Geographical Information System in Geotechnical

Mohammad Reza Torabi, Mohammad Reza Kahourizadeh

Toseh Sahel Darya consulting engineers
torabi151@yahoo.com; m_Kahoorzadeh@yahoo.com
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Name of the Presenter: Mohammad Reza Torabi

Abstract

A geographic information system (GIS) integrates hardware, software, and data for capturing, managing, and displaying all forms of geographically, referenced information for the specific point that we need. GIS allows us to view, understand, question, interpret, and visualize data in many ways that reveal relationship, patterns, and trends and it will display in the form of maps, globs, reports, and charts. A GIS helps us answer questions and solve problems by looking at our data in a way that is quickly understood and easily shared.
The benefits of GIS generally fall into five basic categories; Cost savings and increased efficiency, Better decision making, Improved communication, Better recordkeeping and Managing geographically
Large scale geotechnical earthworks projects, specifically those related to earth dams, dikes, and determining the optimal location to build and reconnaissance soil conditions underground often require construction of deep vertical seepage barriers. With increasing frequency, the demands of contract compliance, quality control, and budget management require structured and efficient management of large data sets. Unless properly recognized, the data management requirements can contribute to the complexity, duration and budget of the project.
This paper discusses an application of geographic information system (GIS) technology to capture information from multiple data streams and provide geotechnical feedback, quality control information about Qeshm island in south of Iran. Also the following subjects will be detailed:

- Data capture
- Data output

Key words: GIS, Geotechnical engineering, Soil engineering parameters, Qeshm Island

1. Introduction

A Geographic Information System (GIS) is a relatively new software tool for geotechnical engineers. Its capabilities range from conventional data storage to complex spatial analysis and graphical presentation. Successful application of the technology required a combination of geotechnical knowledge and the GIS-based skills. This was achieved, in practice, by training the geotechnical engineers to be proficient in using the software as well as understanding the GIS concepts. In terms of technical and financial performance, the multi-tasking functionality of the GIS was found to be well-suited to projects in which large quantities of data were analyzed (Hellawell et al., 2001).

Recently the GIS software with a lot of functions has been developed; it can be used as a tool for analyzing and managing various data creatively. In other words, GIS is not only simply used for memorizing, visualizing, querying and overlaying of map, but also for combining various analysis, comparing various attribute data and therefore solving those problems which are difficult for personal ability (Longley et al., 2001).

GIS tools can be used to integrate existing data with project specific data; identify potential geological hazards; plan and track field work; create maps and figures; and improve communication. These tools can help identify potential barriers to project completion early in the design process that may help to avoid later costly redesign (Player, P.E., (2006).

There are a variety of methods used to enter data into a GIS where it is stored in a digital format. Survey data can be directly entered into a GIS from digital data collection systems on survey instruments using a technique called coordinate geometry (COGO). Positions from a global navigation satellite system (GNSS) like Global Positioning System can also be collected and then imported into a GIS. Remotely sensed data also plays an important role in data collection and consist of sensors attached to a platform. Sensors include cameras, digital scanners and LIDAR, while platforms usually consist of aircraft and satellites. The majority of digital data currently comes from photo interpretation of aerial photographs. Soft-copy workstations are used to digitize features directly from stereo pairs of digital photographs. These systems allow data to be captured in two and three dimensions, with elevations measured directly from a stereo pair using principles of photogrammetry. Satellite remote sensing provides another important source of spatial data. Here satellites use different sensor packages to passively measure the reflectance from parts of the electromagnetic spectrum or radio waves that were sent out from an active sensor such as radar. After entering data into a GIS, the data usually requires editing, to remove errors, or further processing.

Cartography is the design and production of maps, or visual representations of spatial data. The vast majority of modern cartography is done with the help of computers, usually using GIS but production quality cartography is also achieved by importing layers into a design program to refine it. Most GIS software gives the user substantial control over the appearance of the data. Cartographic work serves two major functions: First, it produces graphics on the screen or on paper that convey the results of analysis to the people who make decisions about resources. Wall maps and other graphics can be generated, allowing the viewer to visualize and thereby understand the results of analyses or simulations of potential events. Second, other database information can be generated for further analysis or use.

