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Experimental Assessments of Friction Plate for KTX Bridge Bearings

Soon-Taek Oh[a], Dong Jun Lee[a]*, Shin Hyo Jeong[a], Sung Min Jun[a]
[a] *Civil engineering, Seoul National University of Science and Technology, Korea*

Abstract: KTX train, which is currently operating as a running speed of 300 km/h in Korea will be accelerated to 450 ~ 500 km/h in the future. Various studies of the structural dynamic behaviors of the bridges for the increasing speed is being conducted.
The dynamic responses of traffic load at support of bridge are increasing rapidly for the speed analyzed by an improved 38-degree of freedom model. In PSC box bridges for KTX, the supports of bridges have constructed by the spherical bearings in order to resist the seismic loadings. In this study, a long-term friction test of the spherical bearing is carried out for total sliding distance up to 25,000m by 12 phases of 2 types repeatedly: type A for traffic and type B for temperature simulation according to EN 1337-2 and CUAP03.01/78.
Friction coefficients for serviceability and total sliding distance for durability are compared between PTFE and DP-Mate. This provides the improved long-term test method and an evaluation standard for new generation of KTX.

***Keywords**: spherical bearing, friction test, friction plate, friction coefficient, total sliding distance, durability*

I. INTRODUCTION

Nowadays, compared to the former railway, it is successfully operating KTX at a speed of 300 km/h and GTX at a speed of 200 km/h, and a test operation of distributed traction system HEMU-430X at a speed of 428 km/h makes a success. In the case of the other country, the fastest speed of 575 km/h was tested as TGV-P in 2007 at France. Moreover at China, CRH380B (ICE remodeling version) recorded 487 km/h speed. They held on the metropolitan rapid transit system era and contributed to accelerate the related technology development. It is lead to spread out an introduction plan of nearby country such as USA, India, Brazil, and the Middle East.

Now, in Korea, it is being rapidly developing that the material and shape of the PSC bridge structural system and equipment such as bridge bearing and expansion joint. They are also upgraded against the increasing speed. In the case of bridge bearings under the superstructure to resist vertical and horizontal load, the speed brings additional displacement and rotation to damage the bearings that are not only supporting the superstructure but also tossing the deformations to the substructure. The bridge bearings for the KTX railway are usually applied to the pot or the spherical bearings for satisfying an earthquake resistant in accordance with the national design codes. They are consisted in a PTFE(Poly Tetra Fluor Ethylene) as a friction plate with a low coefficient of friction. It is satisfied with structural stability and durability in the former railway bridges. Recently, the durability problems of PTFE plate appeared to be reported due to the speed. It is necessary to strengthen of the friction plate standards. The experimental method applying to the practical structural movement of the domestic high-speed rail (HSR) bridge bearing in common with limit coefficient of friction is needed to develop.

II. STANDARDS AND CERTIFICATIONS FOR BRIDGE BEARINGS

According to German study in 1979, the movements in a real sliding bearing were investigated for a steel bridge with four road tracks and a tramline. Most of the total sliding distance was summed up due to short strokes of movement caused by traffic, whereas temperature changes contributed less in terms with the increasing speed. The sliding distance of the bearing by traffic was about 15 times higher than the effect of temperature indicated in Fig.1. As the traffic speed and mass are lower than those of KTX, the difference of them is easily expected more higher. In case of the KTX bridges for the running speed, the traffic effect is also greater than the results on the shorter steel bridge.

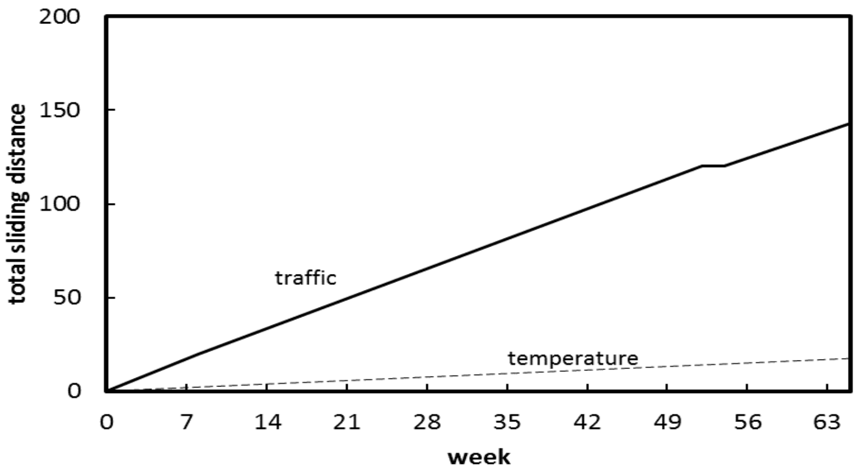

Fig. 1: Total sliding distance of steel bridge bearing (Structural Bearings,2002)

There are relevant international standards; AASHTO and ASTM. The durability evaluation of the code should be considering the accumulated moving distance of the friction plate of the bridge bearings increasing friction with the dynamic characteristic. However, they are insufficient as the standards offer only limited range of elastic deformation associated with the shape of the friction plate. Those are in the same condition of the Korean Standard.

