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An Evaluation and Comparison of Bar Embankment Behavior with Instrumentation Data and Software PLAXIS

Masoud Keyvanipour [1 +], Mahdi Moharrampour [2] and Sina Faghih [3]

[1] Department of civil Engineering, Islamic Azad University ,Torbatjaam Branch, mashad,Iran
[2,3] Young Researchers Club, Islamic Azad University, buinzahra Branch, buinzahra, Qazvin,Iran

Abstract. Permanent control of embankment dam stability during construction, the first impounding and also during utilization of the project, is a significant issue. Instrumentation of such dams which monitor their behavior plays an important role in the dam stability. Regarding that an earth dam is a continuous structure with non-linear behavior, finite element method and appropriate soil modelling could be employed for non linear analysis. In the present research, based on the instrumentation data of bar embankment which is located in the North East of Iran, bar dam, a 35.5 meters high embankment dam was instrumented in order to monitor internal soil behavior such as settlement and soil stresses. Only typical results of the measurement program are presented here. The results that are given have been selected because they provide Quantitative information about the performance of the instrumentation. Afterward, two soil models including Mohr-Coulomb and Hardening models were selected for stress-strain analysis. PLAXIS 2D, a finite element code was employed to simulate the behavior of dam during the first impounding and analyze for stress-strain deformation. The results specified that Hardening model is more capable of predicting the dam behavior determining the dam stability during construction and afterwards.

Keywords: Bar embankment, instrumentation, Finite-Element, dam's behavior, software Plaxis

1. Introduction

Dams are economically, socially and politically important. Because of their high construction costs and the disastrous consequences of their instability, maintaining and constantly evaluating their stability is of vital importance. Bar (Hussein Abad) headwork has been constructed with 14 million m3 capacity off a riverbed near the abandoned village of Hussein Abad and Khorasan Steel Complex to satisfy the local need to drinking and industrial water. Given the shape of the valley, the dam location, proper credit resources and geological characteristics of the area; an embankment was designed on alluvium materials 35.5 m high from its alluvium foundation, with clay core, insulating blanket 15 m long in the reservoir, and a crown 10 m wide and 1500 m long. In order to adjust the water storage, an earth sub dam has been used with clay core, insulating blanket 27.5 m high from the alluvium foundation, a crown 8 m wide and 1730 m long at the end of the reservoir. For transferring the water to the dam reservoir, an earthy canal with concrete lining 5 m wide and 1500m long, and a concrete sub dam with protective backfills 6.7 m high on the Bar river have been built. The sub dam includes an apsidal spillway 50 m and a protective backfill 300 m long. For monitoring the dam; the instruments installed are stressmeter, piezometer, fixed points of surveying, accelograph, water level contour, settlement-meter, deflectometer, thermometer and flow meter. In figure (1), cross section of the dam and the place where stressmeters are installed are shown.

+ Corresponding author. Tel.: +989385502422; fax: +984225316.
E-mail address: m62.mahdi@yahoo.com.

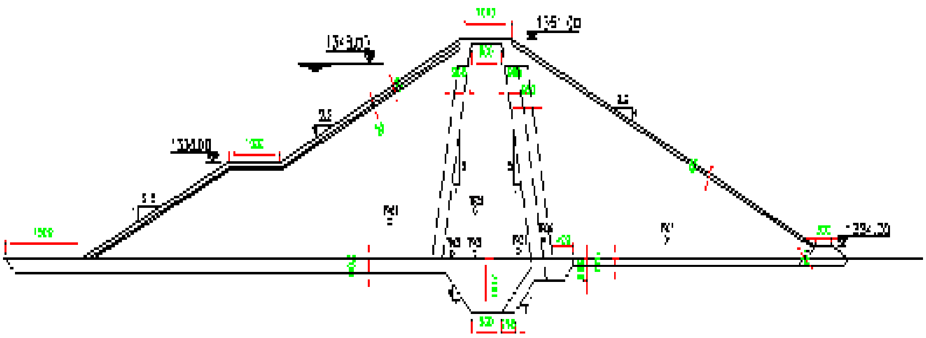


Fig. 1: The cross section of Bar dam and the instrumentation

2. Analysis Tools and Methods

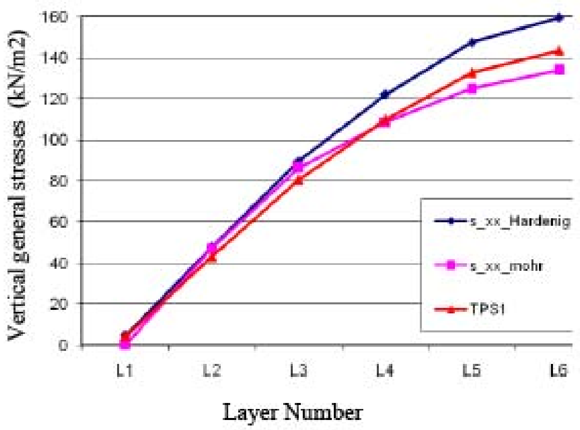
Among many different models of materials behavior, in this study, two common models of Mohr-Coulomb and Hardening has been used. In the former, the failure envelope is considered as a line with the following equation:

$$\tau_f = C + \sigma_n \tan\phi \tag{1}$$

Where τ_f and σ_n are shear stress and normal stress in fracture page; C and ϕ are cohesion and internal friction angle of the soil. In fact, this equation stated that failure is caused not by maximum normal stress nor minimum shear stress but by a critical combination of both. In Hardening model which is a developed form of Bilinear model; it is assumed that during the materials failure, shear modulus is significantly decreased. Generally in the process of analyzing and designing the embankment, the assumption of constructing the whole structure in a single stage is unreal. So the analysis software used should have the possibility of stage construction where first of all the situation before construction is defined as preliminary condition, then the whole structure is built gradually. In this study the Finite-Element software Plaxis which has the above-mentioned conditions has been used for modeling the construction of the dam in 16 and its impounding in 8 stages. The core of the dam, for more strength and stability, was built in 10 stages to be more realistic. Usually the two-dimensional Finite-Element analysis is used to record the behaviors of a dam. Scientific observations has proved the proper estimation of this modeling and only when the dam is arched or the ratio of the length to the height of the dam is lesser than 6 to 1, the three-dimensional analysis is necessary (which is not the case with this study). In the Finite-Element analysis of dams, the main goal is to find the stresses and strains of the materials and the pressure of the pore water with help of which the places of potential cracks and possible hydraulic cracks can be predicted.

3. Results and discussion

In Bar dam, one section was examined and the results are discussed below. The results of general stress meters were compared with those of computer analysis. In figures (2) to (8), seven general stress meters with two behavioral models of Mohr-Coulomb and Hardening are compared.



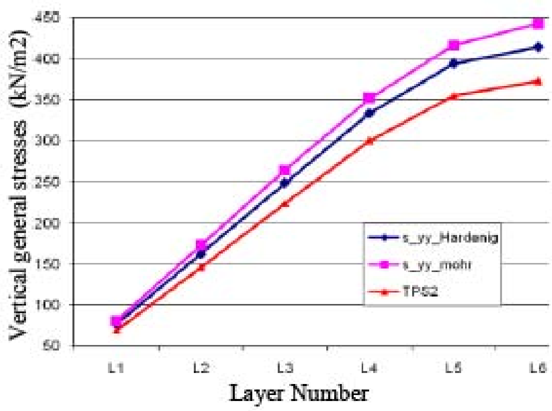
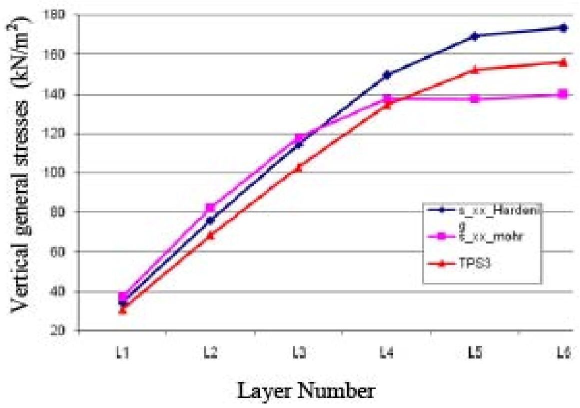


Fig. 2: comparing the results of instrumentation TPC1 with those of Mohr-Coulomb and Hardening models for different stages of backfilling

Fig. 3: Comparing the results of instrumentation TPC2 with those of Mohr-Coulomb and Hardening models for different stages of backfilling



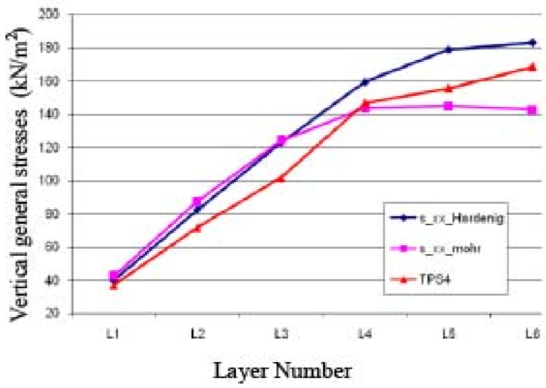
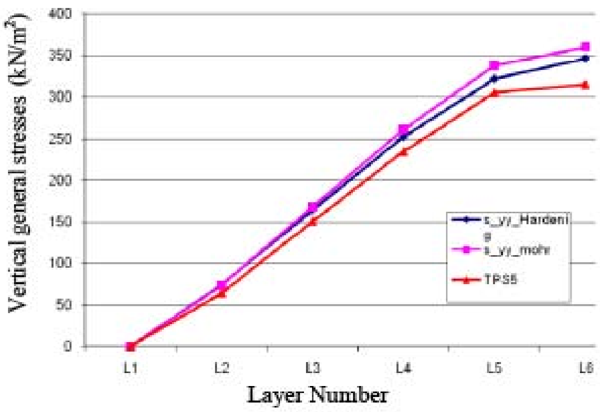


Fig. 4: Comparing the results of instrumentation TPC3 with those of Mohr-Coulomb and Hardening models for different stages of backfilling

