CLAY AS FIRE PROTECTION FOR TIMBER STRUCTURES

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Expertclass 'FSE - Next Generation' at TU/e
May 8, 2025

Credits:
Project HORTUS in Switzerland
Herzog & De Meuron

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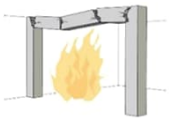
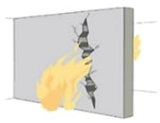
STRUCTURAL FIRE DESIGN OF TIMBER STRUCTURES

FIRE RESISTANCE
PERFORMANCE CRITERIA:



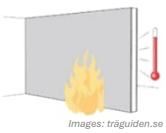
R - Load-bearing capacity

(after a required period of time)



E – Integrity

(no flames or hot gases passing through)



Images: träguiden.se

I – Insulation

(temperature rise control on unexposed side)

SAWA in Rotterdam
https://mei-arch.eu/en/projects/sawa/

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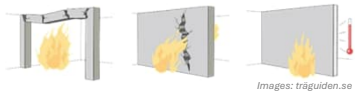
STRUCTURAL FIRE DESIGN OF TIMBER STRUCTURES IN EUROPE



Images: träguiden.se

Eurocode 5 - Design of timber structures
Part 1-2: Structural fire design


EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

EN 1995-1-2

November 2004

English version

Eurocode 5: Design of timber structures - Part 1-2: General - Structural fire design

- EN 1995-1-2:**2004** Currently in use
- **FprEN 1995-1-2:2025** **DRAFT FOR FORMAL VOTE IN 2025**
  NEXT GENERATION IN NEAR FUTURE

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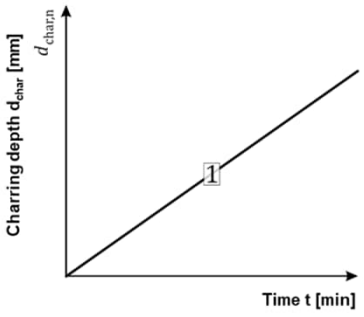
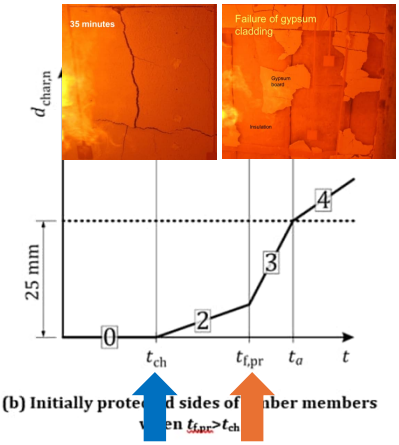
The EUROPEAN CHARRING MODEL
FprEN 1995-1-2:2024



(a) Initially unprotected sides of timber members



(b) Initially protected sides of timber members when $t_{f,pr} > t_{ch}$

Charring begins

Fall-off of protection

- Encapsulated phase (Phase 0) is the phase when no charring occurs behind the fire protection system;
- Protected charring phase (Phase 2) is the phase when charring occurs behind the fire protection system while this system is still in place;
- Post-protected charring phase (Phase 3) is the phase after the failure of the fire protection system before a fully developed char layer has been formed;
- Consolidated charring phase (Phase 4) is the phase with fully developed char layer.

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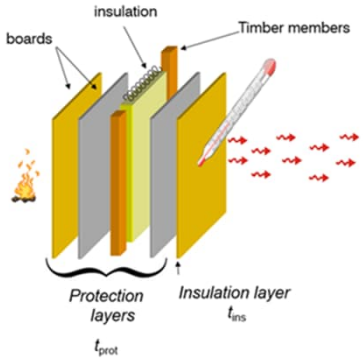
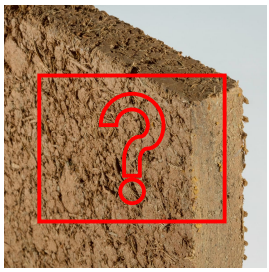
FIRE PROTECTION MATERIALS
In the current Eurocode 5-1-2





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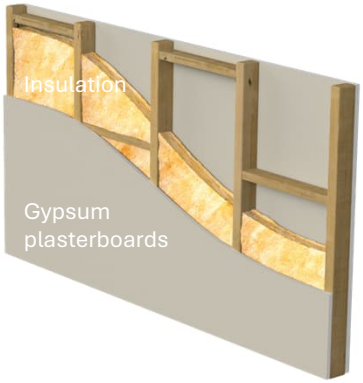
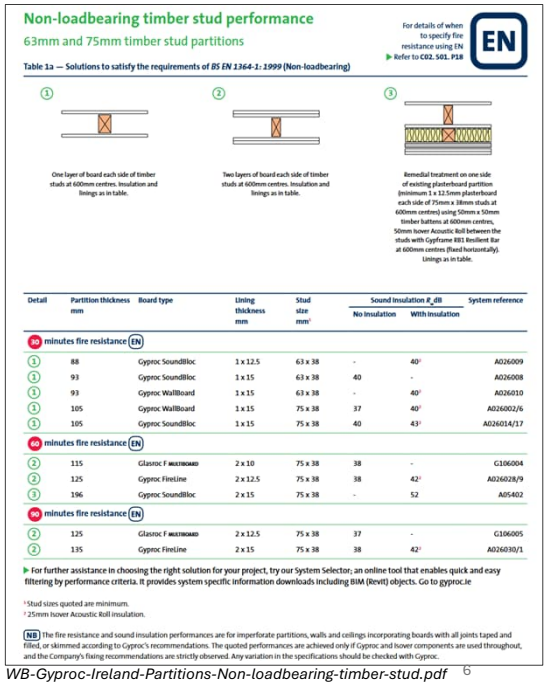
CONVENTIONAL FIRE PROTECTION METHODS FOR TIMBER IN PRACTICE





