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# AN EXAMINATION OF HYBRID STRUCTURES RENOVATED FROM OLD RAILWAY STEEL BRIDGES

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This research offers a new composite-revamping method for railway bridges. It assumes that the composite remodeling process of existing steel bridges has no specific fissure damages or serious corrosion, and effectively makes use of relatively new materials. The effects of noise reduction and improved stiffness were further confirmed through hammer-impact tests (vibration and noise measurement tests) in order to prove the efficacy of the composite remodeling.

*Keywords*: Steel bridge, Rubber latex mortar, Impact test.

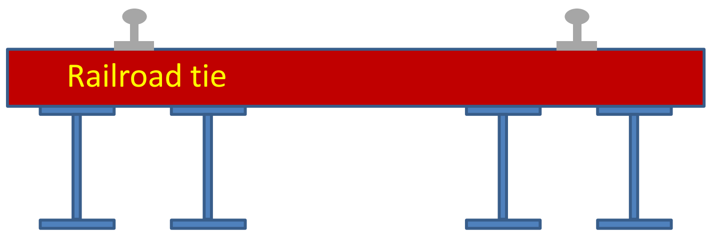
## 1 INTRODUCTION

To extend the structural life and take appropriate noise-dampening measures, this research considers changing steel bridges into composite structures. The change to the bridge composite structure is the installation of concrete materials. As a result, the corrosion of the steel material is controlled. In addition, the stresses at the time of the live load are reduced on the bridge by improving rigidity. As a result, the fatigue life of the bridge is increased. With a steel and concrete material composite, it is unified at the same time. Also, noise is dampened by the steel material.

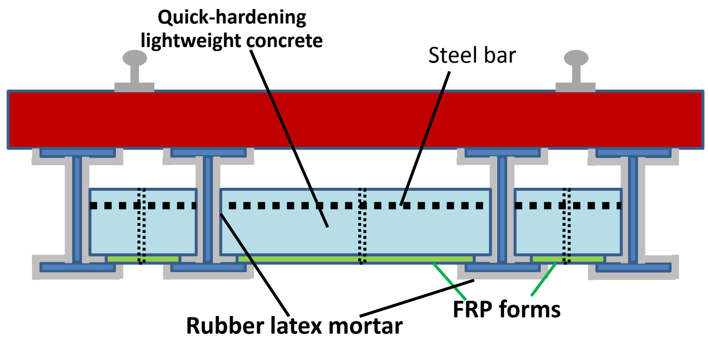
On the other hand, the composite materials increase the deadweight on the bridge, which tends to reduce its resistance for live loads. However, many things assume considerably large design loads in many steel railway bridges, and the deadweight increase is still within safety tolerance levels for many steel railway bridges. Therefore, the change to composite structure is a very effective method of construction that can reduce the stress amplitude for the live load of a bridge with sufficient load resistance.

## 2 SUMMARY OF THE COMPOSITE STRUCTURING

Figure 1 shows the summary of the composite structuring of steel railway bridges to be proposed. We proposed this from the viewpoint of construction characteristics, preventing corrosion, and minimizing related effects on existing steel bridges.




(a) Before the shift to a composite structure




(b) After the shift to a composite structure

Figure 1. The summary of the composite structuring of steel bridges to railways.

Against such a background, rubber latex mortar (Hamanaka 2010, Taniguchi 2009) and a number of other materials have frequently been used on a trial basis for bridges as noise prevention measures. Rubber latex mortar – a mixture of mortar and rubber latex (SBR, Figure 2) – features strong adhesion with steel, eliminating flaking or cracking even when cast relatively thinly. It is also being trialed for its high levels of fatigue durability, weather ability, impact resilience and water resistance to reinforce steel floor slabs. Engineers are also currently discussing its application to the improvement of shear rigidity between steel and concrete.

