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Finite Element Analysis of Elastic Settlement of Shallow Foundation

Arvind Kumar[1*], Naresh Nischol Harry[2], Yeetendra Kumar Bind[3], Parah Salsabeel Jalal[4]

*[*1,4]PG Student Department of Civil Engineering, Sam Higginbottom University of Agriculture, Technology and Sciences,Prayagraj,U.P,India.*

[2,3]Assistant Professor Department of Civil Engineering, Sam Higginbottom University of Agriculture, Technology and Sciences,Prayagraj,U.P,India.

ABSTRACT

Building foundation soil interactions are complex phenomena requiring advanced mathematical and numerical modeling. In this study, the interaction between the super-structure and sub-structure is investigated by modeling the soil as simple as possible to capture the overall response of the system. In the present work effectiveness of modeling in software for determination of settlement behavior of the medium rise building with isolated footing and raft footing in different types of soil considering soil flexibility interaction is studied. The non-linear frame building of 15 storeys is used to study the response of the model in Midas GEN. The simple soil model with isolated and raft foundation is then employed in Midas GTS NX to this nonlinear frame models to quantify the effect of SSI on the overall response of actual structures. The settlement results from Midas GTS NX are compared with the conventional settlement method described by IS: 8009-1976.

Keywords: Soil-Structure Interaction, settlements, solid stresses, Midas GEN, Midas GTS NX

INTRODUCTION

For high rise buildings the interaction between superstructure, subgrade and foundation is of prime importance than that of ordinary buildings. The fast development of numerical method and computational technology, the research on the interaction is generally stepping from theoretical and qualitative research to practical, quantitative and digitalized research. Soil, foundation and structure interact with each other and this collective interaction is called Soil-Foundation-Structure Interaction. The bases for framed structures in the analysis are considered either to be hinged or rigid completely. In order to evaluate the suitability of a foundation or earth structure, it is necessary to design against both bearing capacity failure and excessive settlement. In 1977, the 1st International Conference on Interaction between Subgrade and Structures was held in India and the papers in the proceeding of this conference reflected the high level of research on the interaction. The new conditions of load distribution in the structure may be introduced by foundation settlement which can lead to cracking and distress of its elements and even stress reversal (Meyerhof, 1953). In case of soil settlements of super structures, soil settlement is a function flexural rigidity of the superstructure (Miyahara and Ergatoudis, 1976). The distribution of column loads and moments which are transferred to the foundation can be significantly influenced by structural stiffness and the modification to the pattern of settlement can be done by load redistribution. Differential settlement of frame is generally reduced due to increase in stiffness and the interaction is beneficial when the soil is soft (Goschy, 1978). An economic solution to a differential settlement problem can be found by suitable design and detailing of the structural members and finishes. It results in extra cost when following the common practice of structure analysis for obtaining loads of foundation in which allowance are not provided for foundation settlement, however this extra cost can be avoided by taking into account the soil structure interaction in determination of settlements. A powerful numerical technique is being established by Finite Element Method (FEM) for general engineering analysis. In particular, geotechnical engineering problems involving complicated geometry and material behavior can be solved by FEM, without much effort, to handle such complications. In the present case, the framed structure is modeled in MIDAS GEN and the soil-structure interaction was considered in a coupled manner, with geotechnical software MIDAS GTS NX for overall system simulation. The comparative result presentation is done in terms of vertical loads with and without soil-structure interaction effects. However, to understand the process of settlement prediction using finite element analysis software that uses soil structure interaction a simplified building construction example with footing foundation is illustrated. The soil strata are also simplified. Foundation loads are used to design the foundation considering the allowable settlement criteria. The same information is used as input for finite element analysis in soil structure interaction simulation models in MIDAS GTS NX. Mohr-coulomb soil model is used for soil simulation. Appropriate assumptions are made in any case of missing information for soil modeling. The settlement results from MIDAS GTS NX are compared with the conventional settlement method described by IS: 8009-1976. To acquire an understanding of SSI analysis of settlement prediction of the shallow foundation through FEA simulation software MIDAS GTS NX in a comprehensively simplified manner is the main goal of this study.

