RESPONSE CONTROL AND SEISMIC ISOLATION OF BUILDINGS

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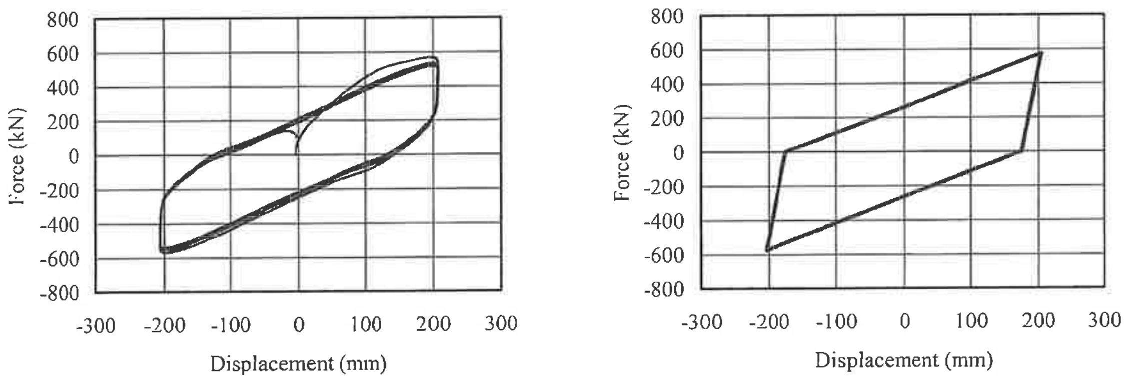
ROUTL

$$h_{eq} = \frac{2}{\pi} \cdot \frac{Q_d \left\{ \gamma \cdot H - \dfrac{Q_d}{(\beta - 1)K_d} \right\}}{K_{eq} \cdot (\gamma \cdot H)^2} \tag{2.2.14}$$

2.2.3.3 Hysteresis Loop

Figure 2.2.9 shows an example hysteresis loop of a round lead rubber bearing with dimensions:

laminated rubber diameter = 1000 (mm), lead plug diameter = 200 (mm),
number of lead plugs = 1, rubber thickness = 6.0 (mm),
number of rubber layers = 34 (layers), total rubber thickness = 204.0 (mm)



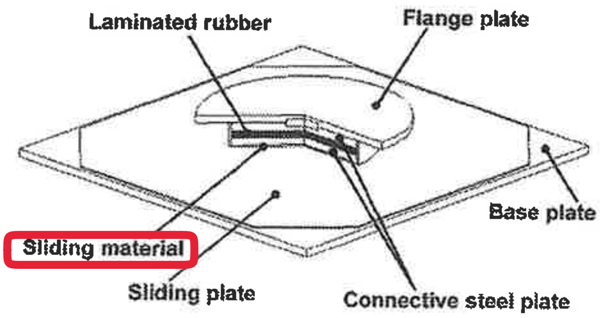
(a) Test Result (b) Analysis Model

Figure 2.2.9 Example hysteresis loop of lead rubber bearing (Round Type)

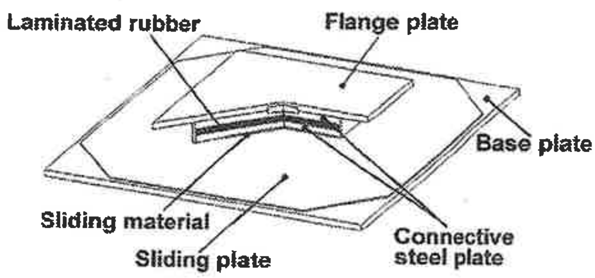
2.2.4 Elastic Sliding Bearing

2.2.4.1 Construction

Figure 2.2.10 shows the construction of round and square elastic sliding bearings. It is principally composed of laminated rubber layers, connective steel plates, flange plates, sliding material, a sliding plate and a base plate. The sliding material is set in the connective steel plate which in turn rests on the sliding plate fixed to the base plate. Before the earthquake force exceeds the yield force associated with sliding given by Equation (2.2.18), the shearing deformation is limited to the laminated rubber layers, whereas, after the yield force has been reached, the bearing assembly slides and thus will accommodate large motion.



