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Maintenance management of ASR structures in Hanshin Expressway

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ABSTRACT

Alkali-silica reaction (ASR) is one of the factors in deterioration of concrete structures and induced by providing water for potential concrete structures for harmful expansions due to ASR. Hence, in order to prevent the structures form being provided with water, we make their surface coated with flexible paint as preventive maintenance. Furthermore, we strengthen the structures of which reinforcing bars are ruptured to recover their load carrying capacity.

Therefore, in order to select measures, it is necessary to find whether their reinforcing bars are ruptured or not. So, we classify structures by degree of their damage from regular inspection and investigate especially damaged structures in particular.

In this paper, an outline of maintenance of the ASR structures, mainly a database of ASR piers and a non-destructive inspection method for reinforcing bars, is described.

Keywords. alkali-silica reaction(ASR), maintenance, database, non-destructive inspection

INTRODUCTION

ASR is one of the factors in deterioration of concrete structures and induced by providing water for potential concrete structures for harmful expansions due to ASR. Hence, in order to prevent structures from being provided with water, we make their surface coated with flexible coatings as preventive maintenance. Furthermore, we strengthen the structures of which load carrying capacity declines.

According to the research carried out before, if reinforcing bars of concrete structures damaged due to ASR are not broken, their load carrying capacity barely declines. But, on the other, if reinforcing bars of ones are ruptured as shown in Photo 1, their load carrying

capacity deteriorates and they need to be reinforced by being jacketed with steel plates or carbon fiber sheets as shown in Photo 2.

In Japan, an official notice of “measures of restraint on ASR” was given at 1989, so the structures constructed according to this official notice have little potential to be damaged due to ASR. But, in Hanshin Expressway, there are about 7,500 of concrete piers and about a half of them were constructed before the restriction was introduced. These old structures possibly have potential to be damaged and some of them have already been damaged due to ASR. Hence, it takes much effort and cost to investigate all the potential structures in detail to select measures. Therefore, it is important to manage maintenance of ASR structures efficiently.

Photo 1. Ruptures of reinforcing bars

Photo 2. Reinforcement of a RC beam damaged by ASR

OUTLINE OF MAINTENANCE OF ASR PIERS

Definition of ASR piers. In Hanshin Expressway, the piers which satisfy the condition (a) or (b) shown in Table 1 are defined as ASR piers. In both cases, it needs to take cores from the structures to make sure that white gel generated by ASR exits. And in case of condition (b), accelerated test of residual expansion capacity (the JCI-DD2 method) using the cores needs to be conducted.

Table 1. Condition to judge concrete piers ASR

Condition	White gel	Total length of cracks wider than { 0.3 mm (RC columns) / 0.2 mm (PC columns) } in the columns	Total expansion of the concrete core taken from a structure
(a)	Exist	≧100m	—
(b)	Exist	RC columns: ≧20m PC columns: ≧30m	≧0.1%

