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Modelling of Piled Raft Foundation on Soft Clay

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Abstract: This study relates to the analysis of un – piled and piled raft foundations with soft clay soil conditions. The subsoil model was assumed uniform underneath the foundation with soil stiffness increasing with depth. Based on these variables a finite element analysis was conducted on un – piled and piled raft foundation. For the un – piled raft, a 8m × 8m raft size with variable thickness varying from0.25m, 0.4m, 0.8m and 1.5m were considered in this study. As for the piled raft, first, an 8m × 8m piled raft size with thickness that varies from 0.25m, 0.4m; 0.8m and 1.5m were considered. Secondly, a piled raft with raft thickness of 0.8m, while the piles spacing is varied as 3d, 4d, 5d, 6d and 7d were considered. The piles are 0.7m diameter and 16m length. For the aforementioned examples; walls were involved in the analysis to study the effect of superstructure. A single value of loading intensity was considered at raft level as 215 KN/m2, whereas line load was considered at level of wall as 385 KN/m. Comparisons were conducted between the various cases and conclusions are made.

Keywords: *Piled Raft; Foundations; Finite Element; PLAXIS, Soft Clay.*

1. INTRODUCTION

The piled raft is a geotechnical composite construction consisting of three elements: piles, raft and soil. The design of piled rafts differs from traditional foundation design, where the loads to be carried either by the raft or by the piles, considering the safety factors in each case. In the design of piled rafts the load share between the piles and the raft is taken into account, and the piles are used up to a load level that can be of the same order of magnitude as the bearing capacity of a comparable single pile or even greater. Therefore the piled raft foundation allows the reduction of settlement and differential settlements in a very economic way compared with traditional foundation concepts [4]. In this study, finite element (PLAXIS 3D Foundation) software is used and a three dimensional analysis is carried out

2. Finite Element Model

Numerical analyses using finite element techniques are popular in recent years in the field of foundation engineering [2]. To date, a variety of finite element computer programs have been developed with a number of useful facilities and to suit different needs. The behavior of soil is also incorporated with appropriate stress – strain laws as applied to discrete elements. The finite element method provides a valuable analytical tool for the analysis and design of foundations. Since the piled raft is a typical example of soil – structure interaction, a special type of element at pile – soil interface, simulating the displacement discontinuity between the pile and the soil mass is needed. Hence, PLAXIS 3D Foundation incorporates "Embedded pile" model [3, 5], in which the pile is assumed as a slender beam element. The pile – soil interaction is governed by relative movements between the pile nodes and the soil nodes. The connection between these nodes is established by means of special – purposed interface elements representing the pile – soil contact at the skin and special – purposed non – linear spring representing the pile soil contact at the base. As for soil properties, table 1 summarizes the soil properties used in the numerical analysis. Table 2 summarizes the concrete properties for raft foundation, the piled raft foundation and the retaining walls. Based on the materials, linear elastic material model is used for concrete structures to simulate their stress – strain behavior, whilst the Mohr – Coulomb model is used for soft clay soil.

Table (1). Summary of soil properties adopted

	Soft CLAY
Thickness (m)	40
Bulk Unit Weight γ (KN/m^3)	18
Saturated Unit Weight γ_{sat} (KN/m^3)	16
Soil Young's Modulus E_{soil} (MN/m^2)	15
Soil Poisson's ratio ν	0.35
Undrained Cohesion c_u (KN/m^2)	30
Friction Angle Ø (deg)	0
Dilatancy Angel ψ (deg)	0

Table (2). Summary of concrete properties adopted

	Element Type		
	Raft	Retaining Wall	Embedded Pile
Thickness (m)	0.25,0.4,0.8 & 1.5	0.3	-
Diameter (m)	-	-	0.7
Length (m)	-	-	16
Concrete Unit Weight γ (KN/m^3)	24	24	24
Concrete Poisson's Ratio ν	0.15	0.15	0.15
Young's Modulus $E_{concrete}$ (MN/m^2)	21.5×10^3	21.5×10^3	21.5×10^3

3. Case Study

Different case studies were carried out in this study and they are as follow:

