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Full Length Article

The Study of Near and far field Earthquake Effects on non-Homogeneous earth dam Dynamic response

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ABSTRACT
Various studies focusing on earthquake's influences on earthen dams have been undertaken, however, the behavioral complexity of these hydraulic structures under various geometric and physical circumstances and different earthquake features nonetheless, have not received elaborate and detailed deliberations to arrive at more accurate results. The purpose of this paper is to critically investigate the influence of height, body slope and near and far fault ground motion features on dynamic response of non-homogeneous earthen dam. The methodology involves assessing effect of reservoir's water level on near and far faults ground motions using finite element software ANSYS 14.0 on Karkheh Dam. The results show that dams with designs that feature low and high heights tend to be more critical against far and near earthquakes respectively. They further show that various body slopes and reservoir's water level do not produce significant effects on dynamic response of earth dams under conditions of far and near earthquakes. It was also found that decrease in Vmax/Amax parameters has a corresponding decrease in dam crest displacements, while for the PGV parameters a completely different behavior is observed. The study shows that the Karkheh dam has a critical response against near earthquakes than those for the far earthquakes and with a considerable strengthening quality that can protects it against potentials earthquakes measuring up to 6.9 Richter scale magnitude and 0.2g PGA.
Keywords: *earth dams, plasticity, near and far earthquakes, dynamic analysis*

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INTRODUCTION

Controlling dam stability under various critical load applications such as the seismic loading is becoming very crucial. Occurrences of earth geological tremor can pose serious problems for the stability and safe operation of these life-enhancing hydraulic structures. Accurate dam reaction against the earthquake is one of the hydraulic engineering issues that have recently attracted the attentions of various researchers. Physical and geometric variations of dams' body, differing earthquake features, coupled with the behavior of structural materials are among the crucial factors that influence the behavior and response of the non-homogeneous earth dams. Incidents of earthquake-related damages on earth dams have refuted the dominant opinion among the community of hydraulic engineering designers that the earth dams cannot realistically thought to be stable against the seismic tremors. Cristal Spring dam in San Andrias fault or Hebgen dam in the United States is the case in point. Generally speaking, retrofitting problem of earth dam against the earthquake considered by designers since the 1950's is but one measure to mitigate the consequences of the seismic termers. This design approach includes the numerical methods, new experimentation methods of soil samples under seismic conditions and analysis of dam reaction against the earthquake. Shahnazari *et al* [8] investigated two types of homogeneous earth dam including clay and sand against the near and far earthquakes. Their results show that homogeneous earth dams with longer response period against the near fault earthquake and homogeneous earth dam with shorter period against the far fault earthquake are more vulnerable to damage. Highly homogeneous dams tend to have a more crest acceleration under near fault earthquake than far earthquake. Byractar [2] modeled Torul earth dam against near and far earthquakes caused by a ground motion and showed that the displacements increase under the circumstances where the dam heights and near earthquakes have critical responses to far earthquakes. Davoodi , Feizi and Hadiani [4] modeled Maroon earth dam against near and far earthquake and showed that the crest settlement and displacements in the near earthquakes is greater than those for the far earthquakes . In modeling the Masjed Soleiman earth dam, Shirdel [14] found that the maximum acceleration and displacement on vertical central axis of dam is an indicative of affectless water level on dynamic response of earth dams . The study was conducted with the application of numerical methods by exhibiting the time history dynamic analysis of non-homogeneous earth dams. In the first stage, the study showed that the dam height increases the horizontal displacement, velocity and acceleration of dam crest, changing of body slope on dam body stability and effect of water level on horizontal displacement of dam crest .In the second stage, the features of near earthquakes are compared with those of the far earthquake's, while in the third stage, the Karkheh dam's response against the near and far earthquakes was checked as a real-time case study.

Characteristics of the near and far field earthquakes

Ground vibration behavior depends on a whole variety of conditions in every moment of recurring earthquake, such as the magnitude, site features and epicenter [8]. So far as the epicenter is concerned, the earthquakes are classified into two distinct categories of the near and far field earthquakes. Based on the earthquake records, it can be found that which near earthquakes have different features to those of the far earthquakes [6]. Near earthquakes epicenter, for instance, is less than the specified range. Some researchers consider this range to span as far as 50 km, while others consider it to be 15 km [8]. Based on the Li & Xie definition, the near earthquakes are normally limited to 20 km of the fault [10]. Hadson, Hosner , Bolt & Bert [1957] undertook systematic studies on a number of features pertaining to the near field earthquakes . Hadson and Hosner for example, found that the near field earthquakes compose of what is referred to as the crisis energy pulses. Their research shows that although these earthquakes may have smaller magnitude and amplitude, they nonetheless, have high destructive potentials. By studying the recorded movements of the Sanfernando earthquake, Bolt [1957] observed for the first time the velocity pulses arising from the quick slip fault. Overall near earthquakes have several features such as their acceleration, velocity and displacement time history are pulse shape. These pulses are relatively longer specially in velocity time history. They show that the maximum ground acceleration to maximum ground velocity ratio and permanent deformation are great. These features are attributed to the directivity and fling-step effect in the vicinity of the seismic source [6]. Directivity effect is classified into three categories: progressive, backward and neutral according to relative location between rupture direction and site location [4]. Directivity effect occurs under the circumstances where the fault rupture spread toward the location and the fault slip direction is toward it. When rupture originates from the epicenter to location of the quake as the fault rupture velocity is somewhere near the seismic shear wave's velocity, released waves are gathered due to the consecutive slips fault different areas. They act like a strong shock to reach the location of the tremor. This shock is recognizable at the beginning of earthquake record in perpendicular direction of slip. Then low duration, great domain pulses and moderate to high period can directivity affect the quake features. Under the circumstances where the site space is far from the epicenter or site is out of directivity affect range, it is bound to result in far earthquakes or neutral directivity range, which for the purpose of this study; it is considered to be 10 km range for near earthquakes.

Analysis method

The analytical framework used in this study is finite element method in conjunction with the ANSYS14.0 software for simulating the earth dam's dynamics. Physical problems are solved by differential equations governing or minimizing the potential energy in finite element. In this method the geometric model is divided into smaller components. Every element has nodes with input and output assigned to them. Every element has behavior with a shape function and it specifies the degrees of freedom in every area of element such as the displacements. The major pre-requisite for selecting a suitable shape function is to meet the boundary conditions by shape function, or if preferably possible, by the quadratic or other functions.

