Certified translation from the German language

Prof. Dr.-Ing. K. Berner

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Schletter Solar-Montagesysteme
Mr. Urban
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09/02/2005 be-schä

Expert opinion no. Z-515 for orienting preliminary test regarding the Schletter fastening system for solar modules on sandwich roof elements from the company Fischer Profil GmbH

Dear Mr. Urban,

Attached I am sending you the expert opinion mentioned above and the associated test report for further utilization.

As already described in my letter of August 26, 2005, I have evaluated the conducted tests and prepared suggestions for the design of the solar fastening systems (see expert opinion, page 23) and the sandwich elements with loads from the solar fastening systems (see expert opinion page 16).

Should you have any questions, please do not hesitate to contact me at any time.

Sincerely,

<<Signature, illegible>>
Prof. Dr.-Ing. K. Berner

Attachments:
Expert opinion no. Z-515
Test report no. 400221-31

Prof. Dr.-Ing. K. Berner

EXPERT OPINION

no. Z-515

Orienting preliminary tests for the Schletter fastening system for solar modules on sandwich roof elements of the company Fischer Profil GmbH

Ordering party:	Schletter Solar-Montagesysteme Heimgartenstrasse 41 83527 Haag and Fischer Profil GmbH Waldstrasse 67 57250 Netphen
Attachment 1:	Test report no. 400221-31 of 08/24/2005 Preliminary tests for determining the load bearing capacity of Schletter fastening systems on FischerTHERM roof sandwich elements with steel top layers and a polyurethane core prepared by the Institute of Sandwich Technology, University of Mainz

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1 TASK

The companies Fischer Profil GmbH and Schletter Solar-Montagesysteme assigned me with an expert opinion on the fastening of the solar elements with the corresponding rated values and on the basic load bearing behavior of the sandwich elements in reference to point loads from the solar systems.

For the sandwich roof building elements of the company Fischer Profil GmbH with the labeling “Isotherm”, there is a valid approval no. Z-10.4-179 of August 21, 2001 by the building authorities with amendment notification of February 7, 2002 (validity period until October 31, 2005). In this approval, it is assumed that the loads are distributed evenly over the section width, which is not warranted by the punctiform fastening of the solar elements.

Hereinafter, the maximum load horizontal to the roof area (pull-off value) and vertical to the roof area (shear force) of the solar module fastening on the sandwich roof elements and the load distribution property of the sandwich roof elements type DL shall be identified in the context of orienting preliminary tests on the basis of the sandwich guideline (test program for sandwich constructions with a support core of PUR rigid foam, edition 3.93).

For the investigation of the bearing capacity of the sandwich elements under point load and the fastening for lifting forces (as a consequence of wind suction) and shear forces (as a consequence of roof thrust), as well as the characteristic values of the sandwich elements, tests have been conducted in the Institute for Sandwich Technology, University of Mainz. The exact description of the samples and the conducting of the tests can be found in the respective test report (see attachment 1).

2 TYPES OF BUILDING ELEMENTS AND OVERVIEW OF THE TEST PROGRAM

From the product range of the manufacturing company, the fastening for the following types of building elements was investigated:

Sandwich roof element: **type DL70:** outer layer: molded
inner layer: lined

Thickness of building element: D = 70 mm
end-to-end core thickness: d = 30 mm
steel sheet thickness: molded top layer $t_N = 0.55$ mm,
lined top layer $t_N = 0.40$ mm

Fastening systems of the solar elements: **type Fix2000**

For more details on the cross-section geometry, see figure 1 and 2.

An overview of the conducted tests can be found in table 1. For the assessment of the load bearing behavior of the sandwich roof elements under point load, three tests of the building elements with point loads on the rim were conducted. And for comparison, three tests with a linear load distributed evenly over the building element width were conducted. The influence of the different positions of load over the span was investigated with this. For the standardization of the maximum load of the fastening, core layer and sheet samples were taken from the building elements and raw material analyses were carried out. The number and type of tests are also displayed in table 1.

