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Quality Control of a Double Deck Railway Bridge in Steel

Contrôle de la qualité d'un pont de chemin de fer à double tablier

Qualitäts-Kontrollen beim Bau einer Doppeldeck-Eisenbahnbrücke aus Stahl

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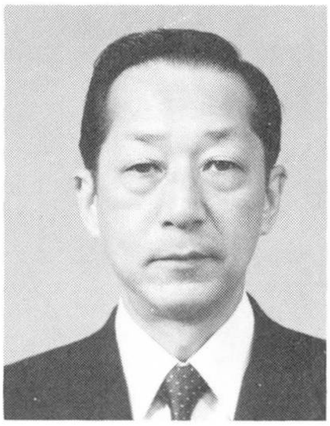

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SUMMARY

This was the first triple-main-truss railway bridge with a double steel deck built in Japan. During the fabrication of this complex structure, quality control was performed to assure the safety, giving priority to maintain both the finishing accuracy of each member and high quality in welding. The method and procedure of fabrication were devised to give the required quality. Excellent results were efficiently achieved.

RÉSUMÉ

Il s'agissait du premier pont de chemin de fer à trois fermes principales et à double tablier supérieur construit au Japon. Au cours de la construction d'une structure aussi complexe, un contrôle de la qualité a été effectué afin d'assurer la sécurité, l'objectif principal étant d'obtenir une grande précision de finition de chacune des membrures et des soudures de qualité supérieure. Les méthodes et procédés de construction ont été établis afin d'obtenir le niveau de qualité requis. Des résultats extrêmement satisfaisants ont été obtenus.

ZUSAMMENFASSUNG

Die als Beispiel dienende Eisenbahnbrücke aus Stahl ist die erste in Japan gebaute Doppeldeck-Brücke mit drei Fachwerk-Hauptträgern. Während des Baus dieser komplexen Konstruktion wurden Qualitäts-Kontrollen zur Gewährleistung der Sicherheit durchgeführt, wobei die Einhaltung der vorgeschriebenen Fertigungsgenauigkeit der einzelnen Teile und der Qualität der Schweissnähte Vorrang hatten. Zur Erreichung der geforderten Qualität wurden neue Methoden und Herstellungs-Verfahren eingesetzt, welche in effizienter Weise ausgezeichnete Ergebnisse erbrachten.

1. PREFACE

The Dai-ichi Yumenoshima Bridge on the Keiyo Line, Japanese National Railways (JNR), is a steel railway bridge spanning National Route 357 at Yumenoshima, Tokyo, Japan. It is a double-decked truss bridge having a double track line and an end part of a passenger platform on each deck (See Fig. 1). This railway bridge is the first one of its type built in Japan.

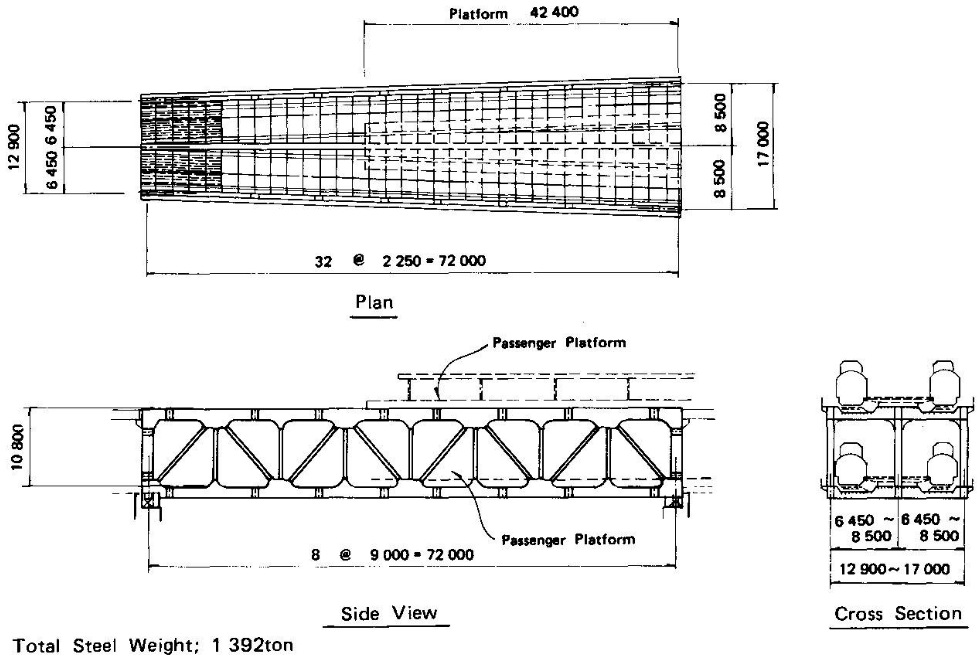

Fig. 1 General View

The major characteristics of the bridge are as follows:

