Journal of Zhejiang University-SCIENCE A (Applied Physics & Engineering)

# Explicit finite element analysis and experimental verification of a sliding lead rubber bearing

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Cite this as: Yi-feng WU, Hao WANG, Ai-qun LI, Dong-ming FENG, Ben-SHA, Yu-ping ZHANG, 2017. Explicit finite element analysis and experimental verification of a sliding lead rubber bearing. *Journal of Zhejiang University-SCIENCE A (Applied Physics & Engineering)*, 18(5):363-376. http://dx.doi.org/10.1631/jzus.A1600302

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# Background and Model Introduction

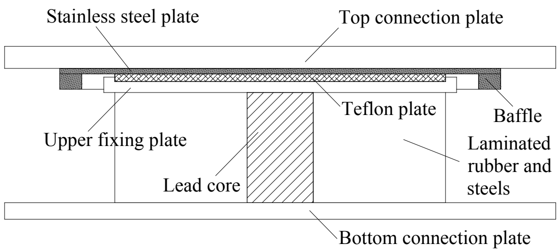



**Fig. 1 Design drawing of the SLRB**

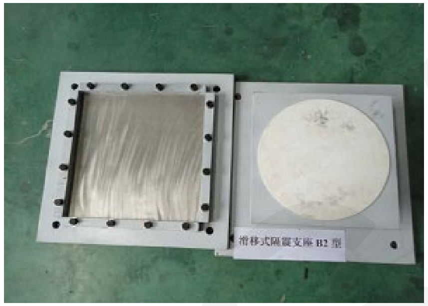


**Fig.2 The sliding device and teflon plate**

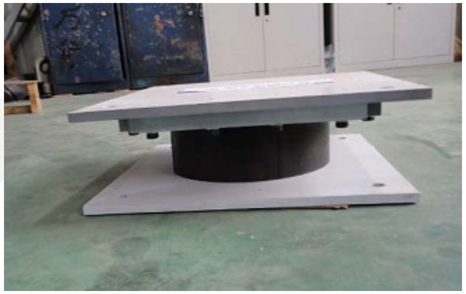


**Fig.3 photograph of a specimen**

**Table 1 Mechanical parameters of the SLRB**

| Parameter | Value | Parameter | Value |
|---|---|---|---|
| Shear modulus of rubber/MPa | 0.392 | Thickness of the rubber/mm | 3.39 |
| Effective diameter/mm | 300 | Layers of the rubber | 18 |
| Diameter of the lead core/mm | 60 | First shape coefficient | 22.12 |
| Thickness of the laminated steel/mm | 1.5 | Second shape coefficient | 4.92 |
| Layers of the laminated steel | 17 | Height of the SLRB/mm | 106.5 |

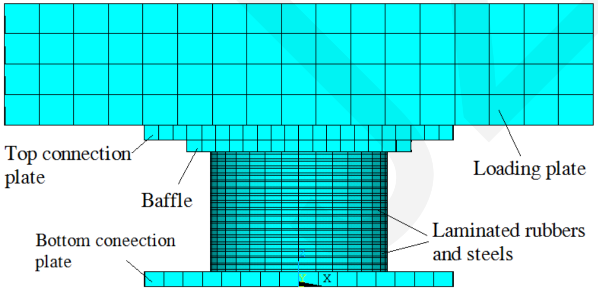



**Fig.4 Total FE model**

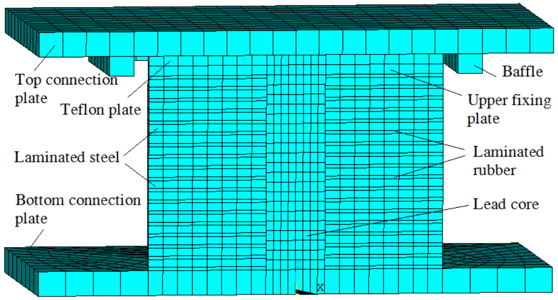



**Fig.5 Semi-model of the SLRB**

# Method

**The critical time step size $\Delta t_e$ of truss element:**

$$\Delta t_e = \frac{L}{c} \qquad c = \sqrt{\frac{E}{\rho}}$$

The influence of these three parameters on the CTSS of solid elements is similar to that on the CTSS of beam elements, meaning that the CTSS has positive correlation with the size and density of elements, while negative with the Young's modulus

**To control the time step size:**

(1)Activate the in-built mass scaling; (2) Modify the thickness of laminated steels from 3.39 mm to 8 mm; (3) Decrease the Young's modulus of steels from 210Gpa to 16.46Gpa; (4)Modify the loading frequency from 0.1Hz to 1Hz。

