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Safety of strawbale walls in the event of fire.

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Headline results

Reaction to fire: clay and lime plastered strawbale wall systems have achieved ratings of **B-s1, d0.**
Resistance to fire: clay and lime plastered strawbale walls (all incorporating timber elements in differing ways) have achieved formal test results of **120 to 135 minutes** without failure (equivalent to **REI 120 to 135**).

Regulatory background

There are two main criteria determining the safety of construction elements in case of fire within the EU and UK:

1. **Reaction to fire** (Concerned with the contribution of a building element to the spread of flame, the production of smoke, and the generation of flaming droplets).
2. **Resistance to fire** (how well the wall resists the penetration of fire or transfer of excessive heat from one side to the other, and in the case of loadbearing walls: the resistance to collapse).

The procedures used for testing are determined by the following standards (current versions listed here; older tests were carried out under the version current at the time):

EN 13823: 2020 - *Reaction to fire tests for building products. Building products excluding floorings exposed to the thermal attack by a single burning item*.
EN 11925-2: 2020 - *Reaction to fire tests. Ignitability of products subjected to direct impingement of flame. Single-flame source test.*
EN 1363-1: 2020 - *Fire resistance tests. General requirements.*
EN 1364-1: 2015 - *Fire resistance tests for non-loadbearing elements. Walls.*
EN 1365-1: 2012 - *Fire resistance tests for loadbearing elements. Walls.*

Formal fire classification (where commissioned) is determined from test results according to the following standards:

EN 13501-1: *Fire classification of construction products and building elements. Classification using data from reaction to fire tests.*
EN 13501-2: 2016 - *Fire classification of construction products and building elements. Classification using data from fire resistance tests, excluding ventilation services.*

EN 13501-1 gives reaction to fire ratings as follows (often given as a combined rating, e.g. A2-s1, d1):

Rating	Definition
A1, A2	non-combustible materials
B	very limited contribution to fire
C	limited contribution to fire
D	medium contribution to fire
E	high contribution to fire
F	easily flammable.

Smoke production		Generation of flaming droplets	
s1	weak or absent	do	no droplets
s2	medium	d1	low
s3	high	d2	high

EN 13501-2 gives resistance to fire ratings in the form a letter indicating the relevant type or types of resistance, followed the certified time of resistance in minutes (e.g. REI45):

Classification	Meaning
R	Resistance to collapse (loadbearing capacity)
E	Resistance to fire penetration (integrity)
I	Resistance to transfer of excessive heat (insulation)
W	Resistance to excessive radiative heat (limitation of radiation)

Building standards for reaction and resistance to fire vary across England, Scotland and Wales, with differing subclauses and criteria. The following tables offer a simplified summary only.

The tables reflect current regulations at time of writing including recent updates to Approved Document B in England. Further changes to the building regulations in England are under review and may also be followed by changes in Wales and Scotland (though Scotland already has more stringent requirements for reaction to fire). Of particular relevance here are proposals to reduce the height threshold from 18 to 11 metres, and to apply the same standards to non-domestic buildings as for domestic (UK. MHCLG., 2020a).

Reaction to fire:

		England	Scotland	Wales
No storey above 18m	Domestic/residential	B-s3, d2	A1, A2, or B	C-s3, d2 [1]
	Non-domestic	B-s3, d2	A1, A2, or B	C-s3, d2
With storey above 18m	Domestic/residential	A2-s1, d0	A1, A2	C-s3, d2 [1]
	Non-domestic	B-s3, d2	A1, A2	B-s3, d2 [2]

(Welsh Government, 2015b, 2015b; Scottish Government, 2019a, 2019b; UK. MHCLG., 2019). [1] No differing height limits given. [2] Includes circulation spaces of blocks of flats.

