Investigation hydrodynamic behavior of tunnels under pressure of earthquake

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Abstract: According to the importance of systems of energy management and the use of dams as one of the most important structures used by human to generate electricity from water; investigation of diversion tunnel of Karoun 4 with respect to the interaction between water and structure and also and vulnerable nature of plug, the factors considered in this study. After reviewing studies on tunnels and simulation methods and especially theories have been developed in this field, the behavior of diversion tunnel of Karoun 4 is investigated at different load combinations considering the hydro-dynamic pressure due to seismic analysis. In this study, three factors are considered. One of them is impact of PGA earthquake in dynamic pressure of the water and the other is the length of the tunnel dynamic pressure and eventually taking behavior modeling tunnel plug in. For this purpose, the software Abaqus applied to simulate the diversion tunnel. The results show that by increasing the length of the tunnel and the PGA, the hydrodynamic pressure increases almost linearly when reach to plug in.
[Abdolhossein Siapush, Mohammad Safi. **Investigation hydrodynamic behavior of tunnels under pressure of earthquake.** *Life Sci J* 2013;10(7s):1201-1210] (ISSN: 1097-8135). http://www.lifesciencesite.com. 191

Keywords: hydrodynamic behavior; earthquake; Karoun 4

Introduction:

Dr. Martin Willand is done researches and arguments concerning the hydrodynamic pressure caused by the earthquake force, pressure tubes, the bottom outlet structures, diversion tunnels plugs, valves, and intake and spillway structures. Pressure tubes, plugs, tunnels, bottom outlet valves, intake structures, spillways, valves and other components of hydro mechanical pressure water systems that may be exposed to strong earthquakes are rarely designed for the hydrodynamic pressure. Overall, hydrodynamic pressures have been founded by Vastgard hypothesis. This hypothesis is plausible for valvulopathy surface spillways but is not correct for weirs surface for valves that are located within tunnels or tubes, pressure valves which are thick. Although the case shows what part of the tunnel pressure during a strong earthquake breaks or is damaged is not known, but research is continuing on seismic safety. Considering that the earthquake will affect all components of water resources, as well as hydrodynamic factors should be examined for all components hydro mechanical discussed. Pressurized water system components that are subject to water resources are very rarely designed for earthquake forces. Earthquakes can occur in pressurized pipes and tunnels are inherently creates hydrodynamic forces. Depending on how the base (soil type) and a tunnel under hydrodynamic pressure maximum peak ground acceleration of 0.3 g for the size is the size of 1 MPa. It's expected that high dynamic pressure in the tunnels under the short length of the dam have been implemented, where the tunnel is located at a higher acceleration response expected on earth. The methods discussed in this paper can order to determine the hydrodynamic pressure in pipes under pressure at valve closure, the dynamic pressure valves, and plug valves, the closing location of pipes, tunnels and tunnels under pressure deviations used. [5]

Interaction of tunnels and fluid simulation techniques:

Three of tunnels and fluid interaction is presented for consideration. These include the added mass method, Formulation of Euler and Lagrange formulation. Westergard added mass approximation method which was introduced by the first part of the mass of the fluid boundary between fluid and structure added to the structure and the structure is the added mass analysis [1]. This method provides accurate results in many cases. Chopra analytically using the fluid compressibility effect on the structural response. [4] The Lagrange formulation approach, the behavior of fluid flow in terms of the element nodal point displacement parameters is defined. [3] Therefore automatic adaptation and the stability condition is satisfied at the node border tunnel fluid. Despite the variety of Lagrange fluid elements have been proposed, most of the elements of the modal deformation energy or suffer zero. These modes are practically zero shear modulus of the fluid, and there are reduced integration methods. Euler's formula, based on the parameters of fluid pressure in the fluid model elements are nodal points. [6] In this case, involving structural and fluid system is solved by solving two separate systems is possible and interaction effects are estimated using trial and error. The two systems can also be summarized in a single system. However, in such circumstances, a non-symmetric system with a relatively large bandwidth solutions arise that it is very time consuming. In this formulation, unlike the Lagrange formulation, due to the pressure of the fluid used parameter is the number of degrees of freedom of the system will be less. In this case, you can search algorithm suitable for solving symmetric systems of equations, it will be a good return. This model does not need to be declared in the interface elements and the hydrodynamic pressure on the dam's reservoir, the equivalent nodal forces are exerted on the dam. The pressure values have been corrected at trial and error to provide more accurate results can be obtained [2]. In addition to these three main compounds of the latter, two methods have been used to determine the response of the fluid. That is important in all methods of how to model the boundary conditions of the fluid.

In this study, the basic model with a length of 650 meters, flow through both the Euler and the acoustic model, and finally taking the time to solve the existing problems in the method of Euler to consider the hydrostatic pressure early, and that this pressure simply apply the acoustic elements, and elements Lagrange acoustic method was used to solve this problem.

