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Nearly 90% Mechanised Bridge Welding

Soudage de pont, automatique ou semi-automatique à près de 90%

Zu fast 90% mechanisierte Schweißarbeiten im Brückenbau

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1. Fabrication Was Carried Out Almost Entirely by Welding

The Unionmelt welding method was freely used, not only in the butt welding of the plates, but also in the fillet welds, using various types of jig (Photograph 1).

According to the actual work already done by the Yokogawa Bridge Works, nearly 50% of the entire welding operations had been made automatic, but the rest had remained non-automatic, and still depended upon manual welding methods. But since 1954, the E. H. method (Photograph 2), which is a kind of semi-automatic welding method, has been adopted in such welding work as the welding of the longitudinal ribs of the box girders to the steel deck.

Furthermore, in addition to the adoption of the Arcos Welder (Photograph 3), a semi-automatic welding method using CO_2 gas and a sliding-holder-semi-automatic process, which is a type of semi-automatic welding process of Japanese invention, have come into increasing use since 1959.

Since 1961, semi-automatic welding methods, such as the Unionarc (Photograph 4) and the Philip methods, have been used in appropriate places and work which was formerly dependent upon manual welding has been made

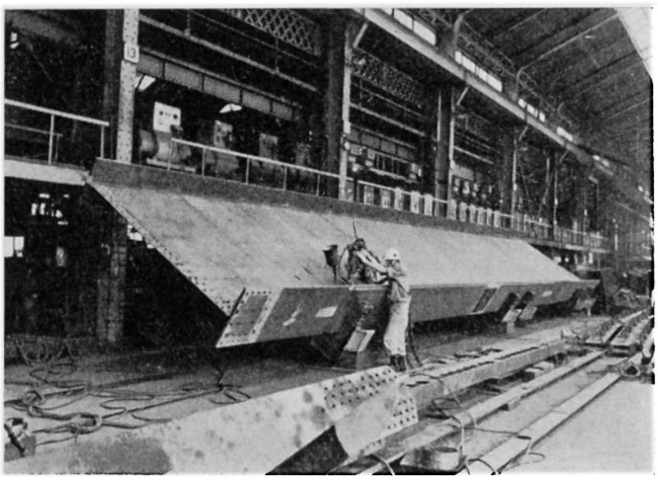


Photo 1.

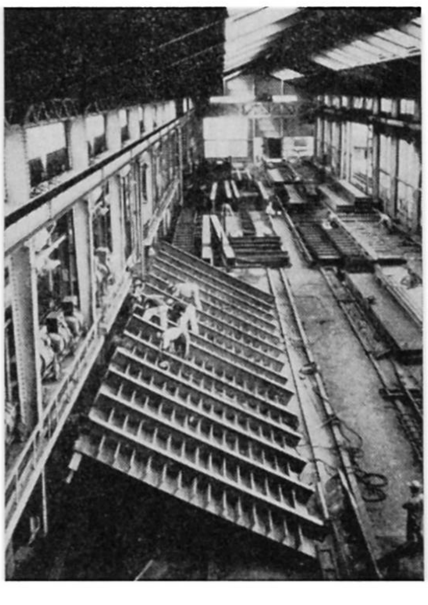


Photo 2.

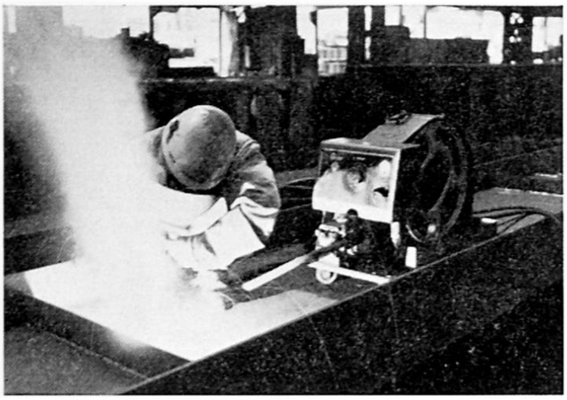


Photo 3.

