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Development of Temporary Girders Using Steel Retaining Wall Braces

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JR East generally uses sleeper hug type temporary girders in the temporary girder method of construction widely used for building under-track spaces. Production of those temporary girders requires a large amount of processing such as cutting and drilling of holes in steel material. This work greatly affects the total construction project in terms of the time and cost of production.

We therefore developed temporary girders with leased material that is generally used for retaining wall braces being a component material of the beams. Thanks to easy procurement and simple processing, the structure of these temporary girders allows for shorter time and lower costs in production. Performance checking by the finite element method (FEM) analysis and tests confirmed that the developed temporary girders sufficiently met the required performance for temporary girders having a span of around 10 m.

●Keywords: Railway temporary girder, General purpose H beam, Steel Retaining wall brace

1 Introduction

The temporary girder method of construction where track is temporarily supported on temporary girders while conducting open-cut excavating has been widely adopted for building structures under tracks. JR East generally uses sleeper hug type temporary girders as the temporary girders (Fig. 1).

Production of those temporary girders involves cutting and drilling of bolt holes in the steel material. Thus, a long production period including raw material procurement and high production expenses greatly affects the total construction project, becoming an issue in terms of efficiently carrying out the project.

We thus developed temporary girders that can be built with just simple fabrication of leased material (Fig. 2) as a component material. That leased material is commonly used as retaining wall braces.

Fig. 1 Sleeper Hug Type Temporary Girder

Fig. 2 Leased Steel Retaining Wall Braces

2 Overview of Conventional and Newly Developed Temporary Girders

Fig. 3 shows brief diagrams of the cross sections of a sleeper hug type temporary girder ("conventional type") and Fig.4 shows the newly developed temporary girder using steel retaining wall braces ("new structure"). With the new structure, the sleeper bearing beam is directly supported by the lower flange of the main girder, while the conventional type has a structure where the sleeper bearing beam is supported by the bracket attached to the web of the main girder.
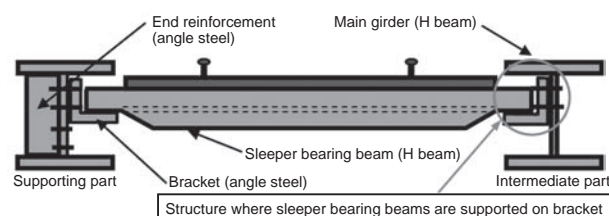

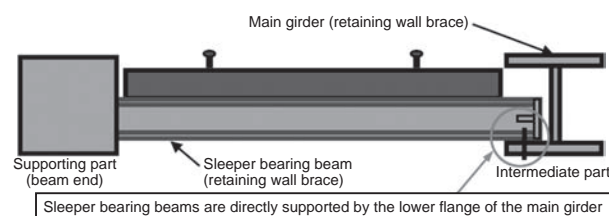Fig. 3 Sleeper Hug Type Temporary Girder (cross section)

Fig. 4 Temporary Girder Using Steel Retaining wall brace (cross section)

Fig. 5 shows the structure of the girder joint and the support of the conventional type, and Fig. 6 shows those of the new structure. The girder joint of the conventional type is a general two-face friction joint where the girders are bolted between two splice plates. On the other hand, the joint of the new structure is a one-face friction joint where a splice plate is attached only to one face of the upper and lower flange because an end plate is welded to the end of the steel retaining wall brace.

The new structure has another difference from the conventional type in that tensile strength acts on the bolt when

a load is applied. The reason is that the joint of the part that acts as the web uses no splice plates. Instead, end plates are bolted to each other. Hence, in designing the new structure, we conducted design calculation so that the new structure could have the required performance only with the friction joints of the upper and lower flanges without considering the tension bolt joints of the end plates.

