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Earthquake Rating of Pore Water Pressure Generation– Induced Liquefaction of Earth Fill Embankments by Numerical Simulation

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ABSTRACT

The collapse of embankments, dams and slopes in the Arab world has become a phenomenon need to stand on the causes and consequences. The magnitude of the devastation due to Liquefaction phenomenon need to take the necessary precautions to reduce potential losses. Investigation of the (naturalist and imitation) of slopes and embankments stability is a hard geotechnical errand. Therefore embankments numerical study is implementing to diminish the situation of falling flat slants and rashes during shaking through appropriate FEM software. The FOS and liquefaction potential trend are obtained using finite element technique "Newmark" deformation analysis. The conformity of the analysis is verified by inquiry a layered slope of two altered soil deposits exposed to earthquake shaking. The conclusion from the study proved that the soil stratified trend has an immediate influence on the stability of the slope due to shaking and it is the simplest technique to reduce shaking effect. All combined phenomena which have delivered serious harm all over the world concentrated under quake examined under a record of 0.1 to 0.5g with particular case study to explore liquefaction zones due to the quake. Changeability of textural properties of soil layers affecting FOS and liquefaction has been examined for embankments. This study comes to put a highlight on Mosul Dam problem and give some suggestion and conclusions to its problems.

تقييم الهزة الارضية لضغط الماء المتولد المكون لتسيل سد املائي باستخدام المحاكاة العددية

الخلاصة

أصبح انهيار السدود والمنحدرات في العالم العربي ظاهرة تتطلب الوقوف على اسبابها وتبعاتها. ان حجم الدمار الذي تخلفه ظاهرة تسييل تحتاج إلى اتخاذ الاحتياطات اللازمة للحد من الخسائر المحتملة. التنبؤ و التحقيق في ديمومة المنحدرات (الطبيعية والاصطناعية) اصبح من اصعب المهمات الجيوتقنية,لذلك تساهم الدراسة العددية للمنحدرات في الحد من حالة انهيارها بسبب الاهتزازات من خلال برنامج مناسب للعناصر المحددة . ان معامل الامان لاستقرارية المنحدرات وظاهرة التسييل يتم بحثها من خلال محاكاة ميول متكونة من طبقتين من ترب المتغيرة الخواص والمعرضة للهزة الارضية عدديا باستخدام تقنية (نيومارك).الاستنتاج من هذه الدراسة أثبت أن التربة الطبقية الاتجاه له تأثير فوري على استقرار المنحدر خلال الهز حيث يمكن اعتبارها من أبسط الطرق لتقليل تأثير اهتزاز. ركزت هذه الدراسة على جميع الظواهر المصاحبة لظاهرة التسييل في ظل قوة هزة ارضية تتراوح ما بين(0.1-0.5) حيث تأتي هذه الدراسة لوضع تسليط الضوء على مشكلة سد الموصل وإعطاء بعض الاقتراحات والاستنتاجات الخاصة لمشكلة ذلك السد .

الكلمات المفتاحية

الانطقة الزلزالية, جيوستديو 2007, السد الاملائي, الميول الاصطناعية, المحاكاة العددية, سد الموصل.

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Introduction

The number of earth dams is vast in Iraq, it plays a major role in agriculture and industry, but it is also disaster source. There will be some cracks, leaks and other damage phenomena in the earth dams or embankments, and the function will affect, some of them will be in serious damaged, even some ones destroyed, the life and property are threat serious.

During ten years, four dams had been collapsed (two dams in Syria, one in Morocco and one in Saudi Arabia) besides the possibility of the Mosul Dam to collapse. In case it happens, the magnitude of the severe damages will have more than ten times what left levees collapsed in some Arab countries. Due to the treasure of high water and degree of inclination of the stream of the Tigris River from Mosul city to the south where the level of headroom between the Euphrates and the Tigris rivers teams about 7 meters in the north. Vice versa, the level rise is reduced to the Tigris from the Euphrates to the south by about 7 meters) will cause disastrous floods, harm aquatic service facilities downstream, and the displacement of about 4-5 million people in the Tigris basin from north to south. Therefore necessary precautions must be taken to reduce potential losses [1].

The highlight to the reasons for the possible collapse of the Mosul Dam and the development of effective solutions must unleash to create a state of confusion and fear among the population. The end desired to examine the reasons for the collapse of the Mosul Dam in a scientific and specialist, especially after the brief on the many inaccuracies contained in the press articles with respect and appreciation of the motives and concern for the security of the citizen [1].

During the last period, the authors were busy in the preparation of a new academic paper on liquefaction and lateral speeding in the slopes, so the time is not available to respond to newspaper articles. However, it is time to view a summary of the reasons for the collapse of dams and methods of treatment, for correct views journalistic non-specialized. By summing up the literature, the earthquake damage forms earth dams and factors affecting it were studied in this paper by improved the earth dam numerical through FE model.
The main ideas in this article are as follows:

(1) The main form of the earth dam earthquake damage and the main factors affecting the dam earthquake damage was analyzed. The earth dam earthquake damage data were counted, and it is found that displacement (lateral spreading), reducing the factor of safety, slip marks, dam crest seismic subsidence, slope damage, and other ancillary due to liquefaction damages is the main damage forms which were the most common form. Seismic intensity, foundation, dam materials, and dam type, are the main factors which decided the damage extent of the earth dam. The factors were calculated quantitatively using the Quake – slope / geostudio2007 analysis and the degree of affecting the earthquake damage was obtained.

(2) The improved earth dam FE model was carried out as software using the Geo-studio a single dam so that the engineering will use easily, and the evaluation efficiency will be improved.

Factors and Forces, which Affect the Fallout of an Embankment or Dam

Structural factors*:* proper geological studies of the soil pose to choose the dam is the foundation stone for the persistence and stability of the site, but it is not sufficient, without regard to design and engineering specifications of building materials, conditions and techniques used. It is associated with the disadvantages of using building materials unmatched with characteristics of the chemical and physical processes balance between the amounts of construction materials used moreover, appropriate conditions for mixing and interaction leads to cracks in the foundations (piles and piles) of dams, with the availability of salinity factor for water increases cracks in construction structure. As a result of the multiplicity of different stresses and unbalanced forces of the construction leads to the time of the collapse of the dam. Also, the quality of soil embankments of the dam and the surrounding environmental influences play a fundamental role in the erosion, and water erosion of soil dam operations weakening their resistance to withstand the various loads and stresses of water collapses the dam and make flooding.

Forces affecting facilities*:* self-weight of the dam and various amusements, hydrostatic water pressure, pressure waves, pressure riverine sediments are positioned in front of the dam, the effect of shaking due to the earthquake, the seismic water pressure (pore pressure), and the pressure of seismic soil (lateral soil pressure).

Effect of various water factors on the water structures*:* static loads of water, dynamic loads, loads due to the hydraulic pressure, Pore Pressure-dynamic loads, different pressure (pressure leakage) loads, the effect of mechanical erosion of filtrate water, the effect of biological effect of water.

Effect of loads and forces not belongs to water effect on the water structures*:* loads of permanent and temporary payloads including cargo temporary (long- short) term temporary loads, and payloads.

The operation of erosion and collapse of the soil texture*:* which can be classified as (internal erosion of the ground) lead to the break-up of the ground (above and below) the dam. Erosion regressive which cause the breakdown of the baseline when the water provides enough in the upper dam side especially when the heterogeneity of the base layers are presence, therefore, the water seepage increases under the dam body which negatively affects the storage capacity; erosion on the borders of dams occurs due to the high permeability of peripheral surfaces and the collapse of dam base due to the water flow movement towards the impermeable construction parts and generate water pressure on the bottom towards the top leading to the collapse of soil particles resistance (liquefaction phenomena).

