



CALCULATION SHEET

Project: EASTLANDS SUBSTATION
Task: PILING MAT
Customer: KABERRY CONSTRUCTION

JOB NO: 8295-01
REVISION: CC0
PREPARED BY: GK
CHECKED BY: WF
DATE: 13/09/2023
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Description:

Revision:

REV	DATE	DESCRIPTION	DES	CHK
N/A	N/A	N/A	N/A	N/A

Aim:

Provide a design for a piling rig working platforms to facilitate the installation of the piles on site for KLEMM KLM4 (KR709-1) piling rig.

Design Approach:

The following documents have been used to prepare this design:

- Geotechnical Testing Results (Appendix 2);
- Schedule of Piling Rig Component Weights, Dimensions, Forces and Pressure for KLEMM KLM4 (KR709-1);
- KLEMM 4 General Specification;

The design has been prepared in accordance with the following standards and guidance:

- BS 5975:2019 - Code of practice for temporary works procedures;
- BRE 470 - Working platforms for tracked plant;
- BS EN 1990 - Basis of structural design;
- BS EN 1997-1 - Geotechnical design - General rules;



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KLEMM KLM4 (KR709-1)

1. LOADINGS AND GROUND BEARING PRESSURES

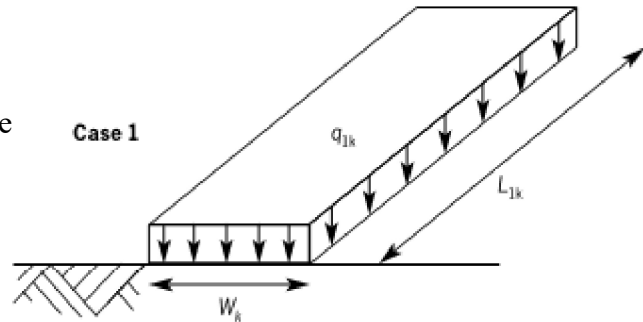
1.1. Piling rig parameters:

Pressure Summary for Platform Design (unfactored)

MODE	BRE LOAD CASE (1 or 2)	Length (m)	Width (m)	UDL Pressure (kPa)
Standing	1	2.54	0.5	46
Travelling	1	2.00	0.5	70
Handling	1	2.29	0.5	54
Penetrating	2	0.89	0.5	95
Extracting	2	1.15	0.5	134
Other	NOT USED	N/A	0.5	N/A

1.2. BRE load case 1:

These loading conditions may apply when the rig or crane operator is unlikely to be able to aid recovery from an imminent platform failure. Operations in which this type of loading condition applies could include: Standing, Travelling, Handling.



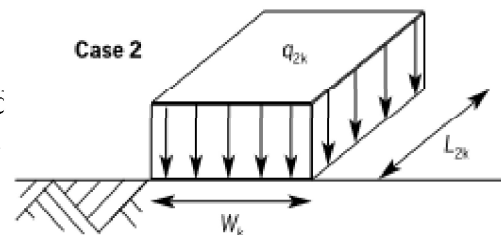
$W_{1d} := 0.5m$ - effective track width in case 1

$L_{1d} := 2.00m$ - effective track length in case 1

$q_{1k} := 70kPa$ - effective ground bearing pressure in case 1

1.3. BRE load case 2:

These loading conditions may apply when the rig or crane operator can control the load safely, for example by releasing the line load, or by reducing power, to aid recovery from an imminent platform failure. Case 2 load is generally given by the worst combination of load and orientation of the rig. Operations in which this type of loading condition applies to a piling rig could include: Installing casing, Drilling, Extracting an auger.



$W_{2d} := 0.5m$ - effective track width in case 2

$L_{2d} := 1.15m$ - effective track length in case 2

$q_{2k} := 134kPa$ - effective ground bearing pressure in case 2



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2. GROUND CONDITIONS:

Note: The ground condition assessment bases on BH1 & BH2 Boreholes Logs, SI Report and Geotechnical Testing Result.

