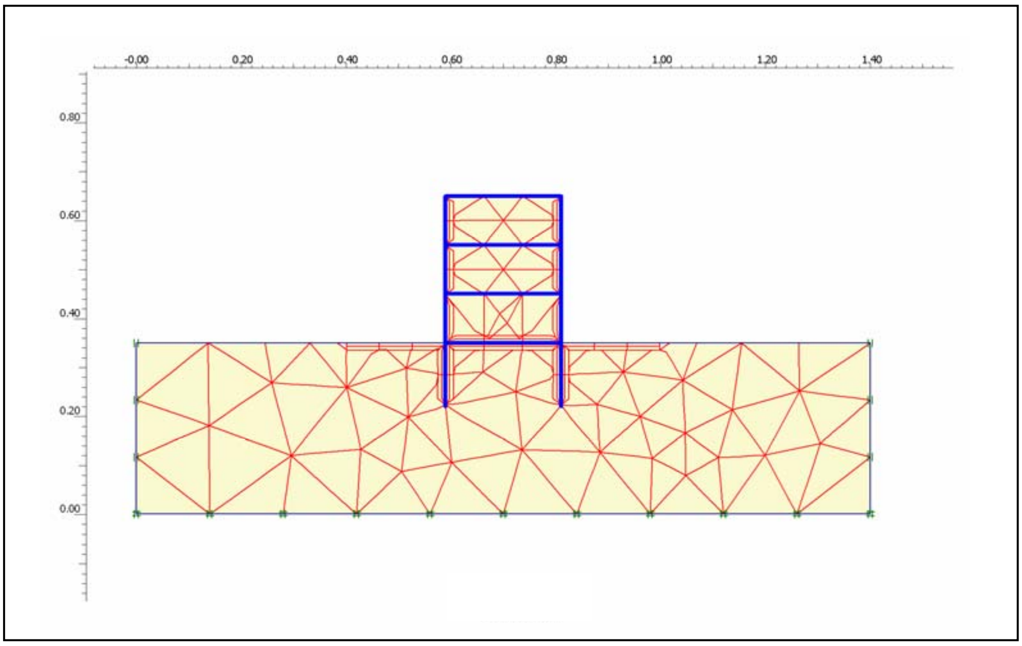

Fig (4): Generated Finite Element Mesh for Retaining Structure with Embedment Depth

Once the mesh has been generated, the finite element model is complete. Before starting the calculations, however, the initial conditions must be generated. In general, the initial conditions comprise the initial groundwater conditions, the initial geometry configuration and the initial effective stress state. The soil layer in the cellular cofferdam project is dry, so there is no need to enter groundwater conditions as shown in figures (5) and (6) **(Brinkgreve, 2008)**.

