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ABSTRACT

A lot of soil nail retaining walls in southern California are under construction. Some of them will be used as shoring systems for bridge or other kind of retaining wall constructions. Design and design review process are very time consuming, and the possibility of mistakes encourages us to find a simplified method for designing the soil nail walls. The maximum height of the soil nail walls in that region were about 14m, including 9 rows of 25mm steel rods (nails) in 150mm diameter holes with different lengths. Whole length of the drilled holes will be filled with grout after setting the nails in. A steel mesh along with the rebar will be set at middle of the shotcrete thickness before placing shotcrete. After placing shotcrete, the bearing plate and the nut will be set at each nail location. At this stage, the shotcrete and the nails would be enough to act like as shoring system. To build a soil nail retaining wall another mesh of rebar will be installed between the shotcrete and the LOL (lay out line) of the wall before placing the wall concrete

The simplified KZP5 method is based on the soil mechanic concepts for the granular soils and the Boussinesq strip load method for the possible surcharge behind the wall. In this paper besides considering the soil nail wall design and construction procedure, regular dimensions and loading, the simplified method (KZP5) will be presented. An example will be solved based on this and the conventional method to show the accuracy of the simplified method. An example will be considered to show the accuracy of this trail and error method.

INTRODUCTION

Most of the current design methods for soil nailed retaining structures are derived from classical slope stability analysis methods modified to incorporate the additional resisting tensile forces provided by the nail reinforcement. These methods of analysis evaluate global factors of safety along assumed failure surfaces. They include: German method, Davis Method and French method, Snail design method developed by the CALTRANS and GoldNail developed by Golder Associates of Redmond.

SIMPLIFIED KZP5 METHOD

Linear failure surface along with the tensile resistance of the nails crossing the failure surface are used in KZP5 simplified method. Shear and moment stability of the retaining structure accordance with the length of the nails will be calculated, and with trial and error method the length of each tier of the nails will be finalized. Nail pullout resistance estimates should be based on experience with open hole methods of constructions or a pre-contract test nail program. Figure 1 shows a typical soil nail during construction.

Fig. 1. Soil nail retaining wall during construction

Four steps has been used in KZP5 method. The Steps are:
Step 1- Define Design parameters
Step 2- Check the preliminary feasibility of the soil screw retaining wall system
Step 3- Determine external earth pressures

Step 4- Check preliminary screw anchor length with respect to sliding
The required design factors of safety for external sliding and overturning stability is 1.5.

Estimating Nail Pullout Resistance for Design

In this method two zones will be considered, Active and resistant zones (Fig. 2). Just the length of the nails in the resistant zone will provide the pullout resistant forces, and the nail pullout resistant in the active zone will be neglected. For example the pullout resistant length for the top nail would be L1-L11 as shown in Fig. 2. Pullout force for the first tier is calculated from equation (1).

$$Pult1 = \pi.D(L1-L11).\gamma.(hm1+hma).(TAN(\Phi)) \qquad (1)$$

D, γ are grout diameter and soil unit weight respectively and hmi+hma is the height of the soil above the center line of the pullout resistant length for each nail (just showed for the fist tier in Fig. 2). It is important to check the Pult for each nail to make sure they are less than the nails allowable tension forces, and if Pult was grater than the allowable nail tension force, the allowable nail tension force should be considered as Pult.

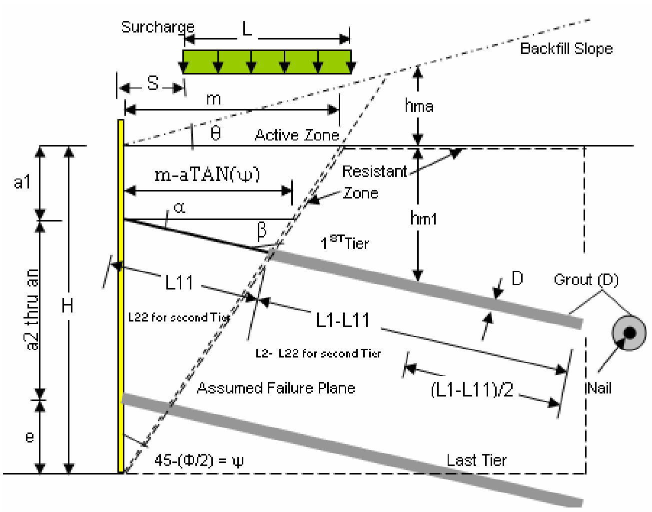

Fig. 2. KZP5 soil nail parameters and zones

Surcharge load with the length of "L" and distance "S" from the face of the wall is considered based on KZP1 & KZP2 methods.

