BUILDING STRUCTURES, BUILDINGS AND CONSTRUCTIONS

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MODELING OF CRACK FORMATION IN STRUCTURES SUBJECTED TO STRESS AND ITS CONNECTION WITH ACOUSTIC EMISSION RESPONSE

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Statement of the problem. Assessment of crack formation parameters of artificial airfield pavements is a difficult problem involving considering changes in the structures of materials used for a particular building. A variety of factors aftecting the performance of pavements required cumulative approach to calculating value deformation constractive elements of airfield pavements. Recurrence impact loading demand inclusion of modification property of pavements in the calculation for different time of maintenance. Modeling the process of stressing and distraction airfield pavements resulting in subsequent failure of cement concrete structures and connecting it with the formation the acoustic emission, we can define its remaining service life.

Result. Definition of the characteristics of concrete constractions is possible on the basis of the evaluation of their current operating state, modeling process of passing acoustic elastic waves at different stage of failure related with specific physical structure and properties of a material. Measuring the speed and damping passing through multicomponent medium waves, we can evaluate the serviceability of a material. The modeling makes it possible to connect the above components with physical and mechanical performance of a material.

Conclusions. The suggested mathematical model of the damping of elastic waves acoustic emission caused bystructural changes in a material of cement concrete structures subjected to loading whose physical and mechanical performance is presented with complex parameters.

Keywords: cement and concrete structures, elastic waves, stressing, acoustic emission response, crack formation.

Introduction

Most items of concrete or ferroconcrete produced in the building industry as well as on site are subjected to force loads and predicting their behavior is crucial as reduction of their performance in such structures involves financial, time and labor costs for maintaining them.

Force effects on any concrete or ferroconcrete element are always associated with cracking. Even when a structure is loaded considerably below its cracking threshold, there are microcracks developing and emerging at its submicro- and microlevels as even under small loads there are areas with a high concentration of stress due to the inconsistence of a structure where in the mouths of micropores and microdefects there are stresses exceeding critical ones and causing cracks to grow.

One of the most common ways of force effects on concrete in structures are compression, eccentric compression and tension. Therefore predicting the compression strength, stretching and tension in bending is important in making judgments as to its actual reliability.

Concrete is a material that is good at resisting compression and considerably worse at resisting cutting and even worse at stretching and thus building structures are generally designed so that concrete was responsive to compressive loads.

It is done based on the strength theory which accounts not only for the structure of a material but its statistical distribution as deterioration of concrete is integral and the outcome might vary depending on a combination of defects of its structure, experimental errors and other factors and statistical laws are indicative of how likely these combinations are to occur. Thus the behavior of concrete under loading is due to structural and statistical factors.

1. Mechanisms of the generation and development of cracks in cement concrete. When concrete is loaded and due to differences in physical and mechanical properties and sizes of its components as well as defects there is a complex distributed stress field. Stress is largely focused on the defect boundaries and components with different properties, i.e. mainly in the contact area and weak mechanical bonds.

Under the effect of stress there are elastic and plastic deformations influencing elastic waves of acoustic emission. It is impossible to understand the causes of acoustic signals in a material during loading unless its properties and composition are physically interpreted [1]; as concrete is an artificial conglomerate where individual filler aggregates are joined using a cement stone, a contact area between a filler and cement stone can be a specific structural element where the latter changes its properties as sometimes does the former.

Elastic deformation is due to changes in the distances between atoms and can change sporadically, i.e. an absolutely elastic body does not change its properties depending on the loading time but in actual bodies there are a lot of pointed and linear dislocations as well as more significant defects. Dislocations move according to plastic deformation with displacements depending on the type and mode of loading. It is most pronounced where stress is concentrated and there are a lot of voids and dislocations causing microporous structures to emerge.