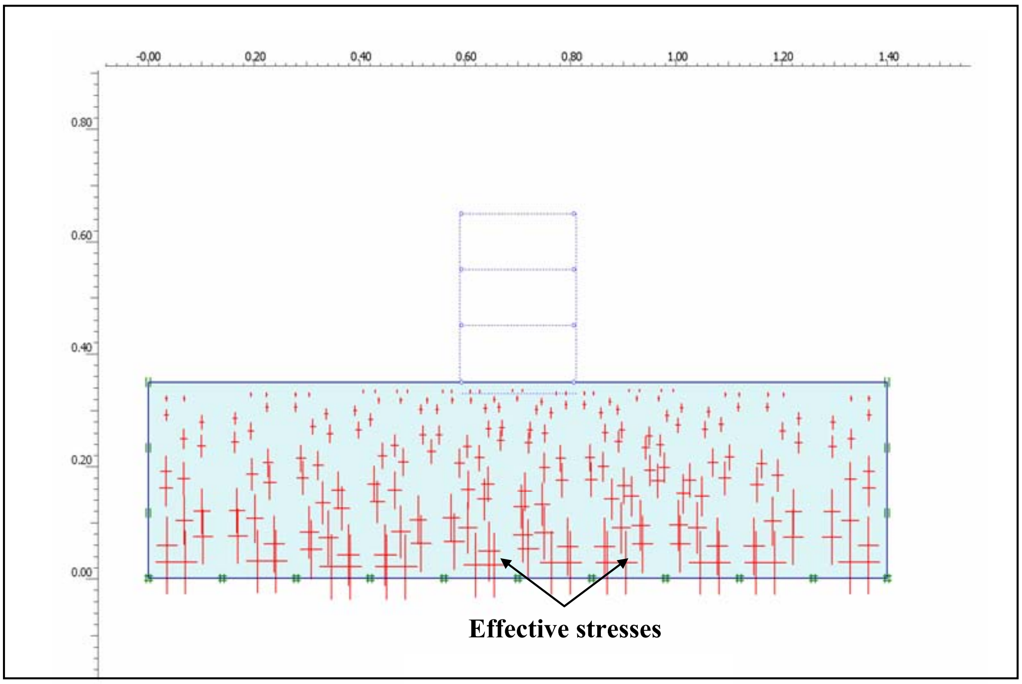

Fig (5): Initial Stress Field in the Geometry of Retaining Structure

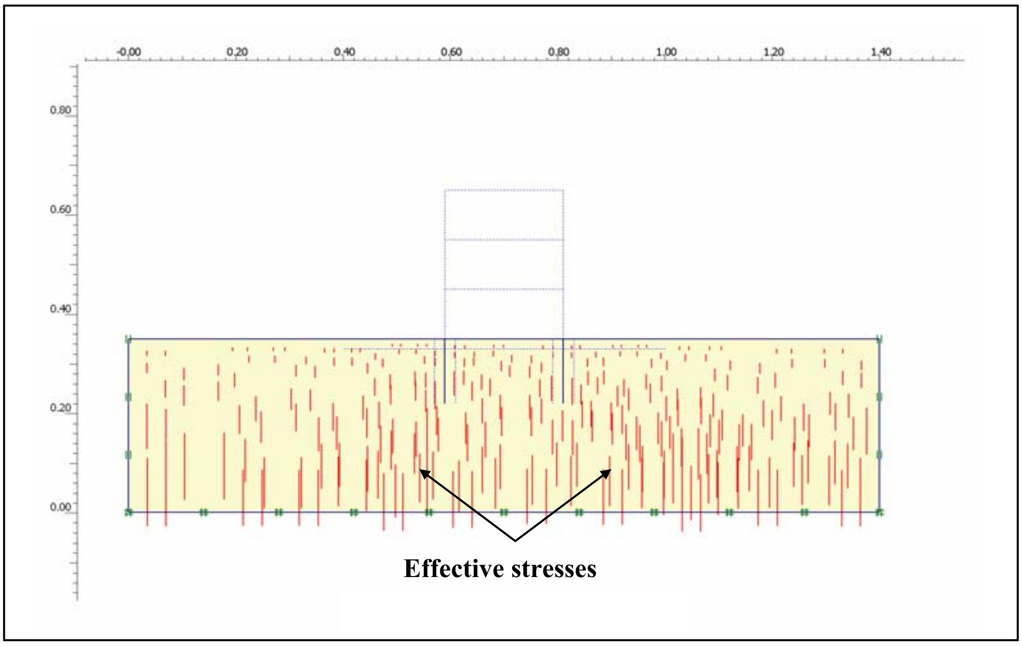

Fig (6): Initial Stress Field in the Geometry of Retaining Structure with Embedment Depth

3: Results of Analysis

The calculations were based on values taken from laboratorial tests for each soil. The results obtained are discussed in the following paragraphs.

a. Fig. (7) Shows the deformation mesh and the extreme total displacement that equals to 0.00373 m. The position of this displacement in the top point of cofferdam, and the Fig. (8) illustrates the deformation mash that occurred in structure that has been embedment depth and the magnitude of displacement equal to 0.00263 m; therefore, the PLAXIS results give a good agreement with observed laboratory tests. Then, the deformation in case of the structure has embedment depth equal to (0.45) height to depth ratio is less than the deformation in case of the structure placed on ground surface.

b. The plots in Fig. (9) and (10) show the magnitude and the direction of the principal effective stresses. The effective stresses are defined as the stress perpendicular to the cross-section. The orientation of the principle stresses indicates large passive zone in beneath part of the load of the cofferdam and the effect continues to the foundation which the soil under right zone for the cofferdam. It can be seen that the effective stresses at the top of the cofferdam and the right hand side of the foundation are nearly zero. Fig (10) shows the stresses by shaded areas which are colored with red color represent the zone large stresses and these zones concerning in toe of the structure.

