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Model of Pontoon by Bamboo Material for Subtituting Land Fill Embankment

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Abstract-This research was intended to find out new way of building foundation which was compatible to soft soil located around swamp or embankment area. This foundation had to have big bearing capacity, gives small settleent by using bamboo that it was affordable and easy to afford. The foundation had to be visible to work out by the bricklayer and did not need sophisticated technology such as heavy machinery that this could give benefit to low economy community living in the area. This research was specifically to find out proper combination between water and soil where its power was mobilized by the foundation, as this has been mobilized by using one of them whether the water (Pontoon Foundation) or the soil itself (Conventional Shallow Foundation). The use of pontoon by far had been limited to raw material (drum). While conventional foundation required, the original soil which would settle significantly because of embankment above it. The method used in the research adopted the use of full-scale testing 1:1 and was done physical test to know the strength with right combination to get distribution of bearing capacity between soil and water. This research was located in the soft clay which was still being used as an embankment located in UNISSULA Semarang.

***Keywords*:** soft soil, embankment, pontoon

1. Background of The Study

In the developing countries where the population has been increasing, Indonesia is one of them where the population growth reaches 1.75% per year. The population growth has brought impact to an area, without exception, the area located in the coast line. In Semarang, the coast line area, in general, is originally swamp, embankment and rice field which are then used as a settlement. What can be seen recently, before the building were established, the area was filled to raise the surface of the building. One of the negative impacts of the coverage was the massive need of landfill supply. Besides, the load of the embankment itself caused massive decrease as the original soil was soft clay and this gave a trouble to bearing capacity either when the shallow foundation or the deep foundation was used. The settlement was not uniform what made the building damaged. Therefore, the use of embankment should have been avoided. One way to avoid this in reclamation within the inundation area is by using pontoon foundation where the bearing capacity used water uplift. In some cases, the use of pontoon can be more expensive therefore research needs to be conducted related to the use of affordable materials to build pontoon foundation. This research was aimed at testing the use of pontoon foundation made of bamboo as substitute of land fill under the building.

2. Literature Review

2. 1. Previous Reserarch Related To Settlement

The main problem in setting up a building in this area was the low bearing capacity of soil, big settlement and the small of lateral resistance. The rate of settlement due to embankment of soil in North Semarang area was 1.4 cm until 7:23 per year [1]. While the settlement of land due to the two factors above in the end of 2013 was predicted to happen about 153 cm [2], 0,13 to 0,81 cm per month [3], 4 cm per year [4], and Notosiswoyo presented the calculation in Table 1[5]. The table shows that the more sliding to the coastline, the decrease caused by the surface load addition due to the land fill and more dominant building load. The research conducted by Marsudi in 2000 showed similar result. In the northern part of Semarang, this land fill was increasing due to the north ring road of the harbor. Therefore, the business people still had the preference to build office, house or warehouse in the area.

Table. 1. The calculation of land subsidance [5]

Location	total 93 (cm)	at. 96 (cm)	t.u. 96 (cm)	total 96 (cm)	at. 2003 (cm)
Tanah Mas	*56,1*	*41,6*	*45,7*	*87,3*	*54,0*
Simpang Lima	*25,7*	*16,5*	*15,3*	*31,8*	*22,5*
PRPP	*44,7*	*38,6*	*30,4*	*69,0*	*52,1*
Tawang	*49,7*	*36,5*	*34,1*	*70,6*	*43,4*
Pengapon	*42,7*	*35,2*	*27,3*	*62,5*	*41,0*
Pelabuhan	*76,2*	*45,4*	*54,1*	*99,5*	*57,0*
Genuk	*30,2*	*29,6*	*26,9*	*56,5*	*42,4*
Tambaklorog	*92,4*	*48,5*	*65,3*	*113,8*	*65,4*
Bulu	*15,7*	*11,8*	*11,1*	*22,9*	*16,5*
Indraprasta	*30,2*	*30,4*	*26,0*	*56,4*	*43,5*
Jl. Pemuda	*23,0*	*18,8*	*17,3*	*36,1*	*29,6*
Krobokan	*13,5*	*9,4*	*13,7*	*23,1*	*19,5*
Kampung Peres	*39,1*	*33,1*	*19,6*	*52,7*	*41,0*

2. 2. Negatif Impact of Land Fill in The Inundation Area

Based on the previous research, landfill and building establishment above have caused many negative impacts, among which are:

1. Excavation at quarry in the slopes of the mountain would cause the slopes become steep that this would potentially cause landslide [6].

