

# COMPARISON OF SINGLE BORED PILE BEARING CAPACITY BASED ON CPT AND SPT

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## ABSTRACT

Field soil testing is very important to determine the bearing capacity of the soil to be able to design a safe foundation. In this research will be compared the results of testing of CPT (Cone Penetration Test) and SPT (Standard Penetration Test) so it can be obtained the safest bearing capacity of the soil. Field soil testing is performed in Dukuh Village, Tegalalang District, Gianyar Regency and in TanjungBenoa, Badung Regency, Bali Province. In Tegalalang area, soil testing is performed at four points and in Nusa Dua area at three points. The bearing capacity of the pile is calculated from 4 meters depth to 10 meters depth and the calculation is performed every 2 meters depth. The diameter of the foundation which is used are 20 cm, 30 cm, 40 cm and 50 cm. Furthermore the results of soil testing in the field is compared based on data SPT and CPT. The result of analysis which is used is the lowest bearing capacity of SPT and CPT.

Based on the combined bearing capacity (the addition of end bearing capacity of bore pile and the bearing capacity of skin friction) of bore pile is obtained a higher value for CPT test at 1700 kN compared with the SPT test that is at 900 kN, this condition are for both of the test location in the Tegalalang and in the Nusa Dua. For the bearing capacity value should use the smallest bearing capacity value so it can achieve a higher safety value.

**Keywords:** *CPT, SPT, bearing capacity, bore pile*

## A. INTRODUCTION

Field soil testing is very important to determine the bearing capacity of the soil to be able to design a safe foundation. Some advantages of soil field test are: 1). Improved efficiency and cost effectiveness compared to sampling and laboratory testing, 2). Large amount of data, 3). Evaluation of both vertical and lateral variability (Mayne et al. 2009). The field soil testing which is commonly performed are CPT (Cone Penetration Test) and SPT (Standard Penetration Test). The CPT is very important for soil investigation in the field because it is fast, repeatable, and economical (Robertson, 2009).

In this research will be compared the results of testing of two field soil testing methods so it can be obtained the safest bearing capacity of the soil. In this study is used bore pile foundation to analyze the bearing capacity of the foundation. Soil testing is performed in Tegalalang, Gianyar regency and Nusa Dua, Badung regency, because in this area tourism development is very rapid so it is important to build a safe building. In addition, the reason for choosing the two locations is because to compare

the test results in the highlands area in the Tegalalang and in the coastal area in the Nusa Dua.

## B. LITERATURE STUDY

The purpose of the soil investigation is to determine the location or position of the soil layer that meets the required bearing capacity so the building is stable and does not occur too large settlement (Gunawan, 1991). Field soil investigation includes CPT and SPT. Further soil investigation results are used to analyze the bearing capacity of the foundation. The foundation being analyzed is bored pile foundation.

The bore pile foundation is included into the deep foundation type. The vertical bearing capacity of the pile foundation is obtained from adding the end bearing capacity of pile and the shear resistance of the pile skin (Lambe et al. 2008).

To make the structures safe, it is important to estimate the factor of safety of soil structure by carrying out an appropriate stability calculation. In general, it is not able to calculate a value of safety factor (SF) for a soil structure directly. Instead, we must usually guess a value for safety factor (SF) the determine whether the reduced soil strength just causes collapse to occur (Atkinson, 1981). At the

calculation of bearing capacity is usually given a safety factor (FS)  $\geq 2$  for sand soil and safety factor (FS)  $\geq 3$  for clay soil (Redana, 2010).

The amount of bearing capacity allowed is as follows (Das, 1990) :

$$Q_a = \frac{Q_u}{SF} = \frac{(Q_p + Q_s)}{SF} \quad (1)$$

where:

- Q<sub>a</sub> = allowable load capacity of bore pile,
- Q<sub>u</sub> = ultimate load capacity of bore pile,
- Q<sub>p</sub> = end bearing load capacity of bore pile
- Q<sub>s</sub> = skin friction load capacity of bore pile
- SF = factor of safety

End bearing load capacity of bore pile based on CPT data is formulated as (Sardjono, 1984):

$$Q_{ap} = \frac{A_p q_c}{SF} \quad (2)$$

where:

- Q<sub>ap</sub> = allowable end bearing load capacity of bore pile,
- A<sub>p</sub> = the cross-sectional area of the foundation,
- q<sub>c</sub> = unit point end bearing load capacity of bore pile
- SF = factor of safety

End bearing load capacity of bore pile based on SPT data is formulated as (Das, 1990):

$$Q_{ap} = \frac{A_p \left( \frac{40NL}{D} \right)}{SF} \leq \frac{A_p \times 400N}{SF} \quad (3)$$

where:

- N = average number of SPT value at end of pile (about 10D above and 4D below the end of pile point)
- Q<sub>up</sub> = ultimate end bearing load capacity of bore pile
- Q<sub>ap</sub> = allowable end bearing load capacity of bore pile
- L = depth of penetration
- D = diameter of pile
- SF = factor of safety

Load capacity of bore pile by skin friction based on CPT data is expressed as (Sardjono, 1984):

$$Q_{as} = \frac{c \times p}{SF} \quad (4)$$

where:

- Q<sub>as</sub> = allowable load capacity of bore pile by skin friction,
- c = soil cohesion,

p = perimeter of bore pile section,

SF = factor of safety

Load capacity of bore pile by skin friction based on SPT data is expressed as (Das, 1990):

$$Q_{as} = \frac{\sum p f_{av} \Delta L}{SF} \quad (5)$$

f<sub>av</sub> = 2N (high displacement of pile)

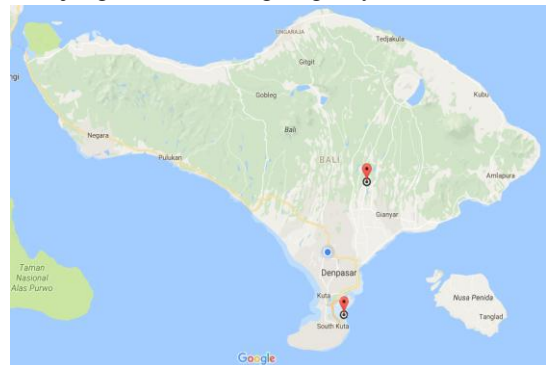
f<sub>av</sub> = N (low displacement of pile)

where:

- p = perimeter of bore pile section,
- f<sub>av</sub> = friction factor of soil and pile,
- N = SPT value at the end of pile point,
- ΔL = depth penetration of pile,
- SF = factor of safety.

### C. METHODOLOGY

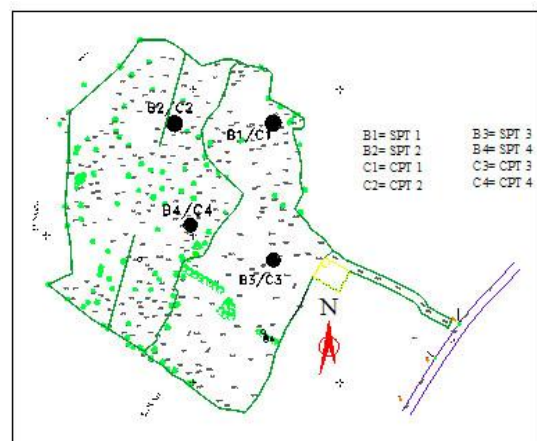
To analyze the bearing capacity of the foundation is required field soil testing data. Field soil testing is performed in BanjarDukuh, Tegalalang District, Gianyar Regency and inTanjungBenoa, Badung Regency, Bali Province.



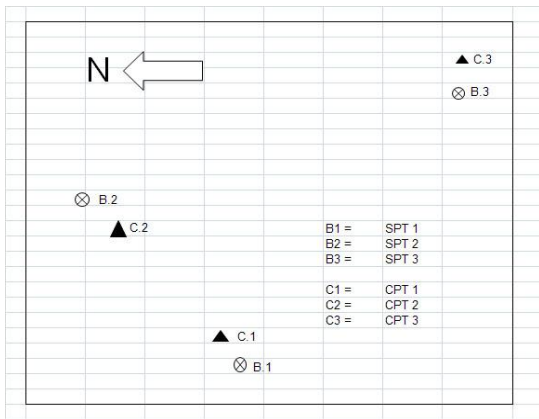
**Figure 1.**Soil investigation sites

Source: Google Map

Field soil testing consists of CPT test and SPT test at each point. In Tegalalang area, soil testing is performed at four points (Figure 2) and in Nusa Dua area at three points (Figure 3).



