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MODELING GEODYNAMICAL PARAMETERS FOR THE LOCAL SEISMIC EFFECTS ESTIMATION. EXAMPLE FOR GALATI AND TECUCI SEISMIC AREAS

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Abstract. A method for local effects estimation is employed here consisting in combining laboratory and in situ test performance, which implies the nonlinear modeling of geodynamical parameters of the soils. The two material functions, dynamic modulus function and damping function are computed here for materials which characterize the selected seismic areas. To accomplish this aim we use geodynamical profiles containing wave velocity measurements and resonant columns tests are performed. The differences between physical variables and natural conditions that influenced the initial values of the dynamic functions and the shape of the nonlinear variation curves are taking into account.

Key words: material function, nonlinear soil behavior, geodynamical modeling, resonant columns, soil profile, shear modulus, damping.

1. INTRODUCTION

The aim of this work is to estimate two material functions (G, D) by modeling nonlinear soil behavior [1], [2] beneath a certain seismic area. This could be useful for the accomplishment of microzonation studies and for the *estimation of the local effects*. The computation of the two function, shear dynamic function $G = G(\gamma)$ and damping function $D = D(\gamma)$, both strain dependent (γ), will be done using laboratory and in situ dynamical tests performed with specific devices [3]. For dynamic modeling of the soils we use a nonlinear dynamic model of Kelvin-Voigt type [4]. For the extended areas it is very unlikely to have a complete network of drills for delivering us the necessary of data for such studies, and besides of this the costs of such studies would be prohibitive. On the other hand, ignoring the nonlinear behavior of soil strata between bedrock and surface would compromise our studies.

However, the nonlinear soil modeling method employed here [5] can be used to provide us an accurate level of local effects estimation and microzonation of the area. It allows us to carry out a reduced dynamic study which can compensate the lack of experimental data through extension of existing one, or from specialty literature. Using this procedure we can estimate the dynamic nonlinear behavior of the materials (soils) between the bedrock and surface with less precision but fair enough for our purpose. This would imply the obtaining of the nonlinear material functions not very different from the those obtained from much detailed site study comprising all necessary test done (laboratory and in situ).

Two methods are available for determination of the material functions, laboratory and in situ, last one consisting in wave velocity measurement. By combining the two methods through the correlation functions we tried to obtain a complete characterization of the materials in which the soils are consisting. The differences between physical variables (humidity, density, spherical state of tension σ_0, porosity) of the materials found at different depths and the natural conditions do influence the initial values of the dynamic functions and the shape of the nonlinear variation curves. For the same type of material, located at different depth, some physical properties could be extrapolated using corrections function [7], [8].

2. ESTIMATIONS OF THE INITIAL MECHANIC CHARACTERISTICS

Starting from a profile for Galati area we try to obtain some initial mechanical features, i.e. dynamic modulus function G_0 in situ and spherical tension that exists in situ σ_0, denoted as follows:

$$G_0 = \rho v_s^2, \tag{2.1}$$

and

$$\sigma_0 = \frac{1}{3}\left(\sigma_1 + \sigma_2 + \sigma_3\right), \tag{2.2}$$

where ρ is density, v_s is the transverse waves velocity and $\sigma_{1,2,3}$ are components of the spherical tension.

Admitting an elastic halfspace we have the relationships:

$$\sigma_1 = p_v,$$

$$\sigma_2 = \sigma_3 = K_0 p_v, \tag{2.3}$$

where p_v is the pressure given by lithological loading and K_0 the bulk modulus (lateral pressure coefficient) in initial state before loading, given by:

$$K_0 = \frac{\upsilon}{1+\upsilon}, \tag{2.4}$$

with υ Poisson coefficient. Equation 2.2 becomes

$$\sigma_0 = \frac{1+3\upsilon}{3(1+\upsilon)} p_v, \tag{2.5}$$

in which

$$p_v = \gamma h = \rho g h, \tag{2.6}$$

where g is gravitational acceleration and h is depth of the sample. Using the longitudinal and the transversal waves velocities

