A Technology to Restore Deteriorated Steel Bridges
-Development of Bridges Integrated with Nail-Reinforced Soils-

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Since Japan started railway operations about 170 years ago, a number of steel bridges have been constructed for railways across the country, with the majority now reaching 50 years or more in service. It is likely, therefore, that the number of steel bridges requiring repair, reinforcement or replacement will continue to increase in the future.

To replace a deteriorated bridge with a new one requires time-consuming construction work at an enormous cost, as it necessitates construction of temporary tracks, erection beams and abutments.

In the case of conventional steel-beam- and abutment-type bridges, as the construction of backfills follows that of abutments, the backfills tend to cause sinking and lateral displacements of abutments. After completed bridges are put into use, various problems are tend to occur including:

(1) Malfunctions caused with corrosion of supporting parts and steel beam flanges under bridge sleepers, settlement of backfills, and
(2) Damage given by earthquakes, for example, abutments inclined, backfills settlements and breakage of shoes.

River bridges are also with following disadvantages:

(1) The horizontal resistance at the front of the abutment decreases due to river bed scour, and
(2) Abutments incline or slide to cause large relative displacements against steel beams, which potentially lead to steel beam failures (fall accidents) (Fig. 1, Table 1).

The outline of the concept

To extend the life and strengthen the earthquake resistance of deteriorated steal-beam- and abutment-type bridges without replacing steel beams, RTRI proposes a method to integrate the following structures:

(1) Abutments and backfills with reinforced concrete (RC) walls that are rigid with nail-reinforced soils (NRSs), and
(2) Connecting steel beams and abutments with reinforced concrete.

These measures improve the functions of steel beams, abutments and backfills in normal service periods. The bridges having such a structure are called "the bridges integrated with NRSs (NRS-integral bridges)" (Fig. 1).

This eliminates the necessity of the maintenance of supporting parts and fixes steel beams at both ends, which hitherto have been a simple support structure. The process reduces the moment generated under live loads, significantly increases the load-carrying capacity and eventually extends the life of deteriorated steel beams.

In addition, passive resistance can be expected from the abutment backfill on the opposite side with the rigid-frame structure. Elimination of the structurally weak supporting parts also considerably improves the earthquake resisting performance of bridges. Steel beam fall accidents due to the damage of supports can be prevented. Elimination of structural joints significantly enhances the safety of train operation during and after earthquakes.

It is also recognized rigid-frame support-less structures cause abutment backfills to sink owing to the elongation/contraction of steel beams resulted from temperature changes and abutments to crack due to the increases in the backfill earth pressure as a result of bridge behavior accumulated for long years. In the case of NRS-integral bridges, however:

(1) Suppresses the horizontal displacement of the abutment crown due to temperature changes,
(2) Decreases the settlement of backfills and the earth pressure by improving the self-supporting performance for abutment backfills. (Table 1).

Proof of the concept

RTRI constructed a 13 m-span actual size test bridge, and integrated steel beams/abutments and abutment/backfills with NRSs to simulate the actual integration work that would be performed in practice. A test of this bridge span was conducted to confirm the viability of the concept (Fig. 2). RTRI measured the long-term behavior of the test bridge by conducting repeated horizontal loading tests to simulate thermal elongation/contraction of steel beams and similar tests with alternating loads to confirm the earthquake resisting performance. Table 1 summarizes the results of the tests that confirm the practicality of the NRS-integral bridge. RTRI will apply this technology to the renewal of steel bridges having comparatively short spans less than 20 m.

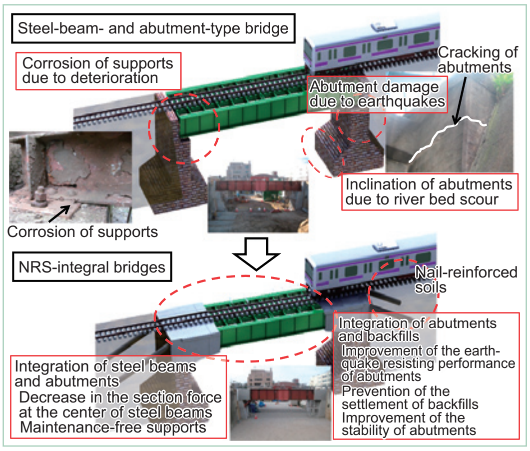
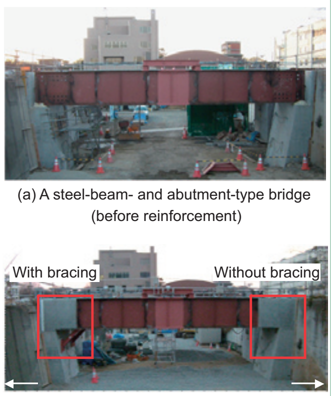


Fig. 1 An outline of NRS-integral bridges



(a) A steel-beam- and abutment-type bridge (before reinforcement)

(b) A NRS-integral bridge (after reinforcement)

Fig. 2 Appearance of the actual size test bridge

Table 1 Subjects for the steel-beam- and abutment-type bridges and features of the bridge integrated with nail-reinforced soils

	Object point	Subjects for the steel-beam- and abutment-type bridges	Features of the bridge integrated with nail-reinforced soils
Under construction / reinforcement		- As backfills and beams are constructed/laid after abutments have been constructed, abutments are subject to settlement or lateral displacements.	- Bridge integration work can easily be performed without manufacture of a new bridge or construction of temporary tracks, beams, abutments or track rerouting, unlike the method to replace beams and abutments after constructing temporary tracks. - Bridge integration work can easily be performed to improve abutment functions without constructing temporary pedestals when compared with the method to laterally replace steel beams.
In the normal state	Steel beam - abutment	- Upkeep and control are required for supports. - Corrosion due to rain water starts from the supports.	- Elimination of the upkeep and control of supports - Decreases in the section force of steel beams generated under train loads extend the fatigue life of the bridge.
	Backfill - abutment	- Backfills sink; abutments incline or supports may lose their functions. - Relative displacements may occur between backfills and abutment crowns to compromise train operation, which requires upkeep and control of backfills.	- Nail reinforced-soils strengthen the self-supporting of backfills and suppress their settlement. - Relative displacements between backfills and abutments are prevented to save the man power in the upkeep and control of backfills.
In abnormal states (earthquakes, abnormal floods)	Steel beam - abutment	- Supports and abutments may be damaged at earthquakes. - Large relative displacements between backfills and abutments potentially cause bridges to fall.	- The rigid-frame structure of steel beams and abutments improves the earthquake resisting performance of the whole bridge. - Prevention of bridge fall accidents at earthquakes
	Backfill - abutment	- Abutments may incline or backfills sink at earthquakes. - Large relative displacements between backfills and abutments potentially compromise the safety of train operation during and after earthquakes.	- Nail reinforced-soils improve the earthquake resisting performance of abutments and backfills. - Relative displacements scarcely occur at earthquakes to ensure the safety of train operation.
	Foundation	- River bed degradation or abutment scour may occur with river bridges to potentially cause abutments to incline.	- River bed degradation and scour do not directly cause decreases in the supporting force, inclination of abutments or bridge fall accidents.