MEASURES TO ENSURE TRAFFIC SAFETY FOR TWO-LANE MOTORWAYS (EXPRESSWAYS) WITH SMALLER TRAFFIC VOLUME (EFFORT IN JAPAN)

Koichi ABE, Yoshinori TANOWAKI, Kota TSUJI
NEXCO East (East Nippon Expressway Co. Ltd.), Japan
k.abe.ac@e-nexco.co.jp

ABSTRACT

Japan's expressway network is roughly 80% complete, and the remaining sections are not expected to see heavy traffic; thus for the foreseeable future, operational planning assumes two-lane, two-way traffic. Tragic head-on collisions have occurred on Japan's two-lane expressways as a result of vehicles straying into oncoming traffic.

With Japan's declining birthrate and a growing proportion of elderly people, no significant increase in traffic demand is expected for the majority of Japan's traffic routes and sections.

Thus, for those roads which expansion to four lanes was not anticipated in initial planning and those expressways which have been maintained as two-lane expressways since their establishment, the speed of certain services and the level of road safety can be effectively increased by installing a safety barrier between the opposing lanes of traffic in order to physically separate them. For some routes and sections, this road structure has been implemented and is in operation.

Thus, this report will look at a) the background study, b) the challenges involved in full-scale implementation and c) the measures taken to overcome those challenges for the implementation of this road structure.

1. CHALLENGES FOR EXPRESSWAYS IN JAPAN

1.1 Status of Development Planning and In-service Operation for Japanese Expressways (including provisional two-lane expressways)

Japan's expansive network of expressways and other high-speed roads (14,000km of arterial high-standard highways) is comprised primarily of a nationwide network of expressways (arterial high-standard highways) supplemented by local high-standard highways.

The following are the plan-specific lengths of Japan's expressways.

- National expressways (development plan length (A route)): 9,342km
  - Of this, toll sections (company maintained sections): 8,520km
    - Toll-free sections (new, directly controlled sections): 822km

・General national route motorways (B route): approx. 2,300km
・General national route motorways with alternate functions (A' route): approx. 2,178km

Expressway and local high-standard highway planning and design requires a road construction tailored to local conditions (road function, traffic volume, traffic volume growth, etc.).

While traffic volume may be low for the for the time being, where it is likely that there will be increased traffic volume in the future, phased construction of four-lane roads is an effective means of road development.

Thus in Japan, when there is little expectation of large traffic volume for the time being, a provisional two-lane road structure is adopted which sufficiently ensures safe, smooth travel for the present traffic volume but which can be efficiently expanded to four lanes in the future.

Of the 9,342km contained in the National expressways, there are 7,641km (81% of the planned length) in service as of April2010. Of this, 2,588km of provisional two-lane expressway was put into service, with 998km of that having been expanded to four lanes to accommodate increased traffic volume; thus, there is currently 1,590km of provisional two-lane expressway in service.

1.2 Road Structure of Provisional Two-Lane Expressways

On provisional two-lane expressways, rubber poles and other lane dividers as well as curbs are used to physically separate the opposing lanes of traffic. This opposing lane road structure is shown in the figure below.

Note that a median strip is not used between the opposing lanes of traffic as a means of separation. Also, while the standard shoulder width is 2.5m, in non-snowy areas (including mountainous areas) where the traffic volume is low, the shoulder is set at 1.75m and emergency parking bays are established every 300m.

The rubber poles used to divide opposing lanes of traffic are 65cm tall with a diameter of 8cm; they are made of a resin that includes rubber so that even if they are knocked over by an automobile, they are able to naturally return to their original shape. Because of this flexibility, a vehicle that runs into them will still be able to stray into the opposing lane of traffic and potentially cause a serious accident.