- The triple main truss structure type was selected taking the various conditions on substructure works and the economic efficiency into account.
- The plan of the bridge has a trapezium shape with its width enlarged toward one end to provide an end part of a passenger platform between the tracks.
- For the prevention of noise, a steel deck using a ballasted floor system was adopted. And the floor was designed to have shallow depth.
- As the member forces of each structural member was expected to be significantly large because of the live loadings on the upper and lower double track lined decks, the web members were designed to be spliced on four planes at each panel point.
  Furthermore, a careful check for the fatigue strength was made for each structural member.

Generally, it is quite important to prevent fatigue failure in the case of steel railway bridges because of the number of stress cycles with large amplitudes due to the repetition of live loadings is more than those of any other steel structure.
Especially as this triple-main-trussed double decked and an unsymmertical bridge had such a complex structures, the utmost safety investigation including a three dimensional analysis of the framework and stress analysis of panel points by means of FEM was carried out at the design stage.
The following is a report of the quality control activities that were achieved, reflecting the intentions of the purchaser, Japan Railway Construction Public Corporation (JRCC), during fabrication.

2. PRODUCTION POLICY AND QUALITY CONTROL

In the production of the bridge, JRCC specified the testing, inspection and quality assurance in detail, based upon Japan Railway Standards (JRS) 05000-1, "Fabrication of Steel Bridges." Furthermore, JRCC had discussed the structural peculiarities of the bridge with the fabricator and established a special fabrication procedure before the commencement of production.
In the abovementioned procedure, careful attention was paid to following items:

2.1 Priority control

2.1.1. Pursuit of dimensional precision

The bridge was a highly complex structure consisting of a huge number of members, joints and connecting bolts and had to have high rigidity. To ensure the design strength and safety of the structure, it was essential that the members be assembled precisely and smoothly. For this reason, the rigorous dimensional precision of each member was pursued to the extreme.

2.1.2. Stringent quality control in welding

For the sake of safety assurance against fatigue failure due to the large number of repetitions of live loadings, special attention was paid to the welding and finishing method at the panel points (especially to fillets) and the welding continuity where stringers cross floor beams.

2.2 Quality control program

In addition to the inspections by JRCC that included mold loft inspection, material inspection, parts inspection, and shop assembly inspection, the fabricator carried out various autoromous quality control activities

2.2.1 Work procedure

A work procedure was established for each production step to assure the quality of products.

2.2.2 Quality control by shop workers

For each production step determined by JRCC, the production staff of the fabricator provided detailed check sheets which clarified and detailed the production procedure, designed dimensions and shapes and given standards, etc. The shop workers autonomously managed the quality control of each product.

2.2.3 Independent inspections

At each major production step, fabricator's quality control specialists executed various inspections such as material inspection, mold loft inspection, bead test, parts inspection, shop assembly inspection, and others.

2.2.4 Investigation of Q.C. team

The managers and production engineers of the fabricator had organized a quality control team and investigated the production shop regularly to verify the achievements of autonomous quality control activities and to give the appropriate instructions.

2.3 Policy in establishment of production procedure

The following procedures were established to efficiently satisfy JRCC's quality requirements without producing any delay in the given production schedule.

2.3.1 Dimensional precision

To minimize the adjustment or modification at the stage of trial assembly of the bridge, stringent dimensional precision of each member was pursued to be extreme for each production step.
For example, Table 1 shows the cutting and boring procedures.
Furthermore, the most suitable fabrication sequence and special jigs were carefully devised.

Table 1 Cutting and Boring of the Pieces

		Cutting			Boring		
					PRE-STAGE		POST-STAGE
		Numerical Control (NC)	Flame Planer (F/P)	Automatic Gas	NC	Girder Type	NC or Compressed Air type
Main Chord	Web PL.	O				O	
	Flange PL.		O	O		O	
	Brakets	O				O	
	Diaphragm	O					
	Splice PL.		O	O	O		O (NC)
Floor system	Deck PL.		O	O		O	
	Stringers		O	O		O	
	Floor Beam	O					O(Air)
	Splice PL.		O	O			

2.3.2 Quality control in welding

Every possible potential problem was carefully forecast and solved prior to the actual welding work. In particular a mock up trial was carried out to determine the fabrication and welding sequence of the steel deck.

