Green Built LLC

(April 2014)

Building Sustainability

Hemp-Lime Construction

What Is Hemp-Lime?

- A renewable, breathable, fire, insect, rodent and rot resistant natural building material
- Utilizes the woody inner core (hurd or shiv) of the fast-growing hemp plant's stem combined with a lime-based binder
- Material is lightweight, easy to use, structurally sound and durable
- Excellent thermal and acoustic properties
- Exceptional insulating qualities
- Non-load bearing, requires timber or other load-bearing frame
- Non-toxic, recyclable, carbon negative

Hemp-Lime Increasingly Adopted as a Mainstream Building Material in Europe

Hemp-Lime is Super-Sustainable

Climate adaptation applications

Carbon-sequestering throughout lifecycle

Durable

Non-toxic

Energy efficient insulation

Recyclable

Renewable bio-material

Eliminates construction waste

Reduces need for HVAC mechanicals

Hemp-Lime Is a Versatile, Strong, Solid Composite Material That Can Be

- Cast like concrete
- Sprayed
- Used as a plaster or render
- Utilized as insulation for floors, walls and roofs
- Cast into blocks, bricks or panels

History of Modern Hemp-Lime Construction

Late 1980s –
Process originally developed in Champagne region of France to repair old buildings

Mid-1990s –
Used in both new “hemp houses” and in the restoration of historic buildings

Late 1990s –
Multiple companies develop processes to manufacture building materials
Increased levels of industrial hemp cultivation



Early 2000s –
Full testing of properties and environmental impact

2000-2010 –
Increasingly accepted as a “Green Building” material in UK/Ireland, Western Europe. Many single family dwellings, social housing projects, industrial and office buildings constructed

Today – Moving into the Mainstream

- 114 unit and 42 unit housing developments in UK
- Many large scale energy efficient commercial and industrial buildings designed and completed
- Widely used in retrofits of historic buildings
- Accredited in France, England, Ireland, other EU countries
- Initial development begun in Canada, Australia, South Africa
- R&D ongoing to develop load bearing products to further reduce CO_2



New Hemp Construction…*in Europe*

7 Story Office Building in Clermont- Ferrand, France

- Regional Government Office of Housing and Environment
- Uses hemp-lime blocks throughout

CANNABRIC®

Houses Under Construction, Spain

Architect: Antonio Garcia Morales

Green Light Trust – Suffolk, England

Community Building designed by Ralph Carpenter, Modece Architects

First “Better than Zero Carbon” building in Suffolk, locks up 4 tons of carbon in building envelope

Hemp-lime used throughout, with materials sourced within 20 miles of site where possible

Green Light Trust basic carbon data

Floor screed	+0.5Te
Floor blocks	- 2.8Te
Walls	- 4.3Te
Windows	+1.3Te
Roof insulation	- 7.2Te
Roof covering	+3.0Te
Brick floor	+2.0Te
Sundries	+3.0Te
Total	**- 4.5Te**

Affordable Housing – Suffolk, England

- Elmswell Affordable Housing Initiative – Suffolk
- Riches Hawley Mikhail Architects
- Hemp-Lime Walls – part of energy efficiency strategy reduces carbon emissions by 60%

Adnams Brewery Warehouse – England

- The 250,000ft^2 distribution center and commercial vehicle maintenance facility, located in Southwold, Suffolk and completed in 2006 for a total cost of £5.8 million, was constructed with a diaphragm wall using 100,000 high density blocks made of hemp, hydrated lime and quarry waste, with an infill of 1000 m^3 of low density hemp-lime material.
- Thermal performance: drinks stored at 12º to 14ºC, without the use of air cooling system, resulting in £400,000 saving on original costs, and £50,000 annually in operating costs.
- Carbon Sequestration: More than 500 tons of CO_2 locked up in the building fabric.

Architect: Aukett Fitzroy Robinson

Structural Engineer: Faber Maunsell AECOM

Wine Society Warehouse – England

Building walls constructed of 730 cubic meters of Tradical® Hemcrete® installed in 400 mm thick sprayed prefabricated 3.6 by 2.4 meter panels within factory manufactured timber cassettes, and supported on a structural steel frame, while a 40mm-thick composite aluminum panel is used to provide weather protection on the external face.