Non-loadbearing timber stud performance

63mm and 75mm timber stud partitions

For details of when to specify fire resistance using EN ▶ Refer to C02. S01. P18

EN

Table 1a — Solutions to satisfy the requirements of *BS EN 1364-1: 1999* (Non-loadbearing)

① One layer of board each side of timber studs at 600mm centres. Insulation and linings as in table.

② Two layers of board each side of timber studs at 600mm centres. Insulation and linings as in table.

③ Remedial treatment on one side of existing plasterboard partition (minimum 1 x 12.5mm plasterboard each side of 75mm x 38mm studs at 600mm centres) using 50mm x 50mm timber battens at 600mm centres, 50mm Isover Acoustic Roll between the studs with Gyproc RB1 Resilient Bar at 600mm centres (fixed horizontally). Linings as in table.

Detail	Partition thickness mm	Board type	Lining thickness mm	Stud size mm[1]	Sound Insulation R_w dB: No Insulation	Sound Insulation R_w dB: With Insulation	System reference
30 minutes fire resistance EN							
①	88	Gyproc SoundBloc	1 x 12.5	63 x 38	-	40[2]	A026009
①	93	Gyproc SoundBloc	1 x 15	63 x 38	40	-	A026008
①	93	Gyproc WallBoard	1 x 15	63 x 38	-	40[2]	A026010
①	105	Gyproc WallBoard	1 x 15	75 x 38	37	40[2]	A026002/6
①	105	Gyproc SoundBloc	1 x 15	75 x 38	40	43[2]	A026014/17
60 minutes fire resistance EN							
②	115	Glasroc F MULTIBOARD	2 x 10	75 x 38	38	-	G106004
②	125	Gyproc FireLine	2 x 12.5	75 x 38	38	42[2]	A026028/9
③	196	Gyproc SoundBloc	2 x 15	75 x 38	-	52	A05402
90 minutes fire resistance EN							
②	125	Glasroc F MULTIBOARD	2 x 12.5	75 x 38	37	-	G106005
②	135	Gyproc FireLine	2 x 15	75 x 38	38	42[2]	A026030/1

▶ For further assistance in choosing the right solution for your project, try our System Selector; an online tool that enables quick and easy filtering by performance criteria. It provides system specific information downloads including BIM (Revit) objects. Go to gyproc.ie

[1] Stud sizes quoted are minimum.
[2] 25mm Isover Acoustic Roll insulation.

NB The fire resistance and sound insulation performances are for imperforate partitions, walls and ceilings incorporating boards with all joints taped and filled, or skimmed according to Gyproc's recommendations. The quoted performances are achieved only if Gyproc and Isover components are used throughout, and the Company's fixing recommendations are strictly observed. Any variation in the specifications should be checked with Gyproc.

WB-Gyproc-Ireland-Partitions-Non-loadbearing-timber-stud.pdf 6

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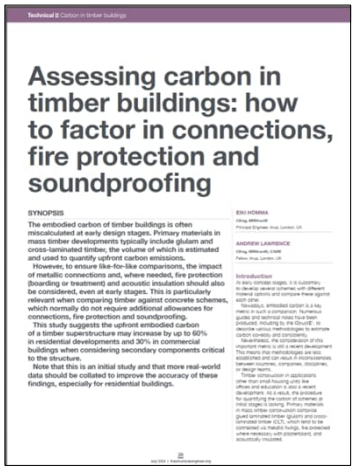
Why Look for Alternatives (NATURAL MATERIALS) to conventional protection materials?

CARBON FOOTPRINT



Assessing carbon in timber buildings: how to factor in connections, fire protection and soundproofing

SYNOPSIS

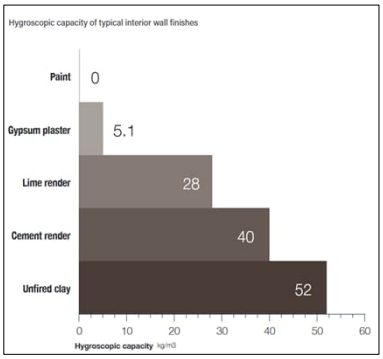
The embodied carbon of timber buildings is often miscalculated at early design stages. Primary materials in mass timber developments typically include glulam and cross-laminated timber, the volume of which is estimated and used to quantify upfront carbon emissions.

However, to ensure like-for-like comparisons, the impact of metallic connections and, where needed, fire protection (boarding or treatment) and acoustic insulation should also be considered, even at early stages. This is particularly relevant when comparing timber against concrete schemes, which normally do not require additional allowances for connections, fire protection and soundproofing.

