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SCI Assessed Report: TekTherm AK200 and AK300HT thermal break products

Report To Thermal Breaks Ltd

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SCI, Silwood Park, Ascot,
Berkshire, UK. SL5 7QN
Tel: +44 (0)1344 636525
Fax: +44 (0)1344 636570

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For information on publications, telephone direct: +44 (0) 1344 636505
or Email: publications@steel-sci.com

For information on courses, telephone direct: +44 (0) 1344 636500
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EXECUTIVE SUMMARY

This report describes the structural properties of Thermal Breaks Ltd TekTherm AK200 and AK300HT products. The properties are supported by test data and have been confirmed by an independent review carried out by SCI.

Thermal Breaks Ltd TekTherm AK200 and AK300HT products can be used in structural applications. Thermal break plates are used between flanged connections of internal and external steelwork or internal concrete and external steelwork to reduce thermal transmittance through the connection to reduce cold bridging.

SCI has examined the test data for Thermal Breaks Ltd TekTherm AK200 and AK300HT products and has derived resistance values suitable for use in structural design. Recommended design methods are presented which should be used when thermal break materials are used in structural connections.

As a result of SCI's independent review, Thermal Breaks Ltd TekTherm AK200 and AK300HT products and the associated technical data presented in this report has been granted "SCI Assessed" status.

SCI Assessed
A list of SCI Assessed products and their associated certificates are given on the SCI Assessed website – www.sci-assessed.com.

Contents

1 INTRODUCTION

This report describes the findings of the SCI assessment of the Thermal Breaks Ltd TekTherm AK200 & AK300HT

1.1 Thermal performance

Energy efficiency is an increasingly important parameter in the design of buildings. The thermal insulation provided by the building envelope is key to energy efficiency but thermal bridges - weak spots in the insulation - lead to local heat losses that reduce the efficiency.

The thermal efficiency of a building envelope is a function of the thermal performance of the planar elements (e.g. wall, roofs, windows) and the local heat losses that can occur around the planar elements and where the planar elements are penetrated by building components. These local heat losses are the result of areas of the envelope where the thermal insulation is impaired. These areas of impaired thermal insulation are known as ‘thermal bridges’ or ‘cold bridges’.

The ongoing process of revisions to Building Regulations requirements have emphasised the importance of the thermal efficiency of building envelopes, including limiting heat losses through thermal bridges. As part of a thermal assessment of the building envelope, it is recognised that local heat losses due to penetrations or similar local effects have to be calculated and where necessary minimised, so that the thermal efficiency of the building envelope is within acceptable limits.

1.2 Thermal bridging

Thermal bridges occur where the insulation layer is penetrated by a material with a relatively high thermal conductivity and at interfaces between building elements where there is a discontinuity in the insulation. Thermal bridges result in local heat losses, which mean more energy is required to maintain the internal temperature of the building and lower internal surface temperatures around the thermal bridge.

Local heat losses caused by thermal bridges become relatively more important, as the thermal performance (i.e. U-values) of the planar elements of the building envelope are improved.

Steel has a high thermal conductivity compared with many other construction materials. The high thermal conductivity means that steel construction systems, both the structural frame and cladding, must be carefully designed to minimise unwanted heat flows.

There are three ways of reducing thermal bridging in steel construction:

- Eliminate the thermal bridge by keeping the steelwork within the insulated envelope
- Locally insulate any steelwork that penetrates the envelope
- Reduce the thermal transmittance of the thermal bridge by using thermal breaks, changing the detailing or by including alternative materials.

1.3 Reducing thermal transmittance

The thermal transmittance of a thermal bridge can be reduced by using thermal breaks, changing the detailing or by including alternative materials.

Thermal breaks may be provided by inserting a material with a low thermal conductivity (e.g. Thermal Breaks Ltd TekTherm AK200 & AK300HT) between elements with higher thermal conductivities, as illustrated in Figure 1.1. Reducing the cross-sectional area of an element can also be used to reduce its thermal transmittance where it bridges an insulated building envelope.

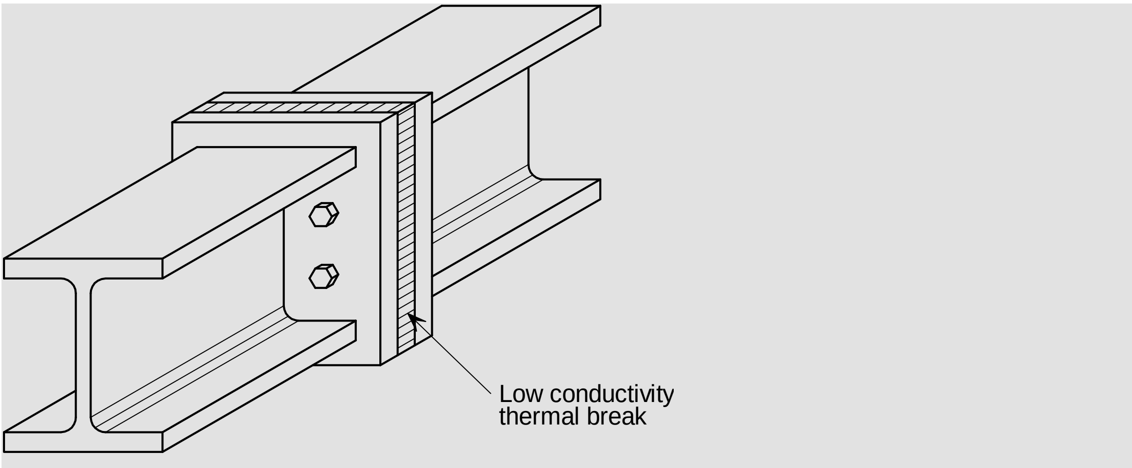


Figure 1.1 Thermal break between steel beams

Thermal breaks are provided in certain manufactured elements, such as metal window frames and composite steel cladding panels, where the steel skins are separated at junctions by a layer of insulation. Similarly, thermal break pads can be provided behind the brackets of brickwork support systems.

Where structural forces are transferred through steel elements that pass through the insulated envelope of a building, such as in balcony connections, brickwork support systems and roof structures, the form of break must be considered carefully. It is vital to ensure that the structural performance remains acceptable. Materials used for thermal breaks may be more compressible than steel. Therefore, deflections, as well as strength, should be checked when thermal breaks are used (see Section 4).

2 PRODUCTS AND APPLICATIONS

2.1 Applications

Thermal break plates are used between flanged connections of internal and external steelwork or concrete and external steelwork to reduce thermal transmittance through the connection to reduce cold bridging. They provide a simple, economical and effective solution to meeting Part L of the Building Requirements by way of reducing heat loss and the risk of internal condensation.

