

A study of the elastic vertical displacement of a roadbed and HSB with an increase in speed on a high speed concrete track (HEMU-430x)

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Abstract

In Korea, a speed up test of a train was performed on a high speed railway. The name of the vehicle is HEMU-430x. While the train increased speed from 300km/h to 421km/h on a railway track designed for 350km/h, elastic vertical displacement was measured on the transition zone of bridge-earth in the Gaya overpass bridge. Until the train speed reached 421km/h, the maximum of elastic vertical displacement measured 0.061mm on top of a reinforced roadbed and 0.311mm on top of a HSB (hydraulic stabilized base). Maximum vertical displacement of HSB measured at 383km/h, displacement decreased over 383km/h. Vertical displacement of reinforced roadbed increased according to the increase in train speed.

Keywords: roadbed, speed up test, elastic vertical displacement.

1 Introduction

When opening the Gyeongbu (2-phase) high-speed railway in Korea, performed the speed increase test (from 300km/h to 421km/h) of HEMU-430X on high speed concrete track. Germany and Japan have many test results of train speed up test over 400km/h about trains, roadbed, concrete tracks, etc. On the other hand, speed up test was first carried out more than 400km/h in Korea, because a relative lack of research on the field monitoring data of track and roadbed with the speed up compared to this growth.

In Germany and Japan, developed countries in the field of railway, a variety of measurement data and database has steadily been accumulated by performed



measurements and experiment to determine the behavioral characteristics of tracks and roadbeds during the operation of high-speed railways. However, Korea has no data measured in field to study the behavioral of the roadbed during the operation of high-speed railway at more than 350 km/h, and acquisition of international data is also not easy, the reality is that informatization of data measured in field needs to be made based on domestic proprietary technology.

In this study, data of elastic vertical displacement were obtained by measuring in a field during period of train speed up test. UIC 719 R explains elastic vertical displacement of earth work is usually not a design criterion, because resistance of continuous supporting structure generally implies very low vertical displacement [1]. Typical range of elastic vertical displacement is 0.1 to 0.2 mm on top of supporting structure. Measured elastic vertical displacement in Gyeongbu (2-phase) high-speed railway give us similar result as compared to UIC 719 R during train operation according to the test on the speed increase up to 421km/h. Gyeongbu (2-phase) high-speed railway was built to the designed speed of 350km/h.

In addition, data measured in field that can be utilized to study design criteria on the roadbed structures technologically available for the operation of 430km/h-grade vehicles. Since the roadbed of the Honam high-speed railway on which trains can operate at the speed of more than 350 km/h is under construction in 2013, this field-test was performed to preliminary analyze the elastic behaviors of the roadbed with the speed increase up test (300–421 km/h).

2 Field measurement tests

2.1 Overview

Field measurement location is a transition zone of bridge-earth in the Gaya overpass bridge. Gaya Overpass Bridge constructed as type of plate girder in Gyeongbu (2-phase) high-speed railway. A vehicle is HEMU-430X developed in Korea. In Speed up test, HEMU-430X speed up from 300km/h to 421km/h repeated to tuning and complement of vehicles.

Fig. 1 shows the location of measurement and drawing of sensor installation. Type of sensor is the linear variable differential transformer (LVDT). Sensors installed one each to HSB named DM-02 and Reinforced roadbed named DM-01.

Fig. 2(a) show photos of the scene in location of measuring in field. Fig. 2(b) show control box consisted of data logger, AVR (Automatic Voltage Regulator), sensor power supply, etc. fig. 3(c) show picture of sensor (DM-01) installed. Table 1 shows the location of measurement in detail.

Table 2 shows the status of sensor installation. Sensors measuring elastic vertical displacement were installed 2EA. The first sensor (DM-01) was installed on top of the roadbed and the second sensor was installed on top of HSB. Depth of displacement fixed point is GL.-3.0m.

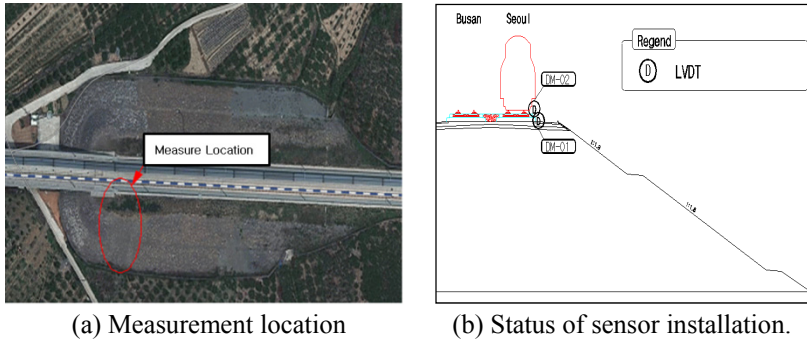


Figure 1: Installation status of sensors.

