Indian Journal of Fundamental and Applied Life Sciences ISSN: 2231– 6345 (Online)
An Open Access, Online International Journal Available at www.cibtech.org/sp.ed/jls/2015/04/jls.htm
2015 Vol. 5 (S4), pp. 984-988/Fereydooni and Jahanbakhsh
Review Article

AN ANALYSIS OF THE HYDRODYNAMIC PRESSURE ON CONCRETE GRAVITY DAMS UNDER EARTHQUAKE FORCES USING ANSYS SOFTWARE

Mehrdad Fereydooni[1] and *Mehdi Jahanbakhsh[2]
[1]*Department of Civil Engineering, Larestan Branch, Islamic Azad University, Iran*
[2]*Department of Civil Engineering, Islamic Azad University of Larestan, Iran*
** Author for Correspondence*

ABSTRACT
Using the finite element software ANSYS in this study, efforts have been done to put a concrete gravity dam under earthquake forces and investigate the hydrodynamic pressure from the reservoir on the dam in several states including the impact of structural damping, rigidity of the intended dam, fluid incompressibility, absorption of the waves in the bottom of the reservoir, and the impact of dam upstream slope. Finally, the obtained results have been presented.

***Keyword**: ANSYS, Earthquake*

INTRODUCTION
Due to the attention to economic issues as well as the efforts to increase the life of dams, dam safety against earthquakes is one of the major issues to be discussed so that in the last two decades, extensive research has been done in the field of seismic safety of concrete gravity dams as well as creating and using a robust process for nonlinear and as-close-as-possible-to-reality analysis of concrete dams under different loads, especially dynamic loads resulting from earthquakes.
Generally, two main reasons can be mentioned for taking into consideration the dams against earthquakes.
1. There is a risk of losses of lives and property resulting from damage to dams that threatens people, industrial facilities, agricultural lands, etc. in areas downstream of dams.
2. Increasing the awareness about the complex nature of earthquakes and the need for further research to take safety measures and investigate the effects of earthquakes on dams across the globe.

Review of the Previous Research
Prior to 1967, all researchers modeled real earthquakes in their studies as some limited movements of the Earth or periodic vibrational motion of the Earth with a fixed period. They never included real earthquake acceleration in their calculations. Due to the complexities of assessing the hydrodynamic pressure on concrete gravity dams during an earthquake, in general, it could be said that all research conducted until 1967 dealt with two separate issues.
1- Response of a dam to the earthquake without considering the effect of hydrodynamic pressure
2- Calculating the hydrodynamic pressure on a rigid dam during an earthquake
Using the basic principles of earthquake engineering, (Chopra, 1967) suggested an analytical solution to calculate the hydrodynamic pressure during an earthquake. In his calculations, he assumed a dam as a rigid structure and, for the first time, presented his calculations for actual earthquakes. Besides, unlike previous researchers, he included both the dam's response to the earthquake and the hydrodynamic pressure together and as an interaction of the dam and reservoir system in the frequency domain, and he also included water compressibility effect in his study.
In another research in (Chopra, 1968) offered a relatively complete solution to the problem of hydrodynamic pressure during an earthquake. Contrary to his previous research, he included the flexibility of the dam structure in his calculations and assumed that the dam structure vibration is on the basis of its main form, and ultimately, he provided his analysis in the frequency domain for the first time
He was the first to achieve interesting results compared with those obtained by previous researchers. For example, he showed that in the same states of main frequencies of the reservoir and the earth vibration, the dam's response takes limited and defined values.

Geometry of the Dam under Study

1- The dam under study had 105 meters height, its heel was 80 meters, and the width of its crest was 10 meters.

2- The studied models were two-dimensional and the analyses carried out were within the time domain (time-history analysis). For horizontal stimulation, Naghan earthquake record (1977) was used.

Acceleration of the design basis to normalize Naghan earthquake record was 0.3g.

Boundary Conditions Applied

1- All points at the bottom of the dam were closed as rigid and the freedom degrees of ALL DOF.

2- The radiation condition was used for the end of the reservoir. To apply the radiation condition at the cutting edge, the quality of wave absorption by the fluid element had been used. For this purpose, fluid elements with full absorption quality had been inserted at the end of the reservoir. Hence, these elements would prevent the full reflection of the waves reaching the outage border. (for the end of the reservoir: Mu=1)

3- The reservoir bottom was rigid.

