Iraqi Journal of Science, 2018, Vol. 59, No.2A, pp: 676-686
DOI:10.24996/ijs.2018.59.2A.6

ISSN: 0067-2904

Zonation liquefaction hazard assessment by GIS and Geotechnical data in southern coasts of the Caspian Sea (Beach Amirabad)

Hamed Barimani*[1], Fatemeh Yazdi[2]
[1]PhD of Civil Engineering, Payame Noor University, Tehran, Iran.
[2]Islamic Azad University of Ayatollah Amoli, Amol, Iran.

Abstract

Investigation of geotechnical vulnerability (liquefaction) and Zonation of the southern region of the Caspian Sea is my most important aim in terms of destructive earthquakes hazard potential. Past geologic events on the south coast of Caspian Sea indicates that destructive earthquakes lead to the death of numbers in this area. Remained evidence of seismic events happening indicates extensive landslides, liquefaction and soil subsidence in the residential and even natural area. Therefore, in this study determination of geotechnical vulnerability (liquefaction) intensity in southern coast of Caspian Sea against natural forces resulting from earthquakes and coastal construction via geographical information system environment (GIS) is considered as the research most important purposes. Therefore, seismic and consequence natural phenomena hazards potential are high in Southern Caspian region. The results of this study indicate that in terms of performance of instability factors such as: storm waves, sedimentary material subsidence and slide, coastal sand liquefaction, the southern part of the Caspian Sea coastal areas and sea bed sections are so vulnerable. So my aim of this study at first is to illustrate the variety of methodologies currently in use for preparation of seismic hazard maps and to evaluate basic principles of zonation for different purposes and at different scales. Guidelines and recommendations for seismic microzonation should be incorporated into seismic regulations. Indeed, by its results susceptible of risk area are determined and high risks areas are identified in terms of occurrence of geotechnical processes such as liquefaction by this recommendations many researchers apply this methods for seismic-geotechnical hazard zonation in three grade.

Keywords: GIS, Zonation, Liquefaction, Hazard, Geotechnical data, Coast.

التصنيف النطاقي لمخاطر تسيل التربة باستخدام نظم المعلومات الجغرافية (GIS) و بيانات جيوتقنية في الجزء الجنوبي من شواطئ بحر قزوين (ميناء امير اباد)

الخلاصة

يهدف هذا البحث إلى دراسة اللاستقرارية الجيوتقنية (تسيل التربة) والتصنيف النطاقي لشواطئ بحر قزوين الجنوبية بسبب الزلزال. تشير الأحداث الجيولوجية في هذه المنطقة إلى امكانية حدوث الزلزال والعديد من الخسائر المادية و المعنوية فيها. الآثار المتبقية من أحداث الزلزال تميط اللثام عن شدة الانزلقات الأرضية و ظاهرة تسيل التربة في المناطق الطبيعية للجزء الجنوبي من ساحل بحر قزوين. فاتجه البحث إلى تحديد الأضرار الجيوتقنية الناجمة عن الزلزال إزاء القوى الطبيعية وفقا لنظم المعلومات الجغرافية .(GIS) و يبدو ان هذه المنطقة تخضع للزلازل و التحركات الطبيعية الناتجة لها. أظهرت نتائج هذه الدراسة أنّ هناك

*Email: hamed_barimani@yahoo.com

عدة عوامل تكمن وراء الوضع اللاستقراري الجيوتقني في هذه المنطقة كالامواج المؤلفة من العواصف و نوعية رواسب طبقة الأرض التحتانية والانزلاقات الترابية وظاهرة تسيل الرمال الموجودة في الشاطئ و سطوح بحر قزوين على السواء. فقمنا بترسيم خريطة لمخاطرها الإقليمية و تمهيد خطط أساسية لها و وتصنيف أراضيها لأغراض مختلفة و فى مقاييس مختلفة.و يجب أن تحظى الارشادات و التوصيات فى تصنيف هذه الأراضي بالأهمية الفائقة لرصد الزلازل و احتواء المخاطر النابعة منها. و هذا الاحتواء يحتاج إلى عملية تحديد النواحي الأكثر إمكانية لوقوع الهزات الأرضية و المخاطر الناتجة للوضع اللااستقراري فيها و التي تشتمل على ظاهرة تسيل التربة .

Introduction

The assessment of geotechnical vulnerability of the southern region of the Caspian Sea is considered as the most important research issues in terms of destructive earthquakes hazard potential, sea water rapid fluctuations effects and human factors. Past geologic events on the south coast of Caspian Sea indicates that destructive earthquakes lead to the death of a number of coastal provinces (Golestan, Mazandaran and Gilan) residents .the most important earthquake happened in June 1990 in Manjil in Gilan province [1]. Remained evidence of seismic events happening indicates extensive landslides, liquefaction and soil subsidence in the residential and even natural area. Therefore, seismic and consequence natural phenomena hazards potential are high in Southern Caspian region. Vast parts of dry beach will submerge and face to damages because of small changes in sea water level. Human constructions along with mentioned factors in the area face to coastline and in shoreline boundary limit increases coastal Soil Geotechnical vulnerability (liquefaction) [2]. And concentrate erosive forces procedures in dry section of coast. It is worth mentioning that the oldest studies on natural hazards and vulnerability have done by D, Applonia, American Company in 1974 that include comprehensive study on sea bed geologic hazards in southern Caspian Sea region. The results of this study indicate that in terms of performance of instability factors such as: storm waves, Mudvolcans, shallow gases, sedimentary material subsidence and slide, coastal sand liquefaction, the southern part of the Caspian Sea coastal areas and sea bed sections are so vulnerable [3]. Moreover it was shown that the southern part of Caspian Sea is very active in terms of regional seismicity tectonic. Therefore, in this study determination of geotechnical vulnerability (liquefaction) intensity in southern coast of Caspian Sea against natural forces resulting from earthquakes and coastal construction via geographical information system environment (GIS) is considered as the research most important purposes. So the aim of the present study was to illustrate the variety of methodologies currently in use for preparation of seismic hazard maps and to evaluate basic principles of zonation for different purposes and at different scales. And next part of this study is an overview of various methodologies for seismic-geotechnical hazard zonation that conform to the recommendations of International Society for Soil Mechanics and Geotechnical Engineering [4]. In this study, input data for seismic microzonation are discussed. Promulgated seismic regulations are a prerequisite for delineation of seismic hazard zones. Guidelines and recommendations for seismic microzonation should be incorporated into seismic regulations. Indeed, by its results susceptible of risk area are determined and high risks areas are identified in terms of occurrence of geotechnical processes such as liquefaction by this recommendations many researchers apply this methods for seismic-geotechnical hazard zonation in three grade [5].

