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Influence of Seismic Waves on Underground Cylindrical Constructions in the Deformable Environment

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***Abstract*—In work the field of dynamic pressure and displacement arising in close a cylindrical body of any density in elastic means is studied at passage of a flat wave of expansion. It is received numerical result on the basis of method of Gauss and especially to functions.**

Keywords—Cylindrical body, waves of expansion, method of Gauss, shifting, equation of motion.

Introduction

In a case enough extended underground constructions and the influence directed perpendicularly of its longitudinal axis, an environment and covering slay are reduced to a flat problem of the dynamic theory of elasticity. In the assumption of the deformed condition generalized plainly the equation of movement in mixtures looks like [1]

$$(\lambda + 2\mu) graddiv\vec{u} - \mu rotrot\vec{u} + \vec{b} = \rho \frac{\partial^2 \vec{u}}{\partial t^2} \qquad (1)$$

Where λ and μ - modules of the elasticity, named constants to the Llama; $\vec{b}$ - a vector of density of volumetric forces $(b=0)$; ρ - density of a material, $\vec{u}-$ a vector of mixture which depends from r, θ, t. On internal $(r=a)$ and external $(r=b)$ ground cylindrical the following conditions should be satisfied. The task in view is solved in potentials of moving:

$$\vec{u} = u_r \vec{i} + u_\theta \vec{k};$$

$$u_r = \frac{\partial \varphi}{\partial r} + \frac{1}{r}\frac{\partial \psi}{\partial \theta};$$

$$u_\theta = \frac{1}{r}\frac{\partial \varphi}{\partial \theta} - \frac{\partial \psi}{\partial r}.$$

Potentials φ and ψ satisfy to the wave equation

$$\nabla^2 \varphi = \frac{1}{C_\alpha^2}\frac{\partial^2 \varphi}{\partial t^2}; \quad \nabla^2 \psi = \frac{1}{C_\beta^2}\frac{\partial^2 \psi}{\partial t^2} \qquad (2)$$

Where φ and ψ - are potentials of moving, C_α and C_β - phase speeds of distribution of waves of expansion and shift. In job [1] it is shown, that its movement nonrational and isothermal is possible to count a liquid ideal. At pressure up to 100 MPa movement of a liquid is well described wave alignment for potentials of speed of particles of a liquid [2]

$$\nabla \varphi_0 = \frac{1}{C_o^2}\frac{\partial^2 \varphi_0}{\partial t^2},$$

Where C_0 - speed of a sound in a liquid. Potential φ_0 and a vector of speed of a liquid $\vec{V}$ are connected by dependence $\vec{V} = grad\varphi_0$. Pressure of a liquid can be determined with the help of linearized integral of Koshi - Lagrange $P = -\rho_o C_0 \frac{\partial \varphi_0}{\partial t}$, where ρ_0 - density of a liquid.

Under condition of a continuous flow of a liquid normal a component of speed of a liquid and an environment on a surface of their contact should be equal, i.e.:

$$\left.\frac{\partial \varphi_0}{\partial n}\right|_{S_o} = \frac{\partial u_r}{\partial t},$$

Where S_0 - a surface of contact; n - normal surfaces of an environment; u_r - moving of an environment on a normal. The falling flat wave of expansion is considered an axis extending in a positive direction x and it is represented as follows:

$$\varphi^{(p)} = \varphi_0 e^{i(\alpha x - \omega t)}; \; \psi^{(p)} = 0; \text{ or}$$

$$\psi^{(p)} = \psi_0 e^{i(\beta x - \omega t)}; \; \varphi^{(p)} = 0,$$

Where φ_0 or ψ_0 sizes of amplitude; ω - circular frequency; $\alpha^2 = \omega^2 / C_p^2$ and $\beta^2 = \omega^2 / C_\beta^2$ wave numbers of expansion and shift accordingly. If border of area in which the wave field is studied leaves in infinity then additional conditions in infinity are required and are in detail discussed in job [1, 2]

$$\lim_{r\to\infty}\varphi = 0 \quad \lim_{r\to\infty}\left(\sqrt{r}\right)\left(\frac{\partial\varphi}{\partial r}\pm ik,\varphi\right)=0,$$

$$\lim_{r\to\infty}\psi = 0 \quad \lim_{r\to\infty}\left(\sqrt{r}\right)\left(\frac{\partial\psi}{\partial r}\pm ik,\psi\right)=0 \qquad (3)$$

If function φ satisfies to equation of Helmholtz (in our case it satisfies) in infinite area can provide unambiguity of the decision of a problem to requirements (3). Here r radius in cylindrical system of coordinates. On border of two bodies, the condition of rigid contact satisfies, i.e. the condition of equality of corresponding moving and pressure satisfies:

$$\sigma_{rr}^{(1)} = \sigma_{rr}^{(2)}\ ;\ \sigma_{r\theta}^{(1)} = \sigma_{r\theta}^{(2)}\ ;$$

$$u_r^{(1)} = u_r^{(2)}\ ;\ u_r^{(1)} = u_r^{(2)}\ .$$

One of problems is devoted to distribution of harmonious shift waves to a bidimentional elastic body with a round aperture (supported). In such statement imposing suitable waves and the waves of shift reflected from an aperture and a stretching - compression that results in concentration of a pressure is studied. The decision of diffractional problems for a flat harmonious shift wave is received in [1] which has the following kind ($\sigma_{\theta\theta}^{*}=\sigma_{\theta\theta}/\ \sigma_0$; $\sigma_\theta=\mu\beta^2\psi_0$; ψ_0 - amplitude of falling waves, μ - factor to the Llama)

$$\sigma_{\theta\theta}^{*} = \frac{8}{\pi}\left(1-\frac{1}{n^2}\right)\sum_{n=1}^{\infty} i^n \frac{n\left(n^2-1-\dfrac{\beta^2\alpha^2}{2}\right)H_n(\alpha a)}{\Delta_n}\sin n\theta\, e^{-i\omega t}$$

