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INFLUENCE OF HEAD ELEVATION ON THE STABILITY OF EARTH FILL DAM, FADA DAM AS A CASE STUDY

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ABSTRACT: - In the present study, slope stability and seepage are analysis for Al-Fada dam. Two software's (Geo-Slope/w and SEEP/W) using Bishop method and finite element method are adopted for stability and seepage calculations, respectively. The usual procedure in the stability analysis of slopes is to calculate the safety factor of various assumed slip surfaces, and then to regard the slip surface having the smallest safety factor as critical. four cases of water level are consider in analysis of slope stability of dam. The final conclusion is the body of the dam and its foundation is safe for the effect of seepage through the dam and foundation, also the analysis of the results of this study showed that Al-Fada earth dam is safe against the danger of piping and slope sloughing under all case of water level.

KEYWORD: Slope Stability, Seepage, Earth Dam.

1- INTRODUCTION

The site of The Al-Fadah Dam is located within the Mesopotamian block between the Makhul-Hemrin Fault and Kirkuk Fault on the edge of Arabic tectonic and this tectonic strike with Iran tectonic whereof make the region of site active with respect to seismic effect. One of the important stages in design of earth fill dam is the exact evaluation of seepage quantity, pore water pressure distribution used in the analysis of slope stability, total head measurements and hydraulic gradients in various sections of the dam to ensure stability and avoid endangering effects such as piping and slope sloughing [1].

Seepage flow of water through porous media depends on the soil media, type of flow, properties of liquid and hydraulic gradient. Seepage piping account for approximately 50% of all earth dam failures [2]. Many methods have been developed to solve seepage problems, these methods can be classified as analytical, experimental and approximate methods [3,4,5,6].

Analysing the slope stability of dam section through a computer program named (Geo-Slope/w and SEEP/W [7]) performing the conventional limit equilibrium method of slices, the simplified Bishop method for slope stability analysis and FEM method for Seepage flow of water through dam body and foundation .

2- SLOPE STABILITY

Every soil mass which has a slope at its end is subjected to shear stresses on internal surfaces or failure plans in the soil mass near the slope. This is due to the gravitational forces that try to pull down parts of the soil mass adjoining the slope. Several models and analytical techniques have been developed to determine the critical slip surface and the associated factor of safety such as method of slices. The factor of safety is:

$$FS = \frac{\tau_f}{\tau} \quad \text{.....1}$$

where, FS safety factor,

τ_f = the failure shear strength of the soil, and

τ = shear stresses of the soil.

Bishop [8] developed a method based on the assumption that the inter slice forces are horizontal. This method is called the Simplified Bishop Method (SBM) in which a circle slip surface is assumed. Janbu (1956) (cited in [9]) developed a simplified method that assumes zero interstice shear forces. Morgenstern and Price (1965) (cited in [10]) developed a general analysis in which all boundary and equilibrium conditions were satisfied and in which the failure surface might be of any shape, circular, non-circular or compound. Wright et al. [11] used the finite element method to determine the factor of safety and associated critical slip surface and compared with the simplified Bishop method. Martins et al. [12] used the rigid-plastic methods (Felonious and Bishop) and the elasto-plastic finite element method (FEM) to analyze the slope stability of embankment with and without surcharge. Hammah et al. [13] compared the finite element method with the limit equilibrium methods for slope stability analysis.

2.1 Simplified Bishop Method

For steady state seepage condition the factor of safety using Bishop method is:

$$FS = \frac{\sum_{i=1}^{n}\left(c' b_i + (W_i - u_i b_i)\tan\varphi'\right)\frac{1}{m_{\alpha i}}}{\sum_{i=1}^{n} W_i \sin\alpha_i} \quad \text{.....2}$$

$$\text{Where, } m_{\alpha i} = \cos\alpha_i + \frac{\tan\varphi \sin\alpha_i}{FS} \quad \text{.....3}$$

c = effective soil cohesion,
L = length of the bottom of the slice,
b = width of the slice and equal to (L cos α),
u = pore water pressure,
W= weight of the slice,
α = inclination of the bottom of the slice, and
φ' = Effective internal friction angle.

2.2 Finite Element Equations

The finite element equation that follows from applying the Galerkin method of weighed residual to the governing differential equation using in a SEEP/W two-dimensional analysis.

3-CONSTRUCTION MATERIALS:

Construction materials required of dam construction are available in areas surrounding the dam site in sufficient quantities and acceptable qualities. Laboratory tests results show the following:

For clay quarries, it found that the clayey borrow area consist of gray to brown clayey SILT with high contents of organics matters, gypsum & salts and mixed with some sand and gravel, this soil presence at depth (2.0 m) below the natural ground level. For gravel quarries, the most soil consists of mixture of cohesive and cohesionless soil and ranged as clayey GRAVEL, silty CLAY with sandy GRAVEL and clayey SILT with SAND. Therefore; A homogeneous compacted mixture of Clay and Gravel GC is recommended with upstream impervious facing.

4-FOUNDATION TREATMENT

From seepage side, The Geological Investigations showed that the Foundation has low to moderate permeability, due to presence of gypsum special treatment is required, a 0.8 m wide plastic concrete Diaphragm wall extends to a depth of 15m is necessary. From Strength Point of view the SPT Tests showed hard layers, moreover the clay materials are mixed with gravel which offers very high shear strength.