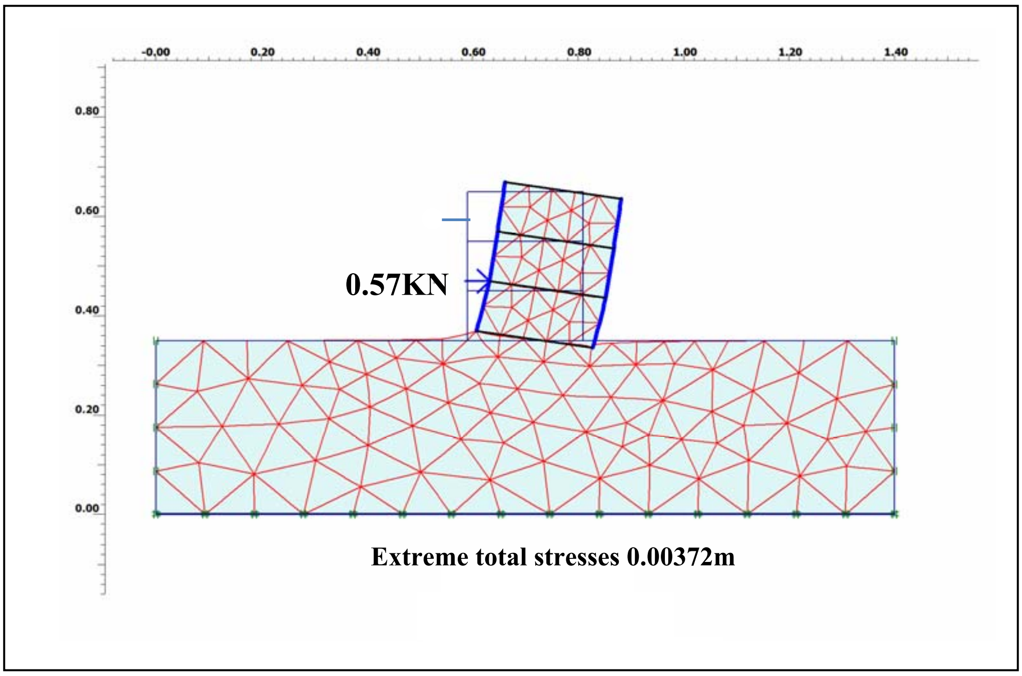

Fig (7): Deformed Mesh in the Retaining Structure and Body Soil

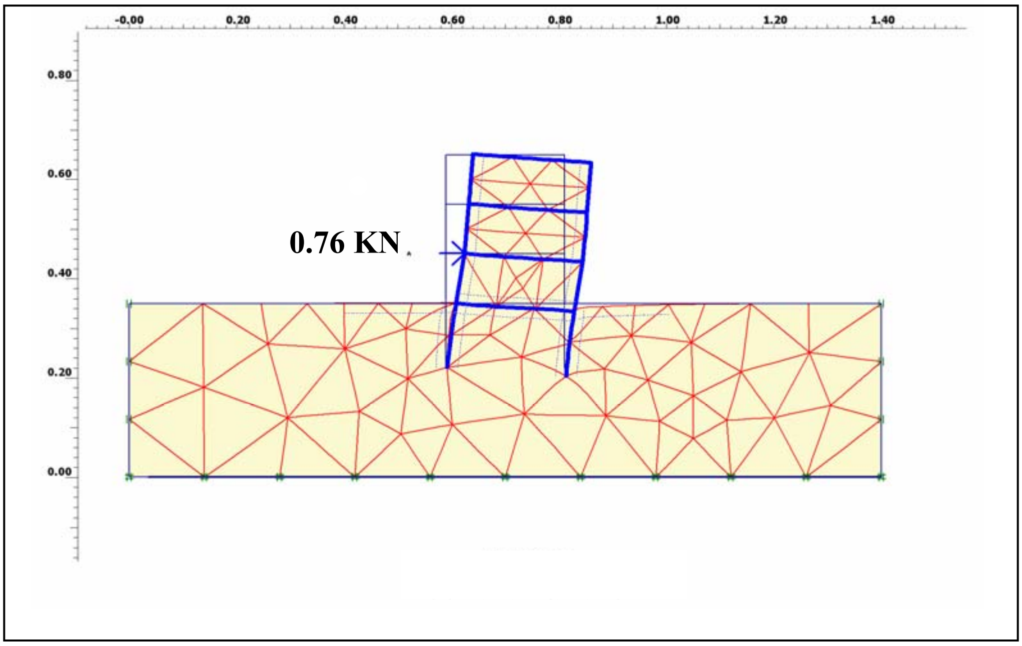

Fig (8): Deformed Mesh in the Cofferdam and Body Soil in the Embedment State

c. The plots in Fig. (9) and (10) show the magnitude and the direction of the principal effective stresses. The effective stresses are defined as the stress perpendicular to the cross-section. The orientation of the principle stresses indicates large passive zone in beneath part of the load of the cofferdam and the effect continues to the foundation which the soil under right zone for the cofferdam. It can be seen that the effective stresses at the top of the cofferdam and the right hand side of the foundation are nearly zero. Fig. (10) shows the stresses by shaded areas which are coloured with red color represent the zone large stresses and these zones concerning in toe of the structure.