Figure 1: Sandwich roof element, type "DL70"

Figure 2: Fastening, type "Fix2000"

Table 1: Program for orienting preliminary tests; company Fischer Profil GmbH and Schletter Solar-Montagesysteme
Type DL70 and Fix2000

1. **Tests of building elements** (static load)

Location of load application	Point load	Linier load over entire panel breadth	Number of tests
At midspan	1	1	2
at x=0.15*L of support	1	1	2
at x=0.30*L of support	1	1	2

2. **Tests at the short beam (l = 0,75 m)**
(Determination of the modulus of rigidity and the shear strength)
D = 70 mm (d = 30 mm) Quantity: 5

3. **Material analyses**
3.1 **Core layer**
3.1.1 Density
D = 70 mm (d = 30 mm) Quantity: 3
3.1.2 Pressure and tensile test (a / b = 100 / 100 mm)

	E module pressure and $ß_D$ (10% compression) at: 20°C	E module tension and $ß_Z$ at: 20°C	Number of tests
D = 70 mm (d = 30 mm)	10	10	20

3.2 **Top layers**
Determination of the mechanical values (thickness of the top layer, yield stress, tensile strength) Quantity: 6

4. **Fastenings**
4.1 **centric load**

Static pull-off tests	Quantity: 10
Dynamic pull-off tests	Quantity: 5
Static shear force tests	Quantity: 10

4.2 **eccentric load**

Static pull-off tests	Quantity: 10
Dynamic pull-off tests	Quantity: 5
Static shear force tests	Quantity: 10

Total quantity: **90**

3. MATERIAL ANALYSES

3.1 PU core layer

3.2 Bulk density means

Core layer samples were taken from the roof building elements which were tested in bearing load tests and the bulk densities of the PU core layer were established by determining the weight and volume (see chapter 5.6 and attachment AC in the test report).

$p = 38.60\ \text{kg/m}^3$ was assessed as the mean value.

3.1.2 Modulus of rigidity and shear strength

In order to determine the modulus of rigidity and the shear strengths, 4-point bend testing was conducted with “short beams” which were taken from the building elements (see chapter 5.6 in the test report). The samples were placed freely rotatable as bending beams in the testing machine and loaded via load distributors. The width and height of the samples resulted from the cross-section geometry of the building elements.

The test results are displayed in detail in the test report, attachment AA and AB.

The modulus of rigidity was calculated according to the following procedure:

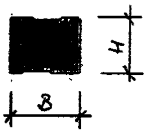
The total deflection is the sum of the bending and shear deformation.

$$f = f_B + f_S$$

The deflection as a consequence of bending stress can be calculated with known formulas, so that the modulus of rigidity can be calculated with the formula

$$G = \frac{F \cdot \ell}{6} \cdot \frac{1}{(f - f_B) \cdot b \cdot d}$$

Building element identification: DL70



Display of the general section properties:

Thickness of core sheet at the top, tko in mm = .52
Thickness of core sheet at the bottom, tku in mm = .33
Edge distance at the top, eo in mm = .43
Edge distance at the bottom, eu in mm = .23
E module at the top in kN/cm^2 = 21000
E module at the bottom in kN/cm^2 = 21000

Test arrangement = Two point loads at L/3

Display of the variable section properties:

test no.	B mm	H mm	L mm	G kN	Fu kN	F kN	f mm
1	101.13	29.78	750	0.000	0.831	0.300	4.357
2	101.16	30.81	750	0.000	0.963	0.300	4.638
3	101.20	30.65	750	0.000	0.941	0.300	4.981
4	101.11	29.88	750	0.000	0.724	0.300	4.829
5	101.15	30.42	750	0.000	0.784	0.300	5.969

Display of the test evaluation

test no.	H mm	F kN	f mm	fb mm	I cm^4	G N/mm²	T N/mm²
1	29.78	0.300	4.357	0.636	1.68	3.473	0.143
2	30.81	0.300	4.638	0.593	1.80	3.083	0.160
3	30.65	0.300	4.981	0.599	1.79	2.860	0.157
4	29.88	0.300	4.829	0.632	1.69	3.069	0.124
5	30.42	0.300	5.969	0.609	1.76	2.358	0.132

