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EVALUATION OF ELASTIC MODULI OF CONCRETE BY ULTRASONIC VELOCITY

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ABSTRACT

One of the recommended practices to evaluate the quality of concrete is to measure the ultrasonic velocity. The velocity is then used to determine the compressive strength. Rebound hammer number and ultrasound absorption are also added to velocity data to enhance the accuracy of estimation. However, these data have not been used to estimate the elastic modulus, often required by structural engineers. A method is proposed to determine the elastic modulus of concrete by ultrasonic method.

INTRODUCTION

The use of non destructive testing (NDT) techniques to measure concrete strength has several advantages like reduction in samples of variablity, to measure concrete strength development with time, in situ and in laboratory specimen. The dynamic modulus (E_d) is successfully correlated with the compressive strength of concrete. This can be calculated from fundamental frequency [1] or the pulse velocity [2] of a concrete member or specimen. For structural applications, designers require that a material not only have compressive strength but also a certain stiffness. Stiffness is predicted by measuring static modulus of elasticity (E_c). Method to measure E_c are very cumbersome, specimen preparation and testing for it takes time, equipment's are also expensive.

Method for the determination of static modulus of elasticity using ultrasonic pulse wave velocity is suggested in the present paper. Measurement of ultrasonic velocity is fast, nondestructive and fairly inexpensive as compared to other methods for measuring static modulus.

METHODOLOGY

To calculate the pulse velocity time (t) measured in the specimens of known length (l) is used. The dynamic modulus of elasticity (E_d) is given by the following relation.

$$E_d = \rho C_L^2 \phi(\sigma) \qquad (1)$$

here $$\phi(\sigma) = \frac{(1+\sigma)(-1-2\sigma)}{1-\sigma}$$

σ is Poisson ratio, ρ being density of specimen material and can be determined from the pull out sample if measurements are made in situ. C_L is the longitudinal wave velocity of specimen material.

Since ϕ (σ) is around 0.9 for most of the concrete (σ varying from 0.8 to 0.22) The value of E_d evaluated. E_d is overestimated by about 10% if it is evaluated directly by using $E_d = \rho C^2{}_L$. The value of E_d evaluated from resonance method is regrated as accurate and comes out to be same as that evaluated from pulse velocity , provided ϕ (σ) is not taken as unity but gives its due value. This means that if density is known, E_d may be evaluated by pulse velocity fairly accurately.

If it is convenient to obtain concrete sample in the form of bar, E_d can be evaluated experimentally from resonance method and density ρ can be evaluated from mass and volume ratio. This is not possible however, in structural members. But shear wave velocity can be measured just as longitudinal wave velocity using the same equipment with different transducers. The shear wave velocity is also related to E_d by simple expression:

(2)

using Eq (1) and Eq(2), a relationship between Poisson's ratio and C_l and C_s can be established giving :

$$\sigma = \frac{C_L^2 - 2C_S^2}{2(C_L^2 - C_S^2)}$$

$$\text{or}\ \sigma = \frac{1}{2}\left[1 - \frac{1}{\left(\frac{C_L^2}{C_S^2} - 1\right)}\right]$$

If the thickness of the member is d, then C_L=d/t_L and C_s=d/t_s where t_L and t_S are the time of flight displayed on the pulse velocity instrument for longitudinal and shear velocity, respectively. The Poisson's ratio can then be written as

$$\sigma = \frac{1}{2}\left[1 - \frac{1}{\left(\frac{t_S^2}{t_L^2} - 1\right)}\right]$$

$$= \frac{t_S^2 - 2t_L^2}{2\left(t_S^2 - t_L^2\right)} \tag{3}$$

Eq(3) can be used to determine Poisson's ratio of a structural member without the knowledge of its thickness.

The stiffness constant and modulus of elasticity are obtained by the relation

K=1.7 E_c - 6.7 Gpa

If the effect of Poisson's ratio is taken into account the equation becomes

E_d = 1.5 E_c -5.9 Gpa or

E_c = E_d + 5.9/1.5 Gpa (4)

by puting the value for E_d determined earlier static modulus of elasticity can be determined.

CONCLUSION

The present work gives a method to determine Dynamic modulus of elasticity (Equation 2) and static modulus of elasticity (Equation 4). The relation to evaluate

Poisson ratio of a structural member is also derived which needs no knowledge of thickness of structural member. These parameters are helpful in prediction of the compressive strength, stiffness and other elastic properties of concrete.

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