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Application of Weathering Steel to Highway Bridges

Application aux ponts routes d'un acier résistant à l'action des intempéries

Verwendung witterungsbeständigen Stahles in Autobahnbrücken

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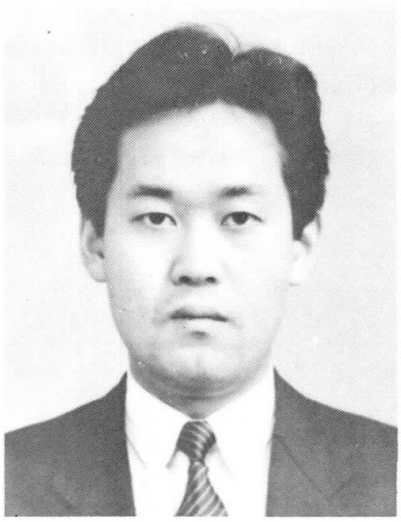

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SUMMARY

This paper outlines the present situation regarding utilization of weathering steel in Japan, the results of exposure tests, and the summary of "The Guideline for Design and Fabrication of Unpainted Weathering Steel Bridges (draft)" prepared by the Public Works Research Institute, the Ministry of Construction.

RÉSUMÉ

Cet exposé présente la situation actuelle de l'acier résistant à l'action des intempéries au Japon, les résultats des essais d'exposition ainsi qu'un résumé du project de "Directives de conception et de fabrication des ponts en acier résistant à l'action des intempéries et non recouverts de peinture", préparé par l'Institut de Recherche des Travaux Publics et le Ministère de la Construction.

ZUSAMMENFASSUNG

Der Artikel gibt einen Überblick über den Stand der Verwendung witterungsbeständigen Stahles in Japan, die Ergebnisse von Verwitterungsversuchen, sowie über die vom Forschungsinstitut für öffentliche Bauten und dem Bauministerium herausgegebenen "Auslegungs- und Herstellungsrichtlinien für wetterfeste Brücken mit Anstrich (Entwurf)".

1. INTRODUCTION

Weathering steel has the property of preventing the further progress of rusting by the formation of a dense and stable rust layer on its surface.
The formation of such a dense and stable rust layer requires a certain environmental condition, such as no adhesion of salt and exposure to repeated drying and wetting, etc. Therefore, in application of weathering steel to highway bridges in rather severe condition of Japan, careful prior examination has to be required.

For this reason, Public Works Research Institute has started the study on application of weathering steel to highway bridges to clarify the suitable environmental conditions for weathering steel bridges and to establish their design and fabrication method. 10 year exposure test of plate specimens has been being carried out at 41 locations throughout the country in this study. The results of the exposure test for the first 3 years were used to prepare "The Guideline for Design and Fabrication of Unpainted Weathering Steel Bridges(draft)" in 1986.

This paper outlines the present situation of utilization of weathering steel in Japan, the results of the exposure test, and The Guideline of Design and Fabrication of Unpainted Weathering Steel Bridges(draft).

2. THE PRESENT SITUATION OF UTILIZATION OF WEATHERING STEEL IN JAPAN

Japan set JIS Standards of weathering steel in 1968,when weathering steel began to be utilized. The JIS Standards include W-type in which weathering steel is used with no treatment or it is used after rust stabilizing surface treatment, and P-type in which it is used after painted, as shown in Table 1.

Table 1 Chemical composition of weathering steel

		Chemical components (%)								
		C	Si	Mn	P	S	Cu	Cr	Ni	Others
SMA 50 A·B·C	W	≦0.18	0.15 ~ 0.65	≦1.40	≦0.035	≦0.035	0.30 ~ 0.50	0.45 ~ 0.75	0.05 ~ 0.30	Chemical elements effective for weather proofing such as Mo, Nb, Ti, V and Zr can be added to any type of weathering steel. However, the total of these elements should not be more than 0.15%.
	P	≦0.18	≦0.55	≦1.40	≦0.035	≦0.035	0.20 ~ 0.35	0.30 ~ 0.55	—	

P-type weathering steel with painting treatment is hardly applied to bridges now because the effect of paint for weathering steel bridges is not sure in comparison with ordinary painted steel bridges.

The rust stabilizing surface treatment is a method to promote the formation of a stable rust layer by covering the surface of W-type weathering steel with porous

film, and the film disappears after the formation of the stable rust layer. This method has been applied to bridges ,as means to control the stable rust layer and to improve the appearance at the early stages of the formation of the stable rust layer. However ,it seems the effect of this method are not clear.

When the poor appearance in the initial stage is allowed and good care is taken to prevent the contamination of the surroundings by the rust film,the use with no treatment is advantageous in terms of the initial cost and the maintenance cost. In the future the use with no treatment is likely to become the main method. The Guideline(draft) mentioned above is also for W-type steel to be used with no treatment.