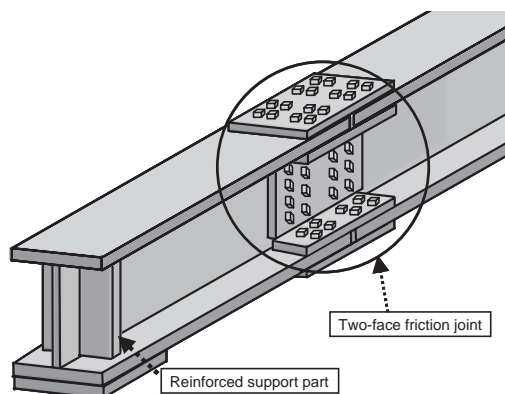The following sections will describe the performance check results.

Fig. 5 Sleeper Hug Type Temporary Girder
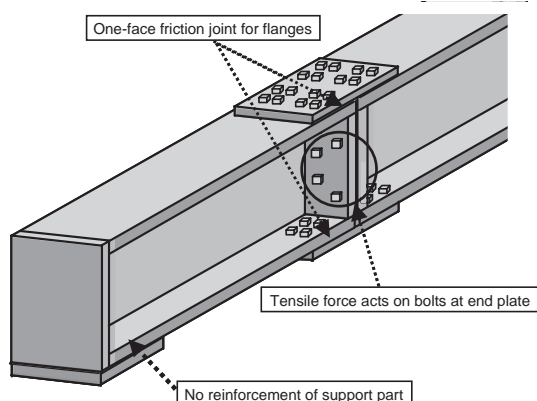(joint and support parts)

Fig. 6 Temporary Girder Using Retaining Wall Brace
(joint and support parts)

3 Static Loading Test of Main Girder

For tests focusing on the joint of main girders, one of the characteristics of the new structure, we made the specimen shown in Fig. 7 and carried out static loading tests using it.

The specimen was a girder of L = 6.0 m consisting of two H500 girders (L = 3.0 m) bolted at two end plates facing the splicing of the upper and lower flanges. Abrasive blasting was applied to the joint to secure a slip coefficient of around 0.4. Using M22 (F10T) bolts, standard tightening axial force 225 kN was applied[1]. The strain of the bolts in relation to the applied axial force was approx. 2,900 μ.

A load was applied on two points at 1,900 mm from each supporting point, and that load was maintained until yield of the specimen and slip of the joint occurred (Fig. 8).

Fig. 9 shows the measurement results of the deflection at the center of the main girder. The dotted line is the load that causes

bending moment equivalent to the design moment (design load: $325 \times 2 = 650$ kN). The deflection at the design load was 6.8 mm, almost equal to the calculated value of 6.93 mm. By continuing to apply a load, the border between the splice plate and the main girder yielded at around 1,460 kN and slip of the splice joint occurred at greater than 1,800 kN.

Fig. 10 shows the change in strain of the bolts of the upper and lower splice plates at loading. The values in the figure are the averages of the strain measured with two gauges attached to the shanks of the bolts. While the change in strain of the bolts on the upper flange was small, the strain of the bolts on the lower flange increased in the bolt axial force direction (compression direction) as the load increased. Still, we found no problems since the change in relation to strain by axial force applied at the design load was around 3%. Fig. 11 shows the change in strain of the bolts that joint the end plates facing each other. While loading caused compression for the bolt at the upper center (Fig. 11 (2)) and tension for the bolt at the lower center
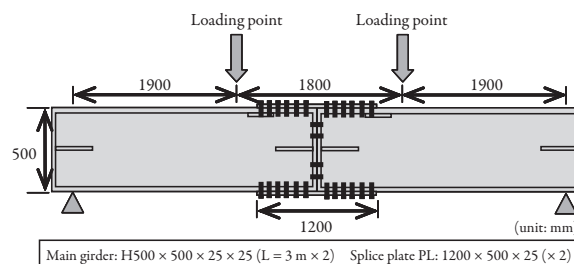

Fig. 7 Main Girder Static Loading Test (side view)

