The role of low impact building materials in sustainable construction: The potential for hemp

<table>
<thead>
<tr>
<th>Title</th>
<th>The role of low impact building materials in sustainable construction: The potential for hemp</th>
</tr>
</thead>
<tbody>
<tr>
<td>Keywords</td>
<td>sustainable, construction, hemp</td>
</tr>
<tr>
<td>Author(s)</td>
<td>Tom Woolley</td>
</tr>
<tr>
<td>Address</td>
<td>School of Architecture, Queens University Belfast BT9 5BY, UK</td>
</tr>
<tr>
<td>Telephone</td>
<td>0044 28 90 97 54 66</td>
</tr>
<tr>
<td>Fax</td>
<td></td>
</tr>
<tr>
<td>Mobile</td>
<td></td>
</tr>
<tr>
<td>e-mail</td>
<td><a href="mailto:t.woolley@qub.ac.uk">t.woolley@qub.ac.uk</a></td>
</tr>
<tr>
<td>Paper ID No</td>
<td>SB014</td>
</tr>
</tbody>
</table>

SUMMARY

The argument is advanced that sustainable construction, in many wealthy developed countries, involves tinkering with existing methods of construction instead of searching for real innovation. Conventional construction methods involve profligate resource use and create both external and internal pollution. Work on environmental assessment tools largely fail to take a global perspective on resource consumption and thus continue to use expensive materials at a high rate. An alternative is developing known as ‘Natural Building’ which tries to use materials and building methods which have a lower impact and use renewable materials.

One example of this is the use of hemp composites and the paper sets out some of the work that has been done in Europe on building with hemp. Hemp can be used for wall, floors and roofs and can be mixed with lime or clay to create an insulating, breathing composite. The paper outlines some of the research and development work which is investigating the best ways to use hemp and raises the possibility of hemp construction being a solution to sustainable construction in Africa.
THE ROLE OF LOW IMPACT BUILDING MATERIALS IN SUSTAINABLE CONSTRUCTION: THE POTENTIAL FOR HEMP

Tom Woolley

Queens University Belfast School of Architecture, UK

1 Sustainable construction as low impact building

There is a substantial body of literature on sustainable building. Much of it is concerned with justifying the continuance of conventional construction methods. A few changes are proposed in terms of better energy efficiency, construction management, less wastage and the inclusion of new technologies. This tinkering with present methods is backed up by a host of environmental assessment tools and standards that are designed as much to improve the image of the construction industry, as they are to ensure genuine sustainability. The small changes that result from these measures are usually justified on the basis that the construction industry is only willing to make small changes and cannot change overnight. Doing a little is seen as better than nothing. Invariably discussion in wealthy northern countries is only of resource efficiency, not resource depletion. (DTI Better Buildings Report 2004)

In global terms, developed countries use energy and resources to fuel their construction industry that is wasteful and way beyond the ability of the planet to support such profligate consumption. Mass materials like cement and concrete cause significant pollution; use a lot of energy and non-renewable resources. Many of the materials such as insulation and finishes contain toxic chemical like brominated fire retardants which can seriously damage our health as well as the ecosystem. (Environmental Building news 2004)

One response to this "greenwash" approach to sustainable construction has been to look for alternative methods of construction which significantly reduce resource consumption, provide energy efficiency without causing pollution, damaging health and eco-systems. This approach has become known as “Natural Building.” While it is a term to be used with care it represents attempts, particularly in rich developed countries to substitute a much lower impact technology for that which is currently used. (Kennedy Smith and Wanek 2002) (Elizabeth and Adams 2000) The aim of natural building is to use materials and technologies which minimise the depletion of planetary resources and thus to reduce or eliminate dangerous and damaging materials such as cement and toxic chemicals.

Natural building began with the work of “mavericks and passionate visionaries” (Elizabeth and Adams op.cit.) creating shacks in the woods without too much concern for planning or building control approval. However there has been a lot of work to try and ‘main-stream’ the use of low impact natural materials so that these methods can be taken up and used by the construction industry. It is important when adopting this approach to develop forms of construction, which are as good as, if not better than conventional building.