The thermal conductivity value of steel is approximately 57 W/mK. Thermal Break Ltd AK200 and AK300HT materials have a thermal conductivity of 0.12-0.18 W/mK and 0.10-0.12 W/mK respectively (see Table 3.1). Further improvements in thermal performance of the connection itself can be achieved by using stainless steel bolts and thermal break washers.

Thermal breaks are typically used in new-build and refurbishment projects in the following building elements:

- Balconies
- Brise-soleil
- Entrance structures / canopies
- Roof plant enclosures
- Façade systems
- Internal / external primary structure junctions
- External staircases
- Balustrading
- Man-safe systems.

Figure 2.1 shows a typical application of Thermal Break Ltd thermal break plate and a corresponding bolted connection detail. The thermal break plate should be the same size (height and width) as the steelwork end plates.

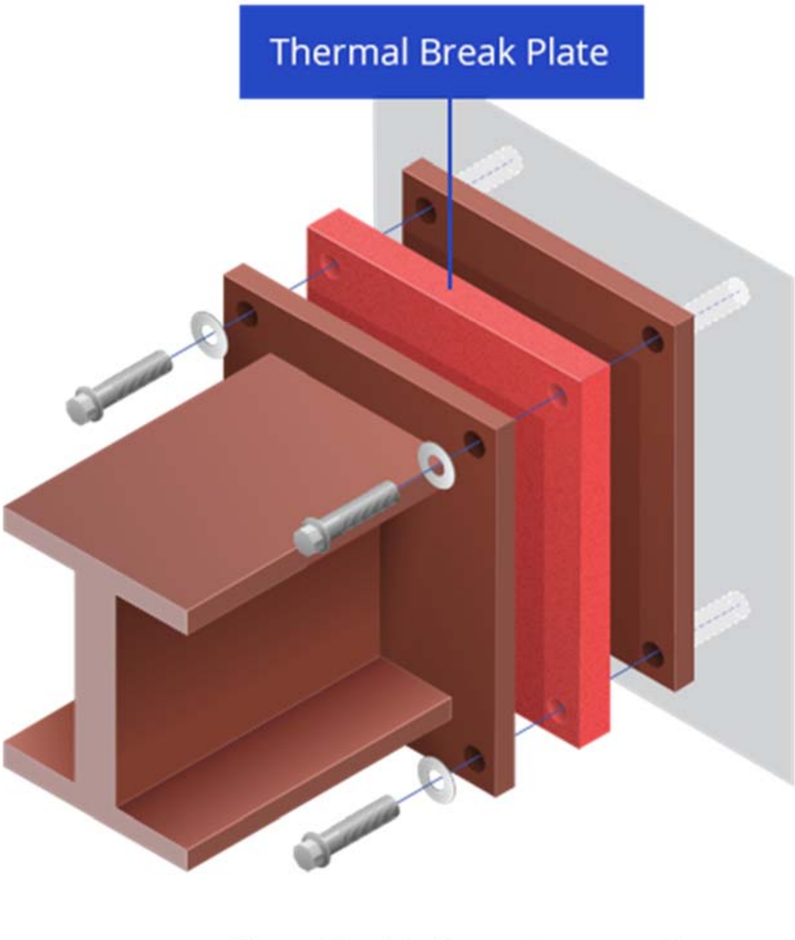


Figure 2.1 Thermal Breaks Ltd thermal break plate between steel and concrete

2.2 Thermal Breaks Ltd products

There are two types of Thermal Breaks Ltd material products included in this report:

- TekTherm AK200
- TekTherm AK300HT

The available product thicknesses are given in Table 2.1.

Table 2.1 Product thicknesses

Product	Available thicknesses (mm)	(inches)
TekTherm AK200	6 - 25	¼ - 1
TekTherm AK300HT	6 - 25	¼ - 1

3 MATERIAL PROPERTIES

3.1 Test data

Laboratory testing of Thermal Breaks products has been carried out by the Engineering Materials Testing Institute (MPA), Braunschweig Germany to determine the material characteristics of two thermal insulation products, namely AK200 and AK300HT.

Thermal Breaks Ltd has provided two assessment reports (1201/364/16 and 1201/364/16-1) for the following tests carried out on their thermal break materials:

- Compressive behaviour
- Thermal conductivity and thermal resistance
- Apparent density
- Long term water absorption by immersion
- Long term compression creep

SCI has examined these assessment reports and has independently verified the material properties listed in Table 3.1. The values given in Table 3.1 are mean values from several tests. Data relating to individual test results are given in Appendix A.

Table 3.1 Material Properties from testing

Property	AK200	AK300HT	Units	Test Standard
Compressive strength	109.4	259.5	MPa	DIN EN 826
Thermal conductivity				
10mm thick @ 10°C	0.1187	0.1027	W/mK	DIN EN 12667
25mm thick @10°C	0.1837	0.1332	W/mK	DIN EN 12667
Thermal resistance				
10mm thick @ 10°C	0.1001	0.0973	m^2K/W	DIN EN 12667
25mm thick @ 10°C	0.1455	0.1895	m^2K/W	DIN EN 12667
Density				
10mm thk	1.15	1.55	kg/dm^3	DIN EN 1602
25mm thk	1.15	1.48	kg/dm^3	DIN EN 1602
Water absorption				
10mm thick	0.95	0.69	% length mm	DIN EN 12087
25mm thick	0.37	0.28	% length mm	DIN EN 12087
Compression creep	See 3.3			DIN EN 1606

- DIN EN 826 - Thermal insulating products for building applications - Determination of compression behaviour
- DIN EN 12667 - Thermal performance of building materials and products - Determination of thermal resistance by means of guarded hot plate and heat flow meter methods - Products of high and medium thermal resistance

- DIN EN 1602 - Thermal insulating products for building applications - Determination of the apparent density
- DIN EN 12087 - Thermal insulating products for building applications - Determination of long term water absorption by immersion
- DIN EN 1606 - Thermal insulating products for building applications - Determination of compressive creep

3.2 Compressive strength characteristic values

For use in structural design calculations, the compressive strength of the thermal break materials which have been obtained from testing must be converted in to characteristic compressive strength values. The characteristic values are used in conjunction with a partial safety factor to obtain a design value of compressive strength. Details of the design process are presented in Section 4.