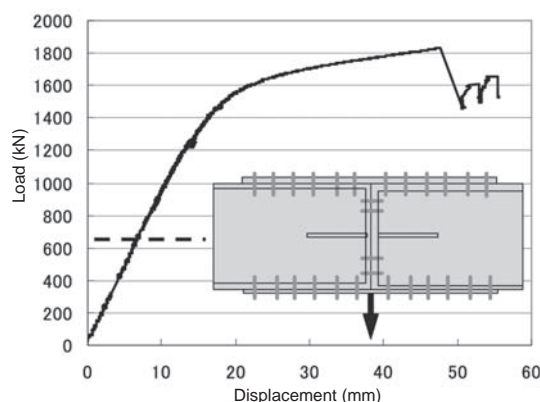
Fig. 8 Main Girder Static Loading Test

Fig. 9 Deflection at Center of Main Girder

(Fig. 11 (3)), almost no strain occurred with the bolts of the upper and lower flanges (Fig. 11 (1) and (4)) because the splice plates restrained the flanges.

Fig. 12 shows the change in strain at three points near the splice plate of the lower flange at loading. The place where the maximum strain occurred in the test was the border between the splice plate and the main girder (Fig. 12 (1)). The strain was, however, 560 μ (112 N/mm^2) at application of design load. That strain is approx. half the 1,175 μ yield strain of 400 N/mm^2 tensile strength steel material used for steel retaining wall braces.

Measuring the gap of the joint at the bottom of the end plates using a PI displacement transducer (Fig. 13), we found no gap at the splice point at application of a load less than the design load. We also found no remarkable strain when measuring strain around the bolt hole.
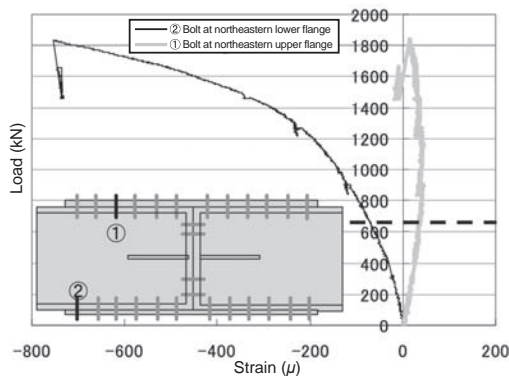

Fig. 10 Comparison of Joint Bolt Strain for Upper and Lower Splice Plates
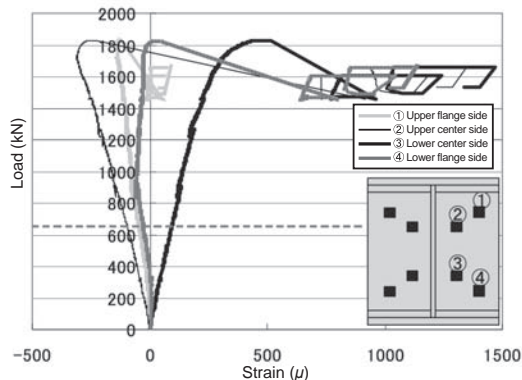

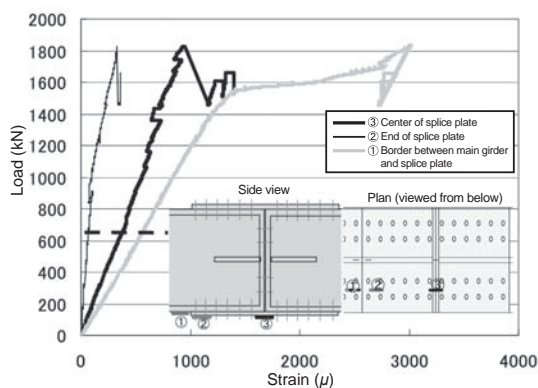Fig. 11 Comparison of Strain for Endplate Bolts

