Maintenance of ASR-affected Structures in Hokuriku Expressway, Japan

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Abstract

Increasing amounts of deicing salts have been used to ensure the safety of road surfaces in Hokuriku district, Japan. Sodium chloride, which accounts for the majority of deicers, has been causing damage to road concrete structures due to alkali-silica reaction. This report describes the current state of maintenance and repair techniques of these road structures affected by deicer-related alkali-silica reaction.

Introduction

Increasing amounts of deicing salts have been used to ensure safety of road surfaces in Hokuriku district, in Japan. The deicers used in this area have been mainly of sodium chloride (NaCl) type. In addition, the structures alongside the Japan sea coastline are subjected to monsoons, which increase its exposure to airborne chlorides from the sea. Therefore, these natural conditions set the road structures of the Hokuriku district in a permanent saline environment. As the effect of this chloride supply, the cases that alkali-silica reaction (ASR) deteriorates road structures have been increasing. On the other hand, river gravels and river sands have been used as concrete aggregates for a long time and these aggregates have been found in seriously ASR-affected structures. ASR has occurred mainly in structures primarily built from 1970 to 1985, a time when high alkali cement had been produced in Japan. Over the course of time, reactive river sands and gravels may not be properly assessed since these aggregates contain a wide variety of rock types, as well as different types and contents of reactive minerals.

Central Nippon Expressway Company has covered the sections from Kinomoto IC (Shiga Prefecture) to Asahi IC (Toyama Prefecture) in Hokuriku Expressway and Oyabe-tonami JCT (Toyama Prefecture) to Shirakawago IC (Gifu Prefecture) in Tokai-Hokuriku Expressway, a total of 300km (9-39 years in service). There are 545 bridges, 1200 C-Boxes and 45 tunnels in these sections. ASR occurs in some of these structures and the application of efficient maintenance techniques have been put in place.

This report presents the current state of inspection and survey of road structures under saline environment in the Hokuriku district, the methods of diagnosis, repair and repair prioritization of ASR damaged structures.

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The ASR Characteristics in Hokuriku district

The Hokuriku district is located approximately in the center part of the Japan Sea coastline and is characterized by severe weather conditions: hot and humid summers and cold and snowy winters (see Fig. 1～Fig. 3).

Figure 4 shows the map of deteriorated structures in the Hokuriku district. In the expressways ASR occurs in almost all areas of Toyama Prefecture and parts of Ishikawa and Fukui Prefectures. The reactive aggregates were confirmed as andesite, rhyolite and tuff, from volcanic rock deposits (see Fig. 5). Deterioration of road structures by ASR has been often assessed as a combined effect of rainwater, road drainage and deicer application (see Fig. 6).

Maintenance

The inspection of road structures is classified as regular inspection or detailed inspection. Regular inspections are conducted once a year, while detailed inspections are carried out in the span of 2 to 5 years. These inspections have been mainly visual. In addition, continuous survey of the expansion behavior of the structures (by contact gauge or by π gauge) is conducted every year and followed by a thorough investigation.

Fig. 7 shows the flow of assessment of ASR-deteriorated structures, which has been applied in reference to the case-studies shown in Fig. 6. In addition, the structure's database is comprised with the construction company, concrete plant, cement maker, aggregate quarry or supplier once construction is elaborated. In the deterioration cases where the assessment is inconclusive, ASR occurance is determined by a comparative evaluation of the database of other structures supplied from the same concrete plant. If it cannot provide a proper judgment, then a detailed investigation has to be carried out.

Detailed ASR investigation includes the mineralogical composition of coarse aggregates, thin section observation with a polarizing microscope, alkali and chloride contents in concrete, and the residual expansion of concrete cores drilled from the structures. In particular, considering the feature of Hokuriku district, the residual expansion test of concrete cores, which is a technique that conforms with the alkali external supply, has been adopted . The test method is described in Table 1 and shown through Fig.7～Fig. 11.

Repair and monitoring

Figure 12 shows the flow of repair method selection of ASR-deteriorated structures. Since there are a considerable number of ASR deteriorated structures in the Hokuriku district and, therefore, a need for reducing maintenance costs, a ranking system based on the visual inspection has been created for chosing the ASR repair method. For ranking "A" structures, crack injection and surface coating is applied, including the time reference results of residual expansivity tests of concrete cores. For ranking "B or C" structures, the road surface drainage countermeasures are applied, followed by close observation of the improvements. Repair rankings are priority for important intersections (such as national road and railway) and the areas affected by concrete spalling or peeling off, works include section repair and coating with fiber sheets. In addition, due to the severe environment conditions in the Hokuriku region, the rehabilitation period has been set to about one or two year long to ensure quality control.

