

**The Performance of Structural
Steel Sections Protected With
Skamotec-C Fireboard**

Report for

Skamol A/S
Østergade 58-60
DK-7900
Nykøbing Mors
Denmark

Warrington
FIRE
research
CONSULTANCY • TESTING

The Professionals in Fire Safety

TABLE OF CONTENTS

SECTION	PAGE
1 INTRODUCTION	3
2 ASSUMPTIONS	3
3 ASSESSMENT PROCEDURE	3
4 BRIEF DESCRIPTION OF THE PROTECTION SYSTEM	4
5 ANALYSIS OF DATA	4
6 CONCLUSIONS	7
7 VALIDITY	8
8 SUMMARY OF SUPPORTING DATA	8
TEST REPORT WARRES No. 50465	8
TEST REPORT WARRES No. 50466	8
TEST REPORT LPC No. TE 80164	9
TEST REPORT IBMB No. 3982/5532	9
TEST REPORT SGS No. J86902/1	9
BS 476: PARTS 20 AND 21: 1987	9
9 DECLARATION BY SKAMOL A/S	10
10 SIGNATORIES	10
TABLE 1 SUMMARY OF ANALYSIS: BEAMS AND COLUMNS – CRITICAL STEEL TEMPERATURE OF 550°C	11
TABLE 2 SUMMARY OF ANALYSIS: BEAMS (3-SIDED WITH CONCRETE SLAB) – CRITICAL STEEL TEMPERATURE OF 620°C	11

1 Introduction

This report presents an assessment of the ability of a rigid board material known as Skamotec-C Fireboard to protect structural steel I-shaped sections for various periods of fire resistance up to a maximum of 240 minutes and differing section factors.

The data that forms the basis of this assessment was obtained from tests on fully loaded steel I-shaped beams and column tested in accordance with BS 476: Part 21: 1987. Included in the furnace during the loaded beam tests were a number of unloaded short steel beam and column sections to provide thermal data about the board material.

The assessment method adopted for this report uses multiple linear regression with section factor, time and protection thickness as variables. This method is commonly used in the UK for assessing the ability of passive protection materials of high predictability to protect structural steel members.

The data referred to in Section 9 has been considered for the purpose of this assessment which has been prepared in accordance with the general principles of the Fire Test Group Resolution No. 82: 2001.

2 Assumptions

It is assumed that the protection material will be applied to the steel sections in a similar manner to that used for the sections tested under the references given in Section 8.

It is assumed that the loading applied to the sections will be calculated on the same basis as the sections subjected to the loaded tests i.e. the load will not exceed the maximum permissible design load for the steel grade in accordance with BS449: Part 2: 1969.

3 Assessment Procedure

The loaded steel sections provide evidence of the ability of the protection material to remain intact and attached (commonly referred to as 'stickability') under standard fire test conditions and the critical temperature at which structural instability occurs under standard fire test conditions. The short section data provides thermal data for the predictive analysis.

The details of each specimen, i.e. the section factor (the ratio of the heated perimeter to cross-sectional area), the protection thickness and duration of heating required for the sections to reach the critical steel temperature derived from the testing of the loaded sections are used as data for the analysis.

The section factor is designated A/V using European nomenclature but is commonly referred to as H_p/A in the UK. This report adopts the European convention.

In the UK the appraisal of a passive fire protection material such as Skamotec-C Fireboard is carried out using multiple linear regression analysis.

For this report the required thickness of protection, for a given steel section and fire resistance period, was assessed by using the following recognised equation:

$$FR = k_0 + k_1 t(V/A) + k_2 t$$

where FR is the time to reach a critical steel temperature, k_0 , k_1 and k_2 are constants determined by means of multiple linear regression analysis of the data from the unloaded steel sections, t is the thickness of the material and V/A is the inverse of the section factor.

4 Brief Description of the Protection System

A full description of the test specimens is given in the appropriate test report listed in Section 8 of this report.