**The time step size in each cycle of the SLRB model is increased from 2.4$\times 10^{-7}$s to 3.5$\times 10^{-6}$ s**

**To Simulate contact relations existing in the SLRB:**

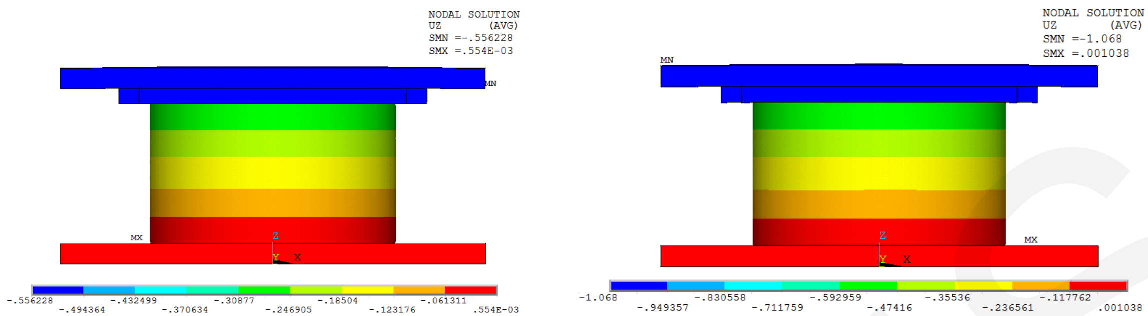
(1) *CONTACT AUTOMATIC SURFACE TO SURFACE SMOOTH to simulate the possible contact between the upper fixing plate and the baffle;

(2) *CONTACT ONE WAY AUTOMATIC SURFACE TO SURFACE SMOOTH to simulate the sliding contact between the teflon plate and the top connection plate

(3) *CONTACT TIED SURFACE TO SURFACE SMOOTH to simulate the interference fit between the lead core and its surrounding items

# Results

## 1. Compression test




$0.7P_0$ $1.3P_0$

$$K_v = \frac{(1.3-0.7)\times 707}{1.068-0.556} = 828.5\ \text{kN/mm}$$

**Fig.6 Vertical displacement of the SLRB model (mm)**

**The error between the numerical result 828.5 kN/mm and the experimental result 862 kN/mm is 3.9%.**

## 2. Shear correlation test

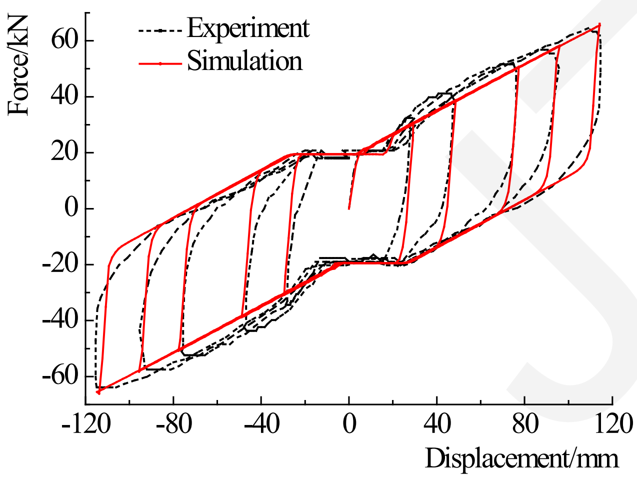
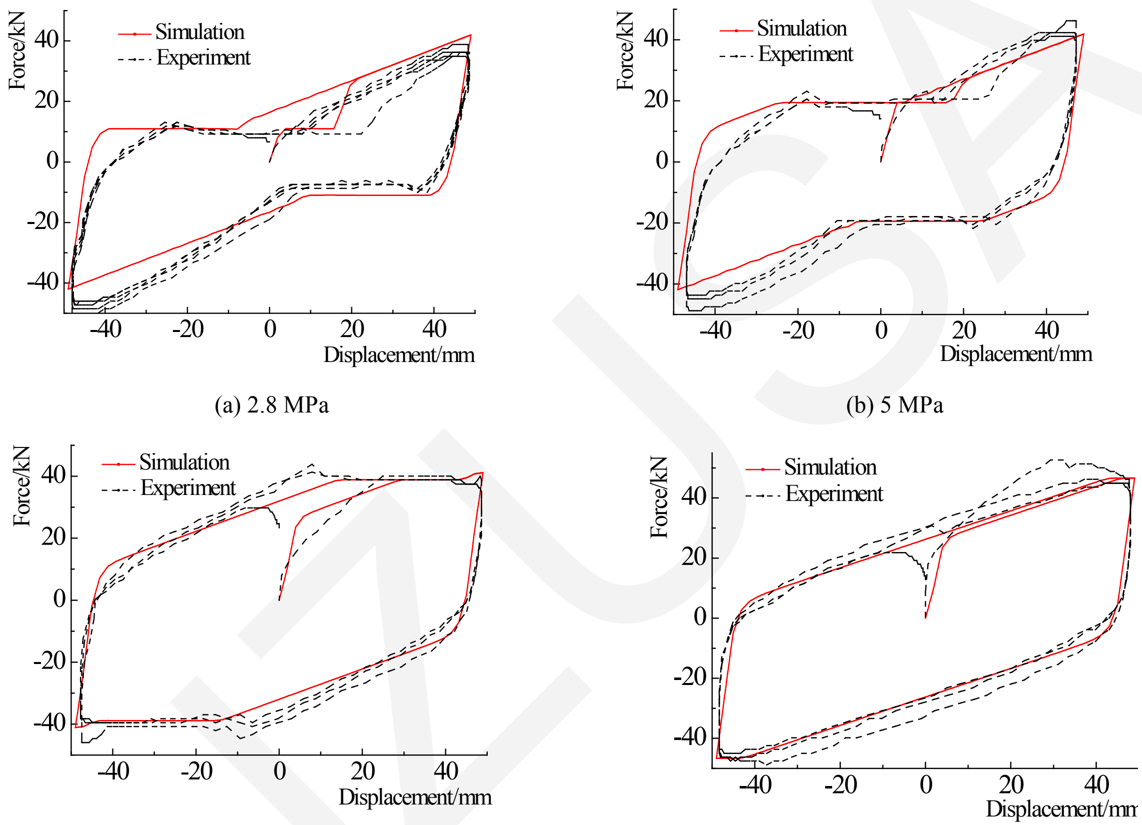