It typically provides adhesive shear strength of about 5.0 $N/mm^2$ at a material age of seven days. In previous applications, as fatigue-prevention measures against steel floor slabs of a road bridge, a structure was proposed with this material cast on the steel floor slabs. In this composite structuring, because of the superior adhesive performance, the authors considered it possible not only to prevent the corrosion of steel members but also to accelerate their unification with concrete slabs. Furthermore, it was also confirmed that even rubber latex mortar cast to a thickness of just 5 mm reduces steel-bridge-borne noise. It should be noted that the Young's modulus of rubber latex mortar is generally about $2.00 \times 10^4$ $N/mm^2$.


Figure 2. Rubber latex (SBR).

The application of Fiber Reinforced Plastics (FRP) has often been examined for its features of lightness and high strength. Therefore, in this structure, the minimization of increases in deadweight by the composite structuring is required, and thus, the authors decided to use Glass fiber reinforced plastics (GFRP) in buried form, because the requirements for forms (including the elastic modulus) are met and GFRP is economically efficient.

Quick-hardening lightweight concrete is a new material focusing on providing the required level of strength in a comparatively short period of time under assumption of the composite structuring railway bridges. Furthermore, in order to reduce the deadweight, the authors adopted concrete made using lightweight aggregates with the unit mass of about 2.03 kg/L and the Young's modulus of about 2.30 x $10^4$ N/mm$^2$. It should be noted that grid pattern reinforcing bars are arranged in order to prevent cracking of the quick-hardening lightweight concrete.

## 3 CONSTRUCTION PROCEDURE CONFIRMATION TESTS

The authors conducted construction procedure confirmation tests with the actual test beams, shown in Figure 2 and Figure 3(a), by implementing the following steps: (1) scraping (removal of coated film with a disk sander); (2) coating with rubber latex mortar; (3) installing FRP forms and grid-pattern reinforcing bars; and (4) casting of quick-hardening lightweight concrete. In these construction tests, the time required to execute the work was measured to enable discussion of whether the method is suitable for night time work on railways. Steps (2), (3) and (4) are shown below along with the results of discussion.

### 3.1 Construction Work of Coating with Rubber Latex Mortar (Figure 3)

The construction work of coating with rubber latex mortar is the same as that implemented in the author's previous work with the construction of a low-noise steel bridge. The coating thickness was aimed at 5 mm. Without moving the beam from its simple support state, spraying of the coating was carried out through the use of one sprayer. Mortar was sprayed to the target thickness of 5 mm with a sprayer in several steps, as spraying all at once would cause the mortar to run. After the mortar was sprayed, the coating thickness was measured with calipers at 21 points on the beams in order to control the thickness, and it was confirmed that all measurements were within the range of 5 to 7 mm.

The spraying operation took 240 minutes, and thus would not have been possible to complete within the time frame assumed for night work on railways when the curing time is also taken into account. However, it is estimated that the work can be completed within the allotted time if two or more sprayers are deployed, although one sprayer was used this time, and/or the work was executed step by step after being separated into several parts. The rubber latex mortar used for spraying had a compressive strength of 24.9 N/mm$^2$ (aged one day) and 33.1 N/mm$^2$ (aged seven days), and a bond strength of 3.0 N/mm$^2$ (aged one day) and 4.6 N/mm$^2$ (aged seven days).

Figure 3. The spraying operation.

Figure 4. FRP forms.

### 3.2 Installation of FRP Forms and Grid-Pattern Reinforcing Bars

Figure 4 outlines the configuration of an FRP form, which is shaped like a ribbed panel. In this experiment, it was divided into seven pieces at the crossbeam positions, and a filler adhesive (methacrylate-based resin with a hardening time of 90 minutes) was used at the contact faces between the beam and FRP forms before fixing with clamps. In actual construction work, there may be sleepers and tracks on the top of the beam. Therefore, for this case the authors brought in FRP forms and grid-pattern reinforcing bars only from the bottom, in order to confirm the feasibility of the work with sleepers and tracks in position. Furthermore, the work took about 60 minutes (5 to 20 minutes per panel) to complete; therefore, depending on the track conditions, the work can easily be executed even in train intervals during the daytime, not at night. The GFRP material used in this study had a tensile elastic modulus of 18.4 N/mm$^2$, a tensile strength of 334 N/mm$^2$ (JIS K 7164), a bending elastic modulus of 14.9 N/mm$^2$, a flexural strength of 366 N/mm$^2$ (JIS K 7017) and a value of theoretical deflection at casting of about 2.5 mm.