Modeling

In this paper, all dams are two-dimensionally modeled on plane strain and on the post-construction and prior to the reservoir's water intake, during which the behavior is assumed to be linear elastic. The paper is structured to have three parts as follows:

1) Part one consists of explanations on variation of the dam body's geometry such as the height, body slope and water elevation in the reservoir against the near and far field earthquake arising from a ground motion.
2) The condition where there are three near and three far earthquakes having varying features against the dams with different heights.
3) Simulating the Karkheh dam's hydraulic behavior against near and far earthquakes arising from a ground motion.

Part 1:

Section 1-1) the chunk of the content here deals with the conditions under which there are seven earth dams having different heights. In all these cases the body and core slope are considered to be 1:3 and 1:4 respectively. The width of the core base is considered to be equal to the dam height. Crest width however, is arrived at using the USBR relation as follows:

$$\mathbf{B = 1.104\sqrt{H} + 0.915} \quad (1)$$

Based on the ICOLD theory (large dam is referred to as a hydraulic structure with a height of greater than 15 m), the theoretical benchmark for the height is 15 m. In order to ensure the reliability and validity of the findings, attempts were also made to include data on dams of less than 10 m and over 30 m for this purpose. More details of the model's characteristic behavior are show in table 1& figure1.

Section 2-1) Four dams of various slope bodies are investigated. The core slope and width crests are assumed to be equal in all models, the major characteristic behaviors of which are shown in table 2 & figure 2.

Section 3-1) Four dams considered with different heights including 15 – 25 – 35 – 100 m, the design and engineering specifications are shown in table 1. For every of these hydraulic structures three water levels all the water intake stage are considered as in figure 3.

Height (H)	Core base	Width crest(B)
8	8	4.03
10	10	4.4
15	15	5.19
20	20	5.85
25	25	6.43
35	35	7.44
100	100	11.95

Table 1: model's characteristic in section 1-1

Height(H)	Slope body (m)	Core base	Width crest (B)
15	1:3	15	8
15	1:2.5	15	8
15	1:2	15	8
15	1:1.5	15	8

Table 2 : model's characteristic in section 2-1

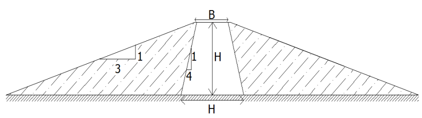


Figure 1: Model's characteristic in 1-1 section

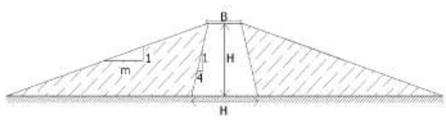


Figure 2: Model's characteristic in 2-1 section

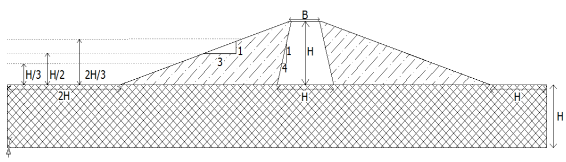


Figure 3: Modeled dams in 3-1 section

Part 2:
Section 1-2) Six dams of different heights are considered in conjunction with the Karkheh dam which is introduced in 2-2 section. For the purpose of this study, slope body and core are considered to be 1:3 and 1:4 respectively for all the parametric dams. The width of the core base is considered to be equal to dam height. Crest width is arrived at using the USBR relation. The major behavioral characteristics of the model are shown in table 3.
Section 2-2) and part 3: Karkheh dam is constructed on the Karkheh River in the north-western Dezful in the Khuzestan province of Iran. This giant water-harvesting hydraulic structure has a 3030 m length and 128 m height, supposed to store some 7 billion m^3 of the Saymareh's run-offs. The major construction material consists of clay core [11]. Karkheh reservoir dam location stands on Bakhtiary formation. Bakhtiary formation includes conglomerate, sandstone and lichen, all of which form the foundation stone. Conglomerates have high permeability and are separated by other lichen layers that have low permeability. For preventing of water permeation in supports and central part of dam, it is used from plastic concrete cutoff wall. Cutoff walls reach up to the core from the top and lichen layers from the bottom. Moreover, cut off wall is vertical and conglomerates and lichens are horizontal [10]. Biggest section of the Karkheh dam is shown in figure 4.

5. Material property

Material properties used in part 1&2 and also Karkheh material properties is showed in table 4 & 5 respectively. Material stress-strain behavior is linear elastic for all models. Viscose and hysteresis damping is given 5%.

6. Choosing earthquakes

Used earthquakes are selected PEER NGA DATABASE SEARCH site. In part1, the earthquakes are used that one of them is related to near field and another is related to far field of one ground motion. They have equal PGA and different PGV and Vmax/amax. Near earthquake is limited to radius of 10 km and far earthquake is out off this range .near and far earthquake are in 9.31 km and 22.68 km range respectively. These earthquakes are shown in table7, diagram 1&2. In part 2 are used three near earthquakes and three far earthquakes which are scaled according to Iran 2800 seismic regulation. It is tried three near earthquakes have PGV and Vmax/amax greater than far earthquakes. These earthquakes are shown in table 8 & diagram 3&4 and scale coefficients in table 6. In part 3, it was considered to use Elam Moormoori earthquake which was occurred in 45 km of Karkheh dam. this earthquake have far earthquake properties but because of seismographs failure and noting available crest response of dam for comparing numerical and instrumentation results it is used part 1 earthquakes . In all analysis earthquake horizontal component is used. Earthquakes intensity and PGA are in 5-8 Richter range and more than 0.1g respectively. According to shear wave velocity, ground type is equal and near to A&B type.