**Figure.2**Soil test lay out in Tegalalang



**Figure 3** Soil test lay out in Nusa Dua

Further data of field soil testing result is used to analyze the soil bearing capacity. Soil bearing capacity is calculated based on CPT and SPT results on the end bearing capacity of the pile and the bearing capacity of skin friction of the pile to obtain the allowable load capacity of the single bore pile. The bearing capacity of the pile is calculated from 4 meters depth to 10 meters depth and the calculation is performed every 2 meters depth. The diameter of the foundation which is used are 20 cm, 30 cm, 40 cm and 50 cm. Furthermore the results of soil testing in the field is compared based on data SPT and CPT. The result of analysis which is used is the lowest bearing capacity of SPT and CPT on end bearing capacity of pile and bearing capacity of pile by skin friction or combination of both bearing capacity.

#### D. RESULTS AND DISCUSSION

The results of CPT testing on the Tegalalang and Nusa Dua areas provide the results of penetration resistance as shown in Table 1 and Table 2.

**Table 1.** The summary of cone penetration resistance based on CPT test in Tegalalang area.

No	depth	cone penetration resistance (qc)			
		point 1 (S1)	point 2 (S2)	point 3 (S3)	point 4 (S4)
	(m)	(kg/cm <sup>2</sup> )	(kg/cm <sup>2</sup> )	(kg/cm <sup>2</sup> )	(kg/cm <sup>2</sup> )
1	0	0	0	0	0
2	2	80	250	20	200
3	4	50	250	35	250
4	6	250	250	40	250
5	8	250	250	250	250
6	10	250	250	250	250

Source: author

**Table 2.** The summary of cone penetration resistance based on CPT test in Nusa Dua area.

No	dept h	cone penetration resistance (qc)		
		point 1 (S1)	point 2 (S2)	point 3 (S3)
	(m)	(kg/cm <sup>2</sup> )	(kg/cm <sup>2</sup> )	(kg/cm <sup>2</sup> )
1	0	0	0	0
2	2	230	130	200
3	4	250	200	250
4	6	250	250	250
5	8	250	250	250
6	10	250	250	250

source: author

The resistance value of friction based on CPT is shown in Table 3 and Table 4.

**Table 3.** The summary resistance value of friction based on CPT in Tegalalang area.

No	dept h	Soil friction			
		point 1 (S1)	point 2 (S2)	point 3 (S3)	point 4 (S4)
	(m)	(kg/cm <sup>2</sup> )	(kg/cm <sup>2</sup> )	(kg/cm <sup>2</sup> )	(kg/cm <sup>2</sup> )
1	0	0	0	0	0
2	2	140	220	100	360
3	4	350	220	210	360
4	6	670	220	400	360
5	8	670	220	670	360
6	10	670	220	670	360

source: author

**Table 4.** The summary resistance value of friction based on CPT in Nusa Dua area.

No	depth	Soil friction		
		point 1 (S1)	point 2 (S2)	point 3 (S3)
	(m)	(kg/cm <sup>2</sup> )	(kg/cm <sup>2</sup> )	(kg/cm <sup>2</sup> )
1	0	0	0	0
2	2	244	1272	280
3	4	244	1562	280
4	6	244	1562	280
5	8	244	1562	280
6	10	244	1562	280

source: author

From the test results with CPT, the maximum penetrating depth for the Tegalalang area is at 8 meters depth and in the Nusa Dua area is at 4

meters depth. When the CPT test is unable to reach the deeper soil layer, the resistance value of soil is used until the depth is able to be achieved.

The result of SPT test in Tegalalang area and Nusa Dua area are shown in Table 5 and Table 6.

