

Soil Structure Interaction Analysis of Microwave Antenna Tower

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Abstract

Microwave antenna towers are, typically, tall structures designed to support antennas (also known as aeriels) for telecommunications and broadcasting including television. The process in which the response of the soil influences the motion of the structure and the motion of the structure influences the response of the soil is termed as soil-structure interaction (SSI).

Here, a microwave antenna tower of 60m height is analysed under different boundary conditions namely stiff, medium and soft soils along with the fixed end condition. Two types of foundations 1) Individual foundation under each leg and 2) Single concrete block under the tower were modelled and analysed. Three-dimensional finite element models were employed for the analysis utilizing the ANSYS software. From all the obtained values it was found that the deformation values at nodal areas of tower is changing according to the change in property of soil and it also differs from fixed condition. It is found that deformation in fixed condition is less than that in different soil conditions. From the above results, it can be concluded that the property or the stiffness of the soil is become more major consideration in tower design and thus the soil-structure interaction must be considered in the design of microwave antenna towers.

Keywords: ANSYS 16, FEM, Microwave Antenna Towers, Soil Structure Interaction, Steel Tower Foundation

Introduction

A structure is an entity consisting of a superstructure and foundation. The function of a structure is to transmit the superimposed and self loads to the supporting soil or the bed rock in such a manner that it does not suffer any distress. Microwave antenna towers are, typically, tall structures designed to support antennas (also known as aeriels) for telecommunications and broadcasting including television. They are mainly of two types:

- Guyed
- Self-supporting structures

They are among the tallest man-made structures. Most of the civil engineering structures involve some type of structural element with direct contact with ground. When the external forces, such as earthquakes, act on these systems, neither the structural displacements nor the ground displacements, are independent of each other. Towers are usually designed using software's nowadays. In most cases, the towers are designed considering that their foundation is fixed at the bottom. In this process, the influence of soil on the tower structure is neglected. The process in which the response of the soil influences the motion of the structure and the motion of the structure influences the response of the soil is termed as soil-structure interaction (SSI). Conventional structural design methods neglect the SSI effects. Neglecting SSI is reasonable for light structures in relatively stiff soil such as low rise buildings and simple rigid retaining walls. The effect of SSI, however, becomes prominent for heavy structures resting on relatively soft soils for example nuclear power plants, high-

rise buildings, towers and elevated-highways on soft soil. The actual response of a structure to various loads is highly complex and depends on interaction of the superstructure, foundation and the soil on which it rests.

This work is an investigation to evaluate the performance of soil structure behaviour under various loads acting on a microwave antenna tower. The main objective of the study is to develop finite element models of 60 m tower and subjecting it to static structural analysis.

Description Of Tower Model

A 60 m high microwave antenna lattice tower is to be built near Agra where the terrain at the site is nearly a level ground with terrain of category 2. The diameter of the hemi-spherical antenna disc, fixed at the top is 3 m. The width of the top has to 3.5 m.

$$\begin{aligned} \text{B/H ratio} &= 1/8 \\ \text{Base width, B} &= 60/8 = 7.5 \end{aligned}$$

The top 12 m portion is kept perfectly straight (ie, vertical) and remaining portion inclined. 6 panels are provided in this top height of 12 m so that length of member in this portion = 2 m

$$\begin{aligned} \text{Inclination of base leg} &= \tan^{-1}((7.5-3.5) / (2(60-12))) \\ &= 2.3859^\circ \text{ or } 1/24, \end{aligned}$$

Which is quite satisfactory

$$\cos 2.3859 = 0.9991$$

The complete height is divided into four segments.

Provided K type bracing and reduced the length the diagonals in the bottom segment by providing secondary bracing.

Details of Foundation

Stability of a tower depends both on strength as well as stability of foundations. The foundation for a tower was designed for the following forces/moments:

- Downward load on the leg
- Uplift on a leg
- Horizontal thrust and
- Over turning moments

Generally, the load acting on the top of a footing is inclined, and this inclined load can be resolved into vertical and horizontal components. The lateral and longitudinal loads acting at a great height cause large overturning moments; which are to be resisted by the foundation with a minimum factor of safety of three. Here, nonlinear static analysis was done for single foundation and four individual foundations in soft, medium and stiff soil. In this analysis, the load on the tower structure coming on to the foundation, whether it is a single or four individual foundations are the same. The size of single foundation has been designed for the load coming from the tower. The size of four individual foundations has been designed based on the same load from the tower structure. This analysis has been done statically in order to compare the

deformation. After considering all the loads which are supposed to act on this tower, the size of individual foundation is given as 3.9m x 3.9m x 3.9m and size of single foundation as 11.4m x 11.4m x 11.4m.

Finite Element Modelling

The investigation was conducted using the FEM Software ANSYS Workbench version 16. The soil was modelled in ANSYS and tower was modelled using STAAD Pro. The loads acting on tower are shown in fig. 1. The properties of soft, medium and stiff soils are tabulated in table 1.

