Lowland Technology International 2021; Volume 23 (3): 11-16
International Association of Lowland Technology (IALT): ISSN 1344-9656

Research Paper

Profile of safety factors (SF) potential liquifaction based on CPT data using GIS and surfer applications

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ARTICLE INFORMATION

Article history:
Received: 03 March, 2021
Received in revised form: 21 June, 2021
Accepted: 03 July, 2021
Publish on: 06 September, 2021

Keywords:

Liquifactions
Earthquake
CPT
GIS
Surfer

ABSTRACT

Earthquakes can cause damage to the structure of the soil layer, one type of hazard resulting from an earthquake is liquefaction. Liquefaction is an event where the loose sand soil layer experiences a drastic loss of shear strength due to increased pore water pressure as a result of the occurrence of cyclic stresses in very fast soil vibrations in a short time. This liquefaction potential can be analyzed using Cone Penetration Test (CPT) data by considering the value of earthquake acceleration (pga). This study aims to analyze soil conditions in the event of potential liquefaction using CPT (Cone Penetration Test) data through GIS and Surfer applications, computer applications which serves to analyze and create distribution contours from coordinate data and output data from CPT. This research also aims to make visualization on the condition of the soil that is experiencing liquefaction or not experiencing liquifaction.

1. Introductions

Liquefaction is the impact of an earthquake natural disaster, where it causes changes in soil conditions which were originally solid to liquid as a result of the loss of soil shear stress due to an increase in pore water stress caused by repeated loads in this case earthquake loads. Liquefaction is an event where the soil loses shear strength due to increased pore water stress as a result of rapid cyclic loading (earthquake load) in a moment (Idriss and Boulanger, 2008). Due to the loss of stiffness and shear stress, the properties of the soil which were initially solid become liquid. Soils that have the potential to experience liquefaction when subjected to cyclic loading are fine sand (sand), silty sand, and loose sand. Because it only occurs in saturated soils, liquefaction generally occurs near rivers, bays, or other bodies of water (Kramer, 1996). From the existing liquefaction potential, it is necessary to conduct a study to reduce losses due to liquefaction, the required liquefaction potential parameters are the CPT (cone penetration test) value, the safety factor value and the coordinates of the research location. The method used to analyze changes in soil profile due to potential liquefaction is the distribution contour at each depth. This analysis can be done through GIS software and Surfer which is an application that can run contour analysis. Based on this background, a final project was prepared with the title: "Safety Factor (Sf) Value Profile for Liquefaction

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Note: Discussion on this paper is open until March 2021

Potential Based on CPT Data Using Gis & Surfer Applications".

2. Literature Review

2.1 Cone Penetration Test

Soil investigation is the initial part of the process carried out before starting work on the construction of a building structure. Soil investigation is carried out in 2 (two) ways, namely: field investigation and laboratory testing. Soil investigations are carried out to obtain data on the technical properties of the soil, which are then used for consideration in the purposes of design and construction of a structure that stands on it. To obtain additional information on a specific location to clarify soil conditions, so that the structural design becomes complete. (Wahyudi & Mutia, 2018).

One method of soil investigation carried out in the field is the static cone penetration test (Conus Penetration Test / CPT / Sondir) (figure 1). CPT is a method used to determine the geotechnical engineering properties of soil and describe soil stratigraphy.

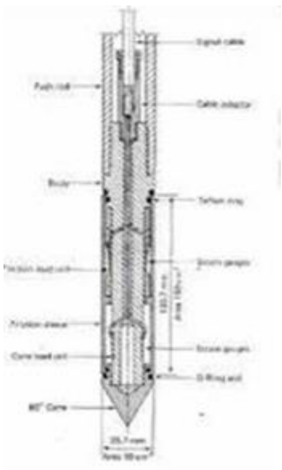

Fig. 1. Cone penetration test tools

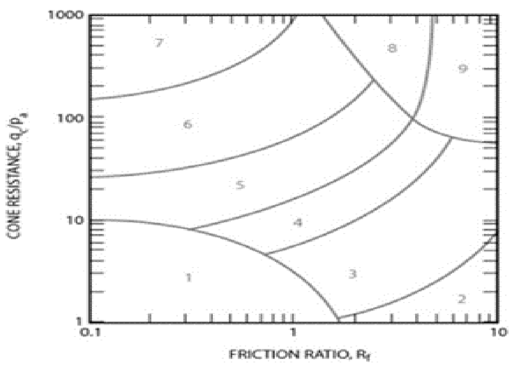

Fig.2. Graph of non-normalized soil behavior type (Robertson et al., 2010)

One of the main applications of CPT is determining soil type. However, CPT is not expected to provide an accurate prediction of soil type, but can provide type soil behavior based on characteristics mechanics (strength,stiffness, compreability).

