# A Maglev Guideway Girder System with Trapezoidal Open Steel Box Girder and Precast Decks Proposed for the Route of the Center for Urban Maglev Program in Korea

No. 33

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ABSTRACT: Generally, steel box type girders are preferred for the curved route of maglev guideway in urban environment. A maglev guideway system with trapezoidal open steel box girder and precast decks was proposed as a basic type for the curved route in test route of the Center for Urban Maglev Program in Korea. The adoption of the precast deck system to the trapezoidal open steel box girder can guarantee the precise construction of maglev guideway, which requires precise cant and its variations in curved routes including transition curves. The precast deck system adopted to guideway girder also enables the rapid construction in urban area.

## 1 INTRODUCTION

The Center for Urban Maglev Program in Korea [1] has been started in late 2006 for the purpose of the practical application of maglev system by 2012. The final goals of the Center are the development of 110km/h ATO maglev train system and the construction of approximately 7km test route. To achieve these final goals, the Center has three core research subjects: 1st, system engineering; 2nd, development of maglev train; 3rd, construction of test track. The 3rd core subject is divided into two details. One is performance improvement of maglev track structures, and the other is development of the switching systems. Authors are responsible for the development of rapid construction of maglev guideway girder for 7km test route as a cooperating research group of the 3-1 subject.

A PSC-U type girder has been proposed as a basic type of maglev guideway girder for the straight route as shown in Figure 1 [2]-[3]. The configurations of the guideway girder systems are the main girder of PSC-U type, the precast deck system and the guiderail system.

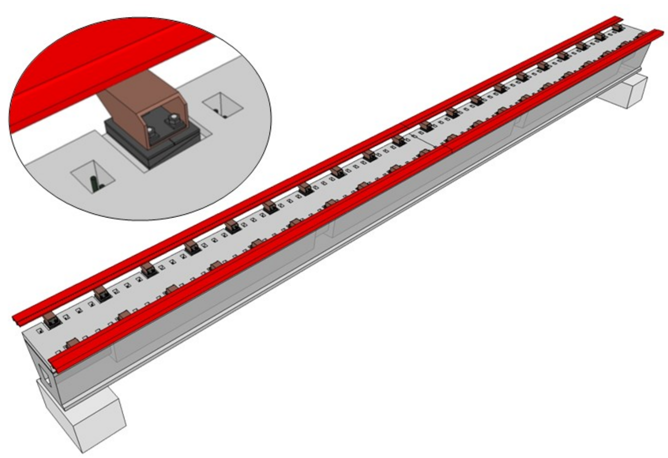


Figure 1. Conceptual drawing of PSC-U type guideway girder system

The structural performances of the connections between the precast deck and the guiderail system shown in magnified figure in Figure 1 have been verified by static and fatigue load tests [4]. And the constructability also has been evaluated by mock-up construction tests [5]. The structural performance tests of the composite system with PSC-U type girder and precast decks are also accomplished by full-scale 20m guideway girder system, and the structural safety of the PSC-U type guideway girder to the live load, i.e., the maglev train loads are guaranteed as the ultimate capacity load above 3250kN [6]. The applicability of precast decks to the vertical curved in urban maglev train route also has been evaluated [7].

For the curved route, especially in urban environment, a steel box type girder is generally preferred. Therefore the maglev guideway girder system with trapezoidal open steel box girder and precast decks was proposed as a basic type for the curved route in test route. The adoption of the precast deck system to the trapezoidal open steel box girder can guarantee the precise construction of maglev guideway, which requires precise cant and its variations in curved routes including transition curves. The precast deck system adopted to guideway girder also enables the rapid construction in urban area.

The main objective of this paper is to introduce current development of a curved maglev guideway system in Korea. The first part of the paper covers the applicability of precast deck system to the curved guideway system followed by the details on the design and manufacturing of the proposed guideway. Finally, various tests are conducted on a full-scale curved maglev guideway girder. Experimental and numerical investigations on the test guideway are then briefly introduced.

## 2 APPLICABILITY EVALUATION OF PRECAST DECK SYSTEM TO THE CURVED ROUT

At present, precast deck systems are widely used because of their superiority to cast-in-place concrete deck systems on quality, constructability, economic efficiency, durability and the periods of works. As early mentioned, the guideway systems proposed for linear route consist of PSC-U type girder, precast deck system and guiderail (track structure) system.

Figure 2 represent a typical curved route consisting of linear section, transition curved section and circular curved section. Because of the geometric shape of curved route, i.e., the curved shapes of steel girder and rail, the precast deck system supporting the track structure may be manufactured by the curved shape. The manufacture of curved precast decks with each curved shapes may result the economic inefficiency and the constructability of precast decks with curved shape are dependent to the curved route shape.

