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Effect of Foundation on Seismic Behavior of Concrete Dam Considering the Interaction of Dam - Reservoir

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ABSTRACT

Concrete dams are considered as the best choices of dam construction in regions where body and base rock have the adequate resistance. In these dams, due to the base narrowing in comparison to earth dams, extra pressure is applied to foundation base and walls. Thus, adequate resistance of foundation and its reformation is required. Dynamic response caused by dam on the basis of different vibrating modes collection is investigated. In this paper dynamic analysis of concrete dam is presented with regard to foundation effects and considering the dam interaction effect with bed lake and lake. All analyses were done by means of ANSYS software and as a case study Pine flat dam is chosen. Complete dynamic interaction of Dam and reservoir with incompressible fluid, absorbing borders of energy in foundation and Supports and far borders are considered in analysis. In addition, foundation is assumed to be rigid and flexible in which various proportions are regarded for elasticity module in analysis. Results of analyses showed an interaction of Dam and reservoir due to decrease frequency.

KEYWORDS: Dynamic Response, Interaction of Dam and Fluid, Concrete Dam, Seismic Effect, Finite Element Method.

1. INTRODUCTION

The seismic analysis of concrete dams with consideration of interaction effects of dams, reservoirs, a significant volume of research. However, analysis of dam and reservoir dynamic interaction unlimited, because more important than the other factors are taken into consideration [1,2].

In 1928, following the failure of St. Francis Dam in California, problems that fail to attract the attention of many large dams led to extensive research in the field. For several events since then for a variety of dams occurred in many parts of the world shows the importance of this issue. Sinfengking Dam in China, Konya dam in India noted that in 1960 it was entered in the quake damage. Another example Sefidrud dam was injured in the earthquake of 1990 Rudbar.

Statistics in this field indicates that no concrete dam in an earthquake is not a complete failure and the only reason to destroy the foundation of the dam has been broken concrete dams[3].

In the late sixties, the majority of studies on the interaction of the dam and reservoir were performed by the analytical method. In the seventies, and with the development of numerical tools and the advent of computers, numerical methods also have their place in an open investigation.

In 1972, Finn and Vagner using finite element method and assuming the reservoir fluid compressibility methods for solving the dam and reservoir interaction explained[4].

Interaction effects of dam and reservoir dam was by modifying the mass and matrix tree. In 1973, Balachandaran assuming heterogeneous reservoir containing fluid and assuming harmonic vibrations of the earth and rigid platform, the hydrodynamic pressure distribution on the dam analyzed.[5] The parameter values were variable density surface water from the bottom of the Reservoir. And sediment and impurities in the fluid, in terms of formulation and solution presented in the frequency domain. From 1976 to 1980, researchers with the irregular geometry upstream of the dam was a relationship.Young assuming the rigid and vibration analysis presented in line perpendicular to the longitudinal axis of the dam and analysis to provide a fluid incompressibility[6].

They Modeling of Westergaard and investigation into the upstream slope in their calculations, the hydrodynamic pressure distribution on the upstream side of the dam was calculated And compared their results with Zenger's work and show satisfactory results have been compared[7].

Careful studies by different researchers over time and the impact of various factors on the hydrodynamic forces exerted on the structure during an earthquake, such as pressure reservoir.assumptions, possible estimates in terms of the equations of hydrodynamics.

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Structure and properties of materials the dam and reservoir was more specific. But what concrete dams to earthquake response analysis of complex problems in structural dynamics makes regular interaction with the environment around the dam structure during earthquakes.

The primary research method proposed and the time to complete the original design of the dam was a way for many decades. This was based on a method called added mass and assuming incompressibility of water, the water in the tank structure interaction during earthquakes on dam model was added to the mass that is in phase with the vibration of the dam.

The method in 1990 was declared by Department of Earthquake Engineering dams obsolete methods that use large errors in the design of the dam creates[8,9].

The seismic safety of concrete dams have always been considered as a major factor in the design of new dams and dam safety assessment after earthquakes in the area are discussed. Generally two reasons for growing concern about dams in earthquake resistance can be cited.

1 - The risks of injury due to the increasing population in the area downstream the dam.

2 - Several earthquakes occur in different areas of the world previously thought was inadequate safety measures and the need for continuing research in this area is felt.

In the present study, the dynamic behavior of concrete dam under El Centro earthquake and the horizontal component of important parameters such as substrate material and fluid interaction on the dynamic response of concrete dam Pine Flat Dam and using software (Ansys) and the modal method are studied.

