A Hysteretic Model of Compressive and Tensile Behavior for Laminated Rubber Bearings

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Abstract

In Japan, Laminated rubber bearings have widely been used in road bridges after Kobe earthquake (1995). In Great East Japan earthquake (2011) and Kumamoto earthquake (2016), some damages were found in the bearings and they might be caused by tensile deformation. In this research, compressive and tensile hysteretic models of the bearings are developed. At first, we conduct loading experiments of single rubber layer, in order to grasp compressive/tensile behavior. Then, based on experimental results, we develop a tensile hysteretic model which combines an elasto-plastic unit and a damage unit in parallel. Finally, a compressive hysteretic model is constructed by adding a nonlinear elastic unit to the tensile hysteretic model in parallel. As a result, the proposed model is found to accurately reproduce the experimental results.

Keywords: laminated rubber bearing; vertical force-displacement relation; hysteretic model; elasto-plastic unit; damage unit; nonlinear elastic unit.

1 Introduction

After Kobe earthquake (1995), Seismic devices such as laminated rubber bearings have widely been used in road bridges. Typical characteristics of laminated rubber bearings are that it is flexible in the horizontal direction and it has high stiffness in vertical direction in order to support superstructures. In previous studies, many hysteretic models for horizontal deformation were developed [1][2][3][4][5]. On the other hand, a design code in Japan considers only compressive deformation of the bearing as effective and neglects tensile deformation, because large compressive pre-loading by gravity exists [6]. Therefore, there exist few hysteretic models of vertical deformation, especially in the tensile deformation. However, in Great East Japan earthquake (2011) and Kumamoto earthquake (2016), some damages were found in the bearings and they might be caused by tensile deformation of the bearing, which originated from rotational response of girders

There are a few researches on the hysteretic models in the vertical direction. For examples, Kikuchi et al. [7] proposed a hysteretic model and they showed that the model could well reproduce their experimental results. However, rules for making hysteresis seemed to be complex and implementation of the model might be difficult. Kumar et al. [8] developed a unified hysteretic