**Table 5.** The summary of SPT test in Tegalalang area.

No	depth (m)	Number of blows SPT			
		borehole 1 (B1)	borehole 2 (B2)	borehole 3 (B3)	borehole 4 (B4)
1	0	0	0	0	0
2	2	8	50	4	50
3	4	14	50	6	50
4	6	34	50	9	50
5	8	50	50	40	50
6	10	50	50	47	50

source: author

**Table 6.** The summary of SPT test in Nusa Dua area.

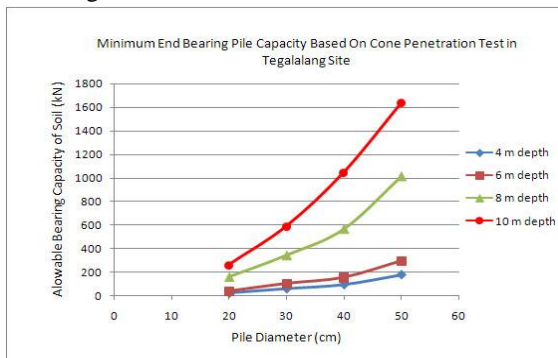
No	depth (m)	Number of blows SPT		
		borehole 1 (B1)	borehole 2 (B2)	borehole 3 (B3)
1	0	0	0	0
2	2	33	15	34
3	4	12	15	20
4	6	3	22	20
5	8	12	1	26
6	10	30	1	26

source: author

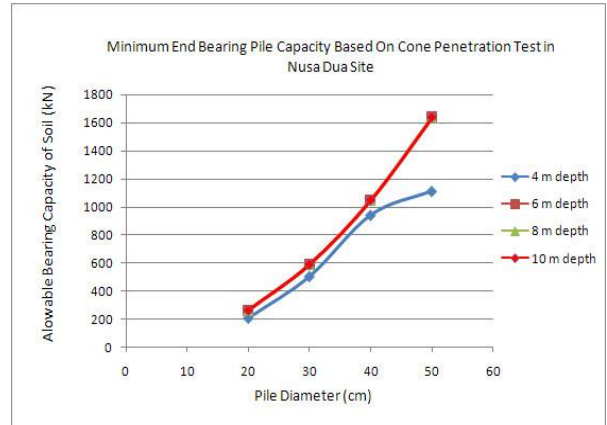
From the results of testing with SPT, especially in the Nusa Dua area on borehole 2 shows that the deeper soil layer does not have more strength than soil layer above it.

### The End Bearing Capacity of Bore Pile Based On CPT Test

After analyzing of the end bearing capacity of the pile with data from CPT, the results are obtained as in Figure 4 for the Tegalalang area and the Figure 5 for the Nusa Dua area.



**Figure 4.** Graph of the end bearing capacity of pile foundation pile in Tegalalang area based on CPT test

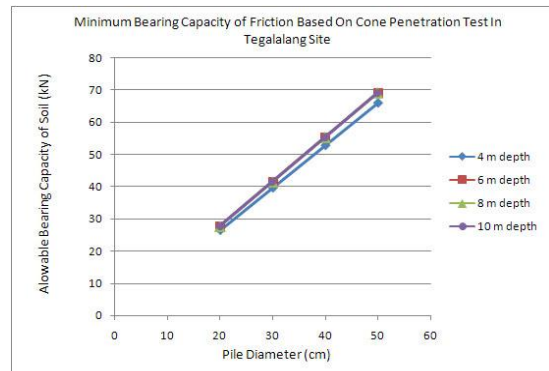


**Figure 5.** Graph of the end bearing capacity of pile foundation pile in Tegalalang area based on CPT test

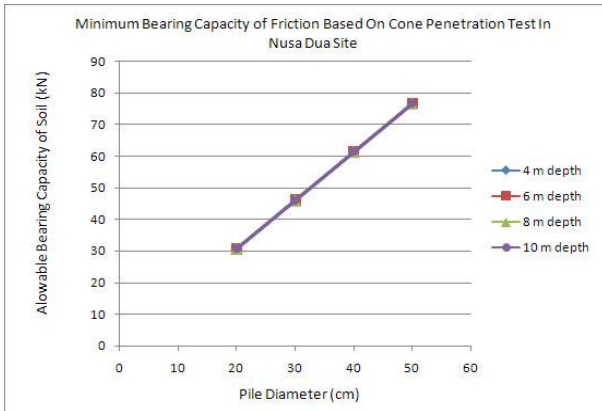
From the graph above can be seen in Figure 4, the graph of bearing capacity to the depth of 4 meters, 6 meters, 8 meters and 10 meters can be seen clearly because each depth has a different bearing capacity. While on Figure 5, the graph of bearing capacity of 4 meters depth is clearly visible but for depth of 6 meters, 8 meters, and 10 meter look to be one line is due to the bearing capacity obtained the same value. The reason for this is because in Tegalalang area soil condition is soft enough so CPT tool still able to test can penetrate the layer of soil. However, in the Nusa Dua area, the soil condition is hard enough to be penetrated by CPT test so it only reaches a maximum depth of 4 meters. The end bearing capacity of the pile with the CPT test in Tegalalang and Nusa Dua areas is almost the same at 1600 kN at 10 meters depth.