Problems encountered in the Mosul Dam*:* Lack of geological studies accurate about the soil foundation of the dam site, which based on a deep horizon composed of fragile gypsum layers insoluble in water, resulting in the occurrence of the collapse of the deep layers and caused varying settlement in the body of the dam. This problem is spotted after the introduction of the dam into use in 1986, where tests drainage water wells showed the presence of a large water seepage under the dam body besides to design errors the site is affected by two earthquakes zones as the type of Mosul dam can be considered as a dams cumulus (earth fill dam) that weak resistance to earthquakes and shaking in opposite of that concrete dams with known with high earthquake resistance, although the last one cost high compared to the former.

Potential risks that accelerate the collapse of the Mosul Dam*:* On 17/12/2007 the terrorist detonated a bomb car on a bridge is about 200 meters from the Mosul Dam, which suggests that the dam targeted by terrorists for their prior knowledge the problems of the dam and the possibility of setting collapse in the event of exposure to strong vibrations weaken approved leads to of the collapse of the dam maintenance procedures.

Seismic Zones affected at the Mosul Dam site

The world follows by sound and the image on television screens the environmental disasters that are caused by earthquakes, with about 250 earthquakes is located in different parts of the world every day and most of these earthquakes happened under the sea either those that are located above the surface of the land, so that infrequent but not cause little damage in most cases, but earthquakes violent. Some may wonder about the reasons for the occurrence of earthquakes or mechanical what happen. Seismic is shaking of the ground as a result of the liberation of the energy stored in the rocks beneath the surface suddenly and fast, and the so-called breakage that occurs rocks (fault or the fault) and continues earthquakes for several seconds. The scientists and the resulting energy equivalent to 200 million tons of TNT high explosives and more than ten times that of the first nuclear bomb energy and cause it killed more than 14,000 people annually. Is released this energy in the form of waves, called seismic waves, and the point on the ground that generate seismic waves called (the epicenter). This represents the point at which happens after that quake, the largest movement of the quake's epicenter, none of this point, which is located directly above and called on the ground (in the center earthquake) in the light of that originated on the ground, a group of vulnerable areas in the earth's crust, and the center of seismic activity and earthquakes are called belts. There is a direct correlation between the seismic activity and the dam high (height with more than 60 m above the ground) in the seismic zones. The intensity of yawing waterway because of the deep earth faults plays a great role in increasing seismic activity specifically in the Mosul Dam area where there is a serious deviation of the Tigris River and its tributaries (Khazar, top and below Zab). Figure.1 shows the seismic acceleration map of Iraq.

between Iraq and Iran and the series extends to the Himalayan belt,"Tectonically Iraq is located in a relatively active seismic zone at the northeastern boundaries of the Arabian Plate" [3]. While Anatolia Seismic Belt represents the second one: extends south cracked Anatolia along the Dead Sea from the south to the Gulf of Suez, South Sinai, then the middle of the Red Sea, the great African, Yemen, Ethiopia. The departure of continental plates to the groove of the Red Sea Movement generates increasing pressure on the rims, multiple deep fault trends and contiguous with the Arab pallet (speed towards the north and northeast up between 4-5 cm per year) lead to the occurrence of earthquakes is being felt up less than 4 degrees for about on the Richter scale. Therefore, to ensure stability analysis "is carried out under static loading and dynamic loading" [4], in any case, inactive tremor area, quakes is one of the critical strengths that can bring failure of embankment and dams, "A slope becomes unstable when the shear stresses on a potential failure plane exceed the shearing resistance of the soil. The additional stresses due to earthquake further increase the stresses on these planes and decrease the factor of safety further" [4].

The Geo Studio software utilized F.E.M technique for finding the basic failure surface of the wide-ranging profile for slope fixity analysis. There have been inconsiderable endeavors to enhance the essential Newmark idea to record relocations "along with a non-planar surface" [4]. Developed multi-square model considering the impact of inner mishappenings and exchange of mass between progressive pieces. Changeless elimination of an incline subjected to element compel was additionally acquired utilizing limited component examination. Different methodologies utilized given FE strategy for the most part shifts "with the constitutive model"[4] embraced to display the conduct of soil. [5], [6] utilized the constitutive relationship, to view the behavior of soil. In this manner, in the vast majority of the techniques accessible for the dynamic investigation of slants, the significance is given for finding the dislodging of the incline as opposed to the variable of FOS.

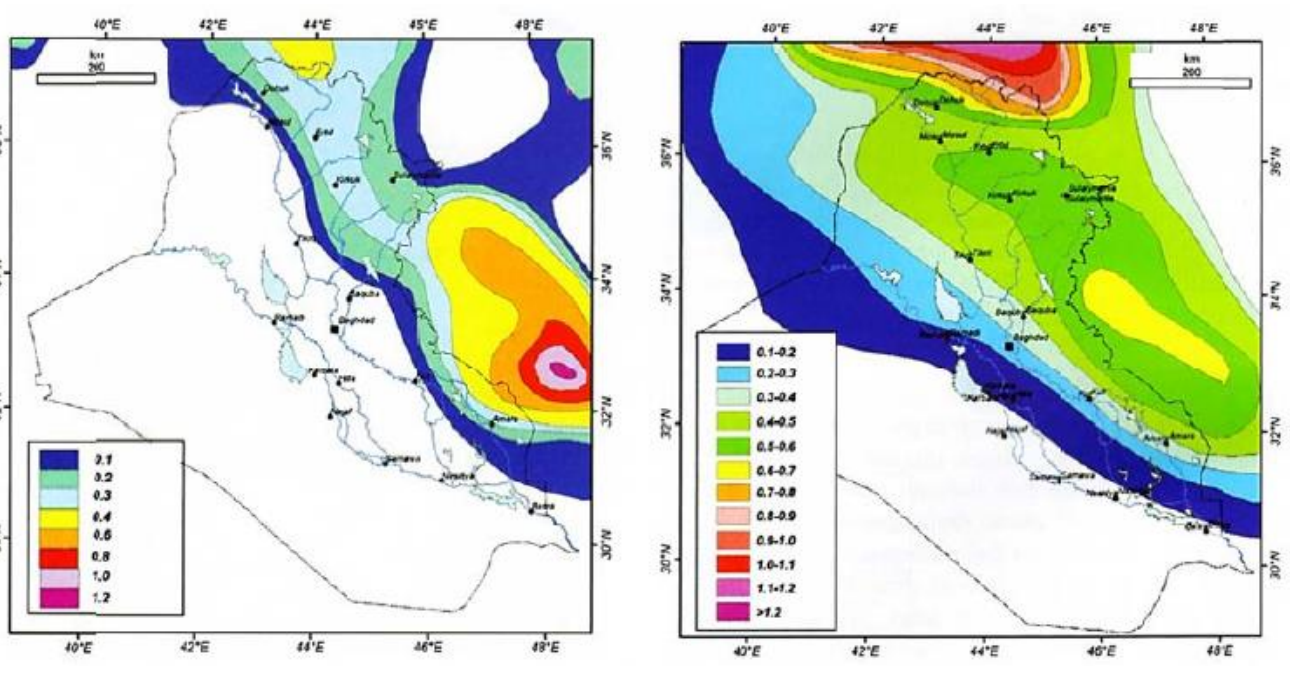


Figure 1. Earthquake acceleration record [2]

Two seismic belts can affect the site of the Dam the first one is seismic belt in the center of the Atlantic Ocean: stretching from the Maghreb as far north as Spain, Italy, Yugoslavia, Greece, Turkey and the north to the southeast of Zageors mountains

Despite the fact that the relocation of an incline is a necessary standard for the outline of a slant, it is likewise essential to cognize the element of the well being of a slant when the exhibit to element stack. Consequently, in the present review, a methodology to get the element of security and removal of an incline subjected to element load is created. The strategy can be utilized to determine the variable of well-being, uprooting and worries in soil at record-breaking interim from the earliest starting point to the end of the quake. In the intend to concentrate the component of security of an incline is acquired utilizing a blend of FE examination Newmark deformation techno.

