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Evaluation of Tang-e-hamam dam stability by changing the angle of internal friction in shell of dam

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Abstract— Composite clay is a mixture of clay, as the main body and aggregates which are floating within the clayey matrix. Undrained behavior of composite clays in its natural or compacted state e.g., core material of embankment dams has a great importance for the geotechnical engineers. On the other hand, experience has shown that significant pore pressure could build-up during cyclic loading in composite clays. In this paper, the results of static analyses performed on Tang-e-hamam embankment dam in Iran, incorporating different core materials, are presented. Appropriate models for the core materials are utilized, based on the laboratory test results. Thus in this research, stress of Tang-e-hamam dam was investigated. Then parametric studies perform, that it was concluded that increasing the angle of internal friction leads to increased safety factor of dam.

Index Terms— embankment dam, plaxis 2D, dam stability, safety factor

1 Introduction

When the reservoir has been full for some time, conditions of steady seepage become established through the dam with the soil below the top flow line in the fully saturated state. This condition must be analysed in terms of effective stress with values of pore pressure being determined from the flow net.

Hossein Moayedi et al in 2011 studied on Effect of Embedding Drainage System on Retaining Wall Structure Stability. Although using drainage systems behind a retaining wall (RW) could control the excess pore water pressure during seismic loading, it has an essential effect on reducing the amount of water pressure adjacent to wall structures. Also, importance of such a system will be more significant when one takes into account the long term usage issues. Different finite element models were carried out to estimate the effects of using drainage layer adjacent to the RW structure. Results observed from the finite element models show significant reduction of forces and bending moments which could be used in wall structure designs due to using the drainage systems. A series of numerical models has been done to predict the response of RWs by applying load after heavy rainfalls where water accumulates behind the wall. The suggested wall response results from the plane strain numerical models are discussed with the measured responses of three different outputs which were bending moment, shear stress value in bottom and horizontal deflection at the top of the wall. It is found that using drainage system for both cases has an important effect in reducing the forces acting for overturning the structures. The reduction factors were 35% and 38% for bending moment and shear stress value respectively. The horizontal deformation reduction factor at the top of the wall observed as 43% in comparison with the non drainage used one.

Tohid Akhlaghi and Ali Nikkar in 2014 investigated on Evaluation of the Pseudostatic Analyses of Earth Dams Using FE Simulation and Observed Earthquake-Induced Deformations: Case Studies of Upper San Fernando and Kitayama Dams. Evaluation of the accuracy of the pseudostatic approach is governed by the accuracy with which the simple pseudostatic inertial forces represent the complex dynamic inertial forces that actually exist in an earthquake. In this study, the Upper San Fernando and Kitayama earth dams, which have been designed using the pseudostatic approach and damaged during the 1971 San Fernando and 1995 Kobe earthquakes, were investigated and analyzed. The finite element models of the dams were prepared based on the detailed available data and results of in situ and laboratory material tests. Dynamic analyses were conducted to simulate the earthquake-induced deformations of the dams using the computer program Plaxis code. Then the pseudostatic seismic coefficient used in the design and analyses of the dams were compared with the seismic coefficients obtained from dynamic analyses of the simulated model as well as the other available proposed pseudostatic correlations. Based on the comparisons made, the accuracy and reliability of the pseudostatic seismic coefficients are evaluated and discussed. The results obtained fromthe analyses conducted for investigating theUpper San Fernando

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and Kitayama dams behavior, respectively, under San Fernando 1971 earthquake and Kobe 1995 earthquake loading indicate that the seismic coefficient increases with the increasing of the height. The ratio of seismic coefficient at the crest of the Upper San Fernando dam over seismic coefficient at the base of the dam is about 1.44 and this ratio for the Kitayama dam is about 2.

Yi Zhu et al in 2005 studied on a 2D Seismic Stability and Deformation Analysis. Two-dimensional (2D) seismic stability and deformation calculations for a 16.5-meter high levee embankment are presented. The embankment is to be constructed on potentially liquefiable foundation soil. A liquefaction triggering analysis is conducted that includes stress calculations for the pre-earthquake condition under steady-state seepage using the finite element program PLAXIS, seismic response calculations using the finite element program TELDYN, and liquefaction resistance estimates. The results of the 2D analysis suggest that the potentially liquefiable soil is confined to approximately the uppermost 10 meters of the natural soil under a limited area of the downstream embankment toe. The 2D analysis clearly illustrates the increased liquefaction resistance and the safety factor against liquefaction in the foundation soil beneath the major portion of the embankment due to the increased confining stress of the embankment loading. The 2D liquefaction triggering analysis results are used to estimate the end-of-earthquake strength using the procedure proposed by Seed and Harder (1990).

