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Artikel: Quality requirements of corner welds of truss chord members

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Total Weight of Quenched and Tempered High-Strength Steel: 21,000 ton

Total Length of Exermined Corner Weld of Main Truss Chord Members: 58,000m (3 Suspension Bridges and 2 Cable Stayed Bridges in Kojima-Sakaide Route of Honshu-Shikoku Bridges)

Quality Requirement of Corner Weld of Truss Chord Members

Honshu-Shikoku Bridge Authority

The Honshu-Shikoku Bridges include many long, large bridges for combination road/railway use that use a great deal of quenched and tempered high-strength steel which was previously not often used in railway bridges. Also, in the particular case of stiffening girders of suspension bridges, since the ratio of the live load stress was greater, close examinations were carefully conducted as to the fatigue due to repeated loading of trains. As one of such examinations, a large-scale fatigue test was carried out on approximately one-third models of the truss panel (Photo 1). As a result, it was found that the fatigue strength would be reduced by reason of the micro welding defects, such as blowholes in the corner joints of box-section members.

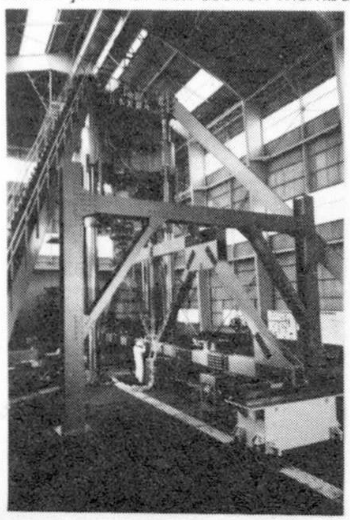

Photo 1 Large Scale Fatigue TEST

Following the aforementioned a relationship between the blowhole dimensions and the fatigue life was found, based on the test results and calculation by fracture mechanics (see Fig. 1). By comparing the results with the design fatigue-life curves allowable dimensions for blowholes has now been determined, considering the working stress (Table 1).

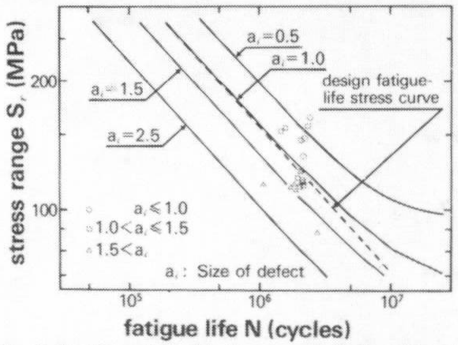

Fig. 1. Predicted S_r–N_p Curves and Test Results

Table–1 Quality Requirements

Size of defect \ Classification	Special A Member	A Member	B Member	Remarks
Minor axis (mm) (W size)	1.5	3.0	6.0	H W
Major axis (mm) (H size)	1.0	6.0	6.0	
σ_r/σ_a	0.7≤	0.5~0.7	0.5>	

σ_r: Working stress range
σ_a: Allowable stress range

During fabrication, all possible occurrence of welding defects has been avoided, by carrying out severe control in welding condition, root gap, cleanliness of the groove face, and so on. Moreover, the suitability of fabricating conditions has been efficiently confirmed, by making actual-sized pilot members prior to the fabrication of the members. At the same time, a nondestructive examination was performed by means of automatic ultrasonic equipment (Photo 2), and when any defects of greater dimensions than the allowable ones were detected, they were soon repaired.

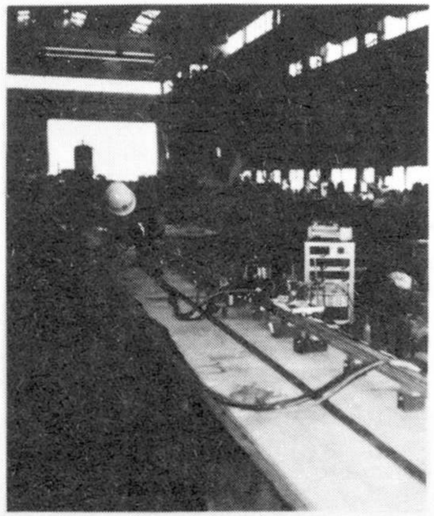

Photo 2 Nondestructive Examination

Quality Requirement of Corner Welds of Truss Chord Members

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1. Introduction

As the Honshu-Shikoku Bridges consist of many large bridges for combined highway and railway use and which use an enormous quantity of quenched and tempored high strength steels that have not often before been used for railway bridges, it was important to examine the fatigue strength due to the running of trains. As a part of the examination a large scale fatigue test was performed, and as a result, it was found that welding defects in the corner joints of the chord members greatly reduce the fatigue strength. These results were reflected in the design and fabrication of large bridges for combined highway and railway use. This report describes the summary of the process thereof.

2. Examination of fatigue

The Kojima-Sakaide route and the Ohnaruto Bridge of the Honshu-Shikoku Bridges are combined highway and railway use. There are three suspension bridges (span: 230 + 940 + 230, 274 + 990 + 274, 274 + 1,100 + 274 m), two cable stayed bridges (span: 185 + 420 + 185, 185 + 420 + 185 m) and truss bridges in the Kojima-Sakaide route, and the Ohnaruto Bridge also is a suspension bridge (span: 330 + 876 + 330 m). These bridges contain an enormous quantity of quenched and tempered high strength steel (580 - 800 MPa class), reaching as much as 21,000 tons for the suspension and cable stayed bridges of the Kojima-Sakaide route alone. During the planning stage there was insufficient data available on the fatigue tests of quenched and tempered high strength steel, requiring verification of the fatigue strengths of various joints. Taking into account the magnitude of the Honshu-Shikoku Bridges, it was considered necessary to perform the examination considering the size effect, welding conditions, etc. Therefore, a fatigue testing machine, with a maximum dynamic loading of 400 tons, was manufactured and fatigue tests were performed.

