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HEMP LIME TECHNOLOGY

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Abstract: *Combining patented formulations of air-lime based binders with the chopped core of the industrial hemp plant stem, delivers a suite of new building products. These Hemp-lime products have excellent performance characteristics for durable, healthy, sustainable and ecologically buildings. They deliver excellent application, combined with sustainability, economic, comfort and health qualities that architects, developers, contractors and customers will value.*

Key words: construction, composite materials, industrial hemp plant stem, health, environmental.

1. Introduction

Hemp (Cannabis sativa), an agricultural crop native to Central Asia, is now widespread throughout tropical and temperate climates.

Fig.1. *Cross section of hemp stalk* [5]

Fig. 2. *Fiber peeled from shiv* [5]

The versatility of hemp can be seen in the wide range of products made from its seed, fibers, shiv and leaf stock. Hemp's main application within the construction industry is lime-hemp [1],[5] .

Hemp is grown for many uses, but is most widely cultivated for the bast (phloem) fiber in the stem. The stem has 'two constituent parts: a fiber sheath around a woody core called shiv (Fig. 1), shive or hurd (Fig. 2).

The fiber is highly valued due to its length, strength and durability with a particular resistance to decay and has been heavily used for ropes, nets, sails and paper.

Hemp is one of the 'oldest sources of textile fibers, with extant remains of hempen cloth trailing back 6 millennia, [5], (Fig. 3).

In contrast to the high quality fiber, the shiv is the least valuable part of the plant. It does have some short fibers but is principally cellulose, 'chemically very close to wood, (Fig. 4).

With low tensile strength it is seen as a bi-product.

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Fig. 3. *Refined hemp fiber* [5]

The mechanical separation of the fibers from the shiv results in the shiv being broken into small pieces which until 1985 were predominantly used as animal bedding and mulch.

Fig. 4. *Shredded hemp shiv* [5]

It is this waste product that is now used within lime-hemp as a construction material, [5].

1.2. Hemp History

It is said that production from the hemp plant has 25,000 known uses. Certainly it was grown as a staple crop to provide oil for lighting and fibers for ropes, nets, rigging, cloth and paper. Hemp has been used for paper production for centuries. In fact, the Magna Carta and the American Declaration of Independence were written on hemp paper as was the first King James' Bible [7] .

Henry VIII passed a law requiring all farms over 60 acres to grow hemp to satisfy his naval requirements. However by the mid 20th century the growing of hemp was outlawed because of its narcotic content (cannabis). The narcotic content has been selectively bred out of the industrial crop and the first licenses for industrial grade hemp farming were issued by the UK Government in 1993. Industrial hemp is now undergoing a renaissance in numerous industries.

As well as in construction industry, hemp products, are being successfully used today in the automotive industry, [7].

2. Building Material

In construction, hemp's use began in France, in the mid 1980s. Shiv (Fig.4) was added to concrete as a less heavy aggregate in an attempt to lighten the wall construction.

The potential of this cheap waste product as an aggregate in construction soon became apparent.

A more sustainable approach to building has emerged at the same time, with the hemp shiv being used in conjunction with materials such as lime or clay.

Fig. 5. *Hemp-lime products(bricks)*

Fig. 6. *Hemp-lime products*

Currently hemp fibers can be used in construction in many different ways.
These products include hemp fibers particle boards, tiles, roofing elements, insulation materials, paneling and short fiber hemp bricks.

Fig. 7. *Hemp-lime products (insulation).*

2.1. Hemp-lime or Hempcrete?

Mixing the hemp shiv and lime with water creates the lightweight lime and hemp mixture that is sometimes referred to by the generic term *hempcrete.*

So, *hemp-lime* is a composite material that combines fast-growing renewable and carbon sequestrating plant-based aggregates (hemp shiv, Fig. 4) with a lime-based binder to form a lightweight material that is suited to various construction applications, including solid walls, roof insulation and under-floor insulation and as part of timber-framed building.

Together these products (hemp shiv and lime) form a bio-composite building material that can be used both for the creation of buildings that have excellent thermal and acoustic properties as well as creating a healthy living and working environment, [1] .

3. Hemp-lime Construction

The most typical form of hemp lime construction uses conventional timber frames with panels constructed of timber studs, and the hemp lime cast around the frame to create a solid wall.

There is often no need to use timber sheathing boards, breather membranes, internal finishes like plasterboard and external cladding which can make normal timber frame construction rather complicated, [1],[6].

Fig. 8. *Conventional timber frames with panels on walls and roofs [1]*

The hemp-lime provides a solid wall, acoustic and thermal insulation, and even an internal finish, [1] .
Hemp-lime can also be cast into bricks and for certain types, of buildings this may be more appropriate than casting it as a solid mass.

The bricks normally require a mortar bed of lime and sand and the overall wall will have different structural characteristics to one cast as a solid mass. Bricks walls are denser and thus will not have such good thermal insulation properties but will provide excellent thermal mass.

Hemp-lime bricks can be used to build solid walls or used as infill inside a frame construction.
Normally, the blocks do not have sufficient strength to be used like conventional concrete bricks though future experiments may produce stronger blocks incorporating fibers as well as shiv, [6] .

Hemp-lime bricks are being made to a compressive strength of 3.0 N/mm^2 although this is achieved through the use of a higher proportion of binder and some aggregate (sand). Blocks may be

appropriate for conservation work and have been inserted into old timber frames.
Hemp lime was first used in the renovation of historic buildings, particularly those with timber frames, and it is now often used in conservation work throughout Europe.

Fig. 9. *Hemp-lime bricks can be used to build solid walls*

The main purpose of this is to replace old wattle and daub of lime, mud straw and horse hair with a modern material. Hemp and lime has proved to be flexible and robust with very little shrinkage when it dries out and yet, being a natural material it works in harmony with the ancient wood frames.