As stresses or time increase, there might be microcracks causing stress concentrations followed by intense movement of dislocations generating deterioration and hence giving rise to microcracks [2]. Microcracks are the first to emerge at the weakest areas. Under certain conditions (growing loads, cracks parallel to the acting compressive effort, preservation of stress concentration, etc.). microcracks increase, join the previous ones and cause main cracks. Each strain corresponds with its own level of the development of movement of dislocations and formation of voids and microcracks. When a number of defects prior to loading and new ones reaches a certain level causing bond-failure cracks, there is failure of concrete.

Based on countless experiments it was found that [3], during concrete failure there two types of the deterioration of surfaces. In the first case when the shear strength of a filler is higher than that of a solution or cement stone, the former deteriorates not involving the filler aggregates. In the second case when the strength of a filler is lower than that of a solution, the former and filler aggregates deteriorate. There can be a mixed deterioration when the strength of aggregates and that of a solution are almost identical and in different parts of a structure either can be stronger. Microscopic and ultrasound research methods showed that long before deterioration of concrete there are failure microcracks caused by inconsistencies of a structure.

In concrete under the effect of cyclic loads there can be irreversible mechanic changes even when maximum macroscopic stresses are not beyond the endurance level. If a number of cycles is high enough, as a result of the accumulation of irreversible mechanic changes at some point of a sample there is a macroscopic crack that eventually causes deterioration. Fatigue failure is similar to deterioration as a result of successive elastic plastic deformations but the latter only occur in macroscopic stresses beyond the endurance level of concrete, while fatigue failure can take place for insignificant stresses. Deterioration causes by successive plastic deformations are proceeded by 10^1—10^5 stress cycles prior to fatigue loading 10. There is no clear distinction between the two types of deterioration.

During deterioration of materials along with the energy approach, a force criterion is important which takes into account the distribution of critical stresses, deformations or displacements in the near-tip area. A force approach to determining the outset of crack propagation in a deformed solid body was first set forth by K. Withard, V.L. William and

J.R. Irvin [3]; they argue that there are three major types of deterioration of materials when cracks are caused by external loads (Fig. 1).

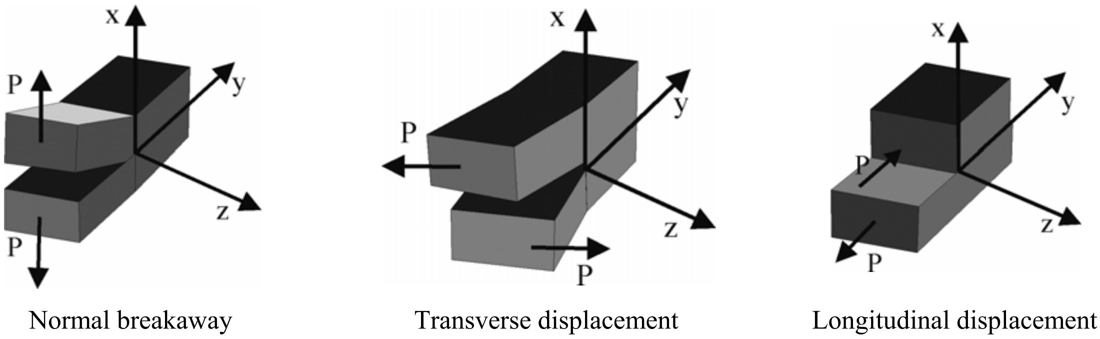

Fig. 1. Model of displacements of the crack edge during failure of solid bodies

The distribution of stresses and displacements near the edge of a random crack for the most common normal breakaway during stretching is given by the following formulas [4]:

$$\sigma_x = \frac{K_1}{\sqrt{2\cdot\pi\cdot r}}\cdot\cos\frac{\theta}{2}\cdot\left(1-\sin\frac{\theta}{2}\cdot\sin\frac{3}{2}\theta\right), \tag{1}$$

$$\sigma_x = \frac{K_1}{\sqrt{2\cdot\pi\cdot r}}\cdot\cos\frac{\theta}{2}\cdot\left(1+\sin\frac{\theta}{2}\cdot\sin\frac{3}{2}\theta\right) , \tag{2}$$

where r is the distance between the tip of a crack to some random point where there are stresses σ_x and σ_y; θ is a polar angle between the axis and radius vector r; K_i is the coefficient of intensity of stresses for normal breakaway which equals the -3/2 product of the force and crack length.