Resistance to fire - England and Wales

	Minimum required period of fire resistance (minutes)					
Type of building	**Basement storey** Depth of lowest storey		**Ground level and above** Height of top floor above ground			
	> 10 m	< 10 m	< 5 m	< 11 m	< 18 m	< 30 m
Residential flats without sprinkler system	90	60	30	60	----	----
Residential flats with sprinkler system	60	60	30	60	60	90
Residential house	----	30	30	60		
Industrial without sprinkler system	120	90	60	90	90	120
Industrial with sprinkler system	90	60	30	60	60	90

(Welsh Government, 2015a, 2015b; UK. MHCLG., 2020b)

Resistance to fire - Scotland

	Minimum required period of fire resistance (minutes)			
Type of building	**Basement**	**Ground level and above** Height of top floor above ground		
		< 7.5 m	< 18 m	< 30 m
Domestic		short	medium	long
Non-domestic, single storey separating walls	medium to long	medium to long	medium to long	long
Non-domestic, multi storey separating walls	medium to long	short to long		

(Scottish Government, 2019a, 2019b)

Minimum resistance period equivalents in different standards

Scotland	England	EU
Short	30	REI30
Medium	60	REI60
Long	120	REI120

(Scottish Government, 2019a)

Fire tests on strawbale building systems relevant to UK construction

This section describes the results of reaction and resistance to fire tests of building systems with direct relevance to strawbale construction in the UK – either through direct testing of products available in the UK or of building systems used in the UK. Reaction to fire tests are reported for bare strawbale, and for strawbale walls within softwood timber frames with lime and clay plaster coatings, both as onsite build and prefabricated panels. Resistance to fire tests are reported for similar constructions, and for tests in the UK of a standard loadbearing strawbale wall onsite construction wall system.

Reaction to fire tests

The EN 11952-2 test involves subjecting the surface of a test specimen to flame for 15 to 30 seconds. The fire reaction is then recorded, in terms of flame size, spread and presence of flaming droplets. A filter paper is placed beneath the specimen which would ignite if flaming droplets are present. Each product is tested 12 times.

The EN 13823 test involves a 20-minute exposure to flame (usually from a gas burner). The heat and smoke release rates are monitored, along with visual observations. Each product is tested at least three times.

General strawbale building

A reaction to fire test and classification of un-plastered strawbale was carried out in France in 2010 according to EN 11925-2 and 13501-1. The test specimen was constructed of dense straw with the surface trimmed, conditioned at ambient relative humidity (RH) of 50%. 6 specimens were tested.

Flames self-extinguished within 20 seconds, no flames were recorded with a height greater than 150 mm, and the filter paper did not ignite (no flaming droplets). The resulting reaction fire classification for bare straw is E (RFCP, 2010).

A reaction to fire classification for plastered strawbale walls with timber frame elements was obtained in France in 2012, using test data from French and German laboratories. EN 11925-2 and EN 13823 tests were carried out on multiple specimens: half with clay plaster coating the straw, half with lime plaster (8 mm plaster thickness – thinner than the 30-40 mm more common in construction).

The resulting classification is B-s1, d0 (i.e. very limited contribution to fire, weak or absent smoke production, and no flaming droplet generation) (RFCP, 2012).

A further classification according to EN 13501-1 was obtained for strawbale plastered with 25-40 mm lime/clay/sand render, with the render reinforced with 19 mm_2 weld-mesh grid, based on testing to EN 11925-2 and EN 13823. This again achieved B-s1, d0.

EcoCocon strawbale panel system

EcoCocon prefabricated panels comprise a lightweight softwood timber frame structure with dense straw infill. The internal surface is finished with approximately 30 mm of clay plaster directly onto the straw (where timber is plastered over it is first covered in a 5mm layer of woodfibre board). The external face of the straw is covered with 60mm woodfibre board (fitted tightly against the straw and fixed to the timber frame) coated with 7 mm lime-based plaster.

The main surface and lower edge of the panels were each tested, with tests repeated for the internal and external surfaces separately. The resulting EN 13501-1 classification for both internal and external surfaces was B-s1, d0, echoing the French results (Fire Research Centre, 2013).