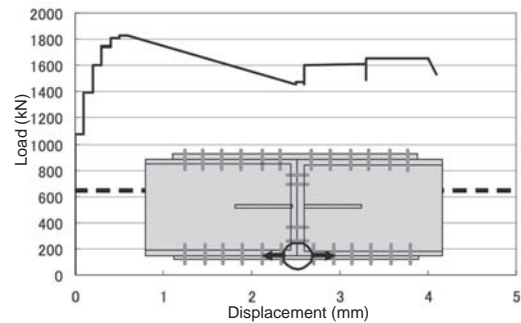Fig. 12 Comparison of Strain Near Lower Flange Splice Plate

Fig. 13 Measurement Results for Gap at Bottom of Joint

4 Sleeper Bearing Beam Static Loading Tests

One of the characteristics of the new structure is jointing of the main girder and sleeper bearing beam where the sleeper bearing beam is directly supported by the lower flange of the main girder. In order to check the performance of that joint, we carried out static loading tests for this model.

The specimen is, as shown in Fig. 14 and 15, two H500 (L = 3,000 mm) main girders that have an H200 (L = 2,500 mm) sleeper bearing beam between jointed with two M22 bolts on each side. Abrasive blasting is applied to the joint as the specimen for the main girder static loading tests.

Main girder: H500 × 500 × 25 × 25 (L = 3 m × 2) Bearing beam: H200 × 200 × 8 × 12 (L = 2.5 m × 1)
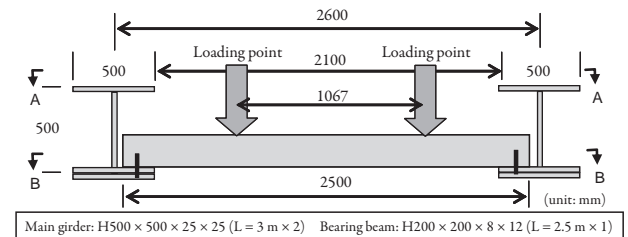
Fig. 14 Specimen for Bearing Beam Static Loading Tests (cross section)
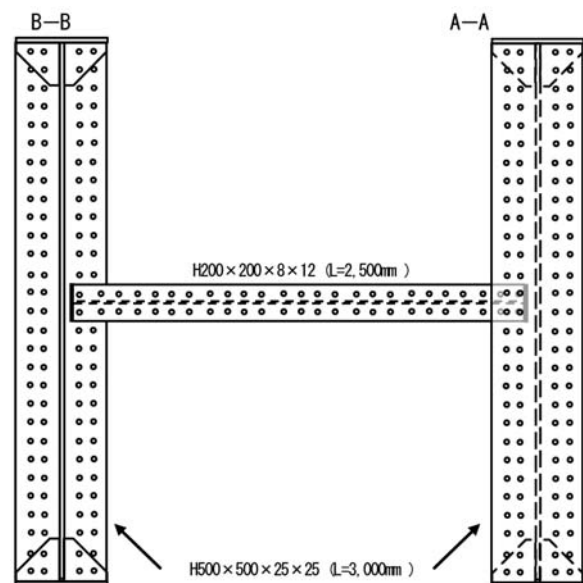

Fig. 15 Specimen for Bearing Beam Joint Static Loading Tests (plan)

Loads were applied at points equivalent to the points where narrow gauge rails are laid, and we checked the behavior of strain and displacement of the main girder and the sleeper bearing beam (Fig. 16). Fig. 17 shows the change in the strain of the lower flange of the main girder at the joint when loads were applied, and it also shows the measurement points. The dotted line in the figure is the design load of the sleeper bearing beam (99 kN). While we found some concentration of stress such as compression just under the web and tension near the joint bolt, the values were small and did not cause structural problems at other measurement points either. FEM analysis also delivered results that indicated a similar tendency (Fig. 18).
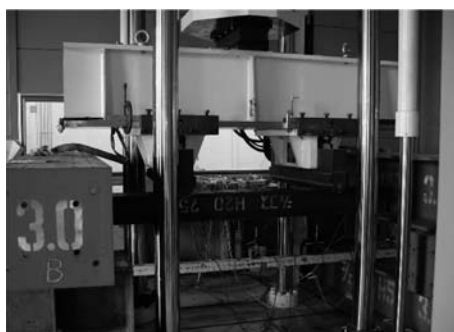
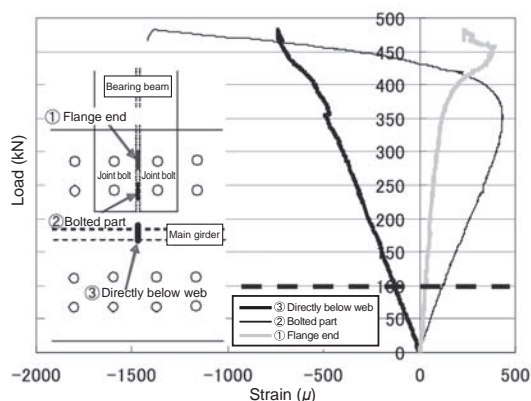