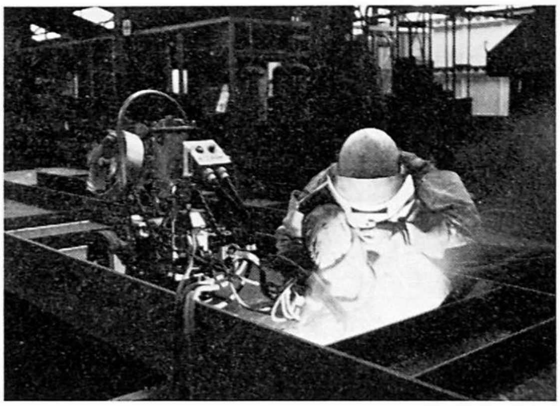


Photo 4.

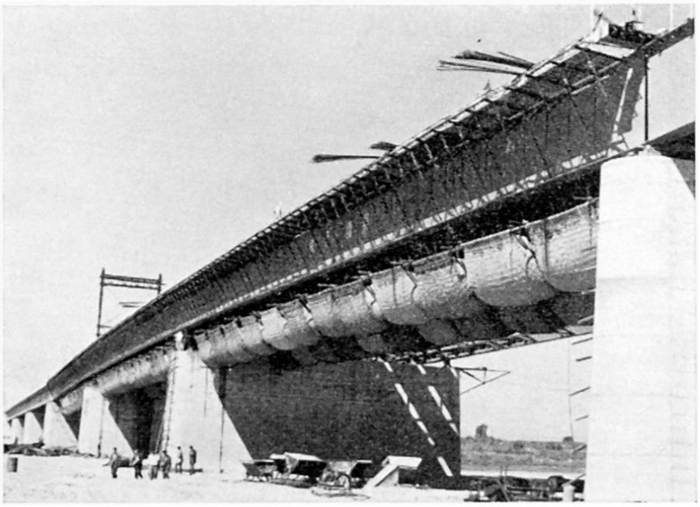


Photo 5.

semi-automatic. Consequently, nearly one-half of the welding work carried out in the factory is now undertaken by automatic and semi-automatic welding methods.

At present, the operation of semi-automatic welding methods using CO_2 gas is somewhat complicated, although there is some difference in the degree of complexity according to the process employed. In addition, the appearance of the beads is not entirely satisfactory. If an all-purpose welding machine could be devised by means of which the above-mentioned disadvantages could be removed and any simple and easy welding operation could be performed economically, 100% of the welding work on steel bridges could be mechanised.

2. Welding Work on the Kisogawa Bridge

2.1. Synopsis

As an example of bridges to which automatic, or semi-automatic welding has been applied, we shall take the Kisogawa Bridge on the Nagoya-Kobe trunk road.