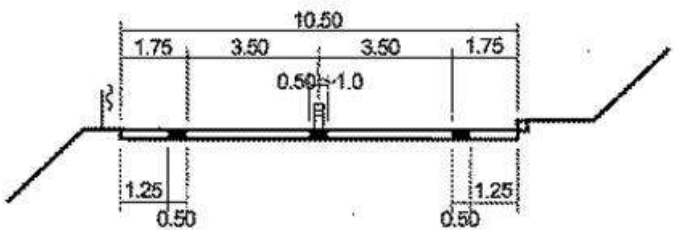


Fig.1 Standard traverse organization and road surface marking positions (for a road with a 1.75m shoulder width)

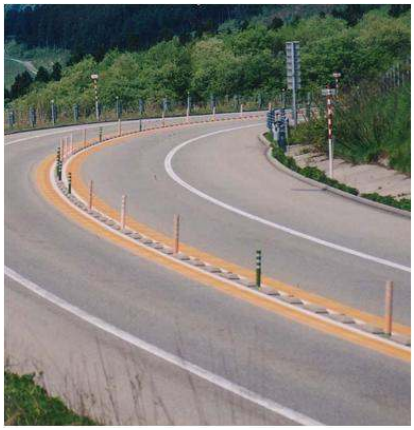


Photo1(left) Provisional two-lane expressway
Photo2(right) Road structure with rubber poles and curbs

1.3 Challenges for Provisional Two-Lane Expressways (accident rate and safety measures, traffic capacity, traffic management)

1.3.1 Accident Rate

○The fatality and injury accident rate for road sections with opposing lanes of traffic (6 fatalities / 100 million vehicle kilometers) is generally equal to the rate for all expressway sections (6 fatalities / 100 million vehicle kilometers).
○The fatality and injury accident rate for road sections with opposing lanes of traffic (6 fatalities / 100 million vehicle kilometers) is 1/18th (approx. 5%) the rate for ordinary roads (99 fatalities / 100 million vehicle kilometers).
○The average annual number of fatalities over the past eight years for road sections with opposing lanes of traffic is seven.
○Also, the fatal accident rate (0.6 fatalities / 100 million vehicle kilometers) is generally equal to the rate for ordinary roads (0.6 fatalities / 100 million vehicle kilometers). However, it is at least double the rate for all expressway sections (0.3 fatalities / 100 million vehicle kilometers).
○The average annual number of fatalities and injuries due to a vehicle straying into oncoming traffic over the past eight years is approximately 29. Of these, five are fatalities.
(Expressway accident statistics are drawn from data compiled by NEXCO East, while statistics for ordinary roads are drawn from National Police Agency data)

1.3.2 Accident Causes

○The main causes (infraction types) of accidents are inattention to the road (looking off to the side, napping, etc.) and carelessness (approx. 74% of all accidents); inappropriate steering or braking operation (approx. 14%); and speeding (approx. 6%). Thus, driver inattention and carelessness are primarily responsible for accidents.
○During winter months, particularly, December to February, the accident rate is elevated. Approximately 33% of all accidents in a year occur during this period.

1.3.3 Past and Current Safety Measures

Based on the accident analysis results discussed above, the following safety measures have been implemented primarily along provisional two-lane expressways located in sections with a traffic volume of 5,000 or more vehicles per day and sections with comparatively high accident rates (bridges, tunnel entrances, sudden declines, S-curves, sections with 1,000m or more of horizontal alignment, etc.) in order to make drivers aware of opposing traffic, to control speeding and to make drivers stay awake and alert.

		
Raised road surface markings	Traffic flow-conducting lane markers	Signage to grab drivers' attention
		
Thin-layer pavement	Grooved pavement	Rubber poles to increase visibility

Photo3 *Safety Measures*

1.3.4 Traffic Capacity

○Survey research of traffic capacity for provisional two-lane expressway sections was conducted by Kikawa et al. It was found that the average traffic capacity for the 16 sections studied was approximately 1,140 vehicles / hour (approximately 950 vehicles / hour after the occurrence of a traffic jam), which was approximately 30% lower per lane than a four-lane section [1].

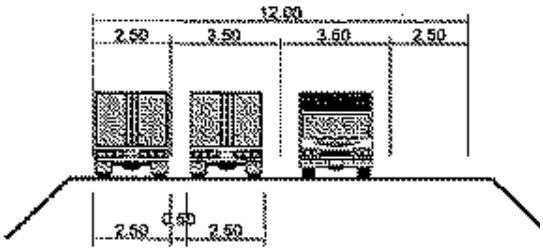
1.3.5 Traffic Management

○Shoulder Usage

On provisional two-lane expressway sections with a shoulder of 2.5m, this shoulder is used

during traffic jams to enable emergency vehicles to get through. Also, when large vehicles break down and need to stop, the shoulder allows enough space for other large vehicles to drop their speed and get past.

