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Stability of Fiber-Reinforced Bridge Bearings under Compression and Shear Load

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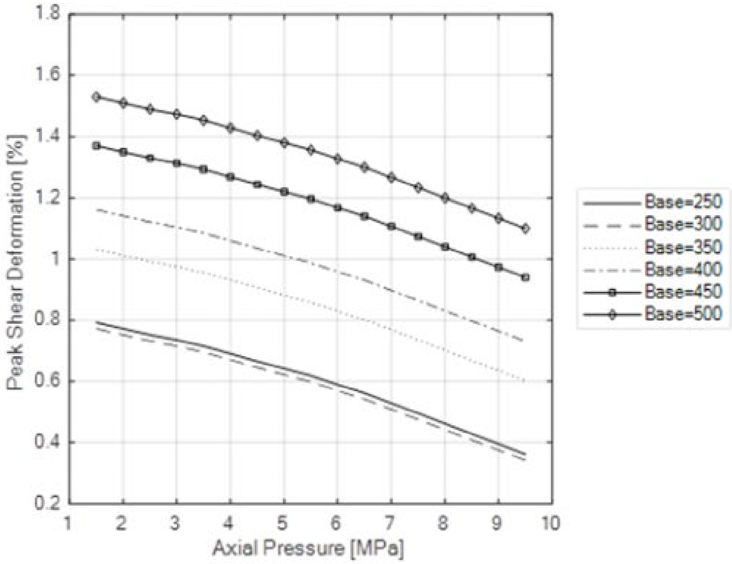

Fiber-Reinforced Bearings (FRBs) have proven to be a valuable rubber-based base isolation technology in which flexible fiber reinforcements are used to replace the steel layers commonly adopted for the manufacturing of Laminated Rubber Bearings (LRBs). Thanks to the low weight and cost of FRBs, these devices could prove to be instrumental for the promotion of base isolation applications to bridges and buildings in seismic prone regions of the world. This report presents the results of a large set of Finite Element Analyses (FEAs) aimed at assessing the performance of FRBs under combined axial and shear loads. The effects of different magnitudes of axial pressure, material properties, primary and secondary shape factors of the bearings on the stability of the devices under combined axial and shear loads are discussed in this work.

Study Methods

Results of this work are bases on a large set of FEAs. FEAs of unbonded rubber bearings with flexible reinforcements under combined axial and lateral load are challenging because they require advanced numerical tools to capture highly nonlinear phenomena such as those occurring in an FRB under large lateral displacements and loads. The nonlinearities include sliding of the bearing at the contact surfaces, variation of the boundary conditions, large strain of the elastomer and its nearly incompressibility, and self-contact of the edges of the bearing, which can be deformed enough to fold over themselves. All these phenomena have been considered for the analyses discussed in this work. The FEAs discussed in this study are based on two-dimensional models where a plane strain assumption is assumed to match the response of a rectangular or strip-type isolation bearing loaded in shear.

Findings

From the results of an extensive series of FEAs, the following assertions can be made:

(i) As expected, an increase of the vertical pressure on an FRB produces a reduction of the peak shear deformation capacity, independently of the aspect ratio;

(ii) The magnitude of the axial pressure modifies the maximum horizontal displacement capacity of the bearings. This modification is nonlinear with the shape factor, and the type of nonlinearity differs for lightly loaded bearings compared to heavily loaded ones;

(iii) The peak strain and stress capacity of the bearings increases with the shear modulus of the rubber while being independent of the bulk modulus of the elastomer.

The simple design formulae commonly adopted for FRBs underestimate the effect of the axial pressure in limiting the lateral displacement capacity of the bearings.

Policy Recommendations

Conclusions of this study underline that the simple design formulae commonly adopted for FRBs underestimate the effect of the axial pressure in limiting the lateral displacement capacity of the bearings. Additional research is needed to extend the results of this study to bearings of other shapes, including circular and square isolators.

About the Principal Investigator

Dr. Calabrese joined the California State University Long Beach, CSULB Civil Engineering and Construction Engineering Management (CECEM) Department CECEM Department as an Assistant Professor in Fall 2017. He gained a PhD in Construction Engineering with an emphasis in Structural Engineering in 2013. He was a visiting research fellow at the Pacific Earthquake Engineering Research Center (PEER) from 2010–2012 along with having been a postdoctoral researcher of the ReLUIS Consortium at the Italian Network of University Laboratories in Earthquake Engineering from 2013–2014. Dr. Calabrese has worked as a Structural Engineer at Foster & Partners (London) and in Italy for a total of seven years. He has been a registered engineer in Italy since 2009 and a Chartered Engineer (CEng) and Full Member of the Institution of Civil Engineers (MICE) in the UK since 2017. Dr. Calabrese's current research interests are in the fields of experimental testing, structural dynamics, base isolation, vibration engineering, and the development of novel low-cost devices for the seismic protection of buildings. His work has been instrumental in developing of low-cost seismic isolation systems for the seismic protection of buildings in developing regions.

To Learn More

For more details about the study, download the full report at transweb.sjsu.edu/research/1929

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