BULETINUL INSTITUTULUI POLITEHNIC DIN IAŞI
Publicat de
Universitatea Tehnică „Gheorghe Asachi” din Iaşi
Tomul LIX (LXIII), Fasc. 5, 2013
Secţia
CONSTRUCŢII. ARHITECTURĂ

DYNAMIC ANALYSIS AND THE SOIL IMPACT ON THE PILED RAFT FOUNDATION OF A TALL OFFICE BUILDING (II)

BY

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Received: November 1, 2013
Accepted for publication: November 19, 2013

Abstract. This study, presented in two parts, aims to analyse the influence of soil type during earthquake upon piled raft foundations (piles with large diameter - columns) of a high civil building. The analysis is performed on two types of earths indigenous to the area of Iaşi city, Romania. The design takes into consideration a foundation system with friction piles (with lateral friction) placed on a homogeneous soil. The research consists of an infrastructure modelling, highlighting the translation modes and foundation system displacement. The entire structural system is made of reinforced concrete devised at superstructure with frames (columns, beams, plates) and structural walls. The foundation mediums taken into consideration are earths sensitive to moisture and earths with swellings and large contractions. The purpose of this research is to obtain a system that supports loads from the normal service of the building and from seismic forces without any major settlements of any kind. This should be possible by adaptation to the environment of foundation soil and by providing safety against quakes.

Key words: piled raft foundation; different soils; high office building; Response Spectrum; Midas GTS.

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1. Introduction

The boundary conditions contain rigid supports in order to simulate the studies conducted on real scale elements in laboratory conditions. Also, with this type of supports the efforts are focusing on the foundation system to highlight the effectiveness of the entire foundation system design. The proportions of earth model is in depth 4 times bigger and respectively at side 5 times bigger than foundation system (Figs. 1 and 2).

2. Verification of Foundation System According to Eurocode 8 Using the Geotechnical Program Midas GTS

2.1. Presentation of the Theoretical Options Chosen for Response Spectrum Analysis

The dynamic equilibrium eq. for a structure subjected to a ground motion used in this analysis can be expressed as follows:

$$[M]\ddot{u}(t)+[C]\dot{u}(t)+[K]u(t)=-[M]w_g(t),$$

where: $[M]$ is the mass matric, $[C]$ – damping matrix, $[K]$ – stiffness matrix, w_g – ground acceleration, $\ddot{u}(t)$, $\dot{u}(t)$ and $u(t)$ – the relative displacement, velocity and, respectively, acceleration.

Response Spectrum Analysis assumes the response of a multi-degree-of-freedom (MDOF) system as a combination of multiple single-degree-of-freedom (SDOF) systems. A response spectrum defines the peak values of responses corresponding to and varying with natural periods (or frequencies) of vibration that have been obtained through a numerical integration process. Displacements, velocities and accelerations form the basis of a spectrum. Response Spectrum Analysis are generally carried out for seismic designs using the design spectra defined in design standards as Eurocode 8.

2.2. Presentation of Spectral Data for Seismic Design

The data for seismic analyse were imputed with respect for city Iaşi, Romania. Analysis were performed by comparison between pile raft foundation systems on both PSU and PUCM soils. For PSU earth the translation modes are represented in Figs. 3,...,11, the displacement in Figs. 12,...,15, and for PUCM earth the translation modes arerepresented in Figs. 16,...,24, the displacement in Figs. 25,...,28.

Midas GTS can easily generate spectral data for seismic design by imputing: spectrum data type (acceleration), damping ratio (0.05), scale factor (1), chose the design spectrum (Eurocode 8, 2004), spectrum type (horizontal design spectrum), ground type (*D*), soil factor (1.35), T_b (0.07), T_c (0.7), T_d (3), design ground acceleration – a_g (0.2 g), behaviour factor – q (5.75), lower bound factor – b (0.2), importance factor – I (1.0) and maximum period (10 s).

3. Response Spectrum Analysis of Soils and Foundation System

For this analysis the dimensions of analysed earths are 170×170×120 m ($L \times L \times h$). The piled raft foundation system has the raft 34 × 34 × 1.7 m. The piles are 29 m long for PSU earth and 28 m for PUCM earth with diameter in both situations of 1 m.

3.1. Idealized Representation of Entire Assembly

The analysis is performed on two types of earths indigenous to the area of Iaşi city, Romania. The system of discretization chosen is MEF (Finite Element Method). The discretization is finer near the foundation system (1.00 m) and the triangles becomes grater as it departs from foundation (maximum 5.00 m) (Fig. 1).

