JOURNAL OF RESEARCH AND INOVATION IN CIVIL ENGINEERING AS APPLIED SCIENCE (RIGID)
Vol. 2 No. 2 (2023) 66 - 75 ISSN Media Elektronik: 2828-3732

COMPARISON OF PILE SLAB WITH SPUN PILE AND BORED PILE

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Abstract

There are three various design concepts for the Oprit Bridge while designing the Deltamas flyover in Bekasi City: slab on spun pile, and slab on bored pile foundations. Given the variations in design options, a detailed analysis of the structure's movement must be done before a plan for the Deltamas flyover oprit structure can be made. The lateral direction was analyzed using the p-y curve method, while the slab on spun pile and bored pile designs were analyzed using the finite element methodology. The axial bearing capacity was analyzed using the Mayerhoff method. At a depth of 24 meters and 8 rows of 0.6-meter-diameter piles, slab on spun pile has enough bearing capacity and defleksi maksimum tiang pada permukaan adalah 9,09 mm. (< 25mm), but reinforcement is needed. In the meantime, slab on bored pile has enough bearing capacity at a depth of 28 m with 5 rows of 0.8 m-diameter piles, and maximum value of piles deflection at the surface is 9.44mm (< 25mm). The author suggests an alternative Slab on Bored Pile design for a variety of factors, including structural stability.

Keywords: Approach Slabs, Bearing Capacity, Deflection, Pile Slab

Abstrak

Terdapat tiga konsep desain oprit jembatan yang berbeda pada saat mendesain jembatan layang Deltamas di Kota Bekasi, yaitu slab on spun pile, slab on bored pile, dan slab on bored pile. Dengan adanya variasi pilihan desain tersebut, analisis detail pergerakan struktur harus dilakukan sebelum rencana struktur oprit jembatan layang Deltamas dapat dibuat. Arah lateral dianalisa dengan menggunakan metode p-y curve, sedangkan desain slab on spun pile dan bored pile dianalisa dengan menggunakan metode elemen hingga. Daya dukung aksial dianalisis dengan menggunakan metode Mayerhoff. Pada kedalaman 24 meter dan 8 baris tiang berdiameter 0,6 meter, slab on spun pile memiliki daya dukung yang cukup dan defleksi maksimum tiang pada permukaan adalah 9,09 mm. (< 25mm), namun diperlukan perkuatan. Sementara itu, slab on bored pile memiliki daya dukung yang cukup pada kedalaman 28 m dengan 5 baris tiang berdiameter 0,8 m, dan nilai defleksi maksimum tiang pada permukaan adalah 9,44 mm (< 25 mm). Penulis menyarankan alternatif desain Slab on Bored Pile untuk berbagai faktor, termasuk stabilitas struktur.

Kata kunci: Pelat Pendekatan, Daya Dukung, Lendutan, Pelat Tumpuan

Diterima Redaksi : 15-01-2023 | Selesai Revisi : 07-07-2023 | Diterbitkan Online : 10-07-2023

1. Introduction

The bridge approach road, or commonly called the oprit, is a part of the connection between the bridge construction and the road after and before. A pile slab is an alternative to filling as an orvit on the bridge. Oprit is one part of the bridge that must be calculated and analyzed to be able to withstand loads according to the planned life of the bridge. The oprit structure must also be calculated based on its retaining capacity, axial and lateral directions.

On the Deltamas flyover, a bridge construction will be planned with a pile slab structure as a bridge oprit. Many phenomena of damage/failure of building structures were still difficult to predict until now, such as foundation failure, tilted buildings, landslides, and collapsed roads [1]. According to Pradipta, this is due to the lack of data and understanding of the type and character of the soil that supports the building [1]. Therefore, the researcher offers 2 alternatives to the pile slab design, namely using bored piles and spun piles.

In analyzing the pile slab, the methods used are the Mayerhoff method for the axial bearing capacity of the pile and the p-y curve for the lateral stability of the pile. The calculation of bridge loads also includes own loads, live loads, and earthquake loads. with terms and conditions in accordance with SNI regulations.

1. The only structure under review is the Oprite bridge itself.
2. The bridge loading refers to SNI 1725-2016 [2]

3. Seismic loading refers to SNI 2833-2016 [3]
4. Geotechnical planning refer to SNI 8460-2017 [4]
5. In this study, it does not compare in terms of cost, quality, and time.

