DETERMINING A SUFFICIENT DEPTH OF PILE FOUNDATION ON THE PERTAMINA GRAVING DOCK DESIGN SORONG PAPUA

by

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ABSTRACT

Engineering geological aspect and bearing capacity of pile foundation are significant for safety of upper structure, especially for substantial constructions such as a docking ship. Moreover, it provides effectiveness and cost efficiency when applies in rural areas of Indonesia. This is due to lack of docking ship appropriately built at rural areas particularly in eastern areas of Indonesia. Karim island of Papua even though is a small island yet is very strategic as Pertamina place its transitory function on that island connecting its oil supply route to Sorong.

Appropriate docking ship construction is required to aim the effective and efficient port management. Choosing the most suitable structure for a docking is also the key. Graving dock structure has been chosen by Pertamina as the most appropriate type of structure for the docking ship in Karim Island. The structure of graving dock planned to be built in Karim island Papua, is projected to be able to serve the maximum 7500 DWT ship capacity, with approximately dimension is 125 x 25 x 8 meters. Therefore, to support the plan, type and design of the best foundation is the key.

There are two methods could be done in determining the type and bearing capacity foundation. Field and laboratory test applied ASTM, field observation result by applying Meyerhoff theory and laboratorial analysis derived from Tarzaghi theory.

Those observation and analysis has confirmed that the soil layer at the graving dock design consists of three layers, those are; cover layer, silt-clay layer and clay rock unit. Therefore, the most suitable foundation to be constructed in that area is a pile massive foundation, with depth of pile foundation approximately -20 m below the land surface, and the ultimate point load pile massive for 30x30 cm – 75x75 cm dimension approximately 79.76 – 406.25 ton, and frictional resistance value approximately 24.59 – 61.48 ton.

Keyword : Pile Pondation, bearing capacity, Graving dock

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SARI

Aspek geologi teknik dan besarnya nilai kapasitas suatu pondasi tiang pancang merupakan suatu hal yang sangat penting demi keamanan pembangunan struktur bagian atas, khususnya untuk bangunan yang besar dan tinggi. Pembuatan dok kapal menjadi tuntutan yang tak bisa dielakkan demi terlengkapinya manajemen pelabuhan yang efektif dan efisiensi pada daerah yang terpencil. Bangunan graving dock kapal yang direncanakan pada Pulau Karim Papua, diproyeksikan untuk dapat melayani kapal dengan kapasitas maksimal 7500 DWT, dengan dimensi berkisar 125 x 25 x 8 meter. Jenis dan perencanaan pondasi yang tepat sangat penting guna menunjang keamanan bangunan graving dock itu sendiri.

Metoda yang digunakan untuk mengetahui jenis pondasi dan daya dukung pondasi didapat dari hasil uji lapangan dan laboratorium. Pengujian lapangan dan laboratorium berdasarkan ASTM, analisis data lapangan mempergunakan metoda Mayerhoff sedangkan analisis data laboratorium mempergunakan metoda Terzaghi.

Lapisan tanah pada rencana graving dock terdiri dari tiga bagian yaitu; lapisan penutup, lempung lanauan dan satuan batuan lempung. Untuk itu jenis pondasi yang dipilih adalah pondasi tiang pancang massif. Kedalaman pemancangan pondasi berkisar -20m dari muka tanah. Hasil analisis menunjukkan kuat tekan tiang pancang massif untuk diameter 30x30 cm hingga 75x75 cm berkisar 79.76 – 406.25 ton, sedangkan untuk nilai tarik berkisar dari 24.59 hingga 61.48 ton.

Kata Kunci : Tiang pancang, nilai kapasitas, Graving dock

INTRODUCTION

The growth of transportation activities in eastern area of Indonesia, in particular Sorong, must be supported by development of docking ship services. Pertamina is recorded as the most active user of docking ship service in Sorong due to its business strategy to supply oil to Sorong. It is unavoidable that Pertamina is required to construct a proper and strong docking ship with capacity of which is adjusted with the needs for supplying oil to Sorong.

