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UDK 624.078.012.35.046
S.M. Auta, A.M. Maslennikov (Saint Petersburg State University of Architecture and Civil Engineering)

DYNAMIC STRUCTURAL ENGINEERING FOR WIND IMPACT BY ANALYTICAL METHOD

It is known, that actual building constructions have infinite number of the degrees of freedom [1]. But their complete recording is unreal even when calculating by means of modern computers. Thus usually one is confined to the finite number of the degrees of freedom, leaving behind, as a rule, modes of vibration with the highest frequencies. Finite number of the degrees of freedom can be obtained immediately at the stage of structural design selection via simulated reduction of the distributed mass to the joint one. Therefore, any actual structure can be represented as a system with finite number of the degrees of freedom.

In [2], there is a program in MatLAB characters for the design of the systems with finite number of the degrees of freedom for kinematic impact. The program was readapted for the force impact design. To assess somehow its effectiveness in case of designing for the wind impact, analytical method was applied. Analytical problem solution gives a chance to analyse the obtained results more completely and to come to conclusions when designing structures. Herewith, it has to be noted that the method applied uses the Fourier transform, hence enabling solving the linear-stated problems only [1], [2].

In this piece of work, the method considered is applied to the structural engineering for wind impact, represented by the pulse component. Full impact of the wind loading is performed by summation with average component. Here, pulse component of the wind is represented in the time-explicit form, i.e. wind pressure is defined as the function of time. This function has a form of the jogged line, which is easily approximated by trapezoid impulses.

Solution of equation [1]

$$\delta_{11} m_1 y_1(t) + \delta_{11} \beta_1 y(t) + y(t) = f(t) \qquad (1)$$

is tried in form

$$y_1(t) = \int_{-\infty}^{\infty} Y(\omega) e^{i\omega t} d\omega , \qquad (2)$$

where $Y(t)$ is a complex-valued function of the real argument [3]. Spectral function for the trapezoid impulse has form [2] (in expression for $F(\omega)$ $S_1 = (F_2 - F_1)/\phi_1$).

$$F(\omega) = \frac{1}{2\pi} \int_0^{\tau_1} (F_1 + St) e^{-i\omega t} dt_1 = \frac{F_1}{2\pi} \frac{1 - e^{-i\omega\tau_1}}{i\omega} + \frac{S}{2\pi} (i\tau_1 - \frac{e^{-i\omega\tau_1}}{\omega} + \frac{e^{-i\omega\tau_1}}{\omega^2} - \frac{1}{\omega^2})$$

Resultant displacement expressions are listed below:

a) for time $t < \tau_1$

$$y_1(t) = \delta_{1F} \left[F_1 + St + e^{-\alpha_1 t_1} \left(-F_1 \cos\omega_1 t_1 - \frac{S}{\omega_1} \sin\omega_1 t_1 \right) \right], \qquad (3)$$

b) for time $t > \tau_1$

$$y_1(t) = \delta_{1F} \left[e^{-\alpha_1 t_1} \left(-F_1 \cos\omega_1 t_1 - \frac{S}{\omega_1} \sin\omega_1 t_1 \right) + e^{-\alpha_1 t_2} \left(F_2 \cos\omega_1 t_2 + \frac{S}{\omega_1} \sin\omega_1 t_2 \right) \right], \qquad (4)$$

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where $t_2 = t_1 - \tau_1$.

In paper [1] the same solution was obtained by means of summation of solutions for square and triangle impulses. TBASIC program was compiled by formulae (3) and (4). The comparison of displacements of mass upon the wind impact, obtained by numerical and analytical methods, is shown using the system with a single degree of freedom (Fig. 1).

Analysis of the diagram shows no complete match of the lines, but displacement values have the same order. This fact allows concluding that the program, compiled in MatLAB characters, can be applied for the systems with several degrees of freedom. It should be noted, that, in the case of numerical solution, decrease of the integration interval D t leads to the refinement of results.

Solutions (3) and (4) can be implemented when designing the systems with infinite number of degrees of freedom, if using master coordinates [2]. To calculate eigenvectors and natural frequencies, it is convenient to apply MatLAB computation system [2], [4], which provides normalized eigenvector matrix and eigenvalues, easily transformed into natural vibration frequencies of the structure.

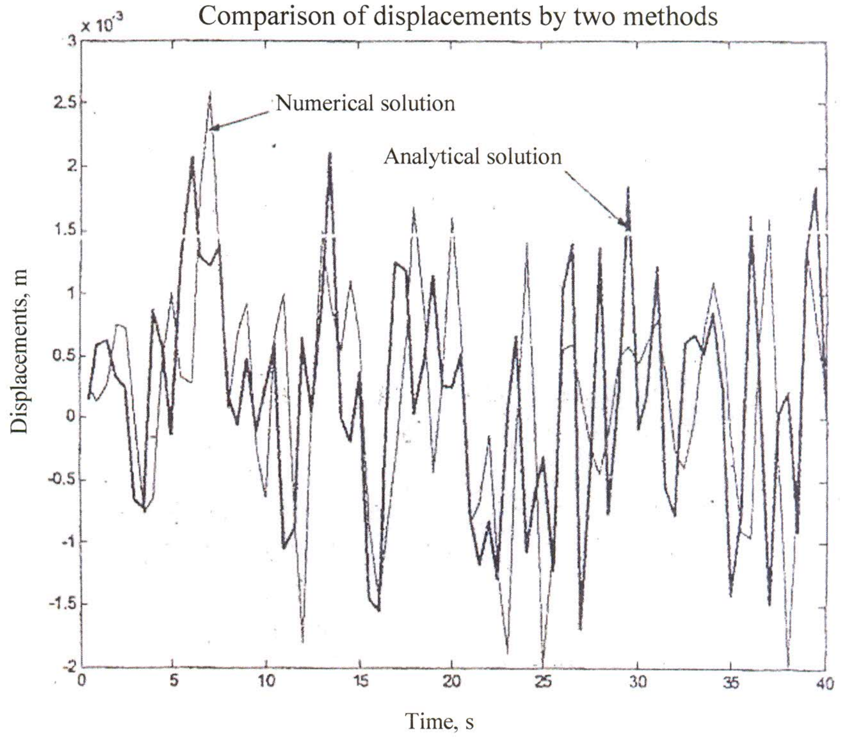

Fig. 1

When solving the set of equations of the type (1), transformation of the basic unknowns into new basis is performed under the property of orthogonality of the fundamental frequency modes.

$$\mathbf{Y}(t) = \mathbf{u}^*\mathbf{q}(t). \tag{5}$$

In case of equality of masses, transformation matrix is obtained by normalization of eigenvectors with masses by formula

$$\mathbf{u} = \frac{1}{\sqrt{m}}\mathbf{v}.$$

During the transformation till the expression, when the system falls into separate equations

$$\mathbf{u'MFMu}\,\ddot{q}(t) + \mathbf{u'Muq}(t) = \mathbf{u'M}\Delta_{jF}\mathbf{f}(t)$$

function of time *F(t)* stays unaltered. And only when defining *q(t)*, the values $F_j(t)$ are substituted from the equation of the type (1), where custom ones for each mass (floor), according to SHiP, i.e.

$$\Delta_{jF}\mathbf{f}(t) = \begin{bmatrix} \delta_{1F} f_1(t) \\ \delta_{2F} f_2(t) \\ \ldots\ldots \\ \delta_{nF} f_n(t) \end{bmatrix}$$

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Yes we can!

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