3. FABRICATION OF MAIN TRUSS AND STEEL DECK

3.1 Fabrication of main truss

Fig. 2 shows a typical block of chord members. To ensure the smooth distribution of stress at the panel points, web members were designed to be spliced on four planes. The following fabrication procedures were executed in order to satisfy the target tolerance (± 1.5 mm) for both each block length and the diagonal length of the gross section of each member.

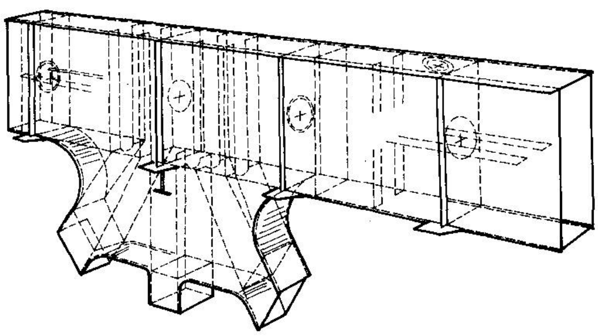

Fig. 2 Block of Upper Chord

- A NC machine was employed to mark and cut the web plates and the gusset plates of the panel points. Prior to cutting, the cutting lines, water-lines and boring positions were checked and confirmed.

- To match the hole positions, pairs of gusset plates were precisely layered and bored to the same size.
- After welding the web plates and gusset plates, the pair of welded members were again layered to reconfirm the dimensions of the hole and check the welding distortion.
- The bolt holes at one end of each block were bored at the stage of piece cutting. The ones at the other end of each block were bored after the abovementioned dimensional reconfirmation.
- To ensure the precision of the sectional dimensions of block, each diaphragm was machined on all four sides to precise dimensions. Furthermore, similar machine - finished temporary diaphragms were set with bolts at each end of the block when the pieces were assembled (See Fig. 3).
- The fillets of panel points were well welded and finished (See Fig. 4).
- Each end face of blocks was machine finished to ensure the designed dimensional precision.
- After machine finishing, the actual dimensions and the location of the bolt holes were carefully measured. A high speed NC boring machine programed with such measured data was employed to bore the splice plates.

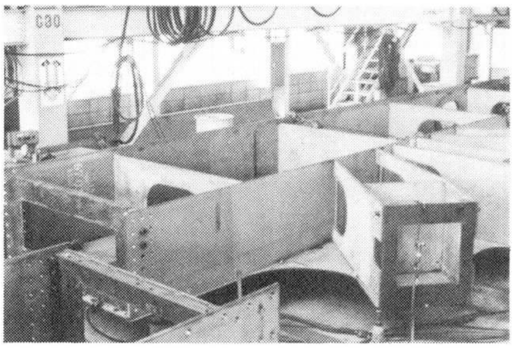

Fig. 3 Shop Assembly of Main Chord

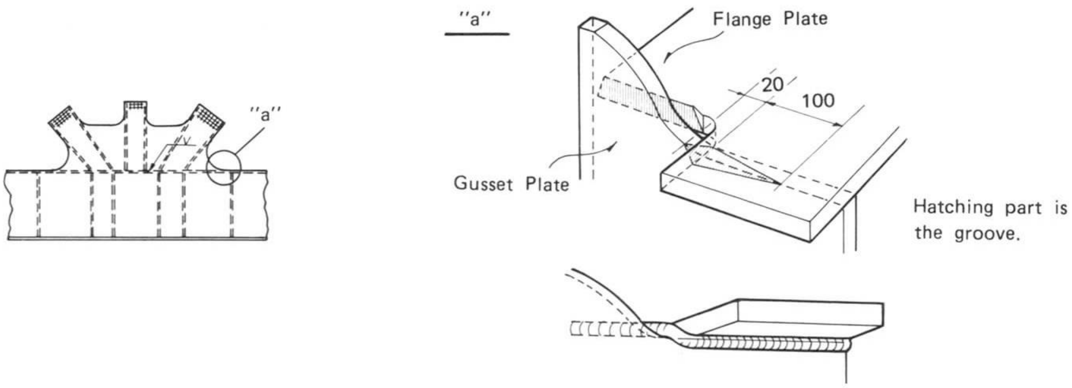

Fig. 4 Details of the Fillet for Welding

3.2 Fabrication of steel deck

Fig. 5 shows a typical block of the steel deck. The block has joints on four sides and the directions of the bend line on both sides are not in parallel. The following delineates the fabrication procedure of the steel deck block.

