# BEHAVIOR OF SOIL NAILED WALLS UNDER CYCLIC DYNAMIC LOADS WITH FINITE ELEMENT METHOD, CASE STUDY

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## ABSTRACT

Soil nailing is a very versatile excavation retaining system suitable for deep excavations in urban areas surrounded by major structures. In this study the behaviour of a deep excavation of a huge structure in the East of Tehran that stabilized by combination methods of nailing and anchoring system has been studied.

Soil nail wall used on this projects are subjected to harmonic dynamic loads due to heavy machinery and industrial plants nearby soil nail wall. The behavior of soil nail wall is investigated in the following sections with respect to the variations frequency. Effects of the pretention force in anchors on the maximum displacement and effects of the amplitude on the maximum displacement are evaluated.

## INTRODUCTION

Soil nailing is an innovative and cost-effective retaining system for deep excavations in steep slopes. The native soil is strengthened by placing steel rods into holes drilled into the walls and grouted. When compared to the conventional retaining wall system, soil nail wall construction requires less space and hence suitable for an urban area where excavations are surrounded by structures. It does not have any potential impact on environment during and after construction. The soil nailing technique can also be used for underground construction. The case histories are available in literature which shows the successful application of the soil nailing for in-situ ground modification.

In the present study the behaviour of a deep excavation of a huge structure in the East of Tehran that stabilized by combination methods of nailing and anchoring has been studied. The height of soil nail wall is 16 m as shown in Figures 1. Soil nail wall used on this projects are subjected to different loads during their service life. Typical applied loads are dead loads which include weight of the soil nail wall system, lateral earth pressure and the harmonic dynamic loads due to heavy machinery and industrial plants nearby soil nail wall. The dynamic loads applied with different frequencies and determine the resonant frequency of soil nail wall.

Many investigators (Chin, 2005 and Dodagoudar, 2010) have proposed soil nailing technique as a suitable method for stabilising vertical/nearly vertical excavations. Carla and Donatella (2008), Muthukumar and Premalatha (2009) and Gosavi et al. (2009) presented an overview of experimental studies conducted on soil nail wall models. All the studies were carried out in test tanks and the difference was noted in the size of tank. The size of tank varied from 48 cm to 2.5 m. In order to study the deformation behaviour of soil nail walls, many researchers (Alhabshi, 2006; Babu, 2009 and Liu, 2010) carried out finite element analysis of soil nail wall (Chia-Cheng Fan 2008). The importance of facing design in the stability of soil nail walls was pointed out in their findings. The behaviour of soil nailed walls under dynamic loads has been studied by very few investigators. Mark and Mladen (2000) performed dynamic centrifuge tests. Debabrata and Aniruddha (2010) conducted a series of laboratory shaking table tests.

Figure 1. Soil nail wall of the present study

## FINITE ELEMENT ANALYSIS OF SOIL NAIL WALL

The performance of soil nail walls is significantly affected by the mutual interaction between the native soil, the reinforcement (nails and anchors) and the facing. Additionally, various other factors such as the construction sequence, the installation method of nails, the connection between the nails and the facing, are also likely to influence the behaviour of the soil nail walls. The finite element analysis (FEA) provides insight into the mechanical behaviour of the wall that is not obtained through conventional limit equilibrium methods.

## NUMERICAL SIMULATION

As stated earlier, Plaxis (2002) is used for simulating and analysing the response of soil nail wall under static and seismic conditions. Numerical modelling is carried out assuming the plane strain state of stresses. The 15-node triangular elements with medium mesh density are used for the finite element discretization. The in-situ soil is simulated as Mohr-Coulomb (MC) material for the static and pseudo static analyses and as hardening soil with small-strain stiffness (HSS) for the dynamic analyses. Various inputs parameters for the HSS model are judiciously adopted from the manual of Plaxis (2002) after calibration for the Houston sand. The advantage of using HSS model is that it accounts for the increased stiffness of soils at small strains. Plate elements are used to model the nails and facing. Figures (2) show the outline and finite element model of the 16-m high vertical soil nail wall.