Height	Slope body	Core base	Width crest
10	1:3	10	4.4
15	1:3	15	5.19
25	1:3	25	6.43
35	1:3	35	7.44
100	1:3	100	11.95
120	1:3	120	13

Table 3 : model's characteristic in part 2

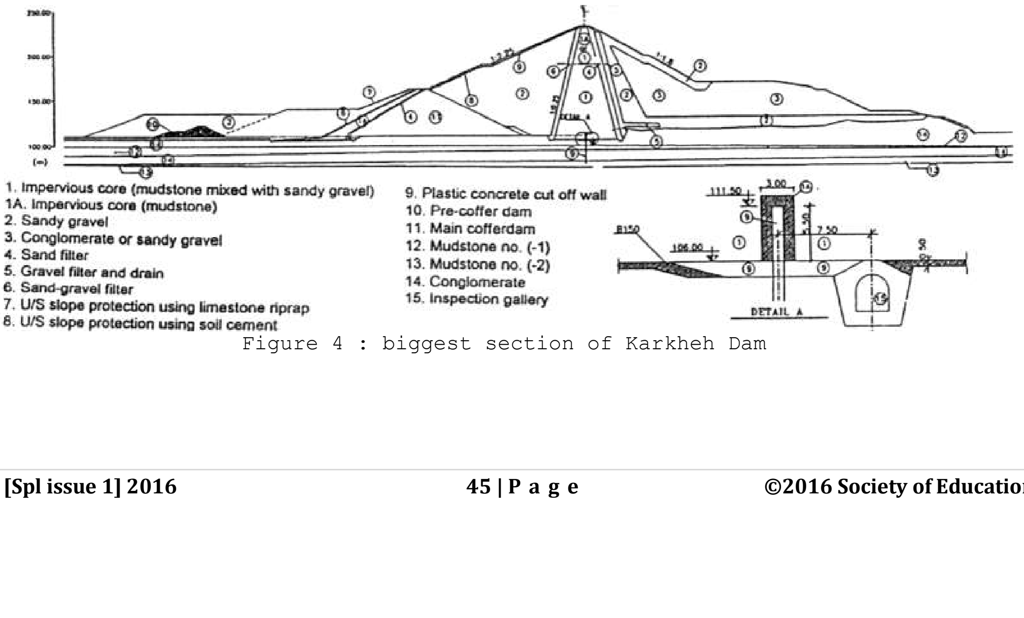


Figure 4 : biggest section of Karkheh Dam

υ	E(kpa)	ϕdeg	C(kpa)	K(cm/s)	γ_d (KN/m³)	Material type	NO
0.45	20000	20	50	10^-7	17.1	Core	1
0.25	80000	43	0	400	21.5	downstream	2
0.25	90000	45	0	500	21.5	Upstream	3
0.31	12000000	–	–	–	24	Foundation	4

Table 4 : Material properties in part 1&2

ψ	υ	E(kpa)*10^4	ϕ deg	C(kpa)	γ (KN/m³)	Material type	NO
2	0.4	3.5	6	70	20.2	Core	1
10	0.27	10.2	39	0	20.5	shell	2
8	0.25	7	35	0	19.5	Filter	3
0	0.25	100	30	1000	21.5	Cut off wall	4
10	0.23	80	39.4	85	23	Conglomerate 1	5
0	0.3	12	22	70	21	Lichen 1	6
10	0.23	100	39.4	85	23	Conglomerate 2	7
0	0.3	15	22	70	21	Lichen 2	8
10	0.23	100	39.4	85	23	Conglomerate 3	9

Table 5 : material properties in part 3

Height (m) earthquake	10	15	25	35	100	120	Karkheh
near	1.43	1.54	1.49	1.4	2.105	2.35	2.35
far	1.47	1.53	1.56	0.98	2.12	2.36	2.35

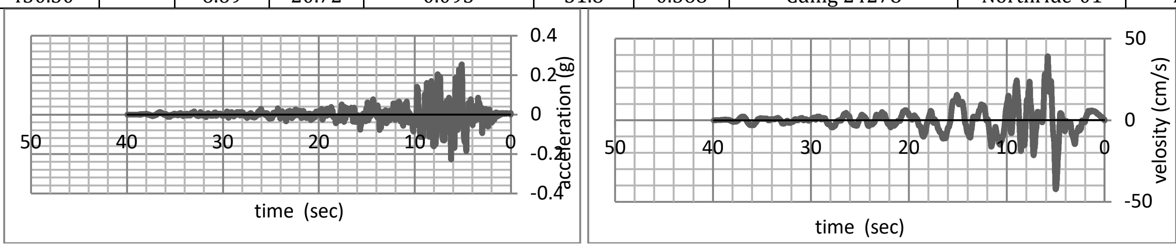
Table 6 : scale coefficients in modeled dams and Karkheh dam

Vs (m/s)	TP (sec)	Mv	D (km)	Vmax/Amax (sec)	PGV (cm/s)	PGA (g)	station	earthquake	Ground motion
380.80	0.32	6.93	9.31	0.17	42.447	0.2	CDMG 57425	lomaprieta	Near
433.9	0.14	7.93	22.67	0.047	16.405	0.2	CDMG 58235	lomaprieta	far

Table7: used earthquakes in part 1 &3

Table 8: Used earthquakes in part 2

Vs (m/s)	TP (sec)	Mv	D (km)	Vmax/Amax (sec)	PGV (cm/s)	PGA (g)	station	earthquake	Ground motion
380.80	0.32	6.93	9.31	0.17	42.44	0.2	CDMG 57425	Lomaprieta	Near
380.10	0.24	7.35	2.05	0.119	97.8	0.836	9101 Tabas	Tabas	Near
766.80	0.66	6.69	8.44	0.106	78.1	0.749	La Sepulvedava Hospital	Northride-01	Near
425.30	–	6.93	30.86	0.196	37.4	0.194	Usgs 1601 Palo Alto	Loma Perita	Far
433.9	–	7.93	22.68	0.074	16.405	0.2	CDMG 58235	Lomaprieta	Far
450.30	–	6.69	20.72	0.093	51.8	0.568	Cdmg 24278	Northride-01	far



(a) (b)