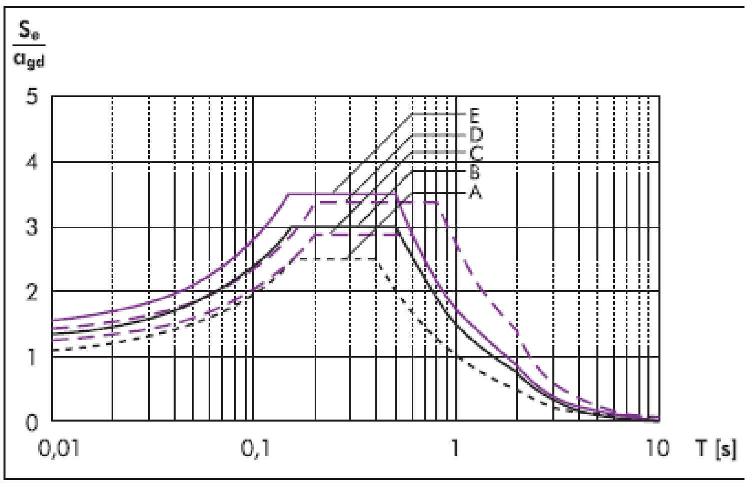


Figure 1: The spectral responses of the ground acceleration (vibration, 5%) for peak ground acceleration agd (with a return period of 475 years), types of soils, rocks, ranging from type A to F [7]

The equations for behavior and interaction of fluid and water tunnels

As he describes it, in order to model the tunnel and fluid Abakous software is used. In order to model the flow in the application of acoustic elements is used. The complete description of the theory governing these elements, how to model boundary conditions and fluid-structure interaction is included.

The fluid field is modeled by finite element method and acoustic

Balance equation for the fluid particle motion assuming a small, compressible, adiabatic energy dissipation rate associated with momentum, the types of relationship.

(1) $$\frac{\partial p}{\partial x}+\gamma(x,\theta_i)\dot{u}^{f}+\rho_f(x,\theta_i)\ddot{u}=0$$

In the above equation, P added to the fluid pressure (pressure in addition to the static pressure), x location of the fluid particle, u^f fluid particle velocity, $\ddot{u}^f$ the fluid particle velocity, ρ_f fluid density, γ volumetric drag (force per unit volume velocity) and θ_i independent variables (such as temperature moisture, salt air or water that may be related to the density and volumetric drag). Terms of d'Alembert equation regardless term momentum transfer (Convection) with the assumption of a constant flow of fluid is neglected. This assumption is often permanent speeds up the flow Mach number of 0.1 is a good accuracy.

Assuming a non-viscous fluid, the compressible linear relation exists.

(2) $$p=-k_f(x,\theta_i)\frac{\partial}{\partial x}.u^f$$

In equation (2), K_f is the bulk modulus of the fluid. The other parameters are as previously defined. The fluid that there is no possibility of cavitations, the total pressure of the fluid medium (total pressure, static and dynamic) can not be less than the cavitations pressure. In cases where cavitations are likely, the fluid pressure is reduced to less than the cavitations pressure. In this case, the fluid begins to expand, and its structural relationship is defined as follows.

(3) $p = \max\{p_v, p_c - p_v\}$

In the above equation, p_v is the pseudo-pressure term is obtained from the following equation.

(4) $p = -k_f(x,\theta_i)\frac{\partial}{\partial x}.u^f$

In equation (3), P_c is the cavitations threshold pressure and P_v is static pressure of the fluid is anywhere in the field.

Interaction of water and structure

In order to model the interaction between fluid and structure Abakous method uses acoustic surface contact elements. In a dynamic analysis is performed by implicit methods, both of these methods can be used. Because of the structure and the fluid surface technique that can mesh with different factions to communicate, that is more efficient than other methods. On the other hand, this method reduces the computational cost. [5, 8] Therefore, this method is used in this thesis. [5] In this method, fluid levels and structures are introduced as master and slave. Schematic overview of the method (1) is visible.

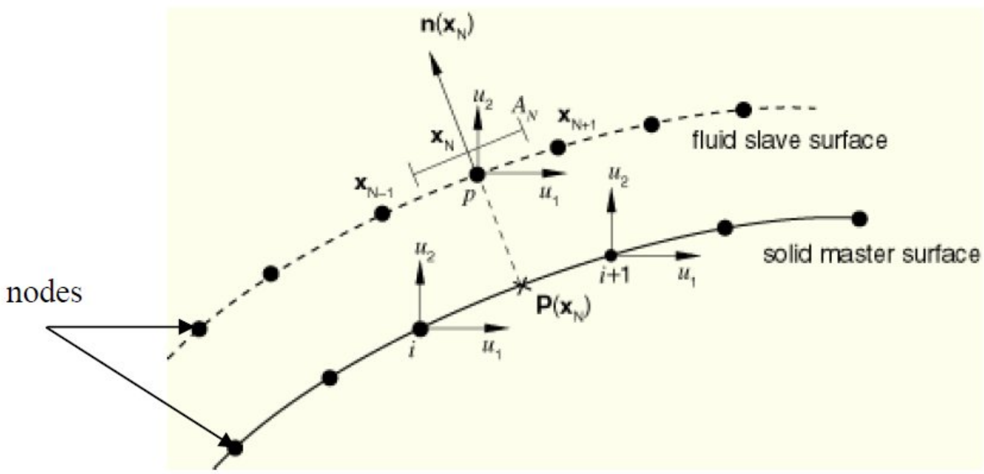


Figure 1: A view of the interaction of water and structures [5]