After the repairing is concluded, monitoring is applied for inspection purposes. Focus point is the effect of road surface drainage. Also, a special attention is paid to bridge abutment front, where the water absorption from the back part often leads to swelling of the surface coating. The effective countermeasures for stopping water migration from the back part of bridge abutments are a matter of serious concern.

Concluding Remarks

The extent of ASR deterioration of concrete structures in the Hokuriku district is significant if compared to other areas of Japan. In some cases, fracture of reinforcing steel bars due to ASR expansion has been reported. The lack of appropriate repairing countermeasures to stop ASR progress is still a matter of fact. If the repair occurs ASR, there will be no drastic measures. At present, ASR in bridge superstructure has not reached deterioration levels which exert influence on the load bearing capacity. In the future we will plan to continue the conduction of detailed inspections and surveys on these ASR-affected structures.

Table 1 Outline of ASR test methods

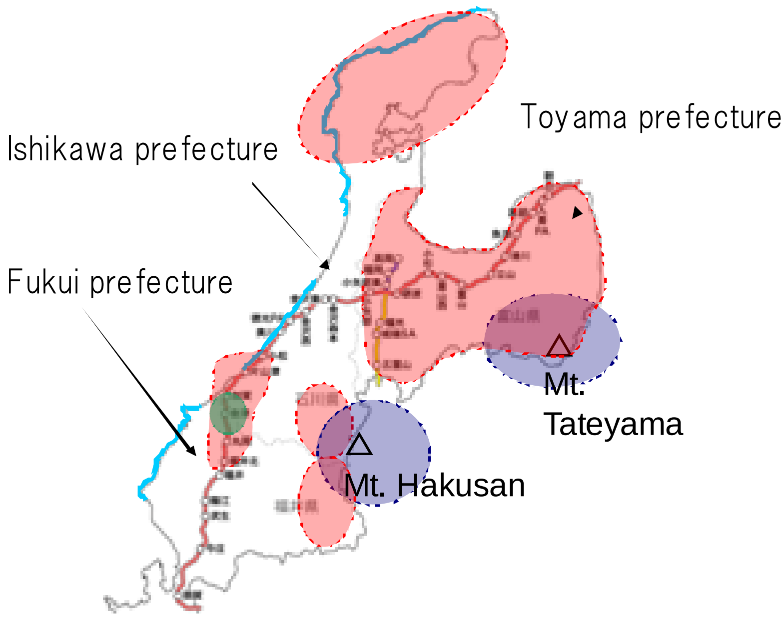
Lithological composition of gravel	In regard to particles 5mm or more in diameter visible on the surfaces of concrete cores, the lithological composition is calculated by the point count method using a 5mm mesh.
Alkali-silica reactivity:	Alkali-silica reactivity is judged by the presence of rims and/or alkali-silica gel around aggregate particles. Thin sections are prepared from some specimens for polarization microscopy observation.
Alkali content of concrete:	A 10-g sample ground to particles less than 150μm in diameter is added to 100ml of distilled water at 40°C and agitated for 30 min. The mixture is then filtered, and the alkali concentration of the filtrate is measured by atomic absorption photometry, to calculate the Na_2O equivalent (Na_2O + 0.658 K_2O).

Chloride ion content:	A 20-g sample ground to between 150 and 300µm particle size is dissolved in a 2N HNO_3 solution and boiled for 5 min. The chloride ion (Cl^-) concentration of the filtrate is then measured by potentiometric titration.
Residual expansion (Canadian method, ASTM C 1260)	The time-related changes in the expansion of drilled concrete cores (ϕ55mm) are measured while being immersed in a 1N NaOH solution at 80°C.
Residual expansion (Danish method):	The time-related changes in the expansion of drilled concrete cores (ϕ55mm) are measured while being immersed in a saturated NaCl solution at 50°C.