III. METHOD

The European Standards; CUAP 03.01/78 and DIN EN-1337-2, offer a long-term friction test and are provided with a consideration of total sliding distance of bearing plate and the coefficient of friction simulated the friction plate behavior by traffic and temperature. The comparison between those standards is shown in Table 1; Types A and B represent simulation of the friction plate test conditions by traffic and temperature respectively.

Table 1: Comparison between EN-1337-2 and CUAP03.01/78

	Type	EN-1337-2	CUAP 03.01/78	unit	remarks
Contact Pressure	A, B	$0.33f_k$ (f_k=180)*		MPa	$^{+3}_{0}$
Temperature	A	21		℃	±1
	B	0/-10/-20/-35/+21	0/-10/-20/-35/+70/+35/+21		
Temperature gradient	A, B	0.5		℃/min	±1
Sliding distance	A	8		mm	$^{+0.5}_{0}$
	B	10			
Number of cycle	A	62500	65000≤n≤650000 (140000)*		11phases
	B	1100	1700		12phases
Sliding speed	A	4	15	mm/s	$^{0.1}_{0}$
	B	2	0.4		

*( ) : the value applied to the test

In this study, those standards are modified to focus on the type A by traffic simulation more significant than type B by temperature one; the number of cycles of type A applied up to 140,000 by each phase repeating 11 times on the other hand, 1700 by 12 phases of type B. The total tested distance between them leads to about 6o times and the sliding speed of type A 15 mm/sec is higher than the speed of type B 0.4 mm/sec. Therefore, the total tested distance is over 25,000m. Also considering the weather condition in Korea, the test of type B was carried in accordance with CUAP 03.01/78 ; including the temperature conditions of +35 ℃ and +70 ℃.

IV. RESULTS

4.1 Dynamic maximum behaviors of KTX bridge bearings

The lateral displacement of PSC bridge bearings using 38 degree of freedom FEM model of KTX up to 500 km/h running speed shown in Fig. 2 is analyzed. The sliding distance of poly-directional bearing and uniaxial bearing predicted by regression analysis are predicted by 3.00 mm and 2.52 mm respectively. The dynamic analyzed result shows 2.59 times compared with the static result of 1.16 mm. According to KTX diary schedule; to 149 times of 20 carriages KTX per a day, the total sliding distance of the poly-directional bearing during one year is expected approximately 3,262 m. In case of the two span continuous bridges, the maximum dynamic response of uniaxial bearing is 0.72 mm at the central pier when running speed is 400 km/h and the value is not reached than the response of single span bridge.