This study suggests the upfront embodied carbon of a timber superstructure may increase by up to 60% in residential developments and 30% in commercial buildings when considering secondary components critical to the structure.

Note that this is an initial study and that more real-world data should be collated to improve the accuracy of these findings, especially for residential buildings.

INDOOR CLIMATE



https://clay-works.com/wp-content/uploads/2024/12/Clayworks-Healthy-Buildings-Data.pdf

CIRCULARITY

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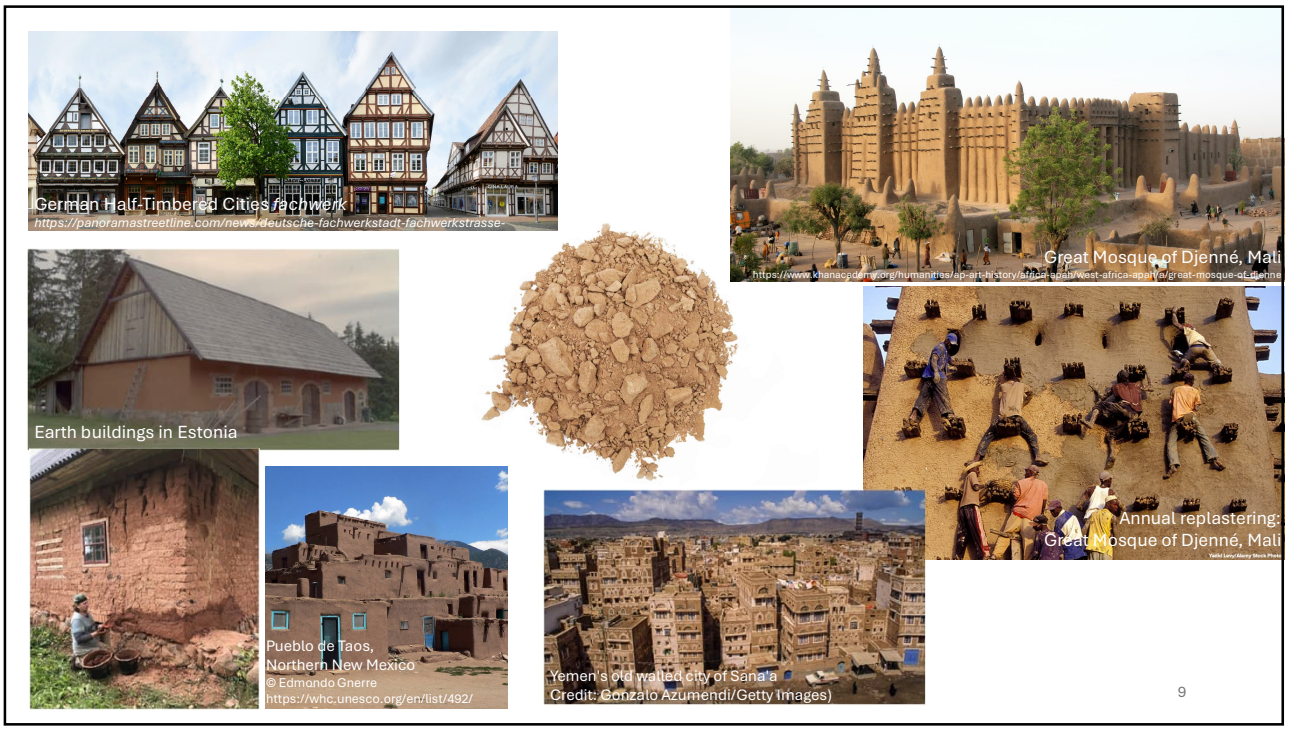
German Half-Timbered Cities fachwerk
https://panoramastreetline.com/news/deutsche-fachwerkstadt-fachwerkstrasse-
Great Mosque of Djenné, Mali
https://www.khanacademy.org/humanities/ap-art-history/africa-apah/west-africa-apah/a/great-mosque-of-djenne
Earth buildings in Estonia
Annual replastering:
Great Mosque of Djenné, Mali
Pueblo de Taos,
Northern New Mexico
© Edmondo Gnerre
https://whc.unesco.org/en/list/492/
Yemen's old walled city of Sana'a
Credit: Gonzalo Azumendi/Getty Images)
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https://en.wikipedia.org/wiki/Wattle_and_daub#/media/File:HeiligenstadtFachwerk.J
Photo: UKU (Saviukumaja OÜ)
https://www.z©fairlight-brighton-hove.secure-dbprimary.com
Photo: Paul Lynch
Photo: UKU (Saviukumaja OÜ)

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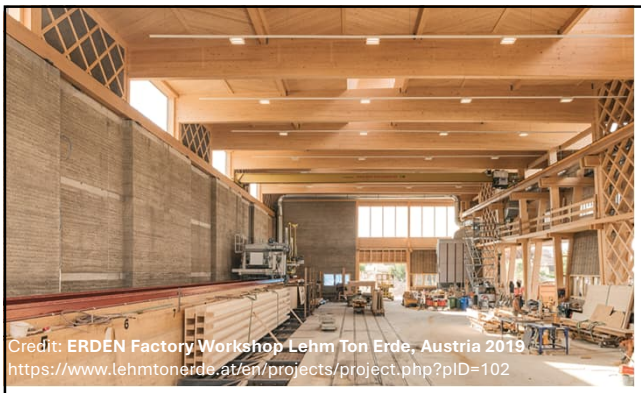