### The Bearing Capacity of Skin Friction of Bore Pile Based On CPT Test

The bearing capacity of skin friction of bore pile based on CPT test can be seen in Figure 6 for Tegalalang location and Figure 7 for Nusa Dua location.



**Figure 6.** Graph of the bearing capacity of skin friction of bore pile based on CPT test in Tegalalang area.

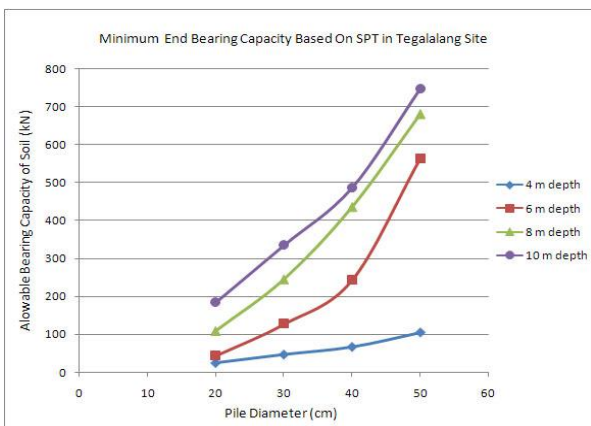


**Figure 7.** Graph of the bearing capacity of skin friction of bore pile based on CPT test in Nusa Dua area.

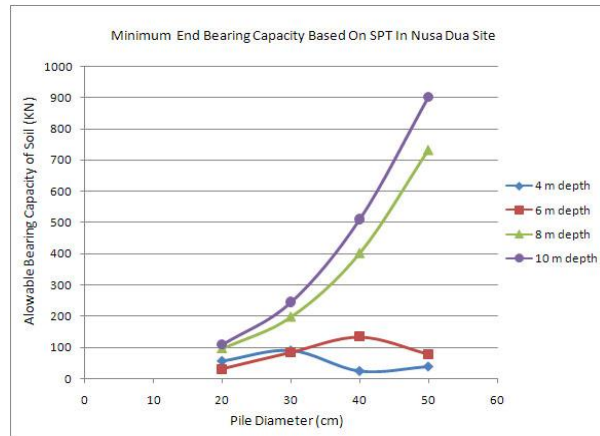
Figure 4 and Figure 5 show the bearing capacity of skin friction of bore pile based on CPT test obtaining almost the same result for each depth of this case because the CPT tool is unable to penetrate the deeper soil layer because the soil conditions are quite hard. The bearing capacity of the bored pile in Tegalalang area is closer to 70 kN smaller than Nusa Dua area which is close to 80 kN at 10 meters depth.

**The End Bearing Capacity of Bore Pile Based On SPT Test**

The result of calculation of the end bearing capacity of bore pile based on SPT data can be seen in Figure 8 for Tegalalang and Figure 9 for Nusa Dua area.