Fig. 16 Bearing Beam Static Loading Test

Fig. 17 Comparison of Joints of Main Girder and Bearing Beam
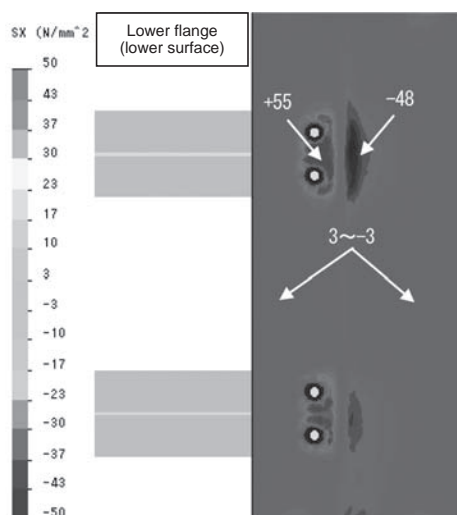(direction perpendicular to main girder)

Fig. 18 FEM Analysis Results of Bearing Beam Joint
(direction perpendicular to main girder)

5 Repeated Loading Test

To confirm the effects of dynamic load by a running train, we repeatedly carried out loading tests. The specimen was of the same specifications as that of the main girder static loading tests, and the number of times tests were repeated was calculated based on Design Standards for Railway Structures[1]. As a temporary girder is not a permanent structure, design lifetime was set at 10 years, locomotive load at E-17, and standard passing tonnage at 200,000 MN/year or more. Focusing on the welding of the end plate and the flange of the general purpose H beam, we set the fatigue level at Level E, which is the level for the non-load transfer type and non-finished fillet welded cross joint.

Based on the moment waveform caused by passing of an E-17 load at the center of the span of a 10 m girder (Fig. 19), the longest applicable girder length for the new structure, we analyzed the frequency by the range-pair method, calculated the number of repeats and fatigue lifetime per stress amplitude, and finally obtained accumulated fatigue damage level. According to this fatigue damage level and the fatigue lifetime for the tested load, the calculated number of repeats was 625,000.
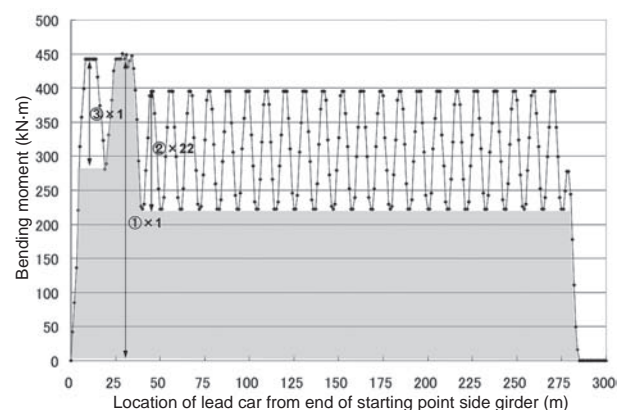
Fig. 19 Moment Waveform of 10 m Span Girder

By coupling two actuators with a loading beam and synchronizing them, we caused loads of 30 kN to 330 kN (amplitude 300 kN) per actuator. Based on the preliminary loading, we decided to make the loading cycle 3 Hz. We measured the initial and final values and suspended loading at 50,000 times, 100,000 times, 300,000 times and 500,000 times to apply static loading of 30 kN to 330 kN (Fig. 20).

