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Numerical Analysis of Truss Foundation Settlement under Various Loadings

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Abstract

The truss foundation settlement, due to the light weight of these structures and their strip construction with some problems like a non-uniform settlement or the assessment of these foundations loading against conventional loading, is among the important problems that are considered in the behavior type and the interaction of the foundation with soil. This research studies the non-uniform soil beds, non-uniform settlement in foundations and its effect on the structure and numerical analysis and modeling in the ABAQUS software. In the following, the conventional loading including snow and wind loadings will be studied for some conditions of these structures with their foundations. In the present research, model behavior of truss sub-structure foundation is studied in three different loadings, three different widths, and three different depths and the following results are obtained. The effect of centrifugal forces (like wind) is almost ineffective for foundations. It seems that deepening the foundation is the best way for settlement decrease in normal settlement reduction. By increasing the foundation depth for about 25 cm, the normal settlement has decreased by about four times in the modeled samples. The effect of soil type on the settlement of software models was impressive and by decreasing the elastic modulus of soil, the foundation settlement will increase by about 25 percent.

Key words: Truss, Foundation, ABAQUS.

Introduction

The earth and building settlement is considered as one of the hazards that threatens the infrastructure and urban structures in the cities, especially in metropolises. Creating a comfortable and ideal living environment and meeting the security of the residents of the building against adverse environmental and climatic conditions are among the fundamental principles of architecture and building (Khorrami, 2018). Therefore, the necessity of dealing with earth settlement in the design and the construction of various structures is of great importance.

Usually, sandy soils will experience the settlement phenomena due to instant settlement as a result of loading over than its loading capacity (structure construction), cyclic wetting or drying (subsidence) or liquefaction caused by the earthquake. The settlement in the clay soils is the consolidation settlement type as a result of water level change or secondary loadings like structure construction. In most studies, soil is considered either homogeneous or layered. In the case of layered soil, the mean value of the parameter through each layer is uniformly assumed as the geotechnical properties of the whole layer (Jamshidi Chenari et al., 2018). In many cases in which the soil is a combination of various soils, the abovementioned factors are effective in a settlement.

By constructing the structures, the settlements would be in two types of differential settlement or general settlement. Mat foundation or sometimes strip foundation are the useful methods against the differential settlement. Also, in order to prevent the general settlement and increase the loading capacity, the applied load transfer to the underlying layers that have higher resistance could be utilized (by drilled shafts or driven piles or load bearing micro piles). Also, pre-loading, drainage or simultaneous utilization of these two methods are among the other suitable construction methods. In utilizing each proposed method, some factors should be considered like construction location, proper construction speed, economic justification, and soil type.

The settlement of truss foundations, due to their light weight and their strip construction, faces some problems like a non-uniform settlement or the assessment of these foundations loading against conventional loading, is among the important problems that are considered in the behavior type and interaction of the foundation with soil.

There have been some studies on this subject. Taherian et al. (2015) in a research titled "The effect of various soil parameters on the surficial foundation dynamic settlement in the sandy soil" showed that the increase of the friction angle and density results in the dynamic settlement decrease and the change in the elastic modulus does not have great effect on the surficial foundations dynamic settlement. Saberi et al. (2014) showed that with low costs and short time precise results about the flexible foundation settlement in the non-cohesive soils can be obtained. Fallah et al. (2015) in research named "An investigation on the asymmetric settlement of aerial U-turns with the construction of non-uniform foundations due to the opposing surfaces" investigated the asymmetric settlement of bridges

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construction with non-uniform foundations that are designed and constructed because of opposing surfaces. Zarfam et al. in research named as “The comparison of a simple frame with X-bracing and frames with restraint connections against consolidation settlement of sub-foundation” resulted that the frame with restraint connection is more economic in case of settlement and shows better behavior. Zhao and Liu (2017) in a study, showed that the foundation differential settlement can not be ignored in vertical deformation calculations and elevation control for supertall structures (Zho and Liu, 2017). Xue et al. (2018) investigated the effect of truss rigidity on the deformation of three-pile foundation.

