Traffic Regulation Technology by Movable Barriers

Toshiharu Tanikawa[a] and Tohya Okishio[b]

[a] Deputy Director General, Kanto Regional Head Office, East Nippon Expressway Company Limited, Japan
[b] Nexco-East Innovation &Communications Company Limited, Japan
E-mail: t.tanikawa.aa@e-nexco.co.jp, t.okishio.aa@e-nexco.co.jp

Abstract –

Approximately a half century has passed since the construction of expressways in Japan, and expressways have become decrepit over the decades. In order to ensure safety and security of expressways for the next generation, expressway companies have been carrying out large-scale renewal works of bridges and tunnels (hereinafter collectively the "renewal works" and individually a "renewal work").

Because renewal works are carried out while vehicles pass by the side of work zones, various types of safety equipment have been used to regulate traffic lanes such as rubber road cones, more rigid temporary barriers and so forth. However, speeds of passing vehicles are fast and, if a vehicle accidentally enters a work zone, rubber road cones cannot prevent from a vehicle entry which endangers workers' lives.

Therefore, East Nippon Expressway Company Limited (hereinafter "NEXCO EAST") group adopted traffic regulation technology by movable barriers, the Road Zipper System (hereinafter "the RZS"), for renewal works. Using the RZS is aimed at improving workers' safety by prevention of accidental vehicle entries and alleviating traffic congestion by more efficient traffic regulation.

This paper examines effects of the RZS introduction, enhancement of safety and prevention of traffic congestion associated with the use of the RZS in traffic regulations and lane reconfigurations according to the time of day, as well as future developments.

Keywords –

expressway; traffic regulation technology; traffic regulation for construction works; lane regulation; lane management; movable barriers; Road Zipper System; safety and security; traffic congestion alleviation; traffic congestion prevention

1 Introduction

The RZS is the lane management system by a Barrier Transfer Machine (hereinafter "BTM") transferring crash-tested barriers from one side to another (Figure 1).

The RZS is a system from a company in the USA, Lindsay Transportation Solutions LLC (hereinafter "LTS"). Nexco-East Innovation & Communications, one of NEXCO EAST group subsidiaries, is appointed to sell and lease BTMs and related products to expressway companies in Japan, based on a formal agreement with LTS.

Figure 1. BTM working situation abroad

An overview of the RZS is transfer of barriers from one side to another through an S-shaped conveyor mounted at the sides and bottom of a BTM (Figure 2 and 3).

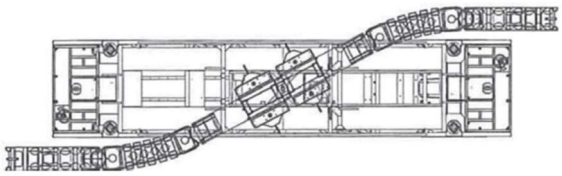

Figure 2. BTM Conceptual Diagram [1]

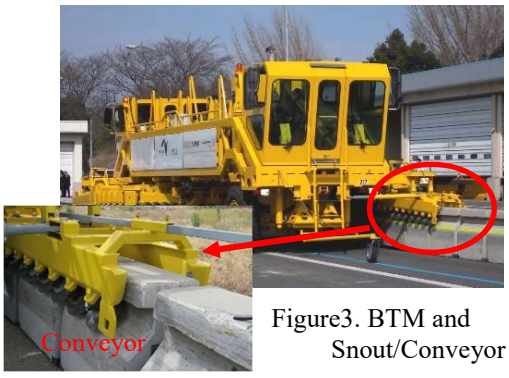

Figure3. BTM and Snout/Conveyor

There are three types of barriers used in the RZS. The main barrier is Concrete Reactive Tension System (hereinafter "CRTS") which is composed of reinforced concrete. (Figure 4).

Other than CRTS, there is a steel barrier called a Variable Length Barrier (hereinafter "VLB") which extends and contracts to adjust a shape and vertical grade of road and is set at regular intervals in alignment of CRTSs (Figure 5). The final component is a crash cushion installed at ends of the CRTS barrier alignment so as to absorb impact of a vehicle crash (hereinafter "Absorb") (Figure 6). There does exist different options within the RZS, but the systems deployed in Japan currently are referenced above and illustrated below.