MATERIAL AND METHODOLOGY

The geometry consists of G+14 Storeys with 4-bay spacing of each is 6m along X and Y direction. The frames are composed of columns, primary beams and secondary beams. There are three stages are involved in the finite element analysis of frame structure interaction with soil, namely frame modeling in Midas Gen Software, exporting model to Midas GTS NX and post-processing. Preparation of data, such as soil modeling, boundary conditions, and mesh generation is carried out using MIDAS GTS NX (2019).
The material properties used in the design of framed structure are given below-

Table 1 Details of RCC Frame

S.No.	Property	Dimensions	Grade of Concrete
1.	Building Height	45m	
2.	Storey Height	3m	
3.	Beam	300mm X 500mm	M25
4.	Columns	300mm X 500mm	M25
5.	Slab	150mm	M25
6.	Isolated Footing	2m X 3m X 1m	M25
7.	Raft Footing	1m	M25

Table 2 Details of Dead and Live Loads

S. No.	Type	Load
1.	External walls	12 KN/m^2
2.	Internal walls	6 KN/m^2
3.	Slab Dead Load	4.75 KN/m^2
4.	Slab Live Load	3 KN/m^2
5.	Parapet wall Load	4 KN/m^2

Modeling of Frame Structure and Analysis
Basically there are five steps in Midas GEN which are required and have been used in modeling:
STEP II: Modeling the structure,
STEP III: Assigning the material property,
STEP IV: Applying boundary condition and loads
STEP VI: Analysis and Results

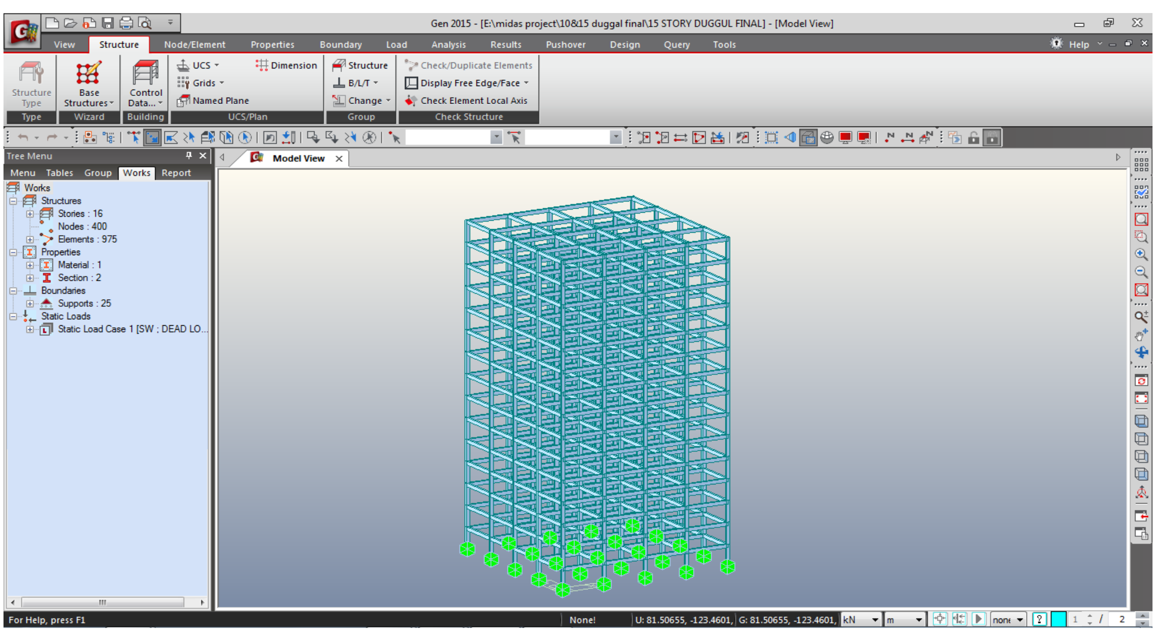

Figure 1 RCC Frame Building with Supports in Midas GEN

Soil modeling in Midas GTS NX

The following steps are involved in the analysis of the structure in Midas GTS NX:

Step I: Geometry Modeling
Step II: Material Models
Step III: Mesh Generation
Step IV: Boundary Conditions
Step V: Perform Analysis
Step VI: Results Output and Report

The study was performed to investigate the vertical settlement and stress distribution for 15 storey building in sand, clay soils. There are following three cases are selected for this study.

