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Simple Dynamic Analysis of Soil at the End of Construction Condition

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ABSTRACT

Todays, hundreds of millions of people worldwide are at risk of losing their properties and their lives because of earthquake. Destruction of man-made structures is one of the main causes of extensive damages during the earthquake. For this reason special attention has been made to build earthquake-resistant structures. The dams by saving millions of cubic meters of water, are considered of the most important structures. The dam failure will lead to huge losses of life and properties. In today's world, construction of earth-fill and rock-fill dams in comparison to other types of dams because of better adaption of such dams to the conditions of the area are of special interest. It also clearly has been given to Iran; so that has been put in the priority action plans. On the other hand, the dangers of embankment and rock-fill dam dams' destruction damages because of earthquake have been increased more in comparison to other types of dams. In this regard, the Dynamic analysis of earth-fill dam in areas prone to earthquakes, such as Iran, is very important. In the current study, the earth-fill dam of "Azad" on the river of "Cham Ghooreh" has been analyzed using "Element method" and then by the method of linear equivalent modeling. The research method included library, numerical studies, dam linear seismic behavior using commercial software of Geo Studio; and in this regard, in addition to study papers and related researches and output data analysis of software has been investigated. Finally, at the end of the dynamic analysis, dam response including acceleration and crest displacement changes and spectral response of the structure were evaluated at the end of construction. Also, the stresses, strains and deformations in the dam axis during DBL and MCL earthquakes were analyzed.
KEY WORDS: earthquake, earth-fill dam, stability, dynamic analysis, the end of construction

1. INTRODUCTION

One of the most important requirement of Iran is to harness and store surface waters for providing water supplies for drinking water, water for agriculture and industry, hydropower generation, flood control and river flooding, etc. In this regard, with the aim of development and utilization of country water resources and establishing high dams are required to analyze changing dam locations during an earthquake at the end of construction. Dynamic Analysis of earth-fill dam is in fact computation of seismic reaction against strong vibrations including earthquakes. By studying these reactions, many obscure points, such as the amount of permanent deformation of the dam body, how to change the profile of the bedrock in different parts of the dam body, the changes of stresses and strains in different parts of the dam, the dam's seismic stability, dynamic strength of remained materials forming dam body and … have been somewhat cleared. Analytical methods for calculating the stability of earth-fill dam against earthquake have been started from quasi-static and have become a comprehensive dynamic analysis. In dynamic analysis methods, bedrock acceleration changes during an earthquake and changes in the material properties to created strain surface by the earthquake and the results of periodic tests on soil have been considered as a model of seismic movements and dam materials [1]. Linear analysis methods are suitable when during earthquake, construction components behavior are located in linear limitation, or few of the components are existed of linear limitation. Also, in linear analysis, only key members have been modeled and non-principal members have been considered just for deformations of control analysis. Because none main members usually under reciprocating loads will have significantly reduced Stiffness and strength and quickly was out of the side bearing system. In the method of linear dynamic analysis, forces and deformation caused by the earthquake using the dynamic balance relationship over the reactionary model of the structure have been determined. Since, in this method, structure dynamic characteristics enters in the analysis and the results are more accurate than the linear static analysis, however, nonlinear behavior of materials of model have not been mentioned [2]. According to the studies, it was observed that heterogeneity has not a large effect on the main natural period of dam. Therefore, predicted natural frequencies by homogeneity models, have demonstrated conformity satisfactorily [3-5]. The aim of this study was to dynamic

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analyzing heterogeneous earth-fill dam at the end of construction. This overall objective was followed by partial and operational goals after which the calculated dynamic stress distribution caused by the Mcl, DBL earthquake and also dam response in dynamic condition has been studied. To answer this question, whether a dynamic analysis of the dam before the earthquake can prevent irreparable damages, the following assumptions of the study were explored.

