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Seismic Response of Different Earthfill Dams to a Recorded Earthquake

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Abstract: Earthfill dams are constructed with soil based materials and therefore their seismic behaviors are very complex. In the present study two different earthfill dams were simulated and their behaviors were analyzed under a recorded earthquake. Simulations were concerned on the influence of soil tensions and water pressures on the seismic response of earthfill dams to a recorded earthquake using the finite element based GEOSTUDIO-QUAKE Software. Results of the numerical analyses were presented at the first, middle and end times of the earthquake to show the seismic behavior of homogeneous earthfill dams during the earthquake loading.

Key words: Earthfill Dam · Seismic Response · Earthquake · GEOSTUDIO-QUAKE Software · Numerical Simulation

INTRODUCTION

Dams regarding their purposes of construction are classified as diverting, storage and hydropower dams. Typically, dams can be constructed with soil or concrete. Choosing the proper material can be a baffling procedure for engineers since it is significantly influenced by several factors namely soil parameter and hydraulics issues. Therefore, choosing the wrong type of material can face dams with different dangers due to faulty design, improper construction and poor maintenance practices and other natural hazards (Fig. 1). Typical reported failure reasons are mainly hydraulic, seepage, piping through dam body, structural failure and due to earthquake. In an earthquake rapid release of energy causes a vibration of the earth [1].

Stability and deformation are two major issues that need to be considered in assessing the seismic performance of earthfill dams under earthquakes [2]. The Augusta dam is the first dam which is failed due to an earthquake. According to the USCOLD reports, less than 30 dams have failed during an earthquake [3]. Some researchers tried to estimate dam deformations due to an earthquake such as Jansen [4], Romo and Resendiz [5]. Newmark [6] succeeded in computing displacements induced by an earthquake in embankments by assuming that movements occur when forces on a rigid block of soils above a fixed potential failure surface exceed its sliding resistance. The dam responds similar to a flexible body and its accelerations are functions of depth within the embankment. Regarding this, Makdisi and Seed [7] estimated the peak crest acceleration from a specified response spectrum and SRSS combination of the spectral accelerations of different modes of dam vibration. Many researchers have tried both theoretically and empirically to estimate strength parameters of used materials (Escario and Sáez [8], Vanapalli *et al*. [9], Khalili and Khabbaz [10], Lee *et al*. [11]). The response and behavior of an earthfill dam as an earth structure subjected to earthquake shaking is highly complex and manifold [12]. In the present study Taleghan and Changureh dams have been modeled by the aid of QUAKE modeling in GEO-STUDIO software. Subsequently, the motion, movement and inertial forces that occur during the earthquake, the generation of excess pore-water pressures and the potential reduction of the soil shear strength are estimated for these dams.

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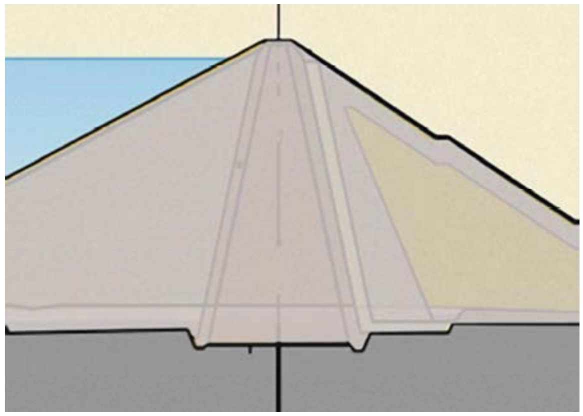


Fig. 1: Schematic view of an earthfill dam.

