A Millimeter-Level Challenge to Construction Accuracy

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Guideway for Linear Motor Train

Photo 1 Test run of Maglev train

GUIDEWAY FOR SIDE-WALL LEVITATION

Yamanashi prefecture is home to the linear motor train (Maglev) test site. The system under test uses side-wall mounted coils, meaning that the ground coils, which provide the forces necessary to levitate, propel, and guide the train, are fitted to the guideway's side walls. Panels fitted with two types of ground coils — propulsion coils and levitation/guidance coils — are bolted to the sides of the U-shaped guideway, while the bottom of the guideway is for the train's support wheels.

The ride comfort of the magnetically levitated linear motor train depends greatly on the accuracy with which the guideway is constructed, and this report describes the high-accuracy installation of the panel structure. (Photo 1)

GROUP CONTROL AND ATTACHMENT OF GROUND COILS

While great accuracy is required in the installation of ground coil panels on the two side walls of the guideway, ease of installation and servicing must also be taken into account. To allow control over the large number of coils in groups, two methods of installation were developed: panel and beam. Further, for sections of the guideway where minimal displacement was anticipated, such as within tunnels, direct-mounting coils were developed.

Panel type

Prestressed concrete panels (12.58 m long by 1.53 m high by 0.35 m thick) fitted with the ground coils and associated cables are fixed to the concrete side walls of the guideway.

Beam type

Prestressed concrete beams (12.58 m long by 1.53 m high by 0.65 m thick) fitted with the ground coils and associated cables are laid on bearings on the concrete sub-grade.

Direct-mounting type

The ground coils are attached directly to the steel-reinforced concrete side walls.

With all three types, the ground coils are fixed directly to the concrete structure, so the accuracy of guideway construction has a direct effect on the ride comfort of the train.

GROUND COIL INSTALLATION AND RIDE COMFORT

The Maglev guideway is a system in which the levitation/guidance coils and the concrete guideway itself are analogous to conventional railway track, while the propulsion coils are equivalent to the motor armature of an electric train. Steady-state acceleration and the rate of change in acceleration with time (which is a measure of the amount of joggling experienced by passengers) are influenced by the speed of the train, curve radius, curve transitions, and track cant, which are determined in the planning phase. Another influence on ride comfort, however, is any error in the distance between the guideway center line and the face of the ground coils, or the coil misalignment. When actually installing the ground coils during the construction phase, therefore, it is important to properly control this distance.

REQUIRED ACCURACY FOR RIDE COMFORT

The errors introduced during each phase of guideway construction were simulated to forecast the ultimate misalignment of the guideway. The PSD (power spectral density) of the misalignment was then calculated and the ride comfort level predicted from the characteristics of the PSD. Control targets were set such that a ride comfort comparable to that of the Tokaido Shinkansen (Bullet Train) would be achieved.

HIGH-ACCURACY CONSTRUCTION OF GUIDEWAY

Good accuracy was achieved in installing the panel type ground coils by strict control over each step in the construction work, as detailed below.

(1) GPS surveying and reference point establishment

A reference point control system was adopted on site to provide a unified approach to higher construction efficiency and greater control accuracy. Both frame reference points and guideway reference points were established by traverses based on points established using an interferometric positioning system relying on satellites, or GPS (Global Positioning System).

Frame reference points were used for the construction of structures, such as those at tunnel entrances, and for the establishment of the track center line once such structures were complete. Guideway reference points were of three types, A, B, and C, established along the center of the guideway after the track center line had been fixed. Reference points C were established at intervals equivalent to the panel length, or 12.6 m, to allow accurate installation of the panels.

The reference point control system was used to ensure the accuracy of reference points A and B over intervals exceeding 100 m through precision surveying. As a logical consequence, the system allowed for extremely accurate installation of the guideway with long wave misalignment automatically controlled. It offers the following advantages:

There is no need to control long wave misalignment, and measurement operations can be simplified and standardized. Using guideway reference points, it is possible to control accuracy throughout all construction phases in a unified manner.