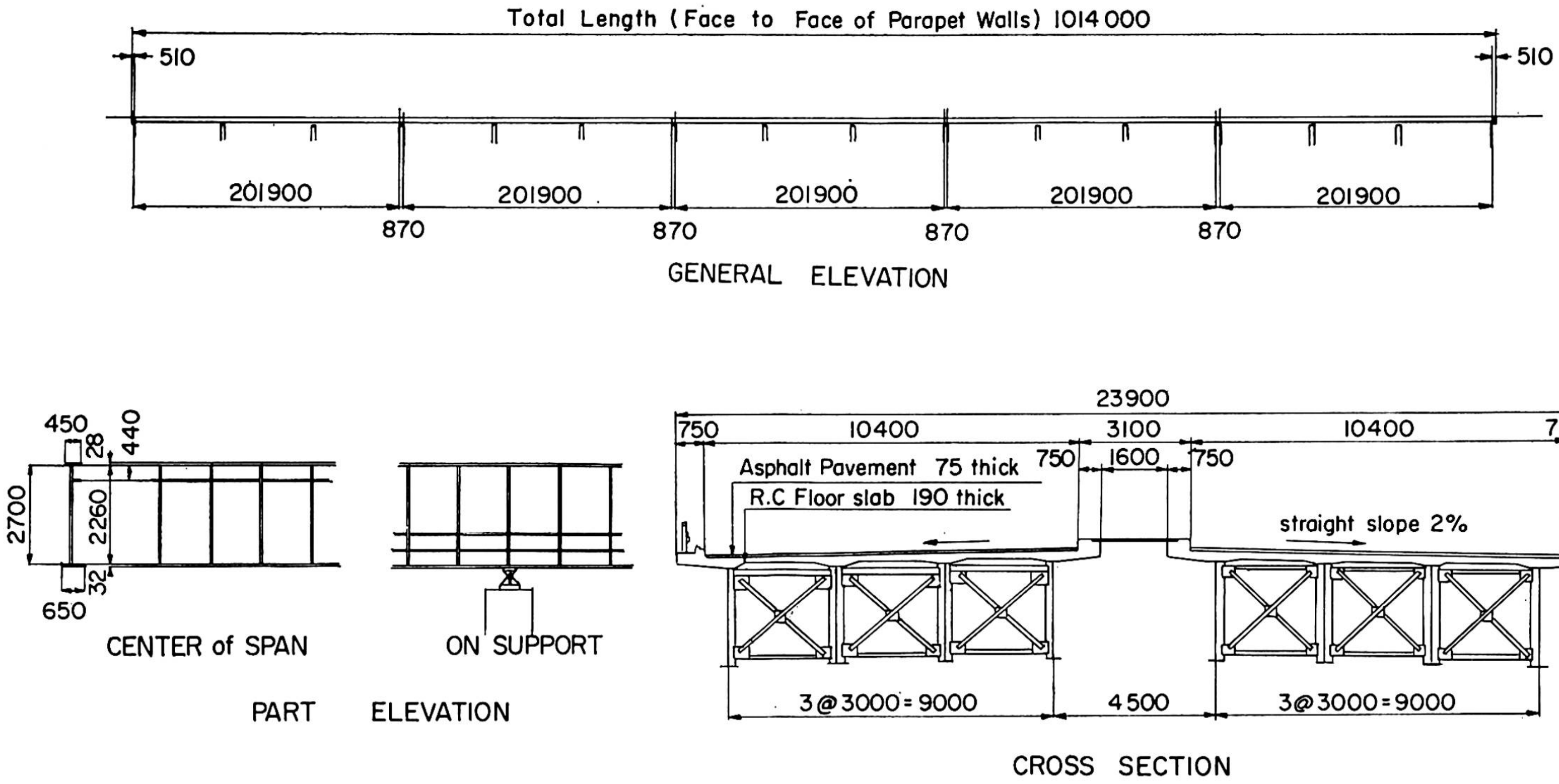


Fig. 1. Outline of super structure.

Table 1. List of Materials Used in the Superstructure of the Kisogawa Bridge

Materials	Weight (t)	Use	
SS-41	648.3	handrail, lateral bracing, sway bracing	Steel structure
SM-41 A	530.9	main girders	
SM-41 B	75.6	main girders	
SM-50 B	3250.2	main girders	
HT-60	1164.2	main girders	
SV-34	10.7	rivets	
SV-41 A	21.9	rivets	
SC-46	132.4	shoes	
S 20 C	50.3	roller	
cast iron	8.8	drainage	
SUS 22 (stainless steel)	1.4	drainage	
high strength bolts	4.7	joints in field	
Total	5899.4		
SS-41	1019.1 t	reinforcing bar	Deck slab
piano wire	76.9 t	Freyssinet cable	
concrete ($28 = 400$ kg/cm^2)	5524 m^3	deck slab	