Shoulder regulations allow for grass cutting and minor road repairs; however, major road maintenance requires that the opposite lane be used for an alternating flow of opposing traffic or that the road be blocked altogether.



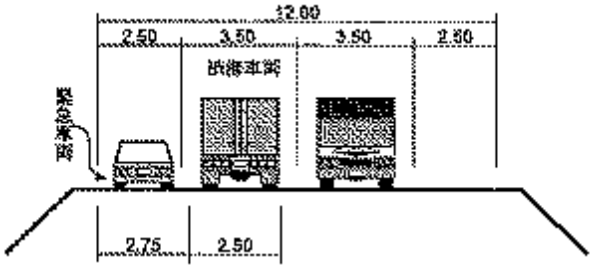


Fig.2(left) Large vehicles stopped
Fig.3(right) Emergency vehicles passing by during traffic congestion

○Opportunities to Overtake and an Added Overtaking Lane

On provisional two-lane expressway sections with rubber poles set in the median, traffic movement is restricted such that vehicles cannot overtake one another, and when there is a large traffic volume, vehicles can get bunched up. When this happens, it not only causes the speed of traffic to drop but also motivates drivers to dangerously attempt to overtake using the shoulder.

Thus, a lane that can be used for overtaking (an added overtaking lane) has been established so that drivers have appropriate opportunities to overtake.

These added overtaking lanes have been established at 6 - 10km intervals and have a standard length of 0.5 - 1.5km; their spacing intervals have been made as uniform as possible.

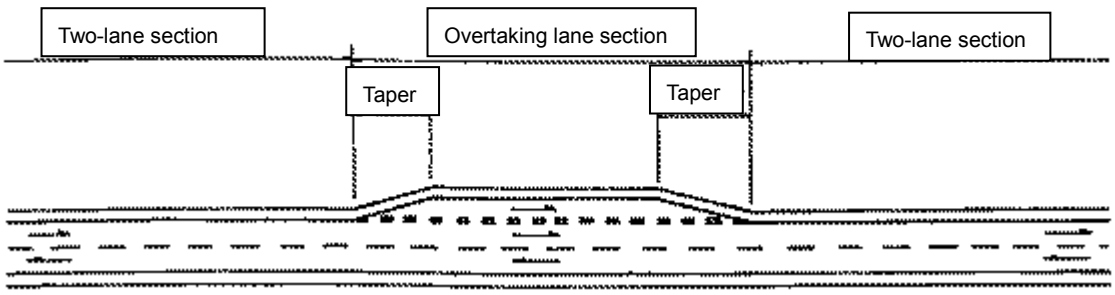


Fig.4 Added overtaking lane utilizing a 'give-way' lane system

2. IMPLEMENTION OF NEW TWO-LANE EXPRESSWAYS

2.1 Changes in the Traffic Environment

Japan's population has been declining since its peak in 2007, and by 2020 there are predicted to be 3.9% fewer people compared with 2007 (median projection by the National Institute of Population and Social Security Research). As the pace of decline in Japan's birthrate and growth in the proportion of elderly people increases, it is expected that there will be even more elderly drivers on the road.

According to future traffic volume estimates, no significant increase in traffic volume is anticipated; hence, there is little possibility that provisional two-lane expressways will be widened. Traffic volume is expected to either remain flat or decrease by 0.1% annually (according to estimates released by the Ministry of Land, Infrastructure, Transport and Tourism on Nov. 23, 2009).

2.2 Improving Safety on Provisional Two-Lane Expressways (separating opposing traffic lanes)

As discussed earlier, there have been a variety of safety measures implemented thus far for provisional two-lane expressways; however, in line with changes to the traffic environment, more drastic safety improvement measures are called for.

Thus for provisional two-lane expressways, one set of options needed for improving traffic safety is to install medians and safety barriers as traffic safety facilities on expressway sections with sharp turns and changes and sections with high numbers of accidents in order to avoid having long stretches of expressway with adjacent, opposing traffic.

Also, new roads on which a large traffic volume is not expected can be developed from the very beginning as two-lane expressways. In July 2003, the road structure standards (in the Road Structure Ordinance) were changed so that, except in unavoidable circumstances, new two-lane roads would, as a rule, have medians and safety barriers to keep the opposing lanes of traffic physically separated.

Thus, a portion of Japan's expressway sections have started adopting the new separated road structure.