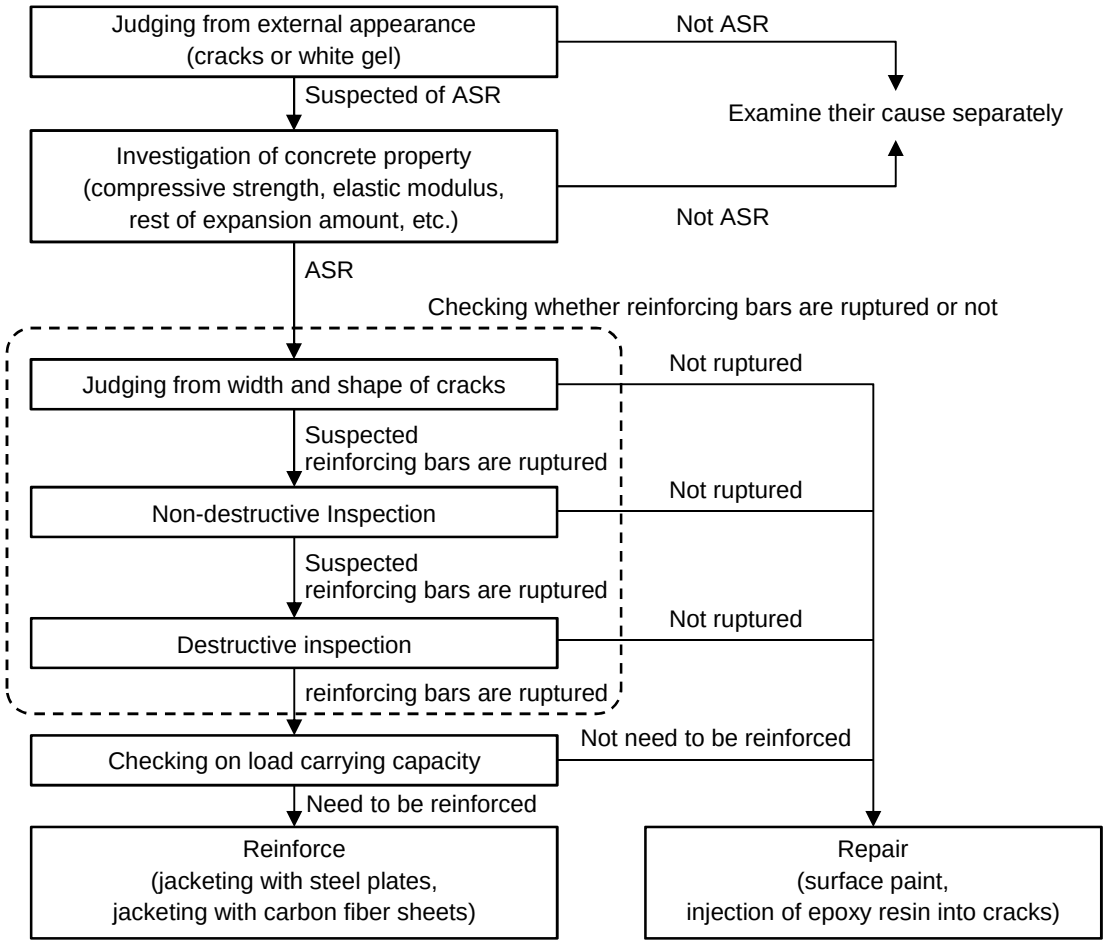


Figure 1. Flow chart of selection of measures against damage caused by ASR

Flow of ASR piers' maintenance. The structures of Hanshin-Expressway, including concrete structures, are inspected on a cycle of 5 to 8 years, using visual inspections at arm-length. And on the basis of the results of the periodic inspections, the damaged structures are repaired or reinforced. If enough information to decide how to repair or reinforce is not got from the periodic inspections, detail investigations are conducted. Thus, the causes of concrete structures' damage, including ASR, are estimated form the external appearance of the structures, such as the results of periodic inspections, first. If the cause of damage is suspected of ASR from the external appearance, cores are taken from the structure and experiments in concrete property are conducted.

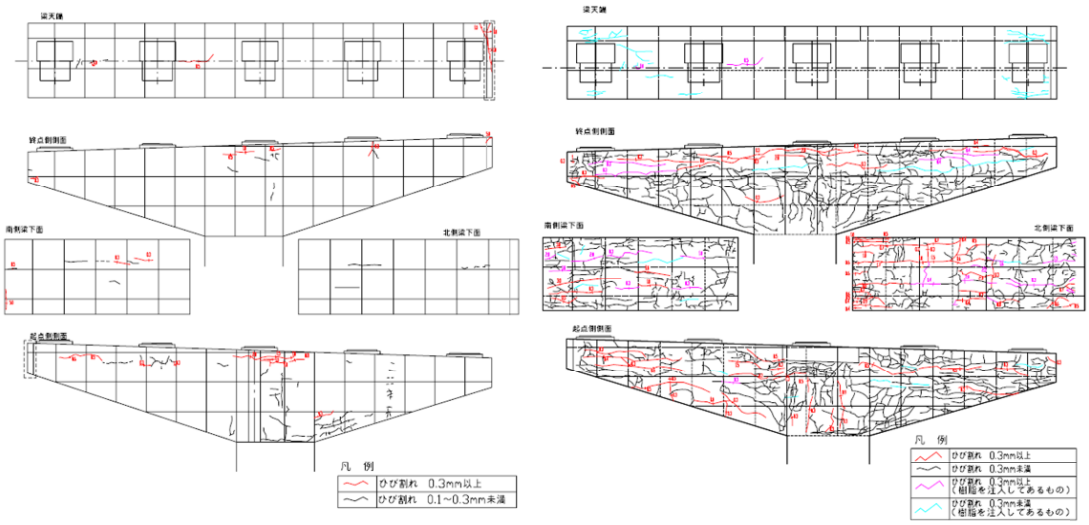
On the structure judged of ASR from the results of the experiments, we check whether the reinforcing bars rupture or not. In checking the reinforcing bars' damage, first, external appearance of position or width of the cracks is checked. Then, non-destructive and destructive detail investigations are conducted on the suspected parts of the structures.