K. Agrahara [4] used a circular surface to calculate the displacements along a slip surface. [7] "Developed multi-block model taking into account the effect of internal deformations and transfer of mass between successive blocks. Permanent displacement of a slope subjected to dynamic force was also obtained using finite element analysis".

"Importance is given for finding the displacement of the slope rather than the factor of safety. Even though the displacement of a slope is a very important criterion for the design of a slope, it is also important to know the factor of safety of a slope when subjected to a dynamic load" [8].

Method of Analysis

The investigation carried out according to the procedures mentioned by Maula et., al [9&10] combination Quake-Slope/w analysis to assessment FOS that ensues as a result of the inertial forces related to a seismic tremor. This category of examination is stated in a Newmark analysis amid a tremor. The dominate software programs in this study are "Quake- Slope" /w. The Quake/w is considered as "a finite element program for analyzing the effect of earthquakes on embankments and moderate inclines grounds. It figures the static, plus dynamic ground stresses at specified intervals during an earthquake. While Slope/w can utilize these stresses to dissect the stability variations during the quake and estimate the resulting" [9] subsequent lasting disfigurement. The validation of the software can comprise three sections as followed:

1- With Quake-Slope /w finding the primary factor of safety at initial stress.
2- With Quake-Slope /w multiple stage analysis for dynamic stresses.
3- Locating the critical liquefaction zones and finding lateral spreading and pore water pressure

Numerical Details of Benchmark Cases Studies

With the aim of exploring the influence of earthquake shaking load on the stability of slopes two benchmark case studies will be discussed in this research.

For benchmark No. 1, four cases, examples were used for comparison with the same shaking load that used different geometries ranged from simple to complex. To hold the investigation uncomplicated, only one level of pore water pressure (piezometric line) was used in this case. The geometry, strength parameters, shaking events, and unit weight of two-layer soil slope where shown in Figures 2and 3 and Table 1. The upper soil layer, cohesion c=50 kN/m2 represent 18, 15, 48 and 30%, respectively of the slope configuration for the four cases. The determination of this benchmark example is to figure the factor of safety under different shacking level . The slope is cut in two materials. The upper layer is 3m thick and the total height of the cut is 11 m. Slopes will be subjected to earthquake shaking according to the time seismic history record illustrated in Figure 3 with peak acceleration 0.1, 0.2, 0.3and 0.5 g and the duration is 10 Sec as represented in Figure 1 to simulate Iraqi map peak acceleration.

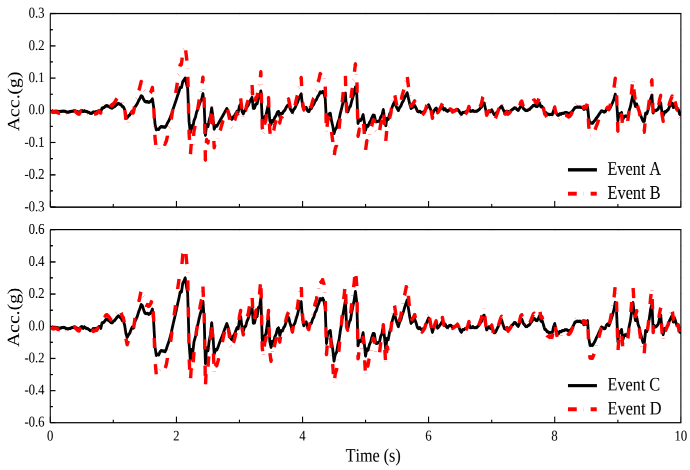


Figure 2. Earthquake time-history record [11]

The height of the slope is 11.0 m for all the four Cassese. The slope meshing is discretized using the 4&3 node of quadrilateral and triangular element of size 1.0m as shown in Figure 3. The upper layer for all case studies consists of a compacted sub base which simulates an earth-fill dam embankment that is lying on a soft clay soil as a foundation, soil strength parameters determined through the experimental work using (Triaxial) tests results are illustrated in table 1.

F.O.S of benchmark No.1 cases

Consideration in this prediction the behavior of the slope problem. "It is intuitively obvious that the earthquake inertial forces will pull the slope in both the up-slope direction and in the down – slope direction"[11]. The velocity and acceleration "vectors are not in the same direction at any instance in time; it is easy to visualize that the factor of safety will go up and down during shaking"[11]. Figure 4 evidence the alteration of a shaking events for stability of case 1 represented by the stress cyclic ratio with pore water pressure when the slope is under the quake acceleration of intensity 0.1, 0.3 and 0.5g. The results, indications that more pore water pressure present in the layer bases a major drop in Factor of safety as shown in Figure 5.

It can catch sight of the figure that the FOS of the slope converts with time. The dynamic factor of safety in case 4 and 3 is more than a dynamic factor for case1and 2 at the same time interval of the strongest events (C&D) whereas it is less than the dynamic factor of safety in case 1 and 2 at the lowest shaking records in the event A and B. The maximum fluctuation sags in the factor of safety take place at a time interval of 6 Sec. There is a good match between this result and that one obtained from [11] which pointed to the effect of soil boundary.

"It was clear that the vertical boundary has a significant effect on FOS for slopes resting on the weak layer"[11], however the cohesion has pronounced influence on liquefaction as FOS beyond the soil boundary (soil layer direction with respect to shaking motion), it was obvious that FOS sag is the identity for the all models when they issued to 0.5 g earthquake shaking as shown in Figure 5.

Table 1. Assumed Soil properties of the modeling benchmark

Soil location	C(kPa)	φ(º)	γ (kN/m^3)	μ
Upper soil	50	40	20	0.33
Lower soil	6	35	18	0.33