During Japan's deliberation over whether or not to adopt this new road structure, Europe 's (particularly Germany and Sweden's) 2+1 lane structure was instructive.

2.3 Examples of 2+1 Roads in Europe

In Northern European countries on rural roads with comparatively little traffic, various traffic safety measures have been put in place. In particular, on their two-lane roads they have actively adopted a 2+1 road structure as a way of addressing the head-on collisions that

occur as a result of drivers trying to overtake.

The 2+1 road structure has three lanes, the central lane being used as an overtaking lane; one direction of traffic will have two lanes for a certain distance, and then the opposing direction will have two lanes for a certain distance. This 2+1 road structure has been developed to accommodate a level of traffic in between that of two or four lane roads; this structure has been adopted primarily in Northern Europe in place of traditional wide lane roads or two lane roads with frequent, comparatively wide shoulders.

The cross-section structure - including the central median - varies from country to country, however. In Germany there are no safety barriers in the median, only two solid white lines; in Sweden the opposing lanes of traffic are physically separated by a cable barrier.

Sweden's 2+1 roads use CEN (European Committee for Standardization) specified N2, H1 and H2 cable barrier types to physically separate lanes. Typically N2 is used, while H2 is used for bridges.

The cables use three or four metal braids and run through support poles typically spaced 2.0m - 3.0m apart.

Photo4 Sweden (Stockholm) 2+1 road

Photo5 Germany divided two-lane road

Photo6 Sweden (Luleå) 2+1 road

Photo7 Sweden (Luleå) 2+1 road

2.4 Implementation of New Two-Lane Expressways

2.4.1 *Application of Finished Two-Lane Expressways*

When planned traffic volume is at or below the traffic volume design standard (i.e., the maximum allowable automobile traffic volume) in the following table, the road is planned and developed as a two-lane road. (Road Structure Ordinance Article 5)

Table1 Application of Two-Lane Expressways in Response to Planned Traffic Volume

Classification (Design Speed and Terrain)		Traffic Volume Design Standard (Vehicles / Day)
Design Speed 100Km/h	Flat	14,000
Design Speed 80Km/h	Flat	14,000
	Mountain	10,000

2.4.2 *Structure of Finished Two-Lane Expressways*

As a rule, two-lane expressways have medians in order to prevent head-on collisions from occurring as a result of vehicles straying into the opposing lane of traffic.

However, in unavoidable circumstances, such as in tunnels, on long bridges, or along highly built-up sections with intermittent earthworks, where it is not possible to physically separate the opposing lanes, non-separating (simple separation) lane dividing structures, like rubber poles, are adopted.

Even still, because of the enclosed nature of tunnels and other such road sections, putting in place medians or other physical lane separators can inhibit rescue activities during disasters, such as by preventing ambulances from making U-turns.

In addition, in the case of long bridges, etc., putting in a median expands the total width of the road and can make its construction extremely uneconomical. In cases like those described here, physical separation through the establishment of a median is not done.

Below, however, is the median widths and shoulder widths adopted for two-lane expressways with equivalent in width to four-lane roads.

2.4.3 *Medians of Finished Two-Lane Expressways*

The standard/minimum values for expressway median widths is shown below and is determined by the design speed; the minimum value for median width represents the minimum value needed in order to ensure traffic safety. Narrow medians require the establishment of safety barriers can fit into such narrow spaces.

Table2 Median Width of finished Two-lane expressway

Road Classification	Standard Value	Minimum Value
Design Speed 100km/h	4.5m	2.0m
Design Speed 80km/h	3.0m	1.5m

2.4.4 *Shoulder of Finished Two-Lane Expressways*

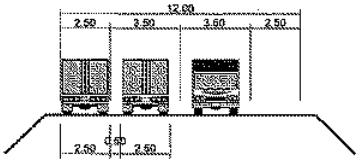
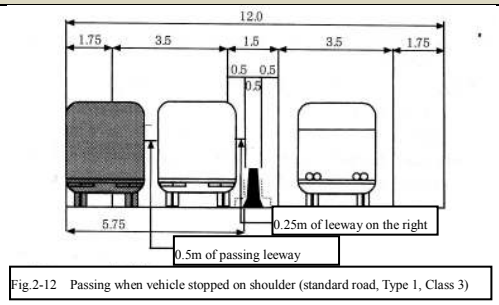
The width of the left-side shoulder of the left-side lane of a physically divided two-lane expressway is typically 2.5m: large enough to allow a large vehicle to pass by when another vehicle is broken down, etc., along the shoulder.