4- The pressure of the nodes of all fluid elements in the surface of the reservoir was zero.

5- For the common side of the dam and the fluid, and for transferring it to a finite element model (ANSYS software) FSI command has been used.

Features of the Dam and the Reservoir

1- The concrete density, Young's modulus, and Poisson's ratio were considered to be $2550\frac{kg}{m^3}$, 35Gpa, and 0.2, respectively.

2- The water density and the speed of the pressure wave were considered to be $1000\frac{kg}{m^3}$ and $1435\frac{m}{s}$, respectively.

The Response of the Hydrodynamic Pressure on a Rigid Dam

To compare the hydrodynamic pressure on a dam in a rigid state, the dam's behavior has to be considered rigid. To create a rigid behavior, if the stimulation is done through displacement, the displacement can be applied to all nodes on the structure. An alternative way is to introduce a large amount of elasticity modulus applied to the dam structure. Therefore, in order for the dam's behavior to be rigid, the elasticity modulus applied to the dam was selected to be as large as $Ec = 3.50e15\frac{kg}{m^2}$, for instance. The distribution contour of the hydrodynamic pressure on a dam for the rigid state is shown in the figure below.

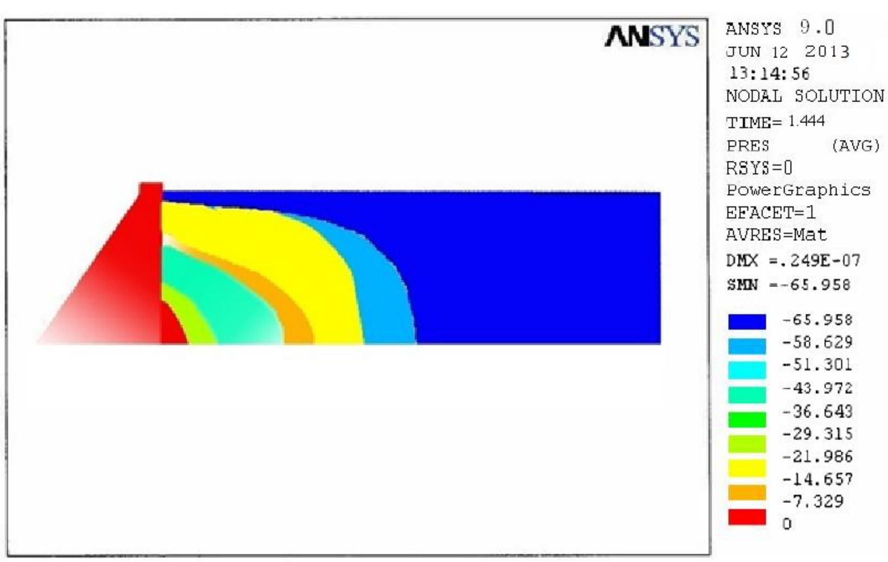

Figure 1: The distribution contour of the hydrodynamic pressure on a dam for the rigid stat

The Structural Damping Impact on the Hydrodynamic Pressure on Dams

In the evaluations conducted, the concrete structures damping has been estimated between 0/03 and 0/05. To investigate this phenomenon, the dam has been analyzed for 3%, 4 % and 5% damping. The diagram below (Figure 2) shows the damping effect on hydrodynamic pressure distribution.