According to Pertamina's plan, the graving dock ship is estimated to be able to serve maximum 7500 DWT capacity ship, with dimension approximately 125 x 25 x 8 meter. It is categorized as medium size of dock ship. For success of the graving dock ship construction, careful consideration in choosing the best foundation of the dock ship is crucial.

GEOLOGICAL CONDITION

Morphology and stratigraphy for Graving Dock Design

Morphology

The topography of the Pertamina's graving dock design in Karim Island has an elevation degree of about +2.5 m from LWS (figure 1).

Stratigraphy

Based on geological regional map, specially as appeared in the Sorong geological map sheet and field observation, Karim Island stratigraphy consists of alluvial river suspended and littoral deposits. The area of which has been dominated by coral rock of

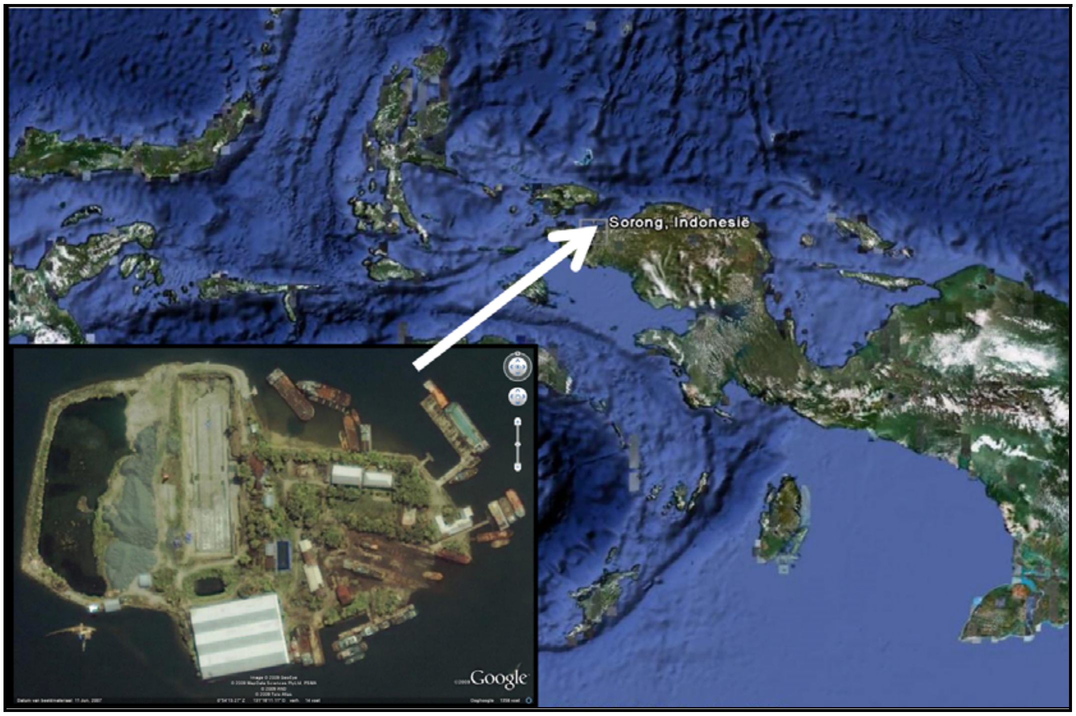

Figure 1. Area of study

quartenary age with depth about 30 meter, which comprises of sand, gravel, mud, organic material and peat moss.

From the drilling result in 5 (five) locations which were executed on the graving dock design area (BM-I, BM-II, BM-III, BM-IV and BM-V), stratigraphy of Karim Island according to age (from the oldest are):

- Claystone (Fm. Klasaman), gray to dark green, low to high plasticity, soft to compact density, consists of sandstone quartz, clay to clay, peat moss and lignite, plants residue, this has been formed since the age of end Miosen – Plistosen.
- Alluvial, brown to white grayish consist of mud, sand, pebble, gravel, (fragment of coral reef) dirty yellow with diameter 1-8 cm, and the loss characteristic, produced from littorals suspended, this has been formed since the age of Resen

Geology Structure

Geological structure in Karim Island, especially for graving dock area, is not developed due to the thickness of suspended alluvium. Lithic surface character of the geological structure could only be found through core drilling BM-III and core drilling BM-V with the slope (dip) 28^o - 30^o, with the direction are northeast – southwest.