(a) Round Type



(b) Square Type

Figure 2.2.10 Construction of elastic sliding bearing

2.2.4.2 Fundamental Dynamic Characteristic

The vertical stiffness of elastic sliding bearing Kv is determined by Equation (2.2.15).

$$Kv = \alpha_v \cdot \frac{Ar}{H} \cdot \frac{E_0(1+2\kappa S_1^{\ 2})E_\infty}{E_0(1+2\kappa S_1^{\ 2})+E_\infty} \tag{2.2.15}$$

where Ar : cross section area of laminated rubber

H : total rubber thickness

S_1 : primary shape factor

α_v : correction modulus on Kv by sliding material

E_0 : longitudinal elastic modulus of rubber

E_∞ : bulk modulus of rubber

κ : correction modulus of rubber hardness

Figure 2.2.11 shows the hysteresis loop model for the elastic sliding bearing, which is a function of the primary stiffness K_1 and the yield force Q.

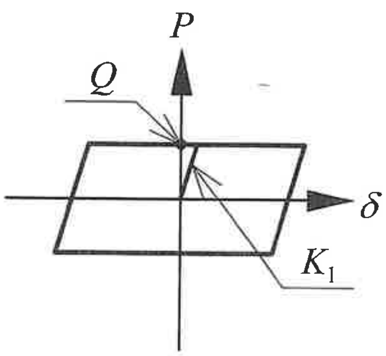


Figure 2.2.11 Hysteresis loop model of elastic sliding bearing

The primary stiffness of the elastic sliding bearing, K_1 at 15 degrees is determined from Equation (2.2.16). Equation (2.2.17) can be used to account for the temperature-dependency of K_1.

$$K_1 = Gr \cdot \frac{Ar}{H} \text{ (at 15 degrees)} \tag{2.2.16}$$

where Gr : shear modulus of rubber

$$K_1(t) = K_1(t_0) \cdot \exp(-0.00271(t - t_0)) \tag{2.2.17}$$

where t_0 : temperature before correction

t : temperature after correction

The yield force of elastic sliding bearing Q is determined from Equation (2.2.18).

$$Q = \mu \cdot W \tag{2.2.18}$$

where μ : coefficient of friction

W : vertical load

The coefficient of friction of the elastic sliding bearing, μ has stress and velocity dependency. The friction coefficient tends to decrease with increasing stress and increase with the increasing velocity. Equation (2.2.19) can be used to account for these dependencies.

$$\mu(\sigma, v) = (0.0801 - 0.0437 \cdot \exp(-0.005 \cdot v)) \cdot \sigma^{-0.33} \tag{2.2.19}$$

where v : velocity

σ : stress

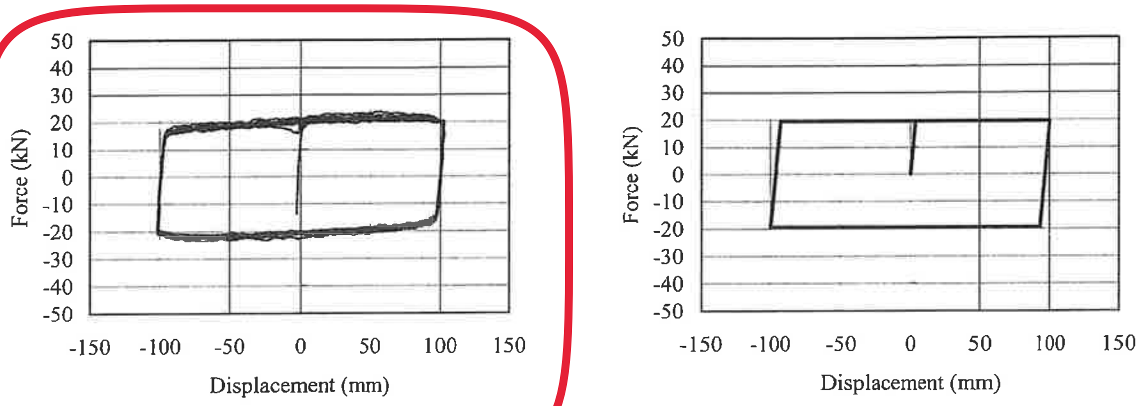
The equivalent stiffness of elastic sliding bearing K_{eq} is determined by Equation (2.2.20).