2.2 Earthquake

An earthquake is an event that causes the earth to vibrate due to the sudden release of energy in the earth, which is marked by the breaking of rock layers in the earth's crust. The accumulation of energy that causes earthquakes results from the movement of tectonic plates. The energy produced is emitted in all directions in the form of earthquake waves so that its effects can be felt to the earth's surface. tends to react with cyclic loads so that the soil loses shear strength due to a decrease in the effective soil stress as the pore water stress increases. Liquefaction events when viewed visually are marked by the appearance of sand mud on the ground in the form of sand (sand soil), sinking of building structures above the surface, water seepage through soil cracks, land subsidence and lateral displacement.

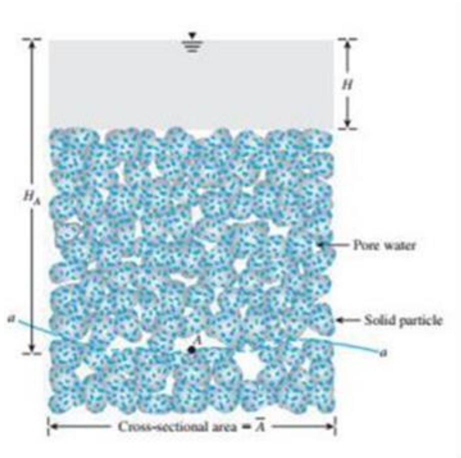

Fig.3. Effective earth stress condition

2.3 Liquifaction

Liquifaction is the loss of soil strength due to an increase in pore water pressure and a decrease in the effective pressure of the soil layer due to cyclic loading. As a result of the cohesionless soil structure receiving successive shear stresses so that the sand soil structure solidifies, but because this cyclic event occurs very quickly, the compaction process does not occur and the pore water stress increases. The impact of an increase in pore water, the soil will lose shear strength drastically due to a decrease in the effective stress of soil pore water (Idriss & Boulanger, 2008). Loose to medium density sand and water-saturated silty sand. The increase in pore water pressure causes the flow of water to rise to the soil surface in the form of mud or sand. For this liquefaction state, the effective soil stress becomes zero and the particles release each other as if they were floating in water as shown in Figure 4. The structure above the sandy soil deposit which was liquefied during an earthquake would sink or fall and the buried channel will float to the surface.

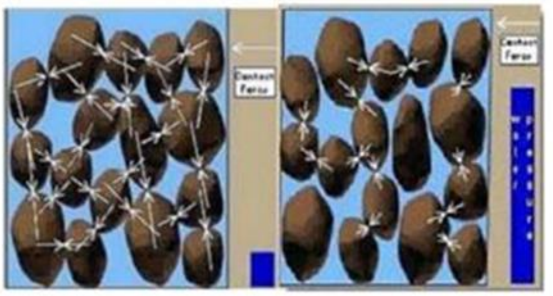

Fig.4. The condition of the soil particles before and after the increase in water pressure pore

Analyze potential occurrence liquefaction assumed during the earthquake vibration, there has not been a significant dissipation in the soil layer, in other words, there has not been a redistribution of pore water pressure in the soil mass. Due to cyclic loads (earthquake loads), the soil experiences pressure before the dissipation process occurs so that it causes the pore water pressure to increase, the groundwater level greatly determines the potential for liquefaction (Tijow & Ticoh, 2018).

3. Methodology of Research

The Cone Penetration Test (CPT) was carried out at a location in Makassar City which is geographically located at the coordinates of 5˚09'30.4" South Latitude and 119˚24'55.7" East Longitude. This research was conducted on lowland areas and close to the coast as shown in Figure 5. The materials used are Cone Penetration Test (CPT) data and Coordinate Point Data at the research site. Tools used in perform data processing namely; Computer/Laptop, Computer Mouse, Internet/Wifi Network, Microsoft Office Software, Microsoft Excel Software, ArcGIS Map Software, Google Earth Pro software, Surfer Software. In conducting research on changes in soil profile, first perform empirical calculations based on secondary data Cone Penetration Test (CPT) in the field. The soil data generated from the CPT will be used in constructing the contours of the safety factor distribution.