Constructing a building requires a truss structure that can carry all the burdens that work on the building and forward them to the supporting soil layer (Lianto, Trisno and Wiguna, 2018). In this research, three types of truss structures are used that are investigated in three different soils and with three different settlements, and therefore, based on the various parameters in the research, a table for the amount of soil settlement and the destruction level of the truss will be obtained. The data gathering was based on the papers and previous works and the modeling was performed in the finite element software. The data was obtained from the computer simulation using the ABAQUS software and was studied in the Excel graphs.

In this research, after the introduction, in the second part, the research methodology is presented and in the third section, the findings of the research are presented and finally, the conclusion will be presented.

Research Methodology

The ABAQUS/CAE software is a comprehensive environment that has simple and user-friendly space for building ABAQUS models, analyzing, and studying the results of the simulation.

The ABAQUS/CAE software is divided into various modules and each module has the responsibility of one section of modeling. For example, there are modules for defining the model geometry, material specification and meshing. By transferring from one module to another module and performing the modeling related to that module and repeating this action to the final module, the finite element model will be constructed. When the model construction is done, the ABAQUS/CAE software creates an output file and gives the model to the processor section of the software and during the analysis, transfers some messages to the ABAQUS/CAE so the user will be informed about the analysis process. Then the database of the output data will be constructed. Finally, the visualization module is used for reading the output data database and displaying them.
For modeling of various parts in this research, the elements are used as follows:
Foundation: For modeling, the foundation, the two-dimensional shell elements that are four nod tetrahedron elements are used.
Structure: For modeling the studied structure, the Beam element with two nods is used.
Soil:

a) Close boundary: the two dimensional Shell elements that are four nod tetrahedron elements are used.
b) Far away boundary: For considering geometrical attenuation in the model, the infinite elements as the four nod tetrahedron Shell element is considered.

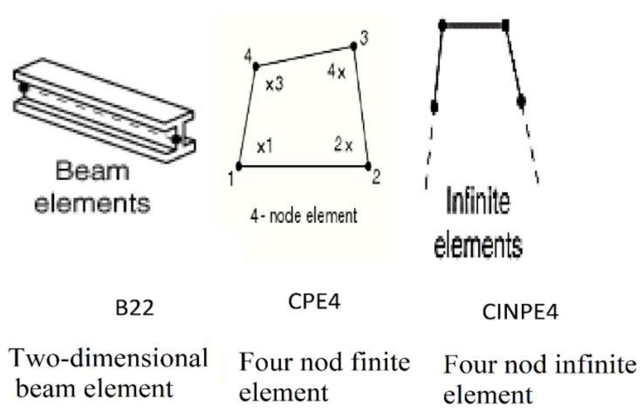

Figure 1: The used elements in the research.

Findings:

In this research, according to Table (1), the modeling was performed in the ABAQUS finite element software that a strip foundation of an industrial structure with the opening of 5 m, foundation width of 75 cm and depth of 75 cm was modeled in tree dimension.

Table 1: The specification of the samples

Sample	Foundation Width	Soil Elastic Modulus	Foundation Depth	Seat Displacement
A1	75	50	75	3
A2	75	75	75	3
A3	75	100	75	3
B1	75	50	75	4
B2	75	50	75	5
B3	75	50	75	6
C1	100	50	75	6
C2	125	50	75	6
D1	75	50	100	6
D2	75	50	125	6

In all the samples, the structure is connected to the foundation in the restraint type and the structure column is made of a box with the dimensions of 60 × 30 and with the thickness of 1.5 cm and for the bracelets, the corner number 10 is used.

Table 2: The specifications of the three modeled soils

Soil Type	Elastic Modulus	Poisson Ratio	Friction angle	Dilation angle	Soil Type
Type 1	50	0.3	20	0	Sandy clay soil with mud
Type 2	75	0.3	23	0	Clay
Type 3	100	0.3	26	0.1	Clay Sand

Results of sample A

According to Table (1), in the samples of A1, A2 and A3, only the elastic modulus of the samples are different, so the effect of soil type on the truss foundations could be observed that varies between 50, 75 and 100 kg/cm^2, respectively. In Figure (2) the normal settlement of the samples under loading in the tie direction could be observed. In Figure (3), the stress of the samples in the tie direction could be observed and in Figure (4), the maximum stress is observed.

