Effectiveness of Fiber Reinforced Elastomeric Bearings as Anti-Seismic Devices

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Summary

In the design of common residential and office buildings the consideration of seismic loads causes significant costs especially when prefabricated elements are used. The application of anti-seismic devices can help to reduce the inner forces. This can be realized by adding elastic horizontal joints to the shear walls using elastomeric bearings. An evaluation of the efficiency of such constructions is show in this study for buildings of three to ten floors.

Keywords: elastomeric bearing, seismic protection, earthquake, damping

1. Introduction

Prefabricated wall components for high-rising structures are common for simple residential and office buildings due to the low cost of construction. This advantage is reduced by costs caused for partly necessary vertical tensile connection associated with seismic loaded shear walls.

These lifting forces can be reduced by a horizontal isolation located between the foundation and the main structure or by avoidance of resonance effects. This can be obtained by lowering the horizontal stiffness of the shear walls by the application of horizontal elastic joints e.g. between the prefabricated wall units. More or less a cantilever with low shear stiffness and therefore a reduced natural frequency is considered. The realization of these joints can be achieved by using fiber reinforced elastomeric bearings as a cost efficient and simple solution for the seismic protection of ordinary residential buildings [1]. The objective of this paper is to present the effectiveness of this type of anti-seismic devices.

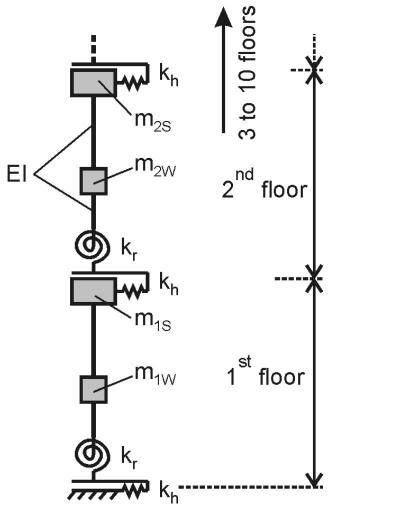

Fig. 1: Structural system of the stiffening structure: mass-spring-system of a building with the masses of the floor slabs $m_{1S} = m_{2S}$ and the masses of the walls $m_{1W} = m_{2W}$; dampers not shown

2. Structural system, horizontal stiffness and damping

The parametric study is carried out on high rising concrete buildings with common dimensions for residential and office buildings with three to ten floors and an assumed length of the shear walls of l = 5.0 m. Two different types of floor plans are taken as a basis for the calculations. The structural difference of the two types is the size of the ground-plan area of the seismically influenced masses acting on a single shear wall (type I: A_I = 24 m^2 with 18.1 t; type II: A_{II} = 48 m^2 with 36.2 t). The seismically influenced masses of the walls are considered to be equal for both building types (15.3 t).

Fig. 1 shows the structural system used in the parametric study. To be able to consider the nonlinear stiffness and damping behavior of the elastic joints the damping is not taken into

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account as a global damping e.g. using a stiffness or mass proportional viscoelastic damping matrix. In this case the damping is applied by adding a specific damper to each structural element.

The damping of the concrete elements is considered using a viscoelastic damping element acting in orthogonal direction of each beam element. The stiffness and damping behavior of the elastomeric joints is modeled to comply with the load-displacement data from numerical simulations of fiber reinforced elastomeric bearings. A combination of an elastic and a viscoelastic spring is suitable to meet the requirements of an element with amplitude dependent and rate independent relative damping.

3. Parametric study on efficiency of anti-seismic device

The parametric study is based on time integration analysis of structural system with two building types and three to ten floors with a variation of the elastic joint. Three different values of horizontal stiffness with the corresponding damping value are used for the joints. The joints are located between the wall elements of all floors or only between the lowest element and the foundation. In addition buildings without rigid joints presenting buildings without anti-seismic devices are analyzed. The calculations are carried out using time integration analysis based on artificial earthquake acceleration data. This analysis type is necessary to be able to consider the non-linear bearing behavior.

The occurring restraint moments at the lower end of the stiffening walls of the buildings with elastic joints are set in relation to those of conventional buildings with rigid joints leading to a reduction factor η. It can be taken as a measurement for the effectiveness of elastomeric bearings as seismic protection devices.

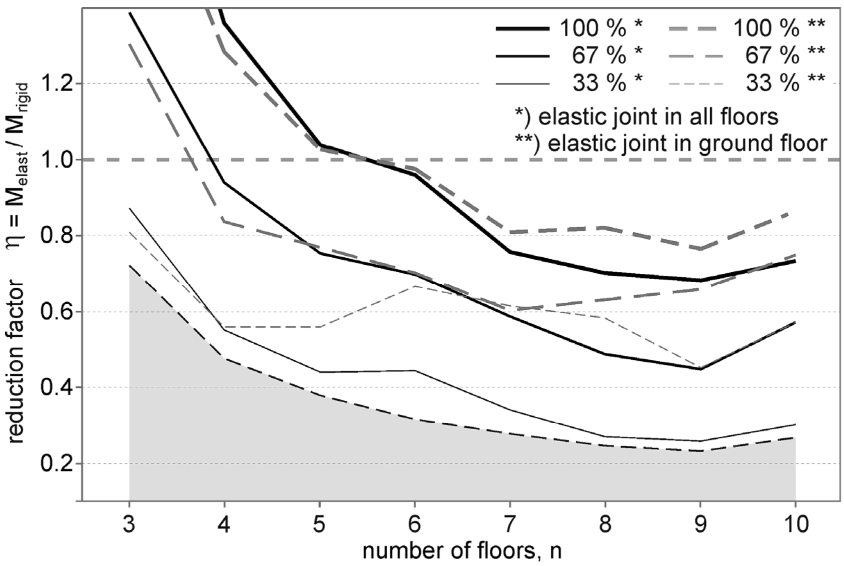

Fig. 2: Structure type I; reduction of the restraint moments at the base point of the stiffening wall due to installation of elastic joints

4. Results and conclusions

The results shown in Fig. 2 give an impression of the vast possible reduction of the inner forces ($\eta < 1.0$). The effect is enhanced by the fact that part of the uplifting forces due to the restraint moment are neutralized by forces from the vertical load transfer (gray area in Fig. 2). It is shown that with the given assumptions the potential savings at the reinforcement are enormous (20 to 95 %). To obtain optimal results a correlated tuning of damping and stiffness of the elastomeric bearings is necessary.