IOP Conf. Series: Materials Science and Engineering **269** (2017) 012067 doi:10.1088/1757-899X/269/1/012067

A research on Performance Efficiency of Rubber Metal Support Structures

Oleg V. Mkrtychev[1], Artem A. Bunov[1*]

[1]Moscow State University of Civil Engineering, 26 Jaroslavskoje shosse, Moscow, 129337 Russian Federation

Abstract. The paper scrutinizes structural behavior of lead rubber bearings by a Chinese manufacturer subjected to a single-component seismic action. Several problems were solved using specialized software complexes, which conducted forth integration of motion equations through the explicit method or response spectrum method. Depending on the calculation method, the diagram of the bearing performance was assumed to be either an actual diagram approximated by an idealized non-linear diagram or an idealized linear diagram with a specific stiffness. The computational model was assumed to be a single-mass oscillator with a lumped mass. The effort undertaken facilitated the investigation of the patterns of horizontal displacement of the bearing top relative to bottom caused by earthquakes modeled as accelerograms with different spectral compositions. The behavior of the support structure was benchmarked against similar supports by another manufacturer. The paper presents the outcomes of the research effort and draws conclusions about the efficiency of using the bearings of this particular type and model.

1. Introduction

Buildings and structures intended for seismic areas often incorporate various kinds of seismic protection in their design. As of today, LRB support is one of the most wide spread systems enhancing seismic resilience of structures [1, 2]. Major manufacturers like Maurer Sohne, FIP Industriale etc. produce bearings of this type. They have a track record of supplying reliable and high-quality products, however, they often lose a certain market share to Chinese companies, whose produce is often of dubious reliability and effectiveness.

2. Problem statement

The present paper considers the efficiency of LRB types 600, 700 and 800 by a Chinese manufacturer and benchmarks them against their counterparts by FIP Industriale [3].

3. Basic calculation provisions

The research was based on the assumption that an isolated structure behaves as a completely rigid body. The computational models were thought of as single-mass linear and non-linear oscillators with lumped mass (figure 1). Such problem setting enables us to draw a general qualitative conclusion about the operational effectiveness of the support structures [4].

IOP Conf. Series: Materials Science and Engineering **269** (2017) 012067 doi:10.1088/1757-899X/269/1/012067

Figure 1. Computational model of the bearing.

To ensure accuracy of the results, the research was conducted in two separate software packages, LIRA 10.6 and Ansys (LS-Dyna) [5].

A verification of the materials and the types of finite elements was also undertaken as part of the research. The software-based numeric modeling, namely the work diagrams and natural periods of oscillation of LRBs, was compared with the outcomes of the in-situ testing. The degree of matching proved to be high.

The response of a building equipped with a seismic protection in the form of LRB support is known to be sensitive to the spectral composition of the seismic load. For this reason the research effort processed accelerograms with a varying spectral composition 1, 1.5, 2 and 3 Hz. Figures 2 and 3 present acceleration curves with the dominant frequencies of 1 and 3 Hz. The vertical load on the bearing was considered in accordance with its estimated bearing capability:

1) vertical load on LRB-D600 – 3393 kN;
2) vertical load on LRB-D700 – 4618 kN;
3) vertical load on LRB-D800 – 6032 kN.

a) b)

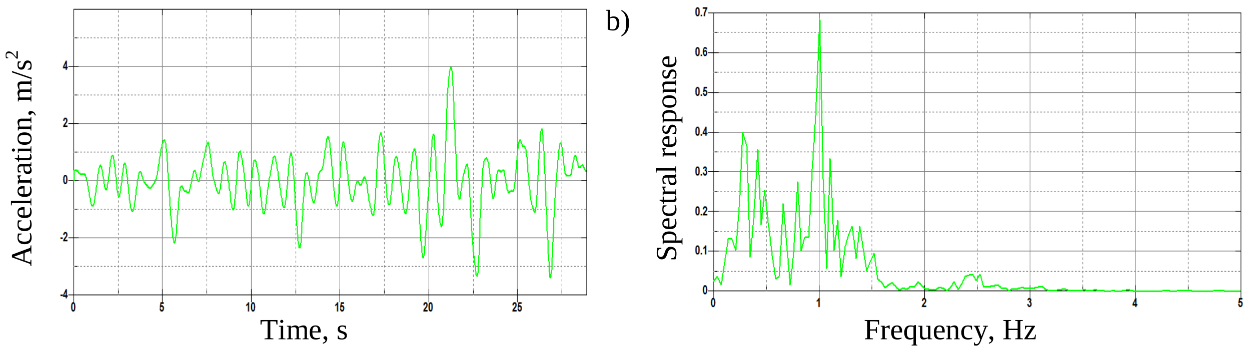


Figure 2 Accelerogram with the dominant frequency f_1 = 1,0 Hz (a) acceleration spectrum (b).