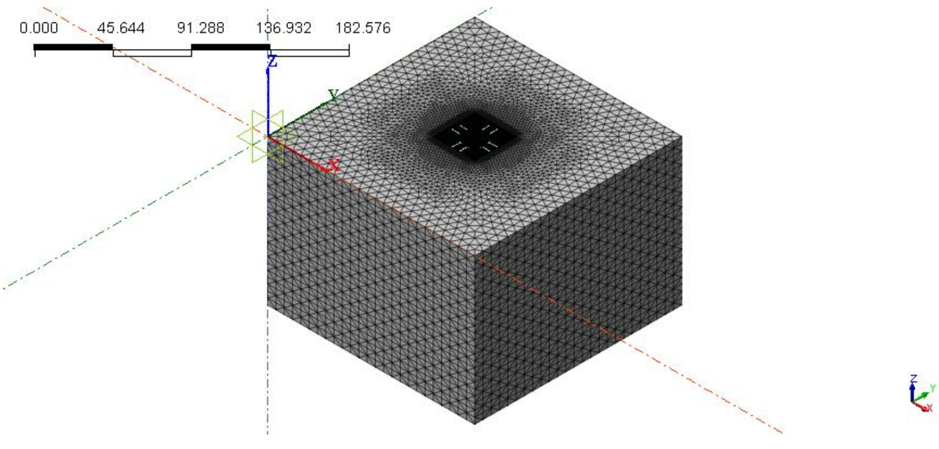

Fig. 1 – Discretization model of earth.

The construction is a 48.00 m high office building with a square base with sides of 30.00 m. The entire structural system is made of reinforced concrete devised at superstructure with frames (columns, beams, plates) and structural walls (Fig. 2).

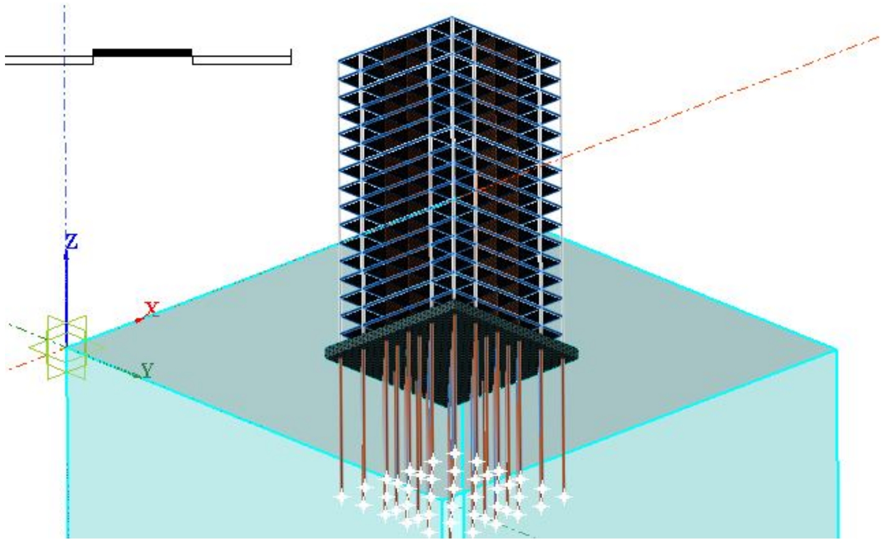

Fig. 2 – Idealized representation of superstructure and foundation system.

3.2. Translation Modes from Response Spectrum Analysis for Piled Raft Foundation on PSU Earth in DXYZ(V) Direction

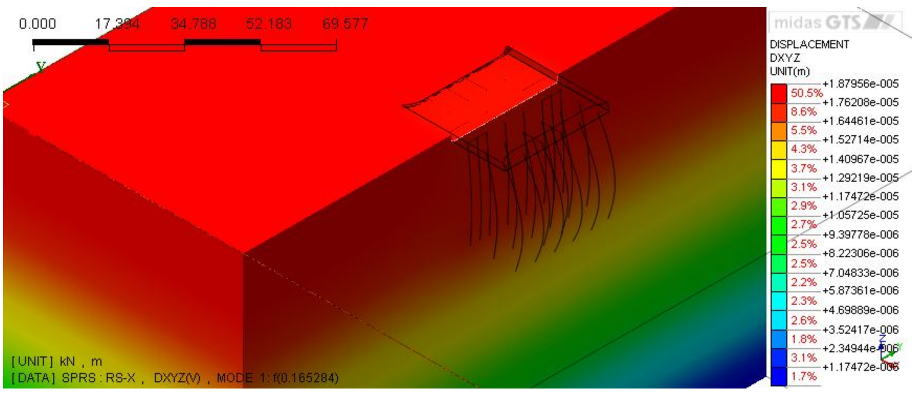

Fig. 3 – The foundation motion in Mode 1 is *f*(0.165s)

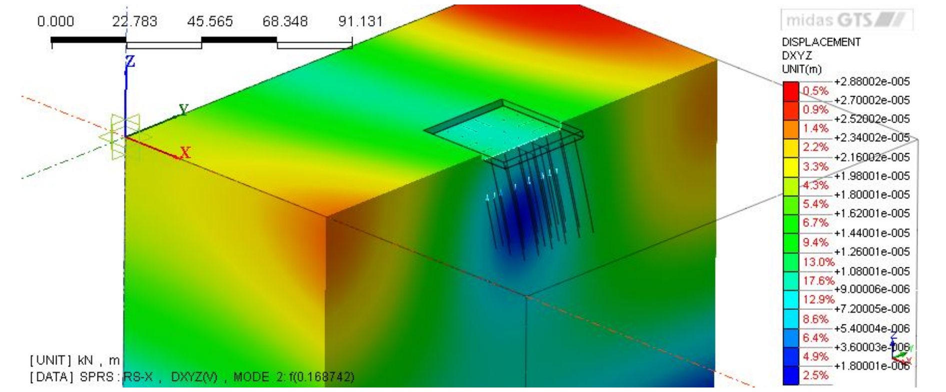

Fig. 4 – The foundation motion in Mode 2 is f(0.168 s).