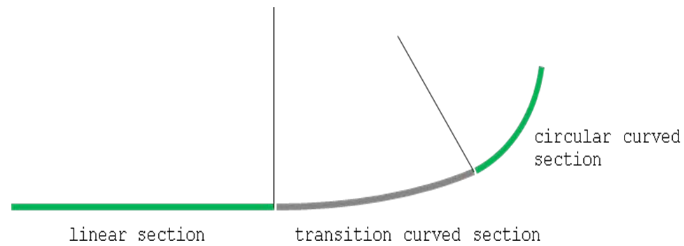



Figure 2. The line shape of curved route

To overcome the inefficiency of application of curved precast decks, smaller rectangular shaped precast decks were virtually installed to the curved route. The locations of guiderail structure and the anchor bolt, where the guiderail structure connected to the precast decks are determined by the curved line shape of the track. The shorter length of the rectangular shaped precast deck produces the more efficient constructability. Thus the maximum length of precast deck was evaluated to permit the allowable construction error. The result is that a 2.5m length of precast deck shown in Figure 3 is sufficient to correspond to the any geometry of curved routes with a radius of 100m or higher.

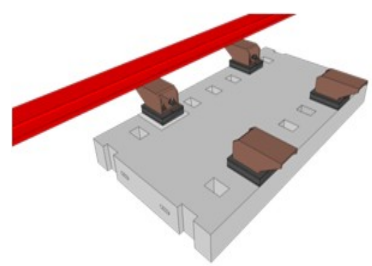


Figure 3. 2.5m-long precast deck with twin block system

Application of these multiply-separate rectangular shape precast deck with unit length of 2.5m can cause cracks on the negative moment zone located in middle support of the 2 span continuous bridges. For this reason, it may be necessary to introduce some longitudinal pre-stressing force to the precast deck to prevent these cracks for the purpose of serviceability. The longitudinal pre-stressing force to the precast deck also has a merit to reduce the required quantity of the steel of the main girder, because the concrete area of precast deck is used as a section of bending resistance area.

## 3 DESIGN OF TRAPEZOIDAL OPEN STEEL BOX GIRDER

The optimal sections of the trapezoidal open steel box girder have been determined by a structural optimization process to minimize the weight of the main girder, i.e., the amount of the steel, under the condition of the live load deflection and stresses within L/2,000 and allowable stresses respectively.

Typically a curved guideway girder system has been chosen as follows: the radius of horizontal curve to be 100m; 2 span continuous bridges with span length 30m (2@30m); and an asymmetric section with different web heights to correspond the 200mm cant are assumed.

Figure 4 shows the finite element model of the curved 2 span continuous guideway girder: the main steel girder with 4-nodes shell elements and precast decks with 8-nodes solid elements and 2-nodes truss elements to model the bracings. Figure 5 shows the deflections and stresses distribution of the optimized girder system.

Finally with this basic design results, the detailed design of curved guideway girder system such as stiffeners, bracings are accomplished.

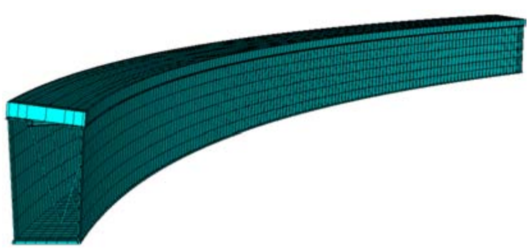


Figure 4. Finite element model for optimal section evaluation

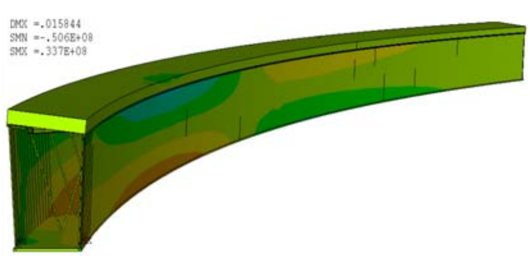



Figure 5. The deflection and stress contour of optimal section

## 4 MANUFACTURING AND INSTALLATION OF EXPERIMENTAL GUIDEWAY GIDER SYSTEM IN FULL SCALE

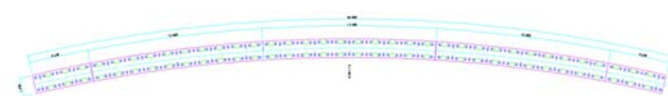
### *4.1 The overview of experimental guideway girder*

The guideway girder proposed to the curved track is designed as a basis of circular radius of 100m, and the cant with 200mm as mentioned early. Methods to correspond the cant of 200mm can be various, an asymmetric section which differ the height of steel girder web in this study has been chosen as shown in Figure 4. The girder is designed to meet the live load deflection regulation of L/2,000.