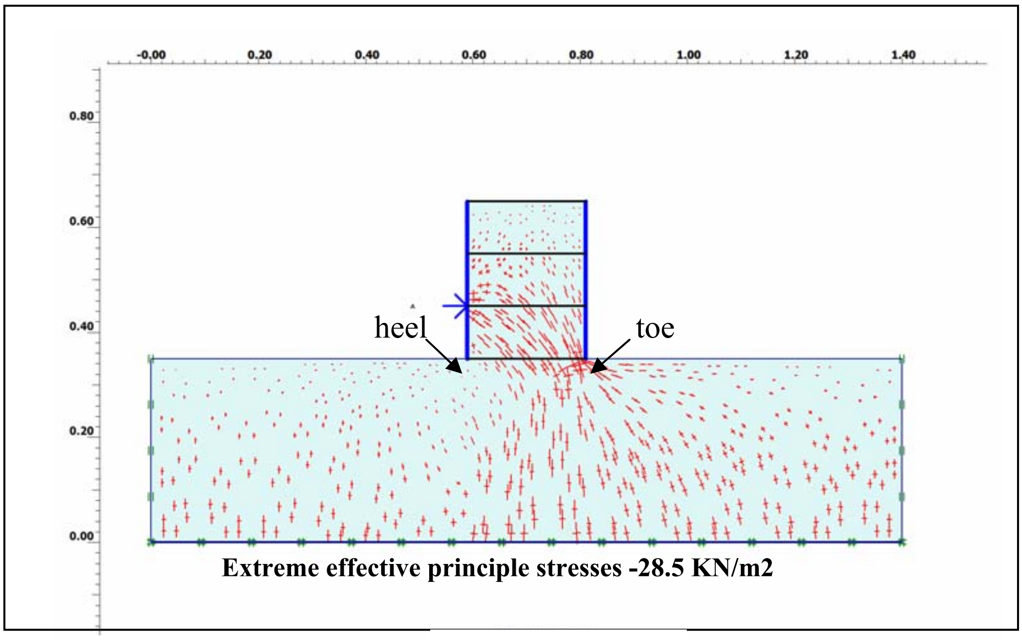

Fig (9): Effective Stresses of the Retaining Structure

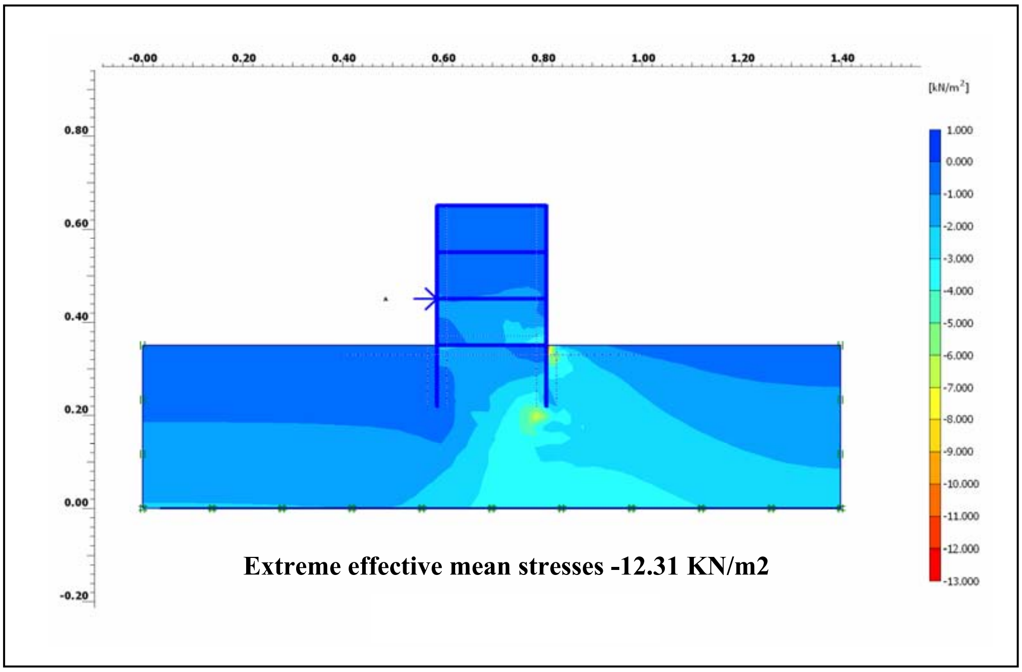

Fig (10): Effective Stresses of the Retaining Structure

d. From the Fig (11): noted the shadings for the shear stresses of the cofferdam, the shear stress is defined as the shear stress along the cross-section line, it can also be seen that there is maximum shear stress concentration under the right side of the sheet pile (toe zone) which equal to (6.27 KN/m۲). Fig (12) shows the maximum shear stress all so in toe zone but behind the right side of the sheet pile which equal to (10.22 KN/m2).

4: Generating A Load-Displacement Curve

In addition to the results of the final calculation step, it is often useful to view a load-displacement curve for purpose of comparison. Therefore, the PLAXIS package is used. In order to generate the load displacement curve as a given in figure (13). For the X-axis is represented the displacement and the Y-axis is represented Sum-Mstage. Hence, the quantity to be plotted on the y-axis is the amount of the specified changes that has been applied. Hence the curve will range from 0 to 1, which means that 100% of the prescribed load (0.76 KN/m2) has been applied and the prescribed ultimate state has been fully reached, and the figures (12) and (14) are represented load-displacement behavior for the cofferdam place on ground surface and the cofferdam with embedment depth respectively and the figures (15) and (16) are represented the comparison between software PLAXIS and experimental test.