Diagram 1(a): acceleration time history of near earthquake in part 1 & 3

Diagram 1(b): Velocity time history of near earthquake in part 1 & 3

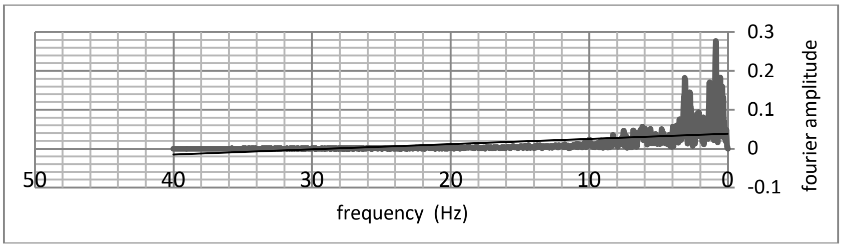
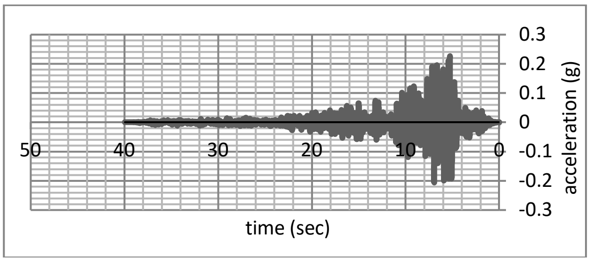


Diagram 1(c): Fourier amplitude of near earthquake in part 1 & 3



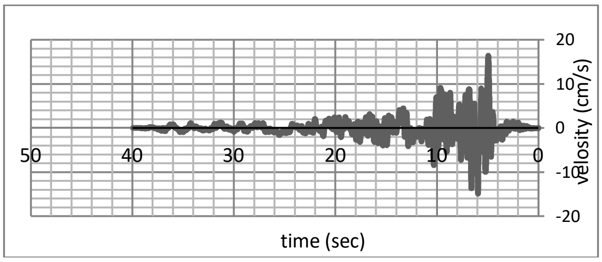


Diagram 2(a): Acceleration time history of far earthquake in part 1 & 3
Diagram 2(b): Velocity time history of far earthquake in part 1 & 3

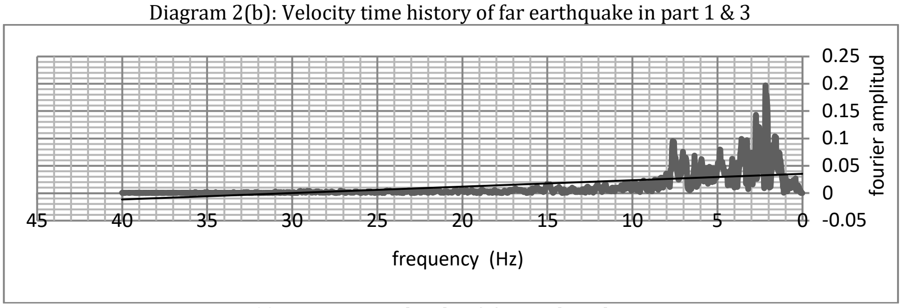
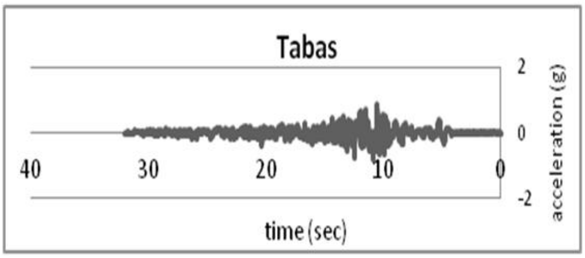
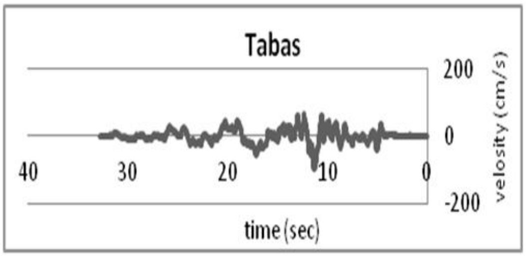


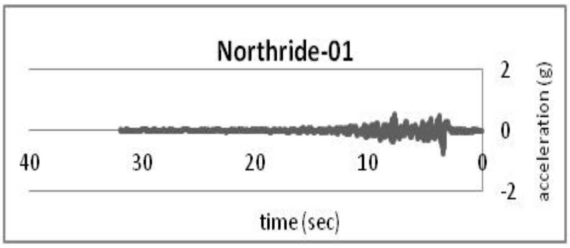
Diagram 2(c) : Fourier amplitude of far earthquake in part 1 & 3

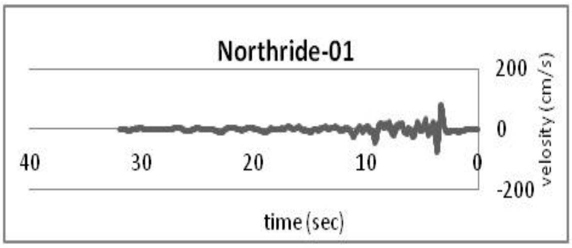




(a-1) (a-2)

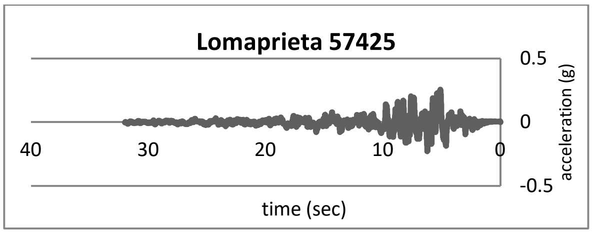
Diagram 3(a-1) : acceleration time history of Tabas earthquake (near field)
Diagram 3(a-2) : velocity time history of Tabas earthquake (near field)





(b-1) (b-2)

Diagram 3(b-1) : acceleration time history of Northride earthquake (near field)
Diagram 3(b-2) : velocity time history of Northride earthquake (near field)



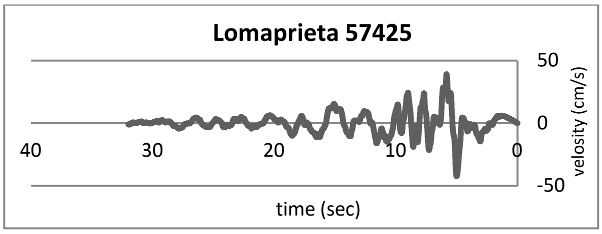
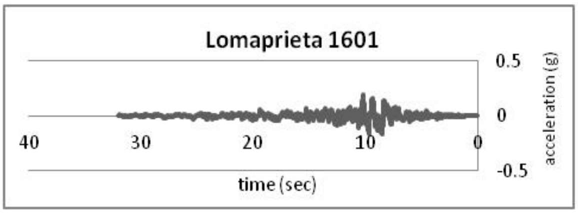


