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Comparative Analysis of Bearing Capacity of Pile Foundation Using Van Der Ween, Philipponnat, and Meyerhof Methods

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ABSTRACT

Soil has different characteristics so that it becomes a lot of problems in Civil Engineering construction, especially in foundation planning, it must be done carefully and use several methods as a comparison. This research is to compare the three methods of calculating the bearing capacity of bored pile foundations: Van Der Ween, Phillipponnat, and Meyerhof. The selection of an apposite method in bearing capacity analysis is important to confirm the safety of the building structure. The Van Der Ween Method is a more modern and detailed approach compared to the Meyerhof Method, it takes into account the negative impact of the lateral deformation of the pile, which improves the accuracy of its calculation. The Philipponnat Method is a method that combines aspects of both the Meyerhof Method and the Van der Ween Method, it considers load characteristics and soil properties like Meyerhof, while also accounting for lateral deflection of the piles like Van der Ween. The results show that each method has advantages and disadvantages in determining the bearing capacity of bored pile foundations. Analysis revealed factors such as pile diameter, soil depth, and maximum applied load affect the accuracy of the three methods. This research provides important insights for construction planners in selecting a suitable method for bored pile foundation bearing capacity analysis. It is recommended that soil characteristics and pile geometry be considered before selecting the most appropriate calculation method. This research can be extended by considering other methods and conducting validation through experimental analysis.

Keywords: *Bearing capacity; Meyerhof; Van der Ween; Philipponnat; Maximum load*

INTRODUCTION

Soil has different characteristics so that it is a problem in many works in the field of Civil Engineering [1]. There are often failures in the implementation of foundation construction due to errors in interpreting existing soil data. The use of bored pile foundations is considered to avoid the impact of vibration due to piling which can cause cracks in existing buildings [2]. The pile tip bearing capacity occurs when the bottom of the pile reaches the depth of the hard soil layer, while the frictional resistance is the result of the interaction between the pile blanket and the soil layer around the pile blanket [3]. The method of calculating the bearing capacity of bored pile foundations used may differ from the method used by the planning consultant [4]. This research is a quantitative study with a correlational approach [5]. In general, the calculation of bearing capacity of bored pile foundations usually uses the Meyerhof Method, but this method has the disadvantage of ignoring additional correction factors such as standard geometric factors and safety factors. The Meyerhof Method often results in inaccurate stiffness of the soil structure, especially when soft soil layers are found between hard soil layers.

The Van Der Ween Method is a more modern and detailed approach compared to the Meyerhof Method, it takes into account the negative impact of lateral deformation of the piles, which improves the accuracy of its calculations. The Philipponnat Method is a method that combines aspects of the Meyerhof Method and the Van der Ween Method, it considers load characteristics and soil properties like Meyerhof, while also accounting for lateral deflection of the pile like Van der Ween [6]. The planning of shallow and deep foundations always takes into account the safety of the superstructure and its economic factors [7]. Proper planning of the lower structure is necessary to be able to maintain the stability of the supported construction. Because errors in the planning of the lower structure will cause a solid building on the upper structure to collapse [8]. Therefore, comparing the Van Der Ween Method, Philipponnat Method, and Meyerhof Method is important to obtain economical and safe planning results.

MATERIALS AND METHODS

In order to conduct a good analysis requires complete and accurate data and information accompanied by relevant basic theory [9]. This research is applied research whose results can be applied both in the current situation and in the future [10].
The following are the technical data that will be evaluated in this study:

1. Building location: SDN 016 South Balikpapan, Balikpapan
2. Category: School Building
3. Building area: 454,90 M2
4. Structure type: Reinforced concrete
5. Foundation type: Bored pile foundation
6. Concrete quality: K-250 / fc 20.75
7. Planning drawing
8. Cone penetration test / sondir data
9. Depth of bored pile foundation plan based on maximum penetration of the sondir
10. Diameter of bore pile foundation 0.3 m

The following are the stages that will be carried out sequentially:

1. Determine the maximum load based on the load combination results in the structural analysis programme
2. Analyse the sondir data to be used.
3. Analysis of foundation permit bearing capacity will be carried out by 3 methods, namely Van Der Ween Method, Philipponnat Method, and Meyerhof Method.
4. Analysis of foundation permissible bearing capacity before the load acts on the bored pile foundation.
5. Draw conclusions based on the analysis of the permissible foundation load capacity for the loads acting on the bored pile foundation.
6. Conclude the method that has safety requirements for bored pile foundations.

