Indian Journal of Science and Technology, *Vol 8(S9), 62-66, May 2015*
ISSN (Print) : 0974-6846
ISSN (Online) : 0974-5645
DOI: 10.17485/ijst/2015/v8iS9/68555

Using GIS Software for Identification and Zoning of the Areas Prone to Liquefaction in the Bed Soil of the Dams

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Abstract

One of the processing seismic geotechnical problems of the researchers and the expert engineers is the liquefaction in the uncompressed saturation soil seed which could highly harm the engineering surface and underground structures. The main goal in this research is to use GIS software for identification and zoning of the areas prone to liquefaction in the bed soil of the dams. In this research the data of Nazlou dam in Urmia are used. When the liquefaction potential (PL) is evaluated via different methods, the zoning plan of risk intensity of the liquefaction of the soils was produced using GIS software. The results show that the use of GIS software for zoning of the areas prone to liquefaction in the bed soil of the dams is appropriate. Geotechnical engineers are able to preparation the zoning GIS map with desired method and to optimize the bed soil of that part in any depth and bore using the different existing methods in this field with more accuracy which finally leads to the increase of the security of the dam and decrease of the construction costs.

Keywords: Arc GIS, Evaluation, Liquefaction Potential, Nazlou Dam, Soil Treatment.

1. Introduction

The increase in the pore water pressure in the sandy soils and the loose saturated layers at the time of earthquake which happens because of the tendency of the soil to lose volume, leads to decrease of the comprehensive tension of the soil. In this status the shear strength of the soil decreases and tends to zero which is called liquefaction. This happening is seen as the considerable subsidence, cracks, and openings, boiling sand and leakage of the water from the pores of the earth surface[1]. The strength of the earthquake and its lasting time, high water table, fine grained percent and the soil paste sign, porosity and relative track and shear stress on the soil at the time of earthquake are of the effective factors in liquefaction[2]. The liquefaction resistance of the soils could be defined by different laboratorial tests like cyclic simple shear, cyclic triaxial, periodic complex cutting and field methods like standard Penetration Resistance Test (SPT), Cone Penetration Resistance method (CPT) and Shear wave velocity measurements (Vs)[3]. In this research the GIS software is used to produce zoning plans of the areas prone to liquefaction of the beds of the dams.

2. General Conditions and Soil Layering

First some bores are dug in the under study area and then different tests take place in them the most important of which is standard penetration resistance test (SPT). The more the number of the bores and the tests, the more valid the data accessed[4]. The plan of the location of the bores of the Nazlou dam is shown in Figure 1. In this research in

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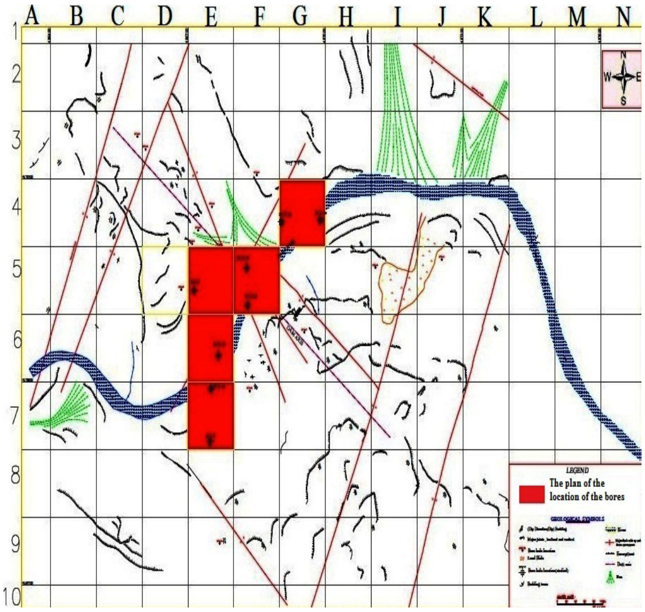

Figure 1. The plan of the location of the bores[7].

Nazlou dam, totally 69 layers are evaluated in 24 of which silty sand oil (SM), in 20 of which silty gravel (GM), in 5 of which clay-silty gravel (GM-GC), in 4 of which well graded gravel and silty gravel (GW-GM), in 4 of which bad graded gravel and silty gravel (GP-GM), in 3 of which bell graded gravel (GW), in 2 of which clay gravel, in 2 of which well graded gravel and silty gravel (SW-SM), in 2 of which silty gravel and clay gravel (SC-SM), in 1 of which silty sand and bad graded gravel (SP-SM), in 1 of which bad graded gravel (GP) and 1 of which clay (ML) are found[5–7].