Diagram 3(c-1) : acceleration time history of Lomaprieta earthquake (near field)
Diagram 3(c-2) : velocity time history of lomaprieta earthquake (near field)
Diagram 3 : acceleration & velocity time history of three near earthquakes in 2part



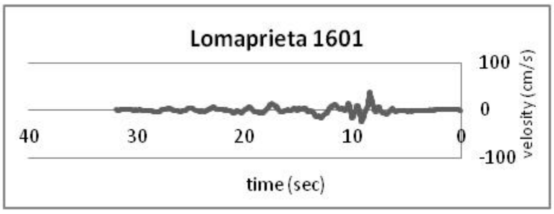
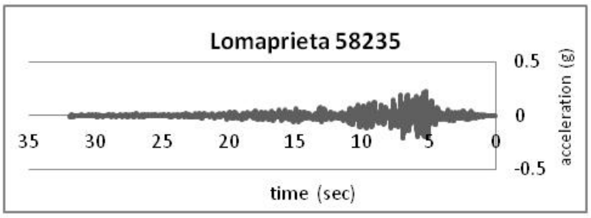


Diagram 4(a-1) : acceleration time history of Lomaprieta 16 earthquake (far field)
Diagram 4(a-2) : velocity time history of Lomaprieta 16 earthquake (far field)



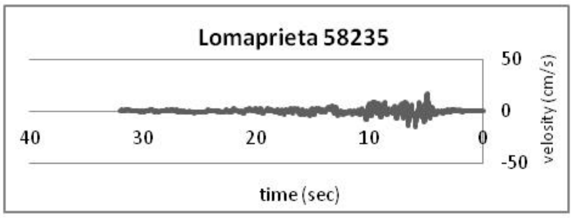
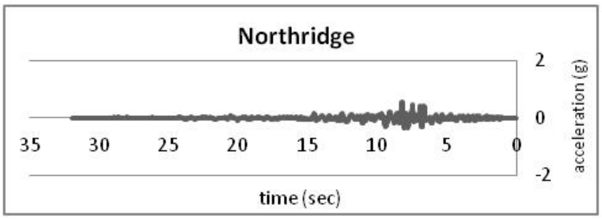


Diagram 4(b-1) : acceleration time history of Lomaprieta 58 earthquake (far field)
Diagram 4(b-2) : velocity time history of Lomaprieta 58 earthquake (far field)



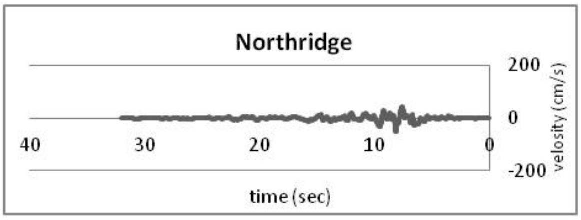


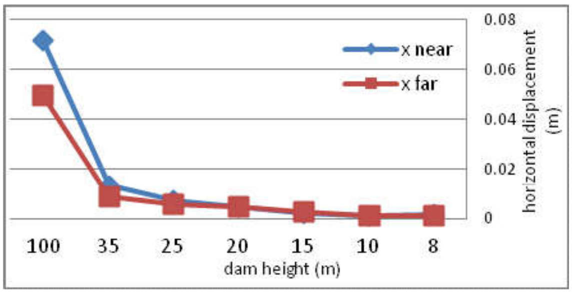
Diagram 4 : acceleration & velocity time history of three far earthquakes in part 2

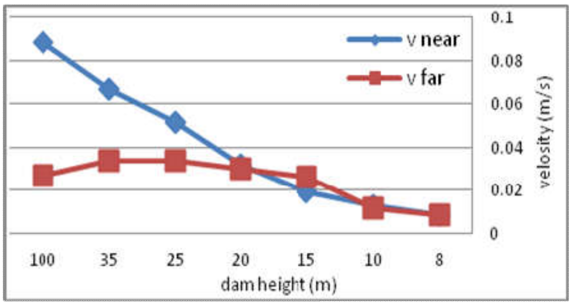
DISCUSSION

Part 1- section (1-1): Checking the dynamic behavior of the non-homogeneous earth dams and the effects of height on earth dam response against near and far earthquakes after using selected earthquakes in horizontal direction and during time history dynamic analysis, horizontal displacements, velocity and acceleration on dams crest is calculated. As can be seen from the diagram 5, results show that under the circumstances of different height dams, displacements increases with increasing height in near and far earthquakes. The diagram shows that the near earthquakes have greater displacement than far earthquakes. This is particularly the case for the high dams, as Vmax/amax parameter is greater in near earthquakes than far earthquakes. The interpretation being that the save in energy reaches the dam in short duration which incidentally creates relatively greater displacements. In diagram 6, on the other hand, depicts the picture of dams with different height crest velocity. It shows that the velocity in near earthquake is significantly greater than that on the far earthquake affecting the dams of more than 20 m height. Diagram 6 shows the increasing trend in the near and far earthquakes due mainly to the elastic behavior of materials. It is therefore logical to conclude that under the circumstances where the materials are plastic, plastic deformation causes reduction of velocity particularly in the upper half of dam. It further shows that the plastic material phenomenon is accompanied by the reduction of velocity resonance. Diagram 7 on the other hand, shows dams with different height crest acceleration. It shows that the dam crest acceleration in far earthquake is more critical than the near earthquake for dams shorter than 25 m. It shows an increasing trend in the near earthquake while a decreasing trend in far earthquake, particularly for dams greater than 25 m heights. The underlying explanation for these fluctuations is the proximity of high and short dams' frequency to near and far earthquakes frequency .