Hence according to the Griffith and Irvin task we get

$$K_i = \sigma\sqrt{2\pi r}\cdot Y\,, \tag{3}$$

where Y is a coefficient depending on the shape of a sample, its loading scheme and type of a crack.

J.R. Irvin obtained a force criterion for determining pey outset of crack propagation and growth in a deformed solid body. The propagation of cracks is when a coefficient of intensity of stresses equals some variable for each material and maximum K_{1c} [3]:

$$K_i = K_{ic}. \tag{4}$$

Further research allowed the generalization of a failure criterion for a complex stress state. In particular when $K_1 \neq 0$, $K_2 \neq 0$ is a two-dimensional task and $K_1 \neq 0$, $K_2 \neq 0$, $K_3 \neq 0$ is a three-dimensional task [5].

The above approaches are indicative of limit equilibrium state of a solid body with a crack. Subsequent growth of cracks can be stable or not. If an external load is constant, a crack is motionless. For a crack to grow by l, there has to be a small increase in an external load ΔP.

The intensity coefficient K_{1c}, K_{2c} and K_{3c} constant for each material are determined through the course of experiments.

There are a lot of methods for calculating coefficients of stress intensity: method of singular integral equations for solving two-dimensional and three-dimensional tasks, finite element method, variation methods, dynamic tasks, etc. Further development of the methods of identifying viscosity allows one to establish new theoretical and experimental methods for necessary parameters of crack-resistance.

In operation of ferroconcrete structures there are normally shear cracks parallel to the longitudinal axis of an element in the compressed area of a section. The development of these cracks controlled by a coefficient of stress intensity causes a structure to loss its bearing capacity.

In [6] there is a quantitative experimental assessment of crack resistance parameters of concrete in an in-plane shear. For tests of concrete there was a slab specimen with two artificial parallel cracks. A coefficient of stress intensity for an in-plane shear is given by the formula:

$$K_{2c} = P \cdot \sqrt{\frac{l \cdot Y(l,b)}{2 \cdot t \cdot H}}, \tag{5}$$

where P is a destructive load; $Y(l, b)$ is a correction coefficient; l is the depth of a cut; b is the height and width of a specimen; t is the thickness of a specimen; H is the distance between a cut to the side of a specimen (shoulder).

A coefficient of stress intensity in eccentric compression of a normal breakaway K_{1c} is determined using a special method. As a result of the experiments, it was found that the resistance of concrete to an in-plane shear is 10 or more times higher than to a normal breakaway [7]:

$$K_{2c} = 11,5 \cdot K_{1c} \tag{6}$$

In a ferroconcrete element depending on a level of an applied load there are force cracks of three types [7]: 1) normal to the longitudinal axis of an element – cracks of a normal breakaway denoted as v; 2) a slant line to the longitudinal axis developing from normal ones as a result of growing shearing stress, i; 3) parallel to the longitudinal axis – cracks of an in-plane shear emerging at a stage followed by failure, h. According to [8], under the effect of a maximum external load on a specimen cracks of a normal breakaway l_c^v reach their maximum and shear cracks l_c^v continue to grow intensely.

Due to failure of concrete and crack formation, it is necessary to consider this process in terms of energy and emission of some of in sound waves. As characteristics of sound waves are associated with formation of cracks [9], there has to be a mathematical model of propagation of these waves for them to be recorded.

Let us look into propagation of acoustic (sound) waves in a cement concrete structure – not restricted, elastic, saturated with gas or liquid porous medium. Physical and mechanical properties of a medium are specified with a complex elasticity modulus.