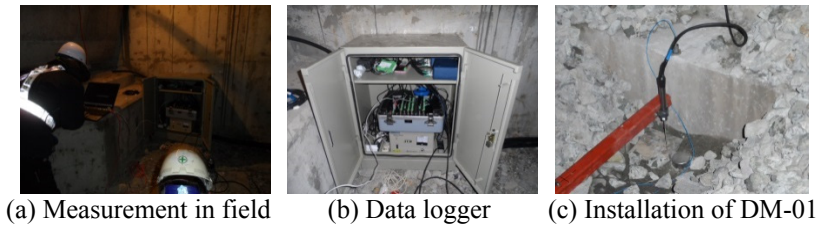


Figure 2: Installation of data logger and sensor in field.

Table 1: Measurement location details.



Name of railway	Track type	Measurement location description	STA	Measurement line	Note
Gyeongbu (2-phase) high-speed railway	Concrete track (RHEDA 2000)	Transition zone of Gaya Overpass Bridge	305k087	Up Line (to Seoul)	Train : HEMU 430X Design speed: 350km/h

Table 2: Status of sensor installation.

Sensor name	Measure item	Installation location	Range	Depth of displacement fixed point.
DM-01	Elastic vertical displacement	Top of Reinforced Roadbed	20mm	GL.-3m
DM-02	Elastic vertical displacement	Top of HSB	20mm	

Table 3 shows the specification of sensors and data logger. Measurement type of sensors is full bridge for measure high-speed over 1000Hz. Displacement range of sensor is 20mm. As for measuring devices, three kinds of data loggers, including DEWETRON, CR9000X and NI cRIO-9025 were used in parallel because there is no existing data carried on the roadbed behavior measurement at the train speed of more than 350km/h in Korea, which leads to the need to verify reliability by cross-examination on the results obtained from different sensors and measuring devices. Main data logger used CR9000X (CampbellSCI) with Trigger measurement. Other data loggers, DEWETRON and NI cRIO-9025, used for verification of measured data.

Table 3: Sensors and data logger specification.

Manu- facturer	Model name	Details
KYOWA	 (DTH-A-20)	<ul style="list-style-type: none"> · Range (mm): 20mm · Rated Output(mV/V): 5mV/V(10000μm/m) · Non-Linearity(%FSO): ± 0.1 · Input Resistance: 350$\Omega \pm 0.1\%$ · Output Resistance: 350$\Omega \pm 0.1\%$ · Operating Temperature ($^{\circ}$C): -10 to 70
Campbell SCI	 (CR9000X)	<ul style="list-style-type: none"> · Maximum Scan Rate: 100,000 Hz · Analog Voltage Accuracy: $\pm(0.07\%$ of) · Analog Resolution: to 1.6 μV · A/D Bits: 16 · Temperature Range: -25$^{\circ}$ to +50$^{\circ}$C · Memory : 128MB–2GB

2.2 Test conditions

Table 4 shows speeds of vehicle from 300km/h to 421km/h order by date [2]. Approximately 10km/h speed up per week. HEMU-430X traveling to same speed 1–3 times at midnight. When vehicle is passing the measurement location, data logger saved elastic vertical displacement about roadbed and HSB during 10 seconds. The Sampling rate was determined to be 2.5 kHz for prevented to miss a maximum of displacement. After train has passed, measured data is automatically sent to remote measure server through 3GPP Long Term Evolution (LTE) wireless modem.

3 Analysis of test results

The representative elastic vertical displacement of reinforced roadbed and HSB measurement values by HEMU-430x were presented in Figs. 3–6. The vertical displacement was measured by increasing the speed of the train by 10km/h from 300km/h to 421km/h.

Table 4: Schedule of speed up test.