For multiple test results characteristic compressive strength values can be calculated in accordance with BS EN 1990, Annex D. The design resistance is calculated using Equation 1, which is based on BS EN 1990, Equation (D.1).

$$X_{\mathrm{d}} = \frac{X_{\mathrm{k}}}{\gamma_{\mathrm{m}}} = \frac{X_{\mathrm{b=1}}\left(m_{\mathrm{b}} - k_{\mathrm{n}} s_{\mathrm{b}}\right)}{\gamma_{\mathrm{m}}} \tag{1}$$

where:

X_{d}	is the design resistance of property X
$X_{\mathrm{k(n)}}$	is the characteristic resistance of property X, derived from n tests
γ_{m}	is the relevant partial safety factor, in this case γ_{M2}
$X_{\mathrm{b=1}}$	is the resistance of property X corresponding to a correction factor of $b = 1$
m_{b}	is the mean correction factor
k_{n}	is an adjustment coefficient that depends on the number of tests that have been undertaken, taken from BS EN 1990, Table D1
s_{b}	is the standard deviation of the correction factor

Six compressive strength tests were carried out on the TekTherm AK200 and AK300HT products for 25mm nom thick samples.

For product AK200,

Characteristic compressive strength, f_{ck} = 105.4 N/mm^2

For product AK300HT

Characteristic compressive strength, f_{ck} = 247.5 N/mm^2

The characteristic values for design to BS EN 1993-1-8 should be converted to design values by using the partial safety factor γ_{M2}, which is defined as 1.25 in the UK National Annex. This value is considered appropriate for TIM due to the mode of failure and the consistency of the test results of similar materials. The design values for compressive strength are given in Table 3.2.

Table 3.2 Compressive strength values for TekTherm AK200 and AK300HT

Property	Characteristic compressive strength, f_{ck} [N/mm^2]	Design value for compressive strength, f_{cd} [N/mm^2]
AK200	105.4	84.3
AK300HT	247.5	198.0

3.3 Compressive creep tests

The compressive creep test for the TekTherm AK200 and AK300HT products were conducted on the basis of DIN EN 1606 over a period of 2352 hours (98 days). Sample sizes were 50mm x 50xx x 26mm for the AK200 product and 50mm x 50mm x 25mm for the AK300HT product.

Graphs showing strain-creep deformation mm x_{ct} against time t hours, in the form of a log-log relationship, are shown in Figures 3.1 and 3.2. Supporting tables of test results are provided in Appendix A.5.

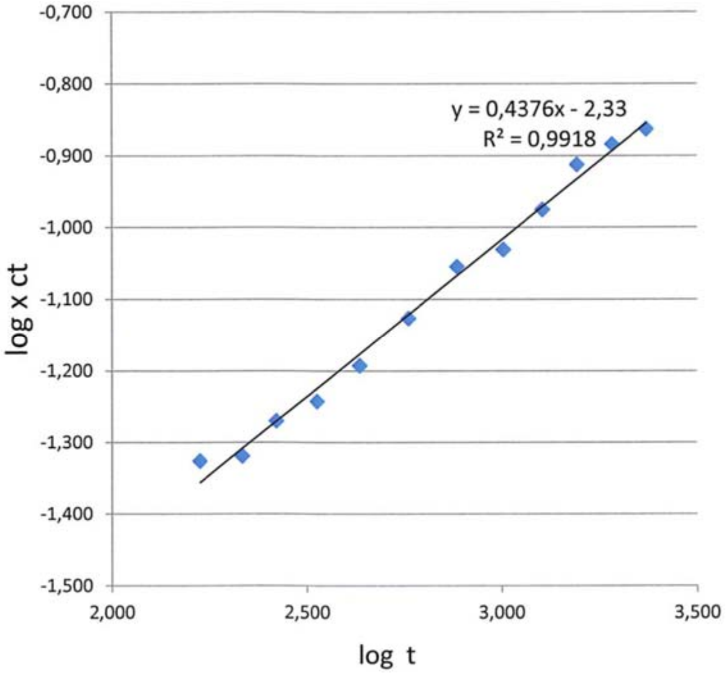


Figure 3.1 Regression analysis of the compressive creep of product AK200

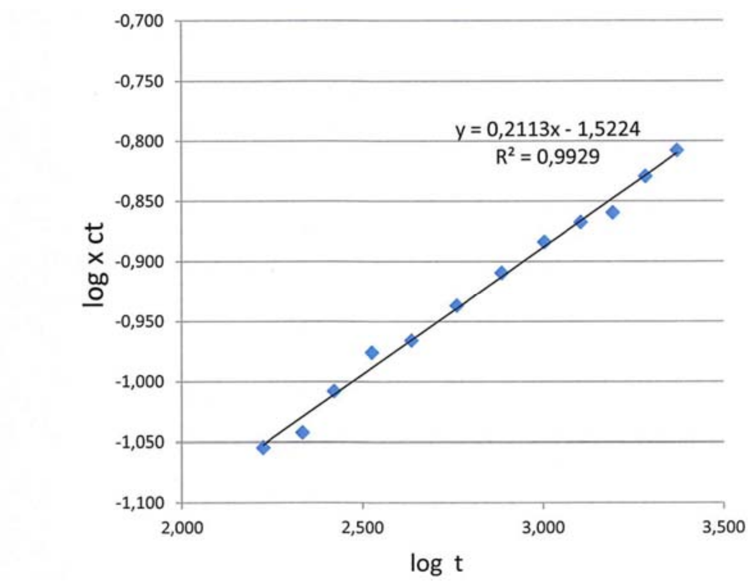


Figure 3.2 Regression analysis of the compressive creep of product AK300HT

4 STRUCTURAL DESIGN GUIDANCE

4.1 General

In general, steelwork connections should be designed in accordance with the latest SCI guidance publications as listed below:

Simple Connections –

- SCI-P212: Joints in steel construction. Simple connections (BS 5950-1).
- SCI-P358: Joints in steel construction. Simple joints to Eurocode 3.

Moment Connections –

- SCI-P207: Joints in steel construction. Moment connections (BS 5950-1).
- SCI-P398: Joints in steel construction. Moment joints to Eurocode 3.

However, additional design checks should be carried out for connections that include thermal break plates between the steel elements. These additional checks are explained in the following Sections 4.2, 4.3, 4.4 and 4.5 (of this report).

4.2 Compression resistance of thermal break

4.2.1 Nominally pinned connections

Nominally pinned connections (also referred to as simple connections) are generally designed to only transmit shear forces and tying forces, as shown in Figure 4.1. Therefore, the thermal break plate is not required to resist compression forces. Hence, for nominally pinned connections there is generally no requirement for the designer to check the compression resistance of the thermal break plate within the connection.