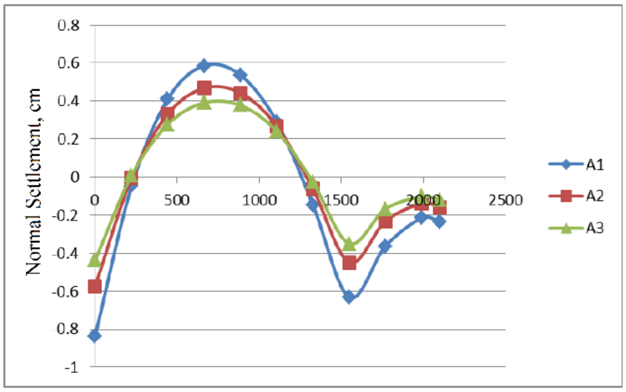

Figure 2: Normal settlement of the samples under loading.

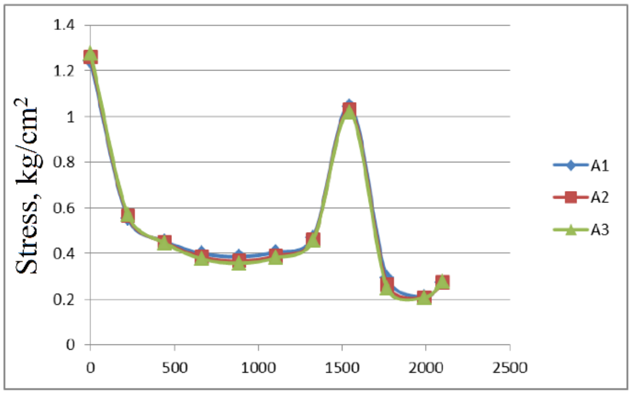

Figure 3: Samples stress under loading.

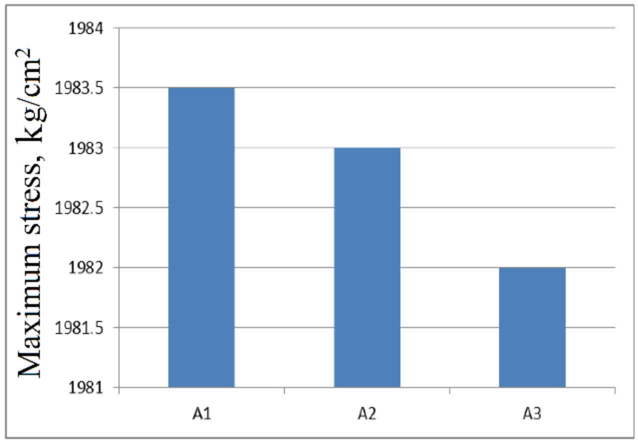

Figure 4: Samples stress under loading.

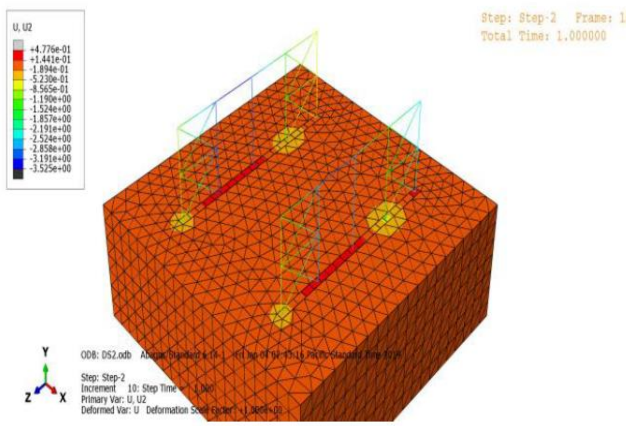

Figure 5: The image of A3 sample settlement distribution under loading.