$$K_{eq} = \frac{Q}{\gamma \cdot H} \tag{2.2.20}$$

2.2.4.3 Hysteresis Loop

Figure 2.2.12 shows an example hysteresis loop for a round elastic sliding bearing with dimensions:

laminated rubber diameter = 450 (mm),
sliding material diameter = 350 (mm),
rubber thickness = 8.0 (mm), number of rubber layers = 3 (layers),
total rubber thickness = 24.0 (mm)



(a) Test Result (b) Analysis Model

Figure 2.2.12 Example hysteresis loop of elastic sliding bearing (Round type)

2.2.5 Curved Plane Sliding Bearing

2.2.5.1 Construction

Figure 2.2.13 shows the construction of curved plane sliding bearing. As shown in the figure, the curved plane sliding bearing is principally composed of concave plates, a slider, sliding material and a dustproof cover.

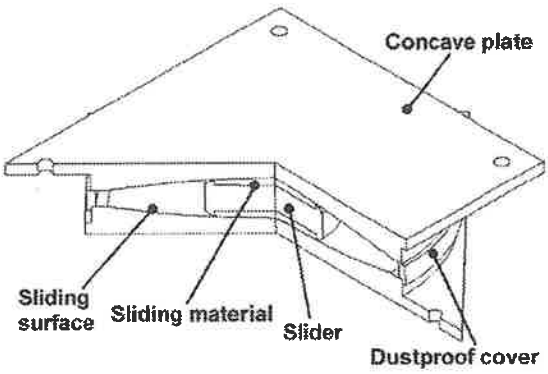


Figure 2.2.13 Construction of curved plane sliding bearing

2.2.5.2 Fundamental Dynamic Characteristic

Figure 2.2.14 shows the hysteresis loop model of the curved plane sliding bearing with secondary stiffness K_2 and the yield force Q.

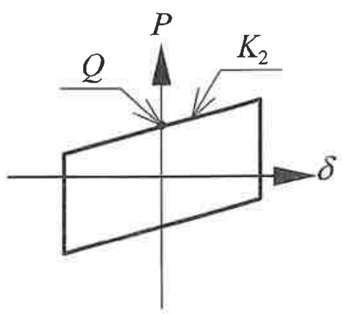


Figure 2.2.14 Hysteresis loop model of curved plane sliding bearing

The secondary stiffness of curved plane sliding bearing K_2 is determined from Equation (2.2.21).

$$K_2 = \frac{W}{2 \cdot SR} \tag{2.2.21}$$

where W : vertical load

SR : spherical radius of sliding surface

The yield force of curved plane sliding bearing Q is determined from Equation (2.2.22).

$$Q = \mu \cdot W \tag{2.2.22}$$

where μ : coefficient of friction

The coefficient of friction of the curved plane sliding bearing, μ has stress and velocity dependency and t tends to decrease with increasing stress and increase with the increasing velocity. Equation (2.2.23) may be used to account for these dependencies.

$$\mu(\sigma, v) = (0.197 - 0.121 \cdot \exp(-0.009 \cdot v)) \cdot \sigma^{-0.57} \tag{2.2.23}$$

where v : velocity

σ : stress

The equivalent stiffness of curved plane sliding bearing K_{eq} is determined from Equation (2.2.24).

$$K_{eq} = \frac{Q}{\gamma \cdot H} + K_2 \tag{2.2.24}$$

2.2.5.3 Hysteresis Loop

Figure 2.2.15 shows an example hysteresis loop of the curved plane sliding bearing with dimensions:

Sliding material diameter = 350 (mm),
Spherical radius of sliding surface = 2500 (mm)