Phase	Test date	Speed (km/h)	No. of speed test	Phase	Test date	Speed (km/h)	No. of speed test
1st speed up test	'12.7.15	300	3 times	2nd speed up test	'12.12.23	396	3 times
	'12.8.12	312	3 times		'12.12.27	394	2 times
	'12.8.16	321	3 times		'12.12.30	394	1 time
	'12.8.23	334	3 times		'13.01.17	370	2 times
	'12.9.01	342	3 times		'13.01.20	396	2 times
	'12.9.08	342	3 times		'13.01.27	400	2 times
2nd speed up test	'12.11.29	351	1 time		'13.02.03	400	2 times
	'12.12.02	354	2 times		'13.02.24	413	2 times
	'12.12.09	355	2 times		'13.02.28	412	2 times
	'12.12.13	378	3 times		'13.03.03	400	1 time
	'12.12.16	383	3 times		'13.03.28	421	2 times
	'12.12.20	386	3 times		'13.03.31	420	2 times

Fig. 3 show displacement of on top reinforced roadbed (DM-01) at 300km/h. Vertical displacement of DM-01 hasn't detected because of raw data measured within the resolution of the sensor. On the other hand, DM-2 (installed on top of HSB) measured 0.05mm very small (fig. 4).

Fig. 5 show displacement of on top reinforced roadbed (DM-01) at 431km/h. Vertical displacement of DM-01 measured 0.05mm and DM-2 measured 0.22mm (fig. 6).

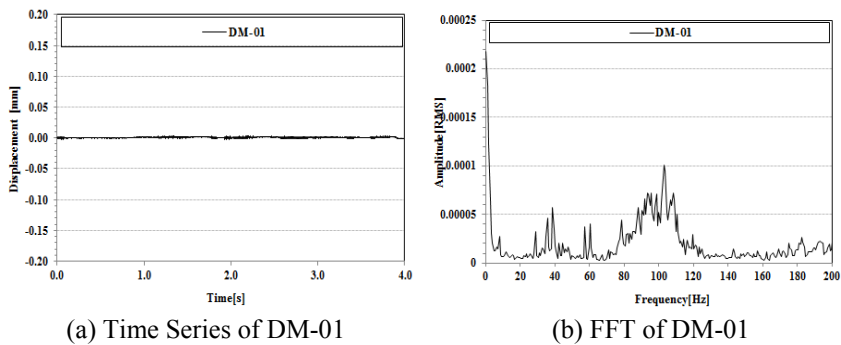


Figure 3: Elastic vertical displacement of DM-01 at 306km/h (HEMU-430X).

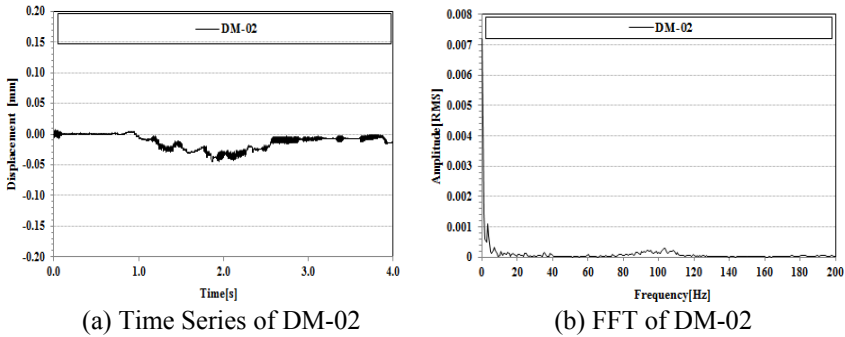


Figure 4: Elastic vertical displacement of DM-02 at 306km/h (HEMU-430X).

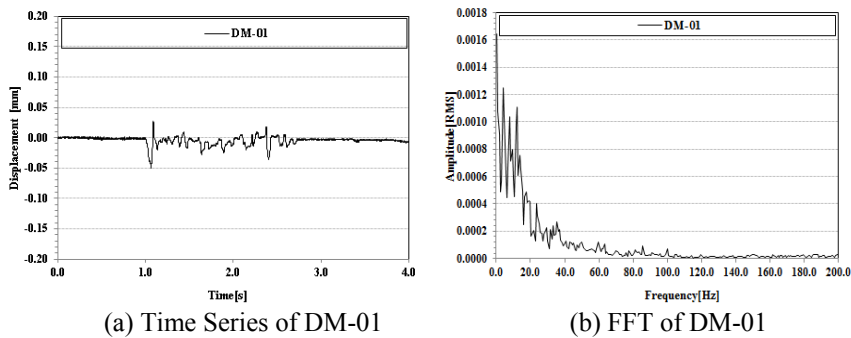


Figure 5: Elastic vertical displacement of DM-01 at 421km/h (HEMU-430X).