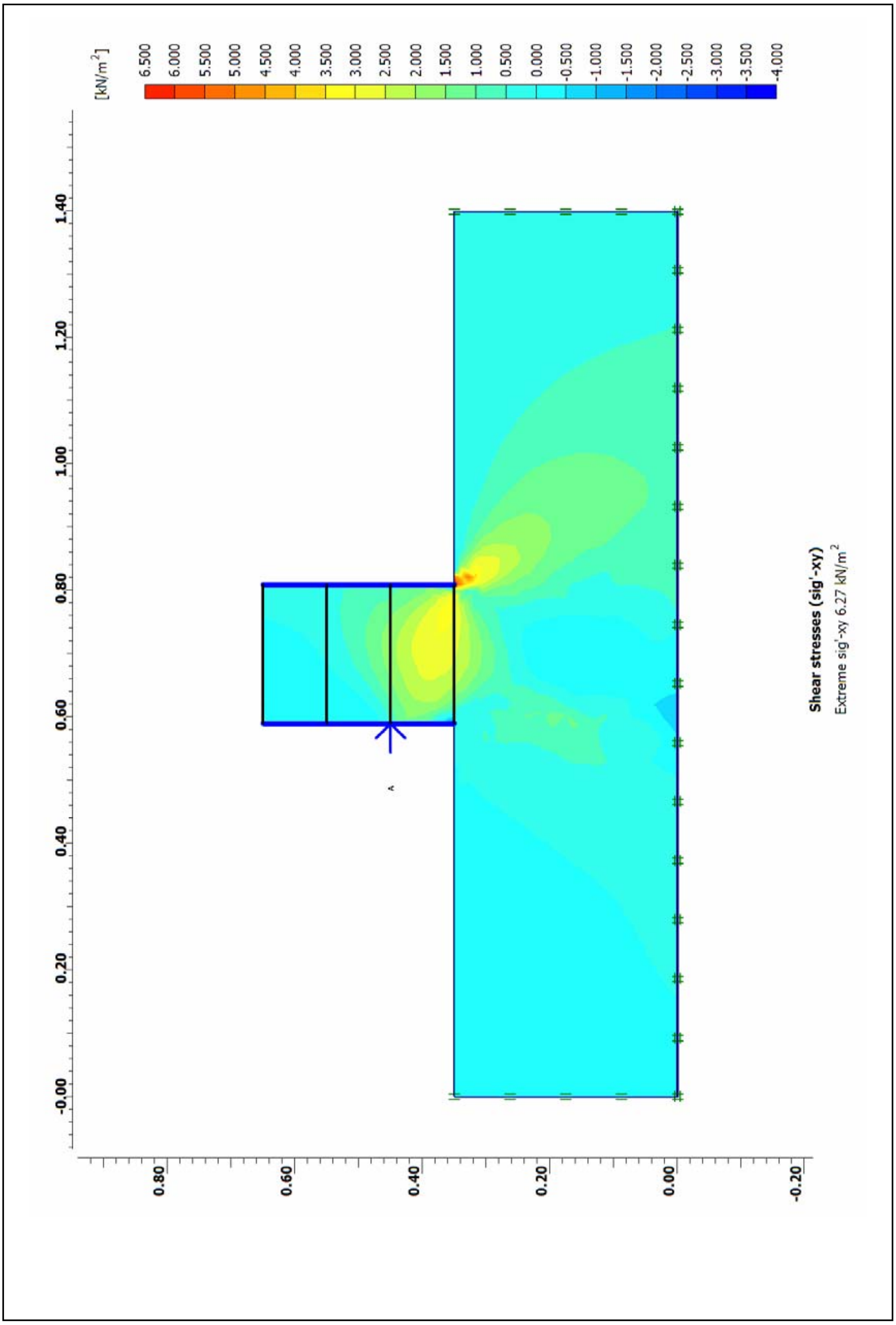

Fig (11): Shear Stress in the Retaining Structure (xy)

