DISTRIBUTION OF NON-STATIONARY VISCOELASTIC WAVES TO POROUS ENVIRONMENTS

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The initial waves that are felled from earthquakes longitudinal waves that mostly appear bass sound or continuous collision .since the bed of most residential areas is of soil and soil is a porous media, witch has been saturated with air or water, therefore study of earthquake effect on porous medias saturated with liquid and gas is very important .according to Frankel-Biots theory, in porous medias saturated with liquid and gas two types of longitudinal waves are propagated. Second type of wave, basically by deformation of solid part of porous media witch is called matrix is known and introduced by Nikolaevskiy. In this paper a mathematical model for propagation of these waves have been introduced so that Frankel-Biots theory can be described and those earthquakes that happen along with sound are oriented. We can characterize the elocity and damping coefficient of those waves that create the sound of earthquakesAccording to frankele-Biots theory, in porous medias saturated with liquid, two types of longitudinal waves are induced [1] first kind wave has more speed and less damping. Second type wave has less velocity but its damping is very high. But for porous perimeters filled with gas, situation can be changed. Nikolaevskiy showed that ,second type waves can be recognized basically by change of shape in solid part of porous perimeter which is called matrix[1].in porous perimeters, filled with fluid, changing shape of matrix can be happen if fluid be able to flow between porous medias. Darsies resistance causes more damping therefore this wave can induce only in a limited interval. With attention to the mater that in porous perimeters filled with gas, gas can be compressed so matrix can change the shape without flowing of gas in porous media, therefore second type waves can have less damping.

In this paper our objective is to present a mathematical model for induction of longitudinal waves, so that, Frankele-Biots theory can be explained. To present this mathematical model, we shall see that there are four basic factors in induction of waves, first continuity of porous perimeter, second is motion of solid perimeter, third is motion of fluid perimeter. In this problem there are four basic unknown, velocity of solid movement, solid body stress and pressure due to fluid inside porous body, therefore if we write the equation of basic factors, we shall have three equations and four unknown, for forth equation, we have used rheology equation of solid body which makes porous media.

Continuity equation of solid perimeter [3]:

$$\frac{\partial m}{\partial t} + \beta_1 \frac{\partial \sigma^f}{\partial t} - \beta_1 (1 - m_0) \frac{\partial p}{\partial t} - (1 - m_0) \frac{\partial v_1}{\partial x} = 0 \qquad (1)$$

In which, σ^f is Terzaghi effective strain, β_1 is compressibility coefficient of solid body, m_0 is initial porosity coefficient, m is porosity coefficient, p is fluid pressure inside porous media, v_1 is velocity of solid body.

Continuity equation of fluid perimeter [3]:

$$\frac{\partial m}{\partial t} + \beta_2 m_0 \frac{\partial p}{\partial t} + m_0 \frac{\partial v_2}{\partial x} = 0 \qquad (2)$$

That, β_2 is compressibility coefficient and, v_2 is fluid velocity.

With attention to, change in porous coefficient, continuity of porous body does not vanish, therefore with deleting m from above two equation, we get continuity equation of porous body.

$$\beta \frac{\partial p}{\partial t} - \beta_1 \frac{\partial \sigma^f}{\partial t} + (1 - m_0) \frac{\partial v_1}{\partial x} + m_0 \frac{\partial v_2}{\partial x} = 0 \qquad (3)$$

When a porous body moves, solid body and fluid body have different type of motion, so for each perimeter, separate equation of motion is written.
Equation of motion of solid body [3].

$$(1-m_0)\rho_{10}\frac{\partial v_1}{\partial t}+(1-m_0)\frac{\partial p}{\partial t}=\frac{\partial \sigma^f}{\partial x}+\frac{m_0^2}{k}\mu(v_2-v_1) \tag{4}$$

That, ρ_{10} is initial density of solid body, μ is viscosity coefficient of fluid, k is permeability coefficient of porous body.
Equation of motion of fluid body [3].

$$m_0\rho_{20}\frac{\partial v_2}{\partial t}+m_0\frac{\partial p}{\partial x}=-\frac{m_0^2}{k}\mu(v_2-v_1) \tag{5}$$

That ρ_{20} is initial density of fluid.

With assumption that, solid body which makes the porous body be elastic, reological equation of it by hook rule becomes as below.

$$\sigma^f=\varepsilon p+k_p e_1 \tag{6}$$

which: $k_p=k_b+\frac{4}{3}G, \varepsilon=\beta_1 k_b$

In which, k_b is balk modulus, G is the shear modulus of the porous matrix, ε softness coefficient of solid body.

