IIW Doc. XV - 401 - 77 (information document)
Stevin report nr. 6 - 77 - 8
TNO - IBBC report nr. BI - 77 - 42/35.3.51210
Cidect report nr. 77/12(5Q)

# BEHAVIOUR OF AXIALLY LOADED K- AND N-TYPE GAP JOINTS WITH BRACINGS OF STRUCTURAL HOLLOW SECTIONS AND AN I-PROFILE AS CHORD

by J. Wardenier
C.H.M. de Koning
A.A. van Douwen

May 1977

CECA-convention/nr. 6210-SA/6/604

Investigation with financial aid of the European Community of Steel and Coal.

# BEHAVIOUR OF AXIALLY LOADED K- AND N-TYPE GAP JOINTS WITH BRACINGS OF STRUCTURAL HOLLOW SECTIONS AND AN I-PROFILE AS CHORD.


## SYNOPSIS

In this document (extract of ref. 4) the results are given of an investigation into the static strength of welded Warren and Pratt type gap joints with bracings of circular or rectangular hollow sections and an IPE or HEA profile as chord. This investigation is part of an extensive research project on predominant statically loaded welded lattice girder joints of different configurations and made of different types of hollow sections or combinations of hollow sections and open profiles.
This programme was set up by the SG-TC-18 study group of the Dutch Steel Association (Staalbouwkundig Genootschap) in cooperation with the Joint Group of Cidect.
This programme is sponsored by the ECSC, the Dutch Steel Association, Cidect, the Dutch Government, Verenigde Buizenfabrieken VBF and the Dutch tube suppliers.

As far as failure was not caused by yielding of the bracings the specimens showed a shear failure of the chord.
The experimental test results are compared with those of a model in accordance with the general rules of plastic design.

Compared with the effective width criterion for beam column connections of I profiles these types of joints tested showed a remarkeble better behaviour.
The results of this investigation in combination with those of a French programme on these types of joints will be the basis for the formation of recommendations and specifications for joints made of hollow sections and I profiles.

CONTENTS

## SYMBOLS USED IN THIS DOCUMENT

$A$ : cross section area of the chord

$A_c$ : cross section area of the compression bracing

$A_s$ : effective cross section for shear load (chord)

$A_t$ : cross section area of the tension bracing

$B$ : width of the chord flange

$F_c$ : load in compression bracing

$F_{cu}$ : ultimate load in compression bracing (end of test)

$F_t$ : load in tension bracing

$F_{tu}$ : ultimate load in tension bracing (end of test)

$H$ : depth of the chord

$N$ : maximum load in the chord

$N_y$ : reduced axial yield load in the chord

$S$ : shear load

$S_y$ : shear yield load of the chord

$T$ : thickness of the flange of the chord

$a$ : throat thickness of the welds

$b_c$ : width of the compression bracing transverse to the chord

$b_m$ : effective width

$b_t$ : width of the tension bracing transverse to the chord

$d_c$ : diameter of the compression bracing

$d_t$ : diameter of the tension bracing

$e$ : eccentricity between system lines

$g$ : gap between bracings (measured between the toes of the bracings)

$r$ : ratio between web and flange of the chord

$t_c$ : wall thickness of the compression bracing

$t_t$ : wall thickness of the tension bracing

$t_w$ : wall thickness of the web of the chord

$\gamma$ : $\dfrac{b_c + b_t}{2B}$ or $\dfrac{d_c + d_t}{2B}$

$\theta_c$ : angle between compression bracing and chord

$\theta_t$ : angle between tension bracing and chord

$\sigma_e$ : yield stress

$\tau_e$ : shear yield stress

CHS : circular hollow section

RHS : rectangular hollow section

SHS : structural hollow section

# BEHAVIOUR OF AXIALLY LOADED K- AND N-TYPE GAP JOINTS WITH BRACINGS OF STRUCTURAL HOLLOW SECTIONS AND AN I-PROFILE AS CHORD

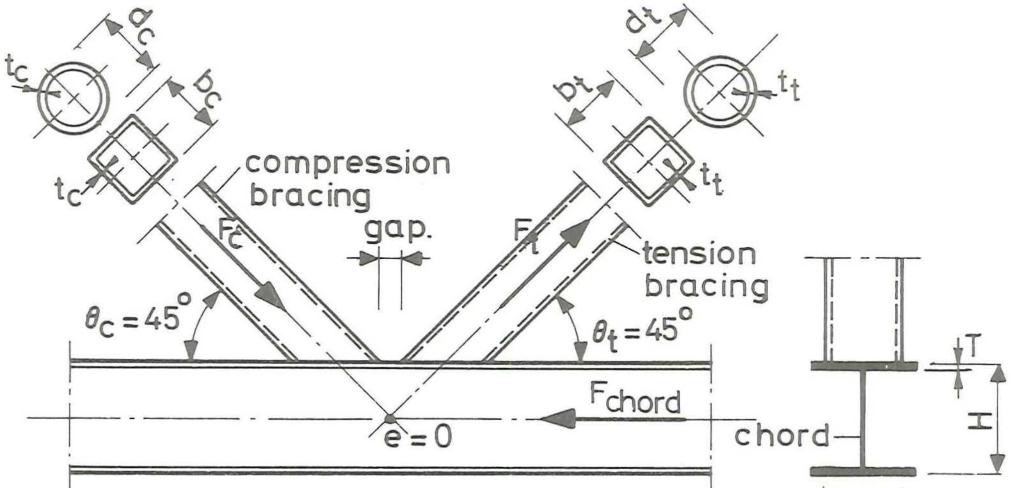
## 1. INTRODUCTION

The last few years an overall investigation was carried out on predominant statically loaded tubular joints.
In this programme different types of welded joints made of structural hollow sections and joints made of hollow sections and open profiles were tested.

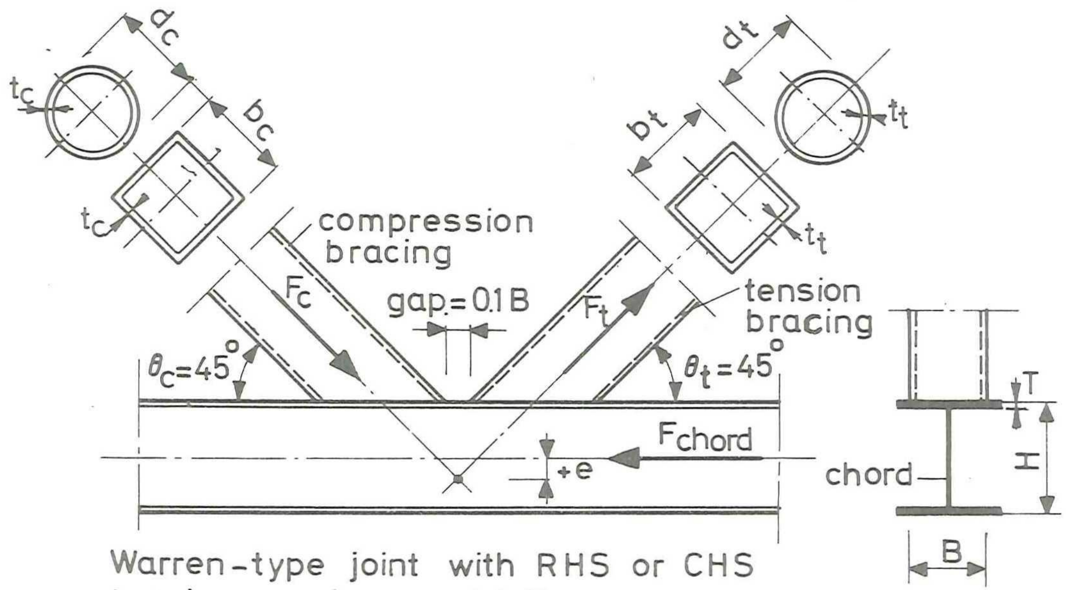
This research programme [1] was prepared by the SG-TC-18 study group of the Dutch Steel Association in co-operation with the Joint Group of Cidect[1].
The programme is sponsored by the ECSC[2], the Dutch Steel Association, Cidect, The Dutch Government, Verenigde Buizenfabrieken VBF and the

This document describes the test results of an investigation into the static strength of "Lattice girder joints with SHS (Structural Hollow Sections) bracings and an I profile as chord".
In this investigation welded K- and N-type gap joints with RHS (Rect. Hollow Sections) or CHS (Circular Hollow Sections) sections as bracings and open sections as chord are studied.
Joints with overlap are part of a French research programme on these types of joints.
These results and the results of tests carried out in France will be the basis for design recommendations and specifications for joints with SHS bracings and I beams as chord.

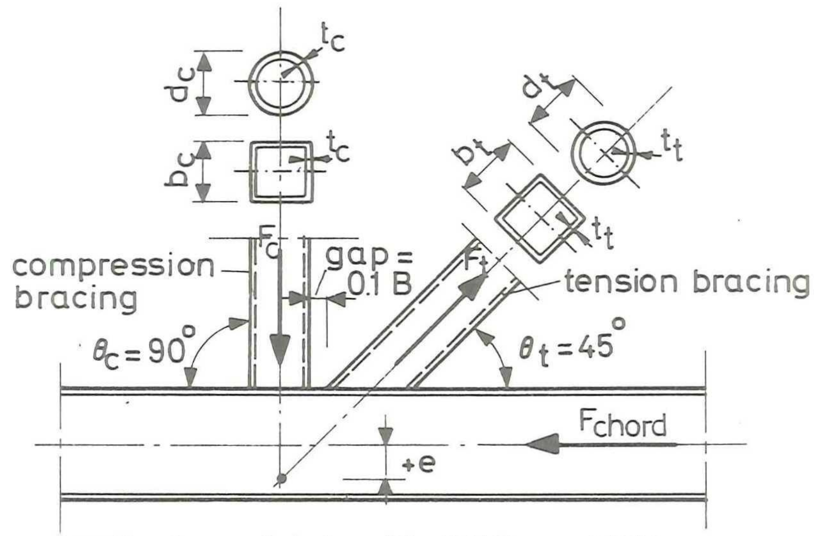
1) Cidect = "Comitée International pour le Dévelopement et l'Etude de la Construction Tubulaire".
2) ECSC = European Community of Steel and Coal.




Warren-type joint with RHS or CHS bracings and no eccentricity (K-type)




Warren-type joint with RHS or CHS bracing and eccentricity. (K-type)




Pratt-type joint with RHS or CHS bracings and eccentricity. (N-type)

figure 1 different configurations of joints tested.