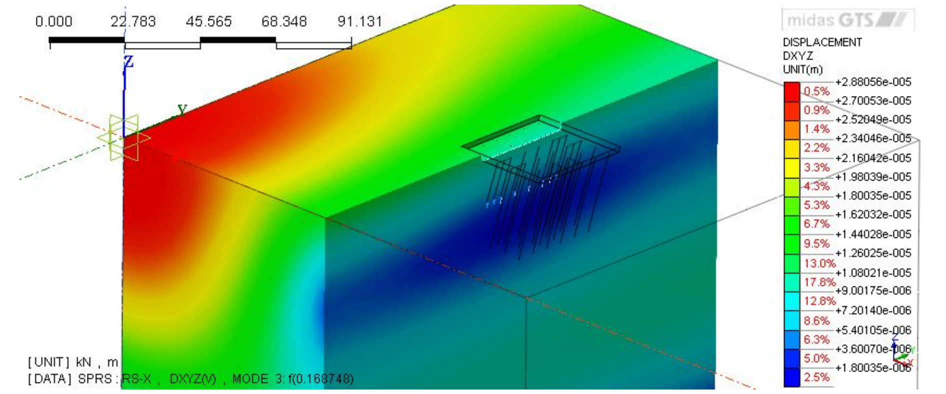

Fig. 5 – The foundation motion in Mode 3 is f(0.168 s).

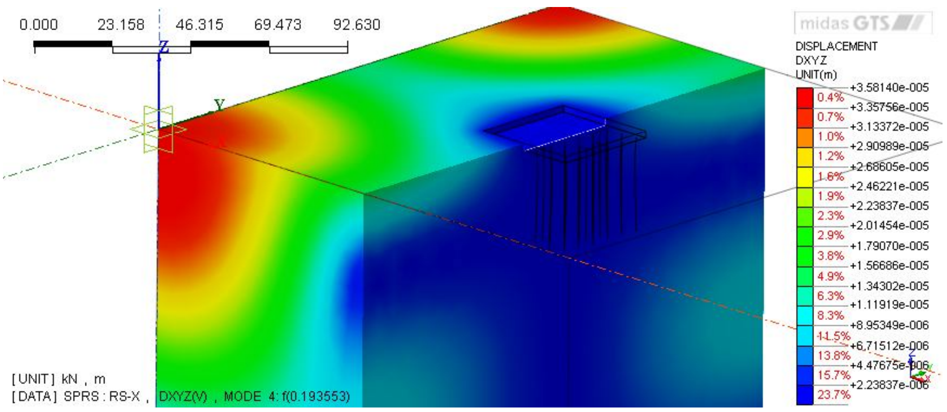

Fig. 6 – The foundation motion in Mode 4 is f(0.193 s).

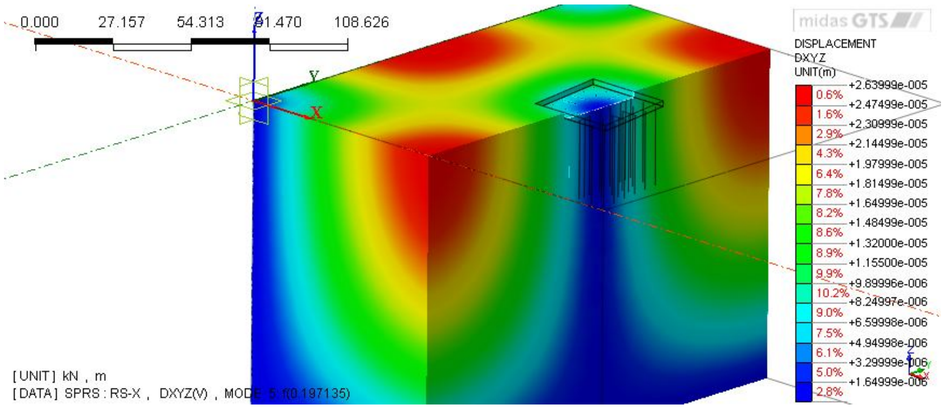

Fig. 7 – The foundation motion in Mode 5 is *f*(0.197 s).

