We have been continuing efforts to increase Shinkansen operation speed with an aim of improving customer service. Since FY 2005, we have been carrying out running tests using FASTECH360 Shinkansen high-speed test trains. Thus, we have examined the impact of the increase of the maximum operation speed on structures, since structures for Shinkansen in our service area where speed increase is scheduled are constructed with a designed maximum speed of 260 km/h.1, 2)

In this paper, we will report the development of a construction method that we implemented on a trial basis for vibration reduction of concrete girders using sound insulating walls.

2.1 Applicable Viaducts

This time, we applied the construction method for vibration reduction to an underpass between Shiroishi-Zao and Sendai on Tohoku Shinkansen. That underpass is a viaduct of a PC girder structure for which common use started in the 1980s and has a single track structure separated into inbound and outbound tracks (with four main girders) crossing a local road at an acute angle. The girder height of that underpass is limited to 1 m due to the overhead clearance despite having a span of 21.2 m. Compared with usual PC viaducts, the ratio of the girder height to the span length is small. Table 1 shows the specs and Fig. 1 shows a general diagram of that underpass.

The results of study of the impact from Shinkansen speed increase proved that the underpass does not meet the standard value of deflection that is provided by the ride quality defined by current design standards (for concrete structures) in case of over 300km/h maximum speed. Accordingly, we examined construction methods to reduce the deflection of that underpass by the load of a running train.

Since the train movement curve plan anticipates that the running speed on the inbound line of that underpass does not exceed 300 km/h, we examined the construction method only for the girders of the outbound line of that underpass.

2.2 Overview of the Construction Method

In order to reduce the deflection by the load of a running train, we have to improve the rigidity of the girders. Increasing the number of main girders is one of the possible methods to improve the rigidity, but that is a realistic measure. So, we focused on the fact that there are cast-in-place reinforced concrete sound insulating walls at that underpass and examined ways to make use of those.
As shown in Photo 1 and Fig. 2, the sound insulating walls have joints at a fixed interval so as not to transmit to sound insulating walls stress by the load of a running train. So, we examined methods to increase rigidity of the girders as a whole by binding the deformation of the joints (Fig. 3).

Specifically, we tried on that underpass a two-phase method as a construction method for vibration reduction of concrete girders using sound insulating walls.

**[First Phase]**
Fill joints with non-shrinkage mortar (Fig. 4)
In order to bind sound insulating walls and make them components that contribute to improvement of the girder rigidity, we cut the existing joints of the sound insulating walls in advance and filled those with non-shrinkage mortar using molds.

**[Second Phase]**
Add reinforcing steel fittings on top of the sound insulating walls (Fig. 5)
Taking into account the long-term use of railway structures, we attached reinforcing steel fittings on the top of the sound insulating walls and fixed them with bolts and resin. The purpose of that is to reduce compression stress that is applied to the top of the sound insulating walls.
Here we will report the issues examined and actual construction in the first phase (filling mortar to joints) conducted this fiscal year in the trial of the construction method for vibration reduction of concrete girders using sound insulating walls.

### 3.1 Selection of Non-Shrinkage Mortar Material

The viaduct to which we would carry out the trial construction was a section of a Shinkansen line in service; so, the construction work could only be conducted at night maintenance time. And also, since running Shinkansen trains apply compression stress to the places filled with mortar, the mortar must reach the required strength (design standard strength for sound insulating walls: 24 N/mm²) by the first train after filling.

Due to those conditions, we conducted strength development confirmation tests to select the appropriate non-shrinkage mortar material. For that purpose, we made five column samples of φ50 × 100 mm per type of non-shrinkage mortar after mixing the mortar for the specified mixing time per type. Assuming the site temperature at the time of construction, we cured the samples in mold cans in iced water (temperature 10 – 15°C, Photo 2). Compression strength tests were conducted every 30 minutes after casting, and changes over time were recorded.

The results are shown in Fig. 6. Considering the train service interval in the construction section (scheduled completion of mortar filling at 1:30 am and running of the first outbound train around 7:30 am), we selected a mortar material that can reach the required strength within six hours after filling.

### 3.2 Non-Shrinkage Mortar Casting Tests

For test casting, we made long molds modeled after a cut joint for the selected non-shrinkage mortar as explained in 3.1 (Photo 3). In the tests, we checked the adjustment method to find the required flow rate for mixing of the mortar material on-site and the actual congealing time. By checking the size of the samples (height and width) after removing the molds, we confirmed that there was almost no shrinkage.
3.3 Advance Check of Sound Insulating Walls

In advance of the trial construction, we checked the track side and the outer side of the sound insulating walls of the girders for which the trial construction would be applied. The purpose of that was to compare the condition of the sound insulating walls before and after construction. We checked cracks etc. in the maintenance time at night before the construction (Photo 4).