- Case 1: raft 8m by 8m with thickness varies between 0.25m, 0.4m, 0.8m, 1.5m. The load intensity is 215 KN/m^2 on the raft and 385 KN/m along the retaining wall.
- Case 2: Piled raft 8m by 8m with thickness varies between 0.25m, 0.4m, 0.8m, 1.5m. The load intensity is 215 KN/m^2 on the raft and 385 KN/m along the retaining wall also the pile length is kept constant and equals to 16m, on the hand the spacing between piles is also kept constant and equals 3d, where (d) represents the pile diameter.
- Case 3: Piled raft with constant thickness of 0.8m, the piles spacing is varied as 3d, 4d, 5d, 6d, 7d and the raft dimensions will increase with increased pile spacing
- Preselected points at each case were selected to investigate the effect of raft thickness, pile spacing and length of piles on maximum settlement, bending moments and the proportion of load shared by piles as shown in figure (1). Boundary conditions were taken in consideration as well; horizontal and vertical boundaries were placed far enough from the region of interest in order not to affect the deformation within the regions

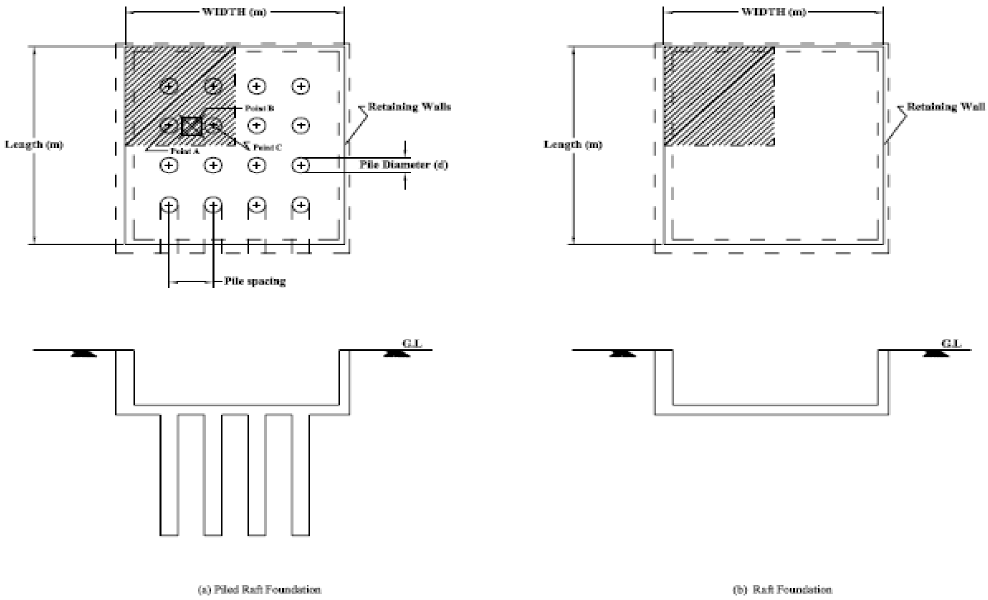

Figure (1). Typical Foundations layout adopted for analysis

4. Results and analysis

4.1 Effect of raft thickness on raft foundation

Due to the presence of soft clay which is underlying the raft foundation; figure (2) shows that in spite of the increase in the raft stiffness by increasing its thickness, yet the settlement pattern is still not promising. The settlement variation manifests clearly for raft thicknesses 0.8m & 1.5m. The settlement values range between 0.033m (t = 0.25m & t = 0.4m), 0.043m (t = 0.8m) and 0.073m for raft thickness of 0.8m. It can be concluded that relying on increasing raft thickness doesn't always yield the best performance for un – piled foundation unless it is underlain by a competent soil stratum i.e. (stiff or hard clay). However increasing raft thickness is beneficial for resisting punching shear from superstructure loads. From this point of view, an alternative for the raft (un – piled) foundation on soft clay can be the piled raft foundation which will not only enhances the settlement performance but also boost the bearing capacity of the raft by utilizing the full capacity of the piles.

