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CONTENTS

THE EFFECT OF DIFFERENT HIGH IMPACT LOADING PRESSURE ON THE DYNAMIC MODULUS OF ELASTICITY OF CONCRETE

Mudiono Kasmuri* and Roszilah Hamid

Department of Civil and Structural Engineering, Universiti Kebangsaan Malaysia, Malaysia

ABSTRACT

The dynamic modulus of elasticity (MoE) of concrete can be determined by measuring the natural frequency and vibration damping of the concrete under dynamic loading. This paper is to determine the dynamic modulus of elasticity of concrete subjected to different pressure of high impact load using split Hopkinson pressure bar. Piezoelectric accelerometer is used to detect the vibration of concrete in the pressure bar system. The accelerometer is placed on the concrete specimen surface to measure the direct vibration of concrete and the fundamental frequency is determined by analyzing the wave signal. The results shows that the fundamental frequency of the concrete increase when the high impact pressure load of increase. The theoretical relationship that relates the fundamental frequency with the modulus of elasticity is used to calculate the MoE of concrete. Calculation shows that the dynamic modulus of concrete is enhanced with the increase of the fundamental frequency of the concrete specimen due to increasing high impact load.

Keywords: Vibration, fundamental frequency, pressure bar system, accelerometer, dynamic modulus of elasticity

1. INTRODUCTION

Concrete structures are exposed to high impact loading such as blast (as such had happened to the World Trade Centre), explosion during bombing (as such during war) and vibration of earthquake. The mechanical properties of concrete under high strain rates loading (i.e. greater than 0.1 sec^{-1}) are different from the static properties of concrete. Several techniques have been developed to determine concrete behavior under dynamic loading such as drop weight, plate impact, Charpy test, and Split Hopkinson Pressure Bar (SHPB). Many researchers (Grote et al., 2001) Forquiun et al., 2008 and Wang et al., 2008) have conducted studies using split Hopkinson pressure bars (SHPB) to to determine the stress and strain of concrete subjected to high strain rates loading.

Another important dynamic property of concrete is the dynamic modulus of elasticity which can be determined from the natural frequency and vibration damping of the concrete during vibration. These three parameters interact with each other. Dynamic modulus is a characteristic which can be determined based on the dynamic response of the material; damping is the characteristic of the

* Corresponding author: Email: mudionokasmuri@yahoo.com

energy dissipation of the material; and the natural frequency is a characteristic associated with the material and structure system.

The static modulus of elasticity of concrete is usually determined through a standard compression test such as ASTM C469 (1994). The dynamic modulus of elasticity of concrete can be determined nondestructively using resonance tests as prescribed in ASTM C215 (1991). Malaikah et al. (2004) have investigated non-destructively samples of concrete to determine the dynamic modulus elasticity with different loading condition using hammer to impact the concrete beam. The result shows that the dynamic modulus of elasticity of concrete is higher than the static MoE of concrete.

The main objective of this research is to measure the dynamic modulus of elasticity of concrete sample of concrete using pressure bar impact test. However, the concrete specimens are destructed due to the high impact load. An accelerometer is used to determine the fundamental frequency of the concrete when the concrete cracks and failure caused by high pressure in the system bar.

2. THEORITICAL ASPECT

The fundamental theory applied in this study is based on the one dimensional wave propagation in the bar. The determination of the dynamic modulus of elasticity of concrete specimens tested is based on the one dimensional wave propagation theory for both rods and beams.

The longitudinal free vibration of rods or bars is described by the equation

$$\frac{\partial^2 u}{\partial t^2} = v_b \frac{\partial^2 u}{\partial x^2} \quad (1)$$

where,

u = the displacement in the x-direction

t = time

x = the longitudinal coordinate

$$v_b = \sqrt{\frac{E}{\rho}} \quad (2)$$

v_b = the bar wave propagation velocity

E = Young's modulus

P = mass density

When a bar is bent, the simplest theory for such bending motion is the Euler-Bernoulli beam theory, which gives accurate results in the thin bar and rods.

The euler-bernoulli to bending vibration of motion can be written by

$$EI\frac{\partial^4 y}{\partial x^4} + \rho A\frac{\partial^2 y}{\partial t^2} = o \tag{3}$$

E, I ,A, ρ are respectively the Young Modulus, second moment of area of the cross section, ρ density and cross section area of the beam. The solution of Eq. (3) can be written as a standing wave $y(x,t) = w(x)u(t)$, This leads to the following characteristic equation that relates the circular frequency ω to the wavenumber k :

$$w^2 = \frac{EI}{\rho A}n^4 \tag{4}$$

Where $w = 2\pi f_n$ (5)

It can be shown that the frequency fundamental of the bar are

$$f_n = \frac{n^2}{4\pi^2}\sqrt{\frac{EI}{\rho A}} \tag{6}$$

From Eq. (5), the dynamic modulus of elasticity was determined as

$$E = \frac{4\pi^2 f_n^2 \rho A}{n^2 I} \tag{7}$$

where, E, f_n, n, are respectively dynamic modulus of elasticity of concrete, frequency fundamental, number mode harmonic fundamental.

3. EXPERIMENTAL

3.1 Materials and Mix Proportions

The materials used for casting the test specimens use the normal concrete. The compressive strength of the mix used was approximately 25 MPa. Design the normal concrete based on British standard. Details of the mix proportions are given in Table 1.