Fig. 20 Repeated Loading Test

As the number of repeats increased, we observed slight value change in the bolt strain at the splice part. That would be the effect of the progress of fitting of components. At other measurement points, the same behavior was demonstrated throughout the test and no damage of components was found. We could therefore confirm that the new structure has no problems in terms of fatigue resistance.

6 Full-scale Loading Tests

To check load transfer in actual structures, we produced a full-scale specimen. It consisted of two main girders of L = 10,000 mm composed of two H500 (L = 5,000 mm) girders spliced to each other and 18 sleeper bearing beams (H200, L = 2,500 mm). Wooden sleepers were bolted on the sleeper bearing beams and 50N rails were laid on the sleepers with spikes (Fig. 21 and 22).

We applied loads of 200 kN to each on four points on the rails for a total of 800 kN. That was a load where the bending moment at the center of the span was equal to that of the E-17 load + the impact load (130 km/h) (Fig. 23).

As a result of the loading, we found no unstable behavior at any measurement points. The load was transferred well via the rails and sleepers to the sleeper bearing beams and the main girders without local concentration of stress, and the supporting parts and splice joints maintained a sound condition. The tendencies of deflection and strain of the main girders and sleeper bearing beams was close to the values in the FEM analysis results.

Fig. 24 shows a comparison between actual measurement values and the FEM analysis values (1/4 model) of the deflection of the main girder. The arrow in the figure is the loading point. The deflection of main girder A on the eastern side exceeded the analysis value by a few millimeters, while that of main girder B on the western side was largely equal to the analysis value. Those values are less than 80% of the design deflection of main girders, and the value of 1/555 was less than 1/400, the deflection limit of a single girder specified in the Design Standards for Railway Structures and Commentary (Displacement Limits)[2]. We could therefore determine that the new structure temporary girder sufficiently meets the required performance.

Fig. 25 shows a comparison between actual measurement values and the analysis values of the deflection of the sleeper bearing beam. The measurement point was the center of each sleeper bearing beam and the amount of deflection includes the deflection of the main girder. Both on the northern and southern measurement points, we obtained amounts of deflection similar to the analysis values.
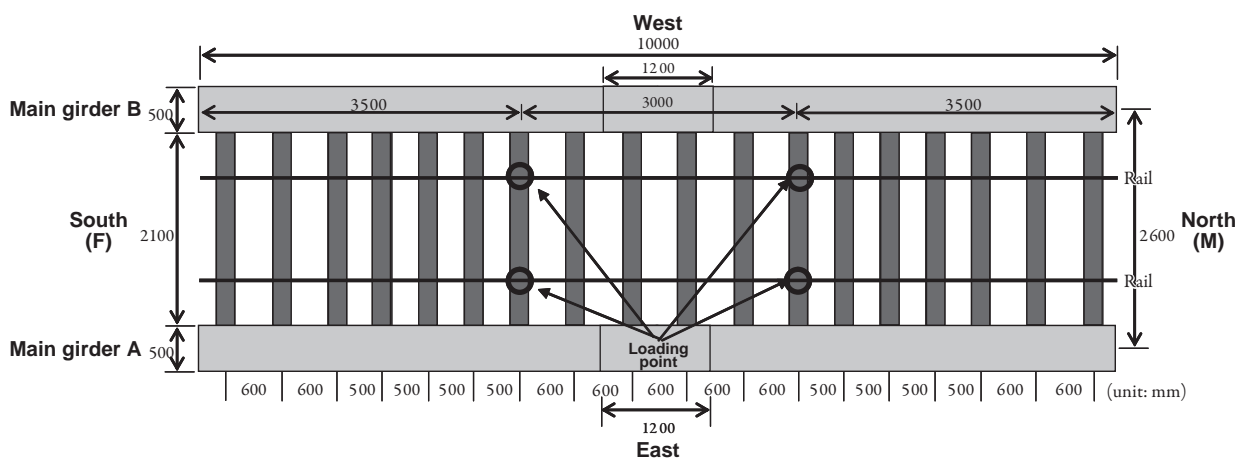