Skamotec-C Fireboard noggins, 100mm wide, are friction fitted between the flanges of the steel sections at maximum 1220mm centres behind each board joint. The thickness of the noggins is at least that of the protection boards. The Skamotec-C web boards are fixed to the noggins with steel screws at 200mm to 250mm nominal centres. The Skamotec-C web boards extend beyond the flanges of the steel sections to allow flange boards to be fixed between them.

The Skamotec-C flange boards protecting the lower flanges of a beam are spaced away from the steel so that Skamotec-C cover strips, 100mm wide, may be fitted behind each flange board joint. The thickness of the cover strips is at least that of the protection boards. The flange boards are fixed to the web boards using steel screws at 200mm to 250mm nominal centres. There are no such cover strips for the boards attached to columns.

The screws used are minimum M3.9, of the deep thread type, with a length at least twice that of the board thickness.

The measured density of the Skamotec-C Fireboards was stated by the test laboratories to be 287 to 295kg/m³. The range of board thicknesses covered by this assessment is between 20mm and 65mm in 5mm steps. Skamotec-C Fireboard is non-combustible in accordance with BS 476: Part 4 (see Section 8).

Alternatively the boards may be fastened with steel staples at 80 to 100mm centres or with steel nails at 200 to 250mm centres. The staples are minimum 11.2mm wide x 1.5mm thick, with a length at least twice that of the board thickness. The maximum fire resistance period for the staple-fixed protection system is 180 minutes. The nails are minimum 3mm diameter with a length at least twice that of the board thickness. The maximum fire resistance period for the nail-fixed protection system is 60 minutes.

5 Analysis of Data

5.1 Data from the Loaded Tests

The tests referenced WARRES No.s 50465 and 50466 and TE 80164 were used to determine the critical steel temperatures to be used in the analysis presented in this report.

The tests also demonstrated the ability of the protection material to remain attached to the sections at elevated temperatures. The tests were carried out on beams and a column that were loaded to produce the maximum permissible stress for the steel grade.

The nominal board thicknesses of the material fixed to the loaded sections were as follows:

Loaded I-Shaped Beam (WARRES No. 50466):	20mm board
Loaded I-Shaped Beam (WARRES No. 50465):	60mm board
Loaded I-Shaped Column (TE 80164):	60mm board

The loaded beams maintained loadbearing capacity for periods of 138 minutes (20mm) and 301 minutes (60mm) and the loaded column for 216 minutes (60mm).

The following critical steel temperatures calculated according to UK principle were derived from the loaded tests and were based on the temperature at which the steel section was no longer capable of satisfying the performance criteria for loadbearing capacity defined by the test standard:

Beams (3 sided protection with a concrete slab):

WARRES No. 50466: >620°C.

WARRES No. 50465: >620°C

Columns and beams (4 sided protection):

TE 80164: >550°C.

For sections fully loaded in accordance with BS449: Part 2: 1969, currently accepted procedures limit the steel temperatures at which assessments may be performed to 550°C for columns and 620°C for beams or lower temperatures which have been shown to be appropriate.

Therefore for the purpose of this report the following critical steel temperatures have been adopted:

Beams (3 sided protection with a concrete slab) : 620°C.

Columns and Beams (4 sided protection) : 550°C.

The loaded beams are considered to be a more severe assessment for 'stickability' compared with columns where the load is applied vertically and the boards and joints are not subjected to any appreciable bending stress. Therefore the analysis is appropriate to both beams and columns.

Assessment guidelines currently used in the UK allow an extrapolation of up to 10% of maximum tested board thickness (60mm) providing there is no significant loss of the protection. The observations provided in test reports show that no significant loss of the material occurred in the tests until 313 minutes. Therefore the maximum thickness of Skamotec-C Fireboard covered in this assessment has been increased to 65mm.

Reference is also made in Section 8 of this report to fire test report no. 3982/5532. This report describes three tests that were carried out on pairs of steel beams protected with Skamotec-C Fireboard in accordance with DIN 4102. These tests on the loaded beams demonstrated the suitability of the fixing methods using steel staples and nails and showed that the 'stickability' of the protection system was maintained when the beams deflected under the imposed load. However the fire resistance period for the staple-fixed system is limited to 180 minutes and for the nail-fixed system is limited to 60 minutes as these were the maximum heating periods that these systems were subjected to in the fire tests.