Fig.5. The site of research conducted

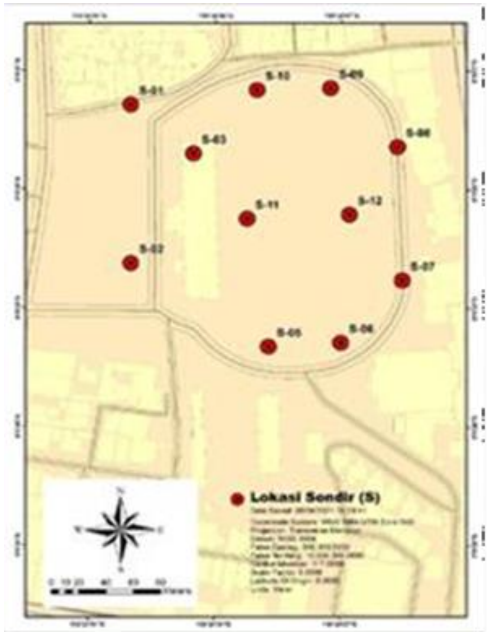

Fig.6. The point of Cone Penetration test

Geographically, this research area is located at coordinates 5˚09'30.4" South Latitude and 119˚24'55,7" East Longitude. This area is formed by alluvium rock (a type of clay), the soil layer generally consists of thick sand, silt and clay material with deep bedrock which causes seismic wave resonance during earthquakes and the location of this research area is relatively low close to the coast (Amaliah, 2021). To evaluate the liquefaction potential, a cone. test was performed. Cone penetration test (CPT) in the research area spread over 12 points as shown in Figure 6.

4. Result and Discussion

4.1 Result

Table 1 shows the coordinates of the cone penetration test (CPT) test point along with the location of the depth of the ground water table.

Table 1. the location of cone penetration point

Code Point	Coordinate		Groundwater Depth (m)
	X	Y	
S-01	767656	9429329	1.4
S-02	767656	9429269	1.6
S-03	767702	9429354	1.4
S-04	7677062	9429250	1.4
S-05	767757	9429204	1.6
S-06	767810	9429207	1.6
S-07	767855.02	9429255.29	1.4
S-08	767851.60	9429358.96	1.4
S-09	767802.57	9429404.71	1.4
S-10	767748.62	9429403.32	1.4
S-11	767741.39	9429303.28	1.4
S-12	767816.33	9429306.43	1.4

The sample of location is used to produce a safety factor value for which a soil contour will be made. Where the safety factor value will be entered in a software and produce a safety factor contour for each depth. The following is an example of the calculation of data analysis carried out by Amaliah 2021. This data encourage researchers to carefully chosen the point of CPT location based on thre area.

4.2 Safety Factor

In this study, the authors use secondary data measured in the field which has 12 points and has a different depth of safety factor so as to form a contours that have various colors. In this study, the authors also used an earthquake acceleration value of 0.3 g. The output results of the distribution contours of the safety factor for each depth obtained from the ArGIS Map are based on each depth, namely:

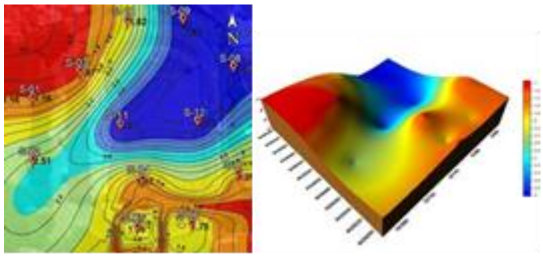

Fig. 7. 2-dimensional and 3-dimensional safety factor contours 1m depth

From the safety factor value data at a depth of 1 meter, the ArGIS and Surfer software depth is inputted, then a safety factor distribution contour is formed as in 9. In the distribution contour above there are various colors, where the safety factor value in this study assumes if fs>1 is said to be safe, fs <1 potential for liquefaction. The colors on the contours have their respective meanings where red symbolizes the area has the potential to experience liquefaction that has a safety value range. factor below 1, the orange color which can be said is quite safe which has a range of SF values between 1.1 – 1.6, the yellow color can be said to be quite safe which has a range of values between 1.7-2.2, and the colors are light green and light blue. which can be said to be safe which has a range of SF values between 2.3-3.2 and the blue area which is assumed to be a very safe area from liquefaction has an SF value above 3. At a depth of 1 m there is a potential liquefaction area of 7,465.3 m2. and a safe land area of 52,534.7 m2. At a depth of 1 m has a wider safe area than the area that has the potential for liquefaction.