After data collection, the next step is the calculation of the bearing capacity of the pile foundation [11]. The bearing capacity of the pile tip in general, the bearing capacity of the pile foundation is expressed using Equation 1 [12].

$$Qu = Qp + Qs \qquad (1)$$

with Qu = ultimate bearing capacity of pile (kg), Qp = tip bearing capacity of pile (kg), Qs = blanket bearing capacity of pile (kg).

The bearing capacity of bored pile foundations can be calculated using a variety of calculation methods. Field soil analysis data is data that can be used. The soil test carried out at the SDN

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016 building is a sondir test or Cone Penetration Test (CPT). Based on the soil survey data for the Sondir or Cone Penetration Test (CPT) test used, the data analysis stage in this study is to compare three methods of calculating the bearing capacity of the pile based on sondir data [13], which are:

1. Van Der Ween Method

   Equation 2 is used to express the tip bearing capacity of bored piles using the Van Der Ween Method, which involves special factors in calculating bearing capacity. In addition, equations 3 and 4 are used to express the blanket bearing capacity and ultimate bearing capacity, providing further information on the maximum capacity and overall bearing capacity of the bored pile foundation.

$$Q_p = \frac{qc}{FK.\alpha}\ x\ Ap \quad (2)$$

$$Q_s = {}^{1}\!/_{2}\ x\ P\ x\ JHP \quad (3)$$

$$Qult = Qp + Qs \quad (4)$$

   with Qp = pile tip bearing capacity (kg), qc = average conus price along 3.5D above the base of the foundation to 1D below the base foundation, FK = factor of safety, α = coefficient depending on soil type and pile, Ap = cross-sectional area of the pile (cm2), Qs = blanket bearing capacity (kg), P = circumference of the pile, JHP = sum of attachment resistance, Qult = ultimate bearing capacity (kg).

2. Philipponnat Method

   Philipponnat developed a commonly used method for estimating pile bearing capacity using CPT or sondir data under different soil conditions. The equations used in this method for tip bearing capacity analysis are listed in equations 5 and 6, while equation 7 is used for blanket bearing capacity analysis, and equation 8 for ultimate bearing capacity analysis is presented.

$$Q_p = \frac{ap\ x\ Ap}{FK} \quad (5)$$

$$qp = \alpha p.Rp \quad (6)$$

$$Q_s = \frac{P}{FK} x\ \ JHP \quad (7)$$

$$Qult = Qp + Qs \quad (8)$$

   with Qp = pile tip bearing capacity (kg), ap = coefficient (values are shown in table 1), Ap = pile cross-sectional area (cm2), FK = factor of safety, Rp = average conus value along the 3D above the pile and 3D below the pile, Qs = blanket bearing capacity (kg), P = pile circumference, JHP = number of attachment barriers, Qult = ultimate bearing capacity (kg).

Table 1: Price of coefficient *ap* (Herman, 1999)

Soil type	αp
Lempung dan kapur	0.5
Lanau	0.45
Pasir	0.40
Kerikil	0.35

3. Meyerhof Method

   Equation 9 illustrates the ultimate load capacity value of bored pile foundation calculated by Meyerhof method.

$$Q_{ult} = (qc\ xAp) + (JHL\ x\ K) \quad (9)$$

   with Qult = ultimate bearing capacity (kg), qc = sondir tip resistance (kg/cm2), Ap = cross-sectional area of the pile (cm2), JHP = total adhesive resistance, K = circumference of the pile (cm).