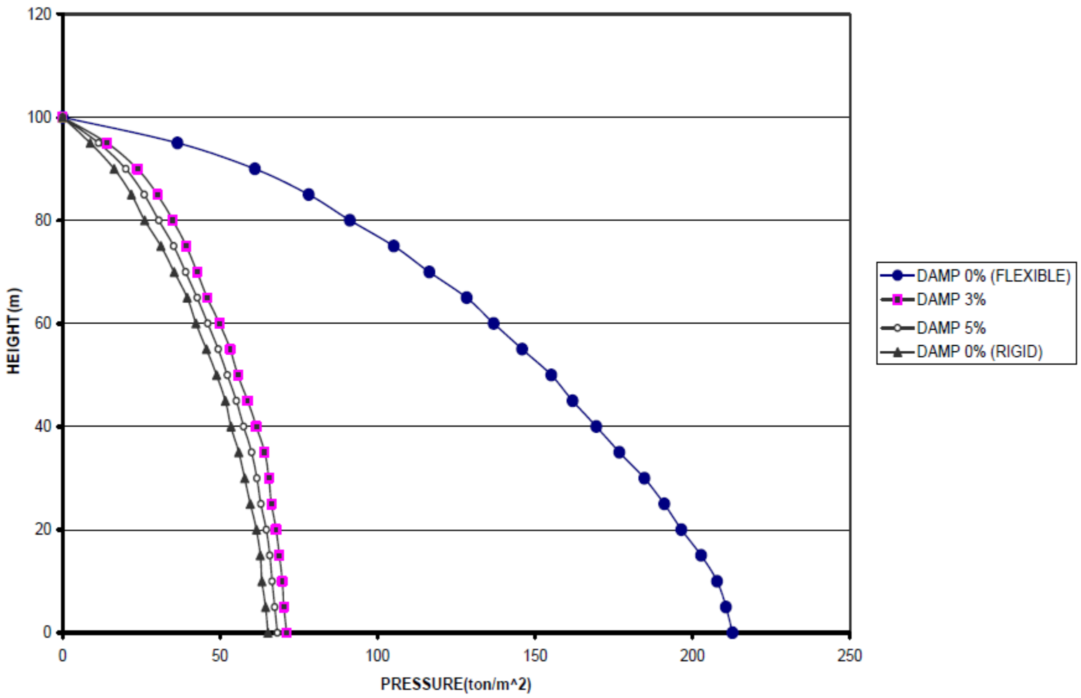

Figure 2: The damping effect on hydrodynamic pressure distribution

It can be inferred from the above diagram that the less the damping structure, the more the hydrodynamic pressure on a dam will be. With the increase of damping, the range of motions and vibrations of the dam decreases, and the waves distributed along the structure as a result of the applied acceleration would be rapidly amortized. In fact, as the range of the dam's motions decreases due to the produced vibrations, the dam's impact on the reservoir and, consequently, the hydrodynamic pressure on the dam decrease as well.

The Effect of Fluid Incompressibility on the Hydrodynamic Pressure on a Dam

In high dams and in loadings with high frequencies, the effect of fluid incompressibility on the dynamic response of the system is impressive. But in the analysis of short dams where the reservoirs' natural frequencies are usually larger than the highest major earthquake energies, the effect of fluid compressibility could be eliminated. The ANSYS software assumes the fluid element as compressible. Therefore, to assume the fluid element as incompressible, the speed of sound in the fluid should to assume as a very large number. $(C = 1435e10\frac{m}{s})$

The Effect of Wave Absorption in the Bottom of the Reservoir

To investigate this issue by ANSYS, the energy-absorption quality of acoustic fluid materials was used. In acoustic fluid elements, when defining the characteristics of their materials by MP command, the energy absorption characteristics are defined by MU parameter. If MU = 0, no absorption is taken into account and if MU = 1, the absorption is assumed to be full. Hence, MU is a value between zero and one that can be achieved in the laboratory depending on the type of sediments.

Table 1 shows this effect for the dam heel. As can be seen, the maximum pressure in the modes 5%, 10%, 15% and 20% absorption in the bottom of the reservoir has decreased 22%, 33%, 41% and 47%, respectively, compared to the 0% mode.

Table 1: The effect of absorption in the reservoir bottom at the hydrodynamic pressure

Damping percentage	Minimum pressure	Time	maximum pressure	Time
0%	-206.50	2.733	210.70	2.876
5%	-172.00	2.733	164.10	2.876
10%	-145.10	2.733	139.40	2.584
15%	-124.15	2.733	123.40	2.588
20%	-108.22	2.736	110.20	2.588

The Effect of Upstream Slope of the Dam in During the Hydrodynamic Pressure Distribution on the Dam

In the previously evaluated models, dam's wall slope had been assumed to be vertical. To investigate the effect of the slope in hydrodynamic pressure distribution behind a dam, some models of 15 and 30 degrees slope to the vertical and 45 degrees with $\frac{H}{3}$ distance from the floor were made. The results indicate that increasing the slope (relative to vertical) would reduce the hydrodynamic pressure on the dam because in a steep surface, velocity is not perpendicular to it. The diagram below shows the pressure distribution of the above states.