Case A: In the first case clayey soil model with single layer of 10m depth is used
Case B: In the second case sandy soil model with single layer of 10m depth is used
Case C: In the third case three layers of soil model with first layer of medium sand (top layer) with depth 2m, second layer of clay soil (middle layer) with depth of 1.5m and third layer (bottom layer) of dense sand of 6.5 in depth is used. The material properties used to model the soil model are discussed above.

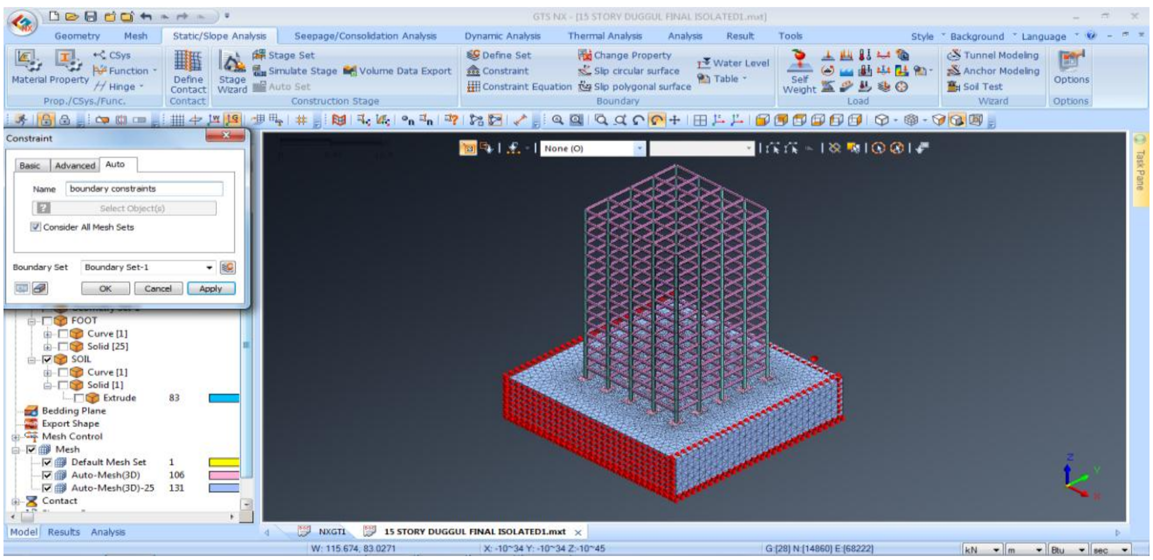