5-The Dam Section

Following the proposed typical design section of the AL-Fada dam is shown in Figure (1).

6- STABILITY ANALYSIS:

Bishop's method [8] for slope stability analysis will be used, The usual procedure in the analysis of stability of slopes is to calculate the safety factor of various assumed slip surfaces, and then to regard the slip surface having the smallest safety factor as critical. If the safety factor is smaller than 1 the slope is considered to be unstable.

In normal conditions the design of such a slope is rejected. In the design of dikes and dams it is usually required that the at least safety factor is greater than 1, say 1.3.

A slope of (1:2.5) may be adopted for upstream and downstream face. The following cases were considered

Case 1- Operational case with max. water level of 174.00 masl

Case 2- Drawdown case – WL Min at 166.90 masl.

Case 3- Dry case – End of construction

Case 4- Downstream case.

A standard computer program is used for the stability analysis; the results are as shown here under.

CASE- 1-

Wet Case: WL 174 Results – Minimum Safety Factor = 1.516 as shown in fig (2)

CASE- 2-

Drawdown case: WL 165.9 Results – Minimum Safety Factor = 1.565 as shown in fig (4)

CASE- 3-

Dry Case Results - Minimum Safety Factor = 1.787 as shown in fig (6)

CASE- 4-

Downstream face - always dry – Safety factor = 1.893 as shown in fig (8)

7- SEEPAGE ANALYSIS

7.1. Seepage Analysis through the foundation of the Dam

Seepage analysis is required to determine the quantity of water passing through the foundation. Geo- slope studio software (SEEP/W) [7] is used to calculate seepage through the foundation of the dam. The results are shown in Fig (10).

7.2 Seepage Analysis through the body of the Dam

The flow net method is used to calculate the seepage through the body of the dam as shown in figure bellow by modelling the dam body by finite element.

8 - SUMMARY AND CONCLUSION

In this paper the following conclusions were reached:

1- The software (Geo-Slope/w) can be used to analyze the homogeneous earth dams. Therefore, the software is applied on four different cases of water levels for the Al-Fada earth dam, the analysis of the results showed that Al-Fada earth dam is safe against the danger of slope failure due to slippage under all case of water level.

2- The finite element software (SEEP/W) can be used to analyze the seepage through and under the homogeneous earth dams. Therefore, the program is applied to find the quantity of seepage through the dam, and the total head measurements. The results from this software showed the body of the dam and its foundation is safe for the effect of seepage through the dam and it's foundation.
3- The worst case for Al-Fada dam for the danger of slope failure due to slippage is the operational case with max. water level.
4- Treatment of plastic concrete Diaphragm wall (a 0.8 m wide extends to a depth of 15m) is required to prevent the danger of piping under the dam due to presence of gypsum in soil layers under dam.

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Table (1): Geometry and material properties for Al-fada earth Dam

Property	Value
Top height of dam	176.00 msal
Max. water level	174.00 masl
Total height of dam	15.2m
D/S and U/S slope	1:2.5
Estimates peak discharge	504 m^3/sec
Unit weight(γ)	18.5 kN/m^3
Friction angle (φ)	20º
Cohesion of soil (C)	35kN/m^2

