Determination of Dynamic Tensile Strength of Concrete Brazil Disc Specimens Using a Split Hopkinson Pressure Bar

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Abstract

1 Introduction

Accurate predictions of material failure are critical to the design of structures and mechanical devices. In order to make useful predictions of failure, materials test conditions must replicate real-world loading scenarios as closely as possible. Standard material tests use application-specific test fixtures and specimen geometries to approximate the expected stress state i.e. tension, compression, shear, or combined loading. An additional, and often overlooked, aspect of the loading condition is the rate at which loads are applied. Many structures and devices are designed to be impacted at high enough speeds that the constitutive response of materials is significantly different from the material's quasi-static behavior. In these applications it is important to quantify a materials failure properties at high rates in order to determine if the use of the material is appropriate.

A major challenge in high rate material testing is accounting for the inertial effects of a rapidly moving load frame. To overcome this challenge, Kolsky adapted a pressure bar technique originally used by Hopkinson, to strike thin material specimens at high speeds. The long and thin bars of a Split-Hopkinson Pressure Bar (SHPB), combined with a thin material specimen, allow strain measurements from the bars to be analyzed with 1 dimensional wave analysis. This simplification of 3D mechanics down to a single dimension allows for the inertia of the striker bar to be accounted for.

In this report, a SHPB is used to investigate the high rate tensile behavior of concrete. Concrete is a very common material used in large structures such as buildings, bridges, and roadways, all of which may be subject to high rate loading. Concrete is strongest in compression and weak in tension, thus concrete structures are usually designed to avoid tensile loading. However, the failure stress of concrete under tension is still a useful design parameter. In order to load the brittle concrete samples in tension, a Brazil disk specimen is used.

2 Methods

2.1 Experimental Techniques

2.1.1 Split Hopkinson Pressure Bar

2.1.2 High Strain Rate Data Acquisition

2.1.3 Statistical Analysis

Central tendency and dispersion are two common ways to quantify the distribution of a data set (ref). Central tendency is quantified using the measures of mean and median. The mean of a data set is given by

$$\bar{x} = \sum_{i=1}^{n} \frac{x_i}{n} \tag{1}$$

where $\bar{x}$ is the mean, n is the number of data points and x_i is the ith data point. The median is the central value of an ordered set of the data. Dispersion represents the distribution of data around the central tendency, usually the mean. Dispersion is measured using standard deviation and variance, given by

$$S_x = \left[\sum_{i=1}^{n} \frac{(x_i - \bar{x})^2}{n-1} \right]^{\frac{1}{2}} \tag{2}$$

$$S_x^2 = \sum_{i=1}^{n} \frac{(x_i - \bar{x})^2}{n-1} \tag{3}$$

where S_x is the standard deviation and S_x^2 is the variance.

For experiments involving strength of materials due to brittle fracture, a Weibull distribution function can be applied to show the probability of failure at a given strength value (ref). The Weibull Distribution is given by

$$p(x) = 1 - e^{-\left[\frac{(x-x_o)}{b}\right]^m} \text{ for } x > x_o \tag{4}$$

$$p(x) = 0 \text{ for } x < x_o \tag{5}$$

where $p(x)$ is the probability of failure occurring at x, x_o is the zero strength value of the distribution, b is scale parameter and m is the Weibull slope parameter. The values of distribution parameters x_o, b and m can be determined iteratively or by use of a commercial software such as MATLAB. MATLAB has a built in function, $wblfit$. that generates the Weibull parameters and probability distribution function with a 95% confidence interval (ref).

2.2 Procedure

Concrete Brazil Disc specimens with a diameter of xx mm and thickness of xx mm were loaded in a SHPB test setup. The SHPB utilized 19.05 mm diameter aluminum 7075-T6 bars for the incident and transmitted bars. The incident bar length was 2.438 m and the transmitted bar length was 1.930 m. Aluminum platens with a matching acoustic impedance were attached to the loading end of the incident and transmitted bars to prevent damage to the SHPB apparatus from the concrete specimens. A 1.058 mm thick, 9.525 mm diameter lead pulse shaper was placed on the non-loading end of the incident bar for each test. The striker bar was propelled using a REL gas gun. The experimental setup can be seen in Figure 1.

