DEVELOPMENT OF AN EXPANSION DEVICE FOR COLD REGIONS

- TEST INSTALLATION OF AN EXPANSION DEVICE ON A NATIONAL ROUTE 274 INTERCHANGE VIADUCT -

Shinya Omote[1]
Dr. Ing.Hiroshi Mitamura[2]
Dr. Ing.Hiroaki Nishi[3]

Abstract

Bridge expansion devices in Hokkaido face severe conditions (including frost/salt damage and impact from snow-removal activities), meaning that they deteriorate and sustain damage faster than other bridge members. As the replacement of damaged expansion devices has increased dramatically in recent years, a model with high fatigue durability and load capacity was developed to reduce future life cycle costs. The expansion device designed for cold regions was installed on a bridge administered by the Sapporo city to examine its workability, load-carrying capacity, waterproof performance and anticorrosive function, as well as to enable on-site verification through data accumulation, including information on the impact of snow-removal activities and stress propagation characteristics under conditions with running vehicles.

Introduction

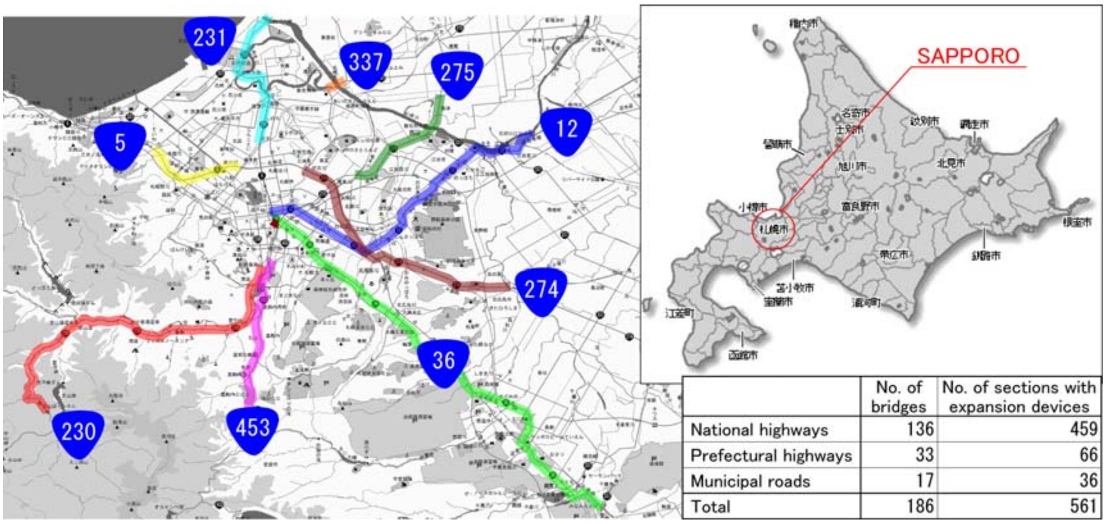
Bridge expansion devices in cold, snowy regions operate in severe conditions (including frost/salt damage and impact from snow-removal activities), meaning that they deteriorate and sustain damage faster than other bridge members. The replacement frequency of damaged expansion devices has increased dramatically in recent years. This paper presents the results of a study on the development and installation of an expansion device with high fatigue durability and load capacity aimed at reducing future life cycle costs.

1 Results of a survey on the conditions of expansion devices

[1]Researcher, Structures Research Team, Public Works Research Institute, Civil Engineering Research Institute for Cold Region
[2] Senior Researcher, Structures Research Team, Public Works Research Institute, Civil Engineering Research Institute for Cold Region
[3] Team Reader, Structures Research Team, Public Works Research Institute, Civil Engineering Research Institute for Cold Region

1.1 Survey overview

The targets of the survey were 561 sections with expansion devices and 186 ridges on heavily trafficked major arterial roads around Sapporo, as shown in Fig. 1.1. of these, 136 bridges and 459 sections with expansion devices were on national highways. In the field survey, the damage conditions of bridges and expansion devices were examined mainly through visual observation.