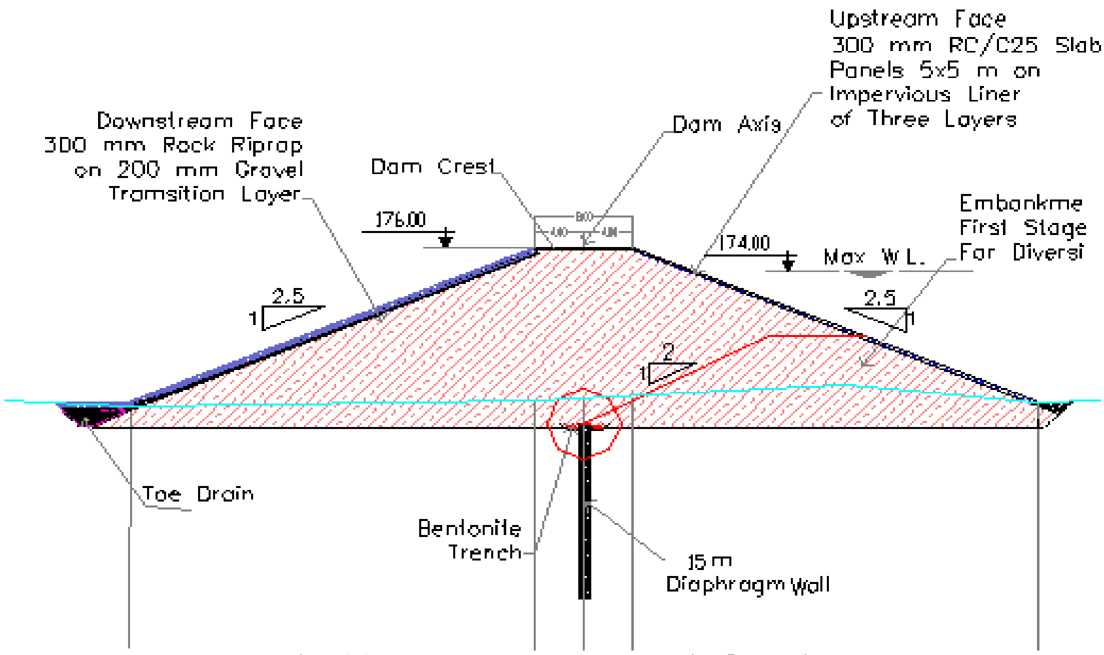


Fig. (1) – AL-FADA Dam Typical Section

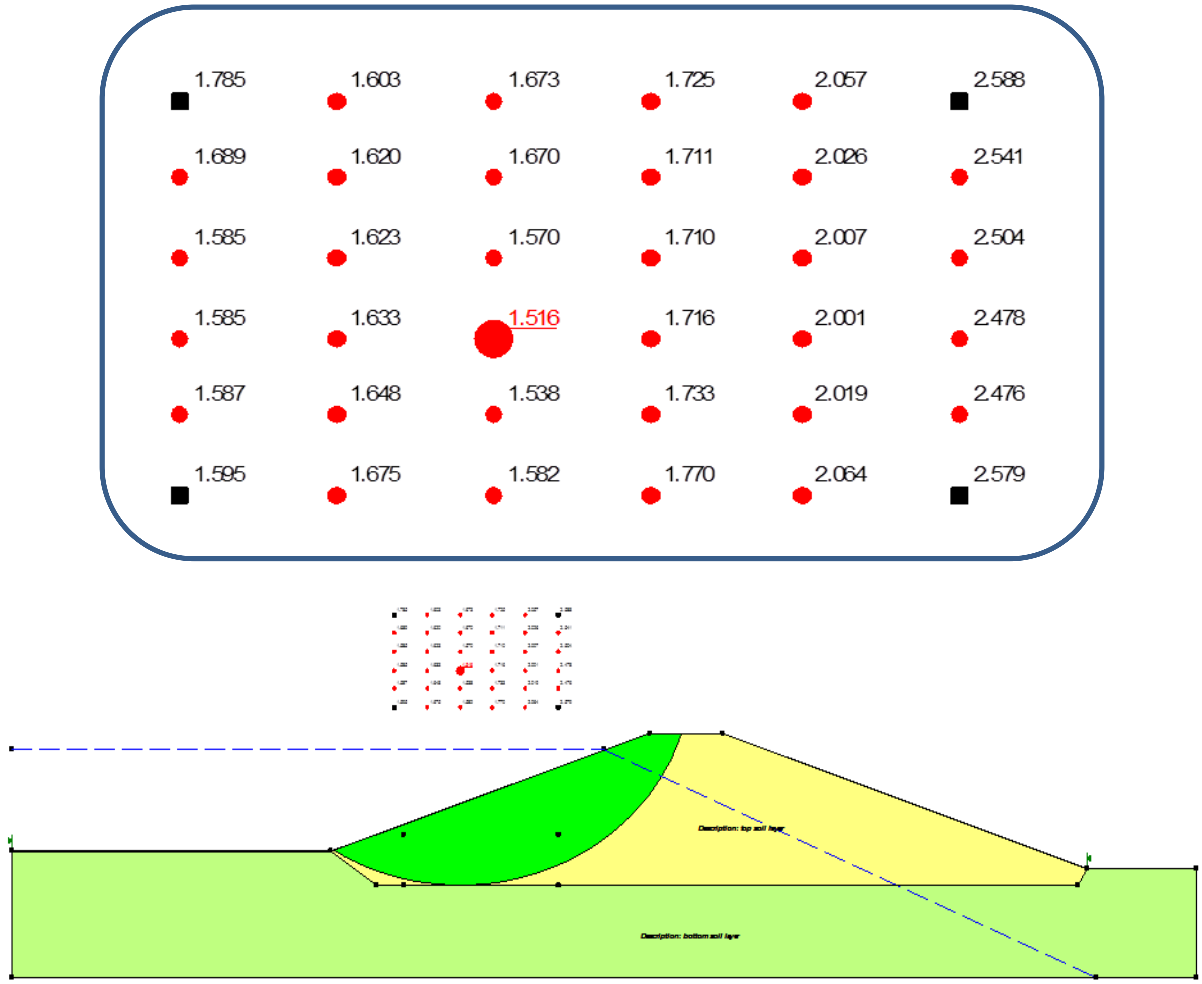


