The Building Test Centre
Fire Acoustics Structures

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Expert Judgement Number BTC 13064FA

AN EXPERT JUDGEMENT COVERING THE FIRE RATED PARTITION HEIGHTS OF A SERIES OF BRITISH GYPSUM SHAFTWALLS FEATURING A LINING OF 3 x 15mm GYPROC FIRELINE BOARD.

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FOREWORD

The Building Test Centre have been requested to assess the maximum fire rated heights possible for a number of shaft wall configurations featuring three layers of 15mm Gyproc FireLine board as the board lining on the corridor side. The fire resistance under consideration is that which would be measured if the shaft walls could be tested at the heights in question against the requirements of BS EN 1364-1:1999.

REPORT AUTHORISATION

Assessor	Confirming Assessor
Robert Evans MEng. (Hons.), AMIMechE, AIFireE Project Leader	**Eur Ing. Paul Howard** BSc. (Hons.), CEng., MOIA Head of Laboratory

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DISCUSSION

The fire resistance test standard BS EN 1364-1:1999 limits the height to which a fire rated partition may be built to a maximum of 4m using the concept of direct field of application. In order for a shaft wall to be built at a height greater than 4m then an engineering appraisal must be conducted in order to ensure that the shaft wall will be stable in view of the induced thermal bow and strength loss in the studs in the fire state condition.

In order to conduct this expert judgement it is necessary to position additional thermocouples on the hot and cold flanges of the stud during the standard 3m test. This data can then be used to establish the height at which the shaft wall will be stable for a given fire duration. British Gypsum have conducted a test fully in accordance with BS EN 1364-1:1999 on a British Gypsum ShaftWall featuring studs at 600mm centres and a board lining on the corridor side comprising a triple layer of 15mm Gyproc FireLine board (BTC 13021F refers). This expert judgement considers data taken from this test in order to establish the maximum fire rated height possible for a number of metal stud variations. In all cases the board lining fixing centres etc. would remain the same.

The Building Test Centre has developed a standard calculation protocol for evaluating the partition height of stud and sheet partition systems in the fire condition. The calculation protocol used is given in Appendix A.

Basic Stud Properties

Stud Code	Stud Depth mm	Stud Type	Stud Gauge mm	Flange Width mm
48I50	48	I	0.50	38
60I50	60	I	0.50	38
70I50	70	I	0.50	38
60I70	60	I	0.70	38
70I70	70	I	0.70	38
146I80	146	I	0.80	38
92I90	92	I	0.90	38
146I90	146	I	0.90	38

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TEST EVIDENCE

BTC 13021F

The test was conducted on a Gypframe 60I70 'I' stud framework featuring studs at 600mm centres. The framework was lined on the corridor side with a triple layer of 15mm Gyproc FireLine board and on the shaft side with a single layer of 19mm Gyproc CoreBoard.

Integrity	186 minutes.
Insulation	152 minutes.

The test was conducted fully in accordance with BS EN 1364-1:1999 on the 2nd October 2003 by The Building Test Centre, on behalf of British Gypsum Limited. The system was tested to resist fire from the corridor side (i.e. triple layer of 15mm Gyproc Fireline on the exposed face).

CONCLUSION

At the duration of 120 minutes the direct field of application lateral deflection rule does not limit the partition systems. Therefore at 120 minutes shaft wall systems with a lining comprising a triple layer of 15mm Gyproc FireLine board can be specified above 4000mm.

At the duration of 120 minutes the shaft wall has sufficient strength to allow an expert judgement to be conducted. At this duration all the shaft walls variants evaluated are stable at the manufacturer's recommended cold state height.

The heights given below are based on 600mm stud centres please consult the partition manufacturer if an evaluation is required at other stud centres.

