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Analysis And Design Of Spread And Pile Foundations Using Geo5

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ABSTRACT

The safe and efficient design of foundation systems is a core focus in geotechnical engineering, particularly for structures subjected to varying soil conditions and load demands. This study presents a comprehensive analysis and design of both spread and pile foundations using GEO5, a robust geotechnical software suite that integrates soil mechanics theories with advanced numerical modelling. Spread foundations are analysed for shallow soil conditions with adequate bearing capacity, while pile foundations are considered where deeper, more stable strata are needed to support heavy loads.

A real-time case study was undertaken to demonstrate the practical application of GEO5 in both scenarios. Site-specific soil data was obtained through borehole investigations and laboratory testing, including parameters such as unit weight, cohesion, angle of internal friction, and unconfined compressive strength. For spread foundations, the software evaluated bearing capacity, settlement behaviour, and safety against shear failure. For pile foundations, vertical and lateral load assessments, bearing capacity calculations, settlement predictions, and group effects like pile interaction were thoroughly examined. The analysis compared results from GEO5 with conventional empirical approaches, revealing improved accuracy and visualization in predicting foundation behaviour under complex loading and stratified soil profiles. All designs adhered to relevant IS codes, ensuring structural safety and serviceability. Optimization studies involving varying foundation dimensions were also conducted to identify cost-effective yet stable solutions.

The findings confirm that GEO5 is a powerful tool for designing both shallow and deep foundations, streamlining the engineering process and enhancing the understanding of soil-structure interaction. Its utility extends from academic research to real-world engineering applications, especially in challenging geotechnical environments.

Keywords: *Spread Foundation, Pile Foundation, GEO5 Software, Geotechnical Engineering, Bearing Capacity, Settlement Analysis, Soil-Structure Interaction, Vertical Load, Lateral Load, Foundation Design.*

1. INTRODUCTION

Foundation design is a vital aspect of civil and geotechnical engineering, serving as the essential interface between a structure and the ground. The fundamental function of any foundation system—whether shallow or deep—is to safely transmit structural loads to the underlying soil or rock without causing excessive settlement, shear failure, or instability. Depending on the subsurface conditions, engineers must choose between spread (shallow) foundations and pile (deep) foundations. Spread foundations are typically used where competent soil exists near the surface, while pile foundations are preferred when the upper soil layers are weak, compressible, or exhibit low bearing capacity.

Spread foundations, such as isolated footings, combined footings, and rafts, are cost-effective and simple to construct, making them suitable for small to medium-sized structures. However, in challenging ground conditions or for heavy loads, pile foundations become necessary. Pile foundations consist of long, slender elements that penetrate through poor-quality surface soils to transfer loads to deeper, more stable strata or bedrock. These foundations are widely used in high-rise buildings, bridges, industrial plants, and marine structures due to their capacity to resist vertical and lateral forces.

Designing both types of foundations involves complex considerations, including soil behaviour, load conditions, settlement characteristics, and structural requirements. Traditionally, engineers relied on empirical methods and simplified analytical equations to perform foundation design. While these approaches offer conservative estimates, they often fall short in capturing the full complexity of soil-structure interaction, especially in stratified or non-homogeneous soils. This limitation has led to the adoption of advanced software tools that provide more detailed, accurate, and efficient analyses.

GEO5 is a modern geotechnical software suite designed to address these challenges. It offers a range of modules to analyse and design various foundation systems, including both spread and pile foundations. With its user-friendly interface, numerical modeling capabilities, and compatibility with geotechnical investigation data, GEO5 allows engineers to simulate realistic conditions, analyse single and group piles, evaluate shallow footing behaviour, and predict settlements with high reliability. It generates comprehensive graphical and tabular outputs such as load-settlement curves, bearing capacity estimates, and stress distribution profiles.

This paper investigates the use of GEO5 in the design and analysis of spread and pile foundations for structures situated on variable subsoil profiles. The study begins with site investigation, including borehole logging and laboratory testing to obtain key soil parameters such as unit weight, cohesion, internal friction angle, and unconfined compressive strength. These parameters are input into GEO5 to model different foundation types under vertical, lateral, and seismic loads. Both isolated footings and piles (end-bearing and friction types) are analysed in detail, considering safety, serviceability, and cost-effectiveness.

Additionally, the paper emphasizes the significance of pile group effects, including interaction and stress overlap, and how GEO5 accommodates these phenomena for realistic modelling. For spread foundations, bearing capacity analysis and settlement predictions are performed under service and ultimate loads. The results are compared with traditional design methods to validate the accuracy and advantages of using software-based analysis. Furthermore, all designs are cross-verified with the relevant Indian Standard (IS) codes, particularly IS 456 for concrete design, IS 6403 for shallow foundations, and IS 2911 for pile foundations.

The overarching objectives of this study are to demonstrate the practical use of GEO5 in professional geotechnical practice, to evaluate its capabilities in modelling different foundation types, and to highlight its effectiveness in optimizing design for safety and economy in complex site conditions.

2. LITERATURE SURVEY

Chimdesa et al. (2023) conducted a comparative study using PLAXIS 2D and GEO5 to analyse pile groups, piled rafts, and footings. Their research highlighted GEO5's effectiveness in assessing factors like settlement and safety across various soil types, demonstrating its utility in geotechnical design.

Cao Van (2024) developed a MATLAB-integrated program that computes bearing capacity and settlement for pile foundations. Validated through a real-world project in Vietnam, the program effectively reduced pile lengths while maintaining elastic behaviour, showcasing its practical applicability in pile design.

Youwai & Thongnoo (2023) introduced a transformer-based deep learning model to predict load-deformation behaviour of bored piles in Bangkok's subsoil. The model achieved a mean absolute error of 5.72%, indicating its potential for accurate predictions in complex soil conditions.

Li et al. (2025) developed an interpretable machine learning model using XGBoost to predict p-y curves for monopile foundations in sand. The model's predictions aligned well with theoretical expectations, enhancing the understanding of lateral pile responses.

Vahab et al. (2022) applied Physics-Informed Neural Networks (PINNs) for forward and inverse analysis of pile-soil interactions. Their approach effectively handled discontinuities in strain fields, offering a novel method for parameter identification in layered soils.

Masud et al. (2024) performed a reliability-based design improvement for steel driven piles in rock-based intermediate geomaterials. Their study emphasized the importance of considering geotechnical uncertainties in pile design, leading to more robust and reliable foundations.

Kumar et al. (2021) conducted a comparative study on the reliability analysis of pile foundations using soft computing techniques. Their research demonstrated that methods like ANFIS and GMDH could effectively model the uncertainties inherent in geotechnical parameters.

Youwai & Pamungmoon (2024) developed an explainable AI model to predict pile driving vibrations in Bangkok's soft clay. Utilizing SHAP analysis, they identified key factors influencing vibrations, aiding in the mitigation of environmental impacts during construction.

