Simulation of Split Hopkinson Pressure Bar Dynamic Brazilian Tests

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Background

Experiments using a Split Hopkinson Pressure Bar (SHPB) and a Brazilian (tension splitting) specimen were conducted on 2-inch diameter concrete specimens, as report by Tedesco et al [1993]. Additional details of the experiments we obtained from Ross [1999] and include the length of the striker bar (25.7 inches or 0.652 m), velocity of the striker in the three tests, 3.04, 3.67, and 13.34 m/s in Tests 1 through 3, respectively, and plots of the measured (strain) stress histories from the three tests.

Preliminary Results

Simulations of Test 2 were performed using both an elastic and damage model representation for the concrete specimen constitutive response. Both models used a concrete density of 2405 kg/m^3 and the elastic model had a Young's modulus of 37.9 GPa, see Tedesco et al [1991], while the damage model had an Young's modulus of 31.9 GPa; shear modulus of 13.89 GPa and bulk modulus of 15.52 GPa.

The model of the SHPB included the specimen and the bearing strips that attach it to the incident and transmission bars, as described previously. The length of both incident and transmission bars in the model is 56 inches (1.42 m) while the bars in the test were 12 feet long (3.65 m). The full length of the striker bar, 25.7 inches (0.65 m), was included in the model to generate the correct stress pulse duration. The axial strain gage measurements were made on both incident and transmission bars at locations 40 inches (1 m) from the bar end nearest the specimen. In the model the distant end of the transmission bar includes a 'silent boundary' which is intended to damp out most of the energy arriving at that end of the bar. Because the incident bar has been shortened in the model, the direct comparison of measured and computed histories is only valid for the first 0.9 milliseconds of the simulation, The X-T diagram shown in Figure 1 shows the wave interactions in the striker and incident bar, with a time profiles at the outer ends of the striker and incident bars, the striker-incident bar interface, and incident bar strain gage location.

