

LOW CARBON BUILDINGS AND TRADITIONAL MATERIALS

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ABSTRACT

The necessity, driven by Government legislation, to deliver more energy efficient buildings with significantly lower climate change impact is supporting the development of new uses for traditional materials, such as straw, hemp, timber and unfired clay. Many traditional, also called natural, materials offer low carbon and sustainable sources of materials for modern building. Plant based materials store carbon through photosynthesis. Unfired clay requires very little processing. However, traditional materials face many challenges in the reintroduction into modern construction, including: the high cost of labour (in the UK); shortage of skills in design and construction; limited performance data; and, limited supply chain.

This paper briefly summarises some recent developments in the UK in the use of unfired clay masonry, hemp-lime composites and modern prefabricated straw bale building. The BRE Centre for Innovative Construction Materials at the University of Bath is leading research into a variety of low carbon building materials.

INTRODUCTION

Plants, including trees (timber), reed, straw, bamboo, and hemp, have provided the raw materials for building throughout much of human history. Many vernacular techniques around the world continue to rely on natural and locally sourced materials. Although the industrial revolution displaced many natural technologies, concerns over the environmental impacts of building and infrastructure have stimulated a renewal of interest in plant crop based materials, such as hemp and straw, and use of unfired clay building techniques such as rammed earth and cob.

Using plant based materials reduces the climate change impact of building development, achieved through use of a sustainably grown renewable resource and the atmospheric CO₂ used up by the plants during their growth. Plant based materials offer other benefits, including very high levels of thermal insulation, passive hygrothermal regulation of building spaces, providing healthier living spaces.

The paper briefly summarises some recent developments in the UK in the use of unfired clay masonry, hemp-lime composites and modern prefabricated straw bale building. The BRE Centre for Innovative Construction Materials at the University of Bath is leading research into a variety of low carbon building materials.

HEMP-LIME CONSTRUCTION

Hemp-lime is a lightweight composite building material that combines renewable plant based aggregates (hemp shiv) with a lime based binder. It is a non-structural material used for walls, roof and under-floor insulation. It is used together with a structural frame, typically of timber construction. The lime binds together the hemp together and protects the shiv from biological decay as well as providing fire resistance.

The shiv used in hemp-lime is sourced from the stem of the hemp plant (*cannabis sativa*). Hemp is an industrial bast fibre crop grown as a break crop in the UK between April and September. After harvesting the higher value outer fibres are stripped away from the inner stem. The shiv is made by cutting the inner stems into chips between 4 and 25 mm in size. Around 60% by mass of the hemp plant is comprised of shiv, with typical total plant yields in the UK of around 8–12 tonnes per hectare.

Hemp shiv is very hydrophilic, with a capacity to absorb up to 450% of its own weight in water. Rapid de-watering of the binder by the hemp during initial mixing can significantly impair the hydraulic set. This has led to the development of specialist formulated lime based binders for hemp construction. These formulated binders are blends of hydrated lime, cement, and pozzolanic additions (such as ground granulated blast furnace slag). The binder initially sets hydraulically and then hardens further through carbonation.

Hemp-lime materials are either cast (lightly tamped) inside formwork (figure 1) or spray applied in-situ (figure 2). Mix proportions of hemp shiv, lime binder and water vary depending on use (wall, floor or roof mixes) and the method of application (casting or spraying). Cast walls are lightly tamped horizontally inside formwork. Sprayed hemp-lime is applied in vertical layers against one layer of permanent formwork. Following initial set and drying the hemp-lime is finished off with a breathable plaster or render, generally lime based.

As well as hemp-lime hemp fibres are also used in construction, to produce insulation quilted batts. Products often include polyester fibres, to improve 'loft' and stability. Hemp-fibre insulation quilt is suitable for a wide variety of building applications, including external walls. Like many other natural materials it is hygroscopic, which enhances its heat storage capacity.

Current research on hemp-lime construction at the University of Bath is focussing on basic characterisation of materials, better understanding of hygroscopic aspects of behaviour and investigating structural performance of composite walls. Although hemp-lime has modest structural properties (compressive strengths around 0.1-0.2 N/mm² typically), by encapsulating the structural timber framework it offers sufficient restraint to prevent premature buckling failure of the compression studs, enhancing compressive load capacity by up to 4-5 times.

MODERN STRAW BALE CONSTRUCTION

Straw bale construction has been used, to varying extents, for over 100 years. Bales may be used to form modest loadbearing walls or as in-fill material in framed construction. Bales are a cheap and abundant renewable crop based resource. But despite success in a number of largely self-build projects, there has been little wider uptake of straw bale. Barriers to wider adoption include uncertainty over technical performance characteristics (especially durability and fire resistance of straw) and high manufacture costs of on-site construction subject to delays due to inclement weather. Although modular in size (nominally 450 mm wide x 350 mm high x 1000 mm long) dimensions and compaction density can also vary significantly; bale lengths can easily vary by ± 100 mm. This causes problems for construction and robust detailing. Loadbearing construction relies on a period of settlement prior to the application of the render, prolonging the period of construction.

Development of off-site prefabricated straw bale panelised construction seeks to overcome these barriers. One approach, ModCell™, uses timber framed panels in-filled with straw bales. Panels are typically 490 mm thick, with varying heights and widths to suit. The thermal transmittance of these panels is 0.19 W/m²K. In construction the straw bales are compressed vertically to improve their structural robustness and dimensional regularity in preparation to receive plasters, renders or timber based fascias. On completion of straw infill and compaction the internal and external faces of the panels are covered in a formulated lime based render (figure 3). It is important that the bales remain for prolonged periods at moisture content levels below which biological decay is likely to occur (around 25%). The facings must therefore protect the bales from direct weathering but also allow water vapour to escape as part of a breathing wall system.

The University of Bath has played a leading role in development of the ModCell system. Tests completed to date include lateral wind load resistance (in and out of plane), fire resistance, thermal transmittance and acoustic resistance.

UNFIRED CLAY MASONRY

Although traditional earthen architecture, such as rammed earth and cob, has stimulated a renewal in interest of building with unfired clay, there is limited scope for wider adoption of these technologies in modern building in the UK. In particular their reliance of labour renders them more expensive compared to contemporary methods of building. However, the use unfired clay brick masonry offers modern cost effective alternative to fired clay or concrete blocks masonry in internal applications, where only modest structural requirements are necessary, such as low rise housing.

A focus on thin (100-150 mm) thick unfired clay walls has necessitated research on mortar development as traditional unfired clay mortars have insufficient bond strength for such slender walls. Work at the University of Bath has successfully developed alternative clay based mortars using novel stabilisers, such as sodium silicate and liginosulphinate.

SUMMARY

Natural building materials, such as hemp, straw and unfired clay, offer exciting new opportunities, broadening the range of materials available to the designer, builder and client. Although their use still remains a small fraction of mainstream construction, interest in these technologies has never been greater. Initiatives in response to climate change, including the Code for Sustainable Homes, has provided the framework and stimulus for this increased interest and encouraged growth in the use of lower carbon building materials. To enable wider market development requires further research and innovation to overcome technical and commercial barriers, supported by both government and private investment.



Figure 1. Cast hemp-lime panel



Figure 2. Spraying hemp-lime (Lime Technology Ltd)



Figure 3. Spraying lime render on ModCell panel