Table 2. Combinations of Welding Materials

Welding method	Electrode or wire		Flux		Base metal	Type of weld
	Brand	Dia.	Brand	Mesh size		
Manual	B-17 TB-24	4—5 mm			SS 41 SM 41	fillet
	LB-55 L-55F	4—5 mm			SM 50 SM 50 + (SM 41, SS 41)	fillet
	L-60	4—5 mm			HT 60 HT 60 + SM 50 HT 60 + SM 41 HT 60 + SS 41	fillet
Union-melt	Y-C	$^5/_{32}''$ $^3/_{16}''$	YF-15	20×206 $20 \times D$	SM 50 SH 50 + SM 41 HT 60 HT 60 + SM 50	butt and fillet
Unionarc	Y-A	$^3/_{64}''$	C.S	$20 \times D$		fillet

Fig. 1 shows an outline of the superstructure of the Kisogawa Bridge. This bridge consists of five, 3-span, twin continuous composite girders, each having a width of 10.4 m, a span of 67.3 m, and a total length of 1014 m.

As this bridge is a continuous composite girder structure, prestressing of the concrete slab was necessary. This prestressing had to be given by jacking up and down of the intermediate supports and by means of the Freyssinet system. In addition, a special process was adopted for placing the concrete slab.

2.2. Material Used for the Kisogawa Bridge

Table 1 shows the type and quantity of the material used for the girders and the deck slab of the bridge. Table 2 shows the brands of the electrodes, welding wires and fluxes that were employed and the purposes for which they were used.

The welding methods were as follows: The Unionmelt method was applied to all the butt welds and to the fillet welds connecting the flange plates with the web plates; the Unionarc method was employed for the welding of the stiffeners and the gusset plates; and manual methods were used for the remaining welds.

2.3. Use of HT 60

For this bridge about 1,200 tons of 60 kg/mm^2 class high-strength steel, WEL-TEN 60, strengthened by quenching and tempering were used. Prior to its use, the welding methods, electrodes, fluxes, CO_2 gas, pre-heating temperature and other conditions to be adopted had been determined by carrying out various kinds of tests and, at the same time, the properties of the steel material were closely studied.

The chemical compositions of the steel plates, 32 mm and 13 mm thick, are shown in Table 3, and their mechanical properties in Table 4.

To check the weldability of the steel, mechanical tests were carried out on butt and fillet welded specimens.

Table 3. Chemical Compositions of HT 60 Plates (%)

Thickness (mm)	Analysis	C	Si	Mn	P	S	Cr	Ni	V	Equivalent carbon value
32	ladle	0.13	0.41	1.20	0.013	0.008	0.21	0.05	0.09	0.397
	check	0.14	0.45	1.20	0.018	0.004	0.21	0.04	0.013	0.403
13	ladle	0.12	0.44	1.18	0.011	0.009	0.19	0.05	0.09	0.381
	check	0.13	0.50	1.18	0.014	0.006	0.20	—	0.013	0.368

Table 4. Mechanical Properties of HT 60 Plates

Thickness (mm)	Tensile test			Bending test	Charpy test kg'm/cm² 0° C
	Yield point (kg/mm²)	Tensile strength (kg/mm²)	Elongation (% l = 200)		
32	51	61	21	good	24.9
13	52	60	15	good	14.8

2.3.1. Hardness test: This test was conducted with 32 mm plates processed by manual and Unionmelt welding methods, with various wire-flux combinations, and varying the temperature of the base metal.

With regard to the 13 mm plates, manual welding, Unionmelt and Unionarc methods were tested, with variations in the welding conditions.

Only in the case of combinations of 32 mm plate, 0° C and manual welding was a value of $Hv\,350$ exceeded (max $Hv = 380$). In the other cases the Hv value was 310 at most. In this bridge all the welding of thick plates was done by automatic methods, so that no difficulties arose. It was necessary to preheat the plates to 80° C by hand. With regard to the 13 mm plates, preheating was not necessary.