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4. Permissible bearing capacity and safety factor
   To obtain the foundation permissible bearing capacity (Qall) for axial loads, a calculation is made by dividing the ultimate bearing capacity (Qult) by a factor of safety (sf). This factor of safety is applied either totally or separately to the bearing capacity of the pile blanket and to the tip resistance, according to equation 10.

$$Q_{all} = \frac{Q_{ult}}{sf} \quad (10)$$

   with Qall = pile permissible bearing capacity (kg), Qult = ultimate bearing capacity (kg), sf = factor of safety (2.5)

RESULTS AND DISCUSSION

1. Structure Loadings Data
   The load analysis is generated from the output of the structural analysis programme and can be seen in Table 2.

Table 2: Element force

Frame (Text)	P (Kgf)	V (Kgf-mm)	M2 (Kgf-mm)	M3 (Kgf-mm)	CodeStation (Text)
1	-40230,73	-6629,95	-81872,41	152801,73	A1
3	-46548,3	-912,2	-54727,47	168131,47	A2
5	-18463,02	2390,84	71204,93	-1067362,75	A3

   The modelling output of the structure analysis program shows the maximum forces occurring due to the combination at frame A2 (which was selected for analysis):
   Axial load (P) = 46.548 Tonnes
   Shear force (V) = 0.912 Tonnes
   Moment in x direction (Mx) = 54.727 Tonnes
   Y-direction moment (My) = 168.131 Tonnes

2. Comparison of Meyerhof method with Van Der Ween method
   Based on the results of the calculation of the bearing capacity of the Meyerhof method with the Van Der Ween method, it can be seen that the ultimate bearing capacity of the Meyerhof method is 31.41% greater than that of Van Der Ween and the permissible bearing capacity of the Meyerhof method is 23.90% greater than that of the Van Der Ween method which can be seen in Table 3 and Figure 1, where this calculation is in line with the research journal of Rajib Bithom Thom et al, which discusses the comparison of bearing capacity methods between the Meyerhof method and the Van Der Ween method, where the ultimate bearing capacity and permit bearing capacity values in the Meyerhof method are greater in value [14].

Table 3: Comparison of bearing capacity of Van Der Ween method with Meyerhof method

Description	Method of calculation	
	Meyerhof	Van Der Ween
Qult (Ton)	185,894	141,451
Qall (Ton)	74,358	56,580

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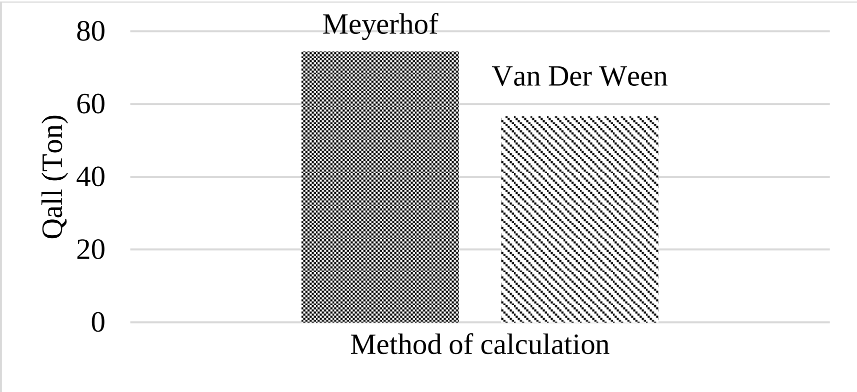

Figure 1: Graph of Van Der Ween and Meyerhof calculation method against Qall

3. Comparison of Meyerhof method with Philipponnat method
   Based on the results of the calculation of the bearing capacity of the Meyerhof method with the Philipponnat method, it is known that the ultimate bearing capacity and permissible bearing capacity of the Philipponnat method are smaller than the Meyerhof method by up to 4 times as can be seen in Table 4 and Figure 2, where this calculation is in line with the research journal of Hendra Cahyadi et al, which discusses the comparison of bearing capacity methods between the Meyerhof method and the Philipponnat method, where the ultimate bearing capacity and permissible bearing capacity of the Meyerhof method are greater in value than the Philipponnat method [15].