Generally investigation about the nature of coastal sediments in the southern coasts of Caspian Sea confirms sedimentary profiles with destructive origins and mentioned coasts in term of sediment variety are categorized to: Fine to medium-grained sand, Sand coasts with coarse-grained gravel components, Sand coast containing large gravel particles, Clay and mud flats [6]. The most important morphodynamical features in the southern coasts of Caspian Sea contains: (Erosive terraces, Erosive crescent line, Sand spits, Sedimentary stratification and Beach Cusps) [7]. So all documents evaluation show that the study area is vital region considering tectonic mobility and earthquake risk is high degree in the southern coasts of the Caspian Sea. Therefore sediments geotechnical instability and vulnerability condition of Coastal area will be increase with this natural forces. Also human activities could be change the structure of the coastal area as parallel and in the some erosive parts they cause [8].

Conducted research objectives

The main aim of this research is beach geotechnical vulnerability hazard assessment in the east

part of southern coasts of the Caspian Sea, Include following objectives:
1. Study of geotechnical vulnerability of the southern region of the Caspian Sea
1-1 Determine earthquakes hazard potential
1-2 Determine High risk area associated to seismic hazard (liquefaction) assessment by GIS in area study
1. Classification of the southern coasts of the Caspian Sea in terms of sediment composition and soil mechanic properties in area study
2. Investigation liquefaction hazard and comparison exist procedure for identify liquefaction potential in case study (Amir abad beach)
3. Determine universal ranking model of geotechnical hazard vulnerability
4. Investigation two important factors in geotechnical instability hazard (liquefaction) such as hazard potential (Side effect) and mobility from earthquake and faults and their correlate in area study
5. Investigation two principal approaches of earthquake loss mitigation; first, land use management and second, the design and construction of individual buildings.

General description of Study area and case study

Study areas are southern coasts of Caspian Sea and case study located at the west of study area (Amir abad beach)

The Caspian Sea as the largest lake in the world is very important from natural and socio-economical point of view. Caspian Sea has north-south direction, its length is about 1204 km and its width is 204 km, which exceptionally reaches up to 566 km in front of the Apsheroun peninsula [9]. This lake is located between 47°/13/00″ and 36°/34/35″ north longitude and 46°/38/39″ and 54°/44/19″ east altitude.

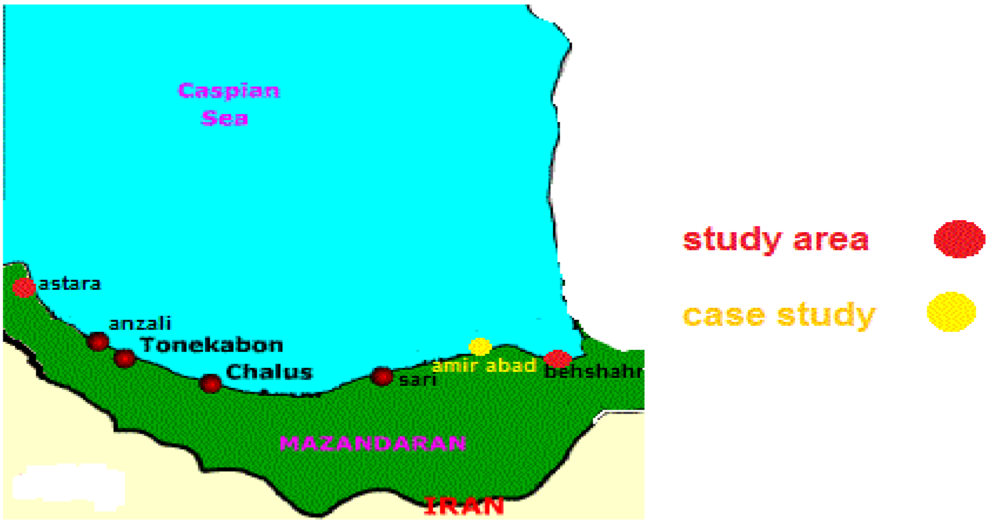

Figure 1-The view of southern Caspian sea.

Its area is about 436000 square kilometers, and its average depth is about 180 meters. Caspian Sea is the largest basin of our planet, located on south east of the continent Europe and on the border of Asia [10, 11]. High volume of water (78 thousand km3; that equals 44% of the world's lakes water's reserve) and great depth (1025 m) is comparable with oceanic seas such as the Black Sea, Baltic Sea and Yellow Sea and is superior to Adriatic, Aegean, Tirana, Solo seas .

Liquefaction occurs in sandy lands and due to the increase of pore water pressure. This phenomenon which is known as liquefaction or flow may happen in the non-condensed and saturated sands. Increase in pore water pressure leads to reduction or complete omitting of shear resistance in soil. Soils which have lost their shear resistance act like a thick or concentrated liquid. In the famous earthquake of Nygata (1964 - Japan). Several cases of soil liquefaction were observed in the earthquake which happened in June 1990 in Rudbar and Manjil in Iran [12].