a) b)

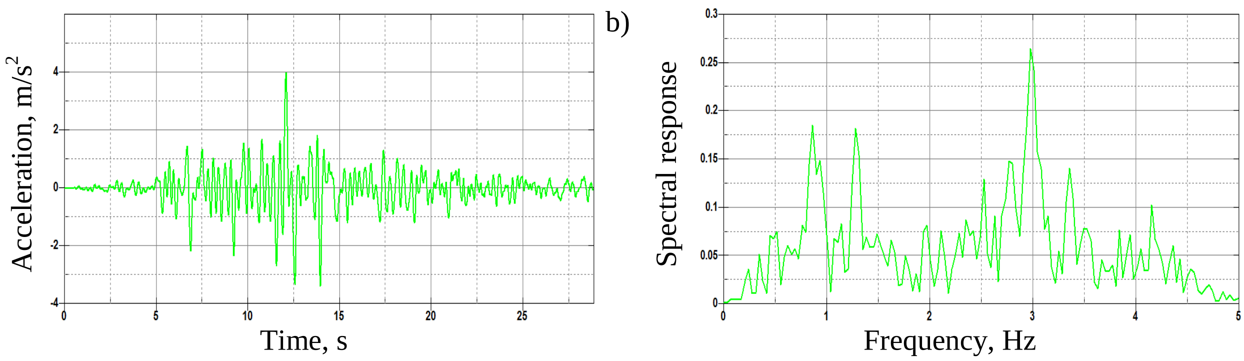


Figure 3. Accelerogram with the dominant frequency f_4 = 3,0 Hz (a) acceleration spectrum (b).

4. The results of calculations

The seismic impact calculation using LIRA 10.6 software made use of the spectrum response method. The research considered the LRB performance diagram to have an idealized linear character and to possess a specific stiffness.

The isofields and the displacement diagram of the support structure LRB-D600 are presented below (figure 4-5).

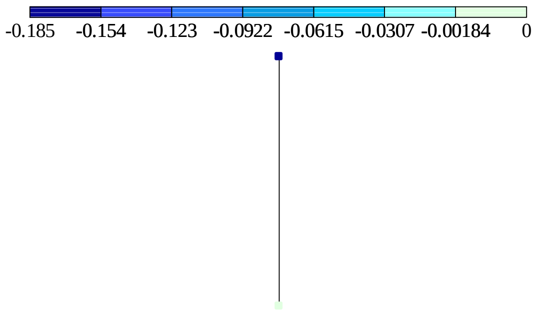
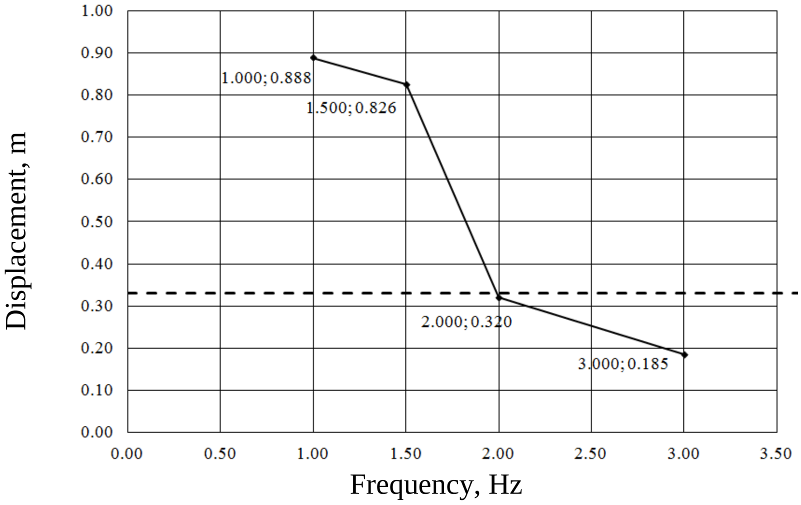


Figure 4. Isofields of LRB top displacements relative to the bottom along the X axis (m), for the accelerogram with the dominant frequency f_4=3,0 Hz.