If the reinforcing bars are broken, the load carrying capacity will be checked and whether reinforce or repair will be judged.

Problem of management. There are many concrete structures we have to maintain, so, it is important to screen them from existing data correctly and without oversight. The data available for judging almost all structures whether ASR or not is external appearance recorded in periodic inspections. In addition, the data from which we judge first whether reinforcing bars rupture or not is external appearance.

Therefore, we used to judge from the current external appearance, but the damage due to ASR were sometimes underestimated. This is because many of concrete structures with harmful cracks have been made their surface coated with highly elastic coatings.

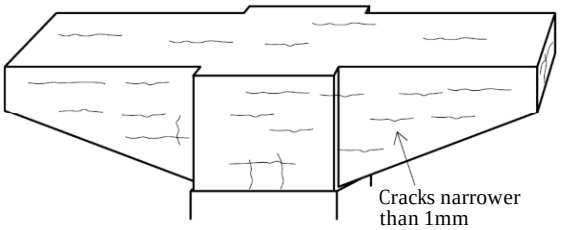
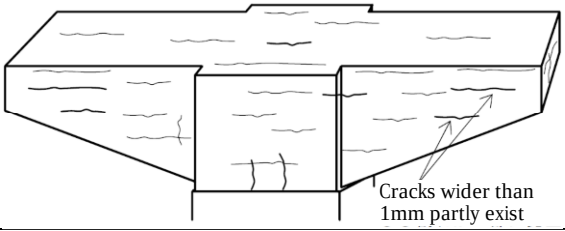
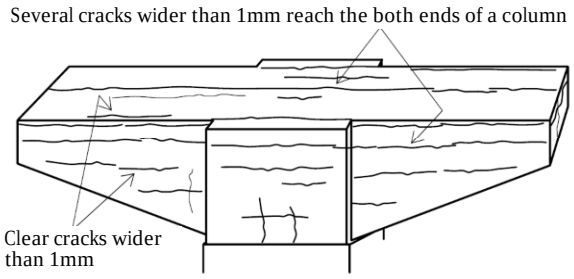
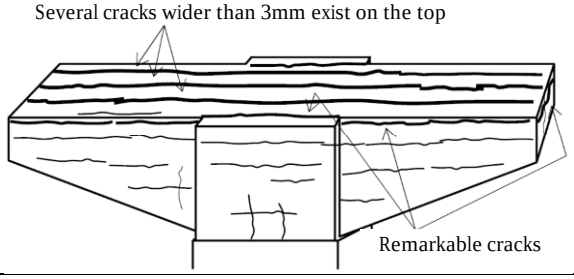
An example of underestimation is shown in figure 2. This pier was judged external damage level 1 shown in Table 2 from the cracks found in the latest periodic inspection. But after removed the surface coatings, much more cracks classified as external damage level 4, appeared. Furthermore, reinforcing bars were found broken, as shown in Photo 1.