4. Benefits and Capabilities

Combining patented formulations of air-lime based binders with the chopped core of the industrial hemp plant stem, delivers a suite of new building products.
Hemp-lime products deliver good application, durability and aesthetic performance characteristics combined with sustainability, economic, comfort and health qualities that architects, developers, contractors and customers will value, [7].

4.1. Design

Hemp-lime products permits architects and engineering to free their imaginations in building design. The products can be used for many structural systems new build and extension applications.
The lightweight nature of the wall form and insulation products means fewer supports and lighter foundations, saving cost and time, [7].

4.2. Application

Hemp-lime products have workability characteristics that make them easy to use. The longer pot-life of the binders combined with excellent plasticity increases the efficiency in the building process and reduces on site waste. The products can be cast into shuttering, moulds or forms or can be spray applied just like concrete or render, [7].

4.3. Durability

Hemp-lime products are a relatively recent
material but its origins lie in the technology of ancient buildings. The use of plant based materials mixed with mineral binders such as lime or clay go back thousands of years. Hemp-lime products have physical characteristics that can cope with the flexure that naturally occurs in buildings. The products are rodent, mould and fungus resistant and have excellent fire resistance to conform to current building regulations. The lime based binder has the extended durability common to lime construction products that have easily outlasted their designers, [7].

4.4. Sustainability

Hemp-lime products are among the most ecologically building products. Hemp does not require agrochemicals in it's cultivation and in common with all similar plants, transforms carbon dioxide during

its rapid growth and captures the carbon, releasing the oxygen into atmosphere.

This has an immediate positive effect in achieving the sequestration of the principal green house gas CO_2. The air lime based binders are formulated with products that have lower energy demands in manufacture and distribution. Hemp-lime products can be used in place of or alongside bricks and blocks, thus reducing the energy required to form building walls, to the benefit of the planet, [7].

4.5. Aesthetics, Comfort & Health

Hemp-lime products provide the possibility for a wide range of excellent quality finishes. These products can be finished in the normal manner to obtain a smooth finish. The hemp-lime products form an ideal substrate for the application of renders, plasters and decorative products.

Hemp products have a high thermal insulation that means they are comfortable to touch and can radiate a warmth in a room.

Their high vapour permeability, that facilitates the through transfer of humidity, avoids the development of condensation and trapped moisture within the building. This has combined effects of improving the air quality and controlling the humidity as well as reducing the potential for growth of irritant moulds and fungi that may affect occupant's health, [7].

4.6. Environmental and Carbon Balance

In these times there is a much greater awareness of the environmental impact of the way we live, than at any time in the past. International agreements like Kyoto [4] and reports such as the Stern Report [3] show that we must act now to combat climate change.

Hemp-lime materials presents a very low environmental impact, locks up carbon (negative emissions) and can create very thermally efficient, healthy, comfortable buildings, [2].

Carbon Balance [7]

In the big cities of the world the construction and use of buildings accounts over 50% of the CO_2 emissions. It is vital that we design and construct buildings that use as little energy as possible in their use. However, it is possible to make a significant additional contribution to the reduction of CO_2 emissions by building with natural products.

When hemp grows it takes in CO_2 and converts it into glucose, cellulose, hemi-cellulose and lignin. The CO_2 molecule is broken down, with the carbon locked up in the plant and the oxygen given back to the atmosphere. It takes 1.84 tons of CO_2 to make each tone of dry hemp. So the more hemp we use, the more CO_2 is removed from the atmosphere.

The materials used in the construction of the walls of a typical house are responsible for tens of tons of CO_2 emissions.

Current government targets are to improve the thermal performance of buildings to such an extent that the emissions from heating fuels can be reduced by 1.0 tons per year per house. The European Government has recently announced that he wants all houses to be zero-carbon by 2020, [7], [4].

4.7. Economics

Using ecological and natural materials construction costs can be lower than for current traditional building materials. These products are lightweight, low density and this allows greater efficiency in transportation and handling and thus saving cost.

The vapour permeability of the hemp lime products also means a reduction in the requirements for forced ventilation and de-humidification through the use of air-conditioning installations. [7]

5. Conclusions

This article includes a review of several documents consulted by the authors, in order to obtain a larger number of information about building materials made from hemp. The conclusions we obtained are presented below and render both the advantages and disadvantages of these materials.

Hemp can play an important role in construction due to its many uses in the field of construction materials. All products that are made from natural hemp, present properties like: there are 100% organic, biodegradable and carbon-positive (they absorb more carbon dioxide than issue). We can build an entire houses using only materials derived from hemp, [2].

The conclusions we obtained are:

- hemp composites materials can be used in a variety of construction applications;
- hemp-lime is a very versatile material because it can be used in many different ways. It can either be cast like concrete within shuttering or sprayed. It can be used as a plaster or cast as a floor screed. It can be cast into blocks or panels;
- it could also be used as ceiling insulation but this is uncommon;
- the mixture of hemp shiv and a lime-based binder with the addition of water produces a bio-composite material;
- as with the early use of hemp within concrete, in hemp-lime the shiv performs as a lightweight aggregate and the lime as binder and preservative. This composite material is rigid, lightweight and durable, while achieving high levels of thermal insulation and vapour permeability;
- the proportions of the hemp-lime can be varied according to the density and characteristics required;
- it has been used successfully on building interiors and exteriors. The mix adheres to most materials, steel, brick, concrete, old plaster and render, and wood. It may not stick so easily to plastic and synthetic materials. A big potential for the material is as an insulating plaster in the renovation of old buildings where it is not sensible to use dry lining and where other materials will not cope with dampness when applied to old walls.

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