Geological Foundation

It is obvious that previous land extension on the area had been done. It is indicated by the different material filling on the upper layer of the extension area and 5.00 meter depth of excavation on the designed graving dock area containing of

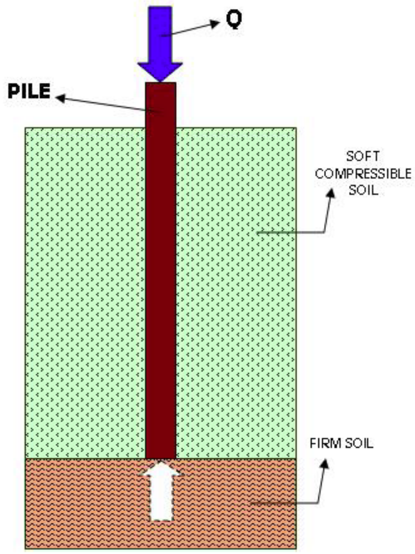

Figure 2. Point Bearing Pile

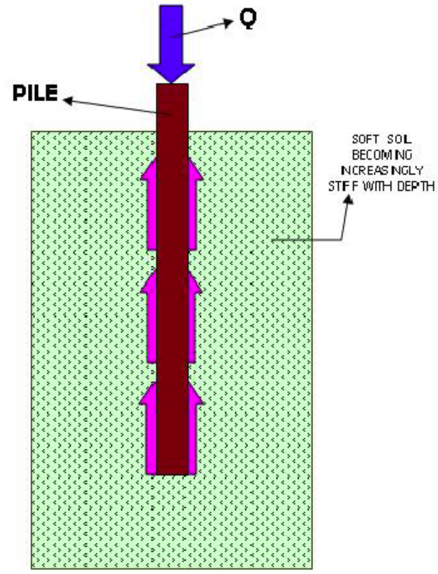

Figure 3. Friction Pile

the clay-sand. However, the core drilling test suggests that clay-stone is found in the 20.00 meter depth.

METHOD

General

To get the sufficient depth of pile, the analysis was started from soil investigation. Pile design could be planned based on laboratory analysis or field observation (cone penetration test or standard penetration test). It is known, foundation is the most vital element in the structure as it supports and holds out the pressure from upper structure. In other words, it has a connecting function between the upper structure pressure and base soil or rock layer resistance. Specifically, a bearing capacity of pile is divided into three types of friction, an end bearing piles (figure 2), a friction piles (figure 3) and a combination both of them.

A different soil can give a different result of resistance respectively. In the next section can be found more detail about bearing capacity of foundation.

Bearing Capacity of Foundation

Bearing capacity of foundation is a foundation capability to support an upper structure, focusing on vertical, lateral, and uplift load force. Bearing capacity of foundation depends on two main factors; material of the foundation and type of soil. Soil sample must be collected to get information about the properties of the soil and correlation with the pile design. To determine bearing capacity, two methods were used: Meyerhof and Terzaghi. Meyerhof used data on field observation and Terzaghi on laboratory analysis.

Mayerhof Method:

$$Qu = 40\ Nb.Ap + 0.2\ N\ As$$
$$Qfs = 0.2\ N\ As$$
$$Qp = 40\ Nb.\ Ab$$

Where:
Qu = Point bearing capacity (ton)
Qfs = Frictional resistance (ton)
Qp = Top pole resistance (ton)
4Nb = Average value N SPT at 4d under pile and 8d above pile
Ab = Average area of cross section of the pile (m^2)
As = Cover wide of pile (m^2)
N = Average value N SPT deep length pile
SF = Safety factor (use 2.5)

Permitted of bearing capacity pile is

Q (-)= Qu/SF
Q (+)= Qfs/SF

Bearing capacity of foundation based on laboratorial test

Calculation of End Resistance (Terzaghi)

Qb = Ab x (1.3 x c x Nc + *pb'* x Nq + 0.4 x γ x b x Nγ)

Where:
Qb = Resistance of point Ultimate (ton)
Ab = Average area of cross section of the pile (m^2)
c = Cohesion of the soil supporting the pile tip (ton/m^2)
Nc, Nγ, Nq=The bearing capacity factors, Costet J & Sanglerat (1983)
γ = Weight of soil volume (ton/m^3)
b = Pile dimension