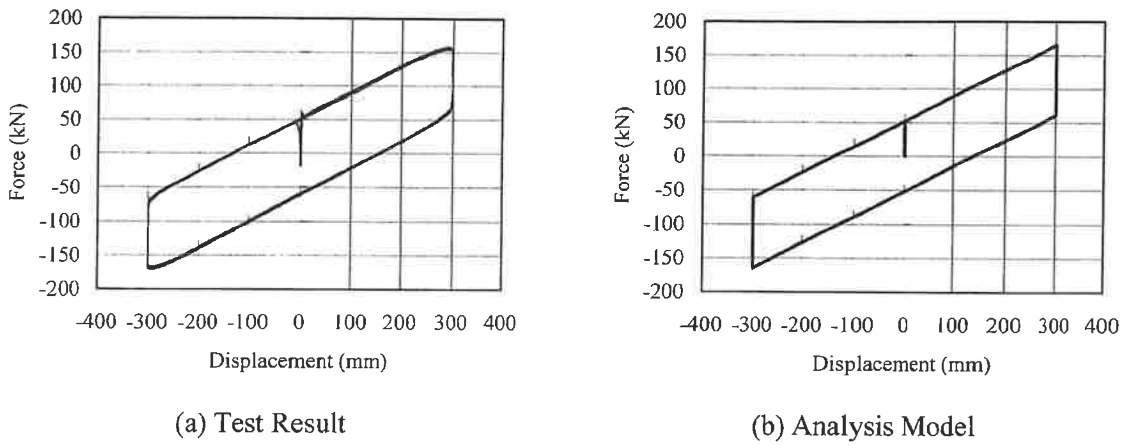


Figure 2.2.15 Example hysteresis loop of curved plane sliding bearing

2.2.6 Plane Roller Bearing (1)

2.2.6.1 Construction

Figure 2.2.16 show the construction of a plane roller bearing which is principally composed of rollers, rails, upper and lower plates, intermediate plates, and rack and pinion. The rolling surface is protected from dust by the dustproof cover.

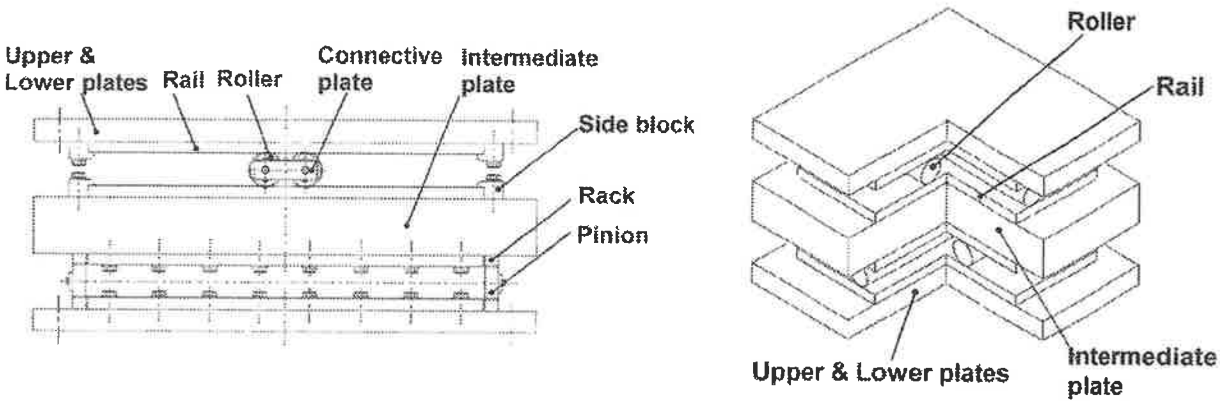


Figure 2.2.16 Construction of plane roller bearing

2.2.6.2 Fundamental Dynamic Characteristic

The vertical stiffness of plane roller bearing Kv is determined by Equation (2.2.25).

$$Kv = \alpha \cdot D \tag{2.2.25}$$

where D : roller diameter

α : coefficient

And the coefficient of friction of plane roller bearing μ is 0.003 or less.

Many countries and cities are located in earthquake-prone areas, and effective seismic design has long been a major issue in structural engineering. Reassuringly, structural response control and seismic isolation have advanced remarkably in recent years following numerous studies internationally. Several major conferences have been held and reports have been written but little has been issued on the application of the technologies to good structural engineering practice. This state of the art report from an internationally-based task group (TG44) of CIB, the international council of building research organisations, presents a highly authoritative guide to the application of innovative technologies on response control and seismic isolation of buildings to practice worldwide.

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