(2) Construction of concrete side walls

To ensure precise alignment of the ground coils, it is first necessary to construct the concrete side walls to an accuracy of millimeters, and movable steel forms were used to achieve this. To obtain the accuracy needed for panel installation, reference points C were used to position the forms in the axial direction (along the track) while verticality was also strictly controlled.

(3) Fabrication of panels

The panels are characterized by three main features: at 0.35 m thick, they are thin as compared with their 12.58 m length and 1.53 m height, they have a complex shape for attachment of about 30-layer ground coils in three layers, and they have inserts for bolting to the side walls that must be placed with an accuracy of ±1 mm. The steel forms used to fabricate the panels were machined to an accuracy of 0.1 mm. Further, to prevent warping and deflection during the concrete casting process, and to

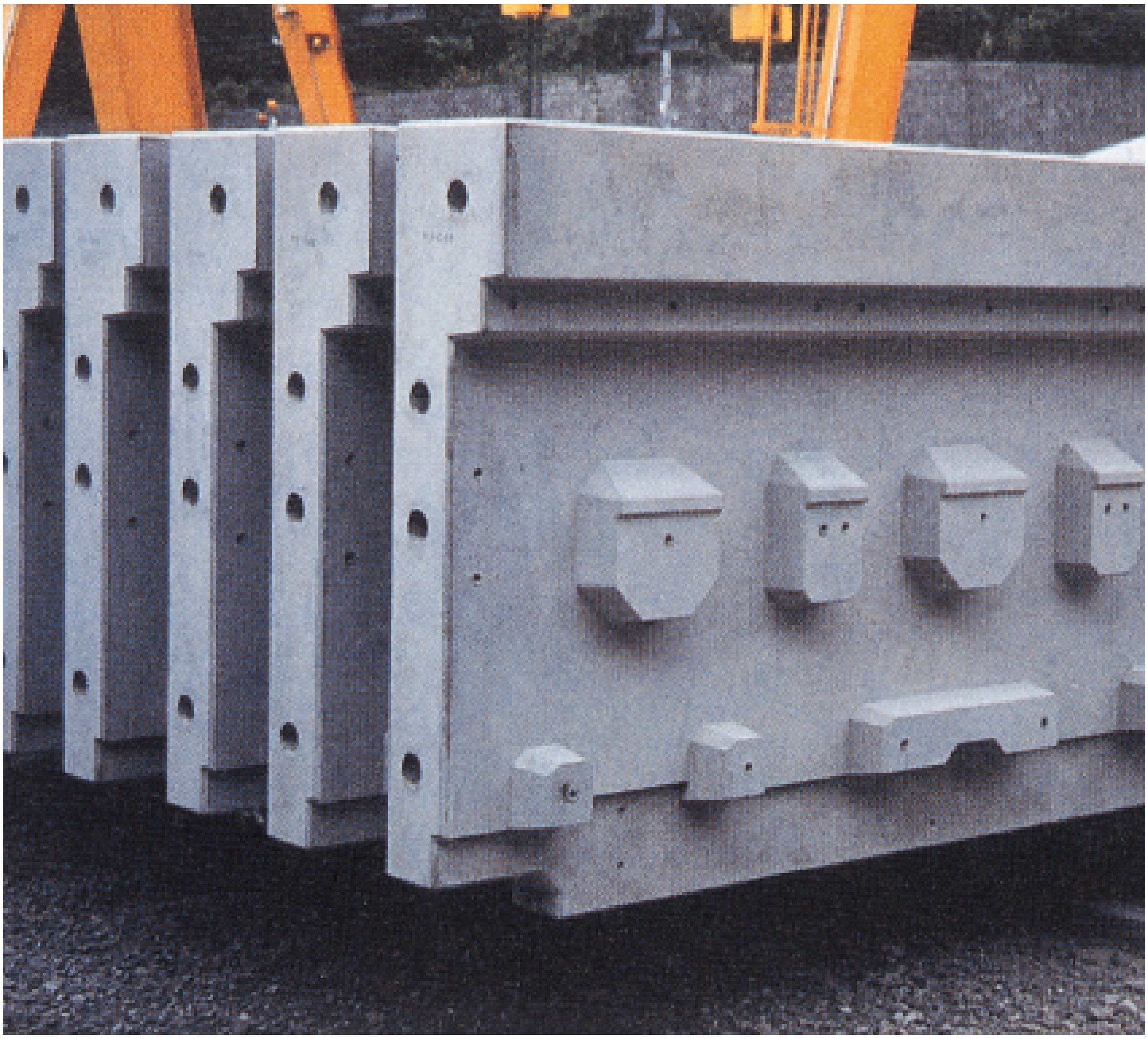

Photo 2　Panel (on which ground coils are mounted)

reduce the danger of chipping the panels as they were removed from the forms, a hydraulic form remover was developed. Use of this remover made it possible to fabricate panels to an accuracy of 2 mm on the coil mounting surface. (Photo 2)

(4)Attachment of ground coils

The flatness of the coil mounting surface was first measured three dimensionally. Flatness was then adjusted to an accuracy of at least 1 mm by inserting adjustment sheets, and the ground coils were then bolted to the panels. As a result, the flatness of the ground coil surface after attachment was held within 2 mm.

(5) Field installation of panels

After temporarily securing each panel to the side wall with 10 stainless steel bolts, its alignment in the longitudinal and vertical directions was adjusted using hydraulic jacks acting against its lower edge. The alignment of the panel in the longitudinal direction was then adjusted by inserting temporary foam-urethane back spacers into the clearance between the side wall and the panel, and then cinching the bolts. With the panel now in the correct position, CA (cement asphalt) mortar was injected into special bags laid out in the clearance. Once the mortar had cured, the panel was finally secured to the side wall by tightening the bolts to a predetermined level of axial force based on earlier tests.

DEVELOPMENT OF PANEL-ALIGNMENT EQUIPMENT

To measure the baseline for panel alignment, special adjustment equipment and a three-dimensional measuring instrument were used. This equipment indicates the reference position for installation of a panel using threads.