Statistical Evaluation:

		Modulus of rigidity G in N/mm^2	Shear stress τ in N/m
Mean	=	2.968588	0.143402
Standard deviation	=	0.142585	0.109136
5% fractile value	=	2.072976	0.109083

Table 2: Module of rigidity G, shear strength $ß_t$,
Building element type DL70, D = 70 mm (d = 30 mm)

Test no.	G (N/mm^2)	β_τ (N/mm^2)
1	3,47	0,143
2	3,08	0,160
3	2,86	0,157
4	3,07	0,124
5	2,36	0,132

$\overline{G} = 2{,}97\,N/mm^2$ $\qquad$ $\overline{\beta}_\tau = 0{,}143\,N/mm^2$

$G^{5\%} = 2{,}07\,N/mm^2$ $\qquad$ $\beta_\tau^{5\%} = 0{,}109\,N/mm^2$

3.1.3 Modules of elasticity (E_D, E_Z) and stabilities ($ß_D$, $ß_Z$)

The modules of elasticity and stabilities during thrust and pull were established with samples with rim measurements of 100*100*H mm (see chapter 5.4 and 5.5 in the test report). The results are described in detail in attachment V through Z in the test report and summarized in the following tables 3 and 4.

The tensile strengths are at the same time also the frontal pull-off strengths as the cover sheets have not been separated for the tests.

Table 3: E_Z module, tensile strength $ß_Z$, adhesive force;
Building element type DL70, D = 70 mm (d = 30 mm)

Test no.	E_Z (N/mm²)	β_Z (N/mm²)
1	2,98	0,066
2	4,00	0,111
3	3,28	0,149
4	4,22	0,134
5	4,21	0,126
6	3,09	0,104
7	3,56	0,132
8	3,58	0,125
9	4,25	0,138
10	3,87	0,126

$\bar{E}_Z = 3{,}70\,\mathrm{N/mm^2}$ $\bar{\beta}_Z = 0{,}121\,\mathrm{N/mm^2}$

$E_Z^{5\%} = 2{,}78\,\mathrm{N/mm^2}$ $\beta_Z^{5\%} = 0{,}073\,\mathrm{N/mm^2}$

Table 4: E_D module, compressive resistance $ß_D$;
Building element type DL70, D = 70 mm (d = 30 mm)

Test no.	E_D (N/mm²)	β_D (N/mm²)
1	2,41	0,136
2	2,58	0,139
3	2,91	0,144
4	2,60	0,145
5	2,12	0,131
6	2,15	0,136
7	3,29	0,150
8	2,63	0,138
9	2,44	0,135
10	2,12	0,133

$\bar{E}_D = 2{,}52\,\mathrm{N/mm^2}$ $\bar{\beta}_D = 0{,}139\,\mathrm{N/mm^2}$

$E_D^{5\%} = 1{,}85\,\mathrm{N/mm^2}$ $\beta_D^{5\%} = 0{,}127\,\mathrm{N/mm^2}$

3.2 Steel top layers

In all 6 tensile tests were carried out with the top and bottom layers of the experimentally examined single-span slabs according to DIN 50114, with which the material properties were determined.

The results are summarized in the tables of attachment AD and AF in the test report.

4 TESTS OF BUILDING ELEMENTS

4.1 Execution of the test

Numerous results are on hand in literature about material and building element tests on sandwich slabs with a PU core layer (e.g. in /1/). The tests within this expert opinion are based on those results.

Within the context of the approval attempts for the general approval no. Z-10.4-179 of the sandwich elements by the building authorities, an evenly distributed load application over the width of the sandwich elements was assumed as usual. This load application is not on hand with the designated Schletter fastening system, i.e. in the worst case scenario the load from the solar modules is applied punctiform in the most outer raised bead of the outer top layer of the sandwich elements. The load distribution breadths that can be applied for the load transfer are not regulated in the approval no. Z-10.4-179 of the building authorities.