## 2. TEST SPECIMENS

The test specimens are of the Warren- and Pratt type configuration with bracings of square or circular hollow sections and an I profile as chord.
The test series is shown in table 1.
All Warren-type specimens had angles between bracings and chord of $45^{\circ}$ whereas the N-type joints had angles of $90^{\circ}$ between compression bracing and chord and $45^{\circ}$ between tension bracing and chord.
As far as possible the system lines of bracings and chord intersect at one point with the restriction that the gap was not taken smaller than 0.1 B, consequently for these specimens eccentricities occurred. (See fig. 1.) For a specified test specimen the compression and tension bracing had the same dimensions.
The length of the compression bracing was determined in such a way that buckling would not occur.
The width ratio between bracings and chord flange $\frac{b_c+b_t}{2B}$ was varied between 0.4 and 1.0.

For the series the test specimens were made of hot-finished sections.
All test specimens were welded with rutile electrodes type Cumulo in accordance with the standards NEN 1063 ERb 212, BS E 213, DIN 1913, Ti VIII, ASTM E 6013 and NEN 43 R3.
All test specimens had welds with a throat thickness equal to the thickness of the connected bracing. For the joints with a $\frac{b_c+b_t}{2B} \simeq 1.0$ ratio, the bracings were bevelled at the sides.
The welds with a throat thickness of $a \leq 4$ mm were welded in one layer and those with a throat thickness of $a > 4$ mm in two layers.
The welding details are given in figure 2.
During welding, the members were held in position.

## 3. MATERIAL PROPERTIES

The hot finished hollow sections were made of mild steel grade Fe 430 - C according to Euronorm 25 - 72 with a specified yield stress $\sigma_e = 280$ N/mm$^2$.
The hot finished I-profile sections were made of mild steel Fe 360 according to Euronorm 25 - 72 with a specified yield stress $\sigma_e = 240$ N/mm$^2$.

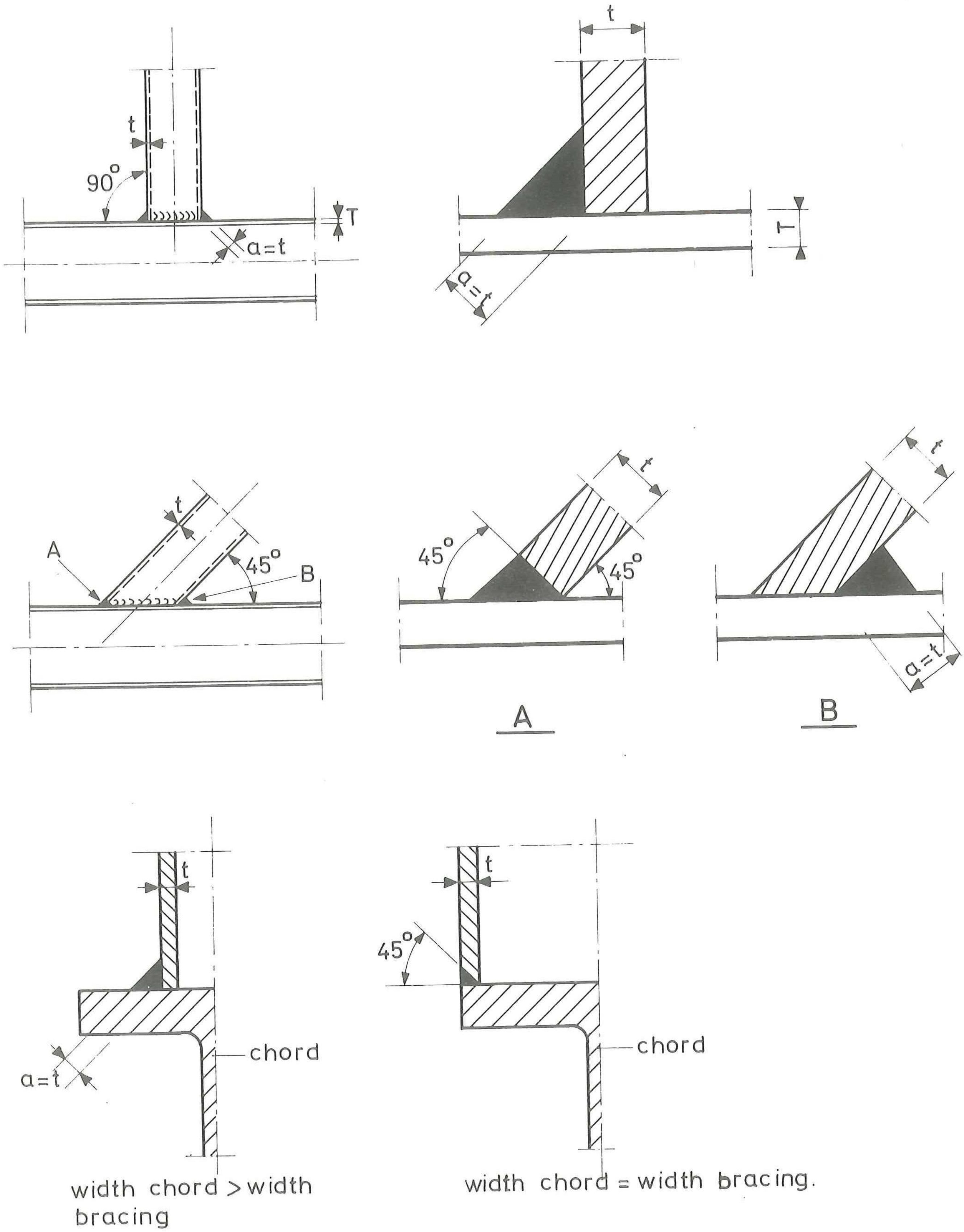



figure 2 weld shape for the different testspecimens.

The measured mechanical properties of the material are given in table II.
For all the sections, the yield stresses $\sigma_e$ were determined with stub column and tensile tests. The analysis is based on the measured dimensions and measured yield stresses (stub column) of the sections. The stub columns had lengths of 3b whereas the measuring length was 100 mm.
The ultimate stress $R_m$, the permanent elongation and the constriction were determined with tensile coupons (dp5) in accordance with Euronorm 2 - 57 "Tensile tests for steel".
The tensile coupons of the hollow sections were taken longitudinally from the centre of the flat sides.
For the I-profiles the tensile test pieces were taken from the flange in longitudinal direction in accordance with Euronorm 2 - 57.

## 4. TEST RIG AND TESTING PROCEDURE

These specimens were tested in the same rig as described in IIW Doc. XV-386-77.
One end of the chord is free, the other end and the ends of the bracings are pin-ended.
The test specimens were tested with the jack load on the compression bracing.
The jack load and the reaction forces should agree with the system lines of the members but these do not always intersect at one point; consequently secondary moments may occur.
The load was applied in steps. The number of steps depended on the type of joint tested.
During this step by step loading the deformation of the joint was measured and recorded.
After first indication of yield, the load increases were reduced for better determination of the ultimate load.

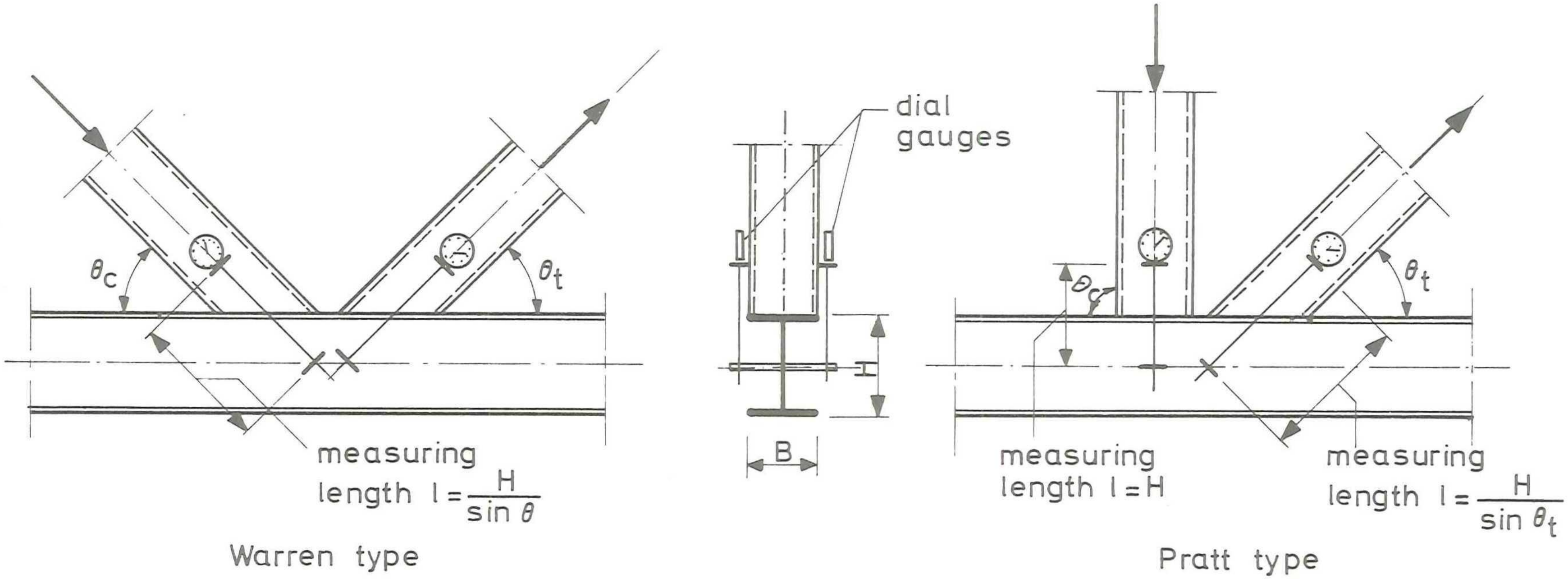



figure 3 joint deformation measurements over bracings.

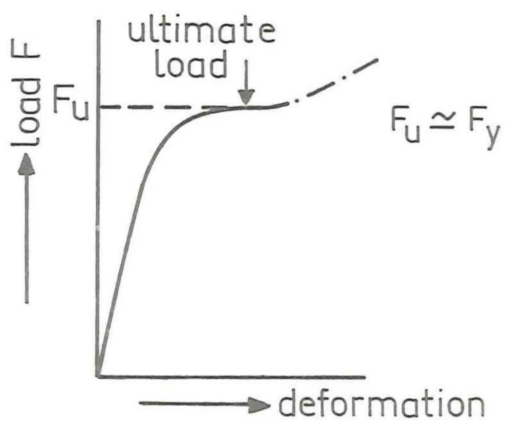



figure 4
determination of the ultimate load.