The analysis of the pile slab is centered on the bearing capacity and deflection of the pile in order to compare the behavior of drilled and driven pile elements with the same soil conditions and loading. The comparison analyzed includes the depth of the pile based on the bearing capacity and also the pile deflection that occurs at ground level.

2. Methods

Stages of Research

The stages of preparing this research are carried out as follows:

1. The first stage is to identify the problem behind the making of this research. In the research also conducted literature studies from books, research journals, websites and also standard guidelines and criteria related to this research.
2. The second stage is data collection, this stage includes the primary data collection stage, namely field test soil data in the form of NSPT (drill logs) and soil lab data. As for the secondary data in the form of preliminary design and bridge planning bridge data.
3. The third stage is data processing, namely analyzing the load of the bridge's upper structure, followed by analyzing N-SPT data, then determining the dimensions to be analyzed, calculating the axial and lateral bearing capacity of the foundation using the Meyerhoff method, and calculating the lateral stability of the foundation using the P-Y curve method.
4. The next step is to compare the results of soil analysis with the output that occurs in structural modeling.
5. The next stage is drawing conclusions and writing a research report based on the results of data processing. research based on the results of data processing. Conclusions are taken based on theory used to answer the problems that have been identified.

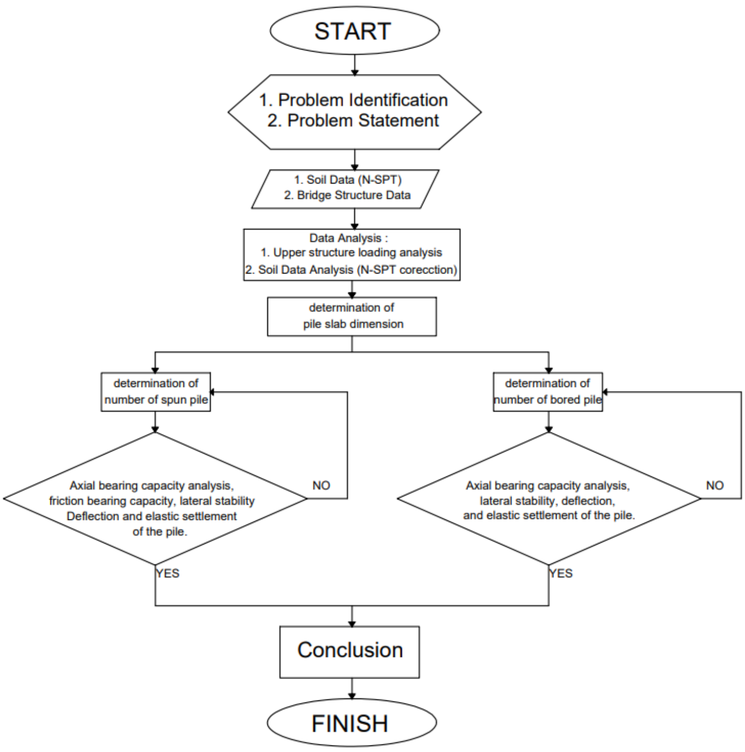

Figure 1 Research Flow Chart

3. Result and Discussion

Oprit, or bridge approach road, is a segment connecting the highway with the bridge that is planned to avoid subsidence [5].

3.1. Slab on Pile/ Pile Slab

A pile slab foundation is a foundation structure supported by a group or single pile system that is used to hold and forward the load from the upper structure into the soil that has the bearing capacity to withstand it [6]. This type of pile slab foundation is suitable for reinforcement in soils with low bearing capacity, such as cohesive clay.

3.2. Pile Foundation

Pile foundations tend to be given limitations with relatively small values of displacement so as not to cause structural damage [7]. The foundation pillar distributes the loads received from the construction above and channels them to the soil layer below. Pole foundation construction can be done by the piling method or by making reinforced concrete poles that are directly cast in place (cast in situ), which has previously made holes in the ground first [3]. Pole foundations are used when the foundation soil at normal depths is unable to support the load, and the hard soil is located at a very deep depth [8]. The pile's bearing capacity is calculated by combining the end bearing capacity and the friction bearing capacity, which is determined by the pile's friction with the surrounding soil [9].