In this study, comprehensive studies of engineering geology and determining the soil mechanics parameters of Qeshm Island, with the goal of providing the required information for land use planning based on information obtained from field surveys, borings and samplings in situ and laboratory and field tests have been conducted. Finally an actual project in Qeshm Island utilizing geotechnical applications of GIS is presented. Qeshm Island is located a few kilometers off the southern coast of Iran (Persian Gulf), opposite the port cities of Bandar Abbas and Bandar Khamir.

The purposes of this study are summarized as: (1) Collecting and use of available geological maps information, soil mechanics studies reports, climatology and completing the survey data, (2) Data processing and analyzing using software and preparing zoning maps based on soil parameters and (3) Determining soil engineering parameters in frame of applicable maps.

2. Data and Material

To conduct this research, the following documents and software have been used:

- Qeshm Island geological map with a scale of 1/100000.
- Geological report of Qeshm Island (Aghanabati and Haghipoor, 2005).
- Report of studies on soil mechanics and geotechnical engineering prepared by soil mechanic laboratory of Qeshm Island transportation department.
- Soil mechanics and geotechnical studies report of Qeshm Island prepared by the "Iran Khak" consulting engineers.
- Soil mechanics and geotechnical studies report of Qeshm Island prepared by "Mandro" consulting engineers.
- Geographical Information System (GIS) software (ARC GIS 9.2)

3. Research Methodology

First, in order to conduct field studies and sampling, after collecting conducted soil mechanics studies reports, the coordinates of the location of boreholes after visiting the field was marked on the map.

Then, In order to cover the whole zone, the Island lattice on map was prepared and location of places to be studied, were implemented on these grids. The location of each grid was trying to check if there is at least one point in each lattice.

Where there were no previous studies, have attempted to have manually drilled boreholes and field sampling and Finally, after completing the required information from about 178 boreholes and 66 drilling projects, Data analysis and Zoning of the area based on soil mechanics parameters of the layers of two meters, were carried out. Figure 1 shows the location of study area and sampling points. Diagram of study procedures, is summarized in Figure 2.

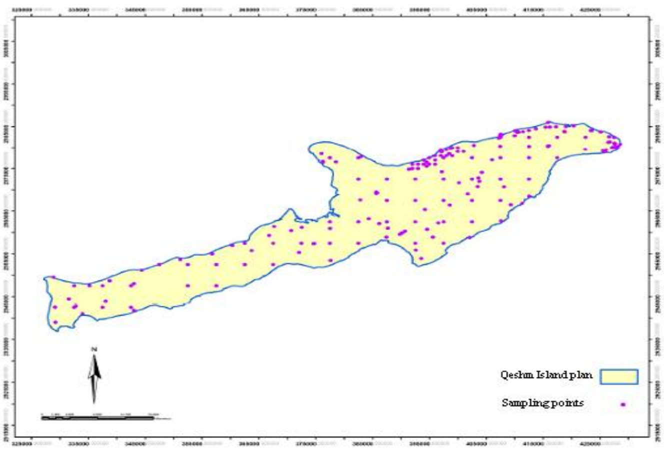

Figure 1. Location of study area and sampling points

4. Results and Analysis

4.1. Zoning Soil Mechanics Parameters of Qeshm Island Using ARC GIS 9.2 Software

In order to zoning soil layers, after providing the required tables from about 180 boreholes in Excel format and editing the information, tables were converted to dbf format and entered into the ARC GIS 9.2 software environment.

Due to the large amount of data and results, in this section only the results of soil classification and two soil parameters including SPT value and Elasticity module of soil are provided in details. The results for the various soil parameters in two tables are presented briefly in the next section.

