Zeitschrift: IABSE congress report = Rapport du congrès AIPC = IVBH Kongressbericht

Band: 10 (1976)

Artikel: Fabrication and erection problems

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DOI: https://doi.org/10.5169/seals-10548

Comments by the Author of the Introductory Report

Remarques de l'auteur du rapport introductif

Bemerkungen des Verfassers des Einführungsberichtes

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Fabrication and Erection Problems

Session Vc is intended for discussions on fabrication and erection problems of long-span bridges for the application of high-strength steels. Since long-span bridge projects are going to be planned in the world, the subject will bring forward the most realistic and important problems for bridge engineers.

Although the introductory report on the present subject was not presented to our regret, we have three Preliminary Reports. Now, the author is going to discuss some problems together with the summary of the Preliminary Reports.

One of the Reports treated Saint-Nazaire Bridge in France which is the world-longest cable-stayed girder bridge with a center span of 404 m. The second report covered the choice of high-strength steels at Osaka Port Bridge in Japan, and at the third report the use of high-strength steels was discussed for support forces of steel bridge girders during their launching. It is thought that each of the reports is characteristics from the point of the present subject.

The author believes that it is the determination of an erection method to influence most on the safety and economy of long-span bridges. Four bridges accidents during their erection have been reported very recently, and the Merrison Committee Report was published and also at the Session VII, Professor Massonnet and Dr. Henderson will make some proposals on erection at their General Reports. It is advisable to consider fully such suggestions or recommendations at the design of future bridges.

Now, the author would like to emphasize that it might be dangerous to apply directly the engineering experience obtained from mild steels to the use of high-strength steels. Generally, uniform elongation of high-strngth steels will decrease with an increase of strength, and particularly, at quenched and tempered high-strength steels over 60 kg/mm^2, their yielding ratio will be increased and their stress-strain curve will be different from mild steels.

For example, judging from fatigue tests of steel plates with a notch, mild steels are a kind of stiff-type steel, but heat-treated high-strength steels become a kind of soft-type steel. From buckling, high-strength steels seem to be advantageous at the effect of residual stresses due to welding, but there are no sufficient test data to verify the effect. Therefore, careful considerations will be required at the design of details of a structure.

On the other hand, as welding problems, crack sensitivity due to welding will be higher at high-strength steels and particularly, brittleness of weld bond parts will be unavoidable in relation to weld heat input at heat-treated high-strength steels.

It will be concluded that a thorough study on the structural behavior of welded structures will be required and at the same time, material properties of high-strength steels and especially, weldability in relation to fracture mechanism have to be understood well at the further study.

Recenly, large-block erection methods have been applied to long-span bridges to satisfy environmental conditions, as seen in erection works of Saint-Nazaire Bridge and Osaka Port Bridge.

At the erection of Saint-Nazaire Bridge, the side spans were erected by a large-en bloc lifting-up method without any staging, and yet the main span was erected by a cantilever method. Since a uniform section of box gorders was used on account of easy works of fabrication and erection, working stresses induced during the erection forced the side spans to be made of steels more than 42 kg/mm^2 in yielding point. It is reported that such steels satisfied the required KCV-20°C in the direction of rolling and the perpendicular direction to it at the pre-and post welding.

At the erection and fabrication of Osaka Port Bridge, it is reported as follows:

1) The suspended truss span (span length is 186 m and steel weight including floor is approximately 4500 tons) was fabricated at a shop and towed to the site by a deck barge in 15,000 tons. Finally, it was lifted using a lifting equipment composed of wires and winches to the ends of the cantilever spans to the height of approximately 50 m above the sea level.

2) Out of the total steel weight 40,000 tons, 4197 tons and 1075 tons of high-strength steels of 80 kg/mm^2 and 70 kg/mm^2 grades, respectively, were used. Furthermore, the maximum plate thickness were 75 mm for the web plate of the chord and 100 mm for the bottom plate of the tower base.

3) To improve the weldability of members and elements, lamellar tear tests, restrained cracking tests, tests on the performance of corner weld joints, and tests to study on the various characteristics of the actual members using full scale models, were conducted prior to the fabrication.

It will be highly evaluated that with such well-prepared tests, the fabrication of the whole bridge structure was completed without any trouble.

It will be recognized at any rate that the use of high-strength steels at long-span bridges is somewhat advantageous because it can reduce their own weight at the erection. Fig. 1 illustrates the relation between allowable stress and cost ratio based on the cost of various steels in Japan. Although there are social and environmental requirements for bridges and all problems cannot be solved by one factor as shown in Fig. 1, it seems that the figure will give you a certain index to choose the material.