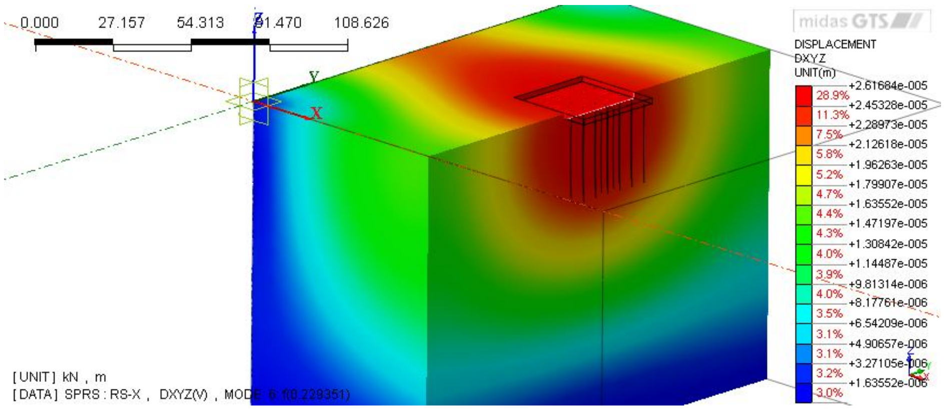

Fig. 8 – The foundation motion in Mode 6 is *f*(0.229 s).

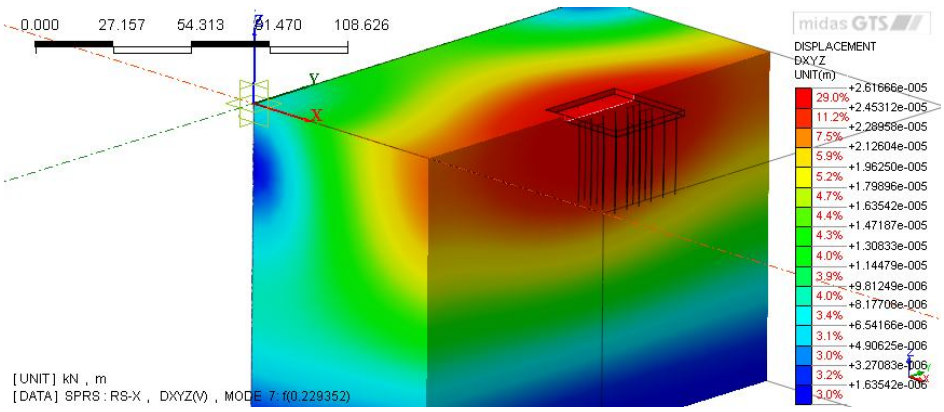

Fig. 9 – The foundation motion in Mode 7 is *f*(0.229 s).

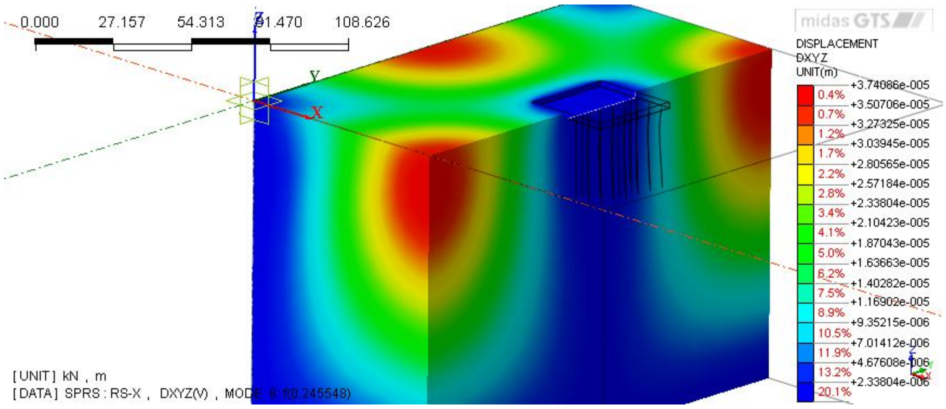

Fig. 10 – The foundation motion in Mode 8 is *f*(0.245 s).

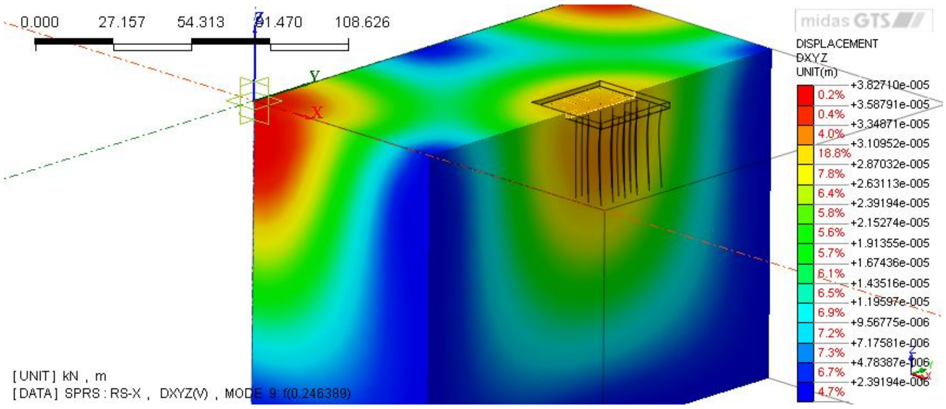

Fig. 11 – The foundation motion in Mode 9 is *f*(0.246 s).