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Standard Gypframe Studs:

Fire Resistance Duration (minutes)	Manufacturer's Stud Code	Maximum Fire Rated Height (mm)	Fire Head Drop at Fire Rated Height (mm)	Manufacturers Recommended Cold State Maximum Height (mm)	Fire Head Drop at Cold State Height (mm)
EI 120	48I50	N/A	N/A	N/A	N/A
	60I50	N/A	N/A	N/A	N/A
	70I50	N/A	N/A	N/A	N/A
	60I70	7300	-69.51	4500	5.81
	70I70	8200	-73.03	4500	6.31
	146I80	N/A	N/A	N/A	N/A
	92I90	10900	-102.25	6700	8.76
	146I90	15400	-108.68	7900	14.09

A negative head drop indicates the specimen has dropped vertically. A positive head drop indicates the specimen has expanded vertically.

It should be noted that the head drop of the shaft wall needs to be accommodated by the shaft wall designer. Two head drop figures are quoted that which would be expected if the shaft wall was built at its maximum permissible fire rated height and also that which would be expected if the shaft wall was built at its recommended cold state maximum height. It should be noted that no special provision is required at the head of the shaft wall system unless the manufacturers recommended cold state height is exceeded. A lesser head drop would be experienced if the shaft wall were to be constructed below the maximum heights quoted in the table above. Please consult the shaft wall manufacturer for more details on the design requirements.

The recommended cold state heights quoted for the shaft wall systems have been evaluated by The Building Test Centre on behalf of British Gypsum Limited. The heights are based on a uniformly distributed load of 200Pa and a limiting deflection of L/240, It is strongly advised that the manufacturers recommended cold state height is not exceeded without first consulting British Gypsum Limited.

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LIMITATIONS

This expert judgement addresses itself solely to the ability of the shaft wall system described to maintain their stability in the event of being exposed to a test furnace run in accordance with BS EN 1364-1:1999. The expert judgement does not imply any suitability for use with respect to any others unspecified criteria.

This expert judgement is issued on the basis of test data and information to hand at the time of issue. If contradictory evidence becomes available to the assessing authority the expert judgement will be unconditionally withdrawn and the applicant will be notified in writing. Similarly the expert judgement is invalidated if the assessed construction is subsequently tested since actual test data is deemed to take precedence over an expressed opinion. The expert judgement is valid initially for a period of two years after which time it is recommended that it be submitted to the assessing authority for re-appraisal. The opinions and interpretations expressed in this expert judgement are outside the scope of UKAS accreditation.

THE BUILDING TEST CENTRE

The Building Test Centre operates as an independent accredited test house for the construction industry. The Building Test Centre has unrivalled experience in the development of drywall systems. The Building Test Centre is UKAS accredited under 0296 for fire resistance, reaction to fire, acoustic and structural testing. The Building Test Centre is wholly owned by British Gypsum Limited, a major manufacturer of building products.

APPENDIX A – CALCULATION METHOD

Step 1
Calculate weight ω of wall per square metre i.e. kg/m^2 x 9,81, and select a test height L mm.

It is essential to start with a low height such as 4000mm and work upwards in 1000mm increments. Once the shaft wall becomes unstable reduce the increments to 100mm until the critical height is found for the duration in question.

Step 2
Obtain stud thickness t mm, stud spacing m mm, stud depth d mm, flange width f_w mm (Note 2). The yield stress σ is assumed to be = 210 N/mm^2
The Young's modulus E is assumed to be 205000 N/mm^2.
Obtain hot flange temperature T_h in deg C and cold flange temperature T_c at the time at which the stability is to be checked. (Note 3)

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Step 3:
Calculate the following terms:

$$k_h = 1 - T_h /800$$
$$k_c = 1 - T_c /800$$
$$k = k_c - k_h$$

Step 4
Calculate the neutral axis y_n from the cold end:

$$y_n = \frac{f_w .(k_h . d + k_c . t/2) + d^2 .(k/6 + k_h/2)}{((k_h + k_c) . (f_w + d/2))}$$

Step 5
Calculate $e = d - y_n$

and calculate the second moment of area of the stud I_h at elevated temperature:

$$I_h = t.(f_w . (k_h . e^2 + k_c . y_n^2) + e^3 .(k_h /3 + k . e/(12.d)) + + y_n^3 .(k_c /3 - k . y_n/(12.d)))$$

Step 6
Calculate the Euler height under the above conditions:

$$L_e = ((2. \pi^2 . E . I_h . 10^6)/(\omega . m))^{0.3333}$$

Step 7
Check that height L is a lower value than the Euler height L_e.

