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The Estimation of Downstream Piping of a Dam (Case Study: Dewerige Dam- Iraq)

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Abstract: The study deals with the geotechnical and hydrological problems in Dewerige dam. It's a new hydraulic stru
The dam is used for flooding control, water storage for irrigation, and recharges groundwater. The current study aime
simulation model at steady stat to evaluate piping downstream (Toe) in saturated soil. Uplift pressure, seepage velocity
piping safety factor was (1.7), Therefore, the dam is relatively safe against piping problems in flooding conditions.

Keywords: SEEP/W; piping; downstream; weir; Dewerige dam; Seepage analysis model

1. Introduction

Movement of water through soil called seepage. It is the most common problem in dams both of earth fill and concrete [1]. This study is concerned with the seepage problem under the concrete dam foundation. Water flows through low permeable media at a slow velocity, this flow can be defined as 'laminar flow'. Increasing flow velocity could change flow pattern to turbulent flow. The Reynolds number is used to identify the type of flow if it was laminar or turbulent [13]. A numerical model was created using SEEP/W software to calculate the amount of seepage, distribution of pore-water pressure under the dam, seepage velocity, and hydraulic gradient, which was used to calculate the actual safety factor of the dam.

2. Location of dam site

Dewerige dam located in south eastern part of Mayssan province, the southeastern of Iraq Fig.1.1. The coordinates of dam axes are (E746239.862, N3551456.909) - (E746256, N3550931) [11].

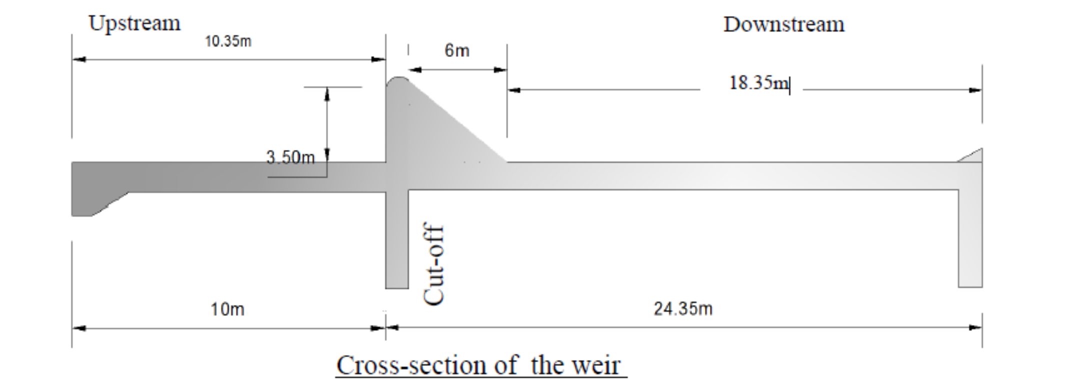

Fig. 1 Design of Dewerige dam

3. Geological condition of the dam site

3.1 Stratigraphic of the studied area

The lithology of the dam site consists mainly of Quaternary deposits, especially floodplain sediments: sandstone, siltstone, and claystone, which is covering Tertiary deposit Mukdadiya and Bai Hassan Formations [12]. The lower Bakhtiari lithological consists of gravely sandstone -sandstone – claystone, with fining upward grained. There are conglomerate beds that represent the border between Mukdadiya and Bai Hassan, however Bai Hassan
The formation comprises (conglomerate - claystone - sandy conglomerate) [2]. The dam site is covered with recent alluvial and aeolian deposits. Quaternary and Tertiary outcrops [3], especially in construction materials quarries south of the dam.

3.2 Geotechnical properties of the dam site

According to the geotechnical investigation report of Dewerige dam site [4]. The geotechnical cross-section is identified based on six boreholes are selected from the site Fig.2

3. Theory

The purpose of Seep/w analysis is to simulate seepage flow through soil is saturated & unsaturated soils. The outputs of seep/w are [5]:

1. Seepage flow or discharge.
2. Distribution of pore-water pressure (very important instability analysis).
3. Water velocity and pathway.