In this study, Numerical simulations of the soil nail wall were performed considering Mohr-Coulomb (MC) model.

The various soil model parameters adopted for the study are summarised in Table 1.

Table 1. Soil properties

| Characteristics of layers | Depth (m) | Specific weight (KN/m3) | internal friction angle (degree) | Cohesion ($KN/m^2$) | Modulus of elasticity ($KN/m^2$) |
|---|---|---|---|---|---|
| Layer one | 12-0 | 19.1 | 29 | 37 | 32000 |
| Layer two | 24-12 | 19.5 | 28 | 35 | 36000 |
| Layer three | 50-24 | 19.5 | 30 | 30 | 38000 |

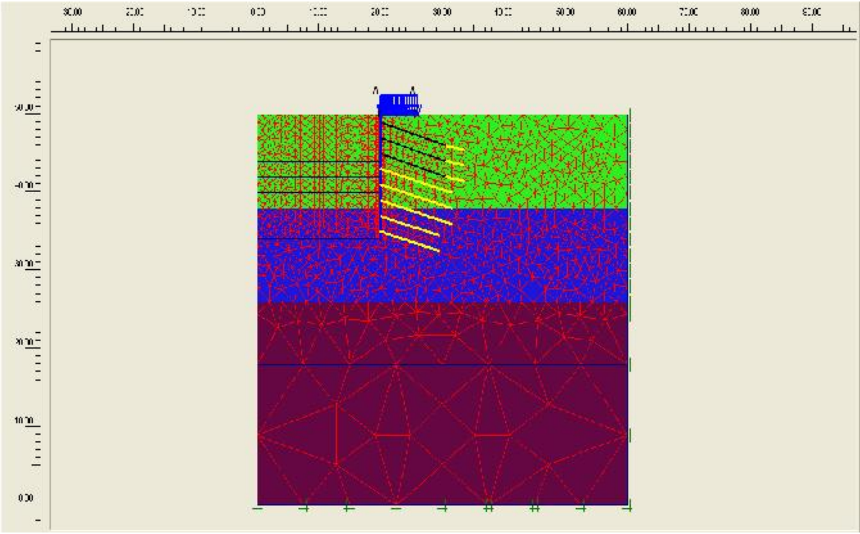

Figure 2. Soil nail wall model

The nail properties used in the study are given in Table 2.

Table 2. Nails properties

| Nails spacing (m) | EA (kN) | Holes drilled diameter (m) | Bars diameter (m) |
|---|---|---|---|
| 2 | $1.36\times10^5$ | 0.01 | 0.028 |

The anchor properties used in the study are given in Table 3.

Table 3. Anchor properties

| Anchores spacing (m) | EA (kN) |
|---|---|
| 2 | $1.2\times10^5$ |

The Shotcrete wall properties used in the study are given in Table 4.

Table 4. Shotcrete wall properties

| EI ($KNm^2/m$) | EA (kN/m) | Thickness (m) |
|---|---|---|
| $1.2\times10^5$ | $1.2\times10^7$ | 0.035 |

## Behavior Of Soil Nail Wall Under Cyclic Dynamic Loads

The behavior of soil nail wall is investigated in the following sections with respect to the variations frequency. Effects of the pretention force in anchors on the maximum displacement and Effects of the amplitude on the maximum displacement are evaluated

Pretention forces in anchors versus different frequencies are compared in Figures 3. Pretention force are applied in three various forces (130, 150, 160 kN). In all cases, the cyclic dynamic load is applied to the soil nail wall with various frequencies and constant amplitude. As shown in figures 3, the maximum displacement will be reducing with increasing pretention force. It should be mentioned the pretention force of bars shouldn't reach ultimate tension. Figure 3 indicate the negligible influence of pretention force on the maximum displacement in frequencies lower than resonant but also it is great in resonant frequency.