Results of sample B

According to Table (2), in the samples of B1, B2, and B3, only the displacement of the structure on the columns are different, so the effect of soil type on the truss foundations could be observed that varies between 4, 5 and 6 cm, respectively. In Figure (6) the normal settlement of the samples under loading in the tie direction could be observed. In Figure (7) the stress of the samples in the tie direction could be observed and in Figure (8) the maximum stress is seen.

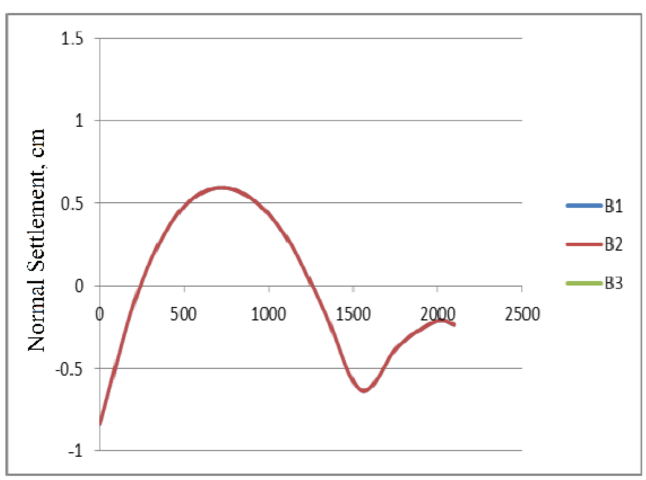

Figure 6: Normal settlement of the samples under loading.

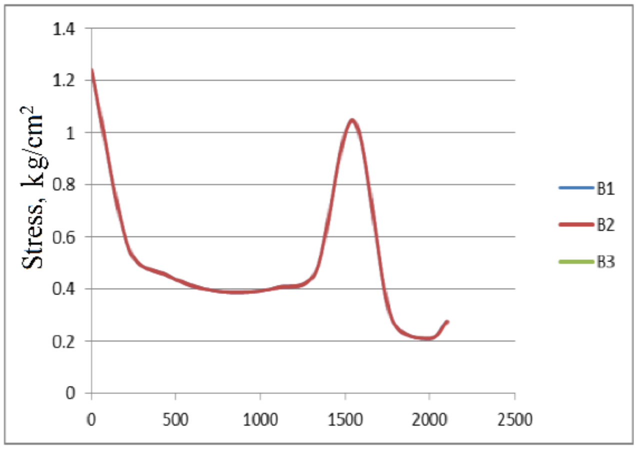

Figure 7: Samples stress under loading.

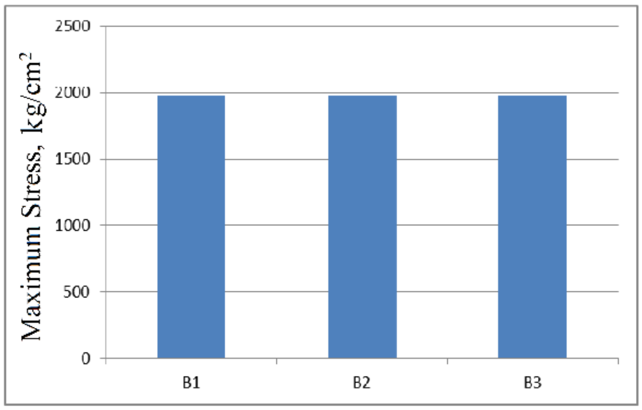

Figure 8: Samples stress under loading.

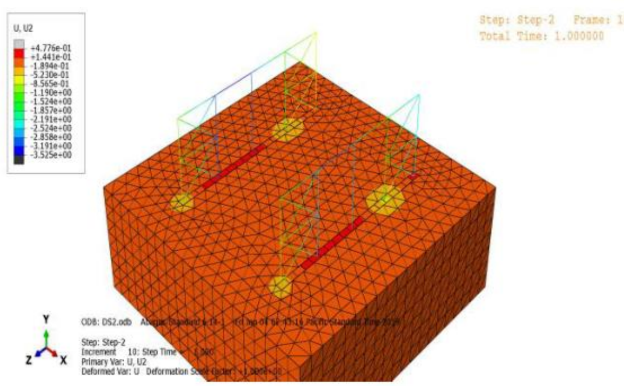

Figure 9: The image of the B2 sample settlement distribution under loading.