$$v_p = \sqrt{\frac{\lambda + 2G}{\rho}} \ , \quad v_s = \sqrt{\frac{G}{\rho}}\sqrt{2} \ , \tag{2.7}$$

and relationship between Lamé coefficient and Poisson coefficient (G being shear modulus)

$$\lambda = \frac{2G\upsilon}{1-2\upsilon}, \tag{2.8}$$

we obtain for the last one

$$\upsilon = \frac{v_p^2 - 2v_s^2}{2\left(v_p^2 - v_s^2\right)}. \tag{2.9}$$

The mechanical features that characterize the initial state of the materials are presented in Table 1 in which the last two columns are parameters computed using the above formulas.

Table 1

Galati profile

Layer	Type of Material	Thickness of the layer [m]	Density [g/cm^3]	v_p [m/s]	v_s [m/s]	σ_0 [Mpa]	G_0 [MPa]
1	Alterațed materials, Loess deposits	0-5	1.55	320	130	0.02	26
2	Loess deposits, gravel, sand	5-40	1.80	600	260	0.21	122
3	Sand, sandy clay, sandy marl	40-250	2.10	1,100	510	1.60	546
4	Marly clay, sands	250-500	2.25	2,300	860	4.47	1,664
5	Crystalline schists	500-1,300	2.50	4,200	1,850	6.58	8,556

The values for G_0 and σ_0 are computed for the middle of each layer.

3. ESTIMATION OF THE NONLINEAR DEPENDENCE OF SOILS

The values presented in Table 1 didn't offer the possibility to estimate the damping capacity, neither the entire dynamic modulus function, just only the initial values G_0. In order to characterize the nonlinear dependence of the soils, we use the curves of the dynamical functions $G_n(\gamma) = G(\gamma)/G_0$ and $D = D(\gamma)$ obtained from resonant columns [6]. The materials used in laboratory method are very alike to those existent in the above profile. The nonlinear variation of the normalized dynamic modulus function G_n and the damping function D with shear strain γ are presented in Figs. 3.1–3.4 for four selected materials.

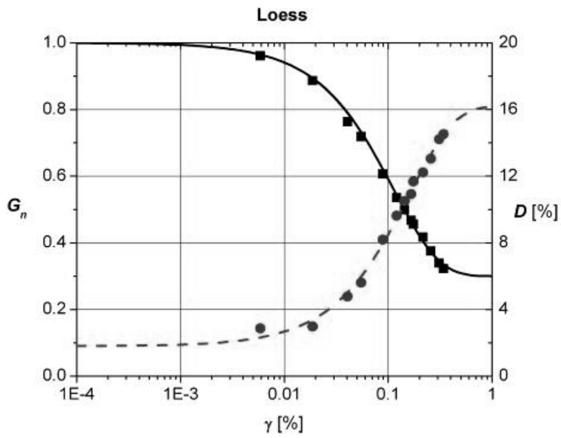

Fig. 3.1 – Material nonlinear function for loess.

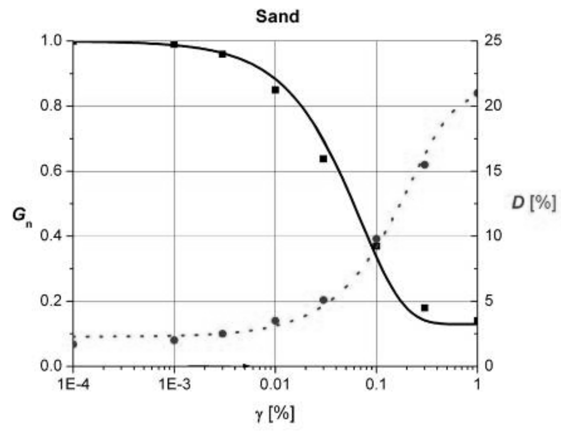

Fig. 3.2 – Material nonlinear function for sand.