- correction of parameters and materials behavior under dynamic condition
- correction of materials parameters based on the cyclic loading based on SEED theory

2. METHODS AND MATERIALS

The current study was a quantitative study that was carried out by linear dynamic analysis method and investigated forces, and deformations originated from earthquake using Equivalent Linear Method prevailing on determined structure elastic model that obtained results were more accurate than Elastic Linear method , however nonlinear behavior of materials of model are not mentioned [2]. Also, the method of Equivalent Linear Method that has been carried out based on experimental results by Sayed (1979) and has been offered for the location that the pore water pressure has no increases. In this study, Coalinga earthquake was considered as DBL earthquake which this earthquake occurred on May 2, 1983, at 23:42:37 in United States, Coalinga region, California. The depth of this earthquake was 10 km, and its severity has been announced 6.3 Richter. In Fig.1, the history of earthquake acceleration was plotted in DBL location. As can be seen, the maximum acceleration of this earthquake was 0.24g which occurred at 8:445 seconds after starting the earthquake.

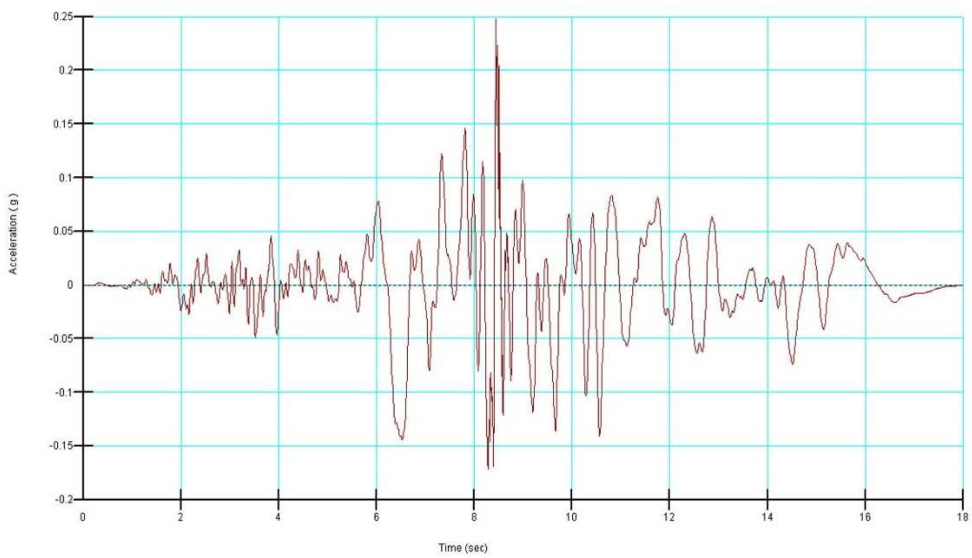

Fig 1. Earthquake acceleration drawer in 1983

In this study, Tabas earthquake has been considered as MCL level earthquake. Tabas earthquake with a magnitude of 8.7 Richter that devastated Tabas city and nearby villages, at about 7 p.m. on 16 September, 1978. The Fig.2 plotted the history of earthquake acceleration in the MCL location and as can be seen, at 10.624 seconds after starting earthquake, the maximum earthquake acceleration reached to 0.54 g.

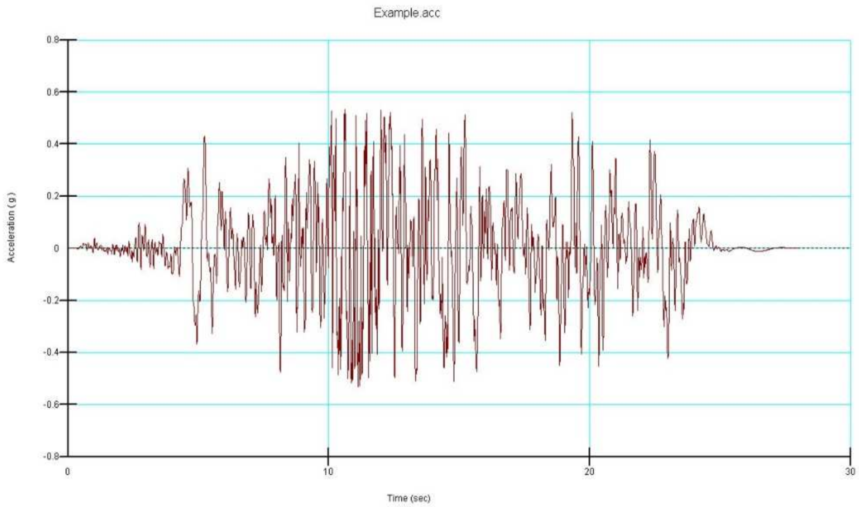

Fig 2. Earthquake acceleration drawer of Tabas city, 2013

Using limit finite element analysis of earth-fill dam, internal stress distribution and displacement will be achieved. For this reason, the plane strain and stress is a general acceptance. Analysis of deformations caused by dam by this method can be used to predict potential slip curve by defining the maximum embankment slope deformations and their direction. Apart from the case of an earth fill dam that should have high long and uniform column, is a prismatic and wide body across the valley. Most performed analyses are two-dimensional and are based on plane strain (Falah Moshfeghi, 2010).