Also, in the case of long bridges, tunnels or other expressway sections with complicating physical terrain elements, and which see little large vehicle traffic (thereby making it unlikely that other large vehicles would need to pass by when a large vehicle is broken down, etc., on the side of the road), the shoulder can be narrowed to 1.75m; this allows smaller vehicles to pass by vehicles stopped on the shoulder without having to stick out into oncoming traffic. Even when the width is narrowed to 1.75m, a passing gap of 0.5m still exists between a large vehicle stopped on the side of the road and another large vehicle attempting to pass it.

2.5 Features of Separated Two-Lane Expressways (expected performance)

The following table compares the structure of new, separated two-lane expressways with the un-separated structure of traditional, provisional two-lane expressways from the standpoint of expected traffic operation, etc.

Table3 Features of Separated Two-Lane Expressways

	Currently (Provisional Two-Lane Expressways)	Separated Two-Lane Expressways
Widths	 10.5m = 1.75+3.5+3.5+1.75	 Fig.2-12 Passing when vehicle stopped on shoulder (standard road, Type 1, Class 3) 12m = 1.75+3.5+1.5+3.5+1.75
Structural Features	・Rubber poles along the middle	・Median zone used to physically separate opposing lanes
Traffic Safety	× Danger of head-on collision with vehicles in opposing lane	○ Eliminates accidents involving vehicles swerving out in front of oncoming traffic z Slightly elevated chance of collisions with median

	Currently (Provisional Two-Lane Expressways)	Separated Two-Lane Expressways
Passing Stopped Vehicles	○ Can get past even large vehicles stopped on the shoulder by driving partly on the center line	z Difficult to get past when large vehicles are stopped on the shoulder
Handling Accidents, etc.	○ Both lanes can be freely utilized to deal with accidents and provide emergency service	z Restricted ability to traverse lanes when handling accidents, etc. Concern about slowed rescue efforts
Roadwork, etc., Restrictions	z Because of narrow lanes, it is common that one lane must be closed while the other lane is used for an alternating flow of opposing traffic	z Because of narrow lanes, it is common that one lane must be closed while the other lane is used for an alternating flow of opposing traffic z When opposing traffic flow is restricted, points where traffic can transfer from one lane to the other are also restricted
Snow and Ice Work	○ Difficult for snow mounds and drifts to accumulate in locations where rubber poles are used	z During heavy snowfall, it is easy for snow mounds and drifts to accumulate in the median
Cost	○ Little need to revisit initial investment when expanding to four lanes	z Both initial investment and expansion cost are large when expanding to four lanes in the future z Cost reduction compared to four-lane expressway if adopted as finished form

* ○ : Good points
z : Matters to be taken into account
× : Bad points

2.6 Examples of Efforts by the Ministry of Land, Infrastructure, Transport and Tourism

With the amendment of the Road Structure Ordinance, the Ministry of Land, Infrastructure, Transport and Tourism has sought to reduce costs in line with demand by actively constructing and putting into service separated two-lane expressways on those general national route motorways (for which it is responsible) and local high-standard highways (for which individual prefectures are responsible) which are not expected to see large traffic volumes.

In all cases, shoulder width has been established at 2.5m; however, the safety barriers in the median adopt a variety of forms, such as guardrails, guard pipes, box beams and rigid concrete barriers.

Photo8(left) Fukagawa-Rumoi Expressway (between the Hokuryu-Himawari IC and the Rumoi-Horonuka IC) 8.9Km
Photo9(right) Sanriku Expressway (between the Tome IC and Tome-Towa IC) 5.0Km

Photo10(left) Aizu-Jukan-Kita Doro (Shiokawa - Yukawa-Kita) 3.2Km
Photo11(right) Higashi-Kyoshu Expressway (Shibushi - Sueyoshi-Takarabe)

3. CONSIDERATIONS FOR (PROVISIONAL) TWO-LANE EXPRESSWAYS WITH PHYSICALLY SEPARATED LANES

3.1 Traffic Management Challenges (Maintenance and Road Width) and Verification

As discussed earlier, there are management-related concerns for physically-separated two-lane expressways; thus, hearings were held with those responsible for road management, accident response, etc., of two-lane expressways with physically separated lanes, particularly in heavy snow regions. The main findings of these hearings are given below.