Figure 4. CRTS

Figure 5. VLB

Figure 6. Absorb

2 Examination for RTS introduction

NEXCO EAST conducted a demonstration experiment on Joban Expressway from April through July in 2016 so as to confirm and examine effectiveness of the RZS for its future introduction in Japan (Figure 7).

Figure 7. Demonstration Experiment
(Left: rubber road cones Right: the RZS)

From the experiment, two results turned out superiority of the RZS in comparison to conventional equipment, rubber road cones.

The outcomes were found from image analyses; lanes were regulated by rubber road cones and the RZS respectively on the expressway, and three fixed cameras on over bridges and tracking cameras set up on a car for cone installation and a BTM captured vehicles' behavior while the vehicles were passing by the regulated lanes.

One result is the ratio of drivers' avoidance behavior to keep a distance from regulation equipment during installment and removal at night by the RZS was approximately 15% lower than by rubber road cones.

Another is the ratio of drivers stepping on the brakes while lanes were regulated at night by the RZS also turned out to be lower than the one of rubber road cones (Figure 9).

Those two results show the RZS ensures a higher level of safety and security towards vehicles and drivers.

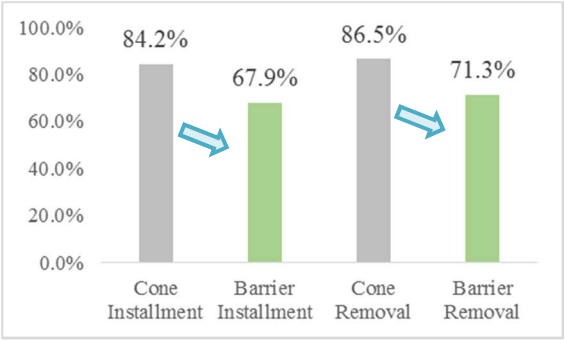

Figure8. Comparison of drivers' avoidance behaviour between uses of rubber road cones and the RZS barriers during instalment and removal [2]

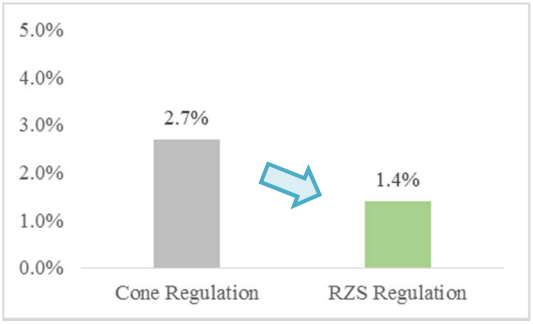

Figure 9. Comparison of drivers' actions of stepping on the breaks between uses of rubber road cones and the RZS barriers [2]

Consequently, NEXCO EAST fully introduced and utilized the RZS for traffic regulations for construction works in some projects such as construction of Tokyo-Gaikan Expressway and additional lane construction of Kan-etsu Expressway in Kanto Regional Head Office. In addition, the RZS has been used in several renewal works for regulating and opening lanes quickly and efficiently, and assuring safety and security.

The next chapter shows concrete examples of full introduction and utilization of the RZS with backgrounds, processes and evaluations.

3 Full introduction and utilization of the RZS

3.1 A renewal work of Shimamatsugawa Bridge of Hokkaido Expressway

Sapporo Operation Office, Hokkaido Regional Head Office of NEXCO EAST utilized the RZS for lane managements and regulations in order to alleviate traffic congestion in a renewal works, the project of floor slab replacement, at Shimamatsugawa Bridge.

About 47 years had passed since the Bridge opened and the Bridge severely deteriorated due to anti-freezing agents and some other influences.

3.1.1 Outline of the project site

The Shimamatsugawa Bridge is located between Eniwa Interchange (Interchange is used as an entrance and exit of an expressway. hereinafter "IC") and Kitahiroshima IC of Hokkaido Expressway (Figure 10).

The section between the two ICs is an important route and part of expressways in Hokkaido because it connects New Chitose Airport, the gateway of Hokkaido, and Sapporo, a major city.

A daily traffic volume of both up and down lanes between the two ICs is approximately 40,000.