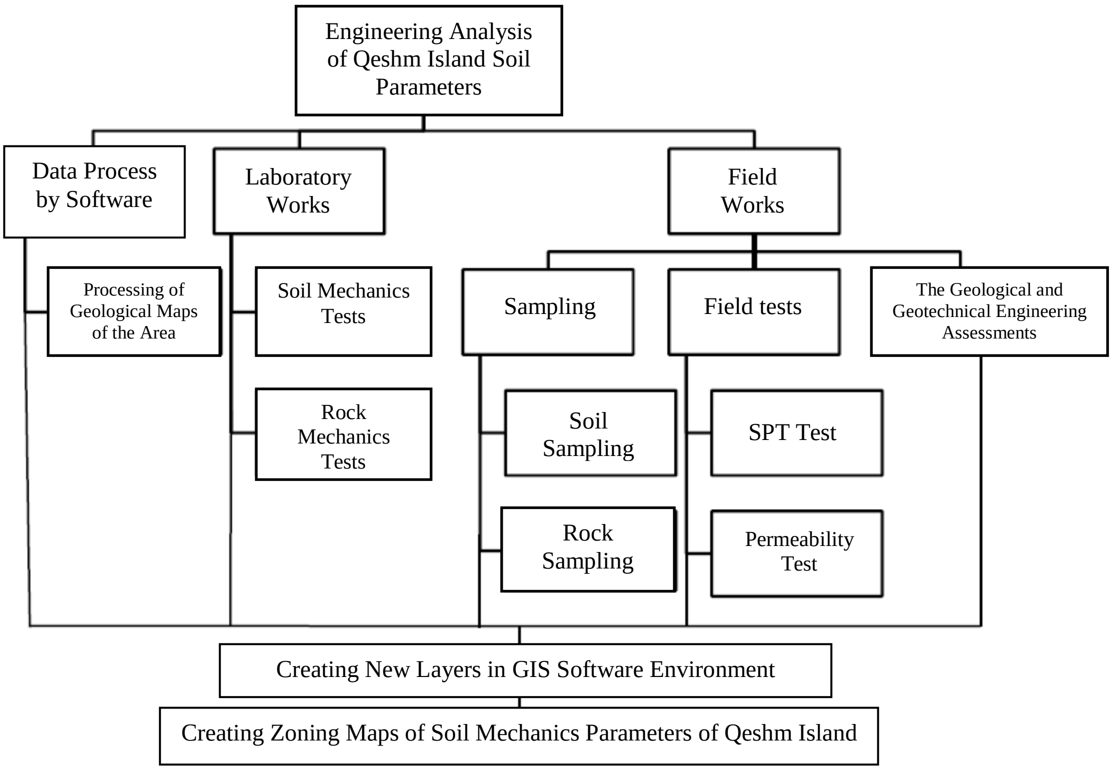

Figure 2. Diagram of the research process

4.1.1. Soil Classification

Soil classification based on Unified Soil Classification system (USCS), in depths of 0 to 10 for two-meter layers is shown in Figure 3 to Figure 7.

