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EVALUATION OF THE DYNAMIC COMPACTION EFFECT WITH VIBRATING ROLLERS BASED ON THE RHEOLOGICAL BEHAVIOUR OF SOIL

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Abstract: *The dynamic response of the vibrant roll in resonance regime highlights the rheologic influence of land. Thus, for the land linear viscoelastic modelled Voigt-Kelvin or Maxwell the dynamic response in resonance may characterize the rheological and dynamic nature of the compactor roller-land interaction. This paper presents the results of the dynamic modelling highlighting the resonance regime and the technological dynamic regime in post-resonance. Thus, there are presented the results obtained for real cases, with "in situ" experiments based on which certain correlations of the response curve with the degree of compaction of the land.*

Key words: *dynamic compaction, soil, rheology*

1. INTRODUCTION

The process of dynamic compaction through vibration of soil is performed with special dynamic equipment such as vibrating rollers. They convey to the layers of earth in the compaction process, harmonic dynamic forces at various frequencies so that the degree of compaction may be achieved after a number of successive passages. In this context, the dynamic compaction process by technological applied to the ground significantly increases density simultaneously with reducing the number of holes in soil.

In this way, it creates the possibility of increasing mechanic resistance and the stability of the natural foundation under dynamic compaction.

The variety of the foundation land by significantly different physical and mechanical parameters on the same working section, makes the rheological modelling an important factor in establishing the parameters of the vibrating system. Thus, it was found that for the same layer of soil, in various areas, placed on the length and with certain distances between them, the rheologic behaviour may be totally different.

Experimentally there have been highlighted two categories of linear viscoelastic rheological models for the process of compaction by vibration, that is: the Voigt-Kelvin and Maxwell model.

Within the research made both " in situ " or the laboratory as well as by number modelling, there highlighted the response curves in dynamic regime both for amplitude-pulse as well as for the force transmitted to the soil – pulse with the due conclusions on areas of interest.

2. THE DYNAMIC MODEL FOR EVALUATING THE VIBRATION COMPACTION PROCESS

The experimental and numerical modelling research highlighted two linear viscoelastic rheological models of the vibratory roll-soil interaction. The number of successive passes of the vibrator roller on the same layer makes the final remnant deformation to highlight the plastic behaviour to the last state by reaching the degree of compaction after which the compaction process is considered completed.

Depending on the content of clay, sand, mineral aggregates, water, fillers, stabilizers, the equivalent viscoelastic rheologic model for each pass, until the end of compaction, can be a Voigt-Kelvin or Maxwell type (fig.1).

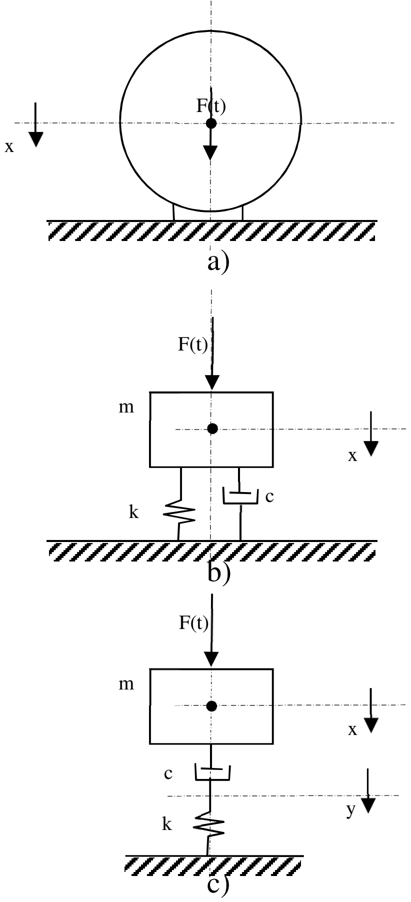


Figure 1: Schematization of the vibrator-roller – soil contact

a) Mass vibrator roller and dynamic force *F*(*t*)
b) Dynamic model (*m, c* | *k*) Voigt – Kelvin with instantaneous displacement *x* at force $F(t)=F_0\sin\omega t$
c) Dynamic model (*m, c* - *k*) Maxwell with instantaneous displacement *x* at force $F(t)=F_0\sin\omega t$

2.1 Voigt-Kelvin dynamic model

The interaction of the vibrating roller with the soil is modelled through the contact area, the nature of the soil, the weight force versus the contact area and the dynamic force of inertial type generated by the vibrator of the compactor roller. The static and vertical dynamic action, the elasticity k and amortization c of the soil as well as mass m in vibratory movement of the compactor roller are physical parameters determinants of the response in displacement and respectively in the transmitted force.