3. The Analysis of the Bores to Evaluate the Liquefaction Potential

3.1 Seismicity Study Area

The site of the Nazlou dam is located in geological Albors state of Azarbaijan. The under study area is the 300 km diamond of the site which is located in seismotectonic Van state from seismotectonic point of view and follows the seismotectonic specifications. The most important earthquake in the 100 km range of the site is the one of 1930 in Salmas with MS=7.2 strength which was located in 66 km north far of the site[8]. Also other strong and weak earthquakes are studied. According to the calculations related to identification of the return period of the earthquakes which happened separately in three 100, 150 and 200 km diamond range and also the seismotectonic Van state, the analysis of the risk of the earthquake to estimate the strong movement acceleration of the earth took place according to the different models and applying the possible and deterministic methods according to the Table 1. One of the important cases of acceleration rate in evaluation of the potential of the liquefaction of the soils is the earthquake, the value of which could be

Table 1. The final values of the maximum of the strong movement of the earth for different seismic design levels[4,7].

Dam site		maximum values of the strong movement of the earth	
Seismic designing level		Horizontal element	Vertical element
CL		0.108	0.062
DBL		0.220	0.150
MDL	2000 years return period	0.309	0.226
MCL (Urmia line)	2000 years return period	0.535	0.403

presented according to the analysis methods of probable seismic risk and deterministic one for the horizontal and vertical elements according to the Table 1. In this research and for the probable method, vertical element of acceleration is assumed 0.226, strength is assumed 6.2, and for the horizontal element of the acceleration 0.309 g is assumed, the strength is assumed 7.1 and for the deterministic method for the vertical and horizontal element the 0.403 g and 0.535g acceleration and the 7.5 strength is assumed (ICOLD, 1986-1989).

3.2 Evaluation of the Potential of the Liquefaction of the Soils via Different Methods

To evaluate the liquefaction of the soils it is possible to use different laboratorial methods like cyclic simple shear, cyclic triaxial, periodic complex cutting, and field methods like standard penetration resistance test (SPT), cone penetration resistance method (CPT), shear wave velocity measurements (Vs)[3]. Three parameters named Cyclic Stress Rate (CSR), Cyclic Resistance Rate (CRR) and confidence factor against liquefaction of the soil (FS) and liquefaction index (PL) must be identified.

The risk rate of any area which changes between 0 and 100 according to PL values could be defined by the Table 2[8].

4. Result

4.1 Zoning

When the liquefaction potential index PL is calculated according to the accelerations of Table 1, the under study area is zoned by ARC GIS software and according to data of Table 4 which includes the name and location of the bore and the total liquefaction potential index. It is necessary to note that the strength of zoning in kriging method

Table 2. Identifying the risk rate of liquefaction according to the liquefaction index PL[4].

PL	The liquefaction risk and the needed arrangements
PL=0	Liquefaction risk is very low and no research and study is needed
0<PL<5	Liquefaction risk is low but there is need for research and study for the important structures
5<PL<15	Liquefaction risk is high. There is need for research and study for any kind of structure. It is necessary to use the methods of decreasing the risks of liquefaction.
PL>15	Liquefaction risk is very high. There is need for research and study for any kind of structure. It is necessary to use the methods of decreasing the risks of liquefaction.

Table 3. The colors of the liquefaction risk rate[7]

Liquefaction potential index	Color	The liquefaction risk rate according to different PLs
PL=0	Green	Very low liquefaction risk (there is no)
0<PL<5	Blue	Low liquefaction risk
5<PL<15	Yellow	High liquefaction risk
PL>15	Red	Very high liquefaction risk

Table 4. The input data to the ARC GIS 9.3 software[7].

Bore name	PL according to acceleration A_{Hmax}=0/309 g	PL according to acceleration A_{Vmax}=0/226 g	PL according to acceleration A_{Hmax}=0/535 g	PL according to acceleration A_{Vmax}=0/403 g
NCH4	5.4	0	19	10.6
NCH5	10.1	5.8	25	18.4
NCH20	0.4	0	5.4	1.5
NCH19	2.4	2.7	27.3	17.4
NCH15	14.5	9.6	23.1	18.4
NCH16	4	0.8	13.2	8.1
NCH17	14.7	5.2	27.2	21.4
NAG2	6.4	0	29.5	18.5

is more than other methods. The software divides the area into 5 parts in different colors according to the input data and the settings of it. Then according to the settings of Legend part and according to the Table 1 and following the Table 3, important categorization of the total status of the whole area from liquefaction risk point in different accelerations is presented in the plan guide part. Then the software calculates the surface of any part and the plans of the Figures 2 to 4 are presented[7–9].

According to the above figures, it is possible to conclude that when the PL rate increases, more surface of the soil bed of the dam is affected. These plans are produced for the total length of any bore.

Now it is possible to use this method for any favored depth in bore length and get more accurate look in that depth.