3.3. Bored Pile Foundation

Drilled pile foundation is the most common type of pile foundation used in construction projects. If the pile foundation has been selected, the dimensions of the pile foundation (cross section and length) are calculated based on the load that the foundation must support and the soil conditions where the foundation is installed. After that, calculate the bearing capacity of the pile foundation based on the planned dimensions [9]. Drilled poles are used if the hard soil layer is deep enough. The bearing capacity on the bored pile is in the form of the tip bearing capacity and also the blanket bearing capacity, although the resulting blanket bearing capacity is affected by the adhesion factor and the value is not as large as the pile[10]. The bored pile is installed into the ground by drilling the ground first, then filling it with reinforcement and poured concrete. These piles are usually used in stable and rigid soils, making it possible to form stable holes with drilling tools [11].

3.4 Spun Pile Foundation

Several combinations of pile materials or drilled piles with piles can be used to overcome problems in certain soil conditions [11]. A pile foundation is a type of deep foundation that functions by receiving and forwarding loads from the upper structure to the ground, with certain depths and dimensions that can withstand loads[10]. Pile piling has significant blanket resistance in providing bearing capacity.

3.5 Soil Data

The following is the Boring Log (N-SPT) soil data at the Deltamas flyover location.

Table 1 DB-02 N-SPT Data

SOIL TYPE	Depth (m)			Δh (m)	N (Blow/ft)
Clay	0	-	4	4	6
Clay	4	-	6	2	5
Clay	6	-	8	2	4
Clay	8	-	10	2	17
Clay	10	-	12	2	16
Clay	12	-	14	2	15
Clay	14	-	16	2	13
Clay	16	-	18	2	15
Clay	18	-	20	2	25
Clay	20	-	22	2	23
Clay	22	-	24	2	24
Clay	24	-	26	2	29
Clay	26	-	28	2	33
Clay	28	-	30	2	36
Clay	30	-	32	2	34
Clay	32	-	34	2	55
Clay	34	-	36	2	60
Clay	36	-	38	2	60
Clay	38	-	40	2	60