It's very necessary to categorize problems that are studied in Seep/w. In the case of Dewerige dam, the problem represents confined flow. To use seep/w effectively it's essential to have a clear understanding of some key fundamentals:

1. Darcy law.
2. Basic finite element equation.
3. Define total head.
4. Water storage capacity.
5. Effect of pore-water pressure on permeability & conductivity.
6. <u>Darcy low:</u> Darcy low applied in case of saturated and unsaturated flow conditions [6].

$$q = Aki \quad (1)$$

$$v = \frac{q}{A} = ki \quad (2)$$

Where:
q= specific discharge.
A= cross-section area.
k= permeability.
i = Hydraulic gradient.
Also, differential equation (Laplace equation) is used to estimate seepage flow in 2D in steady-state [7]:

$$\frac{\partial}{\partial x}\left(Kx\frac{\partial H}{\partial x}\right) + \frac{\partial}{\partial y}\left(Ky\frac{\partial H}{\partial y}\right) + Q = 0 \quad (3)$$

Where:
H= total head.
Kx= horizontal conductivity
Ky= vertical conductivity.
Q = flux

7. <u>Total Head (H):</u> Seep/w is formulated in terms of total head. The boundary condition is specified according to total head [8]:

Total head (H) = pressure head (u) + elevation head (h)

$$H= \frac{u}{\gamma w} + h \quad (4)$$

8. Finite Element Equation/ general finite element method applied in seep/w Simulation model [4]:

$$[K]\{H\} = \{Q\} \quad (5)$$

Where:
K= nodes material properties.
H= nodes total head.
Q= water flow at a node.

4. Methodology

To create a numerical model by using SEEP/W the following procedure are used [4]:

a. Geometry

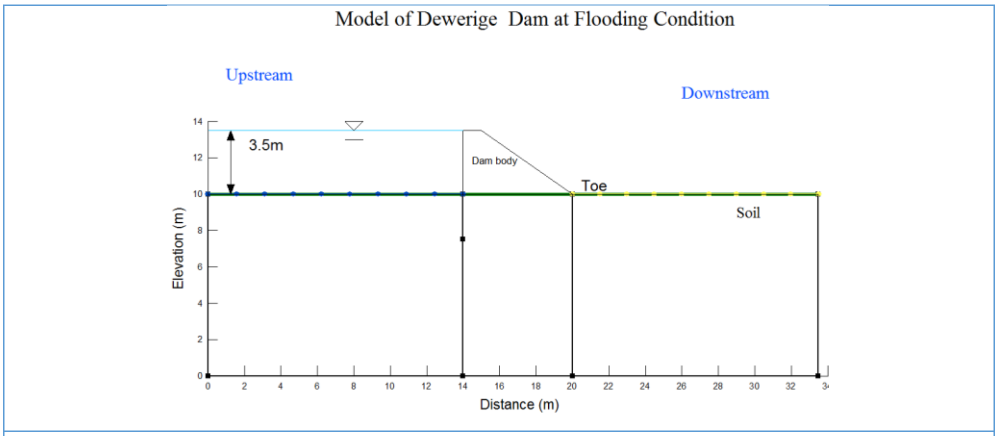

Fig.2 material divisions of model

b. Meshing

The meshing of the finite element method used in this study comprises 517 nodes and 463 elements with quadrilateral and triangular patterns. Element size approximately 1.5m. The problem geometry consists of three regions representing the basic soil divisions Fig.4