Fig. 1 Location of Hokuriku district

Fig.2 Highway snow removal work in winter

Fig.3 Scattering of deicing salts



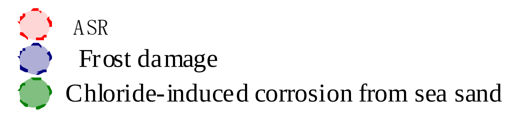
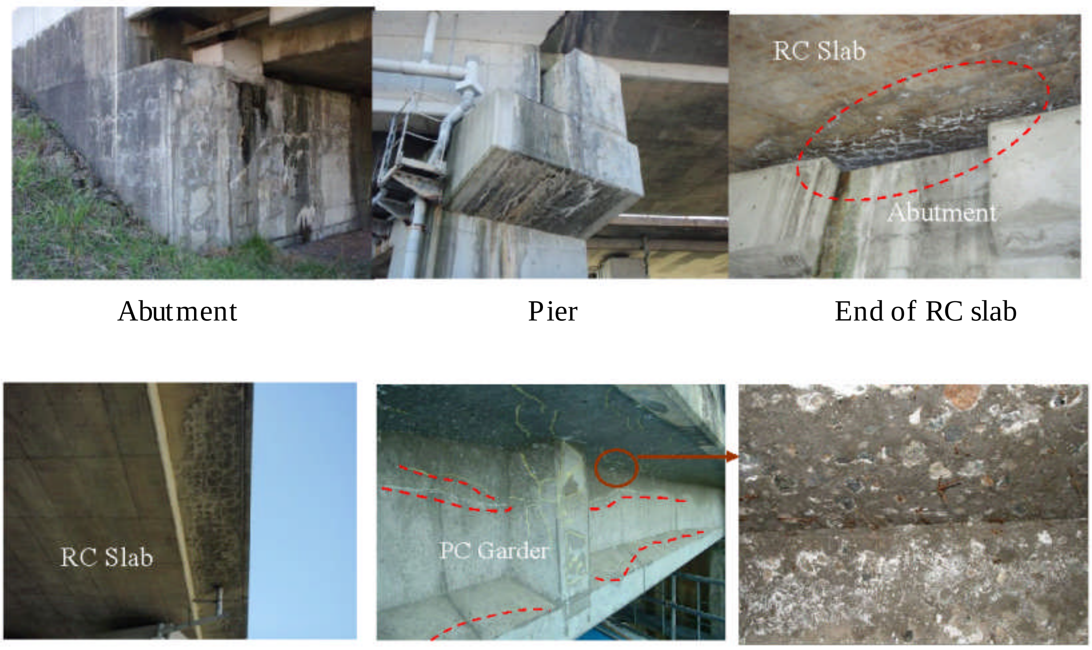