Calculation Friction Resistance Ultimate

Friction Resistance Ultimate from friction component

Qs1 = Kd x *po'* x tgδ x As

Where:
Qs1 = Friction resistance ultimate from friction component
Kd = Material pile coefficient, Brom (1965)
Po' = Average Pressure overburden effective in length of pile (ton/m^2)
Tg δ = Friction angle drainage between wall pile and soil.
As = Cover wide pile (m^2)

Friction Resistance Ultimate from cohesion component

Qs2 = Ad x cu x As

Where:
Qs2 = Friction resistance ultimate from cohesion component
Ad = Adhesion factor for pile (McClelland, 1974)
As = Cover wide of pile (m^2)

Total Friction Resistance:

Qs = Qs1 + Qs2

Pile Capacity:

Qall(-) = (1/FK) x (Qs + Qb - Wp)
Qall(+) = (1/FK) x (Kd x *po'* x tgδ x As)+(Ad x cu x As)

Pile weight: **Wp = L x γ_{btn} x As**

Where:
L = pile length (m)
γ_{btn} = weight volume of concrete 2.4 (ton/m^3)

RESULT

Geological Foundation

Drilling and Standard Penetration Test (SPT) had been executed at 5 points in the dock draft location. Those are BM-I, BM-II, BM-III, BM-IV, and BM-V. Each drilling depth was up to 40 meter. Undisturbed sample had also been taken from the drilling test. This was used to determine engineering properties through a laboratorial test. Whilst, the disturbed sample was taken during the drilling process. Disturbed sample could distinguish the lithology type pursuant to United Soil Classification System that shown in Boring log form. From the log bore result, it is known that geological foundation in graving dock design

Table 1. Test Soil Mechanics Result

No	Number		Depth (m)	Triaxial/Direct Shear		Consolidation Test		
	Lab	Sample		Cohesion C (kg/cm^2)	friction angle φ (°)	*Coef of Consolidation* Cv (cm2/det)	*Compression Index* Cc	*Swell Index* Cs
1	BM I	1	17.00 - 17.50	0.418	9.80	0.00089	0.411	0.094
2	BM I	2	19.50 - 20.01	0.335	15.19	0.0011	0.2093	0.0885
3	BM I	3	23.50 - 24.00	0.191	17.66	0.001	0.1237	0.0732
4	BM I	4	27.00 - 27.50	0.387	17.03	0.0021	0.1924	0.0728
5	BM I	5	31.50 - 32.00	0.153	17.49	0.0007	0.267	0.1157
6	BM I	6	35.50 - 36.00	0.508	15.64	0.0023	0.1654	0.037
7	BM I	7	39.50 - 40.00	0.070	22.27	0.0021	0.2353	0.0293
8	BM II	1	15.50 - 16.00	0.325	15.47	0.0017	0.207	0.0702
9	BM II	2	17.50 - 18.00	0.418	10.70	0.00064	0.246	0.068
10	BM II	3	19.50 - 20.00	0.436	13.98	0.0007	0.1535	0.0914
11	BM II	4	23.50 - 24.00	0.254	15.32	0.0022	0.1715	0.0782
12	BM II	5	27.50 - 28.00	0.109	17.24	0.0014	0.2108	0.0962
13	BM II	6	31.50 - 32.00	0.407	14.12	0.0034	0.1554	0.0858
14	BM II	7	38.50 - 39.00	0.520	16.10	0.00185	0.27	0.038
15	BM III	1	9.60 - 9.85	0.284	8.70	0.00144	0.284	0.033
16	BM III	2	12.00 - 12.30	0.714	12.90	0.00071	0.253	0.084
17	BM III	3	15.60 - 16.00	1.142	7.60	0.00074	0.243	0.097
18	BM III	4	19.60 - 20.00	0.183	9.20	0.0012	0.317	0.094
19	BM III	5	25.50 - 26.00	0.857	14.10	0.00135	0.227	0.078
20	BM IV	1	19.50 - 20.00	0.564	5.60	0.0007	0.262	0.084
21	BM IV	2	21.50 - 22.00	0.380	16.01	0.00175	0.2	0.0867
22	BM V	1	5.50 - 6.00	0.073	4.00	0.001	0.617	0.053
23	BM V	2	7.50 - 8.00	0.070	3.20	0.00125	0.356	0.039
24	BM V	3	14.00 - 14.35	0.114	4.70	0.00147	0.645	0.085
25	BM V	4	23.50 - 24.00	1.397	11.20	0.00125	0.214	0.037
26	BM V	5	29.25 - 29.60	0.857	12.20	0.00108	0.345	0.117
26	BM V	6	39.55 - 40.00	1.112	6.40	0.00082	0.356	0.121