Fig. 21 Specimen for Full-scale Loading Tests (plan)

Main girder: H500 × 500 × 25 × 25 (leased)
Supporting bearing beam: H200 × 200 × 8 × 12 (leased)
Splice plate PL: 1200 × 500 × 25 (leased)
Bolts: M22 (F10T)
Sleeper: Wood (L=2100, b=200, h=140)
Fastening device: Spike
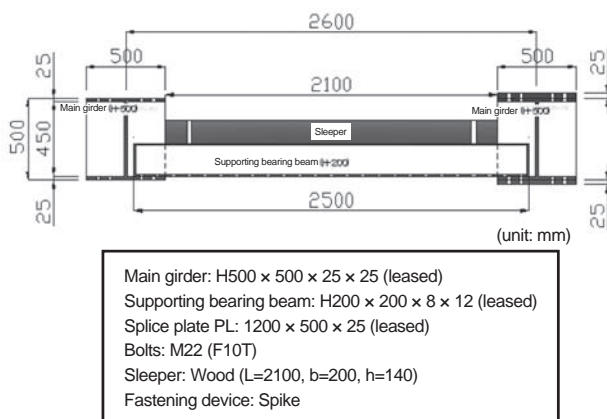
Fig. 22 Specimen for Full-scale Loading Test (cross section)

Fig. 23 Full-scale Loading Test

Span center | Supporting part

Deflection 16.78mm

Analysis model
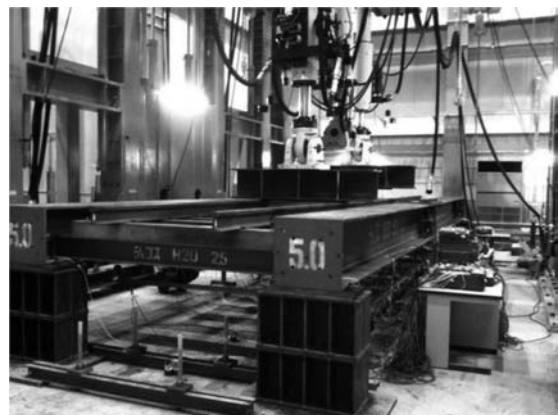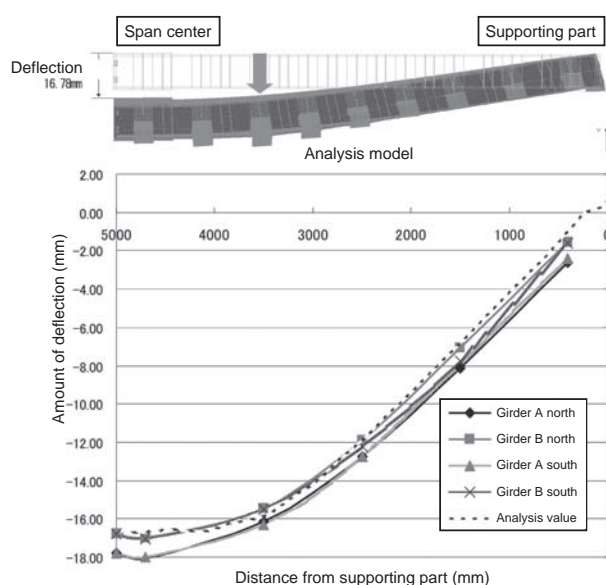
Fig. 24 Full-scale Loading Test: Comparison of Deflection of Main Girders