Piles cut off levels (top of the piling mat)	+53.455 m, +53.405 m
Existing site level in the considered area:	~54.95 m
Approximate considered deep below the existing ground:	$d := 54.95\text{m} - 53.455\text{m} = 1.5\text{ m}$
Type of soil 1.50 m below the existing ground level according to BH1 Borehole Log:	Made Ground (granular), N=13 (SPT)
Type of soil 1.50 m below the existing ground level according to BH2 Borehole Log:	Made Ground (granular), N=8 (SPT)
Groundwater level:	~2.30 m below ground level

2.1. Basic data and characteristic ground properties:

subgrade :=
☐ cohesive
☒ granular

- general type of subgrade (MADE GROUND, slightly clayey slightly gravelly SAND)

water_table :=
☒ low
☐ high

- water table level (use 'low' if the water is at least 2W below surface)

$\varphi'_{pk} := 45\text{deg}$

- angle of shearing resistance of the platform material (compacted 6F2)

$\gamma_{pk} := 20 \frac{\text{kN}}{\text{m}^3}$

- effective bulk unit weight of the platform material (compacted 6F2)

$c_{uk} := 0$

- undrained shear strength of the cohesive subgrade (N/A)

$\gamma_w := 10 \frac{\text{kN}}{\text{m}^3}$

- unit weight of the ground water

$\gamma_{sk} := 20 \frac{\text{kN}}{\text{m}^3}$

- bulk unit weight of the subgrade

$\text{SPT}_N := 8$

- minimum N-value from summary of SPT results

$\varphi'_{sk} = 29.5 \cdot \text{deg}$

- angle of shearing resistance of the granular subgrade (for SPT = 8)



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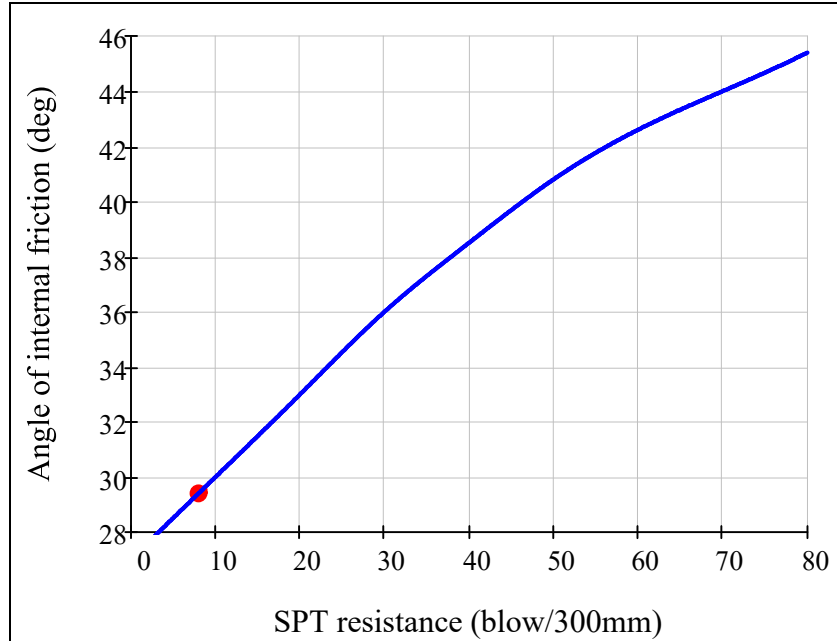
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CBR value corresponding to the designated angle of shearing resistance of 29.5deg:

CBR := 1.5%

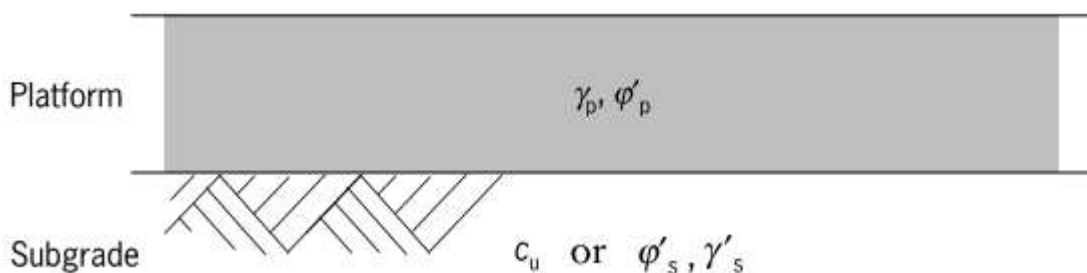
2.2. Design ground properties adopted in the design:

angle of shearing resistance
of platform material (6F2)