Part 1- section (2-1): This section, considers the effect of changing earth dam body slope against the near and far earthquake. Horizontal displacements on horizontal central axis of parametric dams are shown in figure 5. Diagram 8 to 11; show that the maximum horizontal displacements are related to core with shell intersection. These parametric dams have no filter and since one of the basic points in dam designing is the incorporation of filter to ensure dams' stability against the recurring earthquakes. It is also assumed that dams with the aforementioned characteristics are bound to have a better chance of mitigating the effects of seepage in the body after the construction phase of hydraulic structure. In diagrams 8 to 11, horizontal displacements difference that has resulted from near and far earthquake is very small. However, with decreasing body slopes, the far and near earthquake are affected on downstream and upstream respectively. Horizontal displacements on horizontal central axis of dams having different body slopes against near and far earthquake as in diagrams 12&13 show that decrease in body slopes increases the stability of structures in both types of earthquakes. But this result is related to parametric dams with the same height, material and foundation. Under the circumstances where these items change, there will be a corresponding change in the structural response. Results show no clear relationship between the body slope and their stability against earthquake. It can be deducted from the results of this study that the height has a greater influence on displacements than the body slope for the two types of earthquake.

Part 1-section (3-1): Diagrams 14&15 depicts the behaviour of the dams with different height against near and far earthquake . results show that the water level fluctuation in these dams does notsignificantly affect the dam crest's horizontal displacement. The effect of water height changing on dam crest horizontal displacement is very small for dams with 35 m height and shorter but it for high dams over 100 m and more is ineffective. According to available studies, in the first dam water supply, downstream is critical not dam crest moreover near earthquake has bigger displacements than far earthquake.





Dig. 5 Dig.6

Diagram 5 : horizontal dam crest displacement for 8 to 100 meter height

Diagram 6: velocity dam crest for 8 to 100 meter height

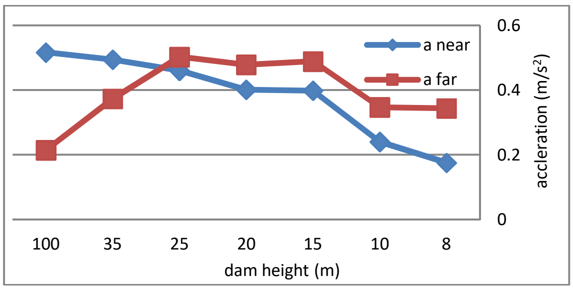


Diagram 7: acceleration dam crest for 8 to 100 meter height

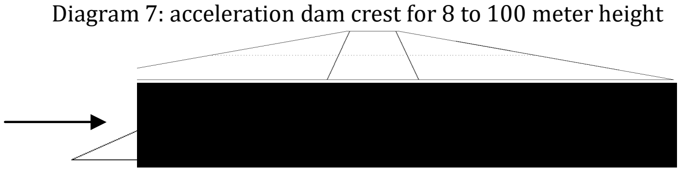
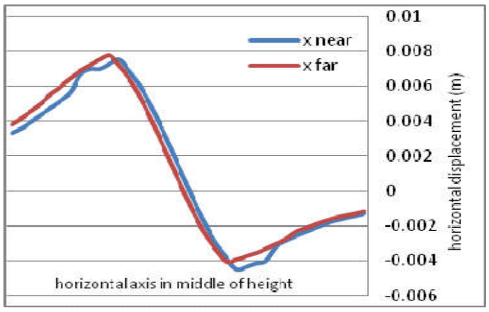


Figure 5 : horizontal central axe of parametric dams



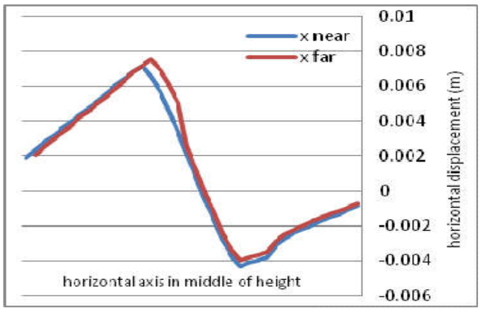
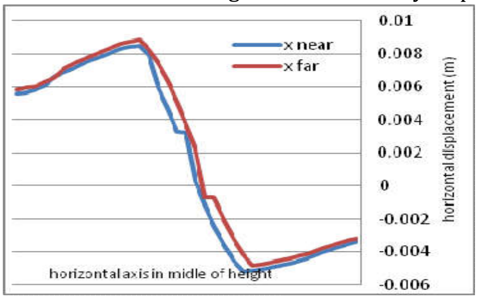


Diagram 8 : 1:3 body slope against near and far earthquake

Diagram 9 : 1:2.5 body slope against near and far earthquake



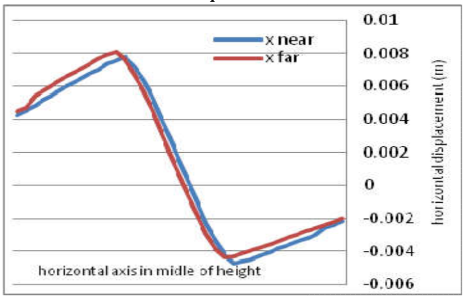
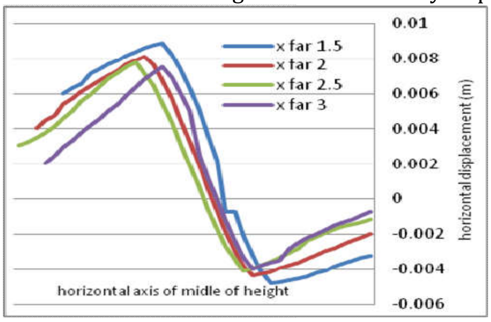


Diagram 10 : 1:2 body slope against near and far earthquake

Diagram 11 : 1:1.5 body slope against near and far earthquake



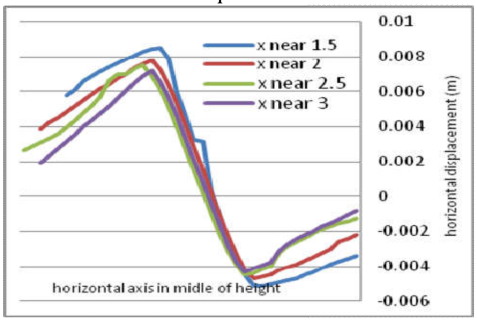
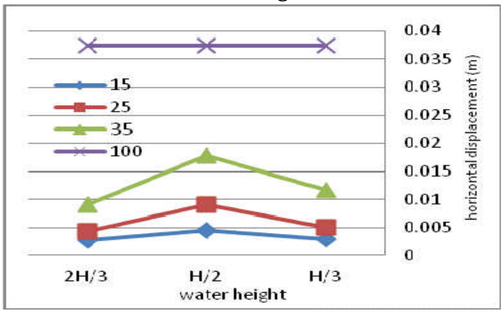