- After cutting of the deck plates a NC styler was laid on the plate to confirm the designed shape and the bending and boring positions. Then, bolt holes except those to be located at the bends, were bored

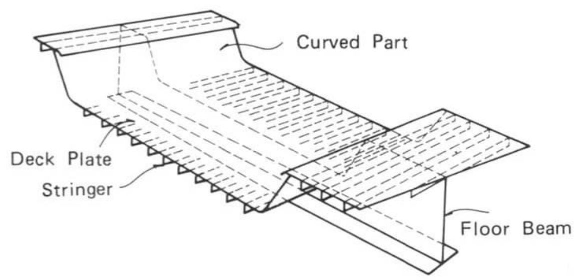

Fig. 5 Block of Steel Deck

before the cold bending of the plate. The bolt holes on the bends were bored during trial assembly of the bridge, considering the tight fitness with splice plates.
- A NC machine was employed for the cutting of the web plates of the floor beams to ensure precision of shape, dimension and root gap of the many slits where stringers crossed floor beams (See Fig. 6).
- Three to six contiguous steel decks were progressively set on the surface plate and assembled to eliminate the deformation of steel deck and ensure the precise facing to the contiguous blocks (See Fig. 7).
- The continuity of welds between the stringers and the deck plate at the crossing point of stringers and floor beams was well ensured as shown in Fig. 8.

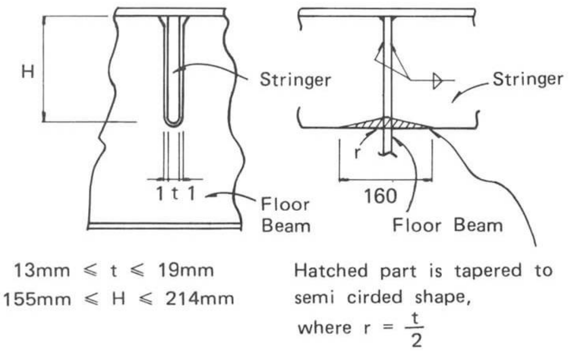

Fig. 6 Details of Slit Where Stringer and Floor Beam Meet

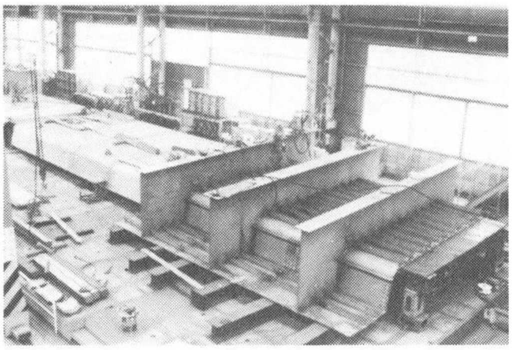

Fig. 7 Assembling of the Blocks

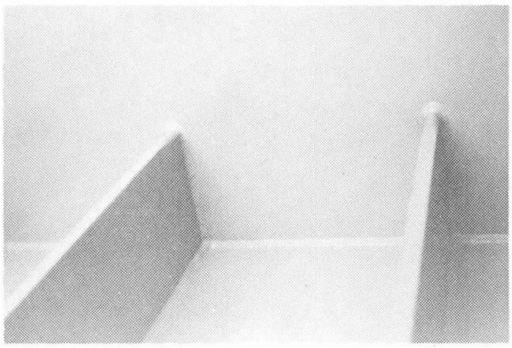

Fig. 8 Weld at the Slit

- To ensure the straightness of the longitudinal axis of each chord, bolt holes of the joints of the floor beams and the main truss were marked and bored after welding was completed. The target tolerance for the distance between both end holes of the floor beam was ± 1.5 mm.

4. POSTSCRIPT

Owing to the appropriate instructions of JRCC and the utmost quality control efforts of the fabricator, the rigorous precision of frame works shown on Table 2, and a high reliability of welding was achieved.
The erection of the Dai-ichi Yumenoshima Bridge was performed in due course and completed in 1986.

Table 2 Comparison Table of Tolerance Values (JRS) and Measured Values

Item	Tolerance (JRS)	Measured Value	
		Range	Mean Value
Span Length	$\pm(5 + 0.15L)$ $= \pm 15mm$	+1 ∿ +2mm	1.6mm
Straightness of the Chord	$(3 + 0.1L)$ $= 10mm$	-5 ∿ +4mm	-0.4mm
Height of Main Truss	$\pm(4 + 0.5H)$ $= \pm 9.4mm$	-1 ∿ +4mm	1.47mm
Width between Main Trusses	$\pm(3 + 0.5B)$ $= \pm 6$ ∿ 7mm	-5 ∿ +5mm	0.78mm
Camber	(+) 3 + 0.15L (−) 3 + 0.05L = -6 ∿ 12mm	-3 ∿ +7mm	2.35mm

L: Span Length 72m, H: Height of Truss 10.8m
B: Width between Main Trusses 6.45 ∿ 8.5m

5. ACKNOWLEDGEMENT

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