Contact area between fluid and structure is where the fluid motion is directly related to structural movement. Aspect that is considered as a slave, the transaction point interpolation based on function, with the corresponding function on the surface of the receiving master. Thus, if the fluid level to be considered as a Slave, the amount of displacement on the surface interpolation based on the values of the equivalent surface structures are constructed. In Figure 1 is shown in this procedure. [5] One node Slave, are highlighted on the master level of the area and its associated normal vector is computed. These files define the master node in the vicinity of the image points used. The variables in nodules on the slave, master surface defined by the variables are interpolated. When it has been selected a master structure as we have related structural change in the fluid spaces. In this case, the fluid pressure is not necessarily related structures. In this case, equation (5) will be true.

(5)

$$\int_{s_{fs}\cup s_{frs}} \delta p\, n.\frac{\partial p}{\partial x}\, ds = -\int_{s_{fs}\cup s_{frs}} \delta p\, \bar{n}.\ddot{u}^{m}\, ds$$

In the near term, we need the right equation (5), respectively. Therefore, equation (6) is presented.

(6)

$$-\int_{s_{fs}\cup s_{frs}} \delta p\, \bar{n}.\ddot{u}^{m}\, ds \approx A_N\left[\sum_i \bar{n}(x_N).N^i(p(x_N))\,\ddot{u}_i^{m}\right]$$

In equation (6), $N^i(p(x_N))$ is structures on the surface interpolation function, $\ddot{u}_i^m$ the velocity vector perpendicular to the surface, $\bar{n}(x_N)$ structure and surface structure (the direction of the flow) are. Considering that the formulation based on the fluid pressure is written, equation (6) for the fluid equation (7) can also be written.

(7)

$$\int_{\cup sfrs} \delta u^{m} . \bar{n} p dS \approx P_N A_N \left[\sum_i \bar{n}(x_N) . N^{i} (P(X_N)) \right]$$

In equation (7), P_N is the pressure in the fluid x_N .Generally, at each time step to solve the fluid equations and the numerical integration is used to construct environment. ABAQUS software for these purpose two types, namely explicit and implicit solution algorithm is presented.

Boundary conditions

In order to model the acoustic fluid elements and boundary conditions boundary-conforming Software, the following concepts are necessary to limit the boundaries of the equation (1) are used.

S_{fp} : In this line of acoustic pressure is predefined. For example, the application of this provision, the modeled surface water or blast wave can be used to limit entry.

S_{ff} : Normal derivative of the pressure boundary is defined in the acoustic environment. The condition also can be used to determine the motion of a fluid particle modeling of acoustic sources, rigid walls, symmetry planes and the incident wave field is used.

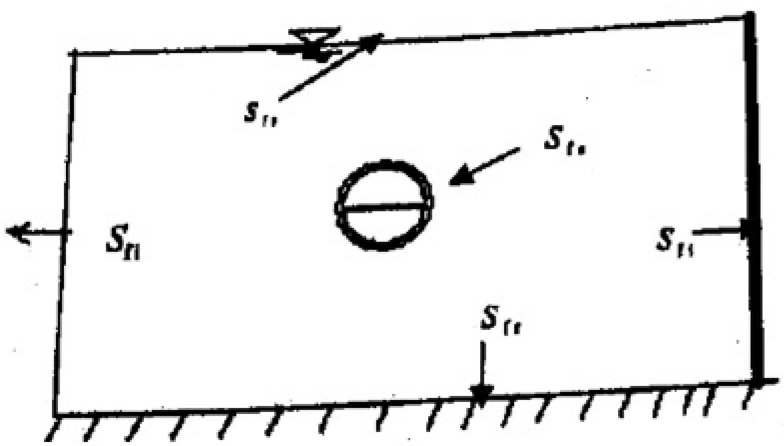


Figure 2: Schematic picture of the boundaries of the applicable [8]

Figure 2 Schematic overview of the issue of boundaries used in the construction of dams and water interaction shows. To derive the partial differential equation, used in the integration of linear transient analysis, equation (1) has been assigned to its derivative with respect to x and the derived values are ignored.

Then the time derivative of equation (2) have combined to equation (8) is obtained.

$$(8)\quad \frac{1}{k_f}\bar{p} + \frac{\gamma}{\rho_f k_f}\dot{p} - \frac{\partial}{\partial x}\cdot\left(\frac{1}{\rho_f}\frac{\partial p}{\partial x}\right) = 0$$

Above equation is the equation of motion of the fluid, the fluid pressure on the weak form of the equation would be.

(9)

$$\int_{v_f} \partial p \left(\frac{1}{k_f}\ddot{p} + \frac{\gamma}{\rho_f k_f}\dot{p} - \frac{\partial}{\partial x}\cdot\left(\frac{1}{\rho_f}\frac{\partial p}{\partial x}\right) \right) dv = 0$$

Using the following equation will be obtained by fractionation.