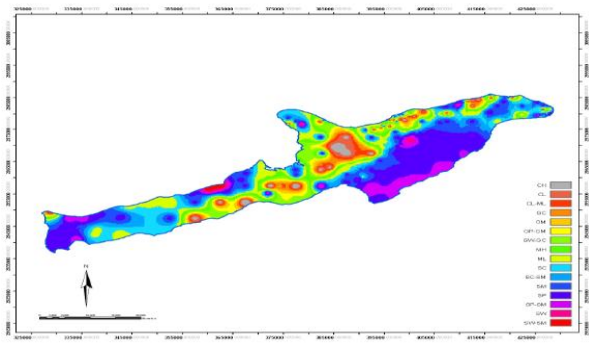

Figure 3. Soil classification at depths of 0 to 2 m

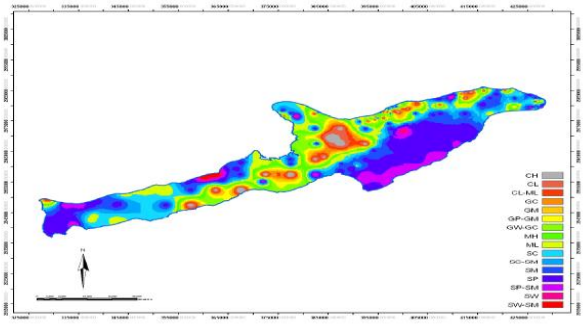

Figure 4. Soil classification at depths of 2 to 4 m

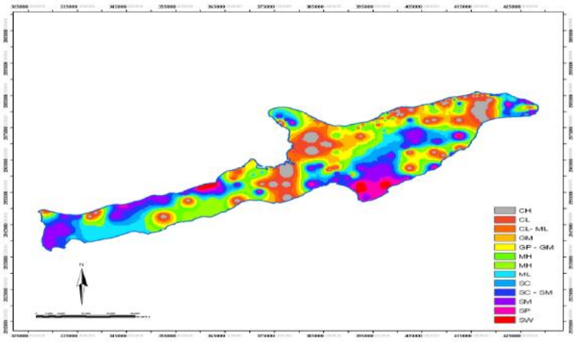

Figure 5. Soil classification at depths of 4 to 6 m

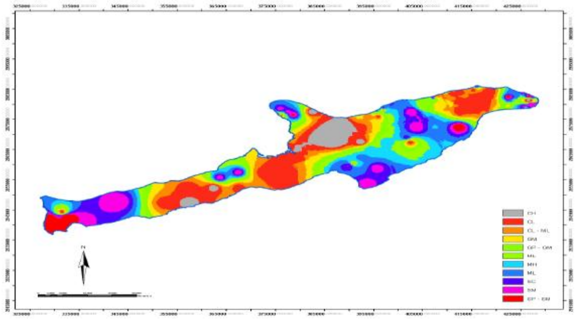

Figure 6. Soil classification at depths of 6 to 8 m

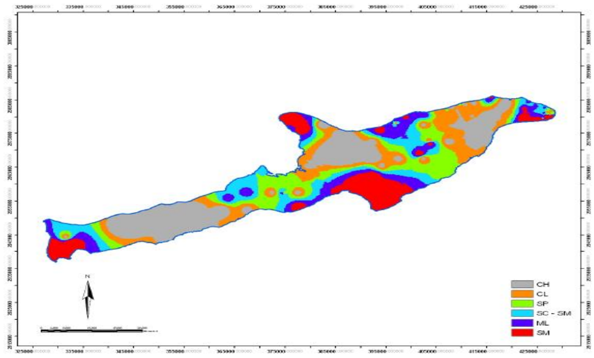

Figure 7. Soil classification at depths of 8 to 10 m

According to zoning maps, the predominant soil types based on USCS in the order of frequency, are as follows:

- Silty sands (SM) in eastern and western parts and the middle and low-lying regions of the Island,
- Inorganic clays of low to medium plasticity (CL) and inorganic clays of medium to high plasticity (CH) in the middle of the Island ("Gavarzin" region),
- Clayey sands (SC) and clayey sands with silt (SC-SM) in the hills of south east and south west,
- Poor graded silty sands (SP-SM) in the southern part of the island.

4.1.2. SPT results

The results of Standard Penetration Tests (SPT) in terms of standard penetration numbers (N_{SPT}) in depths of 0 to 10 for two-meter layers are shown in Figure 8 to Figure 12.