Table 1: Mix proportions normal concrete 25 MPa

No	Material	Quantity (kg)
1	Water	230
2	Cement	390
3	Sand	726.7
4	Coarse aggregate	963.3

3.2 Impact Test Set Up

The impact testing system consists of a gas gun chamber, a striker bar, an incident bar and a transmission bar which the concrete specimen in the middle of the bar. The accelerometer put on the concrete specimen to measure the signal an then using DAQ system to record the signal transfer in the computer. Details of the impact testing setup are given in Figure 1.

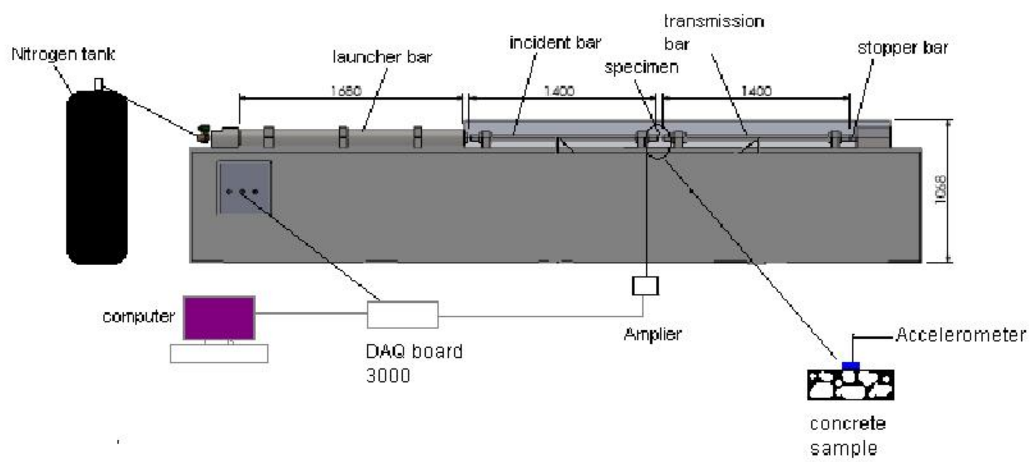

Figure 1: The Impact Testing Set Up

From the DAQ system will be obtain the analog time domain, and then the analog time domain data is transformed to define the frequency, magnitude and phase content of the signal. Since the data is on digital format, the discrete Fourier transform should be used to construct the frequency spectrum of the sampled analog signal. From the frequency spectrum, the natural frequencies, of the tested specimen can be estimated. Once the frequencies are determined the dynamic modulus of elasticity can then be calculated based on Equation (7).

4. RESULT AND DISCUSSION

The normal concrete cylinders were tested dynamically under impact test with different pressure. The impact test is based on the wave propagation in the bar to record the signal in concrete using accelerometer.

The accelerometer was mounted at mid-length of the cylinder and forced impact was performed by the bar pressure and then using FFT in Matlab program to measure frequency fundamental. The result dynamic impact tests are given in Table 2,

Table 2: The Result Dynamic Impact Test

No	Pressure impact test (MPa)	Fundamental frequency F_n (Hz)	dynamic modulus E_d (GPa)
1	2.67	450.89	29.19227
2	2.42	489.43	30.0965
3	2.76	497.354	33.29885
4	3.10	518.7988	33.81681
5	3.45	534.057	38.39487

As shown in Table 2, dynamic test results on the concrete with a high impact loading shows that the higher impact loading given the concrete causing cracks and failure in the concrete, because the fundamental frequency obtained greater with increasing impact loading of the concrete.

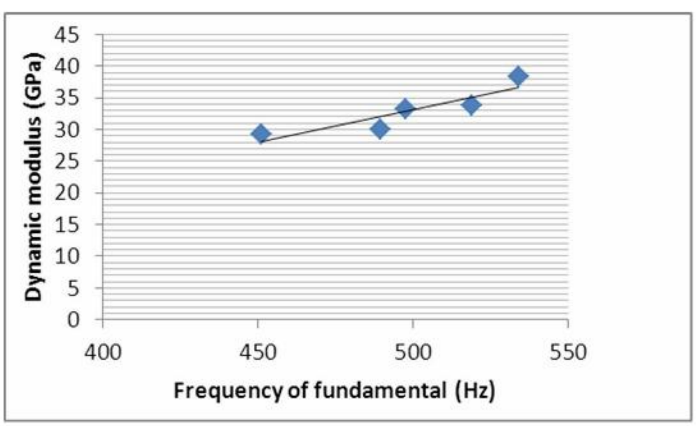

Figure 2: Graph Dynamic Modulus with Frequency of fundamental

Whereas dynamic modulus of concrete could be calculated by using formula 7 which the result shows that dynamic modulus of concrete more increase under different high impact loading with enhance pressure bar in the system, as shown in Figure 2.

5. CONCLUSION

This paper describes the dynamic behaviour of concrete using impact pressure system test to determine fundamental frequency of concrete and dynamic modulus of concrete under different impact loading. The concrete tests performed on the experiment with the destruction of the sample which will be obtained at the fundamental frequency of concrete when the concrete cracks and destruction. The accelerometer device used to record signals on the concrete and using matlab program to measure the fundamental frequency of the concrete. This paper shows the results that increasing the fundamental frequency in concrete with greater impact given the concrete. While for the dynamic modulus of concrete can be calculated by equation (7) in which the results showed that the dynamic modulus of the concrete also increases with increasing impact loads are given in concrete by using high-pressure system impact. This result can be seen from Figure (2), which increases the dynamic modulus is affected rather than a given load on the concrete.

6. ACKNOWLEDGMENTS

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