Fig.(2): Al-Fada Dam Case 1-Safety Factor(1) = 1.516

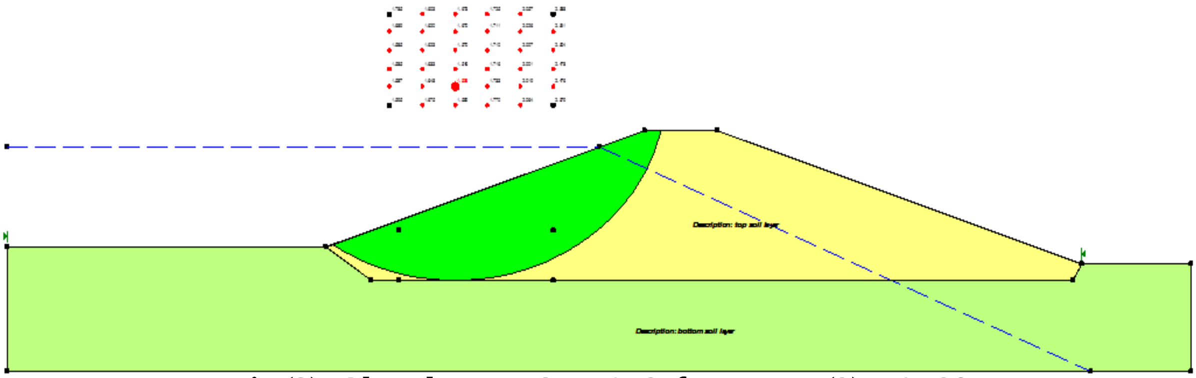
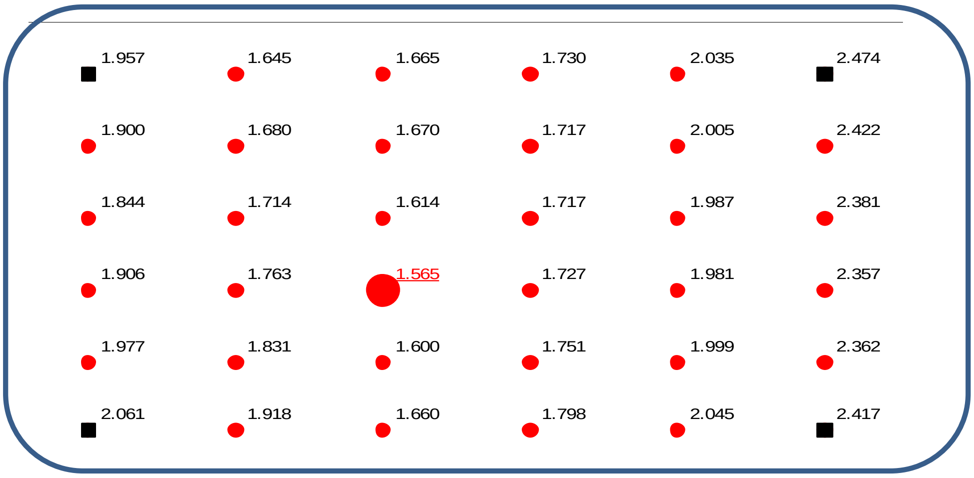


