# Guideway measurement system for geometric control of short- and long-ware curve of the Science Museum Line

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ABSTRACT: The following report geometric control measurements on the track line of the Science Museum in Daejeon, Korea are described. The measurements of the 1 km long line was carried out using a measurement system and evaluated locally. The results will be used for the maintenance of the track and show movements and as a basis for further measurements.

## 1 INTRODUCTION

### *1.1 Daejeon Expo '93*

For the world exhibition in Daejeon in 1993, a monorail of Hyundai Heavy Industries in cooperation with Krauss-Maffei has developed. The girders are manufactured as pre-stressed concrete boxes. The track was 450 m long and extended from the parking lot to the Expo site. After a development period of 5 years, the HML-03-system completed a successful three month operation.

### *1.2 Science Museum Line*

As a secondary use of a maglev train an extension to the Science Museum was realized. The station at the parking lot and some girders were dismounted. 28 new carriers and the station at the Science Museum were and go into operation in 2007. The "New Girders" have a span of 25 meters and a substructure was created also as a prestressed box beam. The equipment of the carrier with the necessary U-profiles was fitted out directly on the construction site. These five 5m modules per girder were successively positioned and fixed on the girder by additional concrete. The existing Expo girders, the "Old Girders" have also been upgraded with new modules on the same principle.

During the commissioning of the new guideway with the magnetic vehicle from Hyundai-Rotem, UTM-01, the planned speed of 50 kph could be reached only conditionally. Mechanical contact, high lateral and vertical accelerations and thus very poor ride comfort were the cause. The record of the acceleration sensors could display some places, but make no statement about geometric deviation.

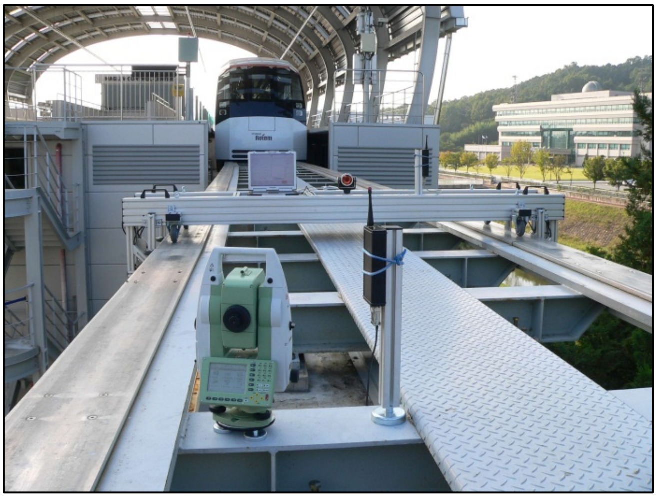

Figure 1. On site after installing - total station and measurement frame

## 2 MEASUREMENT SYSTEM

### 2.1 General

In 2008 the Marx Ingenieurgesellschaft mbH was contracted by Hyundai-Rotem and the operator of the facility, Jungsoel system, to create, build and deliver the measurement system, carry out the first measurement and train the operation engineers. It was ensured that the measurement system can also be used on other systems with different track gauge.

### 2.2 Frame, Sensors

ment frame was fully assembled in aluminum profile design. Thus, the weight could be largely reduced and so the frame can be handled by two people on the guideway. The side wings can be folded down and locked. The frame runs on three wheels and is forced out lateral freely through two rolls. On each side two triangulation-sensors measured the distance in lateral and vertical direction. The tilting of the frame is measured by a centrally positioned tilt sensor. The 3D-positon of the frame will be measured by a total station and a prism. Also inside the frame, a temperature sensor is installed.

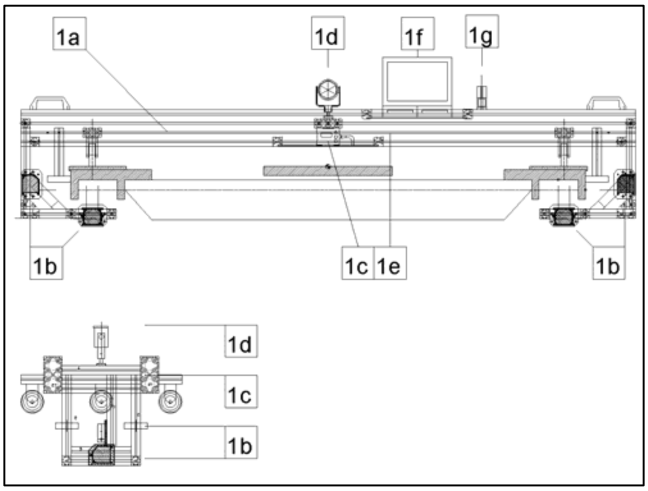


Figure 2. Scheme of the frame with the 4 triangulation sensors, tilt sensor and prism

### 2.3 Preparation

To configure the project a simple database was created. This includes the girder number, the stationing and configuration of the equipment of the girder. The alignment in horizontal and vertical direction was digitized for the analysis. For the measurement also a 3D-benchmark net was installed and measured by the total station.