Results of sample C

According to Table (1), in the samples of C1and C2, only the foundation widths are different, so the effect of foundation width on the settlement could be observed that varies between 1 and 1.25 m, respectively. In Figure (10), the normal settlement of the samples under loading in the tie direction could be observed. In Figure (11) the stress of the samples in the tie direction could be observed and in Figure (12) the maximum stress is seen.

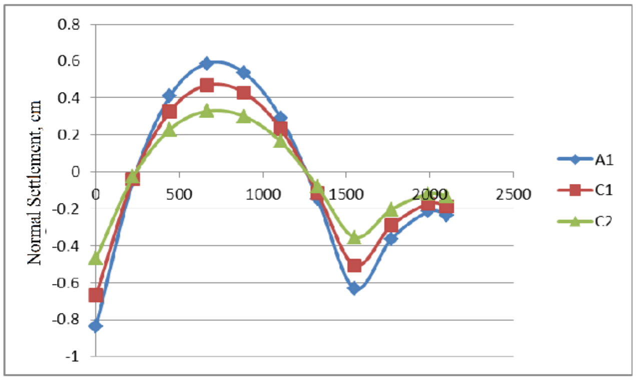

Figure 10: Normal settlement of the samples under loading.

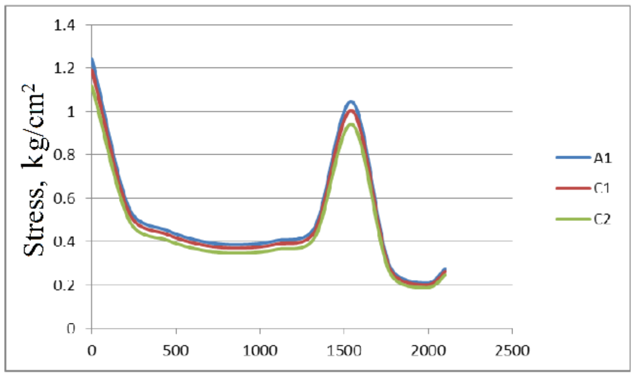

Figure 11: Samples stress under loading

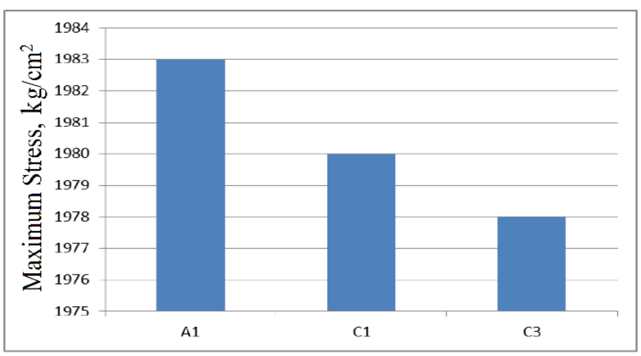

Figure 12: Samples stress under loading.

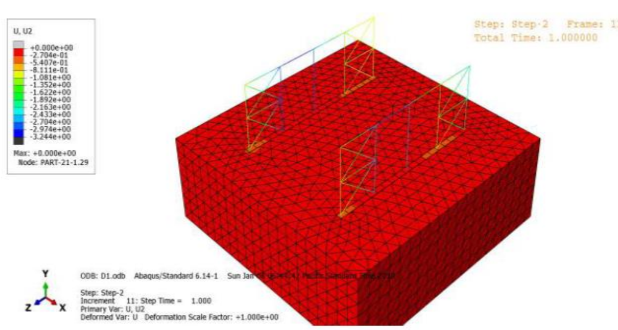

Figure 13: The image of C2 sample settlement distribution under loading.

Results of the sample D

According to Table (1), in the samples of D1and D2, only the foundation depths are different, so the effect of foundation width on the settlement could be observed that varies between 1 and 1.25 m, respectively. In Figure (14), the normal settlement of the samples under loading in the tie direction could be observed. In Figure (15), the stress of the samples in the tie direction could be observed and in Figure (16) the maximum stress is observed.