Srivastava A. and Sivakumar Babu G.L. in 2013 studied on Stability analysis of earth dams under static and earthquake loadings using geosynthetics as a seepage barrier. In recent years, geosynthetics have played a major role in dam and reservoir rehabilitation projects and provided promising solutions to the safety issues for earth dams experiencing seepage losses. In the present study, the structural stability of the earth dam under static and earthquake loading conditions is investigated in which geosynthetics lining system is used as seepage barrier and results are discussed in the light of the results obtained for the same earth dam section with no geosynthetics lining systems. A typical example of homogeneous earth dam of height 10 m and top width 5 m with slope angle 1V:2H (U/S) and 1V:3H (D/S) is considered. The geotechnical properties of the earth dam are chosen in such a way that it is stable under static condition without any geosynthetics lining system. For the dynamic numerical analysis of earth sinusoidal motion of different frequency and displacement amplitude (constant time duration) as well as acceleration time history record of the Bhuj (India) earthquake as well as five other major earthquakes recorded worldwide, i.e., EL Centro, North Ridge, Petrolia, TAFT, Loma Prieta, are used. The objective of doing so is to perform the dynamic numerical analysis of the dam section for the range of amplitude, frequency content and time duration of input motions. The results of the analysis clearly showed that geosynthetics lining system enhance the stability of the dam sections under static as well as earthquake loading conditions apart from providing a better alternative to controlling seepage in earth dams. Commercially available finite element code PLAXIS 2D has been utilized for the analysis.

Abdul Jalil in 2011 studied on The Analysis Slope Stability Reservoir Keuliling with Finite Element Methods. Keruntuhan timbunan tanggul dapat menyebabkan tidak stabilnya lereng baik dihulu maupun di hilir. Keruntuhan permukaan lereng terjadi karena aliran air di dalam tubuh bendung dan tanah pondasi. Kondisi kritis terjadi di lereng hulu waduk pada saat selesai konstruksi dan penurunan muka air tiba-tiba. Tahapan kritis pada hilir bendung pada saat selesai konstruksi dan terjadi rembesan ketika ketinggian air waduk penuh. Penelitian ini difakuskan pada analisa stabilitas lereng Waduk Keuliling di Kabupaten Aceh Besar.

1. Stability of the dam from the construction end of construction for sta 0+500 to sta 0+600 is 2.3 - 2.5. The long term condition safety factor is 2.78 -2.88. The rapid draw down condition show will stable, because the resulting safety factor is 2.2-2.4.
2. The Stability analysis with Ordinary method of slice is 1.23of SF and 4.32 the carry out safety factor with the bishop method.
3. in piping condition that occurs in unstable dam with a safety factor of 3.6 on average in the dam core. This value must match those required by the Safety factor between 3 and 4.
4. Dam is safe against the slopes failure in accordance with the requirements of specification of weir.

Vijayalakshmi Rentala and Neelima Satyam D in 2011 investigated on Numerical Modeling of Rock Slopes in Siwalik Hills Near Manali Region: A Case Study. Landslides are one of the frequently occurring natural hazards in seismically active regions of Northern part of Indian Himalayas. Landslides are the most destructive among all slope instability phenomena. Understanding the behaviour of landslides is very essential for planning and implementing landslide mitigation measures and microzonation studies. In first and second cases the slope is stable but in dynamic case the slope is critical since the displacements observed in the model will reflect the settlement. Excavation profiles of the slopes can be optimized and analyses can be carried out for those displacement profiles.

Linda Ormann et al in 2011 studied on Numerical Analysis of Curved Embankment of an Upstream Tailings Dam. A curved embankment (corner) of an upstream tailings dam was analyzed with the finite element method to identify possible zones of low compressive stresses susceptible to hydraulic fracturing that might initiate internal erosion. The analysis showed that in comparison to the straight section of the dam, the compressive stresses in the corner were (*i*) much lower above the phreatic level, in the rockfill banks and the filter zones, and (*ii*) fairly lower below the phreatic level. The rockfill and the filter contain coarse materials, which are not sensitive to hydraulic fracturing and internal erosion. An increase in radius of the corner is proposed to avoid too low compressive stresses that may develop due to future raisings. The slope stability analysis showed that the corner is currently stable, but an additional rock fill bank on the downstream toe is required for future raisings.

2 FINITE ELEMENT MODEL

The stability of the corner E-F/G-H was analysed with PLAXIS 2D, which is a finite element program for numerical analysis of geotechnical structures. The corner represents a complex

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three-dimensional geometry. An axisymmetric condition was assumed to model this geometry in two-dimensional space. This condition can be used for circular structures with an almost uniform cross section with load distribution around the central axis. In an axisymmetric condition, the *x*-coordinate represents the radius, and the *y*-coordinate denotes the axial line of symmetry. It is previously mentioned that due to horizontal pressure of retained tailings at the inner side of the corner, too low compressive stresses may occur near the surface along the outer side of the corner. It is assumed that if the corner is straightened, then the compressive stresses may be sufficiently high to resist hydraulic fracturing and internal erosion. Therefore, it is important to compare the compressive stresses in the corner with the straight section of the dam. Hence, the corner was also modelled with a plane strain condition, which is appropriate for any geotechnical structure - whose length is large compared with its cross section. Figure 1 illustrates the difference between a plane strain and an axisymmetric condition (Brinkgreve, 2002). In this paper, the compressive stresses are taken as positive and the tensile stresses as negative.