The 2-dimensional and 3-dimensional contours that are formed can be seen that the 3-dimensional contours of the safety factor are not much different from the existing 2-dimensional contours, where the two images have colors and have almost the same safety factor contours. Where on the 2-dimensional and 3-dimensional contours it can be seen that the safety factor contour formed has a dominant area that has an SF value> 1 which can be said to be safe from potential liquefaction.

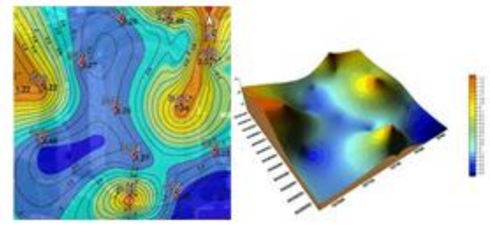

Fig. 8. Contour safety factor 2 dimensions and 3 dimensions depth of 2 m

Based on Figure 8, it can be seen that at a depth of 2 m there is a very small liquefaction area where the potential liquefaction area will be 29.5 m2, it can be seen that the 2-dimensional and 3-dimensional images formed are almost similar, there are only a few different color ranges but have the same contour. At a depth of 2 m can be said to be safe from the potential for liquefaction.

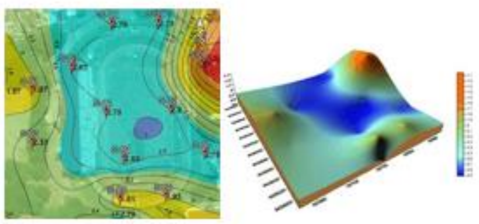

Fig. 9. Contour safety factor 2 dimensions and 3 dimensions depth of 3 m

From Fgure 9 , it can be seen that the contour formed at a depth of 3 m has large blue and green areas where the area is said to be safe and has a red area which means it has the potential for liquefaction. Areas that have the potential for liquefaction have an area of 619 m2, 2-dimensional and 3-dimensional contours formed at a depth of 2 m have a shape that is not much different, only has a slightly different color range, but overall is the same which has a safe area in the middle and has a potential liquefaction area. which is at right angles.

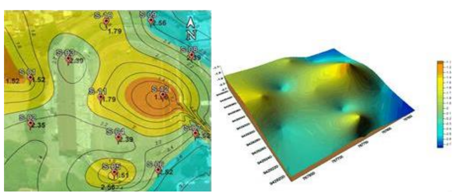

Fig. 10. Contour safety factor 2 dimensions and 3 dimensions depth of 4 m

Based on Figure 10, the contour formed only has yellow, green, and blue areas, and does not have red areas. So the contour formed at a depth of 4 m can be said to be safe from potential liquefaction. The 2-dimensional and 3-dimensional contours that are formed are the same, only have a slightly different color range, where on the contours formed it can be seen that a depth of 4 m does not have the slightest liquefaction potential area. And at this depth it is also the safest depth of potential liquefaction.

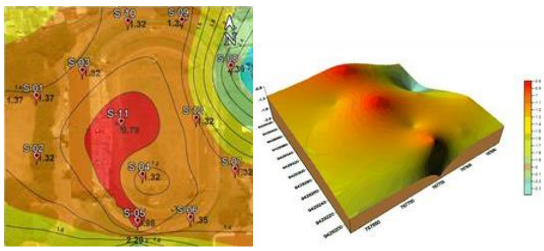

Fig. 11. Contour safety factor 2 dimensions and 3 dimensions depth of 5 m

From figure 11, it can be seen that the contour formed at a depth of 5 m has a liquefaction potential area that is quite spacious and located in the middle. As well as having an area that can be said to be safe also surrounding the area of potential liquefaction. The liquefaction potential area formed on the contour has an area of 4,982 m2. Two-dimensional and 3-dimensional contours have the same contour shape, but only have a slightly different color range. At a depth of 5 m, a contour is formed which has many areas that can be said to be safe against the potential for liquefaction.