Seismic geotechnical hazards

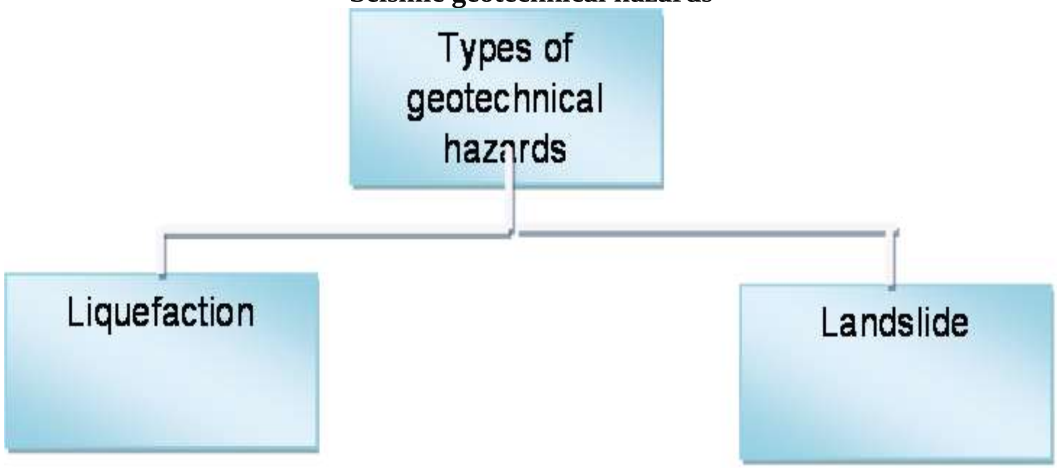

Figure 2-Various seismic geotechnical hazards

Methods

According to Seismic Geotechnical Engineering-Technical Committee, TC4, which was officially recognized by the International Association of Soil Mechanics and Foundation Engineering (ISSMFE) in 1985[4], zoning maps in liquefaction are divided in three different groups according to required precision, available information and budget which are as below mentioned:

1- Geotechnical seismic risk zonation methods (*liquefaction*)

- **Grade I**

Grade I zoning is based on the existing data for geological and geomorphologic properties. Maximum extent of the liquefaction susceptible area can be estimated directly from the magnitude of the predicted earthquake or on the basis of seismic intensity.

- **Grade II**

Grade II zoning uses existing data from various sources and additional data, such as analyses of aerial photographs and interviews with local residents.

- **Grade III**

Grade III zoning requires new special subsurface investigations, field and laboratory testing, and analyses .Liquefaction susceptibility is a function of the capacity for sediment to resist liquefaction when subjected to ground shaking. Grade III zoning requires*:*

1- Liquefaction resistance can be estimated by in situ or laboratory tests. Standard penetration (SPT) and cone penetration tests (CPT) are mostly used to estimate liquefaction susceptibility. SPT-based methods were previously developed by Seed and Idriss [8].

2- The physical properties of soil, such as sediment grain size distribution, compaction, cementation, saturation, and depth, govern the degree of resistance to liquefaction**.**

Standard penetration test (SPT) method

In this method hammers weighing 63.5 kg fall from height of 76 cm caused its 45 cm penetration into soil layers. Split-Barrel Sampler has 38 cm inside diameter and 5 cm outside diameter. And then SPT N equal to number of hammer for 30 cm end penetration Analysis methods considered in this study include: Seed's Method [8] , Tokimatsu Yoshimi's method (T–Y) [10] , A new version of Japan Road Association (JRA) method[5] , Liquefaction analysis software program(L-P) and by using Geographic information system (GIS).

We selected one and two degree zone method for geotechnical hazard with corresponding GIS analysis as following methods:

A. Apply maps processing with large scale (1: 25000) and Data extracting

B. Data layers contains: topography, geological information and map, density of road and river , rainfall , faults and earthquake information , water table , land use and land cover, rock composition , sedimentary environments

2-Method for classify sediments

Mechanical and physical properties of soils to define the physical characteristics of soil, important experiments were performed such as soil classification, grain diameter test, hydrometery, Attterberg limits, density and moisture content test. For sandy layers, quick direct shear test and triaxial compression tests performed generally on remolded samples in 8 station (Astara, Talesh, Anzaly, Nastarood, Sorkhrood, Larem, Miankaleh, Gomishan)

Results and Discussion:

Sampling Stations:

- The procedures to identify Caspian Sea sediments geotechnical properties in study area
- Evaluation of soil mechanics characteristics in onshore part and seabed sediments

Hazard Analysis

We selected one and two grade zonation methods for liquefaction hazard with corresponding GIS analysis as following methods:

- Apply maps processing with large scale (1: 25000) and Data extracting

- GIS software and liquefaction hazard map were prepared and weighted from prepared layers in previous steps and using ArcGIS produced the main results as final maps. Thus with transferring overall mentioned information layers into GIS environment, and with their analysis and also with overlapping of various layers, sensitive areas to incident of liquefaction were identified.

