# Analysis of Liquefaction Potential based on CPT data in the Samas Coastal Area, Bantul Regency, Yogyakarta Special Province, Indonesia

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**ABSTRACT**
Bantul Regency is an area of the Special Region of Yogyakarta Province prone to earthquakes, mainly due to plate tectonic activity. On May 27, 2006, an earthquake of 6.3 Mw hit the Special Region of Yogyakarta and caused considerable damage in Bantul Regency. One of the impacts of the earthquake liquefaction, therefore, it is necessary to analyze the potential for liquefaction in the southern part of Bantul Regency. This research aims to determine the potential for liquefaction at the research location by considering the value of the liquefaction safety factor from the cone penetration test (CPT) data. The method used in this research is potential liquefaction analysis using the calculation method from the NCEER1998 consensus. The results of the potential liquefaction analysis are based on CPT data at three test points and correlated with core drilling data. The liquefaction potential zones in the CPT-1 are at a depth of 0.2 meters to 5.4 meters with a thickness of 5.2 meters. Whereas in CPT-2 potential for liquefaction zone that has the is at a depth of 0.2 - 9.4 meters with a thickness of the liquefied layer of 8.4 meters, then in CPT-4, it is at a depth of 0.2 - 11.2 meters with a layer thickness of 8.2 meters. Based on the three CPT data, the liquefied layers are in a layer of fine sand to coarse sand.

***Keywords:*** *Liquefaction, Cone Penetration Test, Safety Factor, Bantul, Indonesia.*

## 1. INTRODUCTION

Earthquakes are natural disasters that often occur in Indonesia and have claimed many lives or material losses. Bantul Regency, which is part of the Yogyakarta Special Region Province, is an area that is prone to earthquakes that occur due to tectonic activity. The risks caused by an earthquake are the risk of failure of the building structure and the risk of soil structure failure. Damages to the soil structure include settlement, rockfall, landslides, subsidence, and liquefaction [1].

On May 27, 2006, the Mw 6.3 earthquake hit the Province of Yogyakarta Special Region and its surroundings [2]. The joint geotechnical team from Japan and Indonesia investigated the Yogyakarta earthquake and found evidence of liquefaction symptoms in the Bantul area by the bent of 2 pipe wells and rising 70 cm turbid water overflowed 1.3 m from the well [3]. The earthquake caused significant damage in the Special Region of Yogyakarta.

Due to earthquakes, the phenomenon of liquefaction is an event of the loss of strength of the loose sand layer due to increased pore water pressure due to earthquake vibrations. Thus, liquefaction will occur in areas prone to large earthquakes composed of water-saturated sand deposits with low density and areas where the co-seismic surface movement exceeds the threshold value [4]. Samas coastal area and its surroundings, Bantul Regency, Yogyakarta Special Region, comprises a Holocene sedimentary deposit [5]. Therefore, the liquefaction potential will likely occur if an earthquake occurs and the construction load is added to this area. The Samas coastal area and its surroundings are planned to be an area for tourism. Therefore, as a mitigation measure and regional


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development planning, research on potential liquefaction is needed.

## 2. RESEARCH AREA

Physiographically, the research area is in Samas Beach, Bantul Regency, Yogyakarta Special Region Province, Indonesia, which is part of the Solo zone and the central depression zone of Java Island. This zone spreads from the central part of Java Island to the eastern part, as shown in Figure 1 [6].

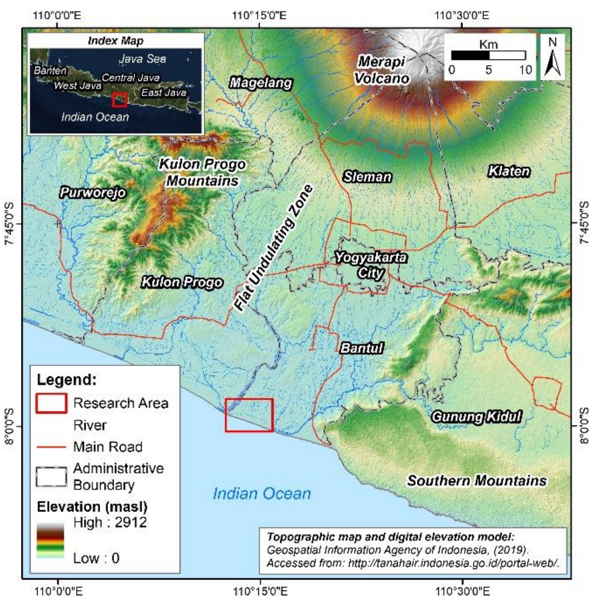


**Figure 1** Research area in the Physiographic of Kulon Progo, Yogyakarta, and Southern Mountains [2]

Referring to the regional geological map Sheet Yogyakarta at a scale of 1: 100,000, as shown in Figure 2 [5], the research area is composed of the Quaternary Alluvium (Qa) sediment unit (<1.8 million years). Alluvium (Qa) deposits consist of sand, silt, and clay deposited by the river (fluvial) and coastal geological processes. Alluvium deposits result from the breakdown of older rocks with a Tertiary age consisting of loose to weakly compacted material grained clay to crust.