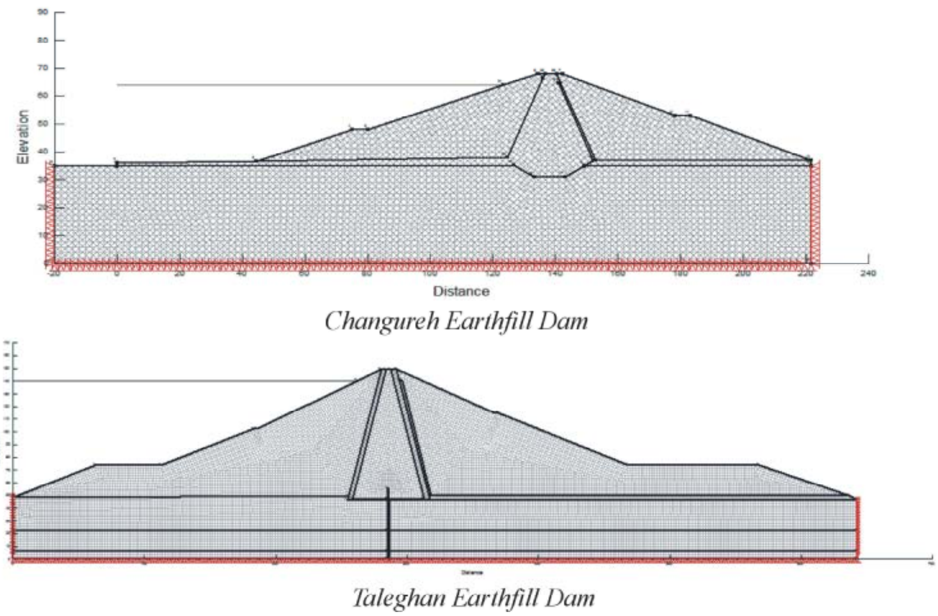


Fig. 2: Cross section of dams with generated mesh

Numerical Simulation: The main objective of this investigation is studying the seismic behavior of Changureh and Taleghan Earthfill dams employing GEOSTUDIO-QUAKE Software which is a geotechnical finite element program used for the dynamic analysis of earth structures subjected to earthquake shaking and other sudden impact loadings [2]. The study focused on the dynamic analysis of the response of the selected dams when they are subjected to an earthquake. Fig. 2 shows the cross section of Changureh and Taleghan Earthfill Dams with mesh.

Both dams have drainage system to control the seepage through the dam. In the dynamic analysis, the drainage system was not simulated in the model. Two regions were considered (one region for the foundation and the second region for the embankment) in the model to analyze the dam geometries.

RESULTS AND DISCUSSIONS

To examine the response of the selected earthfill dams, Avaj recorded earthquake data was used. Fig. 3 shows the time history record of the Avaj Earthquake.

Dam behaviors were presented and analyzed in three different times: at the beginning of the earthquake (t = 1s), after passing several seconds (t = 30.08s) and at the end of the earthquake (t = 58.88s). To be sure about real condition before running QUAKE/W, the SEEP/W was

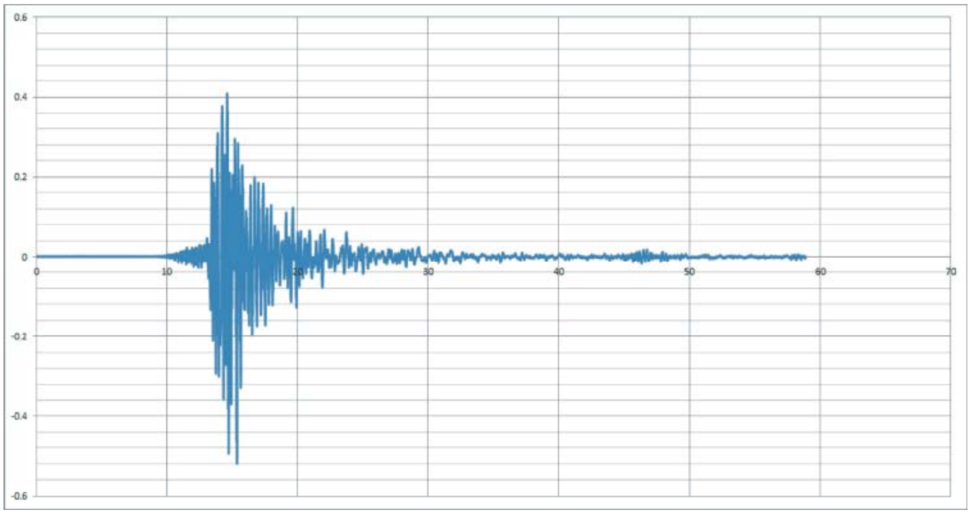


Fig. 3: Avaj Earthquake time history record.