It is also assumed by many people and professionals that using green materials or technology will be much more expensive, but the aim of the natural building movement is for such materials to be as economical, if not cheaper than conventional, to be of a high standard and have a very good life cycle performance.
<table>
<thead>
<tr>
<th>Conventional building</th>
<th>Natural Building</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uses Non renewable resources and material</td>
<td>Uses renewable materials which can be grown and provide cash to farmers</td>
</tr>
<tr>
<td>Uses a lot of energy in extraction – high embodied energy</td>
<td>Uses material which need little energy to extract</td>
</tr>
<tr>
<td>Significant transportation costs</td>
<td>Should use local materials</td>
</tr>
<tr>
<td>Extraction Is often damaging and causes social problems</td>
<td>Uses material such as clay which is of low impact</td>
</tr>
<tr>
<td>Many metals and other polluting materials are extracted and refined in poor countries and shipped to rich</td>
<td>Materials are extracted and processed locally</td>
</tr>
<tr>
<td>Significant energy and chemicals are used to create energy efficient solutions</td>
<td>Generally little energy used</td>
</tr>
<tr>
<td>External air pollution caused by manufacturing processes</td>
<td>Virtually no external pollution</td>
</tr>
<tr>
<td>Internal pollution due to the use of toxic additives like solvents</td>
<td>Natural materials rarely cause health problems if handled properly and not treated with toxic fire retardants etc.</td>
</tr>
<tr>
<td>Waste in manufacturing and installation is a normal part of processes</td>
<td>Little waste if care is taken</td>
</tr>
<tr>
<td>Damage to eco systems at end of life disposal</td>
<td>End of life can be recycled or returned to the earth and decompose naturally.</td>
</tr>
</tbody>
</table>

Table 1: Comparison of possible benefits of conventional and natural materials

2 Obstacles to the use of natural materials

If natural materials are so more sustainable, then why are they not used commonly? In many poorer countries buildings are made from earth and straw and other local materials, however there are a lot of pressures to use modern materials such as cement, concrete and steel, even when these are much more expensive. Where economic standards are rising in less developed countries it is understandable that people want modern materials and forms of construction using concrete, steel and aluminium. In developed countries buildings are symbols and wealth and power and natural materials seem less able to meet these aspirations.

Our work on this subject over recent years has shown that there is little Governmental support for environmental products (Woolley and Caleyron 2003) and attempts to gain research grants has revealed the extent to which the vested interests of main stream construction influence state funding. The power and influence of the mainstream global construction materials groups should not be underestimated and their vested interests are well protected against attempts to introduce environmental reforms.

3 The growth of interest in non-food crops for industry and bio/eco composites

Despite attempts to maintain conventional industrial processes, environmental legislation, particularly in Europe, is changing the market. A good example of this has
been the rise in use of bio composite materials. The internal linings of cars, previously made from synthetic plastics are now made from hemp. There are a wide range of natural insulation products made from hemp, flax, wool, wood waste and recycled cellulose. The German Government has subsidised this development in the teeth of opposition from the synthetic fibre industry. There has been a small growth in the use of crops grown for natural oils both for industrial uses, pharmaceuticals and paints. In the UK the Department of Environment, Food and Rural Affairs (DEFRA) has recently established the National Non Food Crops Centre in York and this body is funding innovative research and development work in renewable materials. (www.nnfccc.co.uk)

Photo 1: **Hemcore Horse bedding used in hemp construction in UK**

### 4 Hemp as a natural building material

One of the most interesting renewable materials is hemp. Like many natural materials it has been used for centuries as a reinforcing binder in “concrete,” in drainage work and for rope and cloth making. So important was hemp that in the UK there are many towns, streets and places that include Hemp in the name. (Woolley 2002) Hemp production was largely discontinued as synthetic replacements were developed such as nylon. So vigorous were companies developing nylon and other products in their efforts to eliminate hemp that they used fears about marijuana as a dangerous drug to make hemp an illegal material in the USA and other countries.