Effects of the amplitude on the maximum displacement are compared in Figure 4. Prameters of cyclic dynamic loads have great inflence on soil nail wall rupture. In order to evaluate effect of cyclic dynamic load prameters Three various amplitude (5, 10, 15) applied to the soil nail wall. As shown in figures 4, the maximum displacement will be increase with increasing amplitude (specially in resonant frequency). Amplitude have negligible effect on maximum displacement In high frequency and also the maximum displacement is going close to resonant condition when amplitude decrease.

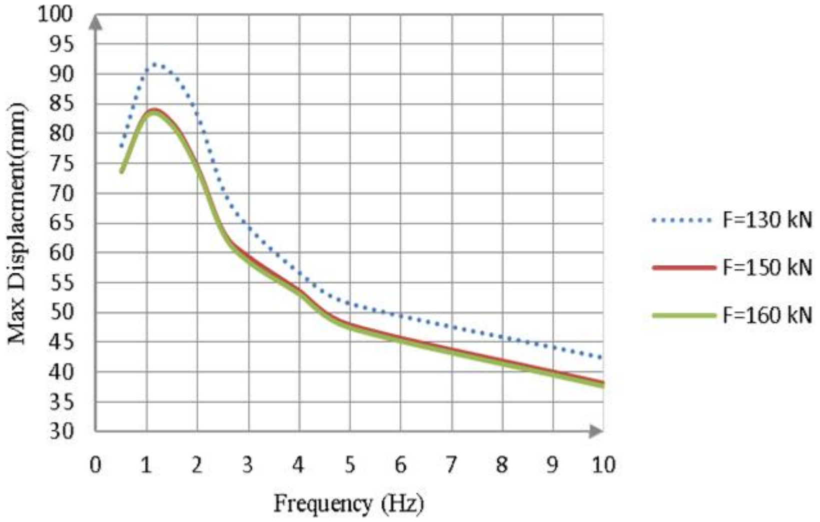


Figure 3. Variation of the maximum displacement of soil nail wall with the frequency for various pretention forces in anchor

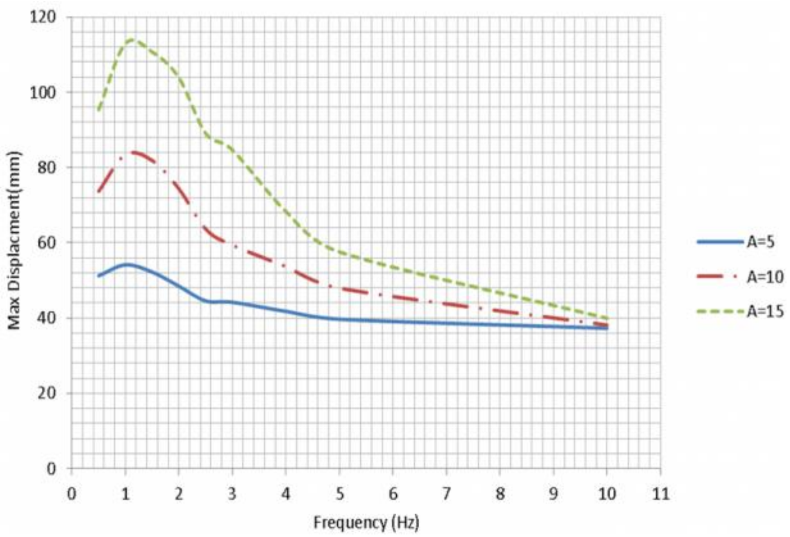


Figure 4. Variation of the maximum displacement of soil nail wall with the frequency for various amplitude

## CONCLUSIONS

For resonance frequency, it can be observed that the displacements are considerably higher for the smaller pretention force. However for frequencies lower than resonance frequency, the effect of pretention force is not significant. Amplitude of dynamic load for different frequencies is compared in Figures 4. For resonance frequency, it can be observed that the displacements are considerably higher for the smaller amplitude. However for frequencies higher than resonance frequency, the effect of amplitude is not significant

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