2.1. Overview of the studied dam in the analysis

The aim of Azad dam construction on the river of Cham Ghooreh, was tapping the water potential of the river for irrigation and agricultural development in the downstream lands. The river of Cham Ghooreh is the main branch of Azad River that flows in Kurdistan province and west of Sanandaj city.

2.2. Plan characteristics

Azad reservoir dam that is rock-fill dam with vertical clay core and coffer dam and drain are part of its body. Based on the water resources studies and hydraulic considerations, normal quantities and dam crown were 1475 and 1480 meters above sea level, respectively. Quantities of natural bed and healthy rocks at the bottom of the river at the location of axis were 1362 and 1357 meters above sea level, respectively. So, the maximum height of the dam from the river bed was 118 meters and from healthy stone foundation, it was 123 meters. The length of dam crown was about 597.5 m (Fig.3).

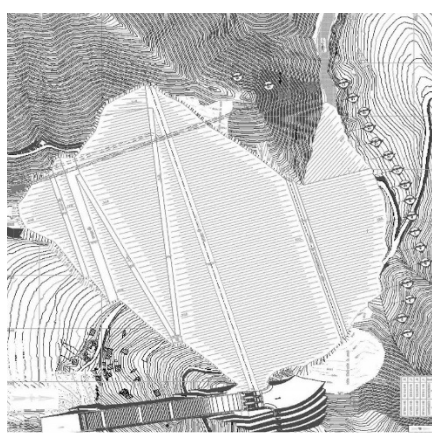

Fig 3. Plan of Azad earth fill dam, 2013

3. RESULTS AND DISCUSSION

3.1. The topography and morphology of the dam site

The location of Azad dam has located in 250 meters upstream of Benidar village and on the river of Cham gooreh. The direction of this river flow limits at the dam location axis from the north to the south and adjacent to the coffer dam axis from the west to the east. The width of river flow bed at the location of dam axis was about 28 meters and the floor level at this location was 1362 meters above sea level.

3.2. Section model of Azad dam

The Fig. 4, shows the section of Azad dam that has been modeled by GEO STUDIO software. Azad dam has designed in rock-fill dam with a central clay core, which its body has completely located on healthy rocks (Table 1).