In use since mid 2008 without heating or cooling equipment, the internal environment has shown remarkable temperature stability (13-16°C) despite daily external temperature variation and extended periods of sub-zero temperatures.

The 2744 m² warehouse, located in Stevenage, Hertfordshire, was completed in September 2008 at a total cost of £3.8 million. The architects were Vincent and Gorbing

Wise Institute for Sustainable Education – Wales

"Britain's Best Building of 2010" –
The Daily Telegraph

- WISE's primary structure comprises a glue laminated timber frame, infilled with a spray-applied hemp-lime composite to a thickness of 500mm, providing a high degree of insulation and air tightness while remaining breathable. As an essentially monolithic form of construction it is also less prone to technical failure than conventional cavity assemblies, and finished externally in a coat of hydraulic lime render.

- WISE is a miniature campus tucked into the folds of the quarry combining a 200-seat lecture theatre, 24 en-suite bedrooms, three seminar rooms, three workshops, a laboratory and new office space for the organization's staff

…*and America*

The Nauhaus Prototype, Asheville, NC

Designed to meet Platinum LEED and Passivhaus standards

NC's humid summer climate presents interior mold issues. Using imported hempcrete for the building envelope, the building achieved R-values of 40 for the wall and 70 for the roof.

The highly insulative hygroscopic wall also served as a perfect substrate for the interior plasters processed from the clay soil excavated for the foundation.

Architect: Tim Callahan, Alembic Studio

The Carbon Impact

"Attractive carbon sink with a lifetime of 100+ years"-- French Life Cycle Assessment

HEMP

- Grows up to 1 foot per week over a 12-14 week growing cycle. During its rapid growth, it captures carbon and releases oxygen into the atmosphere, sequestering CO_2
- 1 acre can produce up to 4 tons of hemp – enough to build a 700 square foot house with 8 inch thick walls
- An organic "aggregate," it replaces quarried and/or synthetic fossil fuel-based materials

LIME

- Lime-based binders emit substantially less energy in manufacturing than other materials (e.g. cement)
- Lower kiln temperatures + lower lime densities = less energy use

TIMBER

- Compared to far more energy intensive rebar used in reinforced concrete buildings, load-bearing timber frame can be a renewable resource, capturing CO_2 during growth

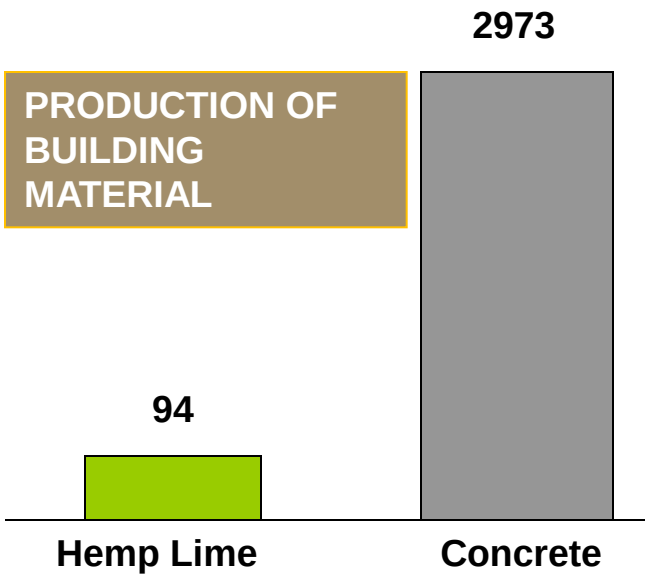
HEMP-LIME BUILDINGS

- During a building's lifetime, the embedded lime carbonates, absorbing CO_2 from the atmosphere

Relative Carbon Load
Hemp-Lime Construction vs. "Business as Usual"

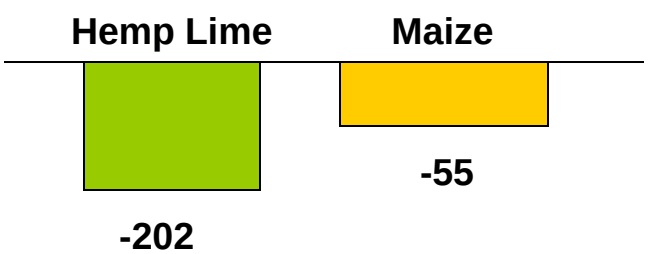
(kg of CO^2 emitted/sequestered per m^3 of wall)