Credit: **ERDEN Factory Workshop Lehm Ton Erde, Austria 2019**
https://www.lehmtonerde.at/en/projects/project.php?pID=102

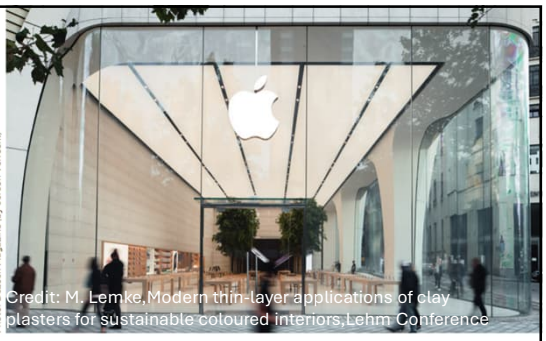

Photo: Dezeen Magazine (by Jeroen Verrecht)

Credit: M. Lemke,Modern thin-layer applications of clay plasters for sustainable coloured interiors,Lehm Conference

Credit: Rematter, High Tech manufacturing of timber-earth floor slabs

Credit: Use of clay building boards in the Reinbeckhallen in Berlin. © Lemix,
https://renewable-carbon.eu/news/clay-sustainable-panel-materials/

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CLAY-BASED BUILDING MATERIALS (FOR TIMBER)

CLAY PLASTER

DIN 18947:2018/2024

DIN 18942-1:2024-03
EN 13914-2:2016

CLAY BOARD

DIN 18948:2018/2024

DIN 18942-1:2024-03

CLAY MASS

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STANDARDS IN EU for clay materials

STANDARDS IN GERMANY:

Standard	German Title	English Title	Application
DIN 18945:2018:2024-03	Lehmsteine – Anforderungen, Prüfverfahren und Kennzeichnung	Clay masonry units – Requirements, testing and labelling	Unfired clay bricks for non-loadbearing walls
DIN 18946:2024-03	Lehmmauermörtel – Anforderungen, Prüfung und Kennzeichnung	Earth plasters – Requirements, testing and labelling for masonry works	Material requirements for earth plasters for masonry works
DIN 18947:2024-03	Lehmputzmörtel – Anforderungen, Prüfung und Kennzeichnung	**Earth plasters – Requirements, test and labelling**	Material requirements and categorisation
DIN 18948:2024-03	Lehmplatten – Anforderungen, Prüfverfahren und Kennzeichnung	**Clay boards – Requirements, testing and labelling**	Prefabricated earth-based boards for dry construction

SWEDEN from 2025:

TERMS AND APPLICATION STANDARDS:

DIN 18942-1:2024-03: Lehmbaustoffe und Lehmbauprodukte – Teil 1: Begriffe - This document defines terms for the application of the standards for earth building materials DIN 18945, DIN 18946, DIN 18947 and DIN 18948.

EN 13914-2:2016 - Design, preparation and application of external rendering and internal plastering - Part 2: Internal plastering

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INFO: https://www.dachverband-lehm.de/wissen/lehmbau-din-normen

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CLAY AS A FIRE PROTECTION IN TIMBER STRUCTURES ?

How do clay materials perform in case of fire?

What is our current knowledge?

*Credit: LEMIX - **Clay boards in timber frame assemblies***

*Credit: Rematter – **Timber Earth Floor slabs***

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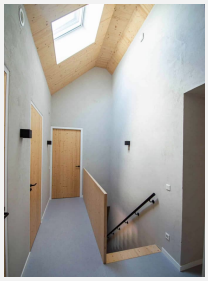
CURRENT STATUS
CLAY BASED MATERIALS IN TIMBER BUILDINGS

- **Clay materials for timber are not integrated into fire design standards at EU level**
- **Limited knowledge** on clay-based materials in the construction sector

→ Today, clay materials mainly used in 'small scale buildings'
→ Increasing interest towards the use of clay in larger building projects





Credit: CLAYTEC - An energy-neutral, modern villa in Steenbergen Noord-Brabant, the Netherlands

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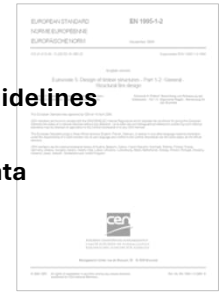
REGULATIVE FRAMEWORK
FIRE PROTECTION MATERIALS FOR TIMBER

Prescriptive design

- **Design standards**
- **(National) design guidelines**
- **Tabulated design data**



- Fast and simple to use
- Conservative
- Design freedom may be limited
- Need for product standarization

Full-scale fire testing

- Time consuming / Costly
- Result only applicable to the tested configuration
- Only option if no design data available

