Seismic performance of Al-wand earth dam: numerical analysis

M Th Al-hadidi¹, I H Abbas²
¹ Civil Engineering Dept., University of Baghdad, Baghdad, Iraq.
² Civil Engineering Dept., University of Baghdad, Baghdad, Iraq.
Email: Mays.thamer@coeng.uobaghdad.edu.iq

Abstract: The seismic can be threatened the stability of the flexible body of the earth dam and can cause completely damaged or deformation on their embankment. Therefore, a geotechnical engineer needs to know the effect of earthquakes on earth structures. The change in the seismic zone that recently Iraq affected is the reason for this research, in general, in 2017, the whole of Iraq, and in particular the region, where the Al-Wand earth dam (the subject of the study) is located, was exposed to several earthquakes. This research project mainly aims to study the behavior of Al-Wand earth dam under seismic load in different conditions by simulating Al-Wand earth dam through numerical modeling and study the influence of water reservoir level, earthquake peak acceleration, and duration. This paper includes an analytical study of the effect of this earthquake on Al-wand earth dam, using the quake/w program, which is a sub-program of geo-studio, also the stability of the dam was studied under the influence of earthquakes of different intensity, and a review of the impact of different water levels on the stability of the body dam. Where the response of the Al-wand dam was analyzed to earthquakes at the normal and the maximum water level, and by using a quake that may have been exposed to Iraq in 2017 and used the time of 100 seconds and using an acceleration of 0.02g, 0.03g, 0.05g measured by units of ground acceleration to identify the behavior of displacements, effective stress and pore water pressure during the earthquake.

Keywords: Al-wand earth dam, QUAKE/W, Finite element method, Geo Studio, Earthquakes.

1. Introduction

Earthquakes are defined as a sudden shaking of the earth that occurs as a result of the movement of rocks below the surface of the earth and their exposure to vertical and/or horizontal displacements between the rocks of the earth and that as a result of their continuous exposure to contractions and great pressures and thus lead to damage and failure of structures on the earth's crust, and earthquakes can Their size ranges from too weak to be felt too violent enough to destroy entire cities.

Earthquakes occur as a result of several natural phenomena [1, 2]. The earth movement that occurs at the dam site due to earthquakes leads to great damage to the dam body, as happened in the Sefid Dam, which was damaged by the summit due to an earthquake that occurred in 1990 with a magnitude of 7.5 in Iran, and other damages occurred in the dams as a result of the earth movement due to earthquakes represented by cracks and cracks in the dam body and loss of strength of the foundations as a result of earthquake vibration
in addition to floods to neighboring areas [4], and from here the dams must be designed to withstand strong earthquakes and because Iraq is located in the northeastern border of the Arab plate, which has been identified as a semi-continuous line from the seismic center as studies have shown. History of earthquakes in Iraq that more than 79 major earthquakes occurred between 1260 BC and 1900 AD, and because Iraq has recently been exposed to seismic activity, especially in the area where the Al-wand Dam is located, Diyala is located in the northeastern part of Iraq and is one of the most active seismic regions in Iraq, with a population of 1.5 million and an area of 17,685 square km. Physical earthquakes occur every year and cause damage to weak structures [11]. Hence, we will study the behavior of the Al-wand Dam under the influence of earthquakes by using the Quake/W program, which is a program used to simulate the behavior of the earth dams under the influence of earthquakes.

2. Quake/W and Seep/W programs

These are sub-programs of the geo studio software, where the Quake/w program is used to analyze the ground structures exposed to earthquake vibration or dynamic point forces from an explosion or sudden impact load. This program determines the movement and increased pressures of pore water that arise due to vibration and is designed to assess the stability of slopes exposed to inertial forces. Liquefaction of earthquake-prone structures, and the potential permanent deformation associated with an earthquake, uses a formula that integrates a set of periods from the start of a specific earthquake to its end [7]. The Seep/W program is used to model groundwater flow in porous media. [3, 10].

3. Materials and method

The Al-wand Dam is located in Diyala Governorate, southeast of the city of Khaniqeen. The purpose of constructing the dam is to use water for irrigation purposes, as the dam's drainage is 3 m/sec, sufficient to irrigate agricultural lands of 21120 acres. The location of the dam was chosen based on the results of the topographic survey and geological investigations, in addition to the availability of the necessary materials for its construction, such as mud, gravel, and filters. Therefore, it was approved as a dirt dam with a clay core surrounded by the filter material and filling its sides with gravel and sand. And it is an effective project to preserve the city from flooding. Figure 1. Cross sectional area of al-wand dam.

1-Clay core, 2-filter, 3-gravel and sand fill for U/S and D/S  4-Foundation, 5-U/S Riprap (0.3 m thickness)

**Figure 1.** Cross –section of Al-wand earth dam (scale 1:500).
First, we calculated the pore water pressure for different points in the Al-wand dam by using Seep/W, after drawing the dam body, specifying the constituent materials, and entering the boundary condition as shown in Figure 2. Thus the pressures we obtained were as in Table 1.