PRODUCTION OF BUILDING MATERIAL

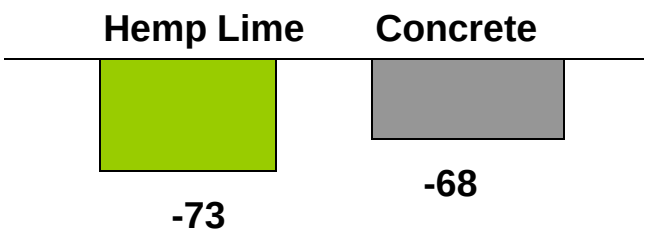


"…at least 5% of humanity's carbon footprint comes from the concrete industry ….."
- National Science Foundation, May 24, 2009

AGRICULTURAL CO^2 SEQUESTRATION

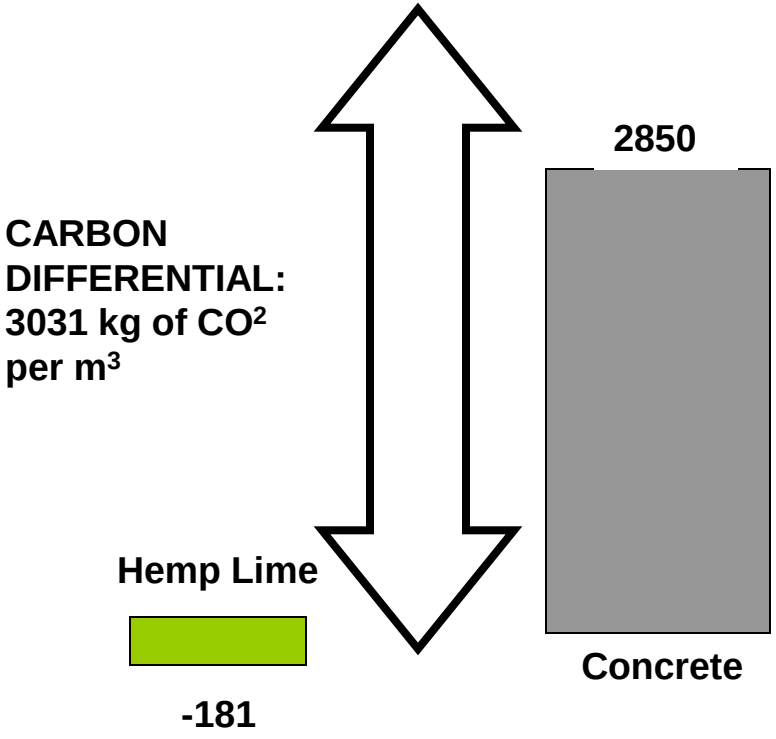


BUILDING LIFECYCLE (30 years)



Opportunities for Additionality

LIFETIME CO^2 IMPACT



One small 1,000 sq. ft. detached house with 12 inch thick walls will contain approx. 1,000 cubic feet of hemp lime material and **will result in sequestration/ avoidance of 332 tons of CO2 emissions**

R&D on Hemp Aggregates

Thermal and Hygroscopic Properties

"The walls are breathable and act as a sort of passive air-conditioning system, meaning that the internal humidity is kept constant and the quality of the air within the house is very good. The walls also have a 'virtual thermal mass' because of the remarkable pore structure of hemp shiv combined with the properties of the lime binder, which means the building is much more thermally efficient and the temperature inside the house stays fairly constant."

Dr. Mike Lawrence, University of Bath, UK, Department of Architecture & Civil Engineering

Mechanical Behavior

"As a mixture of plant particles and binder, hempcrete is an unusual construction material: the high flexibility of the aggregates in conjunction with the rigidity of the cement matrix leads to a non-fragile elasto-plastic behavior. Thus, it is distinguished from other construction materials by a high deformability under stress, lack of fracturing and marked ductility with absorbance of the strains even after having reached the maximum mechanical strength.

It is also helpful to highlight another peculiarity: the variability of the behavior depending on the formulation enables us to adjust and optimize the performances of this material for diverse applications as a roof filling material, in walling or as flagging."