2. In some quarry (mining areas) in the mountain, there was flood caused the change of rainwater run off, due to the lost of land layers that could save water and due to the cut off of ground seepage [7].

3. Former mining land, leaving parts and massive hard rock and no longer worth mining. This area may not be planted unless they got special treatment in the reclamation. [8]

4. The environmental problem caused by reclamation which was less computation could cause massive environmental damage. For example; reclaimed swamp originally as a natural polder used to accommodate runoff of flooding, due to being filled with the land what made it changed its function, and floodwaters would seek for other lower areas [9]. One of examples: When Reclamation of Pantai Indah Kapuk was completed, the problem arose,

when the toll road Ir Sedyatmo (Airport Toll) was experiencing from flood, some said that this was because of the runoff from the area of Pantai Indah Kapuk.

2. 3. Previous Research About Pontoon Foundation

To desain the pontoon foundation, it was necessary to recognize maximum load capacity which had to be handled. Each ponton had to be able to hold the load as much as water removed, however this load had to include the weight of the bridge itself. If the maximum load from the bridge had been passed one or more, the pontoon would be submerged and then would be sunk. The road on the pontoon had to be able to bear the load, and it had to be light enough. So this would not limit the bearing capacity (needham, Joseph, 1986)[10]. In Indonesia, floating foundation in general uses oil drum having outer diameter of 56 cm, inside diameter of 55.5 cm and the height of 88 cm; flanked by rafters with size of 5/7 cm. Those drums were instaled in the collapsed position which was in longitudinal direction of the road (Bina Marga, 2006)[10]. The kind of floating foundation could give bearing capacity in pale of 1 m square as much as 3 ton/m2, and was predicted to support the height of the landfill which was about the same as two-tier wooden beams. The landfill put on the floating foundation made of oil drum could, in fact, hold the load as much as 3.75 ton/m2, equivalent to the load of landfill which was as high as 2.00 m (Bina Marga, 2006)[10]. For permanent construction, this could be developed by using other materials with special design such as in the Figure 1.

3. Research method

This research was aimed to introduce pontoon foundation with bamboo frame with the size of 2 X 2 X 2 m3 like in Figure.2 that the cover was made of tarpaulin gutter [10]. Bamboo and tarpaulin were used due to being affordable, renewable and easily obtained. No choice of diameter and bamboo type, this was because the availability on the materials were varied. For connecting the angles among the bamboos, hemp rope was selected.

Fig. 1. Pontoon foundation with bridge decks

Pontoon foundation was modeled like in Figure.3 as a box having holes B inside. This load was given by filling the basin A on the pontoon. To make the wall and watertight bamboo floor , inside of it was given tarpaulin normally used for gutter.

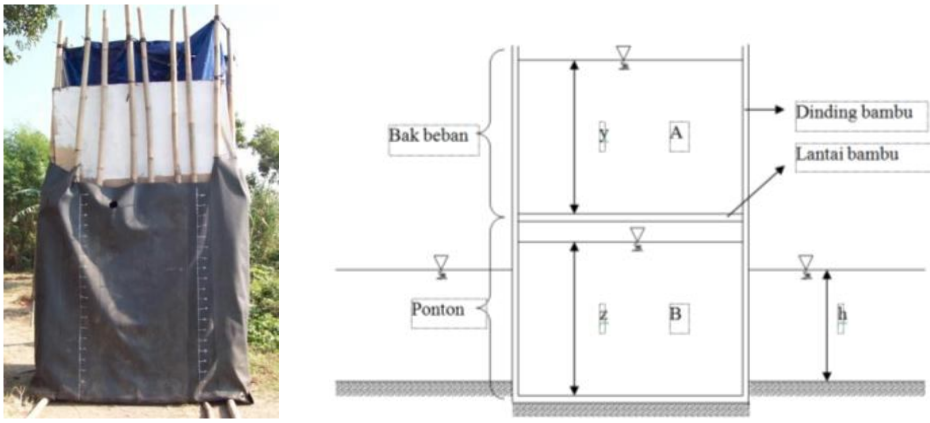

Fig. 2. Pontoon with bamboo materials modeled in this research[10]