Fortunately in countries like France and Hungary, the genetic pool of seed for hemp was kept alive and hemp has been grown in large quantities for many years, particularly for quality paper production. The use of hemp for building is a by-product of this industry. Indeed hemp can be grown for a wide variety of products, the seed and fibre being valuable commodities used for a variety of purposes including food and oil. The left over straw, hurd of shive can be chopped up and used for building. (Leson, Pless and Rulac 1999)(Journal of Industrial Hemp 2002)

Chopped hemp is frequently used as a loose insulation material, though it requires treatment with borax salts or other material to ensure that the fire risk is minimised. To date we have not been able to do any tests on the fire issues or the levels of insulation achievable and have found little literature published on this topic. The main experience of hemp is as a composite mixed with lime that can be cast as a solid wall.

The use of hemp lime composites for building began with the conservation of historic buildings where it became necessary to replace old wattle and daub infill materials in
medieval half-timbered buildings. The hemp and lime mix seemed free of shrinkage and provided a fire resistant weatherproof material which looked much the same as wattle and daub. The potential of this material for new buildings was recognised and has been developed in France and Canada. There are now several hundred hemp buildings in France and a number of businesses either selling materials or carrying out hemp building as contractors. There is a hemp building association in France. (www.construction-chanvre.asso.fr)

5 Hemp walling

Chopped hemp hurd can be mixed with a range of building limes and cast as a form of “concrete” to create walls. The normal practice is to do this around a timber stick frame using plywood shuttering. The lime in the mixture helps to preserve the timber frame and the hemp lime mixture sticks to the wood very well. This creates a composite structure that is very strong. This form of walling is also a breathing wall, allowing the passage of moisture vapour. The hemp is able to absorb quite high quantities of water and then release it again without damage. However it is normal to render the outside of a hemp wall with a lime plaster to keep the rain off. The composite provides a reasonably good level of thermal insulation with the added advantage of retaining warmth due to its thermal mass. There are very few materials which are both an insulant and able to retain warmth. This makes the material especially good for climates where there is a high level of humidity.

It is relatively easy to construct hemp walls; joinery skills are needed to create the timber frame and to construct the shuttering plywood. The hemp is mixed and then placed into the formwork with a little light tamping. The material is strong enough for the formwork to be removed almost immediately. The wall can be constructed in several continuous lifts and then takes 2 weeks to dry out and 2-3 months to reach its full strength.

Our experimental work at Queens University has involved seeing how the technology can be stretched from the normal method of hemp construction with a timber frame. Tests so far show that the material is relatively strong in compression but we have not yet established whether a whole section of wall can be safely constructed without a timber frame. Some work has been done on building with hemp lime blocks but these are not as strong as walls that are cast in situ. We have also started the long process of examining a range of mixes in which hemp can be mixed with different forms of lime and also with clay. One French company recommends using hydraulic lime with 'mineralised' hemp whereas a rival company uses untreated hemp with a mixture of hydrated and hydraulic lime.

We have applied for research funding to investigate the different mixes and properties of the material and there is much work still to be done. Initial findings suggest that there is no difference between chopped hurd that has not been treated, other than to be cleaned and dried and so-called mineralised hemp. As the mineralising process is secret, it is hard to check scientifically, but when hemp is mixed with lime it enjoys a natural protection from decay for the biocidal properties of the lime.
Hemp and hydraulic lime can be cast as a floor slab or screed and there are many examples of where this has been done successfully. Due to the waterproofing qualities of hydraulic lime it is possible to cast floors directly onto hardcore without the use of a damp proof membrane. Hemp and lime, with a weaker mix of lime can also be cast into roofs as a form of warm roof construction.

7 Practicalities of building

While hemp is relatively simple to build with it is critical to ensure that mixes are correct and consistent. Using building limes involves greater care and knowledge than using
cement and it is necessary to ensure that the correct lime is used for the situation. The environmental impact of lime is about 80% that of cement because energy must be used to convert limestone into building lime. However lime can be manufactured at a local level with small-scale limekilns. (Wingate 1985) (Holmes and Wingate 1997) (Foresight Lime Research Team 2003)

The work we have done at Queens University has confirmed that Canadian work on mixing hemp with Earth also has great potential. A hemp and clay mix seems to be very stable and has the properties and ease of construction as cob but the potential for thinner walls similar to rammed earth. Much work has to be done on whether it is necessary to add lime or other materials as a stabiliser, but hemp mixed with earth would be more environmentally friendly with a much lower embodied energy than a lime mix.