○Traffic Accidents

Accidents leading to an increase in property damage do not occur. Hit-and-run incidents involving road infrastructure also do not occur.

○Normal Maintenance

When cutting grass on the shoulder, the work vehicle (a two-ton truck) is parked on the shoulder (w = 2.5m); this causes no noticeable traffic jams, backups or complaints, suggesting that vehicles can get by even large parked vehicles.

○Snow and Ice Work

Because two snow clearing trucks are used to clear snow, overtaking is not possible. Because the safety barrier will be damaged if it comes into contact with the snow clearing vehicle, it is difficult to clear snow all the way to lane edge.

The fact that traffic was light following these expressways going into service, no traffic backups due to major accidents or vehicle breakdowns were reported; thus, we hope to conduct further verification.

Photo12(left)Shirataki and Maruseppu Doro (separated two-lane expressway)
Photo13(right) Akita Expressway (un-separated) snow clearing

○Deliberations by NEXCO East

Among other sections, NEXCO East is considering the southern section (approx. 2km) of the Hokkaido Expressway scheduled to open in 2012 as a candidate for application of a separated two-lane expressway structure and is currently seeking to verify safety and traffic management issues.

3.2 Concerns for 1.75m Shoulder Width

Changing provisional two-lane expressways with a total width of 12.0m into separated two-lane expressways without changing the total width will require narrowing the shoulder width on both sides from 2.5m to 1.75m (assuming a median of 1.5m width).

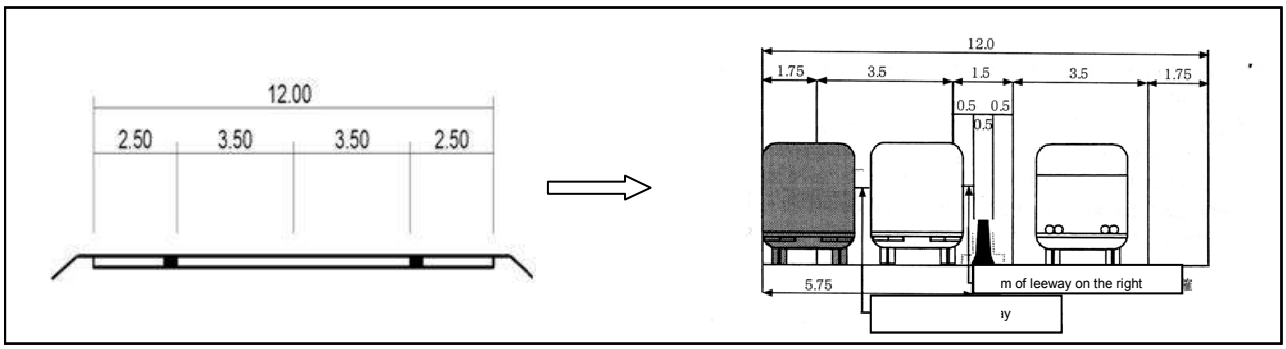


Fig.5 Proposed changes to width structure

When this is done, the lane marker positions will be moved to shift the positions of the traffic lanes, and at the same time, emergency parking bays will be established at roughly 300m intervals so that, if large vehicles stop for long periods of time on the shoulder, it will not create a major inconvenience for traffic.

In this way, expressways which are currently provisionally two-lane will have their lanes physically separated and their shoulders narrowed from 2.5m to 1.75m. On paper, assuming a shoulder width of 1.75m means that two large vehicles should be able to pass one another with 0.5m between the vehicle on the shoulder and the vehicle on the road and 0.25m between the vehicle on the road and the dividing barrier in the median. But when we consider the added width of the vehicles due to their side mirrors, the space between the vehicles on the left and the vehicle and the median on the right disappears; thus, even assuming that the driver of the passing vehicles drops his/her speed sufficiently and exercises great caution, he/she will still likely need to possess advanced driving skills.

4. CONSIDERATIONS FOR SAFETY BARRIERS ESTABLISHED IN THE MEDIAN

4.1 Deliberation on New, Appropriate Types of Safety Barriers for Separated Two-Lane Expressways

Japan has traditionally used comparatively rigid box beams, guard pipes, rigid concrete barriers, etc., in its narrow medians. While Japan could continue to use existing narrow separation safety barriers, the decision has been made for two-lane expressways to develop/employ safety barriers more appropriate to traffic management.