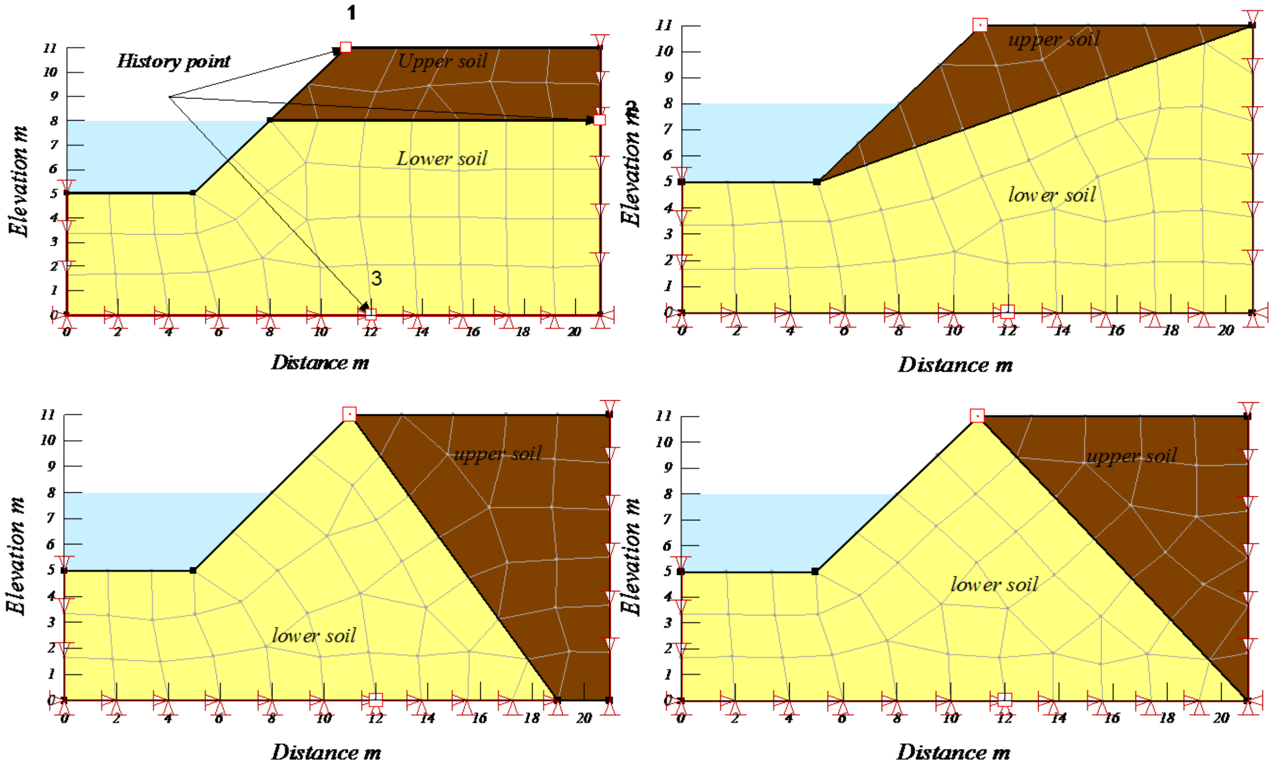


Figure 3. Geo Studio2007 FEM "Geometry and Meshing."

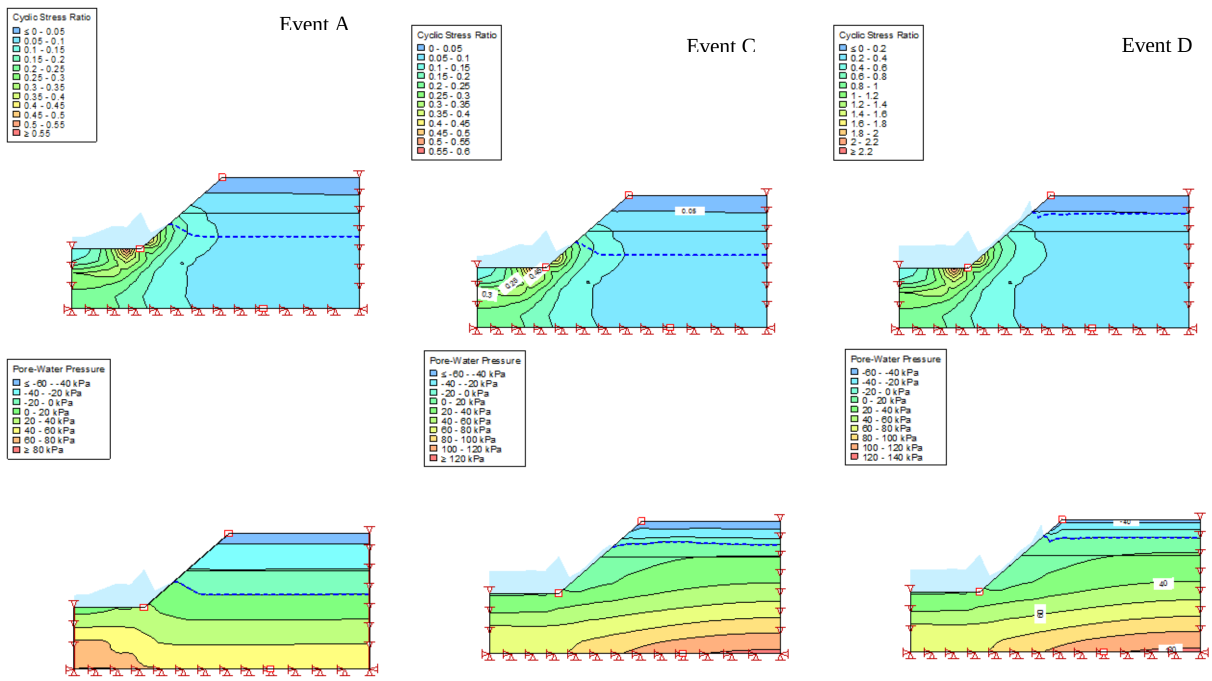


Figure 4. Effect of Shaking Events on Liquefaction Represented by Pore Water Pressure and CSR (Case 1)

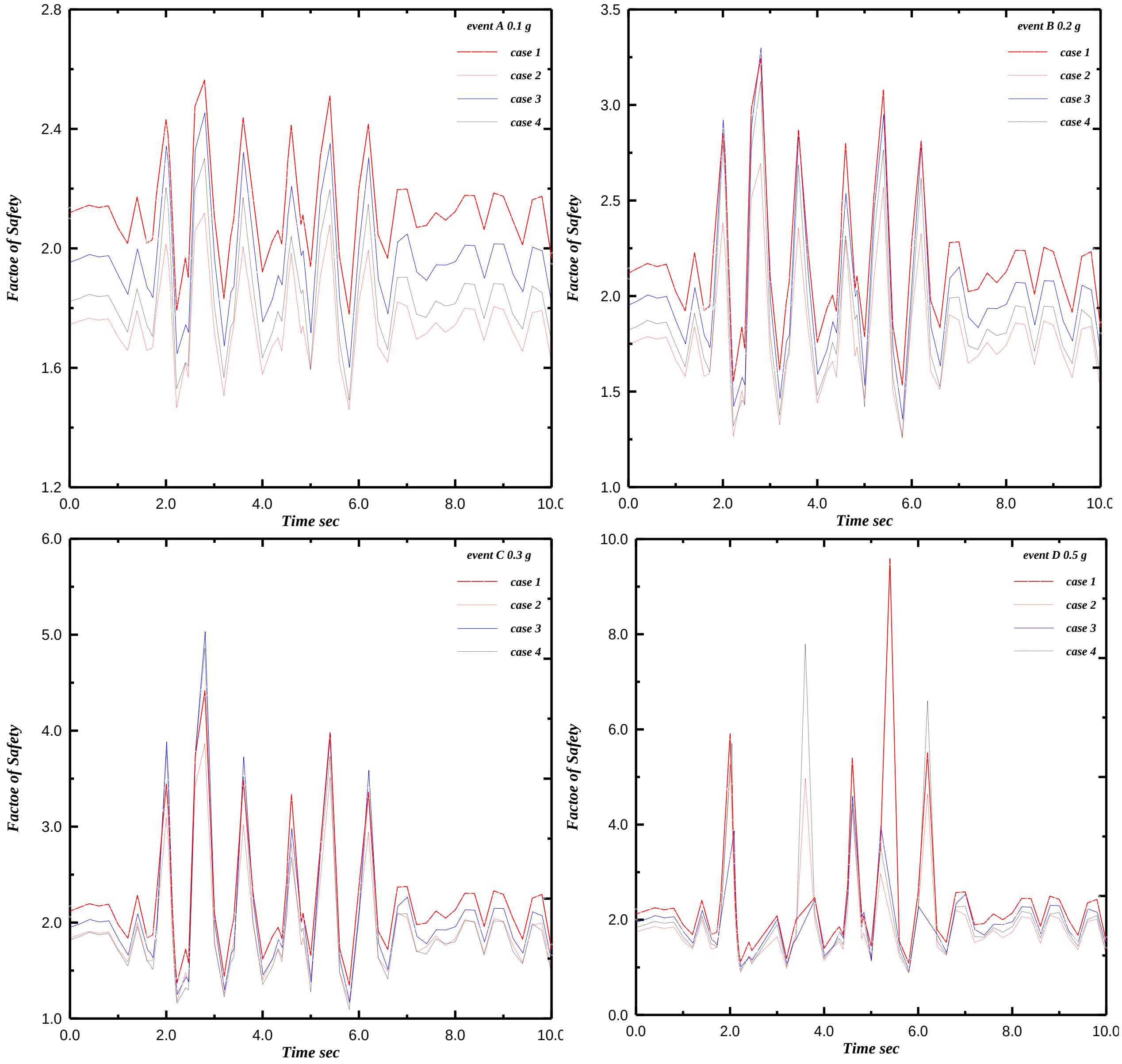


Figure 5. Factor of safety (FOS) time history for an Embankment subjected to earthquake shaking

Liquefaction Zones of cases of benchmark No.2

As well-known processors used to limit landings of the disparate body of the dam by injection Albetona on larger pumps in the depths of the foundation soil to increase soil resistance to the weight loads to the dam and other water forces pressing on the foundation layers.