(10)

$$\int_{v_f} \left[\delta p \left(\frac{1}{k_f}\ddot{p} + \frac{\gamma}{\rho_f k_f}\dot{p} \right) + \frac{1}{\rho_f}\frac{\partial \delta p}{\partial x}\cdot\frac{\partial p}{\partial x} \right] dv + \int_f \delta p \left(\frac{1}{\rho_f}\bar{n}.\frac{\partial p}{\partial x} \right) ds = 0$$

In the above equation, the normal vector to the boundary, the fluid is inside. P is defined on the boundary and using equation (1), the pressure gradient equation (11) is connected to the moving boundary.

(11)

$$\bar{n}\left(\frac{1}{\rho_f}\frac{\partial p}{\partial x}+\frac{\gamma}{\rho_f}\dot{u}^f+\ddot{u}\right)=\dot{0} \qquad on \qquad s-s_{fp}$$

Using this equation, the term relationship (10) will be deleted and the following relation....

(12)

$$\int_{v_f}\left[\delta p\left(\frac{1}{k}\ddot{p}+\frac{\gamma}{\rho_f k_f}\dot{p}\right)+\frac{1}{\rho_f}\frac{\partial\delta p}{\partial x}.\frac{\partial p}{\partial x}\right]dv-\int_{s-s_{fp}}\delta p(T(x))ds=0$$

Where $T(x)$ the surface force term is is defined in order to simplify the equation obtained.

(13)

$$T(x)=\bar{n}.\left(\frac{\gamma}{\rho_f}\dot{u}+\ddot{u}^f\right)=-\bar{n}.\left(\frac{1}{\rho_f}\frac{\partial p}{\partial x}\right) \qquad on \qquad s-s_{fp}$$

The next term in the absence of acceleration and volumetric drag force is equal to the velocity of the acoustic environment of the particles. Thus we have the following relationship.

(14) $T(x)=\bar{n}.\ddot{u}^f$

The term means of boundary conditions. Otherwise, only the boundary conditions are imposed at the boundary. According to the description on how to apply the boundary conditions are given. S_{fp} Boundary: This boundary value of p is determined. S_{ft} Border: normal derivative of the pressure boundary of the unit density are determined. So we will.

(15) $T_{ft}(x)\equiv T_0$

Following relation will drag in the absence of volume.

(16) $\bar{n}.\ddot{n}=T_0$

S_{fr} Border: The border between the acoustic environments is defined as a rigid shield. Therefore, the boundary is defined so that the rate of change of pressure and the acoustic environment is concerned. So we will:

(17) $$-\bar{n}.\dot{u}^f=\left(\frac{1}{k_1}\dot{p}+\frac{1}{c_1}p\right) \qquad on \qquad s_{fr}$$

The relationship between ambient layer of acoustical materials and structural concepts is introduces. The substance of the two parameters (the order of reagent buffer and spring) are presented. Using the above equation for the fluid velocity, the force is in relation to the boundary surface.

(18)

$$T_{fr}(x)\equiv-\left(\frac{\gamma}{\rho_f C_1}p+\left(\frac{\gamma}{\rho_f}\frac{1}{k_1}+\frac{1}{c_1}\right)\dot{p}+\frac{1}{k_1}\ddot{p}\right)$$

S_{fi} Boundary: This boundary is determined by identifying the resistance profile. Thus we have the following relation.

(19) $$T_{fr}(x)\equiv-\left(\frac{1}{c_1}\dot{p}+\frac{1}{a_1}p\right)$$

The values c_1 and a_1 in the above equation, the relations (20) and (21) are defined.

(20) $$\frac{1}{c_1}=\left[\frac{\xi}{\sqrt{\rho_f k_f}}\right]$$

(21) $$\frac{1}{a_1}=\xi\left[\frac{\beta}{\rho_f}+\frac{\gamma}{2\rho_f\sqrt{\rho_f k_f}}\right]$$

The relations (20) and (21) the values of geometry and boundary conditions change. The values in Table 1 are based on the geometry. In Table 1, represents the radius of the circular or spherical boundary at infinity is equal to the center.

Table 1: Parameters of the boundary conditions

Geometery	ξ	β
Plate	1	.
Circular or cylindrical	1	$\frac{1}{2r_1}$
Sepheral	1	$\frac{1}{r_1}$

S_{fs} :Boundary: This boundary as the fluid-structure interface is presented. Relation to the condition of the joint surfaces is equivalent to the fluid displacement structure.

(22) $\bar{n}u^f = \bar{n}u^m$

Wherein u^m a displacement of structures.
Regardless of the volume of the drag due to the low value in terms of acceleration on the boundary $\left(\ddot{u}^m >> \frac{\gamma}{\rho_f}\dot{u}^m \forall u^m(t)\right)$ surface acoustic force structure will be as follows.

(23) $T_{fs}(x) = \bar{n}.\ddot{u}$

S_{frs} Border: The border is a combination of the country. The boundary conditions are imposed on the relative velocity between the outside environment and the structure of the acoustic pressure and the rate of pressure change. Thus we have the following relation.