2 - Dam and Reservoir Modeling

Modeling of two-dimensional form of the linear behavior of concrete has been done. Due to the properties and behavior of materials following elements are used for modeling:

PLANE82 element modeling of dam body. This element is used for two-dimensional surfaces precision results for automatic mesh complex (square - triangle) provides each node has two degrees of freedom is the element. PLANE42 elements for modeling concrete dam foundation are considered. Interaction between the fluid and the structure is modeled using a Fluid29 element. Among the most important applications of this element in the modeling of acoustic wave.

So the 8 node element with four degrees of freedom at each node, including its position (x, y, z) for a range of groups that are in contact with the surface and the pressure is on all nodes[10].

Block geometry highest vertical dam height (Hs) 92/121 m, is shown in Figure 1. (Dimensions in meters) and the material properties of the dam (Table 1) are listed.

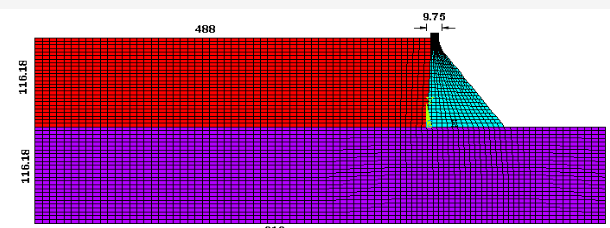

Figure 1 - Dimensions of the dam and reservoir modeling.

Table 1 - Profile of Pine Flat Dam [11]

27.85 Gpa	Modulus of elasticity of the dam body.
22.4 Gpa	Elastic modulus bedrock
.2	Poisson's ratio of body
.33	Poisson's ratio bedrock
24.8 kN/m3	Density concrete

3 - Dynamic Analysis

To analyze the structure against seismic loads, there are different ways depending on the complexity and precision required of them is used.

Dynamic response of structures with low vibration periods, such as concrete gravity dams to earthquake loads, mainly due to their primary vibration mode. Therefore, the main mode of vibration modes that must be considered. Earth dam response to vibration in the vertical direction than the horizontal direction is less important than being ignored. Although the main mode of response to the effects of the interaction between a dam and water, foundation structure is very complex, but the system is almost equivalent to a degree of freedom in a way that expresses a concrete gravity dams is the main mode of response[12,13].

Strong ground motions is appropriate for calculating the response of the dam that blocks vertical dam to separate the two-dimensional case considered in the analysis. It is assumed that each block on a vertical semi-infinite viscoelastic plate is located behind the water, probably associated with sediment deposits are located[14].

Although a degree of freedom model of the dams in the area, but the assumption is valid that the upstream dam is a vertical surface. Because of these at low to diversion upstream is not sensitive to vertical surfaces. Also ignored is the effect of water downstream. The water level is so low because usually it does not affect the dynamic behavior of the dam. Earthquakes used in the analysis, Kern County, California, which is the horizontal component of earthquake on July 21, 1952, Lincoln station Taft (Taft Lincoln School) has been recorded. Figure (2) is shown. [15].

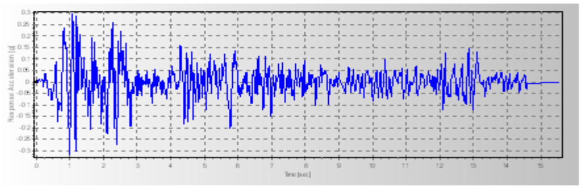

Figure 2 - horizontal component of earthquake Taft Lincoln

3-1 - verified by modeling

Compared to fill and empty the reservoir conditions are shown in Table 2.It is noteworthy that the Chopra models based on analysis of the damping rate of five percent for all modes is calculated. Structural damping coefficients were determined so that the damping riley attenuation frequency of the first and third vibration modes of the dam is equal to five percent of critical damping[16].

Table 2 - Comparison of present model with results from other researchers.

reservoir	**Empty**		**Full**	
researchers	Present	other	Present	**other**
First mode	2.5507	2.563	3.164	3.145
Second-mode	6.2467	6.274	6.7431	6.525
third mode	8.3053	8.740	8.8135	8.729

Models that have been considered for this analysis are as follows.
1) rigid foundation with regard to the dam at reservoir is full (two-dimensional cases).
2) rigid foundation of the dam and reservoir empty.
3) flexible dam foundation and reservoir filling.

With different aspect ratios for the dam and foundation stiffness in Flexible seismic behavior of concrete dam will be reviewed. (Equation (1)) In order to be flexible in assuming the proportions of (n) for the modulus of elasticity of the dam and dam foundation (0.25 and 1) dynamic analysis is performed.