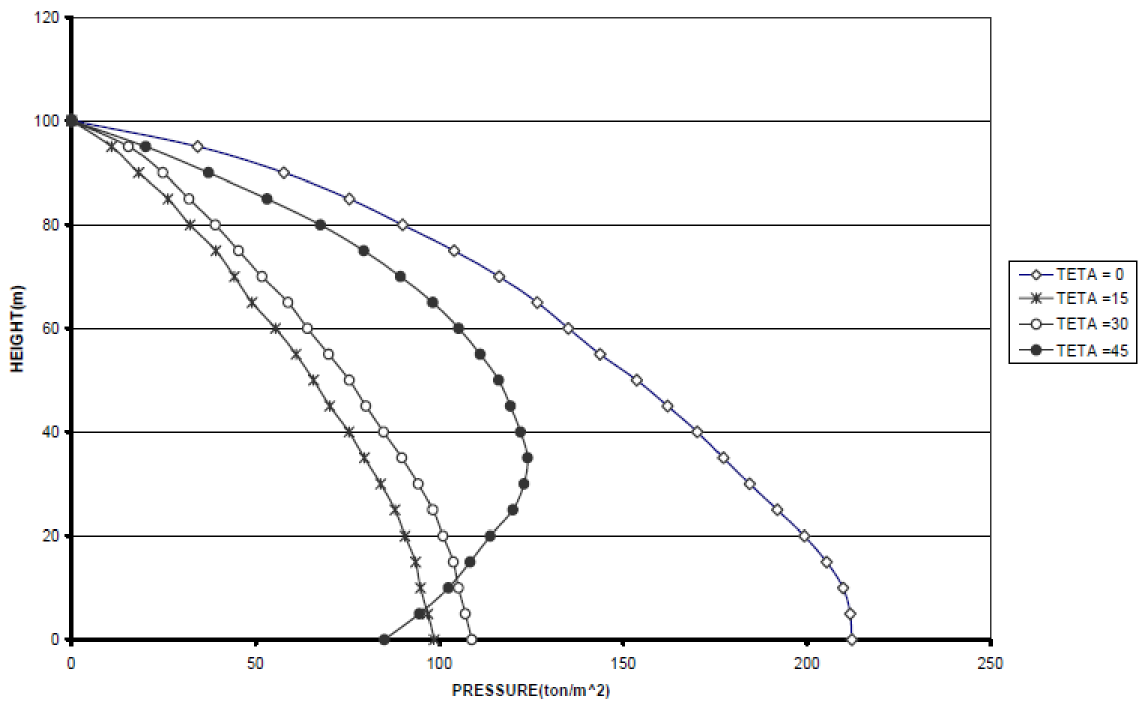

Figure 3: The effect of upstream slope in hydrodynamic pressure distribution

CONCLUSION

1- Assuming a dam to be rigid reduces the hydrodynamic pressure, and assuming it to be flexible increases this pressure.

2- The less the damping of a dam, the higher the hydrodynamic pressure on it will be.

3- 1. Making a slope upstream a dam reduces the hydrodynamic pressure on it. In fact, the more the upstream slope tends to zero, the higher the hydrodynamic pressure on the dam will be.

4- 1. The existence of sedimentary layers aggregated at the bottom of the reservoir over time plays a major role in energy absorption by deflecting the pressure waves into the foundation. This mechanism has a significant affect on energy depreciation of hydrodynamic pressure distribution in the depth of the reservoir. In fact, the more the absorption percentage of the reservoir bottom reduces, the more increase will be seen in the maximum hydrodynamic pressure on the dam.

REFERENCES

Cheraghi N (1998). Dynamic analysis of concrete gravity dams with regard to the interaction between the dam and the reservoir. Master thesis, Sharif University of Technology.

Chopra AK (1967). Hydrodynamic pressures on dams during earthquakes. *Journal of Engineering Mechanics, ASCE* **93**(6) 205-223.

Chopra AK (1968). Earthquake analysis of reservior-dam systems. *Journal of Engineering Mechanics, ASCE*, **96** 1475-1484.

Jamshidi N and Javanbakht B (2007). *Teaching the Component Design and the Strength of Materials by ANSYS Software, Orange Triangle Book Series*, second edition (Afrang publications).

Monazam A (2010). Determine the effective parameters in linear seismic evaluation of concrete gravity dams using nonlinear analysis. Master thesis, Sharif University of Technology.