Before removal of the surface coating After removal of the surface coating

Figure 2. An example of underestimation for damage of a surface coated pier

Table 2. The definition of external damage level

Level 1 Cracks narrower than 1mm exist.	
Level 2 Cracks wider than 1mm partly exits.	
Level 3 Cracks wider than 1mm exist clearly on the top and the sides, some of which reach the both ends of a column.	
Level 4 Several cracks wider than 3mm exist on the top, and ramarakable cracks exist on the edge of a column.	

In addition, the most reliable method to grasp reinforcing bars' condition is destructive inspection by removing cover concrete, but the destructive inspection needs much cost and causes the damages of the structures. Therefore, a reliable non-destructive inspection method is needed.

DATABASE OF ASR PIERS

As mentioned above, especially on surface coated concrete structures, it is difficult to estimate the damage correctly and efficiently from the current external appearance. Therefore, it is important to gather and sort the data of the construction information, and the history of cracks, repair and reinforcement, etc. So we have made the database of the piers which we have to pay attention to as ASR structures.

Subjects of the database of ASR piers. Though the definition of ASR piers is shown in Table1, all the suspected piers are not inspected in detail enough to judge. In addition, there are many piers with the potential of ASR. In particular, the piers constructed in the same construction works in which ASR piers were constructed are highly suspected of having

been made of the same material as ASR piers and having potential for ASR. Therefore, ASR piers and ones constructed in the same construction works as ASR piers are subjects of the database.

Items of the database. As ASR depends on the materials of structures, information of construction work is recorded in the database. Also, the histories of cracks, repairing and reinforcing are recorded. By referring to the past information, the damages, which have already been repaired, can also be taken into consideration and accumulated damage and deteriorating speed can be estimated more correctly. In addition, judgement of the damages due to ASR, such as judgement from the cracks, possibility of reinforcing bars rupture and total judgement, is recorded in the database.

An example of judgement using the database . For example, the pier shown in Figure 2, were judged external damage level 1 from the cracks found in the latest periodic inspection. But, this pier had cracked repeatedly and been repaired 3 times as shown in Table 4. Judging from the history of its cracks, it is the same external damage level 4 as judged after removed the surface coatings. Thus, by putting the history of damage and repair in order, serious damages are not overlooked without special inspections.

Table 3. Items of ASR database

Information of construction work	➢ Year of completion ➢ Construction company ➢ Property of piers ➢ Type of structure (RC or PC)
History of repair and reinforcing	➢ Year of repair and reinforcing ➢ How to repair and reinforce ➢ Length and width of cracks
Information of periodic inspections	➢ Year of the periodic inspections ➢ Length and width of cracks ➢ Judgement of damage in periodic inspections
Information of detail inspections	➢ Year of detail inspections ➢ Results of detail inspections
Judgement of damages due to ASR	➢ Judgement from cracks ➢ Possibility of reinforcing bars' rupture ➢ Total judgement of the damage due to ASR

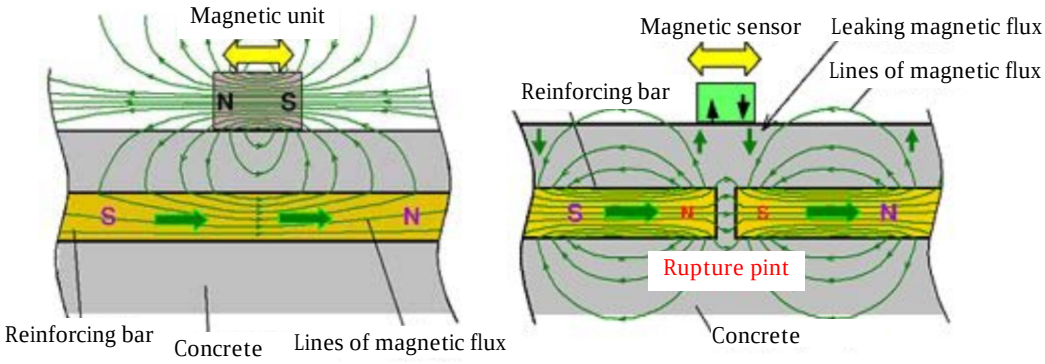
Table 4. The cracks' history of an example pier

year	Total length of cracks	Maximum width of cracks	Occasions
1980	157.4m	No record	Repair works (surface paint, injection of epoxy resin into cracks)
1983	160.1m	0.7mm	
1994	28.5m	3.0mm	
2006	3.7m	5.0mm	Latest periodic inspection