Alternatively, by lowering the water level in the basin of the dam for about 319 m in total to reduce the water pressure on the foundation layers and the body of the dam. Alternatively, use an anther technique like the proposal to establish a body Betona unequivocally at the front of the dam to reduce the water pressure on the dam body size. The previous processors are not radical solutions to end the problem of the possible collapse of the dam, but solutions to stop the deterioration and the reduction of successive landings in the body of the dam and increase the resilience of the soil foundation of the weight loads and other aquatic powers. Iraq, especially in Mosul Dam, demands the establishment of artificial barriers (temporary) on sections downstream of dams to intercept the water mine (perhaps used by terrorists) are going with the stream of water and maybe hit the body of the dam and spoke a huge explosion might lead, for example, the collapse of the Mosul Dam.

To investigate the liquefaction phenomena, four examples were used for comparison between each other with different soil profiles with the same investigated geometries.

The geometry, strength parameters and unit weights of the non-homogeneous slope of the four examples was shown in Figure 6 and Table 2.

Figure 7 shows deformed mesh, with liquefaction zones for these examples due to earthquake recodes 0.5 g. The yellow shaded zones are where the pore water pressure has reached the maximum which is equal to the initial static effective confining stress. Example no.4 shows the lower values for liquefaction; giving the impression about the value of the friction angle is associated with the value of the shear coefficient known as cohesion. Figure 7-11 showing CRS ratio vs distance and the evolution of pore water pressure with distance during time of shaking.

Table 2: Soil properties for four examples used for Benchmark No.2

Example no.	Layer no.	$\gamma (kN/m^3)$	φ (°)	C (kPa)
1	1	17	20	15
	2	20	40	50
2	1	18.2	10	50
	2	21	38	0
3	1	20	40	50
	2	18.3	0	40
4	1	20	40	50
	2	18.3	50	40

There is a need to approximate values of shear parameters to control the liquefaction. The zone of a liquefaction is under up layers of the embankment in the foundation and near ground surface (case 1and 2) while the yellow shaded layer was noticed near the soil surface where the confining stress is very low (case 3 and 4) which can produce more stable and fixity. Three parameters are used to define the fluctuating state of the soil layer in these example tests, effective mean stress (p'), deviatoric stress(q) and specific volume(V). The soil of benchmark No.2 profile is frequently sheared and it will ultimately reach a critical state (CSS) in which further shear strains can arise without fluctuations in effective stresses or volume as revealed in Figure 8.

$$q / p' = M \tag{1}$$

Where: ***M*** is a constant for a particular soil

Earthquake shaking generates deformation, which leads the stress state to failure. Values of pore water pressure was shown in Figure 9 for the same tests plotted in Figure 6 and 7 Figure 8 specifies that the maximum records of pore water pressure was notice at the start of shearing, regians issues to more shear stress values demonstrated lesser pore water through quaking distortion. This datum specifies that the mobilized friction angle is practically has a vital influence regardless of shear stress levels and density of the soil layer. Figure 7 is the plot of volumetric strain associated with deformation mesh.

It can be seen that the volume alteration of soil profile throughout deformation is influenced by the density of the material.

Ingeneral, the behavior of sand in example no.3 swell more water which leads to dilate and display large shear deformation.

It's clear from the results example 2&3 can be considered as the worst cases subject to liquefaction effects due to the cohesion lowest values (c=0 for foundation layer (example 2) and φ=0 for lower layer (example no. 3)), while the results show less influenced by liquefaction for example 1& 4 due to highest values of cohesion for the lower layer in the same time it can concluded that there is a relation between friction and cohesion during quake, the CSR eq contour lines appeared in liquefaction zones in example no.3 more than that one notice in example 1&4 ; this behavior repeated largely for example 2 due to lowest values of friction and due to soil properties of the lower layer which consider as a saturated sandy soil.

The results confirmation that the constancy of slope layer increases with an increase in cohesion (c) and internal friction angle(φ). Though, more pore water pressure extant in the soil layer bases a major deformation in both x-y directions. In addition, the increase in unit weight (γ) of soil layer creates lower volumetric strain as shown in Figure 7.

Remarking that a linear relationship exists between these three parameters, it is observed that when lowering the pore water pressure from the upper soil layer, the shear strength of the soil increases.

From the finite element calculations, it is found that the four parameters studied have significant influence on the slope stability problem.