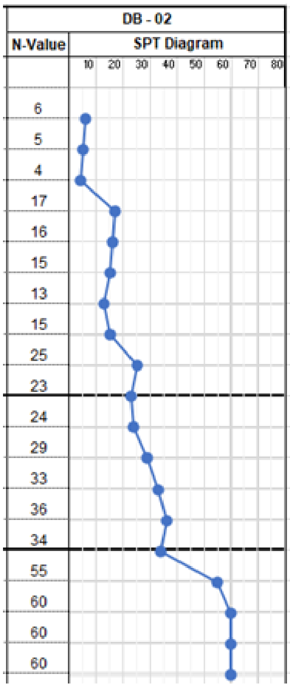

Figure 1 DB-02 N-SPT Graphic

3.6 Loading of Pile Slab

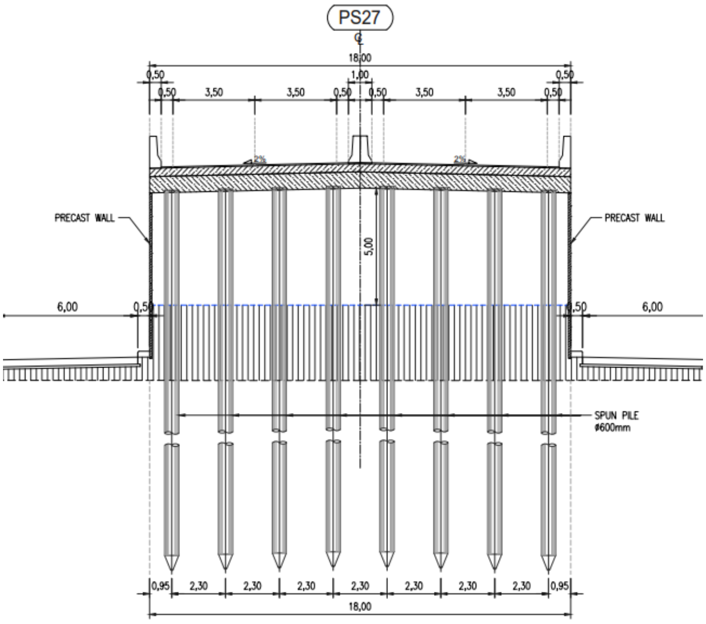

Figure 2 Cross section slab on spun pile

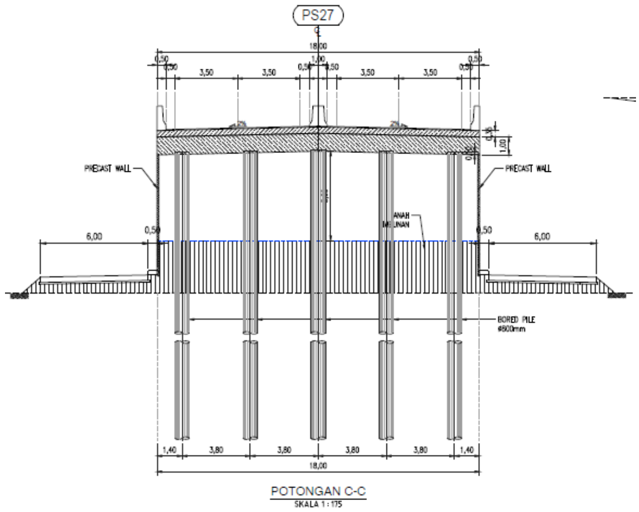

Figure 3 Cross section slab on bored pile

Based on the preliminary design data obtained, the dimensions of the slab piles analyzed are piles with a diameter of 0.6 m and drilled piles with a diameter of 0.8 m with soil data in the form of boring logs or N-SPT.

The oprite has a width of 18 m and a free standing height of 7 m. The transverse pile configuration is 8 pieces for piles and 5 pieces for drilled piles, with a longitudinal distance of 7 m.

For loading on top of pile slab is as follows :

Table 2 Loadings for Bridge

Load	Q area (kN/m^2)	Q line (kN/m)
Self Load		
Pile Head Load	By Software	
Spun Pile Load	By Software	
Slab Load	8.75	
Pavement Load	3.3	
Rain water load	0.49	
Barrier Load		9.25

Lane Load		
Uniform Load	9	
Line Load		68.6

The earthquake load is designed in accordance with SNI 2833 2016 and the 7% earthquake map in 75 years [3]. then the earthquake acceleration as follows

PGA = 0,293 g

SS = 0,587 g

S_1 = 0,234 g

Taken as soft soil classification then :

F_{PGA} = 1,25

F_a = 1,526

F_v = 3,064

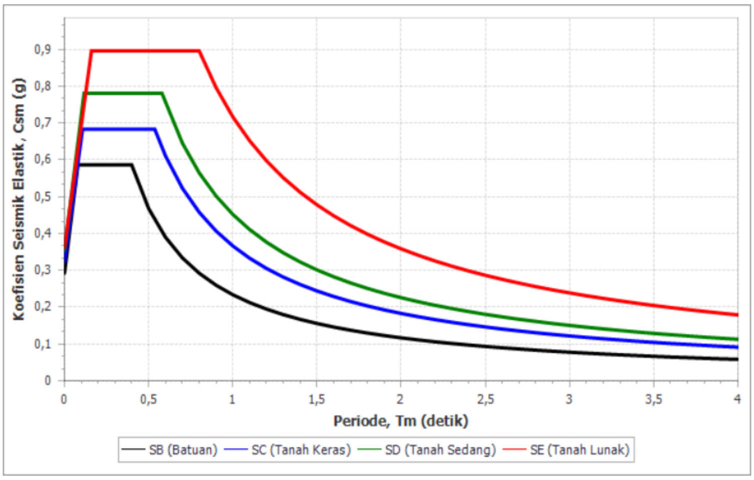

Figure 4 Respond Spectrum Graphic

The earthquake acceleration data is then input into a structural modeling program to be analyzed using the Respond spectrum method.

3.7 Spring Constant of the Pile

In calculating the spring constant value, the Lpile application is used to find the p and y values. The p-y curve method is a commonly used method because the working steps are not too complicated and the results are accurate. This method is used for homogeneous soil types along the pile. In this research, the author will describe the p-y curve with the procedure proposed by Georgiadis (2010) in the form of a hyperbola curve. Then the p-y curve proposed by Reeses will be created using the LPILE program [12].

The following is the p-y curve graph for DB-02 soil data obtained from the Lpile application:

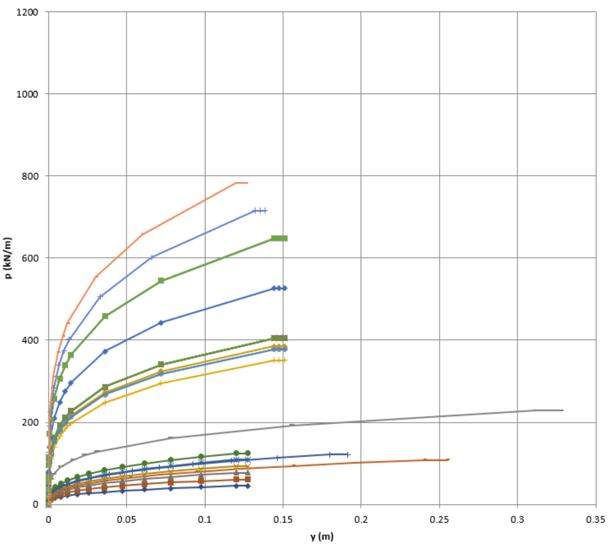

Figure 5 p-y Curve spun pile DB-02 graphic

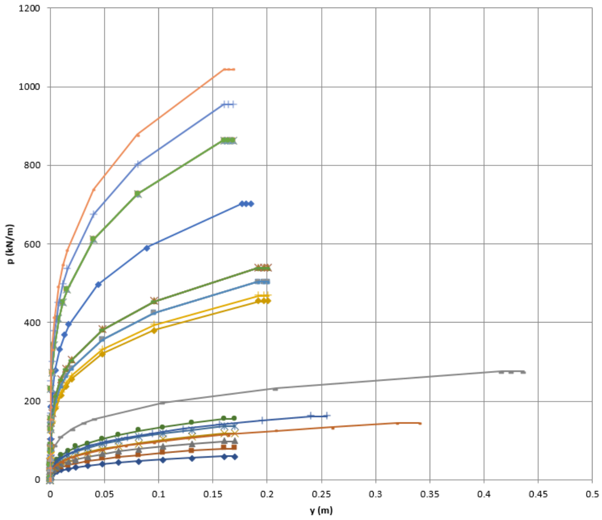

Figure 6 p-y Curve bored pile DB-02 graphic

In both graphs we can see that 1 line represents 1m of soil layer down. Each line has a constant point/stopping point of the deflection generated by a certain amount of force. This means that at that depth, the soil is only able to withstand a force equal to the resulting constant point / stopping point.

In Lpile, the results of the p and y values at each depth are illustrated in the following graph:

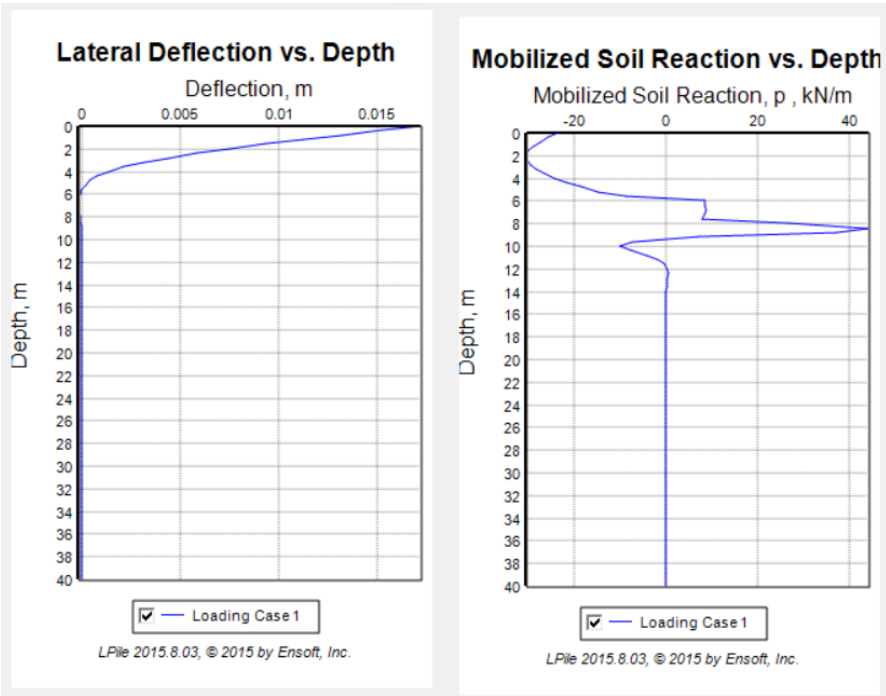

Figure 7 Graph of p and y with Depth for Spun pile

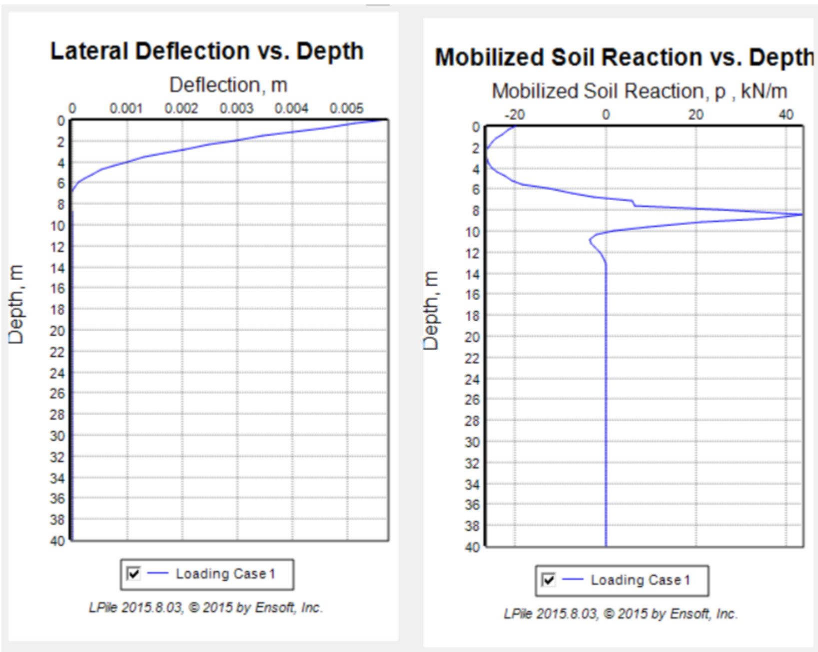

Figure 8 Graph of p and y with Depth for Bored pile

And the spring constant value is obtained as follows :

Table 1 Spring constant of spun pile diameter 0,6 m

DEPTH	DB-02		Soil Spring (kN/m)
	DEFLECT	SOIL RES.	
L (m)	y (m)	p (kN/m2	P/y (DB-02)
0	1.7.E-02	-2.4.E+01	913.47
1	1.1.E-02	-2.9.E+01	1727.60
2	7.5.E-03	-3.0.E+01	2707.90
3	3.2.E-03	-2.8.E+01	6017.65
4	1.4.E-03	-2.4.E+01	11931.72
5	1.9.E-04	-1.5.E+01	52889.96
6	-6.2.E-05	8.5.E+00	91968.61
7	-1.2.E-04	8.5.E+00	48654.60
8	-6.1.E-05	2.7.E+01	294734.09
9	-2.2.E-06	6.8.E+00	2101080.25
10	3.1.E-06	-1.0.E+01	2152777.78
11	5.6.E-07	-1.8.E+00	2151300.24
12	-7.8.E-08	2.5.E-01	2148817.20
13	-5.5.E-08	1.8.E-01	2149235.47
14	-5.5.E-09	1.6.E-02	2007326.01
15	4.0.E-09	-1.1.E-02	1865000.00
16	1.2.E-09	-3.6.E-03	2011299.44
17	-1.7.E-10	5.4.E-04	2146825.40
18	-1.0.E-10	3.0.E-04	1910256.41
19	5.5.E-12	-1.8.E-05	2205971.97
20	5.7.E-12	-1.9.E-05	2281011.17
21	1.9.E-12	-7.0.E-06	2421416.23

Table 2 Spring constant of borerd pile diameter 0,8 m

DEPTH	DB-02		Soil Spring
	DEFLECT	SOIL RES.	
L (m)	y (m)	p (kN/m2)	P/y (DB-02)
0	5.73E-03	-1.98E+01	2300.67
1	4.00E-03	-2.42E+01	4037.40
2	2.95E-03	-2.59E+01	5856.95
3	1.65E-03	-2.63E+01	10634.14
4	9.95E-04	-2.51E+01	16784.66
5	3.48E-04	-2.06E+01	39490.23
6	1.14E-04	-1.27E+01	73977.78
7	-2.13E-05	5.83E+00	182497.65
8	-2.79E-05	2.50E+01	596704.90
9	-7.60E-06	2.10E+01	1844429.82
10	-5.36E-07	1.61E+00	2004850.75
11	9.75E-07	-3.14E+00	2149059.83
12	4.32E-07	-1.39E+00	2149691.36
13	-6.36E-09	2.05E-02	2149895.18
14	-4.40E-08	1.32E-01	2006060.61
15	-1.50E-08	4.19E-02	1864000.00
16	-2.12E-09	6.37E-03	2003144.65
17	1.58E-09	-5.10E-03	2151898.73
18	8.30E-10	-2.47E-03	1983935.74
19	3.82E-11	-1.26E-04	2198952.88
20	-5.81E-11	2.04E-04	2340791.74
21	-2.21E-11	8.50E-05	2564102.56
22	-2.89E-12	1.17E-05	2698961.94
23	2.03E-12	-8.87E-06	2912972.09
24	1.49E-12	-6.70E-06	2997762.86

3.8 Deflection of The Pile

To calculate the defection, the service combination and earthquake combination were used.