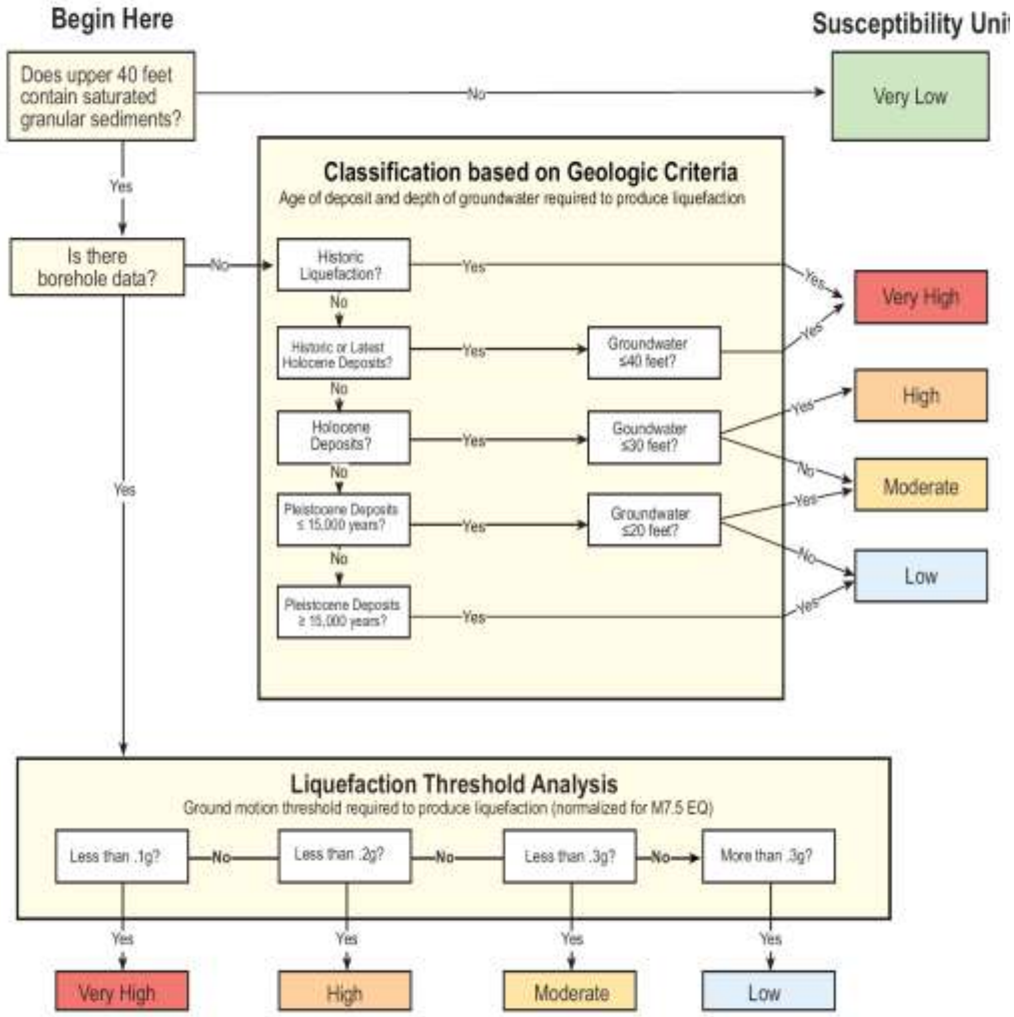

Figure 3- Flowchart to determine the risk of liquefaction in the coastal areas.

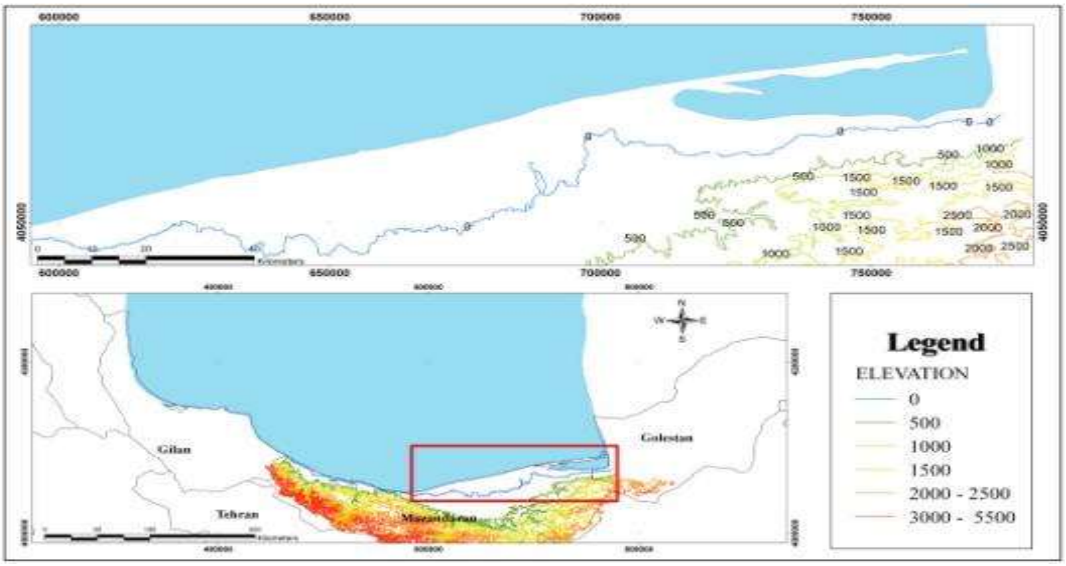

Figure 4- The map of topography in the study area.