5.2 Summary of Test Data

The appropriate data to be used in the analysis is taken from the test reports referred to in Section 8 of this report and is summarised as follows:

Test WARRES No. 50465

Ref	Size mm x mm x kg/m	Section Factor m ⁻¹	Thickness of Skamotec-C mm	Time to 550°C minutes	Time to 620°C minutes	Loadbearing capacity minutes
LB1	305 x 127 x 42	138	60	293	303	301
SB1	356 x 171 x 67	103	50	245	278	-
SB2	305 x 102 x 25	216	50	147	167	-
SB3	254 x 146 x 31	157	40	139	159	-
SC1	152 x 152 x 30	159	25	95	110	-
SC2	203 x 203 x 52	120	60	208	235	-

Test WARRES No. 50466

Ref	Size mm x mm x kg/m	Section Factor m ⁻¹	Thickness of Skamotec-C mm	Time to 550°C minutes	Time to 620°C minutes	Loadbearing capacity minutes
LB2	305 x 127 x 42	137	20	127	146	138
SB4	305 x 102 x 25	220	20	84	98	-
SB5	254 x 146 x 43	122	30	139	161	-
SB6	356 x 171 x 67	105	25	133	155	-
SC3	254 x 254 x 132	61	20	172	193*	-
SC4	254 x 254 x 89	90	20	129	150	-

* - Extrapolated value.

Test TE 80164

Ref	Size mm x mm x kg/m	Section Factor m ⁻¹	Thickness of Skamotec-C mm	Time to 550°C minutes	Time to 620°C minutes	Loadbearing capacity minutes
LC	203 x 203 x 52	131	60	218	-	216

LB - loaded beam, LC – loaded column, SB - short beam, SC - short column.

5.3 Result of the Analysis

From the above data (short sections only) the following regression parameters were obtained:

Critical Temp	Coefficient k ₀	Coefficient k ₁	Coefficient k ₂	Coefficient of Determination r ²
550°C	49.490	361.536	0.0013	0.941
620°C	60.585	401.153	-0.0135	0.939

If the above coefficients of determination (r²) are in excess of 0.95, this indicates a high degree of predictability and therefore the data is considered acceptable for use in the analysis. However, in this case, the coefficients of determination are less than 0.95. The low values of r² were mainly the result of two short sections, SB1 and SC2, which had very similar predicted times to 550/620°C of 225/255 minutes. The actual times for SB1 were 20/25 minutes longer than predicted and for SC2 were 20/25 minutes shorter than predicted. Therefore the two results effectively cancelled each other with regard to the result of the regression but significantly lowered the value of r². There was no obvious reason for the discrepancy in these two results and therefore the two sections were left in the regression even though the value of r² was reduced.

In order to determine whether the appraisal was conservative with respect to the overall performance of the short sections, the actual times to reach the critical temperatures were compared with the predicted times calculated using the above coefficients. This showed that the overall predictions were slightly conservative.

In addition, the performance of the loaded beams and column must compare favourably with their predicted performances since short sections are not unduly affected by 'stickability'.

The comparisons of actual and predicted performances are given as follows:

Section	Protection thickness mm	Actual time to 550°C minutes	Predicted time to 550°C minutes	Actual time to 620°C minutes	Predicted time to 620°C minutes
Loaded beam	20	127	102	146	119
Loaded beam	60	293	207	303	234
Loaded column	60	218	215	-	-

It can be seen from the above that, in each case, the actual performance of the loaded section was greater than the predicted performance.

The results of the analyses are shown in Tables 1 and 2 for critical steel temperatures of 550°C and 620°C respectively. Table 2 is used for beams with a concrete slab in intimate contact with the top flange. Table 1 is used for columns and for beams in situations other than for Table 2.

The assessment is applicable to steel I-sections, and other sections with a re-entrant profile, up to a maximum web size of 686mm and a flange size of 305mm. It is also applicable to profiles that are not re-entrant provided that the fixing system for the protection system is equivalent to that tested.