2.3.2. Tests on butt welded joints. The 32 mm and 13 mm plates were welded by the Unionmelt process, varying the edge preparation and the number of passes.

The test results on free bend, side bend and V-notched Charpy test specimens were all good, and we selected the best combination of wire and flux (Table 2).

In the Charpy test at 0° C, we found the values 11.4 kg′ m/cm² for the deposited metal and 24.0 kg′ m/cm² for the heat affected zone.

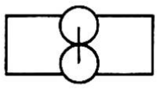
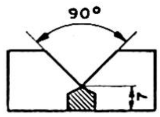
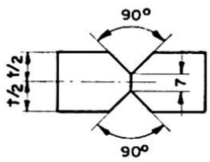
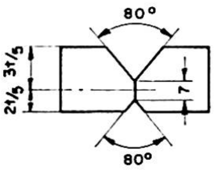
2.3.3. Tensile tests on fillet-welded specimens. The cross-shaped specimens were welded by the Unionmelt and Unionarc methods. Only the specimen welded by the Unionarc method was broken off at the fillet, and we found that the tensile strength of the fillet weld metal was at least 60—61 kg/mm².

2.3.4. Welding conditions and joint geometry of the butt weld. The standard joint geometry and welding conditions are shown in Table 5.

2.3.5. Preparation for welding. The vicinity of the welding joint was thoroughly cleaned by a grinder to remove water, oil and rust.

End tub, having the same edge as the base metal was preset up.

Table 5. Joint Geometry and Welding Condition of Butt Joint by Unionmelt

Thickness of plate (m/m)	Joint geometry	Diameter of wire (in)	Arc current (A)	Arc voltage (V)	Welding speed (cm/min)
9～11		5/32	600 650	32 34	30 35
12～18		5/32	600 650	32 34	30 35
19～27		3/16	750 800	31 31	25 20
28～40		3/16	800 900	31 32	20 15

A width of about 100 mm on both sides of the welding line was preheated by a flame of propane gas.

The standard preheating temperatures are shown in Table 6.

Table 6. Standard Temperatures of Preheat

Method	Type of steel and thickness of plate				
	Type HT 60			Type SM 50	
	$t \leqq 15$ mm	$15 < t \leqq 25$ mm	$25 <$ tmm	$25 \geqq$ tmm	$25 <$ tmm
Manual	—	60°—80°C	80°—120°C	20°C	50°—100°C
Unionmelt	—	—	60°— 80°C	20°C	50°—100°C
Unionarc	—	—	60°— 80°C	20°C	50°—100°C

2.3.6. Welding operations. Welding operations were undertaken in the flat position. The welding method and procedure were selected so as to reduce the distortion and the residual stress.

The fillet weld between the flange and the web plate was welded by the Unionmelt process and the welding conditions are shown in Table 7.

Table 7. Welding Conditions for Fillet Welding by the Unionmelt Method

Size of fillet mm	Current A	Voltage V	Speed cm/min	Wire and flux	
				for SM 50	for HT 60
6 7 8	550 600 650	28 30 32	60 55 50	Y-CM $^5/_{32}'' \varnothing$ YF-15 12×65	Y-CM $^5/_{32}'' \varnothing$ YF-15 12×65

For welding the stiffeners the Unionarc Machine was used and the welding conditions employed are shown in Table 8.

Table 8. Welding Conditions for Fillet Welding by the Unionarc Method

Size of fillet mm	Brand of wire	Brand of flux	Current A	Voltage V	Speed cm/min	Consumption of CO_2 gas (l/min)	Ratio of wire to flux
6	Y-A	CS	200	28—30	0.6/1	40	20

2.3.7. The welding lengths. Table 9 shows the welding lengths of the members of the Kosogawa Bridge.

2.3.8. The quantities of welding materials required. The quantities of wire, flux and CO_2 gas required for welding are shown in Tables 10 and 11.