The dynamic vibrator roller-soil model for a soil with natural stabilizer has a linear viscoelastic behaviour highlightable until the last pass. In this case, the level of compaction was reached, with plastic remnant deformation, corresponding to final compaction. Figure 1 presents the schematization of the vibrator roller-soil interaction and the dynamic models of Voigt-Kelvin calculation. For the dynamic model of figure 1b, the differential equation of movement of mass m, formulated in measures of the complex functions, may written down as

$$m\ddot{\tilde{x}} + c\dot{\tilde{x}} + k\tilde{x} = F_0\exp(j\omega t) \qquad (1)$$

where we have

$$\tilde{x} = \tilde{X}\exp(j\omega t)$$
$$\tilde{X} = X_0(-j\varphi)$$
$$F_0 = m_0 r\omega^2$$

where $m_0 r$ is the static moment of the vibrator.
ω – pulse of frequency of rotation of the vibrator
F_0 – amplitude of the perturbator force $F(t)$
Introducing $\ddot{\tilde{x}}, \dot{\tilde{x}}, \tilde{x}$ in relation (1) it merges the amplitude in complex form as

$$\tilde{X} = F_0[k - m\omega^2 + jc\omega]^{-1} \qquad (2)$$

The amplitude of the vibrations of the vibrator roller of mass m emerges as being $X_1 = |\tilde{X}|$ from relation (2) as follows

$$X_1 = m_0 r\omega^2[(k - m\omega^2)^2 + c^2\omega^2]^{1/2} \qquad (3)$$

The dynamic force transmitted to the land in complex formulation is

$$\tilde{Q} = (k + jc\omega)\tilde{X}\exp(j\omega t) \qquad (4)$$

or

$$\tilde{Q} = F_0(k + jc\omega)[(k - m\omega^2) + jc\omega]^{-1} \qquad (5)$$

The amplitude of the transmitted force Q_1 emerges from (5) as being $Q_1 = |\tilde{Q}|$, as follows:

$$Q_1 = m_0 r\omega^2(k^2 + c^2\omega^2)[(k - m\omega^2)^2 + c^2\omega^2]^{-1/2} \qquad (6)$$

2.2 Maxwell dynamic model

Fig. 1, c presents the Maxwell schematization specific to the rheological models for soils with predominantly viscous characteristics. In this case, dusty clay predominates, mixed with sand, water and the natural stabilizer (ecologic).

The differential equations of movement in complex formulation may be written down as

$$\begin{cases} m\ddot{\tilde{x}} + k\tilde{y} = F_0\exp(j\omega t) \\ c(\dot{\tilde{x}} - \dot{\tilde{y}}) = k\tilde{y} \end{cases} \qquad (7)$$

where we have

$$\tilde{x} = \tilde{X}\exp(j\omega t) \text{ cu } \tilde{X} = X_0(-j\varphi)$$
$$\tilde{y} = \tilde{Y}\exp(j\omega t) \text{ cu } \tilde{Y} = Y_0(-j\theta)$$
$$F_0 = m_0 r\omega^2$$

By solving system (7) we obtain

$$\tilde{X} = F_0(k + jc\omega)\tilde{D}^{-1}$$
$$\tilde{Y} = F_0(jc\omega)\tilde{D}^{-1} \qquad (8)$$
$$\tilde{D} = -m\omega^2 k + jc\omega(k - m\omega^2)$$

Amplitude $X_2 = |\tilde{X}|$ from relation (8) emerges as

$$X_2 = m_0 r\omega^2 c[m^2\omega^2 k^2 + c^2(k - m\omega^2)^2]^{-1/2} \qquad (9)$$

The force transmitted to the soil is given by the complex function $\tilde{Q} = k\tilde{Y}\exp(j\omega t)$ or as follows

$$\tilde{Q} = jc\omega k F_0 \exp(j\omega t)\tilde{D}^{-1} \qquad (10)$$

The amplitude of the transmitted force $Q_2 = |\tilde{Q}|$ which emerges from relation (10) as