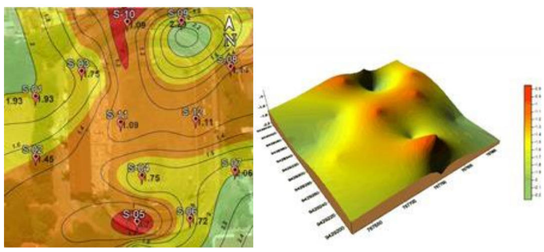

Fig. 12. Contour safety factor 2 dimensions and 3 dimensions depth of 6 m

In Figure 12, it can be seen that the safety factor contour at a depth of 6 m has a dominant yellow area or an area that is said to be quite safe from potential liquefaction, and has a liquefaction area of 2,785 m2. The 2-dimensional and 3-dimensional contours formed have the form the same contour. But only have a slightly different color range. At a depth of 6 m, a dominant contour is formed that has a safe area, and has an area that has the potential for liquefaction at the corners of the contour of the safety factor.

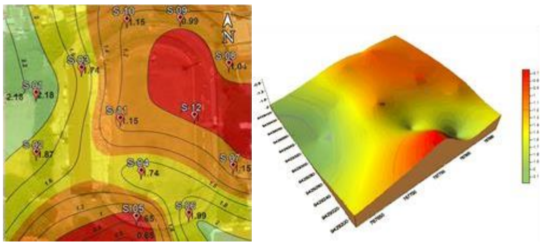

Fig. 13. Contour safety factor 2 dimensions and 3 dimensions depth of 9 m

In Figure 13, the contour which formed has several points that have the potential for liquefaction and also has a safe area, at a depth of 8 m has an area of 11,625 m2 potential for liquefaction. From the 2-dimensional and 3-dimensional contours that are formed, they have the same contour shape, only having a different color range where at a depth of 8 m, has a potential liquefaction area at the bottom right and left corners and the top corner of the safety factor contour. a contour formed at a depth of 9 m, where at a depth of 9 meters has a dominant safe area and has a liquefaction potential area of 9,817 m2. The 2-dimensional and 3-dimensional contours formed have the same shape where at a depth of 9 m there are areas that have the potential to experience liquefaction on the right and bottom sides of the safety factor contour. And there are also areas that have a high safety factor value, dominantly on the left side of the safety factor contour.

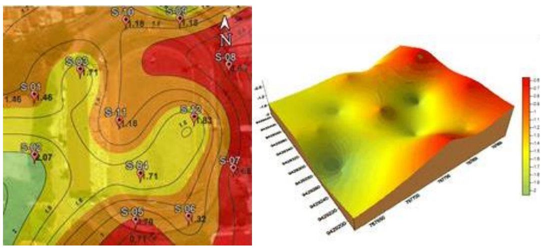

Fig. 13. Contour safety factor 2 dimensions and 3 dimensions depth of 15 m

The contour area of the safety factor that has the potential for liquefaction is quite large, where the area of potential liquefaction is found in the lower left and upper right areas of the safety factor contour formed at a depth of 14 m. The area of potential liquefaction at a depth of 14 m is 22,443 m2. The 2-dimensional and 3-dimensional contours have the same shape and the same color, which at a depth of 14 m has a fairly wide liquefaction potential area and is located in the corner area of the safety factors. At depth 15 m contour of the safety factor is formed as shown in Figure 23. Where at a depth of 15 m there is a dominant liquefaction potential area in the right area, which has an area of 11,081 m2. The 2-dimensional and 3-dimensional contours have the same shape and color, which at a depth of 15 m has a potential liquefaction area in the right area and the bottom of the safety factor contour.

5. Conclusions

The condition of the safety factor contour for each depth that is given an earthquake acceleration value of 0.3 g has a different value for each depth, so that the resulting contours vary. From the use of GIS and Surfer software, a different safety factor distribution contour is formed at each depth. The distribution contour that has many points with a safety factor value of <1 which means it has many points that have the potential to experience liquefaction is at a depth of 11 meters with an area of 24,055 m2, and a contour that has a safety factor value of> 1 is at a depth of 4 meters, where at a depth of 4 meters. can be said to be safe for all points. Comparison of 2-dimensional and 3-dimensional contour images produces almost the same contours, it's just that some contours have a slightly different color range, causing 3-dimensional contours to look different from 2-dimensional contour images.

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