System of equations {(2-3),(2-4),(2-5),(2-6)} is mathematical model that is required. Now, above equations are solved as harmonic signals.

$$(v_1,v_2,p,\sigma^f)=(A_1,A_2,A_3,A_4)\exp[i(\omega t-\xi x)] \tag{7}$$

In which, ω is angular velocity of waves, ξ is a complex number which is called waves vector. By substituting (2-7) in equations system and deleting $\exp[i(\omega t-\xi x)]$ we shall get a second order equation with respect to ξ^2 .

$$a_1\xi^4-(a_2\omega^2-ia_3\omega)\xi^2+a_4\omega^4-ia_5\omega^3=0 \tag{8}$$

$$a_1=k_p m_0, a_2=k_p m_0\rho_{20}\beta_2+(1-m_0)(m_0\rho^*-\varepsilon\rho_{20}), a_3=b[1+k_p\beta-(\varepsilon+k_p\beta_1)],$$

$$a_4=\rho_{10}\rho_{20}(1-m_0)(\beta-\varepsilon\beta_1), a_5=b\rho_0(\beta-\varepsilon\beta_1), a=m_0 k_p\beta_2\rho_{20}, b=\frac{m_0\mu}{k}$$

$$c=bk_p(\beta-\beta_1), \rho^*=\rho_{10}+(1-m_0)\frac{\rho_{20}}{m_0}, \rho_0=\rho_{10}(1-m_0)+m_0\rho_{20}$$

By solving equation (2-8) we get two answers of which each one shows one single wave this matter proves Frankel-Biots. For investigating different positions by help of numerical methods, solid material which makes porous media is considered a material with below properties:

$$m_0=0.25, k=1.8*10^{-11}m^2, k_p=10^8\,pa, \beta_1=2*10^{-10}\,pa^{-1}, \rho_{10}=2500\frac{kg}{m^3}$$

Assuming porous perimeter is filled by a unique liquid with properties given as below

$$\beta_2=2*10^{-9}\,pa^{-1}, \rho_{20}=1000\frac{kg}{m^3}, \mu=10^{-3}\,pa.\sec$$

In this case we get two roots for equation (2-8) that are called $\xi_{\pm}$, which corresponds to each other, propagate one wave, wave of high velocity is called first kind and wave of low velocity is called second kind, we shall see that the wave of first kind is corresponded to ξ_{-} and the wave of second kind is corresponded to ξ_{+} .

Propagation of first kind wave:

With attention to Fig.1 we can see this type of wave has high velocity, and by increasing of frequency, velocity increases too. But rate of velocity changing is not very much and in our porous perimeter is about 864m/sec.

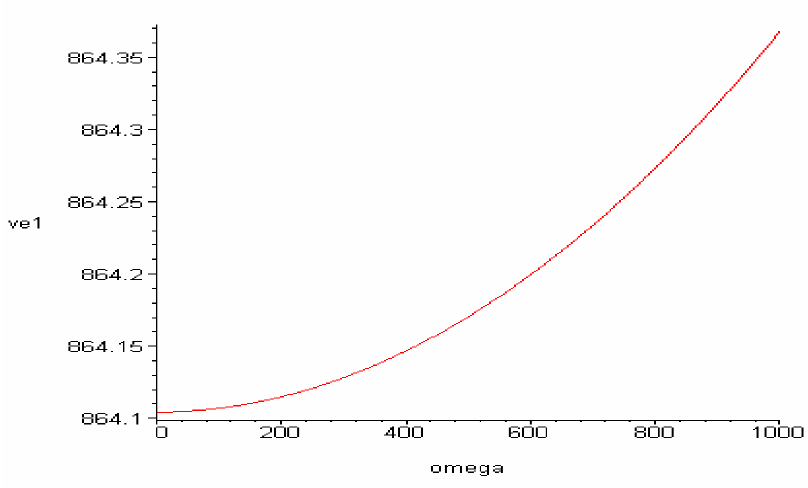

Fig.1. Propagation velocity of first kind viscoelastic wave in saturated by liquids porous media

Propagation of second kind wave:

With attention to Fig.2 we shall see that velocity of this wave in comparison with velocity of first kind wave is very less, and by increasing of frequency also increases and in $\omega = 1000$ reaches to 60.