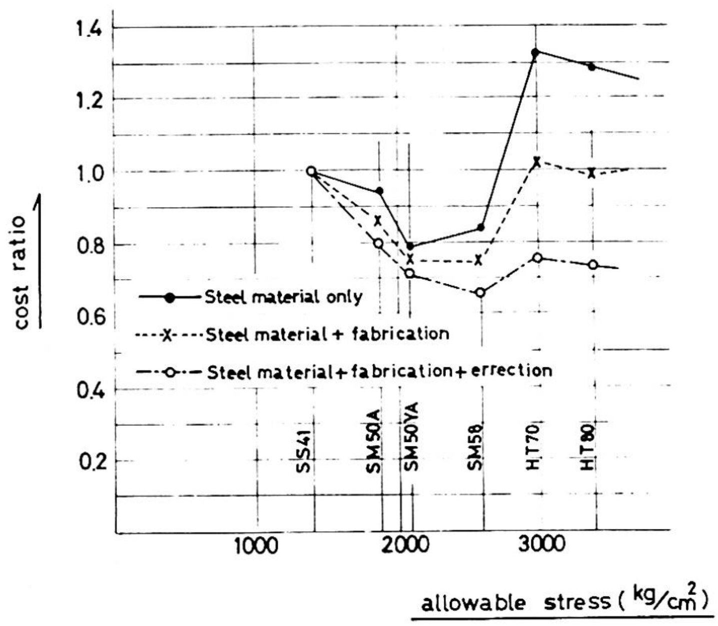

Fig. 1 Relation between allowable stress and cost ratio

At the paper presented by Prof. Bergfelt and Mr. Wilson, when a bridge was erected by launchimg, they observed experimentally girder behaviors due to local yielding, buckling and their combined action, and they concluded the use of high-strength steels would be advantageous to avoid damages of a structure due to concentrated loadings.

It is the author's opinion that the improvement of material properties in the direction of plate thickness is required from the point of stress transmission, when member sections of bridges are going to be larger and higher-strength steels are required for detailed design of welded sections. At 80 kg/mm^2 grade steels in Osaka Port Bridge, the improvement of manufacturing steels was tried to reduce the impurity of steels, so that the contents of S and P were kept around or within 0.01 %. Then, HT80 steels could be satisfactorily applied to this bridge, as seen in Table 2, in comparison with 60 kg/mm^2 steels in Table 1.

Fig. 2 shows the relationship among sulphur content, elongation in the direction transverse to the plate, and non-metal inclusion. Fig. 3 gives the relationship between elongation in the direction transverse to the plate and crack-growth rate by Cranfield Test which is a representative test of lamellar tear due to welding.

Finally, the author suggests that, since it is very important to pay close attention to the improvement of material properties in the direction of plate thickness at the use of high-strength steels, fabrication and erection of long-span bridges have to be done in cooperation with manufacturers of steels.

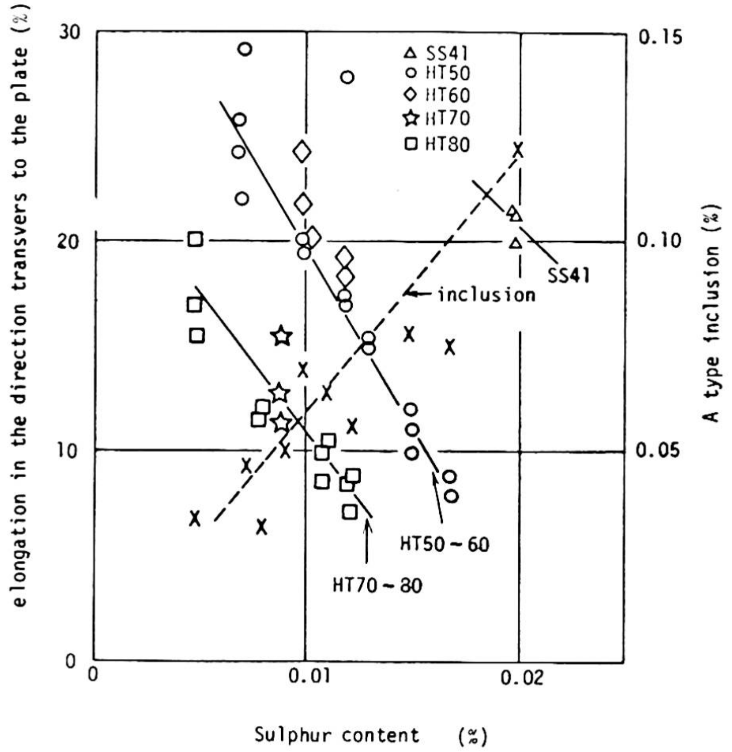

Fig. 2 Relationship among sulphur content, elongation in the direction transverse to the plate and non-metal inclusion