2. Mathematical model of damping of elastic waves caused by acoustic emission during their propagation in cement concrete structures. Formation of cracks is a spatial statistical process of defects of a material resulting in sound waves propagated along different trajectories of a continuous medium which is commonly a porous material.

Dynamic deformation of such a porous medium is described with a system of equations [10—13]:

$$\lambda^{\bullet}\frac{\partial^2 u_j^{(1)}}{\partial x_i \partial x_j}+\mu^{\bullet}\frac{\partial^2 u_j^{(1)}}{\partial x_i \partial x_j}+\mu^{\bullet}\frac{\partial^2 u_i^{(1)}}{\partial x_j^2}+R^{\bullet}\frac{\partial^2 u_j^{(2)}}{\partial x_i \partial x_j}-\rho_{11}\frac{\partial^2 u_i^{(1)}}{\partial t^2}-\rho_{12}\frac{\partial^2 u_i^{(2)}}{\partial t^2}=0,$$
$$R^{\bullet}\frac{\partial^2 u_j^{(1)}}{\partial x_i \partial x_j}+Q^{\bullet}\frac{\partial^2 u_j^{(2)}}{\partial x_i \partial x_j}-\rho_{12}\frac{\partial^2 u_i^{(1)}}{\partial t^2}-\rho_{22}\frac{\partial^2 u_i^{(2)}}{\partial t^2}=0, \tag{7}$$
$$\rho_{11}=\rho_1-\rho_{12},\ \rho_{22}=\rho_2-\rho_{12},\ \ \rho=\rho_{11}+\rho_{22}+2\rho_{12},$$

where $u_i^{(x)}(x=1,2)$ are components of a displacement vectors of phases; $\lambda^{\bullet},\mu^{\bullet},R^{\bullet},Q^{\bullet}$ are complex moduluses of elasticity of the first and second phase in a volume unit of a medium; α_1 and α_2 characterize proportions of a volume of a mix occupied by each phase ($\alpha_1 + \alpha_2 = 1$, $\alpha_1 > 0$, $\alpha_2 > 0$).

The solution of the system is presented by an attenuating wave [11—12]:

$$u_j^{(\chi)}=C_j^{(\chi)}\exp(i\omega t-\theta x_k \nu_k),\ \theta=\alpha+i\beta,\ \beta=\omega/c,\ \chi=1,2, \tag{8}$$

where $C_j^{(\chi)}$ is an oscillation amplitude; ν_i are coordinates of a unit vector in direction of a wave propagation speed; c > 0 is a wave speed; α > 0 is a coefficient of damping of a wave; ω is an angular frequency; β is a phase constant.

Inserting (8) into (7), we get a system of two equations:

$$(\lambda^{\bullet}C_j^{(1)}\nu_i\nu_j+\mu^{\bullet}C_j^{(1)}\nu_i\nu_j+\mu^{\bullet}C_i^{(1)})(\alpha+i\beta)^2+R^{\bullet}(\alpha+i\beta)^2C_j^{(2)}\nu_i\nu_j+\rho_{11}\omega^2C_i^{(1)}+\rho_{12}\omega^2C_i^{(2)}=0,$$
$$R^{\bullet}(\alpha+i\beta)^2C_j^{(1)}\nu_i\nu_j+Q^{\bullet}(\alpha+i\beta)^2C_j^{(2)}\nu_i\nu_j+\rho_{12}\omega^2C_i^{(1)}+\rho_{22}\omega^2C_i^{(2)}=0. \tag{9}$$