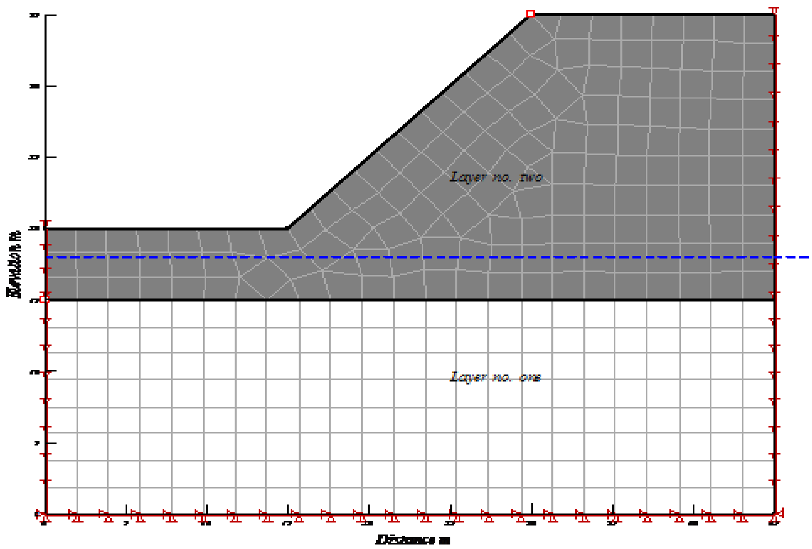


Figure 6. Geometry of slope for Benchmark No.2

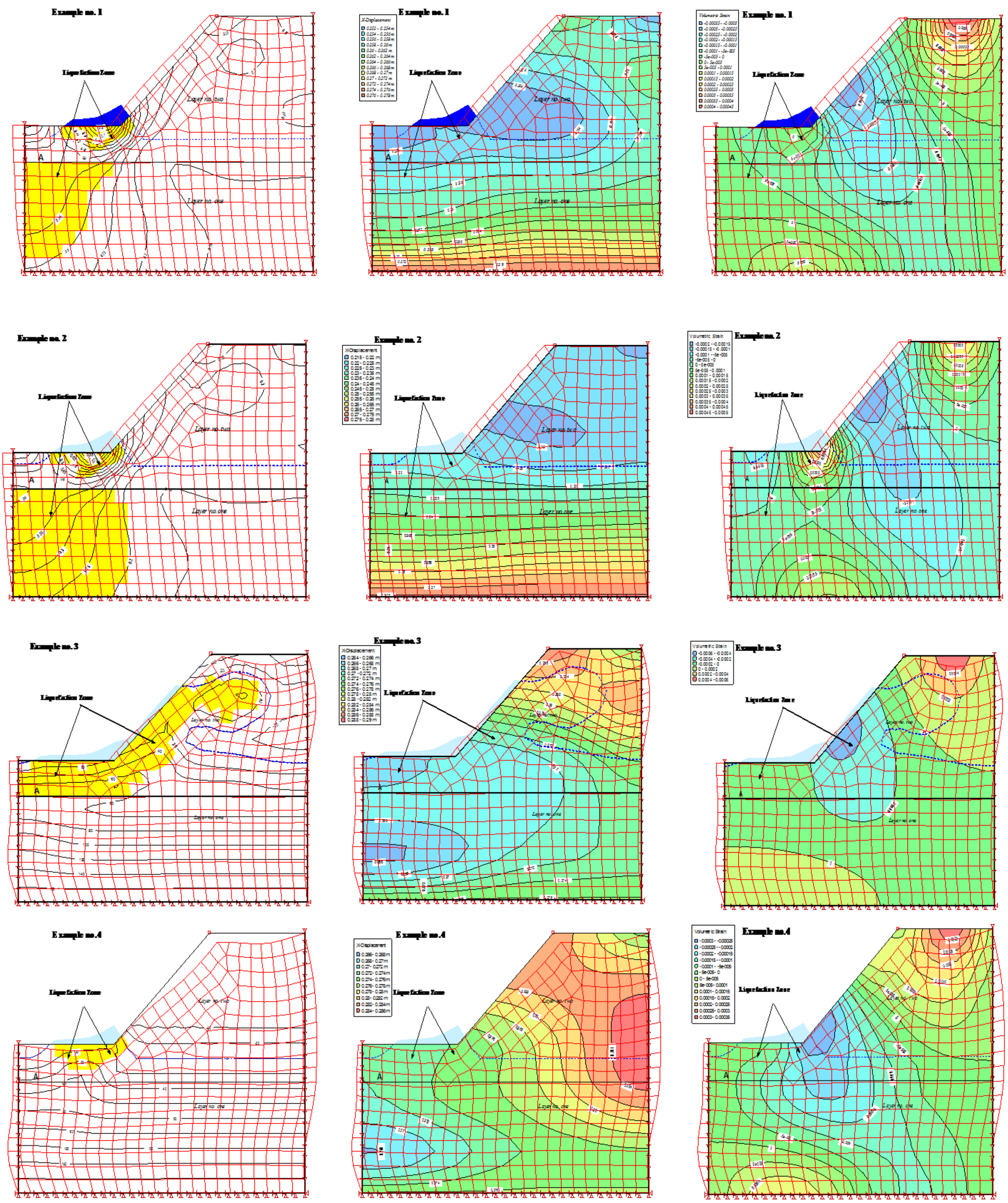


Figure 7. Liquefaction Zone as (CSR/eq) and deformed mesh, counters in finite element method due to earthquake

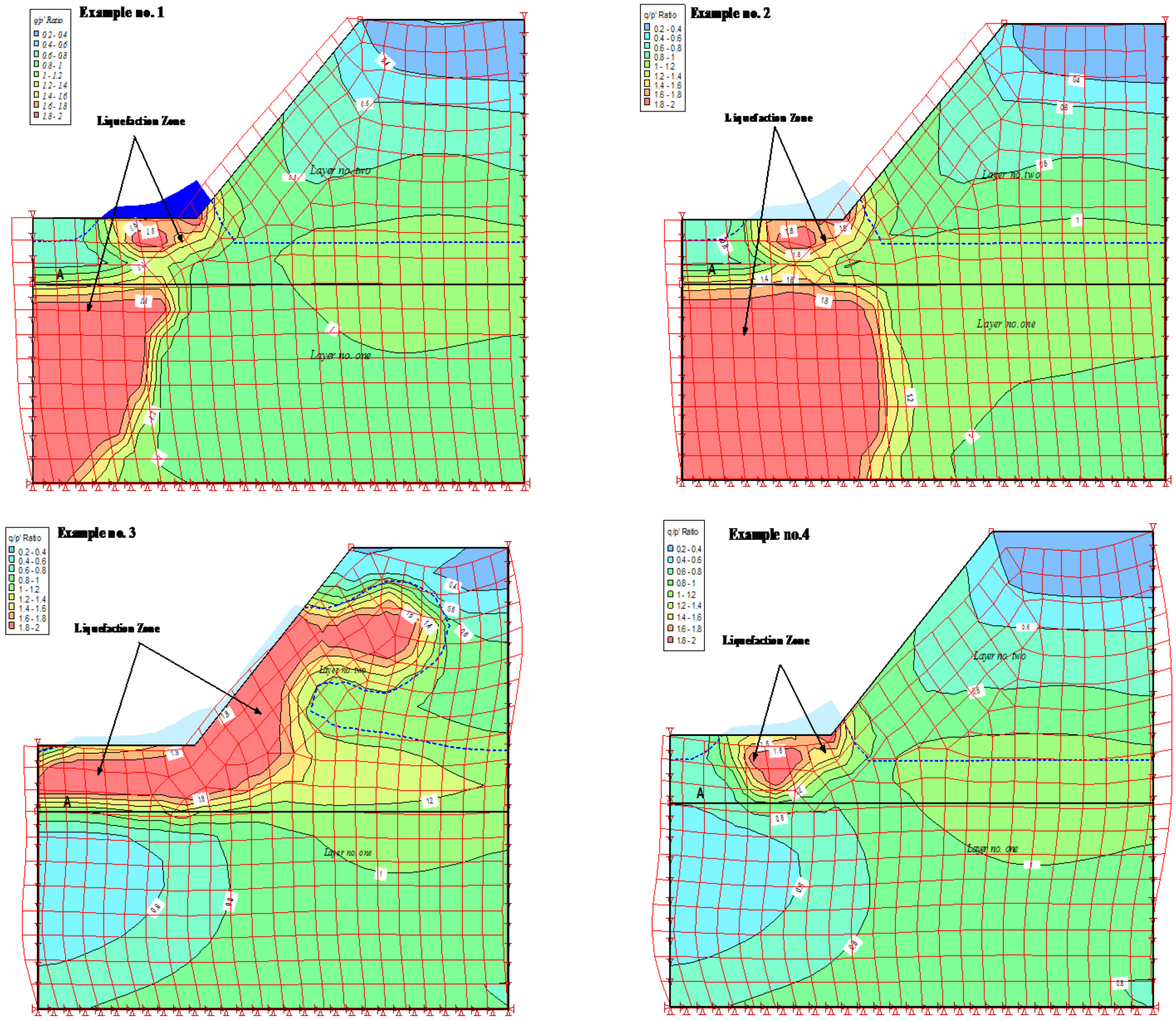


Figure 8. Prediction of Critical State as q/p' ratio

Aimed at further research on the shear stress-strain manners the Geo-studio 2007 program based on finite element method. The displacement in both horizontal and vertical directions (x-y) by finite element software, the maximum displacement in x-direction is detected on lower layer for example no.1&2, while its show minimum values in lower layer for example no. 3&4 respectively. This fact related with the influence of $\mathbf{q / p'}$ ratio to describe the zones of critical state as shown in Figure 8.

In contray the upper layer gain the hieghest values for vertical displacement at example no.1&2, whereis in example no.3 &4 the highest values occurred in lower layer as a result of pore water pressure increasments see Figure 9. The genrate of highest pore water pressure was located at the lower layer in example no.3 which is commonly consider as a saturated unliquefied soil that will lost its strength and is converted into a heavy fluid condition during earthquake.

Ingenral there is an adverse relationships concerning displacement and the depth of embankment(upper layer) and

subsoil layer (lower layer), besides the sensitive zones in the toe of embankment and adjacent to that, which can be reflect the zones of liquefaction.