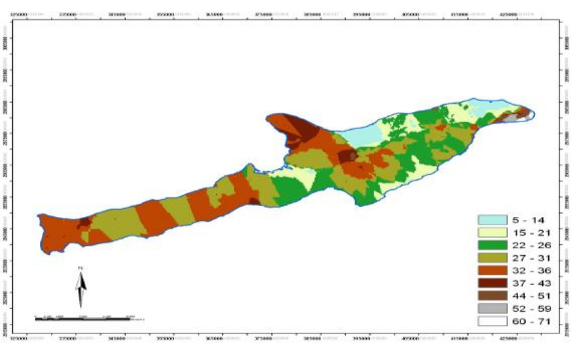

Figure 8. SPT number at depths of 0 to 2 m

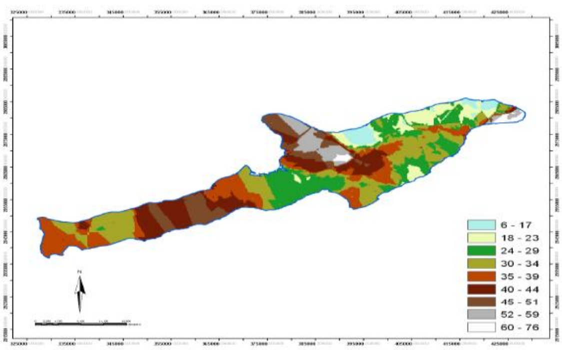

Figure 9. SPT number at depths of 2 to 4 m

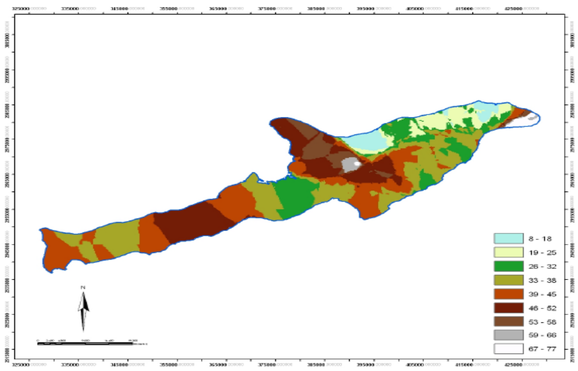

Figure 10. SPT number at depths of 4 to 6 m

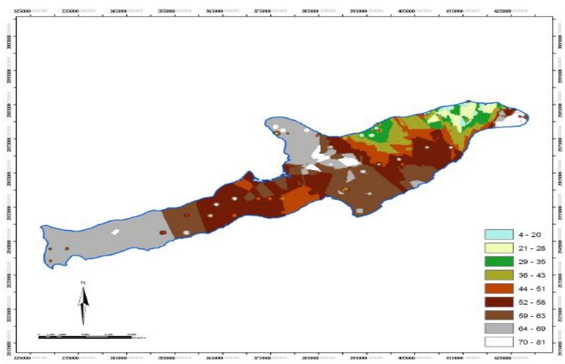

Figure 11. SPT number at depths of 6 to 8 m

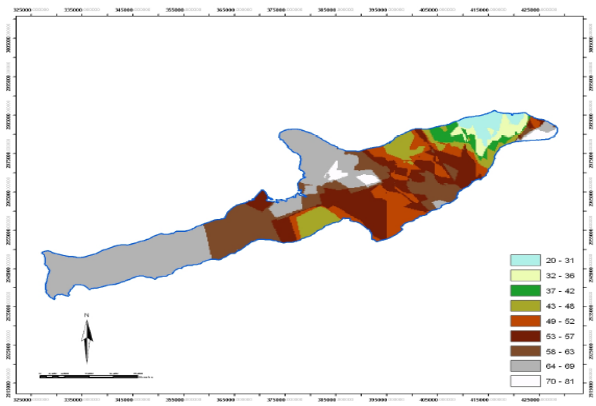

Figure 12. SPT number at depths of 8 to 10 m

Range of values obtained for the Standard Penetration Test, is as follows:

- N_{SPT}: 5 to 31, in the margins of the northeast and the industrial site of "Tula",
- N_{SPT}: 21 to 42, in the middle parts of northeast,
- N_{SPT}: 44 to 88, in the South, Southeast, and West area of study.

4.1.3. Soil Elasticity Module

The results for elasticity module of soil in kilograms per square centimeter (kg/cm^2) in depths of 0 to 10 for two-meter layers are shown in Figure 13 to Figure 17.