These safety barriers established in medians must be able to meet the following requirements.

a. They must meet the safety barrier standards dealing with strength performance, deformation performance, vehicle occupant safety performance, vehicle guidance performance and constituent component shatter-resistance performance established by the Japanese government. They must satisfy Class A collision conditions for safety barrier collision performance.
b. Taking into account the need to facilitate accident handling, road maintenance, etc., they must utilize quick-release safety barriers (support posts and wire rope) established at given intervals and of sufficient length.
c. They must be able to be easily replaced and restored in the event of damage from an accident.
d. Their cost must be kept as low as possible.
e. They must have a format which multiple manufacturers can produce and sell.
f. They must not be complicated, must be highly durable and must be easy to maintain.
g. When the safety barriers are capped by snow in the winter, they must not create unstable

snow mounds or allow the mounds to narrow the effective width of the road.


Photo14(left)Two-sided guard rail (Aizu-Jukan-Kita Doro)
Photo15(right) Box beam (Akita Expressway)


Photo16(left)Guard pipe (Sanriku Expressway)
Photo17(right) Rigid concrete barrier (Tohoku Expressway)

Tough wire ropes combined with comparatively low-strength support posts represent a promising safety barrier set-up that meets the above requirements. It has no front and back, and as long as the support posts are spaced out, it is easy to put in place and remove; thus, it can effectively be used to upgrade existing roads and to provide a narrow separator.

When struck by a vehicle, the support posts would be easily knocked down and the wires would come free of the poles while maintaining the prescribed height; the deformation of the wire ropes absorbs the impact energy in the manner of a classically flexible fence.

The section of the support posts buried in the ground have a sheath tube structure that allows them to be easily removed as needed. Thus, when an accident occurs and the vehicles behind the accident are backing up, this barrier structure allows flexible measures (such as opening up a space for U-turns to relieve traffic congestion) to be taken.

This sort of wire rope-style safety barrier is already used in many countries, where there are several types being developed and manufactured, and they are well regarded for their functionality and utility.

4.2 Examination / Development of High-Impact Wire Rope-Style Safety Barriers

The wire rope-style safety barriers (CEN N2 type) used in Europe (Sweden) have a simple structure with a design impact energy roughly 60% smaller compared to Japanese expressway safety barriers.

In Europe, the wire rope-style safety barriers are not expected to prevent a large vehicle from straying into oncoming traffic but, rather, to lessen the degree of injury sustained by vehicle occupants in the event of such collisions; however, the safety barriers established along Japanese expressways are expected to not only meet safety performance requirements with regard to occupant safety, they are expected to be able to withstand 130KJ of collision shock, e.g., give no more than 1.5m in the event of a 25 ton vehicle striking the barrier at 15° and a speed of 45km/h.

Thus, Japanese safety barrier manufacturers and research institutes are working on developing a new type of safety barrier that is flexible yet capable of handling high energy collisions.

Table4 Comparison of Western Safety Barrier Standards (EN1317) and Japanese Safety Barrier Standards

	Class	Vehicle Weight (Kg)	Collision Speed (Km/h)	Collision Angle (degree)	Shock (KJ)	Maximum Give (m)
Japan	Class B	25,000	30	15	58.1	1.1
		1,000	60	20	16.2	1.1
	Class A	25,000	45	15	130.8	1.5
		1,000	100	20	45.1	1.5
EN1317	N2	900	100	20	40.6	1.7
		1,500	110	20	81.9	1.7

Photo15(left) Wire rope being developed in Japan
Photo16(right) Wire rope trial installation (NEXCO East Asahikawa)

Photo17 Checking effects from snow removal work

5. FURTHER POINTS TO CONSIDER

With two-lane separated expressways having 2.5m shoulders, head-on collision safety has dramatically improved without producing fatal traffic management issues.

However, before full-scale adoption is undertaken, a variety of issues need to be addressed, including the installation of new safety barriers currently being developed and examined, the trial operation on actual expressways to gauge response flexibility when dealing with road accidents and disasters, and whether or not there is sufficient capacity to handle unforeseen events.

It also needs to be determined whether or not traditionally non-separated provisional two-lane expressways can be separated and, if they can, how this would be accomplished and what the shoulder width would be.

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