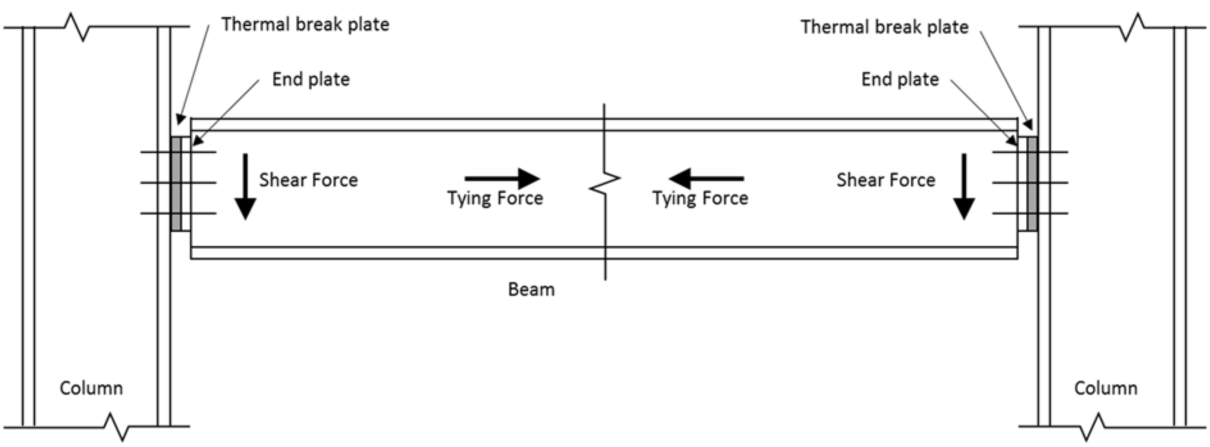


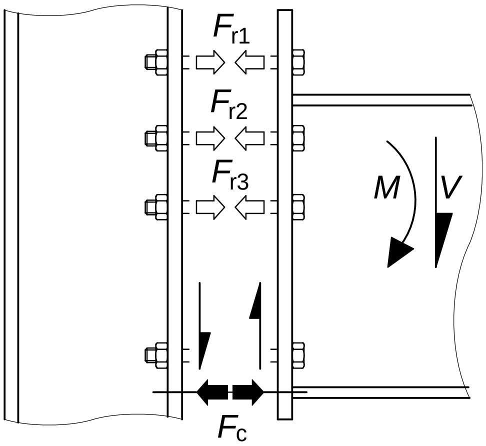
Figure 4.1 Nominally pinned connection with thermal break plate

However, there may be situations where beams are also subject to axial load, in these situations the thermal break plate is required to resist compression forces and should be designed accordingly. The design procedure presented in Section 4.2.2 can be adapted to suit thermal break plates subject to compression. Alternatively, the thermal break plate can be treated in a similar way to the concrete under a column base plate (see Section 7 of SCI publication P358).

4.2.2 Moment connections

Applications where thermal break plates are required in connections will generally be moment resisting connections e.g. steel beams supporting balconies or canopies.

In moment resisting connections one part of the connection is in tension and the other part of the connection is in compression, as shown in Figure 4.2. Therefore, a thermal break plate within the connection is required to resist compression forces. Hence, for moment connections there is a requirement for the designer to check the compression resistance of the thermal break plate within the connection.



M = Applied moment
V = Applied shear
$F_{r1,2,3}$ = Bolt row tension forces
F_c = Compression force

Figure 4.2 Forces in a typical moment connection

The designer must check that the compressive stress applied to the thermal break plate is less than the design compression strength of the thermal break material. This is achieved by satisfying the Expression (2), given below.

$$F_c \leq \frac{B \times L \times f_{ck}}{\gamma_{M2}} \qquad (2)$$

where:

F_c is applied design compression force

B is the depth of the compression zone on the thermal break plate

L is the width of the compression zone on the thermal break plate

f_{ck} is the characteristic compression strength of the thermal break plate

γ_{M2} is a partial safety factor, which is defined as 1.25 in the UK National Annex. This value is considered appropriate to Thermal Breaks Ltd AK200 and AK300HT products due to the mode of failure and the consistency of the test results.

The compression force F_c can be obtained from published data for standard moment connections (see SCI-P207 and SCI-P398). Alternatively, F_c is calculated as part of the normal connection design process if standard moment connections are not used.

The dimensions B and L are calculated based on a dispersal of the compression force from the beam flange as shown in Figure 4.3 and Figure 4.4. Dimensions B and L are defined in expressions (3) and (4). However, it should be noted that B and L must be reduced if the beam end plate projection is insufficient for full dispersal of the force or if the column flange width is insufficient for full dispersal of the force.

$$B = t_{f,b} + 2(s + t_p) \tag{3}$$

where:

$t_{f,b}$ is the beam flange thickness

s is the weld leg length

t_p is the end plate thickness.

$$L = b_b + 2 \times t_p \tag{4}$$

where:

b_b is the beam flange width

t_p is the end plate thickness.

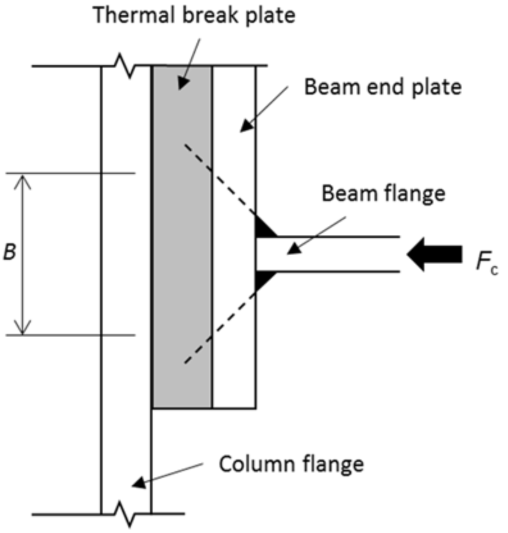


Figure 4.3 Dispersion of force through connection compression zone

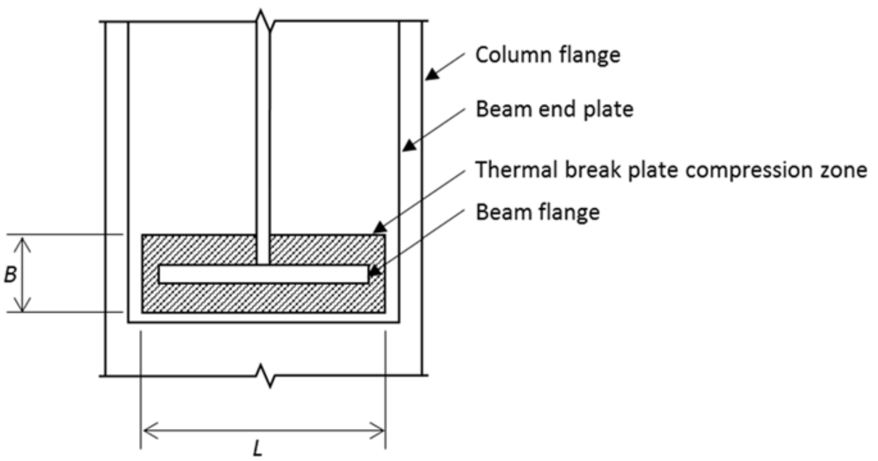


Figure 4.4 Thermal break plate compression zone

4.3 Additional rotation due to compression of thermal break

4.3.1 Nominally pinned connections

Nominally pinned connections are designed to rotate and therefore any additional rotation due to the presence of a thermal break plate within the connection can generally be neglected in the design process.