The height of the girder and the width and the thickness of the flange and the web respectively are determined as these design bases. The total length of the experimental guideway girder is 45.9m with two-span continuous bridge and the total weight of the main girder is approximately 50tons.

The height of the main steel girder at sectional center is 1757mm. the width of the flange is just 450mm and the width of the bottom flange is 750mm. the thickness of the precast deck is 200mm and the width and length of the precast deck is 1350mm and 2480mm respectively.

The weight of one precast deck is about 1.62ton. Total weight of the guideway girder is approximately 80tons. Figure 6 shows the plan and sectional view of the experimental guideway girder. The precast deck with 2.5m length of each one is applicable to any curve line section as discussed earlier.



(1) plan view

(2) sectional view

Figure 6. plan and sectional view of experimental guideway girder

### *4.2 Manufacturing of precast deck*

As the total length of the experimental steel girder is total 45.9m, the required number of precast decks is 18. The configuration of the precast decks are 4 precast decks on spliced connections, 2 precast decks for anchorage for tendon in precast decks and 12 precast decks for general section. Figure 7 shows the standard view of precast decks.

Three 2480mm by 1350mm sized steel forms have been made to product total number of 18 precast decks. And the reinforcement bars, 12 shear pockets, 4 leveling bolts and 4 anchor bolts and 2 flat ducts depicted in Figure 7 are installed within each one steel form as shown in Figure 8. Concretes designed for the compressive strength of 40MPa were casted into the form as shown in Figure 9. The 18 precast decks after curing were transported to the structural laboratory and stacked up as shown in Figure 10.

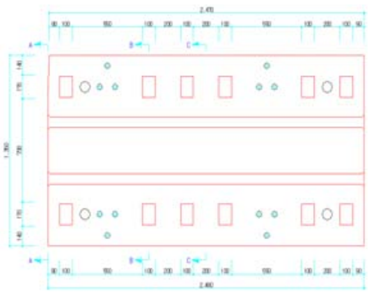


Figure 7. General drawing of 2.5m rectangular precast deck

Figure 8. 3 Steel forms and arrangement of reinforcement bar

Figure 9. Casting of concrete into steel form

Figure 10. Stack of 2.5m rectangular precast deck

### *4.3 Manufacturing of trapezoidal open steel box girder*

The 45.9m-long steel girder consists of 5 segments and integrated by 4 spliced connections. The biggest segment of the steel girder is 12.5m-long and weighs 13.5 tons. The two-medium and two-smallest sized segments of the steel girder is 10.0m-long, 10.9 tons and 6.7m-long, 7.3 tons respectively.

The asymmetric open steel girder segments are manufactured by the stiffener details shown in Figure 11. Figure 12 shows the manufacturing process of asymmetric open steel box girder, and the cant of 200mm is coped with the different heights of the inner and outer webs as shown in Figure 13. It was argued that a steel girder with different web height, i.e., a steel girder coping with cant indeed could be manufactured, but it is not something.

The vertical stiffeners are located in longitudinal direction with spaces of 2.5m. Also total 14 diagonal bracings in the segments itself are used to prevent the torsional deformations during the transportation and 4 diagonal bracings between the segments. The longitudinal stiffeners are minimized as shown in figure 13.

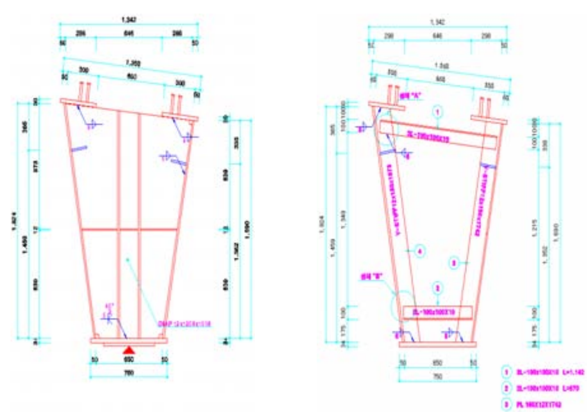


Figure 11. Section drawing of trapezoidal open steel box girder

Figure 12. Manufacturing the trapezoidal open steel box girder segment

Figure 13. Section view of trapezoidal open steel box girder

### *4.4 Installation of experimental girder*

The installation processes of trapezoidal open steel box girder (five segment, 6.7m + 10m + 12.5m + 10m + 6.7m, two-span continuous bridge) are shown in Figure 14-15. After installation of the main steel girder, precast decks are put down on the girder and integrated to the girder as shown in Figure 16-18.

The placements of total 19-precast decks onto the girder took half the day. The insertion and post-tensioning of the total 8-tendons took times within an hour.