consists of fill material, clay-sand unit, and clay rock unit.

Filling material

Filling material is white-brown-gray color, consists of sand material, small gravel, mud, big gravel, ϕ 1 – 8 cm, non plastic, apart compaction – middle, with the thickness of 4,00 – 8,45 m. From the result of the boring log, it is also revealed that the depth of filling material turns out to be thicker towards the sea. Based on observation, ground water level in this area is about 50 cm from ground surface. Since the filling material has loose to compact characteristic, careful attention from the contractor during excavation process is highly required.

Silt-Clay Unit

Silt-clay is in bright gray to brown color, low to middle plasticity, soft to very rigid consistency, middle level of compact. The thickness is about 3,90 – 13 m and the SPT range is 4 – 25.

Clay stone unit

Clay stone is in gray to green color, middle to high plasticity, middle toMove to discussion section. solid compact, and very rigid. The thickness is about 23 – 29,70 m and the SPT range is >20.

Laboratory analysis and Standard Penetration Test

In order to get the information of the soil index properties and soil engineering properties, some tests were done such as, unit weight, grain size, water content, atterberg limit, specific gravity. Besides, to obtain engineering properties the UU triaxial test and consolidation test should be done.

Soil test was carried out on undisturbed and disturbed soil. See Table 1 for result. The test result of the sample in the laboratory shows soil engineering properties. This is to gauge the soil strength parameters from cohesion value (c) and angle of internal friction. This could be used as a basis to draw the foundation design. The following is the test result of the calculation of pile bearing capacity which has been prepared based on soil parameters that are held in the laboratory by applying some pile dimension alternative and pile depth in every drilling location (BM). In addition, the pile dimension has been created as 30x30 cm, 40x40 cm, 50x50 cm, 60x60 cm, and 75x75 cm. Standard Penetration Test was implemented during borings. Soil test by SPT was supposed to recognize soil strength and bearing capacity of soil. Standard Penetration Test should be done together with drilling process and shall comply with ASTM D1586.

Foundation Analysis

Foundation analysis's recommendation, is prepared based on the observation data and field test as appeared in the bore hole log description and (n-SPT) also laboratory test (Triaxial test). The observation and field test indicates that the hard soil layer (n>30) is located in the depth of -20 m below soil surface. Thus, the capacity calculation will be applied at -20m depth. However, a bearing capacity of pile has been executed based on two data:

Observation data (N-SPT)

Parameters that is used is depth, N-SPT (strike number), and pile dimension.

Laboratory test data (Triaxial Test)

Parameters that is applied are cohesion (c), angle of internal friction (φ), soil

Table 2. Bearing Capacity of pile based on laboratory analysis for depth -20m

Pile diameter (m)	BH 1		BH 2		BH 3		BH 4		BH 5	
	Q(-) ton	Q(+) ton	Q(-) ton	Q(+) ton	Q(-) ton	Q(+) ton	Q(-) ton	Q(+) ton	Q(-) ton	Q(+) ton
0,30	18,67	16,02	20,77	16,38	20,70	13,92	18,67	1,49	10,43	10,01
0,40	40,25	21,35	49,71	18,46	66,78	18,56	25,14	2,68	16,33	13,34
0,50	56,23	26,69	71,93	23,07	98,56	23,20	31,75	3,10	21,34	16,68
0,60	74,57	32,03	98,08	27,69	136,36	27,84	38,49	3,52	26,73	20,02
0,75	106,54	40,04	144,69	34,61	204,39	34,80	48,84	4,16	35,52	25,02