– Laurent Arnaud, et. al., Bio-Aggregate Based Building Materials, Applications to Hemp Concretes

Life Cycle Analysis

‘Banked hempcrete, for its part, is particularly well adapted for building renovation; quite apart from its thermal resistance, which satisfies the thermal regulations in force with walls of less than 30 cm in thickness, “its hygrothermic performance, which combines mass transfer and phase change with the other thermal phenomena, means it is able to greatly exceed the expected energy performances. In addition, users have noted that they attain a satisfactory level of thermal comfort at relatively low ambient temperatures (17^0 or 18^0C, or sometimes less), which leads to a significant decrease in energy consumption”’ (*Construire en Chanvre*).

– Laurent Arnaud, et. al., Bio-Aggregate Based Building Materials, Applications to Hemp Concretes

Comparison of dry-lining versus a hemp and lime insulating render for internal thermal renovation

The main conclusions are:

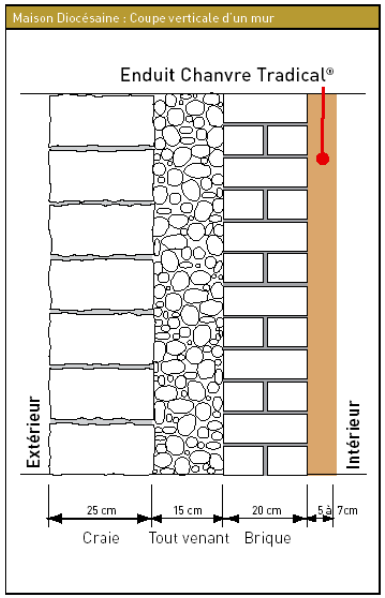
- Dry Lining causes moisture to accumulate in the wall and space behind it which will lead to rot, internal structural damage and increased frost damage.
- Hemp renders are not only insulating but also dry out the external wall and handle moisture well suggestive that they reduce the risk of rot, mould and frost damage overtime.
- Hemp renders sequester significant amounts of carbon dioxide which could be used to offset the embodied carbon of renewables in a win-win scenario.
- U-values can underpredict actual performance.

– **Marion Wright, Naomi Miskin, Andrew Flower & Ranyl Rhydwen,** University of East London & Graduate School of the Environment, Centre of Alternative Technology, Machynlleth,Wales

Chalon en Champagne Diocesan House

Rénovation

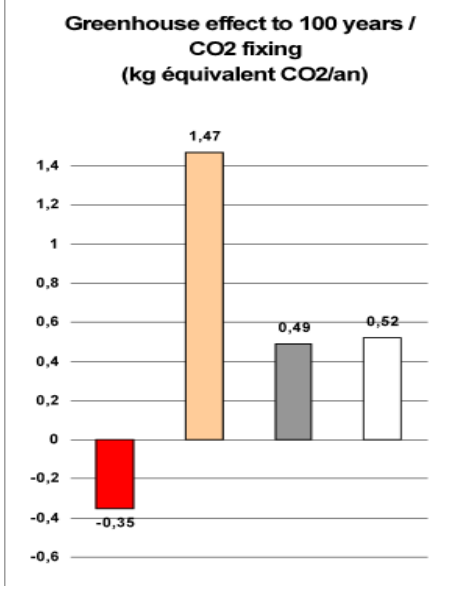
Walls insulated with hemp-lime concrete (only 5 to 7 cm)

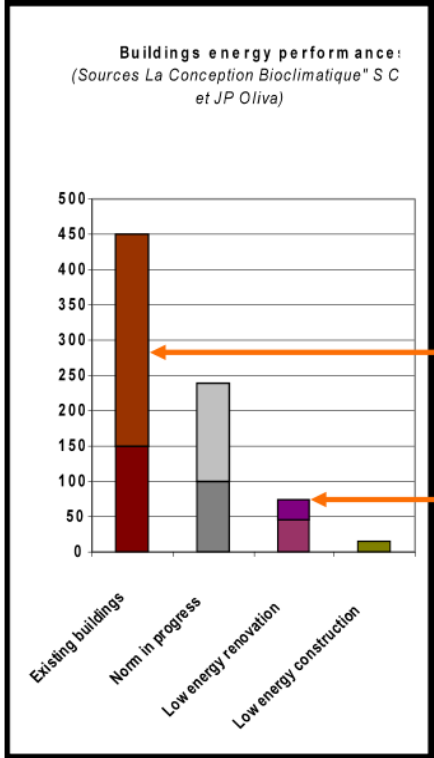


Jean Louis Coutarel
l'École nationale supérieure d'architecture de Clermont Ferrand