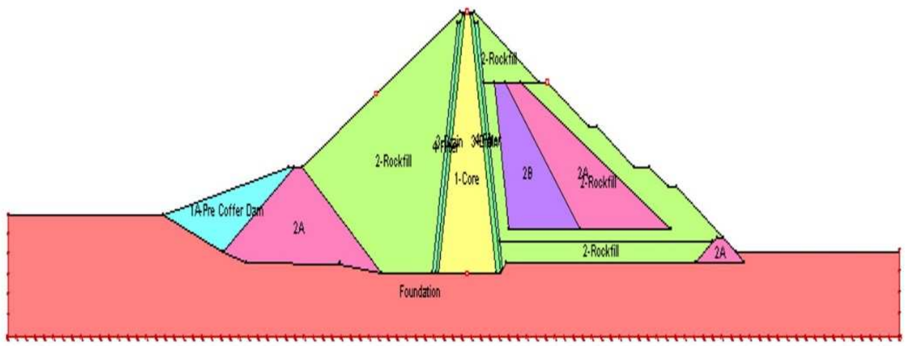

Fig 4. Sectional model of Azad dam, 2013

Table 1. Material properties of Azad earth fill dam

permeability K	angle of friction φ	Viscous C	Poisson ratio υ	elasticity modulus E	wet specific weight γ_{wet}	Dry specific weight γ_{sat}	
m/sec	Degree	(kPa)		(kpa)	(kN/m^3)	(kN/m^3)	
5.0E-09	20	0	0.35	Based On Diagram	19.5	20	**Core-CD**
	14	30					**Core-CU**
	4	60					**Core-UU**
5.0E-05	47	0	0.3	Based On Diagram	22	22.5	**Rockfill (2)**
5.0E-05	43	0	0.3	Based On Diagram	22	22.5	**Rockfill (2A)**
1.0E-05	40	0	0.3	Based On Diagram	22	22.5	**Rockfill (2B)**
1.0E-05	35	0	0.3	Based On Diagram	19	19.5	**Filter**
1.0E-04	35	0	0.3	Based On Diagram	19	19.5	**Drain**
1.0E-06	30	0	0.35	Based On Diagram	18.5	19	**Cofferdam Cover (1A)**
1.5E-06	35	100	0.25	100000	22.5	23	**Foundation**

Table 1, shows the saturation specific weight, wet density, Poisson ratio, viscous, friction angle and permeability in different parts of the dam, and elasticity modulus has been calculated based on the drawn diagrams (Fig 5-7).

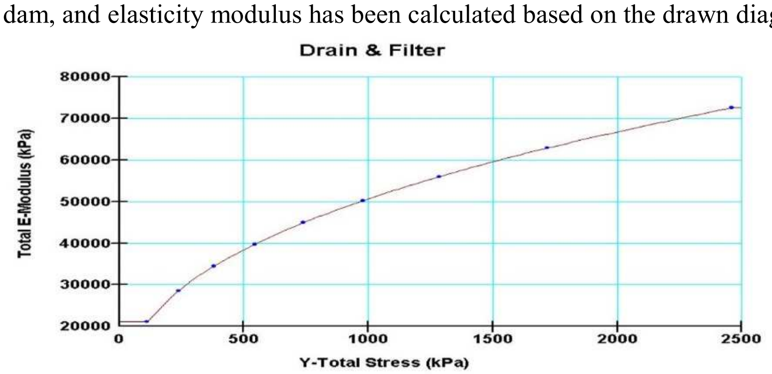

Fig 5. Shell elasticity modulus, 2013

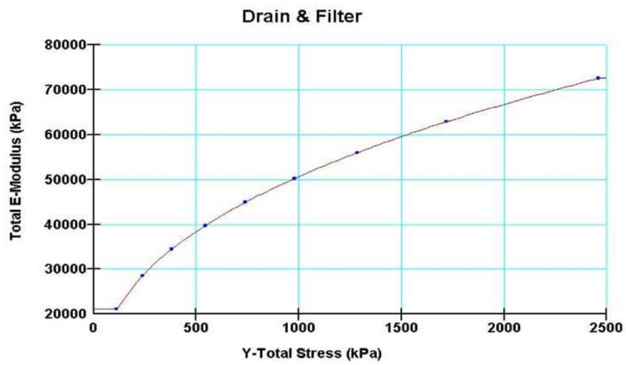

Fig 6. Elasticity modulus of filter and drain, 2013

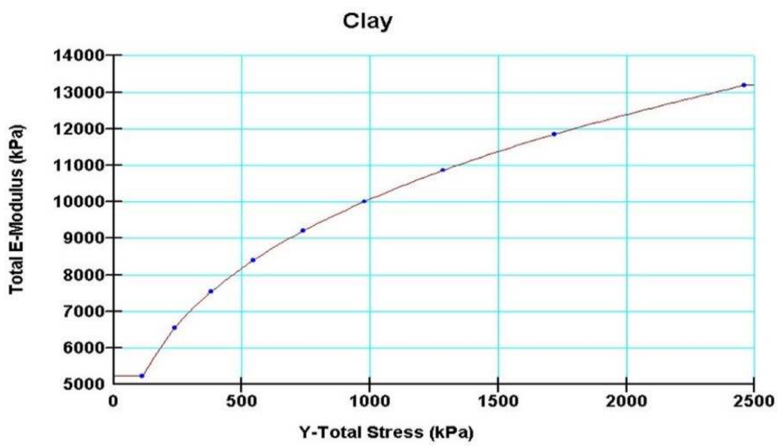

Fig 7. Clay elasticity modulus, 2013

The following diagram shows Azad dam acceleration response in the x-direction. The most acceleration regarding the following graph at the time of 7.5 seconds was 0.8g. The next maximum acceleration was recorded at the time of 9.5 seconds and its amount was 0.9g. Regarding the earthquake accelerograph of Coalinga, the highest acceleration was 0.25g that occurred at the time of 8.5 seconds. Comparing the two graphs with each other shows that in Coalinga earthquake, at the time of 8.5 seconds, the maximum acceleration was 0.25g but in the dam crown in the chart of crest acceleration, acceleration response at the time of 9.5 seconds reached to 0.9g. This comparison shows that Azad dam crown had 260 per cent increase in acceleration and has shown 260% more acceleration and intensification has been created (Fig. 8).