Figure10. Location of Shimamatsugawa Bridge [3]

3.1.2 Traffic Regulation Examination

Since the section of the project site is considered to be important, it is difficult to close both up and down lanes for a long term. Therefore, the method regulating a down lane and dividing into two-way traffic was adopted while the floor slab replacement of up lanes were carried out.

Regarding to traffic characteristics in the section on Monday through Saturday, traffic volume rises in the morning on the up lane from Sapporo to New Chitose Airport, and the peak time is mostly at around 7 am.

This is associated with passengers using New Chitose Airport and commercial vehicles which are mainly from Sapporo. On the other hand, traffic volume increases in the afternoon on the down lane from New Chitose Airport to Sapporo, frequently at around 6 pm.

As clearly shown, there is a significant difference of hourly traffic volume between up and down lanes; the volume of one lane at peak time on both lanes surpass a traffic capacity (1,400 unit per hour) therefore it was predicted traffic congestions would happen every single day (Figure11).

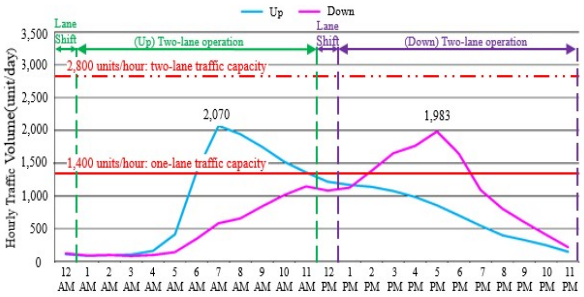

Figure11. Hourly traffic volumes of the up and down lanes between Eniwa IC and Kitahiroshima IC on weekdays [3]

On the purpose of traffic congestion prevention, three traffic lanes were ensured on the down lane by narrowing the width of road shoulder from 1.25m to 0.5m and traffic lanes from 3.50m to 3.25m.

A combination of two lanes and one lane for the up and down lanes were shifted by time of day from Monday through Saturday depending on the traffic characteristics (Figure 12).

Traffic volume of the up lane in Sunday afternoon does not go below the one-lane traffic capacity, hence two lanes were open operated as the up lanes so as to ensure access punctuality to New Chitose Airport.

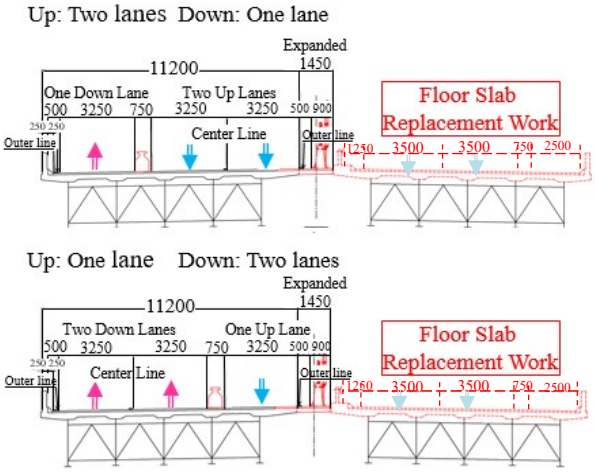

Figure12. Lane management cross-section view (unit: mm) [3]

With regard to daily lane shifting in two-way traffic, traffic administrator had an opinion towards a usage of conventional regulation equipment, rubber road cones, as temporary central median for two-way traffic regulation: there is a high risk of head-on vehicle collision in the heavy traffic section.

In addition, it is impossible to shift lanes by rubber road cones without expressway closure. In order to resolve and adjust the problem, the RZS was put on the table to ensure safety of vehicles and streamline lane regulation work since the RZS have proven records of lane managements and shifts in other countries.

The regulation plan of the renewal work was reviewed and changed to the one by the RZS: using temporary medians composed of barriers and transferring them by time of day for lane shifts. In the end, with the consent of traffic administrator, the RZS was adopted for the first time in Japan to regulate traffic by shifting lanes from one to two and vice versa on the expressway.

3.1.3 Traffic Regulation Operation by the RZS

Traffic regulations were implemented during the period from May 29th to July 12th, 2018, except for Sundays, by shifting the number of up and down lanes between 12 pm and 1 pm and 12 am and 1 am in a day by transferring temporary center median composed of barriers (Figure13 and 14).