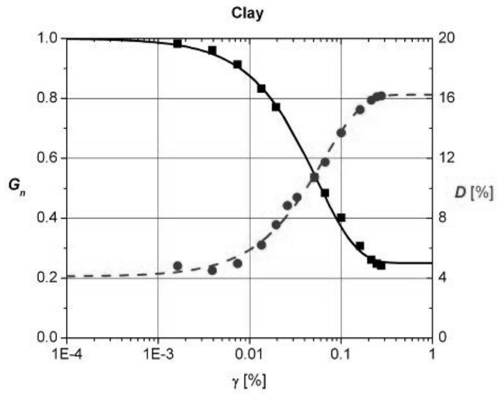

Fig. 3.3 – Material nonlinear function for clay.

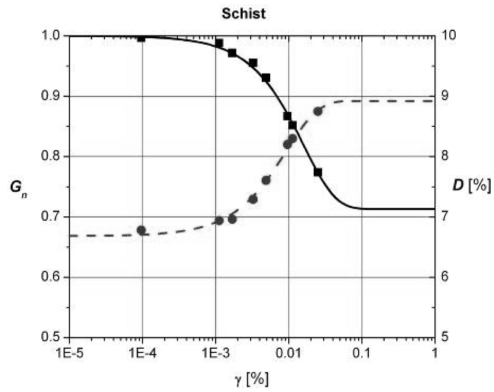

Fig. 3.4 – Material nonlinear function for schist.

4. CORRECTION FOR THE MATERIAL FUNCTIONS SHAPE

The depth where we find the material do influence the initial values of the material functions and the shape of the strain level dependence. In order to obtain the dependence curves from the laboratory test close as much possible to the real behavior of the materials presented in Table 1, the depth correction need to be performed. Depth correction for the shape of dynamic modulus function can be obtained also from experiments on resonant columns using different values for the pressure σ_0. The functions $G = G(\gamma)$ obtained for different σ_0 values show differences in the initial values G_0 and in their dependence of γ. In this circumstances it can be see that analytical expression for modulus function is preserved but its parameters take different values. It follows that the shape of function is changed and the normalized modulus function became:

$$G_n(\gamma,\sigma_0)=a_g(\sigma_0)+b_g(\sigma_0)\left[1+k(\sigma_0)\cdot c_g\cdot\gamma^{e_g}\right]^{-1}. \quad (4.1)$$

This effect on the function curvature is illustrated by introducing a correction function, $k(\sigma_0)$, which depends on consolidation pressure.

The same thing is happening for the damping function:

$$D(\gamma,\sigma_0)=a_d(\sigma_0)-b_d(\sigma_0)\left[1+k(\sigma_0)\cdot c_d\cdot\gamma^{e_d}\right]^{-1}. \quad (4.2)$$

The parameters (a_g, b_g, c_g, e_g, a_d, b_d, c_d, e_d) can be determined from experimental data obtained in resonant columns at different consolidation pressure. With these depth corrections the material functions for the Galati profile became:

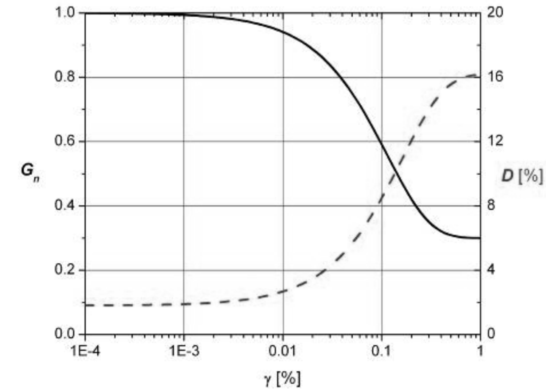

Fig. 4.1 – Corrected material nonlinear function for loess.