4.3.2 Moment connections

For moment connections, such as those supporting balconies, the rotation of the connection under load is an important design consideration, typically for aesthetic and serviceability requirements.

The amount of compression of the thermal break plate ΔT is calculated as given in expression (5).

$$\Delta T = \frac{t_{\mathrm{tb}} \times \sigma_{\mathrm{tb}}}{E_{\mathrm{tb}}} \qquad (5)$$

where:

t_{tb} is the thickness of the thermal break plate

σ_{tb} is the stress in the compression zone of the thermal break plate

E_{tb} is the elastic modulus of the thermal break plate.

The additional rotation of the connection (θ) due to the presence of a thermal break plate within the connection can be calculated using the expression (6).

$$\theta = \mathrm{Arcsin}\left(\frac{\Delta T}{h_{\mathrm{b}}}\right) \qquad (6)$$

where:

h_{b} is the depth of the beam.

All connections (with or without a thermal break plate) will rotate when loaded. In most typical cases the additional connection rotation due to the presence of a thermal break plate will be small. A typical example is presented in Table 4.1, as can be seen the additional rotation for AK200 is 0.131°.

Table 4.1 Example rotation

Connection property	AK200
Depth of beam (mm)	150
Thickness of thermal break plate (mm)	25
Stress in compression zone of thermal break plate at serviceability limit state (N/mm^2) (84.3/1.5)	56.2
Elastic modulus of thermal break plate (N/mm^2)	4100
Compression of thermal break plate (mm)	0.343
Additional rotation of connection (Degrees)	**0.131**

4.3.3 Long term creep

The Thermal Breaks materials exhibit creep behaviour (see Section 3.3). Therefore, in the consideration of additional rotation due to compression of the thermal break plates the designer should include an allowance for long term creep.

Based on the test results provided by Thermal Breaks Ltd it is recommended that additional rotation calculated using the data and methodology given in Section 4.3.2 should be increased as follows:

- For AK200, increase deformation by 16 % to allow for long term creep.
- For AK300HT, increase deformation by 7 % to allow for long term creep.

4.4 Bolt shear resistance

4.4.1 Packs

A thermal break plate in a connection must be considered as a pack in terms of connection design. Where packs are used in connections there are detailing rules that should be followed and depending on the thickness of packs it may be necessary to reduce the shear resistance of the bolts within the connection. Design rules for bolts through packing are given in clause 6.3.2.2 of BS 5950-1 and clause 3.6.1(12) of BS EN 1993-1-8.

The number of packs should be kept to a minimum (less than 4).

The total thickness of packs t_{pa} should not exceed $4d/3$, where d is the nominal diameter of the bolt.

If t_{pa} exceeds $d/3$ then, the shear resistance of the bolts should be reduced by the factor β_p given in expression (7).

$$\beta_{\mathrm{p}} = \frac{9d}{8d + 3t_{pa}} \quad (7)$$

where:

d	is nominal bolt diameter
t_{pa}	is the total thickness of packs.

4.4.2 Large grip lengths

A thermal break plate in a connection will increase the total grip length (T_g) of the bolts. The total grip length is the combined thickness of all the elements that the bolt is connecting together (e.g. end plate, thermal break plate, column flange, additional packs etc.) Depending on the size of the grip length it may be necessary to reduce the shear resistance of the bolts within the connection. Design rules for bolts with large grip lengths are given in clause 6.3.2.3 of BS 5950-1. BS EN 1993-1-8 does not include design rules for bolts with large grip lengths, however, it is recommended that the following design guidance is followed.

If T_g exceeds $5d$ then, the shear resistance of bolts with large grip lengths should be reduced by the factor β_g give the expression given in expression (7).

$$\beta_g = \frac{8d}{3d + T_g} \qquad (8)$$

where:

d is nominal bolt diameter

T_g is the total grip length of the bolt.

4.5 Frictional resistance

4.5.1 Non-preloaded bolts

The coefficient of friction of the thermal break plate is not a relevant property for the structural design of connections with non-preloaded bolts.

4.5.2 Preloaded bolts

For the structural design of connections with preloaded bolts the coefficient of friction of the thermal break plate will be required. The slip resistance of the bolted connection is calculated in accordance with Section 3.9 of BS EN 1993-1-8. The number of friction surfaces is required for this calculation.

The coefficient of friction of 0.15 is quoted in the AK300HT Specification sheet supplied by Thermal Breaks Ltd. The manufacturer should be consulted for the necessary data for the AK200 product.

In addition, the local compression force around the bolt holes on the thermal break plate must be checked to ensure the compressive strength of the thermal break plate is not exceed.

Preloaded bolts are also known as HSFG bolts.

4.6 Structural design summary

Connections that include thermal break plates should be designed in accordance with the relevant design standards (e.g. BS EN 1993-1-8) or industry guidance (e.g. SCI publications). The following additional checks should also be undertaken:

1. Check that the thermal break plate can resist the applied compression forces (see Section 4.2).
2. Check that any additional rotation due to the compression of the thermal break plate (including allowance for long term creep) is acceptable (see Section 4.3).
3. Check that the shear resistance of the bolts is acceptable given that there may be a reduction in resistance due to:
    a. Packs (see Section 4.4.1).
    b. Large grip lengths (see Section 4.4.2).
4. For connections using preloaded bolts:
    a. Check the slip resistance of the connection taking into account the coefficient of friction and number of friction surfaces (see Section 4.5.2).

b. Check that the thermal break plate can resist the local compression forces around bolts (see Section 4.5.2).

5 OTHER DESIGN ISSUES

Other design issues that are not directly addressed with test data are discussed below. In the majority of situations Thermal Breaks Ltd thermal break plates will be used in a protected environment within the façade of a building. Therefore, the thermal break materials are not exposed to the full extent of the environment.

5.1 Moisture & UV

Thermal breaks are typically used in protected cavities or within protected roof envelopes and both Thermal Breaks Ltd materials have very low water absorption rates which limits their vulnerability to moisture and humidity.

Within the protected environment the materials are protected from UV degradation. However, where an application poses a greater risk (e.g. a fully exposed external location) then additional protection can be provided. If necessary, it is possible to use cladding flashing details to protect thermal breaks.

5.2 Frost

Thermal breaks are not normally exposed to extremes of temperatures because they are located in the protected environments in the insulation layer of a façade.

In the event that the Thermal Breaks Ltd thermal break materials are exposed to frost, TekTherm AK200 and AK300HT has very low water absorption rates which limits their vulnerability to any damage caused by frost action.