$Ef/Es=n$ (1)

Elements of the dam in 2594 and 2384 the number is the number of nodes. Propagation phenomena and structures Immersion in water. Analysis of selected time step equal to 0.005 seconds and 7.5 seconds for the analysis of the Taft earthquake record are given.

3-2 - Dynamic analysis in rigid state and reservoir full

Natural frequencies and modes of such structures are important parameters in the analysis. The determination of these parameters can be very useful in interpreting the behavior of the dam. Assuming a rigid dam with the foundation and fill the reservoir to seismic effects will be discussed.

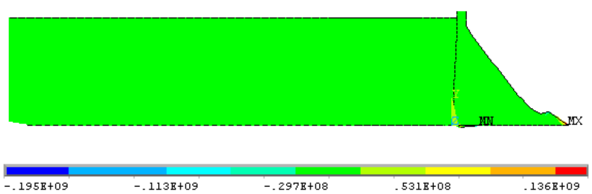

Figure 3 - Maximum stress in Sec .005 of the start of the seismic record.

As shown in Figure 3, the maximum amount of tension 53.1 MPa.

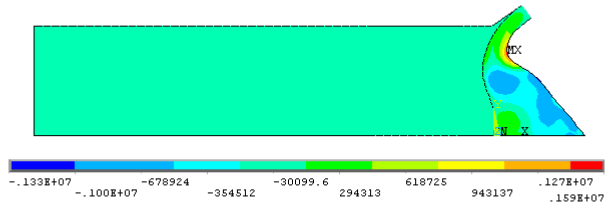

Figure 4 - Maximum stress in Sec 7.5

As shown in Figure (4) shows the highest stress was observed in 1.59 MPa. In fact, the beginning and end of the analysis results for Maxim stress, decreased approximately 97% has been achieved.

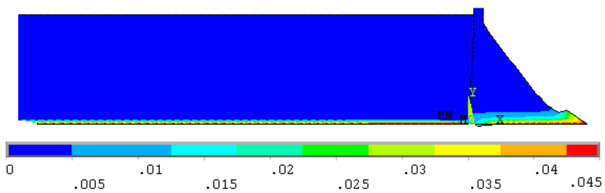

Figure 5 - Change the shape of the S .005 in the earthquake record

The maximum displacement into the sample average modeled, 4.5 cm at the toe of the dam will be the largest quantities.

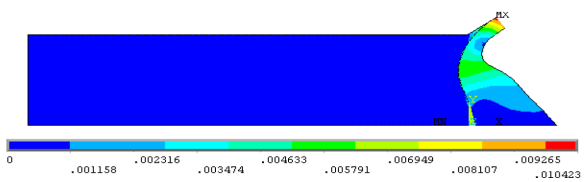

Figure 6 - Change the shape of the S 7.5 in the earthquake record

Actual concrete gravity dam with a vertical upstream or are very close to vertical. Hydrodynamic pressure slope Figure (6), the maximum deformation occurs at the crest of the dam, but the highest value of the average displacement is less than the initial value s 0/005 would be (1.04 cm). Finally, the graph in Figure (7) compares the maximum amounts shown are displacement dam.

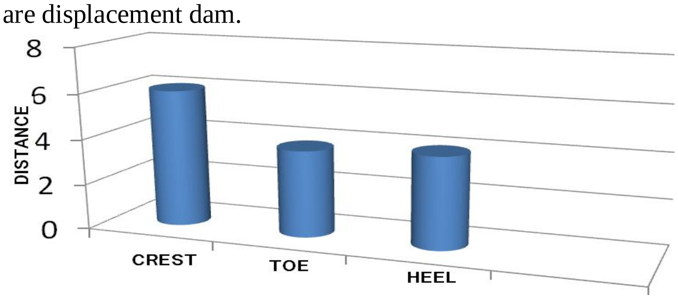

Figure 7 - Maximum displacement in rigid dam and reservoir filling.

3-3 - dynamic analysis in terms of rigid foundation and empty the reservoir.

Due to lack of fluid damping system in a way that reduces the amount of energy loss analysis because of poor response from the analysis of seismic response will reduce the upward journey. However, due to the proximity dam body fluids reduces the effective mass of the vibrating system. (Figure 8)

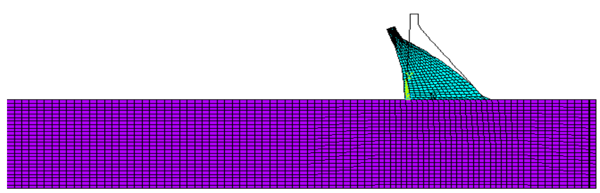

Figure 8 - Comparison of before and after rigid foundation and dynamic analysis of the dam with an empty reservoir

Average maximum displacement during the dynamic analysis in Sec .005 are shown in Figure 9.

