In the 1995 Great Hanshin Awaji Earthquake, which struck an urban area, various railway concrete structures in Japan sustained extensive damage never experienced before. In light of that damage, seismic retrofitting of existing structures was started in earnest. However, as space under railway viaducts in urban areas is used for railway equipment, commercial facilities, and other buildings, construction of seismic retrofitting has to be done in a constrained environment. This paper describes the present state of three seismic retrofitting methods that are actually applied to seismic retrofitting construction in the space under railway viaducts.

Keywords: Seismic reinforcement, RC viaduct, Seismic reinforcement by wrapping steel plates, Rib bar (RB) seismic reinforcement, Seismic reinforcement by wrapping multiple thin plates

1 Introduction

JR East has been reinforcing structures such as reinforced concrete (RC) rigid frame viaducts based on the analysis results of damage to railway structures in the 1995 Great Hanshin Awaji Earthquake and subsequent earthquakes. For rigid frame viaducts, by reinforcing of RC columns (shear reinforcement) to prevent shear fracture, a type of brittle fracture, and enhancing deformation performance of those columns, we make RC column toughness reinforcement whereby toughness performance absorbs seismic force.

This paper covers our recent efforts on and seismic reinforcement effects of the method of seismic reinforcements by wrapping steel sheets, by use of rib bar (RB), and by wrapping multiple thin sheets as methods of reinforcing RC rigid frame viaducts.

2 Recent Efforts in Seismic Reinforcement Methods

2.1 Method of Seismic Reinforcement by Wrapping Steel Plates

This is a method where steel plates are placed around existing RC columns and the like and filler is filled in the space between the steel plates and the column, etc. to prevent shear fracture of the column, etc. In this method, deformation performance of the column, etc. is also improved by binding the concrete with steel plates. We applied this seismic reinforcement method to many sites at JR East.

2.1.1 Change to Painted Area and Specifications of Steel Plate

Since we found some cases where the steel plates corroded near the ground surface in sites where we applied the method of seismic reinforcement by wrapping steel plates, we changed the paint specifications to apply paint to the underground area of the steel plates to the depth of 200 mm beneath the ground surface. Furthermore, in order to reduce spatial obstruction by painting work of viaducts in use, we changed the paint type to a polyurethane paint for medium- and longtime durability almost equal to that required for ordinary bridges.
2.1.2 Method of Seismic Reinforcement by Wrapping Steel Sheets in Stages

The method of seismic reinforcement by wrapping steel sheets has advantages in workability and cost, so it has been applied at many sites. However, this method cannot be applied at sites where there are obstacles or shops near the viaduct columns, because the whole perimeter of the column needs to be wrapped in this method. Specifically, if a column stands on the border between adjacent shops, reinforcement work cannot be done unless both shops are vacant. The method of seismic reinforcement by wrapping steel sheets in stages is a method whereby a half of the perimeter of the column on the side of a shop that becomes vacant first is wrapped with steel sheets first, and then the remaining half of the perimeter is wrapped when the other shop becomes vacant.

In this method, the shop on the side where reinforcement is done first can reopen without waiting for reinforcement to be done on the other side. Adopting this method therefore allows effective use of under-viaduct space. It should be noted that reinforcement effects are only achieved when all faces are wrapped with steel sheets.

2.2 RB Seismic Reinforcement Method

The RB seismic reinforcement method is a method whereby steel reinforcements are placed around an existing RC column and the like and fixed at all four corners to enhance shear resistance and toughness of that column. This method has advantages in that seismic reinforcement can be applied easily by manual work even in a construction environment such as that with an RC column with a partition and narrow spaces that cannot be handled by conventional reinforcement methods.

Table 1 and Fig. 6 show a comparison between the conventional corner support Type B and the corner support Type BS (slim RB) recently developed.