$$\varphi'_{pd} = 45 \cdot \text{deg}$$

bulk unit weight of
platform material (6F2)

$$\gamma_{pd} = 20 \cdot \frac{\text{kN}}{\text{m}^3}$$



angle of shearing resistance
of subgrade material
(made ground, slightly clayey
slightly gravelly SAND)

$$\varphi'_{sd} := \varphi'_{sk} = 29.5 \cdot \text{deg}$$

bulk unit weight of
subgrade material
(made ground, slightly clayey
slightly gravelly SAND)

$$\gamma_{sd} := \gamma_{sk} = 20 \cdot \frac{\text{kN}}{\text{m}^3}$$



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3. BEARING CAPACITY AUXILIARY COEFFICIENTS:

3.1. Bearing capacity factors:

$$N_c := (\pi + 2) = 5.14 \quad - \text{for cohesive subgrade}$$

$$N_{\gamma s} := 2 \cdot \tan(\varphi'_{sd}) \cdot \left[1 + e^{\pi \cdot \tan(\varphi'_{sd}) \cdot \left(\tan\left(45\text{deg} + \frac{\varphi'_{sd}}{2}\right) \right)^2} \right] = 20.81 \quad - \text{for subgrade}$$

$$N_{\gamma p} := 2 \cdot \tan(\varphi'_{pd}) \cdot \left[1 + e^{\pi \cdot \tan(\varphi'_{pd}) \cdot \left(\tan\left(45\text{deg} + \frac{\varphi'_{pd}}{2}\right) \right)^2} \right] = 271.75 \quad - \text{for platform}$$

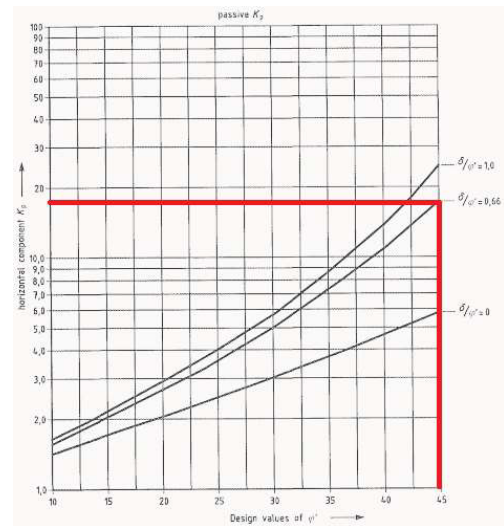
3.2. Punching shear resistance coefficient:

$$\delta_{vv} := \frac{2}{3} \cdot \varphi'_{pd} = 30 \cdot \text{deg}$$

$$K_p := \text{linterp} \left[\begin{pmatrix} 30\text{deg} \\ 35\text{deg} \\ 40\text{deg} \\ 45\text{deg} \end{pmatrix}, \begin{pmatrix} 5 \\ 7 \\ 11 \\ 19 \end{pmatrix}, \varphi'_{pd} \right]$$

$$K_p = 19$$

$$K_p \cdot \tan(\delta) = 10.97$$



[Figure C.2.1 from BS EN 1997-1]

3.3. Shape factors (for load case 1 and load case 2):

$$s_{c1} := 1 + 0.2 \left(\frac{W_{1d}}{L_{1d}} \right) = 1.05$$

$$s_{c2} := 1 + 0.2 \left(\frac{W_{2d}}{L_{2d}} \right) = 1.09$$

$$s_{\gamma 1} := 1 - 0.3 \left(\frac{W_{1d}}{L_{1d}} \right) = 0.93$$

$$s_{\gamma 2} := 1 - 0.3 \left(\frac{W_{2d}}{L_{2d}} \right) = 0.87$$

$$s_{p1} := 1 + \left(\frac{W_{1d}}{L_{1d}} \right) = 1.25$$

$$s_{p2} := 1 + \left(\frac{W_{2d}}{L_{2d}} \right) = 1.43$$



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4. BEARING CAPACITY CHECK WITHOUT A WORKING PLATFORM:

4.1. Design bearing capacity of the subgrade:

$$R_{d1} := \begin{cases} c_{ud} \cdot N_c \cdot s_{c1} & \text{if subgrade = "cohesive"} \\ 0.5 \cdot \gamma_{sd} \cdot W_{1d} \cdot N_{\gamma s} \cdot s_{\gamma 1} & \text{if subgrade = "granular"} \end{cases} = 96.25 \cdot \text{kPa}$$

$$R_{d2} := \begin{cases} c_{ud} \cdot N_c \cdot s_{c2} & \text{if subgrade = "cohesive"} \\ 0.5 \cdot \gamma_{sd} \cdot W_{2d} \cdot N_{\gamma s} \cdot s_{\gamma 2} & \text{if subgrade = "granular"} \end{cases} = 90.48 \cdot \text{kPa}$$

4.2. Design loadings in the two load cases:

$$q_{1d} := 2.0 \cdot q_{1k} = 140 \cdot \text{kPa}$$

$$q_{2d} := 1.5 \cdot q_{2k} = 201 \cdot \text{kPa}$$

$$\text{therefore} := \begin{cases} \text{"platform required"} & \text{if } R_{d1} < 2.0 \cdot q_{1k} \vee R_{d2} < 1.5 \cdot q_{2k} \\ \text{"platform not required"} & \text{if } R_{d1} \geq 2.0 \cdot q_{1k} \wedge R_{d2} \geq 1.5 \cdot q_{2k} \end{cases}$$

therefore = "platform required"

Table A3 Values for loading factors γ_q		
Loading condition	Platform required	
	No	Yes
Case 1	2.0	1.6
Case 2	1.5	1.2

5. BEARING CAPACITY CHECK OF THE PLATFORM MATERIAL:

5.1. Design bearing capacity of the platform material itself:

$$R_{d1.p} := 0.5 \cdot \gamma_{pd} \cdot W_{1d} \cdot N_{\gamma p} \cdot s_{\gamma 1} = 1256.83 \cdot \text{kPa}$$

$$R_{d2.p} := 0.5 \cdot \gamma_{pd} \cdot W_{2d} \cdot N_{\gamma p} \cdot s_{\gamma 2} = 1181.51 \cdot \text{kPa}$$

5.2. Design loadings in the two load cases:

$$q_{1d} := 1.6 \cdot q_{1k} = 112 \cdot \text{kPa}$$

$$q_{2d} := 1.2 \cdot q_{2k} = 160.8 \cdot \text{kPa}$$

$$\text{therefore} := \begin{cases} \text{"platform material too weak"} & \text{if } R_{d1.p} < 1.6 \cdot q_{1k} \vee R_{d2.p} < 1.2 \cdot q_{2k} \\ \text{"platform strength sufficient"} & \text{if } R_{d1.p} \geq 1.6 \cdot q_{1k} \wedge R_{d2.p} \geq 1.2 \cdot q_{2k} \end{cases}$$

therefore = "platform strength sufficient"

Table A3 Values for loading factors γ_q		
Loading condition	Platform required	
	No	Yes
Case 1	2.0	1.6
Case 2	1.5	1.2

6. REQUIRED PLATFORM THICKNESS:

6.1. Minimum platform thickness:

$$D_{\min} := \min(0.5 \cdot W_{1d}, 0.5 \cdot W_{2d}, 300\text{mm}) = 250 \cdot \text{mm} \quad - \text{the lesser of } 0.5W \text{ or } 300\text{mm}$$

6.2. Punching failure mechanism theory:

In a typical situation where a working platform of relatively shallow thickness is placed on a weak subgrade, a simple approach to the design calculations can be based on the analysis of punching failure. In this analysis the bearing resistance R is considered to be the sum of the shear required to punch through a vertical plane in the granular platform material and the bearing capacity of the subgrade (Figure A3). It is considered that this simplified approach has within it a degree of conservatism.

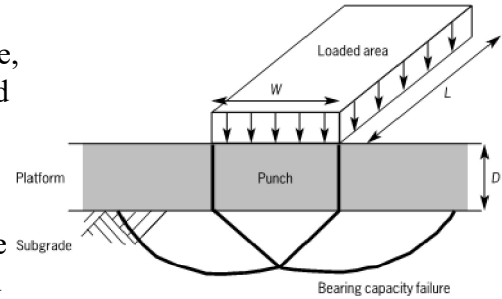


Figure A3 Punching failure mechanism

Using the simplified analysis developed by Meyerhof and his co-workers for a footing punching through a dense sand layer overlying soft clay, the following expression is obtained for the bearing resistance of a platform on a cohesive subgrade:

$$R = c_u \cdot N_c \cdot s_c + \frac{(\gamma_p \cdot D)^2}{W} \cdot K_p \cdot \tan(\delta) \cdot s_p$$