5.3 Fire

Thermal Breaks Ltd TekTherm AK200 product has been tested to UL94 Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances and achieves a UL94 HB rating.

Thermal Breaks Ltd TekTherm AK300HT product has been tested to IEC 60695-11-10 Fire hazard testing - Part 11-10: Test flames - 50 W horizontal and vertical flame test methods and achieves a UL94 V-0 rating.

Generally, the thermal breaks supplied by Thermal Breaks Ltd are used in locations that do not require fire protection. Where the connection requires a fire rating then the following options are available;

- A board fire protection system can be applied.
- Sprayed fire protection can be applied. The compatibility of the applied fire protection material should be checked with the thermal break material. Advice from the manufacturer should be obtained.
- The connection may be designed on the assumption of complete loss of thermal break material in the accidental condition. For accidental conditions excessive deformations are acceptable provided that the stability of the structure is maintained.

6 UK PROCUREMENT ROUTE AND RESPONSIBILITIES

Thermal breaks are normally procured by the steel fabricator as part of the steel frame package on a project. The delivery from Thermal Breaks Ltd is normally co-ordinated with the steelwork contractor erection schedule.

Safety data sheets (COSHH) are made available and all operatives handling the thermal breaks on UK construction sites should use appropriate PPE in line with the requirements of the safety data sheets (primarily gloves & safety glasses). Thermal Breaks Ltd thermal breaks are bespoke products and no alterations are expected to be undertaken on site.

The general handling requirements for thermal breaks should be in line with other component accessories expected to be handled with the primary steelwork. This is covered in the NSSS: Section 8 Workmanship – Erection. The NSSS also sets out the requirements of the Quality Management System expected to be adopted by all competent steelwork contractors working on UK construction projects.

Material handling can be obtained from Thermal Breaks Ltd.

7 ENVIRONMENTAL DATA

No data provided from Thermal Breaks Ltd.

This section will be removed.

Appendix A TEST DATA

All tables presented in the Appendices (including table numbers) are presented in reports (1201/364/16 and 1201/364/16-1) provided by Thermal Breaks Ltd.

A.1 Compressive strength and Modulus of Elasticity

Table 8: Compressive strength of the material AK200

Sample	Dimensions			Load	Compressive strength
	Length [mm]	Width [mm]	Height [mm]	[kN]	[N/mm²]
1	49.9	50.0	26.6	276.2	110.7
2	49.9	49.3	26.6	276.0	112.2
3	49.9	50.0	26.6	267.2	107.1
4	49.9	50.0	26.5	270.1	108.3
5	49.9	49.9	26.6	270.4	108.6
6	49.9	50.0	26.5	272.4	109.2
Mean value	-	-	-	-	109.4

Table 16: Compressive strength of the material AK300HT

Sample	Dimensions			Load	Compressive strength
	Length [mm]	Width [mm]	Height [mm]	[kN]	[N/mm²]
1	49.9	50.1	25.11	641.1	256.4
2	50.0	50.1	25.11	649.5	258.1
3	50.0	50.1	25.11	657.9	262.6
4	50.0	50.1	25.11	659.9	263.4
5	49.8	50.1	25.11	625.5	250.7
6	49.8	50.1	25.11	662.5	265.5
Mean value	-	-	-	-	259.5

A.2 Thermal Conductivity and thermal resistance

Table 1: Results of thermal conductivity and thermal resistance of AK200, 10 mm

Sample	Heat flux density [W/m^2]	Temperature difference [°C]	Mean temp. [°C]	Lambda [W/mK]	r [m^{2}K/W]
AK200 10 mm, Sample 3/4	145.91	8.0	10.0	0.1182	0.0998
AK200 10 mm, Sample 3/4	146.08	8.0	19.6	0.1184	0.0996
AK200 10 mm, Sample 3/4	146.72	8.0	29.3	0.1193	0.0989
AK200 10 mm, Sample 7/8	147.55	8.1	10.0	0.1193	0.1008
AK200 10 mm, Sample 7/8	148.06	8.1	19.6	0.1199	0.1003
AK200 10 mm, Sample 7/8	148.75	8.1	29.3	0.1208	0.0996

Table 2: Results of thermal conductivity and thermal resistance of AK200, 25 mm

Sample	Heat flux density [W/m^2]	Temperature difference [°C]	Mean temp. [°C]	Lambda [W/mK]	r [m^{2}K/W]
AK200 25 mm, Sample 1/2	90.45	7	8.9	0.1828	0.1461
AK200 25 mm, Sample 1/2	90.47	7	18.6	0.1829	0.1460
AK200 25 mm, Sample 1/2	90.66	7	28.2	0.1836	0.1454
AK200 25 mm, Sample 5/6	90.62	7	8.9	0.1848	0.1450
AK200 25 mm, Sample 5/6	90.65.	7	18.6	0.1846	0.1452
AK200 25 mm, Sample 5/6	90.70	7	28.2	0.1849	0.1450

Table 3: Calculated thermal conductivity at 10° C of material AK200, 10 mm and 25 mm.

Sample	Lambda [W/mK]	Sample	Lambda [W/mK]
AK200 3/4 10 mm	0.1181	AK200 5/6 25 mm	0.1827
AK200 7/8 10 mm	0.1192	AK200 5/6 25 mm	0.1847
Mean value 10 mm:	0.1187	Mean value 25 mm:	0.1837

Table 9: Results of thermal conductivity and thermal resistance of AK300HT, 10 mm

Sample	Heat flux density [W/m²]	Temperature difference [°C]	Mean temp. [°C]	Lambda [W/mK]	r [m²K/W]
AK300HT 10 mm, Sample 1/2	150.06	8.5	10.2	0.1028	0.1032
AK300HT 10 mm, Sample 1/2	150.55	8.5	19.8	0.1032	0.1027
AK300HT 10 mm, Sample 1/2	151.28	8.4	29.6	0.1040	0.1020
AK300HT 10 mm, Sample 5/6	164.42	8.3	10.2	0.1116	0.0914
AK300HT 10 mm, Sample 5/6	164.98	8.3	19.8	0.1121	0.0910
AK300HT 10 mm, Sample 5/6	165.53	8.3	29.5	0.1127	0.0905

Table 10: Results of thermal conductivity and thermal resistance of AK300HT, 25 mm

Sample	Heat flux density [W/m²]	Temperature difference [°C]	Mean temp. [°C]	Lambda [W/mK]	r [m²K/W]
AK300HT 25 mm, Sample 3/4	78.86	7.8	9.3	0.1342	0.1876
AK300HT 25 mm,. Sample 3/4	79.30	7.8	18.9	0.1354	0.1860
AK300HT 25 mm,. Sample 3/4	79.65	7.7	28.6	0.1371	0.1837
AK300HT 25 mm,. Sample 7/8	77.83	7.8	9.4	0.1317	0.1914
AK300HT 25 mm,. Sample 7/8	79.08	7.8	19.1	0.1349	0.1868
AK300HT 25 mm,. Sample 7/8	79.39	7.8	28.7	0.1358	0.1857