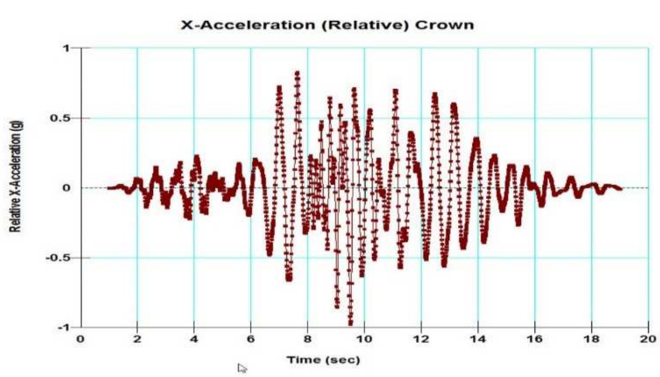

Fig 8. Azad dam crown acceleration response of dynamic analysis in the earthquake level of DBL at the end of construction, 2013

The following graph shows the x-direction movement of dam crown that in dynamic analysis of Azad dam at the end of construction location, the acceleration based on Coalinga earthquake was entered to software and displacement of crown dam drew according to the following graph (Fig. 9). The maximum displacement of 8 cm and would be occurred at the time of 7 seconds. This suggests that the dam necessarily at the time of maximum acceleration, will not tolerate the most location displacement. It means that, yet the maximum acceleration has not taken place but the greatest shift has taken shape.

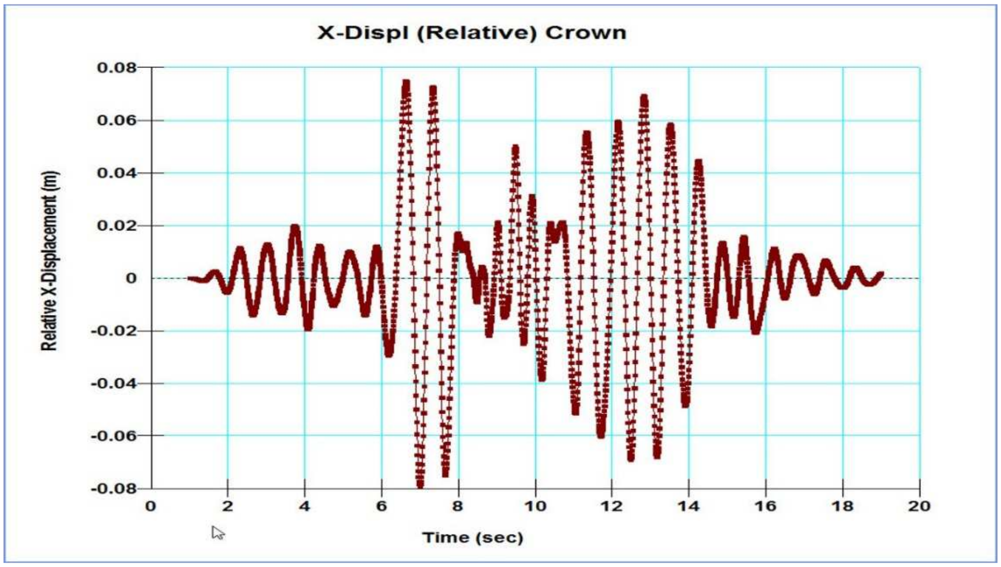

Fig 9. X displacement response of Azad earth fill dam crown acceleration of dynamic analysis in the earthquake level of DBL at the end of construction, 2013

The Fig. 10, shows the speed response of the Azad dam crown that has been expressed at linear dynamic analysis. As can be seen, the maximum speed was at the time of 7 seconds that was equal to 0.7 meters per second.