Srujana & Biswas (2024) conducted a numerical analysis of geogrid-strengthened pile foundations subjected to machine-induced vibrations. Their findings indicated that geogrid reinforcement effectively reduced lateral displacement amplitudes, enhancing the dynamic performance of pile systems.

Kumar et al. (2023) explored the design and reliability analysis of energy piles using soft computing techniques. Their study highlighted the potential of energy piles in sustainable construction and the effectiveness of soft computing models in handling geotechnical uncertainties.

3. PROPOSED METHOD

The proposed methodology outlines a systematic approach for the analysis and design of pile foundations using GE05 software. The procedure integrates geotechnical investigation, software-based modelling, and validation against standard codes to ensure structural safety and economic feasibility.

Step 1: Site Investigation and Soil Data Collection

- Conduct detailed geotechnical investigation including borehole drilling, standard penetration tests (SPT), and laboratory testing of soil samples.
- Record essential soil parameters: unit weight, cohesion, angle of internal friction, modulus of elasticity, and water table depth.
- Stratify the subsoil layers based on observed borehole logs.

Step 2: Load Determination

- Obtain load data from the structural design team or calculate based on preliminary architectural and structural plans.
- Consider dead load, live load, and lateral/seismic loads (if applicable).
- Estimate total design load for foundation planning.

Step 3: Input Modelling in GE05

- Launch GE05 software and choose the appropriate module (e.g., “Pile Bearing Capacity” or “Pile Group Analysis”).
- Input site-specific soil profile, groundwater table, and layer properties.
- Define pile type (bored or driven), cross-sectional dimensions, material properties, and pile layout (for group pile design).

Step 4: Pile Capacity Analysis

- Compute pile bearing capacity using:
  - End bearing resistance (based on base layer properties).
  - Skin friction resistance (based on side layer friction values).
- Apply safety factors in accordance with IS 2911 or equivalent standards.

Step 5: Settlement Analysis

- Use the settlement module in GE05 to calculate:
  - Immediate (elastic) settlement.
  - Consolidation settlement based on soil compressibility and drainage conditions.
- Evaluate total settlement and compare with permissible limits.

Step 6: Group Effect Evaluation

- For multiple piles, perform group pile analysis considering:
  - Pile-to-pile interaction.
  - Group efficiency.
  - Load redistribution.
- Adjust pile spacing and arrangement for optimal performance.

Step 7: Optimization

- Conduct a sensitivity analysis by varying pile length and diameter.
- Select the most economical design satisfying bearing capacity, settlement, and code compliance.
- Evaluate alternative materials or configurations if required.

Step 8: Validation and Documentation

- Compare GE05 results with traditional analytical methods (e.g., Meyerhof, Terzaghi).
- Cross-check with IS code recommendations (IS 2911) for design validation.
- Prepare detailed design drawings and a report with all assumptions, results, and safety checks.

4. RESULTS

The analysis and design of pile foundations were carried out using GE05 software based on geotechnical data from the site and structural loading information. The results focus on pile capacity, settlement behaviour, and group interaction effects. Spread footing

4.1 Spread footing verification Input data

The details of the settings and material standards are listed below.

Settings

Standard - EN 1997 - DA1

Materials and standards

Concrete structures : EN 1992-1-1 (EC2)

Coefficients EN 1992-1-1 : standard

Settlement

Analysis method : Analysis using oedometric modulus Restriction of influence zone : by percentage of Sigma,Or

Coeff. of restriction of influence zone : 10.0 [%]

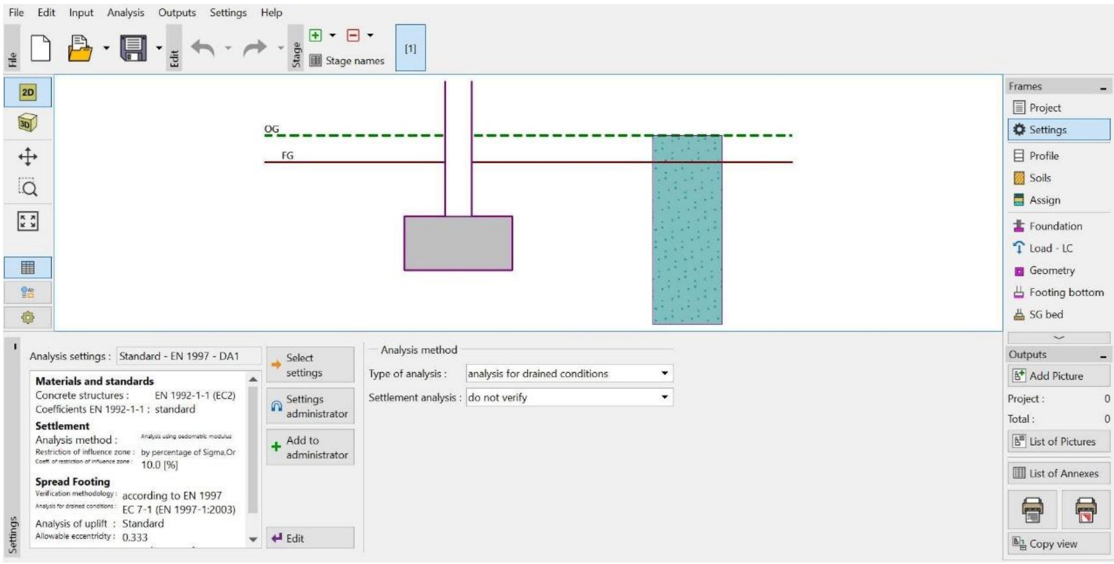


Figure 4.1 – Settings and Material standards – Spread Footing

Table 4-1: Spread Footing – Partial factors

Partial factors on actions (A)									
Permanent design situation									
		Combination 1				Combination 2			
		Unfavourable		Favourable		Unfavourable		Favourable	
Permanent actions :	γG =	1.35	[–]	1.00	[–]	1.00	[–]	1.00	[–]

Table 4-2: Partial Factors for Soil Parameters

Partial factors for soil parameters (M)					
Permanent design situation					
		Combination 1		Combination 2	
Partial factors for soil parameters (M)					
Permanent design situation					
Partial factor on internal friction :	γϕ =	1.00	[–]	1.25	[–]
Partial factor on effective cohesion :	γc =	1.00	[–]	1.25	[–]
Partial factor on undrained shear strength :	γcu =	1.00	[–]	1.40	[–]
Partial factor on unconfined strength :	γv =	1.00	[–]	1.40	[–]

4.2 Profiling and Soil properties

In the next step the soil profile with different thickness of the soil layers can be considered, in this analysis a single soil layer “Gravel Sand” is considered. The details are mentioned below.

