Agro-food chain entering construction market

Product development from renewable resources

For a long time, building with materials of organic origin apart from wood, was not seen as suitable for mainstream construction. However, recent developments in research and technology have provided scientific insight into performance and led to the development of professional products for the construction industry. Production facilities are being built and new products introduced onto the market. However, there are many more options available which should be investigated, as discussed by Jan van Dam.

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Renewable plant materials for building applications

Sources for renewable building materials can be found in the woody tissues of all plants – the ligno-cellulosic fibres – combined with the protecting mechanisms nature provides against moisture and the invasion of micro-organisms. Waxes and oils, tannin and lignin, proteins, silica and many other plant constituents have interesting natural properties that can be exploited for building products, coatings, adhesives, additives and protective agents. Methods need to be developed to produce and commercialise these components as novel "green chemical" resources for building applications.

Fibre crops

Fibre crops can play a more prominent role in building and construction applications as fibre board material (Van Dam 2004a,b, Fig. 2c), insulation material, and reinforcement or filler in many different composite products. In lightweight concrete, bricks and loam building blocks (Fig. 1c), cellulosic fibres are known to have good properties. For processing in thermoplastic and thermosetting polymers various ligno-cellulosic fibres have been extensively studied and shown to perform well. New applications for fibre composite materials are emerging, starting with the automotive industries, with a large potential for building applications as well.

The technical performance of thermal insulation materials based on natural fibres (hemp, flax, jute, coir, etc., Fig 1b, 2a) and

The construction industry is contributing greatly to the depletion of resources, waste generation and energy consumption (Vanegas et al., 1996), while the built environment is vital to economic development (Emmanuel, 2004). Promoting the utilisation of renewable resources and CO_2-neutral building materials can only be considered sustainable when this does not result in more rapid deforestation and its effects on bio-diversity. Renewable resources have been used as major building and construction materials since mankind left the caves. So when the age of steel and concrete construction comes to an end, wood and straw-based building products should be developed and promoted for industrial-scale construction systems. Switching to alternative building methods utilising ecologically sustainable products derived from by-products of the agro-food chain, combined with safe binders, coatings and additives, could dramatically alter the impact of the building industry on the environment.

Innovation in the building industry is at present mainly dictated by environmental legislation intended to result in more sustainable building. To enhance the ecological performance of buildings a great deal of effort has gone into research on ways to reduce energy consumption during the building materials production process, and into recycling building and demolition waste.

One of the main areas of concern in international environmental policy is the limited availability of many resources that are now consumed in vast quantities for human needs. The policy to restrict the use of petrochemical resources and the extraction of minerals, ores, lime and sand in the near future, has so far been

cellulose is good (Valovirta and Vinha, 2002). The ecological profile compared with the energy requirement for the production of mineral wool insulation or expanded polystyrene can also be assumed to be positive, despite the lack of detailed data (Hoefnagels et al., 1994). However, a publication of the stone wool industries counters these arguments and reaches the opposite conclusion for mineral wool insulation products, claiming that these products have the lowest total energy consumption (Schmidt et al., 2004).

The use of fibre crops in fibre boards (Fig 1 a, 2b) for building has to compete with wood fibres. Substitution will only be feasible when the fibres can be produced more cheaply than wood chips or the performance of the product exceeds that of wood-based building products. In most cases the amount of synthetic or natural glue or resin required to bind the fibres to form strong board materials is greater than for non-wood fibres. This will have a negative impact on the economics of the board product and its ecological performance (LCA).
Coatings, paints and adhesives required for the production of high performance and durable building products from renewable resources are currently largely based on petrochemical products. To increase the environmental performance of these building materials, the use of varnishes, paints and coatings based on plant oils should be promoted. Similarly, natural resins derived from plants (e.g. lignin, furans) are being developed on a commercial scale and are becoming available as adhesives and components in protective coatings.

Board from wood fibres

Insulation from non-woven jute

Reed, bamboo and straw

Thatched roofs are still common on old farms and rural villas in Western Europe. However, the harvesting of reed and cane for thatching has declined in recent decades, even though the positive effects of reed cutting on landscape management in swamp areas are recognised. Novel methods for processing and applying reed and cane in prefab roofing are of interest. Therefore, the development of ecologically safe additives for protection against fire and preliminary decay are essential.

limited. The major result has been promotion of the use of more certified sustainable wood (FSC) and wood products. However, besides wood, there are a large number of renewable resources, such as hemp, flax, cork, reed, shells, paper and straw, which could potentially be used in building and construction[1] that are receiving renewed interest in environmental architecture.

