Influence of Mullins and hardening effects of seismic isolation rubber bearings on the seismic response

Hiroshi Shimmyo; Tolga Onal

Kawakin Core-Tech Co., Ltd. Saitama, Japan

Prof. Shozo Nakamura, Dr. Engineering; Kazuya Tokunaga

Nagasaki University, Nagasaki, Japan

Contact: h-shinmyou@kawakinkk.co.jp

Abstract

In the current Specifications for Highway Bridges of the Japan Road Association, a bilinear force-displacement relationship is recommended as the hysteresis loops of the seismic isolation rubber bearings for the dynamic structural analysis of seismically isolated bridges. However, it has been confirmed that the restoring force characteristics of the actual devices are different from the bilinear model due to the Mullins effect and the hardening phenomenon of the rubber under large shear strains. In this study, the effect of these two factors on the seismic response of a bridge is investigated through the dynamic analysis with the tri-linear double target model considering the factors. The parameters of the model are obtained from product test results of lead-plugged laminated rubber bearings and high-damping laminated rubber bearings.

Keywords: seismic isolation rubber bearing; restoring force characteristics; Mullins effect; hardening; earthquake response.

1 Introduction

Based on the experience of road bridge damages caused by the 1995 Hyogo-ken Nanbu (Kobe) Earthquake, seismic isolation rubber bearings have been widely introduced to bridges for the purpose of improving seismic performance. In the design of seismically isolated bridges using seismic isolation rubber bearings, the mechanical characteristics of the seismic isolation rubber bearings used have to be properly modeled in the analysis for design as the seismic isolation performance of the bridge largely depends on the energy absorption capacity of the seismic isolation rubber bearings. In the current Specifications and Commentary for Highway Bridges, V Seismic Design [1], it is common to model the restoring force characteristics of seismic isolation rubber bearings by bilinear force-displacement relationship in the dynamic analysis of bridges with seismic isolation rubber bearings.

However, in actual products, it is known that the mechanical characteristics of the same excitation shear strain depend on the magnitude of the maximum shear strain experienced, which is called the Mullins effect. Furthermore, the hardening phenomenon of the rubber under large shear strains has been also confirmed. Due to these effects, the actual response of bridges can be significantly different from that obtained by the design calculation using the bilinear model.

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