First, the device was positioned properly by collimation using the three-dimensional measuring instrument, and then threads were stretched tight on three levels. The position of each panel was adjusted in fine increments while measuring the distance between the ground coils and the threads.

Reducing installation time

Getting the equipment into the correct position for each panel proved time-consuming, since it had to be swiveled, raised, lowered, and extended and contracted (with a motion interlocked with right and left movement) into place, and a great deal of time was spent calculating travels to bring the strings to the correct coordinates. To speed up the process, a computer program for calculating the travels was developed and a travel calculation/ instruction system that gives instructions to workers was structured using a personal computer in synchronization with the measuring instrument. This reduced the installation time to about 15 minutes for each panel.

Improvements in panel installation accuracy

Errors were introduced primarily in making the three-dimensional measurements and in ascertaining the distance between threads and ground coils. The three-dimensional measuring instrument suffered errors when the incident wave was not perpendicular to the target, so an angled target was fabricated to improve accuracy. Further, a special straight edge was developed to allow the separation between threads and ground coils to be measured from above while maintaining plumb. Other improvements were made to the foam-urethane temporary back spacers and the hydraulic jacks. As a result, efficient and accurate installation of the panels was made possible.

RESULTS OF MILLIMETER-ACCURACY CONSTRUCTION

The average misalignment was 0.20 mm. The frequency distribution curve indicates that the panels tended to be positioned slightly too far from the center line. This is probably because it was easier to adjust panel position in this direction by tightening the bolts. The average deviation from the level was 0.12 mm. Since the panels were initially found to be somewhat low, they were later moved slightly upward. Although variations in this direction were slightly larger than those in the alignment, the results are satisfactory.

FUTURE ISSUES

The test center will be used to verify the actual ride comfort of the train as influenced by ground coil installation accuracy. Efforts will also be made to improve the accuracy of train motion simulations and to verify the load transfer mechanism as a train passes above a panel type guideway. Further, toward the practical realization of a Maglev railway system, cost effectiveness will have to be pursued through high-accuracy, rational, and mechanized construction methods.