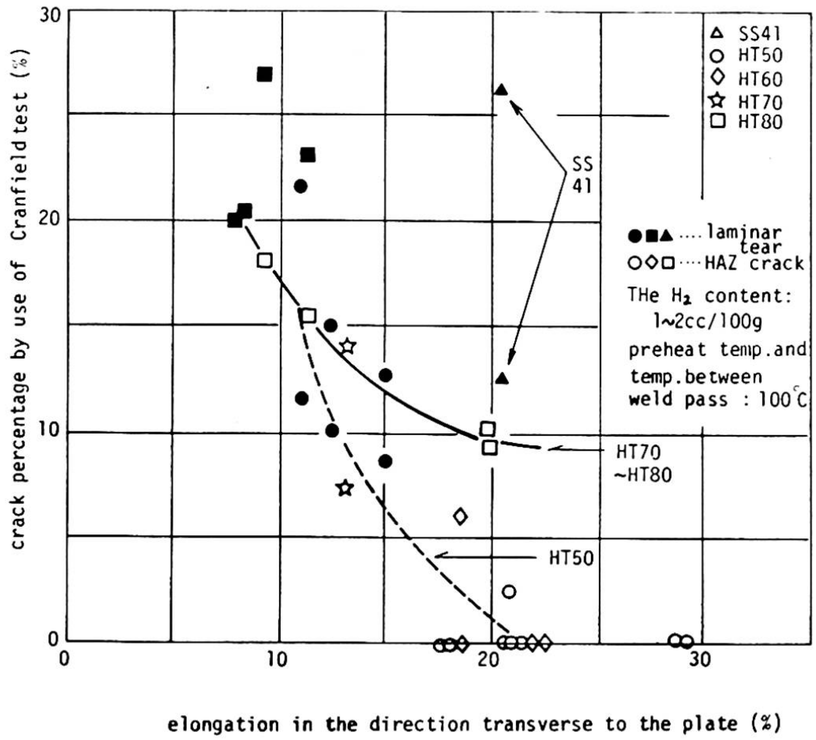

Fig. 3 Relationship between elongation in the direction transverse to the plate and Cranfield crack-growth rate

Table 1 Properties of 60 kg/mm^2 high-tensile steel plate

T*	Chemical composition											Properties in longitudinal and cross direction (JIS 4)									Properties in direction of thickness						Remarks
mm	C	Si	Mn	P	S	Cu	Cr	Ni	Mo	V	Ceq	P*	D*	Y.P.	T.S.	El.	R.A.	vEo	vTs	vTe	Y.P.	T.S.	El.	R.A.	vEo	vTs	
75	13	26	132	10	6	20	15	38	14	4	438	t/4	L	57.1	67.4	27.3	75.7	29.3	-63	-66	55.9	65.6	21.9	-	3.4	+15	D=14mm
													C	56.2	67.2	25.3	69.0	19.8	-42	-42							
85	15	30	137	18	10	3	3	2	24	6	461		L	59.2	68.7	21.8	-	VE-5 23.4	-30	-34	56.5	65.9	20.7	-	VE-5 1.5	+20	GL=50mm
													C	59.6	68.9	19.5	-	VE-5 6.6	+5	- 8							

Table 2 Properties of 80 kg/mm^2 high-tensile steel plate

T*	Chemical composition												Properties in longitudinal and cross direction (JIS 4)									Properties in direction of thickness						Remarks
mm	C	Si	Mn	P	S	Cu	Cr	Ni	Mo	V	B	Ceq	P*	D*	Y.P.	T.S.	El.	R.A.	vEo	vTs	vTe	Y.P.	T.S.	El.	R.A.	vEo	vTs	
33	12	27	87	11	7	27	47	99	45	3	15	500	t/4	L	80.4	85.0	25.6	69	19.4	-110	-99	76.6	82.3	15.0	33	-	-	D=8.5mm GL=30mm
														C	81.7	85.3	21.1	55	6.4	-81	-92							
44.5	12	28	95	10	8	27	48	106	47	3	13	531		L	82.8	87.3	22.7	67	19.0	-91	-91	77.4	82.6	15.9	35	-	-	
														C	83.7	87.8	20.8	58	6.8	-80	-97							
50	11	27	100	10	9	26	49	108	47	4	12	533		L	77.3	83.6	24.7	68	17.0	-50	-59	71.6	79.4	17.8	52	-	-	
														C	73.7	80.3	19.7	64	11.0	-60	-76							
50	10	31	90	7	5	26	47	103	47	3	12	502		L	81.7	86.0	23.6	72	20.9	-93	-92	79.8	83.1	11.5	33	7.2	-66	D=14mm GL=50mm
														C	81.6	85.8	22.6	66	132	-72	-66							
63.5	12	27	87	11	7	27	47	99	45	3	15	500		L	81.9	86.9	23.3	66	19.0	-90	-90	77.9	83.2	16.5	39	-	-	D=8.5mm GL=30mm
														C	80.5	85.4	23.6	60	9.2	-74	-77							
78	13	28	86	8	6	23	47	129	47	4	13	530		L	80.7	85.9	23.6	67	20.8	-96	-93	79.8	84.4	17.8	39	21.2	-122	D=14mm
														C	80.1	84.8	23.1	62	13.8	-76	-71							
100	12	27	89	8	5	24	52	143	48	3	18	542		L	77.1	84.2	25.2	71	23.4	-105	-93	74.8	81.5	22.0	-	11.9	-32	GL=50mm
														C	77.0	83.5	24.4	68	19.4	-95	-90							

C, Si, Mn, Cu, Cr, Ni, Mo, V : (10^{-2})
P, S, Ceq. : (10^{-3})
B : (10^{-4})

Y.P., T.S. : (kg/mm^2) , vTs, vTc : (C)
El., R.A. : (%)
vEo : (kg-m)

T*=thickness
P*=position
D*=direction of test

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