Table 11: Calculated thermal conductivity at 10 C of material AK300HT, 10 mm and 25 mm

Sample	Lambda [W/mK]	Sample	Lambda [W/mK]
AK300HT 1/2 10 mm	0.1027	AK300HT 3/4 25 mm	0.1342
AK300HT 5/6 10 mm	0.1116	AK300HT 7/8 25 mm	0.1322
Mean value 10 mm:	0.1072	Mean value 25 mm:	0.1332

A.3 Water Absorption

Table 6: Long term water absorption by immersion of the material AK200, 10 mm

Sample	Dimensions			weight before [g]	Weight after [g]	Water absorption [%] length [mm]
	Length [mm]	Wide [mm]	Height [mm]			
1	200.0	199.9	11.2	512.5	516.9	0.98
2	200.0	200.0	11.1	510.2	514.7	1.01
3	200.0	199.9	11.1	516.4	520.7	0.96
4	199.9	200.0	11.2	515.3	519.6	0.94
5	200.1	199.9	11.2	514.3	518.3	0.89
6	200.1	200.0	11.1	514.7	518.8	0.91
Mean value	-	-	-	-	-	0.95

Table 7: Long term water absorption by immersion of the material AK200, 10 mm

Sample	Dimensions			weight before [g]	Weight after [g]	Water absorption [%] length [mm]
	Length [mm]	Wide [mm]	Height [mm]			
1	200.0	200.0	26.2	1211.0	1214.5	0.33
2	200.0	199.8	25.7	1175.5	1179.4	0.38
3	200.0	199.9	26.6	1218.6	1222.6	0.38
4	199.7	199.9	26.4	1215.3	1219.3	0.38
5	199.9	199.9	26.3	1212.3	1216.3	0.39
6	199.9	200.0	26.5	1212.2	1216.4	0.39
Mean value	-	-	-	-	-	0.37

Table 14: Long term water absorption by immersion of the material AK300HT, 10 mm

Sample	Dimensions			weight before [g]	Weight after [g]	Water absorption [%] length [mm]
	Length [mm]	Wide [mm]	Height [mm]			
1	200.3	200.2	10.4	624.9	627.6	0.66
2	200.3	200.2	10.0	625.3	628.4	0.78
3	200.3	200.2	10.1	627.6	630.9	0.81
4	200.4	200.1	10.0	627.9	630.4	0.63
5	200.4	200.1	10.1	626.1	628.7	0.65
6	200.4	200.2	10.1	624.5	626.9	0.59
Mean value	-	-	-	-	-	0.69

Table 15: Long term water absorption by immersion of the material AK300HT, 25 mm

Sample	Dimensions			weight before [g]	Weight after [g]	Water absorption [%] length [mm]
	Length [mm]	Wide [mm]	Height [mm]			
1	200.1	199.6	25.0	1493.3	1496.3	0.30
2	200.1	199.6	25.1	1488.7	1491.5	0.27
3	200.2	199.7	25.1	1476.1	1478.6	0.25
4	200.1	199.9	25.1	1484.1	1486.6	0.25
5	199.9	199.9	25.1	1493.1	1496.2	0.31
6	200.0	199.8	25.2	1495.8	1498.6	0.28
Mean value	-	-	-	-	-	0.28

A.4 Apparent density

Table 4: Apparent density of the material AK200, 10 mm

Sample	Dimensions			Weight [g]	Density [kg/dm^3]
	Length [mm]	Wide [mm]	Height [mm]		
1	200.0	199.9	11.2	512.50	1.15
2	200.0	200.0	11.1	510.20	1.15
3	200.0	199.9	11.1	516.38	1.16
4	199.9	200.0	11.2	515.34	1.15
5	200.1	199.9	11.2	514.34	1.15
6	200.1	200.0	11.1	514.70	1.15
Mean value	-	-	-	-	1.15

Table 5: Apparent density of the material AK200, 25 mm

Sample	Dimensions			Weight [g]	Density [kg/dm^3]
	Length [mm]	Wide [mm]	Height [mm]		
1	200,0	200,0	26,2	1211.04	1.16
2	200.0	199.8	25.7	1175.52	1.15
3	200.0	199.9	26.6	1218.56	1.15
4	199.7	199.9	26.4	1215.26	1.15
5	199.9	199.9	26.3	1212.25	1.15
6	199.9	200.0	26.5	1212.21	1.15
Mean value	-	-	-	-	1.15

Table 12: Apparent density of the material AK300HT, 10 mm

Sample	Dimensions			Weight [g]	Density [kg/dm^3]
	Length [mm]	Wide [mm]	Height [mm]		
1	200.3	200.2	10.4	624.86	1.50
2	200.3	200.2	10.0	625.30	1.56
3	200.3	200.2	10.1	627.64	1.55
4	200.4	200.1	10.0	627.89	1.56
5	200.4	200.1	10.1	626.13	1.55
6	200.4	200.2	10.1	624.54	1.55
Mean value	-	-	-	-	1.55

Table 13: Apparent density of the material AK300HT, 25 mm

Sample	Dimensions			Weight [g]	Density [kg/dm^3]
	Length [mm]	Wide [mm]	Height [mm]		
1	200.1	199.6	25.0	1493.30	1.49
2	200.1	199.6	25.1	1488.74	1.49
3	200.2	199.7	25.1	1476.07	1.47
4	200.1	199.9	25.1	1484.11	1.48
5	199.9	199.9	25.1	1493.08	1.49
6	200.0	199.8	25.2	1495.76	1.48
Mean value	-	-	-	-	1.48

A.5 Long term creep

Table 1: Measurement data creep deformation „AK200" under compressive strain of 38 N/mm²

stress duration t [h]	deformation x_t [mm]	strain-creep deformation [1)] x_{ct} [mm]	Total compression of sample ε_t [%]	log x_t	log x_{ct}
168	0,594	0,047	2,227	2,225	-1,326
216	0,595	0,048	2,230	2,334	-1,319
264	0,601	0,054	2,252	2,422	-1,270
336	0,604	0,057	2,265	2,526	-1,242
432	0,611	0,064	2,291	2,635	-1,192
576	0,622	0,075	2,330	2,760	-1,126
768	0,635	0,088	2,381	2,885	-1,054
1008	0,640	0,093	2,400	3,003	-1,030
1272	0,653	0,106	2,448	3,104	-0,975
1560	0,670	0,123	2,509	3,193	-0,912
1920	0,678	0,131	2,540	3,283	-0,884
2352	0,684	0,137	2,565	3,371	-0,862