### 2.4 Guideway measurement

After the preparations had been shot down, the girders are measured sequentially in profiles. The stop-and-go measurement is preferable because of higher measurement accuracies of the total station on a continuous measurement of static targets. The measurement for each girder (25 profiles) takes about 10 minutes.

The complete measurement of the 1 km track could be completed within a day's performance. Thus repeated measurements within a reasonable time is possible to detect changes.

The girders are measured and stored in an outdoor laptop at the measurement frame. The calculated 3D-position on the track supports the nominal geometry of the girder. A comparison with the measured geometry was calculated in tabular form and graphically.

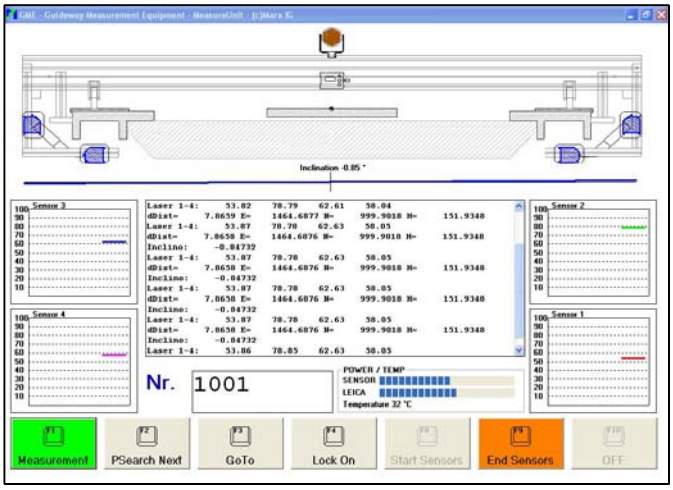


Figure 3. Software to control measurement on a Panasonic Toughbook

### 2.5 Calibration

To calibrate the measuring system, a girder profile at the Station Museum was determined in 3D. Daily before the measurement-campaign starts the measurement frame make a test measurement and the deviations stored in the calibration file.

### 2.6 Comparison

The results of the first measurement campaign provide a comparison of the girder in 2008 to the planning. The girder-wise evaluation is divided into lateral (y) and vertical (z). The table shows the deviations of the measured profile in each profil. The deviations are calculated first globally (to the complete guideway). In a second step the deviations are normalized to the girder ends.

The graph shows the course of the long-wave deviations. In vertical and lateral direction deviations should be detected by more than 20 mm compared to the nominal.
The track diagram shows the deviations from the global planning. Thus there could be missalignements and settlements identified.

The high accuracy of the system can be verified on the example of the graph. The girder does not exactly follow the planned curve, but the small unit, the module has just been built and arranged polygonal. This minimal polygonal arrangement is exactly measured.

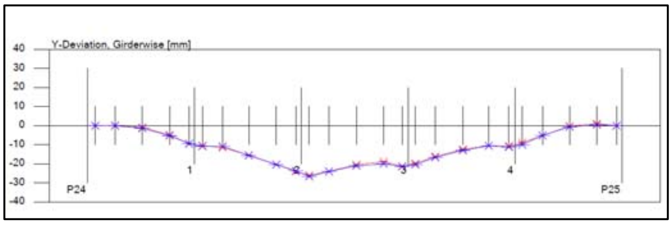

Figure 4. Polygonal arrangement of the 5m-modules in curve in y-direction

## 3 VALUATION OF RESULTS

A compensatory curve is placed through the values. Added to this long-wave a short-wave-band is placed, inside should include all values. The values of the 39 girders will be examined statistically on these two criteria.

The permissible limits for these long- and short-wave variations are determined by the system. Technically, the control system responds very slowly at 1 Hz. With the planned maximum speed of 60 kph the system reacts so only once a 25m beam. Therefore the reason for the high accelerations and mechanical contacts are also the long-wave uncontrolled high gradients.

The trackwise graph shows a polygonal shape of the deviations in the column places. Presumably, these are from a combination of settlements, temperature characteristics and imperfections in the fine positioning.

## 4 FURTHER USAGE

For other projects with different gauge the measuring system can be transformed by a small modification. After the configuration (database, alignment and benchmark network) the system can be used for as-build comparisons. The results could be used to check the acceptance criterion and as a maintenance tool.

The system was taken over by the operator of the maglev system in Daejeon, and is still used here. Through follow-up measurements could be the temperature behavior of the girders and settlements are shown in the columns.

## 5 CONCLUSION

The measurement system could be used successfully and could determine the geometrical problems. A correction of the deviations within the girder is possible only with great effort and under total closure of the guideway. For further projects is strongly recommended to optimize production and assembly of the track in terms of geometry. In addition, a specification with unique tolerances for long-and short-wave deviations within the girder and at the beam joints is to provide. To ensure passenger comfort and to establish permanent settlements this measurements must be performed in regular intervals.