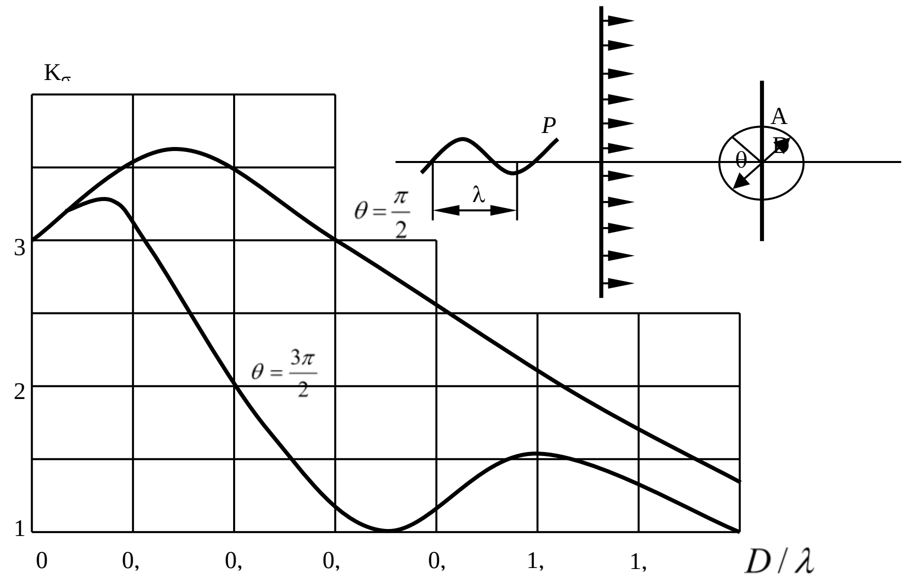
$$\Delta_n = \alpha a H_{n-1}(\alpha a)\left[(n^2-1)\beta a H_{n-1}(\beta a)-(n^3-n+\frac{1}{2}\beta^2\alpha^2)H_n(\beta a)\right]+$$

$$+H_n(\alpha a)\left[-(n^3-n+\frac{1}{2}\beta^2\alpha^2)\beta a H_{n-1}(\beta a)+(n^2-n-\frac{1}{4}\beta^2\alpha^2)\beta^2\alpha^2 H_n(\beta a)\right],$$

Where $H_n(\beta a)$ - function of Henkel; $\alpha = \omega/C_p$; $\beta = \omega/C_S$; C_p and C_S - according to speed of distribution of longitudinal and cross-section waves; ω - circular frequency, π = 3,14. Calculations by methods of the theory of elasticity give at absence covering slay around of an aperture and length of a wave of the essentially greater of diameter of the aperture, the following approached expression for pressure on perimeter:

$$\sigma_{\theta\theta} = \frac{2G\upsilon_0}{c_S}\left(1-c_S^2/c_p^2\right)\sin 2\theta\,\sin\omega t,$$

Where G - the module of shift for a ground, υ_0 - amplitude of speed falling seismic waves. Whereas long seismic waves, as a rule, exceed the characteristic sizes cross-section cut developments (for example, diameter *D*), especial interest is represented with the decision of diffractional problems for long-wave influences, i.e



Picture 1. Dependence of factor of concentration of a pressure on length of a wave.

when $\frac{D}{\lambda} < 1$. At the big lengths of waves ($\frac{D}{\lambda} = 0{,}04 \div 0{,}16$) the maximal factors of dynamic concentration appeared on 5 - 10 % more, than at corresponding biaxial static weighting (λ→∞) [1]. At $\frac{D}{\lambda} > 0{,}16$ dynamic concentration of pressure is essentially lower static. The submitted numerical results shows, that as against a case of rigid inclusion [1], size K_σ very strongly depends from $\frac{D}{\lambda}$. These are distinctions it is possible to attribute to an opportunity of distribution of the generalized waves such as Relay on a concave free cylindrical surface of a cavity. The account of viscous properties of a material of an environment at calculation on action of seismic waves, reduces pressure and moving on 10 - 15 %.

Calculations show, that at the fixed values of amplitude and duration of action of a falling wave with increase in acoustic parameters of a liquid, deflections and efforts also increase. In the field of long waves of distribution of a pressure of a pipe with a liquid and without a liquid differ up to 15 %, and in the field of short waves in some values of frequency they differs up to 40 %.

The received numerical results allow to draw the following conclusions:

- the phenomenon of a local resonance is shown more strongly for seismic influence as SV - waves than P - waves.
- presence of water in pipes increases seismic influence by them on 10-20 %.
- the more densely a ground of an embankment, the less seismic influence on underground pipes. At l > 10D the dynamic problem is reduced to quasistatic.
- change of thickness of a wall and a class of concrete practically does not influence dynamic pressure of a ground upon ferric-concrete pipes at seismic influence. It is possible to note, that designing optimum covering slay in view of influence of dynamic loading demands generally, except for a usual choice of thickness and a constructional material, the coordination of the last with properties of a surrounding hills.

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