Characteristics of longitudinal waves are determined if we assume that $C_i^{(\chi)}\nu_i \neq 0 \ (\chi = 1, 2)$, $\alpha = \alpha_l$, $\beta = \beta_l$. Let us multiply equations (9) by ν_i and sum them using a repetitive index i.
Using a system (9) we get a biquadratic equation in relation to $\alpha_l + i\beta_l$:

$$(\sigma_{11}^{\bullet}\sigma_{22}^{\bullet} - \sigma_{12}^{\bullet 2})(\alpha_l + i\beta_l)^4 + (\gamma_{11}\sigma_{22}^{\bullet} + \gamma_{22}\sigma_{11}^{\bullet} - 2\gamma_{12}\sigma_{12}^{\bullet})\delta_l^2(\alpha_l + i\beta_l)^2 + (\gamma_{11}\gamma_{12} - \gamma_{12}^2)\delta_l^4 = 0, \quad (10)$$

$$\delta_l = \omega/G_l, \ G_l = \sqrt{H/\rho},$$

where

$$\Lambda^{\bullet} = \lambda^{\bullet} + 2\mu^{\bullet}, \ \sigma_{11}^{\bullet} = \Lambda^{\bullet}/H, \ \sigma_{12}^{\bullet} = R^{\bullet}/H,$$

$$\sigma_{22}^{\bullet} = Q^{\bullet}/H, \ H = \Lambda_1 + Q_1 + 2R_1, \ \Lambda^{\bullet} = \Lambda_1 + i\Lambda_2,$$

$$\gamma_{11} = \rho_{11}/\rho, \ \gamma_{12} = \rho_{12}/\rho, \ \gamma_{22} = \rho_{22}/\rho$$

are dimensionless complex coefficients; G_l, δ_l is a speed of propagation of a longitudinal wave and a phase constant when the coefficients of a porous medium are real numbers.
For the solution of a phase task to meet the equations of elastic propagation with damping the following must hold true

$$\sigma_{11}^{\bullet} + \sigma_{22}^{\bullet} + 2\sigma_{12}^{\bullet} = \gamma_{11} + \gamma_{22} + 2\gamma_{12} = 1.$$

A biquadratic equation (10) is solved in relation to a real $\left(\alpha_l^2 - \beta_l^2\right)$ and imaginary $(\alpha_l\beta_l)$ parts:

$$\alpha_l^2 - \beta_l^2 = -2kb_1\delta_l^2/(b_1^2 + b_2^2), \ \alpha_l\beta_l = kb_2\delta_l^2/(b_1^2 + b_2^2), \quad (11)$$

$$k = \gamma_{11}\gamma_{22} - \gamma_{12}^2, \ b_1 = \Gamma_1 \pm \sqrt{r}\cos(\phi_1/2),$$

$$b_2 = \Gamma_2 \pm \sqrt{r}\sin(\phi_1/2), \ \Gamma_1 = \gamma_{11}\sigma'_{22} + \gamma_{22}\sigma'_{11} - 2\gamma_{12}\sigma'_{12},$$

$$\Gamma_2 = \gamma_{11}\sigma''_{22} + \gamma_{22}\sigma''_{11} - 2\gamma_{12}\sigma''_{12}, \ \sigma_{11}^{\bullet} = \sigma'_{11} + i\sigma''_{11},$$

$$\sigma_{12}^{\bullet} = \sigma'_{12} + i\sigma''_{12}, \ \sigma_{22}^{\bullet} = \sigma'_{22} + i\sigma''_{22}, \ r = \sqrt{\theta_1^2 + \theta_2^2},$$

$$\theta_1 = \Gamma_1^2 - \Gamma_2^2 - 4kE_1, \ \theta_2 = 2(\Gamma_1\Gamma_2 - 2kE_2), \ E_1 = \sigma'_{11}\sigma'_{22} - \sigma''_{11}\sigma''_{22} - \sigma'^2_{12} + \sigma''^2_{12},$$

$$E_2 = \sigma'_{11}\sigma''_{22} + \sigma''_{11}\sigma'_{22} - 2\sigma'_{12}\sigma''_{12}, \ tg\phi_1 = \theta_2/\theta_1, 0 \le \phi_1 \le \pi/2.$$