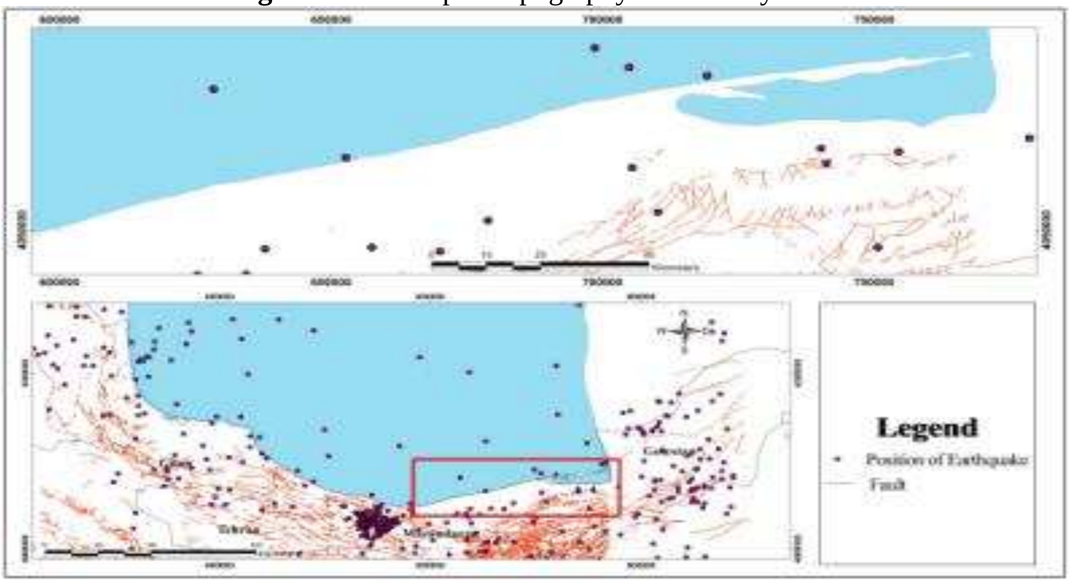

Figure 5-The map of main active faults and seismic potential in the study area

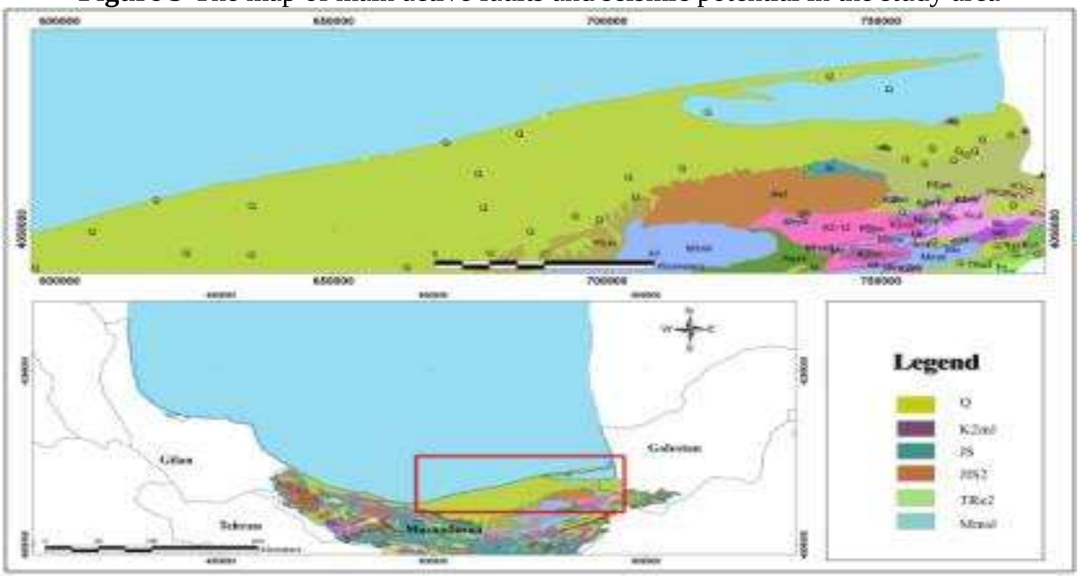

Figure 6- The Geology map and rocks composition of study area.

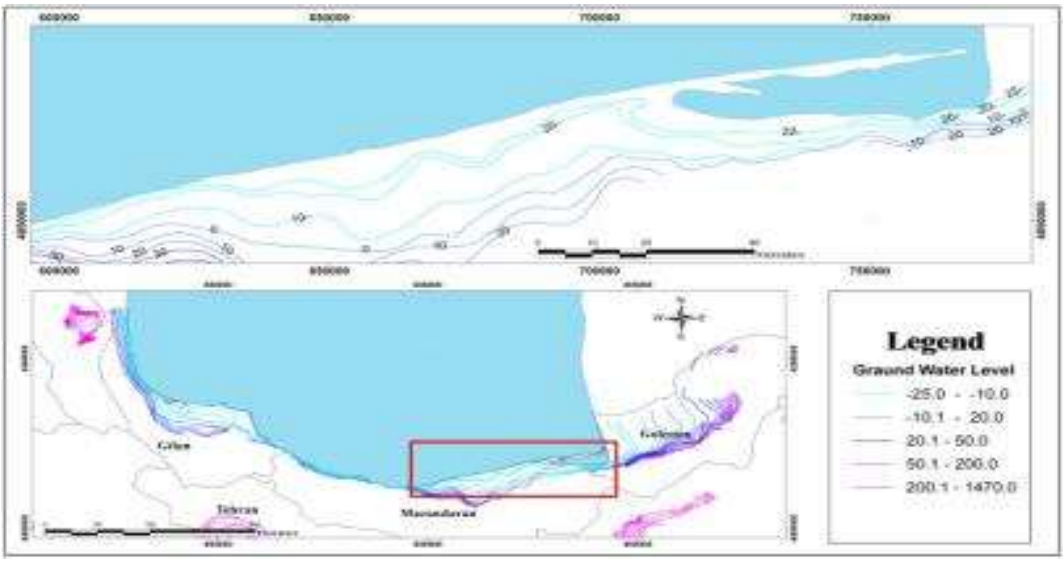

Figure 7- The map of water table level in the study area.

