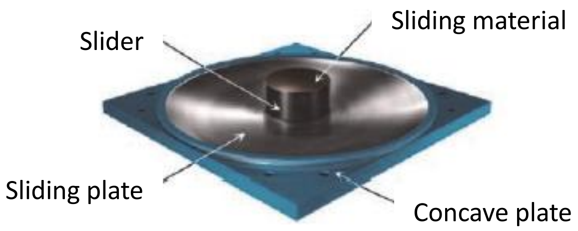
Spherical Sliding Bearing, NS-SSB®, Low Friction Type

1 Introduction

The spherical sliding bearing called NS-SSB[1)] is a seismic isolation device that extends an isolation period based on the principle of a pendulum, as well as controls seismic responses by frictional damping, by sliding a slider on a spherical plate. NS-SSB has advantages that the isolation period is defined by the radius of curvature alone and is not affected by dead/live load as compared with a rubber bearing, it has a compact bearing achieved by using steel as the main material and its bearing stress is approx. three times higher than a rubber bearing laminated with rubber and steel plates. After certification by Japan’s Minister of Land, Infrastructure, Transport and Tourism (hereinafter referred to as the “MLIT”) in 2014, the use of NS-SSB for logistic warehouses and condominium buildings has been increasing. However, currently the friction coefficient of NS-SSB (at the third cycle under the conditions of bearing stress of 60 N/mm^2, temperature of 20°C, velocity of 400 mm/s, displacement amplitude of±200 mm; hereinafter referred to as the “standard conditions”) is only 0.043 (hereinafter referred to as the “medium friction type”), and isolated buildings are designed using only NS-SSB, rather than with a combination of other seismic isolation devices. The application of NS-SSB is limited because it may be difficult to adjust the seismic response to the requirement, or it cannot be applied to isolated buildings with a response acceleration limitation such as a hospital. Given this situation, we have developed a low friction type NS-SSB with a coefficient of 0.013 so that the friction coefficient can be adjusted by combining a medium friction type NS-SSB.

(a) View of product



(b) View of lower half of product

Fig. 1: Top perspective views of NS-SSB

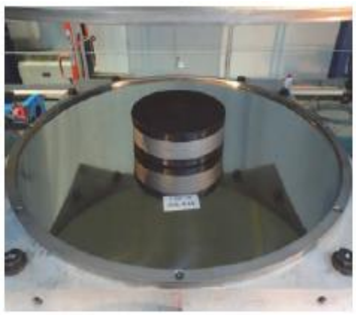


Fig. 2: Photo of lower half of NS-SSB of low friction type

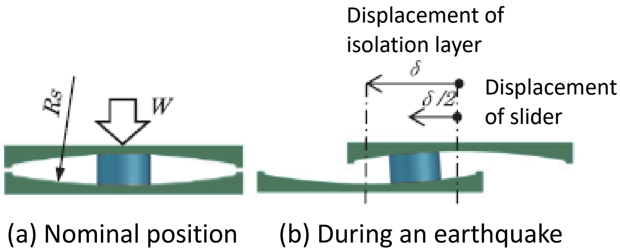


Fig. 3: Behavior of NS-SSB

2 Overview of Low Friction Type NS-SSB

Figure 1 shows images of the components of the NS-SSB, while Fig. 2 shows the appearance of the new NS-SSB. The appearance and components of the low friction type are the same as those of the existing medium friction type. A slider is placed between two spherical sliding plates of stainless steel attached to respective steel concave plates. Sliding materials are bonded to the upper/lower faces of the slider. While the medium friction type uses double polytetrafluoroethylene (PTFE) fabric for the sliding material, the low friction type uses the PTFE double fabric impregnated with a lubricant. The lubricant is silicone oil that shows almost no aging degradation and is suitable for the performance of NS-SSB.

Figure 3 shows the movement of NS-SSB during an earthquake. The hysteresis model is a bilinear model, as shown in Fig. 4, represented by friction force Q_d and secondary rigidity K_2; Friction force Q_d is determined by friction coefficient μ and vertical load W, and secondary rigidity K_2 by vertical load W and spherical radius R_S. Natural period T_0 of the isolation layer is $2\pi\sqrt{2R_S/g}$ (g: gravitational acceleration) and is determined by the spherical radius alone. Friction coefficient μ under the standard conditions is 0.043 for the medium friction type and 0.013 for the low friction type is 0.013.

