



Parametric finite element investigation of the critical load capacity of elastomeric strip bearings

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ABSTRACT

Elastomeric bearings are used in non-seismic bridge applications and for seismic isolation of structures. These bearings consist of a number of elastomeric (rubber) layers bonded to intermediate steel shim plates. For seismic isolation, the total thickness of rubber provides a low horizontal stiffness, whereas the close spacing of the intermediate shim plates provides a high vertical stiffness, relative to the horizontal, for a given bonded rubber area and shear modulus. During earthquake ground shaking, large lateral displacements will develop across the isolation interface and the individual bearings. The design of elastomeric bearings for seismic isolation requires that the stability of the individual bearings be demonstrated at the maximum bearing displacement. A component of the stability assessment is the determination of the critical load of the bearing at a given lateral displacement. Currently, the critical load is estimated using an approach whereby a ratio, that of the overlapping area between the top and bottom bearing endplates to the bonded rubber area, is used to reduce the critical load at zero lateral displacement, referred to herein as the overlapping area method. This study verifies the finite element method for predicting critical loads in elastomeric bearings, and uses the finite element method to investigate the dependency of the critical load on the bearing geometry. The results of the parametric study were also used to evaluate the predictive capabilities of the overlapping area procedure.

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1. Introduction

Elastomeric bearings are one type of commonly used seismic isolation hardware consisting of layers of elastomer (e.g., natural rubber) bonded to intermediate steel shim plates. The total thickness of rubber provides the low horizontal stiffness required to shift the structure's period of vibration, whereas the close spacing of the intermediate steel shim plates provides a large (relative to the horizontal) vertical stiffness. During earthquake ground shaking, relative displacements in the isolated structure will be concentrated across the isolation interface, therefore subjecting the individual bearings to simultaneous large lateral displacement and axial compressive force as a result of overturning forces. Prior experimental studies [1–3] have shown that elastomeric bearings with both doweled and bolted connection details exhibit instability under simultaneous lateral displacement and axial compressive force, although the mechanisms leading to instability are quite different for each of these connection details. Doweled connections have been used in the past as a method to prevent the development of

significant tensile stresses in the elastomeric bearing, but they are susceptible to an instability termed rollover [1]. Bearings with bolted connections are more commonly used, but they are also susceptible to instability, as has been demonstrated from past experimental studies [2,3] of square elastomeric bridge bearings and more recent studies of annular low-damping natural rubber and lead-rubber seismic isolation bearings [4,5]. These more recent studies have further demonstrated that the critical load capacity decreases with increasing lateral displacement for an expanded set of bearing geometries and types, including shape factors up to 12 and lead-rubber bearings. Analytical models have been proposed [6,7] for circular and square elastomeric bearings that account for the influence of axial load on the shear force response, and have been verified with experimental cyclic shear results. However, the focus of these studies [6,7] was not on determination of the critical load capacity.

An important step for the design of seismic isolation systems and the individual bearings is demonstrating the stability of individual bearings for service level and seismic loading; see, the AASHTO Guide Specifications [8]. For service loading, stability is assured by demonstrating that the critical load at zero lateral displacement, P_{cr} , i.e., the buckling load of a column accounting for shear deformations [9–13], is greater than a combination of dead

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