(24) $\bar{n}.\left(\dot{u}^m - \dot{u}^f\right) = \frac{1}{k_1}\dot{p} + \frac{1}{c_1} + p$

Applying the above equation to define, we will:
(25)

$$T_{frs}(x) \equiv \bar{n}.\ddot{u}^m - \frac{\gamma}{\rho_f}\frac{1}{c_1}p + \left(\frac{\gamma}{\rho_f}\frac{1}{k_1} + \frac{1}{c_1}\right)\dot{p} + \frac{1}{k_1}\ddot{p}$$

Equation (25) is the sum of the definitions and boundaries.
Using the above definitions and applying them to equation (12) the final state of the acoustic environment, the relation (26) is reached.
(26)

$$\int_{v_f}\left[\delta p\left(\frac{1}{k_f}\ddot{p} + \frac{\gamma}{\rho_f k_f}\dot{p}\right) + \frac{1}{\rho_f}\frac{\partial \delta p}{\partial x}.\frac{\partial p}{\partial x}\right]dv - \int_{s_{fr}}\delta p T_0 ds$$
$$+ \int_{s_{fr}}\delta p\left(\frac{\gamma}{\rho_f c_1}p + \left(\frac{\gamma}{\rho_f k_1} + \frac{1}{c1}\right)\dot{p} + \frac{1}{k_1}\ddot{p}\right)ds$$
$$+ \int_{s_{ft}}\delta p\left(\frac{1}{c_1}\dot{p} + \frac{1}{a_1}p\right)ds - \int_{s_{fs}}\delta p\bar{n}.\ddot{u}^m ds$$
$$+ \int_{s_{frs}}\delta p\left(\frac{\gamma}{\rho_f c_1}p + \left(\frac{\gamma}{\rho_f}\frac{1}{k_1} + \frac{1}{c_1}\right)\dot{p} + \frac{1}{k_1}\ddot{p} - \bar{n}.\ddot{u}^m\right)ds = 0$$

Methods of solving equations involving water systems and structures:

Based on what was already described equations governing fluid was determined. In the following we will study the interaction of water and the structure and how it functions. Expressed in relation to the structural behavior is permitted.
(27)

$$\int_v \delta\varepsilon : \sigma dv + \int_v \alpha_c \rho \delta u^m.\dot{u}^m dv + \int_v \rho \delta u^m.\ddot{u}^m dv + \int_{s_{fs}} p\delta u^m.n ds - \int_{s_t}\delta u^m.t ds = 0$$

In the above equation, the stress at a point on the structure, p the pressure surface water interactions and structures, n-vector perpendicular to the outside structure, density of material in the structure, mass proportional damping (Raleigh damping assumption for some structures), and the velocity and acceleration of a point on the structure, respectively, t force applied on the surface structure of virtual displacement and strain allowed. In equation (26) the first term represents the internal forces, the second term represents the damping force, the third represents the volume and inertial forces, including four with wide dynamic loads on buildings and other large structures such as V is applied. In order to solve equations (26) and (27) into the definition of the functions that should have been dismissed, the building is used.

The functions of the fluid and the structure are introduced. The functions p and N, respectively, the fluid pressure and displacement degrees of freedom refers to the structure. The following functions and relations are assumed to be values (Superscript) represented by detached model is degrees of freedom. Variables p and Q degrees of freedom of the fluid pressure, and N and M are the degrees of freedom of displacement structures. Galerkin method is used for structural system is defined as the field changes. $\delta p = H^p \delta p^p$ Relation to the use and placement of the fluid used $\delta p^p = \frac{d^2}{dt^2}\left(\delta \hat{p}^p\right)$. New function which makes the equation changes a unique collection of relations (26) and (27) with the dimensional consistency is reached. Consequently, equation (28) exists.
(28)

$$-\delta\hat{p}\left\{\left(M_f^{pQ} + M_{fr}^{pQ}\right)\ddot{p}^Q + \left(C_f^{pQ} + C_{fr}^{pQ}\right)\dot{p}^Q + \left(k_f^{pQ} + k_{fr}^{pQ} + k_{fr}^{pQ}\right)p^Q - S_{fs}^{pM}\ddot{u}^M - p_f^p\right\}$$
$$+ \delta u^N\left\{I^N + M^{NM}\ddot{u}^M + C_{(m)}^{NM}\dot{u}^M + \left[S_{fs}^{QN}\right]^T p^Q - p^N\right\} = 0$$

In equation (28), the transfer matrix between all nodes on the fluid-structure interaction is defined. Within the normal vector of the surface. In equation (28) to simplify the equations (29) to (41) is considered.
(29), (30), (31) and (32)

$$M_f^{pQ} = \int_{v_f} \frac{1}{k_f} H^p H^Q dv$$

$$M_{fr}^{pQ} = \int_{s_{fr} \cup s_{frs}} \frac{1}{k_1} H^p H^Q ds$$

$$C_f^{pQ} = \int_{v_f} \frac{\gamma}{\rho_f} \frac{1}{K_f} H^p H^Q dv$$

$$C_{fr}^{pQ} = \int_{s_{fr} \cup s_{frs}} \left(\frac{\gamma}{\rho_f} \frac{1}{K} + \frac{1}{c_1} \right) H^p H^Q ds + \int_{s_{fr}} \frac{1}{c_1} H^p H^Q ds$$

