Zeitschrift: IABSE reports of the working commissions = Rapports des commissions de travail AIPC = IVBH Berichte der Arbeitskommissionen

Band: 11 (1971)

Artikel: Additional study on static strength of hybrid plate girders in bending

Autor: Maeda, Yukio

DOI: https://doi.org/10.5169/seals-12077

III

Additional Study on Static Strength of Hybrid Plate Girders in Bending

Contribution à l'étude de la résistance statique des poutres hybrides fléchies

Zur statischen Tragfähigkeit hybrider Blechträger unter Biegung

YUKIO MAEDA
Dr.-Eng.
Professor of Civil Engineering
Osaka University, Osaka, Japan

A part of study on ultimate static strength of hybrid plate girders in bending, which is being carried out at Osaka University, is presented in this paper.

1. Static Bending Tests

The concept of "hybrid construction" has been introduced to meet the functional, economic, and safety requirements of a structure. To examine hybrid feature at a plate girder in terms of its static flexural behavior and ultimate strength, four large-scale welded hybrid plate girders with longitudinal stiffeners were tested statically up to their failure under two concentrated loads. Web slenderness ratio of a test panel, which is arranged at the middle part of girder and subjected to a uniform bending moment, was intended for the value of 150, 200, 250 and 300.

A section at the test panel consists of such three steel materials as SM58 for a compression flange, SS41 for a web and HT80 for a tension flange. SM50 steel is used for stiffeners. SS41, SM50 and SM58 steels are specified at the Japanese Industrial Standards, and respectively an ordinary carbon steel, a high-strength structural steel and a high-yield strength quenched and tempered steel. HT80 steel is a high-yield strength quenched and tempered alloy steel, not yet specified at the Japanese Industrial Standards. The average values of upper yield stresses σ_{yu}, lower yield stress σ_{yl} tensile strength σ_t and elongation ε of these steels were shown by coupon tensile tests as follows:

Steel	σ_{yu} (kg/mm^2)	σ_{yl} (kg/mm^2)	σ_t (kg/mm^2)	ε (%)
HT80	84.64	84.28	88.40	12.3
SM58	54.80	53.64	62.02	19.6
SM50	38.06	36.81	51.52	25.4
SS41	31.44	30.06	42.94	36.5

Sectional areas of the upper and lower flanges of the test girders, are designed so that the both flange materials may reach their yielding stress at the almost same time at the extreme fibers of flanges.

Actual dimensions of the test girders and the yielding stresses of steels for calculations are summarized in Table 1.

2. Discussions of Test Results

(1) Collapse loads P_{ex}, ultimate bending moments M_u, modes of failure of test panels and locations of failure are shown in Table 2.

A contribution of web post-buckling strength to ultimate bending strength of the test panel, a benefical effect of longitudinal stiffeners on the web post-buckling strength and a mode of final failure of the girders being controlled by the rigidity of compression flange and longitudinal stiffeners, have been observed in hybrid girders as well as in non-hybrid girders.

The failure of BL-3 and BL-4 girders is shown in Figs. 1 and 2.

(2) First of all, the web showed a larger lateral deflection after the web yielding at its compression edge for BL-1, -2, and -3 girders and before the web yielding for BL-4 girder, and then the yielding of web penetrated toward the neutral axis of section. Thereafter, the yielding in compression flange developed and extended over its entire thickness, and then its lateral buckling with a torsional buckling in BL-1, -2, and -3 girders and with a vertical buckling in BL-4 girder, was observed. In non-hybrid girders, when a compression flange yielded, a web had not yielded, but in the hybrid girders, the web had already yielded before the flange yielding.

Hence, it follows that the compression flange area alone may resist against a buckling of the flange without a contribution of effective strip of the web, although in non-hybrid girders a compression flange area plus an effective strip of web along the flange can resist flange buckling. At a girder with high hybridness, it will be optimum to select a material for web which buckles at its yielding stress.

Such a behavior can be seen clearly at a typical flexural strain distributions in the test panel of BL-2 and -3 girders as shown in Figs. 3 and 4.

(3) In non-hybrid girders, a loss of web section was observed for a girder with web slenderness ratio larger than 250, but at the present tests the girder with web slenderness ratio of about 300 showed a slight loss of the web section.

(4) Larger initial web deflections were observed for the less rigidities of anchoring frames consisting of flanges and stiffeners. This tendency was recognized more remarkably than in non-hybrid girders. It does not seem that the initial web deflections which were measured to be 0.11 t, 0.36 t, 0.89 t and 1.08 t respectively for BL-1, -2, -3, and -4 girders, influenced greatly on the ultimate strength. The final web deflections were measured to be about 1.0 t - 2.0 t.