Diagram 12 : different body slope against near earthquake

Diagram 13: different body slope against far earthquake



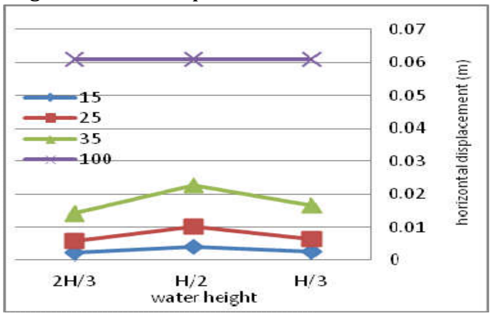
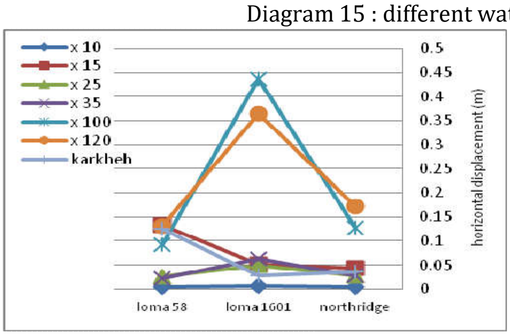


Diagram 14 : different water level against near earthquake

Diagram 15 : different water level against far earthquake



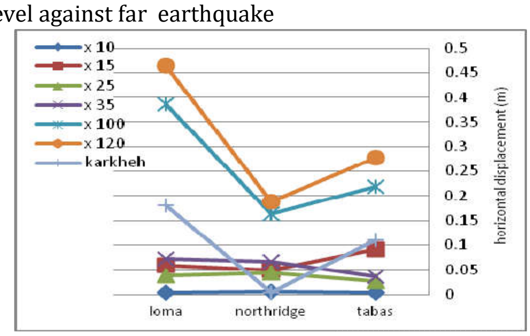
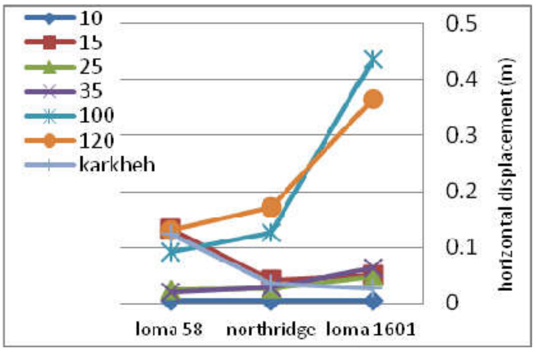


Diagram 16 : three near earthquakes according to PGV parameter

Diagram 17 : three far earthquakes according to PGV parameter



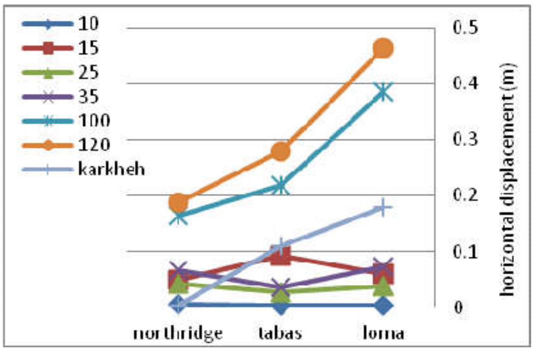
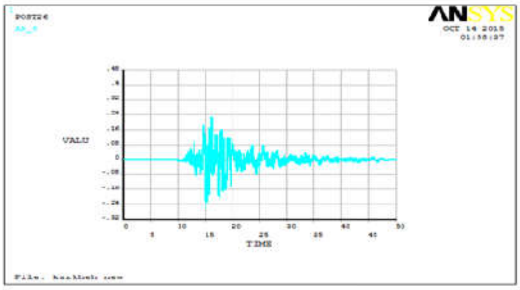
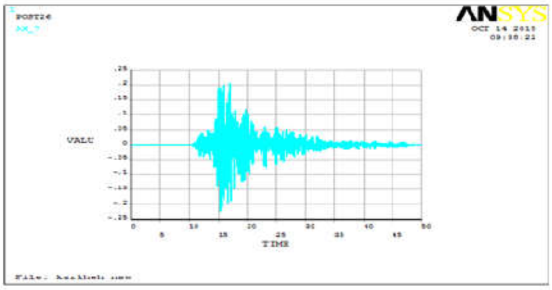


Diagram 18 : three near earthquakes according to Vmax/amax parameter
Diagram 19 : three far earthquakes according to Vmax/amax parameter



Dig. 20



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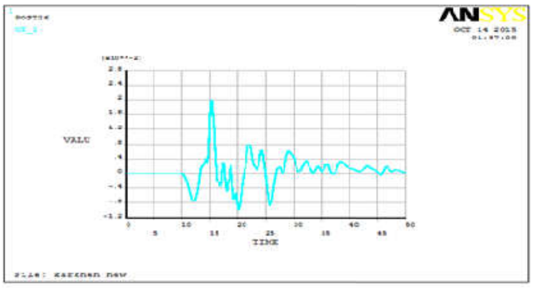
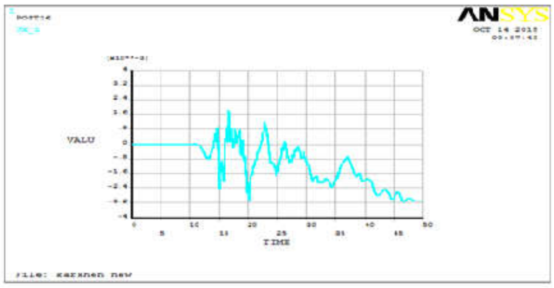
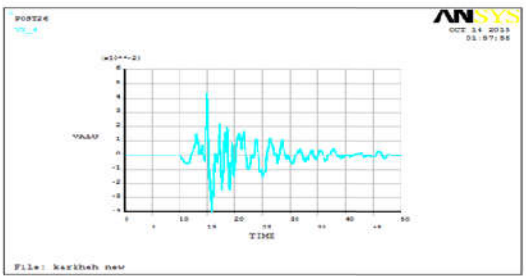


