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USE AND EFICIENCY OF MULTIPLE MASS DAMPERS IN CONSTRUCTION FOUNDATIONS

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Abstract: *In the first part of the paper an overview of methods for vibration reduction of construction is presented from the point of solutions of dampers, as well as excitation of dynamic harmonic and seismic forces. In the second part of the paper the vibration of circle foundation under the harmonic excitation is analyzed. The spring-mass system is attached to the foundation. The horizontal and rotational vibrations of rigid foundation is analyzed. Foundation rests on the elastic half space. Based on the theory of body resting on the half space under dynamic excitation, the problem is described by means of differential and then matrix equation. The effects of reduction of foundation vibration are studied in detail. Several plots of the amplitude deflections of the foundation are also given and discussed.*

Keywords: Multiple mass dampers, tuned vibrations, dynamic absorbers.

1. Introduction

Technological progress and needs of civil engineering development in the area of dynamic excitations: seismic, para-seismic loads cause searching methods and means of protection building objects against vibration. Considerable attention has been paid to researches of effectiveness of multiple mass dampers. Snowdon J.C. (1974) summarize methods in order to reduce level of vibrations such as removal of vibration source, balancing, aligning of device resting on the foundation, modification of technological process, sliding of devices producing vibrations in a distance from object sensitive to vibrations, increasing base stiffness, active, semi-active, passive, hybrid vibration isolation, application of passive, active, semi-active, hybrid dynamic dampers, use of passive, active, semi-active, hybrid bracing. Cox S.J.(1998), Soong T.T., Spencer B.F. (2002) and Soong T.T., Constantinou M.C. (1993) in their researches showed wide application of dynamical protection of structure in civil engineering. What is important in practice vertical or sloping trenches filled with isolation materials are applied to protect structures against seismic or para-seismic excitation. Reducing of propagation of surface waves is possible by covering the base surface with dynamical vibrations dampers, as well Nashif A., Johes D., Henderson J. (1985) presented the direction of development of reduction vibrations. A well accepted strategy in utilizing dynamic control systems is based on the increase of structural damping. As a first idea damping devices can be installed. Then, they have the task to damp the relative motion between two structures, two parts of the same structure, or the structure and the 'rigid' vicinity. The damping effects may be obtained by friction, plastic deformation or viscose behavior inside the device. The protection of the environment from vibrations is a priority requirement to be achieved. Methods of vibration reduction using absorbers are an effective way to reduce vibrations, which was presented among others at work Warburton G.B. (1982). The problem of vibration of structural systems and their reduction was analyzed in terms of the seismic excitation. In the papers of Dutkiewicz M. (2005) and Dutkiewicz M. (2006) is shown the effectiveness of the reduction of such vibrations model stamp and beams under seismic excitation.

2. Horizontal and rotational vibrations of foundation with multiple tuned mass damper

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Application of dynamic dampers in order to reduce vibration foundations for the machine or reduce the harmful effects of vibration transmitted on structures and buildings was the subject of research of Szwec H.S., Sedin W.Ł., Kiriczek A. (1987) and Gołębiowska I, Dutkiewicz M. (1999). Dynamic damper can be used both at the design stage as well as on the existing foundations. Efficiency one mass dynamic dampers for vibration foundations, resting directly on the ground floor, loaded with harmonic forcing limited unstable frequency was investigated by Korieniew B. G., Reznikow L. M. (1988). Foundations rest on the ground, have an increased damping properties. This is most evident with the vibration of vertical and horizontal vibrations, regardless of the adopted model, describing the deformable surface. In such situations, the effectiveness one mass vibration dampers may be insufficient, particularly in the case where the forcing frequency is unstable. The frequency narrow-band dampers can be removed using eg. multiple mass damper (MMD). The issue of the use of MMD to reduce vibration massive foundation is still insufficiently explored. In this section the use of MMD for horizontal and rotational vibrations is analysed

This analytical analysis can be useful as computational schemes of foundations of many real objects, eg. foundations for antennas and chimneys, have a circular base, besides the circular base of the foundation may be accepted also as a result of approximation of the foundations of other complex geometric form.

2.1. Assumptions

Horizontal and rotational vibrations of foundation equipped with two mass damper were analysed. Foundation with the circle basement rests on the spring half space. Two cases of excitation are analyzed: horizontal harmonic force and rotational momentum. The effectiveness of tuned mass damper fixed to foundation is studied.