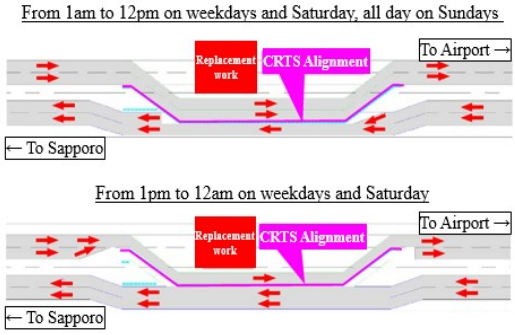

Figure13. Illustration of lane shiftting [3]

Figure14. Lane shifted by the RZS

3.1.4 Result of Traffic Regulation by the RZS

The results of traffic regulation by the RZS came out as follows.

- If conventional two-way traffic regulation was implemented, the estimated number of days and maximum length of traffic congestion during the project period would be 37 days and 18 km on the up lane and 27 days and 18 km on the down lane, while the actual occurrences of traffic congestion were 0 days and 0 km on the up lane and 6 days and 3.4 km on the down lane.
- On holidays, the estimation of number of days and the maximum length of traffic congestions were 5 days and 14 km on the up lane and 6 days and 8 km on the down lane. However, the actual number of days and maximum length were 0 day and 0km on the up lane and 6 days and 5.1km on the down lane.

The RZS contributed to safety of drivers by alleviation of traffic congestion compared to prediction both on weekdays and weekends, and reduction of major accidents by blocking breakthrough of temporary central medians.

3.2 A renewal work of Takase Bridge of Hokuriku Expressway

Nagaoka Operation Office, Niigata Regional Head Office of NEXCO EAST used the RZS for lane management and regulation in the project of floor slab replacement of Takase Bridge on the up line of Hokuriku Expressway in the direction to Nagaoka. About 40 years had passed since the Bridge opened and the Bridge had faced severe deterioration.

3.2.1 Outline of the project site

Takase Bridge is located right before diverging lanes of Nagaoka Junction between Nagaoka Junction and Nakanoshimamitsuke IC of Hokuriku Expressway (Figure15).

The Bridge includes a ramp (a speed change lane) of Hokuriku Expressway bound for Toyama therefore three-lane width was ensured at the site.

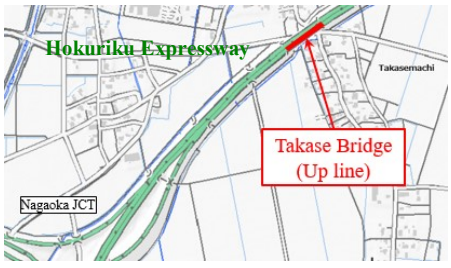

Figure15. Location of Takase Bridge [4]

3.2.2 Traffic Regulation Examination

The traffic volume in this section is relatively large and a cross section traffic volume of approximately 32,000 vehicles. In the case that floor slab replacement work is carried out on an up line, that up line is normally closed and two lanes on a down line are used as two-way traffic: one lane for the up and another for the down. However, it was highly predicted severe traffic congestions would happen on both of the one up and one down lane at this project site, which also requires large-scale traffic regulations.

Thus, in order to take an advantage of three-lane width of this Bridge, the floor slab replacement work was divided into three steps based on each of three traffic lanes (Figure16) and the width was reduced from 3.5m to 3.25m; two traffic lanes remained open while one lane was under the replacement work.

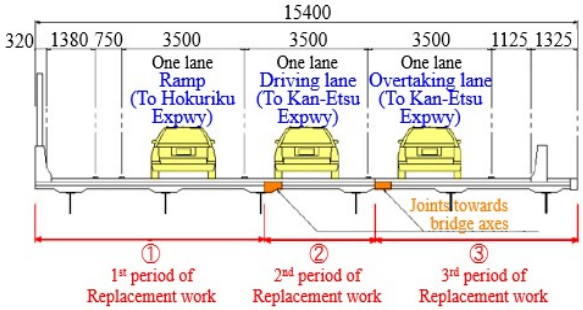

Figure16. Replacement work steps (unit: mm) [5]