Resistance to fire tests

The test procedures for EN 1364-1 and EN 1365-1 are similar. Both involve placing one face of a test wall specimen into a test furnace, with any gaps between specimen edges and the opening of the test furnace filled with fire-resistant material. The temperature in the furnace is increased rapidly in the first stages (to around 700 °C in 10 minutes) and continuously increased to around 1000 °C at a reduced rate thereafter. Temperature is recorded at various points on the external surface, along with visual observations and further checks for integrity throughout using a cotton pad (which will combust easily if integrity fails). For EN 1365-1 tests of loadbearing elements, the test specimen is additionally loaded hydraulically throughout the test, with horizontal and vertical deflection recorded.

UK loadbearing strawbale construction

A 2.65 by 3 by 0.41 metre loadbearing strawbale wall, with 30 mm of clay plaster to the internal face was tested to EN 1365-1. The wall was constructed according to standard UK loadbearing strawbale practice (differing from current practice only in that woodfibre board was not fitted to the faces of head and base plates). Head and base plates were softwood timber with OSB top and bottom of each plate, with voids filled with expanded clay aggregate. Vertical softwood posts were positioned in the centre of the strawbale layer, nominally 840 mm apart. The external surface was not plastered (BM TRADA, 2013a).

The test was halted at 135 minutes with no failure of the test criteria (BM TRADA, 2013b). After 70 minutes smoke escaped through the head plate, via a crack in the plaster on the exposed face. The test report notes that the test was terminated due to concerns over the safety of a panel protecting the hydraulic ram (not part of the test specimen), with no recorded integrity or insulation failure from the test specimen.

Plaster remained attached when the was removed from the test furnace. Dismantling of the specimen found that loadbearing posts embedded within the straw were discoloured but not charred. The straw behind the plaster was charred to approximately 50 mm. Deflection recorded at 120 minutes was 6 mm vertical, and 22mm horizontal (towards the furnace). (BM TRADA, 2013a).

French loadbearing strawbale construction

A 3.9 by 3.57 by 0.9 metre loadbearing strawbale wall, with 50mm lime/sand plaster on each side, tested to EN 1365-1. Construction closely resembled UK loadbearing strawbale construction with timber/OSB base and top plates, albeit using larger bales (0.8 m width). Vertical softwood posts were not present, but timber base and top plates were pinned vertically into the straw wall. (CERIB, 2019).

Cracks in plaster of the exposed face were noted before the test began. Further cracks occurred after 13 minutes of exposure, with some plaster detaching at 16 minutes. At 20 minutes cotton pad tests were begun around cracks in the plaster of the non-exposed face, with no failure (pad did not ignite). Further cracks observed at 40 minutes. At 65 minutes some ignition of exposed straw occurred. At 120 minutes a second area of plaster detached. Test ended at 122 minutes without failure of test criteria. Vertical deflection was recorded as 36 mm.

EcoCocon loadbearing strawbale panel system

Three metre by three metre sections of wall were tested to EN 1365-1, comprising 3 joined panels constructed in a similar manner as for the reaction to fire tests described above, with the omission of external render. The test was carried out once with the internal clay-plastered side facing into the furnace, and once with the external woodfibre board surface facing into the furnace.

The tests were halted in both cases at 121 minutes with no failures recorded. This was translated into classification according to EN 13501-2 of RE, REI and REW 120 from both internal and external sides (FIRES, 2016).

ModCell loadbearing strawbale panel

There are different models of ModCell panel available. The model tested in this case comprised a 2.7 m by 3 m panel, with dense strawbale within a glulam frame, with internal I-Joist studs at 300 mm centres. On the internal face (exposed to the furnace) 11 mm OSB was fixed to studs, with timber battens over on which were fixed 15 mm Fermacell boards. The external face of the straw was covered with 12 mm Timbervent board (BM TRADA, 2014b). The panel thickness was reduced to 233 mm although the standard thickness is 400 mm.

At 18 minutes 5 mm gaps opened between the Fermacell panels on the exposed face, increasing to 10 mm by 28 minutes. From 30 minutes cracks were observed in the Fermacell boards, beginning to fall away at the top of the specimen at 39 minutes. At 52 minutes integrity failure was recorded as first burn-through and then flaming were observed towards the top left quarter of the

external Timbervent panel. The test was ended at 52 minutes 30 seconds, with integrity failure recorded, but no failure of insulation elsewhere. Deflection recorded at 51 minutes was 46 mm horizontally (toward the furnace) and 0 mm vertically (BM TRADA, 2014b).