As shown in Fig.1, the consumption of unpainted weathering steel has increased gradually, and the recent annual consumption reaches approximately 10,000 tons in steel weight or 60 cases yearly.

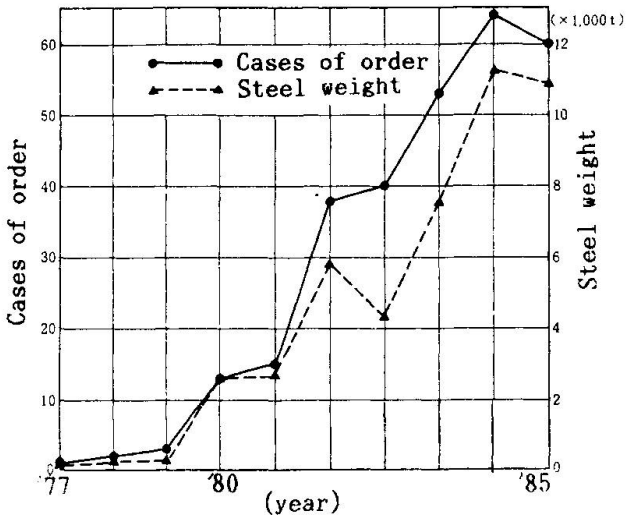

Fig.1 Trend in application of unpainted weathering steel to bridges

3.NATIONWIDE EXPOSURE TESTS OF PLATE SPECIMENS

3.1 Outline of the Tests

3.1.1 Test Specimens

The size of test specimen is 100mm×150mm×8mm, and both the surface and the back are subjected to blasting treatment. The chemical composition of the test specimen meets the JIS Standards.

3.1.2 Environmental Condition at Exposure Locations

The test specimens are placed on actual bridges at 41 locations in different environmental conditions (coastal area, mountainous area, rural area, urban area, and industrial area) extending from Hokkaido to Okinawa. The amount of the airborne salt(NaCl) and the amount of SO_2 were measured for 1 year at the exposure locations in order to examine the relations between these factors and the quantity of corroded weathering steel.

3.1.3 Placement of Test Specimens

The test specimens are placed at lateral bracing in the horizontal and vertical derections, where the corrosive condition is most severe in actual bridges.

3.2 Results of the Tests

3.2.1 Annual Change in Corroded Steel

Typical examples of the results,which were obtained by converting the results of weight analysis of test specimens to the reduction in the plate thickness of one

side of the test specimens are given in Fig.2(a) and (b). Fig.2(a) refers to the annual change in the plate thickness reduction of test specimens exposed in areas along the Pacific coast. The rate of plate thickness reduction proceeds rather quickly. This indicates that the environmental condition of the locations does not allow the use of unpainted weathering steel. Fig.2(b) illustrates the plate thickness reduction of test specimens exposed in the inland rural area. The case of (b) shows less plate thickness reduction in comparison with the case of (a).

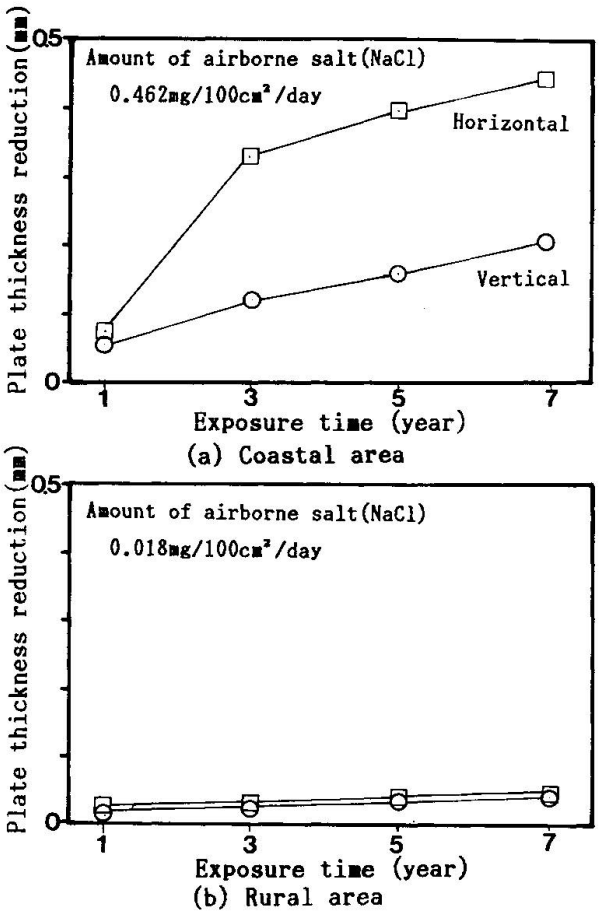

Fig.2 Annual change in plate thickness reduction

Weathering steel can perform its original function by the formation of a stable rust layer. It takes a fairly long time before one can identify the stabilization of rust from testing. In good environmental condition as shown in Fig.2(b),it is assumed that it takes a much longer time before the formation of a stable rust layer,because rusting itself proceeds very slowly.