Fig.(3): Al-Fada Dam Case 1 -Safety Factor(2) = 1.538



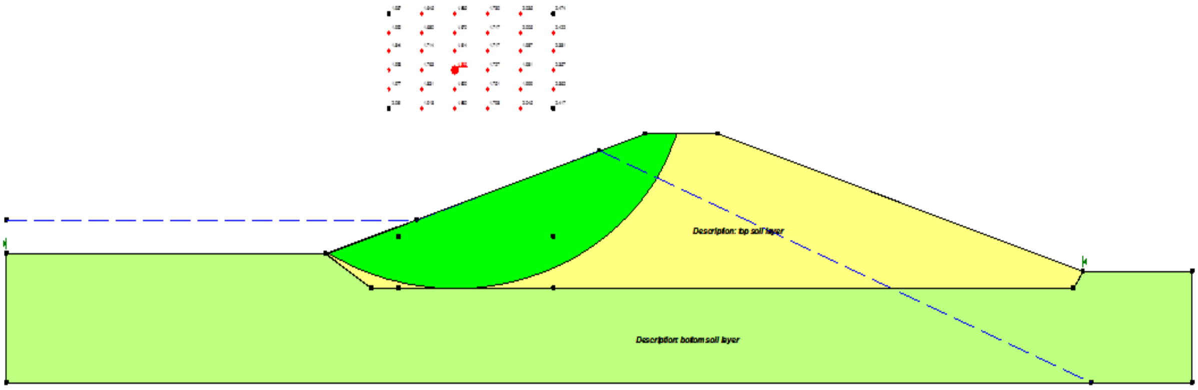


Fig.(4): Al-Fada Dam Case 2 -Safety Factor(1) = 1.565

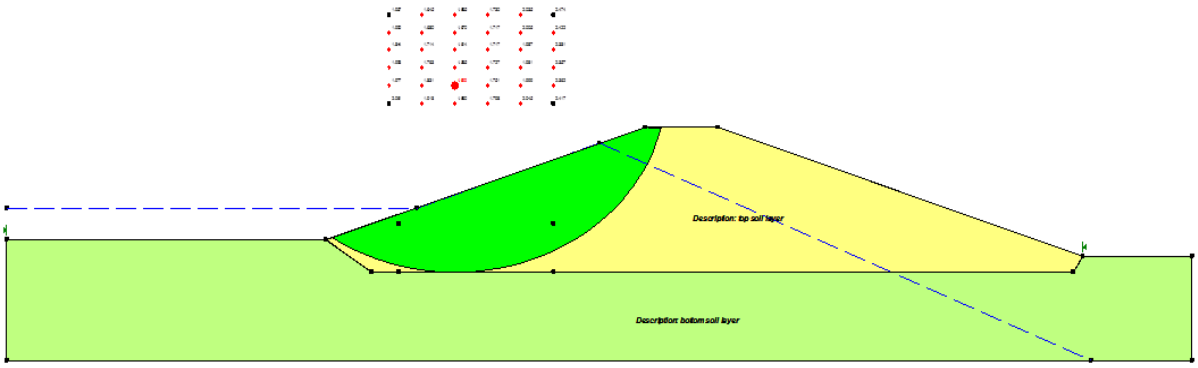
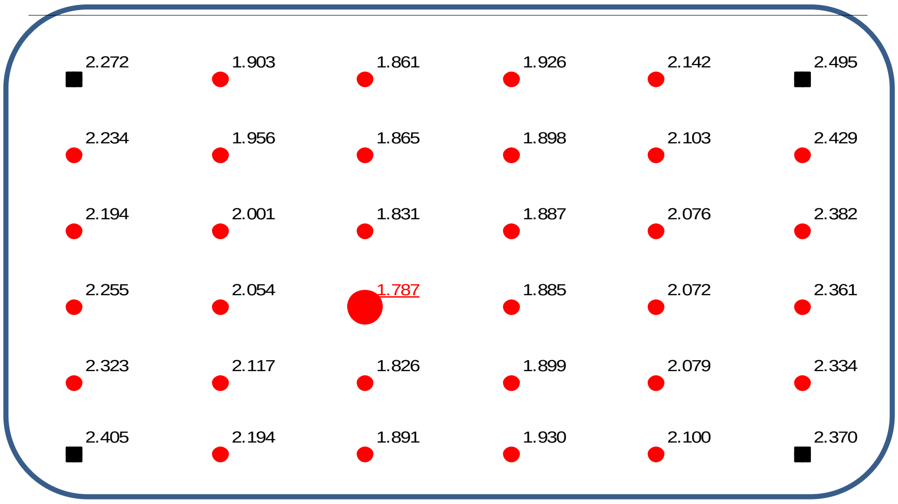