The 'normal' form of hemp construction uses a conventional timber frame but we have also done some work on using a range of timber frame alternatives. This includes using green forest thinnings, simple wattles and composite I beams. A great deal more work needs to be done to investigate ways of reducing the amount of timber used in hemp construction.

8 Research in the field

Important work has been published by the UK Building Research Establishment about two experimental hemp lime houses in Haverhill in Essex. Designed by Modece Architects this low cost, housing association project, has been carefully monitored and the results of this work published on the Internet. (www.suffolkhousing.org) (www.bre.co.uk) The BRE Haverhill reports have confirmed reasonably good performance from these buildings when compared with two identical brick clad houses. However the results on thermal performance were inconclusive.

Photo 4: Thermographic image of hemp house in Haverhill (photo BRE)

More in depth research has been done in France by Laurent Arnaud and others at ENTPE in Lyon. Their work has considered the variety of composites, physical characteristics of hemp and lime including mass and porosity. They have published data on moisture characteristics, thermal performance, structural strength, acoustic properties and ability to withstand fire and degradation. (Construire en Chanvre Betons 2003)
9 Potential in Africa?

Some work has already been carried out in South Africa into the growing of different varieties of hemp. If marijuana grows well then hemp will also grow but it is important to find out which variety best suits the climatic conditions. Hemp does not need fertiliser or pesticides and will grow in fairly wet or dry conditions. Harvesting and processing presents particular demands, as this will determine the quality of fibre and seed. Good processing equipment is also needed to chop hemp for building. However this can be done with relatively low technology equipment if large processing factories are not available.

Hemp can be mixed with lime for a high quality walling product but if lime is not available then hemp mixed with earth or clay would be a very good substitute. This has the potential to create a sophisticated natural building material that could be used at relatively low cost in many parts of Africa.

While it has become fashionable in some wealthy parts of the world to use natural materials like straw and earth for buildings. In California, some second homes of wealthy people are made with straw-bale walls for instance. In developing countries many people want to use more modern and high tech materials as these symbolise progress and economic improvement. As a result multi national businesses are importing technologies based on cement and similar materials into poorer parts of the world. If the natural building alternatives to this are perceived to be more like “mud huts” than modern building, then this may not be very attractive to many people who want a higher standard of living. However hemp and lime or hemp and clay composite walls can be formed to look very modern and sophisticated. Main stream construction companies can also use the technology. Thus it has the benefit of being a very low impact, environmentally responsible material, but with the appearance of a modern concrete building, if that is what is required.

If hemp is grown and processed at a local level if can provide a valuable cash crop for farmers in Africa. The seed or fibre can be sold and the left over straw used as a building material. The chopped hemp hurd can be dried and cleaned of dust and sold in bags, with or without the correct lime or clay mixes. The use of the technology in building can be taught very easily and used at a local level either by communities, self-builders or contractors. It is much less labour intensive than mud walling which involves mixing straw and clay. The hemp binds the material together so that it is much stronger. It is also flexible and therefore potentially a very useful form of construction in earthquake areas.

10 References


Bob Berkebile in Elizabeth and Adams op cit.p.xii


*Journal of Industrial Hemp*, Production, Processing and Products Vol. 7 Number 1 2002 ISSN: 1537-7881 Haworth Press Inc.([www.haworthpressinc.com](http://www.haworthpressinc.com))


[www.bre.co.uk/pdf/hemphomes.pdf](http://www.bre.co.uk/pdf/hemphomes.pdf)

[www.construction-chanvre.asso.fr](http://www.construction-chanvre.asso.fr)

[www.nnfcc.co.uk](http://www.nnfcc.co.uk)

[www.suffolkhousing.org](http://www.suffolkhousing.org)