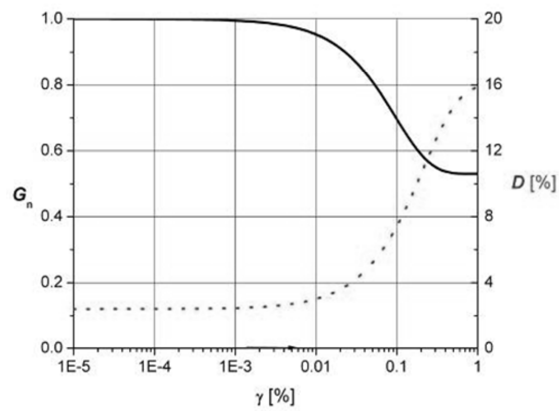

Fig. 4.2 – Corrected material nonlinear function for sand.

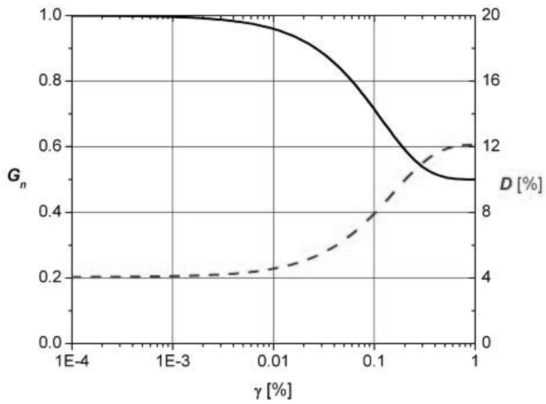

Fig. 4.3 – Corrected material nonlinear function for clay.

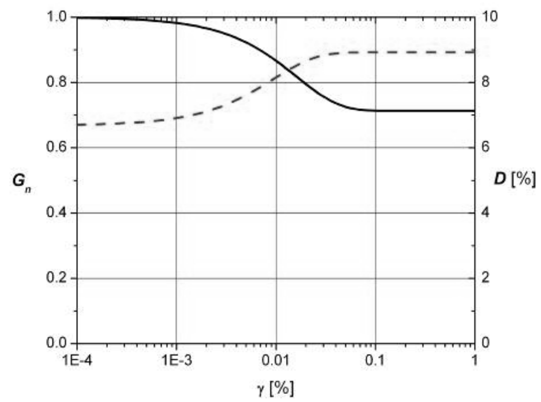

Fig. 4.4 – Corrected material nonlinear function for schist.

In this part of our study we considered the first two layers as being just only one. It can be seen we have the same expressions for the nonlinear functions in Fig. 3.1 and in Fig. 4.1 because we have used the same pressure (for the outcropping layer). Furthermore, for the deepest layer the correction is small because the schists are rigid materials, so is not necessary to perform it. Thus Fig. 3.4 is identical to Fig. 4.4. Anyway, the deepest layer could be considered as bedrock and the nonlinearity is reduced for it.

5. ESTIMATION-CORRECTION FOR TECUCI AREA

The same approach is introduced for the Tecuci city area. The Tecuci profile used is presented in Table 2:

Table 2

Tecuci profile

Layer	Type of Material	Thickness of the layer [m]	Density [g/cm^3]	v_p [m/s]	v_s [m/s]	σ_0 [Mpa]	G_0 [MPa]
1	Sand, gravel, loess deposits	0-10	1.65	360	150	0.04	37
2	Gravel, sand, loess deposits	10-250	1.85	950	400	1.27	296
3	Clay, sand	250-650	1.95	1,700	630	4.65	774
4	Clay, sand	650-1,300	2.10	2,200	780	10.88	1,278
5	Sandy clay, marly limestone, clay marl	1,300-2,200	2.50	3,500	1,600	28.90	6,400

With the same corrections and considerations from Galati area we propose the next nonlinear material functions:

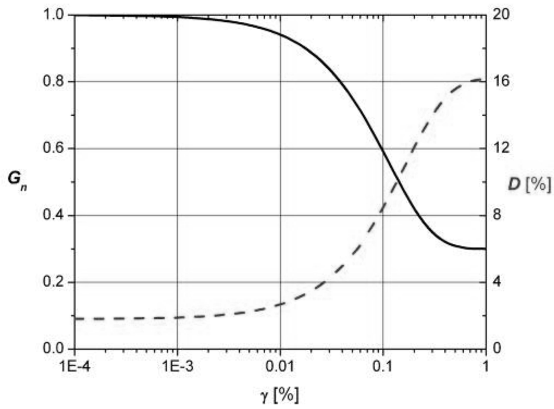

Fig. 5.1 – Corrected material nonlinear function for loess.

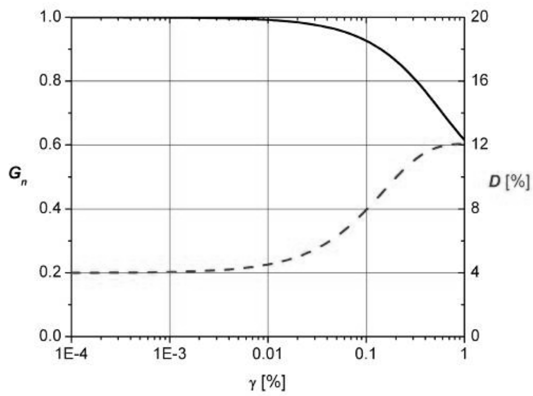

Fig. 5.2 – Corrected material nonlinear function for sand.

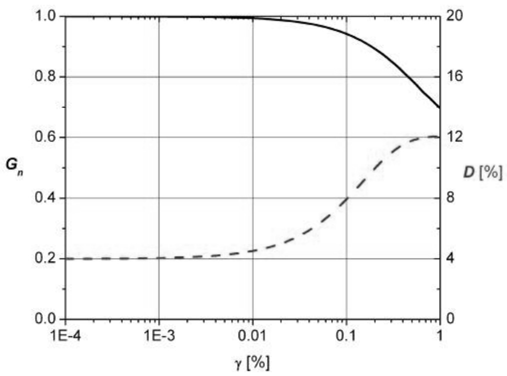

Fig. 5.3 – Corrected material nonlinear function for clay.

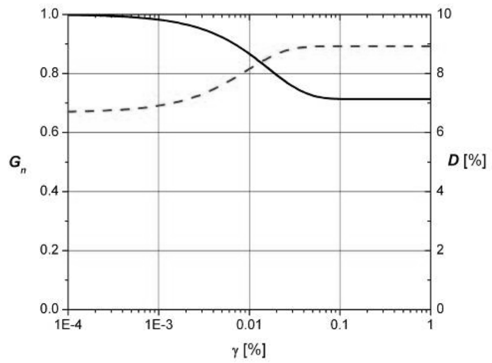

Fig. 5.4 – Corrected material nonlinear function for schist.

6. CONCLUSION

The two material functions (G, D) were estimated by modeling nonlinear soil behavior beneath a certain seismic area. The pictures are representing the dynamic modulus function $G(\gamma)$ and damping function $D(\gamma)$ for materials considered to be founded beneath the interest areas accordingly to knowing geodynamic profiles. The initial values G_0 are known from the geodynamic profiles and Tables 1 and 2 but the damping function $D(\gamma)$ and dynamic modulus function $G(\gamma)$ behavior are obtained from laboratory measurements consisting in experiments on resonant columns. This way, the in situ observations are completed with laboratory tests and give us an overview regarding nonlinear behavior of the superficial soils. Some depths corrections to the G and D functions shape were needed to be performed in order to accomplish our tasks. These combined methods could be useful for the estimation of the local effects and in microzonation studies also.

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