3. 86.6% Automatic and Semi-Automatic Methods

If the total weld deposit metal is assumed to be 174,000 m of 6 mm fillet weld, then 41.4% of the weld metal is deposited by automatic methods 45.2% by semi-automatic methods and 13.4% by manual welding.

Thus, in all, 86.6% of the total weld metal was deposited by mechanised welding.

Table 9. Summary of Welding Lengths of Each Member

Member	Weight of steel	Total length of weld length of weld per ton of steel *		Proportion of automatic and semi-automatic welding		Manual by welded part
	t	L (m)	m/t	L (m)	ratio to total %	
main girder	4,877	137,709	28.2	126,464	92.0	stiffener + flange
sway bracing	330	21,655	65.8	13,224	60.8	horizontal stiffener + stiffener
lateral bracing	191	10,926	57.2	10,926	100.0	gusset plate, stiffener
expansion joint	45	1,870	42.0	121	6.7	all except butt weld
drainage	19	1,821	101.0	0	0	
bearing	203					
slab holder	108					
total	5,773	173,981				

* Calculated as 6 mm fillet weld.

Table 10. Welding Materials Required per Unit Length, Calculated as 6-mm Fillet

Welding method	Shape of joint	Dia. of wire	Materials required		
			wire (kg/m)	flux (kg/m)	CO_2 gas (l/m)
Unionmelt	x 13	3/16	0.90	0.72	
	x 22	1/4	1.43	1.10	
	x 25	1/4	1.65	1.32	
	x 28	1/4	2.16	1.72	
	x 32	1/4	2.40	1.92	
	⊿ 7	5/32	0.21	1.16	
	⊿ 8	5/32	0.25	0.20	
Unionarc	⊿ 4–6	3/64	0.16	0.12	42.2
	⊿ 8	3/32	0.36	0.22	63.0

Table 11. Total Welding Materials Required

Material	Unionmelt	Unionarc	Manual
wire	13,118 kgs	15,533 kgs	
flux	8,219 kgs	11,152 kgs	
CO_2 gas	—	3,780 m^3	
electrode	—	[illegible]	6,507 kgs

Summary

The report first describes the recent tendency towards mechanization in bridge welding in Japan. About 50% of the total welding deposits on a bridge may be carried out by automatic methods, about 40% by semi-automatic methods, and only the remaining 10% need be undertaken by manual methods.

The report gives details regarding the materials and the welding methods employed and the tests made on the Kisogawa Bridge, a part of which was made of 60 kg/mm² class high strength steel.

Résumé

Les auteurs décrivent tout d'abord l'évolution de la mécanisation du soudage dans la construction des ponts au Japon. Le soudage d'un pont peut être exécuté au moyen de procédés automatiques dans une proportion correspondant à environ 50% du métal déposé, de procédés semi-automatiques dans une proportion de 40%, tandis que le soudage à la main n'est nécessaire que pour les 10% qui restent.

On donne le détail des matériaux utilisés et des procédés de soudage employés et on décrit les essais exécutés pour le pont de Kisogawa, réalisé en partie en acier à 60 kg/mm² de résistance.

Zusammenfassung

Die Verfasser beschreiben zuerst die Entwicklung der Mechanisierung bei Schweißungen im japanischen Brückenbau. Die Schweißarbeiten bei einer Brücke können zu ca. 50% des aufgebrachten Schweißgutes mit automatischen Verfahren ausgeführt werden, weitere 40% setzen halbautomatische Verfahren voraus und der Restbetrag von ca. 10% ist noch Schweißarbeit von Hand.

Am Beispiel der Kisogawa-Brücke, die teilweise aus hochwertigem Stahl mit einer Festigkeit von 60 kg/mm² besteht, werden die Einzelheiten der gewählten Werkstoffe und der verwendeten Schweißverfahren beschrieben und es werden die in diesem Zusammenhang durchgeführten Versuche angegegen.