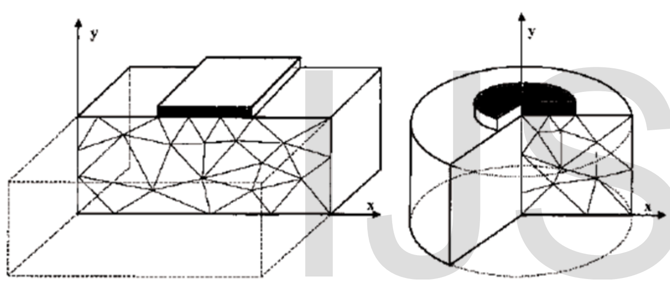

Figure 1- (*a*) Plane strain condition, and (*b*) Axisymmetric condition(Brinkgreve *et al.*, 2010).

It has been assumed that the stored tailings and the dam are raised 3 meter per year starting from the level 376 m above mean sea level. The crest level of the dam is 2 m above the level of the stored tailings. The present crest level of the dam in year 2010 is 387 m. The cross section of the corner is shown in figure 2. The estimated radius is 195 m (Figure 3). It is supposed that the dam is to be raised in stages with the upstream construction method with side slope of 1:6 (vertical to horizontal). Each stage comprises a raising phase of 10 days and a consolidation phase of 355 days.

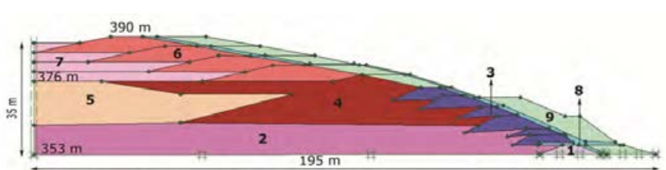

Figure 2- Cross section of corner E-F/G-H.

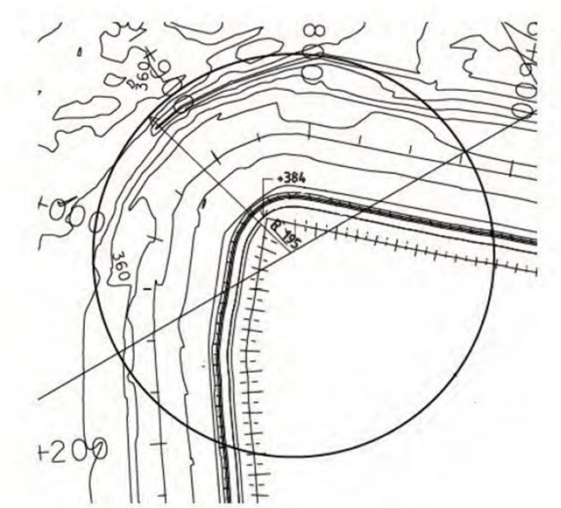

Figure 3- Plan of existing corner between the dam sections E-F and G-H. The radius is 195 m.

3 NUMERICAL ANALYSIS

In this article, the deformation of embankments is investigated by finite element modeling in PLAXIS software. Like other systems of analysis, in this analytical system, that is composed from dam and its surrounding soil. Initially the Mohr–Coulomb failure criterion and drained behavior was considered for all the materials. Material properties that have been adopted in this study are presented in table 1.

TABLE 1- MATERIAL PROPERTIES

Layer of dam	γ (KN/m^3)	Φuu $(^0)$	Cuu (Kpa)	Φcu $(^0)$	Ccu (Kpa)	Φ'	C'
core	20.6	0	100	15	70	30	0
filter	19	--	--	--	--	40	0
Drain	19.5	--	--	--	--	36	0
Shell 1	21.5	--	--	--	--	42	0
Shell 2	22.5	--	--	--	--	40	0
Shell 3	22	--	--	--	--	40	0
foundation	25	--	--	--	--	36	100

The first step for the analysis of Dam system and its interaction with soil and the surrounding fluid, is creating geometry. For this purpose, from existing tools in plaxis software were used. Fig. 4 shows the geometry of dam and foundation.