Fig.(5): Al-Fada Dam Case 2 -Safety Factor(2) = 1.600



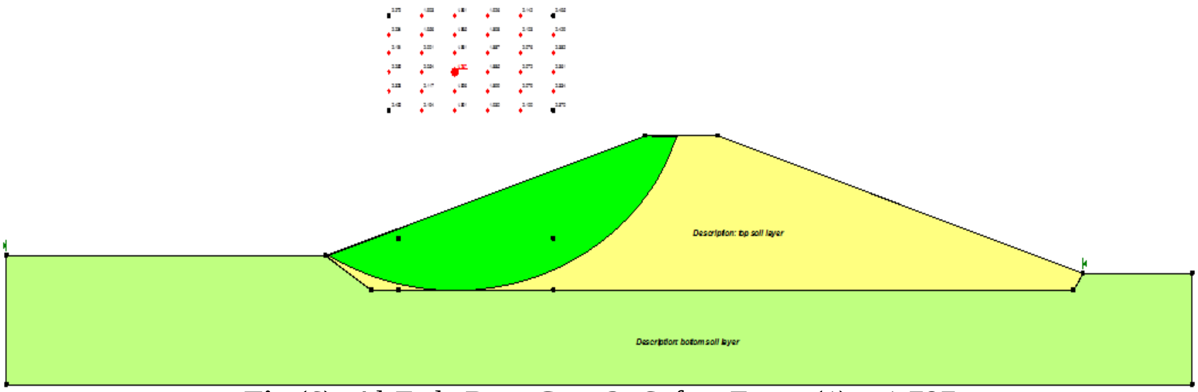


Fig.(6): Al-Fada Dam Case 3 -Safety Factor(1) = 1.787

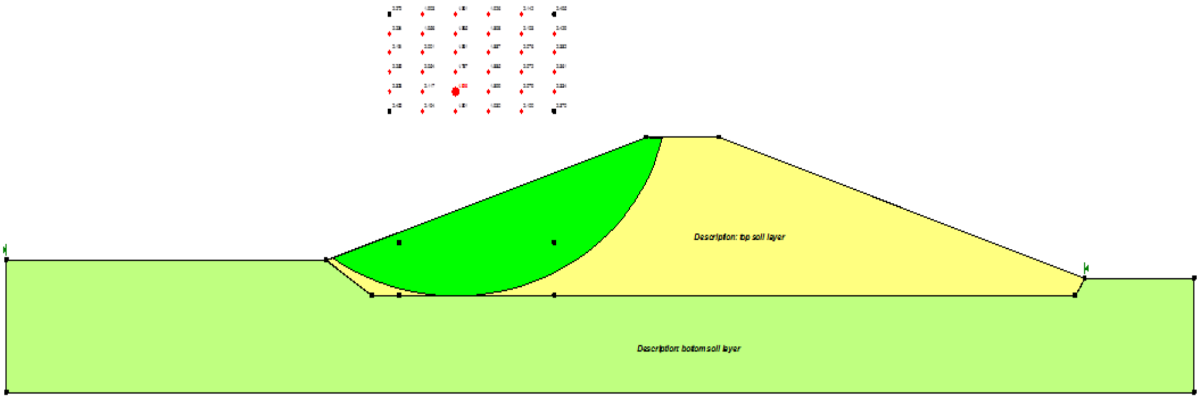


Fig.(7): Al-Fada Dam Case 3 -Safety Factor(2) = 1.828

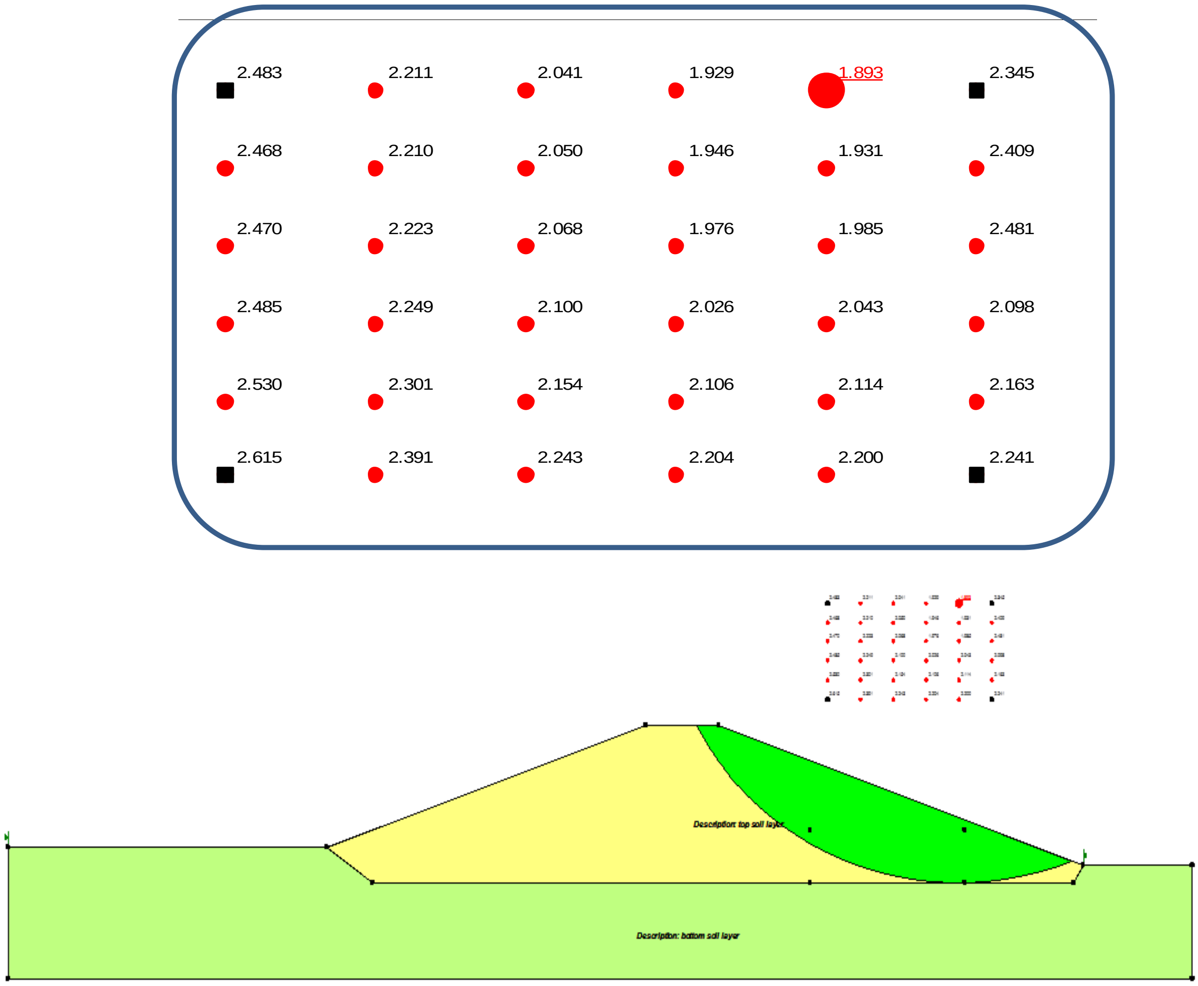


Fig.(8): Al-Fada Dam Case 4 -Safety Factor(1) = 1.893

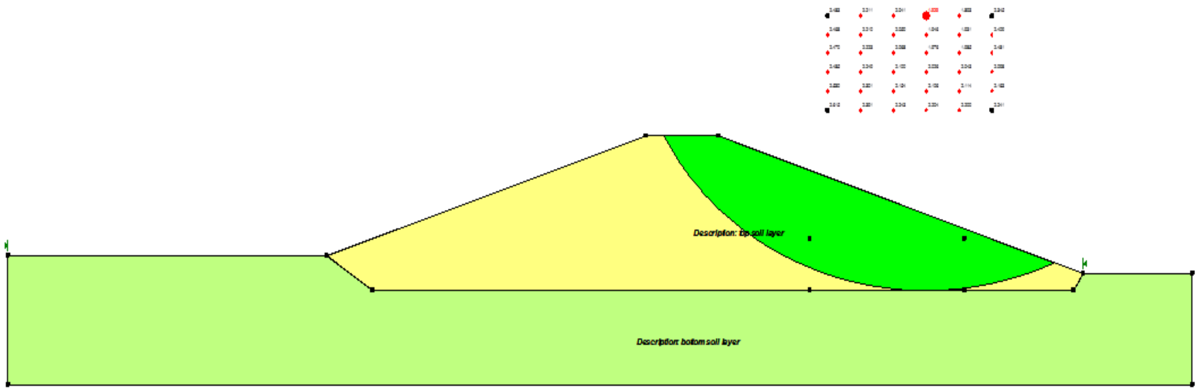