(5) Since restraining of the web against a buckling of the compression flange may not be expected after the web yielding, a width-thickness ratio of the compression flange has to be made smaller, to be provided with an equivalent rigidity which is secured by contribution of the effective strip of web section in non-hybrid girders.

(6) The use of a very high strength steel HT80 for the tension flange is beneficial for the compression side of a section, because the neutral axis of the section moves upward, due to the tension flange area about 40% smaller than in non-hybrid girders.

(7) The observed ultimate bending moment M_u is non-dimensionalized by dividing by the theoretical full-plastic moment M_p^{th}, as shown in Table 3 and Fig. 5, and M_u divided by the theoretical flange yielding moment M_{yf}^{th} is given in Table 3 and Fig. 6. The theoretical moments were calculated following the models of stress and strain in Fig. 7.

The tests of non-hybrid girders consisting of SM58 - SM50 - SM58 showed that the flange yielding moment could be secured up to about $\beta = h/t_w = 400$.

At the present hybrid girders of SM58 - SS41 - HT80, however, the possible web slenderness ratio to secure the flange yielding moment has been lowered down to about 300.

Fatigue tests of longitudinally stiffened hybrid plate girders will be soon carried out at Osaka University.

Table 1 Dimensions of Test Girders and Yielding Stresses of Steels

GIRDER	COP.FLANGE ($2b \times t_c$ mm)	TEN.FLANGE ($2b \times t_t$ mm)	WEB ($h \times t_w$ mm)	$t_s \times b_s$ (mm)	$\beta = \frac{h}{t_w}$	b/t_c	$\alpha = \frac{a}{b}$	γ/γ^*	$\rho = \frac{A_w}{A_{fc}}$	σ_{yfc} (kg/mm^2)	σ_{yft} (kg/mm^2)	σ_{yw} (kg/mm^2)
BL-1	200× 12.9	200× 8.0	675× 4.8	8× 65	141	7.75	1.0	5.34	1.26	53.6	84.3	30.1
BL-2	200× 12.9	200× 8.0	900× 4.8	8× 70	188	7.75	1.0	5.67	1.67	53.6	84.3	30.1
BL-3	200× 12.9	200× 8.0	1125× 4.8	8× 75	234	7.75	1.0	6.06	2.00	53.6	84.3	30.1
BL-4	200× 12.9	200× 8.0	1350× 4.8	8× 80	281	7.75	1.0	6.50	2.50	53.6	84.3	30.1

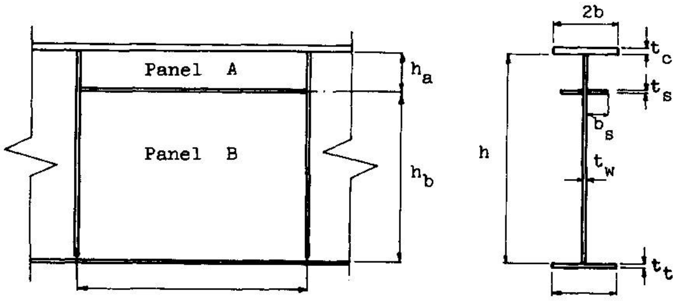


Table 2 Test Results of Failure of Test Girders

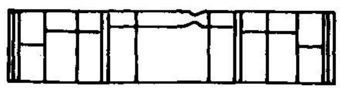
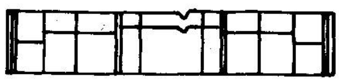
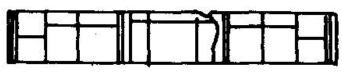
GIRDER	P_{ex} (t)	M_u (t-m)	MODE OF FAILURE	LOCATION OF FAILURE
BL- 4	147	257	VERTICAL BUCKLING LATERAL BUCKLING	
BL- 3	110	220	VERTICAL BUCKLING LATERAL BUCKLING	
BL- 2	85	170	OUTSIDE OF TESTPANEL (VERTICAL BUCKLING) LATERAL BUCKLING	
BL- 1	62.5	125	OUTSIDE OF TESTPANEL (TORSIONAL BUCKLING) LATERAL BUCKLING	

Table 3 Ultimate Bending Moments

GIRDER	ß	M_u (tm)	M_{yf}^{th} (tm)	M_p^{th} (tm)	M_u/M_{yf}^{th}	M_u/M_p^{th}
BL-1	141	125	111	113	1.126	1.106
BL-2	188	170	156	160	1.090	1.063
BL-3	234	220	205	210	1.073	1.048
BL-4	281	257	259	265	0.992	0.970