This large scale fatigue test was performed using large scale specimens of various joints and partial structural specimens of nearly the same size as the actual members. As a result of the fatigue tests performed on an approximately one-third model of the truss panel (phot 1 in poster), it was verified that the fatigue strength greatly decreases due to welding defects in the corner joints of the chord members, such as root blow-holes, lack of penetration, drooping, etc. Reflecting these results, from the relationship between the fatigue life and defect size calculated based on the fracture mechanics and from the results of the test, the allowable size of welding defects was determined. (Fig.- 1, Table- 1 in poster).

3. Fabrication

As the allowable welding defect size determined from the test results, etc. was extremely small, the measures to be taken to prevent the welding defects from occurring were examined, the main items of which are as shown below.

1 Thoroughly clean the groove face and adjacent area, and when using a grinder, match the grain of the grinder with the direction of the welding line.

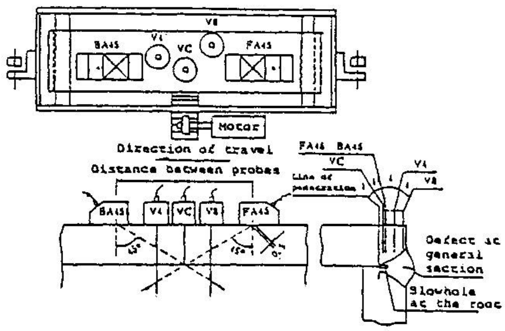
2 When assembling, the root gap must be smaller than 0.5 mm after tack welding.

3 Pay attention to the selection of welding methods and welding conditions such that the tack weld can be completely rewelded and pay attention to the device, etc. used for stable welding condition.
For fabrication, control items and execution procedures were laid down for each fabrication process. Also, prior to the fabrication, a welding test was performed using actual size pilot members and the adequacy of the welding method in meeting the required quality was confirmed.

4. Nondestructive inspection

Nondestructive inspection of the fabricated members was performed and the members were repaired as necessary. An ultra-sonic defect probing device was employed in the nondestructive inspection, as it was difficult to apply the radiograph test because the members have box-shaped sections. However, conventional ultra-sonic defect probing is not aimed at detecting the micro-defects that are subject of this test nor has it the recording capability. Therefore, a new ultra-sonic defect probing system was developed, eight types of which were recognized to have sufficient capability to probe the defects, and these were used for the inspection of members. The required capability was that the system must have an accuracy to detect defects of size W (refer to Table-1 in poster), i.e. = 1.5 mm in diameter with n ± 0.8 mm.

An automatic ultra-sonic defect probing system can be operated automatically, and divided into two by the traveling method. One is the type that traces the weld line and the other scans the weld in a zigzag course. Both types use more than one probe, and by adopting the combined use of a vertical probe and an ablique angle probe, in addition to using a focus type probe, an improvement in probing capability was attempted.
Fig-1 shows an example of probe position.



(Example of probe position)

VC	Vertical probe to detect penetration
V4,V8	Vertical probe for general section
FA45	Forward oblique angle probe at the root
BA45	Backward oblique angle probe at the root

Fig-1 Example of probe position

5. Results of fabrication

As an example of the results, Table-1 shows the results of the nondestructive inspection of a cable stayed bridge. The occurrence rate of welding defects was controlled to 0.12 - 0.13/m and they were all micro-defects, allowing us to consider that high quality welding was obtained.

Table-1 Results of Automatic Ultra-sonic Defect Probing

	Stress level	Size of defect							Number of defects per length inspected No./m
		W dimension (mm)			H dimension (mm)				
		0.5 - 1.5	1.6 - 3.0	3.1 -	1.0 - 2.0	2.1 - 4.0	4.1 - 6.0	6.1 -	
Corner weld	Special A	11	2	0	9	1	3	0	$\frac{13}{217}$ = 0.06
	A	73	13	1	62	19	6	0	$\frac{87}{610}$ = 0.14
	B	19	0	0	7	12	0	0	$\frac{19}{76}$ = 0.25
	Total	103	15	1	78	32	9	0	$\frac{119}{903}$ = 0.13
Fillet weld	Special A	69	5	0	61	12	1	0	$\frac{74}{217}$ = 0.34
	A	26	3	0	26	3	0	0	$\frac{29}{610}$ = 0.05
	B	4	3	0	4	1	2	0	$\frac{7}{76}$ = 0.09
	Total	99	11	0	91	16	3	0	$\frac{110}{903}$ = 0.12

6. Conclusion

As mentioned above the design and fabrication was performed based on the results of the fatigue examination performed in advance. However, the role to be played by the checking and inspection of the bridge after it opens to traffic is considered important. Therfore, while arranging and storing the results of the non-destructive inspection performed at the time of fabrication, so as to create a valuable reference for the maintenance of the bridge, are promoted, the establishment of an inspection system by which a fatigue crack can be detected while it is still small and a method of repairing fatigue cracks are also being promoted.