1. Service: 1.3DL+2SDL+1.8LL
2. EarthquakeX: EQx+0.3EQy+DL+SDL
3. EarthquakeY: EQy+0.3EQx+DL+SDL

For the service combination the deflection should not be more than 12.5 mm, and for the earthquake combination the deflection should not be more than 25 mm [4]. And the deflection reviewed is a 2-way deflection, the longitudinal direction of the traffic direction fund.

Table 5 Maximum Deflection of Spun Pile Surface

Combination	Maximum Deflection	
Service	X Direct.	4,41 mm
	Y Direct.	0,0275 mm
Earthquake	X Direct.	3.67 mm
	Y Direct.	9.09 mm

Table 3 Maximum Deflection of Bored Pile Surface

Combination	Maximum Deflection	
Service	X Direct.	3.07 mm
	Y Direct.	0,0687 mm
Earthquake	X Direct.	7.7 mm
	Y Direct.	9.44 mm

3.9 Soil Bearing Capacity of Pile Based on N-SPT Data

The axial bearing capacity of the piles was calculated using the mayerhoff method (Sulistia, 2018).

a. End Bearing Capacity

$$Q_p = 9 \times Cu \times Ap$$

Description :

Q_p = End Bearing Capacity (kN)

Cu = Undrained cohession (kN/m^2)

Ap = Pile sectional area (m^2)

SF = Safety Factor = 3 [4]

b. Friction Bearing Capacity

$$Q_s = \alpha \times Cu \times K \times \Delta h$$

Description :

Q_s = Friction bearing capacity (kN)

α = adhesion coefficient

K = Perimeter of the pile (m)

Δh = Soil layer thickness

SF = Safety Factor = 2,5 [4]

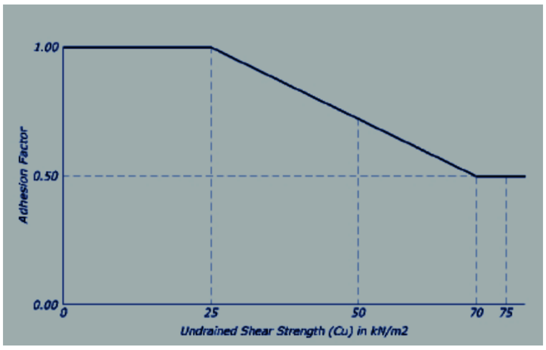

Figure 9 Relationship graph of Cu value and adhesion factor

c. Allowable Bearing Capacity

$$Qall = Qp/SF + \Sigma Qs/SF$$

From the description of the existing Meyerhoff formula, the carrying capacity results are obtained as follows:

Table 4 Soil Bearing Capacity of Spun Pile

SOIL TYPE	Depth (m)			Qp / SF (kN)	ΣQs / SF (kN)	Qall (kN)
Clay	0	-	4	25.45	85.45	110.90
Clay	4	-	6	21.21	123.15	144.36
Clay	6	-	8	16.96	153.31	170.27
Clay	8	-	10	72.10	217.40	289.50
Clay	10	-	12	67.86	264.31	332.17
Clay	12	-	14	63.62	320.86	384.48
Clay	14	-	16	55.13	375.32	430.45
Clay	16	-	18	63.62	431.86	495.48
Clay	18	-	20	106.03	526.11	632.14
Clay	20	-	22	97.55	612.82	710.37
Clay	22	-	24	101.79	703.30	805.09

The Pmax of the pile is 730 kN with a pile depth of 24 m.

Table 5 Soil Bearing Capacity of Bored Pile

SOIL TYPE	Depth (m)			Qp / SF (kN)	ΣQs / SF (kN)	Qijin (kN)
Clay	0	-	4	45.24	66.35	111.59
Clay	4	-	6	37.70	94.00	131.70
Clay	6	-	8	30.16	116.11	146.27
Clay	8	-	10	128.18	210.11	338.29
Clay	10	-	12	120.64	298.58	419.21
Clay	12	-	14	113.10	381.52	494.61
Clay	14	-	16	98.02	453.39	551.41
Clay	16	-	18	113.10	536.33	649.43
Clay	18	-	20	188.50	674.56	863.06

Clay	20	-	22	173.42	801.73	975.15
Clay	22	-	24	180.96	934.44	1115.39
Clay	24	-	26	218.65	1094.78	1313.44
Clay	26	-	28	248.81	1277.25	1526.06

The Pmax of the pile is 1457 kN with a pile depth of 28 m.