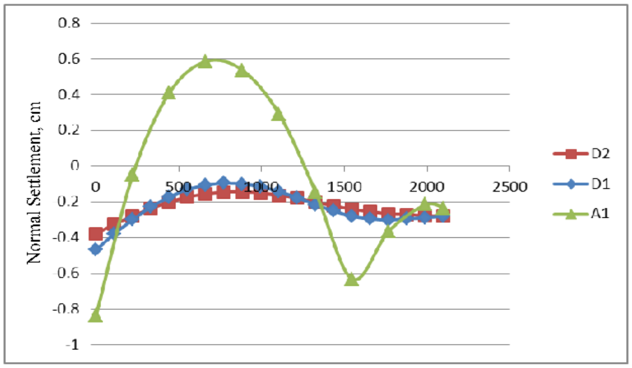

Figure 14: Normal settlement of the samples under loading.

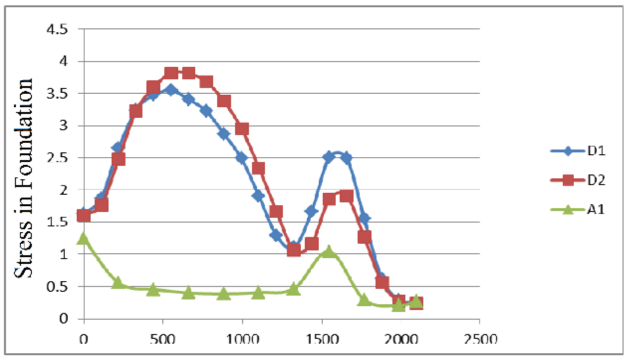

Figure 15: Samples stress under loading.

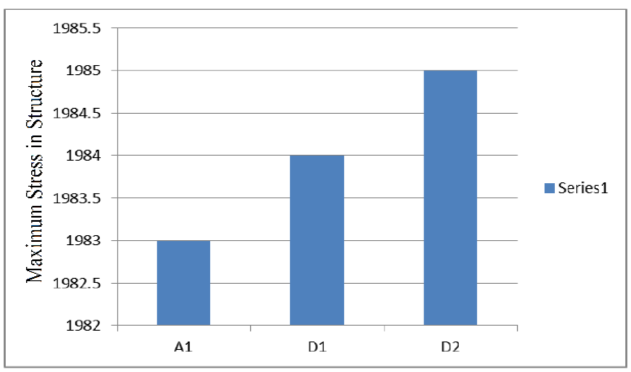

Figure 16: Samples stress under loading

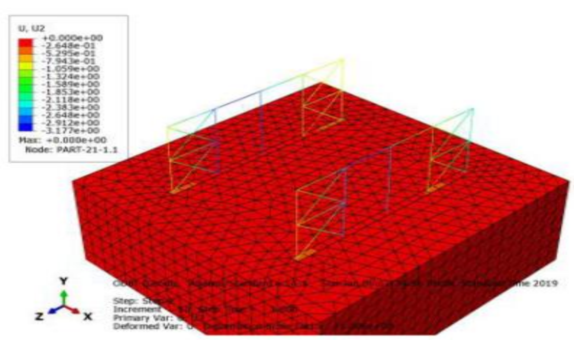

Figure 17: The image of D2 sample settlement distribution under loading.

Conclusion

According to the findings of the research and the software output, the following results could be analyzed. The effect of centrifugal forces (like wind) for the foundations is almost negligible. For reducing the stress in the foundations, that does not look so important, deepening the foundation is not a proper solution and works contrary. The best method for decreasing the normal settlement seems to be deepening the foundation that by increasing the foundation depth for about 25 cm, the normal settlement has decreased by about four times. The effect of soil type in the settlement was impressive in the software models and by decreasing the elastic modulus of the soil, the foundation settlement will be increased by about 25 percent. In the foundation, it seems that the important investigated component is the foundation displacement and the settlement and horizontal displacement seem very important. The stress in the analyzed foundation's samples is in the lower levels and optimization is not required.

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