6 Conclusions

An assessment of the ability of a rigid board material known as Skamotec-C Fireboard to protect structural steel sections in accordance with BS 476: Part 21: 1987 has been undertaken.

The data that forms the basis of this assessment was obtained from tests on fully loaded steel I-shaped beams and column tested in accordance with BS 476: Part 21: 1987. Included in the furnace during the loaded beam tests were a number of unloaded short steel beam and column sections to provide thermal data about the board material.

The assessment method adopted for this report used multiple linear regression with section factor, time and protection thickness as variables. This method is commonly used in the UK for assessing the ability of passive protection materials of high predictability to protect structural steel.

This assessment relates to periods of fire resistance up to 240 minutes. The assessment is applicable to steel I-sections, and other sections with a re-entrant profile, up to a maximum web size of 686mm and a flange size of 305mm. It is also applicable to profiles that are not re-entrant provided that the fixing system for the protection system is equivalent to that tested.

Tables 1 and 2 show the results of the analyses of the data.

7 Validity

This assessment is issued on the basis of test data and information available at the time of issue. If contradictory evidence becomes available to WFRC the assessment will be unconditionally withdrawn and Skamol A/S will be notified in writing. Similarly the assessment is invalidated if the assessed construction is subsequently tested because actual test data is deemed to take precedence over an expressed opinion. The assessment is valid initially for a period of five years, i.e. until 1st May 2008, at which time it is recommended that it be returned for re-appraisal.

This appraisal is only valid provided that no other modifications are made to the construction other than those described in this report.

8 Summary of Supporting Data

Test report WARRES No. 50465

Report on a fire resistance test in accordance with BS 476: Part 21: 1987, Method 5, performed on a specimen of an I-shaped steel beam of serial size 305mm x 127mm x 42kg/m. The steel beam supported a concrete slab on its upper flange and it was protected on three sides with Skamotec-C Fireboard, 60mm thick. The beam was loaded to produce the maximum allowable bending stress of 165N/mm² calculated in accordance with BS 449: Part 2: 1969. The specimen satisfied the performance criteria for loadbearing capacity defined in BS 476: Part 21: 1987 for the following period:

Loadbearing capacity: 301 minutes

Included in the test were a number of short sections for assessment purposes, the appropriate details of which are summarised in the body of this report.

Test Date: 10th July 1990
Test Sponsor: Skamol A/S

Test report WARRES No. 50466

Report on a fire resistance test in accordance with BS 476: Part 21: 1987, Method 5, performed on a specimen of an I-shaped steel beam of serial size 305mm x 127mm x 42kg/m. The steel beam supported a concrete slab on its upper flange and it was protected on three sides with Skamotec-C Fireboard, 20mm thick. The beam was loaded to produce the maximum allowable bending stress of 165N/mm² calculated in accordance with BS 449: Part 2: 1969. The specimen satisfied the performance criteria for loadbearing capacity defined in BS 476: Part 21: 1987 for the following period:

Loadbearing capacity: 138 minutes

Included in the test were a number of short sections for assessment purposes, the appropriate details of which are summarised in the body of this report.

Test Date: 29th June 1990
Test Sponsor: Skamol A/S

Test report LPC No. TE 80164

Report on a fire resistance test in accordance with BS 476: Part 21: 1987, Method 6, performed on a specimen of an I-shaped steel column of serial size 203mm x 203mm x 52kg/m. The steel column was protected on four sides with Skamotec-C Fireboard, 60mm thick. The column was loaded to produce the maximum allowable stress of 136N/mm² calculated in accordance with BS 449: Part 2: 1969. The specimen satisfied the performance criteria for loadbearing capacity defined in BS 476: Part 21: 1987 for the following period:

Loadbearing capacity: 216 minutes

Test Date: 21th June 1990

Test Sponsor: Skamol A/S

Test report IBMB No. 3982/5532

Report on three fire resistance tests in accordance with DIN 4102: Part 2, performed on pairs of I-shaped steel beams of serial sizes IPE 140 or HE 220 M. The steel beams supported aerated concrete slabs on their upper flanges and each beam was protected on three sides with Skamotec-C Fireboard, 25mm or 40mm thick, as follows:

- Test 1 – IPE 140 beams – 25mm Skamotec-C
- Test 2 – IPE 140 beams – 40mm Skamotec-C
- Test 3 – HE 220 M beams – 25mm Skamotec-C

The beams were loaded to produce the maximum allowable bending stress of 160N/mm² calculated in accordance with DIN 18800: 1981. The specimens satisfied the performance criteria for stability/loadbearing capacity defined in DIN 4102: Part 2 for the following periods:

	Test 1	Test 2	Test 3
Loadbearing capacity:	51 minutes	61 minutes	186 minutes

Report Dated: 13th July 1993

Test Sponsor: Skamol A/S

Test report SGS No. J86902/1

Report on a non-combustibility test in accordance with BS 476: Part 4: 1970, performed on samples on Skamotec-C Fireboard. The material was found to be non-combustible.

Report Dated: 7th November 1990

Test Sponsor: Skamol A/S

BS 476: Parts 20 and 21: 1987

Fire test on building materials and structures. Part 20. Method for determination of the fire resistance of elements of construction (general principles). Part 21. Method for determination of the fire resistance of loadbearing elements of construction.

9 Declaration by Skamol A/S

We the undersigned confirm that we have read and complied with the obligations placed on us by the UK Fire Test Study Group Resolution No. 82: 2001.

We confirm that the components or elements of structure, which are the subject of this assessment, has not to our knowledge been subjected to additional fire testing to the Standard against which the assessment has been made.

We agree to amend the assessment so as to incorporate the data derived from such tests, failing which the assessment will be withdrawn.

We are not aware of any information that could adversely affect the conclusions of this assessment.

If we subsequently become aware of any such information we agree to cease using the assessment and ask Warrington Fire Research Centre to withdraw the assessment.

Signed: 
For and on behalf of Skamol A/S.

10 Signatories

Richard Earle

Prepared by..... * R. H. Earle

Reviewed by: *P. W. Crewe* *P. W. Crewe

This report is not valid unless it incorporates the declaration duly signed by the applicant. This is included in Section 9 of this report.

*For and on behalf of Warrington Fire Research Centre.

Report Issued: 23rd April 2003

This report may only be reproduced in full. Extracts or abridgements of reports shall not be published without permission of Warrington Fire Research Centre.

Table 1 Summary of Analysis: Beams and Columns – Critical Steel Temperature of 550°C

Section factor A/V (m^{-1}) up to	Fire resistance period (minutes)						Product thickness (mm)
	30	60	90	120	180	240	
	310	310	179	103	-	-	20
310	310	223	128	69	-	25	
310	310	268	154	83	57	30	
310	310	310	180	97	66	35	
310	310	310	205	111	76	40	
310	310	310	231	125	85	45	
310	310	310	257	139	95	50	
310	310	310	282	152	104	55	
310	310	310	308	166	114	60	
310	310	310	310	180	123	65	

Maximum durations for fixing systems:-
 Screws – 240minutes,
 Staples – 180 minutes,
 Nails – 60 minutes.

Table 2 Summary of Analysis: Beams (3-sided with concrete slab) – Critical Steel Temperature of 620°C

Section factor H_p/A (m^{-1}) up to	Fire resistance period (minutes)						Product thickness (mm)
	30	60	90	120	180	240	
	310	310	270	134	-	-	20
310	310	310	168	84	-	25	
310	310	310	201	100	67	30	
310	310	310	234	117	78	35	
310	310	310	268	134	89	40	
310	310	310	301	150	100	45	
310	310	310	310	167	111	50	
310	310	310	310	184	122	55	
310	310	310	310	200	134	60	
310	310	310	310	217	145	65	

Maximum durations for fixing systems:-
 Screws – 240minutes,
 Staples – 180 minutes,
 Nails – 60 minutes.