3.3. Displacement from Response Spectrum Analysis for Piled Raft Foundation on PSU Earth

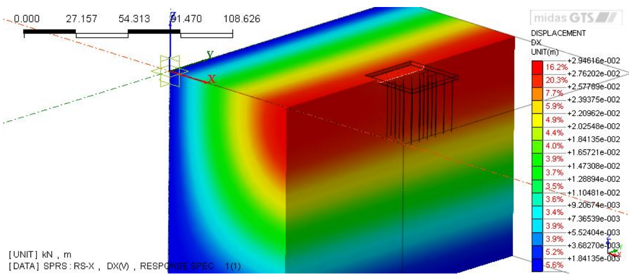

Fig. 12 – RSx (2.94 cm) on *DX*(*V*).

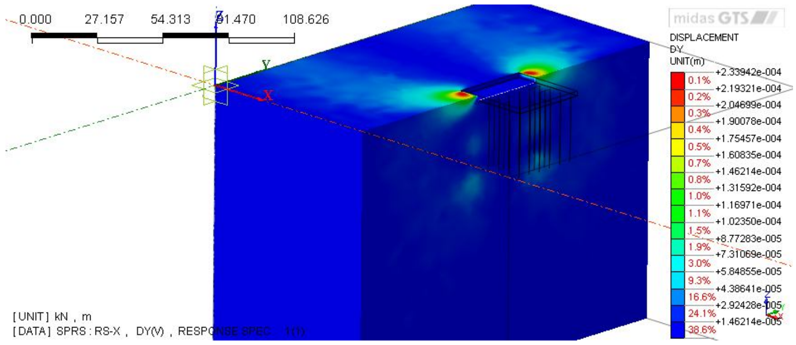

Fig. 13 – RSx (0.029 cm) on *DY*(*V*).

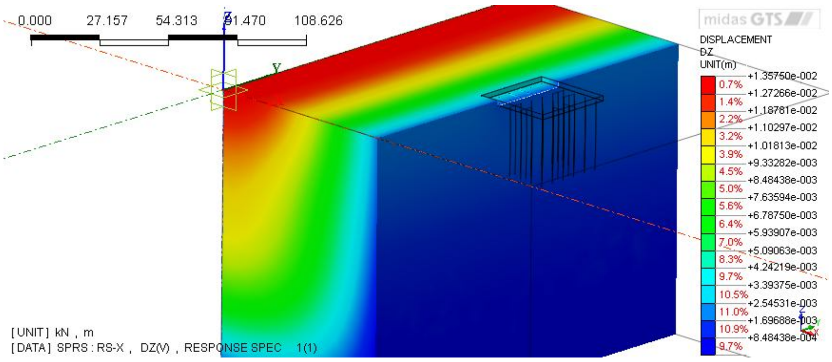

Fig. 14 – RSx (1.35 cm) on *DZ*(*V*).

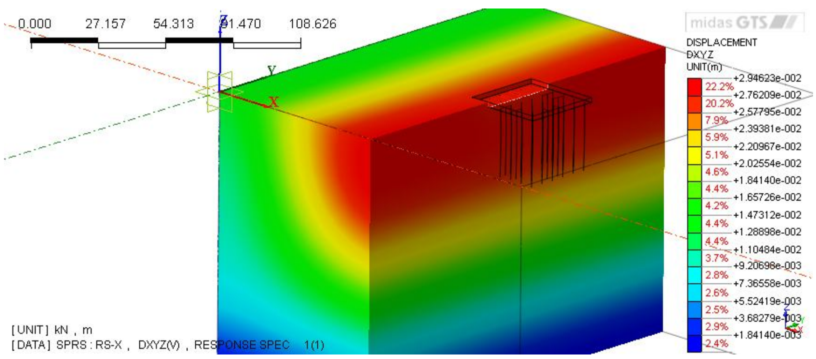

Fig. 15 – RSx (2.94 cm) on *DXYZ*.

3.4. Translation Modes from Response Spectrum Analysis for Piled Raft Foundation on PUCM Earth in *DXYZ*(*V*) Direction

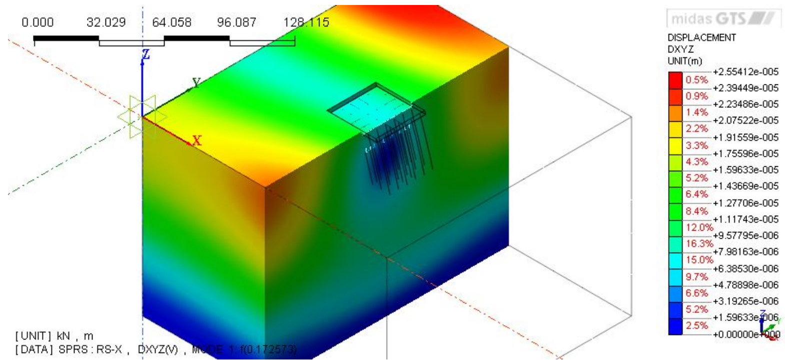

Fig. 16 – The foundation motion in Mode 1 is *f*(0.172 s).