Load distribution breadths with cross distributional inter layers that can be applied are regulated in the trapezoidal sheeting standard DIN 18807, part 3, paragraph 3.1.7.3. However, without further documented evidence it only applies to concrete-lined trapezoidal cross sections. With other cross distributional inter layers, such as the PU core layer of the sandwich elements, their effectiveness has to be proven, see DIN 18807, part 3, paragraph 3.1.7.3.2.

For the determination of the existing load distribution breadths, three tests on building elements with different positions of point load each were executed and, for comparison, three tests with the same positions of load and a load application distributed evenly over the breadth of the building element.

In order to examine the worst case scenario, sandwich roof elements with the thinnest end-to-end core layer of d = 30 mm (according to the approval Z-10.4-179 of the building authorities) were tested.

The test set-up, the representations of the failure situation and the test results are displayed in attachments S through U in the test report.

The load was applied via load distribution beams. The widths between supports approximately complied with the intended application area. The deflection at midspan was determined by continuously increasing the load. An overview of the bearing loads can be found in table 5.

Table 5: Single-span beam tests
Building element type: DL70, D = 70 mm (d = 30 mm), fastening system: Fix2000

Test no. Load type	Position of load (Distance from support) [m]	System length [m]	Bearing load [kN]	Reason for failure
B_1- point load	0.32	2.29	2.088	shear failure
B_2 - linear load	0.32	2.29	7.518	"
B_3 - point load	0.64	2.29	3.204	"
B_4 - linear load	0.64	2.29	5.628	failure through crumbling of the pressured top layer
B_5 - point load	1.47	2.94	3.336	"
B_6 - linear load	1.47	2.94	3.414	"

4.2 Evaluation of the test results

The load distribution breadths are calculated based on the bearing loads achieved in the single-span beam tests and summarized in the following table 6:

Table 6: Single-span beam tests; achieved load distribution breadths
Building element type: DL70, D = 70 mm (d = 30 mm), fastening system: Fix2000

Test no.	$F_{max,point}$ [kN]	$F_{max,line}$ [kN]	$b_{w,test}$ [m]
B_1 / B_2	2.088	7.518	0.278
B_3 / B_4	3.204	5.628	0.569
B_5 / B_6	3.336	3.414	0.977

$$b_{w,test} = \frac{F_{max,point}}{F_{max,line}} \cdot B$$

$b_{w,test}$ = achieved load distribution breadth
$F_{w,point}$ = achieved bearing load at point load application
$F_{w,line}$ = achieved bearing load at linear load application
B = element breadth of the sandwich elements (B = 1.0 m), see test report, page 3

The achieved load distribution breadths are compared to the calculated load distribution breadths according to DIN 18807, part 3, table 2, see the following table 7.

Table 7: Single-span beam tests, calculated load distribution breadths according to DIN 18807, part 3
Building element type: DL70, D = 70 mm (d = 30 mm), fastening system: Fix2000

Test no.	Decisive stress resultant	L [m]	x [m]	b_w [m]	$b_{w,test}$ [m]
B_1 / B_2	Q	2.29	0.32	0.20	0.278
B_3 / B_4	Q	2.29	0.64	0.36	0.569
B_5 / B_6	M	2.94	1.47	1.00	0.977

According to DIN 18807, part 3, table 2, the following has been applied for the:

decisive stress resultant Q (shear force at support):

$$b_w = b_e + 0,5 \cdot x$$

decisive stress resultant M (bending moment at midspan):

$$b_w = b_e + 2 \cdot x \cdot (1 - x/L) \leq B$$

b_w = calculated load distribution breadth
b_e = load application breadth $b_e = 0.04$ m
(On the secure side, only the top chord breadth of the outer molded top layers of the sandwich elements is applied. The application of the load distribution within the core layer in the area of load application is disclaimed.)
x = Distance of the load application from the support (position of load)
L = system length (support width)
B = element breadth of the sandwich elements (B=1.0 m)
$b_{w,test}$ = achieved load distribution breadth

One can see, that the load distribution breadths achieved in the test for proving the shear force stress are way above the applicable calculated values according to the trapezoidal sheeting standard DIN 18807, part 3. The entire building element width should be applied as the calculated distributional width in the test for the momentary load. This could be confirmed with the preliminary tests.