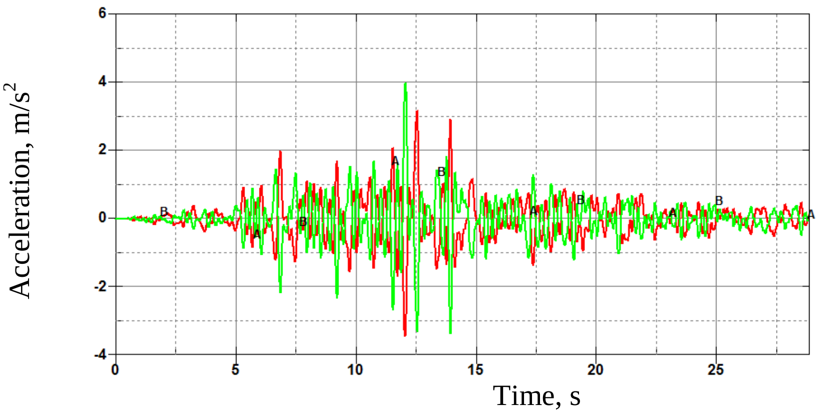


- Maximum allowable displacement of the top of the bearing 0,330 m

Figure 5. Dependency between the maximum relative displacement of the top of the isolator and the dominant frequency of the external effect.

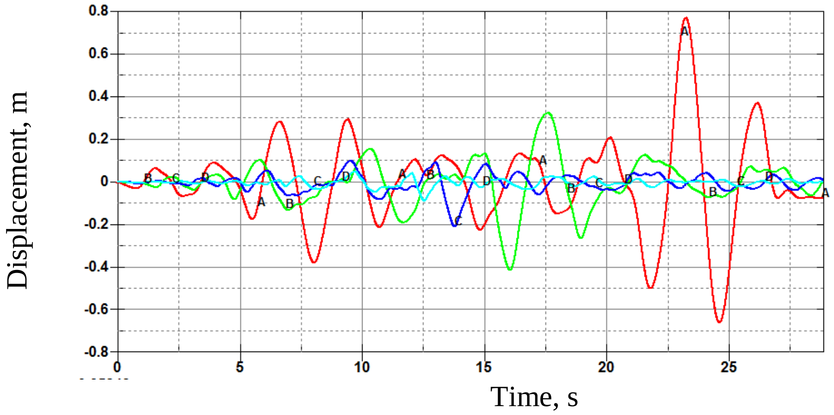
The seismic impact calculation performed using the Ansys (LS-Dyna) software package utilized the central differences method, which in turn employs the explicit method of integrating motion equations. The LRB behavior diagram was set as an actual diagram approximated by an idealized non-liner diagram [6]. The computational model of the bearing in its general form is presented in figure 1.

The diagrams displaying the accelerations and displacements of the LRB-D600 are presented below (figure 6-8).



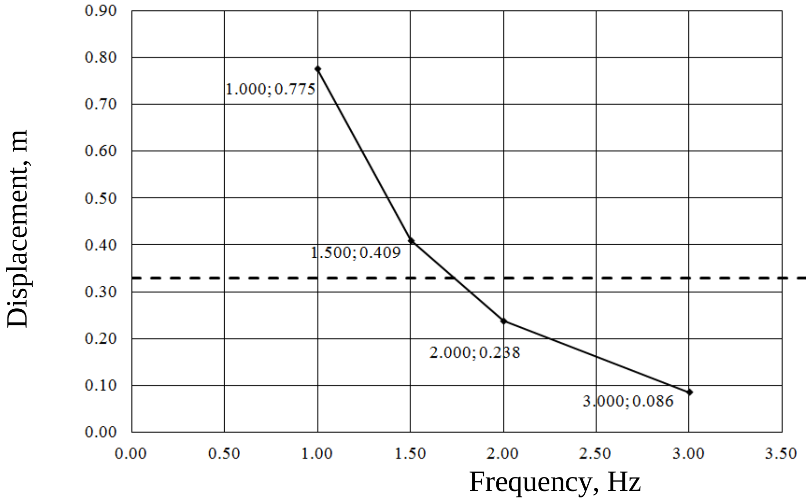
1) red curve – accelerations of the top of LRB;
2) green curve – the original accelerogram

Figure 6. Acceleration diagrams of LRB top and the original accelerogram with the dominant frequency f_4=3,0 Hz along the X axis (m/s^2).