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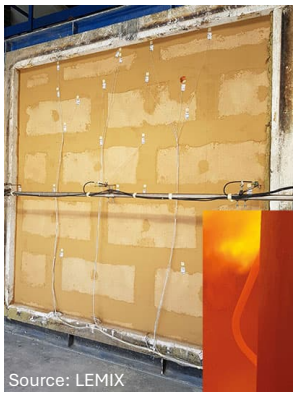
FIRE RESISTANCE TESTS BY THE INDUSTRY


Source: LEMIX


https://ecococon.eu/us/blog/2021/fire-resistance-2021


HORTUS project / Source: IGNIS

- **Clay boards** as fire protection – Full-scale fire tests at MFPA Leipzig,Germany, up to **REI120**
- **Straw panel systems with clay plaster** – building solutions up to **REI120**
- **Timber-Earth floor systems** - Lehm Ton Erde GmbH, Rematter® AG, IGNIS Fire Design Consulting, **REI60**

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CASE STUDY

HORTUS PROJECT IN SWITZERLAND

Architecture: Hersog & De Meuron

Woodwork: Blumer Lehmann

***TIMBER EARTH FOR SLABS**: Lehm Torn Erde GmbH,* Rematter® AG

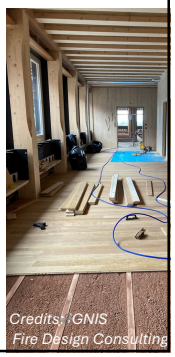
*Dry walls with **CLAY BOARDS**: LEMIX, Claytec*


Credits: Hersog & De Meuron


Credits: Hersog & De Meuron


Credit: Blumer Lehmann, https://www.lehmit.com/en/


Credits: Hersog & De Meuron


Credits: GNIS Fire Design Consulting

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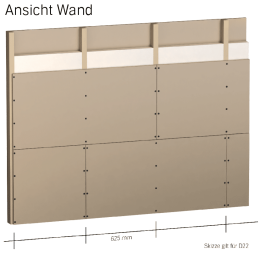
CASE STUDY

HORTUS PROJECT IN SWITZERLAND

- **23,000 m2 of CLAY BOARDS**: heavy (LEMIX) D22 and D16

Ansicht Wand



Parameters
Surface hardness ≤ 15mm, Bending tensile strength ≥ 0.8 N/mm², Surface Tensile Strength ≥ 0.1 N/mm². Bulk density class 1.6, bulk density approx. 1.550 kg/m³, thermal conductivity 0.353 W/mK, μ 5/10. Water vapour sorption class WS III. Heat storage: Cp 1.1 kJ/kgK, D22= 35.1 kJ/m2K, D16= 25.5 kJ/m²K. Construction material class A1.

Fixation:
Mounting on wood with Lemix clay building board **screws 5 x 60 mm** or FN drywall screws with coarse thread.
Screwing distance ≤ 200 mm, i.e. 4 mounting points are required for each board/ substructure crossing (wall 12 or 20, ceiling 20 screws / boards).

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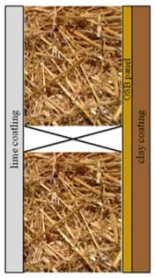
RESEARCH PROJECTS

FIRE RESISTANCE TESTING

- TU Braunschweig, **Germany**

  Multi-storey straw bale buildings (Dr. Judith Küppers)
  Encapsulation criteria **$K_2$60 achievable with clay and lime coatings**



- Tampere University, **Finland (2023)**

  Timber frame assemblies with clay plaster

- Tallinn University of Technology, **Estonia**

  Development of design parameters in view of **Eurocode 5-1-2 for traditional clay plaster as fire protection material**

  (Doctoral thesis by Liblik, 2023)

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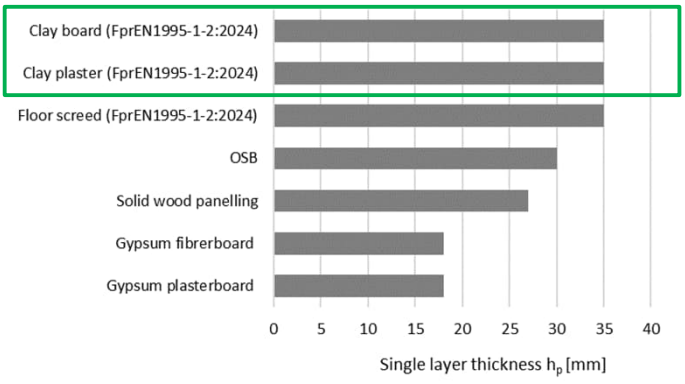
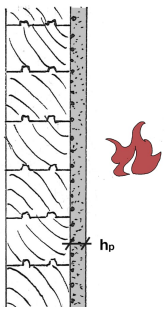
FIRE PROTECTION DESIGN WITH CLAY

- **Design parameters** for CLAY PLASTER and CLAY BOARD are **proposed for NEW GENERATION OF EUROCODE 5-1-2**