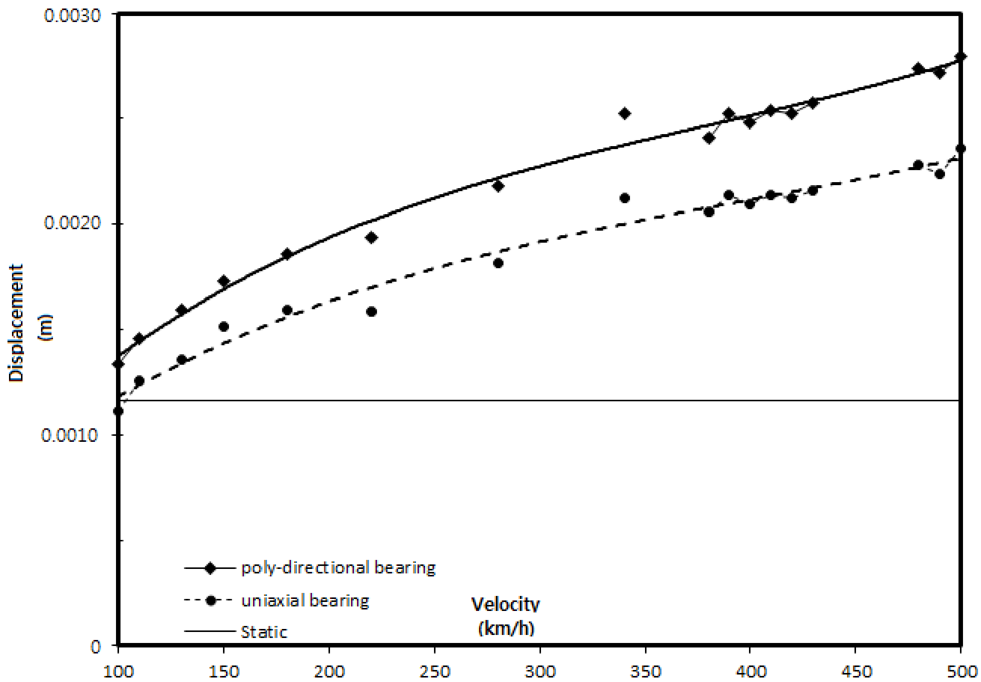

Fig. 2: Maximum displacement of bearings at the single span bridge

Typical HSR bridges should be ensured to keep the minimum required service life of more than 50 years and the service life of spherical bearings should be at least five years. Including the both behaviors due to traffic and temperature loads, the total sliding distance is required to guarantee over 1,000 m annually by AASHTO code. If you are using a molybdenum lubricant at the bearings, it secures the durability of the decade. As a result of this study, the bearings of KTX bridge, 40m single span PSC Box bridge should be damaged within 3 service years due to exceed the limit sliding distance in spite of satisfying the AASHTO code requirements.

4.2 Long-term test of bridge bearings

According to CUAP03.01/78, a Long-term friction test of the bearing was conducted as long as total sliding distance of 25,000 m under constant vertical pressure with variable sliding speeds.

In spite of low coefficient results, existing plate (PTFE) was damaged at the 4,548 m of the sliding distance that appears wear loss shown in Fig. 3. Then the test using PTFE was stopped. On the other hand, the test using newly developed plate (DP-Mate) was successfully finished to endure the long-term friction period (almost a month), even if the friction coefficient was higher than the PTFE. During the long-term testing 24 phases, the DP-Mate was performed to keep the friction coefficient successfully. A low-speed test(-35 ℃ to 70 ℃)and a high-speed test(21 ℃) using a friction test equipment developed for 32 days was performed.