Soil parameters

Gravel Sand

Basic data

Unit weight : γ = 21.00 [kN/m3]

Internal friction angle : φef = 36.00 [°]

Cohesion : cef = 0.00 [kPa]

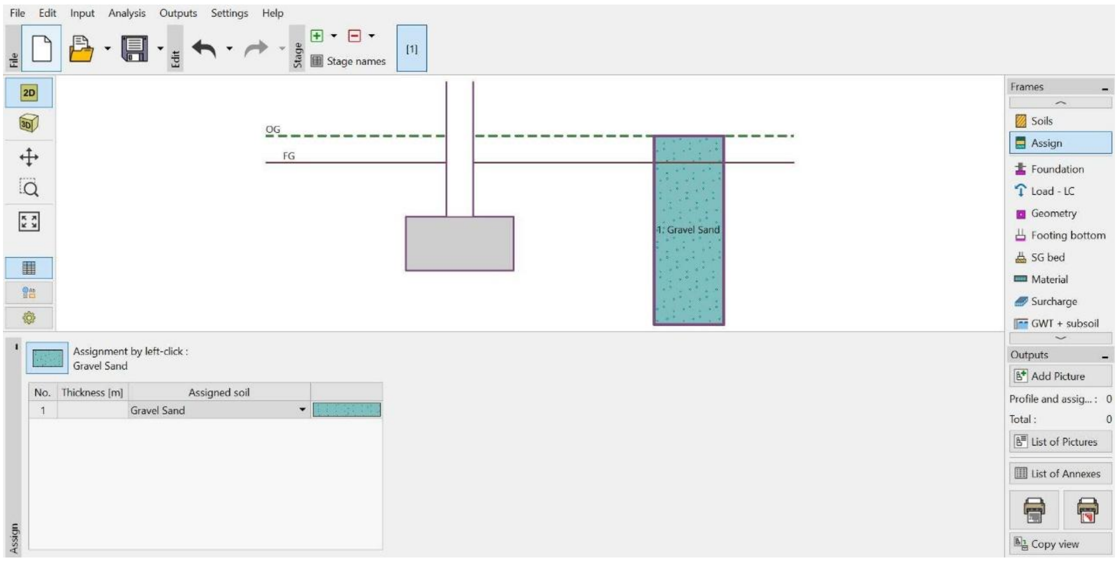


Figure 4.2 – Soil Profiling and Properties

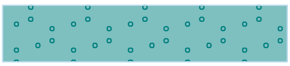
Uplift pressure

Uplift calculation : standard

Unit weight of saturated soil : γsat = 21.5.00 [kN/m^3]

View

Soil pattern :



4.3 Geometry of the foundation

2m X 2m size and 1m thick isolated footing at 2.5m from original ground level and 2m from finished grade level is considered with unit over burden weight of 20 kN/m3. The details are presented in Figure 4.3 and Figure 4.4.

Foundation Foundation type	=	centric spread footing
Depth from original ground surface (hz)	=	2.50m
Depth of footing bottom (d)	=	2.00m
Foundation thickness (t)	=	1.00m
Incl. of finished grade (s1)	=	0.00°
Incl. of footing bottom (s2)	=	0.00°
Overburden Type	=	input unit weight
Unit weight of soil above foundation	=	20.00 kN/m3
Geometry of structure Foundation type	=	centric spread footing
Spread footing length (x)	=	2.00 m
Spread footing width (y)	=	2.00 m
Column shaperectangle		
Column width in the direction of x (cx)	=	0.50 m
Column width in the direction of y (cy)	=	0.50 m
Spread footing volume	=	4.00 m3
Volume of excavation	=	8.00 m3
Volume of fill	=	3.75 m3

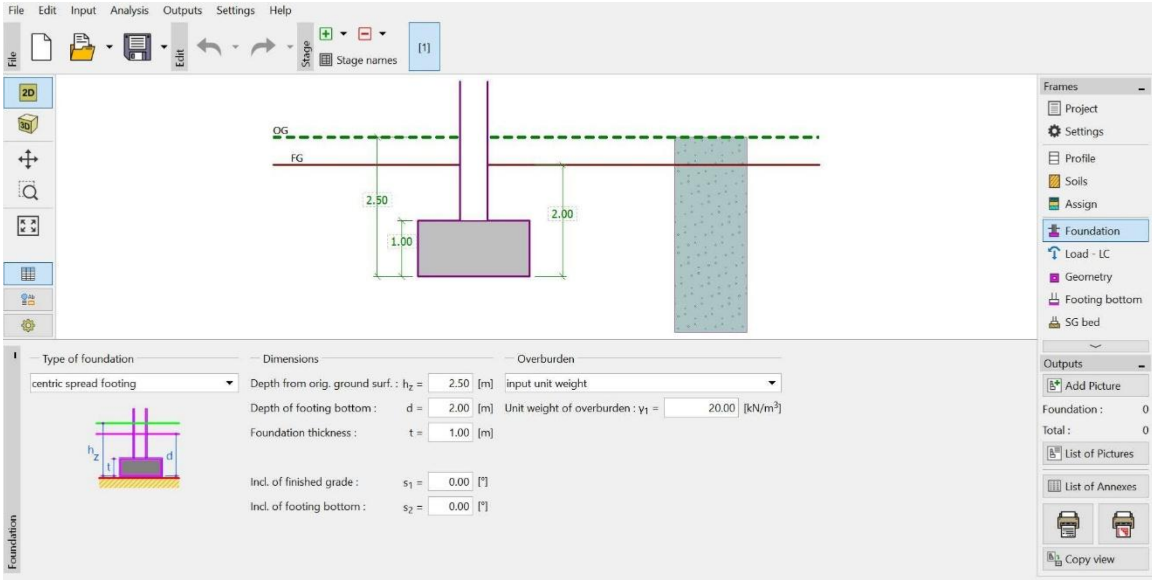


Figure 4.3 – Foundation Details

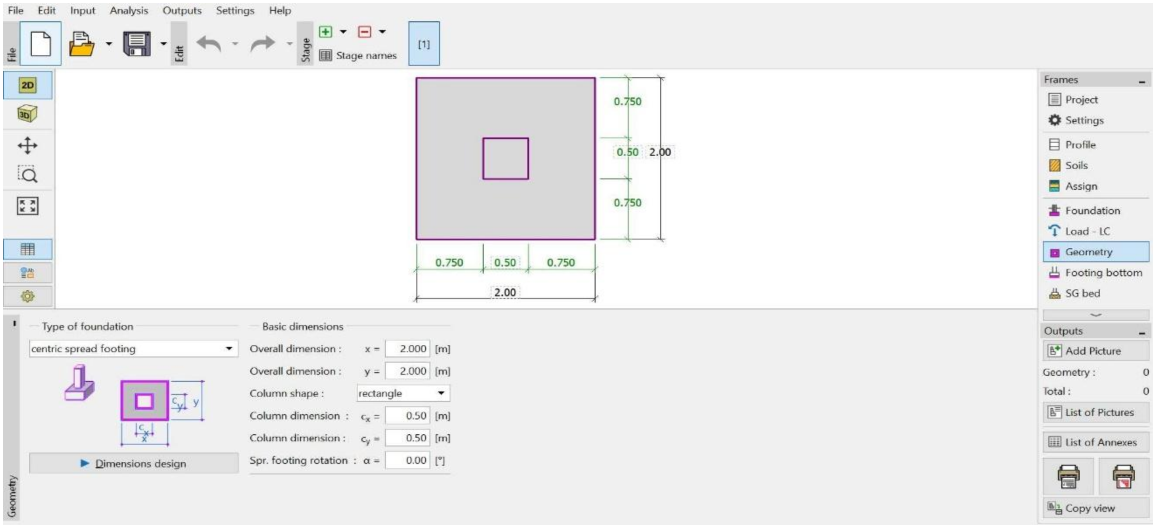


Figure 4.4 – Geometry of the Foundation

4.4 Loads and Materials

Loads and materials considered in the analysis are presented below and Figure 4.5.