The differential equation of motion can be written in the form:

$$M\ddot{X} + C\dot{X} + KX = P(t) \tag{1}$$

where M, C, K represent the mass, damping and stiffness matrices, respectively. P(t) is force excitation, in the first part of analyses is a horizontal harmonic force, in the second part of analysis is the harmonic momentum.

The following non-dimensional parameters are defined as:

$$\xi_k = \frac{k}{2m_0\omega_0}, \quad \xi_c = \frac{c}{2m_0\omega_0} \quad \mu_1 = \frac{m_1}{m_0}, \quad \mu_2 = \frac{m_2}{m_1}, \quad M_0 = \frac{m_0}{\rho_0 R^3}, \quad g = \frac{\nu}{\omega_0}, \quad k_c = R\nu\sqrt{\frac{\rho}{G}}$$

m_0 – mass of the foundation, m_1 is the first mass damper, m_2 is the second mass damper, k,c are parameters of the damping system, ρ is the density of the half space, R is the radius of the circle foundation, υ is force frequency, G is the shear frequency of the half space,

μ_1 ratio of masses of the TMDs on the first level to the main mass,

μ_2 ratio of masses of the TMDs on the second level to the main mass. In above expressions ω_0 is the natural frequency

The equations of dynamic equilibrium of the horizontal vibration stamp have a similar form to that of the vertical vibration, except that the coefficients γ and δ depending on dimensionless force frequency and shear modulus.

2.2. Horizontal vibrations

Selection of the optimum parameters of dynamic vibration dampers in case of horizontal vibrations of foundation was carried out in such a way as to obtain reducing vibration amplitudes in the greatest band without exceeding the allowable predetermined value of amplitude. As a result, the optimum parameters for the horizontal vibrations were found for m_0 = 25; A_{1max} = 4.9715, for one mass damper μ_1=0,075, $\xi_{k,1}$= 0,472, $\xi_{c,1}$= 0,472 and for two mass damper is μ_1=0,075, μ_2=0,0375 $\xi_{k,1}$= 0,486, $\xi_{c,1}$= 0,105,

$\xi_{k,2}$ = 0,493, $\xi_{c,2}$ = 0,146. The effectiveness of the one- and two mass damper in case of horizontal vibrations of the foundation is illustrated in figure 1. The use of the one mass damper provides the reducing of the maximum amplitude by 12% in relation to amplitude of vibration of foundation without the damper and by 25% in case with two mass damper. The wide band frequency in which the vibration amplitude reaches the similar values is achieved.

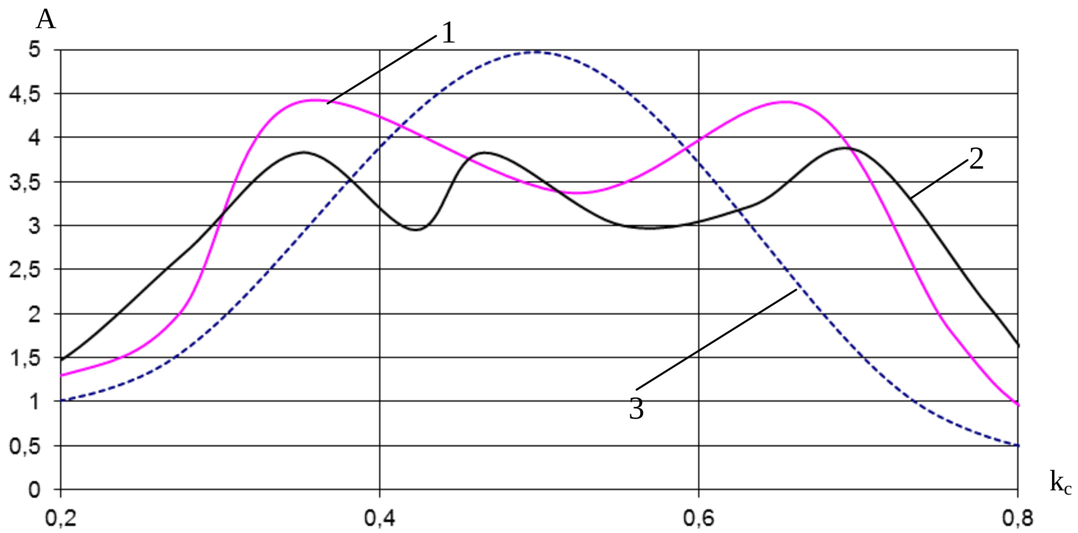

Fig.1. Amplitude – frequency characteristic of horizontal vibrations for foundation with one- and two mass damper in case of optimal parameters:1- for one mass damper, 2- for two mass damper, 3- without mass damper.