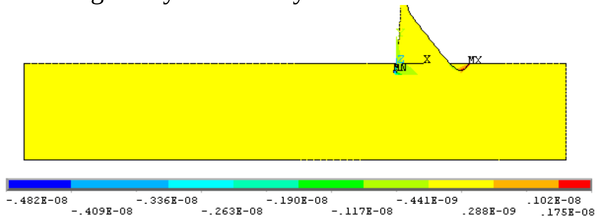

Figure 9 **-** Average maximum displacement in Sec .005 in the earthquake.

After the earthquake record 7.5 seconds, also the second maximum average initial displacement incremental changes (about 76 percent) (Figure 10).

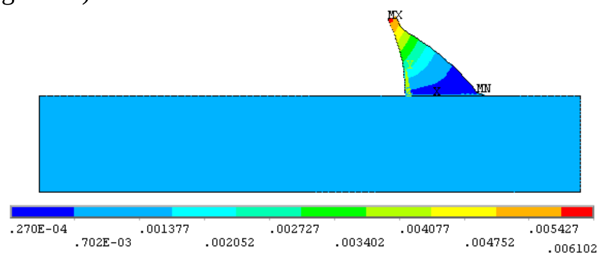

Figure 10 **-** Average maximum displacement s 7.5 of the earthquake

Von Mises stress after the earthquake in Figure (11) shows that the maximum value of 794.825 Pascal. It is noteworthy that in contrast to the rigid foundation and a full reservoir, about 98 percent less stress occurred.

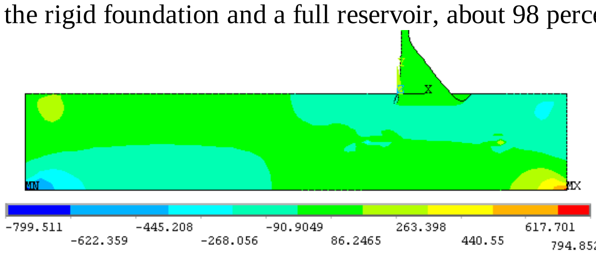

Figure 11 **-** von Mises stress

3-4 - the dynamic analysis of a flexible foundation and reservoir full

To study the effect of foundation flexibility on seismic behavior of concrete dam, by including a numerical comparison to the modulus of elasticity of the dam foundation, the analysis is done tests (n = 1).

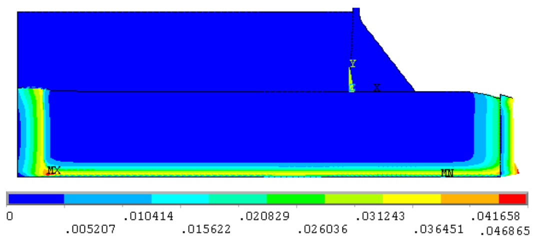

Figure 12 **-** Average maximum displacement in Sec .005 in earthquake

Figure 12 shows the average maximum displacement of the second .005 earthquakes of 4.68 cm. Compared with the rigid foundation increases of about 5 percent.

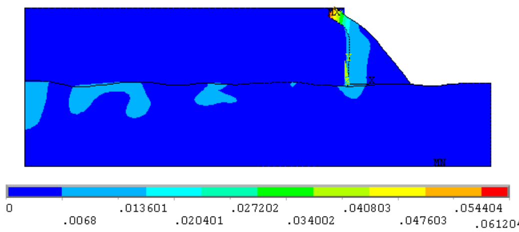

Figure 13 - Average maximum displacement s 7.5 of the earthquake

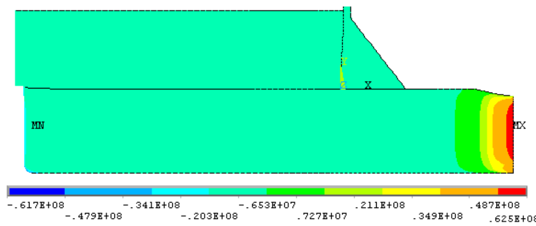

Figure 14 - Stress Maxim s 0.005 from the start of seismic records

Figure 14 shows the stress on the second Maxim .005 is the start of a seismic record, with maximum tension 62.5 MPa during the dynamic analysis.