Table 4: Comparison of bearing capacity of Philipponnat method with Meyerhof method

Description	**Method of calculation**	
	Meyerhof	**Philipponnat**
Qult (Ton)	185,894	37,933
Qall (Ton)	74,358	15,173

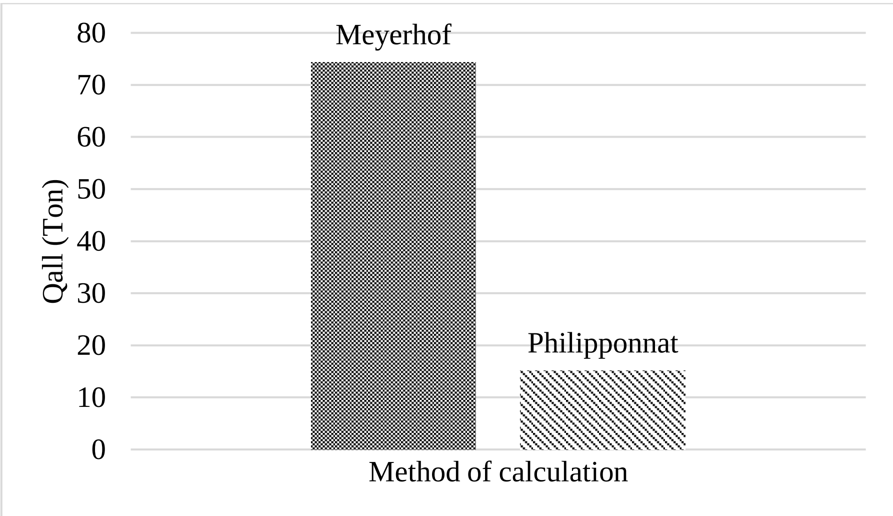

Figure 2: Graph of Philipponnat and Meyerhof calculation method against Qall

4. Comparison of Van Der Ween method with Philipponnat method
   Based on the results of the calculation of the bearing capacity of the Van Der Ween method with the Philipponnat method, it is known that the ultimate bearing capacity and permissible

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bearing capacity of the Van Der Ween method is greater in percentage than the Philipponnat method by 73.13% which can be seen in Table 5 and Figure 3, where this calculation is in line with the research journal Agil Faruha and Drs. H. Machfud Ridwan, M.T., which discusses the comparison of bearing capacity methods between the Van Der Ween method and the Philipponnat method, where the ultimate bearing capacity value in the Van Der Ween method is greater in value [13].

Table 5: Comparison of bearing capacity of Philipponnat method with Van Der Ween method

Description	Method of calculation	
	Van Der Ween	Philipponnat
Qult (Ton)	141,451	37,933
Qall (Ton)	56,580	15,173