2.3. Rotational vibrations

Analyzing the vibration of rotating foundation with circular base one can use the equilibrium equations describing the vertical vibrations, in which the displacement are replaced to rotating angles, and masses can be replaced to respective moments of inertia of damper and foundation. Selection of the optimum parameters of dynamic dampers for rotation vibration was carried out as in previous analyzed cases, ie. for reducing of vibration amplitudes of foundation in the greatest frequency band, without exceeding the allowable predetermined value of amplitude. The optimum parameters were found for the case of rotational vibration of the foundation equipped with:

M_0 = 30; A_{1max} = 6.3121 for one mass damper μ_1=0,095, $\xi_{k,1}$ = 0,439, $\xi_{c,1}$ = 0,138 and for two mass damper is μ_1=0,095, μ_2=0,0475 $\xi_{k,1}$ = 0,484, $\xi_{c,1}$ = 0,136, $\xi_{k,2}$ = 0,491, $\xi_{c,2}$ = 0,127. Effectivennes of two mass damper fixed to the foundation is illustrated in the figure 2.

3. Conclusions

In this paper the posibility of reducing the foundation using the multiple mass vibration damper is investigated. The study can be concluded as follows: effectiveness of multiple mass dampers arises with increase of number of masses from one to two masses, use of damper mass causes of amplitude vibration peaks.

The performed analysis can be useful in real solutions as computational schemes of foundations of many real objects, eg. foundations for antennas and chimneys, have a circular base, besides the circular base of the foundation may be accepted also as a result of approximation of the foundations of other complex geometric form.

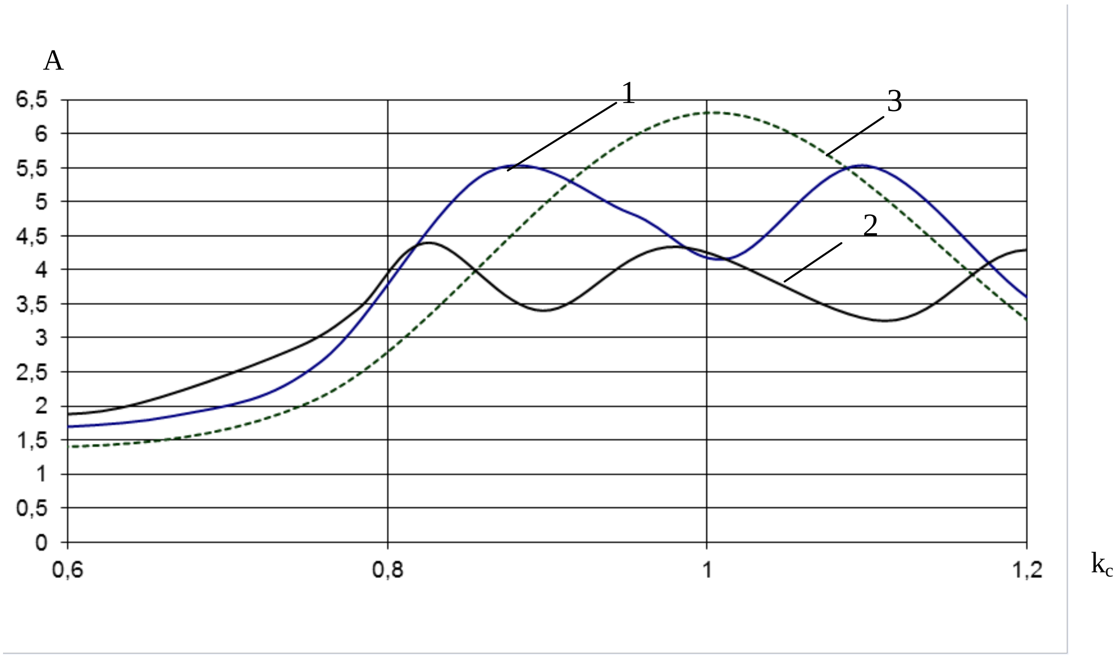

Fig.2. Amplitude – frequency characteristic of rotational vibrations for foundation with one- and two mass damper in case of optimal parameters:1- for one mass damper, 2- for two mass damper, 3- without mass damper.

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