The test led to classification under EN 13501-2 of RE 30, REI 45 (BM TRADA, 2014a).

ModCell non-loadbearing strawbale panel

The panel tested in this case consisted of a 3 m by 3 m by 0.49 m wall, consisting of strawbale within a glulam frame. Stainless steel threaded bar braced the frame, positioned against either face of the straw. 150 mm of fibre mesh reinforcement was placed in plaster over the threaded steel, with 30 mm of lime plaster applied directly to internal and external straw surfaces. At 47 minutes some smoke was visible between render and glulam frame. At 76 minutes small cracks were visible in the plaster of the exposed face. At 110 minutes the external render detached, exposing the straw. Cotton pad integrity tests were conducted from 117 minutes at the join of frame and bale, with no failure. The test was ended at 135 minutes with no integrity failure of test criteria.

Conclusions

Repeated tests on the reaction to fire of lime or clay plastered strawbale walls, and strawbale walls with 60 mm woodfibre board fitted tightly against the straw, have found reaction to fire results of B-s1, d0. Tested specimens all incorporated timber in differing ways behind the plaster or woodfibre board. Reaction to fire tests for the standard UK loadbearing construction system have not been carried out, but the results of tests on equivalent constructions strongly suggest results would be similar.

Currently the reaction to fire rating of B-s1, d0 would make such strawbale construction compliant with fire safety requirements of building regulations in England, Wales and Scotland for domestic and non-domestic buildings with maximum storey height of 18 metres. For non-domestic buildings in England and Wales it would permit use above 18 metres under current regulations. It would permit use in domestic buildings with storey heights above 18 metres in Wales only.

This may be subject to change under proposed revisions of the fire safety requirements of building regulations across the UK. This may see strawbale walls excluded from use in any building above 11 metres. In any case, compliance with current regulations must be checked at design stage of any building.

In tests of resistance to fire of circa 3 metre by 3 metre plastered strawbale wall assemblies, four tests were halted at between 120 and 135 minutes without failure of any test criteria. Three of these were of loadbearing construction (EN 1365-1) and one was non-loadbearing. In some instances, plaster cracked and detached from walls, but fire resistance and loadbearing capacity were maintained. Though none of these systems were officially classified, these results suggest classification of at least REI 120. This would enable compliance with building regulation fire resistance requirements across England, Wales, and Scotland.

The only resistance test with a failure reported was for a ModCell panel construction without any plaster directly onto strawbale, with only an 11 mm layer of OSB directly fixed to the inner face of the bale (BM TRADA, 2014b). It seems likely that this did not offer the same level of protection as either clay or lime plaster, or 60 mm of woodfibre board (as used in the other tests above). Gaps and cracks that opened on the exposed face of Fermacell board in this case allowed heat and flames to reach the OSB board through the cavity behind the Fermacell. This highlights the importance of a close connection between straw and a layer with good fire resistance – Approved Document B in England further specifies that panels with a combustible core should be sealed to prevent exposure of the core to a fire, including at joints and service penetrations (UK. MHCLG., 2019). However, the panel in this case still achieved a classification of REI 45, suitable for domestic houses or flats with a top storey height up to 5 m.

Formal classification of resistance and reaction to fire of the current standard UK loadbearing construction system has not been carried out. Although results are likely to be the same as for the constructions described in this report, it would be advantageous to complete any further testing necessary and seek formal classification if funding could be found.

Disclaimer: The results reported refer only to wall systems. All the test and classification reports discussed state their applicability only to the precise constructions tested. This report has not been compiled by a fire safety professional. Building regulations requirements and fire test results have been reported accurately and to the best of the author's knowledge according to information available at the time of writing.

NB: All building regulations documents are publicly available at the URLs given below. All other documents referenced can be accessed in the UpStraw Zotero database – please contact School of Natural Building for details (eileen@schoolofnaturalbuilding.co.uk)

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