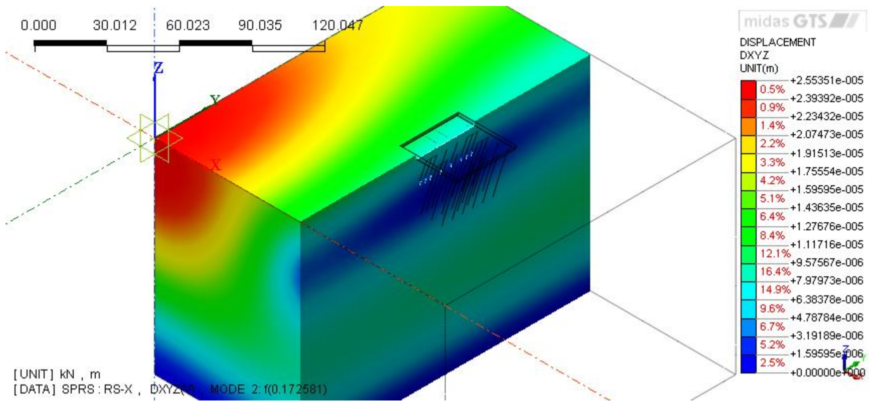

Fig. 17 – The foundation motion in Mode 2 is *f*(0.172 s).

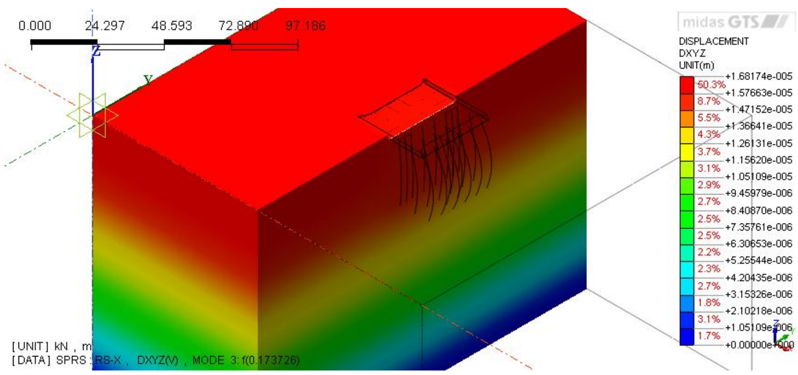

Fig. 18 – The foundation motion in Mode 3 is *f*(0.173 s).

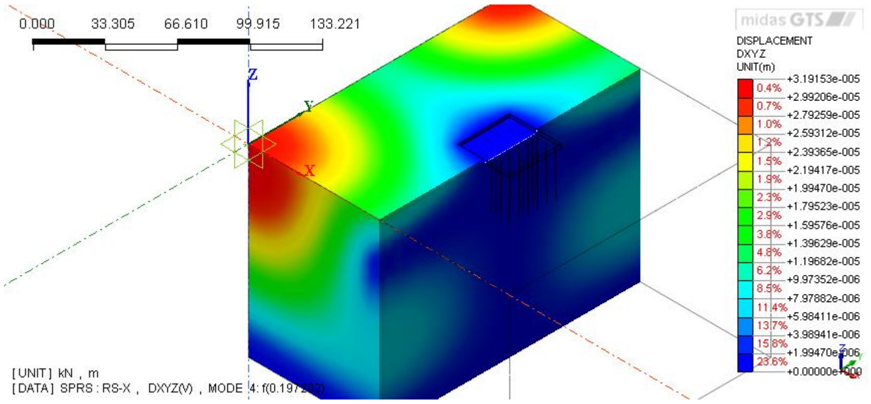

Fig. 19 – The foundation motion in Mode 4 is *f*(0.197 s).

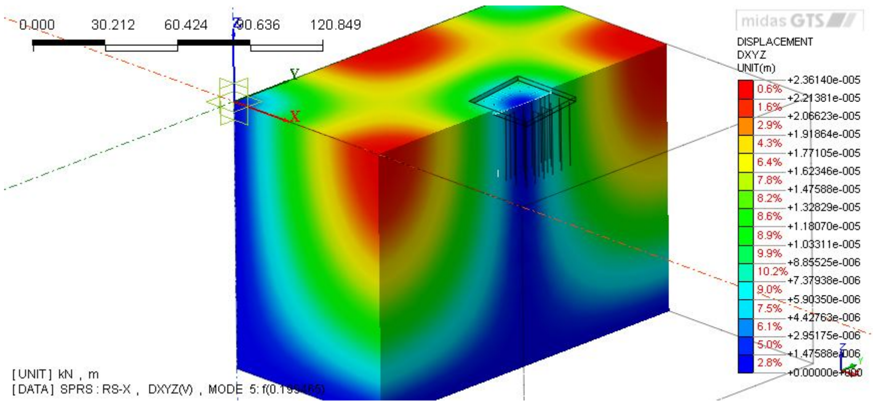

Fig. 20 – The foundation motion in Mode 5 is *f*(0.199 s).