FIRE DESIGN OPTIONS
NEW GENERATION OF EUROCODE 5-1-2

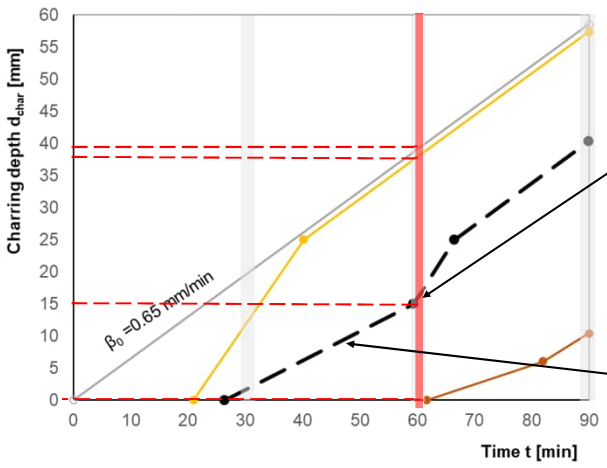
MATERIAL THICKNESS TO **PROTECT TIMBER FROM CHARRING FOR 30 MINUTES**

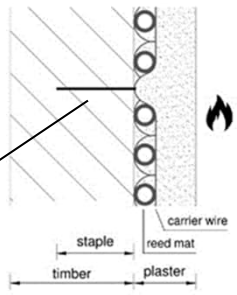




FIRE PROTECTION PERFORMANCE

CLAY PLASTER vs GYPSUM PLASTERBOARD





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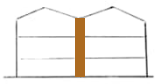
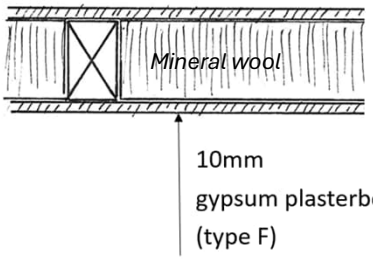
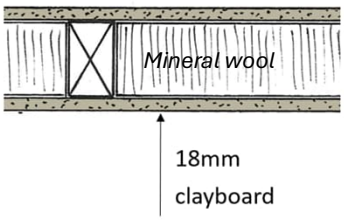
EXEMPLARY APPLICATIONS FOR WALLS
REI30



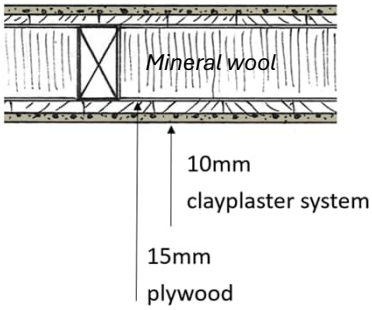
A - conventional



B - clayboards



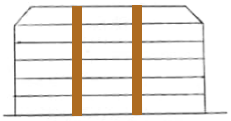
C – clay plaster & woodboard



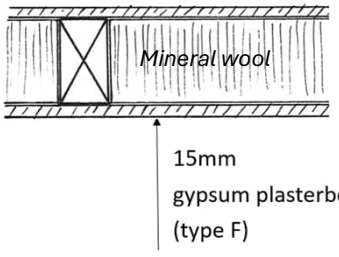
*Calculation basis in paper:

***From tradition to future prospects: Clay as fire protection for timber** at LEHM Conference 2024 Weimar, Germany*

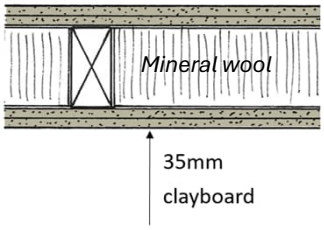
EXEMPLARY APPLICATIONS FOR WALLS
REI60



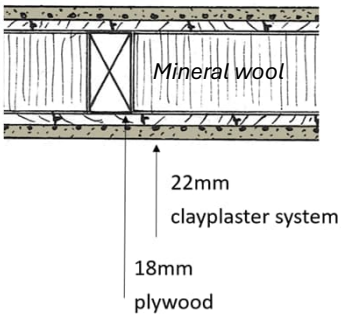
A - conventional



B - clayboards



C – clay plaster & woodboard



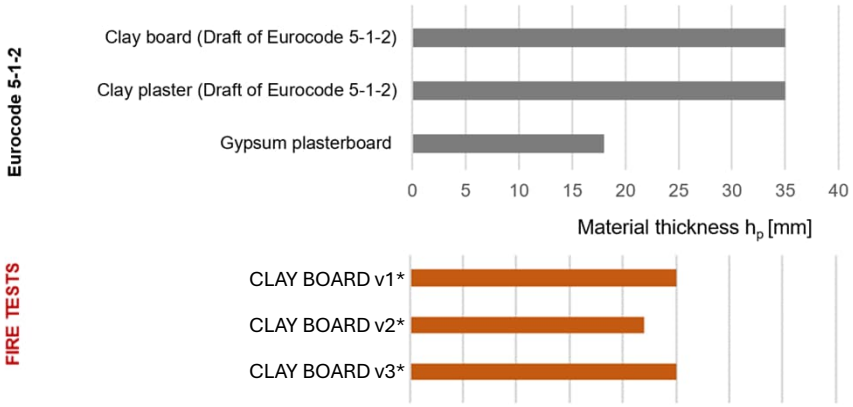
*Calculation basis in paper:

***From tradition to future prospects: Clay as fire protection for timber** at LEHM Conference 2024 Weimar, Germany*

FIRE PROTECTION PERFORMANCE

OUTLOOK FOR CLAY BOARDS

MATERIAL THICKNESS TO **PROTECT TIMBER FROM CHARRING FOR 30 MINUTES**



*Refer to paper: Liblik et al. 2024 ***From tradition to future prospects: Clay as fire protection for timber*** *at LEHM Conference 2024 Weimar, Germany*

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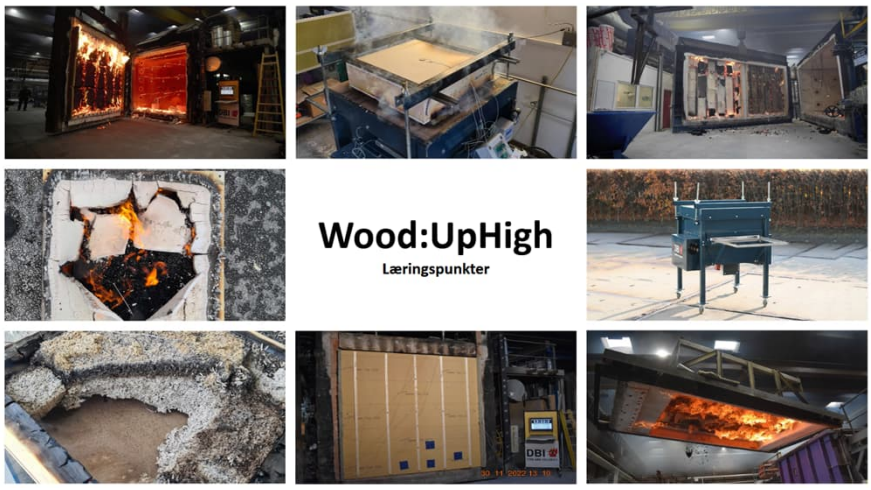
BIO-BASED LOAD-BEARING STRUCTURES

PROJECT IN DENMARK (2022-2023)

DBI



https://brandogsikring.dk/files/Pdf/FogU/Wuh/L%C3%A6ringspunkter.pdf

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BIO-BASED LOAD-BEARING STRUCTURES

PROJECT IN DENMARK (2022-2023)

WOOD:UPHIGH

The government, has through the Climate Act, set a target for Denmark to reduce its CO2 emissions by 70% by 2030 compared to 1990 levels. In April 2021, the government launched a National Strategy for Sustainable Construction, which aims to contribute to achieving this goal. The strategy aims to develop pre-accepted solutions for load-bearing structures made of combustible materials, specifically designed to support the construction of timber buildings up to 5 stories in height. The objective is to have pre-accepted solutions available for timber constructions, like non-combustible building materials. Fire regulations are a significant barrier to volumetric construction, as only a few bio-based construction types and material compositions have been documented in terms of fire safety and are therefore not included as pre-accepted solutions. This results in the use of conventional and carbon-intensive materials instead.

https://brandogsikring.dk/en/research-and-development/development-of-fire-safe-bio-based-and-circular-construction-products/wooduphigh/

https://brandogsikring.dk/files/Pdf/FogU/Wuh/WUH6_PGA12247A_public.pdf

- 10 accredited full-scale fire tests
- 30-40 small-scale indicative fire tests

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PROJECT IN DENMARK (2022-2023)

https://brandogsikring.dk/en/research-and-development/development-of-fire-safe-bio-based-and-circular-construction-products/wooduphigh/wooduphigh-reports/

DBI BRAND OG SIKRING

3 Clayboard with clay plaster B

(37.5 kN/m)

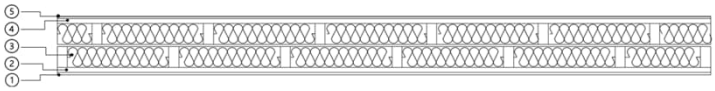
The 6th construction from Wood:UpHigh is a loadbearing wall using clay board with clay plaster as covering. The test was stopped after 66 minutes, reaching REI60.

The test specimen has been subjected to a standard fire test in accordance with the standard: DS/EN 1363-1:2020 Fire resistance tests – General requirements, in conjunction with EN 1365-1:2012 Fire resistance tests for loadbearing elements Part 1: Walls.

This data is extracted from DBI test report PGA12247A.

About the construction (exposed side)

1. 10 mm clay board + 3 mm clay plaster
2. 22 mm clay board
3. 45x95 mm construction spruce wood with four layers of seaweed wool
4. 22 mm clay board
5. 10 mm clay board + 3 mm clay plaster



