Impact of Seismic Waves on Structures in a Deformable Medium

Sh.R.Akhmedov
T.O. Juraev
U.Kh.Umedova
"National Research University of
Tashkent Institute of Irrigation and
Agricultural Mechanization Engineers"
Bukhara Institute of Nature Management
E-mail: jurayev1964@mail.ru ,
umedaumedova766@gmail.com

Abstract: In this paper, we study the stress-strain state that occurs when a cylindrical body of arbitrary density is exposed to and around it. The problem is solved with the help of special functions and the Gauss method, numerical results are obtained.

Keywords. shell; elastic medium; Heaviside function; transmitting wave; daytime

In the case of sufficiently extended underground structures and an impact directed perpendicular to its longitudinal axis, the environment and lining are reduced to a plane problem of the dynamic theory of elasticity (or viscoelasticity). Assuming a generalized plane strain state, the equation of motion in mixtures has the form [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 - elastic moduli, called Lame constants; $\vec{b}$ - volume force density vector $(b=0)$; ρ - material density, $\vec{u}-$ - material density $(r=a)$ and external $(r=b)$ Gruniya cylindrical must satisfy the following conditions. The problem is solved in the displacement potentials:

$$\vec{u}=u_r\vec{i}+u_\theta\vec{k}; \quad u_r=\frac{\partial\varphi}{\partial r}+\frac{1}{r}\frac{\partial\psi}{\partial\theta} \quad ; \quad u_\theta=\frac{1}{r}\frac{\partial\varphi}{\partial\theta}-\frac{\partial\psi}{\partial r}.$$

Potentials φ and ψ satisfy the wave equation

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

where φ and ψ - are displacement potentials, C_α and C_β- phase velocities of propagation of expansion and shear waves. It was shown in [1] that the fluid can be considered ideal, and its motion is irrotational and isothermal. At pressures up to 100 MPa, the motion of a liquid is more fully and satisfactorily described by wave equations for the velocity potentials of liquid particles [2].

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

where C_0- the speed of sound in a liquid. Potential φ0 and fluid velocity vector $\vec{V}$ addicted $\vec{V}=grad\varphi_0$. The fluid pressure can be determined using the linearized Cauchy-Lagrange integral $P=-\rho_o C_0\frac{\partial\varphi_0}{\partial t}$, where ρ_0- liquid density. Under the condition of non-separated flow around the liquid, the normal component of the liquid velocity and the shell on the surface of their contact must be equal, i.e..:

ISSN NO: 2770-4491
Date of Publication:28-04-2022

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

where S_0- contact surface; n-normal shell surfaces;
u_r - moving the shell along the normal. An incident expansion (or shear) plane wave is considered to propagate in the positive x direction and is represented as follows:

$$\varphi^{(p)} = \varphi_0 e^{i(\alpha x - \omega t)}; \quad \psi^{(p)} = 0; \text{ или } \quad \psi^{(p)} = \psi_0 e^{i(\beta x - \omega t)}; \ \varphi^{(p)} = 0,$$

where φ_0 or ψ_0 – amplitude values; ω- circular frequency; $\alpha^2 = \omega^2 / C_p^2$ and $\beta^2 = \omega^2 / C_\beta^2$ - wave numbers of expansion and shift, respectively. If the boundary of the region in which the wave field is studied goes to infinity, then additional conditions at infinity are required and are discussed in detail in [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 the function φ satisfies the Helmholtz equation (in our case it satisfies), then the uniqueness of the solution of the problem in an infinite region can be ensured by the requirements (3). Here r is the radius in a cylindrical coordinate system. At the boundary of two bodies, the condition of rigid contact is satisfied, i.e. the condition of equality of the corresponding displacements and stresses is satisfied:

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

One of the problems is devoted to the propagation of harmonic shear waves in a two-dimensional elastic body with a round hole (reinforced). In this formulation, the superposition of suitable waves and shear and tension-compression waves reflected from the hole is studied, which leads to stress concentration. The solution of the diffraction problem for a plane harmonic shear wave was obtained in [1], which has the following form ($\sigma_{\theta\theta}^* = \sigma_{\theta\theta} / \sigma_0$; $\sigma_\theta = \mu\beta^2\psi_0$; ψ_0 – incident wave amplitude, μ - Lame coefficient)

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

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

где $H_n(\beta a)$ – Hankel function; $\alpha = \omega/C_p$; $\beta = \omega/C_S$; C_p и C_S – respectively, the propagation velocity of longitudinal and transverse waves; ω - circular frequency, π = 3,14. Calculations by methods of the theory of elasticity give, in the absence of a lining around the hole and a wavelength significantly greater than the diameter of the hole, the following approximate expression for stresses along the 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 – soil shear module, υ_0 – velocity amplitude of the incident seismic wave. In view of the fact that long seismic waves, as a rule, exceed the characteristic dimensions of the cross-sectional workings (for example, diameter D), of particular interest is the solution of diffraction problems for long-wave effects, i.e. when $\frac{D}{\lambda} < 1$. At long wavelengths ($\frac{D}{\lambda} = 0{,}04 \div 0{,}16$) the maximum coefficients of dynamic concentrations turned out to be 5 – 10% more than with the corresponding biaxial static loading (λ→∞)[1].

ISSN NO: 2770-4491
Date of Publication:28-04-2022

At $\frac{D}{\lambda} > 0{,}16$ dynamic stress concentrations are significantly lower than static ones. The presented numerical results show that, in contrast to the case of a hard inclusion [1], the value K_σ depends very much on $\frac{D}{\lambda}$. This difference can be attributed to the possibility of propagation of generalized Rayleigh-type waves on the concave free cylindrical surface of the cavity. Taking into account the viscous properties of the environmental material when calculating the action of seismic waves reduces stresses and displacements by 10–15%.

Calculations show that at fixed values of the amplitude and duration of the incident wave, with an increase in the acoustic parameters of the liquid, deflections and forces also increase. In the region of long waves, the stress distributions of pipes with and without liquid differ by up to 15%, and in the region of short waves, in some frequency values, they differ by up to 40%.

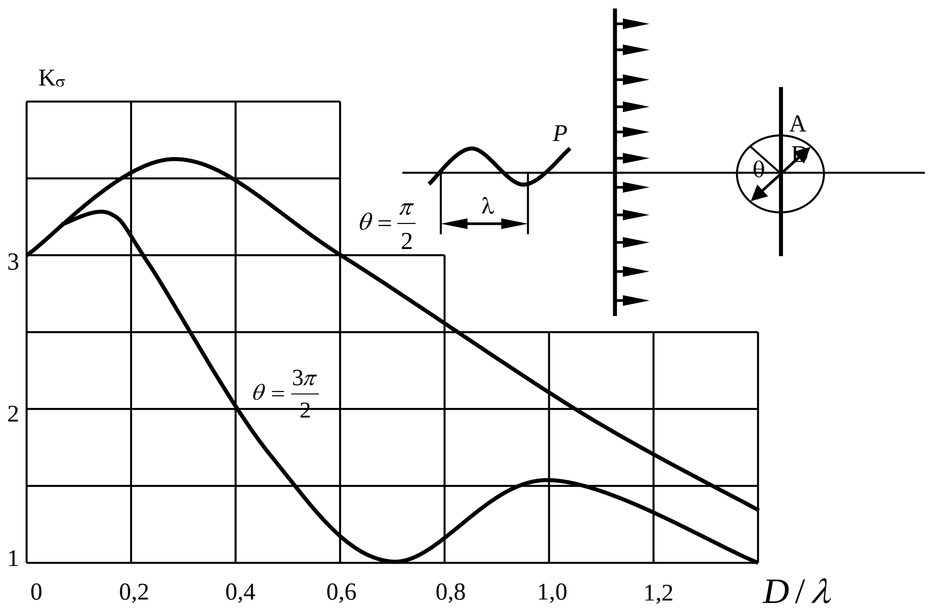

Fig.1 Dependence of the stress concentration factor on the wavelength.

