

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

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Background and Model Introduction

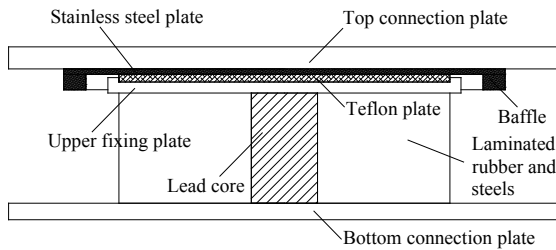


Fig. 1 Design drawing of the SLRB

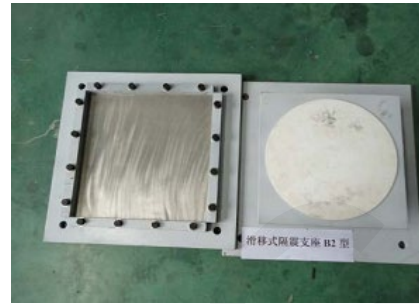


Fig.2 The sliding device and teflon plate

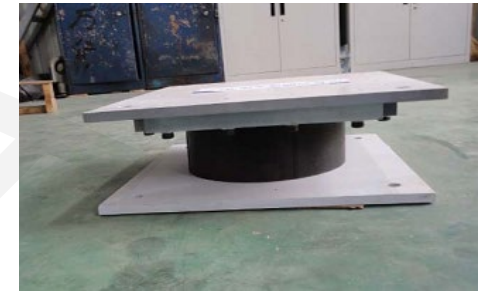


Fig.3 photograph of a specimen

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

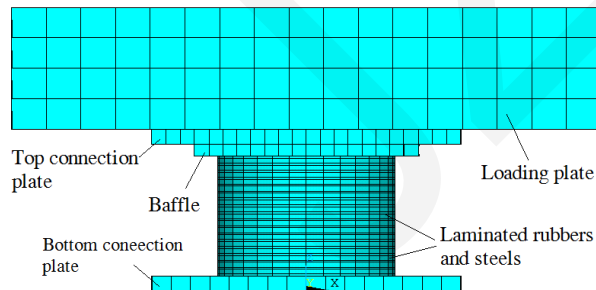


Fig.4 Total FE model

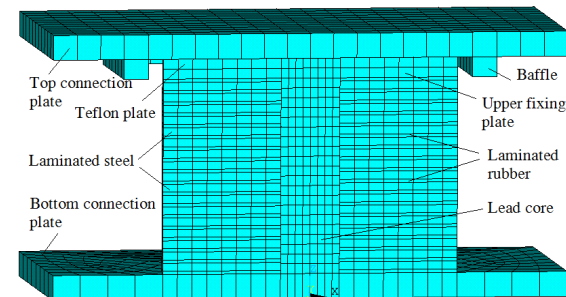


Fig.5 Semi-model of the SLRB

Method

The critical time step size Δt_e of truss element:

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

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 2.4×10^{-7} s to 3.5×10^{-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

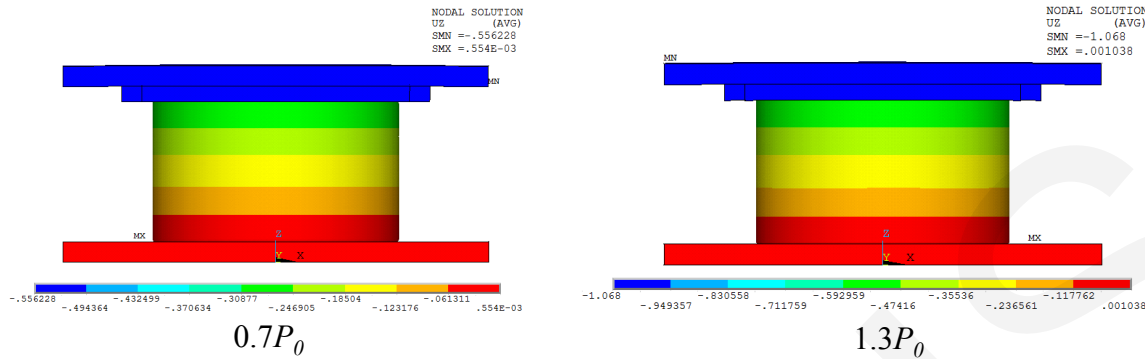


Fig.6 Vertical displacement of the SLRB model (mm)