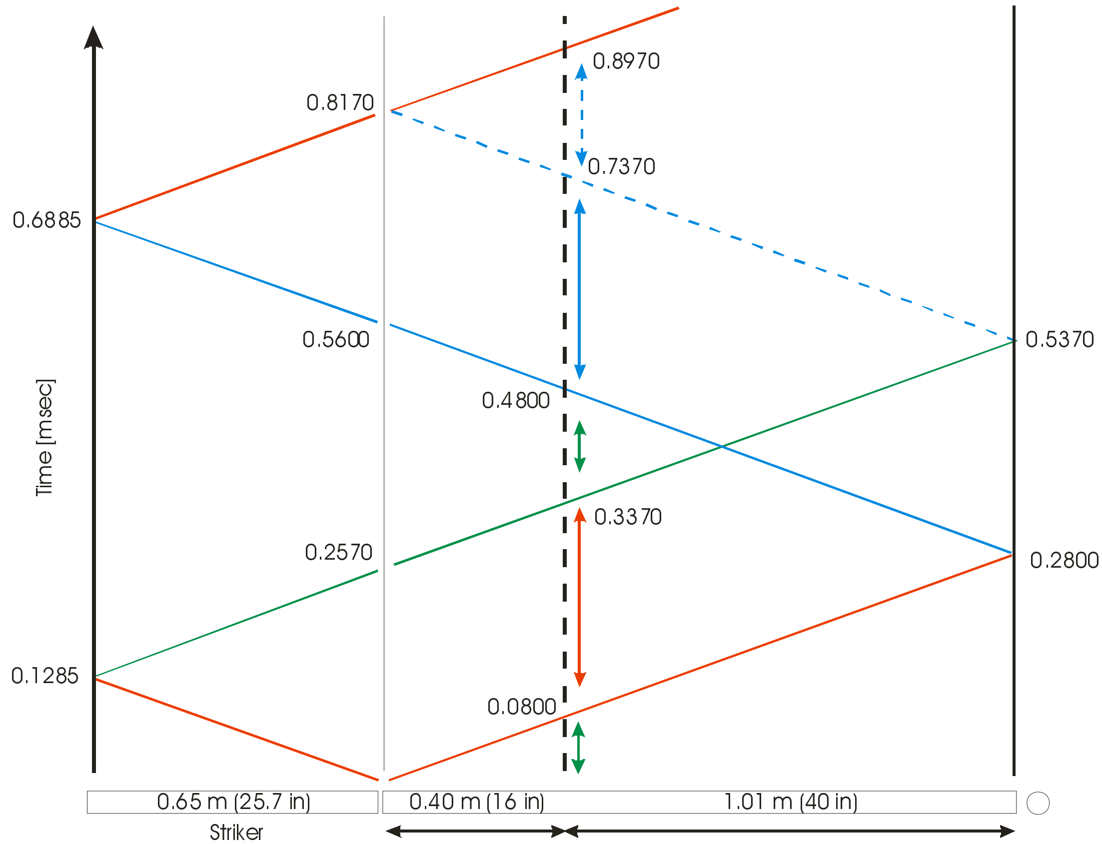

Figure 1 Wave interaction diagram for striker and incident rods.

Figure 2 shows the measured and computed axial stress histories at the incident bar gage location. As expected both calculations reproduce the measured elastic compressive stress wave traveling down the incident bar until about 0.50 milliseconds when a difference between the computed elastic concrete specimen and the measured and damage model concrete specimens is first evident. The reflected stress response differs markedly after about 0.55 milliseconds.

From the interaction wave diagram, shown previously, the effect of the specimen end of the incident bar first arrives at the strain gage location at 048 milliseconds. The time difference of 0.07 milliseconds (0.55 – 0.48 milliseconds) can be interpreted as the time to damage the specimen.

The elastic concrete specimen's affect on the reflected stress is to reduce the magnitude of the stress from about 60 MPa in the measured, and damage model, response to about 40 MPa in the elastic response. This reduction in reflected stress can be thought as due to the fact that the elastic specimen is able to transmit more stress to the transmission bar than the damage model specimen, as will be shown. Another way to think of this is that the damage model specimen, and measurement, show more of a reflected stress response of a free end than does the elastic specimen response which represents an end condition between free and fixed, i.e. an elastic spring.