Thickness of sample d_S= 26,68 mm
[1)] Increase of sample deformation under constant strain

Table 2: Measurement data creep deformation „AK300HT" under compressive strain of 91 N/mm²

stress duration t [h]	deformation x_t [mm]	strain-creep deformation [1)] x_{ct} [mm]	Total compression of sample ε_t [%]	log x_t	log x_{ct}
168	1,069	0,088	4,250	2,225	-1,054
216	1,072	0,091	4,260	2,334	-1,042
264	1,079	0,098	4,290	2,422	-1,008
336	1,087	0,106	4,319	2,526	-0,976
432	1,089	0,108	4,329	2,635	-0,966
576	1,097	0,116	4,359	2,760	-0,936
768	1,104	0,123	4,389	2,885	-0,909
1008	1,112	0,131	4,419	3,003	-0,884
1272	1,117	0,136	4,439	3,104	-0,867
1560	1,119	0,138	4,449	3,193	-0,859
1920	1,129	0,148	4,488	3,283	-0,829
2352	1,137	0,156	4,518	3,371	-0,808

Thickness of sample d_S= 24,16 mm
[1)] Increase of sample deformation under constant strain

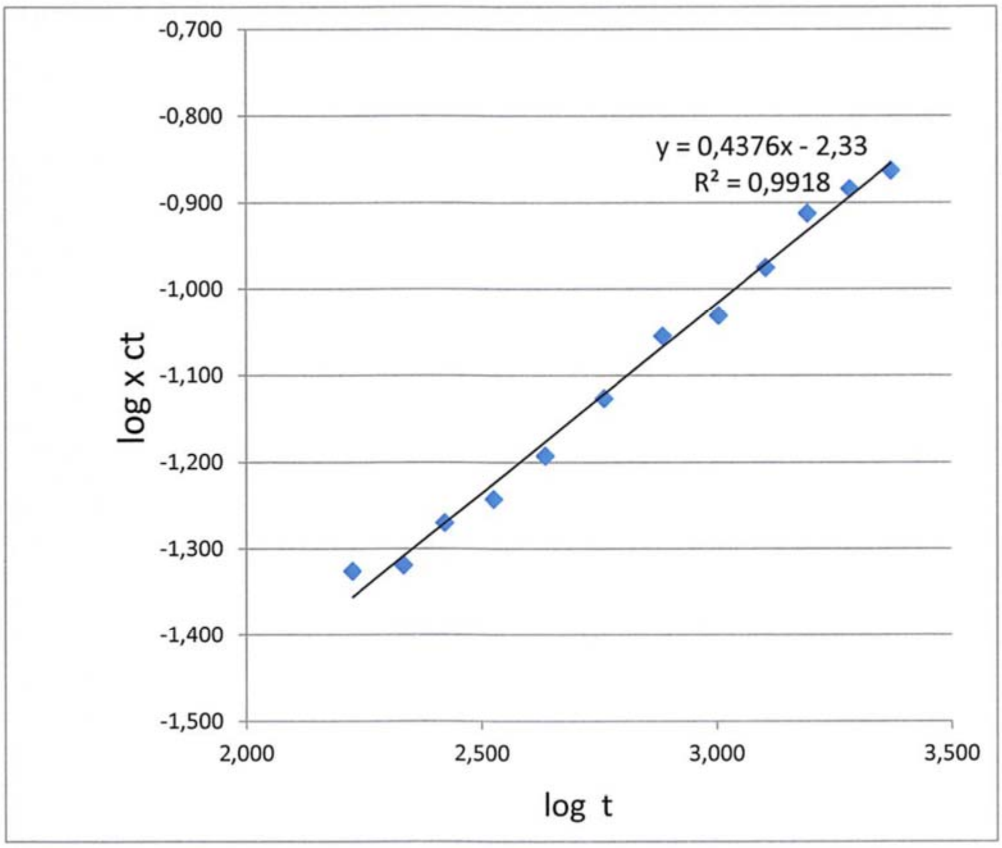


Figure 1: Regression Analysis of the compressive creep behavior of the Material „AK200“

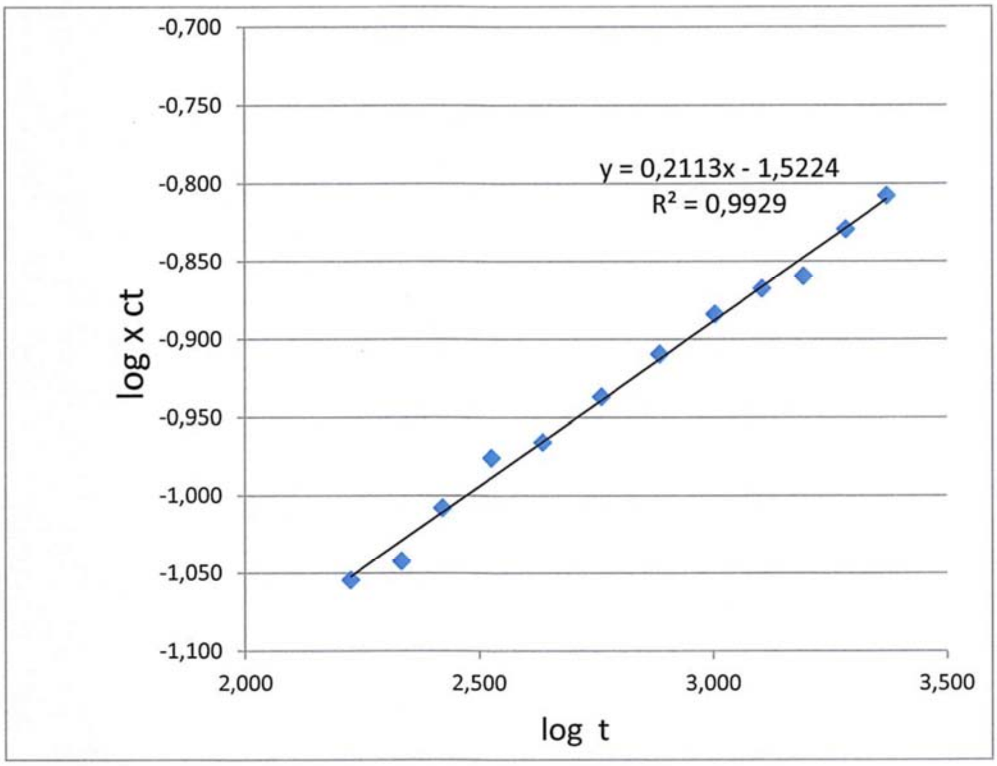


Figure 2: Regression Analysis of the compressive creep behavior of the Material „AK300HT“