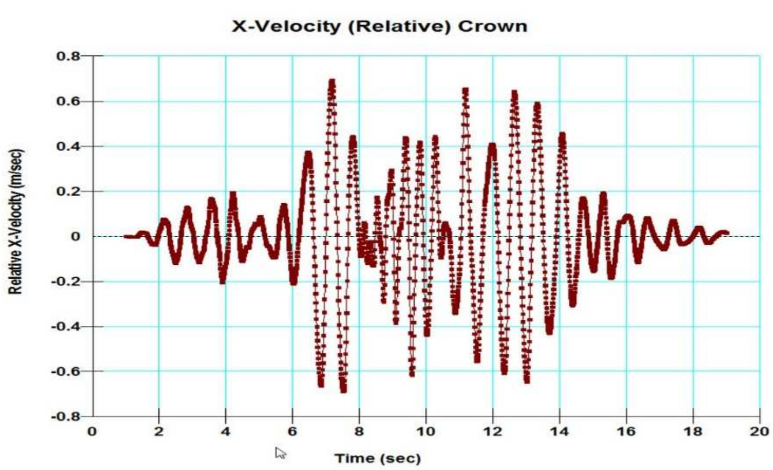

Fig 10. Speed response in the X direction of earth fill dam of dynamic analysis in the earthquake of DBL level at the end of construction condition, 2013

The Fig.11, shows the acceleration response of Azad dam in x-direction, that the most of acceleration with respect to the following graph was at the time of 7 seconds, and its value was 1.9g. However, regarding the accelerogram of Tabas earthquake, the most acceleration was recorded as 0.5g, at the time of 12 seconds. Comparison of these two charts show that in Tabas earthquake at the time of 12 seconds, the maximum acceleration was 0.5g. But, dam crown in the figure of acceleration response at the time of 7 seconds has reached to 1.9g. This comparison shows that the Azad dam crown had 280% increase acceleration. It means that the response of Azad dam will show 280% more acceleration and intensification.

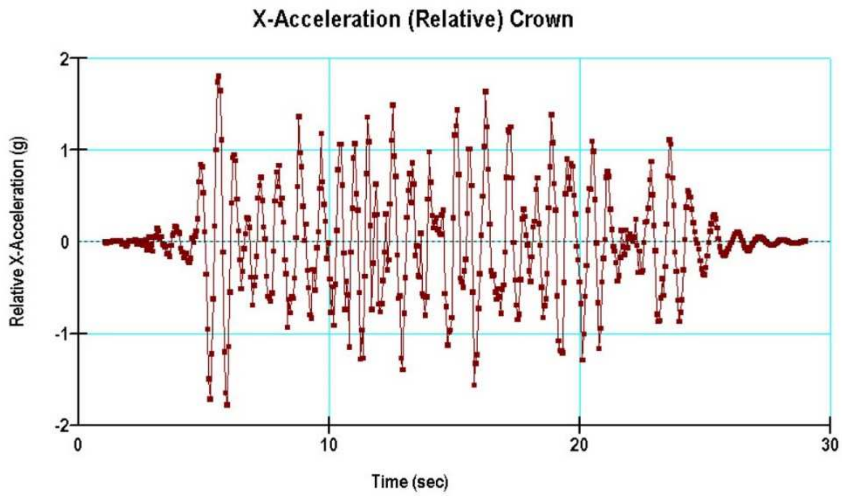

Fig 11. Acceleration response of Azad earth fill dam crown of dynamic analysis in MCL earthquake level at the end of construction condition, 2013

The fig.12, shows displacement of Azad dam crown in the x-direction. In dynamic analysis of Azad dam at the end of construction condition, acceleration was entered to the software based on the Tabas earthquake and displacement of dam crown was drawn as below. The maximum displacement was occurred at the time of 6 seconds and with the amount of 23 cm. This suggests that, when the acceleration is maximum, the dam will not necessarily tolerate the greatest shift and means that yet, the highest acceleration are not reached, but the greatest shift has taken shape.