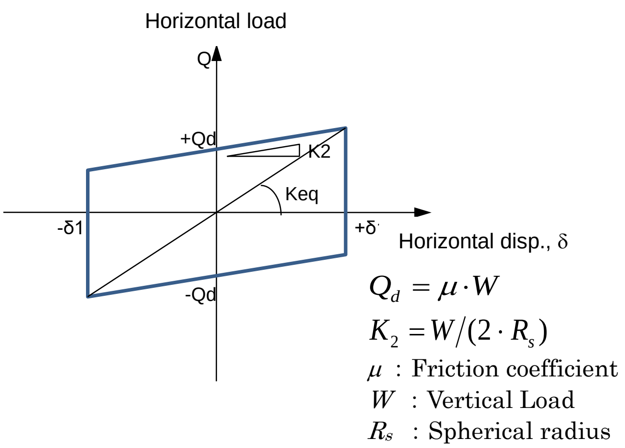


Fig. 4: Hysteresis loop model of NS-SSB

3 Performance of Low Friction Type NS-SSB

The horizontal properties of low friction type NS-SSB were verified through static/dynamic tests using full-scale test specimens with a slider diameter of φ150 to φ600 (1,060 kN to 16,960 kN of the vertical load under the bearing stress of 60 N/mm^2).

(1) Variation in the friction coefficient

Figure 5 shows an example of the relationship between the value obtained by dividing the horizontal load by the vertical load and the horizontal displacement (hereinafter referred to as the "friction hysteresis loop") of a static test. As

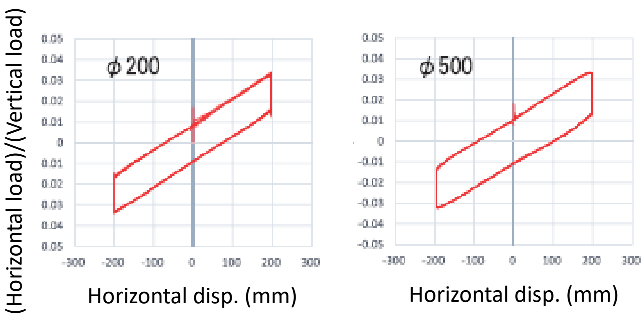


Fig. 5: Hysteresis loop of test

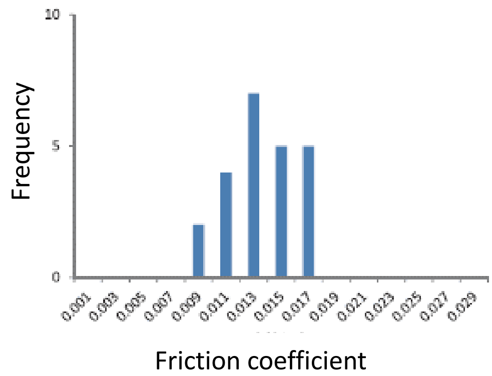


Fig. 6: Histogram of the friction coefficient

shown in Fig. 6, the average of the friction coefficient under the standard conditions of the test results is approx. 0.013 and the range is between 0.007 and 0.017.

(2) Dependencies of the friction coefficient

Figures 7, 8, 9, and 10 show dependencies of the friction coefficient on temperature, velocity, bearing stress and durability.

The temperature dependency of low friction type NS-SSB is not significant at the same velocity, unlike the medium friction type whose friction coefficient tends to drop when the temperature increases.[1)]

Regarding the dependency on velocity, the dependency on velocity of the friction coefficient at a third cycle of the low friction type is similar to the dependency on velocity of the coefficient in a hysteresis loop because the low friction type has a friction coefficient small enough almost not to be affected by frictional heat. On the other hand, these velocity dependencies of the medium friction type are because the friction heat is larger than the low friction type and the friction coefficient is affected by the friction heat.[2)]

Regarding the bearing stress dependency, the friction coefficient of the low friction type tends to increase along with a surface pressure decrease, similar to the friction coefficient of the medium friction type.[2)]