	No. of bridges	No. of sections with expansion devices
National highways	136	459
Prefectural highways	33	66
Municipal roads	17	36
Total	186	561

FIG. 1.1 SURVEY LOCATIONS

1.2 Status of bridges and existing expansion devices

(1) Status of bridges

River bridges accounted for approximately 80% of the total, while the ratios of viaducts and bridges over railways were a little less than 10% each.

(2) Status of expansion devices

Figure 1.3 shows the types of target expansion devices, of which 60% were the load-support types, 20% were the no-joint type and the other 20% were the match type.

FIG. 1.3 TYPES OF EXPANSION DEVICE

1.3 Age occurrence conditions

Figure 1.6 shows the results of the survey on damage to expansion devices.

(1) Load-support type

(a)Unevenness of face plates (Photo 1), insufficient expansion gaps (Photo 2) and cuts made by snowplows (Photo 3) were observed in many cases with the steel-finger type, and sediment accumulation, clogging and corrosion were found at water cutoff parts.In cases using the beam type, differences in beam level and deformation were observed (Photo 4). At water cutoff parts, blockage of expansion gaps with sediment (Photo 5) and loss of cutoff rubber (Photo 6) were found.

(b)Extrusion of sealing material (Photo 7) was observed in many cases with horizontal simple-installation-type expansion devices made of steel, although there was little damage to their main bodies. In cases with vertical-type devices, deformation (Photo 8), breakage and corrosion of the main bodies were significant, loss of waterproof ness was observed and water leakage was severe.

(c)In all cases with the load-support type, scaling of the pavement around expansion devices (Photo 9) and hollowness, scaling and wear of site-placed concrete (Photo 10) were observed. Such damage was significant on the front side in the side facing the direction of traffic.

(2) Match type

(a)Breakage of steel beams (Photo 11) and other serious damage to main units were found in some cases with the beam type. Blockage of water cutoff parts with sediment and loss (Photo 12) and cracking (Photo 13) of cutoff rubber were also observed. In cases with devices made of rubber, peeling of surface rubber was seen.

(b)Scaling of the pavement around expansion devices (Photo 14) and hollowness, scaling and wear (Photo 15) of site-placed concrete were observed in all types.

(3) No-joint type

(a)While the status of internal structures was unknown because the survey was conducted through visual observation only, cracking (Photo 16), loosening, scaling, unevenness, caving and other damage to pavement were observed in the vast majority of cases.