**Table 1.** Pore pressure in (kPa) at nodes 1, 2, 3 and 4 respectively using Seep/w program

| Node 1 | Node 2 | Node 3 | Node 4 |
|--------|--------|--------|--------|
| 115.5  | -5.2   | 90     | 14.5   |

After completing the Seep/W program and making sure that the results that emerged are comparable to the real results, we moved to the initial state and then the freedom to know the effect of earthquakes using the Quake/W program, where the characteristics of the soil composing the dam were entered which are shown in Table 2, and then the boundary condition was entered, which is the restriction of movement. In the directions x, y at the bottom of the dam and the vertical movement is restricted in the sides of the dam, then the earthquake values were entered (determined from a tremor that the region was subjected to in 2017), then the shock acceleration values were entered 0.08g, 0.1g and these are the results of seismic monitoring in terrestrial acceleration units. and using the time of the earthquake 100sec as shown in Figure 3, for the three cases of acceleration and by using the normal water level and maximum water level.

**Table 2.** Materials properties of al-wand dam [6, 9]

| material    | Permeability m/sec | Unit weight KN/m³ | C KN/m³ | Ø degree |
|-------------|--------------------|-------------------|---------|----------|
| core        | 4.8x10⁻⁹           | 18                | 210     | 10       |
| shell       | 0.001              | 18                | 0       | 25       |
| Fine filter | 0.07               | 18                | 0       | 30       |
| Coarse filter | 0.11             | 18                | 0       | 30       |
| Upper layer | 8x10⁻⁵             | 20                | 30      | 30       |

*Figure 2.* Cross section of al-wand dam and elements mesh and the selected nodes using geo-studio program.
4. Results and Discussion

1. Pore water pressure

There is no change in the value of the pore water pressure at node 1, 2, 3, 4 when increasing the acceleration when the water is at the maximum level and the minimum level of water as shown in Figure 4.

![Figure 3](image-url)  
*Figure 3. Acceleration – time history record for the earthquake.*

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![Figure 4](image-url)  
*a) Pore water pressure-time at node 1 at (0.08g, 0.1g)  b) Pore water pressure at node 2 at (0.08g, 0.1g)*
c) Pore water pressure-time at node 3 at (0.08g, 0.1g)

d) Pore water pressure-time at node 4 at (0.08g, 0.1g)

**Figure 4.** Pore water pressure-time at nodes 1, 2, 3 and 4 using (0.08g, 0.1g) at the maximum water level and the normal water level.

2. **Displacement**

The x-displacement at nodes 1, 2, 3 and 4 at the normal water level and at the maximum water level is shown in Figure 5. The X-displacement increased by 0.2 m when increase the acceleration from 0.08g to 0.1g.

**Figure 5.** X-Displacement –time at nodes 1, 2, 3, 4 at the maximum and normal water level.
The Y-Displacement that develops due to the excited earthquake in nodes 1, 2, 3 and 4 at the maximum water level are shown in Figure 6. We observe that the y-displacement increases with increasing values of acceleration, and the highest displacement is in node 2 at acceleration 0.08 at the maximum water level.

a) Y-displacement-time at nodes 1,2,3,4 at the acceleration 0.08 at the maximum water level.
b) Y-displacement-time at nodes 1, 2, 3, and 4 at 0.1 acceleration at the maximum water level
c) Y-displacement-time at nodes 1, 2, 3 and 4 at 0.08 acceleration at the normal water level
3. Effective stress

The x-effective stress at nodes 1, 2, 3 and 4 at the maximum water level shown in Figure 7. We note that the X-effective stress in node 1, 2 and 3 increased when increase the acceleration at the maximum water level, at node 4 X-effective stress is goes down a little when the acceleration is 0.1g but still the maximum value at the maximum water level at 0.08g and 0.1g. The Y-effective stress –time does not change significantly when increasing the acceleration from 0.08 to 0.1g and the greatest amount is in node 4, and the minimum Y-effective stress is in node 1 at the maximum water level as shown in Figure 7. The X-effective stress and Y-effective stress did not change with increasing the acceleration at the normal water level.

Figure 6. Y-displacement –time at nodes 1,2,3 and 4 using 0.08g and 0.1g acceleration at the maximum and minimum water level.
Node 3

a) X-effective stress-time at nodes 1,2,3 and 4 using 0.08g at the maximum water level

Node 4

b) X-effective stress at nodes 1,2,3 and 4 using 0.1g at the maximum water level
c) Y-effective stress at nodes 1,2,3 and 4 using 0.1g at the maximum water level
Figure 7. The X-effective stress and Y-effective stress in nodes 1,2,3,4 using (0.08g,0.1g) at the maximum and the minimum water level.
5. Conclusion

1- The magnitudes of the pore water pressure in the base of the dam greater than that at the top of the dam.
2- There is no clear effect of increasing the amount of acceleration on the pore water pressure values.
3- The x and y displacement increasing with time during the earthquake.
4- The effective stress decreases with time during the earthquake and that is mean that the soil continues to weaken.

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