Using (11) we find a coefficient of damping of a longitudinal wave and a phase constant:

$$\alpha_l = \sqrt{\frac{kb_2^2\delta_l^2}{(b_1^2 + b_2^2)(b_1 + \sqrt{b_1^2 + b_2^2})}}, \ \beta_l = \sqrt{\frac{k\delta_l^2(b_1 + \sqrt{b_1^2 + b_2^2})}{b_1^2 + b_2^2}}. \quad (12)$$

Considering that for a longitudinal wave a phase constant $\beta_l = \omega / c_l$ and coefficient characterizing a propagation medium of an elastic wave are complex numbers, we find a propagation speed of a longitudinal wave:

$$c_l = \sqrt{G_l^2 (b_1^2 + b_2^2) / k (b_1 + \sqrt{b_1^2 + b_2^2})} .$$

In an elastic porous medium saturated with gas there are two types of longitudinal waves as b_1 and b_2 have a «±» sign. Given that $\eta_1 = \sqrt{1+(b_2/b_1)^2}$ is a propagation speed, coefficient of damping of waves and phase constants are the following:

$$\alpha_{l_{1,2}} = \sqrt{\frac{k\omega^2(\eta_1 - 1)}{b_1 G_l^2 \eta_1^2}}, \ \beta_{l_{1,2}} = \sqrt{\frac{k\omega^2(\eta_1 + 1)}{b_1 G_l^2 \eta_1^2}}, \ c_{l_{1,2}} = \sqrt{\frac{b_1 G_l^2 \eta_1^2}{k(\eta_1 + 1)}}, \tag{13}$$

$$G_l = \sqrt{\frac{H}{\rho}} = \sqrt{\frac{\Lambda_1 + Q_1 + 2R_1}{\rho}} = \sqrt{\frac{\lambda_1 + 2\mu_1 + Q_1 + 2R_1}{\rho}} . \tag{14}$$

Using the formulas for R_1, Q_1, λ_1, μ_1 from [11, 14—15] and the expression for G_l, we get

$$\alpha_{l_{1,2}} = \sqrt{\frac{(\rho_{11}\rho_{22} - \rho_{12}^2)\omega^2(\eta_1 - 1)\rho}{b_1\eta_1^2\left(\dfrac{E(1-\nu)}{(1+\nu)(1-2\nu)} + R_0(2-m)\right)}},$$

$$c_{l_{1,2}} = \sqrt{\frac{b_1\eta_1^2\left(\dfrac{E(1-\nu)}{(1+\nu)(1-2\nu)} + R_0(2-m)\right)}{(\rho_{11}\rho_{22} - \rho_{12}^2)(\eta_1 + 1)\rho}}, \tag{15}$$

where m is porosity of a medium; R_0 is a compressibility of a gas (air); v is the Poisson coefficient; E is Young's modulus; $k = (\rho_{11}\rho_{22} - \rho_{12}^2)$.

Coefficients of damping and propagation speed of acoustic waves in the formulas (15) are presented in detail. Here b_1 and η_1 are calculated using variables Γ_1, Γ_2, E_1, E_2 which are determined as follows:

$$\Gamma_1 = \rho_{11}Q_1 + \rho_{22}(\lambda_1 + 2\mu_1) - 2\rho_{12}R_1, \ \Gamma_2 = \rho_{11}Q_2 + \rho_{22}(\lambda_2 + 2\mu_2) - 2\rho_{12}R_2, \tag{16}$$

$$E_1 = (\lambda_1 + 2\mu_1)Q_1 - (\lambda_2 + 2\mu_2)Q_2 - R_1^2 + R_2^2,$$

$$E_2 = (\lambda_1 + 2\mu_1)Q_2 + (\lambda_2 + 2\mu_2)Q_1 - 2R_1R_2.$$

The characteristics of a transverse wave are identified using (3) if we assume that $C_j^{(\chi)}\nu_j = 0$ $(\chi = 1, 2)$ and move on to the dimensionless coefficients:

$$\left[\gamma_{11}\delta_t^2 + \mu^\bullet(\alpha_t + i\beta_t)^2\right]C_i^{(1)} + \gamma_{12}\delta_t^2 C_i^2 = 0, \tag{17}$$

$$\gamma_{12}C_i^{(1)}+\gamma_{22}C_i^{(2)}=0,$$

where $\delta_t=\omega/G_t$ and $G_t=\sqrt{H/\rho_{11}}=\sqrt{H/\rho_1}$ is the speed of a transverse wave at μ_2= 0, $H=\mu_1$.

Given that $\eta_2=\sqrt{1+\left(\mu_2/\mu_1\right)^2}$ we get the following ratios:

$$\alpha_t=\sqrt{\frac{k\delta_t^2(\eta_2-1)}{2\gamma_{22}\eta_2^2\mu_1}}=\sqrt{\frac{k\omega^2(\eta_2-1)}{2\gamma_{22}G_t^2\eta_2^2\mu_1}},\ \beta_t=\sqrt{\frac{k\delta_t^2(\eta_2+1)}{2\gamma_{22}\eta_2^2\mu_1}}=\sqrt{\frac{k\omega^2(\eta_2+1)}{2\gamma_{22}G_t^2\eta_2^2\mu_1}}\,. \quad (18)$$

The speed of a transverse wave is determined knowing that $\beta_t=\omega/c_t$:

$$c_t=\sqrt{\frac{2\gamma_{22}\eta_2^2\mu_1\omega^2}{k\delta_t^2\left(\eta_2+1\right)}}=\sqrt{\frac{2\gamma_{22}\eta_2^2\mu_1G_t^2}{k\left(\eta_2+1\right)}}\,. \quad (19)$$

Let us write the formulas (18) and (19) in detail considering physical and mechanical properties of a medium:

$$\alpha_t=\sqrt{\frac{\left(\rho_{11}\rho_{22}-\rho_{12}^2\right)\rho_{11}\omega^2\left(\eta_2-1\right)}{2\rho_{22}\eta_2^2\mu_1^2}}=\sqrt{\frac{\left(\rho_{11}\rho_{22}-\rho_{12}^2\right)\rho_{11}\omega^2\left(\eta_2-1\right)2\left(1+\nu\right)^2}{\rho_{22}\eta_2^2E^2}}, \quad (20)$$

$$c_t=\sqrt{\frac{2\rho_{22}\eta_2^2\mu_1^2}{\left(\rho_{11}\rho_{22}-\rho_{12}^2\right)\rho_{11}\left(\eta_2+1\right)}}=\sqrt{\frac{\rho_{22}\eta_2^2E^2}{\left(\rho_{11}\rho_{22}-\rho_{12}^2\right)\rho_{11}\left(\eta_2+1\right)2\left(1+\nu\right)^2}}\,.$$

A logarithmic decrement of oscillations of a wave is

$$\delta=\pi tg\phi_2=2\pi\frac{\alpha_t\beta_t}{\beta_t^2-\alpha_t^2}=2\pi\frac{\alpha_t\omega c_t}{\omega^2-(\alpha_tc_t)^2}, \quad (21)$$

where $tg\phi_2$ is a tangent of an angle of mechanical losses:

$$tg\phi_2=\frac{JmM^\bullet}{\mathrm{Re}M^\bullet}=\frac{2\alpha_t\beta_t}{\beta_t^2-\alpha_t^2}\,.$$

A logarithmic decrement of oscillations of a transverse wave in a porous medium depends on a coefficient of damping of a wave and the speed of a wave passing through a signal source (crack) to the device.