**Figure8.** Graph of the end bearing capacity of bore pile in Tegalalang area based on SPT test

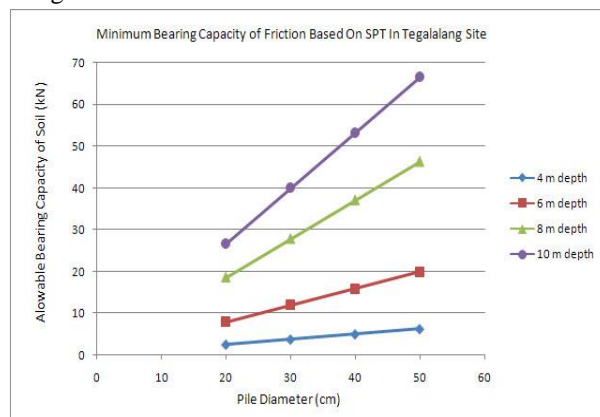


**Figure9.** Graph of the end bearing capacity of bore pile in Nusa Dua area based on SPT test

The result of calculation of end bearing capacity of bore pile can be seen in Tegalalang area deeper penetration and wider of pile size can increase the bearing capacity. Different conditions are seen at the locations in Nusa Dua for 4 meters and 6 meters depth. For a diameter of 20 cm and 30 cm, the bearing capacity is higher at 4 meters than 6 meters depth, this is due to a decrease in soil strength at 6 meters depth. The value of end bearing capacity of bore pile based on SPT test in Tegalalang area about 750 kN smaller than in Nusa Dua area that is 900 kN.

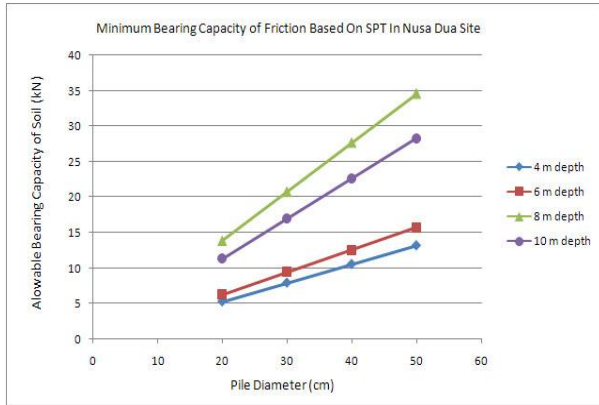
**The Bearing Capacity of Skin Friction of Bore Pile Based On SPT Test**

The bearing capacity of skin friction of bore pile based on SPT test can be seen in Figure 10 and Figure 11.



**Figure10.** Graph of the bearing capacity of skin friction of bore pile in Tegalalang area based on SPT test



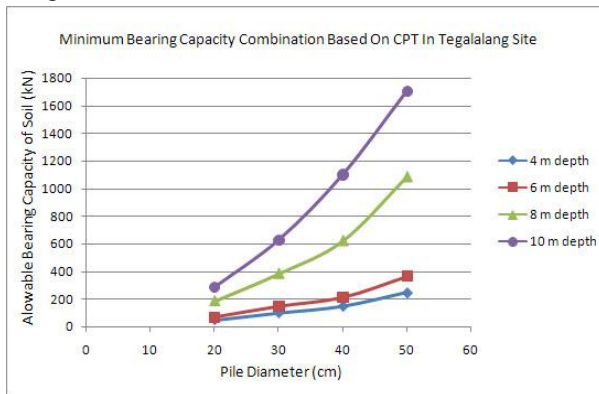


**Figure 11.** Graph of the bearing capacity of skin friction of bore pile in Tegalalang area based on SPT test

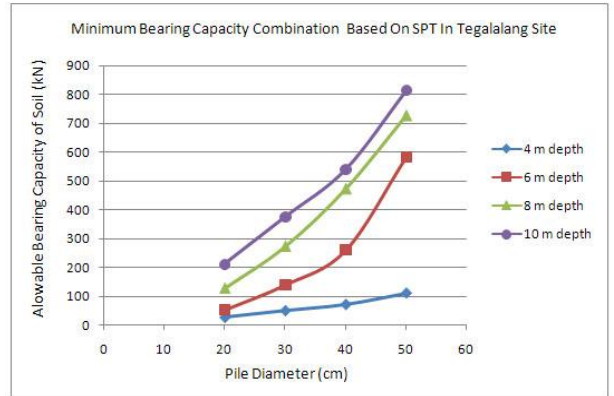
The results of analyzes show that the deeper of penetration the carrying capacity becomes higher. The bearing capacity in the Tegalalang area is close to 70 kN higher than in the Nusa Dua area which is close to 35 kN.

**Combined of Bearing Capacity of Bore Pile in Tegalalang**

The result of the combined bearing capacity is the addition of end bearing capacity of bore pile and the bearing capacity of skin friction for CPT test and SPT. For Tegalalang area the combined of bearing capacity can be seen in Figure 12 and Figure 13.