Regarding durability, since the influence of friction heat is small, the friction coefficient of the low friction type decreases due to the duration of sliding by approx. 10% at a sliding distance of

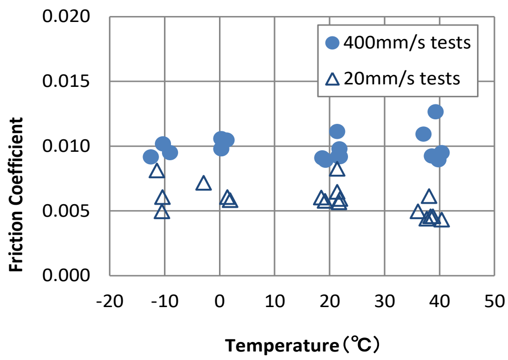


Fig. 7: Temperature dependency

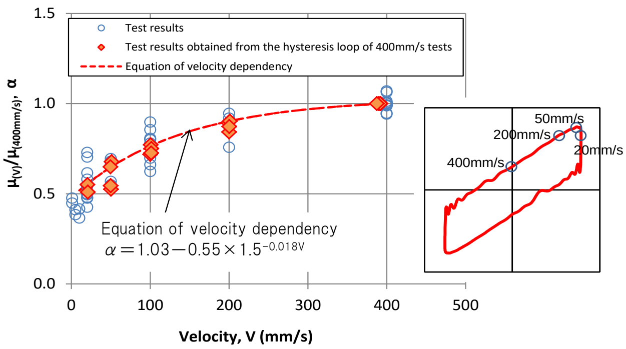


Fig. 8: Velocity dependency

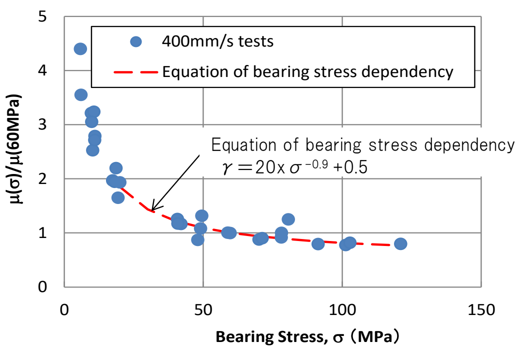


Fig. 9: Bearing stress dependency

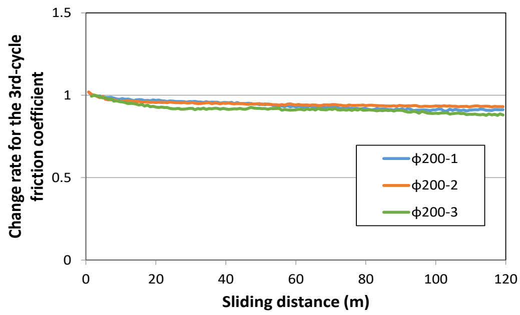


Fig. 10: Durability

120m, showing a smaller reduction in the friction coefficient of the medium friction type, which marked a 40% reduction.[1)]

4 Conclusion

The low friction type NS-SSB was certified as a seismic isolation device by MLIT in April 2017, making it applicable to seismic isolated buildings. Using the low friction type and medium friction type together has optimized the design of the seismic isolated building and made it more flexible. And the type and number of base isolated buildings applicable to NS-SSB is expected to increase. Furthermore, NS-SSB can be used to develop measures against long-period and long-duration earthquake motion that is likely to occur in future major earthquakes of increasing concern such as those in the Tokai, East Nankai, and Nankai regions. We will strive to assist society in spreading safe and reliable buildings that can withstand earthquakes by supplying NS-SSB.

* "NS-SSB" is a registered trademark owned by Nippon Steel & Sumikin Engineering Co., Ltd.
Registration No.: 5671985

References

1) Hideji NAKAMURA et al.: Development of Spherical Sliding Bearing, Nippon Steel & Sumikin Engineering Co., Ltd. technical review, Vol.6, 2015
2) Koji NISHIMOTO et al.: Surface Bearing Stress And Velocity Dependency of Spherical Sliding Bearing through Large-scale Tests, ummaries of technical papers of annual meeting, Architectural Institute of Japan, August 2016

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