Fig.4 Map of deterioration in Hokuriku district

Fig.5 ASR gel（Core fracture surface）



Abutment | Pier | End of RC slab

RC slab | PC girder | Pop out

Fig.6 Cases of ASR deterioration

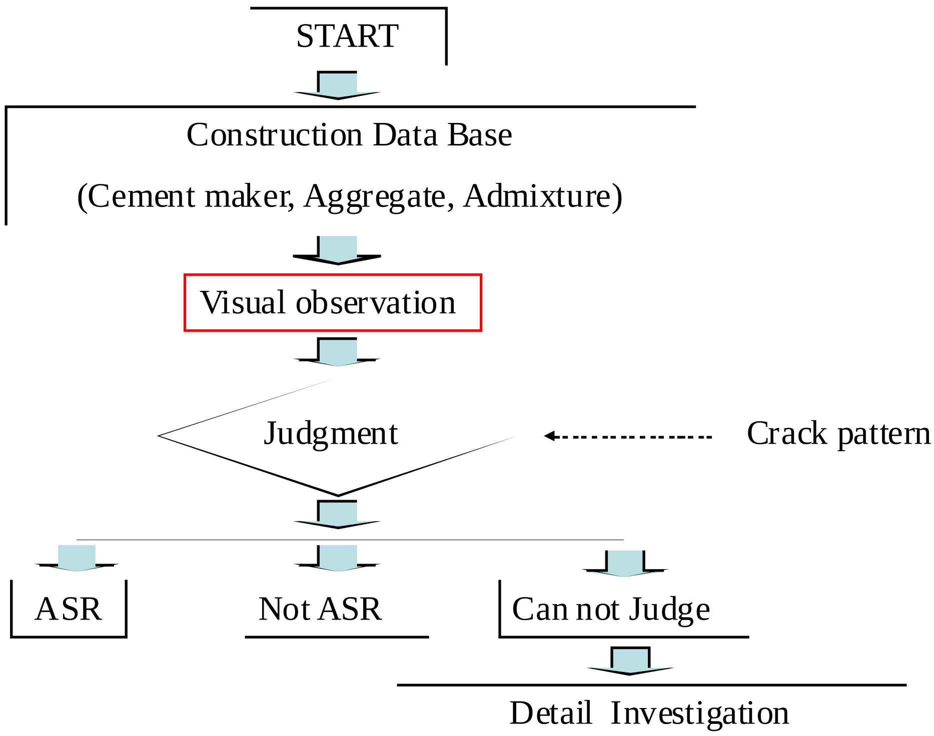


Fig.7 Flow of Assessment of ASR Structures

Fig.7 Lithological composition of gravel

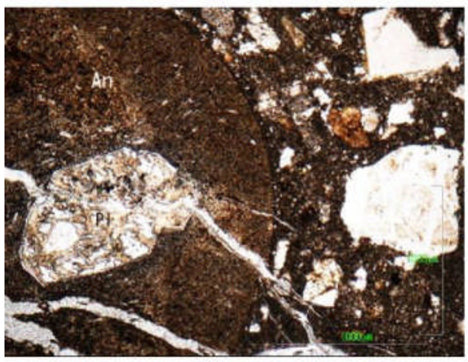


Fig.8 Observation of thin section by polarization microscopy

Fig.9 Alkali content of concrete by Atomic Absorption Spectroscopy Apparatus

Fig.10 Chloride ion content by Potentiometric Titration Apparatus

Fig.11 Residual expansion test of concrete cores

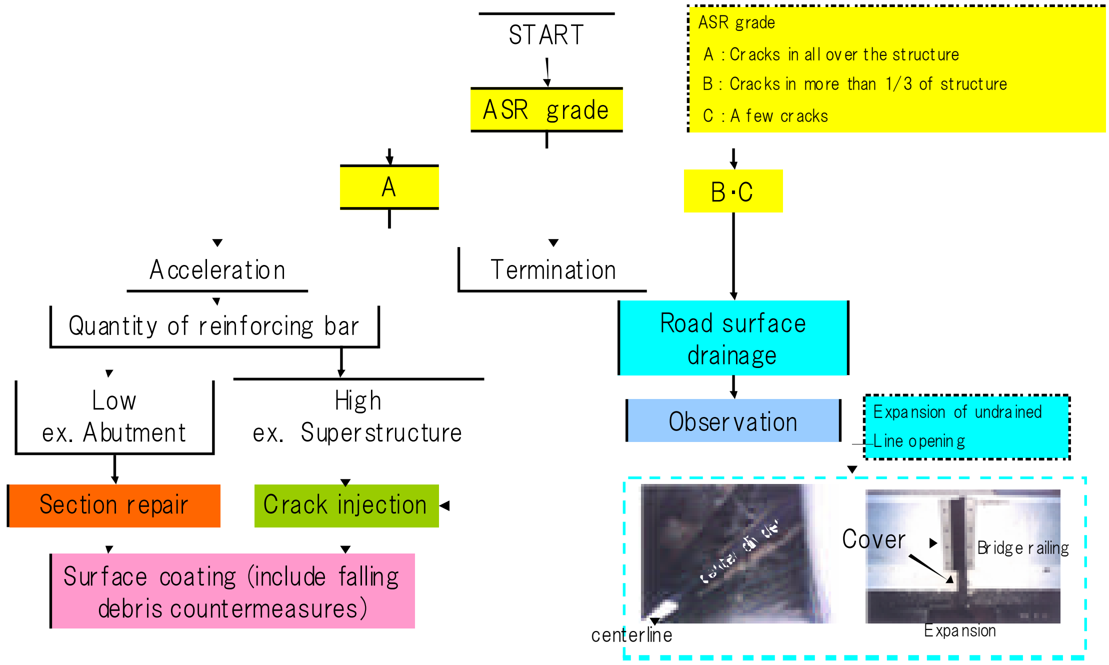


Fig.12 Selection of ASR Maintenance Method



Crack injection Surface coating Water jet



Section repair with shotcrete Execution of fiber sheet coating Completion of repairing works

Fig.13 Maintenance of ASR-affected bridges