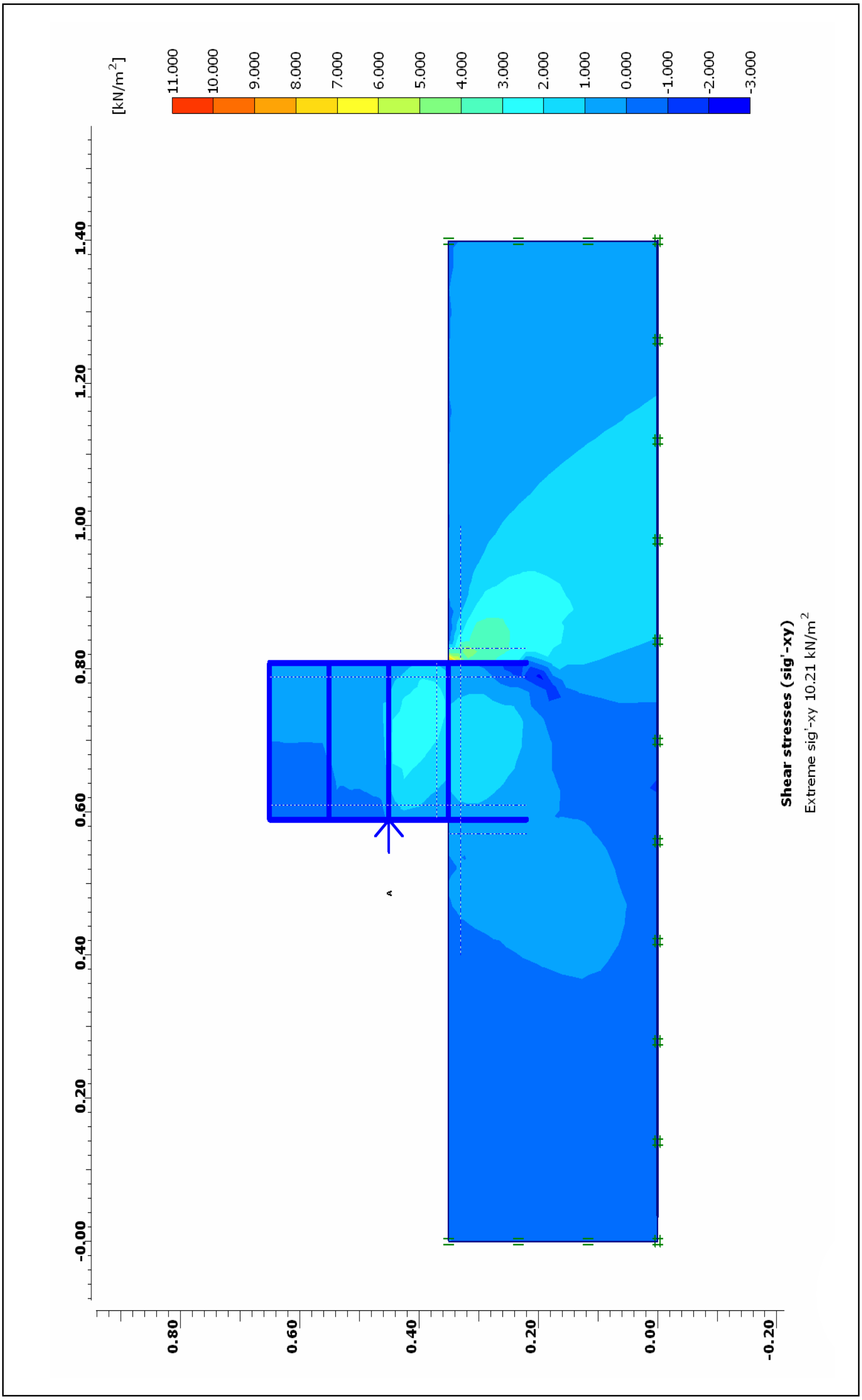

Fig (12): Shear Stress in the Retaining Structure (xy)

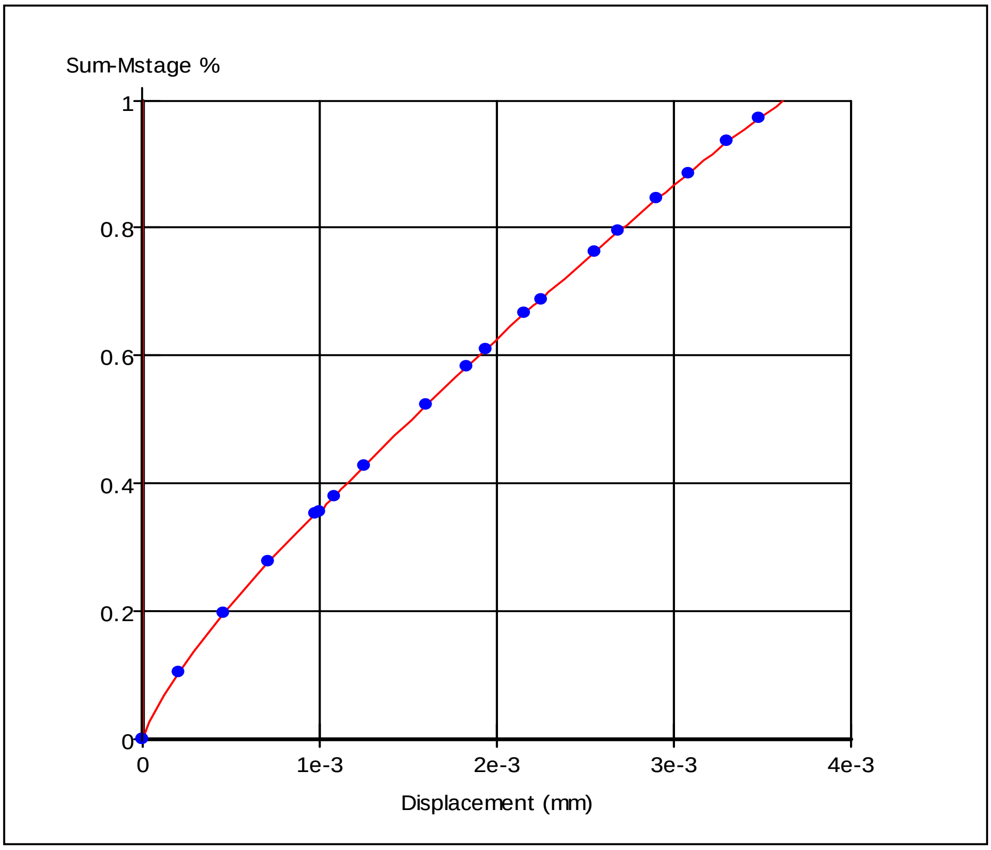

Fig (13): Load- Displacement Curve for the Retaining Structure Place on Ground Surface