<u>Material of structure</u>

Unit weight (γ) = 23.00 kN/m3

Analysis of concrete structures carried out according to the standard EN 1992-1-1 (EC2).

<u>Concrete: C 20/25</u> Cylinder compressive strength (fck)	=	20.00 MPa
Tensile strength (fctm)	=	2.20 MPa

Elasticity modulus (Ecm)	=	30000 MPa
Longitudinal reinforcement	=	B500B
Transverse reinforcement	=	B500B
Yield strength (fyk)	=	500.00 MPa

Design approach : 1 - reduction of actions and soil parameters

Table 4-3: Loads applied on Footing

No.	Load		Name	Type	N	Mx	My	Hx	Hy
	new	change			[kN]	[kNm]	[kNm]	[kN]	[kN]
1	Yes		Load	Design	2500.00	150.00	200.00	100.00	75.00
2	Yes		Load	Service	1755.00	92.00	114.00	57.00	43.00
3	Yes		Load	Design	2170.00	110.00	165.00	85.00	60.00
4	Yes		Load	Service	1523.00	77.00	116.00	59.00	42.00
5	Yes		Load	Design	1850.00	105.00	120.00	65.00	30.00
6	Yes		Load	Service	1295.00	74.00	86.00	32.00	13.00
7	Yes		Load	Design	1920.00	135.00	160.00	95.00	70.00
8	Yes		Load	Service	1637.00	96.00	108.00	64.00	23.00

Global settings

Type of analysis : analysis for drained conditions

The settlement is not analyzed.

Settings of the stage of construction

Design situation : permanent

Table 4-4: Load Case Verification

Name	Self w.	ex	ey	σ	Rd	Utilization	Is satisfactory
	in favor	[m]	[m]	[kPa]	[kPa]	[%]	
Load	Yes	-0.04	-0.08	756.55	2951.79	25.63	Yes
Load	No	-0.04	-0.08	770.96	2959.06	26.05	Yes
Load	Yes	-0.03	-0.07	532.59	1363.77	39.05	Yes
Load	No	-0.03	-0.07	532.59	1363.77	39.05	Yes
Load	Yes	-0.03	-0.07	652.42	2977.82	21.91	Yes
Load	No	-0.03	-0.07	666.88	2985.49	22.34	Yes
Load	Yes	-0.03	-0.07	470.37	1351.13	34.81	Yes
Load	No	-0.03	-0.07	470.37	1351.13	34.81	Yes
Load	Yes	-0.03	-0.07	555.57	3030.42	18.33	Yes
Load	No	-0.03	-0.07	570.07	3037.88	18.77	Yes
Load	Yes	-0.04	-0.06	403.53	1404.36	28.73	Yes
Load	No	-0.04	-0.06	403.53	1404.36	28.73	Yes
Load	Yes	-0.03	-0.10	597.18	2879.10	20.74	Yes
Load	No	-0.03	-0.10	611.55	2890.17	21.16	Yes
Load	Yes	-0.02	-0.07	494.92	1363.73	36.29	Yes
Load	No	-0.02	-0.07	494.92	1363.73	36.29	Yes

Analysis carried out with automatic selection of the most unfavourable load cases. Computed weight of spread footing (G) = 92.00 kN

Computed weight of ov erburden (Z) = 75.00 kN

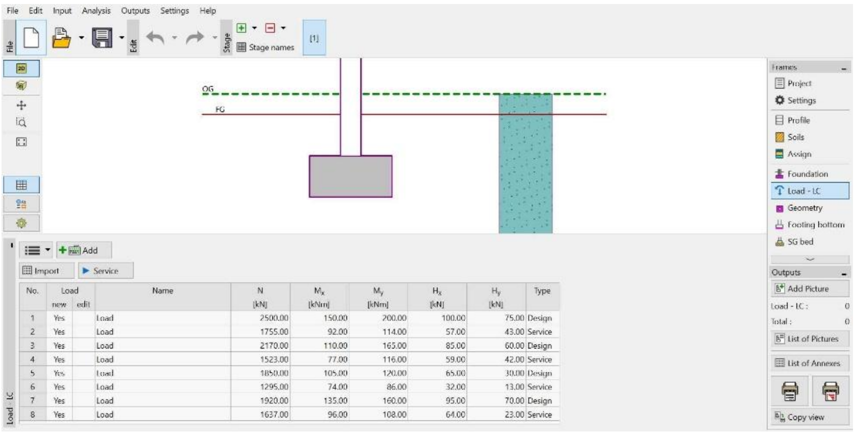


Figure 4.5 – Loads applied on the Foundation

4.5 Ground Water Table

No ground water table is considered in the analysis.

4.6 Bearing Capacity Checks

Considering the permanent design situation vertical and horizontal bearing checks are "Satisfactory" the details are listed below and outputs are presented in Figure 4.6 and Figure 4.7.

Vertical bearing capacity check		
Shape of contact stress	:	rectangle
Most unfavorable load case No. 2. (Load)		
Combination No. 2, service load		
Parameters of slip surface below foundation:		
Depth of slip surface (zsp)	=	3.80 m
Length of slip surface (lsp)	=	12.52 m
Design bearing capacity of found. Soil (Rd)	=	1363.77 kPa
Extreme contact stress (σ)	=	532.59 kPa

Bearing capacity in the vertical direction is SATISFACTORY

Verification of load eccentricity Max. Eccentricity in direction of base length	(ex)	=	0.019<0.333
Max. Eccentricity in direction of base width Max. Overall eccentricity (et) **Eccentricity of load is SATISFACTORY** **Horizontal bearing capacity check**	(ey)	= =	0.049<0.333 0.052<0.333
Most unfavorable load case No. 7. (Load) Combination No. 1, design load Earth resistance		=	not considered
Horizontal bearing capacity (Rdh) Extreme horizontal force (H)		= =	1516.29 kN 118.00 kN

Bearing capacity in the horizontal direction is SATISFACTORY Bearing capacity of foundation is SATISFACTORY Dimensioning No. 1

Analysis carried out with automatic selection of the most unfavourable load cases.