3.4 Joint Check

Using a reinforcing bar inspector, we checked the arrangement of reinforcing bars in the sound insulating walls around the joints to determine where to cut. We decided to cut four joints, and specified the width of cutting to be 130 mm for the place where the joint material was largely bent and 60 mm for other three places (Fig. 7, 8 and 9).

3.5 Through Bolt Hole

We decided to leave the molds at the places of joint cutting due to the limitation of work time. To prevent those molds from falling off by vibration or wind pressure of running Shinkansen trains, we chose a structure where steel plates (SS400, t = 4.5 mm, with hot dip zining) are secured by M10 through bolts (Fig. 10). We expected that drilling holes for those bolts at the points exactly as planned would be difficult, because those holes could affect the reinforcing bars in the sound insulating walls; so, we made the holes approximately two weeks before cutting the joints (Photo 5). Using hammer drills, we carried out the work from on a construction car for high-place work. Based on the drilling results, we determined the drilling points for steel molds and started drilling. While we found some peeling around the hole, we solved that problem by enlarging the width of the steel molds.
3.6 Cutting of Joints and Setting of Steel Molds

We cut the joints and set the steel molds immediately after completion of the above-mentioned processing of the molds. Considering the required time for each of four joints and the maintenance work time, we allocated a day per joint and carried out the work four days in a row. The cutting was carried out from a construction car for high-place work using the wall sawing method where a rotating diamond blade that runs on the rails fixed at the cutting point with anchors makes straight cutting.

LCX communication cables are laid on the top on the track side of the sound insulating walls to be cut. So, in order to prevent damaging the LCX cables, we cut the joints using a wall saw upon setting steel plate protectors (Photo 6).

Photo 7 shows the joint after cutting.

After setting steel molds at the cutting place during the work night, we completed the work (Photo 8). We fixed the molds with through bolts (M10) with a double nut per bolt on the outer side of the sound insulating walls. Each of two nuts of the double nut tightens the mold in a different direction to each other to prevent them from falling off easily.

3.7 Filling Non-Shrinkage Mortar to the Joint

We filled non-shrinkage mortar to four joints during a night’s work.

Before filling, we applied epoxy caulking material on the outer periphery of steel plates to prevent leakage of the mortar from the gap between the steel plate and the sound insulating wall. Then, immediately after the specified mixing using a hand mixer, we filled the mortar. In the area where the height of any falling of mortar exceeded 1.5 m, we prevented separation of material using a flexible pipe. At the end of the filling work, we applied membrane curing agent after trowel finishing of the upper part (Photos 9 and 10).

After completion of filling, we confirmed that no abnormalities were found on the sound insulating walls after each of five Shinkansen trains ran on the underpass and completed the work (Photo 11).
After the trial construction in the method for vibration reduction (first phase), we measured the deflection of the center of the girder when a Shinkansen train passes. Using a CCD camera, measurement was done on the girder at the left end (on the side of the sound insulating wall) among four girders.

Table 2 shows the comparison of the results of maximum deflection that were measured when the trains of the same train set ran at similar speed (assuming only a small variation of axle load). Fig. 11 shows plotting of all measurement data.

As shown in those figures, the results proved that the construction could reduce the deflection of girders to approx. 50% compared to the deflection before the trial.

**Table 2 Change in Maximum Deflection of Girder by Running of Current Trains**

<table>
<thead>
<tr>
<th></th>
<th>Before filling (measured on Feb. 5, 2007)</th>
<th>After filling (measured on Sep. 13, 2007)</th>
<th>Change (after(before filling)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hayate + Komachi</td>
<td>6.0 mm (274 km/h, Hayate No. 17)</td>
<td>3.21 mm (265 km/h, Hayate No. 15)</td>
<td>-2.79 mm (0.54)</td>
</tr>
<tr>
<td>Max Yamabiko train</td>
<td>5.72 mm (204 km/h, Max Yamabiko No. 113)</td>
<td>2.92 mm (236 km/h, Max Yamabiko 113)</td>
<td>-2.80 mm (0.51)</td>
</tr>
</tbody>
</table>

*Measured at the center of the girder*

**Reference:**
3) Railway Technical Research Institute; Design Standards for Railway Structures and Commentary (Concrete Structures), April 2004