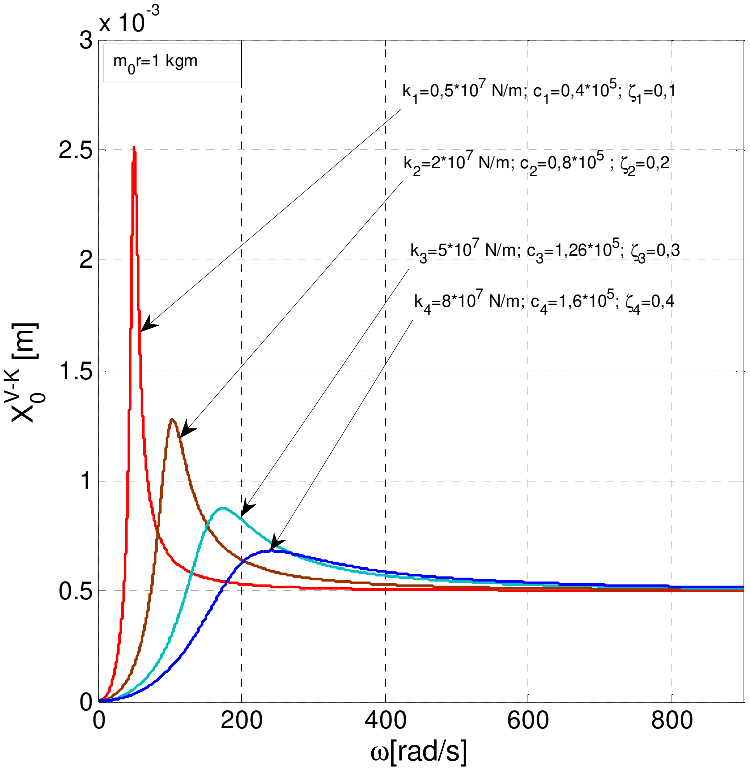
$$Q_2 = m_0 r\omega^2 ck[m^2\omega^2 k^2 + c^2(k - \omega^2)^2]^{-1/2} \qquad (11)$$

3. DYNAMIC RESPONSE OF THE VIBRATOR ROLLER – SOIL SYSTEM

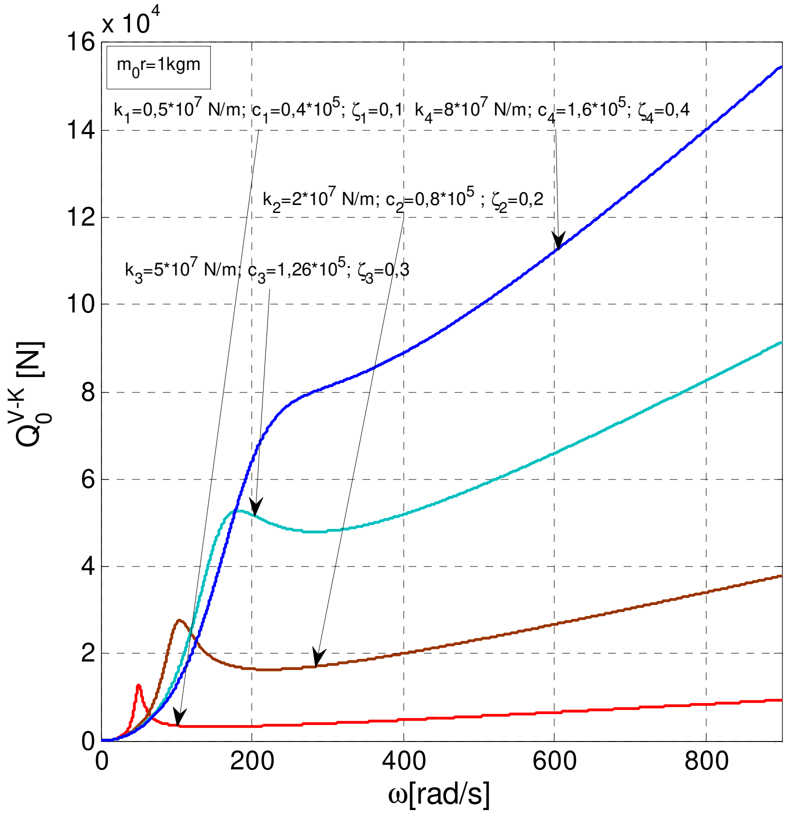
The compaction process was analysed for two distinct types of soil under its rheologic aspect, Voigt-Kelvin and Maxwell being modelled. As a result of the experimentation in the field with the same vibrator roller, there were evaluated the parametric values for amplitudes $X_1 = X_0^{K-V}$, $X_2 = X_0^M$ and the maximum transmitted force $Q_1 = Q_0^{K-V}$and $Q_2 = Q_0^M$. The experimental assessment and the numeric testing based on the calculation relations were made for each passing modifying the rigidity of the compacted layer k_i, i=1, 2…4 and of the amortization by the amortization rate ζ_i. i=1, 2…4, knowing the amortization factor of the dissipative force $c_i = 2\zeta_i\sqrt{mk_i}$ for the linear viscoelastic behaviour case.

The parameters of the experimental roller vibrator are mass m=2000kg, static moment m_0r= 1kgm, and rigidity after each pass are k_1 = 5 MN/m, k_2 = 20 MN/m, k_3 = 50 MN/m, k_4 = 80 MN/m, and ζ_i=0.1; 0.2; 0.3; 0.4, where i=1, 2…4

Figures 2 and 3 present the dynamic response curves for the Voigt-Kelvin model and respectively for the Maxwell model.