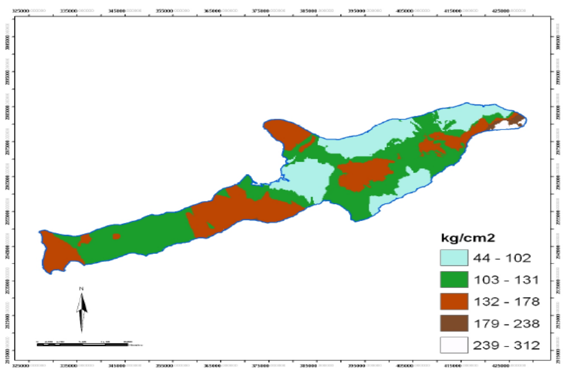

Figure 13. Elasticity module of soil at depths of 0 to 2 m

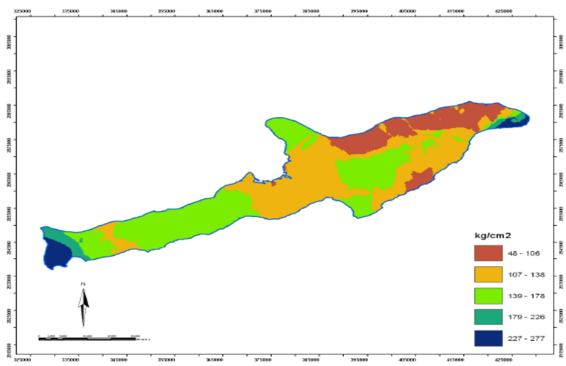

Figure 14. Elasticity module of soil at depths of 2 to 4 m

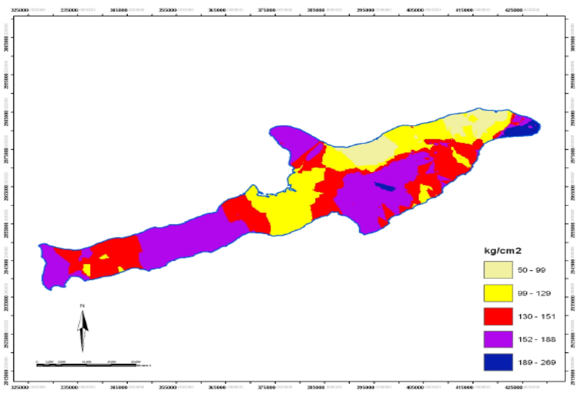

Figure 15. Elasticity module of soil at depths of 4 to 6 m

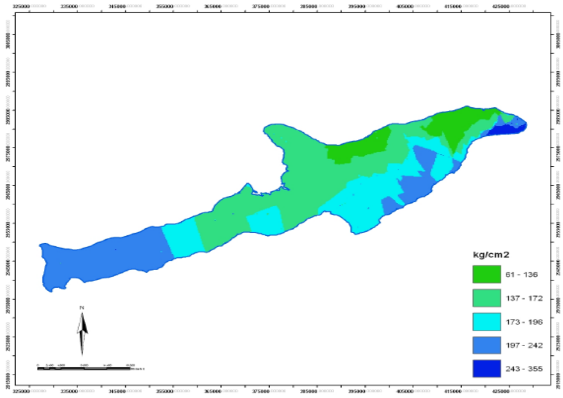

Figure 16. Elasticity module of soil at depths of 6 to 8 m

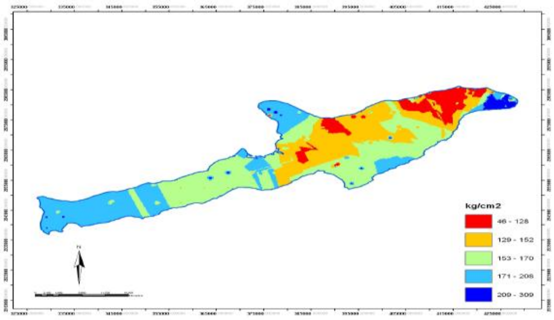

Figure 17. Elasticity module of soil at depths of 8 to 10 m

Module of elasticity of soil, E_S (kg/cm^2), in the study area is as follows:

- E_S: 44 to 138, in the margins of the northeast and central and east parts of study area,
- E_S: 139 to 226, at the height of the middle, west and south of the study area,
- E_S: 200 to 355, in the southeast, west, and east of "Namakdan" Mountains.