Based on the regional geological map of the Yogyakarta sheet [5], the regional structure is found in the east of the research area, i.e., the Opak fault with a northeast-southwest direction. This fault is the boundary between the Yogyakarta depression and the Southern Mountains. The Opak Fault is a normal fault resulting from the previously existing sinistral shear fault [7]. No faults were found in the western part of the Yogyakarta depression, but there may be sub-surface faults covered by younger soil and sediment [8].

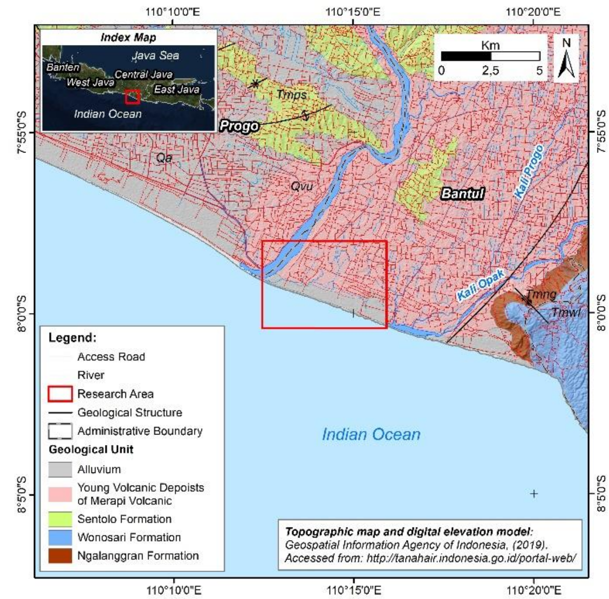


**Figure 2** Research area in the Physiographic of Kulon Progo, Yogyakarta, and Southern Mountains [2]

## 3. METHODOLOGY

The research method used in this research includes subsurface geotechnical investigations consisting of technical drilling and a cone penetration test (CPT) of 3 points with a depth of 20 meters each, which are spread over the research location as shown in Figure 3. Prediction of potential liquefaction based on CPT data is one of the quantitative methods of evaluating the potential for liquefaction using the cyclic stress approach [9]. The cyclic stress ratio (CSR) and the cyclic resistance ratio (CRR) are needed to analyze the liquefaction potential. After getting the CSR and CRR values, it calculates the value of the safety factor from the comparison of the CRR (Cyclic Resistance Ratio) value, namely the CSR (Cyclic Stress Ratio). The calculation of the liquefaction potential is carried out based on the CPT data and the seismicity. The PGA value of the research area has an average of 0.3 - 0.4 g [10] with an earthquake scenario on a scale of 7.5 SR. with the maximum groundwater level. It is assumed to reach the ground surface due to earthquake vibrations and rising groundwater levels.

### *3.1. Cyclic stress ratio (CSR)*

The cyclic stress ratio is a function of the average cyclic shear stress ($\tau_{av}g$) against overburden stress ($\sigma'_{vo}$) [9]and is formulated in Equation (1):

$$CSR = (\tau_{av} / \sigma'_{vo}) = 0.65 (a_{max} / g)(\sigma_{vo} / \sigma'_{vo}) r_d \quad (1)$$

where,

$a_{max}$: the maximum horizontal acceleration at the ground surface;

g: the acceleration of gravity;

$\tau_{av}$: the average cyclic shear stress generated by the earthquake;
$\sigma_{vo}$: total vertical stress;
$\sigma'_{vo}$: effective vertical stresses;
$r_d$: a shear stress reduction factor

The stress reduction factor ($r_d$) compares cyclic stress in flexible and rigid soils [11]. To calculate the stress reduction due to overburden ($r_d$), it can use the Equation (2), Equation (3), and Equation (4) [12]:

$$r_d = exp(\alpha(z) + \beta(z) Mw) \quad (2)$$

$$\alpha(z) = -1.012 - 1.126 \sin(z/11.73 + 5.33) \quad (3)$$

$$\beta(z) = 0.106 + 0.118 \sin(z/11.28 + 5.142) \quad (4)$$

Where z is the depth of the soil (m) under consideration and Mw is the moment of magnitude.