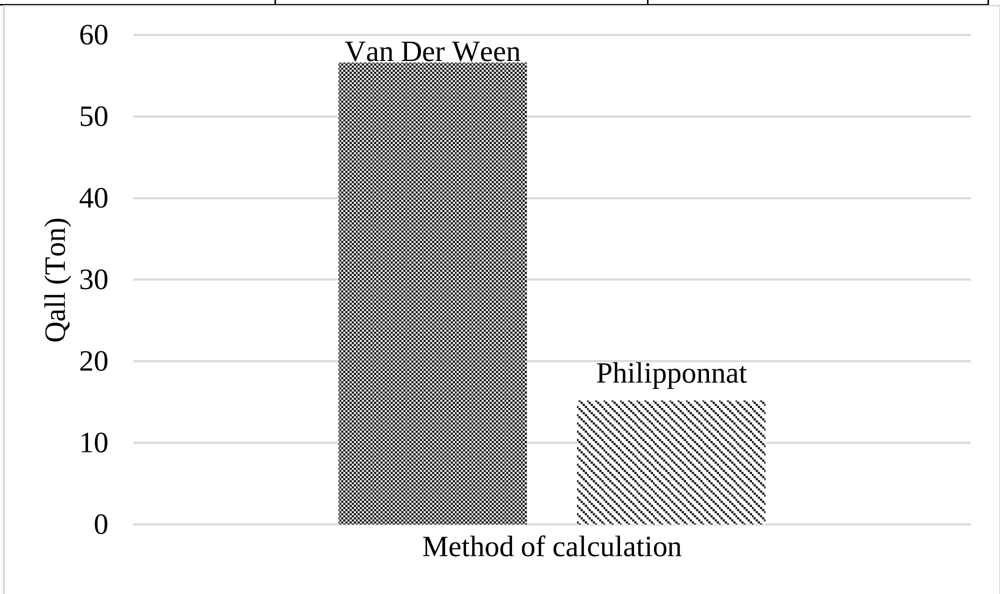

Figure 3: Graph of Philipponnat and Van Der Ween calculation method against Qall

5. Comparison of pile bearing capacity
   The results obtained for each method are different. This difference is based on different calculation formulas for each method. From the results obtained from each method, namely by finding the capacity of the pile head (Qp) and the load capacity of the pile body (Qs), which are then summed up to find the Qult value [16]. The results of the analysis with the three methods can be seen in Table 6 and Figures 4, and 5.

Table 6: Bearing capacity analysis of bored pile foundation

Description	Method of calculation		
	Meyerhof	Van Der Ween	Philipponnat
Qult (Ton)	185,894	141,451	37,933
Qizin (Ton)	74,358	56,580	15,173

