Rate Dependent Behavior of High Damping Rubber Bearings in Low Temperature and Rheology Model

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Summary

High Damping Rubber Bearings (HDRBs), one of most important isolation device in Japan. The rate dependent behavior of HDRBs were observed by a serial dynamic loading tests. A modified rheology model is proposed for bridge seismic design. The concepts of equilibrium and instantaneous are used to measure the basic rate dependent component and rate independent component. Parameters in the proposed model describing the rate dependent behavior of HDRBs is identified from dynamic loading test. Experimental verification for the proposed method was also conducted use multiple types of loading tests.

Keywords: rheology model, High Damping Rubber (HDR), rate dependent behaviour, numerical model, dynamic loading tests.

1. Introduction

In this study, dynamic loading tests are carried out to investigate the rate-dependent hysteresis behavior of HDRBs at room (23oC) and low temperatures (-10oC, -30oC). A modified rheology model is proposed to represent the rate dependent hysteresis behavior reliably for HDRBs. Finally, the ability of the proposed model and parameter identification procedure are verified by comparing the numerical simulation results and various types dynamic loading data.

2. Modified Rheology model

A layout of rheology model is proposed as in Fig. 1.

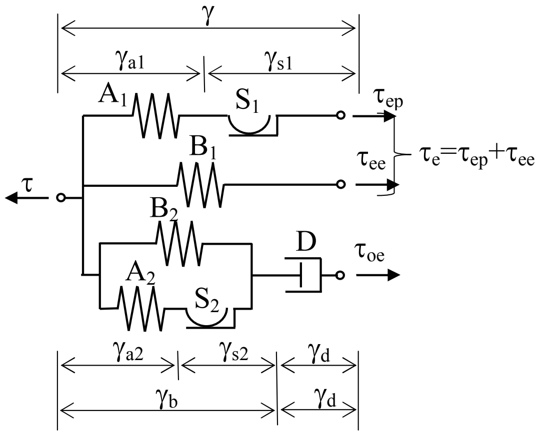
The total stress of HDRBs τ is presented as the resultant of rate independent equilibrium stress τ_e and rate dependent overstress τ_{oe}.

$$\tau = \tau_e + \tau_{oe} \tag{3}$$

Three branches of the proposed model, as shown in **Fig.1**, define elasto-plastic stress τ_{ep}, nonlinear elastic stress τ_{ee}, and the rate-dependent overstress τ_{oe}.

A similar structure to the equilibrium part is used in the rate dependent overstress part, where the three elements A2, S2, and B2 would present elasto-plastic behavior if they were used independently. This elasto-elastic part is connected with a dashpot, as can be seen in **Fig. 1**, to construct an expanded Maxwell model.

This layout for overstress can also be seen as a Maxwell model installed a nonlinear elasto-plastic spring to instead the original linear elastic spring. Thus, when the bearing is loaded in low strain rate, the overstress keeps low, as Maxwell model performing its relaxation property by letting the dashpot absorbing most of deformation. In the other hand, when the bearing is loaded in high strain rate, the deformation of dashpot is jammed up, and the overstress shows bilinear shape behavior.



3. Experimental Verification

To evaluate the validity of the proposed model, the numerical simulation of MSR loading, Sinusoidal Shear (SS) loading and Simple Relaxation (SR) loading were conducted [1]. From MSR loading test result the parameters for equilibrium stress are identified by Least Square Method, and parameters for rate dependent over stress are identified from SS tests by curve fitting.

Hysteresis curves due to MSR loading due to experiments and numerical models are plotted in **Fig. 2**. It can be clearly seen that hysteresis curves due to the proposed model truthfully presented the rate dependent behavior, such as those local relaxation effect due to holding the strain temporarily and the rising up curve due to the restarted fast loading.

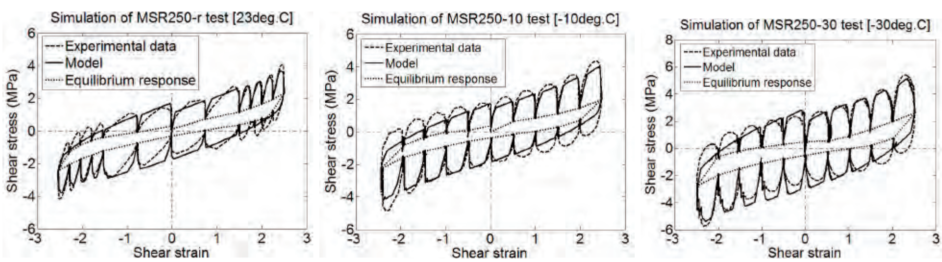


Fig. 2. Numerical simulation of MSR tests at (a) 23^{o}C (b) -10^{o}C (c) -30^{o}C.

4. Conclusions

A Modified rheology model is proposed to describe the mechanical behaviors of HDRBs. The basic layout of the proposed model is considered to present the behavior of HDRBs in rate independent and dependent states, equilibrium state and instantaneous state, as observed in loading tests.

The equilibrium parameters are determined from multi-step relaxation tests. The overstress parameters are identified from sinusoidal loading tests.

The model was verified adequately successful in simulation introducing the mechanical behavior of HDRBs for numerical analysis by comparing of the simulation results with the simple relaxation tests and multi-step relaxation tests at both low temperatures and room temperatures.