### 3.2. Cyclic resistance ratio (CRR)

The Cyclic Resistance Ratio (CRR) value is the value of the resistance of a soil layer to cyclic stress. The CRR value can be obtained in several ways, including field testing results, namely the CPT. The calculation of the Cyclic Resistance Ratio (CRR) value can be formulated with the Equation (5) and Equation (6):

If the value $(q_{c1N})_{cs} < 50$, then,

$$CRR_{7.5} = 0.833[(q_{c1N})_{cs}/1.000] + 0.05 \quad (5)$$

and if $50 \leq (q_{c1N})_{cs} \leq 160$, then,

$$CRR_{7.5} = 93[(q_{c1N})_{cs}/1.000]^3 + 0.08 \quad (6)$$

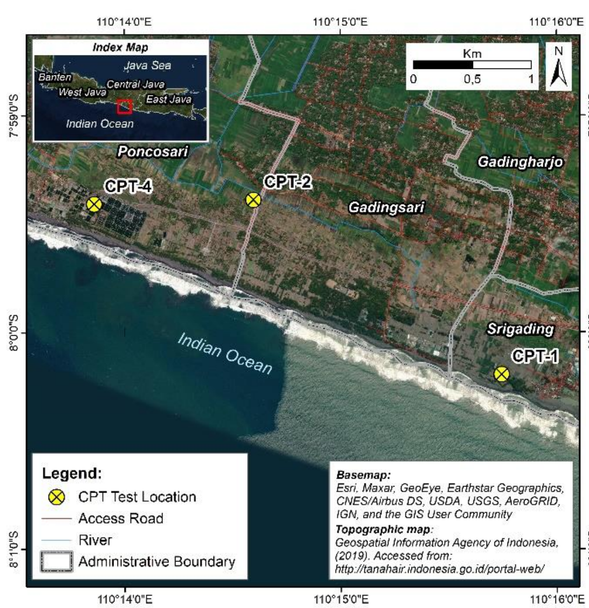


Figure 3 CPT test location

## 4. RESULTS AND DISCUSSION

### 4.1. Liquefaction Potential

This research generally aims to analyze the safety factor of the CPT data. CPT data collection was carried out at three points in the research area. The liquefaction potential was conducted with a maximum depth of 20 meters. The existing CPT test data is processed to obtain the value of CSR, CRR, and the safety factor (FS). The calculations were conducted using Microsoft Excel software.