Analysis was performed Compared with the rigid foundation and the reservoir is full, it shows a trend increase of about 17 percent.

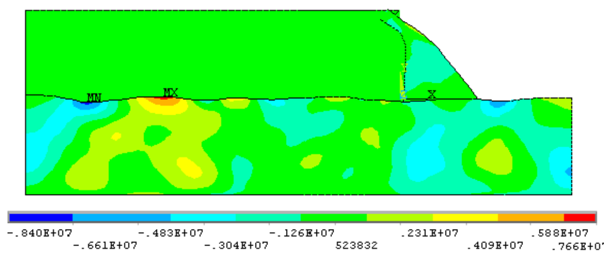

Figure 15 - Stress Maxim s 7.5 from the start of seismic records

Maximum stress values were observed in 7.66 MPa. (Figure 15). In fact, the beginning and the end results for Maxim stress analysis, the increase is about 79% were attained.

For a closer look at the seismic response of concrete dam, the number 0.25 for the modulus of elasticity of the dam foundation, are considered.

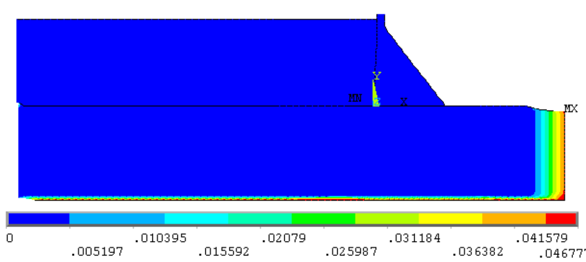

Figure 16 - Average Maximum displacement in Sec 0.005 in the earthquake.

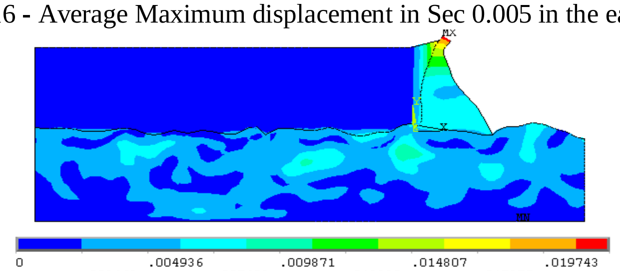

Figure 17 - Average Maximum displacement s 7.5 of the earthquake.

Figure 16 shows Average maximum amount of displacement s 0.005 earthquakes of 4.68 cm. Compared to the rigid fondation increases by about 5% compared to the state (n = 1) did not show noticeably changes.

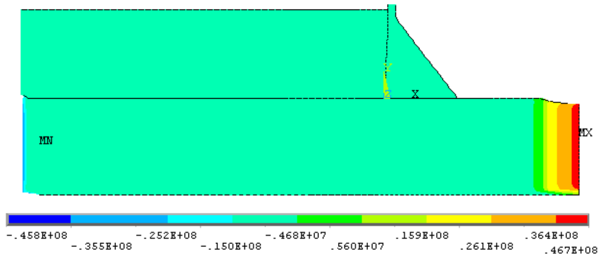

Figure 18 - Maximum stress in Sec .005 earthquakes.

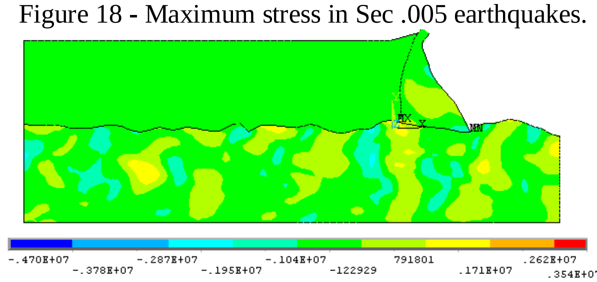

Figure 19 - Maximum stress in Sec 7.5 earthquakes.

Maximum stress values of 0.005 seconds earthquake46.7 Mega Pascal. Maximum stress was observed in 3.45 MPa. (Figure 19)

In fact, the results for Maxim stress of rigid state, the increase of about 54% has been achieved.

4 - Conclusion

Interaction between the fluid and the dam body Cause Increases the effective mass and vibrational frequencies of the system is reduced. The percentage increase or decrease substantially depending on how the tension modulus of elasticity is the foundation and dam body.

But how to increase this reduction does not follow a particular style. fondation flexibility is Stiffness reduced. However, in certain frequency ranges increases answers are obvious.

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