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

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

2. Shear correlation test

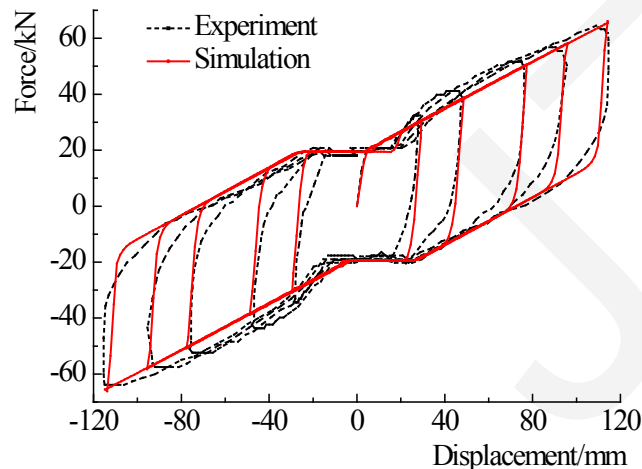


Fig.7 Hysteresis curves with different shear strain

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

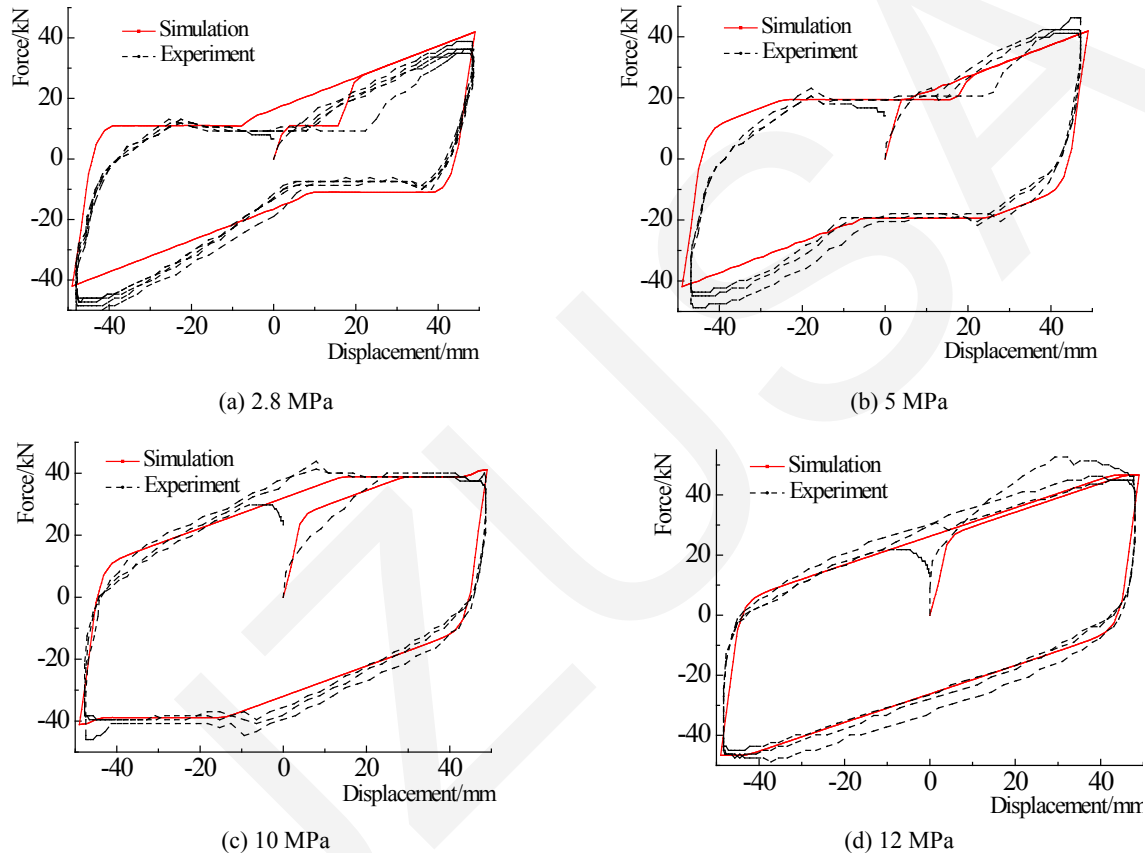
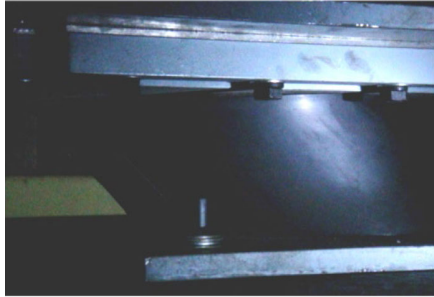


Fig.8 Hysteresis curves with different vertical pressure

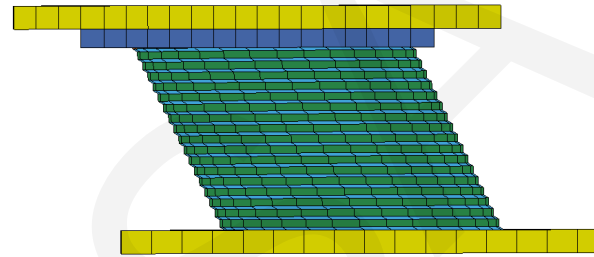
In sum, hysteresis curves from numerical simulation with different vertical pressure are consistent with those from the experiment.

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.**