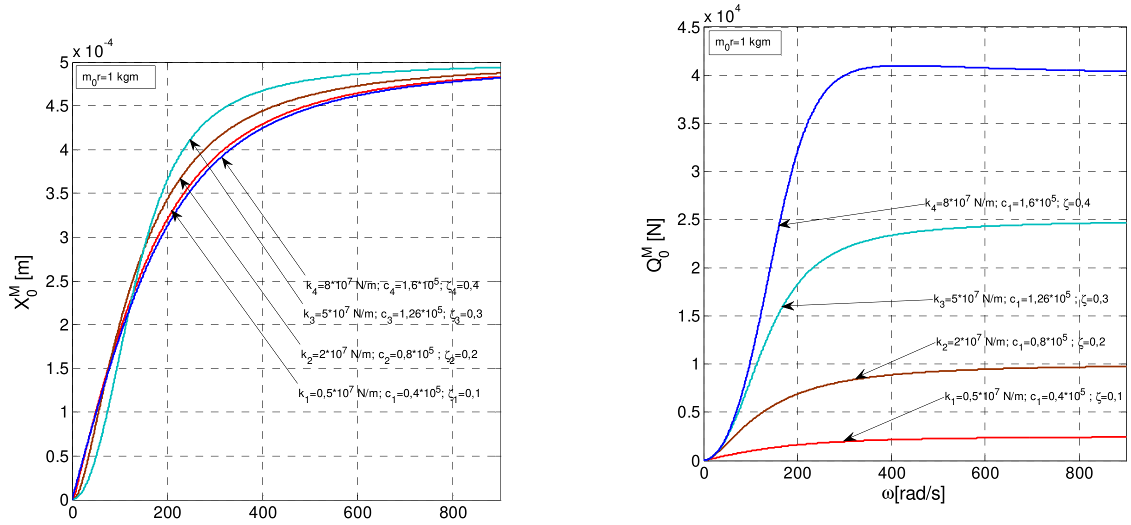


a)



b)

Figure 2: Dynamic response for the Voigt – Kelvin rheologic model:
a) Variation of amplitude according to pulse ω and rigidity k;
b) Variation of the force transmitted to the soil.



b)

a)

Figure 3: Dynamic response for the Maxwell model:
a) Variation of amplitude according to pulse ω and rigidity k;
b) Variation of the force transmitted to the soil.

4. CONCLUSIONS

For natural lands with adding of mineral aggregates and ecological stabilizers, the dynamic compaction process is of the structure of the soil. Thus, the content of clay, sand, natural aggregates, blanket and ecological stabilizers determines two categories of distinct rheological models. For the ecologically stabilized soils, the experimental results in the laboratory and "in situ", there may be established two types of rheological models, namely:

- the Voigt-Kelvin rheologic model for clay soils (30%), with sand (18%) and river mineral aggregates (10%) and water (10%) with stabilizer (2%)
- the Maxwell rheologic model for clay soils (5%), sand (30%), river mineral aggregates (5%), water (12%) and stabilizer (3%)

The experimental tests were carried out in a trial field, with successive passages on the same layer at an excitation pulse $\omega = 400$ rad/s with the roller movement speed of 6 km/h. There were prepared two test tracks, arranged in parallel, with 10 m width and 1200 m length with soil layers with the compositions and dosages previously referred to.

Based on the "in situ" parametric measurements and the numerical assessments using the calculation relations from Chapter 2, the following conclusions emerged:

a) the Voigt-Kelvin model for the first category of soils, assures the significative description of the compaction process with amplitudes of vibrations included between the range of (0.50....0,52) mm and with the maximum force transmitted after each passage from 5 kN to 85 kN, reaching the compaction degree of 95% at the last passage.

b) the Maxwell model is able of describing the process of compaction of the second category f soil, with the response amplitude in the range of (0.425....0,470) mm with maximum forces transmitted from 2.5 kN to 41 kN, reaching the compaction degree of 91% at the last passage.

Consequently, it is found that the Voigt-Kelvin rheological model shows more efficient compaction of the soil in the first category at compaction by vibration. By trials "in situ" the soil in the second category may be improved in order to increase the transmitted force and the degree of compaction.

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Evaluarea efectului de compactare dinamică cu rulouri vibratoare pe baza comportării reologice a terenului

Rezumat: Răspunsul dinamic al ruloului vibrator în regim de rezonanță evidențiază influența reologică a terenului. Astfel, pentru terenuri modelate vâscotic liniar Voigt-Kelvin sau Maxwell răspunsul dinamic în rezonanță poate caracteriza natura reologică și dinamică a interacțiunii rulou compactor-teren. În cadrul lucrării sunt prezentate rezultatele modelării dinamice evidențiindu-se regimul de rezonanță și regimul dinamic tehnologic în postrezonanță. Astfel, se prezintă pentru cazuri reale, cu experimenări "in situ" rezultatele obținute pe baza cărora pot fi stabilite corelații certe ale curbei de răspuns cu gradul de compactare a terenului.

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