Due to the results of the preliminary tests, it seems reasonable to apply the load distribution breadths according to DIN 18807, part 3, table 2 for a static calculation of the sandwich elements DL with a building element width of ≥ 70 mm under load from the solar fastenings Fix2000, see also /14/ and/or attachment 2. Furthermore, the tests have shown that the shear force is mainly carried by the outer molded top layer, when the solar modules are fastened in close proximity of the support area for the tested sandwich building elements with a relatively small end-to-end core thickness (d = 30 mm). The tests have also shown that the sandwich theory specified in the general approval of the sandwich elements by the building authorities cannot be applied by implication. I therefore recommend, on the basis of DIN 18807, part 1, paragraph 4.2.6.1, to limit the maximum load pressure of the sandwich elements to $F_{rd} = 3.6$ kN/m (corresponding to the bearing capacity of the trapezoidal sheets) if the solar modules are close to the bearings ($x \leq 0.3 * L$). In order to estimate the load capacity of thicker elements, further tests have to be executed to possibly find a verifiable load sharing effect of the core for the shearing force transfer. The principal analysis concept and the applicable rated values for the sandwich elements themselves can be taken from the general approval Z-10.4-179 of the building authorities.

As the executed tests are orienting preliminary tests, further tests need to be executed which might have to be coordinated with the *Deutsches Institut für Bautechnik* [German Institute for Structural Engineering], Berlin, in order to achieve a general approval of the building authorities with rated values for linear and point loads.

5 FASTENING OF THE SOLAR MODULES

5.1 Mode of operation of the fastening

For the fastening system Fix2000, cuffs are custom-fitted to the raised beads of the sandwich elements and fastened with four drilling screws each, see test report, page 4. The solar module construction is then assembled and connected on these cuffs with two M10 screws each.

5.2 Load bearing behavior and reason for failure

The following **reasons for failure** could be established due to the observations in the tests with lifting forces and roof shear loads (see also test report, attachment G, J, M and P):

- Long hole in the outer cover sheet of the sandwich roof elements
- Separating of the outer cover sheet of the sandwich roof elements from the core layer.

5.3 Execution of the test

10 static and 5 dynamic tensile tests with eccentric and centric load application were executed on roof elements with a thickness D = 70 mm in order to establish the permissible forces of the cuff fastening Fix2000. Furthermore, 10 static shear force tests with eccentric and centric load application were carried out.

For a better overview, the test results are summarized again in the following tables and the means and 5% fractile values are indicated.

Table 8: Summary of the test results for **centric load application** for the fastening of the solar modules with **lifting forces**, cuff type **Fix2000**

Static load

Test no.	max. F (kN)
1	5.50
2	4.86
3	5.02
4	5.13
5	5.66
6	5.65
7	5.51
8	5.90
9	5.13
10	5.34

$$\max \bar{F} = 5{,}37\,\text{kN}$$

$$\max F^{5\%} = 4{,}71\,\text{kN}$$

Table 9: Summary of the test results for **centric load application** for the fastening of the solar modules with **lifting forces**, cuff type **Fix2000**

Dynamic load

Test no.	max. F (kN)
1	6.35
2	4.68
3	5.50
4	5.09
5	5.39

$$\max \bar{F} = 5{,}40\,\text{kN}$$

Table 10: Summary of the test results for **eccentric load application** for the fastening of the solar modules with **lifting forces**, cuff type **Fix2000**

Static load

Test no.	max. F (kN)
1	3.59
2	4.00
3	3.36
4	3.56
5	3.55
6	3.75
7	3.29
8	3.45
9	3.65
10	3.41