Figure 10 shown the shear stress as deviatoric strees (q) and shear strain in x&y direction from Geo-studio2007 software in the lower layer. From the Figure, it's easy to detect the lowest deformation for both directions as illustrated in Figure10(a)**.** From the behavior of the layer it is assumed that minimum shear strain is in the dense zone. Measurments of Shear strain in x-y direction shows its peaks values in example 3&4 along $\gamma \approx 18.3$ kN/m^3 see Table 2. Results in Figure 10(b),(c) show that the strain required to liquefy sands is considerably smaller than the strain required to overcome the peak strength of cohesive soils

Figure 9-10 shows that there is a negative correlation between pore water pressure buildup in the soil skeleton with lower layer density and horizontal and vertical distance (depth).

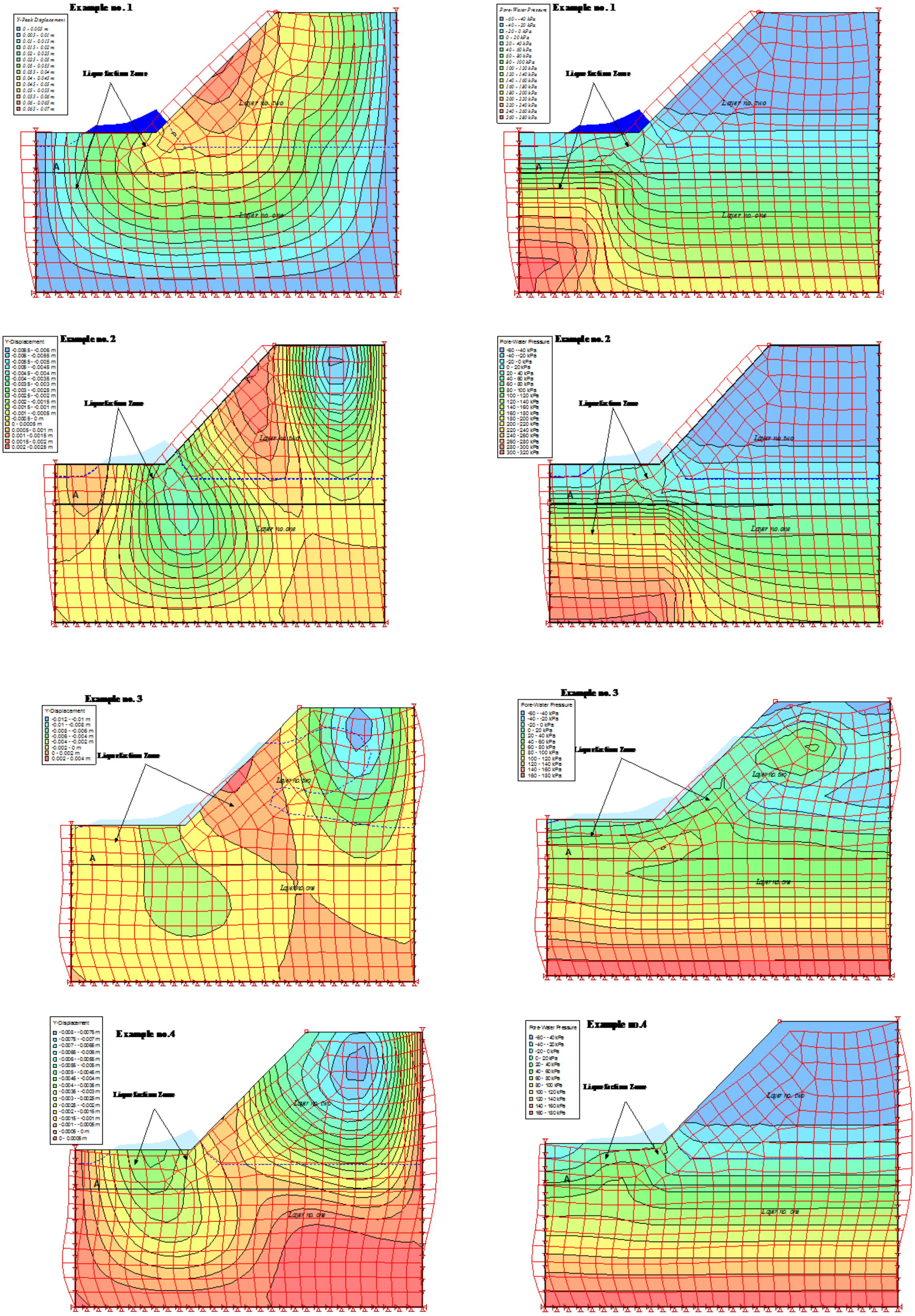
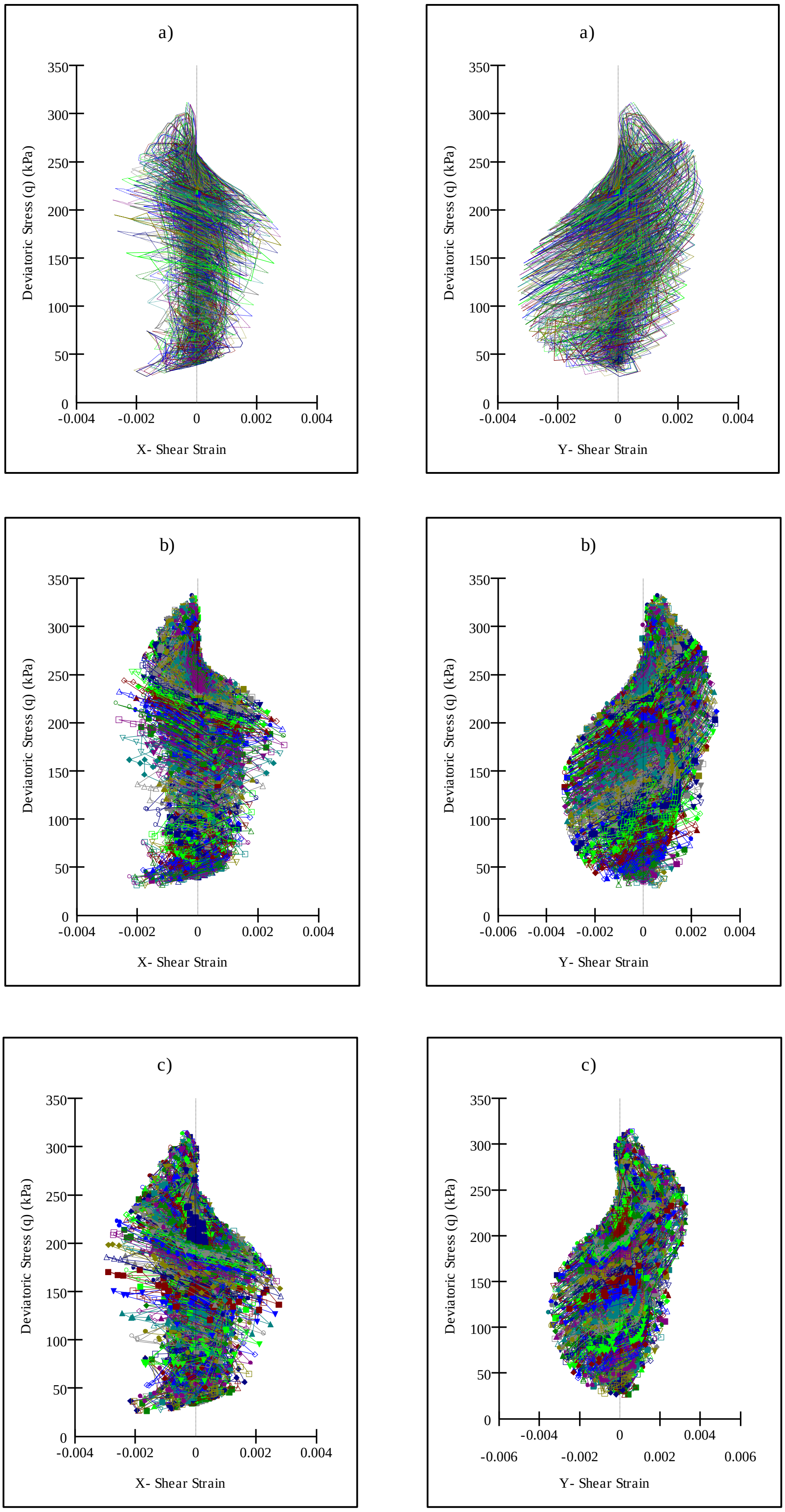