In a similar way the following expression can be obtained for the bearing resistance of a platform on a granular subgrade:

$$R = 0.5 \cdot \gamma_s \cdot W \cdot N_{\gamma s} \cdot s_{\gamma} + \frac{(\gamma_p \cdot D)^2}{W} \cdot K_p \cdot \tan(\delta) \cdot s_p$$

6.2. Required platform thickness without a geogrid reinforcement:

$$D_{1.\text{req}} := \sqrt{\max \left[\left[\frac{W_{1d} \cdot (1.6q_{1k} - R_{d1})}{\gamma_{pd} \cdot K_p \cdot \tan(\delta) \cdot s_{p1}} \right]^{0.5} \right]^2, 0} = 169 \cdot \text{mm} \quad - \text{load case 1 with } q_{1d} = 1.6q_{1k}$$

$$D_{2.\text{req}} := \sqrt{\max \left[\left[\frac{W_{2d} \cdot (1.2q_{2k} - R_{d2})}{\gamma_{pd} \cdot K_p \cdot \tan(\delta) \cdot s_{p2}} \right]^{0.5} \right]^2, 0} = 334 \cdot \text{mm} \quad - \text{load case 2 with } q_{1d} = 1.2q_{1k}$$

$$D_{\text{req}} := \max(D_{1.\text{req}}, D_{2.\text{req}}, D_{\min}) = 334 \cdot \text{mm}$$



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7. FINAL BEARING CAPACITY OF THE DESIGNED PLATFORM:

7.1. Final provided platform parameters:

$D := 350\text{mm}$ - final provided thickness of the platform

geogrid := ☒ no ☐ yes - use of geogrid reinforcement

7.2. Design bearing capacity of the subgrade with platform:

$$R_{d1.fin} := \begin{cases} R_{d1} + \left(\frac{D^2}{W_{1d}} \right) \gamma_{pd} \cdot K_p \cdot \tan(\delta) \cdot s_{p1} & \text{if geogrid = "no"} \\ R_{d1} + \left(\frac{D^2}{W_{1d}} \right) \gamma_{pd} \cdot K_p \cdot \tan(\delta) \cdot s_{p1} + 2 \cdot \frac{T_d}{W_{1d}} & \text{if geogrid = "yes"} \end{cases} = 163.44 \cdot \text{kPa}$$

$$R_{d2.fin} := \begin{cases} R_{d2} + \left(\frac{D^2}{W_{2d}} \right) \gamma_{pd} \cdot K_p \cdot \tan(\delta) \cdot s_{p2} & \text{if geogrid = "no"} \\ R_{d2} + \left(\frac{D^2}{W_{2d}} \right) \gamma_{pd} \cdot K_p \cdot \tan(\delta) \cdot s_{p2} + 2 \cdot \frac{T_d}{W_{2d}} & \text{if geogrid = "yes"} \end{cases} = 167.6 \cdot \text{kPa}$$

7.3. Design loadings in the two load cases:

$$q_{1d} := 1.6 \cdot q_{1k} = 112 \cdot \text{kPa}$$

$$q_{2d} := 1.2 \cdot q_{2k} = 160.8 \cdot \text{kPa}$$

Table A3 Values for loading factors γ_q		
Loading condition	Platform required	
	No	Yes
Case 1	2.0	1.6
Case 2	1.5	1.2

therefore := "provided platform not sufficient" if $R_{d1.fin} < 1.6 \cdot q_{1k} \vee R_{d2.fin} < 1.2 \cdot q_{2k}$
"provided platform satisfactory" if $R_{d1.fin} \geq 1.6 \cdot q_{1k} \wedge R_{d2.fin} \geq 1.2 \cdot q_{2k}$

therefore = "provided platform satisfactory"

$$\frac{q_{1d}}{R_{d1.fin}} = 68.53\%$$

$$\frac{q_{2d}}{R_{d2.fin}} = 95.94\%$$

DESIGN SUMMARY:

Provide minimum 350 mm thick 6F5 piling mat on the existing granular subgrade with minimum CBR value of 1.5%.