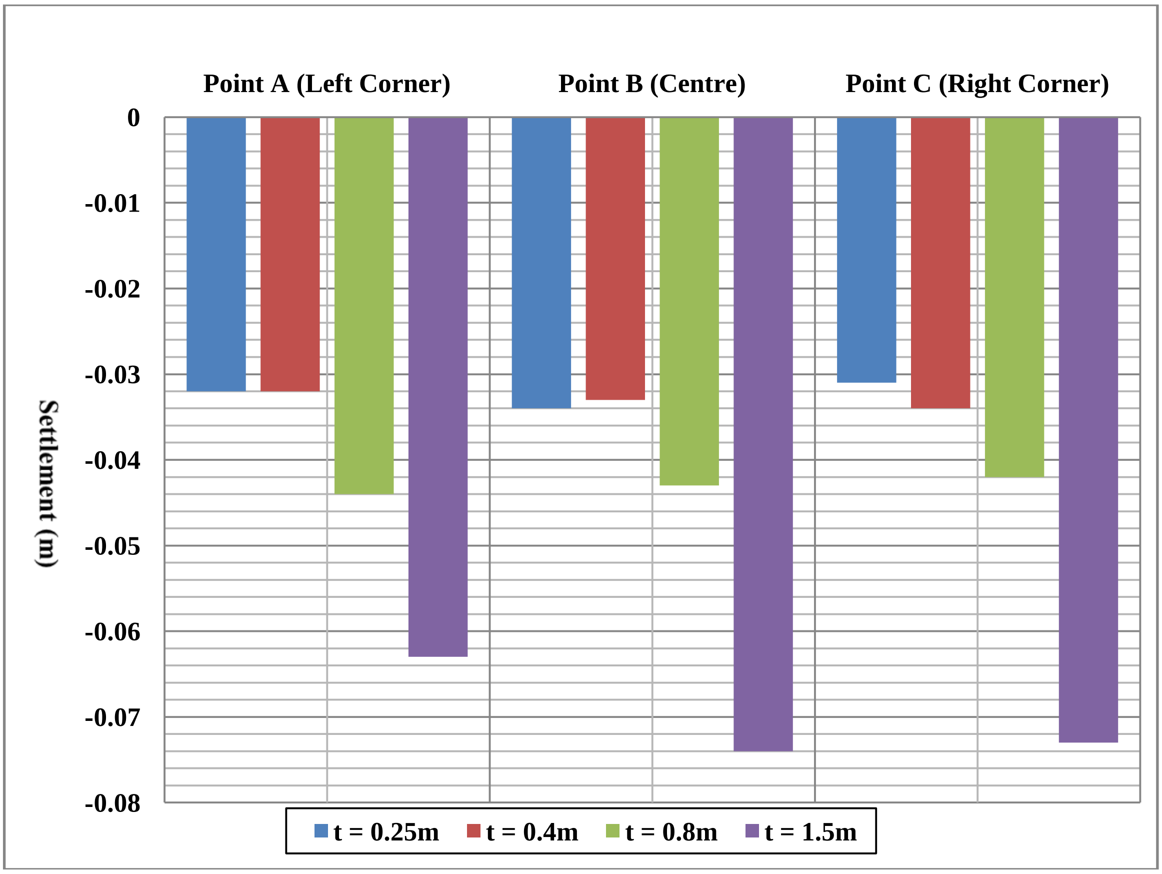

Figure (2). Raft thickness effect on Raft foundation

4.2 Effect of raft thickness on piled raft foundation

In this analysis, the effect of raft thickness is studied for settlement. The piles diameter is 0.7m and the spacing between the piles is 3 times the piles diameter. Along with the increase of raft thickness, the presence of piles underneath the raft will not only boost the performance of raft in term of bearing capacity by assuming that the load is entirely taken by the piles, but also will act as "settlement reducers" in which the piles will reduce the excessive settlement yielded at the case of un – piled raft. Figure (3) shows the contribution of piles in piled raft foundation. Apparently as the raft thickness is varied, the maximum settlement pattern is reduced drastically compared to the case of raft. The settlement range between 0.01m for raft thickness (t= 0.25m), 0.009m for raft thickness (t= 0.4m), 0.011 for raft thickness (t= 0.8m) and 0.011 for thickness (t=1.5m).