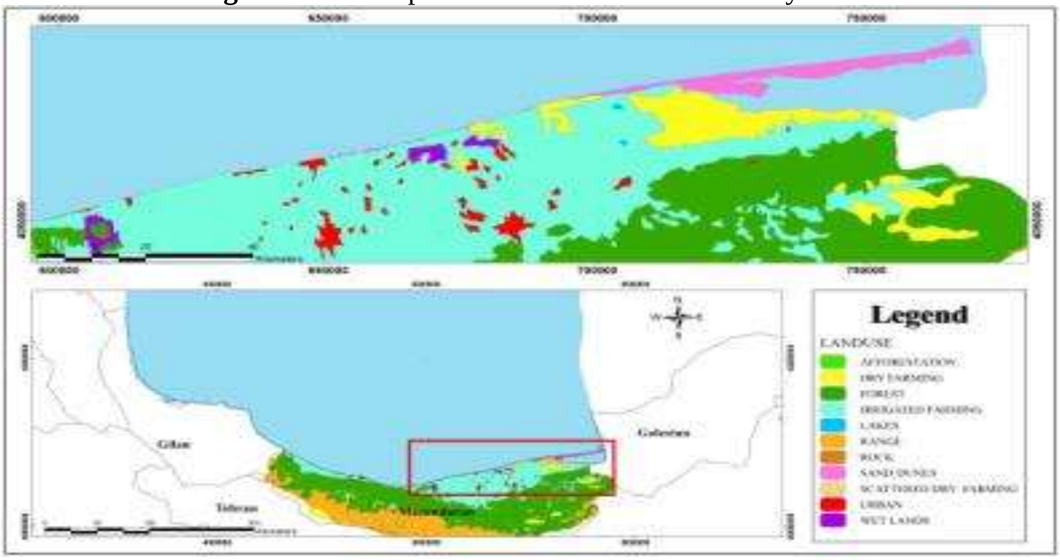

Figure 8 -The map of land use and land covering in the study area.

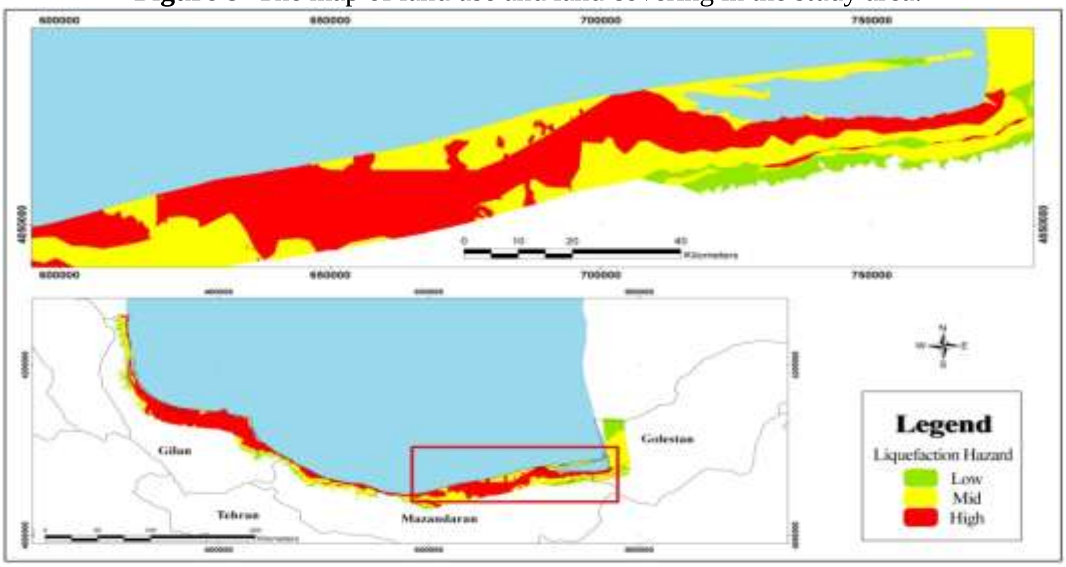

Figure 9- Zoning map of the liquefaction risk potential in the study area.

2-Liquefaction Hazard by SPT:

2-1- The results of investigation Caspian Sea sediments geotechnical properties

2.1-1- Evaluation of soil mechanics characteristics in Beach zone

2.2-2- Evaluation soil mechanics properties of seabed sediments

2.2-3- Investigation Liquefaction hazard by results of SPT in case study (Amir abad beach)

Also with collecting samples from 8 coastal stations from Gomishan to Astara (Torkaman Port, Amirabad, Larim, Sorkhroud, Nashtaroud, Anzali, Talesh, Astara) the soil mechanics and geotechnical characteristics of the coastal soils were examined. Some of the geotechnical in-situ tests performed on the collected samples such as determination bulk density and determination of the sand and clay frequently percentage. Other tests were conducted on the samples only in the laboratorial conditions. These tests include determination of the plasticity limit coefficient of coastal soils, sizing of the sediments grains uniformity coefficient determination and sediments curvature measurement (Cc, Cu), determination of soil type and the amount of hollow ness and porosity, moisture percentage and dry density and special gravity.

In the southern coast of the Caspian Sea as mentioned before, the natural essence of coastal sediments considering composition, grain structure, and textural characteristics shows considerable dissimilarity in diverse regions. This has direct relation with seabed topography and dominant hydro dynamical regime in the area.

*** Coastal zone of Torkman Port-Gomishan**

This coastal zone consists of very fine-grained sedimentary substances made of gray clay with high adhesion and including organic materials as a result of decomposition of plants and sea soft-shell creatures. On occasion, beside these sediments, sandy substances consisting of fossil of the soft-shell sea animals' skeleton is observed. Unsteadiness of sands considering the incapacitated fossils and continental erosive elements is quite understandable. The topographic slope of this area is extremely mild which is considered as a significant cause for occurrence of fine-grained sediments in this area. The value of sand percent test in this coastal area is 80.4%. The measured liquid and plasticity limits for this area is equals to: LL=31% and PL=15% area is 80.4%. The measured liquid and plasticity limits for this area is equals to: LL=31% and PL=15%

***Amirabad coastal zone**

In this zone sediments own considerable density and strength. Decreasing the amount of porosity and increasing the quantity of calcium carbonate in the composition leads to appearance of cementation phenomenon and as a result increasing the strength coefficient of sediments. The special weight of solid grains in this area holds the lowest quantity of Gs. The sandy soil in this area is clean and fine-grained with acceptable density (concentration).