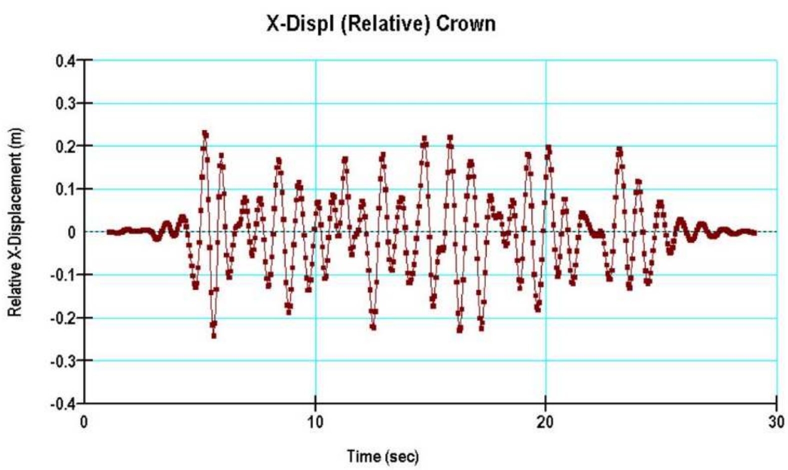

Fig 12. Displacement response in the X direction of Azad earth fill dam of dynamic analysis in the earthquake level of MCL at the end of construction condition, 2013

The Fig.13, shows the speed response of Azad dam that has been shown in linear dynamic analysis. As can be seen, the maximum created speed was at the time of 6 seconds, and its value was 2meters per second.

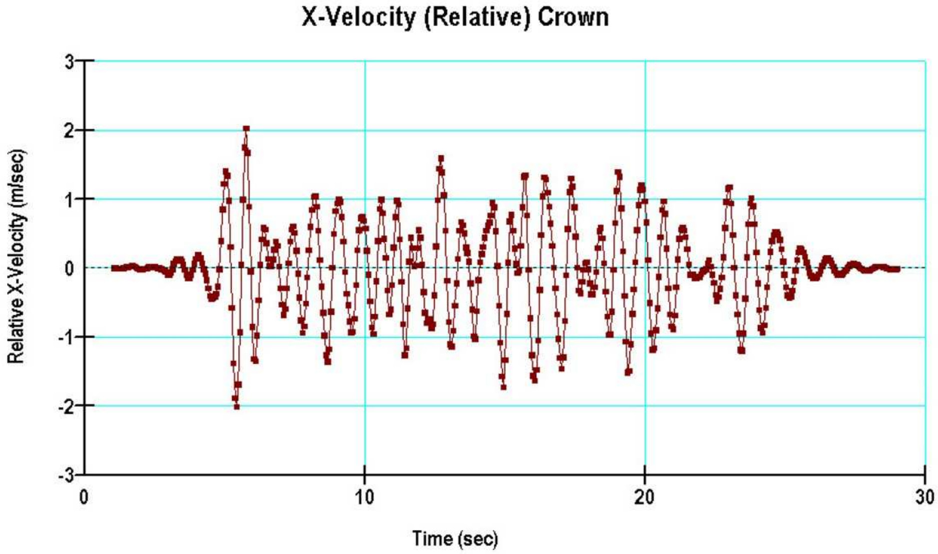

Fig 13. Speed response in the X direction of earth fill dam from dynamic analysis in the earthquake level of MCL at the end of construction, 2013

4. CONCLUSIONS

In this article, the earth fill dam as an earthen structure under dynamic loads of earthquake was examined. Since, earth fill dams play a very important role in the economy, so, their design principles under static and dynamic conditions is very important and any damage to them, especially under dynamic loads can cause irreparable and heavy damage [6-9]. Therefore, in this study it is taken into consideration. In this context, to examine the behavior of this earthen structure, an earth fill dam of "Azad" was selected and under Coalinga earthquake at the level of DBL and Tabas at the level of MCL, numerically by software of Geo studio was dynamically analyzed. Performed dynamic analysis was based on seed assumptions for equivalent making of dynamic behavior and numerical analysis method was also the finite element method. This dam analysis has been made at the end of the construction and tank fill dam (leakage stable). According to the figures obtained from the response of the structure during an earthquake and at different times, it has been observed that the maximum acceleration and maximum shift in momentum does not necessarily occur at the time of maximum earthquake acceleration and shortly after the earthquake maximum acceleration occurring, maximum displacements has been experienced. Generally, maximum displacement and maximum acceleration response of structures have been observed in the third upside of the structure. As it can be understood from the acceleration response of earth dams, by applying earthquake, resonance and resonance phenomenon occurs in the structure that by increasing the water level in the reservoir, the amount of resonance on structures has decreased and this is probably due to the weight of the water and its resistance against the swing structure in upper [10-17].

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