4.1.4. Major and minor faults

Main and minor faults are shown in Figure 18.

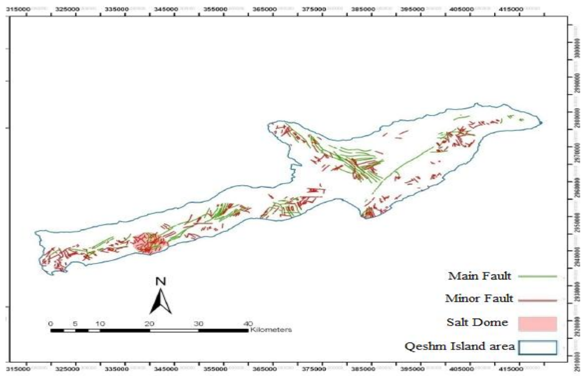

Figure 18. Main and minor faults

4.2. Dominant Soil Engineering Parameters

Dominant soils engineering parameters for a depth of 5 meters from the ground and a depth of 5 to 10 meters from the ground are shown in Table 1 and Table 2.

Classification	LL (%)	PL (%)	PI (%)	W (%)	γ_w (gr/cm^3)	γ_d (gr/cm^3)	G_s	N_{spt}	Ø' (Deg)	C' (kg/cm2)	e_0	(v)	E_S (kg/cm^2)	D_{10} (mm)	Permeability (m/s)
SM	—	—	NP	5 – 10	1.60-1.74	1.42-1.65	2.62-2.64	15-30	29-32	0.0	0.670-0.800	0.28-.30	80-200	0.013-0.028	$1.0*10^{-3} – 2.0*10^{-5}$
CL	36-39	21-23	14-17	13-19	1.74-1.85	1.45-1.54	2.71-2.73	14-23	24-27	0.03-0.09	0.700-0.830	0.32-0.35	75-110	0.001-0.0017	$1.3*10^{-7} – 1.5*10^{-9}$
ML	—	—	NP	9-16	1.63-1.71	1.44-1.49	2.62	9-18	27-29	0.01-0.03	0.676-0.831	0.32	19-98	0.0011-0.0031	$1.1*10^{-5} – 5.0*10^{-6}$
CH	58-62	28-29	28-34	10-17	1.75-1.85	1.59-1.61	2.72-2.75	27-40	24-28	0.02-0.11	0.688-0.718	0.31-0.35	102-132	0.0012-0.0021	$1.3*10^{-8} – 1.5*10^{-9}$
SP-SM	—	—	NP	5-8	1.68-1.74	1.59-1.62	2.63	32-48	32-35	0.0	0.580-0.621	0.3	210-220	0.07-0.08	$1.5*10^{-1} – 6.1*10^{-3}$

Table 1. Engineering parameters of the dominant soils to a depth of 5 meters from the ground

Classification	LL (%)	PL (%)	PI (%)	W (%)	γ_w (gr/cm^3)	γ_d (gr/cm^3)	G_s	N_{spt}	Ø' (Deg)	C' (kg/cm2)	e_0	(v)	E_S (kg/cm^2)	D_{10} (mm)	Permeability (m/s)
SM	—	—	NP	7-12	1.67-1.85	1.53-1.64	2.63-2.64	30-40	31-34	0.0	0.605-0.732	0.28-0.30	145-215	0.0043-0.0258	$1.0*10^{-3} – 1.7*10^{-5}$
CL	37-43	22-27	12-17	15-22	1.78-1.91	1.52-1.62	2.71-2.73	18-25	26-30	0.03-0.07	0.644-0.808	0.29-0.37	100-135	0.001-0.0015	$1.7*10^{-6} – 2.1*10^{-9}$
ML	—	—	NP	12-20	1.74-1.84	1.47-1.58	2.62	22-32	28-31	0.01-0.02	0.676-0.764	0.32	85-144	0.0021-0.0038	$1.7*10^{-4} – 4.3*10^{-6}$
CH	54-60	27-28	27-30	14-23	1.84-1.94	1.53-1.66	2.71-2.74	35-45	25-29	0.04-0.1	0.634-0.784	0.32-0.35	111-134	0.001-0.0012	$1.9*10^{-7} – 2.6*10^{-9}$
SP-SM	—	—	NP	7-15	1.74-1.91	1.63-1.66	2.63	45-55	34-35	0.0	0.575-0.616	0.3	179-272	0.07-0.08	$2.2*10^{-2} – 3.8*10^{-3}$