Fig.(9): Al-Fada Dam Case 4 -Safety Factor(2) = 1.931

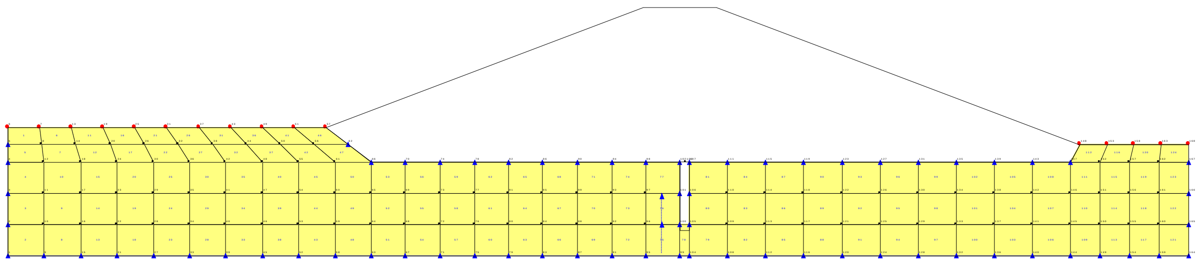


Fig.(10):Finite Element Mesh For foundation of Al-Fada Dam

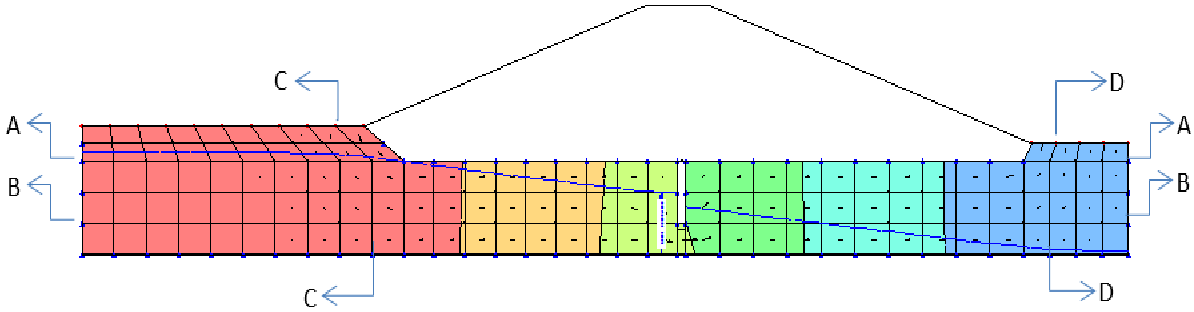


Fig.(11):Result of Seepage Through The foundation of Al-Fada Dam

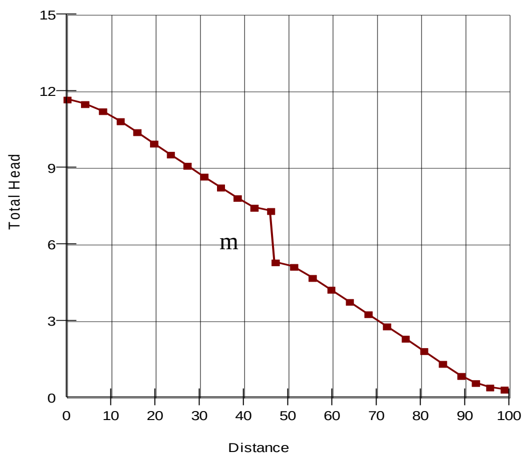


Fig.(12):Sec. A-A Head of water pressure
Horizontal section (Top Layer)