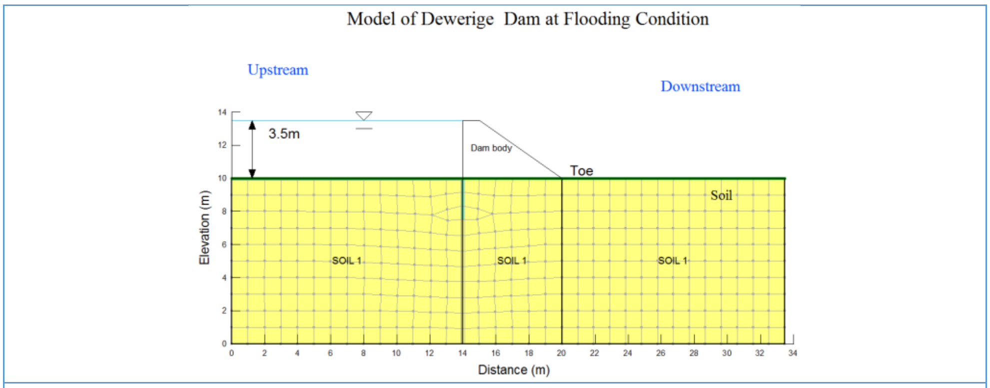

Fig.3 Cross-section of Dewerige dam by Seep/w model

c. Material properties

Material properties are a fundamental part of the finite element equation for the setting of the seepage simulation model. Hydraulic parameters are used in Seep/w explained in detail in Table1

Table 1 Hydraulic parameters in Seep/w software

Geologic region	Hydraulic Saturated conductivity (m/day)	Saturated water content	Material type
Region1	0.5002559	0.427	Saturated only
Region2	0.5002559	0.427	Saturated only
Region3	0.5002559	0.427	Saturated only

d. Boundary condition

The total head defines a boundary condition of the Seep/w problem in normal and flooding conditions [10].

e. Outputs of Seep/w model

Distribution of: pore water pressure, pressure head, total head, hydraulic gradient, and flow velocity, in soil foundation of Dewerige dam.

5. Results

5.1 Summary of the numerical model

The results of SEEP/W model can be summarized based on hydraulic parameters which shown in Table 3.

Table 3 summarized the outputs of simulation model

Hydraulic parameters	Min.	Depth	Max.	Depth
Total head	10 m	1m upstream	13.5 m	1m downstream
Pore-water pressure	0 kPa	0 m	129.06 kPa	10 m
Pressure head	0 m	0 m	13.15 m	10 m
X-velocity		0 m		At toe & cut-off
Y-velocity		0 m		At toe & cut-off
XY - Hydraulic gradient	0.004	2m	1.2	At toe & cut-off

5.2 Calculation of piping safety factor under the dam

Hydraulic gradient as explained concentrated under the dam at heel and toe.
To compute piping safety factor in downstream at toe [14]:
1. Extraction hydraulic gradient at toe, Fig.5 (i exit, hydraulic gradient = 0.45).
2. Calculation critical hydraulic gradient (i critical)

Critical hydraulic gradient and piping safety factor by the following equations [9],

$$\text{Piping safety factor } (P_{iping}) = \frac{\text{i critical}}{\text{i exit}} \quad (6)$$

Since critical hydraulic gradient (i critical) is 0.98. Hydraulic gradient (i exit,) have to be less than (i critical), according to the result of simulation model in Table 3 hydraulic gradient under the dam range (0.005 –1.2). F piping in soil equals to 2.1.

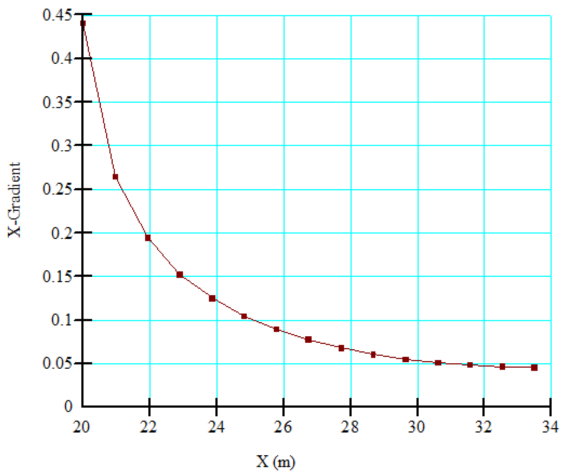

Fig.4 Hydraulic gradient at water exit (toe)

6. Conclusions

- SEEP/W software which used to analyze seepage in foundation soil of Dewerige dam in 2D provide a good accuracy outputs compared with hand solutions, which make it a very important tool in geotechnical studies.
- Hydraulic gradient and seepage velocity can be observed in maximum values under the dam body, especially in heel and toe, which produce internal erosion threaten stability of dam.
- Dewerige dam is safety from piping problem, because of piping safety factor is 2.1, while piping safety factor have to 5 or more according to design studies of small dams.

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Conflicts of Interest: The authors declare no conflict of interest.

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