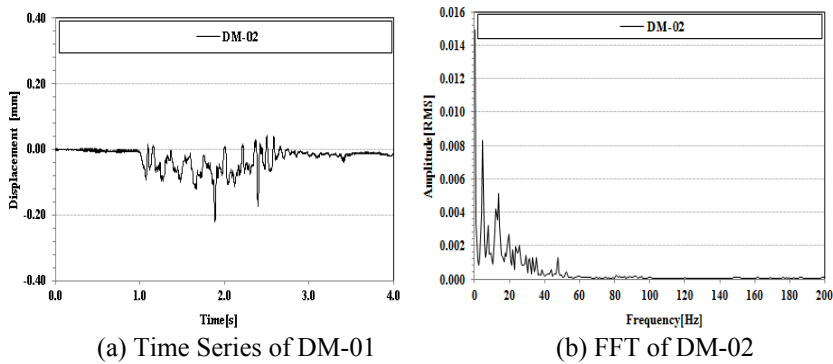


Figure 6: Elastic vertical displacement of DM-01 at 421km/h (HEMU-430X).

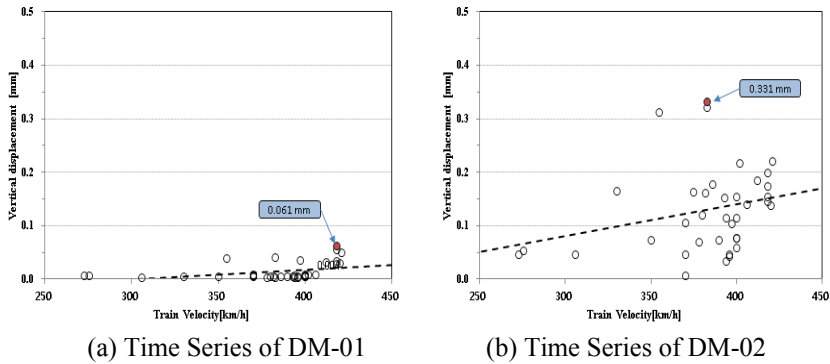


Figure 7: Elastic vertical displacement of DM-01 at 306km/h (HEMU-430X).

Fig. 7 shows a schematic diagram that displays measurement values of the reinforced roadbed and HSB compared to standard values during speed increase test of HEMU-430X. Until the train speed reach to 421km/h, maximum of elastic vertical displacement measured 0.061mm on top of reinforced roadbed and 0.311mm on top of HSB (Hydraulic Stabilized Base). Maximum vertical displacement of HSB measured at 383km/h and displacement decreased over 383km/h. Vertical displacement of reinforced roadbed is increased according to increase train speed.

As shown in Table 5, elastic vertical displacement was measured at less than 2.4% compare to design criterion in the roadbed [3], but it was 33% compared to the criterion in HSB of the concrete track. Accordingly, the results of performance evaluation on the elastic displacement of the roadbed and HSB in the transition zone of Gaya Overpass with HEMU-430X as targets were all evaluated to be behaviors within the range of design criterion.

Table 5: Elastic vertical displacement performance evaluation.

Measurement location	Design criterion	Maximum measurement value (train speed)	Evaluation	Remarks
Reinforced roadbed	2.5mm	0.061mm (418km/h)	Within criterion (2.4%)	Maximum value of LPF 300Hz
HSB (hydraulic stabilized base)	1mm	0.331mm (383km/h)	Within criterion (33%)	Maximum value of LPF 300Hz

4 Conclusion

During the increase in train speed from 300km/h to 421km/h on a railway line designed for 350km/h in Gyeongbu (2-phase) high-speed railway, elastic vertical displacement was measured at less than 2.4% compared to design criterion (2.5mm) in the reinforced roadbed and at less than 33% compared to the criterion (1mm) on top of HSB in the transition zone of Gaya Overpass with HEMU-430X. The results of performance evaluation on the elastic displacement of the roadbed and HSB in the transition zone of Gaya Overpass with HEMU-430X as targets were all evaluated to be behaviors within the range of design criterion.

Acknowledgement

This work is financially supported by Ministry of Land, Transport and Maritime Affairs (MLTM) through a research project “Development of Infra Technology for 400km/h High Speed Rail”.

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