*Larim station

From the soil mechanics point of view, Larim's sediments are granular and fine-grained sand that is categorized as Sp or poorly-graded regarding the sand type in the integrated method. In this area, sediments have low density. The interference of river hydraulic forces and hydrodynamic forces of the sea results in increase of the pore pressure and decrease of the sediment strength. Occasionally, increase of the weight vertical pressure on the sediments causes sand liquefaction; such a problem was quite tangible at the time of sampling.

***SorkhRoud coastal zone**

Geotechnical structure of sediments in SorkhRoud is poorly-graded coarse-grained sand type or Sp. In this part of coast, the specific gravity of the sediments is very high due to the presence of heavy minerals.

***Nashtaroud coastal zone**

Sediments are poorly-graded sand type in this area of the Caspian Sea. The liquid limit coefficient and the plastic limit for soils of this area is almost zero.

***Anzali coastal zone**

By geotechnical classification, sediments of this area are poorly-graded sand type. Their liquefaction capacity against application of stress forces is high and sand percent test shows that 97.1% of sediment volume has been composed from sand.

***Talesh coastal zone**

Soil mechanics structure of coastal sediment in onshore part of Talesh is sandy sediments with coarse-grained, badly graded structure. The high quantity of consistent heavy minerals in sediments contributes to increasing special weight and dynamical resistance in them.

***Astara beach**

Sediments are coarse grained sand with well graded structure and soil type is SW. frequency of river fine-grained substances and organic materials between sediments gives increase to their adhesion.

Table 1- Caspian Sea beaches geotechnical quantitative parameters of soils

E index	porosity	specific gravity	Sand%	PL	LL	W%	Cu	Cc	D50	Kind of soil	station
E	n	Gs		%	%						
0.83	0.45	2.57	80.4	15	31	32.5	2.05	0.99	0.32	Sp	Gomishan
0.56	0.36	2.52	100	0	0	22.6	1.35	0.92	0.22	Sp	Amirabad
0.51	0.34	2.61	100	0	0	19.6	1.94	0.99	0.3	Sp	Larim
0.68	0.4	2.62	98.4	0	0	26.2	1.94	0.96	0.35	Sp	Sorkhroud
0.28	0.21	2.55	931	0	0	11.2	1.64	0.92	0.25	Sp	Nashtaroud
0.82	0.45	2.54	97.1	0	0	32.4	1.43	0.88	0.22	Sp	Anzali
0.54	0.35	2.34	100	0	0	23.3	1.5	0.95	1.3	Sp	Talesh
0.74	0.42	2.52	97.2	0	0	29.3	10.9	1.49	1.5	Sw	Astara

2-2-2- Evaluation soil mechanics properties of seabed sediments

In the southern coast of the Caspian Sea as mentioned before, the natural essence of coastal sediments considering composition, grain structure, and textural characteristics shows considerable dissimilarity in diverse regions. This has direct relation with seabed topography and dominant hydro dynamical regime in the area. Based on the performed measurement, it is known that according to the wave dominant regime and coastal streams in depths between 2.5 to 5 meters in central and west coasts of Mazandaran and central Gilan, the intensity of influence of stress forces from waves upon seabed soils is very high in the fracture region. Consequently, sediments in these regions have considerable geotechnical vulnerability and Strength of consolidation coefficient of sediments in these depths is very low. This situation is observed in the eastern coasts of Mazandaran and western coast of Gilan as vulnerable regions in depths between 1 to 2.5 meters in coasts of Miankaleh, Talesh and Astra. However with depth increase, in the region between depths of 5 to 7 or 7 to 10 meters, the amount of sediments Strength of consolidation enormously increases in a way that sampling procedure from seabed encounters serious difficulties. Usually, the Fine-grained structure of sediments in these regions is accompanied by the increase of the quantity of carbonate and cement components that in the parts far from the wave breaking point's sediments have a good strength. This situation is observed in depths between 5 to 7 and 7 to 10 meters in this regions Table-2.

Table 2- Geotechnical parameters of the seabed soils in the southern of the Caspian Sea

Station	Depth(m)	*PI*			γw	γd	w	Gs
		LL	PL	PI	gr/cm^3	gr/cm^3	%	
Larim	0	-	-	<4	1.53	1.34	14	2.64
Larim	1	-	-	<4	1.59	1.27	25	2.63
Larim	2.5	-	-	<4	1.84	1.49	24	2.62
Larim	5	-	-	<4	1.57	1.23	27	2.62
Larim	7	-	-	<4	1.45	1.05	38	2.66
Larim	10	-	-	<4	1.77	1.40	27	2.62
Larim	15	-	-	<4	1.69	1.20	40	2.63
Larim	20	38	29	9	1.48	1.02	44	2.67

2-3-Investigation Liquefaction hazard by results of SPT in case study (Amir abad beach)

In the finer resources, zoning will be done in three grades, in this research, grade 3 is used for identify liquefaction hazard. In this procedure with circular drilling operations up to depth of 40 meters in 5 bored holes, the sequence stratigraphy of sediments at present ages and late quaternary in Amirabad coastal zone and western edge of Miankaleh (west of study area) is investigated. By drilling bores, in situ sampling from soil layers and tests were performed in order to:

2-3-1-Determination of type and thickness of soil layers and water level and SPT number in case study. Figure-11

2-3-2-Determining the physical characteristics and soil mechanics. Figure-12

2-3-3-the evaluation sediments geotechnical properties in case study

2-3-4-Evaluaate the probability of occurrence of liquefaction phenomenon with use of SPT-N based analysis methods

Calculation of the potential of liquefaction hazard in the study area is accomplished according to diverse methods. Seed and Idris (1971), Tokmatsu and Ushimi (1983) and NJRA (1996) methods (Muhsiung Chang 2011) and software liquefy defining method have been applied.that show, in depth that Fs<1 liquefaction is occurred.