Figure 2 Building Model in Midas GTS NX with soil model

RESULTS

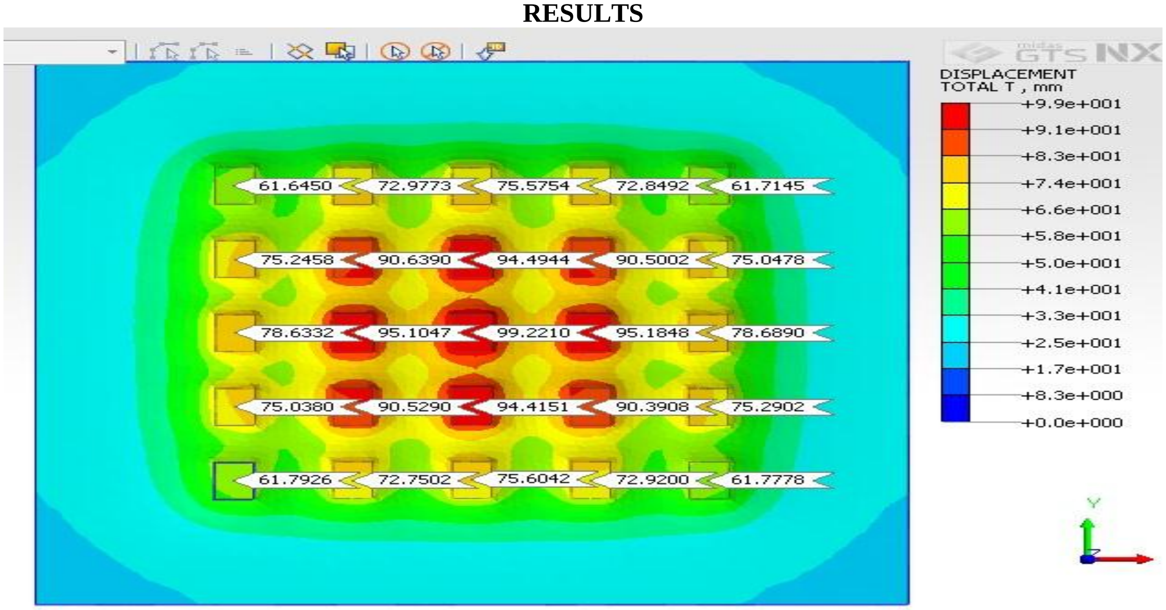

Figure 3 Settlements in Clay Soil with Isolated Footing

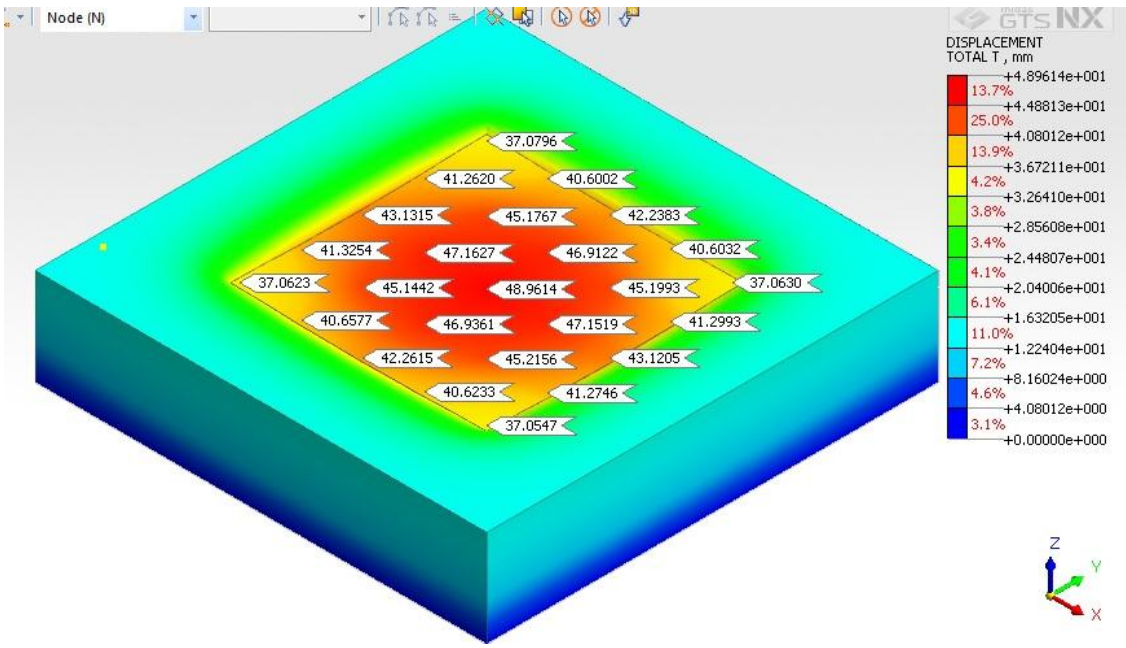

Figure 4 Settlement in Sand Soil with raft

Table 3 Percentage reduction in settlement with raft footing

Soil Model	Isolated footing Settlement (mm)	Raft footing Settlement (mm)	% Reduction in settlement
Case A	57.49	48.96	14.84
Case B	99.22	84.07	15.27
Case C	70.39	61.15	13.13