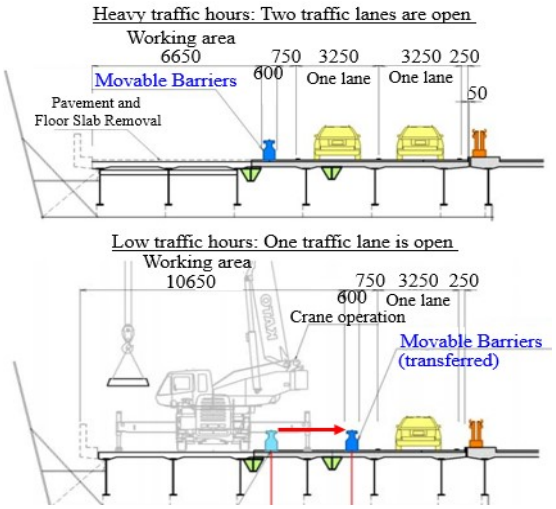

Figure17. Lane management based on hourly traffic volumes (unit: mm) [5]

By using this method, two lanes were always open while any lane was under the replacement work. Moreover, two lanes were closed for operation by a crane which requires larger working area, during time of low traffic volume, and lanes were shifted on a daily basis depending on the time of day (Figure17).

3.2.3 Traffic Regulation Operation by the RZS

For implementation of traffic regulations from the end of August to the mid of November, 2018, two driving lanes were secured from 7 am to 12 pm: the time period when hourly traffic volume is heavy on weekdays from Monday to Saturday. During the other time period from 12pm to 7 am, only one lane was open for traffic and the replacement work proceeded in the two closed lanes.

On holidays, two lanes were open from 7 am to 8 pm and one lane was designated as a traffic lane from 8 pm to 7 am the following day by RZS (Figure18 and 19).

Figure18. Traffic Management by the RZS

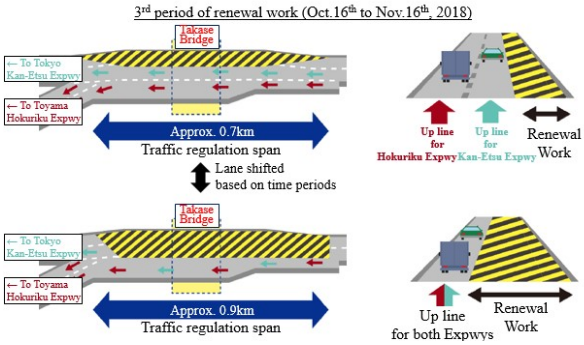

Figure19. Traffic regulation by the RZS in the 3rd period of renewal work [5]

This renewal work was completed within the scheduled period although it was difficult to manage a work process by the influence of rain on works accompanying the replacement work due to many rainy days.

During the project period, traffic congestions occurred twice and both were relatively small in scale: one is 3.0km at maximum for 30 minutes on Wednesday, September 26th and another is 1.7km at maximum for 2 hours on Saturday, October 6th.

From the perspective of congestion by traffic regulation for construction works, impacts on drivers was minimized and there were no breakthrough of temporary central medians and no major accident; hence, the RZS contributed to safety of drivers and workers..

3.3 The RZS implementation by another company, Central Nippon Expressway Company Limited

Although NEXCO EAST introduced the RZS for the first time in Japan, RZS is also used by Tokyo Regional Head Office of Central Nippon Expressway Company Limited (hereinafter "NEXCO CENTRAL") so as to regulate traffics in renewal work of Tomei Expressway.

They introduced the RZS in order to prevent serious accidents caused by breaking through temporary central medians, and to shorten a period of time for installment and removal of barriers used as the medians. Two examples of projects are listed below.

- Renewal work in 2017 (Numazu IC – Fuji IC, Tomei Expressway)
  Regulation: Two-way regulation by day and night
  Project: Floor slab replacement work of Akabuchigawa Bridge (down line)

- Renewal work in 2018 (Susono IC – Fuji IC, Tomei Expressway)
  Regulation: Two-way regulation by day and night
  Project: Floor slab replacement work of Kaminagakubo Bridge (up line) and Ashitaka Bridge (up line)

4 Future Developments

4.1.1 More uses and developments of the RZS

Currently, the RZS is being used in a number of renewal projects and construction works by NEXCO EAST and NEXCO CENTRAL.