**Fig.7 Hysteresis curves with different shear strain**

**The modeling method for the SLRB in this study is capable of reproducing the hysteresis properties of the SLRB very well, including the pre-yield stiffness, post-yield stiffness, sliding force, maximum restoring force, etc., which demonstrates the accuracy of the developed FE model of the SLRB.**

# Results

## 3. Vertical pressure correlation test




(a) 2.8 MPa

(b) 5 MPa

(c) 10 MPa

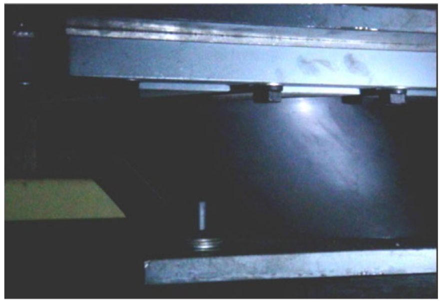
(d) 12 MPa

**Fig.8 Hysteresis curves with different vertical pressure**

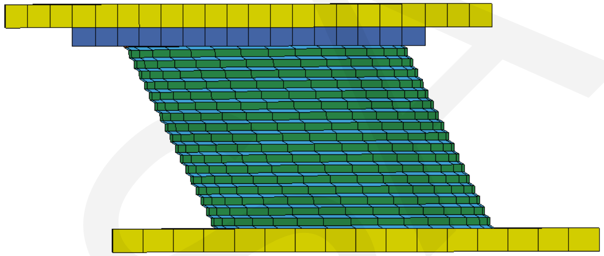
**In sum, hysteresis curves from numerical simulation with different vertical pressure are consistent with those from the experiment.**

# Results

## 4. Comparison of the deformed shapes



(a) experiment



(b) numerical simulation

Fig. 10 Deformed shapes of the SLRB

## 5. Comparison of shear stresses of rubbers

| | Shear displacement (mm) | | | | |
|---|---|---|---|---|---|
| | 29 | 48 | 77 | 95 | 115 |
| Shear strain | 22.9% | 54.1% | 101.6% | 131.1% | 163.9% |
| Theoretical shear stress /MPa | 0.08994 | 0.2120 | 0.3983 | 0.5139 | 0.6424 |
| Actual shear stress /MPa | 0.09007 | 0.2114 | 0.3944 | 0.5121 | 0.6284 |
| Error | 0.15% | -0.28% | -0.98% | -0.36% | -2.18% |

# Conclusions

**(1) All contact relations existing in the SLRB can be well analyzed by three types of contact relations in ANSYS/LS-DYNA.**

**(2) The modeling method for the SLRB by the explicit FE program in this study is capable of reproducing the vertical stiffness and particular hysteresis behaviors of the SLRB. Besides, the shear stress of the intermediate rubber layer obtained from numerical simulations are well consistent with theoretical results.**

**(3) In the numerical simulation, it is observed that both ends of the lead core have already generated plastic deformation even if no additional lateral load is applied. Moreover, the lead core generated extremely large plastic deformation when the shear displacement of 115 mm is applied.**

**(4) It is noted that the explicit algorithm is running more efficiently than the implicit algorithm in the numerical simulation of the SLRB.**