Verification of longitudinal reinforcement of foundation in the direction of x

18 prof. 14.0 mm, cover 60.0 mm Cross-section width Cross-section depth	= =	2.00 m 1.00 m		
Reinforcement ratio ρ =	0.15 % > 0.13 %		=	ρmin
Position of neutral axis (x) =	0.06 m < 0.58 m		=	xmax

Ultimate moment MRd = 1096.80 kNm > 392.66 kNm = MEd

Cross-section is SATISFACTORY.

Verification of longitudinal reinforcement of foundation in the direction of y

18 prof. 14.0 mm, cover 60.0 mm

Cross-section width = 2.00 m

Cross-section depth		=	1.00 m		
Reinforcement ratio ρ	=	0.15 % > 0.13 %		=	ρmin
Position of neutral axis (x)	=	0.06 m < 0.58 m		=	xmax

Ultimate moment MRd = 1096.80 kNm> 430.84 kNm = MEd

Cross-section is SATISFACTORY. **Spread footing for punching shear failure check**		
Column normal force	=	2500.00 kN
Maximum resistance at the column perimeter Force transferred into found. Soil	=	156.25 kN
Force transferred by shear strength of foundation	=	2343.75 kN
Considered column perimeter (u0)	=	2.00 m
Shear stress at the column perimeter (vEd,max)	=	1.71 MPa
Resistance at the column perimeter (vRd,max)	=	2.94 MPa
Critical section without shear reinforcement Force transferred into found. Soil	=	1166.49 kN
Force transferred by shear strength of foundation	=	1333.51 kN
Distance of section from the column	=	0.47 m
Section perimeter (u)	=	4.93 m

Shear stress at section (vEd)	=	0.36 MPa

Shear resistance of section without shear reinforcement (vRd,c) = 1.11 MPa vEd < vRd,c => Reinforcement is not required

Spread footing for punching shear is SATISFACTORY

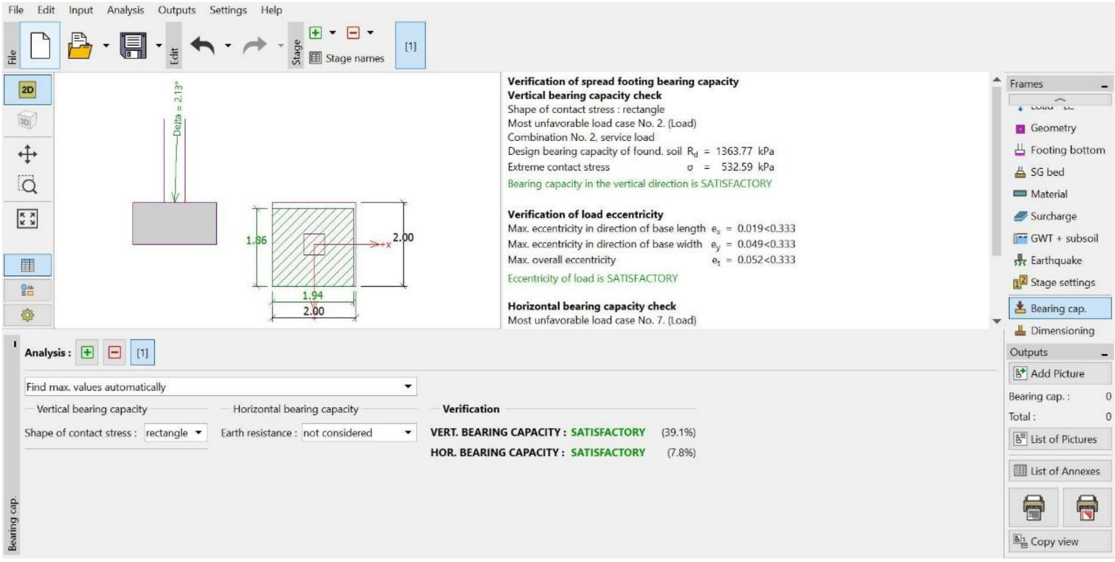


Figure 4.6 – Bearing Capacity Check

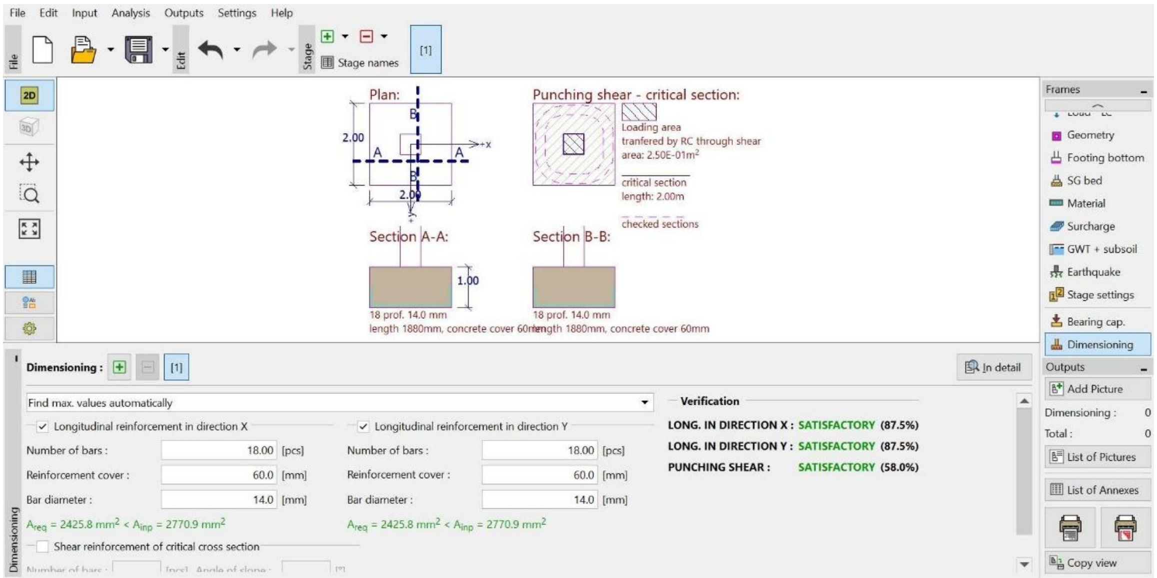


Figure 4.6 – Dimension Check

4.7 Pile Foundation

4.7.1 Input Data

<u>Settings</u>

(Input for current task)

<u>Materials and standards</u>

Concrete structures : EN 1992-1-1 (EC2)

Coefficients EN 1992-1-1 : standard

Circle pile shear : simplified method

Steel structures : EN 1993-1-1 (EC3) Partial factor on bearing capacity of steel cross section :$\gamma M0$ = 1.00 **Pile Group**

Verification methodology : according to EN 1997

Vertical bearing capacity : NAVFAC DM 7.2

Efficiency of pile group : La Barré (CSN 73 1002)

Design approach : 2 - reduction of actions and resistances

Table 4-5: Pile Foundation – Partial factors

Partial factors on actions (A)					
Permanent design situation					
		Unfavourable		Favourable	
Permanent actions :	γG =	1.35	[–]	1.00	[–]