In addition, Kansai Regional Head Office of West Nippon Expressway Company Limited is also planning traffic regulations for construction works and lane managements by the RZS for a renewal work of Chugoku Expressway. The uses of RZS on expressways has been promoted across Japan.

4.1.2 Modification of BTM for further safety and efficiency

Meanwhile RZS is widely used on expressways, there are also several challenges. One is a size of a BTM; RZS has been used a lot in other countries including America and expressways, highways and roads in those countries consists of more and wider traffic lanes compared to those in Japan.

Examples of BTM dimensions are in Table 1 and actual machines are shown in Figure19 and 20.

Table 1. RTS BTM dimensions

Element	BTM for traffic regulation for construction works [(Numbers) are without conveyors]
Width	4.32m (2.54m)
Length	14.8m (12.8m)
Weight	22t (20t)

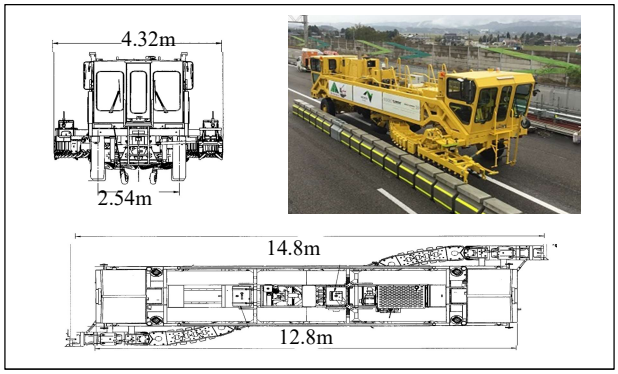

Figure 19. BTM for traffic regulation for construction works [1]

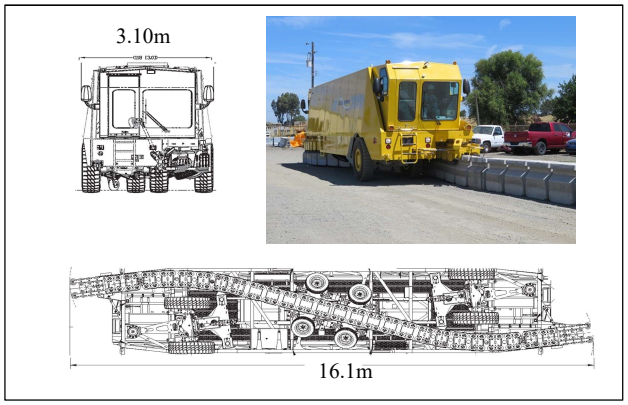

Figure 20. BTM for permanent lane management [1]

Other than a BTM for construction applications, there are other BTM models used for permanent lane management. Some have a width that fits within a traffic lane in Japan. However, the weight is heavier than 25t therefore investigation and confirmation about safety to pass through bridges and other road structures is necessary.

As a result, it does take time and effort to transport such a BTM.

In addition, the BTM exceeds general limits required by law for dimensions of vehicles in Japan therefore conveyors must be removed and transported by a special low-floor trailer, which also requires additional time, effort and expense.

Hence, in order to utilize RZS more safely and efficiently in Japan, after a request from NEXCO EAST, LTS agreed to and currently develop the new model "N-Class", a downsized BTM (named after NEXCO Group), for consideration of the machine size that the BTM fits and drives in the regulated area for construction (within the width of one driving lane) without removing conveyors and can be transported by a normal low-floor trailer rather than a special one.

5 Conclusions

The number of renewal works are expected to increase more and more in the future so as to ensure the safe use of expressways. However, there have been many accidents due to incursions of general vehicles into area regulated for construction works; hence, it is important to ensure safety of construction works in regulated area on heavy traffic lanes for a long span of time.

At the same time, it is necessary to carry out works in traffic regulation area more efficiently during limited time periods such as at night time with the low volume of traffic. It is believed that the RZS will contribute to improvement of safety and efficiency of traffic regulation for construction works

, and will be utilized by more companies and organizations as a measure to ensure safety and alleviate traffic congestion through development and improvement of the RZS.

References

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