As one of the major buyers and users of resources the building industry is jointly responsible for sustainable developments in the building production chains. Quantified life cycle assessment (LCA) for renewable alternatives compared to the building products currently used would provide an objective tool for decision-makers involved in planning, design and construction, to select the most sustainable option. Apart from economic or aesthetic arguments, the functionality of alternative building products should also be of an equivalent standard.

This paper discusses the possibilities for ecological product innovation in the building industry. Which niche markets offer the best opportunities for the application of renewable resources as a substitute for synthetic petrochemical products or minerals? The technological and economic feasibility of novel developments for renewable products in building applications has to be established. The aim of the "Agrodôme" project in Wageningen is to provide a foundation for sustainable building by demonstrating the potential of construction using renewable building products as much as possible[2].

1 *Tjeerdsma, B.F., Van Dam, J.E.G., and Fraanje, P.J., "Hernieuwbare grondstoffen als bouwmateriaal; tien leverbare producten (publ. Min. LNV/VROM, ISBN:90-901628 3-6) [Renewable resources as building materials: ten commercially available products].*

2 *www.agrodome.nl*

Panels from fibre-cement

Flax-wool insulation

Building and construction with bamboo is common practice in China and many tropical countries (Janssen, 2000) and is now being investigated as "tomorrow's timber" for use in innovative designs in Europe too (Van der Lugt et al., 2003).

Straw bale building has been widely demonstrated and results in reliable structures with outstanding architectural possibilities. Straw bale building is commonly combined with lattice truss or timber frame building and loam or lime plaster cover. So far this type of traditional building has been carried out only by craftsmen and no commercial building system has yet been developed using these materials on larger scale. Development of standard size building blocks and prefab elements could help to reintroduce the straw based building products. Another way of applying straw in building elements may be in the use of silica ashes derived from rice husks or straw, which could be used as a renewable pozzolanic additive in cement paste (Zhang et al., 1996).

Plant components as coatings, adhesives and additives

Plant oils have traditionally been used in building applications such as varnishes, coatings and putty. These mainly linseed oil based products are still available on the market, despite the stiff competition from synthetics. Even new water-based products have entered the market due to restrictions on the use of volatile organic solvents. Tall oil and rosin as a by-product of paper pulp production, finds industrial use in adhesive formulations and specialty products.

Apart from cellulosic fibres, biomass is largely composed of lignin which binds the fibres together and gives strength and stiffness to all woody tissues. In paper production the lignin is largely liberated as a black liquor and used as fuel. Lignin is a highly underestimated resource that has many valuable properties. Apart from gluing fibres as a natural resin, the antioxidant and anti-microbial properties of lignin protect the plant from preliminary decay. Development of novel wood-protecting agents based on lignin is currently being investigated. Ligno-sulphonate is currently used as a plasticizer in concrete processing. Similarly, many other organic plant components such as tannin, furfural and proteins could be more widely applied in "green chemical" products and used in building materials. Proteins can be used as a glue or foaming agent in cellular concrete. Furfural-based resins could substitute phenolic resins for use in fibre boards, veneers, multiply and oriented strand boards.

Many other options for the use of plant (or animal) products in ecological building could be discussed. However, the effects of these on the environmental impact of building materials is poorly documented. The impact of the usage phase on the LCA of building products in particular, should be included in decision-support when choosing materials (Paulsen and Borg, 2003).

Agrodôme demonstration project

The purpose of the Agrodôme demonstration building project in Wageningen is to construct four houses composed largely of renewable raw materials. The selection of building materials was primarily based on commercially available renewable products and partly on experimental and novel ecological products from commercial partners. The aim is to show the construction industry that building with alternative materials can produce an attractive and comfortable house at a lower cost in terms of fossil fuel resources.

Important aspects of the project are monitoring the performance of the building products at all stages of the project, from the design and construction phase to the utilisation phase, including maintenance, indoor climate and emissions. Highly relevant to the selection of materials in building and construction is the effect on indoor climate and the comfort and wellbeing experienced by the residents. Despite the fact that people spend much of their time in their home, this aspect is largely neglected in the scientific literature.

Binderless board from coconut shells

After successful laboratory experiments at A&F Wageningen, The Netherlands, for the production of binder less board from whole coconut husks, currently in the Philippines production trials are being performed on pilot scale. In this process the high lignin content of the husk is used as thermosetting resin and no additional chemicals are required.

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