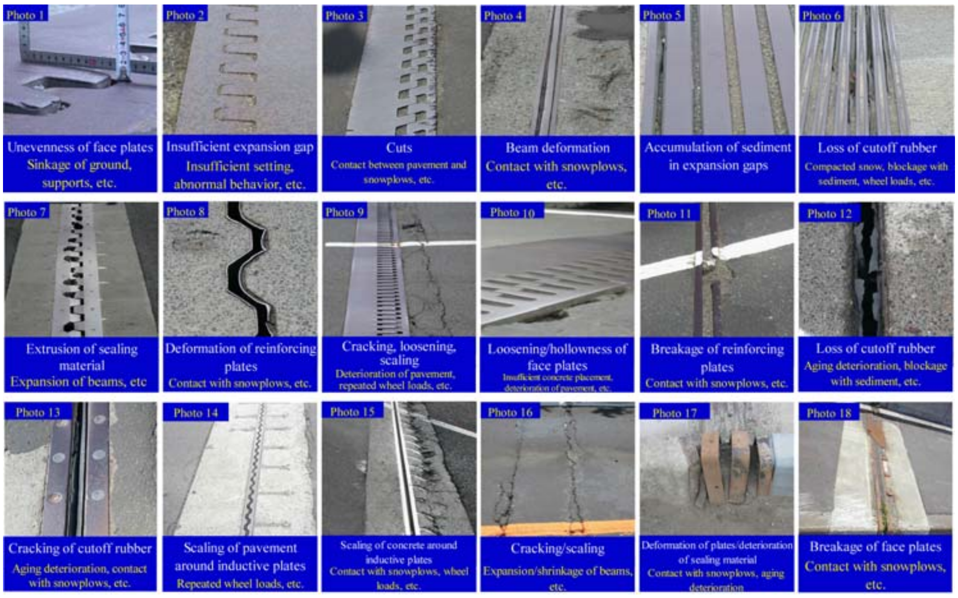


FIG. 1.6 CONDITIONS OF DAMAGE TO EXPANSION DEVICES

(4) Other

(a) Many cases of curb breakage and edge-plate breakage/deformation (Photo 17) were observed at wheel guard parts, while deterioration and peeling of sealing materials and blockage with sediment were seen at the water cutoff parts of expansion gaps.

(b) Significant breakage of main units (Photo 18), rusting, corrosion and other serious damage were observed in some parts of sidewalk areas. Scaling and loosening of surrounding pavement and damage to site-placed concrete were also found in all types.

2 Estimation of the causes of damage

Possible causes of damage to expansion devices peculiar to Hokkaido are listed below.

(1) Damage caused by snowplows
Scaling of pavement and concrete around expansion devices was thought to result from contact with snowplows during snow removal work and from fatigue caused by the wheel loads of large vehicles.

(2) Damage caused by sediment and compacted snow
Breakage and loss of cutoff material was thought to result from the transmission of wheel loads to expansion gaps due to blockage with sediment and compacted snow.

(3) Damage caused by insufficient performance at low temperatures
Extrusion and loss of cutoff rubber was thought to be a result of adhesive failure caused by the corrosion of steel materials and insufficient performance at low temperatures.
Scaling and loosening in cases with the no-joint type were thought to be a result of repeated beam expansion and shrinkage due to temperature variations and insufficient load-following capability in the expansion devices themselves.

(4) Damage caused by spreading of antifreeze agent
Rusting of steel material and scaling/wear on concrete were thought to result from aging deterioration and the acceleration of rusting and corrosion from the spreading of antifreeze agent on road surfaces.

3 Improvements to expansion devices for cold regions

3.1 Performance requirements in cold-region environments

To satisfy performance requirements in the conditions of cold, snowy regions with wheel loads and aging deterioration, the following considerations are desirable for expansion devices:

(1) Safety against snowplow-related impact must be ensured.

(2) The cutoff structure must be strong enough to resist damage from sediment accumulation and compacted snow in expansion gaps where wheel loads are transmitted.

(3) Resistance to corrosion resulting from the spreading of antifreeze agent, etc. must be improved. Examination of the internal structure of expansion devices Figure 3.1 presents the examined part, and Photo 3.1 shows the improved expansion device.

(4) Installation structure of snowplow inductive plates

To decrease the impact of snowplows, the installation intervals of inductive plates were reduced from 300 to 225 mm. This structure was adopted to control snowplow-related damage and disperse wheel loads.

(5) Installation of dust-proof material and slide plates

To prevent the blockage of expansion gaps with sediment or snow and avoid damage to cutoff materials when wheel loads are transmitted, the entry of sediment was inhibited and the indentation force of compacted snow was supported by placing dust-proof material (polyethylene foam) under face plates and laying slide plates under it. This structure was used to maintain the durability of the elastic sealant used as the cutoff material.

(6) Improvement of anti-corrosion performance

The anti-corrosion performance of expansion devices was improved by spraying Al-Mg (aluminum-magnesium) plasma on the steel materials used (the inside of the main units, the face plates, the sides of the main units on the pavement surface and the inductive plates on the pavement surface). The metal spraying method involves the application of a layer of aluminum/magnesium (95:5) approximately 100 microns thick melted with plasma onto metal surfaces after Type 1 surface preparation. The adhesion of sprayed metals can reach more than four times (around 7 N/mm^2) that of paint. In a combined cycle test, no corrosion was observed even after 6,000 hours (representing more than 100 ordinary years of service), and a self-healing, corrosion-inhibiting effect from the eluted magnesium was observed at cross-cut sections[1)].

