Design and development of fiber reinforced elastomeric bearings

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Summary

The use of reinforced elastomeric bearings for simple and cheap earthquake isolation systems has been discussed for some years. The advantages of the use of fiber reinforcement for these isolators (e.g. high damping, large range of horizontal deflection) are known and have often been described. However, the current design codes give no appropriate formulas to calculate the behavior of fiber reinforced elastomeric isolators.

This study presents a first step to develop advanced design guidelines for elastomeric bearings taking nonlinear effects into account. Based on a parametric study on numerical models and the formulas given in the current design codes and other publications a new formula to describe the horizontal stiffness is developed. Hereby specific nonlinearities of fiber reinforced elastomeric bearings are taken into account as well as the influence of vertical loads on the horizontal stability.

Keywords: Elastomeric bearing, fiber, reinforced, earthquake isolator, horizontal stiffness

1. Introduction

The seismic isolation of structural systems requires bearing devices with a large lateral deformation capability and sufficient damping behavior. Elastomer bearings provide cheap and robust solutions for this range of application. However, the lateral displacement and the damping of common steel reinforced elastomer bearings (SREB) are limited. As presented in many publications, e.g. in [1], these characteristics can be improved by replacing the steel plates with flexible fiber reinforcement (e.g. glass fibers).

For seismic isolation systems but also for other bearings with dynamic horizontal loads the most important factors for the design are the horizontal stiffness and the damping ratio. The formulas for the horizontal stiffness given in current construction codes for SREB do not consider the effects of geometrical or material nonlinearities. Also the additional nonlinearities of fiber reinforced elastomeric bearings (FREB) like for example the rolling out are not considered.

The aim of the present study is to discuss the influence of the specific nonlinearities and to develop a formula for the horizontal stiffness that considers the influence of the vertical load and the horizontal deflection.

2. Geometrical nonlinearities influencing the bearing behavior

The geometrical nonlinearities are investigated using a parametric study based on numerical models of SREB and FREB. This is used to show influence of the rollout and the vertical load on the horizontal stiffness and to develop an appropriate formula describing the stiffness.

2.1 Influence of rollout

As the bearings are not fixed to a steel plate at the top and the bottom they perform a lifting off from the horizontal planes and rolling out. This effect has to be considered in the calculation of the horizontal stiffness as it has a significant influence. Fig. 1 shows the decrease of the horizontal

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force due to rollout.

The comparison of the horizontal forces of SREB and FREB in Fig. 1 shows that for low vertical forces the decrease of the horizontal force is a linear function of the displacement. The gradient complies with the ratio of height t_r and length a: t_r / a = 38 %, 50 % and 30 % respectively. For small vertical loads the effect of rollout onto the horizontal force can therefore be considered by:

$$H_{FREB} = H_{SREB} \cdot \left(1 - \frac{v_x}{a}\right) \tag{1}$$

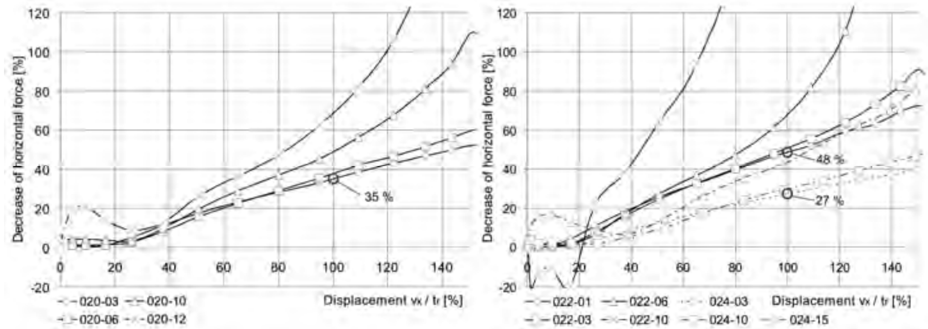

Fig. 1: Decrease of horizontal force of FREB due to rollout in comparison to SREB (fixed, without rollout) with (left) a height of 75 mm and (right, red) heights of 60 mm and (right, blue) 100 mm

2.2 Compression load and critical load

The stability behavior of an elastomeric bearing loaded with a vertical load is similar to the buckling behavior of an ordinary column with low shear stiffness under a critical load P_{crit} as shown in [2]. An approximation of the horizontal stiffness only valid for $v_x = 0$ is given in [2]. Including a factor for the reduction of the p_{crit} due to horizontal displacements as described in [3] and considering the rollout effect using formula (1) leads to:

$$K_{h,FREB} = \frac{G \cdot a^2}{t_r} \cdot \left[1 - \left(\frac{p}{p_{crit} \cdot \left(1 - \frac{v_x}{a}\right)}\right)^2\right] \cdot \left(1 - \frac{2 \cdot v_x}{a}\right) \tag{2}$$

The comparison of the results of the numerical models with those from formula (2) showed that it gives a fair approximation of the horizontal stiffness for horizontal deformations of 70 to 100 % of the height t_r. It considers the rollout effect as well as the influence of the vertical load.

3. References

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