Based on the expressions (15), (21), coefficients of damping and propagation speed of longitudinal and transverse elastic waves of acoustic emission depend on the Poisson's coefficient *v*, Young's modulus *E*, porosity *m*, density ρ and mass of the components of a medium, i.e. characteristics and properties of a material.

Fig. 2—3 show dependencies of a coefficient of damping and propagation speed of a longitudinal elastic acoustic wave on the porosity of cement concrete.

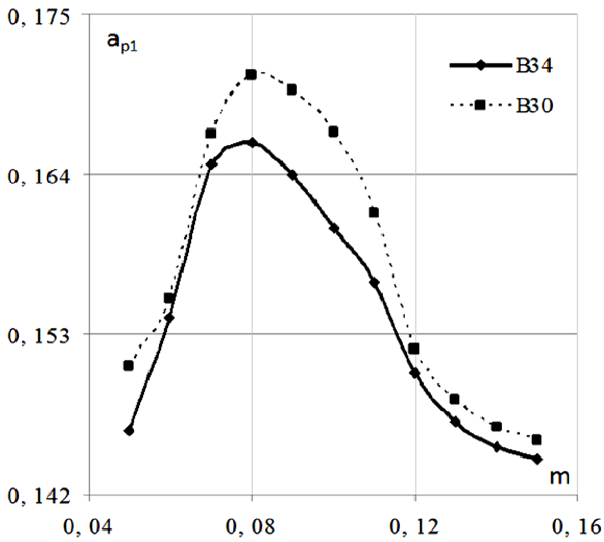

Fig. 2. Dependence of a coefficient of damping of an elastic longitudinal acoustic wave on the porosity of cement concrete

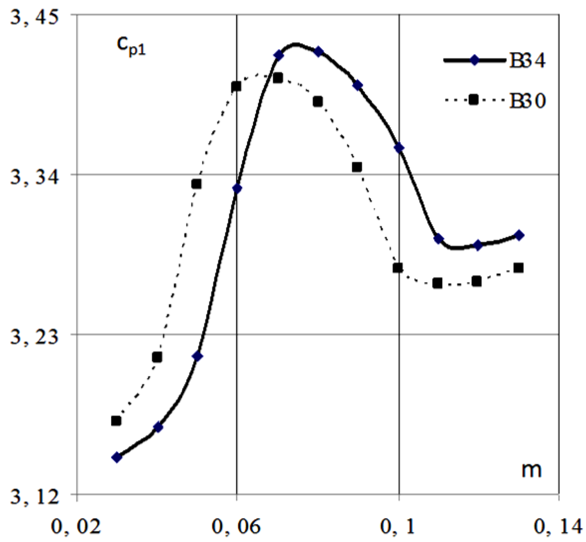

Fig. 3. Dependence of the propagation speed of an elastic acoustic wave on the porosity of cement concrete

It is obvious that growing damping is caused by dislocations transforming into a new state [16] and the speed decreasing in this porosity range characterizing stationary processes of elastic interaction.

This can be used as a criterion of threshold porosity of a medium as well as in predicting a resource of cement concrete pavements.

Conclusions

1. Development of technologies of determining the concrete parameters using acoustic non-restrictive methods of control focus on the parameters of the porosity of a medium of elastic wave propagation.

2. Determining crack resistance using acoustic emission is due to physical and mechanical parameters of a medium of propagation of sound waves being necessary to identify as well.

3. Determining the speed and damping of sound waves in cement concrete can be used not only in identifying porosity but also in predicting crack formation.

4. The obtained mathematical model of dissipative processes (formation of cracks) occurring during harmonic excitation of elastic porous media saturated with gas excited by sound waves specified by complex numbers allows more accurate prediction of crack resistance of concrete materials. The formulas for determining propagation speeds of longitudinal and transverse sound waves, coefficients of damping and logarithmic decrement of oscillation damping which are expressed by the characteristics of a medium: the Poisson coefficient, Young's modulus, porosity, compressibility and density of gas.

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