Table 4-6: Partial Factors for Resistance

Partial factors for resistances (R)			
Permanent design situation			
Partial factor on shaft resistance :	γs =	1.10	[–]
Partial factor on base resistance :	γb =	1.10	[–]

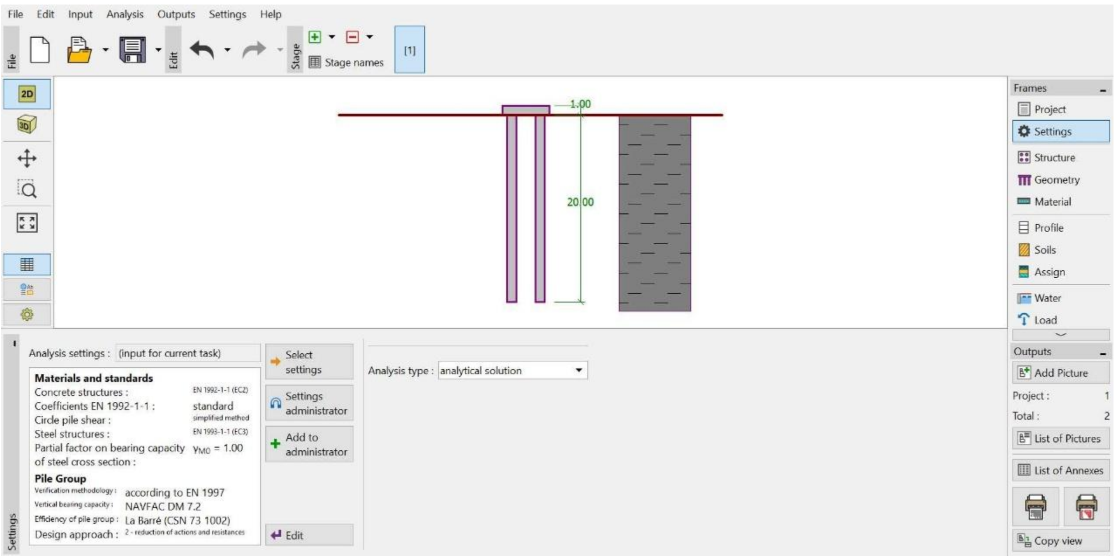


Figure 4.7 – Settings and Material standards – Pile Foundation

4.7.2 Profiling and Soil properties

In the next step the soil profile with different thickness of the soil layers can be considered, in this analysis a single soil layer “Silty Clay” is considered. The details are mentioned below.

<u>Soil parameters</u>

CS - Sandy clay Basic Data

Unit weight : γ = 16.00 [kN/m3]

Poisson's ratio : ν = 0.35 [-]

NAVFAC method

Soil type: cohesive

Cohesion : cu = 50.00 [kPa]

Adhesion factor : α = 0.60 [-]

Deformation characteristics

Modulus type : input Eoed

Oedometric modulus : Eoed = 8.00 [MPa]

Uplift pressure

Uplift calculation : standard

Unit weight of saturated soil : γsat = 16.50 [kN/m3]

View

Soil pattern :

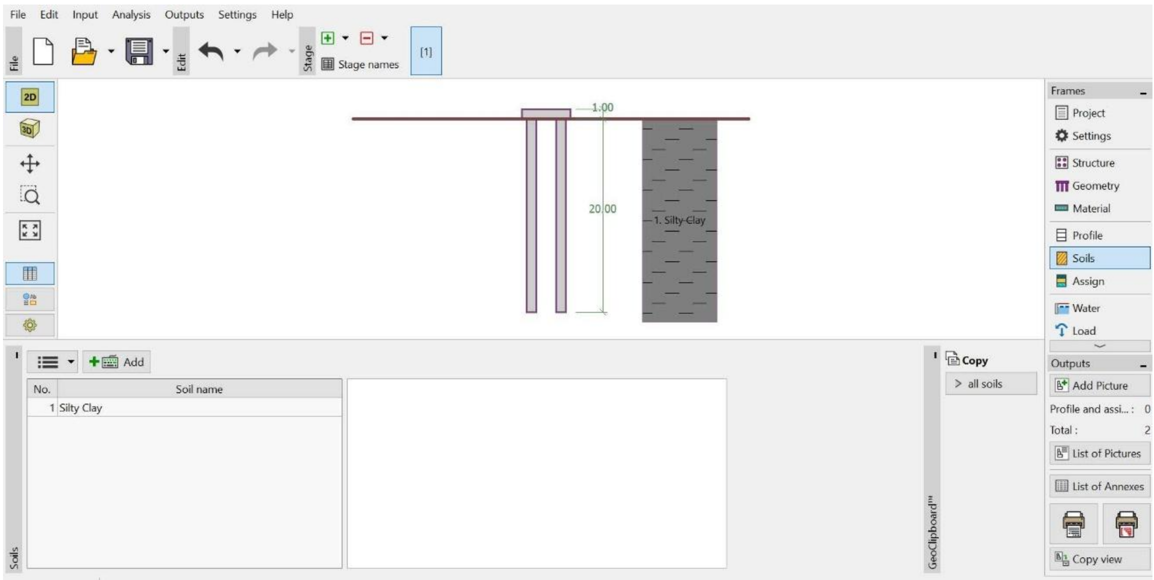


Figure 4.8 – Soil Profiling and Properties

4.7.3 Geometry of the Pile Cap

5m X 5m size and 1m thick pile cap with 4 no of 1m diameter piles at 3m center to center spacing with 20m length. The details are presented in Figure 4.9 and Figure 4.10.

Construction		
Width of pile cap (bx)	=	5.00 m
(by)	=	5.00 m
Pile diameter (d)	=	1.00 m
Number of piles (nx)	=	2

(ny)	=	2
Spacing of piles (sx)	=	3.00 m
(sy)	=	3.00 m
<u>Geometry</u>		
Depth from ground surface(hz)	=	0.00 m
Pile head offset (h)	=	0.00 m
Thickness of pile cap (t)	=	1.00 m
Length of piles (l)	=	20.00 m