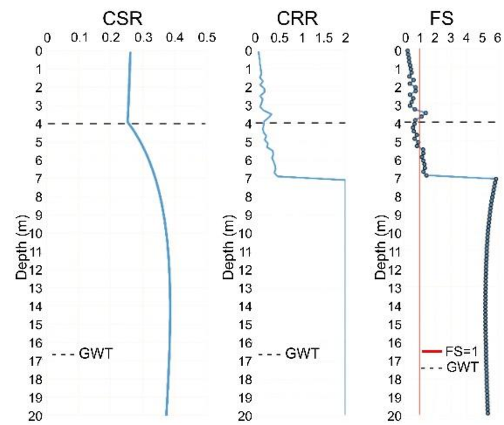


**Figure 4** Graph of CSR, CRR, Factor of Safety (FS) CPT-1 test data versus to depth

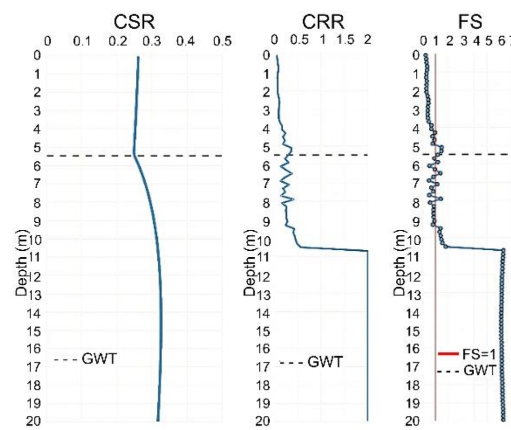


**Figure 5** Graph of CSR, CRR, Factor of Safety (FS) CPT-2 test data versus depth

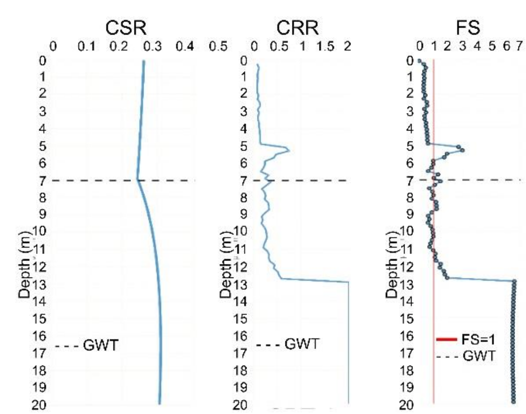


**Figure 6** Graph of CSR, CRR, Factor of Safety (FS) CPT-4 test data versus depth

The graph of CSR, CRR, and FS CPT-1 tests is shown in Figure 4. Analysis of the potential for liquefaction at the CPT-1 test point shows a weak zone that will experience liquefaction at a depth of 0.2 meters to 5.4 meters. In addition, it can be seen that the value of the safety factor below 5.4 meters to a depth of 20 meters has a value of more than 1, which means that the zone is not prone to liquefaction.

The CPT-2 value analysis results are based on the CSR, CRR, and FS charts of the CPT-2 test, as shown in Figure 5. It shows that the liquefied layer is divided into several zones. The first is at a depth of 0.2 - 5 m, and then the second zone is 5.8 - 9.4 m. The results of the CPT-4 value analysis based on the graph of CSR, CRR, and FS compared to the depth as shown in Figure 6 shows that the liquefied layers are at a depth of 0.2 - 5 m, 6 - 6.6 m, 7.6 - 8.2 m, 9 - 11.2 m. The thickness of the liquefied layer on the CPT-4 was around 8.2 m.

### 4.2. *Comparison of the Safety Factor Value*

The comparison of the safety factor from the CPT data and soil layer data for each depth is shown in Figure 7. Based on the graph, it can be seen that part of the layer has the potential for liquefaction and the type of sediment. In the graph data, the value of the safety factor (FS) CPT-1 shows a value of less than 1 (potentially liquefaction) at a depth of 0.2 - 5.4 meters in a medium sand sediment layer. Meanwhile, the safety factor (FS) of CPT-2 has the potential for liquefaction at a layer of 0.2 - 9.4 meters in depth, which is fine sand and medium sand deposits. At the CPT-4 point, liquefaction has potential in layers with a depth of 0.2 - 5 m, 6 - 6.6 m, 7.6 - 8.2 m, 9 - 11.2 m, composed of sediment of fine sand to coarse sand. Based on comparing the safety factor values of the three CPT data, the thickness of the layer that has the potential for liquefaction for CPT-1 is 5.2 m, CPT-2 is 8.4 m, and CPT-4 is 8.2 m.

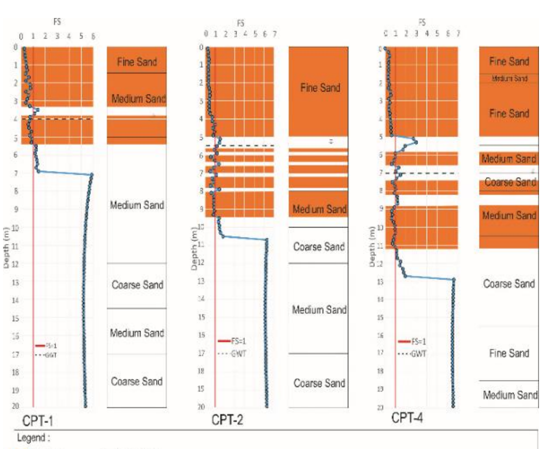


**Figure 7** Graph of comparison of safety factor values (FS) among CPTs

## 5. CONCLUSIONS

The calculation of potential liquefaction analysis based on CPT data from three locations in Samas Beach, Yogyakarta Special Region, shows potential liquefaction at all CPT test points. In the CPT-1 data, the liquefaction potential zone is at a depth of 0.2 meters to 5.4 meters with a thickness of 5.2 meters. The CPT-2 test data for the liquefaction zone occurs at a depth of 0.2 - 9.4 meters with a layer thickness of 8.4 meters, and then for the CPT-4 test data, the liquefaction zone is at a depth of 0.2 - 11.2 meters with a layer thickness of 8.2 meters. Based on the three CPT test data, the layers that can occur liquefaction are the fine sand layer to coarse sand. Therefore, this area is not suitable for the settlement area. However, it can be used if some soil treatments should be conducted to minimize the liquefaction risk.

## ACKNOWLEDGMENTS

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