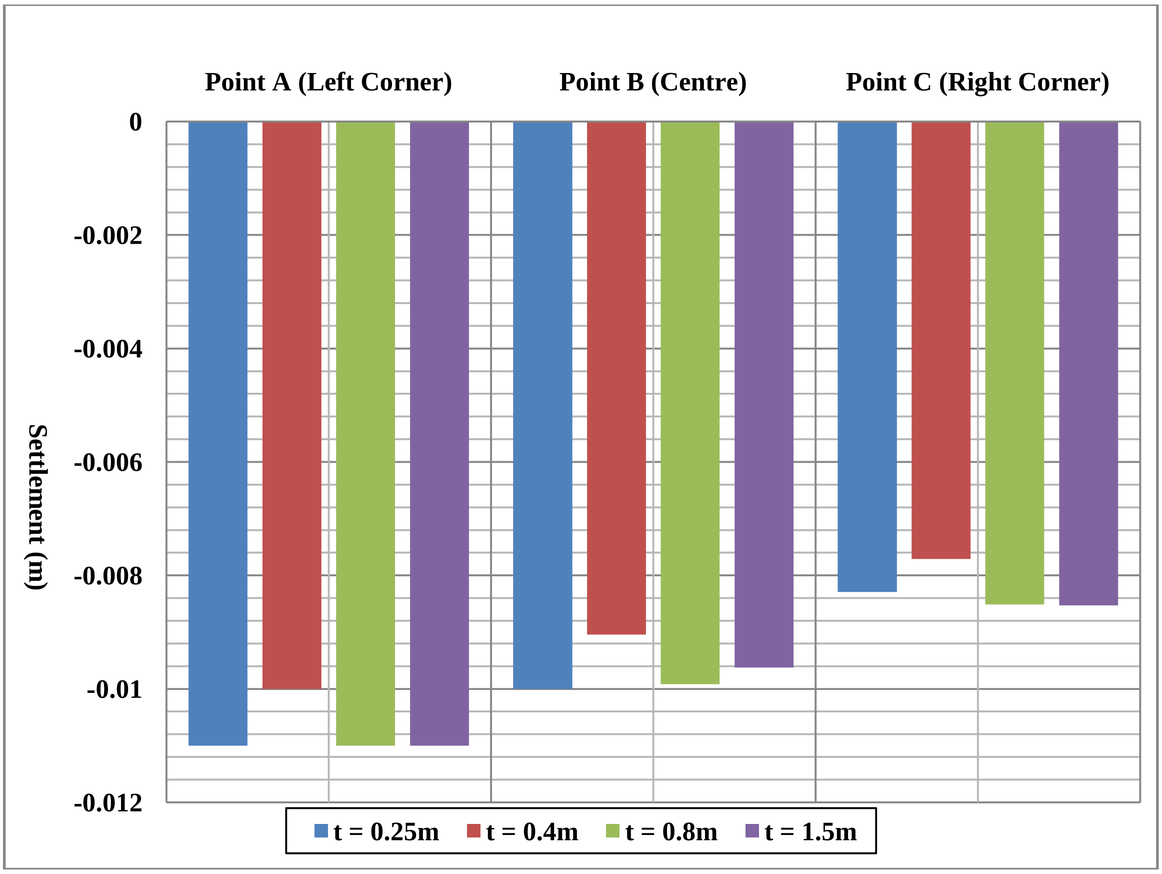

Figure (1). Effect of piles on settlement for piled raft foundation

4.3 Effect of pile spacing

The spacing effect is studied for bending moment and settlement of the raft for five values of spacing as shown in figure (4) & figure (5). In the analysis, the raft thickness is 0.8m and the piles length is 16m and the dimensions of the raft will increase with increased pile spacing. The increase in pile spacing has the effect of increasing the raft settlement as shown in figure (4). The settlement is significantly increased when the spacing reaches 7d and equals 0.111m at point A (left corner). Figure (5) indicates that increasing pile spacing is accompanied with increase of bending moment at pile locations.

4.4 Effect of superstructure

The superstructure effect tends to restrict the free response of the footing to the soil deformation. Redistribution of reactions occurs within the superstructure frame as a result of its stiffness, which reduces the effects of differential settlement.

5. Concluding remarks

In this study, few cases for un – piled and piled raft foundations were conducted in soft clay subsoil conditions. The following conclusions can be deduced:

- The settlement pattern showed no reduction under the applied load as seen in case (1) figure (2), in spite of the increase in raft thickness; since soft clay is unfavourable condition to place raft foundation unless it is accompanied with earth work process to increase soil stiffness underneath foundation.
- Piled raft foundation as such case (2), explicitly reduced the settlement compared to the values obtained for un – piled foundation. The piles with the aid of the increasing stiffness with depth contributed in reducing the settlement underneath raft a shown in figure (3).
- The increase in piles spacing as shown in figure (4) increases the settlement, and so for the bending moment as seen in figure (5).