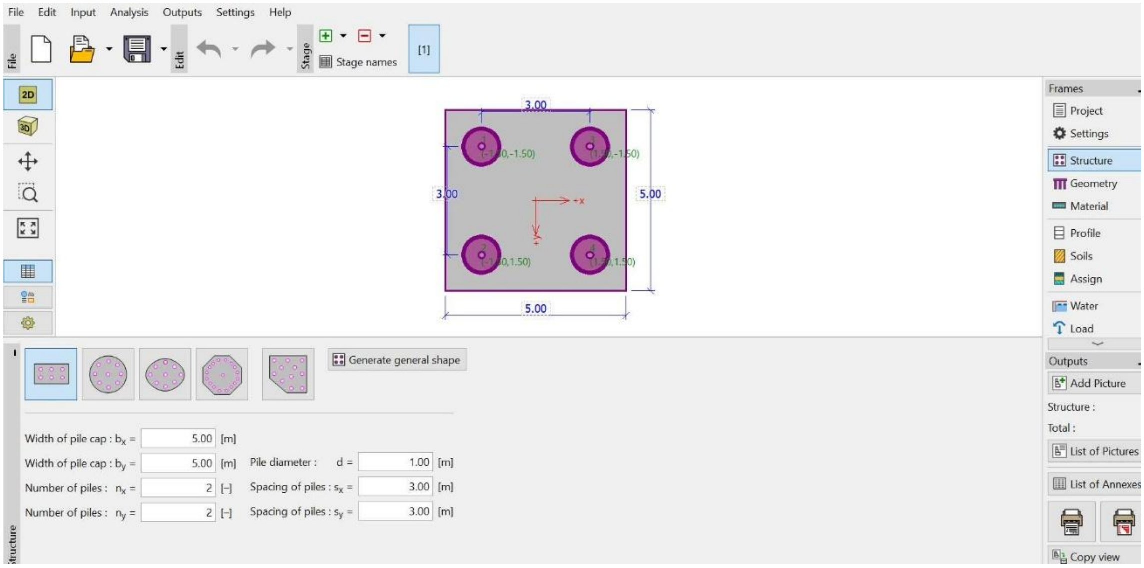


Figure 4.9 – Geometry of pile cap

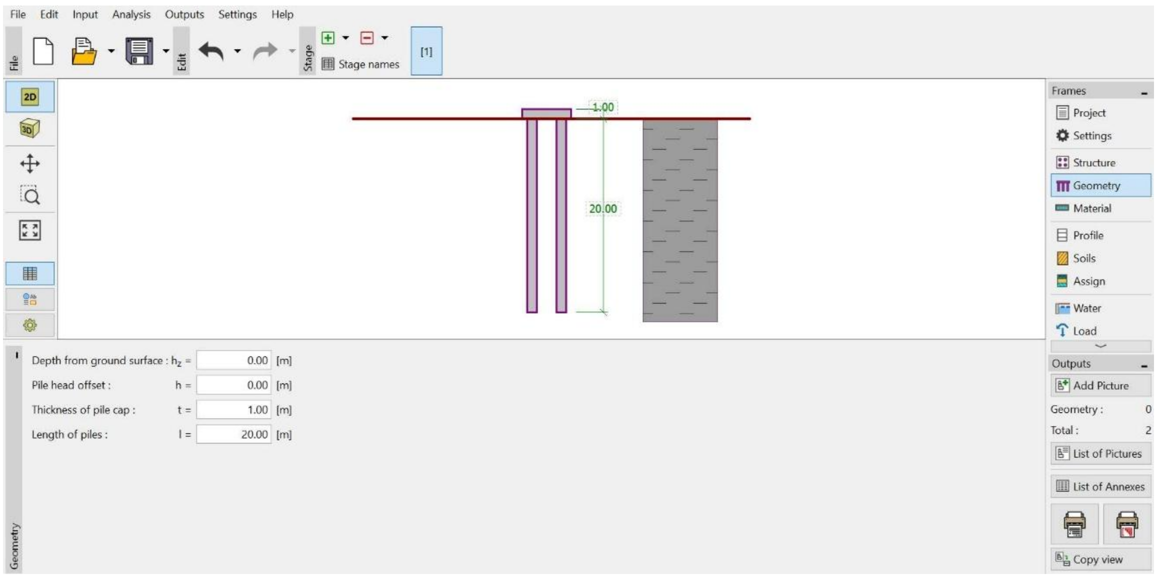


Figure 4.10 – Thickness and Length of Pile

4.7.4 Loads and Materials

Loads and materials considered in the analysis are presented below and Figure 4.11.

<u>Material of structure</u>

Unit weight (γ) = 23.00 kN/m3

Analysis of concrete structures carried out according to the standard EN 1992-1-1 (EC2).

Concrete: C 20/25 Cylinder compressive strength (fck)	=	20.00 MPa
Tensile strength (fctm)	=	2.20 MPa
Elasticity modulus (Ecm)	=	30000.00 MPa
Shear modulus (G)	=	12500.00 MPa
Longitudinal reinforcement: B500B Yield strength (fyk)	=	500.00 MPa
Transverse reinforcement: B500B Yield strength (fyk)	=	500.00 MPa
Table 4-7: Loads		

No.	**Load**		**Name**	**Type**	**N**	**Mx**	**My**	**Hx**	**Hy**	**Mz**
	new	**change**			**[kN]**	**[kNm]**	**[kNm]**	**[kN]**	**[kN]**	**[kNm]**
1	Yes		Load No. 1 - design	Design	5680.00	0.00	480.00	310.00	0.00	0.00
2	Yes		Load No. 2 - service	Service	4000.00	0.00	320.00	240.00	0.00	0.00

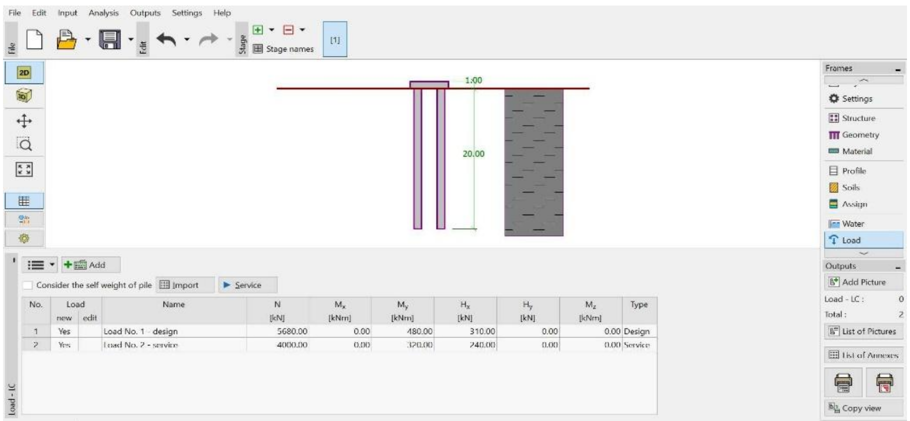


Figure 4.11 – Loads on Pile

4.8 Ground Water Table

No ground water table is considered in the analysis.

4.9 Bearing Capacity Check

Considering the permanent design situation vertical and horizontal bearing checks are "Satisfactory" the details are listed below and outputs are presented in Figure 4.12 and Figure 4.13.

Settings of the stage of construction

Design situation : permanent

Verification No. 1

Analysis of bearing capacity - input data

Analysis carried out with an automatic selection of the most unfavorable load cases. Factor determining critical depth: (k_{dc}) =1.00

Coefficient of bearing capacity: (N_q) = 10.00

Bearing capacity coefficient N_c was calculated.

Analysis of bearing capacity of pile group in cohesionless soils

Max. Vertical force includes self-weight of pile cap.