Active pressure "Pa" would be soil pressure with taking into account the backfill slope on top of the wall. Nail distances from the overturning point "O" and active pressure "Pa" are shown in Fig. 3. The coefficient of active earth pressure for a vertical soil nail wall with a continuous slope above the top f the wall (Fig. 3) is determined using the equation (2).

$$Ka=COS(\theta)\{COS(\theta)-[(COS^2(\theta)-COS^2(\Phi)]^{0.5}\}/\{COS(\theta)-[COS^2(\theta)-COS^2(\Phi)]^{0.5}\} \qquad (2)$$

Φ = Internal soil friction angle
θ = the angle of the slope above the top of the wall measured from horizontal

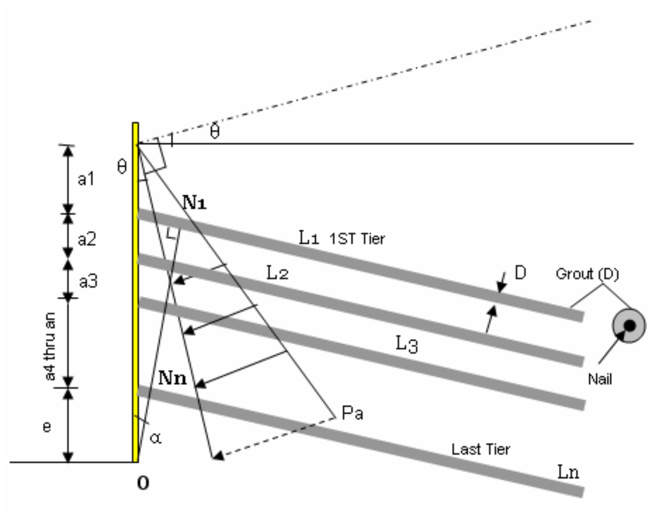

Fig. 3. Active soil pressure "Pa ", and nail distances from O

Factors of safety against sliding will be calculated from equation (3).

$$\text{Sliding F.S} = [\gamma.H.Lx.Tan(\Phi)\}/(F1+F2) \qquad (3)$$

In which:
Lx = Horizontal length of the nails (Fig. 4)
F1 = Pa.H/2
Ps = Ka. Surcharge
F2 = Ps.H

Factor of safety against overturning associated with pullout failure will be as follows;

$$\text{Overturning F.S} = \Sigma\ (Puti.ONi)/(RaH.Ha) \qquad (4)$$

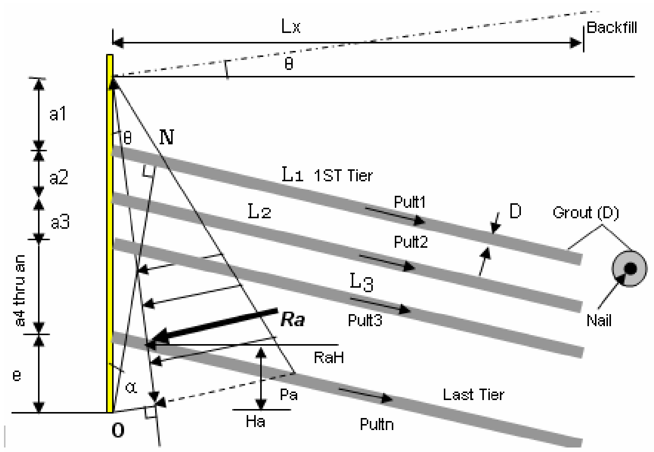

Fig. 4. Horizontal length of the nails and soil pressure Ra

Following empirical constraints on the design analysis nail length pattern are therefore recommended for use when performing the limiting equilibrium design calculations:

a) Nails with heads located in the upper half of the wall height should be of uniform length.
b) Nails with heads located in the lower half of the wall height should be considered to have a reduced length.

A computer program is written for this trial and error method and the designer will be able to change the length of each nail from top to the bottom of the wall. The calculated sliding and over turning stability factors of safety help the designer to finalize the nail lengths.

EXAMPLE

The unit weight (γ) and internal friction angle (Φ)of the silty sand are 120pcf and 30deg respectively. A design live surcharge load of 100pcf is considered to be applied uniformly across the ground surface at the top of the wall. The face is vertical, and other parameters for steps 1 & 2 are as follows;

Steps 1 & 2:
H (Height of the wall) = 23ft
Φ = 30deg
a1 (Vertical distance of the top nail from top) = 3ft
e (Vertical distance of the bottom nail from bottom) = 5ft
D (Grout diameter) = 8in
θ= 0.0 deg
α (The angle of the nails measured from horizontal)= 15 deg
Vertical and horizontal distance between the nails $S_V = S_H$ = 5ft.
Preliminary screw anchor length (L) for all 4 tiers = 19ft
Step 3:
Ka = Tan(45- $\Phi/2$) = 0.33
Pa = γ.H.Ka= 911 psf
F1 = 1074 lb/ft
Ps = 100.Ka= 330 psf
F2= Ps.H= 759 lb/ft
Step 4:
Find the nails length (L) to satisfy sliding and overturning factors of safety.
First try for all four tiers is 16ft. Table 1 shows the final factor of safety for different nail length considerations.

Table 1. Nail lengths and factors of safety per KZP5 method

Nail Length (ft)				Factor of safety	
L1	L2	L3	L4	Sliding	Overturning
19	19	19	19	2.67	2.2
18	18	16	14	2.39	1.81

This example has been solved with other software and results are shown in Table 2.

Table 2. Nail lengths and factors of safety per other method

Nail Length (ft)				Factor of safety	
L1	L2	L3	L4	Sliding	Overturning
19	19	19	19	2.61	2.1
18	18	16	14	2.2	1.7

Comparing the results will show the accuracy of the KZP5 method, and the difference is about 5%.

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