5. Conclusion

Generally according to the accessed data in the under study area and the zoning plans which are produced from these data, a general look is provided from the liq-

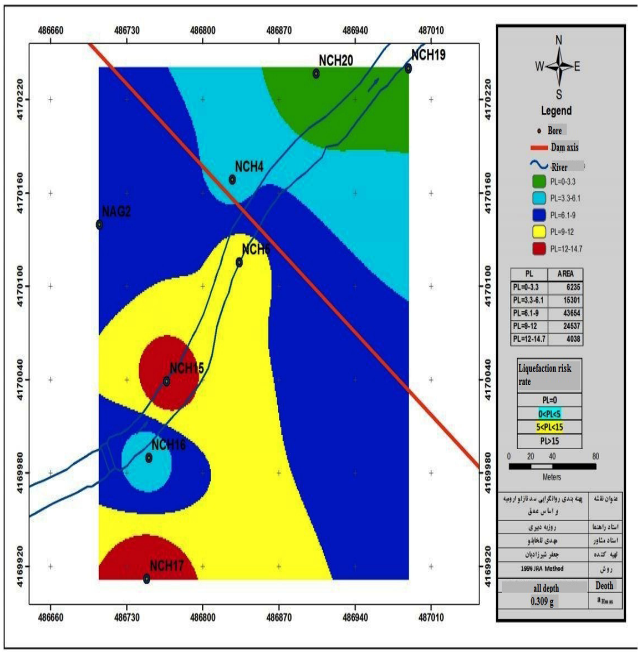

Figure 2. Image of the zoning plan of the liquefaction of Nazlou dam according to depth- Japan superhighways bridges method 1996- horizontal acceleration aH_{max}=0.309g (probable method)[6,7].

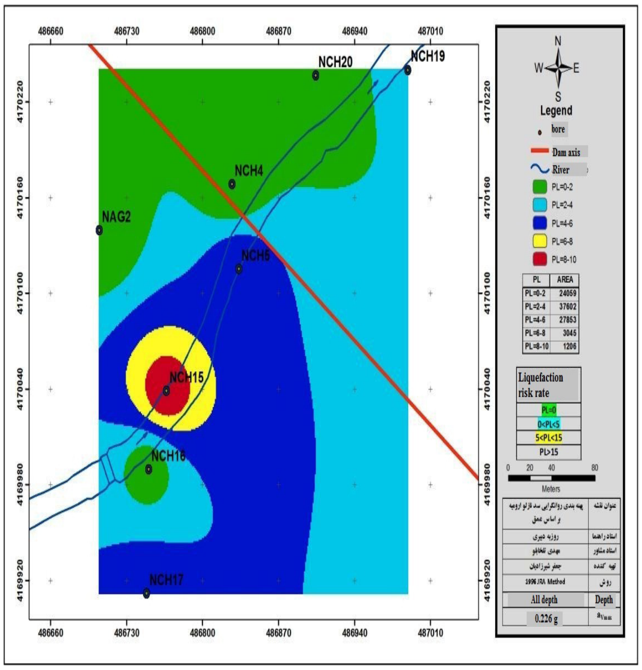

Figure 3. Image of the zoning plan of the liquefaction of Nazlou dam according to depth- Japan superhighways bridges method 1996- horizontal acceleration aV_{max}=0.226g (probable method)[6,7].

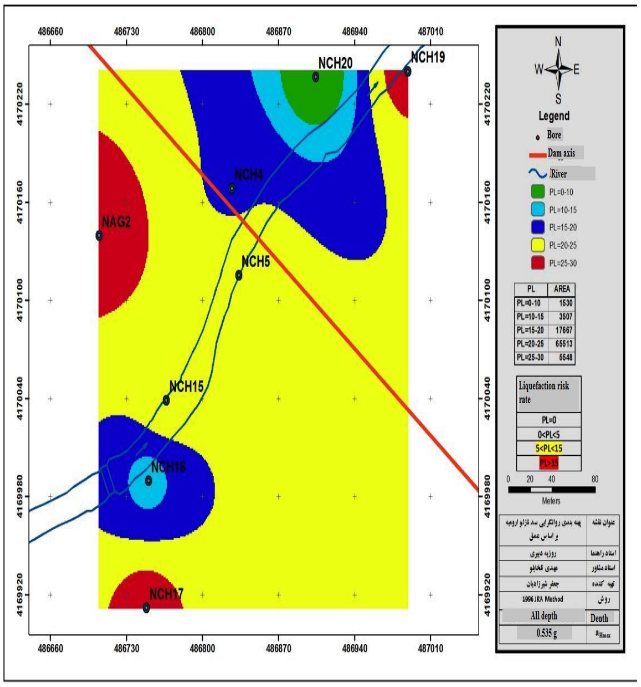

Figure 4. Image of the zoning plan of the liquefaction of Nazlou dam according to depth - Japan superhighways bridges method 1996 - horizontal acceleration aH_{max} = 0.535g (deterministic method)[6,7].

uefaction status of the soil layers in different depths. The results show that the use of GIS software for zoning of the areas prone to liquefaction in the bed soil of the dams is appropriate. Now Geotechnical engineers are able to preparation the zoning GIS map with desired method and to optimize the bed soil of that part in any depth and bore using the different existing methods in this field with more accuracy which finally leads to the increase of the security of the dam and decrease of the construction costs.

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