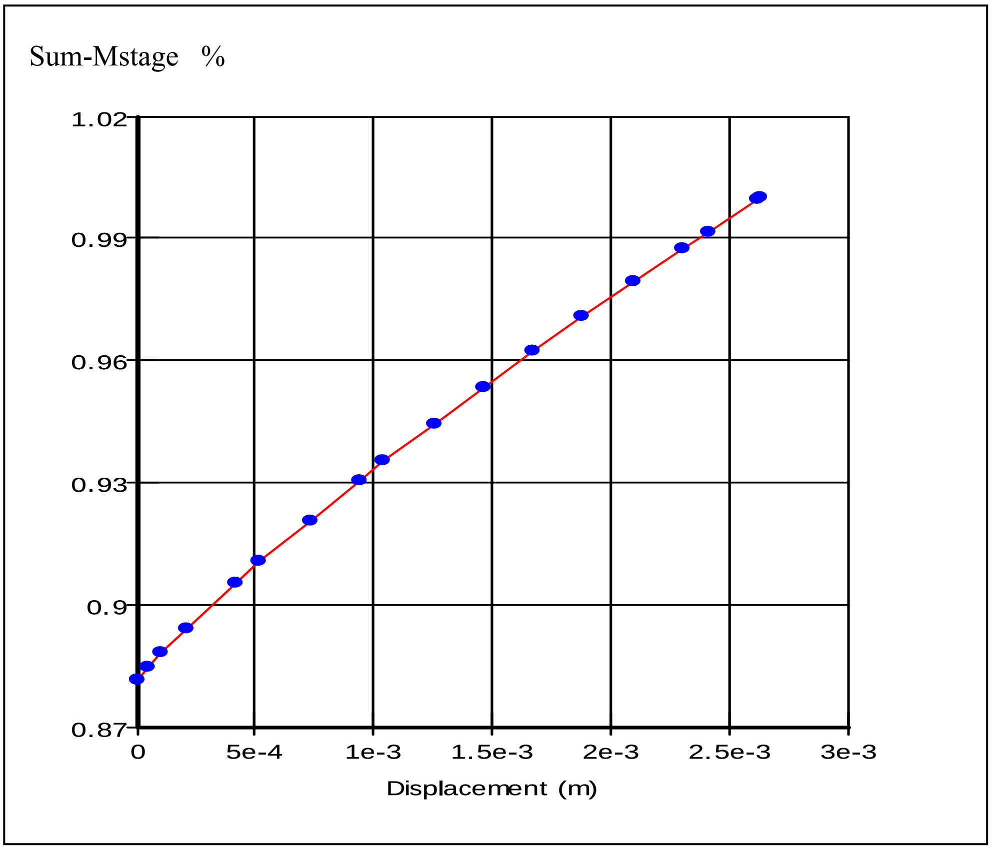

Fig (14): Load- Displacement Curve for the Cofferdam with Embedment Depth H/D=0.45

5: Comparison between Laboratory Tests and Theoretical

The results of the PLAXIS analysis compared with experimental tests were presented in Figures 15 and 16. It can be seen that the displacement for the retaining structure place on ground surface in the laboratory test equal 0.00322m and the displacement that obtain from PLAXIS equal to 0.00372m, and the displacement for retaining structure with embedment depth in laboratory test equal to 0.00321m and the displacement from software PLAXIS equal to 0.00263m. Therefore, the different between two methods is very small but the different between the retaining structure place on ground surface and the retaining structure with embedment depth equal 0.45 depth to height ratio is 23.3%. The PLAXIS software prediction of lateral retaining structure displacement agrees with laboratory test.

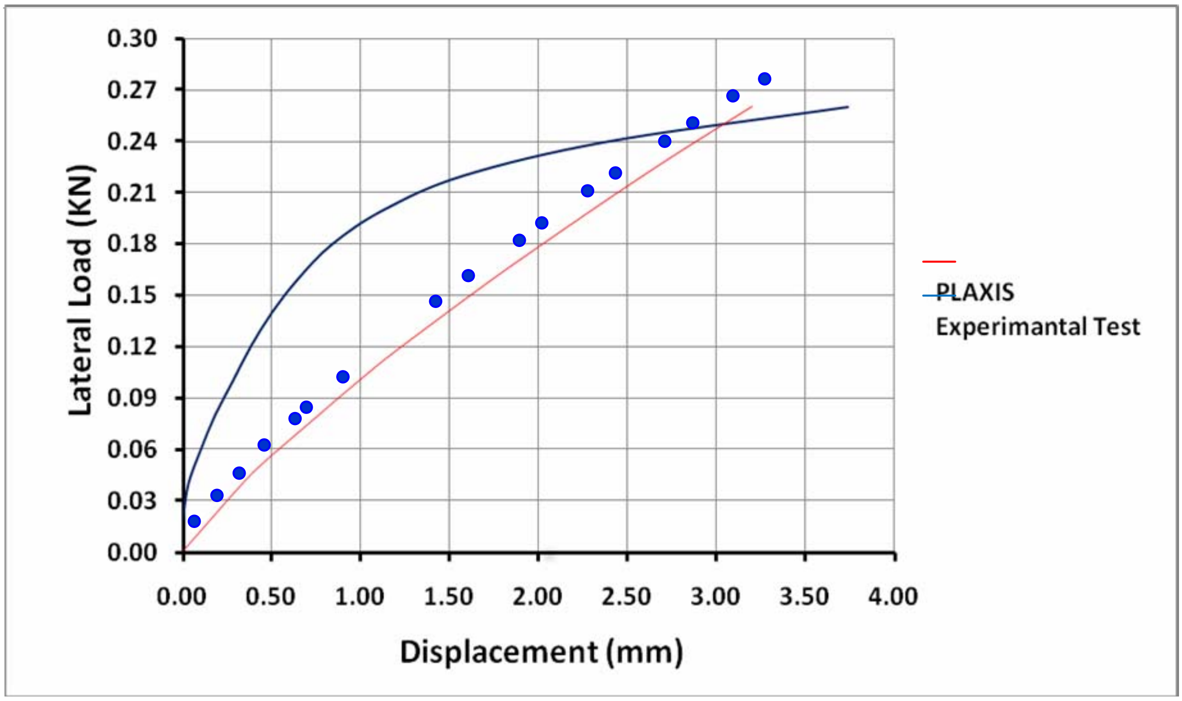

Fig (15): Load- Displacement Curves Comparison for the Cofferdam Place on Ground Surface