The construction processes of the composite steel box girder with precast decks can be summarized as follows:

* Installation of the main girder
* Placement of the precast decks onto the main girder
* Fill the interfaces b/w precast decks
* Insert the tendon into the ducts in precast decks
* Induce post-tensioning forces
* Fill the bedding layer and shear pockets

Figure 14. View during installation of main girder segments

Figure 15. View after installation of main girder

Figure 16. Placement of precast decks onto the main girder

Figure 17. Introduction of prestressing forces to the decks

Figure 18. Overview of integration of trapezoidal open steel box girder and precast decks

## 5 STATIC AND DYNAMIC TESTS

Static and dynamic load tests are accomplished as following 5 cases:

Case A: Dynamic load tests before/after the integration precast decks to the main steel girder
Case B: one-span loading test (the 1st span) of composite system of precast decks and main steel girder
Case C: one-span loading test (the 2nd span) of composite system
Case D: two-span loading test (the 1st and 2nd span) of composite system
Case E: eccentric loading test (the 2nd span) of composite system

The maximum loading up to 900kN is applied to the structure at the center of each span. In the case of the test B & C (1 or 2 span loading up to 900kN), the maximum deflections are occurred with the ratio of 1.2mm/100kN, which shows a linear behavior.

Figure 19 shows the cracks occurred on the negative moment zone of the girder when the girder is being loaded about 900kN which is several times of the live load.

Figure 19. Cracks on the negative moment zone

## 6 FINITE ELEMENT ANALYSES

Finite element analyses of static load tests have been accomplished by using ABAQUS. The steel girder is modeled by using 4 nodes shell elements (S4), and precast decks and bedding layers are modeled as 8 node solid elements (C3D8) shown in Figure 20. Figure 21 and Figure 22 show the results of the test case B and case D respectively. The computed deflections are well matched with the experimental deflections as the ratio of 1.2mm/100kN for the test case B.

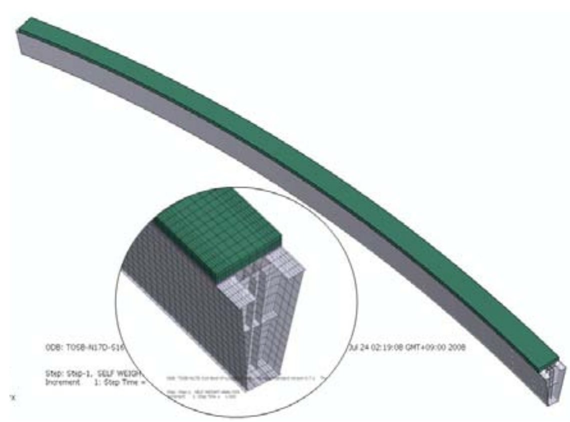


Figure 20. Finite element model of the guideway girder system

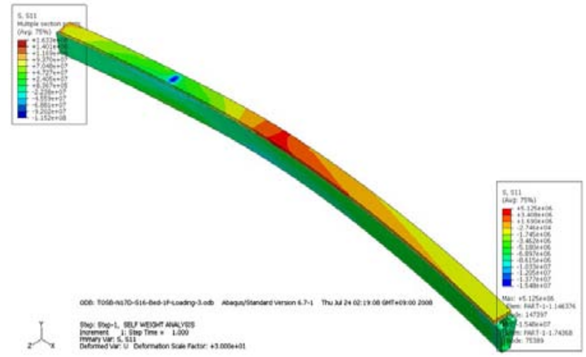


Figure 21. FEA results for test case B

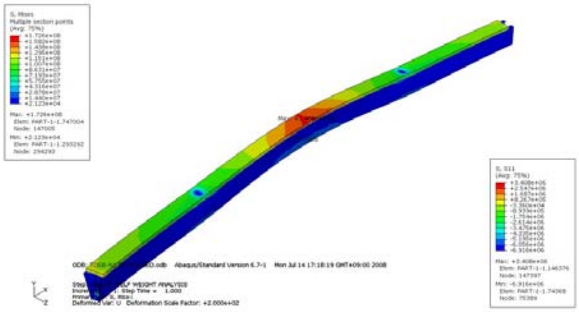


Figure 22. FEA results for test case D

## 7 CONCLUSIONS

As a cooperating research subject of the Center for Urban Maglev Program in Korea, the constructability and structural performance of the proposed curved guideway girder system are accomplished.

It has been found that there are no special difficulties of manufacture, installation and construction of the proposed guideway system. The structural performances meet the requirements such as the live load deflection regulations and the allowable stresses. This confirms that the proposed guideway girder system with the composite system of precast decks and trapezoidal open steel box girder guarantees the structural safety.

Finally, it is concluded that the proposed guideway girder system using precast decks can shorten the periods of works and is suitable to the precise and rapid construction especially in urban area.

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