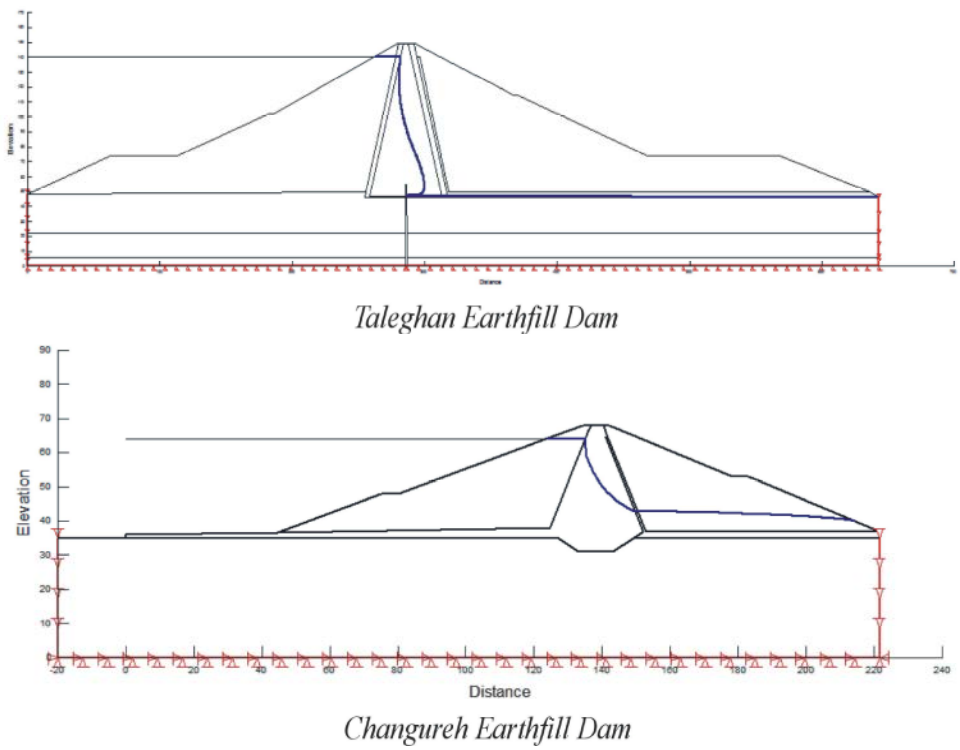
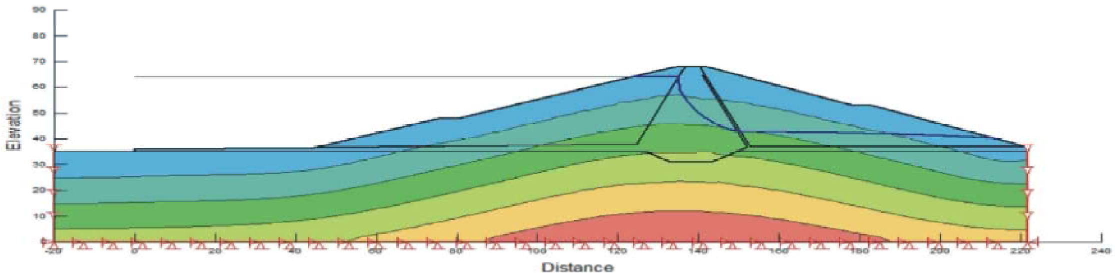


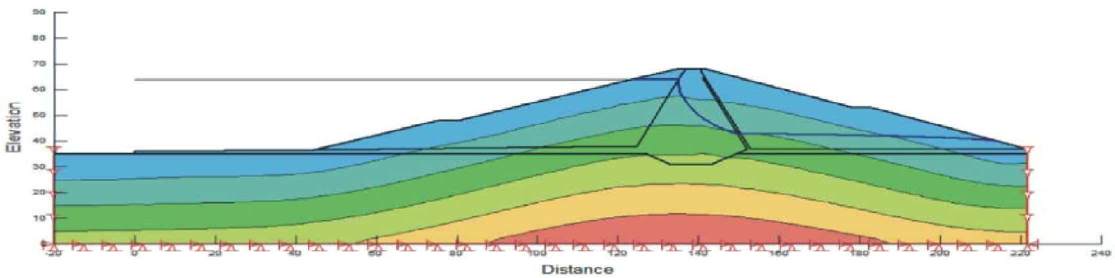
Fig. 4: The flow path line through the dams.

used to establish the long term steady state seepage conditions and pore pressures. The QUAKE/W Initial Static analysis type is conducted to establish the initial, total and effective static stress distribution throughout the dam. The previously computed SEEP/W pore-pressures are also used in the static stress analysis. The flow path line through the dams is illustrated in Fig. 4.