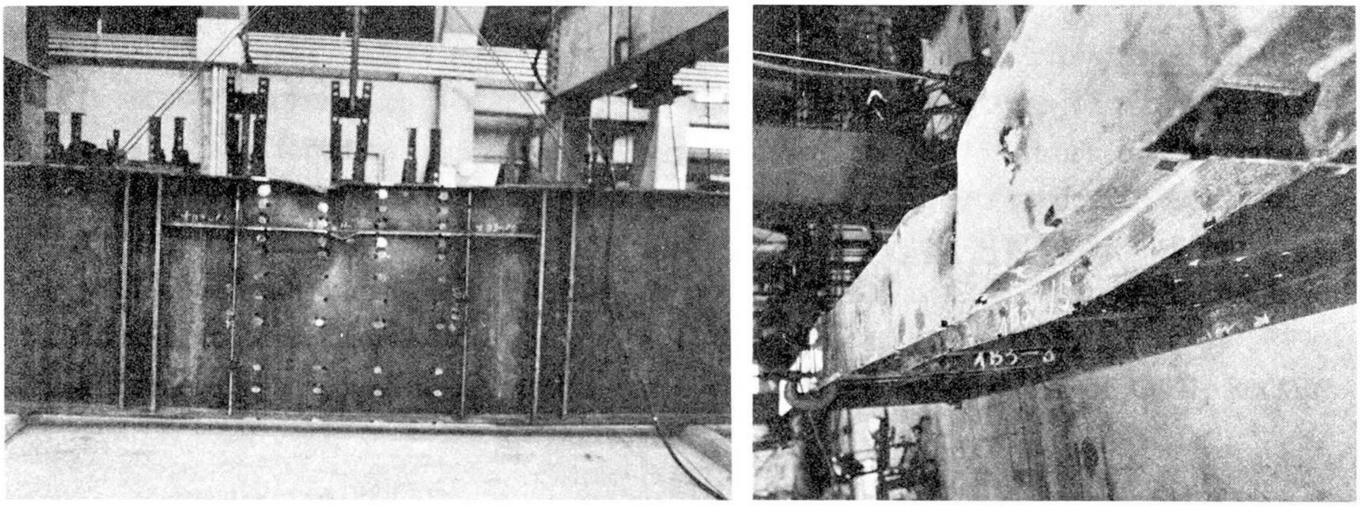


Fig. 1. Failure of Test Girder BL-3

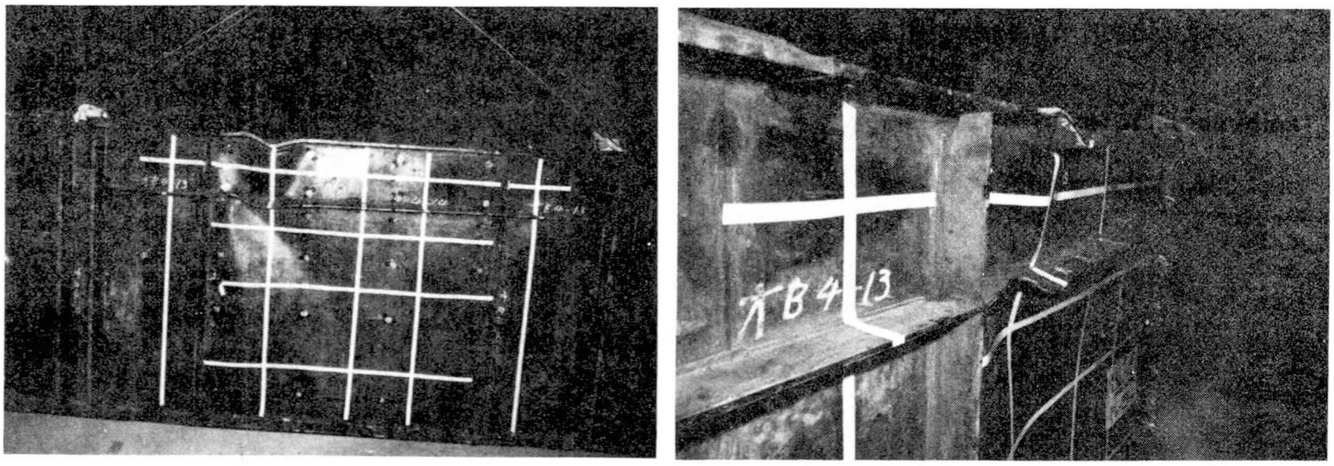


Fig. 2. Failure of Test Girder BL-4

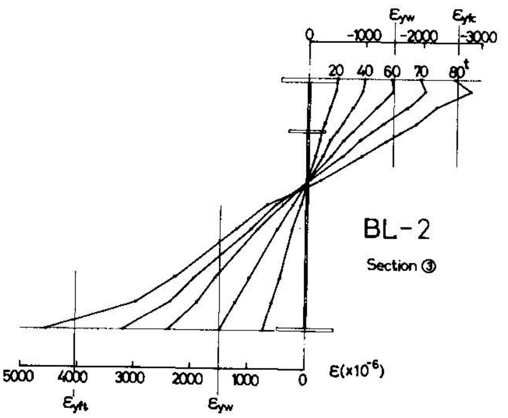


Fig. 3. Strain Distribution in Test Panel of BL-2 Girder

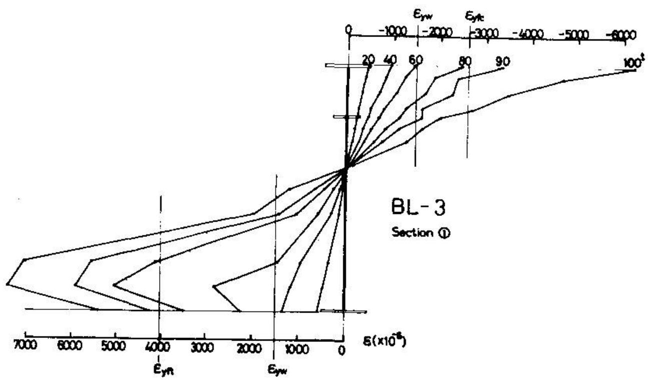


Fig. 4. Strain Distribution in Test Panel of BL-3 Girder