Initial calibration and bar wave speed were determined without specimens using a gas gun pressure of 10.2 psi. A total of ten specimens were tested at four separate gas gun pressures - 8, 9, 10.2 and 12.4 psi. Strain gauges attached to both the incident and transmitted bars were used to detect the incident, reflected and transmitted waves in the bar. The strain gauges were located 1.219 m from the loading point on the incident bar and 0.965 m from the loading point on the transmitted bar. Voltage outputs from the strain gauges were collected using a Tektronix DPO 2004B oscilloscope. All analysis was completed in MATLAB.

2.3 Error and Uncertainties

3 Results

4 Discussion

5 Conclusion

6 Figures

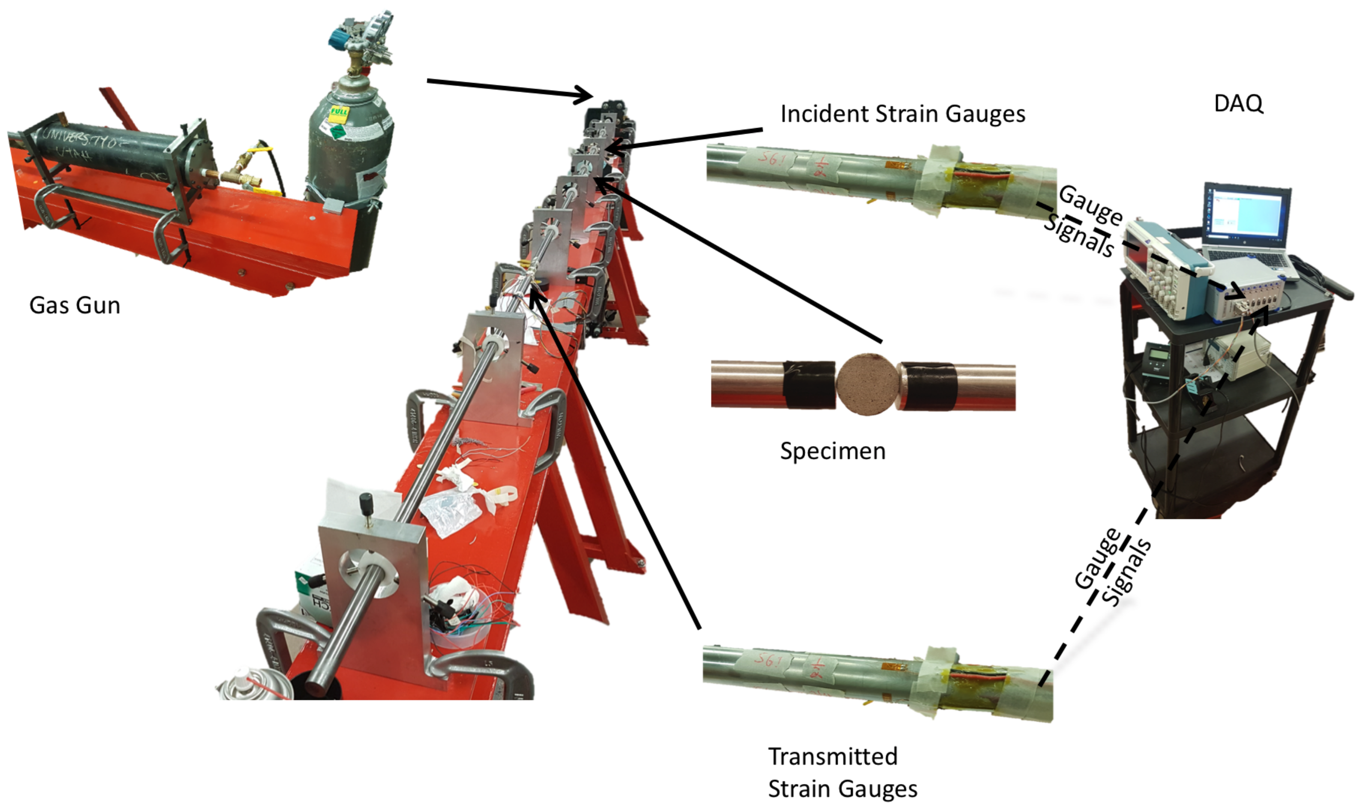

Figure 1: Experimental setup of the Split Hopkinson Pressure Bar

7 Tables

References