Figure 9. Evaluation of Pore water pressure vs. Distance (m)


a)
Deviatoric Stress (q) (kPa)
X- Shear Strain
a)
Deviatoric Stress (q) (kPa)
Y- Shear Strain
b)
Deviatoric Stress (q) (kPa)
X- Shear Strain
b)
Deviatoric Stress (q) (kPa)
Y- Shear Strain
c)
Deviatoric Stress (q) (kPa)
X- Shear Strain
c)
Deviatoric Stress (q) (kPa)
Y- Shear Strain

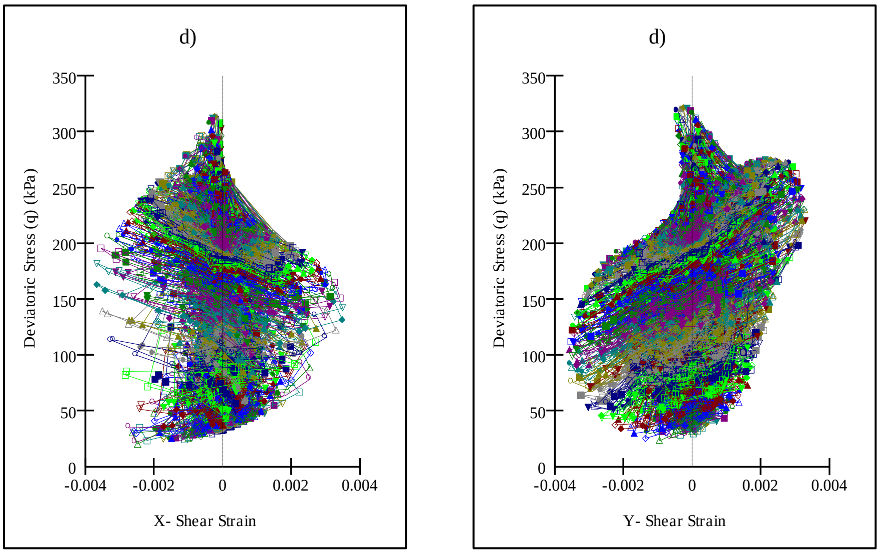


Figure 10. Stress Strain History in the lower layer Below Embankment

For more investigation cyclic strees ratio verse depth was shown in Figure 11, all gained results exposs the same manner started with 0.1 to 0.4 at till depth of 15 m (interference line) then it will increase till the depth of 20m which represent the ground suface of the embankment.

"All examples have the same cycle stress ratio peak generated by earthquake motion (CSReq) about 0.8 - 0.9"[8] near the ground level. The factor of safety for level ground resistance has been calculated as "F.S. = CSR liq / CSR eq where CSR liq is the cyclic stress ratio required to generate liquefaction" [12].

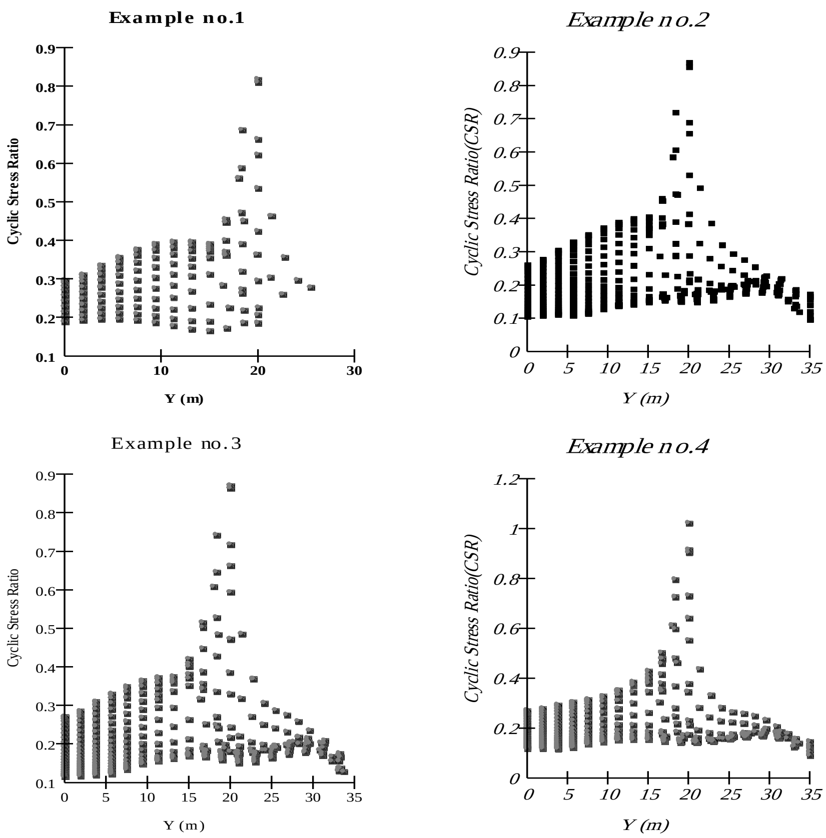


Figure 11. Evaluations of CRS ratios vs. Vertical Distance (m)

Conclusions

Soil profile of the consideration benchmark case studies slopes varies from losing, medium to the dense sandy soil. It can see that liquefaction-induced lateral spreading displacement due to the prone of pore water generation; surface displacement proceeds downslope, or stream bank especially; softening, and liquefaction during an earthquake. The obtained results show and indicate that liquefaction takes place in the horizontal - lateral spread in several meters more than in the vertical direction (with in depth) so the lateral spread can be noticed in the first 5 m of the ground level surface. For all soil profiles, soil profile and its layer thickness' have a significant effect on liquefaction. In example no.1 results of increasing pore water pressure from 120 to 236 MPa. Moreover, it is about 50%, rising in pore pressure, this case investigated slope of thin dense to thick medium sand layer. Example no.2 results of increasing pore water pressure from 176 to 300 MPa and about 78%, increasing in pore water pressure, this case investigated slope of thin dense with thick lose a sand layer. Example no.3, and example no.4 results of increasing pore water pressure from 176 to 180 MPa and about 2.3 % increasing in pore water pressure.

These examples investigated slope of thin lose to thick, dense and thin and thick dense sand layer respectively. From these examples, we can get the effect of thin, loose soil to rest on thick, dense sand layer have the same increasing in pore water pressure, which can eliminate ground improvement by compaction for long distance because it is not economical.

There is a possibility Mosul dam area can be hit with the vulnerability of the earthquake measuring between (5-6) on the Richter scale, which is sponsored to make dam collapse completely besides to the dam suffers from varying settlements as a result of the weakness of the soil foundation resistance and its fragile cohesion due to the injection by Albetona which is useless. Therefore, individual decisions to launch massive amounts of water from reservoirs for the production of hydroelectric power, which deliberately to water authorities in the northern region, could lead to shine a double pressure on the body of the dam, causing its collapse. Numerical investigation based on gypsum soil is highly recommended to predict soil behavior of dam Mosul foundation.

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