Span center | Original | Supporting part
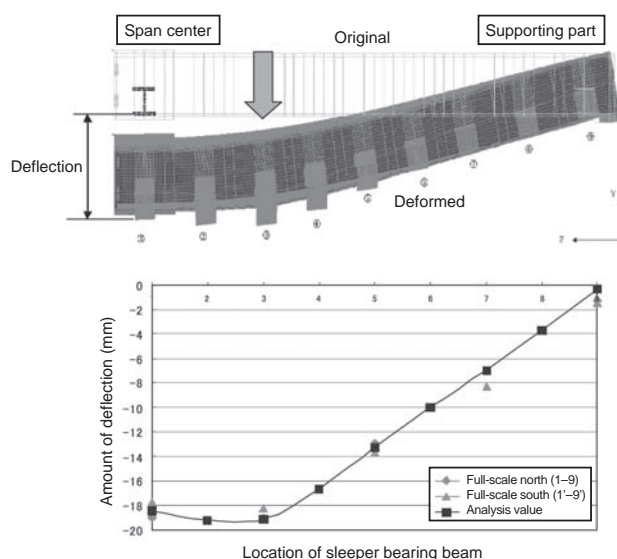
Deflection

Deformed

Fig. 25 Full-scale Loading Test: Comparison of Deflection of Sleeper Bearing Beams

7 Anticipated Application to Actual Structures

The maximum span obtained from the design deflection of the new structure is approx. 10 m (at a maximum train speed of 130 km/h, as specified in the Design Standards for Railway Structures and Commentary (Displacement Limits)[2]). In the tests including full-scale tests at the maximum span, we were able to confirm that the new structure is applicable to actual structures of spans up to 10 m.

In applying the new structure, no special reinforcement is required and the main structures including main girders and it is possible for sleeper bearing beams to be comprised of just general purpose steel. Special processing and fabrication required is processing of the friction surfaces of joints for only the main structure. Other required processing is production of plates for supporting parts and drilling of bolt holes in sleepers to secure

them to the sleeper bearing beams. We used standard sleepers in the tests, but we plan to specify as standard in actual application bridge sleepers that have higher sleeper height than that of standard sleepers. That way, we can secure margin in terms of clearance gauge and compatibility with curves.

Based on those results, we calculated the material costs of the upper structure (main girders, sleeper bearing beams, bolts and sleepers) of an L = 10 m construction girder of the conventional type and of the new structure. The calculation results showed that construction girders of the new structure could be produced at lower cost for a usage period shorter than four and a half years. Construction work that needs temporary girders of 10 m (the applicable span of the new structure) or shorter span is small- or medium-scale work with relatively short construction periods. Thus, by applying the new structure to such work, construction costs are expected to be reduced.

8 Conclusion

As shown, we confirmed that temporary girders using steel retaining wall braces sufficiently meet the required performance as approx. 10 m span temporary girders. The new structure consists of easily available material and requires only slight processing and easy assembling. It thus has an advantage of shorter production time including material procurement than that of the conventional type. For shorter usage periods in particular, it can be produced at a lower cost. We are now working on verification and standardization of details for application to actual structures.

Reference:

1) Railway Technology Research Institute, "*Design Standards for Railway Structures and Commentary (Steel and Composite Structures)*" (March 2010)

2) Railway Technology Research Institute, "*Design Standards for Railway Structures and Commentary (Displacement limits)*" (June 2007)

3) Ryo Shirakami, Ken-ichi Yaginuma, "Han'yo H-gata Ko o Shiyo Shita Tetsudoyo Kojiketa no Kozo Tokusei ni kansuru Kaisekiteki Kento [in Japanese]," Summary of lectures at the 65th annual meeting of the Japan Society of Civil Engineers (September 2010)

4) Hiroyuki Kon, Ken-ichi Yaginuma, Takashi Goto, Shinji Kudo, "Han'yo H-gata Ko o Shiyo Shita Tetsudoyo Kojiketa no Kozo Tokusei ni kansuru Jikkenteki Kento [in Japanese]," Summary of lectures at the 66th annual meeting of the Japan Society of Civil Engineers (September 2011)