(33), (34), (35), (36), (37), (38), (39) and (40)

$$K_f^{pQ} = \int_{v_f} \frac{1}{\rho_f} \frac{\partial H^p}{\partial x} . \frac{\partial H^p}{\partial x} dv$$

$$K_{fr}^{pQ} = \int_{s_{fr} \cup s_{frs}} \frac{\gamma}{\rho_f} \frac{1}{c_1} H^p H^Q ds$$

$$K_{fr}^{pQ} = \int_{s_{fi}} \frac{1}{a_1} H^P H^Q ds$$

$$S_{fs}^{PM} = \int_{S_{fr} \cup S_{frs}} H^P \bar{n} . N^M ds$$

$$P_f^P = \int_{S_{ft}} H^P T_0 ds$$

$$M^{NM} = \int_V \rho N^N . N^M dV$$

$$C_{(m)}^{NM} = \int_V \alpha_c \rho N^N . N^M dV$$

$$I^N = \int_V \beta^N : \sigma dV$$

$$P^N = \int_{S_t} N^N . tds$$

In equation (40), β^N is the strain interpolation function. P_f^p Semester to semester nodal P^p degrees of freedom acoustic force applied to the degrees of freedom. The term derives from the integral of the normal density of acoustic pressure on the surface of a boundary Korea obtained.

Analysis Method:

For modeling efforts tunnel from Elements C3D8R and from the Elements AC3D8R for modeling water has been used. To consider the fluid-structure interaction is used for the tie. The surface structure as the master and the slave is used as the fluid level.

The loading of this compound, hydro-dynamic pressure caused by the earthquake are also entered in the analysis. Seismic excitation of the tunnel, a component of the Tabas earthquake record has been recorded. In this study, has been working on three parameters. One impact of the earthquake PGA dynamic pressure of the water and the length of the tunnel dynamic pressure, finally, consider the behavior of the tunnel modeling plug in.

First type reloading:

PGA earthquake accelerograms applied in the horizontal direction and impact of the dynamic pressure of the water Horizontal earthquake acceleration in the direction of applying the model, the following results are obtained. In this analysis, a diagram of the dynamic pressure is presented in the following figure, the earthquake acceleration on the structural dynamic pressure increases.

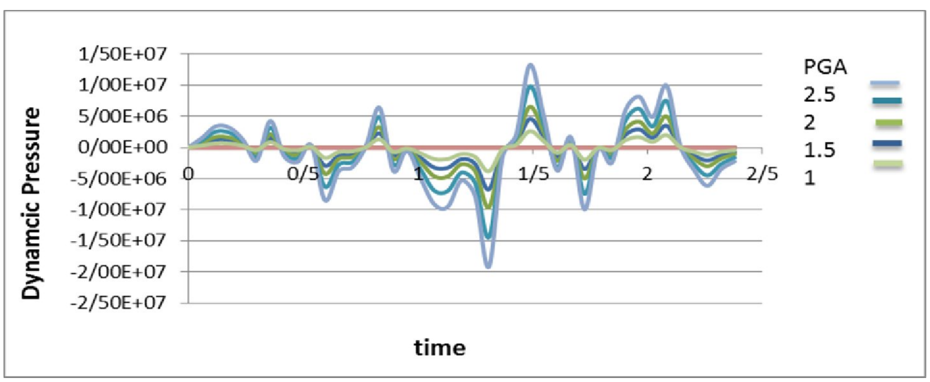


Chart 1 compares the dynamic pressure exerted on the plug of the PGA
Pga increase of 0.4 * g to .52 * g Maximum pressure on the plug increases almost linearly.

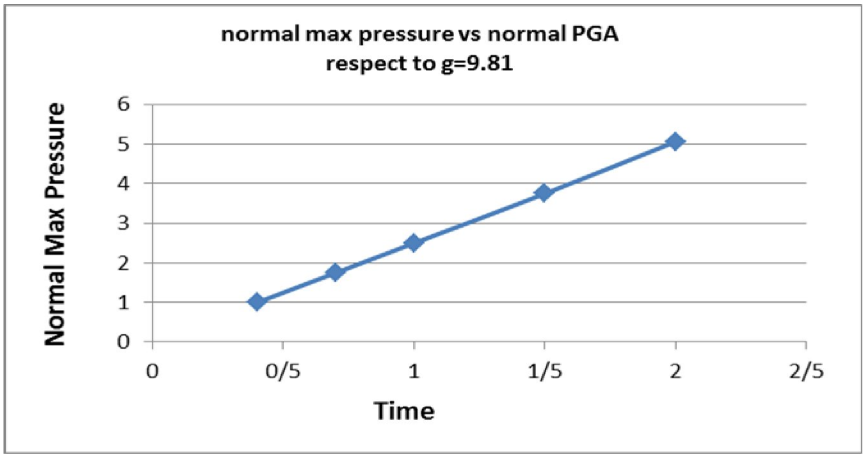


Chart 2 graphs with maximum dynamic pressure normal to the maximum normal acceleration structures

The following formula is provided for the maximum pressure exerted on the structure:

P max/P0) = 2.5355*(PGA /PGA0) - 0.0264

The second type of analysis:

Accelerogram applied in the horizontal direction and length of the tunnel dynamic pressure, to evaluate the effect of pressure on the plug in the plug,

Different length of the tunnel from 1800 to 3600 m, are studied. Note that in each round, different frequency components of the pressure wave enters, because the frequency content of the transmitted beam to construct the tunnel.