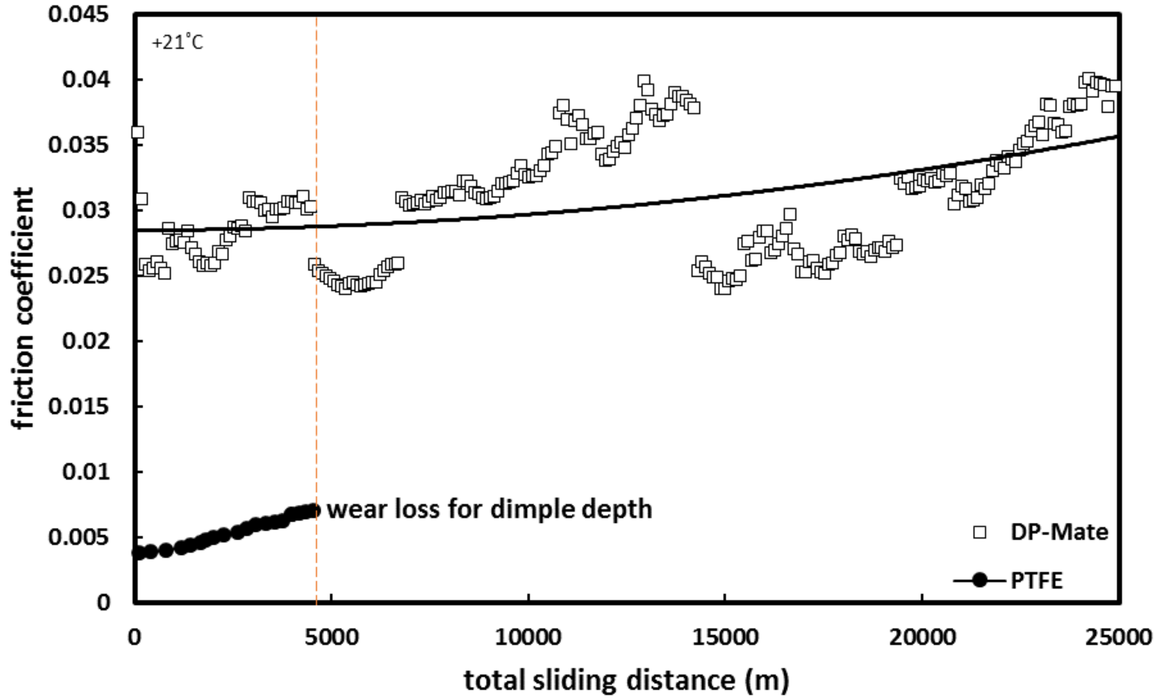

Fig. 3: Maximum coefficient of friction in high speed test

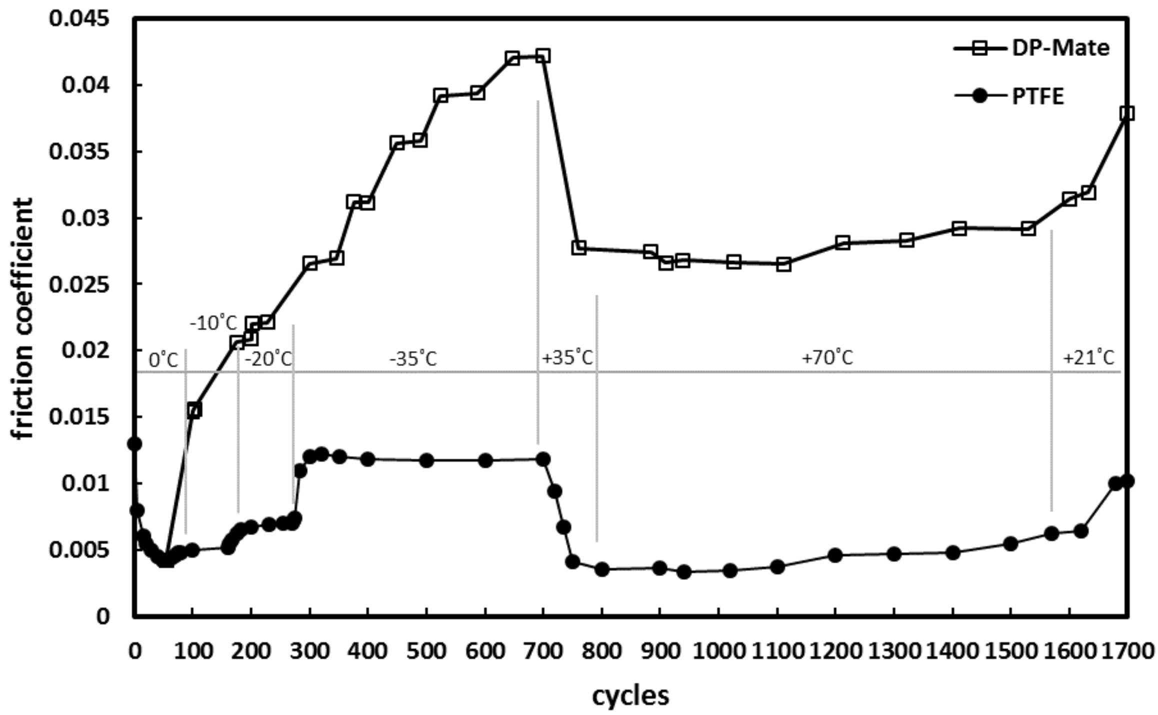

Fig. 4: Maximum coefficient of friction in low speed test

In results of type A test maintaining the temperature of 21 ℃ and the sliding speed of 15 mm/sec, the coefficient of friction of DP-Mate was averagely about 5.15~5.71 times greater than the coefficient of test using a PTFE plate indicated in Fig. 3. In the type B test varying from -35 ℃ to 70 ℃ of temperature change, the maximum coefficient of friction at -35 ℃ was about 3.58 times greater than the test using a PTFE plate shown in Fig. 4. The coefficient of friction and temperature variation had an inverse relationship.

V. CONCLUSIONS

Numerical analysis using 38 degree of freedom FEM model of KTX is conducted to find the effect of the running speed on the bearings of the bridge. The lateral sliding distance of the bearing is analyzed by 3.00 mm per a train vehicle. According to KTX diary schedule, 3,262 m of total sliding distance occur at the poly-directional bearing annually is accumulated due to 149 times of 20 carriages KTX passing on the bridge for a day. The existing KTX bridge bearings are guaranteed over 10,000 m of sliding distance in accordance with AASHTO code. The bearings are damaged around 3 service years by running speed up to 500 km/h of the new generation HSR.

Two long-term friction plate tests of the bearing were carried out according to CUAP03.01/78 and EN 1337-2. Friction coefficient and endured total sliding distance between PTFE and DP-Mate during the tests were compared. The maximum coefficient of friction of DP-Mate was about 5.71 times and 3.58 times greater than the one of PTFE plate between type A and type B test respectively. However, DP-Mate plate is endured by 25,000 m whereas, PTFE plate is wearing out at 4,548 m. Those results are indicated to the excellent durability of friction plates using DP-Mate and the long-term friction test of the beatings is need for the increasing running speed of train.

VI. ACKNOWLEDGEMENTS

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