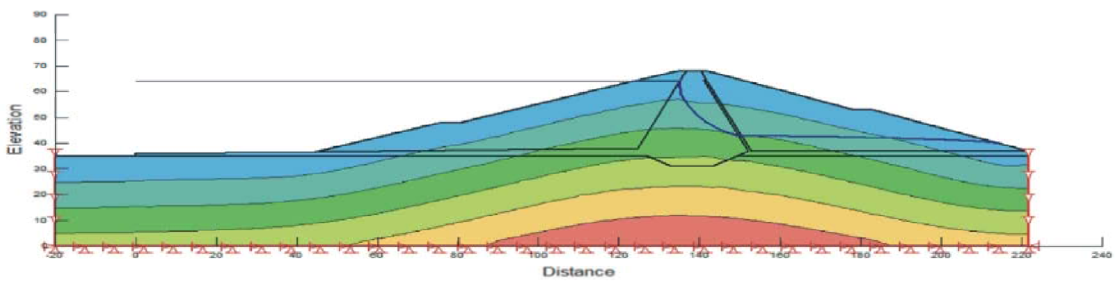
The resulting total and effective vertical stress contours and pore pressure contours are presented in Fig. 5, 6 and 7 in three different times during the earthquake. The purpose of the dynamic analysis is to determine the excess pore pressures that may develop and to identify zones where the soil may have liquefied. In the given figures, dams are subjected to earthquake shaking according to the time history record shown in Fig. 3.



$t = 1.00$s

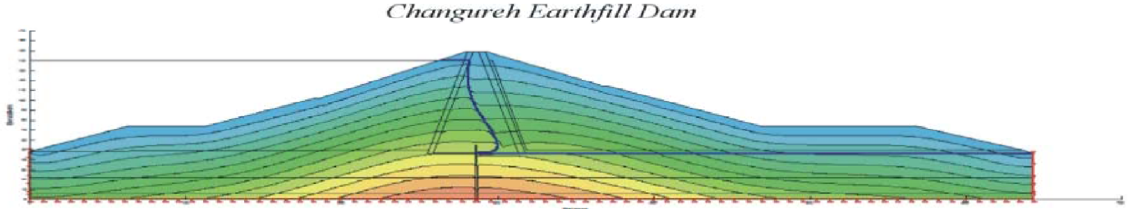


$t = 30.08$s

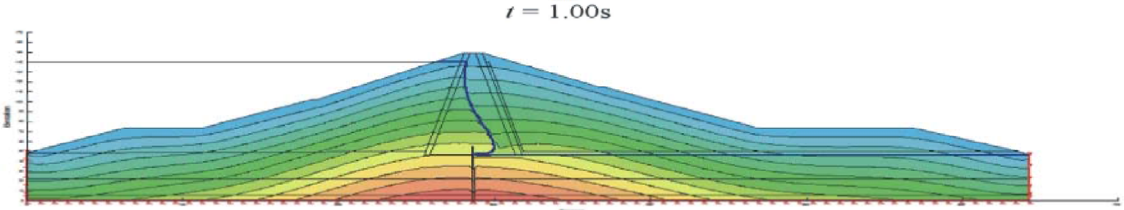


$t = 58.88$s

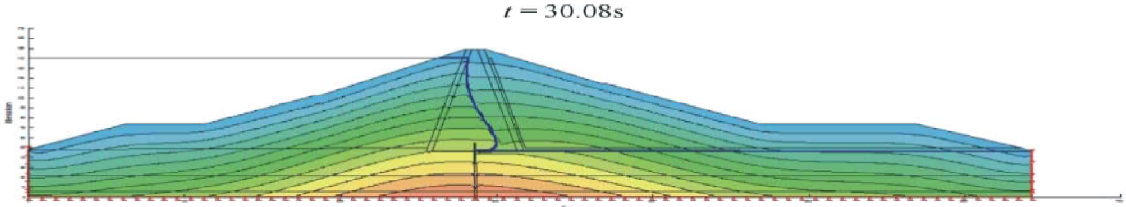
Changureh Earthfill Dam



$t = 1.00$s



$t = 30.08$s



$t = 58.88$s

Taleghan Earthfill Dam

Fig. 5: Total vertical stress contours.