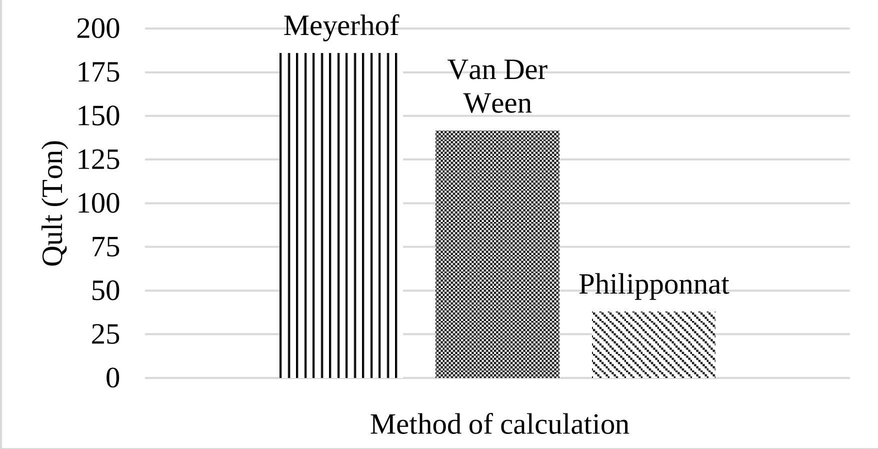

Figure 4: Graph of the connection between calculation method and Qult

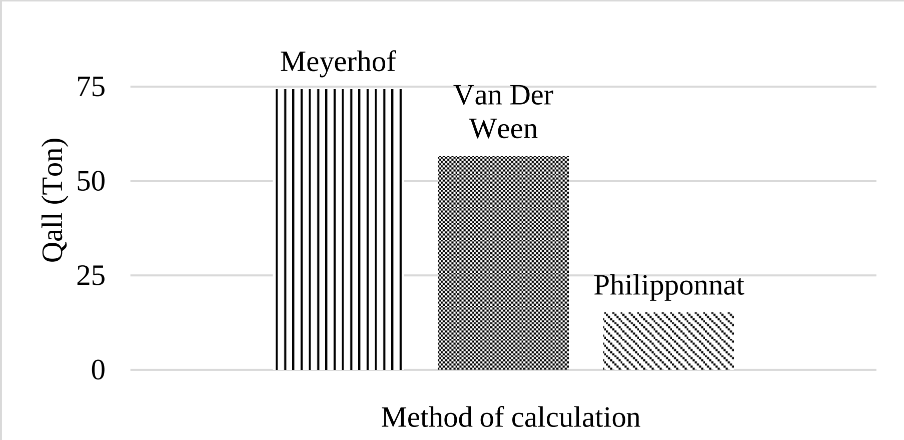

Figure 5: Graph of the connection between calculation method and Qall

From the output of the structure analysis, it is found that the bored pile foundation is able to withstand a maximum axial load of 46,548 Tonnes, which is the highest load that the foundation has to handle. The calculation method of the bearing capacity of the bored pile foundation gives different values for each method. The Van Der Ween method yields 56,580 tonnes, the Philipponnat method yields 15,173 tonnes, while the Meyerhof method gives a value of 74,358 tonnes. Comparison of the bearing capacity of the three methods with the maximum axial load is shown in Table 7 and Figure 6. The difference in bearing capacity values affects the safety, stability, and efficiency of foundation design, so the selection of appropriate calculation methods is important in planning efficient and safe foundations according to soil characteristics. This research makes a significant contribution to the field of geotechnical engineering, particularly in designing safe and reliable building foundations with an appropriate number of bored piles.

Table 7: Analysis of permissible bearing capacity against maximum axial load

Method of calculation	Qall (Ton)	Axial/P (Ton)	Bored pile requirement
Meyerhof	74,358	46,548	1
Van Der Ween	56,580	46,548	1
Philipponnat	15,173	46,548	4

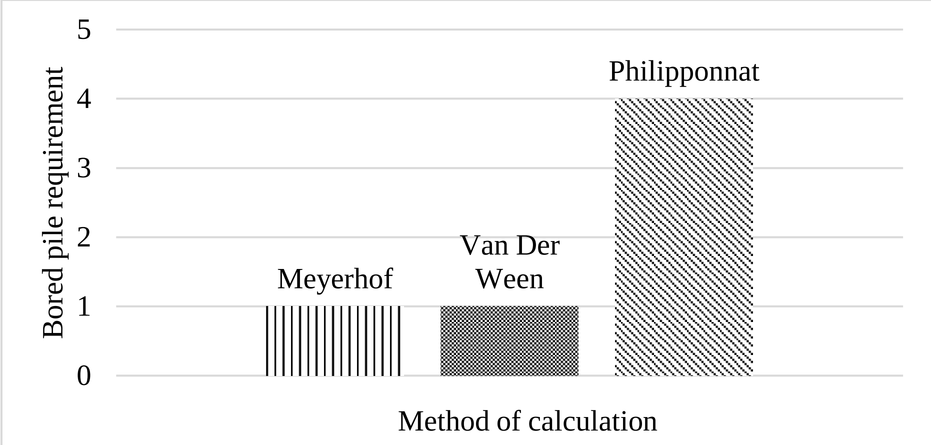

Figure 6: Quantity of bored piles based on calculation method

Based on Table 7, the analysis of the permissible load capacity of the load received by the pile foundation shows the level of safety in the two methods used, which are the Van Der Ween method and the Meyerhof method. This can be seen in the permissible load capacity value greater than the maximum axial load value of the building.

CONCLUSION

Based on the results of the calculation of the bearing capacity of the piles above, it can be concluded from this study that the selection of the method of calculating the bearing capacity of the soil must be adjusted to the local characteristics of the soil and the complexity of geotechnical conditions [17]. Based on the results of the discussion in the research on the analysis of the bearing capacity of pile foundations based on sondir data with the Van Der Ween, Philipponnat and Meyerhof methods, the following conclusions can be reached [18]. The result of the Van Der Ween Method permission bearing capacity analysis with a diameter of 0.3 m is 56,580 Tonnes. For the results of the analysis of the bearing capacity of the Philipponnat method permission with a diameter of 0.3 m of 15.173 Tonnes. While for the results of the Meyerhof method permission bearing capacity analysis with a diameter of 0.3 m amounting to 74.358 Tonnes. Three methods used in the calculation and analysis of bearing capacity are Van Der Ween Method, Philipponnat Method and Meyerhof Method. The Philipponnat method itself does not have a bearing capacity value to meet the foundation safety requirements, where the foundation permit foundation load capacity value must be greater than the load received by the foundation. While the Van Der Ween method and Meyerhof method qualify the foundation safety.

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