To facilitate measurement during the investigation, the wall made of pontoon box was given a size in every 10 cm like in the Figure 2. Pontoon model then was pondered to seek the weight of pontoon foundation itself. In weighing process using scale with a maximum capacity of 500 kg. Drowning for pontoon to the bottom of embarkment in the depth of h that would be done to get shear resistance between land and bottom of pontoon in order to make balance towards horizontal force to be more stable. Independent variable of this research is the ratio between bearing capacity of land and floating force that can be determined by setting the height of y in the water box (A) and z in the pontoon hole (B) like in the Figure 2. while the dependent variable was the water height around the embankment which was around 1.5 – 2 m, type of load use was the static load using water and shear strength parameter of soil were take from the bottom of the embankment. Research location was located in the back pond of UNISSULA Semarang. To measure the shear strength of soil, test was done in the laboratorium of soil mechanic UNISSULA.

4. Analysis And Research Implementation

4. 1. Analysis And Research Implementation

Shear strength parameters of the pond bottom is c = 0.02775 kg/cm2 and ϕ = 1.69428°. The weight of pontoon at each corner are 188 kg, 187 kg, 165 kg dan 163 kg. Empty weight of foundation was = 703 kg. After everything was ready then the pontoon was inserted into the swamp like in Figure 3. Once pontoon in the swamp, pontoon will float. Soon after the pump was installed to the pump like Figure. To give stability to the pontoon, water was inserted into the pontoon hole (space B) using pump like Figure 4. After the pontoon was little bit sunk and stable, the load was done by putting water in the upper box (space A) by using pump like Figure 4.

Fig. 3. The pontoon was inserted into the swamp [10]

After the bottom of pontoon reached the bottom of swamp, then the pontoon became stable, floating force was mobilized by reducing the water height in the pontoon holes (space B). In this research measurement of every water load variation, water volume variation in the pontoon hole is presented by the water height in the upper box (space A), the water height in the lower hole (space B).

Figure 4. All instrument was installed to the pontoon and sinking process of pontoon [10]

The pontoon was stable enough if the height of pontoon submerged of 170 cm (the pontoon reached the bottom of the embankment).

4. 2. Data Analysis

Bearing capacity of pontoon foundation could be calculated by Terzaghi formula for square foundation :

$$q_u = 1{,}3\ cN_c + q(N_q - 1) + 0{,}5\ \gamma BN\gamma \qquad (1)$$

Where qu = net ultimate bearing capacity Based on the shear strength parameters from laboratory, friction angle of the soil is very small. So it is not problem to assume friction angle of the soil is zero. Because of shear strength soil below the pontoon was in the undrained condition, so its shear strength is defined by s_u. Since the fiction angle under undrained condition is zero, The Mohr-Coulomb strength formula $s = c + \sigma' \tan \phi$, reduces $s_u = c_u$. So the calculation of bearing capacity of pontoon by the soil below is qu = 1.3 X 5,14 X c, where c = cohesion of swamp bottom. Therefore, it was obtained qu = 1.3 X 5.14 X 0.02775 = 0.187 kg/cm2. The data obtained from the field on the stability of pontoon foundation were then analyzed. The load given to the pontoon foundation was the sum from the weigh of the pontoon foundation itself, the weigh of water placed on the upper box and the weigh of water which was inserted in the pontoon holes. While uplift force was obtained from the pontoon height sunk by the water. The total force working upward was the floating force from the pontoon added bearing capacity of the soil below foundation. The calculation is descibed in Table 2, Table 3, and Table 4.