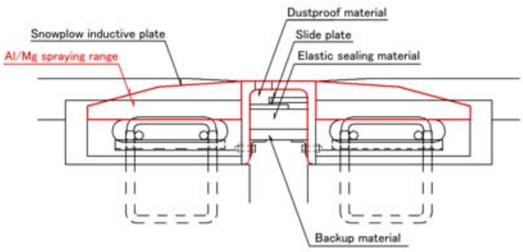


FIG. 3.1 CROSS SECTION OF THE INTERNAL STRUCTURE OF AN EXPANSION DEVICE

PHOTO 3 IMPROVED EXPANSION

4 Performance evaluation of the improved expansion device for cold regions

A full-scale specimen was produced for fatigue experiments to evaluate the performance of the improved expansion device. The specimen had a maximum expansion gap and a difference in level with the road surface. A wheel running machine was used for the experiment.

4.1 Running test

(1) Purpose

This experiment was conducted to clarify the process of damage to expansion devices, and to confirm and summarize the mechanism behind the transmission of wheel loads to such devices and subsequently to the concrete in the installation section. The results of the transmission mechanism investigation can also be used to clarify the damage process.

(2) Wheel running machine overview

In the fatigue experiment, the method of using a crank-type wheel running machine (owned by the Civil Engineering Research Institute for Cold Region) was adopted. This technique has been established as a method of testing fatigue durability acceleration for road bridge slabs. The experiment is currently under way using a machine with rubber tires rather than the conventional iron wheels (as shown in Photos 4.1 and 4.2) to simulate actual running conditions.

PHOTO 4.1 WHEEL RUNNING MACHINE (FULL VIEW)

PHOTO 4.2 WHEEL RUNNING MACHINE

4.2 Running test on an actual bridge

(1) Test construction overview

For a running test on an actual bridge, an expansion device for cold regions was installed at the section shown in Fig. 4.1. The bridge was an IC viaduct (957 m in length) constructed in November 1981.The test construction is expected to clarify the impact of snow removal in winter and the stress propagation of actual loads applied by many types of large vehicle, as well as to verify water cutoff and freezing conditions.

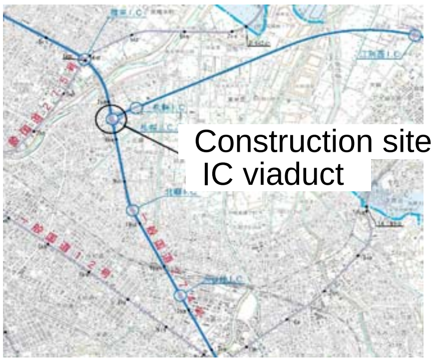


FIG. 4.1 LOCATION OF THE TESTCONSTRUCTION SITE

(2) Overview of the specimen and measurement

As shown in Fig. 4.2, vibration accelerometers (in the vertical and horizontal directions) and strain gauges (weld gauges) were attached to the specimen. The actual running tests are currently under way.