3.2.2 Relations between Environmental Conditions and the Quantity of Corroded Weathering Steel

The results of the 3 year exposure test indicate that the plate thickness reduction in 50 years assumed by data extrapolation is less than 0.4 mm at 17 locations in mountainous,rural and urban areas,while the total plate thickness reduction after 3 year exposure is more than 0.2mm,or the unstable stratified rust is formed on the steel surfaces at 10 locations in Okinawa,the Sea of Japan coastal areas and the areas facing the open sea. Fig.3 summarizes the results of the exposure tests at 41 locations all over the country;the former areas are marked with a white circle. The latter areas are marked with a black circle. Other unclassified areas which do not belong to either of them are marked with a black dot.

Broadly speaking, the following can be conducted as to environmental conditions: The environmental condition in Okinawa,the Sea of Japan coastal areas and the Pacific coast areas facing the open sea is generally unsuitable for weathering steel bridges. In particular,in the Sea of Japan coastal areas,the areas placed fairly distant from the coast even in a plain,if it opens in the seasonal wind direction, are unsuitable. In contrast,in mountainous areas excluding Okinawa, and plains excluding the above,many of them are suitable. Further obsevation of

the future exposure tests results is necessary for judgement at the locations which are close to relatively calm sea such as Setouchi Inland Sea.

Fig.4(a)and (b) show the relations between the amount of NaCl, and the amount of SO_2 and the plate thickness reduction after 7 year exposure. The classification of the marks used in these figures is same as those used above. These figures indicate the plate thickness reduction correlates much with the existence of airborne salt and less with the existence of SO_2 in their environment.

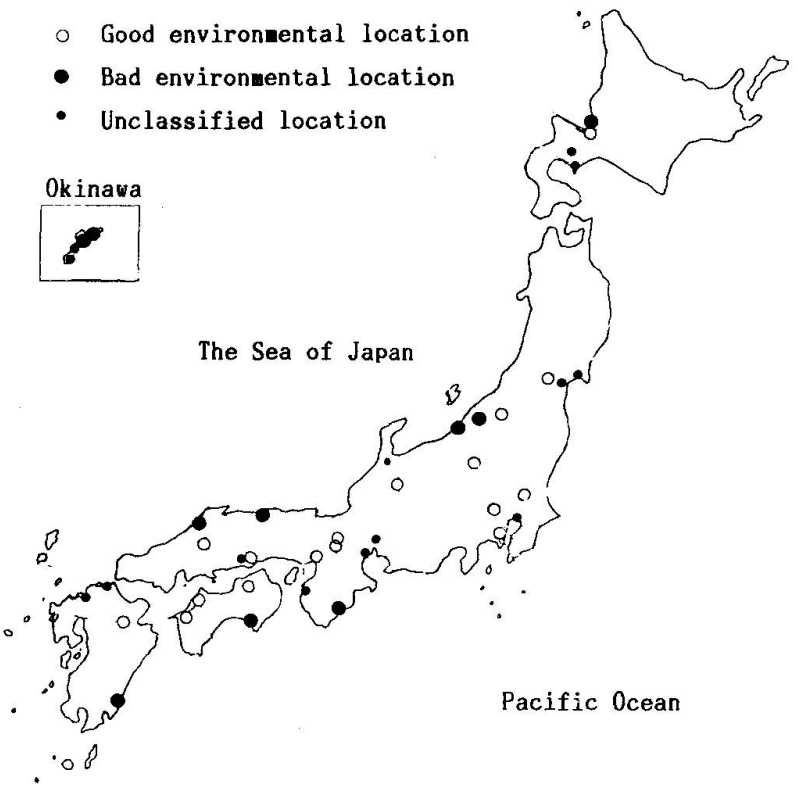

Fig.3 The results after 3 year exposure

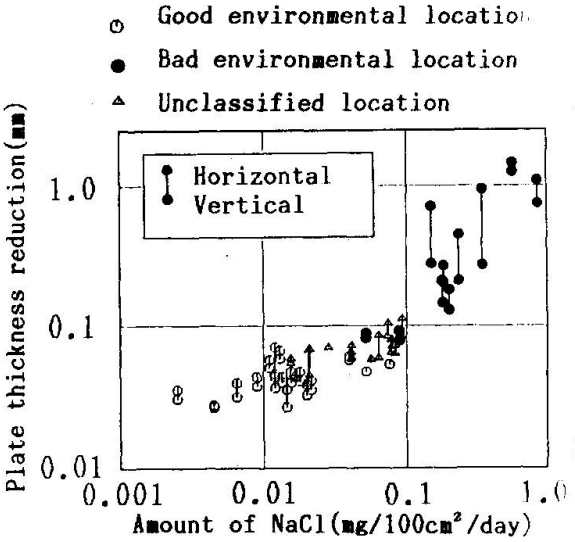

Fig.4(a) The relation between the plate thickness reduction after 7 years exposure and the amount of NaCl