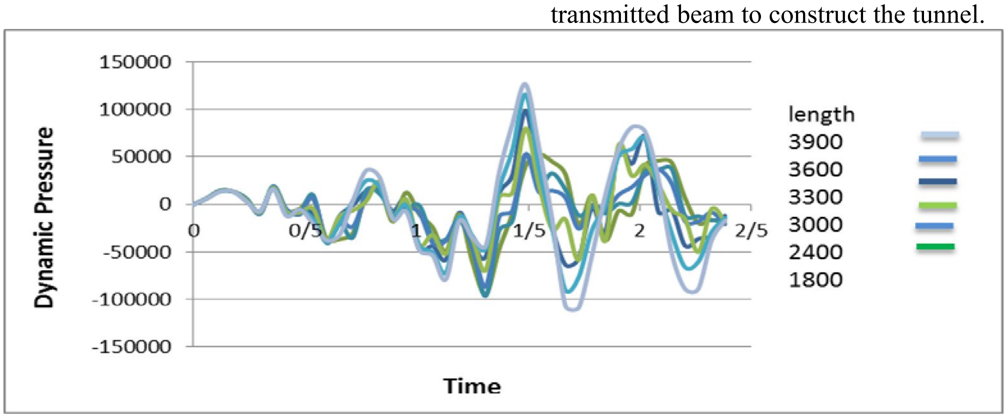


Figure (3) Comparison of dynamic pressure on the plug

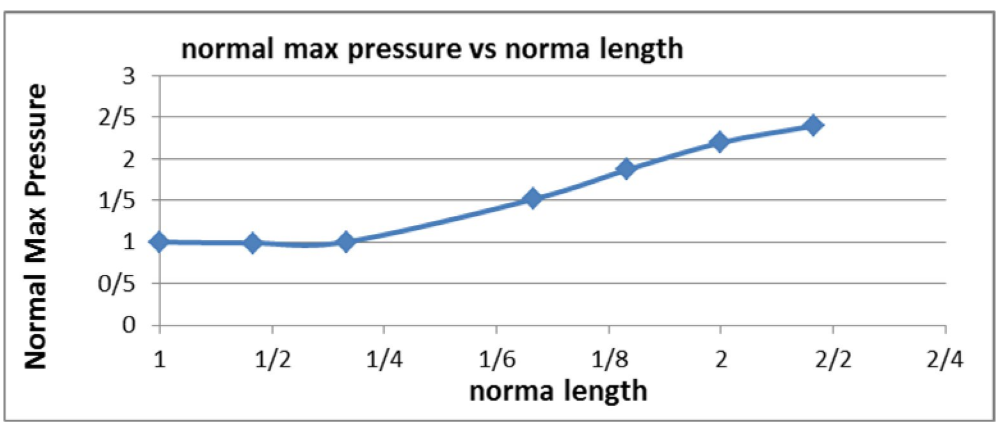


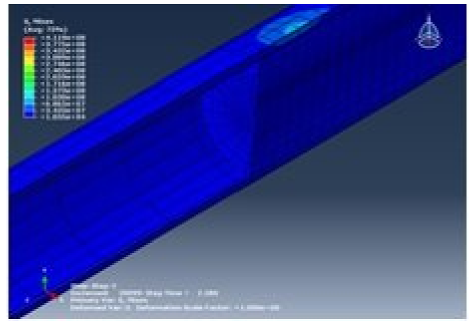
Figure 4 Graph normalized maximum dynamic pressure tunnel with a length of normal

To evaluate the effect of tunnel length, interpolation was used for the different relationships and ultimately suggested the following relationship:

$P\ max/P0 = -10.7073(L/L0)^3 + 9.0779(L/L0)^2 - 14.133(L/L0) + 7.7826$

The third type of analysis:

Between the plug and the plug tunnel, and the possibility of landslides caused by the earthquake motion is considered.