Dig. 22



23



Dig. 24

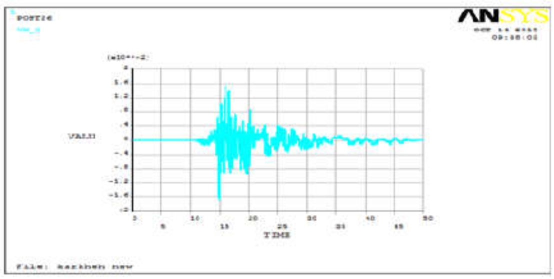


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Diagram 20 : dam crest displacement response of Karkheh dam (near field)
Diagram 21: dam crest displacement response of Karkheh dam (far field)
Diagram 22 : dam crest velocity response of Karkheh dam (near field)
Diagram 23 : dam crest velocity response of Karkheh dam(far field)
Diagram 24 : dam crest acceleration response of Karkheh dam (near field)
Diagram 25: dam crest acceleration response of Karkheh dam (far field)

Part 2: diagrams 16 & 17 check the effect of PGV parameter in three near earthquakes and three far earthquakes on crest horizontal displacements of dams with different heights. Diagram 16 shows Lomaprieta earthquake which has lower PGA and PGV than Tabas and North earthquakes but has the most dam crest displacement. This problem is explainable with acceleration and velocity time history diagrams of Lomaprieta earthquake (3(c-1) & 3(c-2) diagrams). acceleration time history and velocity especially of Lomaprieta earthquake has pulses with longer period than other earthquakes other point that is dominant pulse of Lomaprieta earthquake which is in the time history beginning and in 5 seconds but dominant pulse of Tabas earthquake (3(a-1) & 3(a-2) diagrams) is in 10 seconds . On the other hand dominant pulse of North earthquake (3(b-1) &3(b-2) diagrams) is in the time history beginning and in 5 seconds but its period pulses is shorter than other earthquakes. Moreover, these pulses have short duration to other. results on near earthquakes behavior show the reducing of numerical PGV parameter does not lead to dam crest displacement but it is related to near earthquakes properties contains time history pulse like . since the increase of height cause the increase of dam crest displacement for dams with 100 meter height and more in near and far earthquake results of diagram 17 shows the effect of PGV parameter is low in far earthquakes .diagrams 18 & 19 check the effect of Vmax/amax parameter on dam crest horizontal displacement against to near and far earthquakes respectively. Diagram 18 shows which decrease of Vmax/amax cause decrease dam crest displacement. In fact Vmax/amax is an impact like movement index which it can cause more displacements. Diagram 19 shows the low effect of Vmax/amax on displacements in far earthquakes. Karkheh dam as a real dam show same behavior like high dams against near earthquakes in diagram 16 & 18. Numerical differences in displacements are because of different geometric, material and foundation.

Part 3: diagrams 20 to 25 show the Karkheh dam crest response against two earthquake of table 6. Displacement, velocity and acceleration time history diagrams of the Karkheh dam show that they are similar pulse type for near earthquake than far also near earthquake pulses have more period of time than far earthquake. Pulse type property as observed in velocity time history especially. Examination of the time histories shows the maximum amounts obtained from dynamic analysis is related to near earthquake. However, differences of displacement and velocity in near and far earthquake are more tangible than acceleration. The more critical response of near earthquake than far earthquake is to do with the pulse of their time histories. In fact, time histories of near earthquakes have pulses with long periods because of directivity effects. On the other hand , proximity of dam frequency to earthquake frequency which in this case for the Karkheh dam is 0.53 HZ and near and far earthquake frequency are 0.9HZ and 2.6 HZ respectively. Furthermore, maximum acceleration and velocity of dominant pulse are factors that cause structure big response. In near earthquakes energy aggregation within a pulse in a short time is bound to have a sudden impact on dam that causes significant transformations in pulse time. Diagrams 20 to 25 show the horizontal displacement, velocity and acceleration of the Karkheh dam to be minimal. Since the Karkheh dam is a great structure, the impact of the earthquake is insignificant as the numerical results comply with the observation data after the earthquake. Short transverse cracks (about 1 meter) observed on the dam crest which did not cause serious problem for dam stability. Since near earthquake is assumed in 9 km distance with 6.9 Richter magnitude and peak acceleration 0.2g shows if Moormoori earthquake occurred in 10 km of dam , with similar seismic specifications to those used earthquake in part three, do not produce great damage to dam . The Karkheh dam is shown to be resistant against earthquakes with 6.9 Richter magnitude and 0.2g acceleration. According to velocity of shear wave ground kind is one or two which is similar to Karkheh dam ground kind.

CONCLUSIONS

The overall conclusions being that increasing dam height cause under elastic state for near earthquakes correspondingly increases the velocity, acceleration and displacement. High dams (35 meter or higher) have more crest displacement against near earthquake relative to the far earthquake and dam crest displacement for dams shorter than 35 m height is similar for two types of earthquake. In dams with similar height, materials and foundation, decrease in body slope causes dam stability. The effect of near and far earthquake on dams with different body slopes and same height is the same. Increasing or decreasing reservoir water elevation has a little effect on elastic displacement of dam crest in both the near and far earthquakes. The effect of change in the dam body slope and reservoir's water elevation on dam crest displacement does not have significant impact as variation of height. Short dams (with a higher period) have a more critical acceleration of crest of in far earthquake, while in high dams (with down period) this is bound to occur in near earthquake. Decreasing PGV rate does not have a corresponding decrease in dam crest displacement , rather it is related to near earthquake's properties like time history pulse-type especially velocity time history. Decreasing of Vmax/amax parameter in near earthquake, causes decrease in crest's horizontal displacement. The Karkheh dam has a greater critical response (displacement, velocity and acceleration) against far earthquake than near earthquake. The Karkheh dam is more resistant against earthquakes with magnitude 6.9 Richter and 0.2g peak acceleration in 10 km range.

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