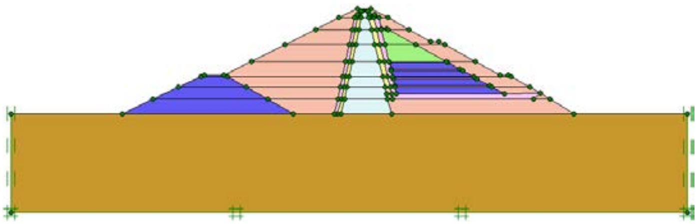

Figure 4. geometry of dam and foundation

After the geometry of the model, should create the appropriate mesh. Then, the calculate phase done, that showed in figure 5.

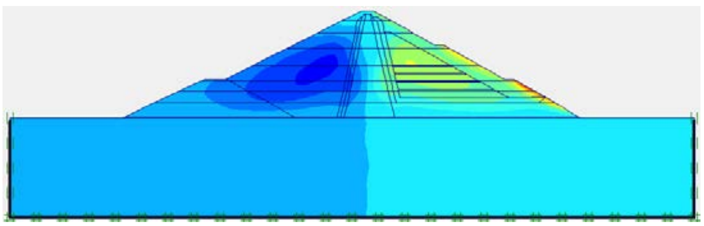

Figure 5. horizontal displacement of Dam at the end of construction (Fs = 1.681)

4 CHANGES IN INTERNAL FRICTION ANGLE OF THE SHELL:

In this section, by changing the angle of internal friction, the results are obtained.

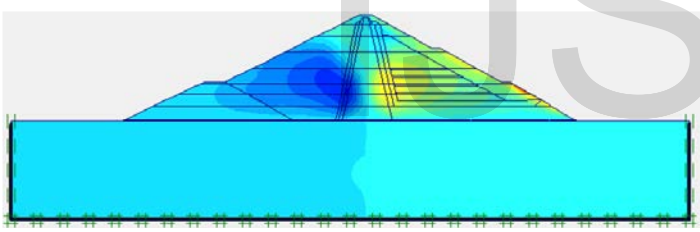

Figure 6--horizontal displacement of dam at the end of construction for $\varphi_{shell} = 32$

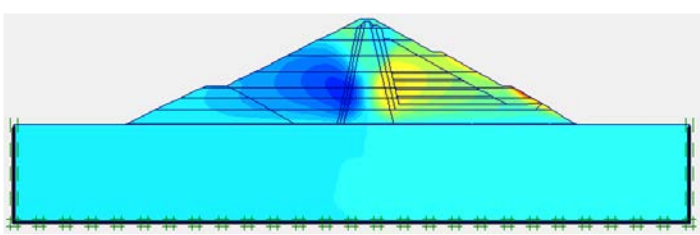

Figure 7--horizontal displacement of dam at the end of construction for $\varphi_{shell} = 37$

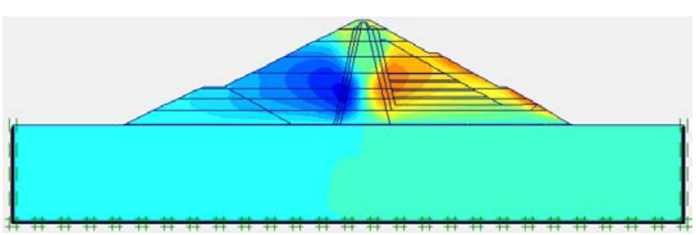

Figure 8--horizontal displacement of dam at the end of construction for $\varphi_{shell} = 40$

According to the above figures and the result of plaxis, the changes of safety factor against the variations in the internal friction angle of the shell, as shown in following diagram.

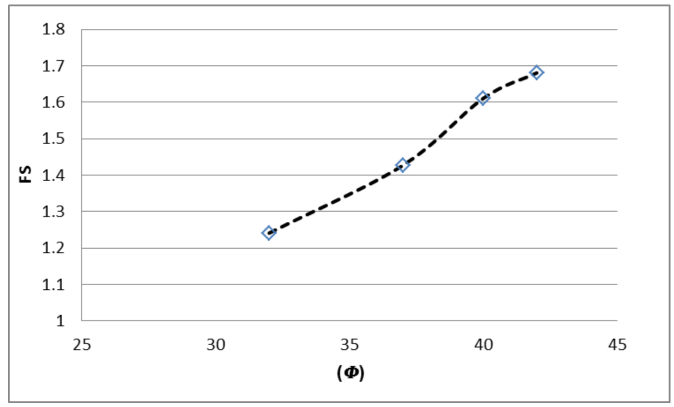

Figure 9- The changes of safety factor against the variations in the internal friction angle of the shell

As shown in Figure 9, an increase of 10 degree in angle of internal friction leads to increased 35 percent in safety factor. On the other hand we can say that the critical friction angle is 37 degrees that safety factor is equal to 1.427.

5 CONCLUSION

In this study, behavior of Tang-e-hamam dam were studied. The results indicate that increase of 10 degree in angle of internal friction leads to increased 35 percent in safety factor. On the other hand we can say that the critical friction angle is 37 degrees that safety factor is equal to 1.427.

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