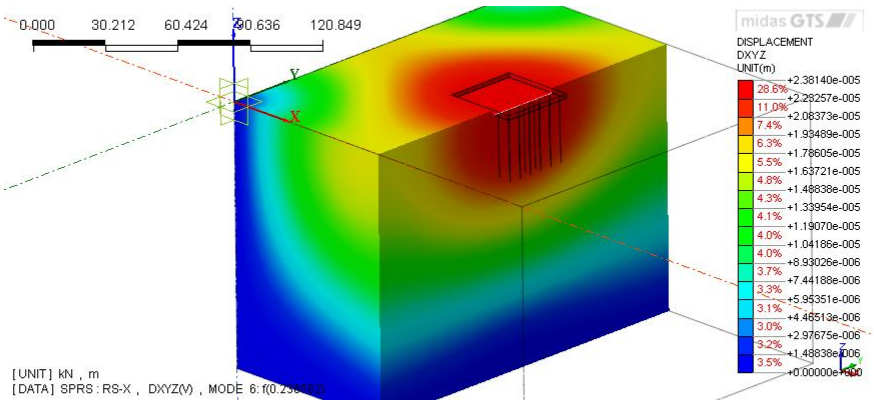

Fig. 21 – The foundation motion in Mode 6 is *f*(0.236 s).

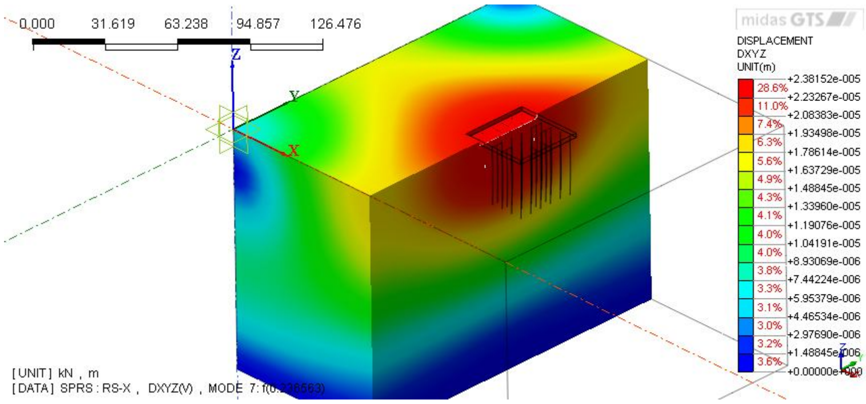

Fig. 22 – The foundation motion in Mode 7 is *f*(0.236 s).

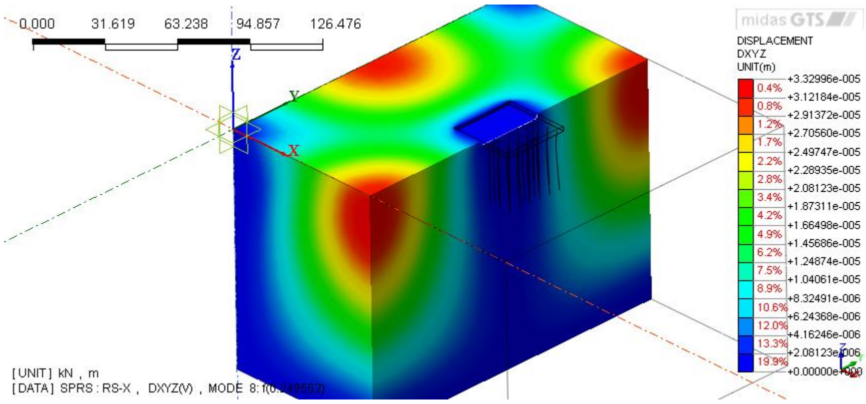

Fig. 23 – The foundation motion in Mode 8 is *f*(0.249 s).

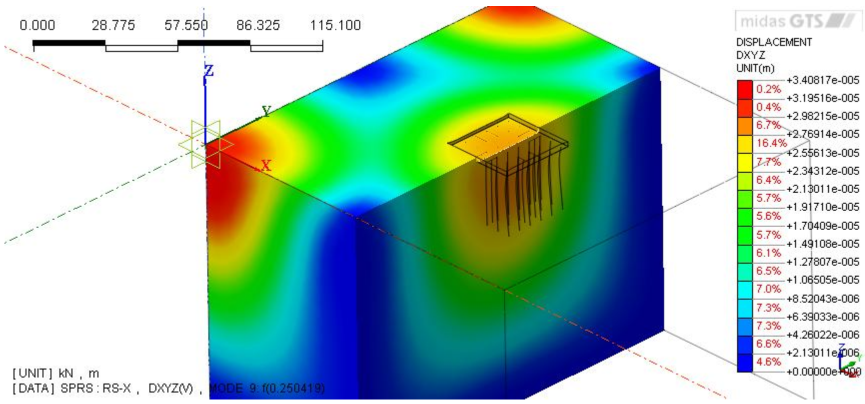

Fig. 24 – The foundation motion in Mode 9 is *f*(0.250 s).