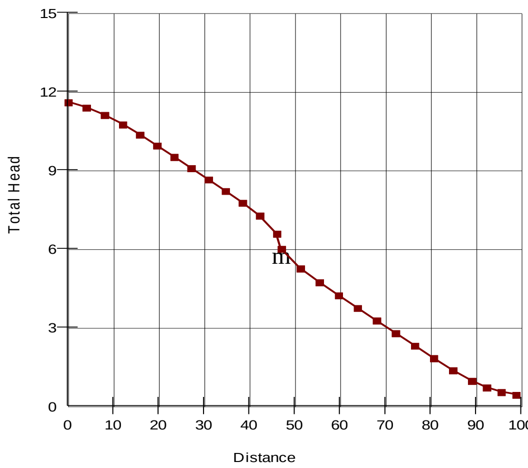


Fig.(13):Sec. B-B Head of water pressure
Horizontal section (Bottom

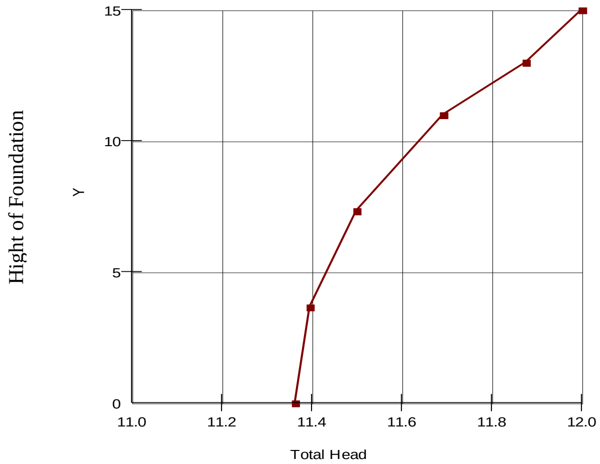


Fig.(14): Sec. C-C Head of water pressure
Vertical section U/S

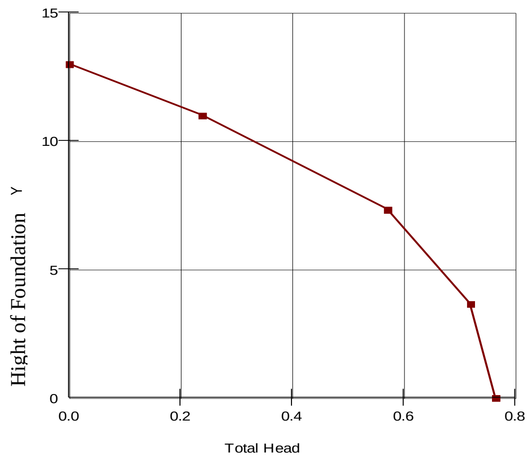


Fig.(15): Sec. D-D Head of water pressure
Vertical section D/S

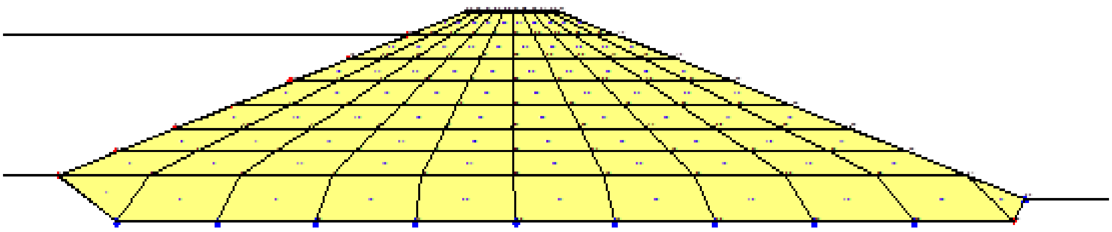


Fig.(16): Finite Element Mesh For Al-fada Dam

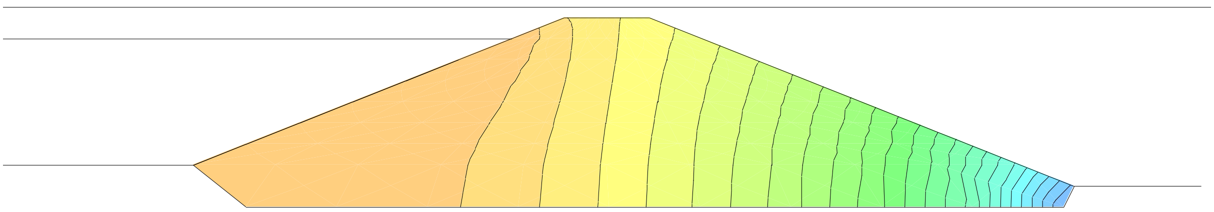


Fig.(17):Result of Seepage Through The Body of Al-Fada Dam

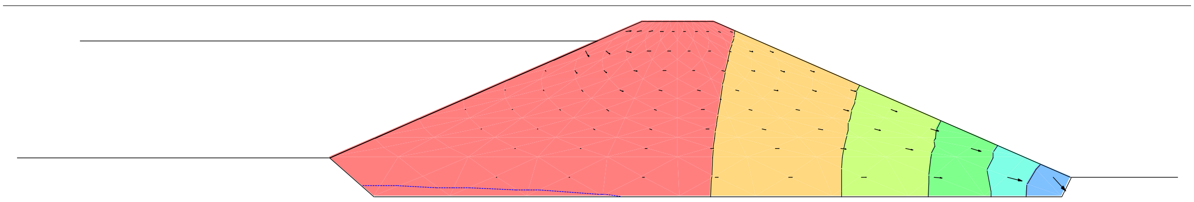


Fig.(18):Direction of Seepage Through The Body of Al-Fada Dam

تأثير مستوى الماء على استقرارية السدود الترابية
(سد الفضى نموذج دراسة)

الخلاصة:

تم في هذا البحث دراسة استقرارية الانزلاق والنز خلال جسم سد الفضى واساسه. تم التحليل باستخدام (Geo– Slope/w and SEEP/W) . حيث استخدمت طريقة بيشوب في حساب استقراريه التربة وكذلك تم استخدام العناصر المحددة لحساب النز خلال جسم السد واساسه .حيت تم اعتبار اقل عامل امان لجميع السطوح المنزلقة هو عامل الامان الحرج. نم كذلك اعتماد اربع حالات اساسيه متوقعة خلال عمر السد لمستوى الماء في الخزان لغرض بيان تأثير وجود ومستوى الماء في الخزان . وبعد اجراء التحليل للحالات الأربعة تبين ان السد امين ضد فشل الانزلاق ولجميع الحالات التي تم دراستها وكذلك امين من الفشل النز.