From the above remarks, it can be concluded that:

1. The raft thickness greatly affects the settlement criteria.
2. Pile spacing has a significant effect on the performance of piled raft foundation i.e. maximum settlement and bending moment.
3. For soft clay subsoil condition, soil stiffness is greatly affecting the settlement; therefore increasing soil stiffness is a key for optimized performance [1].

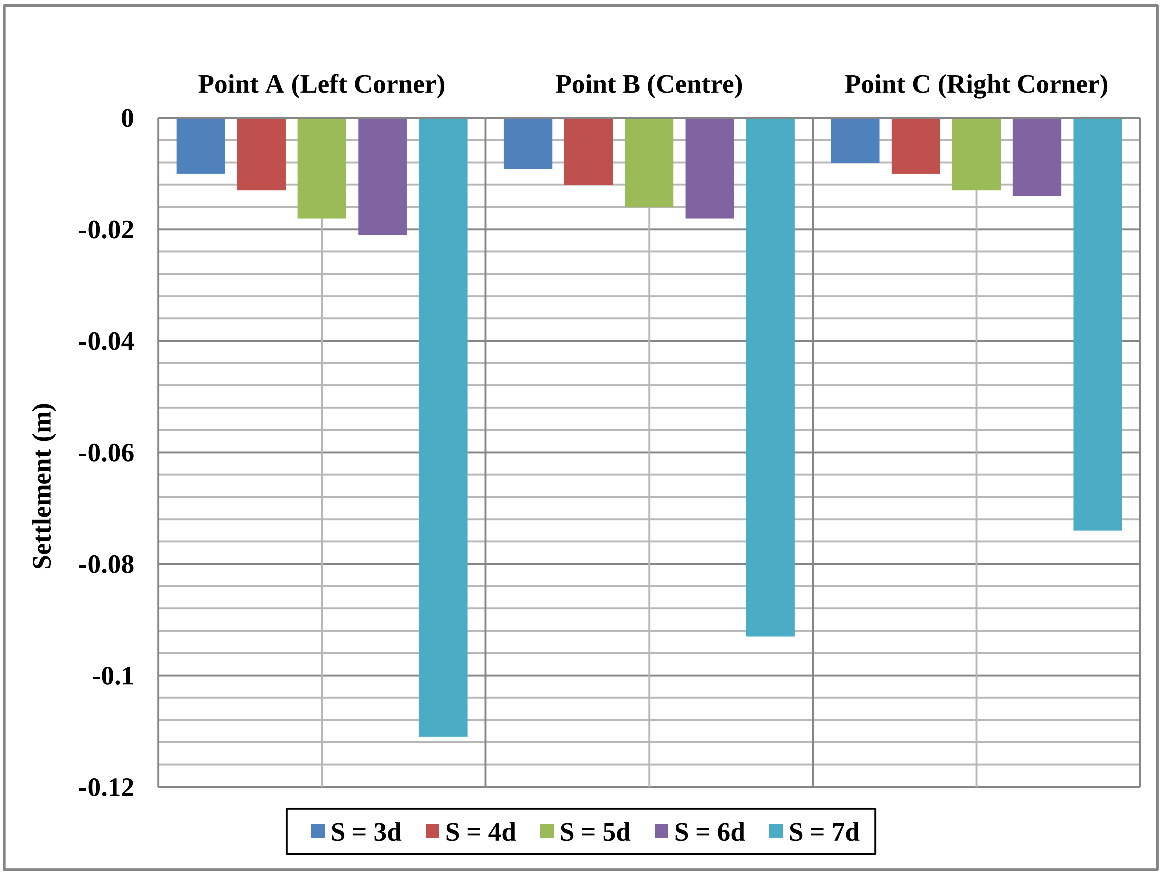

Figure (2). Effect of pile spacing on Settlement

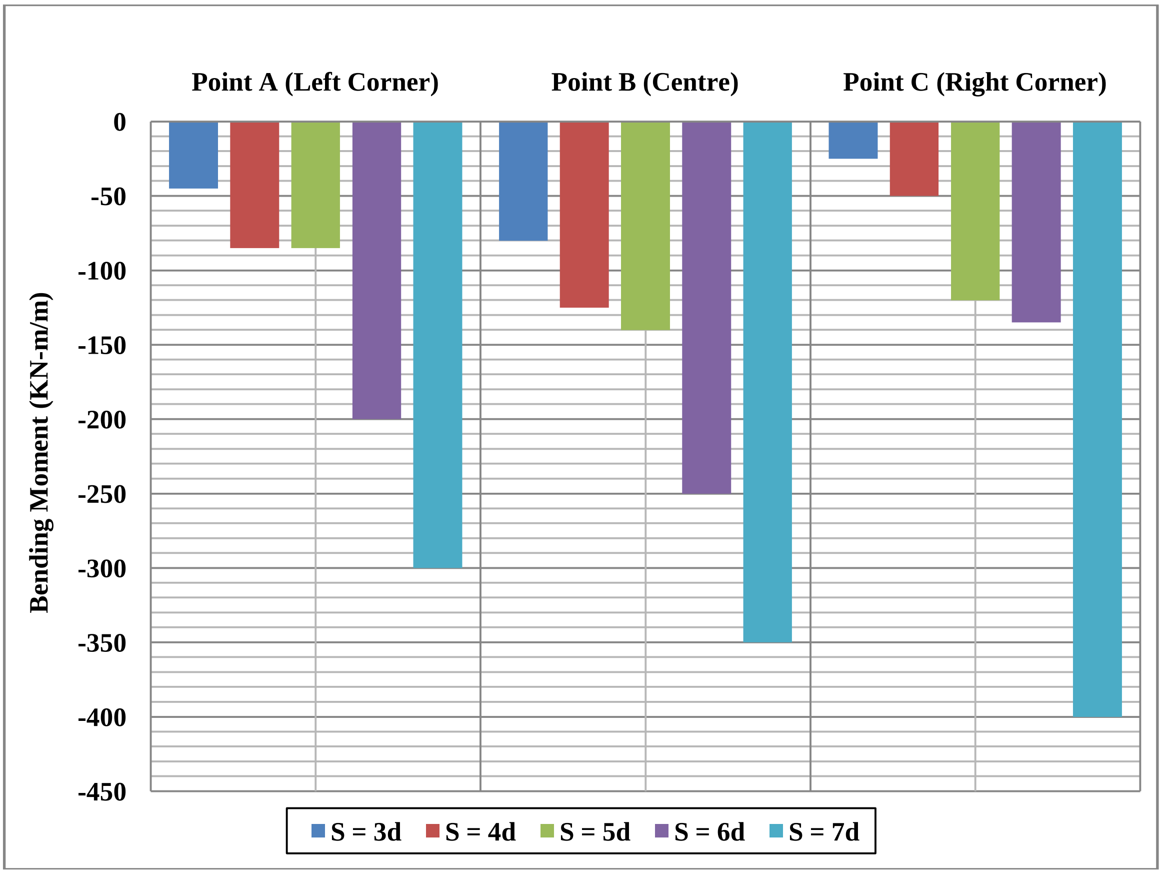

Figure (3). Effect of pile spacing on moment distribution in piled raft foundation

REFERENCES

[1] Chow, Y. T. (2003). DESIGN OF PILED RAFT ON SOFT GROUND. Kuala Lumpur, Malaysia.

[2] E.Y.N OH, M. C. (2008). FINITE ELEMENT MODELLING FOR PILED RAFT FOUNDATION. Eleventh East Asia - Pacific Conference on Structural Engineering & Construction (EASEC - 11), (p. 8). Taipei, TAIWAN.

[3] Engin, H. K., Septanika, E. G., Brinkgreve, R. B., & Bonnier, P. G. (2009). Modelling piled foundation by means of embedded piles. Geotechnics of Soft Soils - Focus on Ground Improvement - Karstunen & Leoni (eds) , 5.

[4] Hemsley, J. (2000). Design Applications of Raft Foundations. London: Thomas Telford Ltd.

[5] PLAXIS 3D FOUNDATION (REFERENCE MANUAL), Version 2.0. PLAXIS BV, Delft, The Netherlan