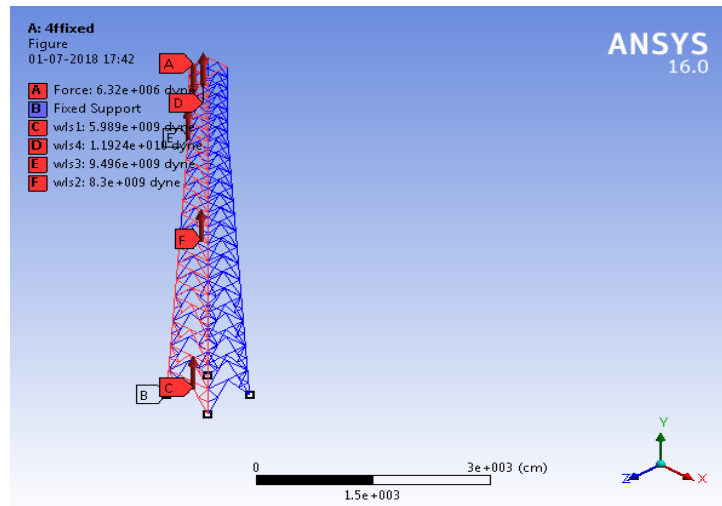


Fig. 1 Loads Acting on Tower

Table 1 Properties of Soil

Properties	Homogenous soil		
	Soft soil	Medium soil	Stiff soil
Modulus of Elasticity, E_s (kN/m ²)	15×10^3	25×10^3	60×10^3
Poisson's ratio	0.3	0.35	0.20
Density (kg/m ³)	1800	2000	2100
Cohesion (kN/m ²)	37.5	50	100
Coefficient of friction	0.95	0.75	0.5

Results and Discussion

Nonlinear static analysis was done for single foundation, 4 individual foundations in soft, medium and stiff soil. In this analysis the load on the tower structure coming on the foundation whether it is a single or four individual foundations is the same. The size of single foundation has been designed for the load coming from the tower. The size of four individual foundations has been designed based on the same load from the tower structure. This analysis has been done statically in order to compare the deformation and other values from the dynamic analysis. The static structural analysis shows that the deformation of the tower structure varies in soft, medium and stiff soil. Deformation will be more in soft soil and less in stiff soil. The soil deformation which only comes near to the leg of the tower structure and soil deformation is almost negligible.