NON-DESTRUCTIVE INSPECTIION OF REINFORCING BARS

As mentioned above, in choosing measures for the structures damaged due to ASR, it is important to grasp the rupture of reinforcing bars correctly. In addition, it needs to reduce the damage to the structures and the cost in the inspection. Therefore, we select the objects of the inspection by using the ASR database and conduct non-destructive inspection using a magnetic method to detect the breaks of reinforcing bars.

Principle of magnetic method. Magnetic method is a non-destruction inspection method using the property of reinforcing bars as magnetic bodies. First, magnetic unit is touched to cover concrete and slid along the reinforcing bar to be inspected. That makes the reinforcing bar magnetized. If the reinforcing bar is not ruptured, both sides of the section where magnetic unit has been slid become North and South magnetic poles. But, if the reinforcing bar is ruptured, the broken part also becomes North and South magnetic poles. Therefore, by measuring the magnetic - flux density with the magnetic sensor, the rupture of the reinforcing bar can be detected. An example of magnetic-flux density measured with the magnetic sensor is shown in Figure 4.



Magnetizing a reinforcing bar Measuring magnetic-flux density

Figure 3. Principle of the magnetic method

Magnetizing a reinforcing bar Measuring magnetic-flux density

Photo 3. Measurement by the magnetic method

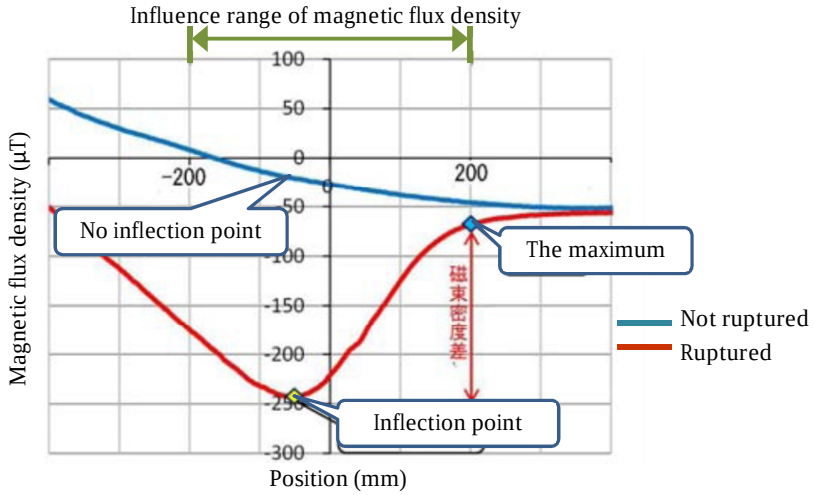


Figure 4. An example of measured waveform

Table 5. Comparison of results of non-destructive and destructive inspections

Destructive inspection / Non-destructive inspection	Not broken	Broken
Not broken	11	0
Broken is suspected	2	5
Broken	0	57

An example of application to a structure. Here is an example of application of the magnetic method to a column of a RC pier. At the corners of this pier's column part, remarkable cracks were found and it was suspected the reinforcing bars of ruptured. Therefore, non-destructive inspection by the magnetic method and destructive inspection by removing their cover concrete were conducted. The results of these inspections are shown in Table 5. Comparing the results of both inspections, if the state of reinforcing bars can be clearly judged from the magnetic method, its results correspond to the state confirmed after removing cover concrete. Thus, it can be said that the magnetic method is reliable non-destructive inspection method for reinforcing bars rupture.

CONCLUSION

By using the database of ASR piers, it became possible to select the piers need to be repaired or reinforced from many piers efficiently. In addition, checking whether reinforcing bars are ruptured or not by the magnetic method, which is a non-destructive method for reinforcing bars, it became possible to select the measure efficiently and without damage.

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