Table 3-Calculation of the potential of liquefaction hazard in five boreholes

Location		**Liquefaction Resistance Factor**					
BH-NO.	**Depth (m)**	**U.S.C.S.**	**Seed (2001)**	**T-Y (1983)**	**NJRA (1996)**	**Software (Liquefy)**	**Average**
BH-1	2.0	GP-GM	—	—	—	—	—
BH-1	4.0	SP	2.01	1.85	1.97	2.24	2.02
BH-1	6.0	SM	1.79	1.78	1.78	1.94	1.82
BH-1	7.5	SM	1.47	1.17	1.83	0.83	1.33
BH-1	9.8	SM	1.86	1.80	1.89	0.99	1.64
BH-1	11.8	SM	0.66	0.61	0.84	0.48	0.65
BH-1	13.5	SM	0.42	0.52	0.47	0.37	0.44
BH-1	15.5	SM	0.94	0.77	1.31	0.69	0.98
BH-1	17.5	SM	1.39	1.06	1.75	0.95	1.29
BH-1	19.5	SM	2.34	2.02	2.25	2.40	2.25
BH-1	22.0	SM	1.53	1.33	2.43	1.34	1.66

Conclusion

1. Human interference through construction of engineering structures on the bank of coastal line and the area of sea territory results in increased level of environmental forces and intensity vulnerability in the study area. Occasionally in mild-slope areas extended fluctuation due to aforementioned parameter together with hydrodynamic forces result in great erosion of the coast and subsequent devastation.
2. Considering the deposition sedimentary layers found in the study area, which are mainly sand components from sea and fine-grained clay materials resulted from marginal wetlands, the overall strength of these components against the tension forces due to loading is relatively low according to high porosity of sediments and water saturation; and in case of destructive earthquakes and excessive increase in pore pressure, possibility of soil liquefaction is considerable. But due to low slope, the coast good stability against slip phenomenon.
3. the most significant Geotechnical instability phenomena in the study area according to the nature of natural sandy soils and marine environmental conditions, and human interference include: sand Liquefaction. Erosion and destruction and simultaneously retreat of the coast due to propagation of water into it.
4. Absence of control over constructed applications in of coastal areas and development of them in the coming years lead to the loss of a large part of the coastal soils and consistent features inside it, in a way that compensation and reconditioning it to previous state require spending enormous costs.

5. To prevent devastation and erosion of coastal areas, it is recommended that soft engineering methods be applied such as feeding the beach by accumulated sand and planting coastal plants on the soft sands on the beach in the back shore areas, artificial sand dunes in order to create.
6. Respecting privacy of seabed and considering the emergency limit as well to ensure construction of large engineering structures in the study area is necessary.
7. Due to dynamic and high capacity of environmental forces in the area mentioned region, respecting environmental standards to protect coastal areas and water resources in it is required.
8. Land use management and design and construction of individual buildings, must be considered as components of urban planning and building design.
9. With investigation two important factors such as hazard potential (Side effect) and mobility from earthquake, faults and their results in area study, that show , the weight and effect of Side effect (susceptibility factors) is more important than mobility factors(Stimulating factor) in geotechnical instability hazard.

Reference

1. Barimani, H, Khoshravan, H. **2011.** Caspian sea southern coasts seismic vulnerability. The 21st International offshore (ocean) and polar engineering conference (ISOPEH-2011).USA, June 19-24, 2011.
2. Berberian, M, **1983.** The Southern Caspian: Compression depression flood by a trapped, modified oceanic crust. Can. J .Erth.120 , 163-183
3. Ghanghermeh, A. **2005.** Mazandaran province landuse evaluation model with use GIS, Caspian Sea national research center, internal report, pp: 34-46
4. ISSMGE,**1999**,manual for Zonation on Geotechnical hazard, The Japanese Geotechnical study,ISSMFE,209pp
5. Japan Rail Association (JRA). Design code and explanations for roadway, bridges, Part V – seismic resistance design, Japan; **1996.**
6. Khoshravan, H. **2000.** Morphological zone of the southern coasts of Caspian Sea, National research center of the Caspian Sea, internal report, 156 pages
7. Khoshravan. H, B BTRRJRDarimani. H. **2009**. Caspian beach modification hazard assessment by use remote sensing and GIS modeling, 6th International Symosium on Digital Earth (ISDE), biijing , China , September 9-12,2009
8. Seed HB, Idriss IM. Simplified procedure for evaluating soil liquefaction potential. *J Soil Mech Found Div*, ASCE 1971; **97**(9): 1249–73
9. Shahriyari, M. **2003**. hydrodynamic zone of the Caspian sea by use morphodynamic record, Azad university of Tehran, M. Sc thesis, pp 232
10. Tokimatsu K, Yoshimi Y. **1983.** Empirical correlation of soil liquefaction based on SPT-N values and fines content. *Soils Found, JSSMFE*, **23**(4): 56–74.
11. Yasini, I. **1987.** Paleogeography and paleoshoreline reconstruction of the Caspian Sea in the south coasts, NIOC, internal report, pp: 124- 165
12. Zare, M, Ghafory-Ashtiany, M. and Bard, P.Y. **1999.** Attenuation law for the strong –motions in Iran, pp.345- 355of: proceedings of the Third International conference on Seismology and Engineering, Tehran, vol.1.