Table 2. Engineering parameters of the dominant soils to a depth of 5 to 10 meters from the ground

5. Conclusions

According to the results of conducted study and the maps of soil parameters, it is recommended that:

- In coastal parts and low-lying regions of Qeshm Island which is consisted of sandy and silty soil with relatively low density (Southeast, northeast and northwest parts of the Island) and the groundwater level is high (near the surface), liquefaction due to the dynamic forces (earthquakes, explosions, artificial vibrations, etc.) is likely to occur. If critical facilities are proposed to be constructed in these areas, Necessary measures (such as soil stabilization, soil compaction and the use of deep foundations) should be considered to prevent damage to these structures.
- Basically unstable places or areas that have a relatively high variability and rapid changes or movements (such as "Namakdan" salt dome) for installations susceptible to these risks, are not recommended.
- Critical and major facilities to the extent possible should be located away from known faults capable of causing earthquakes and shifts, fractures and Lineaments that are likely to be fault (considering the map of major faults and lineaments), or at least the structures should not be constructed on both sides of the fractures.

Acknowledgements
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References

Aghanabati, A., Haghipoor, A., (2005). Qeshm Island geology map with a scale of 1/100000. Geology organization and mine exploration publication.

Aghanabati, A., Haghipoor, A., (2005). Qeshm Island geology report. Geology organization and mine exploration publication.

Balaneji, M. N., Manuchehri, H., Owfi, F., (2012). Coastal–Marine Ecological Classification Standard (CMECS) of Caspian Sea – Iranian Coasts of Mazandaran Province (Nowshahr–Babolsar region), Using the Geographical Information System (GIS). Journal of Basic and Applied Scientific Research, 2(3) 2889-2895.

Bartlett, D., Smith, J., (2005). GIS for coastal zone management. CRC press.

Hellawell, E. E., Lamont-Black, J., Kemp, A. C., Hughes, S. J. (2001). GIS as a tool in geotechnical engineering. Proceedings of the ICE-Geotechnical Engineering, 149(2), 85 –93.

Longley, P. A., Goodchild, M. F., Maguire, D. J., and Rhind, D. W. (2001). Geographic Information System and Science. John Wiley & Sons, Ltd.

Player, P.E., (2006). Geographic Information System (GIS) Use in Geotechnical Engineering. GeoCongress, United States, 1-6.

Ravanbod, Kh., (2010). Soil engineering analysis of Qeshm Island by using of GIS. MS thesis on engineering geology, Islamic Azad University of Zahedan.

Soil mechanics and geotechnical studies of Qeshm Island. "Iran Khak" consulting engineers, Report.

Soil mechanics and geotechnical studies of Qeshm Island. "Mandro" consulting engineers, Report.

Studies on soil mechanics and geotechnical engineering. Soil Mechanic laboratory of Qeshm Island transportation department, Report.

Sun, C. G., Kim, D. S., Chung, C. K., Geotechnical Information System Based on GIS in Gyeongju and Hongsung for seismic design and hazard mitigation.

Williams, T., Szary, P., Thomann, T., Konnerth, C., and Nemeth, E. (2002). GIS Applications in Geotechnical Engineering. Final Report, FHWA 2002-06, Federal Highway Administration, U.S. Department of Transportation, Washington, D.C., 1-20.