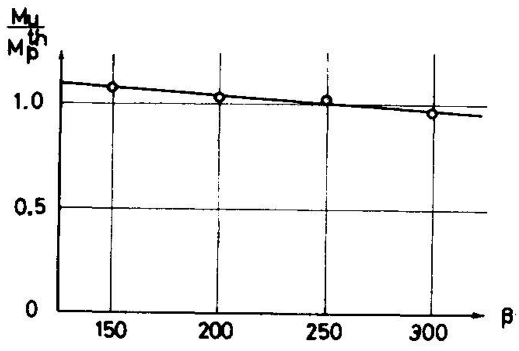


Fig. 5. M_u/M_p^{th} versus $\beta = h/t_w$

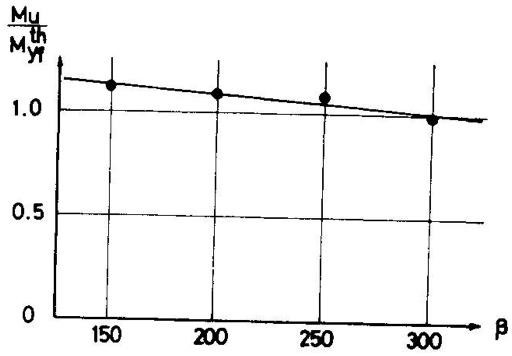


Fig. 6. M_u/M_{yf}^{th} versus $\beta = h/t_w$

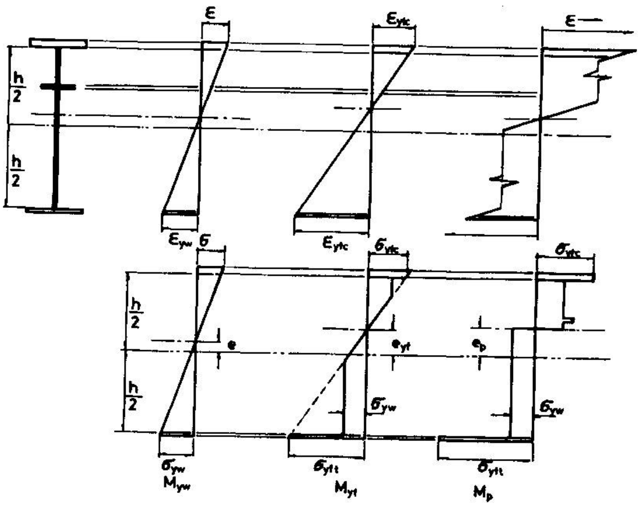


Fig. 7. Models of Development of Stress and Strain

Leere Seite
Blank page
Page vide