Table 2. Comparison Between Elevation and Force [10]

Elevation (cm)		Self	Force (ton)		
Pontoon	Load	weight (t)	Ponton	Basin	uplift
155	45	0,70	6,20	1,98	8,23
143	55	0,70	5,72	2,43	8,23
132	65	0,70	5,28	2,87	8,23
123	75	0,70	4,92	3,31	8,23
114	85	0,70	4,56	3,75	8,23
101	95	0,70	4,04	4,19	8,23
95	105	0,70	3,80	4,63	8,23
81	115	0,70	3,24	5,07	8,23
70	125	0,70	2,80	5,51	8,23
59	135	0,70	2,36	5,95	8,23
48	145	0,70	1,92	6,39	8,23
31	155	0,70	1,24	6,84	8,23
21	162	0,70	0,84	7,14	8,23
10	180	0,70	0,40	7,94	8,23

Table 3. Comparison Between Elevation, Up Lift and Down Force[10]

Elevation (cm)			Uplift	Down
pontoon	Load	outside	(t)	force (t)
155	45	170	8,89	8,23
143	55	170	8,85	8,23
132	65	170	8,85	8,23
123	75	170	8,93	8,23
114	85	170	9,01	8,23
101	95	170	8,93	8,23
95	105	170	9,13	8,23
81	115	170	9,01	8,23
70	125	170	9,02	8,23

Elevation (cm)			Uplift (t)	Down force (t)
pontoon	Load	outside		
59	135	170	9,02	8,23
48	145	170	9,02	8,23
31	155	170	8,78	8,23
21	162	170	8,69	8,23
10	180	170	9,04	8,23

Table 4. Comparison Between Elevation, and Soil Stress [10]

Elevation (cm)			Balance (t/m2)	Soil stress (t/m2)
pontoon	load	outside		
155	45	170	-0,66	0,14
143	55	170	-0,62	0,13
132	65	170	-0,62	0,13
123	75	170	-0,70	0,15
114	85	170	-0,78	0,16
101	95	170	-0,70	0,15
95	105	170	-0,91	0,19
81	115	170	-0,79	0,16
70	125	170	-0,79	0,16
59	135	170	-0,79	0,16
48	145	170	-0,79	0,16
31	155	170	-0,55	0,11
21	162	170	-0,46	0,09
10	180	170	-0,81	0,17

From the result of investigation, it was found that the best stability happened when the water height in the pontoon hole = 155 cm, in the load box which was 40 cm in height and the height of pontoon submerged = 170 cm. this was because the focus of the pontoon model laid in the lowest part. The maximum force which could be handled by the pontoon was the weigh in the pontoon box which was 7.94 ton. Shortly that per m2 of pontoon foundation could handle the load as much as = 7.94 ton/ (2.2 X 2.2) = 1.638 ton. In the Table 4. it was found that the adding of maximum intensity toward the land which was only 0.19 t/m2. The addition of very low intensity would only cause insignificant land decrease. From the field investigation, it was found that γ = 1.56 t/m3, c_c = 0,501 - 0,554, e^0 = 1,754 - 1,923. The depth of the investigated land was found to be aroound 10 m. By using terzaghi consolidation formula, it was found that there was settlement of consolidation as much as 0.012 m.

4. 3. The Benefit Of Using Pontoon Compared To The Building Constructed By Filling The Land As Embankment

By far, what could be done in setting up building in the location formerly used as a swamp, the location had to be filled with land prior of use and then it was continued by establishing building. The time interval between the landfill and the construction on it is usually not less than 1 year. And of course That the land was still suffering from consolidation from the load of the landfill. Therefore, the settlement did not only happen due to the building but also due to the landfill. Normally, the height of landfill given, minimum was as big as 1 m above ground water level. Parameter of soil used in this calculation were γ = 1.56 t/m3, c_c = 0,501 - 0,554, e_0 = 1,754 - 1,923. The depth of the soil was calculated to the depth of 14 m. Result of this calculation, the settlement was as big as 0.85 m. The elevation surface of land as bid as 1 m from the water surface of the embankment would give land subsidence of 0,84 m.

5. Conclusion And Suggestion

5.1. Conclusion

This Pontoon foundation this model is promising to be used for substituting the land fill as this will not cause addition of effective intensity caused settlement.

5.2. Suggestion

It is suggested that further research need to be conducted related to pontoon foundation by using bamboo frame. The hydraulics analysis of floating material is suggested to be conducted in order to give more horizontal stability of the pontoon.

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