## 5. MEASUREMENTS

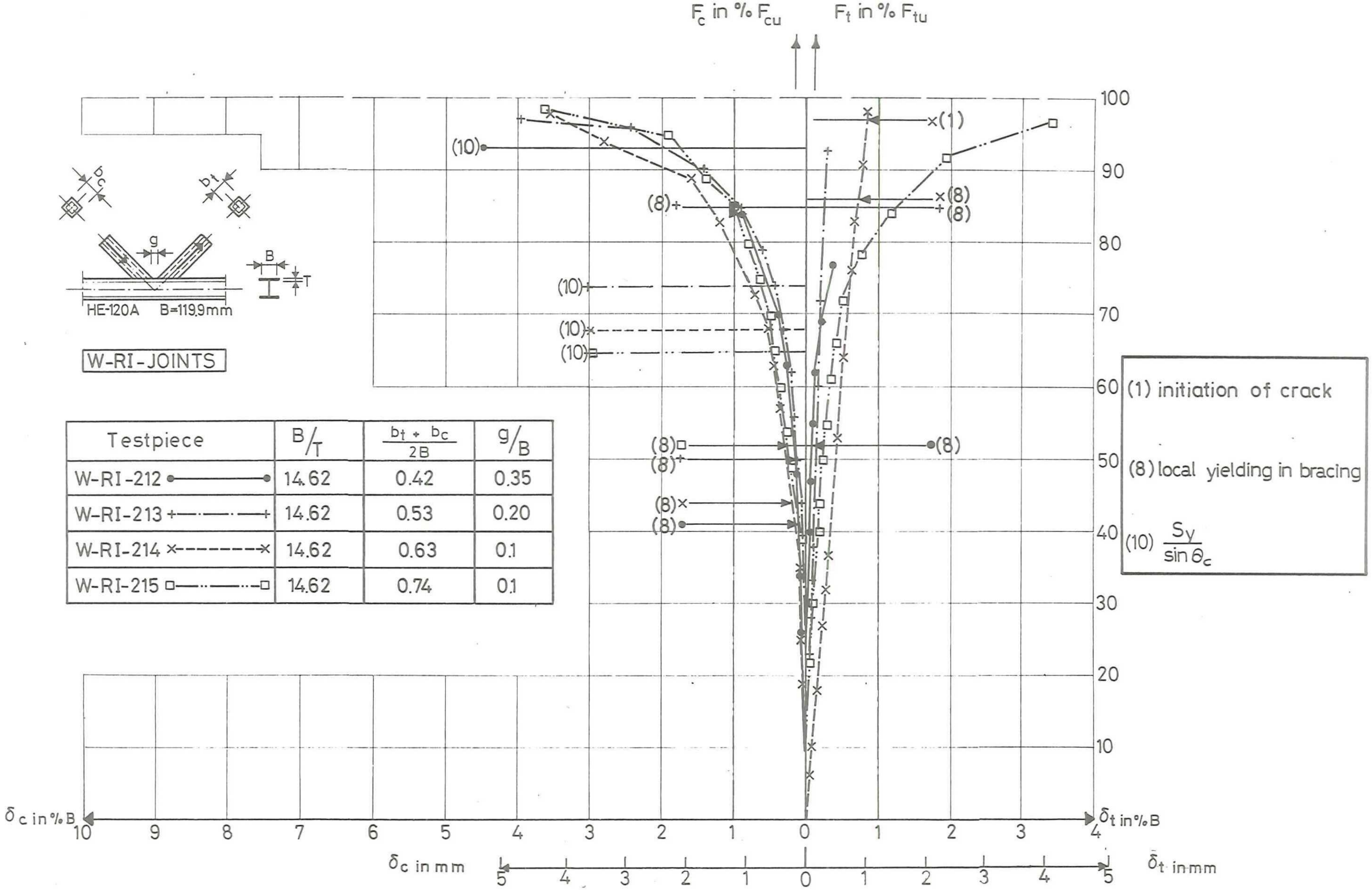
During testing for each stage in loading the axial forces in the chord and bracings were measured with dynamometers.

The deformation of the joint was measured axially across the compression bracing and the tension at each side of the joint as shown in figure 3.
The measuring length is $l = \frac{H}{\sin \theta}$ (H = depth of chord, $\theta$ = angle between chord and bracing).

During testing modes of failure such as yielding, local buckling, shear etc. were visually observed and recorded.
In all cases failure of the joint was considered to exist when the "maximum" load carrying capacity was reached as shown in figure 4. (full yielding)

## 6. TEST RESULTS

The test results are summarized in tables III and III-A which show:
- the measured dimensions of the sections,
- the measured yield stresses $\sigma_e$ of the sections determined with stub column tests,
- the ultimate joint load $F_{cu}$ and $F_{tu}$ in the compression and tension bracing respectively at the end of the test,
- the load $F_{chord}$ at failure of the joints,
- the shear load $S = F_{cu} \sin \theta_c$,
- the shear yield load of the chord $S_y = A_s \cdot \tau_e$,
- the type of failure,
- parameters for the analysis




| Testpiece | B/T | $\frac{b_t + b_c}{2B}$ | g/B |
|---|---|---|---|
| W-RI-212 •——• | 14.62 | 0.42 | 0.35 |
| W-RI-213 +—·—·—+ | 14.62 | 0.53 | 0.20 |
| W-RI-214 ×--------× | 14.62 | 0.63 | 0.1 |
| W-RI-215 □—··——··□ | 14.62 | 0.74 | 0.1 |

FIGURE 5. RELATION BETWEEN THE LOAD IN % F AND THE DEFORMATION OF THE JOINT IN % B

For indication the load- deformation behaviour of some of the joints tested (measured axially across the bracings) is shown in figure 5.
The loads are given in percentages of $F_{cu}$ and $F_{tu}$, respectively and the deformation in percentage of B and in mm.
These figures also show the visually observed indication for initiation of cracks, yielding, local buckling etc.
For joints with a shear failure these diagrams do not show the real deformation of the chord because the chord deforms in a shape which deformation does not effect the length between the measuring points.

In two specimens (Nos 203 and 214) initiation of cracks were observed just before failure.
In the other test specimens initiation of cracks did not occur during loading.

## 7. DISCUSSION OF THE TEST RESULTS

Although for the bracings sections were chosen with the thickest available walls, for some specimens yielding of the bracings was the failure mode which is not a failure of the joint itself.
Generally the mode of failure was shear of the chord sometimes in combination with local buckling of the compression bracing.
Local buckling of the compression bracing was only observed in a few specimens at loads which already caused a shear failure in the chord.
In this chapter the test results will be compared with the analytical determined failure loads based on yield.

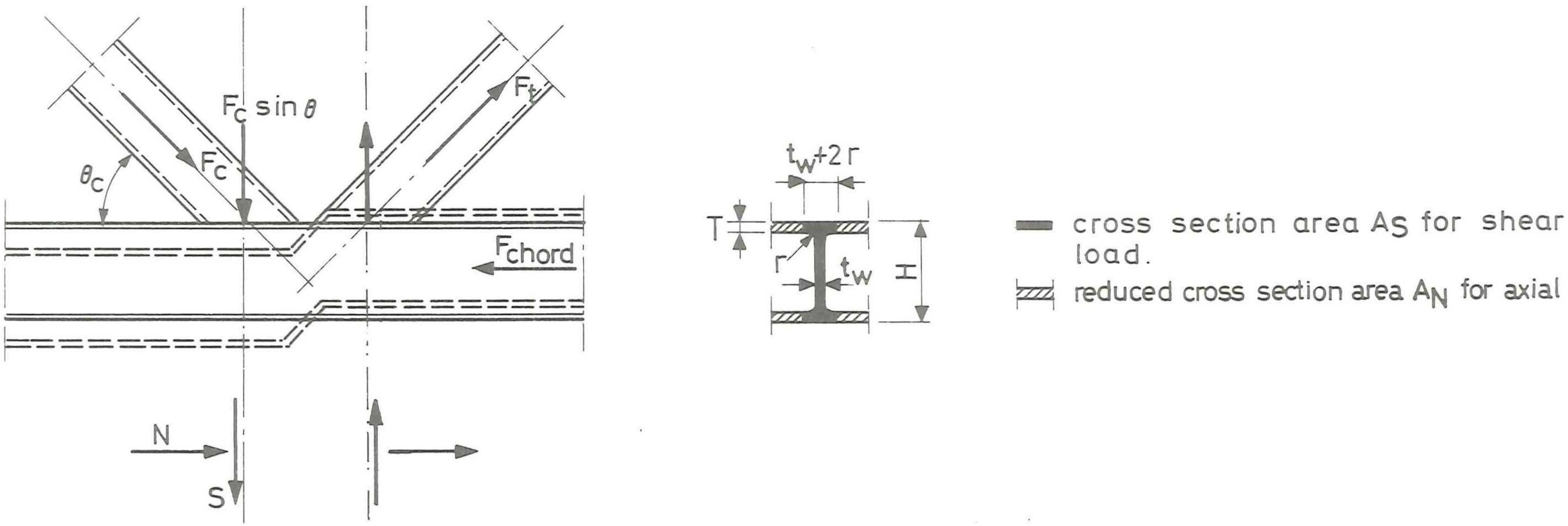



figure 6 determination of the shear yield load of the chord

7.1. Shear failure

For a shear failure of the chord following general plastic design calculation method exists:
The shear load $S = F_{cu} \cdot \sin \theta_c$ will be transmitted by the web of the chord and a part of the flanges as shown in Figure 6.

The maximum shear yield load which can be transmitted is:

$$S_y = A_s \cdot \tau_e \qquad (1)$$

with (as an approximative formula)

$$A_s = (H-2T)t_w + 2(t_w+2r)T + 0.86\, r^2 \qquad (2)$$

$\tau_e$ = shear yield stress of the chord.

The horizontal bracing load component $F_{cu} \cdot \cos \theta_c$ and a possible additional axial load in the chord must be transmitted by the remaining part of the cross section of the I profile.
For these tests the chords were not prestressed therefore only the horizontal bracing load component must be taken into account.
The general interaction formula for axial and shear loads in I profiles [5] is as follows:

$$N \leq (A - A_s)\,\sigma_e + A_s \sigma_e \sqrt{1 - \left(\frac{S}{S_y}\right)^2} \qquad (3)$$

For shear loads S equal to $A_s \cdot \tau_e$ following horizontal load component can be transmitted.

$$N_y = (A - A_s)\sigma_e \qquad (4)$$

The influences of moments of eccentricity are neglected although these have an influence.
Joints with small angles between bracings and chord or with additional axial loads in the chord may have a reduced joint strength.
Gap joints of the Warren type with no additional axial loads can be in full yield if:

$$\frac{F_{cu} \cdot \sin \theta_c}{F_{cu} \cdot \sin \theta_c} = \frac{S_y}{N_y} \qquad (5)$$

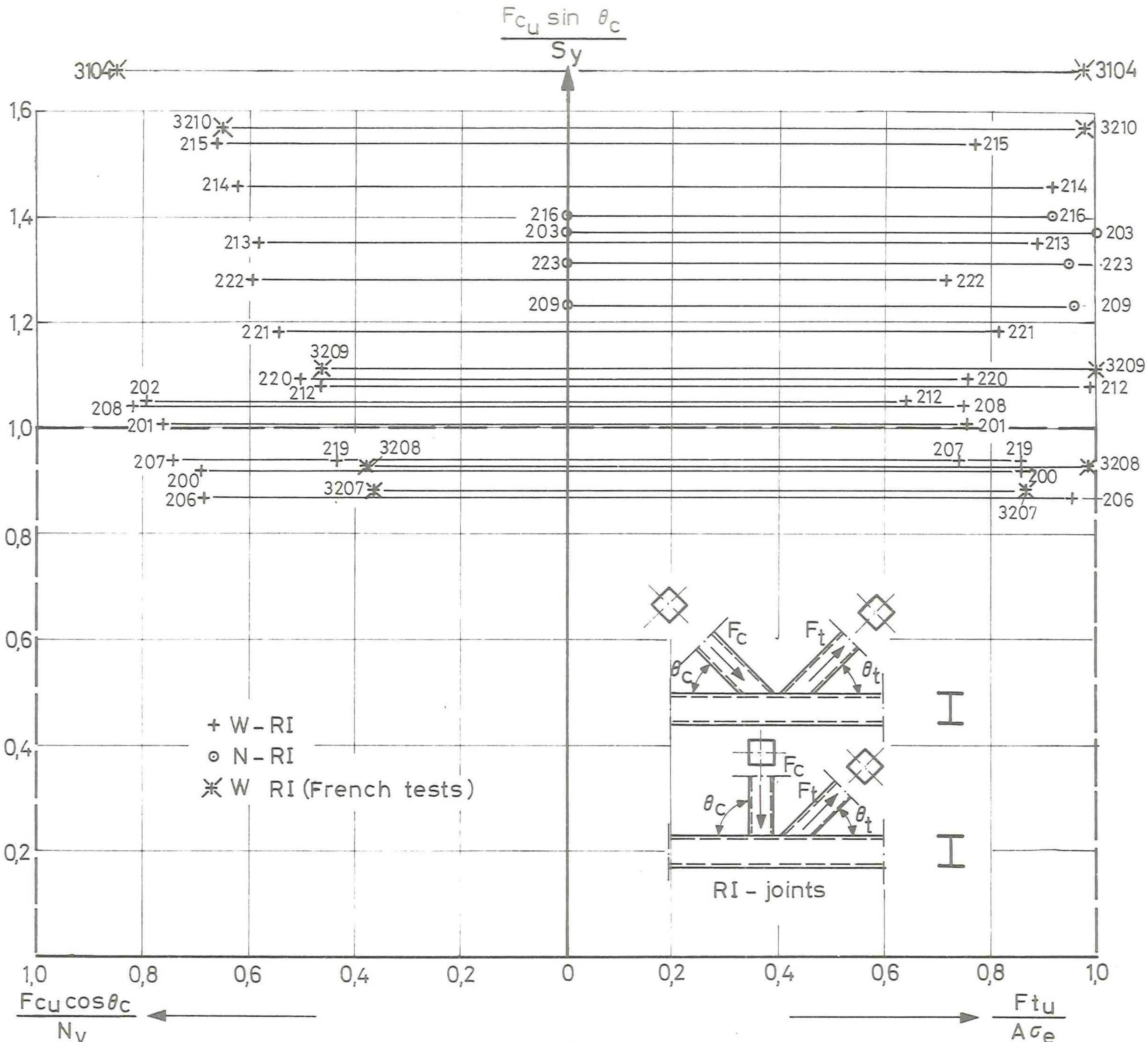



figure 7 relation between $\frac{F_{t_u}}{A\sigma_e}$, $\frac{F_{c_u} \cos \theta_c}{N_y}$ and $\frac{F_{c_u} \sin. \theta_c}{S_y}$ for RI joints

For Warren type joints this results in:

IPE profiles $\theta \simeq 37^o$

HEA profiles $\theta \simeq 24^o$

This means that for the investigated specimens the shear yield strength of the chord was theoretically not reduced by the influence of the axial load in the chord.
With formula (3) it can be shown that shear loads in the chord web up to about 0.4 $S_y$ do not reduce the yield load of the chord more than 5%.

Regarding the cross section of the chord between the two bracings it can be concluded that for the specimens investigated only the shear yield criterion is decisive.

In those cases in which the bracings were much stronger than the theoretical shear yield capacity of the chord ultimate loads were found greater than those corresponding to this theoretical shear yield capacity of the chord.
This was especially found for those specimens in which the chord flanges were low stressed by the horizontal bracing load component e.g. HEA sections.

At loads equal to the theoretical shear yield load the total cross section was not full in yield which leads to greater ultimate loads.
The greater strength may also be caused by bending and membrane effects in the chord flanges.
Joints with small gaps showed greater strengths than those with greater gaps due to a greater restraining effect.
Specimens in which the yield strength of the bracings could be reached before or at the same time as the shear yield in the chord generally showed yielding at loads which were 85-100% of the full yield strength $A\sigma_e$ of the bracings or the shear yield strength $A_s.\tau_e$ of the chord.

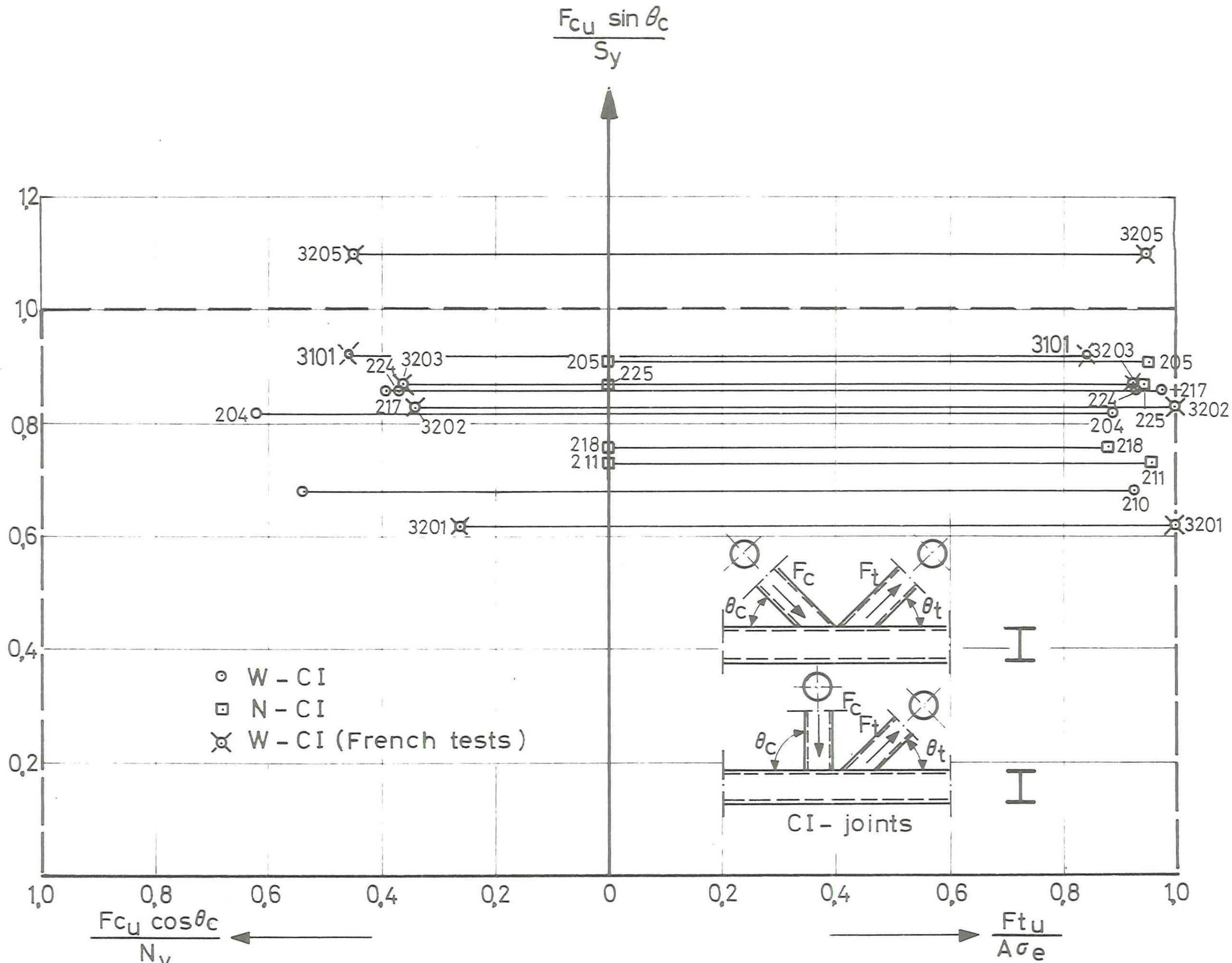



figure 8 relation between $\frac{Ft_u}{A\sigma_e}$, $\frac{Fc_u \cos\theta_c}{N_y}$ and $\frac{Fc_u \sin\theta_c}{S_y}$ for CI joints

This may be caused by secondary bending effects due to partial yielding of the bracings. Joints which are part of a truss are more restraint at the ends of all members than isolated joints with a free end of the chord.

At this moment girder tests are carried out in France and final conclusions can be expected after completion of these girder tests.

For a visual indication of the loading situation at failure in figures 7 and 8 the test results are plotted against the parameters,

$$\frac{F_{cu}}{A_t \sigma_{e_{t.b}}} , \quad \frac{F_{cu} . \sin \theta_c}{S_y} \quad \text{and} \quad \frac{F_{cu} . \cos \theta_c}{N_y}$$

In figures 7 and 8 also test results are recorded derived from a French research programme [2] on these types of joints. For these test results the same conclusions can be drawn as made before.

From the French test results, summarized in Table IV it can also be concluded that an overlap of the bracings gives a greater joint strength. The test results 3205 and 3210 show that joints with a gap g=0 can have a greater strength than gap joints with greater gaps as far as the bracings are made of RHS.

In this case the vertical bracing load component can partly directly be transferred by the intersecting bracing faces which results in a lower shear load in the chord web.

In case of circular bracing members this influence is less.

For gap joints the yield criteria for the cross section of the chord between the bracings can be summarized as follows:

$$S = F_{cu} . \sin \theta_c \leq A_s . \frac{\sigma_e}{\sqrt{3}} \qquad (1a)$$

$$N \leq (A-A_s)\sigma_e + A_s . \sigma_e \sqrt{1 - \left(\frac{S}{S_y}\right)^2} \qquad (3)$$

These formulae can also be given in the following simplified form:

$$\frac{S}{A_s \tau_e} \leq 1.0 \qquad (1b)$$

$$\frac{S}{A . \tau_e} + \frac{N}{A\sigma_e} \leq 1.0 \qquad (3a)$$

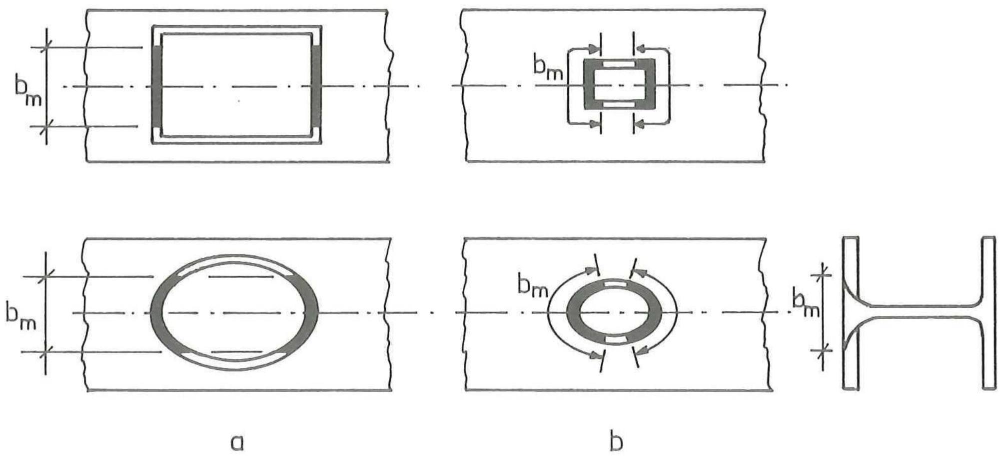



Figure 9 : Effective width criterion.

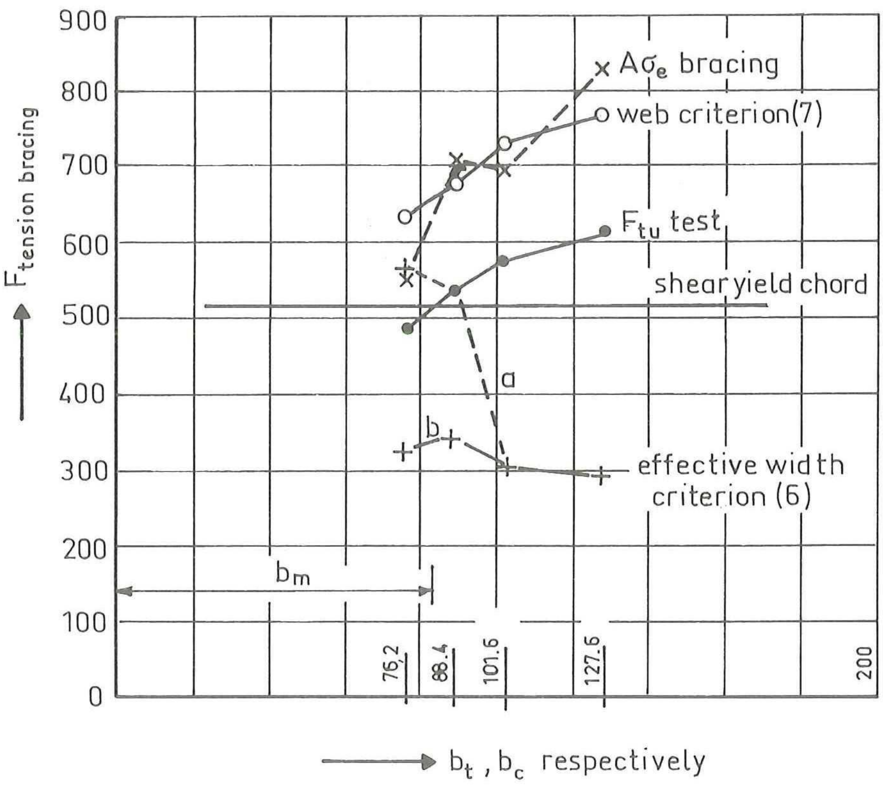



Figure 10 : Comparison of some criteria with the test results for Warren-type specimens with HE 200A chord and square bracing sections

## 7.2. Failure by cracking

Only two specimens in the Dutch test series showed a crack initiation at or just before failure.
As can be concluded from table III both specimens were then already loaded to about 140% of the theoretical shear load of the chord.
In this case there was an extra factor of 1.4 between the decisive yield criterion and crack initiation.
Based on these test results it may not be concluded that this is always true for all such types of joints independent of the type of I section.

In ref. [6] for beam column connections of I profiles (Fe 360) following effective width criterion is given for the flanges loaded in tension:

$$F_{ty} = 2.\sigma_e.t_t.(2t_w+7T) \qquad (6)$$

Figure 9 shows two situations:

a. The area within a certain width is effective.
   This criterion is not acceptable for rectangular bracings because of its discontinu behaviour.
b. The effective length is measured along the intersection of the bracing with the chord flange.
   This criterion is better but may be conservative when not corrected for the flanges parallel to the chord axis.

Although these tests are not representative for the determination of an effective width criterion (only in two specimens cracks) for indication the test results were compared with the condition of formula (6).
Figure 10 only shows the results for the Warren type specimens with a chord HE 200 A and square bracing members.
For the other specimens similar relations were found.
Better information for this criterion of failure can be derived from cross joint tests loaded in tension.
In ref. [2] cross joint tests were carried out with a HE 100 A section as chord and circular or square bracings.
Comparison of the ultimate loads with criterion (6) shows a ratio of 1.8 to 2.1.
Two cross joints with a HE 100 A as chord and rectangular bracings ⌀ 100x50x3 and ⌀ 100x150x5 respectively were tested in Delft.

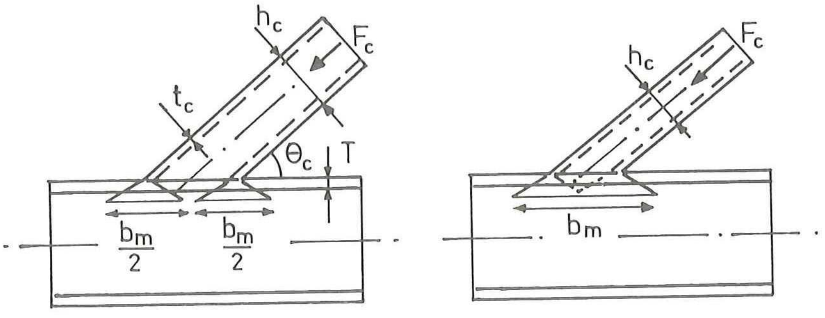



Figure 11: Yield criterion for web.

In this case it was also found that the ratio between ultimate strength (cracking) and criterion (6) was about 2.

Based on the tests carried out up to now it seems that criterion (6) is rather conservative for axially loaded joints with structural hollow sections as bracings and an I profile as chord.

This criterion has to be studied more in detail with some principal simple basic tests before a properly defined criterion can be given.

7.3. Other criteria

- The load in the bracing must be transferred by an effective area in the web of the chord.
  Two conditions exist as shown in figure 11.
  Based on yield following criteria are used in beam column connections:

$$F_c \cdot \sin \theta_c = b_m . t_w . \sigma_e \qquad (7)$$

with

$$b_m \leq 2.\{t_c + 5\ (T + r)\} \qquad (8)$$

$$b_m \leq \frac{h_c}{\sin \theta_c} + c\ (T + r) \qquad (9)$$

  In figure 10 this condition is shown for c=5.
  Compared with the shear yield criterion of the chord this criterion (7) was not decisive.

  A factor c=2 shows very conservative values compared with the test results and is not further given in this document.

- For bracings loaded in tension other criteria exist because a part of the load is taken by the flanges in which a yield pattern exists. It is clear that due to the stiffening of the chord flange by the side walls of the bracings the situation is more favourable than for beam column connections in I-profiles.

- For very thin walled chords local buckling of the web has to be considered whereas for very thin walled hollow sections local buckling of these sections must be considered.

- The welds should have a sufficient throat thickness to guarantee redistribution of stresses.
  In tubular structures it is common to choose the throat thickness equal to the wall thickness of the connected bracing.

- To prevent cracks in the bracings near the weld the steel material should have a sufficient ductility.

- Failure of the chord flange due to imperfections in the flange of the I-profile or lamellar tearing (more probable for very thick walled chord flanges)
  These tests as well as those in France were generally carried out on relatively thick walled, hot formed sections.
  For final recommendations strict limitations for the range of validity have to be defined.
  These limitations can be based on simple basic tests which have to be carried out.
  If and to what degree extrapolation is possible and acceptable is still a point of discussion.

## 8. SUMMARY AND PRELIMINARY CONCLUSIONS.

In this document the test results are given of an investigation into the static strength of welded joints with bracings of square or circular hollow sections and an I profile as chord.
In this investigation Warren- and Pratt type gap joints with IPE or HEA profiles as chord were investigated.

With respect to the static strength following conclusions can be given:

- As far as yielding of the bracings was not the criterion of failure all specimens showed a shear yield failure of the chord.

  In those cases for which the remaining part of the cross section of the chord was low stressed by the horizontal bracing load component e.g. Pratt type joints and most joints with a HEA profile as chord, the ultimate joint strength was increased due to restraining of the flange of the chord by the bracings, membrane effects in the flange of the chord and possible strain hardening effects in the web.

- For the specimens in which the yield strength of the bracings could be reached before or at the same load as the theoretical shear yield load of the chord yielding was observed at loads which were about 85 to 100 % of the full yield strength $A\sigma_e$ of the bracings.

- Compared with the analytical strength of the cross section of the chord in the gap area the observed strength of joints with circular bracings was lower than those of joints with square bracings
$\left( \frac{d_1 + d_2}{2.B} \quad \frac{b_1 + b_2}{2.B} \right)$
In joints with circular bracings the chord flange in the gap area is less restraint for deformations out of plane than in joints with square bracings which may lead to a little greater joint strength for joints with square bracings,

- The N-type joints tested generally showed as far as yielding of the bracings was not the criterion, a greater strength than the Warren type joints. This was caused by the absence of a horizontal bracing load component in the critical cross section of the chord and a smaller gap size.

The measured deformations up to yield generally were small.
Only in two specimens crack initiation in the tension bracing just above the weld was observed just before failure. In both cases the applied loads were about 40% greater than those which cause shear yield in the chord.

From these tests and those carried out in France [2] it could be concluded that the joints with weld gap can be calculated according to the general plastic design rules.

However, additional basic tests have to be carried out to verify in which cases an effective width criterion can be omitted and when necessary the conditions have to be determined for these types of joints.
Comparison of the test results with the effective width criterion for beam column connections [5] shows that this criterion is very conservative for these types of joints.

For the presentation of final recommendations therefore, it must be born in mind that other types of failure then only shear failure are possible and attension must be paid to the ductility of the steel quality as well as the weld dimensions.
The joints with overlap are investigated in a French programme [2].

These test results and those of the French programme will be used for further analysis for the drafting of design recommendations and specifications.
Members of the committee XV of the IIW who have more information regarding these types of joints are asked for information.

REFERENCES:


1. SG-TC-18 : Research programme: The static strength of welded lattice girder joints in structural hollow sections. (revised programme).
Stevin report 6-74-6*
TNO-IBBC report BI-74-39*/05.3.11.270.

2. : Etude d'assemblages de profiles creux sur profils ouverts.
Essai No. 212 187, Laboratoire National d'Essais
Cidect programme 5N.
Compte rendu No. 1.
Compte rendu No. 2.
Compte rendu No. 3.

3. Tournay, M. : Les assemblages des profils creux sur profils ouverts
VDI- Beratungsstelle für Stahlverwendung, Cidect, Gipec.
Conference on Hollow Sections, Düsseldorf. 30.9.1975.

4. Wardenier, J. Koning, C.H.M. de : Investigation into the static strength of welded joints with SHS bracings and an I profile as chord.
TNO-IBBC report nr. BI-76-89/35.3.51210
Stevin report nr. 6-76-19
September 1966.

5. Roik, K Wagenknecht, G. : Traglastdiagramme zur Bemessung von Druckstäben mit doppelsymmetrischem Querschnitt aus Baustahl
Konstruktiver Ingenieurbau, Heft 27, Januar 1977.

6. IIW-XV : Design Rules for Arc-welded connections in Steel submitted to static loads (Doc. XV-358-74 revised).

TABLE I. TEST SERIES

| 2 | | | Profile for chord | | | |
|---|---|---|---|---|---|---|
| | | | IPE 120 | IPE 160 | HE 120 A | HE 200 A |
| ratio $\frac{b_c+b_t}{2B}$ or $\frac{d_c+d_t}{2B}$ | a | ≃1.0 | W-RI - 202 | | | |
| | b | ≃0.9 | W-RI - 201<br>N-RI - 203 | W-RI - 208 | | |
| | c | ≃0.8 | W-CI - 204<br>N-CI - 205 | W-RI - 207<br>N-RI - 209<br>W-CI - 210<br>N-CI - 211 | W-RI - 215 | |
| | d | ≃0.6 | W-RI - 200 | W-RI - 206 | W-RI - 214 | W-RI - 222 |
| | e | ≃0.5 | | | W-RI - 213<br>N-RI - 216<br>W-CI - 217<br>N-CI - 218 | W-CI - 221<br>W-CI - 224<br>N-CI - 225 |
| | f | ≃0.4 | | | W-RI - 212 | W-RI - 219<br>W-RI - 220<br>N-RI - 223 |

<u>Test specimen indication:</u>

W-RI-b-201 means:

W = Warren-type joint.

R = Rectangular sections for bracings.

I = I-profile for chord.

b = ratio $\frac{b_c+b_t}{2B}$ ≃ 0.9

201 = number test specimen.

TABLE II. MECHANICAL PROPERTIES

| Test specimen No. | Chord: Stub column $\sigma_e$ (N/mm²) | Chord: Tensile test (Full section) $\sigma_e$ (N/mm²) | $R_M$ (N/mm²) | $\frac{\sigma_e}{R_M}$ *) | Elongation % | Constriction % | $\frac{\sigma_e}{R_M}$ **) | Bracings: Stub column $\sigma_e$ (N/mm²) | Bracings: Tensile Test ($d_p$ 5) $\sigma_e$ (N/mm²) | $R_M$ (N/mm²) | $\frac{\sigma_e}{R_M}$ *) | Elongation % | Constriction % | $\frac{\sigma_e}{R_M}$ **) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W-RI - 200 | 273 | 270 | 382 | 0.71 | 40 | 59 | 0.71 | 335 | 345 | 502 | 0.69 | 30.5 | 64.5 | 0.67 |
| W-RI - 201 | ,, | ,, | ,, | ,, | ,, | ,, | ,, | 311 | 309 | 489 | 0.63 | - | 44.5 | 0.64 |
| W-RI - 202 | ,, | ,, | ,, | ,, | ,, | ,, | ,, | 352 | 376 | 449 | 0.84 | 40.7 | 52.7 | 0.78 |
| N-RI - 203 | ,, | ,, | ,, | ,, | ,, | ,, | ,, | 311 | 309 | 489 | 0.63 | - | 44.5 | 0.64 |
| W-CI - 204 | ,, | ,, | ,, | ,, | ,, | ,, | ,, | 365 | 326 | 420 | 0.78 | 39 | 64.7 | 0.87 |
| N-CI - 205 | ,, | ,, | ,, | ,, | ,, | ,, | ,, | 365 | 326 | 420 | 0.78 | 39 | 64.7 | 0.87 |
| W-RI - 206 | 316 | 295 | 458 | 0.64 | 39 | 54 | 0.69 | 324 | 313 | 473 | 0.66 | 48.7 | 68.1 | 0.68 |
| W-RI - 207 | ,, | ,, | ,, | ,, | ,, | ,, | ,, | 344 | 320 | 493 | 0.73 | 50 | 49.8 | 0.70 |
| W-RI - 208 | ,, | ,, | ,, | ,, | ,, | ,, | ,, | 296 | 291 | 482 | 0.60 | - | 47.4 | 0.61 |
| N-RI - 209 | ,, | ,, | ,, | ,, | ,, | ,, | ,, | 344 | 320 | 493 | 0.73 | 50 | 49.8 | 0.70 |
| W-CI - 210 | ,, | ,, | ,, | ,, | ,, | ,, | ,, | 295 | 294 | 417 | 0.71 | 39 | 71 | 0.71 |
| N-CI - 211 | ,, | ,, | ,, | ,, | ,, | ,, | ,, | 295 | 294 | 417 | 0.71 | 39 | 71 | 0.71 |
| W-RI - 212 | 278 | 280 | 395 | 0.71 | 36 | 60 | 0.70 | 324 | 313 | 473 | 0.66 | 48.7 | 68.1 | 0.68 |
| W-RI - 213 | ,, | ,, | ,, | ,, | ,, | ,, | ,, | 344 | 320 | 493 | 0.73 | 50 | 49.8 | 0.70 |
| W-RI - 214 | ,, | ,, | ,, | ,, | ,, | ,, | ,, | 296 | 292 | 482 | 0.61 | - | 47.4 | 0.61 |
| W-RI - 215 | ,, | ,, | ,, | ,, | ,, | ,, | ,, | 295 | 296 | 483 | 0.61 | 50.7 | 51.4 | 0.61 |
| N-RI - 216 | ,, | ,, | ,, | ,, | ,, | ,, | ,, | 344 | 320 | 493 | 0.73 | 50 | 49.8 | 0.70 |
| W-CI - 217 | ,, | ,, | ,, | ,, | ,, | ,, | ,, | 295 | 294 | 417 | 0.71 | 39 | 71 | 0.71 |
| N-CI - 218 | ,, | ,, | ,, | ,, | ,, | ,, | ,, | 295 | 294 | 417 | 0.71 | 39 | 71 | 0.71 |
| W-RI - 219 | 261 | 272 | 365 | 0.75 | 41 | 62 | 0.72 | 342 | 371 | 502 | 0.74 | 40.3 | 48.9 | 0.68 |
| W-RI - 220 | ,, | ,, | ,, | ,, | ,, | ,, | ,, | 347 | 338 | 493 | 0.69 | - | 53.2 | 0.70 |
| W-RI - 221 | ,, | ,, | ,, | ,, | ,, | ,, | ,, | 298 | 300 | 481 | 0.62 | 55.7 | 54.5 | 0.62 |
| W-RI - 222 | ,, | ,, | ,, | ,, | ,, | ,, | ,, | 285 | 291 | 444 | 0.66 | - | 51.7 | 0.64 |
| N-RI - 223 | ,, | ,, | ,, | ,, | ,, | ,, | ,, | 347 | 338 | 493 | 0.69 | - | 53.2 | 0.70 |
| W-CI - 224 | ,, | ,, | ,, | ,, | ,, | ,, | ,, | 279 | 277 | 423 | 0.65 | 37 | 61.2 | 0.66 |
| N-CI - 225 | ,, | ,, | ,, | ,, | ,, | ,, | ,, | 279 | 277 | 423 | 0.65 | 37 | 61.2 | 0.66 |

*) Tensile test.

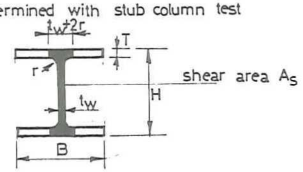
**) Stub column test.

TABLE III. TESTRESULTS

| Test No. | Type | chord: Measured dimensions (mm) Section | H | B | T | $t_w$ | r | A ($mm^2$) | $\sigma_e$ *) ($N/mm^2$) | $A\sigma_e$ (KN) | GAP g (mm) | g/B | Eccentricity e(mm) | bracings: Measured dimensions (mm) | $A_{t(c)}$ ($mm^2$) | $\sigma_e$ *) ($N/mm^2$) | $A\sigma_e$ (kN) | $F_{c_u}$ (KN) | $F_{t_u}$ (kN) | F chord (kN) | Type of failure | F crack in % $F_{t_u}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 200 | W-RI | IPE-120 | 119.3 | 64.2 | 6.2 | 4.4 | 7 | 1310 | 273 | 357.6 | 66.3 | 1.03 | 0 | ⌀37.8-3.89 | 531 | 335 | 178 | 151 | 153 | 215 | G3 | - |
| 201 | W-RI | ″ | ″ | ″ | ″ | ″ | ″ | ″ | ″ | ″ | 48.4 | 0.75 | 0 | ⌀56 -3.82 | 711 | 311 | 221 | 167 | 169 | 238 | G3 | - |
| 202 | W-RI | ″ | ″ | ″ | ″ | ″ | ″ | ″ | ″ | ″ | 30.5 | 0.48 | 0 | ⌀64.2-3.24 | 801 | 352 | 282 | 173 | 180 | 252 | G3 | - |
| 203 | N-RI | ″ | ″ | ″ | ″ | ″ | ″ | ″ | ″ | ″ | 6.4 | 0.1 | +14.3 | ⌀56 -3.82 | 711 | 311 | 221 | 161 | 221 | 167 | $\sigma_e$ in t.b.+G3 | ∞100 **) |
| 204 | W-CI | ″ | ″ | ″ | ″ | ″ | ″ | ″ | ″ | ″ | 48.1 | 0.75 | 0 | Ø51.3-3.13 | 430 | 365 | 157 | 136 | 140 | 196 | G3 | - |
| 205 | N-CI | ″ | ″ | ″ | ″ | ″ | ″ | ″ | ″ | ″ | 6.4 | 0.1 | + 8.6 | Ø51.3-3.13 | 430 | 365 | 157 | 106 | 149 | 109 | $\sigma_e$ in t.b. | - |
| 206 | W-RI | IPE-160 | 159.8 | 82.2 | 7.3 | 5.2 | 9 | 2025 | 316 | 639.9 | 88.4 | 1.08 | 0 | ⌀50.4-4.69 | 877 | 324 | 284 | 261 | 272 | 370 | G3+$\sigma_e$in t.b. | - |
| 207 | W-RI | ″ | ″ | ″ | ″ | ″ | ″ | ″ | ″ | ″ | 70.5 | 0.86 | 0 | ⌀63.4-4.75 | 1116 | 344 | 384 | 283 | 284 | 403 | G3 | - |
| 208 | W-RI | ″ | ″ | ″ | ″ | ″ | ″ | ″ | ″ | ″ | 52.6 | 0.64 | 0 | ⌀76 -4.81 | 1382 | 296 | 409 | 314 | 305 | 442 | G3 | - |
| 209 | N-RI | ″ | ″ | ″ | ″ | ″ | ″ | ″ | ″ | ″ | 8.2 | 0.1 | + 4.6 | ⌀63.4-4.75 | 1116 | 344 | 384 | 263 | 368 | 283 | $\sigma_e$ in t.b.+G3 | - |
| 210 | W-CI | ″ | ″ | ″ | ″ | ″ | ″ | ″ | ″ | ″ | 70.5 | 0.86 | 0 | Ø63.5-4.25 | 759 | 295 | 224 | 205 | 208 | 290 | $\sigma_e$ in brac. | - |
| 211 | N-CI | ″ | ″ | ″ | ″ | ″ | ″ | ″ | ″ | ″ | 8.2 | 0.1 | + 4.6 | Ø63.5-4.25 | 759 | 295 | 224 | 155 | 216 | 161 | $\sigma_e$ in t.b | - |
| 212 | W-RI | HE-120 A | 116.6 | 119.9 | 8.2 | 5 | 12 | 2592 | 278 | 720.6 | 42.4 | 0.35 | 0 | ⌀50.4-4.69 | 877 | 324 | 284 | 269.5 | 280 | 382 | G3+$\sigma_e$ in brac. | - |
| 213 | W-RI | ″ | ″ | ″ | ″ | ″ | ″ | ″ | ″ | ″ | 24.5 | 0.20 | 0 | ⌀63.4-4.75 | 1116 | 344 | 384 | 337 | 343 | 476 | G3 + yielding in t.b. | - |
| 214 | W-RI | ″ | ″ | ″ | ″ | ″ | ″ | ″ | ″ | ″ | 12 | 0.1 | + 1 | ⌀76 -4.81 | 1382 | 296 | 409 | 364.5 | 374.5 | 510 | G3+G6+yielding in t.b. | 97 **) |
| 215 | W-RI | ″ | ″ | ″ | ″ | ″ | ″ | ″ | ″ | ″ | 12 | 0.1 | + 3.68 | ⌀88.2-5.02 | 1668 | 295 | 492 | 385 | 380 | 543 | G3+G6 | - |
| 216 | N-RI | ″ | ″ | ″ | ″ | ″ | ″ | ″ | ″ | ″ | 12 | 0.1 | +29.9 | ⌀63.4-4.75 | 1116 | 344 | 384 | 249 | 354 | 269 | $\sigma_e$ in t.b.+G3 | - |
| 217 | W-CI | ″ | ″ | ″ | ″ | ″ | ″ | ″ | ″ | ″ | 24.5 | 0.20 | 0 | Ø63.5-4.25 | 759 | 295 | 224 | 216 | 219 | 303 | $\sigma_e$ in brac. | - |
| 218 | N-CI | ″ | ″ | ″ | ″ | ″ | ″ | ″ | ″ | ″ | 12 | 0.1 | +29.9 | Ø63.5-4.25 | 759 | 295 | 224 | 135.5 | 198 | 144 | yielding in tension brac. | - |
| 219 | W-RI | HE-200 A | 188.8 | 201.3 | 9.8 | 6.7 | 20 | 5427 | 261 | 1416 | 82.6 | 0.41 | 0 | ⌀76.2-5.87 | 1650 | 342 | 564 | 478 | 486 | 700 | G3+$\sigma_e$ in brac. | - |
| 220 | W-RI | ″ | ″ | ″ | ″ | ″ | ″ | ″ | ″ | ″ | 64.7 | 0.32 | 0 | ⌀88.4-6.04 | 2029 | 347 | 704 | 557 | 537 | 810 | G3+yielding in t.b. | - |
| 221 | W-RI | ″ | ″ | ″ | ″ | ″ | ″ | ″ | ″ | ″ | 46.8 | 0.23 | 0 | ⌀101.3-6.18 | 2349 | 298 | 700 | 603 | 573 | 870 | G3+yielding in brac. | - |
| 222 | W-RI | ″ | ″ | ″ | ″ | ″ | ″ | ″ | ″ | ″ | 20 | 0.1 | +40.6 | ⌀127.6-6.31 | 2996 | 285 | 854 | 654 | 619 | 948 | G3+G6 | - |
| 223 | N-RI | ″ | ″ | ″ | ″ | ″ | ″ | ″ | ″ | ″ | 20 | 0.1 | +67.1 | ⌀88.4-6.04 | 2029 | 347 | 704 | 473 | 670 | 523 | $\sigma_e$ in t.b.+G3 | - |
| 224 | W-CI | ″ | ″ | ″ | ″ | ″ | ″ | ″ | ″ | ″ | 64.7 | 0.32 | 0 | Ø89.7-6.9 | 1692 | 279 | 472 | 437 | 441 | 640 | G3+$\sigma_e$ in brac. | - |
| 225 | N-CI | ″ | ″ | ″ | ″ | ″ | ″ | ″ | ″ | ″ | 20 | 0.1 | +68.7 | Ø89.7-6.9 | 1692 | 279 | 472 | 315 | 446 | 345 | $\sigma_e$ in t.b. | - |

*) determined with stub column test

*)




— no cracks observed

**) cracks in tension bracing

TABLE III.A TESTRESULTS

| Test No. | Type | $\frac{b_c+b_t}{2B}$ / $\frac{d_c+d_t}{2B}$ | $\frac{b_c}{b_t}$ or $\frac{d_c}{d_t}$ | $\frac{F_{cu}}{A\sigma_{e\,c.b}}$ | $\frac{F_{tu}}{A\sigma_{e\,t.b}}$ | $\frac{F\ chord}{A\sigma_{e\,chord}}$ | $F_{cu}\cdot\sin\Theta$ (kN) | Shear*) Area $A_s$ ($mm^2$) | Shear yield load $S_y$ (kN) | $\frac{F_{cu}\cdot\sin\Theta}{S_y}$ | reduced area $A-A_s$ for axial load ($mm^2$) | reduced axial yield load $N_y$ (kN) | $\frac{F_{cu}\cdot\cos\Theta}{N_y}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 200 | W-RI | 0.59 | 9.72 | 0.85 | 0.86 | 0.60 | 107.2 | 740 | 117.1 | 0,92 | 570 | 155.6 | 0.69 |
| 201 | W-RI | 0.87 | 14.66 | 0.76 | 0.76 | 0.67 | 118.6 | ″ | ″ | 1.01 | ″ | ″ | 0.76 |
| 202 | W-RI | 1.00 | 19.81 | 0.61 | 0.64 | 0.70 | 122.8 | ″ | ″ | 1.05 | ″ | ″ | 0.79 |
| 203 | N-RI | 0.87 | 14.66 | 0.73 | 1.0 | 0.47 | 161 | ″ | ″ | 1.37 | ″ | ″ | 0 |
| 204 | W-CI | 0.80 | 16.4 | 0.87 | 0.89 | 0.55 | 96.6 | ″ | ″ | 0.82 | ″ | ″ | 0.62 |
| 205 | N-CI | 0.80 | 16.4 | 0.68 | 0.95 | 0.30 | 106 | ″ | ″ | 0.91 | ″ | ″ | 0 |
| 206. | W-RI | 0.61 | 10.75 | 0.92 | 0.96 | 0.58 | 185.3 | 1164 | 213.4 | 0.87 | 861 | 272 | 0.68 |
| 207 | W-RI | 0.77 | 13.35 | 0.74 | 0.74 | 0.63 | 200.9 | ″ | ″ | 0.94 | ″ | ″ | 0.74 |
| 208 | W-RI | 0.92 | 15.80 | 0.77 | 0.75 | 0.69 | 222.9 | ″ | ″ | 1.04 | ″ | ″ | 0.82 |
| 209 | N-RI | 0.77 | 13.35 | 0.68 | 0.96 | 0.44 | 263 | ″ | ″ | 1.23 | ″ | ″ | 0 |
| 210 | W-CI | 0.77 | 14.9 | 0.92 | 0.93 | 0.45 | 145.6 | ″ | ″ | 0.68 | ″ | ″ | 0.54 |
| 211 | N-CI | 0.77 | 14.9 | 0.69 | 0.96 | 0.25 | 155 | ″ | ″ | 0.73 | ″ | ″ | 0 |
| 212 | W-RI | 0.42 | 10.75 | 0.95 | 0.99 | 0.53 | 191.3 | 1101 | 177.5 | 1.08 | 1491 | 414.5 | 0.46 |
| 213 | W-RI | 0.53 | 13.35 | 0.88 | 0.89 | 0.66 | 239.3 | ″ | ″ | 1.35 | ″ | ″ | 0.58 |
| 214 | W-RI | 0.63 | 15.80 | 0.89 | 0.92 | 0.71 | 258.8 | ″ | ″ | 1.46 | ″ | ″ | 0.62 |
| 215 | W-RI | 0.74 | 17.57 | 0.78 | 0.77 | 0.75 | 273.4 | ″ | ″ | 1.54 | ″ | ″ | 0.66 |
| 216 | N-RI | 0.53 | 13.35 | 0.65 | 0.92 | 0.37 | 249 | ″ | ″ | 1.40 | ″ | ″ | 0 |
| 217 | W-CI | 0.53 | 14.9 | 0.96 | 0.98 | 0.42 | 153.4 | ″ | ″ | 0.86 | ″ | ″ | 0.37 |
| 218 | N-CI | 0.53 | 14.9 | 0.60 | 0.88 | 0.20 | 135.5 | ″ | ″ | 0.76 | ″ | ″ | 0 |
| 219 | W-RI | 0.38 | 12.98 | 0.85 | 0.86 | 0.49 | 339.4 | 2393 | 362.3 | 0.94 | 3034 | 791.8 | 0.43 |
| 220 | W-RI | 0.44 | 14.64 | 0.79 | 0.76 | 0.57 | 395.5 | ″ | ″ | 1.09 | ″ | ″ | 0.50 |
| 221 | W-RI | 0.50 | 16.39 | 0.86 | 0.82 | 0.61 | 428.1 | ″ | ″ | 1.18 | ″ | ″ | 0.54 |
| 222 | W-RI | 0.63 | 20.22 | 0.77 | 0.72 | 0.67 | 464.3 | ″ | ″ | 1.28 | ″ | ″ | 0.59 |
| 223 | N-RI | 0.44 | 14.64 | 0.67 | 0.95 | 0.37 | 473 | ″ | ″ | 1.31 | ″ | ″ | 0 |
| 224 | W-CI | 0.45 | 13.0 | 0.93 | 0.93 | 0.45 | 310.3 | ″ | ″ | 0.86 | ″ | ″ | 0.39 |
| 225 | N-CI | 0.45 | 13.0 | 0.67 | 0.94 | 0.24 | 315 | ″ | ″ | 0.87 | ″ | ″ | 0 |

TABLE IV TEST RESULTS OF FRENCH RESEARCH PROGRAMME [2]

| Testp. No. | Type | Chord: Dimensions *) (mm) Section | H | B | T | $t_w$ | r | A ($mm^2$) | $\sigma_e$ ..) ($N/mm^2$) | $A\sigma_e$ (kn) | gap g (mm) | g/B | Eccentri-city e (mm) | Bracings: Dimensions*) (mm) | $A_{t(c)}$ ($mm^2$) | $\sigma_e$ ..) ($N/mm^2$) | $A\sigma_e$ (kN) | $F_{c_u}$, $F_{t_u}$ (kN) | $F_{chord}$ (kN) | Type of failure |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3101 | W-CI | HE-100 A | 96 | 100 | 8 | 5 | 12 | 2120 | 275 | 583 | 10 | 0.1 | - 1.82 | ø 60.3 - 4.5 | 789 | 310 | 244.6 | 204.8 | 290.5 | |
| 3102 | W-CI | " | | | | | | | 256 | 543 | - 11 | - 0.11 | + 2.44 | ø 76.1 - 4.5 | 1010 | 240 | 242.4 | 218.8 | 310.4 | |
| 3103 | W-CI | " | | | | | | | 243 | 515 | - 29 | - 0.29 | + 0.78 | ø 88.9 - 5.4 | 1410 | 277 | 390.6 | 385 | 546.1 | |
| 3104 | W-RI | " | | | | | | | 244 | 517 | 11 | 0.11 | - 3.48 | ø 60 - 5.0 | 1080 | 316 | 341.3 | 332.5 | 471.6 | |
| 3105 | W-RI | " | | | | | | | 247 | 524 | - 3 | - 0.03 | - 5.25 | ø 70 - 5.0 | 1280 | 315 | 403.2 | 367.5 | 521.3 | |
| 3107 | W-RI | " | | | | | | | 240 | 509 | - 31 | - 0.31 | - 3.05 | ø 90 - 6.0 | 1996 | 263 | 524.9 | 402.5 | 570.9 | |
| 3201 | W-CI | HE-200 A | 190 | 200 | 10 | 6.5 | 18 | 5380 | 240 | 1291 | 82 | 0.41 | - 4.85 | ø 76.1 - 4.5 | 1010 | 260 | 262.6 | 274.8 | 389.7 | |
| 3202 | W-CI | " | | | | | | | 266 | 1431 | 64 | 0.32 | + 0.71 | ø 88.9 - 5.4 | 1410 | 266 | 375.1 | 402.5 | 570.9 | |
| 3203 | W-CI | " | | | | | | | 358 | 1926 | 46 | 0.23 | + 2.53 | ø 101.6 - 7.1 | 2110 | 291 | 614 | 570.5 | 809.2 | |
| 3205 | W-CI | " | | | | | | | 347 | 1867 | 0 | 0 | + 4.05 | ø 139.7 - 7.1 | 2960 | 250 | 740 | 700 | 992.9 | |
| 3206 | W-CI | " | | | | | | | 308 | 1657 | - 43 | - 0.22 | - 0.84 | ø 168.3 - 7.1 | 3600 | 278 | 1000.8 | 840 | 1191.5 | |
| 3207 | W-RI | " | | | | | | | 250 | 1345 | 77 | 0.39 | - 1.88 | ø 80 - 6.0 | 1760 | 263 | 462.8 | 402.5 | 570.9 | |
| 3208 | W-RI | " | | | | | | | 278 | 1496 | 63 | 0.32 | + 1.04 | ø 90 - 6.0 | 1996 | 239 | 477 | 472.5 | 670.2 | |
| 3209 | W-RI | " | | | | | | | 326 | 1754 | 49 | 0.25 | + 2.07 | ø 100 - 7.0 | 2580 | 254 | 655.3 | 665 | 943.3 | |
| 3210 | W-RI | " | | | | | | | 310 | 1668 | 0 | 0 | + 2.31 | ø 135 - 7.0 | 3560 | 257 | 914.9 | 892.5 | 1265.9 | |

*) Nominal dimensions

..) Determined on full section

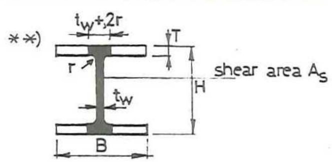
**) 

TABLE IV A

| Testp. No. | Type | $\frac{b_c + b_t}{2B}$ or $\frac{d_c + d_t}{2B}$ | $\frac{b_c}{t_c}$ or $\frac{d_c}{t_c}$ | $\frac{F_{cu}}{A\sigma_{e\,c.b}}$ | $\frac{F_{tu}}{A\sigma_{e\,t.b}}$ | $\frac{F_{chord}}{A\sigma_{e\,chord}}$ | $F_{c_u}.\sin\Theta$ $F_{c_u}.\cos\Theta$ (kN) | Shear area $A_s$ **) ($mm^2$) | Shear yield load $S_y$ (kN) | $\frac{F_{c_u}.\sin\Theta}{S_y}$ | Reduced area $A$-$A_s$ for axial load ($mm^2$) | Reduced axial yield load $N_y$ (kN) | $\frac{F_{c_u}.\cos\Theta}{N_y}$ | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3101 | W-CI | 0.6 | 13.4 | 0.84 | 0.84 | 0.50 | 144.8 | 988 | 157.5 | 0.92 | 1132 | 311.3 | 0.47 | |
| 3102 | W-CI | 0.76 | 16.9 | 0.90 | 0.90 | 0.57 | 154.7 | " | 146.6 | 1.06 | " | 289.8 | 0.53 | lap joint |
| 3103 | W-CI | 0.89 | 16.5 | 0.99 | 0.99 | 1.06 | 272.2 | " | 139.2 | 1.96 | " | 275.1 | 0.99 | lap joint |
| 3104 | W-RI | 0.6 | 12 | 0.97 | 0.97 | 0.91 | 235.1 | " | 139.8 | 1.68 | " | 276.2 | 0.85 | |
| 3105 | W-RI | 0.7 | 14 | 0.91 | 0.91 | 0.99 | 259.8 | " | 141.5 | 1.84 | " | 279.6 | 0.93 | lap joint |
| 3107 | W-RI | 0.9 | 15 | 0.77 | 0.77 | 1.12 | 284.6 | " | 137.5 | 2.07 | " | 271.7 | 1.05 | lap joint |
| 3201 | W-CI | 0.38 | 16.9 | ~1.0 | ~1.0 | 0.30 | 194.3 | 2234 | 310.9 | 0.62 | 3146 | 755 | 0.26 | |
| 3202 | W-CI | 0.45 | 16.5 | ~1.0 | ~1.0 | 0.40 | 284.6 | " | 344.6 | 0.83 | " | 836.8 | 0.34 | |
| 3203 | W-CI | 0.51 | 14.3 | 0.93 | 0.93 | 0.42 | 403.3 | " | 463.8 | 0.87 | " | 1126.3 | 0.36 | |
| 3205 | W-CI | 0.7 | 19.7 | 0.95 | 0.95 | 0.53 | 494.9 | " | 449.6 | 1.10 | " | 1091.6 | 0.45 | |
| 3206 | W-CI | 0.84 | 23.7 | 0.84 | 0.84 | 0.72 | 593.9 | " | 399 | 1.49 | " | 969 | 0.61 | lap joint |
| 3207 | W-RI | 0.4 | 13.3 | 0.87 | 0.87 | 0.42 | 284.6 | " | 324 | 0.88 | " | 786.5 | 0.36 | |
| 3208 | W-RI | 0.45 | 15 | 0.99 | 0.99 | 0.45 | 334.1 | " | 360.2 | 0.93 | " | 874.6 | 0.38 | |
| 3209 | W-RI | 0.5 | 14.3 | ~1.0 | ~1.0 | 0.54 | 470.2 | " | 422.4 | 1.11 | " | 1025.6 | 0.46 | |
| 3210 | W-RI | 0.68 | 19.3 | 0.98 | 0.98 | 0.76 | 631 | " | 401.6 | 1.57 | " | 975.3 | 0.65 | |