Fig. 5: Comparing the results of instrumentation TPC4 with those of Mohr-Coulomb and Hardening models for different stages of backfilling



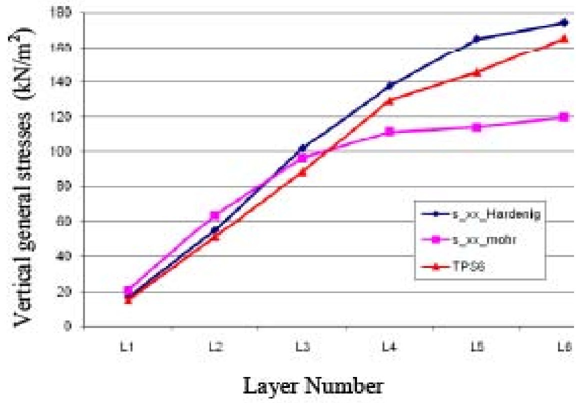
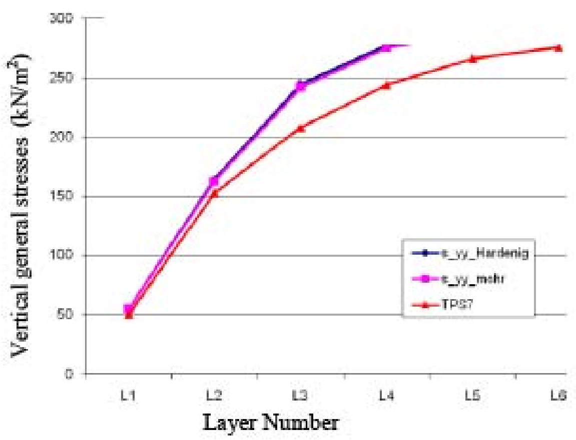


Fig. 6: Comparing the results of instrumentation TPC5 with those of Mohr-Coulomb and Hardening models for different stages of backfilling

Fig. 7: Comparing the results of instrumentation TPC6 with those of Mohr-Coulomb and Hardening models for different stages of backfilling



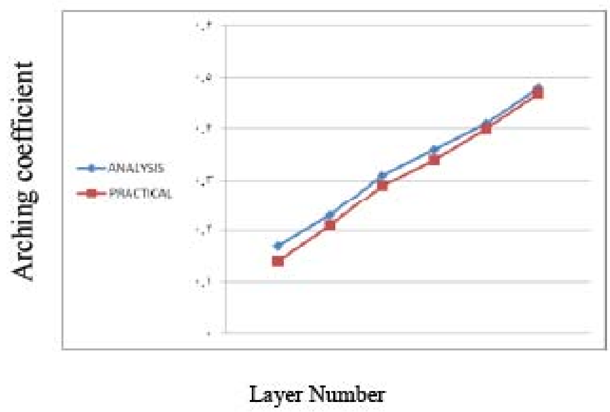


Fig. 8: Comparing the results of instrumentation TPC7 with those of Mohr-Coulomb and Hardening models for different stages of backfilling

Fig. 9: Arching coefficients in Bar dam resulted from instrumentations and analysis

As it is shown in figures (38-8) to (44-8), Mohr-Coulomb model in most cases reveals less stresses than Hardening model. Also the difference of Hardening model from the results of instrumentation is lesser than that of Mohr-Coulomb model. Specially as the height of the backfilling in the dam increases, the difference between the two models increases too and Hardening model has more favorable results.

The arching is the hanging of core from the shell of the dam which causes an decrease in vertical pressure in the core. This coefficient is calculated as follows:

$$\text{Arching coefficient} = \sigma_v / \gamma \cdot h \quad (2)$$

In this equation, σ_v is the total normal stress inside the core, γ is the specific weight of the core materials and h is the height of backfilling.

The arching coefficient during the construction for different heights resulted from instrumentation and analysis is depicted in figure (9).

4. Conclusion

1. Given the fact that the laboratory tests data according to which analytical modeling is carried out and that whatever done in construction and execution processes is always limitedly accurate, instrumentation is still the most important means for investigation of dam's behaviors and ensuring that the designing and execution parameters are accurate. Nevertheless the results of this study reinforces the validity of laboratory and modeling results.
2. Mohr-Coulomb model, In most cases, reveals less stresses than Hardening model does. Also the difference between Hardening behavioral model and instrumentation results is lesser than that of Mohr-Coulomb model. Specially as the height of the backfilling in the dam increases, the difference between the two models increases too and Hardening model has more favorable results.
3. As it is shown in figure (9), the difference between analysis and arching coefficient instrumentation decreases as the height of the dam increases during the construction.
4. As the software PLAXIS and two models (Mohr- Coulomb and Hardening) show; the results of the study, efficiency of the method and the software used for modeling the embankment behavior during construction are acceptable.
5. Mohr- Coulomb model is one of the simplest models of soil behavior; on the other hand, Hardening model has more flexibilities in modeling and involves more parameters in soil modeling. However, in the modeling of this study the two models demonstrated similar and close numbers.

5. Acknowledgements

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