(1) Type BS can be applied to existing beveled columns with a corner angle of 90° ±1°.
(2) By using D19 (SD490) steel reinforcement, cross-sectional area after reinforcement can be made smaller (distance from the column surface approx. 39 mm). This method can be applied to cases with a small amount of reinforcement.
(3) Using D19 as steel reinforcement can reduce weight per horizontal reinforcement (approx. 40% reduction for a column of 1 m width), improving workability in reinforcement construction.
Method of Seismic Reinforcement by Wrapping Multiple Thin Plates

The method of seismic reinforcement by wrapping multiple thin plates is a method whereby thin steel plates are affixed with adhesive and wrapped a specified number of times to an existing RC column of a viaduct to add shear reinforcement and toughness. Due to the light weight of the reinforcement material, reinforcement work can be done manually in narrow spaces.

In this method, the increase to the column cross section after reinforcement is small (usually by 10 to 20 mm from the column surface), so reduction of floor area of shops in particular after reinforcement can be minimized. Furthermore, this method does not need filler mortar and heavy machinery, so dust generation and water leakage when using mortar and noise when using heavy machine can be prevented. Due to these advantages, there have been examples of shops continuing operation near the worksite.

Recently, we have made the following improvements to this method.

(1) Expansion of application
Application of this method was limited to indoor RC columns and the like, taking into account corrosion of steel plates. By adding highly corrosion-resistant plated steel plate to the specified material, we made this method applicable to outdoor RC columns and the like within the range of corrosion resistance performance only when using high corrosion-resistant plated steel plates. However, in severe conditions such as possible salt damage, the corrosion resistance cannot be maintained, so we need to take into account the surrounding environment when applying this method.

(2) Addition of materials used for thin plate
Conventionally, the standard material for this method was cold-rolled high-strength steel plate SPFC440 (thickness of 0.8 mm), but we added more readily available rolled steel plate SS400 for ordinary structures (thickness of 1.6 mm) and high corrosion-resistant plated steel plate (thickness of 1.6 mm) to the standard.

(3) Addition of materials used for adhesive
When applying this method to an environment where the worksite is next to a shop or the like under a viaduct, we have to minimize the odor of adhesive as much as possible. We thus added a less odorous type adhesive than the adhesive used before.

(4) Addition of method used for overlapping of thin plates
In order to improve workability and reduce the amount of adhesive used, we added a new overlapping method (Type B) to the conventional method (Type A).
Adhesive performance of the resin adhesive used to attach thin plates in this method lowers even after hardening if the temperature at the adhered part increases. We therefore need to apply this method carefully to places such as those that receive direct sunlight or that are located near equipment that emits hot exhaust.

This method involves higher costs than the method by wrapping steel plates, however we can reduce costs with this method in terms of use of under-viaduct space and workability. We need to decide on the reinforcement method while considering total construction costs including removing obstacles.

Effects of RC Viaduct Seismic Reinforcement

Many RC columns to which the method of seismic reinforcement by wrapping steel sheets or the RB seismic reinforcement method introduced in this article were applied experienced the 2004 Niigata Prefecture Chuetsu Earthquake and the 2011 Earthquake off the Pacific Coast of Tohoku, and we carried out damage surveys on those.

After the Niigata earthquake, we investigated the RC columns of RC rigid frame viaducts near the epicenter to which the method of seismic reinforcement by wrapping steel plates was applied as those seemed to have received large horizontal seismic force. The results revealed no deformation of steel panels. We removed steel plates of some columns and found that filler mortar inside the steel plates and the existing RC columns was sound.

After the Tohoku earthquake, in visual inspection, we found some peeling off and small cracks of cover concrete at the upper joint of the reinforcement by wrapping steel plates, but there were no damage that would affect train operation. In investigating soundness of filler mortar by hammering tests, we found slight lift, but confirmed that the mortar was still sound.

In visual inspection of RB reinforcement, we found slight cracks, but no loosened or fallen nuts.

Those damage surveys proved the effect of seismic reinforcement after the 1995 Great Hanshin Awaji Earthquake, so we continue seismic reinforcement by these methods.

Conclusion

This paper introduced three seismic reinforcement methods for RC columns of RC viaducts. Those have been employed from the past, but we have made further improvements not only in terms of workability and cost, but also in terms of securing under-viaduct space during and after reinforcement work.

Reference: