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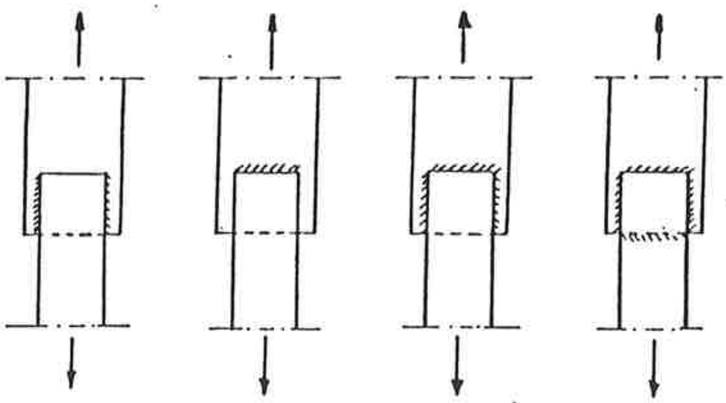
Report No.: BI-88-139

EVALUATION OF TEST RESULTS ON WELDED CONNECTIONS IN ORDER TO OBTAIN STRENGTH FUNCTIONS AND SUITABLE MODEL FACTORS - PART B: EVALUATIONS



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EVALUATION OF TEST RESULTS ON WELDED CONNECTIONS IN ORDER TO OBTAIN STRENGTH FUNCTIONS AND SUITABLE MODEL FACTORS - PART B: EVALUATIONS

Background report to Eurocode 3
"Common unified rules for steel structures"

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CONTENTS OF PART A: RESULTS

CONTENTS OF PART B: EVALUATIONS

ABSTRACT

On European level work is going on to come to harmonisation of design procedures for steel structures in the form of common unified rules in Eurocode No. 3. The Eurocode is presented in a limit state design (LFRD) format. In this report background information is presented on the strength functions and model factors for welded connections, given in Eurocode No. 3 (EC 3).

In order to arrive at strength functions and suitable model factors for welded connections, a statistical re-evaluation of available test results has been carried out.

The following procedure has been used for the determination of the design rules on welds in the 1988 revision of EC 3. Based on observation of actual behaviour in tests and on theoretical considerations a "design model" is selected. Then by statistical interpretation of all available test data i.e. regression analysis, the efficiency of the model is checked. Eventually the design model has to be adapted until the correlation of the theoretical values and the test data is sufficient. Then through manipulation with the statistical data of the test population, the model factor γ_M can be determined. Dividing the strength function by the model factor γ_M gives the design expression.

Starting points for the strength functions for welded connections are the functions presented in [1]. The results of the statistical analyses of the available test data of these connections are presented. Eventually, strength functions and model factors included in the 1988 revision of Eurocode No. 3 are determined.

The report has been split up into two parts:

- Part A: Results;
- Part B: Evaluations.

NOTATION

a	=	the throat size of a weld
a_1, a_2	=	constants
A	=	throat area, $A = a\ell$
A_1	=	throat area for welds perpendicular to the loading direction, $A_1 = ab$
A_2	=	throat area for welds parallel to the loading direction, $A_2 = a\ell$
b	=	the weld length
$\bar{b}$	=	mean value correction
f_u	=	specified ultimate tensile strength of plate material
$f_{u,w}$	=	the ultimate tensile strength of the fillet weld
$f_{u,wm}$	=	the ultimate tensile strength of the weld metal
f_y	=	the yield stress of the plate material
F	=	the force due to design loads
F_i	=	the theoretical resistance of the weld
k	=	a parameter in the strength function for fillet welds
k_d	=	fractile factor for a 75% predicting probability
k_s	=	fractile factor for estimating 5% fractiles
ℓ	=	the weld length
n	=	number of welds
r_n, r_k, r_d	=	nominal, characteristic and design resistance
r_{ei}	=	experimental resistance for specimen i
t_{ti}	=	theoretical resistance obtained by using the strength function for specimen i
R_k	=	characteristic resistance factor, 5% fractile
R_d	=	design resistance factor
t	=	plate thickness
V	=	coefficient of variation
V_δ	=	coefficient of variation of observed error terms
β	=	reliability index or coefficient in the strength function for fillet welds
β_w	=	the efficiency coefficient of a fillet weld
γ_M	=	model factor (partial safety factor) related to the 5% fractile
γ_M^*	=	modified model factor $\gamma_M^* = \gamma_M \Delta K$
ΔK	=	ratio between nominal and characteristic resistance: $\Delta K = r_n/r_k$

σ_w = the mean stress on the throat section of a weld

$\sigma_\perp$ = the tensile or compressive stress acting perpendicularly to the throat section

$\sigma_{//}$ = the tensile or compressive stress acting parallel to the weld axis on the cross section of the weld

τ_u = the ultimatie shear strength of the parent metal

$\tau_{u,w}$ = the ultimate shear strength of the weld

$\tau_\perp$ = the shear stress acting perpendicularly to the weld axis, lying in the throat section

$\tau_{//}$ = the shear stress acting parallel to the weld axis, lying in the throat section

| | — ⊓ □ are symbols referring to weld configurations; see e.g. figure 5.3 or table I.1.1.

Note:

The values for γ_M, ΔK and γ_M^* as defined here, result from the evaluation procedure [3]: $\gamma_M^* = \gamma_M \ \Delta K$. The γ_M^*-values are harmonised into one γ_M^o-value which, for convenience, is represented by γ_M in codes and in the parts A and B of this report.

APPENDIX I: STATISTICAL ANALYSIS OF STRENGTH FUNCTIONS FOR WELDED CONNECTIONS WITH RESPECT TO AVAILABLE EXPERIMENTAL DATA

I.1 Method 1: stress component method

The strength function analysed is:

$$\sqrt{\sigma_{\perp}^2 + 3\ (\tau_{\perp}^2 + \tau_{//}^2)} \le \frac{f_u}{\beta} \qquad \text{..... (I.1.1a)}$$

$$\sigma_{\perp} \le f_u \qquad \text{..... (I.1.1b)}$$

where:

$$\beta = 0.7 \quad \text{for} \quad \text{FeE235} \qquad \text{..... (I.1.1c)}$$

$$\beta = 1.0 \quad \text{for} \quad \text{FeE355} \qquad \text{..... (I.1.1d)}$$

The samples and subsamples considered are defined by the numbers given in figure I.1.1.

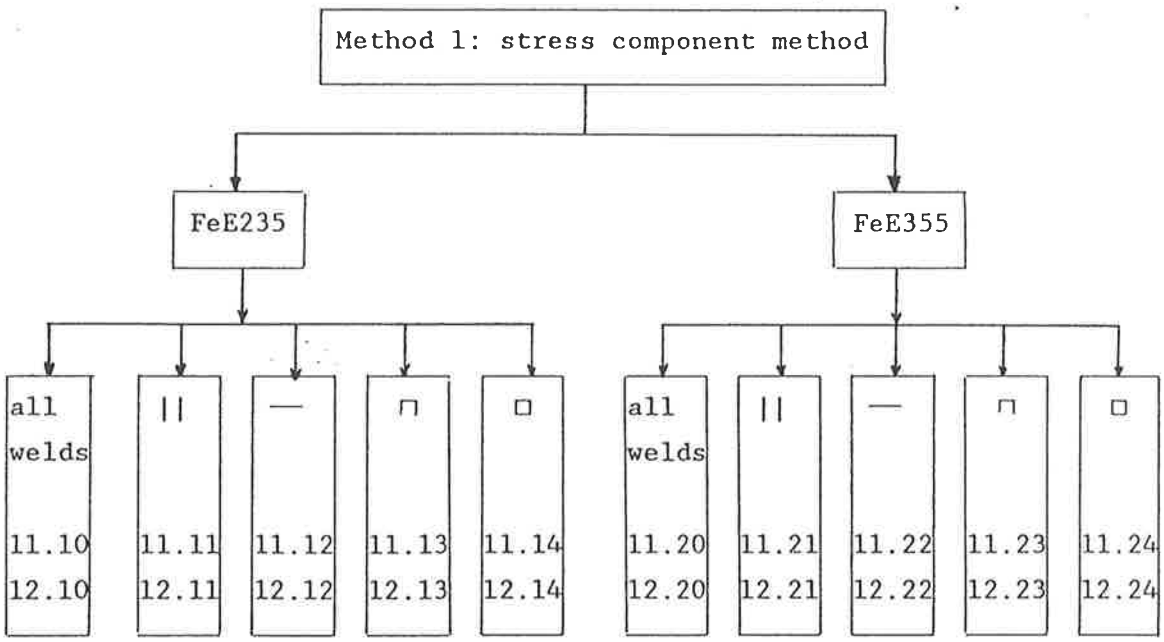


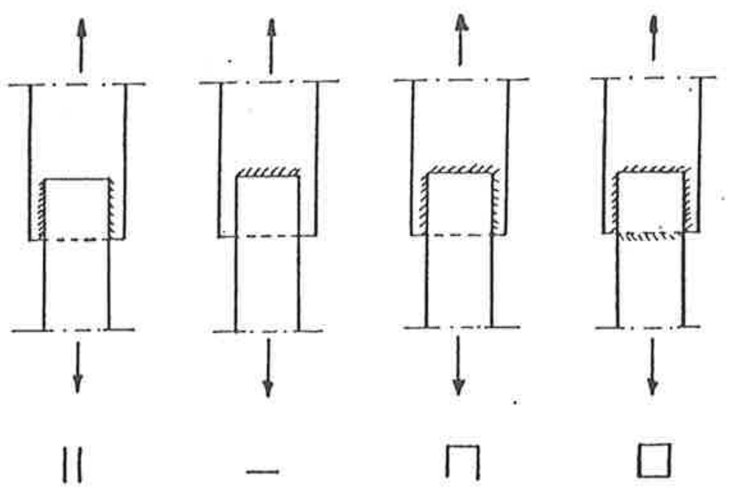
Figure I.1.1.: Samples and subsamples considered for method 1: stress component method.

The code of sample and subsample numbering is given in table I.1.1. The numbers of samples and subsamples correspond to those given in [2].

Table I.1.1: Code of sample and subsample numbering for method 1: stress component method.

first number before decimal point	method	1 = method 1: stress component method
second number before decimal point	number of strength function	1 = eqn. (I.1.1) 2 = eqn. (I.1.2)
first number after decimal point	plate material	1 = FeE235 2 = FeE355
second number after decimal point	weld configuration	0 = all configurations 1 = || 2 = — 3 = ⊓ 4 = □

weld configuration



symbol used

In the figures I.1.2 and I.1.3 the test results r_{ei} are plotted versus results obtained by using the strength function r_{ti}. How r_{ti} values are calculated is given in appendix II.1.

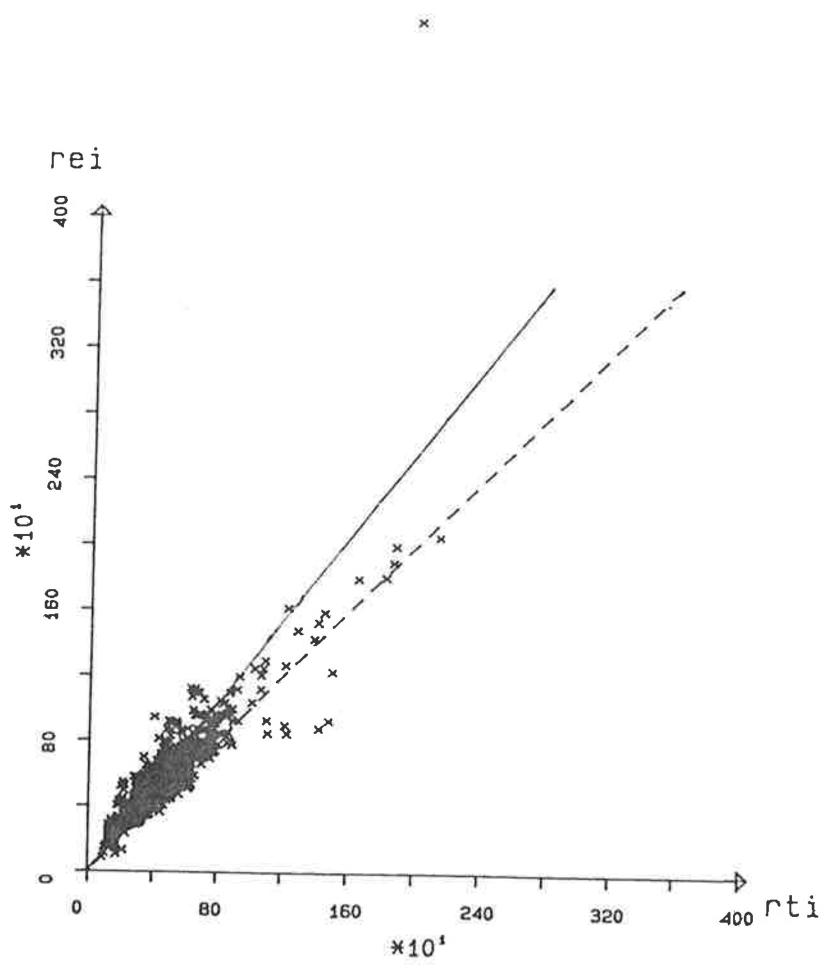


Figure I.1.2: Sample 11.10, method 1, eqn. (I.1.1), FeE235, all weld configurations, $\bar{b}$ = 1.289.

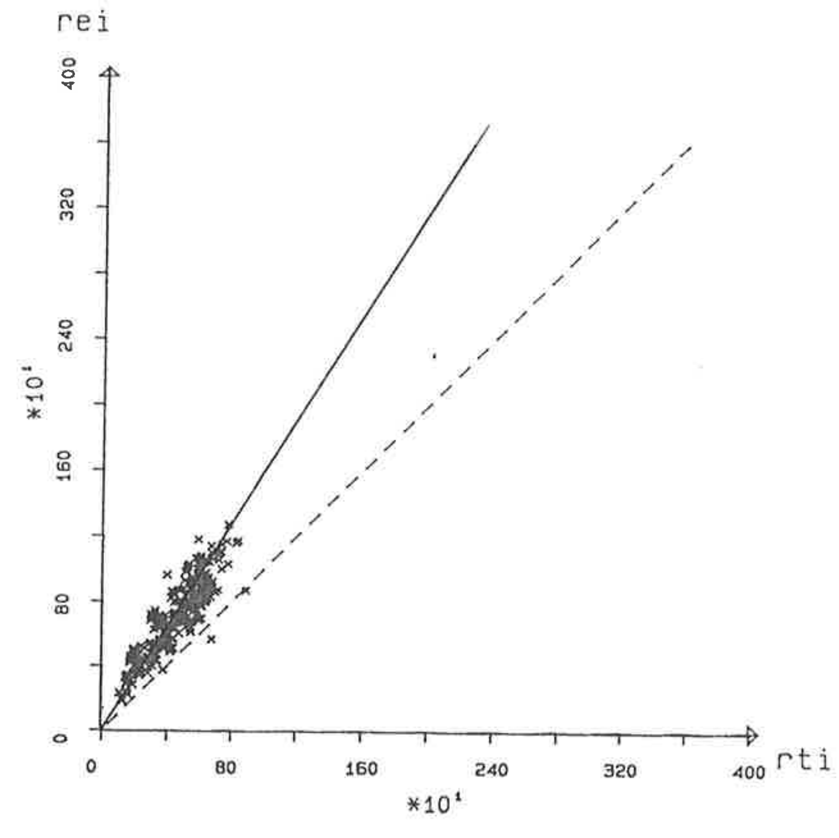


Figure I.1.3: Sample 11.20, method 1, eqn. (I.1.1), FeE355, all weld configurations, $\bar{b}$ = 1.589.

In the figures I.1.4 and I.1.5 sensitivity diagrams are shown for weld configuration.

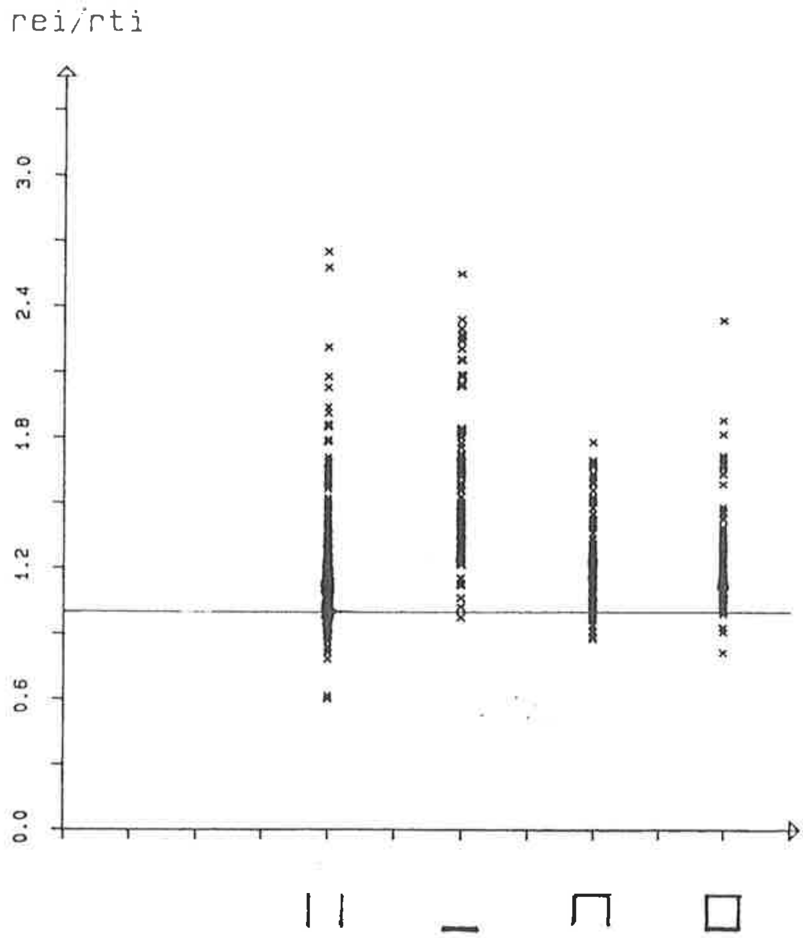


Figure I.1.4: Sensitivity diagram for weld configuration, FeE235, sample 11.10.

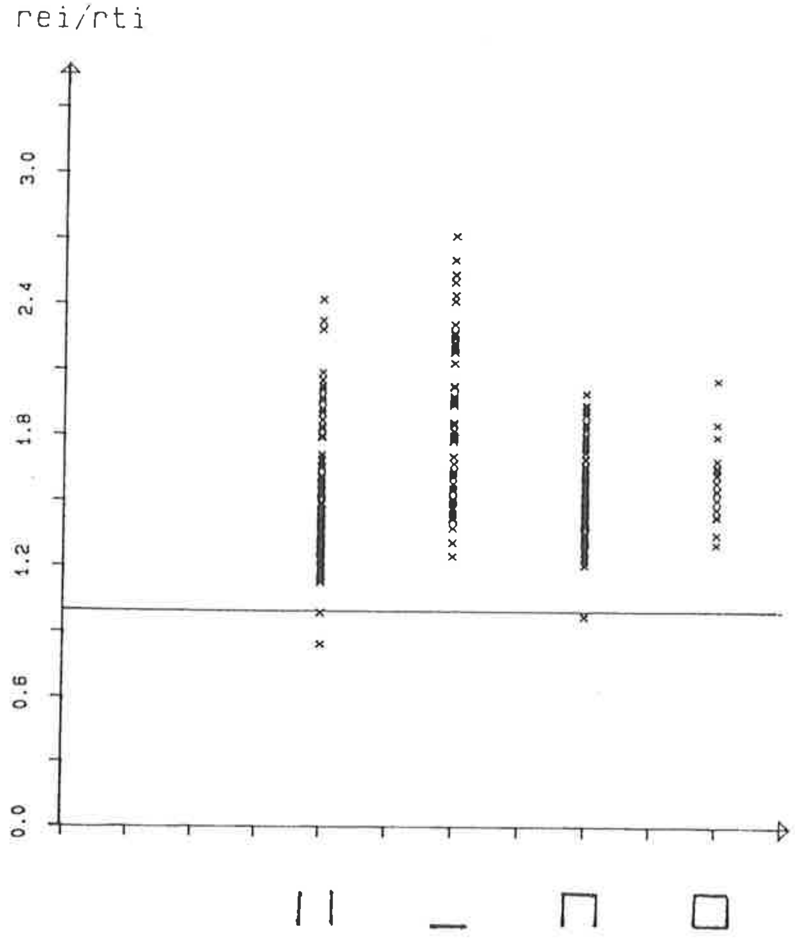


Figure I.1.5: Sensitivity diagram for weld configuration, FeE355, sample 11.20.

For the weld configuration || of FeE235 the strength function seems to be unconservative. For FeE355 the strength function seems to be too conservative. For all subsamples, the test results r_{ei} are plotted versus results obtained by using the strength function r_{ti} in the figures I.1.6 to I.1.13.

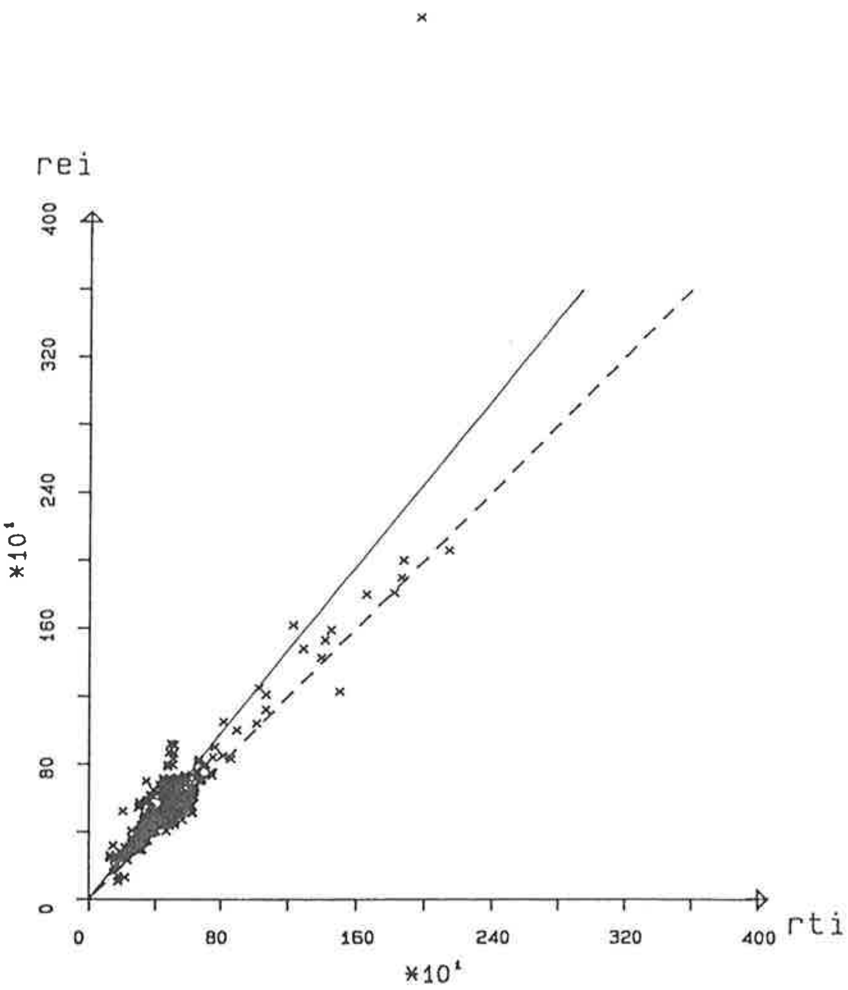


Figure I.1.6: Sample 11.11, method 1, eqn. (I.1.1), FeE235, configuration ||, $\bar{b}$ = 1.225.

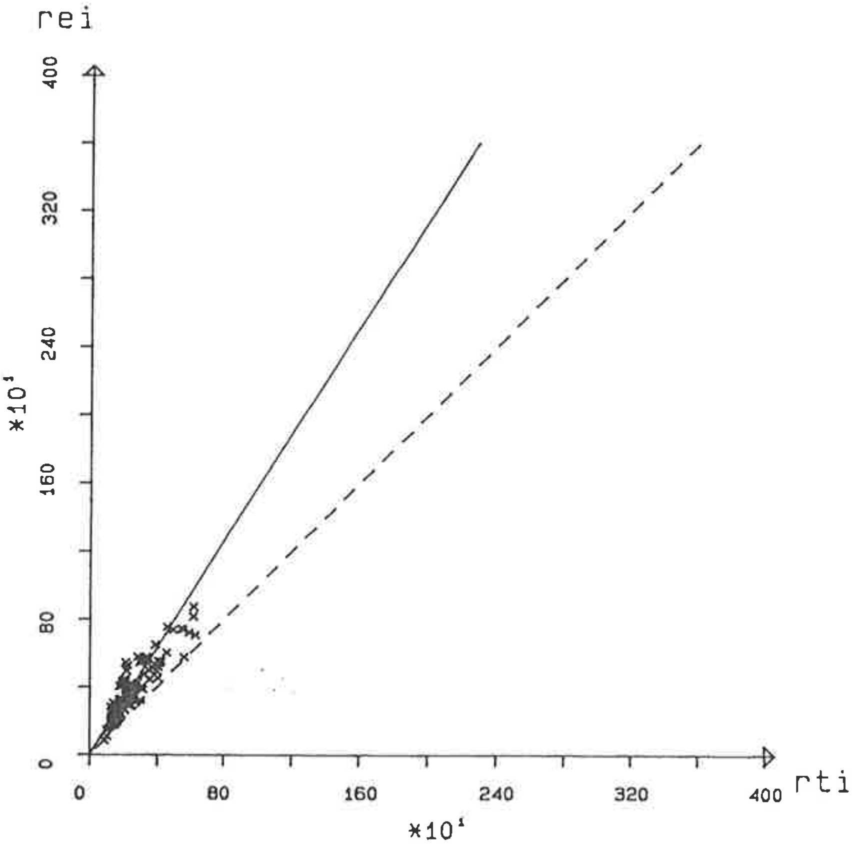


Figure I.1.7: Sample 11.12, method 1, eqn. (I.1.1), FeE235, configuration —, $\bar{b}$ = 1.571.

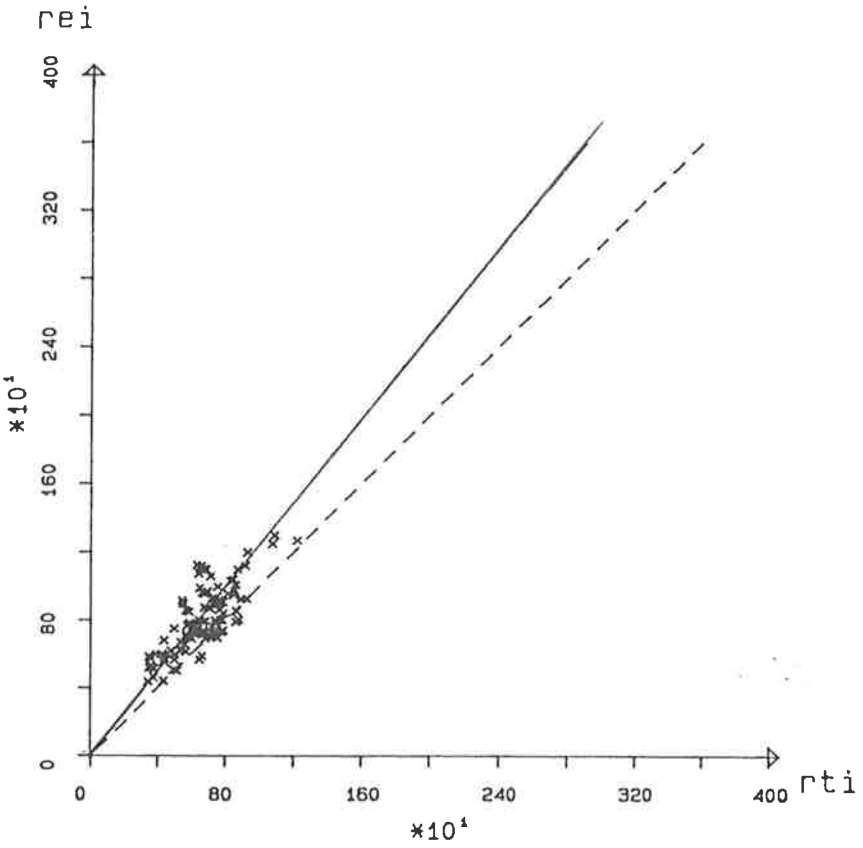


Figure I.1.8: Sample 11.13, method 1, eqn. (I.1.1), FeE235, configuration ⊓, $\bar{b}$ = 1.238.

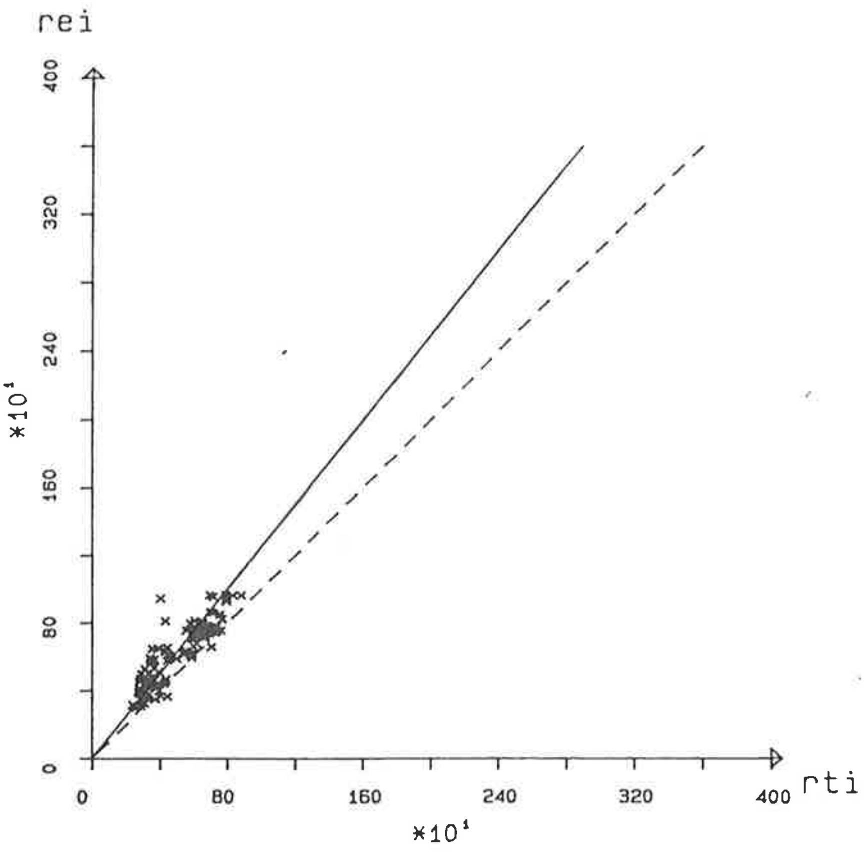


Figure I.1.9: Sample 11.14, method 1, eqn. (I.1.1), FeE235, configuration □, $\bar{b}$ = 1.245.

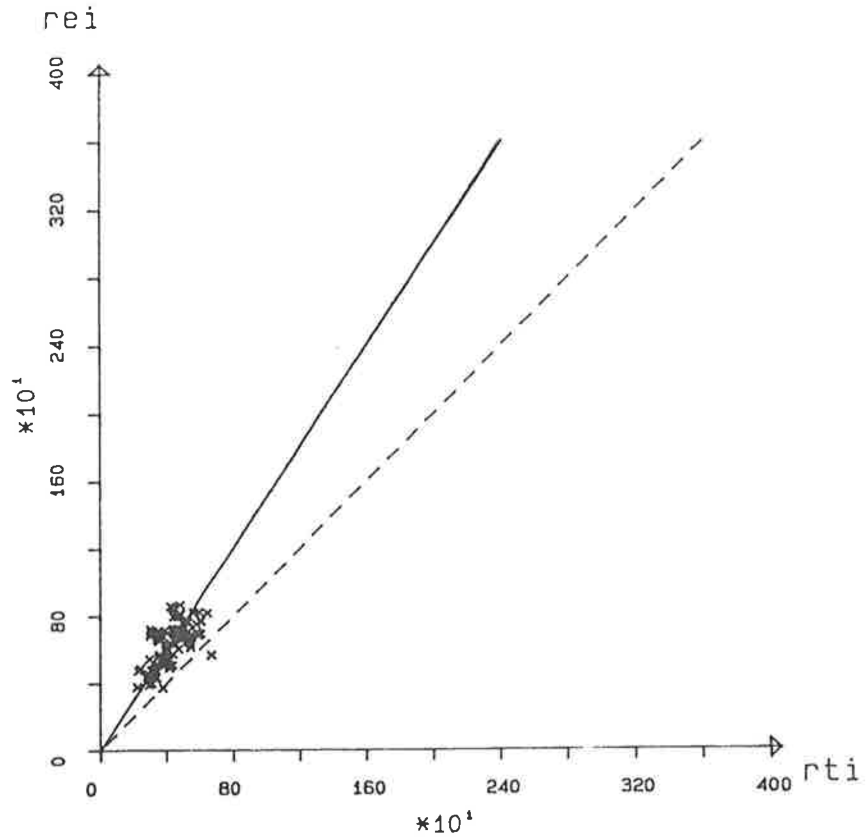


Figure I.1.10: Sample 11.21, method 1, eqn. (I.1.1), FeE355, configuration ||, $\bar{b}$ = 1.494.

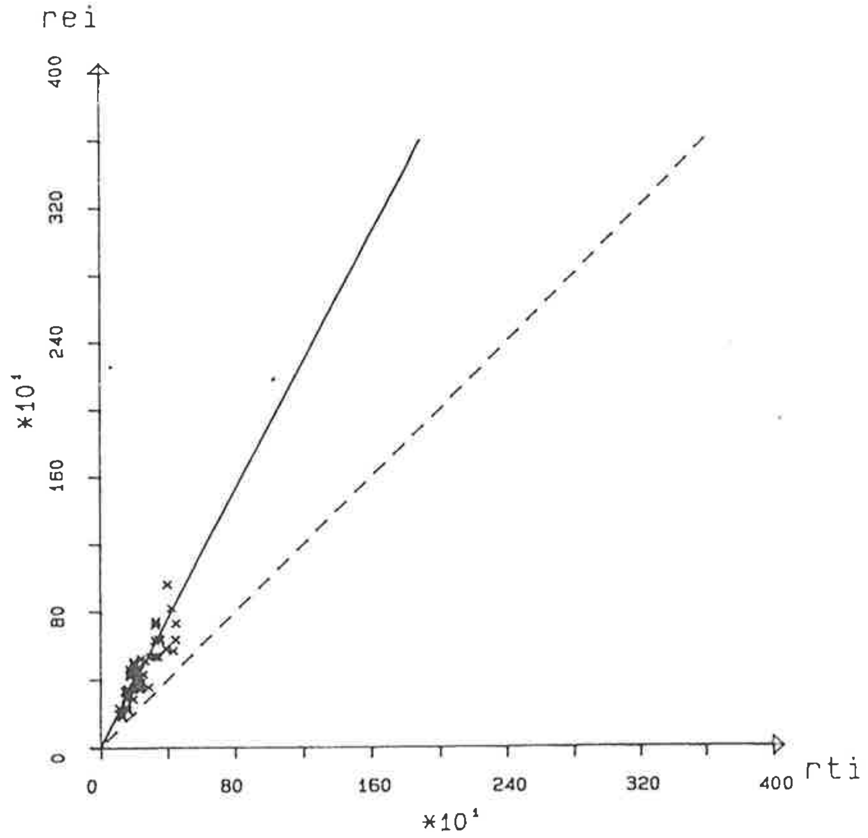


Figure I.1.11: Sample 11.22, method 1, eqn. (I.1.1), FeE355, configuration —, $\bar{b}$ = 1.903.

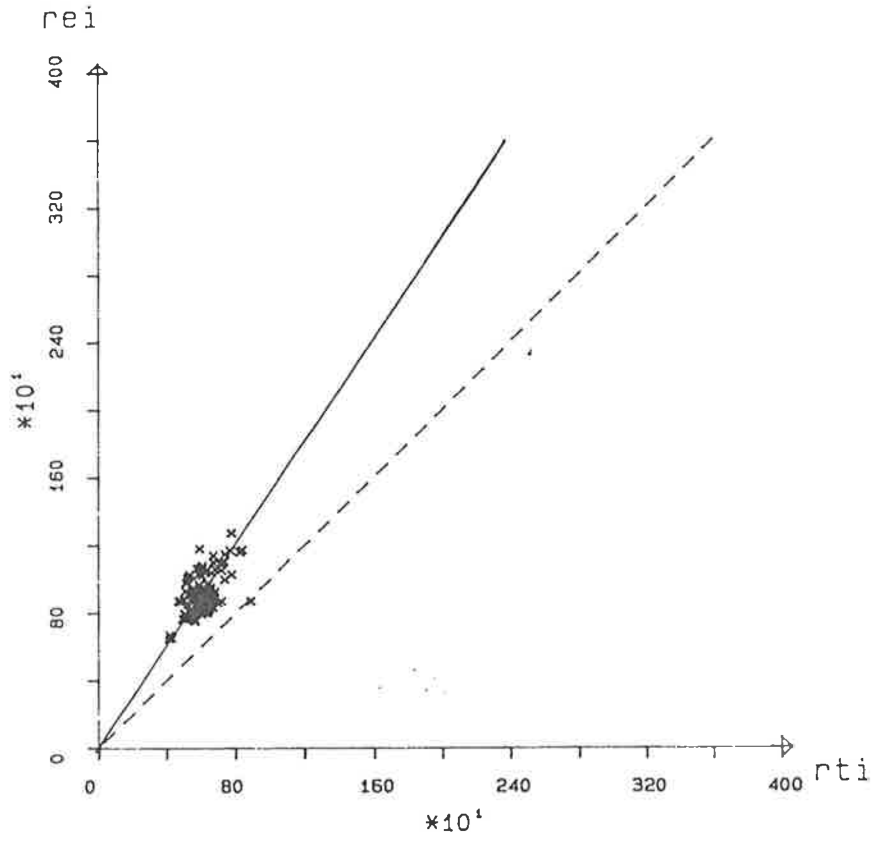


Figure I.1.12: Sample 11.23, method 1, eqn. (I.1.1), FeE355, configuration ⊓, $\bar{b}$ = 1.514.

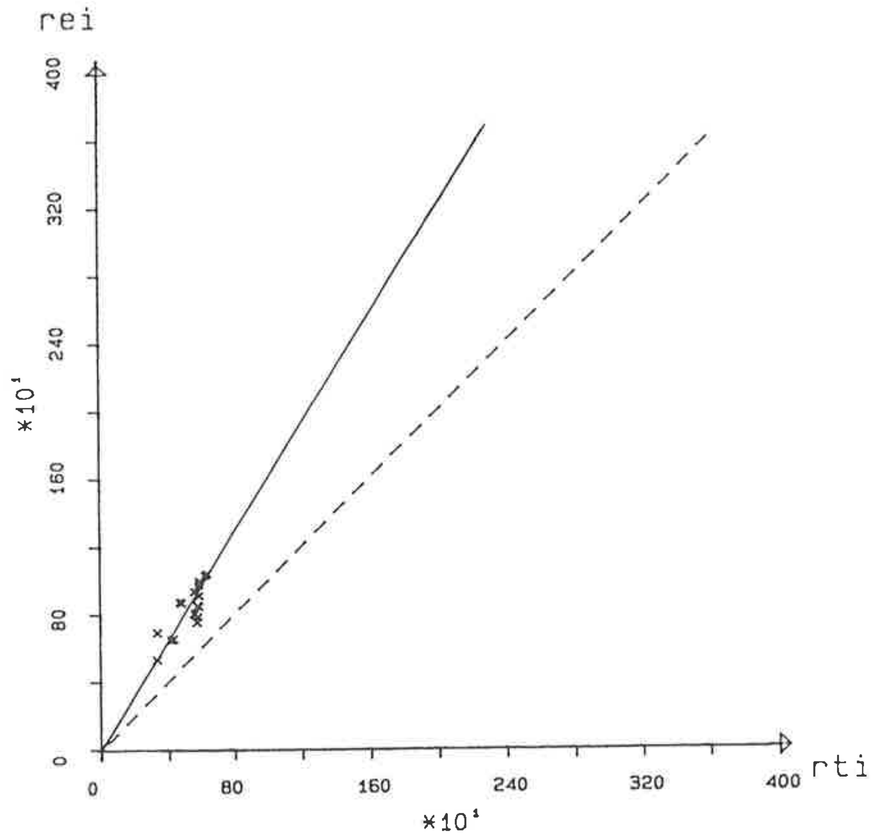


Figure I.1.13: Sample 11.24, method 1, eqn. (I.1.1), FeE355, configuration □, $\bar{b}$ = 1.603.

In table I.1.2 the results of the statistical evaluation [3] are summarized.

Table I.1.2: Statistical evaluation, eqn. (I.1.1).

(sub) sample	no. of tests	k_s	k_d	$\bar{b}$	V_δ	R_k	R_d	γ_M	ΔK	γ_M^*
11.10	581	1.64	3.04	1.289	0.238	0.639	0.448	1.445	0.873	1.262
11.11	241	1.64	3.04	1.225	0.235	0.630	0.438	1.440	0.915	1.318
11.12	108	1.64	3.04	1.571	0.209	0.657	0.470	1.397	0.685	0.956
11.13	107	1.64	3.04	1.238	0.174	0.707	0.536	1.331	0.814	1.084
11.14	115	1.64	3.04	1.245	0.177	0.704	0.531	1.335	0.813	1.086
11.20	300	1.64	3.04	1.589	0.198	0.681	0.501	1.379	0.665	0.918
11.21	114	1.64	3.04	1.494	0.191	0.676	0.494	1.368	0.700	0.957
11.22	60	1.64	3.04	1.903	0.195	0.672	0.489	1.374	0.553	0.759
11.23	109	1.64	3.04	1.514	0.131	0.754	0.600	1.269	0.625	0.793
11.24	17	1.64	3.04	1.603	0.118	0.769	0.620	1.244	0.576	0.717

For FeE235 $\gamma_M^* > 1.25$ is found for all weld types together and for longitudinal welds ||. On the other hand, for FeE355 $\gamma_M^* \ll 1.25$.
It can be seen in table I.1.2 that the longitudinal welds || form the most severe subsample. It was decided to adjust β-values in such a way that $\gamma_M^* =$ 1.25 can be used for longitudinal welds ||. This results in the following strength function:

$$\sqrt{\sigma_\perp^2 + 3\,(\tau_\perp^2 + \tau_{//}^2)} \le \frac{f_u}{\beta} \qquad \text{..... (I.1.2a)}$$

$$\sigma_\perp \le f_u \qquad \text{..... (I.1.2b)}$$

where:

$$\beta = 0.74 \quad \text{for} \quad \text{FeE235} \qquad \text{..... (I.1.2c)}$$

$$\beta = 0.77 \quad \text{for} \quad \text{FeE355} \qquad \text{..... (I.1.2d)}$$

The results of the statistical evaluation based upon this strength function are given in table I.1.3.

Table I.1.3: Statistical evaluation, eqn. (I.1.2).

(sub) sample	no. of tests	k_s	k_d	$\bar{b}$	V_δ	R_k	R_d	γ_M	ΔK	γ_M^*
12.10	581	1.64	3.04	1.362	0.238	0.639	0.448	1.445	0.826	1.193
12.11	241	1.64	3.04	1.295	0.235	0.630	0.438	1.440	0.865	1.246
12.12	108	1.64	3.04	1.661	0.209	0.657	0.470	1.397	0.648	0.905
12.13	107	1.64	3.04	1.308	0.174	0.707	0.536	1.331	0.770	1.025
12.14	115	1.64	3.04	1.316	0.177	0.704	0.531	1.335	0.769	1.027
12.20	300	1.64	3.04	1.224	0.198	0.681	0.501	1.379	0.864	1.192
12.21	114	1.64	3.04	1.151	0.191	0.676	0.494	1.368	0.909	1.243
12.22	60	1.64	3.04	1.465	0.195	0.672	0.489	1.374	0.718	0.986
12.23	109	1.64	3.04	1.166	0.131	0.754	0.600	1.269	0.812	1.030
12.24	17	1.64	3.04	1.235	0.118	0.769	0.620	1.244	0.748	0.931

It can be seen that $\gamma_M^* = 1.25$ can be used for all subsamples. For some subsamples this leads to very conservative results, but for longitudinal welds || $\gamma_M^* = 1.25$ is a good value.

In the figures I.1.14 and I.1.15 the final results are shown for the complete samples 12.10 and 12.20 respectively.

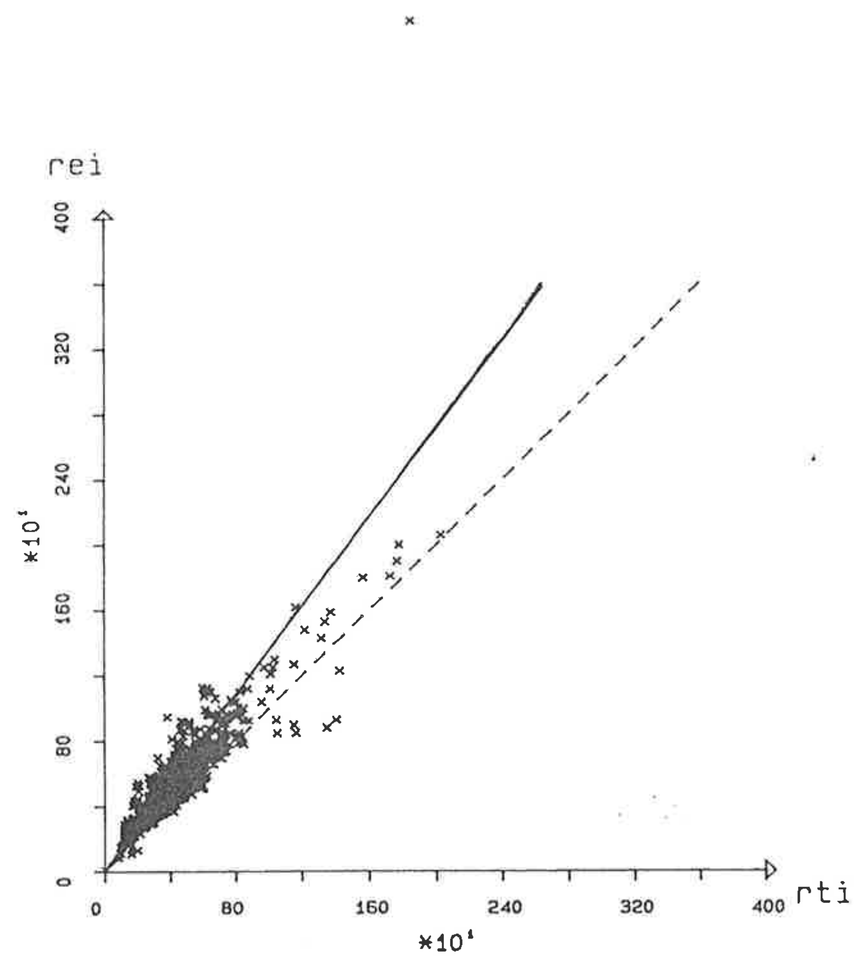


Figure I.1.14: Sample 12.10, method 1, eqn. (I.1.2), FeE235, all weld configurations, $\bar{b}$ = 1.362.

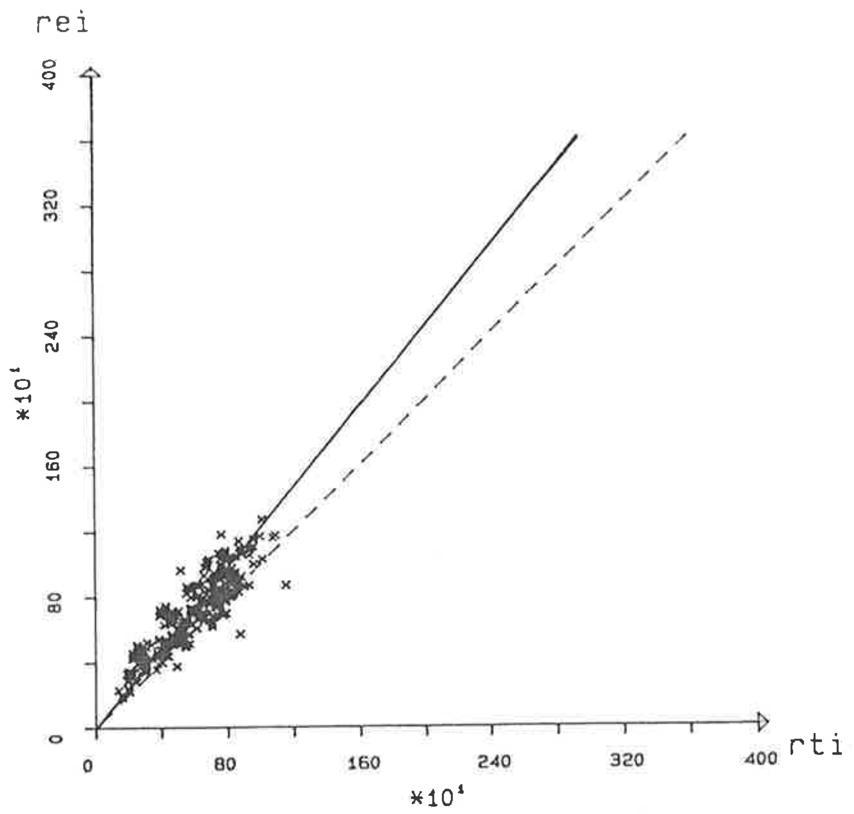


Figure I.1.15: Sample 12.20, method 1, eqn. (I.1.2), FeE355, all weld configurations, $\bar{b}$ = 1.224.

The corresponding sensitivity diagrams for weld configuration are shown in the figures I.1.16 and I.1.17.

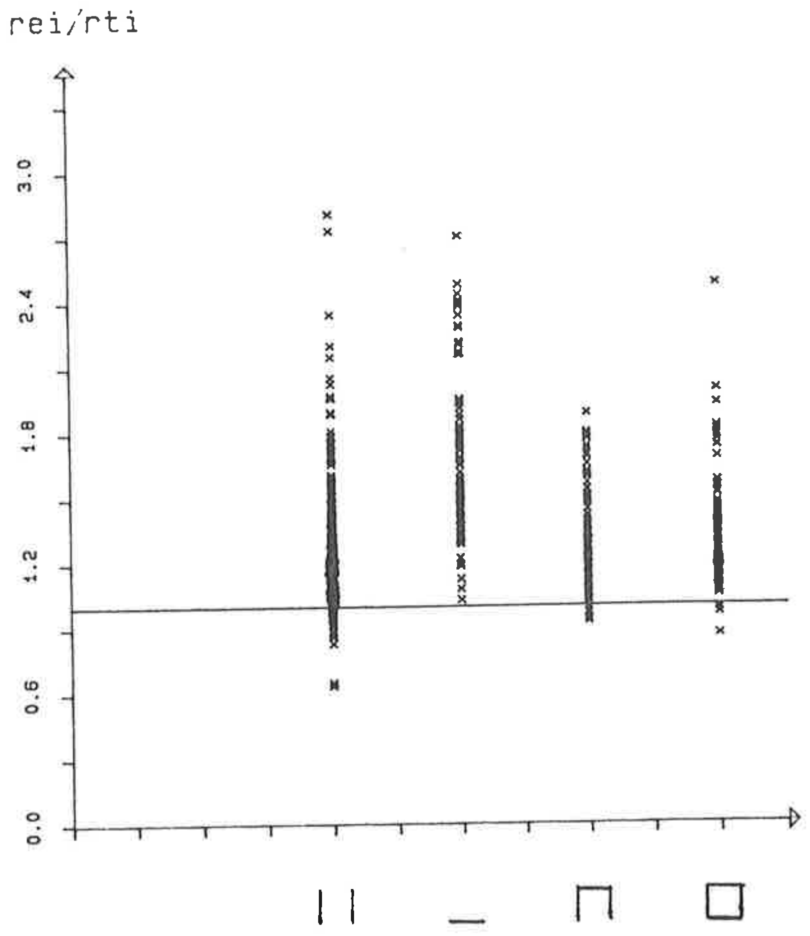


Figure I.1.16: Sensitivity diagram for weld configuration, FeE235, sample 12.10.

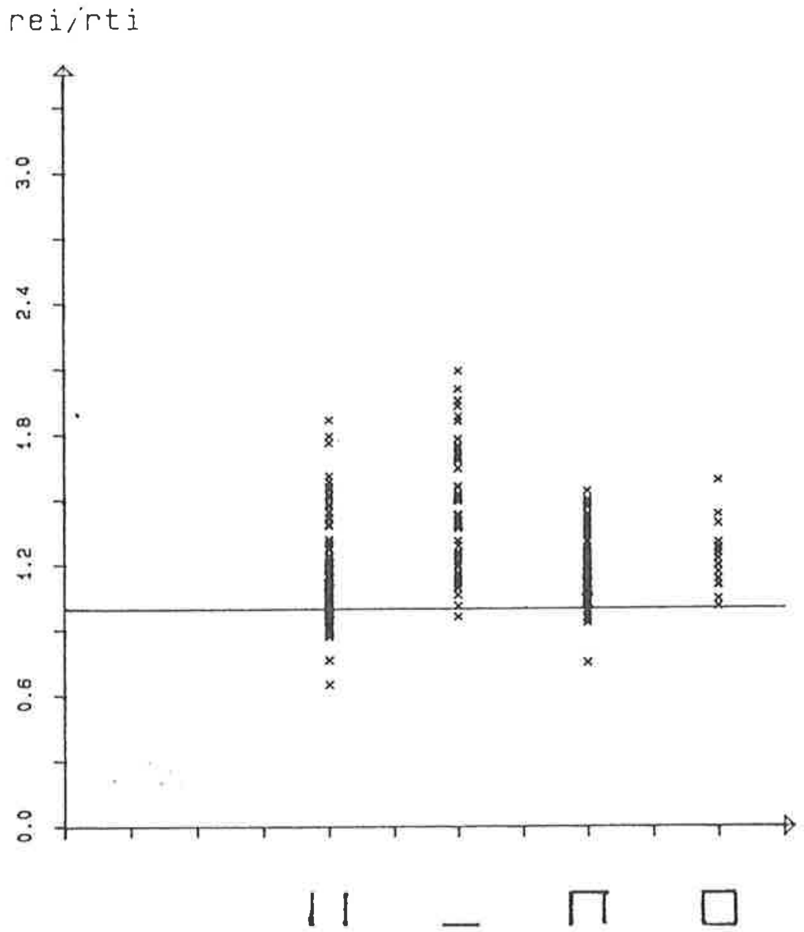


Figure I.1.17: Sensitivity diagram for weld configuration, FeE355, sample 12.20.

In the figures I.1.18 and I.1.19, the rest results r_{ei} are plotted versus results obtained by using the strength function r_{ti} for the longitudinal welds ||.

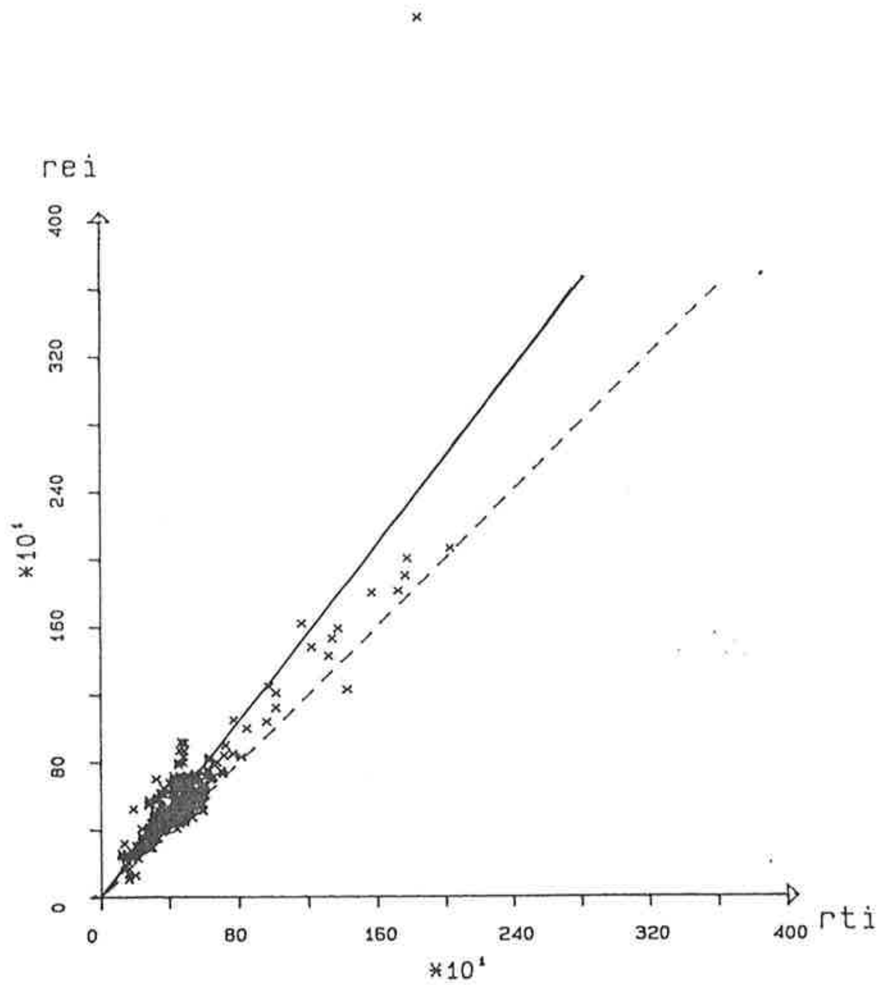


Figure I.1.18: Sample 12.11, method 1, eqn. (I.1.2), FeE235, configuration ||, $\bar{b}$ = 1.295.

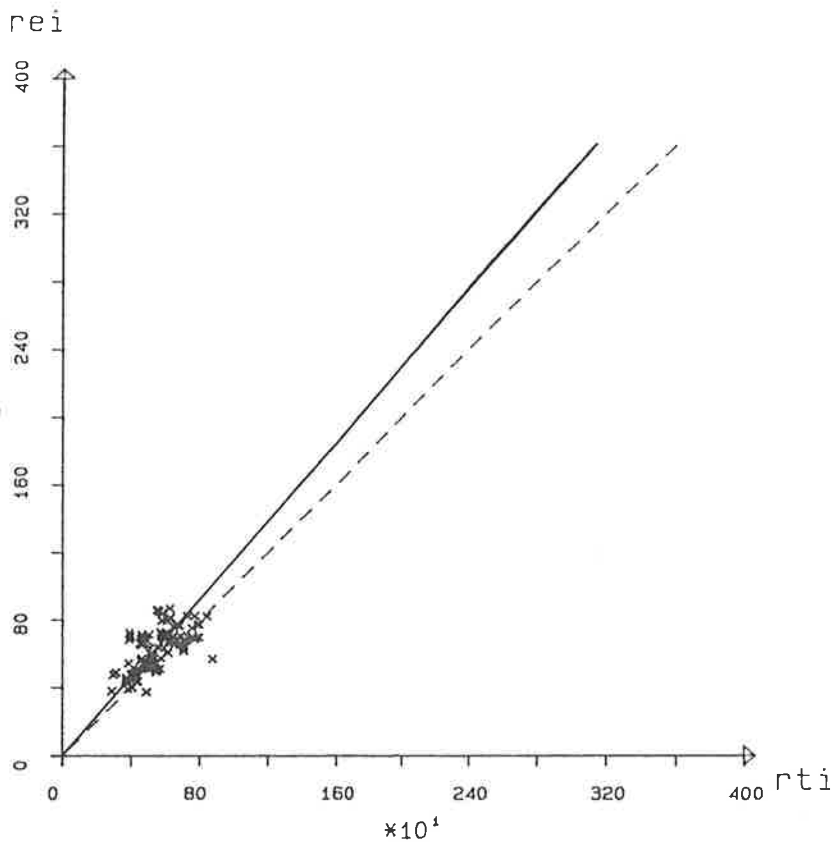


Figure I.1.19: Sample 12.21, method 1, eqn. (I.1.2), FeE355, configuration ||, $\bar{b}$ = 1.151.

The design function given in eqn. (I.1.3) can be accepted:

$$\sqrt{\sigma_{\perp}^2 + 3\,(\tau_{\perp}^2 + \tau_{//}^2)} \leq \frac{f_u}{\beta\ \gamma_M} \quad ; \quad \gamma_M = 1.25 \qquad \text{..... (I.1.3a)}$$

$$\sigma_{\perp} \leq \frac{f_u}{\gamma_M} \quad ; \quad \gamma_M = 1.25 \qquad \text{..... (I.1.3b)}$$

where:

$\beta = 0.74$ for FeE235 ..... (I.1.3c)

$\beta = 0.77$ for FeE355 ..... (I.1.3d)

It should be noted that in the tables I.1.2 and I.1.3 upper bound values are given for R_k, R_d, γ_M, ΔK and γ_M^* caused by adding of weld capacities for some of the weld configurations. This is so for all configurations and the configurations ⊓ and □, but not for the configuration || since only a distinction is made in transverse and parallel welds.

I.2 Method 2: mean stress method

The strength function analysed is:

$$\sigma_w \leq \frac{f_u}{\beta \sqrt{3}} \qquad \text{..... (I.2.1a)}$$

where:

$$\sigma_w = \frac{F}{\Sigma \, a\ell} \qquad \text{..... (I.2.1b)}$$

$$\beta = 0.7 \quad \text{for} \quad \text{FeE235} \qquad \text{..... (I.2.1c)}$$

$$\beta = 1.0 \quad \text{for} \quad \text{FeE355} \qquad \text{..... (I.2.1d)}$$

The samples and subsamples considered are defined by the numbers given in figure I.2.1.

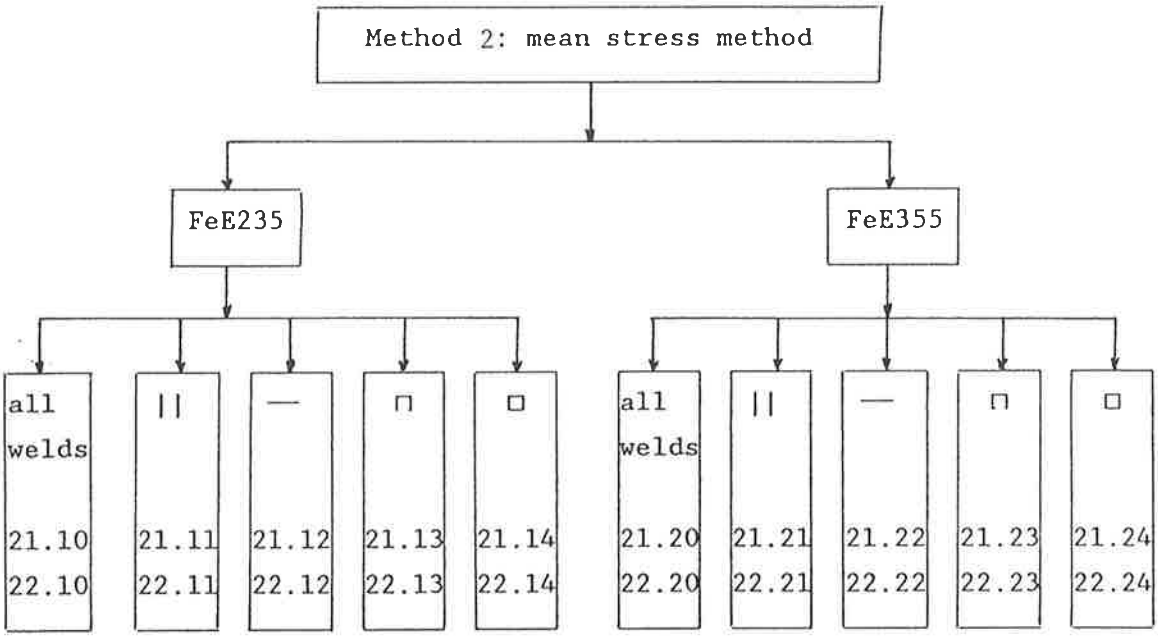


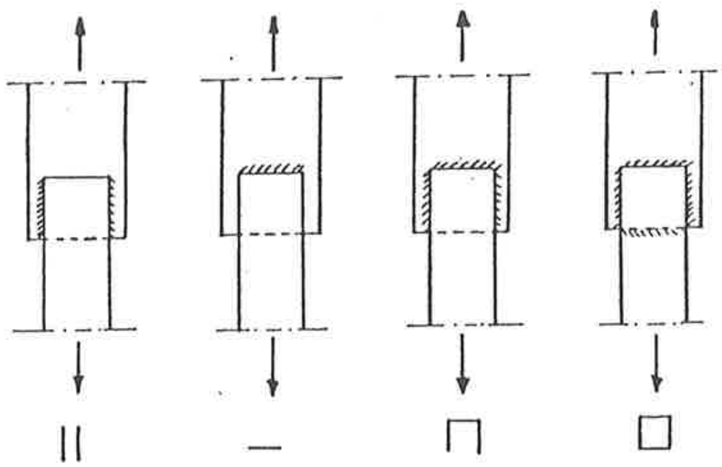
Figure I.2.1.: Samples and subsamples considered for method 2: mean stress method.

The code of sample and subsample numbering is given in table I.2.1. The numbers of samples and subsamples correspond to those given in [2].

Table I.2.1: Code of sample and subsample numbering for method 2: mean stress method.

first number before decimal point	method	2 = method 2: mean stress method
second number before decimal point	number of strength function	1 = eqn. (I.2.1) 2 = eqn. (I.2.2)
first number after decimal point	plate material	1 = FeE235 2 = FeE355
second number after decimal point	weld configuration	0 = all configurations 1 = ‖ 2 = — 3 = ⊓ 4 = □

weld configuration



symbol used

In the figures I.2.2 and I.2.3 the test results r_{ei} are plotted versus results obtained by using the strength function r_{ti}. How r_{ti} values are calculated is given in appendix II.2.

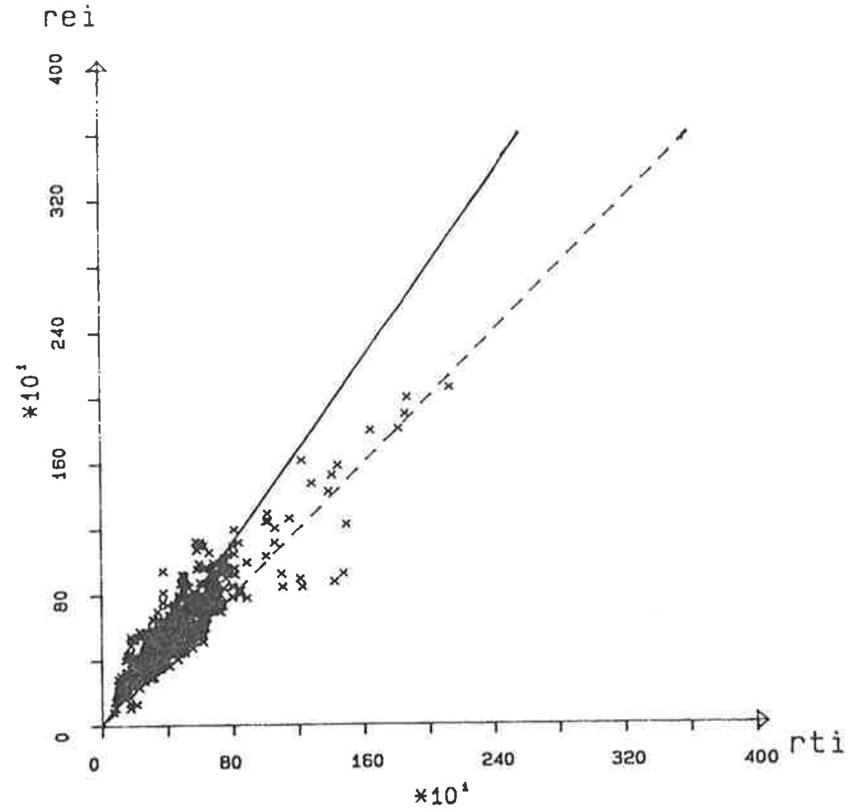


Figure I.2.2: Sample 21.10, method 2, eqn. (I.2.1), FeE235, all weld configurations, $\bar{b}$ = 1.400.

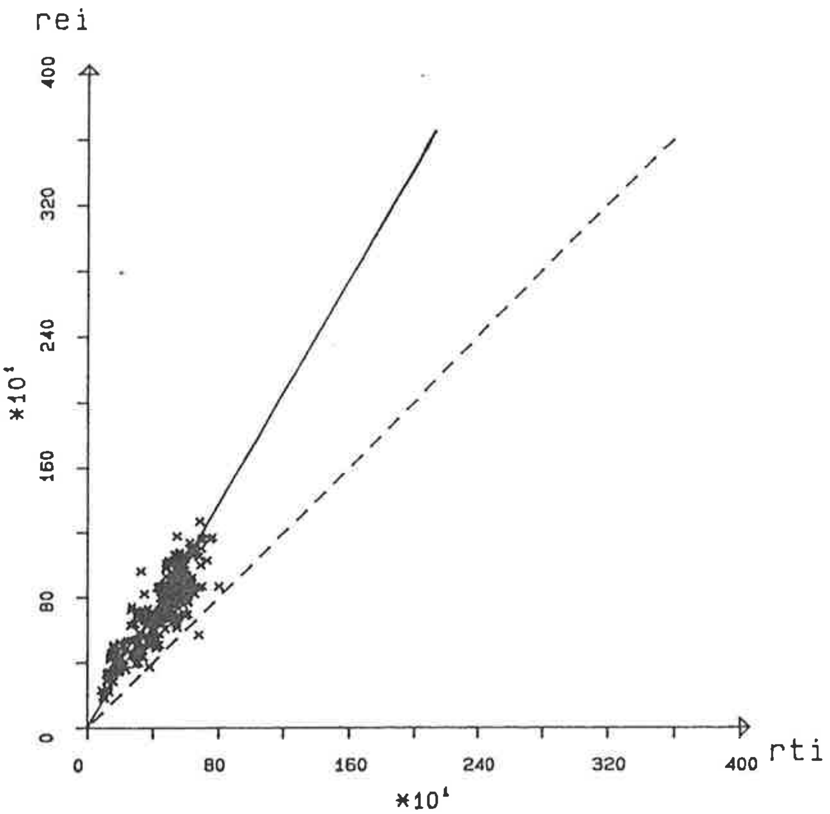


Figure I.2.3: Sample 21.20, method 2, eqn. (I.2.1), FeE355, all weld configurations, $\bar{b}$ = 1.716.

In the figures I.2.4 and I.2.5 sensitivity diagrams are shown for weld configuration.

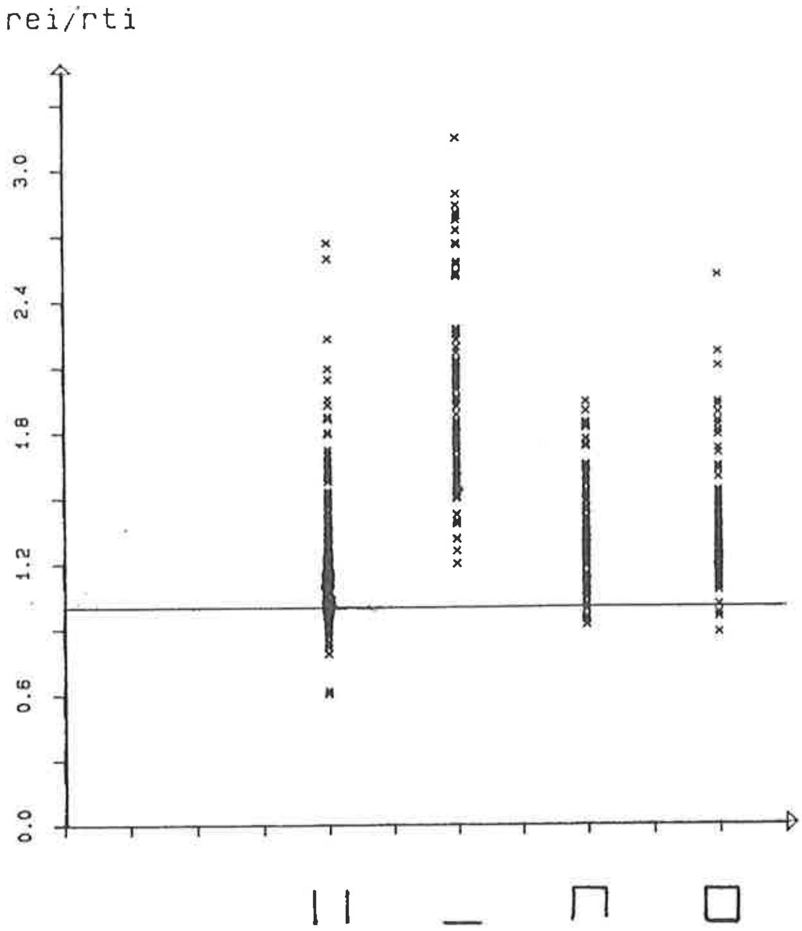


Figure I.2.4: Sensitivity diagram for weld configuration, FeE235, sample 21.10.

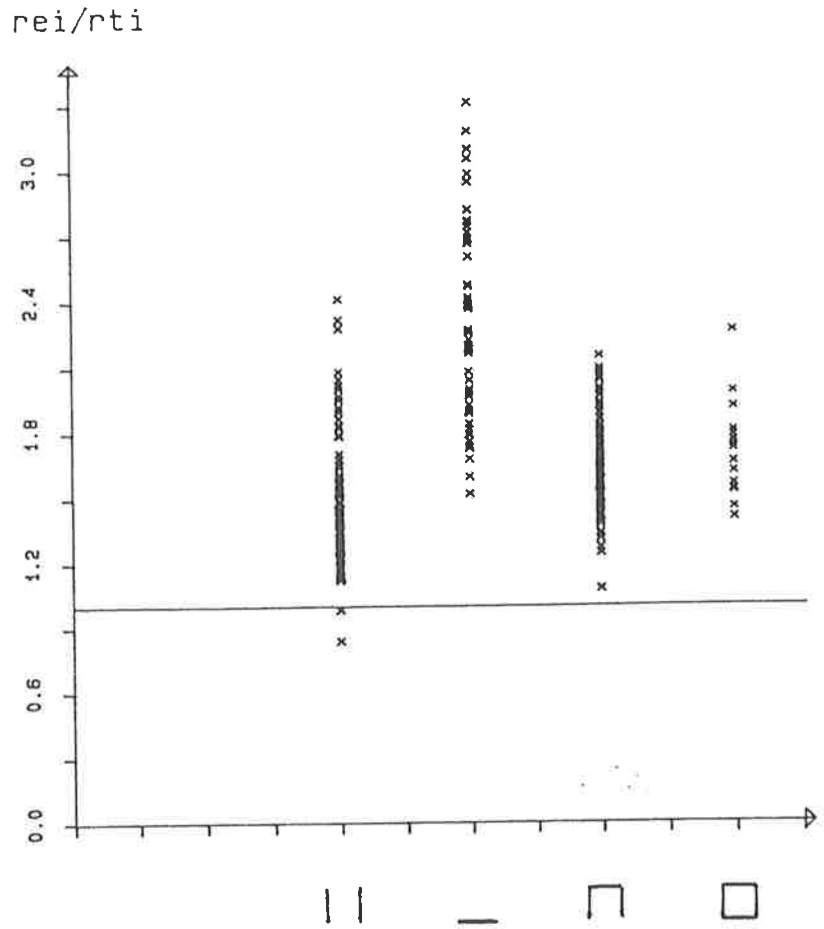


Figure I.2.5: Sensitivity diagram for weld configuration, FeE355, sample 21.20.

For the weld configuration || of FeE235 the strength function seems to be unconservative. For FeE355 the strength function seems to be too conservative. For all subsamples, the test results r_{ei} are plotted versus results obtained by using the strength function r_{ti} in the figures I.2.6 to I.2.13.

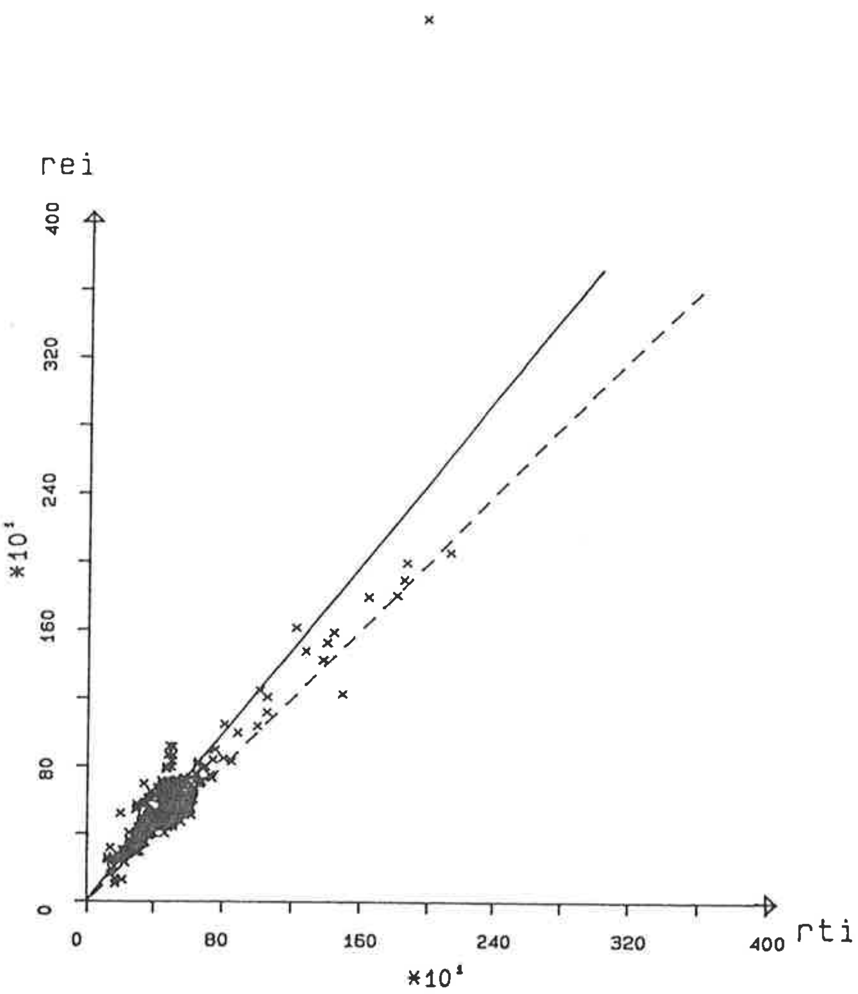


Figure I.2.6: Sample 21.11, method 2, eqn. (I.2.1), FeE235, configuration ||, $\bar{b}$ = 1.232.

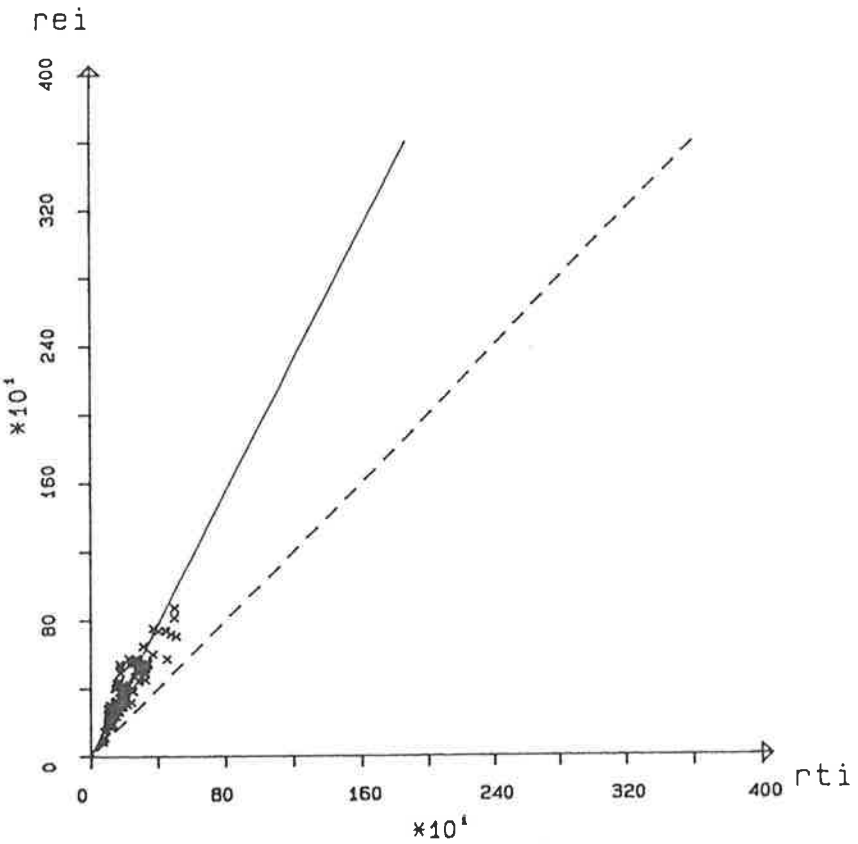


Figure I.2.7: Sample 21.12, method 2, eqn. (I.2.1), FeE235, configuration —, $\bar{b}$ = 1.936.

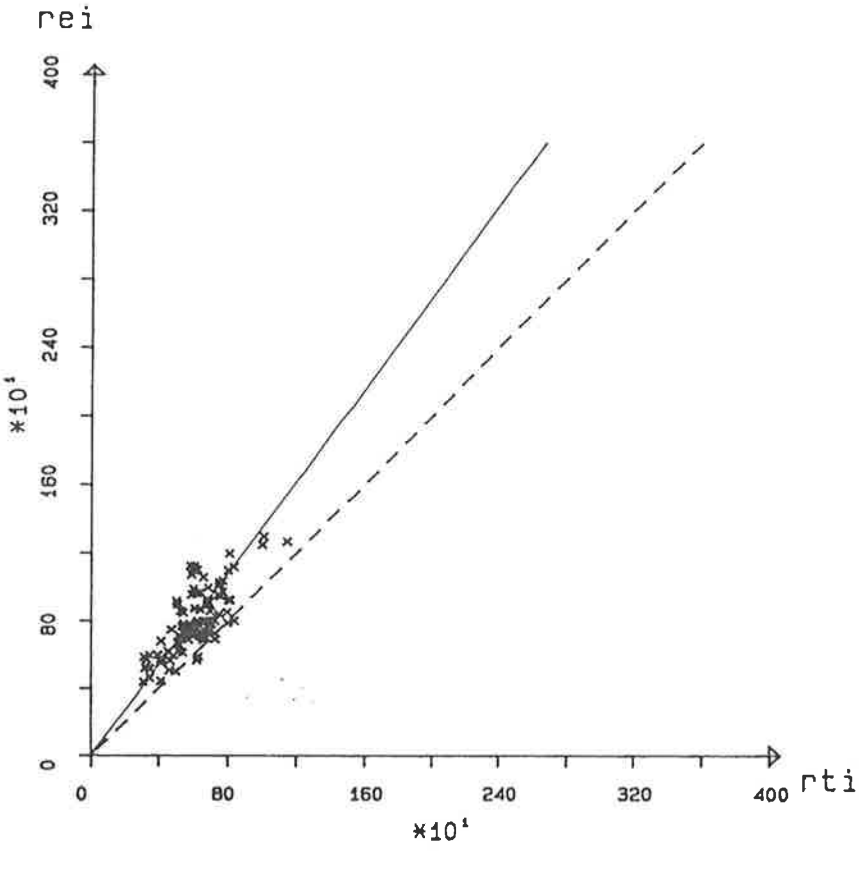


Figure I.2.8: Sample 21.13, method 2, eqn. (I.2.1), FeE235, configuration ⊓, $\bar{b}$ = 1.345.

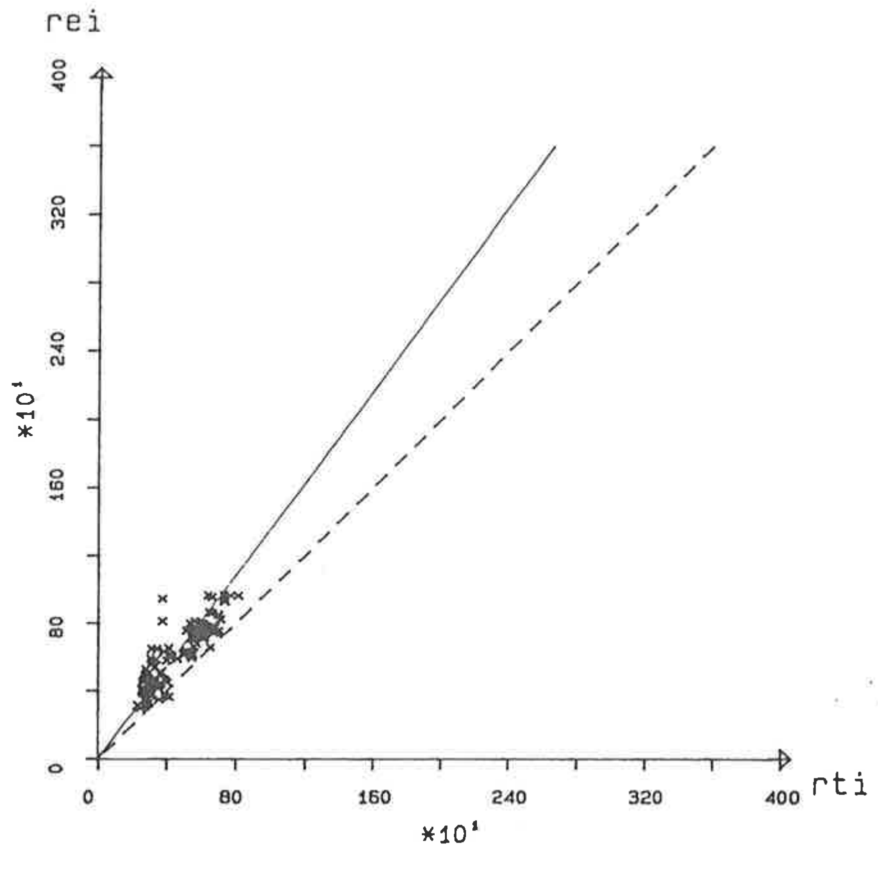


Figure I.2.9: Sample 21.14, method 2, eqn. (I.2.1), FeE235, configuration □, $\bar{b}$ = 1.352.

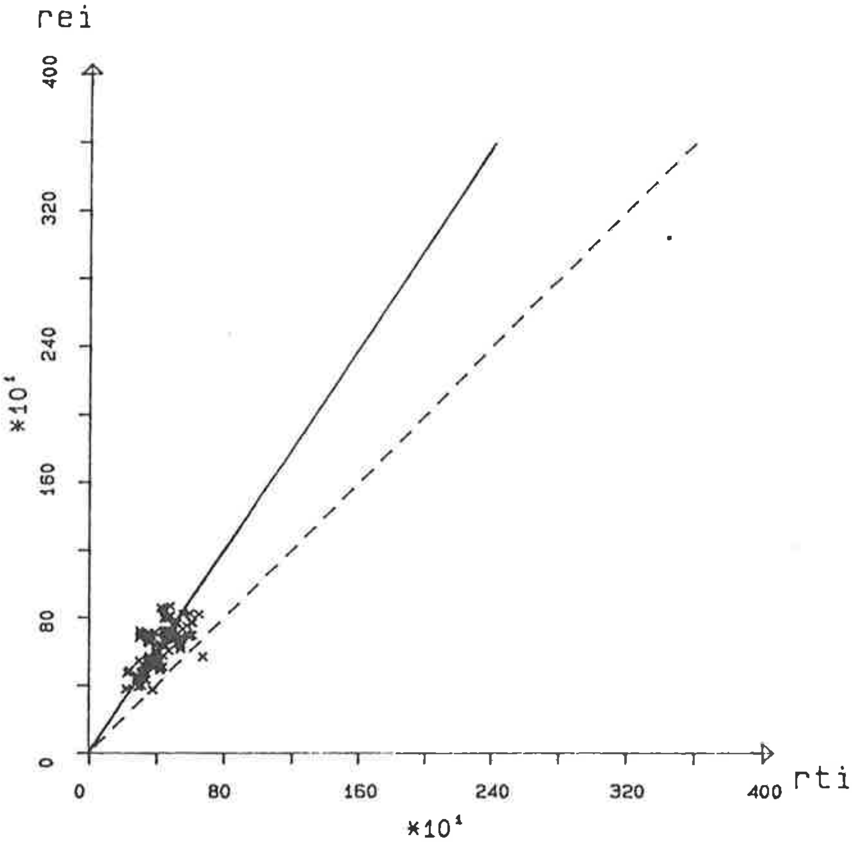


Figure I.2.10: Sample 21.21, method 2, eqn. (I.2.1), FeE355, configuration ||, $\bar{b}$ = 1.487.

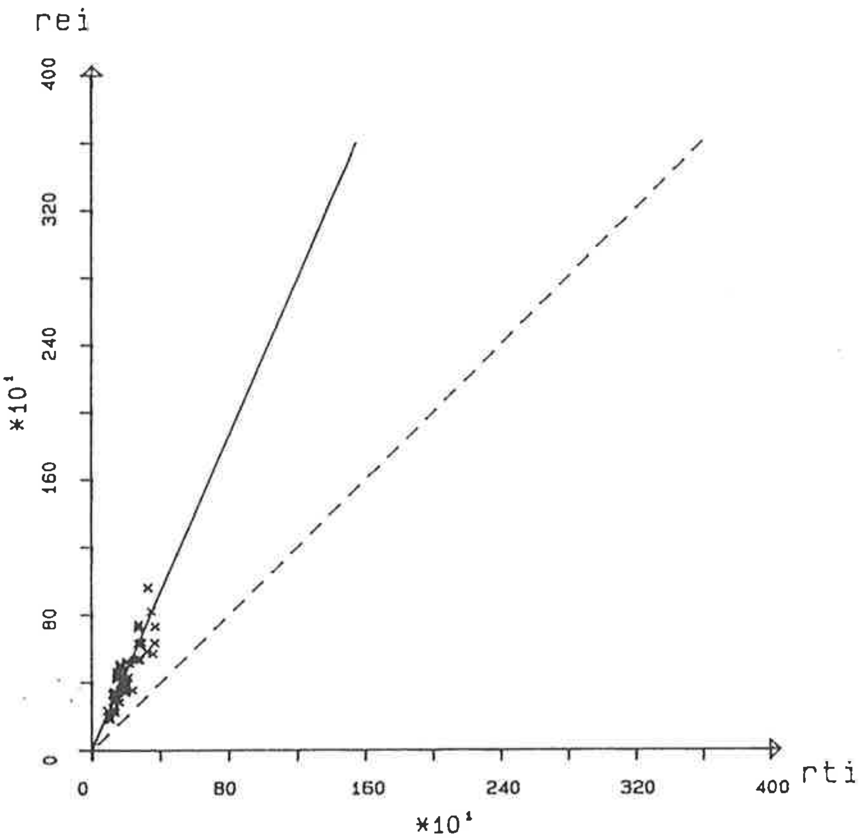


Figure I.2.11: Sample 21.22, method 2, eqn. (I.2.1), FeE355, configuration —, $\bar{b}$ = 2.320.

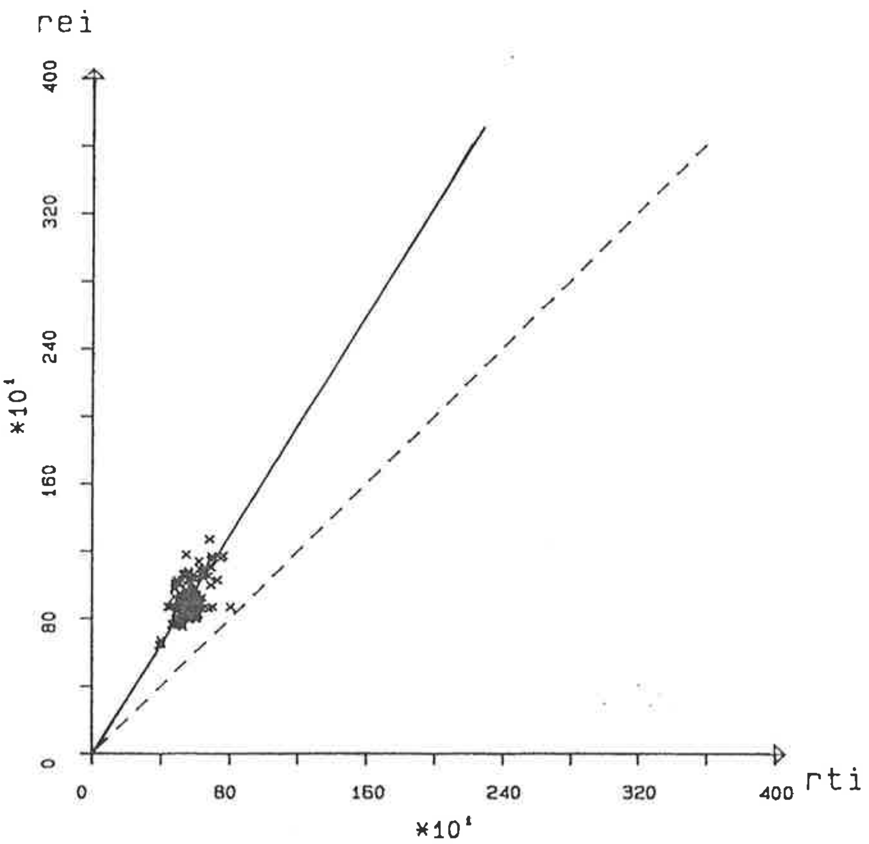


Figure I.2.12: Sample 21.23, method 2, eqn. (I.2.1), FeE355, configuration ⊓, $\bar{b}$ = 1.622.

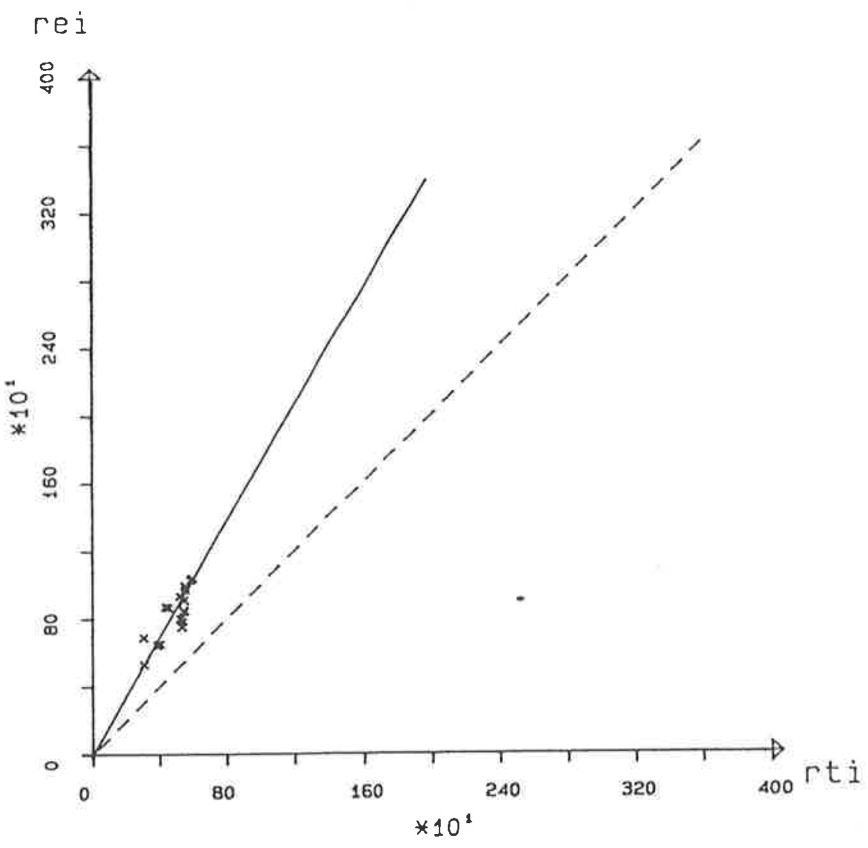


Figure I.2.13: Sample 21.24, method 2, eqn. (I.2.1), FeE355, configuration □, $\bar{b}$ = 1.716.

In table I.2.2 the results of the statistical evaluation [3] are summarized.

Table I.2.2: Statistical evaluation, eqn. (I.2.1).

(sub) sample	no. of tests	k_s	k_d	$\bar{b}$	V_δ	R_k	R_d	γ_M	ΔK	γ_M^*
21.10	581	1.64	3.04	1.400	0.286	0.588	0.388	1.531	0.870	1.332
21.11	241	1.64	3.04	1.232	0.235	0.630	0.438	1.440	0.910	1.310
21.12	108	1.64	3.04	1.936	0.209	0.657	0.470	1.397	0.556	0.776
21.13	107	1.64	3.04	1.345	0.182	0.700	0.525	1.343	0.759	1.019
21.14	115	1.64	3.04	1.352	0.188	0.693	0.516	1.350	0.760	1.026
21.20	300	1.64	3.04	1.716	0.252	0.624	0.430	1.469	0.671	0.985
21.21	114	1.64	3.04	1.487	0.191	0.676	0.494	1.368	0.703	0.962
21.22	60	1.64	3.04	2.320	0.195	0.672	0.489	1.374	0.453	0.623
21.23	109	1.64	3.04	1.622	0.135	0.751	0.595	1.275	0.588	0.750
21.24	17	1.64	3.04	1.716	0.122	0.765	0.614	1.247	0.540	0.674

For FeE235 $\gamma_M^* > 1.25$ is found for all weld types together and for longitudinal welds ||. On the other hand, for FeE355 $\gamma_M^* \ll 1.25$.
It can be seen in table I.2.2 that the longitudinal welds || form the most severe subsample. It was decided to adjust β-values in such a way that γ_M^* = 1.25 can be used for longitudinal welds ||. This results in the following strength function:

$$\sigma_w \leq \frac{f_u}{\beta\sqrt{3}} \qquad \text{..... (I.2.2a)}$$

where:

$$\sigma_w = \frac{F}{\Sigma\, a\ell} \qquad \text{..... (I.2.2b)}$$

$$\beta = 0.74 \quad \text{for} \quad \text{FeE235} \qquad \text{..... (I.2.2c)}$$

$$\beta = 0.77 \quad \text{for} \quad \text{FeE355} \qquad \text{..... (1.2.2d)}$$

The results of the statistical evaluation based upon this strength function are given in table I.2.3.

Table I.2.3: Statistical evaluation, eqn. (I.2.2).

(sub) sample	no. of tests	k_s	k_d	$\bar{b}$	V_δ	R_k	R_d	γ_M	ΔK	γ_M^*
22.10	581	1.64	3.04	1.472	0.286	0.588	0.388	1.531	0.828	1.267
22.11	241	1.64	3.04	1.295	0.235	0.630	0.438	1.440	0.865	1.246
22.12	108	1.64	3.04	2.035	0.209	0.657	0.470	1.397	0.529	0.738
22.13	107	1.64	3.04	1.414	0.182	0.700	0.525	1.343	0.722	0.970
22.14	115	1.64	3.04	1.421	0.188	0.693	0.516	1.350	0.723	0.975
22.20	300	1.64	3.04	1.327	0.252	0.624	0.430	1.469	0.868	1.274
22.21	114	1.64	3.04	1.150	0.191	0.676	0.494	1.368	0.909	1.244
22.22	60	1.64	3.04	1.794	0.195	0.672	0.489	1.374	0.586	0.805
22.23	109	1.64	3.04	1.254	0.135	0.751	0.595	1.275	0.760	0.969
22.24	17	1.64	3.04	1.327	0.122	0.765	0.614	1.247	0.698	0.871

It can be seen that $\gamma_M^* = 1.25$ can be ued for all subsamples. For some subsamples this leads to very conservative results, but for longitudinal welds || $\gamma_M^* = 1.25$ is a good value.

In the figures I.2.14 and I.2.15 the final results are shown for the complete samples 22.10 and 22.20 respectively.

The corresponding sensitivity diagrams for weld configuration are shown in the figures I.2.16 and I.2.17.

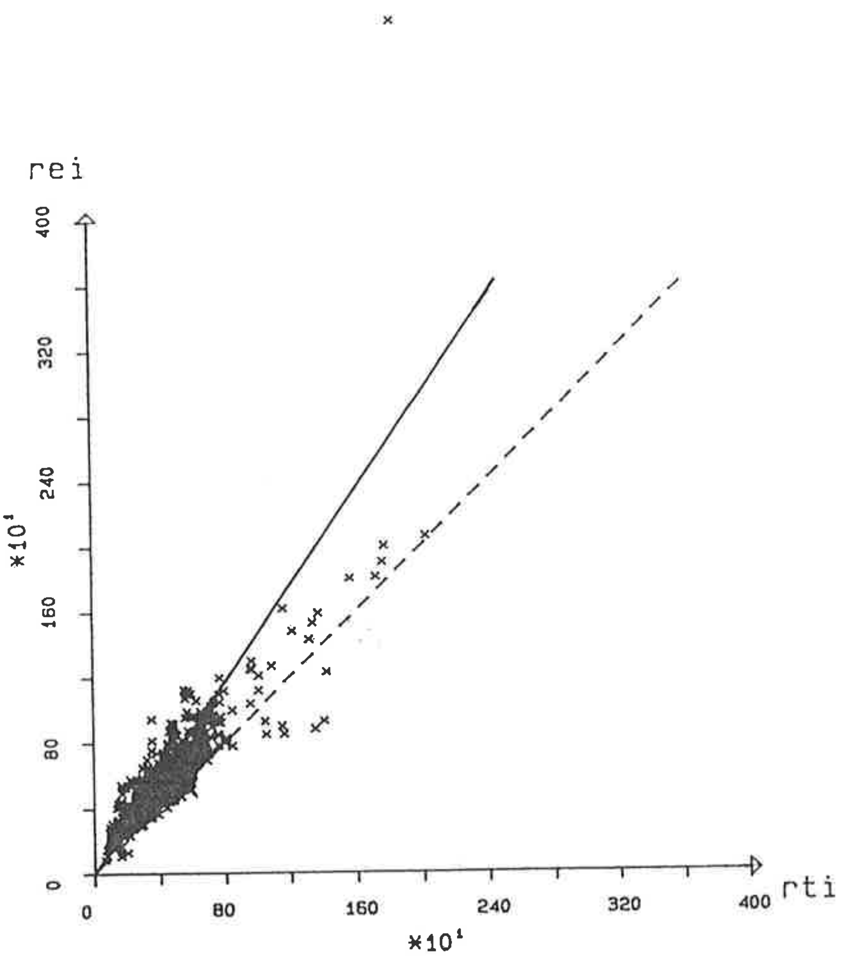


Figure I.2.14: Sample 22.10, method 2, eqn. (I.2.2), FeE235, all weld configurations, $\bar{b}$ = 1.472.

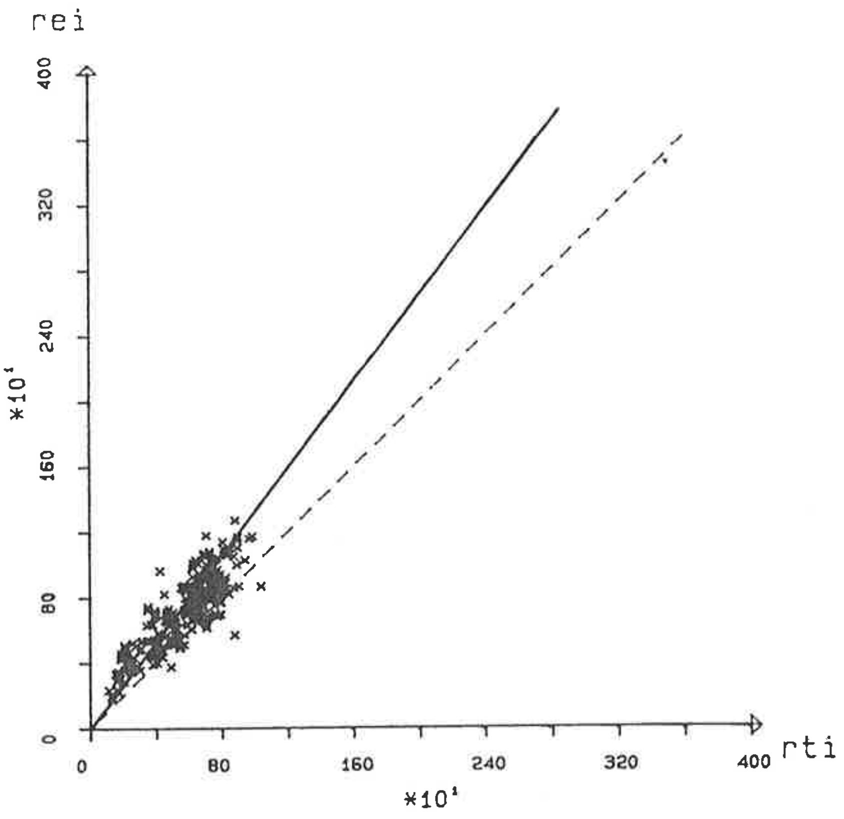


Figure I.2.15: Sample 22.20, method 2, eqn. (I.2.2), FeE355, all weld configurations, $\bar{b}$ = 1.327.

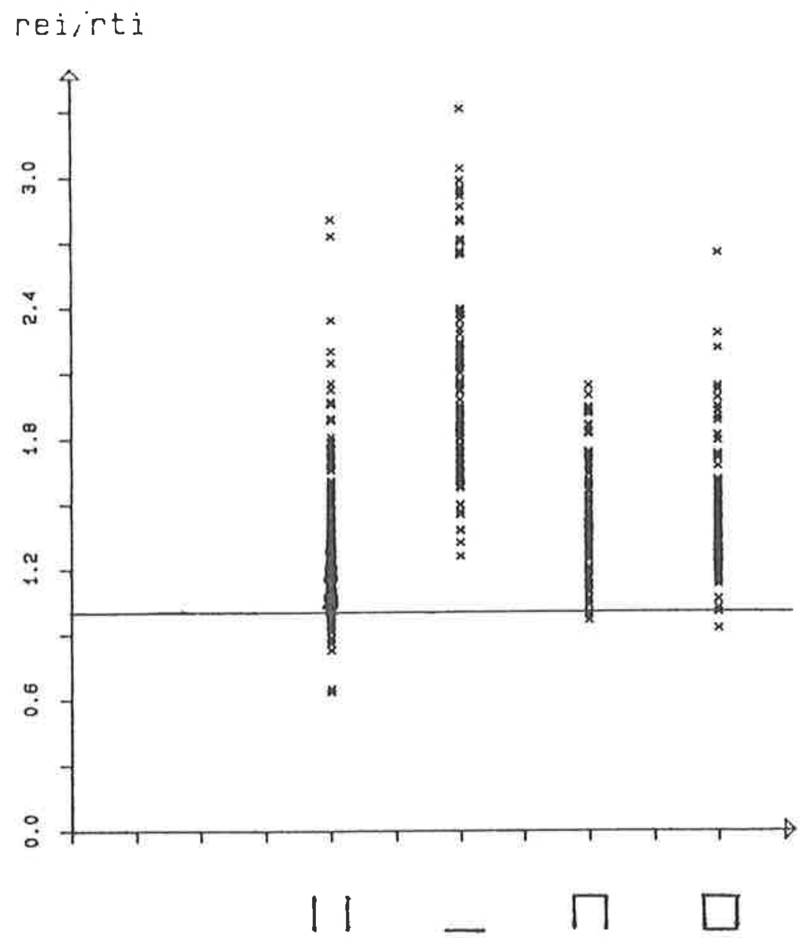


Figure I.2.16: Sensitivity diagram for weld configuration, FeE235, sample 22.10.

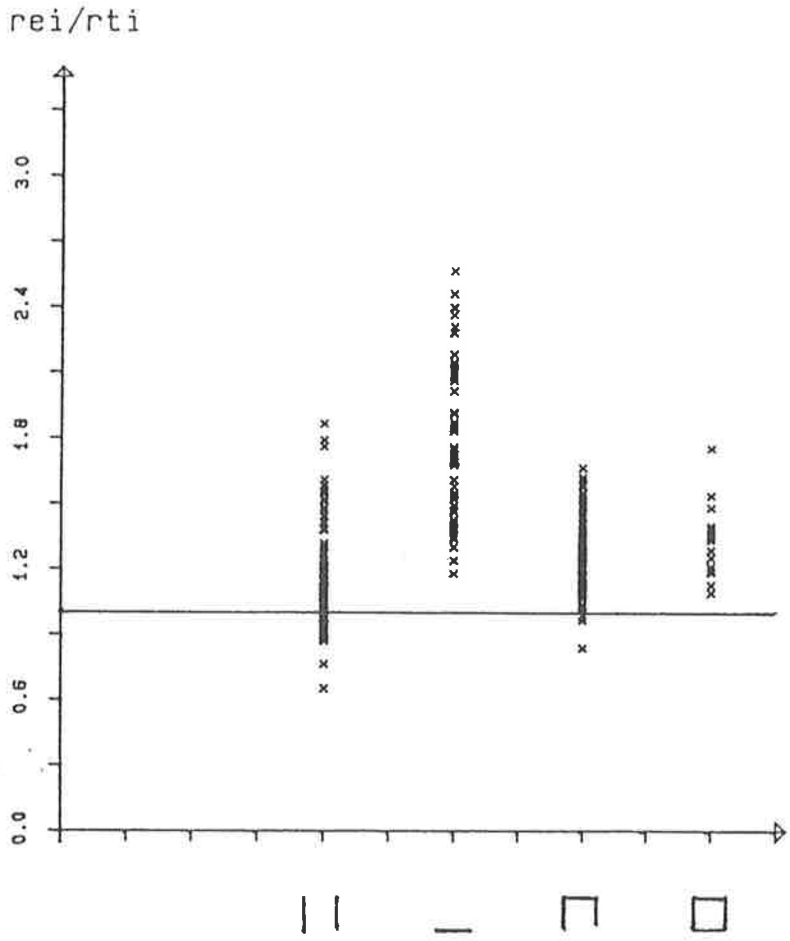


Figure I.2.17: Sensitivity diagram for weld configuration, FeE355, sample 22.20.

In the figures I.2.18 and I.2.19, the test results r_{ei} are plotted versus results obtained by using the strength function r_{ti} for the longitudinal welds ||.

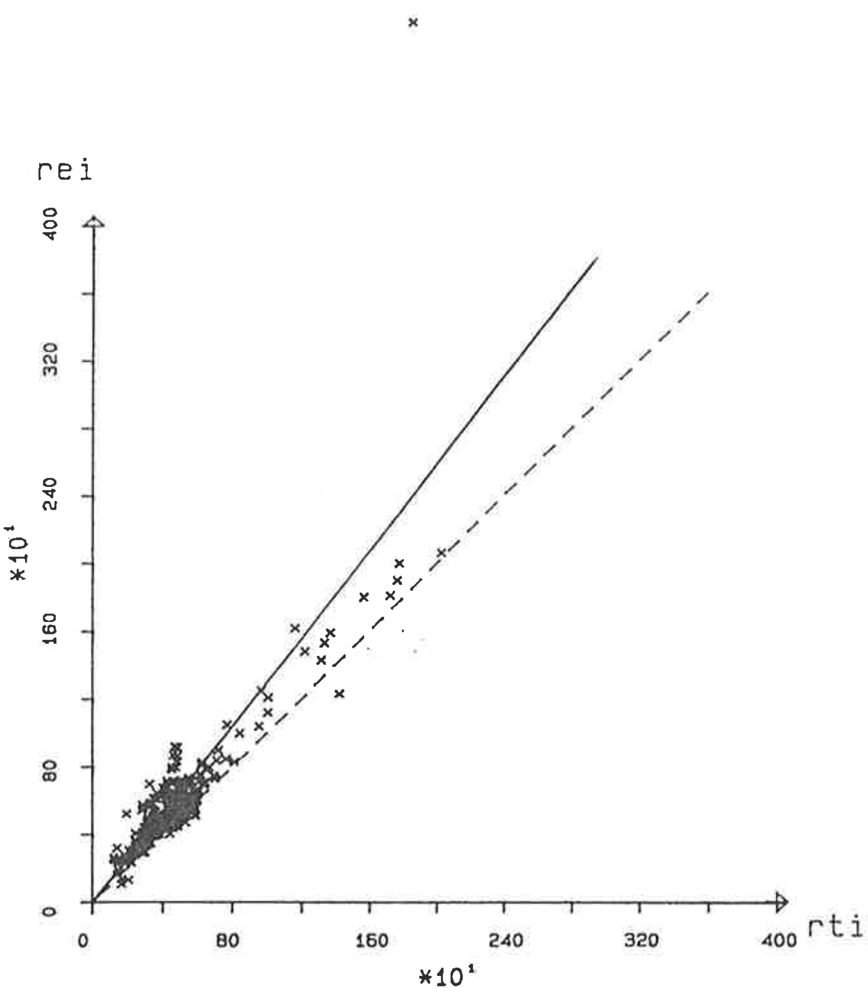


Figure I.2.18: Sample 22.11, method 2, eqn. (I.2.2), FeE235, configuration ||, $\bar{b}$ = 1.295.

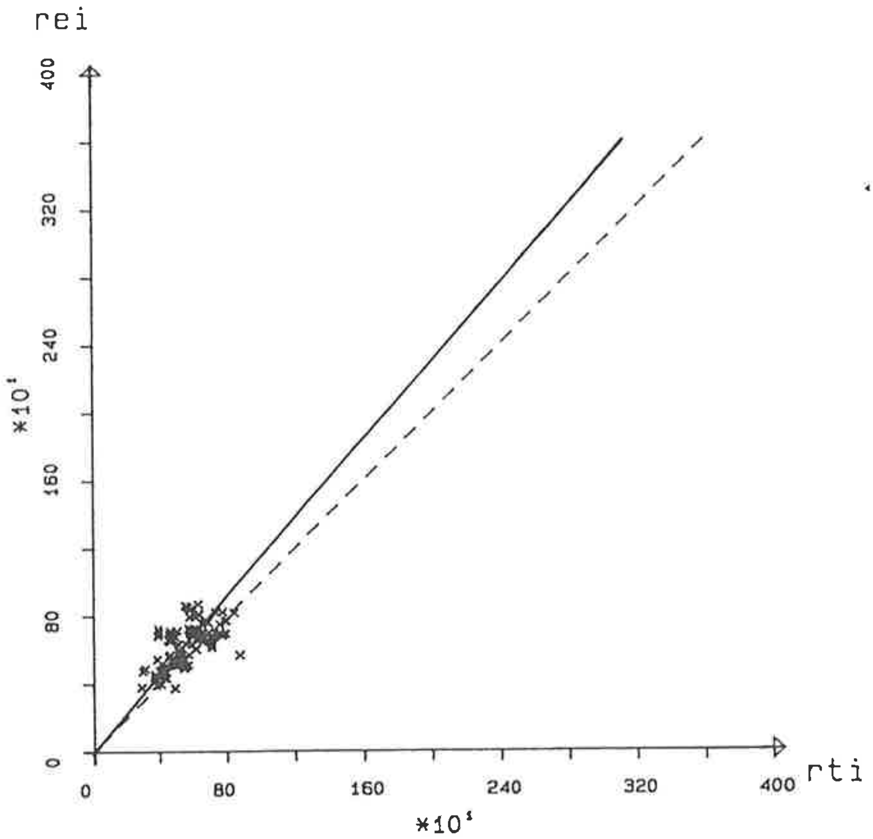


Figure I.2.19: Sample 22.21, method 2, eqn. (I.2.2), FeE355, configuration ||, $\bar{b}$ = 1.150.

The design function given in eqn. (I.2.3) can be accepted:

$$\sigma_w \leq \frac{f_u}{\beta\ \gamma_M\ \sqrt{3}} \quad ; \quad \gamma_M = 1.25 \qquad \text{..... (I.2.3a)}$$

where:

$$\sigma_w = \frac{F}{\Sigma\ a\ell} \qquad \text{..... (I.2.3b)}$$

$$\beta = 0.74 \quad \text{for} \quad \text{FeE235} \qquad \text{..... (I.2.3c)}$$

$$\beta = 0.77 \quad \text{for} \quad \text{FeE355} \qquad \text{..... (1.2.3d)}$$

It should be noted that in the tables I.2.2 and I.2.3 upper bound values are given for R_k, R_d, γ_M, ΔK and γ_M^* caused by adding of weld capacities for some of the weld configurations. This is so for all configurations and the configurations ⊓ and □, but not for the configuration ∥ since only a distinction is made in transverse and parallel welds.

APPENDIX II: DETERMINATION OF THEORETICAL RESISTANCE

II.1 Method 1: stress component method

When the strength function is:

$$\sqrt{\sigma_{\perp}^2 + 3\ (\tau_{\perp}^2 + \tau_{/\!/}^2)} \leq \frac{f_u}{\beta} \qquad \text{..... (II.1.1a)}$$

$$\sigma_{\perp} \leq f_u \qquad \text{..... (II.1.1b)}$$

where:

$$\beta = a_1 \quad \text{for} \quad \text{FeE235} \qquad \text{..... (II.1.1c)}$$

$$\beta = a_2 \quad \text{for} \quad \text{FeE355} \qquad \text{..... (II.1.1d)}$$

and:

a_1, a_2 are constants

then the theoretical resistance based upon this strength function depends on the welds that form the weld configuration. The total theoretical resistance for the weld configuration is the sum of the theoretical resistances of the individual welds:

$$r_{ti} = \sum_{i=1}^{n} F_i \qquad \text{..... (II.1.2)}$$

where:

n = the number of welds in the configuration

F_i = the theoretical resistance of one weld in the configuration

The value of F_i depends on the orientation of the weld with respect to the direction of the load. If the direction of the weld is perpendicular to the load direction (figure II.1.1a) then:

$$F_i = \frac{f_u}{\beta} \frac{A_1}{\sqrt{2}} \qquad \text{..... (II.1.3)}$$

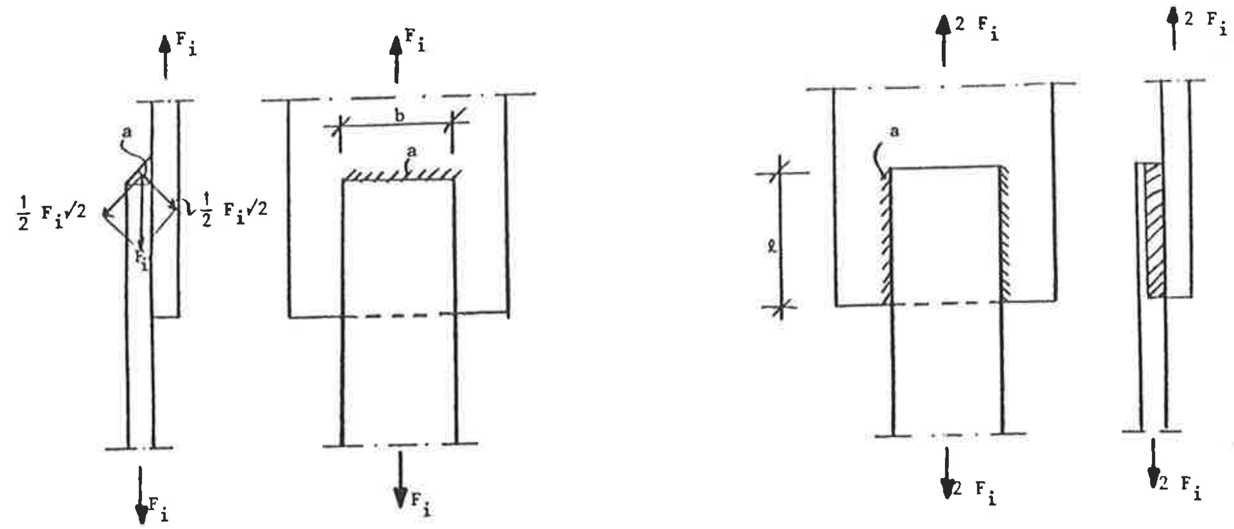
If the direction of the weld is in the direction of the load (figure II.1.1b) then:

$$F_i = \frac{f_u}{\beta} \frac{A_2}{\sqrt{3}} \qquad \text{..... (II.1.4)}$$

In the eqns. (II.1.3) and (II.1.4):

A_1 = the throat area for welds perpendicular to the loading direction (measured value)
A_2 = the throat area for welds parallel to the loading direction (measured value)
f_u = the tensile strength of the parent material (measured value)
β = given in the eqns. (II.1.1c) and (II.1.1d)

Note that $\beta > 0.5$ which means that eqn. (II.1.1b) does not govern.



$$\sigma_\perp = \frac{\frac{1}{2}\sqrt{2}\,F_i}{ab}$$

$$\tau_\perp = \frac{\frac{1}{2}\sqrt{2}\,F_i}{ab}$$

$$\tau_{/\!/} = 0$$

$$\sqrt{\sigma_\perp^2 + 3\,(\tau_\perp^2 + \tau_{/\!/}^2)} =$$

$$\sqrt{\frac{\frac{1}{2}\,F_i^2}{a^2b^2} + 3\,\frac{\frac{1}{2}\,F_1^2}{a^2b^2}} =$$

$$\frac{F_i\,\sqrt{2}}{ab} \le \frac{f_u}{\beta}$$

$$F_i = \frac{f_u}{\beta}\,\frac{A_1}{\sqrt{2}}$$

a transverse

$$\sigma_\perp = 0$$

$$\tau_\perp = 0$$

$$\tau_{/\!/} = \frac{F_i}{a\ell}$$

$$\sqrt{\sigma_\perp^2 + 3\,(\tau_\perp^2 + \tau_{/\!/}^2)} =$$

$$\sqrt{3\,\frac{F_i^2}{a^2\ell^2}} =$$

$$\frac{F_i\,\sqrt{3}}{a\ell} \le \frac{f_u}{\beta}$$

$$F_i = \frac{f_u}{\beta}\,\frac{A_2}{\sqrt{3}}$$

b parallel

Figure II.1.1: Theoretical resistance of one weld.

II.2 Method 2: mean stress method

When the strength function is:

$$\sigma_w \leq \frac{f_u}{\beta \sqrt{3}} \quad \text{..... (II.2.1a)}$$

where:

$$\sigma_w = \frac{F}{\Sigma a\ell} \quad \text{..... (II.2.1b)}$$

$$\beta = a_1 \quad \text{for FeE235} \quad \text{..... (II.2.1c)}$$

$$\beta = a_2 \quad \text{for FeE355} \quad \text{..... (II.2.1d)}$$

and:

a_1, a_2 are constants

then the theoretical resistance based upon this strength function depends on the welds that form the weld configuration. The theoretical resistance for the weld configuration is the sum of the theoretical resistances of the individual welds:

$$r_{ti} = \sum_{i=1}^{n} F_i \quad \text{..... (II.2.2)}$$

where:

n = the number of welds in the configuration
F_i = the theoretical resistance of one weld in the configuration
The value of F_i is for each weld:

$$F_i = \frac{f_u}{\beta} \frac{A}{\sqrt{3}} \quad \text{..... (II.2.3)}$$

where:

- A = the throat area (measured value)
- f_u = the tensile strength of the parent material (measured value)
- β = given in the eqns. (II.2.1c) and (II.2.1d)