3.10 Settlement of The Pile

According to Bowles, 1993 in Simalango, Astrya, pile settlement can be determined as follows [14]:

$$S = S_{e(1)} + S_{e(2)} + S_{e(3)}$$

Dimana :

$$S_{e(1)} = \frac{(Qwp+\xi Qws)\times L}{Ap\times Ep}$$

$$S_{e(2)} = \frac{(Qwp\times Cp)}{d\times qp}$$

$$S_{e(3)} = \frac{(Qws\times Cs)}{L\times qp}$$

Dimana :

Q_{wp} = End bearing capacity (kN)

Q_{ws} = Friction bearing capacity (kN)

L = Pile length (m)

Ep = Modulus of elasticity of the pile material (kN/m^2)

ξ = distribution factor per unit friction resistance of the pile (fs)

d = pile diameter (m)

Cp = empirical coefficients

Cs = Empirical Constant

The pile drop requirement used is according to Skemptom and Mac Donald which is 65mm [14].

Table 6 Maximum settlement requirement table

Type of Foundation	Limit for Settlement (mm)
Split foundation on clay soil	65
Split foundation on sand soil	40
raft foundation on clay soil	65 – 100
raft foundation on sand soil	40 – 65

The settlement of the spun piles is as follows:

$S_{e(1)}$ = 0.898 mm

$S_{e(2)}$ = 0.007 mm

$S_{e(3)}$ = 0.038 mm

S_e = $S_{e(1)} + S_{e(2)} + S_{e(3)}$

= 0.944 mm

The settlement of the bored piles is as follows:

$S_{e(1)}$ = 1.920 mm

$S_{e(2)}$ = 0.012 mm

$S_{e(3)}$ = 0.030 mm

S_e = $S_{e(1)} + S_{e(2)} + S_{e(3)}$

= 1.96 mm

The drop value above still meets the requirement of 65 mm according to Skemptom & Mac Donald in Astra Simalango [14].

4. Conclusion

Based on the results of the analysis of Slab on Boren Pile and Slab on Spun Pile, the results of structural movement and other information are obtained as follows:

Table 7 Comparison table of movement results of slab on spun pile and slab on bored pile structures [15]

Comparison	*Slab On Spun Pile*	*Slab On Bored Pile*
Settlement	0,944 mm	1,964 mm
Surface deflection	9,09 mm	9,44 mm
Pile concrete quality	50 MPa	30 MPa
Pile diameter	0,6 m	0,8 m
Number of pile/ 7m	8 tiang	5 tiang
Pile length	31 m	35 m
Bearing capacity	805 kN	1526 kN

Based on the results of the comparative analysis of the two alternative designs of the Bekasi City Deltamas Fly Over Oprit, the researcher advises the relevant parties to use the Slab On Bored Pile design alternative in the Oprit design. Apart from the results of the above calculations, the social and economic aspects economic aspects are also more supportive if using the Slab On Bored Pile design alternative. For further research, it can review in terms of reinforcement analysis, cost considerations and processing time in the field. In addition, there is a need for caution in the implementation of Oprit work in the field to be more optimal.Oprit in the field to be more optimal.

5. Acknowledgement

In this section, I would like to express my gratitude to God Almighty and thank my parents for providing support for the completion of this research. I would also like to thank the various parties and institutions that have contributed to the completion of this research. Therefore, we would like to express our deepest gratitude, among others, to:

1. Mrs. Dyah Nurwidyaningrum, S.T., M.M., M.Arc as the Head of the Civil Engineering Department, Politeknik Negeri Jakarta.
2. Mr. Dio Akbar Hakim, S.Tr. as Supervisor who has provided guidance and direction.
3. Mr. Putera Agung Maha Agung, S.T., M.T., Ph.D as Supervisor who has provided guidance and direction.
4. Politeknik negeri jakarta, as a place where I studied for 4 years which has given me a lot of valuable knowledge and experience.
5. Ms. Mulyani Purwaningsih as a person who has provided assistance in the form of a place of shelter and food supply for some time during this research work.
6. Lastly, I would like to thank myself for continuing to struggle and getting to this point. Thank you for continuing to believe and not stopping trying no matter what the obstacles until completion of this research.

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