r: 66 minutter | Opnåede REI60

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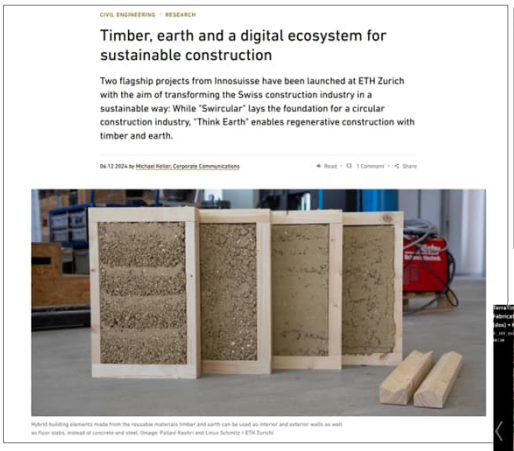
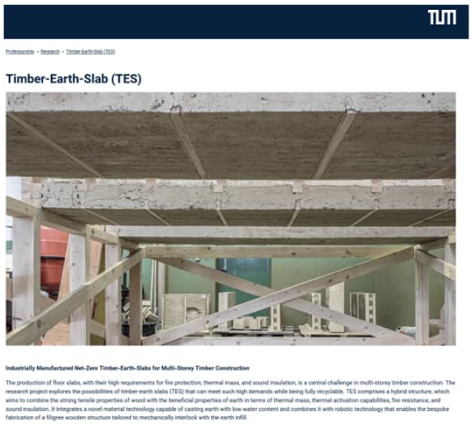
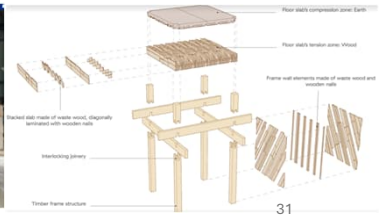
FUTURE PERSPECTIVE - RESEARCH

CURRENT PROJECTS IN EU







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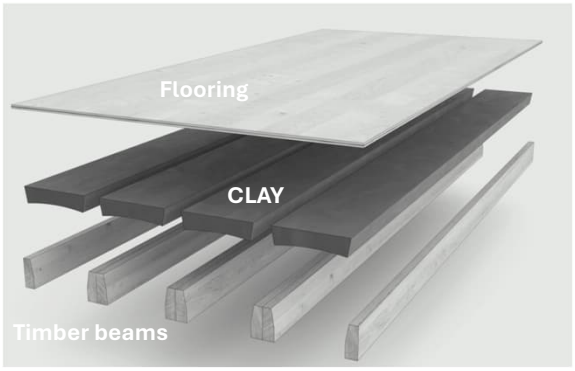
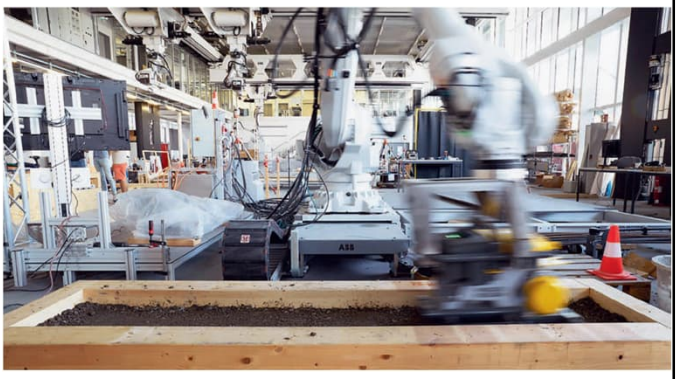
FUTURE PERSPECTIVE – PRODUCT/SYSTEM DEVELOPMENT

TIMBER EARTH FLOOR SLABS





REI 60

Credits:
REMATTER AG, Switzerland
TIMBER-EARTH FLOOR SLABS
High-tech manufacturing
Designed for disassembly and performance

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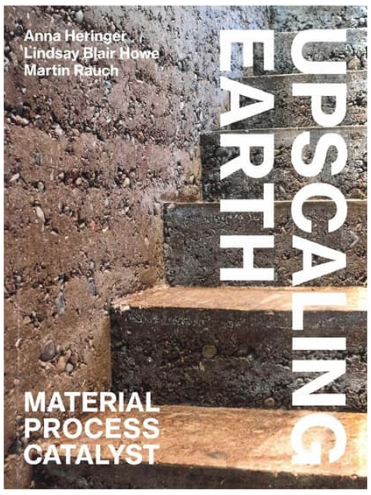
FUTURE PERSPECTIVE – RETHINKING HOW WE BUILD



Credits:
Project HORTUS in Switzerland
Hersog & De Meuron

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TERRATimber - Earth and reuse of timber
Karlsruhe Institute of Technology (KIT), Digital Design & Fabrication (DDF), dos - Design of Structures

THANK YOU!

johanna.liblik@taltech.ee

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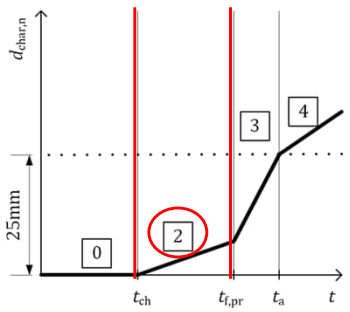
RESULTS
DESIGN EQUATIONS - WALLS

- **Clay protection system directly applied on timber structures**

h_p = 15 … 40 mm



$t_{ch} = t_{prot,0,i}$

Start time of Charring (Basic protection time):

$$t_{ch} = t_{prot,0,i} = 1.1 h_p - 6.6$$

Plaster system with plaster carrier:

$$k_2 = 1 - 0.01 \cdot h_p$$

$$t_{f,pr} = t_{ch} + \frac{l_f - 10}{\beta_{n,Phase2}}$$

Plaster system without plaster carrier:

$$t_{f,pr} = t_{ch}$$

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