Pile skin bearing capacity (Rs) = 1713.60 kN

Pile base bearing capacity (Rb)	=	321.30 kN
Vertical bearing capacity of single pile (Rc)	=	2034.90 kN
Vertical bearing capacity of pile group (Rg)	=	6472.33 kN
Maximum vertical force (Vd)	=	6456.25 kN
Rg = 6472.33 kN > 6456.25 kN = Vd		

Vertical bearing capacity of pile group is SATISFACTORY Verification No. 1

Table 4-8: Analysis of load settlement curve - input data

Layer	Origin	End	Es
No.	**[m]**	**[m]**	**[MPa]**
1	**0.00**	**20.00**	**17.00**

Maximum pile settlement (s_{lim})	=	50.0 mm
Analysis of load settlement curve - partial results		
Correction factor for pile compressibility (Ck)	=	0.94
Correction factor for Poisson's ratio of soil (Cv)	=	0.84
Correction factor for stiffness of bearing stratum (Cb)	=	1.00
Base-load proportion for incompressible pile (β0)	=	0.07

Proportion of applied load transferred to pile base (β)	=	0.05
Influence coefficients of settlement:		
Basic - dependent on ratio l/d (I0)	=	0.08
Correction factor for pile compressibility (Rk)	=	1.10

Correction factor for finite depth of layer on a rigid base (Rh) = 1.00

Correction factor for Poisson's ratio of soil (Rv) = 0.93

<u>Analysis of settlement of pile group in cohesionless soils</u>

Max. Vertical force includes self-weight of pile cap.

Group settlement factor (gf) = 2.24

Load at the onset of mobilization of skin friction (Ryu) = 7976.80 kN The settlement for the force Ryusy = 922.8 mm Total resistance (Rc) = 8336.56 kN

Maximum settlement (slim) = 50.0 mm The settlement for maximum service load V = 4575.00 kN is 13.1 mm.

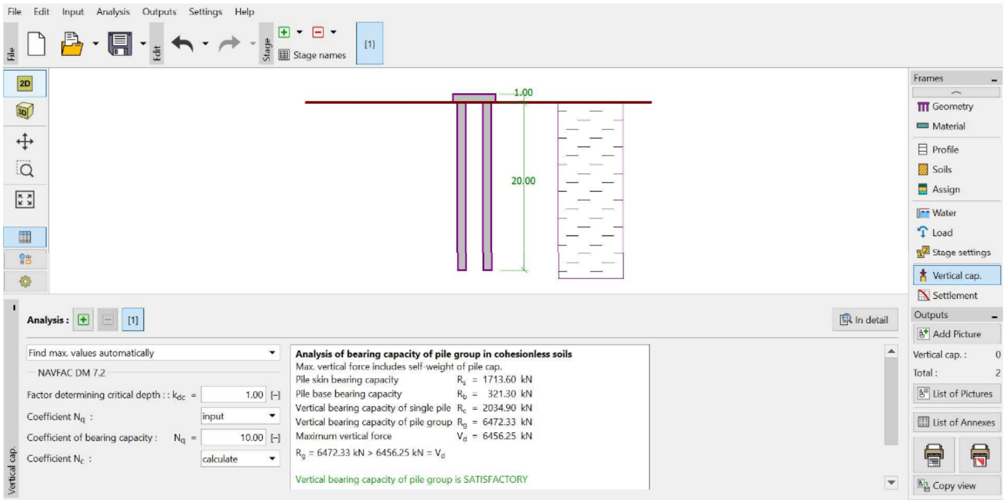


Figure 4.11 – Vertical Capacity of Pile

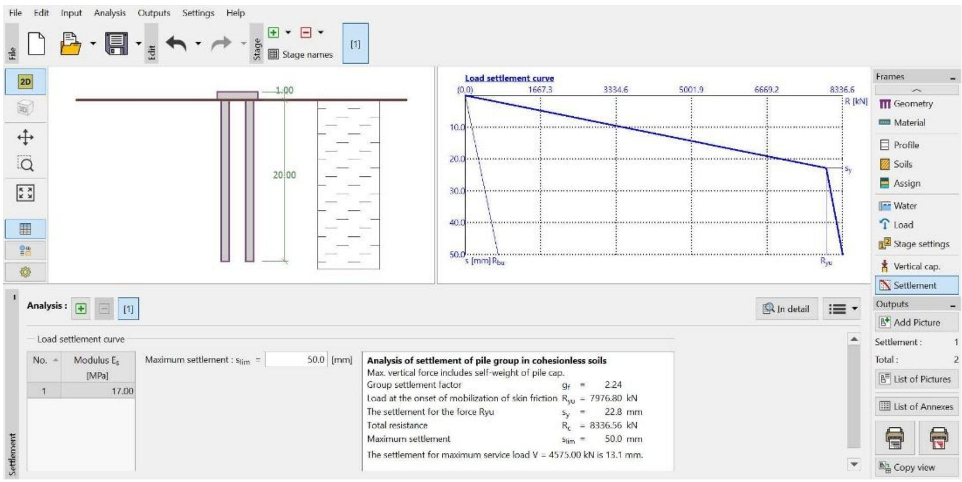


Figure 4.12 – Load Vs Settlement Curve

5. CONCLUSION

This study has successfully demonstrated the practical application of GE05 software in the comprehensive analysis and design of pile foundations. From geotechnical data acquisition to structural load application and final design optimization, each phase of the process was integrated and streamlined through the software environment, allowing for a highly accurate and efficient design workflow.

The geotechnical parameters obtained from borehole and laboratory investigations were effectively modelled in GE05, enabling accurate simulation of soil-pile interaction under various loading conditions. The software's detailed analytical capabilities, including the computation of both end bearing and skin friction resistance, allowed for the realistic evaluation of single piles as well as pile groups. Notably, the settlement analysis—accounting for both immediate and long-term consolidation—ensured that serviceability criteria were thoroughly addressed, which is often a limitation in traditional manual design methods.

Moreover, the study highlighted the importance of considering pile group efficiency and interaction effects, especially for high-load structures where uniform load distribution cannot be assumed. GE05's capacity to model these effects and visualize the distribution of stress and settlement across piles added a valuable dimension to the design process. The ability to optimize pile length and diameter through iterative simulations helped identify the most cost-effective and structurally viable solution, which is crucial for projects with budget constraints or difficult soil conditions.

One of the critical strengths of this approach is its alignment with Indian Standards (IS 2911) and international best practices, ensuring regulatory compliance and facilitating field implementation. The software's output was validated against conventional design approaches, with close agreement observed, thereby reinforcing the credibility of its computational framework.

In the broader context, this study emphasizes the growing relevance of digital tools in geotechnical engineering. As site conditions become increasingly complex and construction demands more precision, the reliance on advanced modelling software such as GE05 is not just beneficial but necessary. It allows for better risk management, material efficiency, and design safety, while also improving communication between design and construction teams through well-documented outputs.

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