### 3.3 Casting of Quick-Hardening Lightweight Concrete (Figure 5)

The casting work was completed within about an hour, with the concrete reaching a compressive strength of 17.7 N/mm$^2$ at the age of four hours. Since the rate at which strength develops can be adjusted, the casting test indicated the feasibility of the technique's application to night work on railways. Meanwhile, it is known that this type of concrete exhibits expansion behavior by about 250µ at a material age of 28 days after contracting.

Figure 5. Casting concrete.

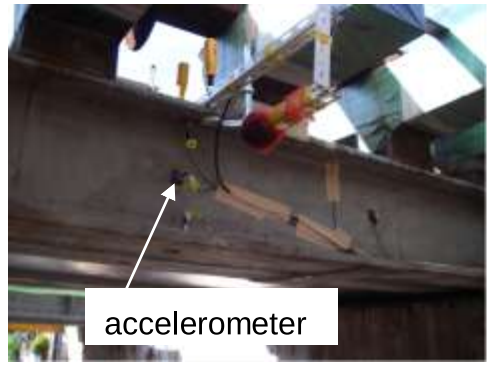



Figure 6. Impact test.

## 4 TESTS TO CONFIRM THE EFFECT OF COMPOSITE STRUCTURING

In order to comprehend the effects of the composite structuring in terms of reducing structure-borne noise, the authors performed an impact test with trains passing over. Measurement of the vibration and noise acceleration were then performed using accelerometers placed at the span center web of each test beam (Figure 7).

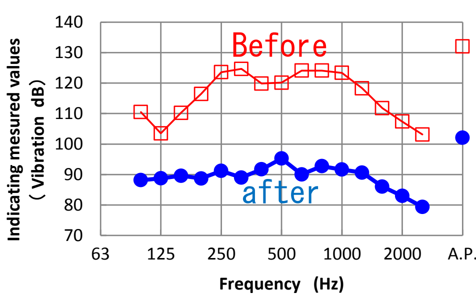



Figure 7. Results of impact tests (Vibration).

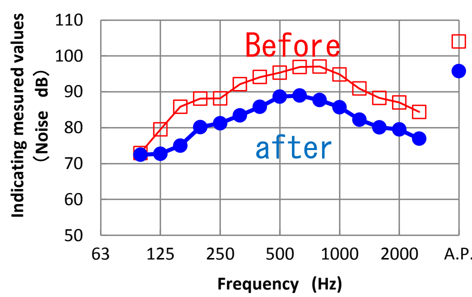



Figure 8. Results of impact tests (Noise).

Among the measurement results, Figures 7 and 8 show the measurement results and summarizes their averages, with the Y-axis indicating measured values calculated with $10^{-5}$ $ms^{-2}/N$ set as 0 dB, and the X-axis representing the frequency in each 1/3 octave band.

From Figure 7, it can be confirmed that the composite structuring work tended to reduce the vibration level by around 10 to 35 dB and the AP value by about 30 dB. In a similar test conducted by the authors in the past using a specimen coated with rubber latex mortar alone, the noise level was reduced by about 10 dB. Therefore, it can be considered that the composite structuring further reduces structure-borne noise more than rubber latex mortar coating alone.

## 5 CONCLUSIONS

From the above discussions, the following conclusions can be drawn:

(1) As this composite structuring work can be executed step by step by separating the relevant structure into several parts, it can be completed in around three to four days by combining daytime and night time work on railway bridges.

(2) The impact tests results indicate that the present composite structuring work reduces the noise level on the main beam web plate by about 15dB. The technique's effectiveness as a preventive measure against structure-borne noise was thus able to be verified.

(3) Composite structuring work improves rigidity in the direction perpendicular to the bridge axis (i.e., the direction of the cross beam), thereby suppressing torsional movement outward of the beam plane.

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