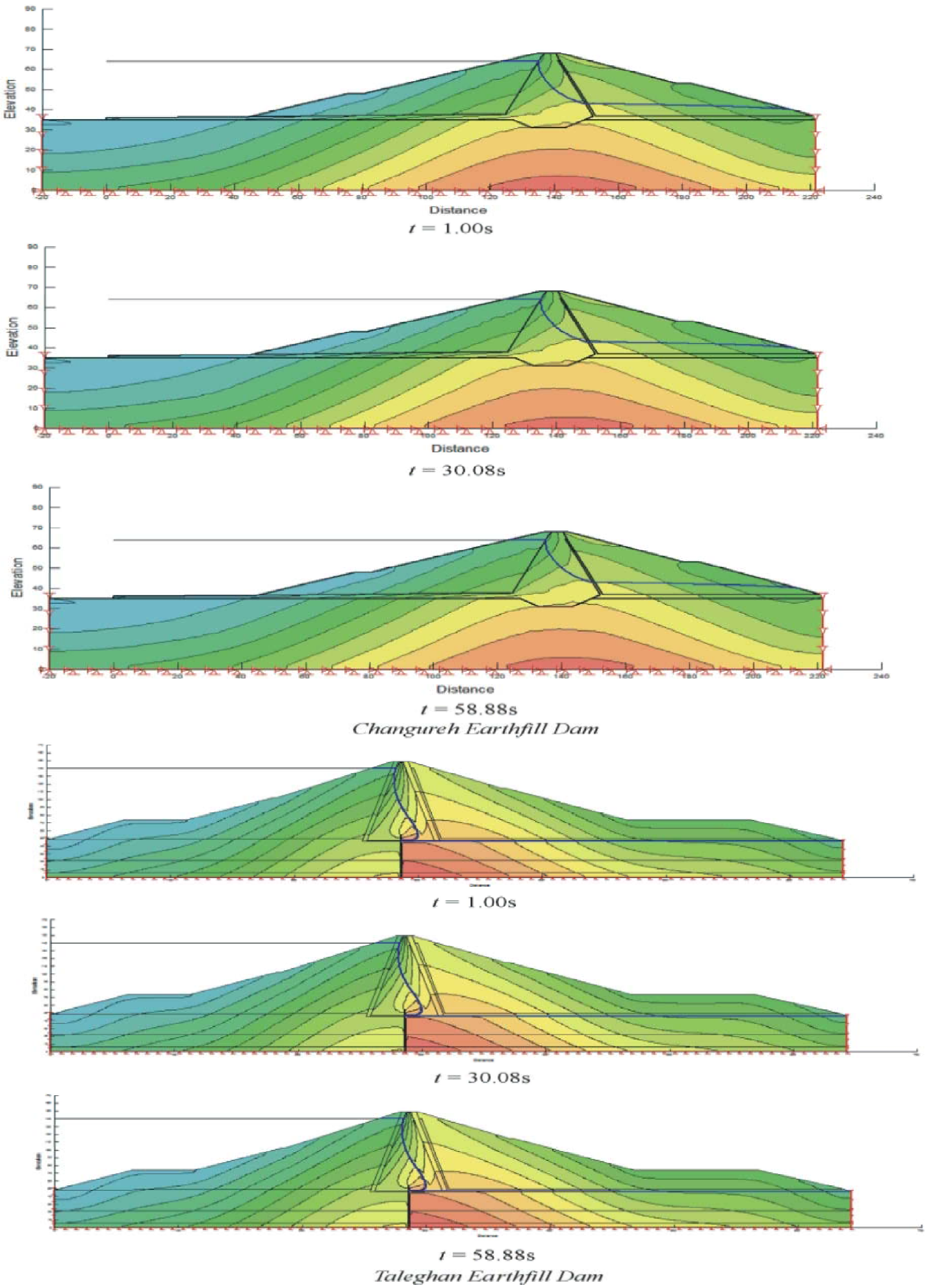


Fig. 6: Effective vertical stress contours.