Analyse du Cycle de Vie des bétons de chanvre

- Hemp Concrete (26cm) R = 2,36m2.K/W
- Clay brick (37cm) R = 2,5m2.K/W
- Concrete blocks and polystyrene/plasterboa R = 2,36m2.K/W
- AAC (30cm - 400 kg/m3) R = 2,5m2.K/W





- Consumption before renovation > 250 kWh/m2/an
- 64KWh/m2/an

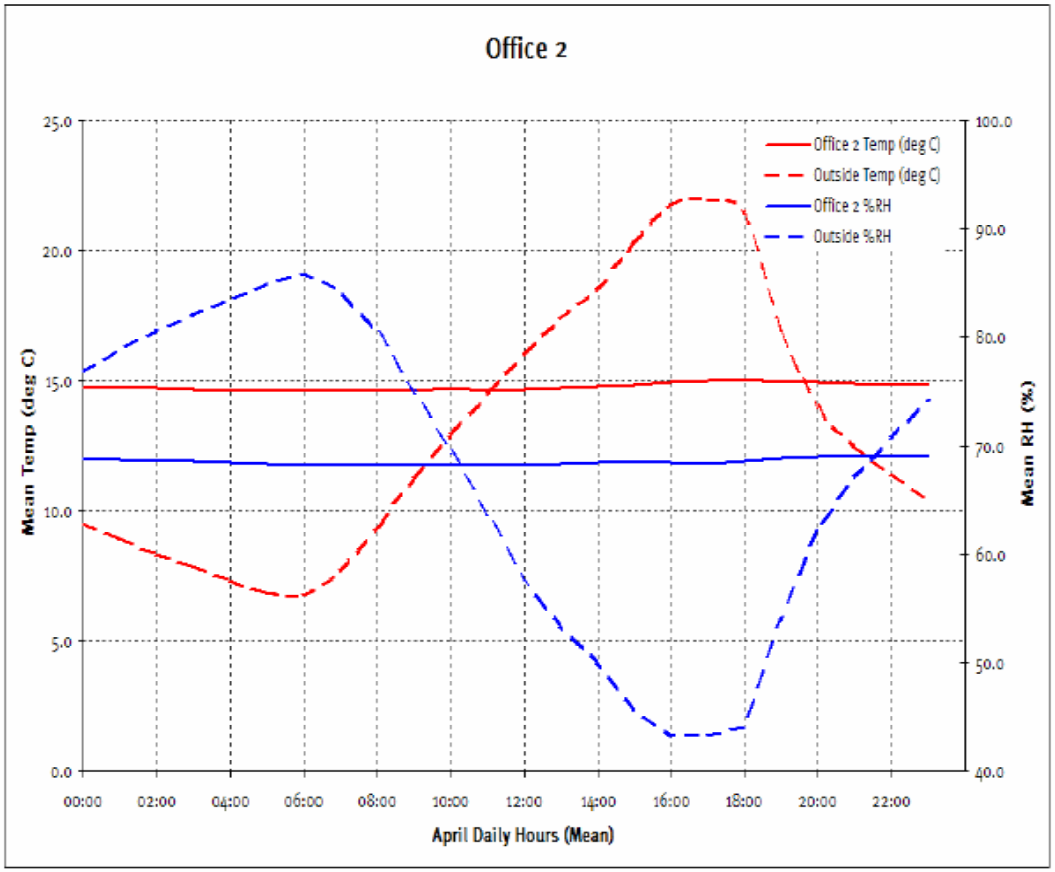
Compliance with UK Building Codes

- Structural Performance (Bldg. Reg. A) – Not load bearing, but provides excellent racking resistance; studwork requires no noggins or bracing; does not compact, remains stable over several stories; floors will support normal domestic loading
- Fire Resistance (Bldg. Reg. B) – Hemp/Lime is naturally fire resistant; will resist fire up to 1800°C (cement shatters at 400°C)
- Moisture (Bldg. Reg. C) – Walls remain dry and do not allow moisture to penetrate (testing by Building Research Establishment, Ltd. – BRE)
- Sound Resistance/Absorption (Bldg. Reg. E) – Open-pored hemp absorbs sound, reduces echo and sound transmission; provides better acoustic performance than mineral wools in floor voids; BRE testing in Haverhill showed 58db sound reduction
- Ventilation (Bldg. Reg. F) – Highly breathable; testing shows mechanical extraction not required as moisture migrates through structure in 3 hours
- Thermal Insulation (Bldg. Reg. L) – Light weight, dense material provides good insulation and energy storage, minimal air infiltration and low ventilation heat loss; tests of thermal conductivity show 0.072w/m^{2}K, loose hemp 0.064w/m^{2}K

Based on Presentation by Ralph Carpenter, Modece Architects, 2009

Improved Temperature/Humidity Performance

Office refurbished with hemp-lime insulating materials results in dramatically improved temperature and humidity stabilization – and thus substantially lower heating and cooling expense



126 Milton Park, Abingdon, Oxfordshire

Improved Comfort

- Monolithic -- inherently air tight.
- A 250mm wall can reduce external temperature changes by around 98%.
- A 20^0C change over 24 hrs is almost completely dampened.
- Any temperature change that does occur can be greatly delayed.
- High vapor permeability and absorption coefficient allows Hemp-Lime to buffer high humidity, combat condensation and improve air quality.

Additional Hemp-Lime Benefits

- Safe handling during installation
- No VOCs post-installation
- Pest repellent
- Mold/rot resistant