**Figure 12.** Graph of combined bearing capacity of bore pile based on CPT test in Tegalalang area

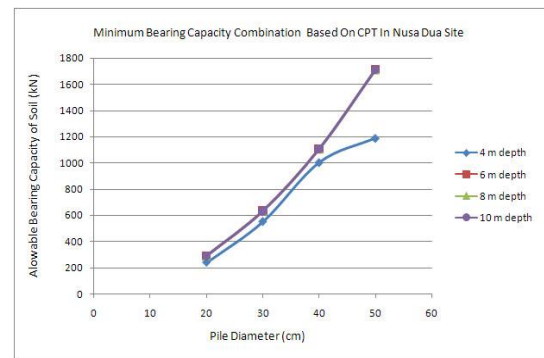


**Figure 13.** Graph of combined bearing capacity of bore pile based on SPT test in Tegalalang area

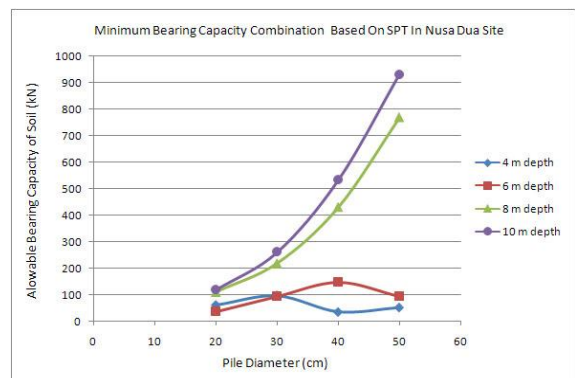
The CPT test obtains a higher bearing capacity value of approximately 1700 kN compared to the SPT test obtains of approximately 800 kN.

**Combined of Bearing Capacity of Bore Pile in Nusa Dua**

In the Nusa Dua area the results of the combined bearing capacity of the bore pile are shown in Figure 14 for CPT test and Figure 15 for the SPT test.



**Figure 14.** Graph of combined bearing capacity of bore pile based on CPT test in Nusa Dua area



**Figure 15.** Graph of combined bearing capacity of bore pile based on SPT test in Nusa Dua area

Hasil perhitungan memperlihatkan hasil dayadukung berdasarkan uji CPT lebih besar yaitu kira-kira pada 1700 kN dibandingkan dengan SPT yaitu kira-kira 900 kN.

The calculation results show the carrying capacity based on CPT test is approximately at 1700 kN larger compared with the SPT test is approximately 900 kN.

## E. CONCLUSION

From the description that has been made above it can be concluded several points:

1. Based on the CPT test, the deepest hardest soil layer in Tegalalang is at 6 meters depth while in Nusa Dua area is at 4 meters depth. Based on SPT test, hard soil layer in Tegalalang area is founded at 10 meters depth while in Nusa Dua area is at more than 10 meters depth.
2. The end bearing capacity of bore pile based on the CPT test at Tegalalang which is location at 4 meters, 6 meters, 8 meters and 10 meters depth have different bearing capacity, while at Nusa Dua the bearing capacity differ only at 4 m depth and the other at 6 meters, 8 meters and 10 meters depth have the same bearing capacity. This is because the CPT test tool is not able to penetrate the soil layer so it can not be known soil conditions in more than 4 meters depth.
3. Based on SPT data, the end bearing capacity of the bore pile in the Tegalalang area the deeper of penetration the bearing capacity is higher, while for Nusa Dua location at 6 m depth the bearing capacity decrease for bore pile with diameter 20 cm and 30 cm due to the decreasing of soil strength.
4. The bearing capacity of skin friction of bore pile based on CPT data resulted in a similar trend line in the Tegalalang area and Nusa Dua area because the CPT test was not able to penetrate deeper soil layers.
5. Based on the combined bearing capacity of bore pile is obtained a higher value for CPT test at 1700 kN compared with the SPT test that is at 900 kN, this condition are for both of the test location in the Tegalalang and in the Nusa Dua.
6. For testing soil bearing capacity for soft soil can use CPT but for hard soil layer the CPT test is not good because it is not able to penetrate the layer of soil. For hard soil layer

should use SPT because by drilling can reach deeper layer of soil.

7. For the bearing capacity value should use the smallest bearing capacity value so it can achieve a higher safety value.

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