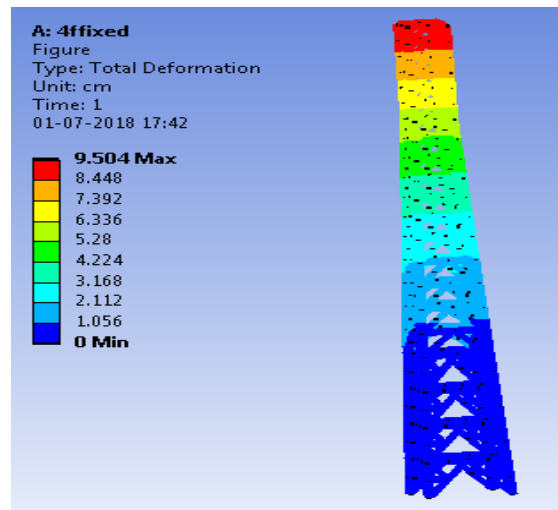


Fig. 2 Static Structural Deformation in Fixed Condition

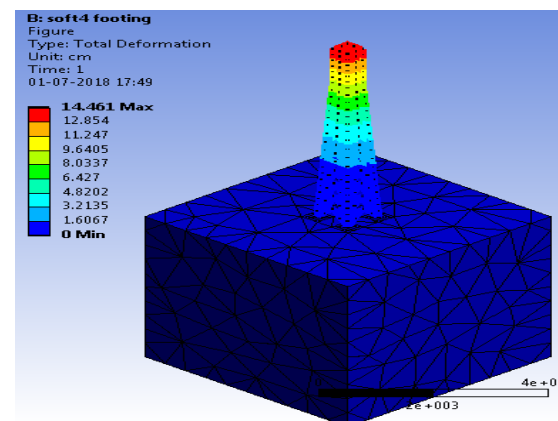


Fig. 3 Static Structural Deformation of Soft Soil in Separate Footing

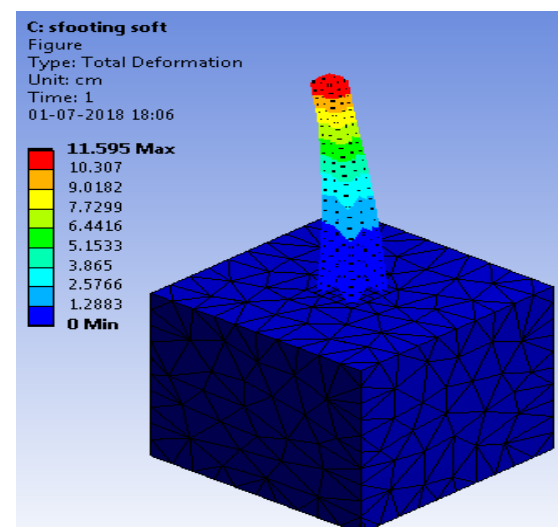


Fig. 4 Static Structural Deformation of Soft Soil in Single Foundation

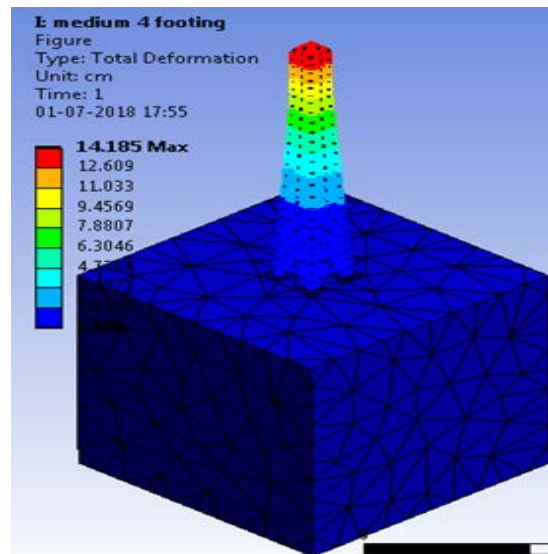


Fig. 5 Static Structural Deformation of Medium Soil in Separate Footing

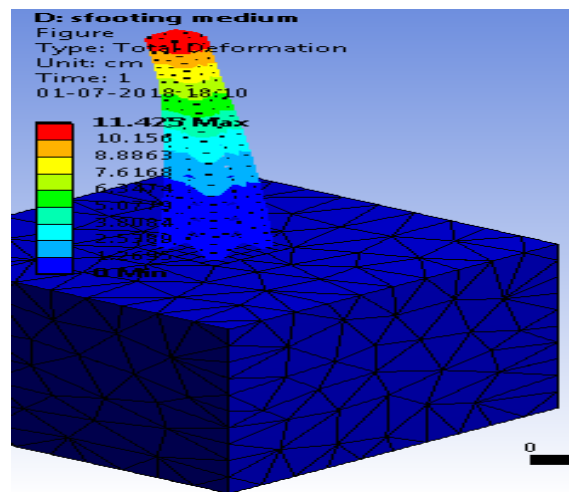


Fig. 6 Static Structural Deformation of Medium Soil in Single Foundation

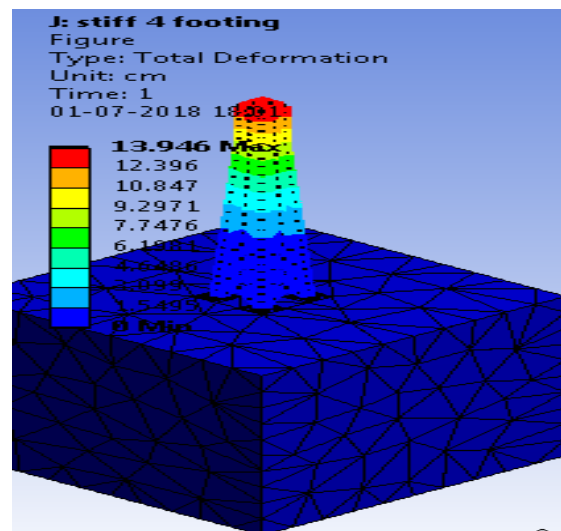


Fig. 7 Static Structural Deformation of Stiff Soil in Separate Footing

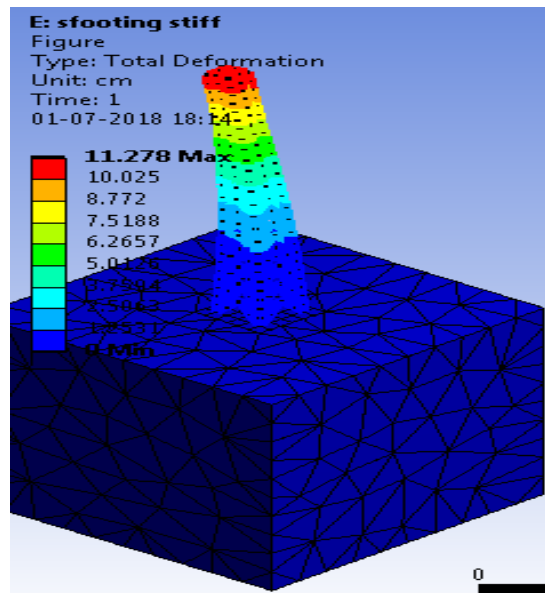


Fig. 8 Static Structural Deformation of Stiff Soil in Single Foundation

Conclusions

The important conclusions formulated are as follows:-

1. The static structural analysis shows that the deformation of the tower structure varies in soft, medium and stiff soil.
2. The vertical deformation or settlement decreases by respectively for medium and stiff soil with respect to that of soft soil.
3. The deformation values are varying according to the type of foundations.
4. The deformation values of tower having individual foundations are safe in stiff and medium soil but unsafe in soft soil conditions
5. The deformation values of tower having single concrete block as foundation are safe under all the three different soil conditions
6. The property or the stiffness of the soil is become more major consideration in tower design.
7. The soil-structure interaction must be considered in the design of microwave antenna towers.

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