- Improves indoor air quality
- Racking resistance – can eliminate need for cross-bracing
- Monolithic hemp-lime walls reduce building complexity
- Material does not compact – does not develop pockets for air infiltration
- Air-tight envelope eliminates thermal bridging

- Regulates humidity
- Protects structural wall elements from moisture
- Thermal mass imparts thermal control and consistency
- Flexible in its uses
- Acoustic barrier
- Low-tech throughout life-cycle
- Simple lime-render finish
- Durable
- Removable
- Eliminates construction and demolition waste in landfills

Hemp-Lime Solves Current Building Material Issues

Including:

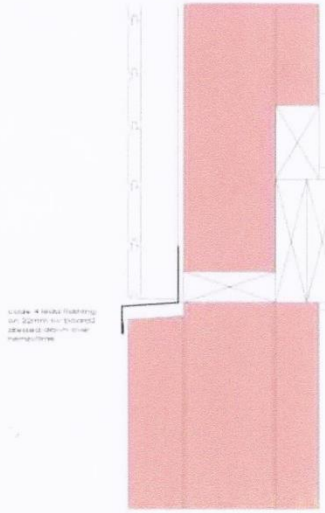
- Moisture accumulation in historic brick walls due to vapor-impermeable insulation
- Condensation in gaps between wall and insulation
- Pest attraction to insulation (e.g. fiberglass, soy based products)
- Embodied energy from non-renewable materials
- Exterior fire-resistant sheathing

Steve Allin – Building with Hemp
http://www.youtube.com/watch?v=FeW6kuZgPY4&feature=player_detailpage

Hemp-Lime – Different from Conventional Building

- No vapor barrier
- Fewer wall layers
- No air gap in ceiling between insulation and sheathing
- Material needs time to cure, as does the render (finish coat)
- Must use vapor-permeable sheathing, e.g. MgO board, not drywall
- Must use vapor-permeable paints, e.g. mineral paint
- Simple lime render as exterior finish
- Monolithic insulating protocols (eliminate gaps)
- Minimal maintenance requirements

First Floor Detail – developed after experience of construction



RALPH CARPENTER

Modece Architects

Friday 18th September 2009

In Sum: Hemp-Lime's Unique Properties

- Air-tight yet vapor-permeable
- Acts like passive air-conditioning system
- Highly flame-resistant without addition of toxic chemical flame retardants, e.g. PDBEs
- Recyclable, biodegradable
- Thermal & Hygroscopic qualities improve insulation performance
- R-value underestimates thermal performance – Studies show occupant comfort higher and fuel use lower than model predictions

Hemp-lime building systems are virtually unknown in the United States…

…but their use as a replacement material for existing insulation and concrete will have a substantial impact on emissions and waste in the built environment

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