The stress field shape

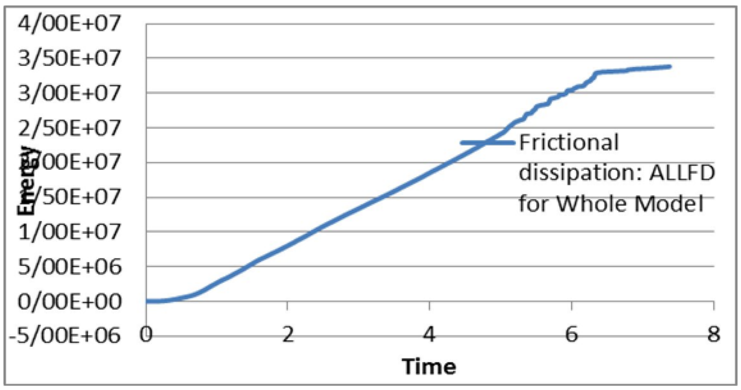


Figure (5) Energy diagram of the friction model with time

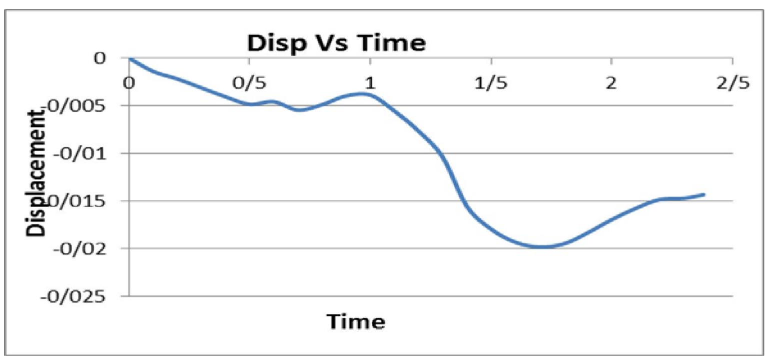


Figure (6) removable center plug with a time chart

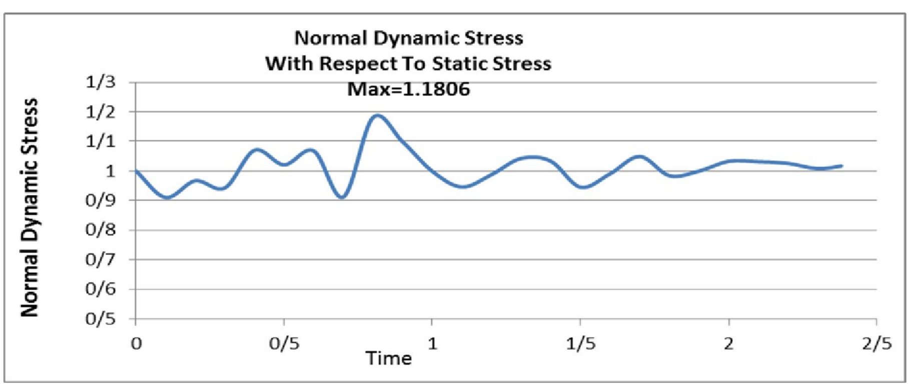


Figure 7 graphs the normalized dynamic pressure to static pressure with time

The maximum dynamic pressure of the main tunnel is 18% higher than the hydrostatic pressure. In the case of defining the relationship between the plug and the lining of the penalty method was used, Friction force for movement control Plug and consider the effects of gravity involved as is evident from Figure 5, During the analysis of energy dissipated by friction is added. The amount of energy and irreversible work done seismic and gravity of the load is deducted. The displacement of the center of the plug varies nonlinearly with time; this is due to the non linear accelerator friction and non-linear algorithms governing the issue, happened.

Modeling methods:

Water interaction structure of the equations governing the structure and behavior of the fluid varies according to differ increases the complexity of the simulation environment. In cases where the fluid is Sloshing, due to large deformation, the level of complexity is added. The elements used, the level of high transform the experience, this makes the solution of problems in numerical integration.

To overcome these problems, from the perspective of the issues that the Euler transforms is used up. Abakous has other capabilities. This allows the possibility of remeshing in Abakous manually or by defining criteria. In case studies performed on the tunnel Karun 4, due to the lack Aslvshyng model, Euler and Lagrange was not much difference between the two approaches, but the scientific approach and compare these two methods and different hair were examined. In terms of modeling, the Euler, Euler elements EC3D8 of water were used.

EC3D8R: An 8-node linear eulogia brick, reduced integration, hourglass control

C3D8R was used for the structural elements remain. But given that the advantage of the Euler formulation of acoustic point of view, in this case, to model the behavior of fluid, the equation of state must be used.

Water-related parameters in EOS:

C0 = 1500m / s, s = 0, gamma0 = 0

After modeling and compare the results on the structure, confirmed that when the fluid is deformation, these two methods are used depending on the boundary conditions and the accuracy of the structural equations, with no significant difference.

References:

1) Mard fekri, M., 2007. Application of simplified nonlinear analysis of concrete gravity dams, Tehran University.
2) Vaseghi Amiri, J., 2008. Dynamic analysis of arch dams under earthquakes, M.Sc. Thesis, Sharif University.
3) A.K. Chopra (1987), "Hydrodynamic Pressure on Dams During Earthquakes", journal of Engineering Mechanics,ASCE,Vol.93,205-223.
4) Alemdar Bayraktar-sevket Ates-“The effect of reservoir length on seismic performance of gravity dams to near- and far-fault ground motions”- Nat Hazards (2010) 52:257–275.
5) Chandra Kishen J.M., Darunkumar Singh K., (2001), Stress intensity factors based fracture criteria for kinking and branching of interface crack: application to dams, Journal of engineering fracture mechanics, 68, 201- 219
6) Chen, S.G., Zhao, Jian, 2002. Modelling of tunnel excavation using a hybrid DEM/BEM method, Computer-Aided civil and infrastructure engineering, volume 17, number 5, pp 381-386.
7) Eurocode 8 (2004) Design of structures for earthquake resistance, Part2: Bridges, Euro Pean standard pr EN 1998-2:200X,Draft5,june2004.
8) Leclerc M, Le´ger P, Tinawi R. RS-DAM Seismic rocking and sliding of concrete dams, USERS Manual. Department of Civil Engineering, E´ cole Polytechnique, Montre´al, Quebec, Canada, 2002.

12/28/2012