3.5. Displacement from Response Spectrum Analysis for Piled Raft Foundation on PUCM Earth

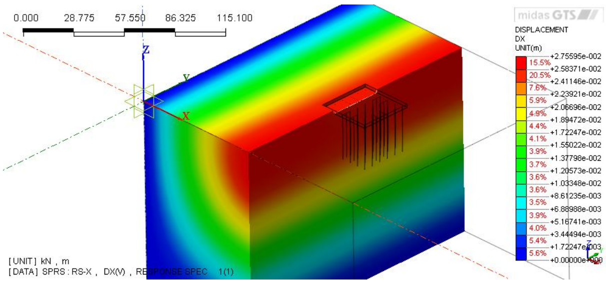

Fig. 25 – RSx (2.75 cm) on *DX*(*V*).

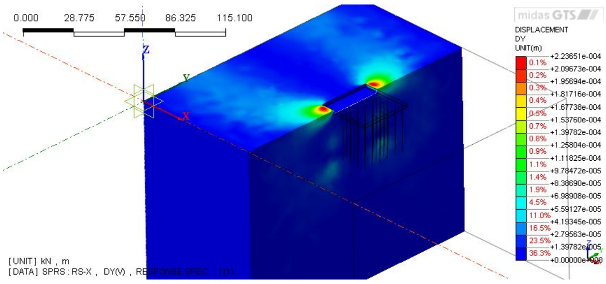

Fig. 26 – RSx (0.029 cm) on *DY*(*V*).

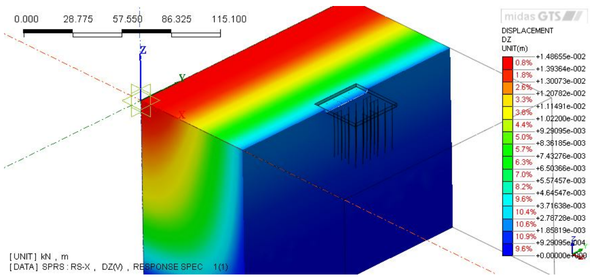

Fig. 27 – RSx (1.48 cm) on *DZ*(*V*).

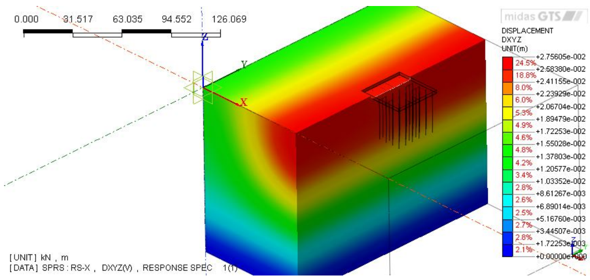

Fig. 28 – RSx (2.75 cm) on *DXYZ*.

5. Conclusions

The Response Spectrum Analysis was performed using geotechnical computer program Midas GTS 2013 v1.1 to obtain the behaviour of soil and foundation system in an event such as earthquake.

On both soils targeted it can be seen the way in which the design foundation system behaves on a homogeneous earth located in a seismic region like city of Iaşi, Romania.

It stands out from automatic calculation that the design fulfils the imposed purpose to obtain a foundation that will withstand to seismic force without having an amplifying effect on the superstructure. Also it can be seen that the vertical movement during the simulated earthquake in the program is ranged in acceptable limits.

Thereby the general criterion which aims that the designed foundation system to adapt to the environment of foundation soil and to ensure safety against quakes for occupants and building has been reached.

Acknowledgment. The first author would like to thank: to “Gheorghe Asachi” Technical University of Iasi and to the Faculty of Civil Engineering and Building Services for Guidance and Education Received; to University of Padova and to the Department of Civil, Environmental and Architectural Engineering for availability, guidance and for being a great host; and not least to Erasmus Organization for making this partnership, study and experience possible. Special thanks to Midas IT Family Programs for the program Midas GTS 2013 v1.1.

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ANALIZA DINAMICĂ ŞI IMPACTUL PĂMÂNTULUI ASUPRA FUNDAŢIEI RADIER PE PILOŢI A UNEI CLĂDIRI DE BIROURI ÎNALTE (II)

(Rezumat)

Prezentul studiu, realizat în două etape, urmăreşte evidenţierea influenţei tipului de pământ în condiţiile acţiunii seismice asupra fundaţiilor radier pe piloţi (piloţi de diametru mare – coloane) pentru o clădire înaltă. Analiza este efectuată pentru două tipuri de pământuri originare din zona oraşului Iaşi, România. Proiectarea are în vedere un sistem de fundare pe piloţi flotanţi (cu frecare laterală), amplasaţi pe un teren omogen. Cercetarea constă în modelarea infrastructurii evidenţiind modurile de vibrare şi deplasarea sistemului de fundare. Întregul sistem structural este realizat din beton armat, iar suprastructura este proiectată în cadre de beton armat (stâlpi, grinzii, planşee) şi pereţi structurali. Mediile de fundare luate în considerare sunt din categoria pământurilor sensibile la umezire, precum şi din categoria pământurilor cu umflării şi contracţii mari. Scopul acestei cercetări este de a obţine un sistem constructiv viabil care să asigure exploatarea atât din punct de vedere al domeniului static cât şi din cel al domeniului seismic, fără a permite tasări majore de nici un fel. Îndeplinirea acestui obiectiv este posibilă atât prin adaptarea la mediul de fundare cât şi prin asigurarea unui grad sporit de siguranţă în timpul cutremurelor.