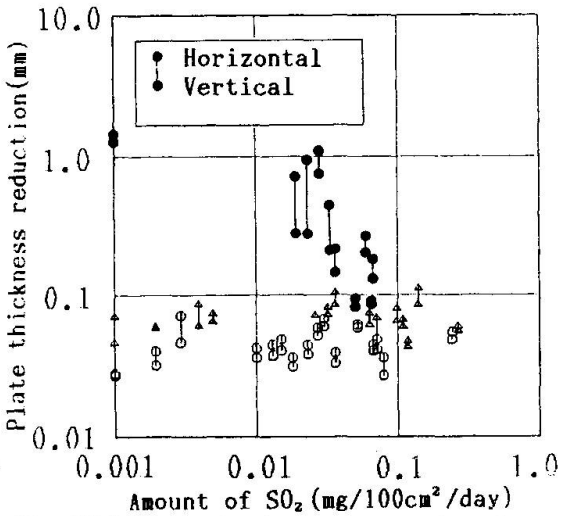

Fig.4(b) The relation between the plate thickness reduction after 7 years exposure and the amount of SO_2

Besides,Fig.5 shows the relation between the linear distance of exposure locations from the shoreline and the plate thickness reduction. This figure suggests that the plate thickness reduction correlates with the distance from the shoreline.

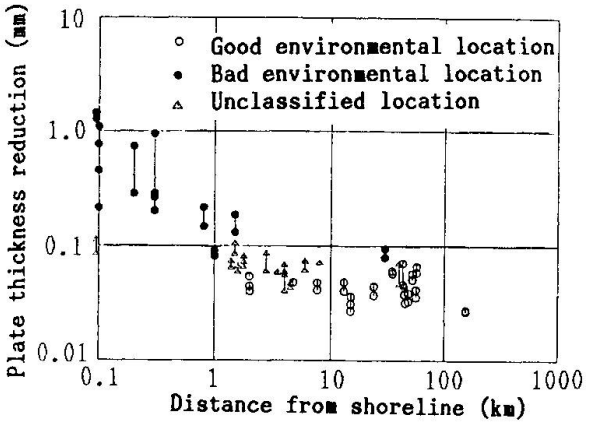

Fig.5 The relation between the distance from the shoreline and the plate thickness reduction after 7 years exposure

4.THE GUIDELINE FOR DESIGN AND FABRICATION OF UNPAINTED WEATHERING STEEL BRIDGES(DRAFT)

The Guideline(draft) was prepared in 1986 based on the results of the 3 year exposure tests as reference information for application of unpainted weathering steel to bridges.The Guideline(draft) is a kind of interim report in the 10 years program. In the Guideline(draft),area of country was divided into following 3 categories;

1)Area where the effect of airborne salt is minor and unpainted weathering steel can be used
   a)Mountainous areas
   b)Rural areas and Urban areas(but coastal areas and plains opening towards the sea are excluded)
2)Areas where unpainted weathering steel can not be used because of serious effect of airborne salt.
   a)All of Okinawa
   b)Japan Sea coast areas and other areas facing the sea directly

The basic ideas for dividing areas is given below:The plate thickness reduction in 50 years at 41 locations is assumed by extending the linear line intersecting the plate thickness reduction in 1 year and that in 3 year. Taking account of the fact that the rate of the plate thickness reduction gets smaller with the lapse of time, this assumed value gives a figure on the safe side. When the plate thickness reduction after 50 years is equal or less than that due to the formation of a stable rust layer,then there is no serious problem even if the rust is not yet stabilized. It has been recognized that the formation of a stable rust layer results in the plate thickness of approximately 0.1~0.2mm even in an good environmental condition. In the Guideline(draft), the limit was set as 0.4mm in consideration of the measuring precision of the plate thickness reduction, and suitable areas is thus judged. On the other hand, when the plate thickness reduction after 3 year exposure exceeds that(0.2mm) due to stable rust, or unstable stratified rust can be seen by the serious effect of airborne salt,we can not expect the formation of a stable rust layer, and non-suitable areas are thus judged.

The guideline(draft) also mentions the notice on design and fabrication of unpainted weathering steel bridges.