Dominant frequency of impact, Hz
1) Red curve – 1 Hz;
2) Green curve – 1,5 Hz;
3) Darkblue curve – 2 Hz;
4) Lightblue curve – 3 Hz

Figure 7. Curves of LRB top displacements relative to the bottom along the X axis (m) exposed to the dominant frequency f_4=3,0 Hz.



- Maximum allowable displacement of LRB top 0,330 m

Figure 8. Maximum relative displacement of the isolator top and its dependence on the frequency of external effect.

Another research was dedicated to benchmarking of China-made LRB against LRB with a range of similar characteristics produced by a major well-known manufacturer FIP Industriale. The analogous bearings by FIP Industriale were selected by such characteristics as diameter, maximum horizontal displacements and rated bearing capacity.

The seismic impact modeling was performed using the software package Ansys (LS-Dyna). The LRB work diagram was set as the actual diagram approximated by the idealized non-linear diagram. The computational model of the bearing in its general form is presented in figure 1.

Table 1 presents the results of benchmarking the bearings.

Table 1. Benchmarking of LRB-D600, LRB-D700, LRB-D800 against FIP Industriale bearings.

Comparative characteristics	Dominant frequency of impact, [Hz]							
	1		1,5		2		3	
LRB model	LRB-D600	LRB-SN 600/180-150	LRB-D600	LRB-SN 600/180-150	LRB-D600	LRB-SN 600/180-150	LRB-D600	LRB-SN 600/180-150
LRB top accelerations, [m/s^2]	4,71	2,89	3,72	3,12	3,69	3,21	3,43	3,47
LRB top displacements, [m]	0,775	0,655	0,409	0,371	0,238	0,234	0,086	0,09

LRB model	LRB-D700	LRB-SN 700/203-170	LRB-D700	LRB-SN 700/203-170	LRB-D700	LRB-SN 700/203-170	LRB-D700	LRB-SN 700/203-170
LRB top displacements, [m/s^2]	4,76	2,93	3,86	3,16	3,87	3,21	3,40	3,46
LRB top displacements, [m]	0,733	0,688	0,440	0,384	0,234	0,240	0,089	0,093
LRB model	LRB-D800	LRB-S 800/200-175	LRB-D800	LRB-S 800/200-175	LRB-D800	LRB-S 800/200-175	LRB-D800	LRB-S 800/200-175
LRB top displacements, [m/s^2]	3,96	3,15	3,58	3,16	3,31	3,21	3,41	3,39
LRB top displacements, [m]	1,02	0,825	0,418	0,409	0,209	0,219	0,074	0,111

5. Summary

The research we have conducted gives rise to the following conclusions:

1. The values of the compared parameters vary depending on the calculation technique: the response spectrum method or non-linear dynamic methods. The response spectrum method overrates the actual values of displacement.
2. In case the spectrum composition of the earthquake accelerograms varies, the Chinese-made LRBs demonstrate a decrease in accelerations up to 21%.
3. The critical values of seismic action dominant frequencies have been obtained, which may cause LRB to fail as the displacement limit is reached, and the structure to collapse.
4. A benchmarking of LRB-D600, LRB-D700, LRB-D800 and FIP Industriale bearings has been conducted. It has been established that the difference intensifies as the dominant frequency reduces. The benchmarking by the principal parameters has shown close matching for exposures to dominant frequencies between 2 and 3 Hz. Benchmarking for the case of exposure to dominant frequencies below 2 Hz exhibits considerable dissimilarity.

6. References

[1] Murav'ev N P 2013 *Far East: Problems of development of architectural-construction complex.* **1** 212-8.
[2] Bubis A A, Yun A J, Petryashov S O and Petryashov N O 2012 *Earthq. Eng. Saf. Build. Seism. Constr.* **2** 31-5.
[3] Catalogue on lead rubber bearings series LRB, FIP Industriale S.P.A.
[4] Mkrtychev O V 2000 *Reliability of multi-element truss systems of engineering structures,* Dissertation for the degree of doctor of technical sciences. Moscow.
[5] LS-DYNA, Keyword user's manual, Volume I, II. Livermore Software Technology Corporation (LSTC).
[6] Mkrtychev O V, Dzhinchvelashvili G A and Bunov A A, 2014 *Proc. Eng.* **91** 48-53.

Acknowledgements

This study was performed with the support of the RF Ministry of Education and Science, grant №7.1524.2017/Project Part.