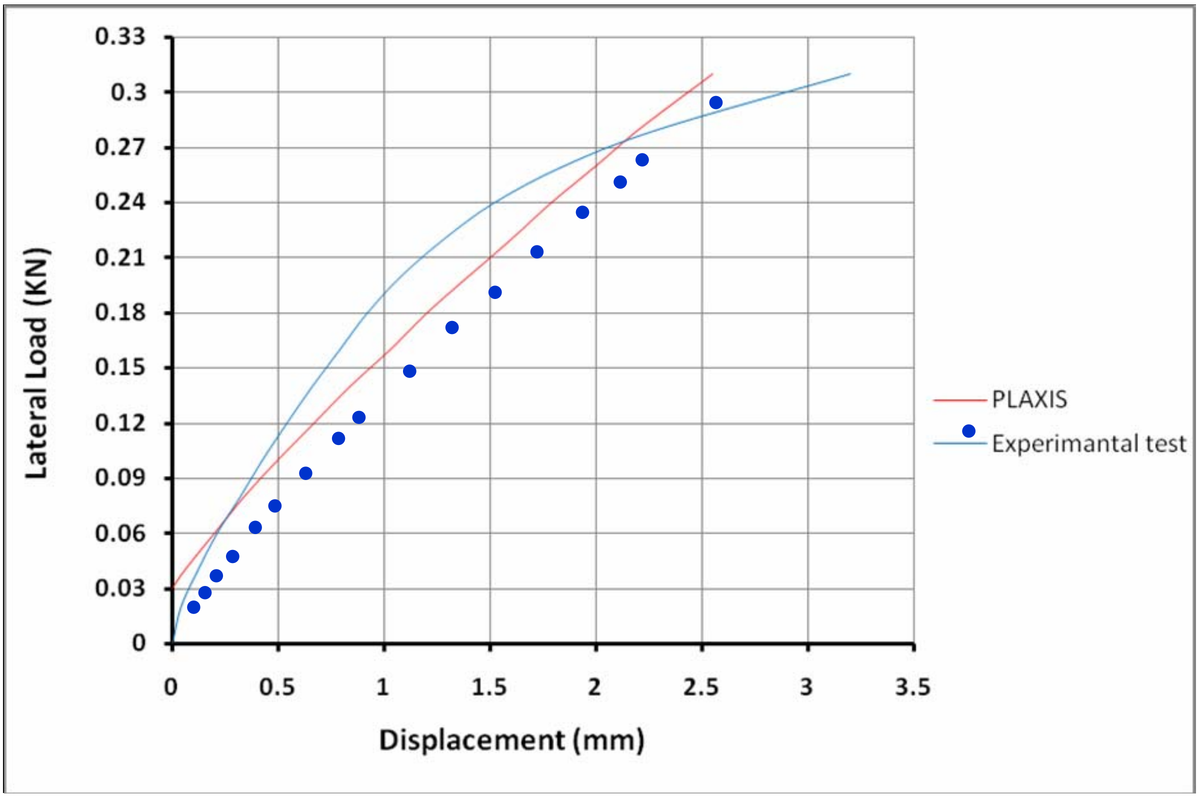

Fig (16): Load- Displacement Curve for the Cofferdam with Embedment Depth

6: Evaluation of the Current Design Method

Tables (2) and (3) show comparison of the deformation that obtained from experimental and the results obtained from PLAXIS software. The different ratio height to depth of embedment and so that different of soil material is adopted.

Table (2): Comparison of the Deformation Observed and PLAXIS Software, with (b/H)=0.75

Soil type	Applied load KN/m	Deformation (m) in experimental	Deformation mesh (m) in PLAXIS
Subbase	0.57	3.75E-3	3.1E-3
Sand passing No.4	0.47	3.6E-3	1.9E-3
River sand	0.42	2.8E-3	1.65E-3
Sandy-clay	0.47	4E-3	1.8

Table (3): Comparison of the Deformation Observed and PLAXIS Software, with D =0.135mm

Soil type	Applied load KN/m	Deformation (m) in experimental	Deformation mesh (m) in PLAXIS
Subbase	0.76	3.1E-3	2.63E-3
Sand passing No.4	0.71	1.9E-3	2.24E-3
River sand	0.57	3E-3	2.04E-3
Sandy-clay	0.66	2.8E-3	2.98E-3

7: Conclusion

The analysis of retaining structure by software PLAXIS is based on laboratory tests for the retaining structure placed on ground surface and the retaining structure with embedment depth, the different between two methods is very small but the different between the retaining structure place on ground surface and the retaining structure with embedment depth equal 0.45 depth to height ratio is 23.3%. The PLAXIS software prediction of lateral retaining structure displacement agrees with laboratory test. Therefore, the deformation is decrease when increase the resistance and to increase the strength of soil most be used the properties of soil (**ϕ, c and E**) with large and used embedment depth equal to 0.45 height to depth ratio.

8:References

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