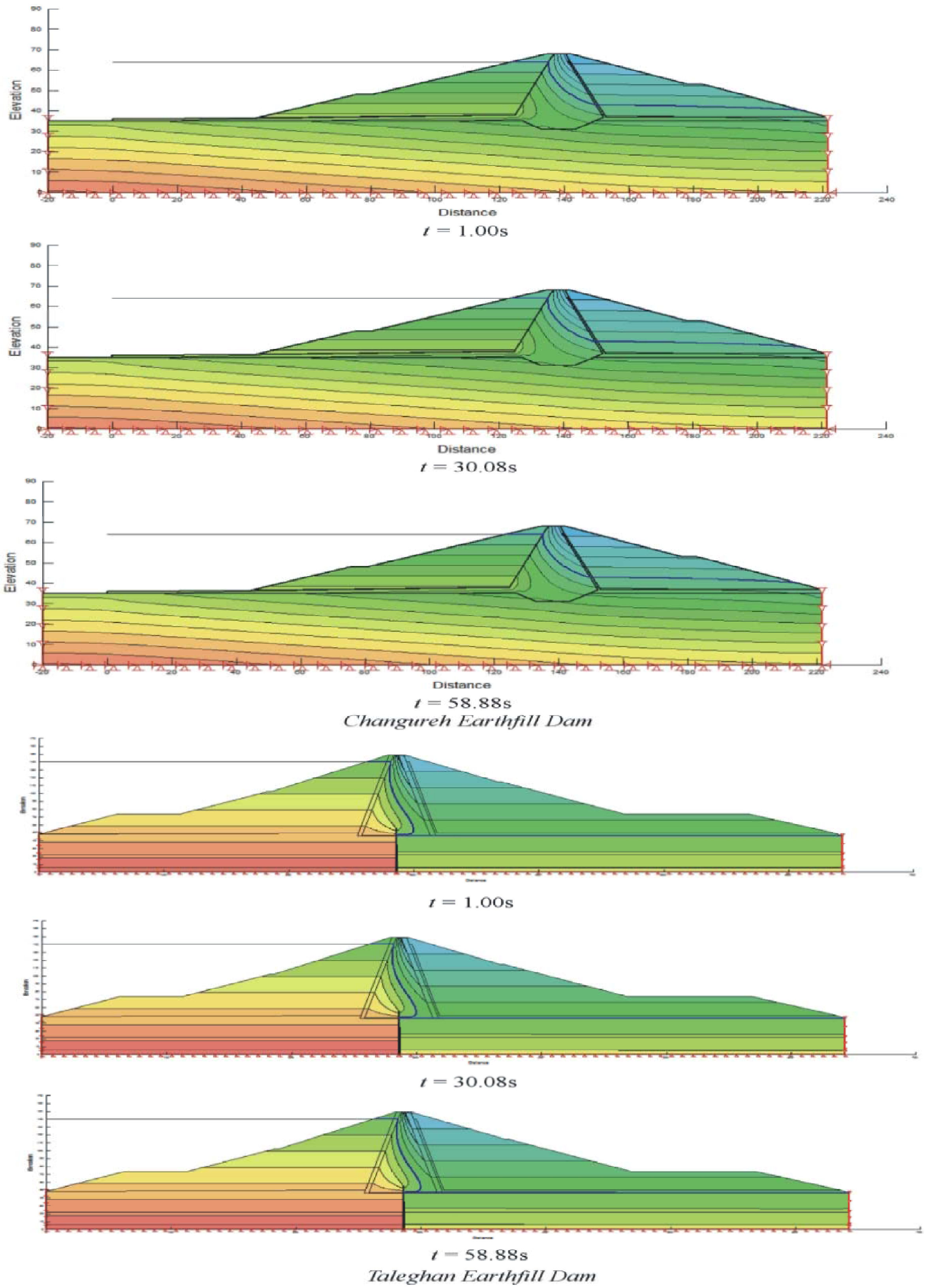


Fig. 7: Pore pressure stress contours.

CONCLUSIONS

Infrastructures are encountered with different natural hazards usually. One of the most important these infrastructures are earthfill dams which are faced with earthquake hazard. In the present numerical study, by employing GEOSTUDIO-QUAKE/W Software, Taleghan and Chngureh earthfill Dams are simulated and their seismic response on Avaj Earthquake was analyzed. The material properties used in this analysis are simple estimates which were adequate for understanding the key issues and mechanisms. The dynamic response of dams under earthquake loading was compared in different times of earthquake duration. Three selected times which are considered are first, middle and end of earthquake duration. Total and effective vertical stress contours and pore pressure contours were plotted in different times and compared for both dams.

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