If it is not lower then the shaft wall will be unstable regardless of any thermal bow. Otherwise proceed to step 8.

Step 8
Calculate the the moment capacity M_s of the stud at elevated temperature:

$$M_s = t. (f_w .(k_h . e + k_c. y_n)+ e^2 .(k_h /2 + k . e/(6.d))+ + y_n^2 .(kc /2 - k . y_n /(6.d))). \sigma$$

Step 9
Calculate the moment capacity M_c of the stud frame per metre width:

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$$M_c = M_s .1000/m$$

Step 10
Calculate the load P_e:

$$P_e = \pi^2 . E.I_h.1000/(L^2 . m)$$

Step 11
Calculate the thermal bow *b*:

$$b = ((14x10^{-6}) . L^2 . (T_h - T_c))/(8.d)$$

Step 12
Calculate the total weight *P* per metre width:

$$P = \omega . L/1000$$

Step 13
Calculate the additional bow b_e due to self weight from

$$b_e = b /(2.P_e/P -1)$$

Step 14
Calculate the term:

$$\alpha = 2 . \tan^{-1} (2 . (b + b_e)/ L) \text{ (in radians)}$$

Step 15
Calculate the moment *M* produced by the self weight acting eccentrically:

$$M = (\omega. L^2 . \alpha . (1 - \cos\alpha))/ (4 .1000. \sin^2 \alpha)$$

Step 16
Now compare the moment M with the moment capacity M_c.
If M is greater than M_c then the wall will be unstable and collapse.
If the wall is stable return to step 1 and increment the test height repeat this process until the maximum fire rated height is established to the nearest 100mm.

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Note 1: Wall comprising metal C or I-studs lined each side with plasterboard. Plasterboard assumed to provide no extra stiffness to wall but its full weight to act downwards at all times. Wall assumed to be free at each side edge and with unrestrained head.

Note 2: Where the flange has a turn down this is included in f_w and where an I-stud has a double thickness due to folding, this is included in f_w.

Note 3: Temperature information can be obtained from a normal fire resistance test and should be available at every minute during the test. The calculation will need to be done at all time increments in case conditions exist whereby stability failure occurs. A number of studs will need thermocouples attached the data should be used from the most onerous stud position it is not correct to average this data. In the calculation, hot flange temperature T_h must be assigned a value of no greater than 800 deg C since metal strength is effectively zero above this value. If information is available on metal temperatures then this model assumes a linear temperature distribution across the web and the data must be persuaded to fit the model.

Design aspects of fire rated shaft walls within buildings

There are various design aspects which must be considered such as the total movement due to the bow and the movement at the head of the shaft wall.

Dealing with the total bow first, this can be calculated by adding the result from Steps 11 and 13 i.e. the thermal bow and the self weight induced bow.

The extent of the head movement depends on the net result of the vertical upward expansion due to temperature and the drop caused by the thermal bow.

The thermal expansion coefficient of steel is approximately 14 x 10^{-6} (between 100 and 700 degC) and therefore the upwards expansion at the head y_u mm of the shaft wall is:

$$y_u = (14\text{x}10^{-6}) \,.\, L \,.\, T_s$$

T_s = stud average temperature in deg C (above ambient)

If the cladding material does not protect the steel studs adequately, then quite large expansion at the head is possible and clearly therefore, it is best not to allow the metal to get too hot!

This upward deflection however could be reduced by the effect of thermal bowing (and self weight) of the shaft wall and when a large bow is expected then the head detail might need

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to accommodate the shaft wall dropping at the head and yet still be adequately restrained laterally.
The head drop y_d mm caused by the bow is:

$$y_d = L \cdot (\alpha - \sin\alpha) / \sin\alpha$$

where $\alpha = 2 \cdot \tan^{-1}((2 \cdot b_t)/L)$ (in radians)
and b_t = the total bow in mm (addition of Steps 11 and 13)

The resulting net movement at the head is $y_u - y_d$.