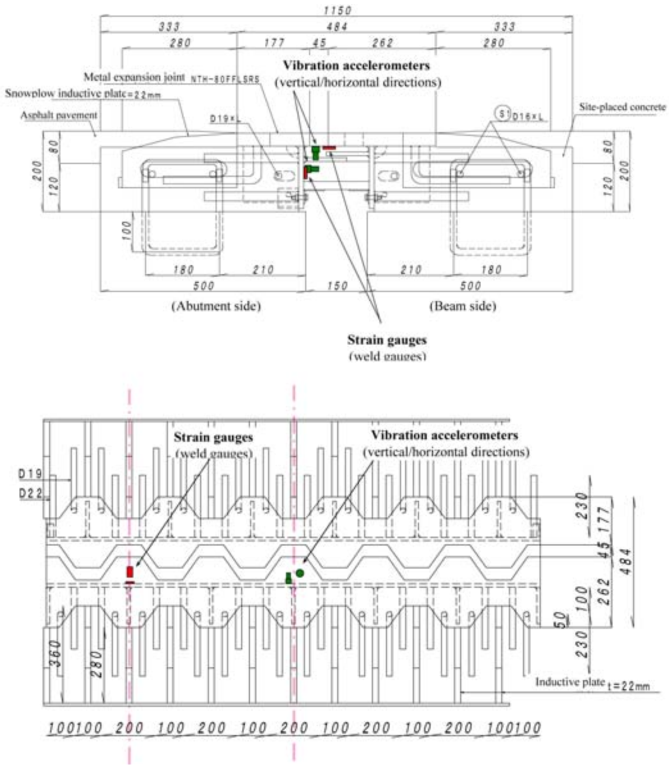


FIG. 4.2 SCHEMATIC DIAGRAM OF THE SPECIMEN

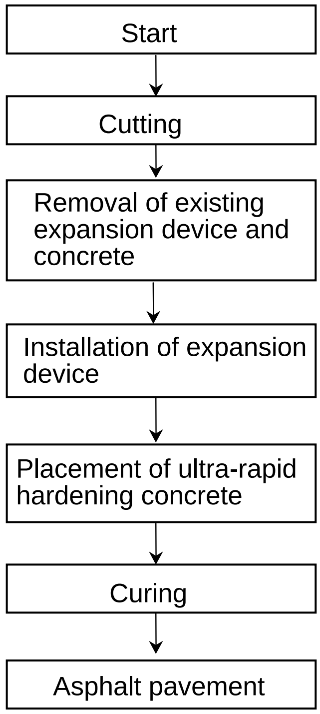


FIG.4.3 CONSTRUCTION PROCEDURE

(3) Installation conditions

The expansion device was installed following the procedure shown in Fig. 4.3. Since a main arterial road was being used, the work was conducted at night. Installation on the main part of the route was conducted separately for the inside and outside lanes, and that on the ramp lanes was conducted simultaneously by completely closing the section to traffic. The steps of the installation process can be summarized as follows:

1) Cutting: Cutting was conducted by marking the predetermined positions (Photo 4.3).

2) Removal of the existing expansion device and concrete: Existing concrete was removed using a breaker. The existing expansion device was removed by gas-cutting the finger parts of the face plates (Photo 4.4).

3) Installation of the expansion device: The expansion device was installed in the rectangular opening by setting a hanging angle after temporary assembly (Photo 4.5).

4) Placement of ultra-rapid hardening concrete**:** Ultra-rapid hardening concrete was placed after installation of the expansion device was complete. The concrete was blended and mixed on site using a jet mixer truck. After placement, a curing time of three hours was observed in principle (Photo 4.6).

5) Asphalt pavement: After the ultra-rapid hardening concrete had cured, its top s urface was paved with asphalt. While concrete is usually placed up to the installation surface in repair work due to time constraints, asphalt pavement was used in this case in consideration of preventing damage to the surrounding pavement (Photos 4.7 and 4.8).

PHOTO 4.3 CUTTING

PHOTO 4.4 REMOVAL OF EXISTING DEVICE

PHOTO 4.5 INSTALLATION OF NEW DEVICE

PHOTO 4.6 CONCRETE PLACEMENT

PHOTO 4.7 PAVEMENT

PHOTO4.8AFTER COMPLETION

Conclusion

The survey results indicated that the most important points were rust proofing, protection of cutoff material, and snowplow countermeasures. These measures also lengthen service life, not only for expansion devices but also for bridges themselves, and result in higher LCC assessment. In this paper, an improved expansion device and its performance evaluation method were presented in consideration of the above matters. In the future, the authors intend to summarize the experimental data obtained from the wheel running test and the driving test on an actual bridge to confirm the transmission mechanism of wheel loads.

Reference

[1] The Plazwire System – a long-term anti-rusting technology involving plasma spraying, Kyushu Electric Power Co., Inc. Research Laboratory