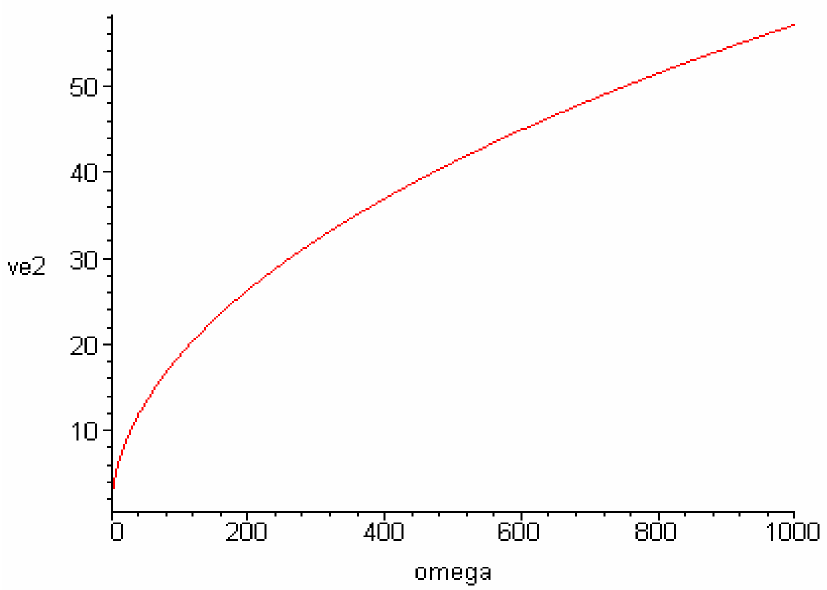

Fig.2. Propagation of second kind viscoelastic wave in saturated by liquids porous media

Assuming that a porous perimeter is filled with a single and unique gas having below particulars:

$$\beta_2 = 2.4*10^{-6}\, pa^{-1}, \rho_{20} = 2\frac{kg}{m^3}, \mu = 2*10^{-5}\, pa.\sec$$

In this case we get two roots for equation (2-8) that are called $\xi_{\pm}$, which corresponds to each other, propagate one wave, wave of high velocity is called first kind and wave of low velocity is called second kind, we shall see that the wave of first kind is corresponded to ξ_{+} and the wave of second kind is corresponded to ξ_{-} .

By paying attention to Fig.3 it shows that velocity of this wave in comparison with speed of first kind wave is very high and by increasing frequency it reduces, but its changes is not much, approximately we shall say that is 232m/sec.

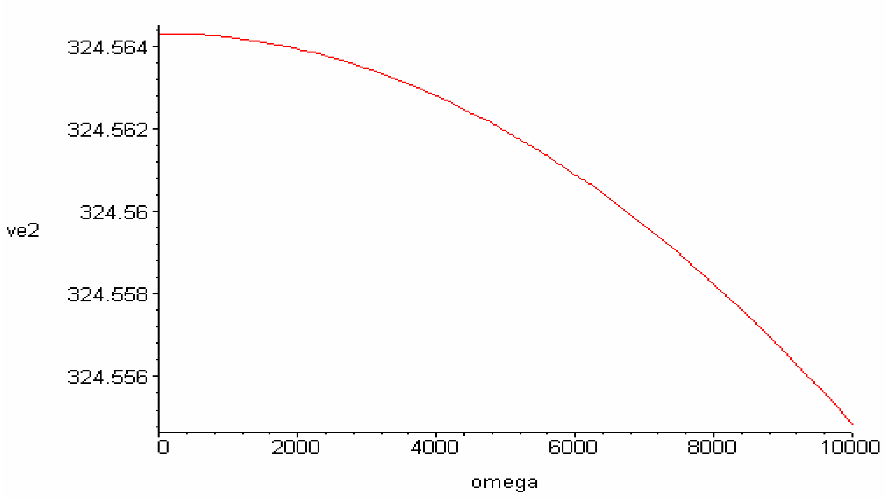

Fig.3. Propagation velocity of second kind viscoelastic waves in saturated by gas porous media

Therefore we see that the behavior of waves in porous perimeter which one filled with liquid or gas is very much different.

The longitudinal waves that come from earthquakes vibrate air on the surface of earth and create the sound waves in air. The sound waves frequency between 20...20000 HZ can be heard. It means that waves possess ω greater than 126 can be heard. Hence we investigate propagation of waves with this property.

By pay attention to above discussion we can obtain these results

A: in porous media saturated by liquids in comparison with porous media saturated by gas the first kind of waves can propagate far away and velocity of these waves is great, hence in this media sound of earthquake can be heard soon as the other media.

B: the rate of decreasing propagation domain by increasing frequency in porous media saturated by liquid in comparison with porous media saturated by gas is very fast.

C: the effect of second kind wave on porous media only is near the source of earthquake.

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