$\max \bar{F} = 3{,}56\ \text{kN}$

$\max F^{5\%} = 3{,}15\ \text{kN}$

Table 11: Summary of the test results for **eccentric load application** for the fastening of the solar modules with **lifting forces**, cuff type **Fix2000**

Dynamic load

Test no.	max. F (kN)
1	3.68
2	3.95
3	3.68
4	3.53
5	3.95

$\max \bar{F} = 3{,}76\ \text{kN}$

Table 12: Summary of the test results for **centric load application** for the fastening of the solar modules with **roof shear loads**, cuff type **Fix2000**

Static load

Test no.	max. F (kN)
1	8.70
2	7.98
3	8.81
4	8.45
5	8.54
6	9.00
7	7.87
8	7.82
9	8.70
10	8.16

$\max \bar{F} = 8{,}40\ \text{kN}$

$\max F^{5\%} = 7{,}55\ \text{kN}$

Table 13: Summary of the test results for **eccentric load application** for the fastening of the solar modules with **roof shear loads**, cuff type **Fix2000**

Static load

Test no.	max. F (kN)
1	7.25
2	6.92
3	7.28
4	7.05
5	7.54
6	6.56
7	6.81
8	6.51
9	6.90
10	7.06

$\max \bar{F} = 6{,}99\ \text{kN}$

$\max F^{5\%} = 6{,}34\ \text{kN}$

5.4 Test evaluation

When interpreting the test results, the following should be considered in my opinion:

a) According to sandwich guideline, dynamic tensile tests were carried out with the cuff fastening Fix2000. As the achieved bearing load is always bigger than $1.3 \cdot F_{U,stat} / 2$ after the 5000 load alternation strains, one can then basically apply $F_U = F_{U,stat}$ or for perm. $F = F_U / 2$ ($y = 2.0$) according to the sandwich guideline.

b) Due to the material parameters, one should generally carry out a standardization. In my opinion, the supporting core layer and the cover sheets are primarily decisive for the bearing behavior of the fastening. The standardization in reference to the core layer does not necessarily have to be carried out as the established shear and tensile strengths of the core layer are within the range of and/or partially marginally below the demanded values of the valid general approval Z-10.4-179 of the building authorities. Please note that in order to avoid a disadvantageous standardization, the manufacturer paid special attention to the parameters of the core layer in the samples lying at the lower limit of the permissible values and/or under the values of the approval. However, the manufacturer confirms that the approved values are observed during production.

A standardization in reference to the tensile strength of the even outer top layer and the thickness of the cover sheet is suggested according to the information on the standardization of the test results during the determination of the maximum loads of trapezoidal sheet joints (see DIN 18807, part 7, paragraph 4.10.1.3 and outline of DIN 18807, part 4, paragraph 5.7.1.4).

$$f = \frac{\beta_{KN}}{\beta_{KV}} \cdot \frac{t_{KN}}{t_{KV}}^{*}$$

$ß_{KN}$ = nominal tensile strength
$ß_{KV}$ = measured tensile strength (see test report)
t_{KN} = nominal thickness of core sheet $t_K = t_N - 0.04$ mm
t_{KV} = measured thickness of core sheet (see test report)

* If the results are the quotients $ß_{KN} / ß_{KV} > 1$ and/or $t_{KN} / t_{KV} > 1$, then $ß_{KN}/ß_{KV}$ and/or $t_{KN} / t_{KV} = 1$ have to be used for the calculation (see DIN 18807, part 7, paragraph 4.10.1.3 and outline for DIN 18807, part 4, paragraph 5.7.1.4).

$$f = \frac{420}{487} \cdot \frac{0{,}51}{0{,}52} = 0{,}846$$

This leads to the following values for each **fastening of the solar modules**:

Table 14: Bearing loads (F_U) and permissible values (perm. F) for cuff fastening, type Fix2000 on sandwich roof building elements, type DL with top layers ($t_{Na} \geq 0.55$ mm) made of steel conforming to the approval Z-10.4-179

Requirements:

Construction and arrangement of the screws according to figure 2

Screws: for each cuff 4 screws, type EJOT-JT3-2H-5.5 E16 (or equivalent) for the fastening of the cuff at the top chord of the sandwich elements, for each cuff 2 M10 screws

Direction of load	Type of support	Standardization factor	Standardized bearing load F_U (kN)	Security factor	Permissible value perm. F (kN)
Lifting	centric	0.846	3.98	2.0	1.99
	eccentric	"	2.66	2.0	1.33
Roof thrust ~~(Shear force)~~	centric	"	6.39	2.0	3.20
	eccentric	"	5.36	2.0	2.68

Taking into consideration the annotations and permissible pull-off forces above, there are no objections against the cuff fastening, type Fix2000 of the company Schletter Solar-Montagesysteme on sandwich roof elements, type DL of the company Fischer Profil GmbH within the scope of these preliminary tests .

Darmstadt, August 30, 2005

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Stahlbaunormen-angepaßt, Ernst&Sohn-Verlag 1999

Attachment 1

Test report no. 400221-31

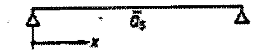
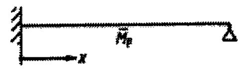
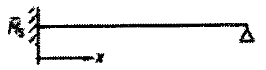
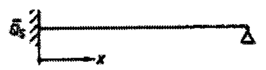
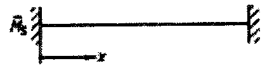
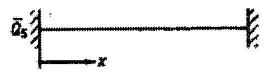
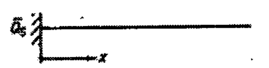
Preliminary tests for determining the load bearing capacity of Schletter fastening systems on FischerTHERM roof sandwich elements with steel top layers and a polyurethane core

prepared by the Institute for Sandwich Technology, University of Mainz

of 08/24/2005

Attachment 2

Excerpt from /14/ on DIN 18807, part 3, table 2

	1	2	3
No.	Static system Stress resultants	Calculated load sharing breadth b_w	Validity limits
1		$b_w = b'_e + 2 \cdot x \cdot \left(1 - \frac{x}{l}\right)$	$0 < x < l/2$ $b_e < 0{,}8 \cdot l$
2		$b'_w = b_e + 0{,}5 \cdot x$	
3		$b_w = b_e + 1{,}33 \cdot x \cdot \left(1 - \frac{x}{l}\right)$	$0 < x < l$ $b_e < 0{,}8 \cdot l$
4		$b_w = b_e + 0{,}45 \cdot x \cdot \left(2 - \frac{x}{l}\right)$	
5		$b'_w = b_e + 0{,}3 \cdot x$	$0{,}2 \cdot l < x < l$
6		$b'_w = b_e + 0{,}4 \cdot l \cdot \left(1 - \frac{x}{l}\right)$	$0 < x < 0{,}8 \cdot l$ $b_e \leq 0{,}4 \cdot l$
7		$b_w = b_e + 0{,}8 \cdot x \cdot \left(1 - \frac{x}{l}\right)$	$0 < x < l/2$ $b_e < 0{,}8 \cdot l$
8		$b_w = b_e + 0{,}46 \cdot x \cdot \left(2 - \frac{x}{l}\right)$	$0 < x < l/2$ $b_e < 0{,}4 \cdot l$
9		$b'_w = b_e + 0{,}3 \cdot x$	$0{,}2 \cdot l < x < l/2$ $b_e < 0{,}4 \cdot l$
10		$b_w = b_e + 1{,}33 \cdot x$	$0 < x < l_k$ $b_e \leq 0{,}8 \cdot l_k$
11		$b'_w = b_e + 0{,}3 \cdot x$	$0{,}2 \cdot l_k < x < l_k$ $b_e \leq 0{,}4 \cdot l_k$

Authentication

I have examined the German original / photocopy / facsimile and this is a true translation of the same into English.

Barbara Wohanka, registered translator for the English language at the District Court of Landshut, Germany

Geisenhausen, 23 September 2011

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