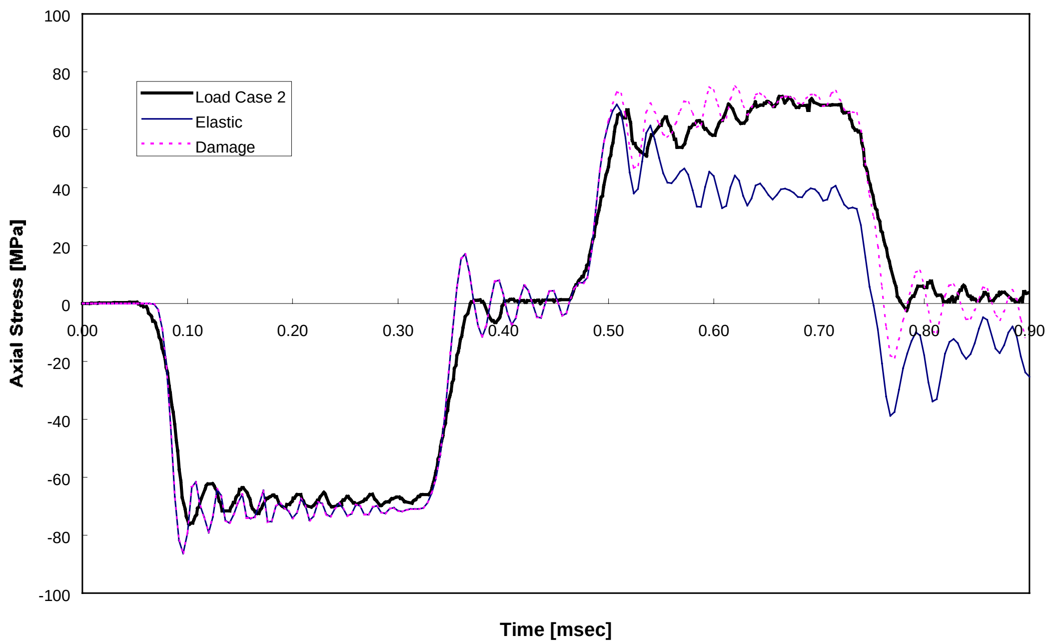

Figure 2 Comparison of measured and computed axial stress histories at the incident bar gage location.

Figure 3 shows the measured and computed axial stress histories at the transmission bar gage location. In this figure it is clear that the elastic specimen has transmitted a significantly larger stress than either that measured or calculated using the damage model specimen. The fact that the calculated stress from the damage model is only about 60% of that measured is not a current concern as the damage model parameters were not selected to match this concrete specimen, but merely to provide a means of assessing and comparing the effect of some type of damage in the specimen on the computed and measured responses.

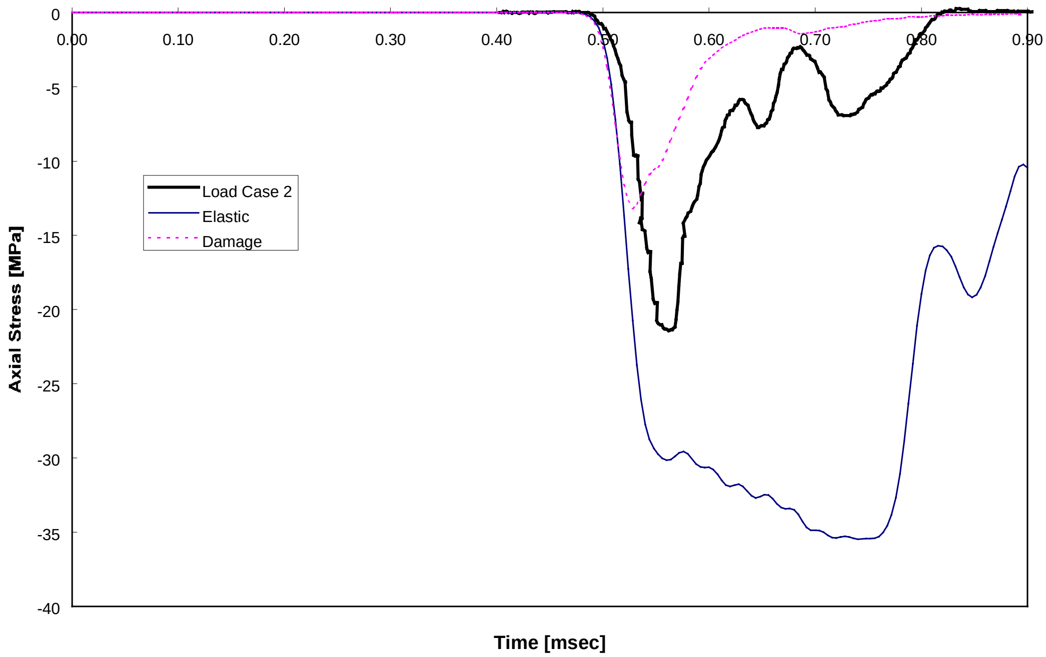

Figure 3 Comparison of measured and computed axial stress histories at the transmission bar gage location.

References

Ross, A., Email Communication, August 1999.

Tedesco, J.W., C.A. Ross, P.B. McGill and B.P. O'Neil, "Numerical Analysis of High Strain Rate Concrete Direct Tension Tests," *Computers & Structures*, Volume 40, Number 2, pages 313-327, 1991.