The obtained numerical results allow us to draw the following conclusions:

- the phenomenon of local resonance manifests itself more strongly for seismic action in the form of SV-waves than P-waves.
- the presence of water in the pipes increases the seismic impact on them by 10-20%.
- the denser the soil of the embankment, the less seismic impact on underground pipes. For l>10D, the dynamic problem is reduced to a quasi-static one.
- Changes in wall thickness and concrete class have practically no effect on the dynamic soil pressure on reinforced concrete pipes under seismic impact. It can be noted that the design of the optimal lining, taking into account the influence of dynamic loading, generally requires, in addition to the usual choice of thickness and structural material, the coordination of the latter with the properties of the surrounding rock mass.

Literature:

1. Kabulov V.K.Algorithmization in the theory of elasticity.-T:FAN.1968.-394c.
2. Strelchuk N.A., Slavin S.K., Shaposhnikov V.N. Investigation of the dynamic stress state of tunnel lining under the influence of blast waves. // Izv.Universities. Building and architecture, 1971, No. 9, - S. 129-136.

3. Chekalkin A.A., Pankov A.A. Lectures on structural mechanics from composite materials / Perm. state tech. Univ., Perm, 1999 .- 150 p.
4. Safarov I.I. Oscillations and waves in dissipative inhomogeneous media and Designs - Tashkent. Fan. 1992 - 250 s.
5. 5.Safarov I.I., Edgorov U.T., Zhuraev T.O., Dzhumaev Z.F. About steady-state oscillations of three-layer cylindrical bodies // Mechanics muammolari. 2000.№. 1, p. 31-34.
6. Akhmedov Sh.R., Zhuraev T.O., Agzamova D. On resonance damping vibrations of tubular structures. - Bukhoro, 1998.-c. 44-45
7. KMK 11-7-81 Construction in seismic areas. Design Standards. - M.,1981.-49 p.
8. Demin A.M. Patterns of manifestations of slope deformations in quarries. - M: Science. 1981. - 144 p.
9. Vlasov V.Z. Structural mechanics of thin-walled spatial systems. -M.:Stroyizdat, 1949, -250 p.
10. Muskhelishvili N.I. Some basic tasks of the mathematical theory of elasticity. –M: Nauka, 1966.- 478 p.
11. Rashidov T.R. The dynamic theory of earthquake resistance of complexsystems of underground structures. – Tashkent: Fan. 1973. - 180 p.
12. Pac Y.H., Mow C.C. The Diffraction of Elastic Wufes and Dunamic stress Constration-N.J. Crane Russah and 1973. - 675.
13. Okamoto S. Seismic resistance of engineering structures. - M.: Stroyizdat,1980 - 344 p.
14. Sultanov K.S. Interaction of an extended underground structure with soil underdynamic loading // Sat. scientific labor. Dynamics of heterogeneous media and the interaction of waves with structural elements.-Novosibirsk.-1987.-S.150- 157
15. Muborakov Ya.N. Earthquake resistance of underground structures such as cylindrical shells. - Tashkent: Fan, 1991, - 218.
16. Shirinkulov T.Sh., Zaretsky Yu.K. Creep and soil consolidation. - Tashkent:FAN, UzSSR, 1986. - 391 p.
17. Abdurashidov K.S. , Eisenberg. M., Zhunusov T.Zh. and other seismic resistance of structures. - M.: Science, 1989. - 193 p.
18. Mirsaidov M.M., Troyanovsky I.E. Dynamics of heterogeneous systems. –Tashkent: Fan. - 1990. - 106 p.
19. I.M. Idriss, H. B. Sed and H. Dezflulian Influence of Geometry and Material Properties on the Seismik Respose of Soil Deposits, Prog. of IV - WCEF.,1969, pp 255 - 261.
20. Safarov I.I. Oscillations and waves in dissipative heterogeneous media and structures - Toshkent. Fan. 1992 - 250 s.