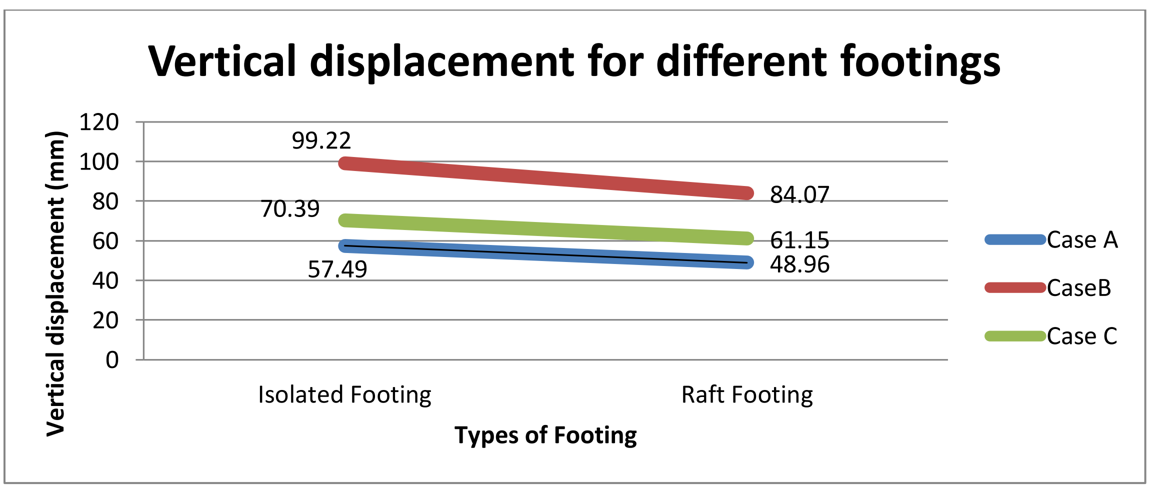

Figure 6 Comparison of settlement with different types of footing

Table 4 Comparison of elastic settlements from GTS NX and Manual method.

Soil model	GTS NX Settlement (mm)			Manual Settlement (mm)		
	Case A	Case B	Case C	Case A	Case B	Case C
Isolated footing	99.22	54.15	70.39	97.13	57.49	71.37
Raft footing	84.07	48.96	61.15	87.77	48.93	64.5

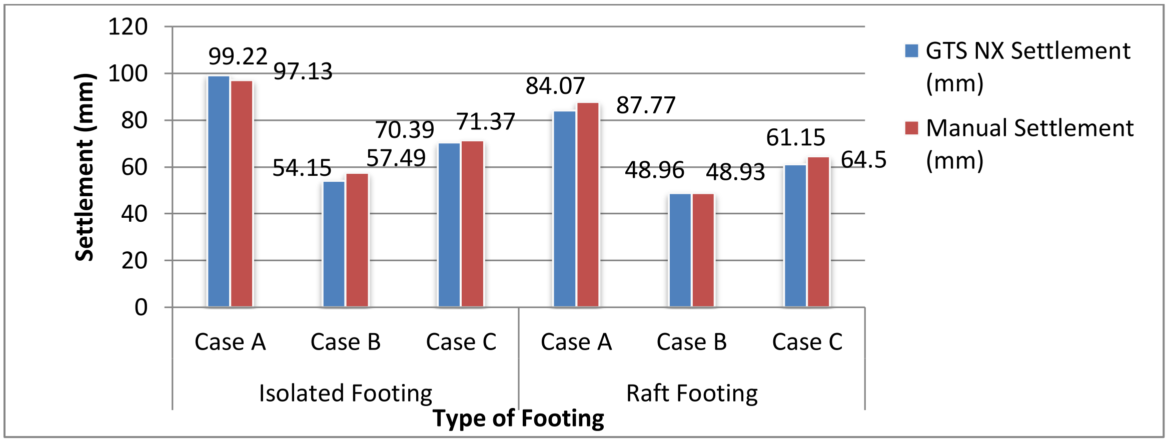

Figure 7 Comparison of settlement with different methods

CONCLUSIONS

From the study carried out following results are drawn:

1. From the above study it is concluded that vertical displacement for isolated footing reduced 14.84% with the use of raft foundation in sandy soil.
2. It is also observed that Vertical Displacement for Isolated footing reduced 15.27% with the use raft foundation in clay soil.
3. Vertical Displacement for Isolated footing is 13.13% more than raft foundation for case C.
4. It is also observed that for case B there is 5.8% and 0.06% difference in settlements from GTS NX and manual calculation for isolated and raft footings respectively.

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