Table 3. Bearing Capacity of pile based on SPT for depth -20m

Pile diameter (m)	BH 1		BH 2		BH 3		BH 4		BH 5	
	Q(-) ton	Q(+) ton	Q(-) ton	Q(+) ton	Q(-) ton	Q(+) ton	Q(-) ton	Q(+) ton	Q(-) ton	Q(+) ton
0,30	68,88	21,40	94,63	29,07	87,87	29,09	48,08	14,17	99,32	29,24
0,40	112,94	28,54	155,31	38,76	143,28	38,79	79,18	18,89	163,58	38,99
0,50	167,55	35,67	230,56	48,44	211,76	48,48	117,81	23,61	243,41	48,73
0,60	232,71	42,81	320,39	58,13	293,30	58,18	163,98	28,34	338,82	58,48
0,75	350,24	53,51	482,44	72,67	440,10	72,72	247,37	35,42	511,13	73,10

weight volume, depth (H) and pile dimension.

It can be seen in table 2 and table 3 the results of bearing capacity of pile for different dimensions. In addition, large differences of the results assumed.

DISCUSSION

An attention and consideration are highly required for data selection as there is an obvious difference between soil data and observation data. In this case, we choose observation data.

Based on the above condition of geological foundation, it is recommended that the depth of foundation to be built at -20 m from ground surface, thus the position of the end of the pile is placed at clay stone layer. Hope the depth sufficient enough for design.

CONCLUSION

Soil layer in the graving dock draft consists of filling materials; silt-clay, and clay rock unit. The SPT data is assumed as an appropriate data compared to laboratory test. It might be caused by the transportation of undisturbed sample. The most suitable type of foundation for this location is the pile massive foundation with the depth approximately of -20 m below the soil surface.

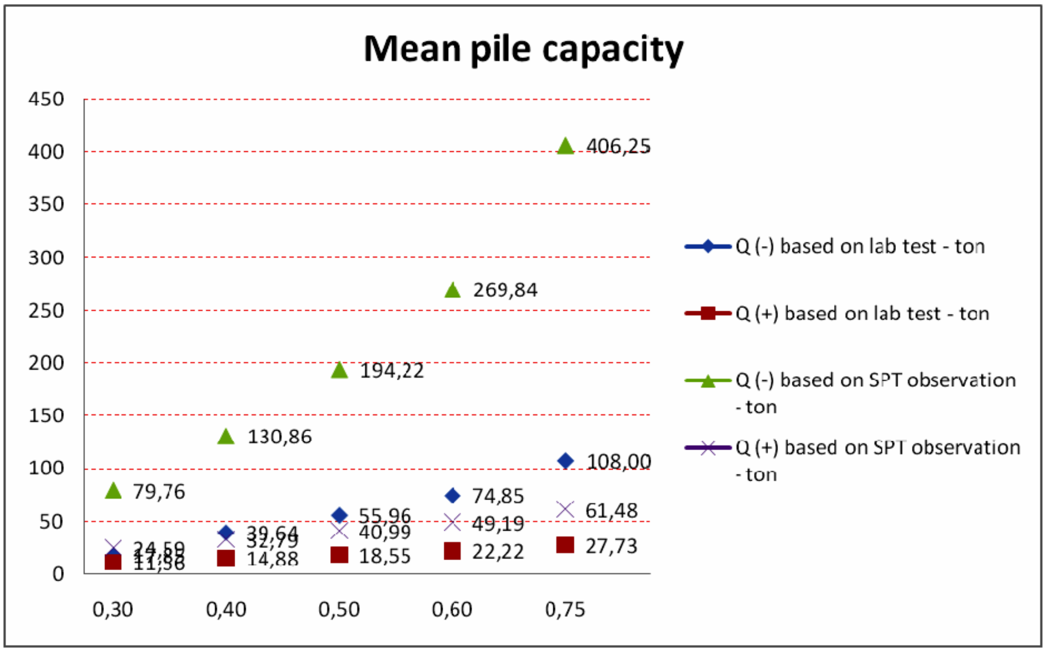

Figure 4. Average values of pile capacity based on two different data

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