Notes
6. At first, social criteria were deliberately kept in the background, mainly because at this point the discussion of social indicators on both the national and international level has not yet reached a level equal to that of the development of environmental and economic indicators.

Construction products and life-cycle thinking

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Summary
Life-cycle concepts, in the context of the building and construction sector, are particularly suit- ed to analysis of building products. Such products play an essential role in increasing the energy efficiency of buildings and contributing to economic prosperity. It has been estimated that the construction sector is responsible for up to half of material resources taken from nature and of total waste generation. To manage and minimize the impacts of construction products, the impacts have to be measured using a life-cycle approach. This article reviews life-cycle concepts and considers recent developments. Materials and sustainable construction, environmental product declarations, embodied energy and differences encountered in the assessment of construction products in the North and South are among the topics addressed.

Résumé
Dans le contexte du bâtiment, les concepts fondés sur le cycle de vie se prêtent particulièrement bien à l’analyse des produits de construction, lesquels jouent un rôle essentiel dans l’amélioration de l’efficacité énergétique des bâtiments et la prospérité économique. On estime que le secteur du bâtiment est responsable de près de la moitié des ressources naturelles consommées et du volume total de déchets produits. Pour gérer et limiter le plus possible les impacts des produits de construction, il faut pouvoir les mesurer selon une méthode fondée sur le cycle de vie. L’article fait le point sur les concepts liés au cycle de vie et sur les tendances récentes dans ce domaine. Matériaux et techniques de construction durables, déclarations de produits respectueux de l’environnement, contenu énergétique et différences entre le Nord et le Sud dans la façon d’évaluer les produits de construction figurent parmi les sujets abordés.

Resumen
Los conceptos de ciclo de vida, en el contexto del sector de la construcción y edificios, resultan particularmente apropiados para los productos de construcción. Estos productos desempeñan un papel capital para el aumento de la eficiencia energética de los edificios y el desarrollo de la prosperidad económica. Según estimados, el sector de la construcción utiliza la mitad de los recursos materiales provenientes de la naturaleza y es responsable de la mitad de todos los desechos generados. Para poder administrar y minimizing el impacto de los productos de construcción, es necesario medir dicho impacto utilizando criterios de ciclo de vida. Los autores examinan conceptos de ciclo de vida y analizan la evolución reciente. Algunos de los temas tratados son: materiales y construcción sostenible, declaraciones de productos ambientales, energía incorporada y diferencias en la evaluación de productos de construcción en el Norte y el Sur.

Different contexts for considering construction products: North and South
When considering differences related to construction products in the North and South, it is important to make a distinction between “global” and “local” construction. At the most simplistic level, this can be considered as a split between city-based commercial buildings and dwellings, and rural dwellings and public buildings. The distinction can also be applied to products required to
create the buildings. There are inherent differences in the nature of materials, the technologies used in extraction and manufacture, and health and safety issues for workers involved in construction product manufacture and construction activities. Global construction products (whether globally traded or locally produced) include cement, steel, aluminium, glass and timber. Local products might include local fired/unfired brick, rammed earth, local timber, bamboo, and other renewable products.

Modern building materials can also have a place in local dwellings. The balance must be made between the desirable qualities of indigenous, traditional materials in terms of internal comfort and relatively benign environmental impacts, and the social need for providing quickly constructed, affordable housing solutions on a mass scale. The decision to use different materials will be influenced by a number of factors; for example, M batu (corrugated sheet) roofs are now commonly used across Africa despite the fact that they offer less protection against extreme temperatures than traditional thatch. To illustrate the complexity of the situation, one of the reasons for this choice is that house owners do not have land rights to grow the thatch material. Clearly the most pressing concern in Southern countries must be the achievement of better living conditions. However, an increasing number of solutions for affordable housing are being imported to the South, often with international funding. Work is urgently needed to understand the social, economic and environmental implications of different products and building solutions. The findings should be fed into national housing strategies and those of the lenders and aid providers, in order to plan ahead and ensure that the best overall solutions are provided.

This article focuses on initiatives related to “global” construction products, as defined above, because this is the area in which the most work has been carried out to date. However, life-cycle thinking has a role in construction at every level. For this reason, many of the concepts discussed are also of relevance to local construction techniques in Southern countries.

Another aspect of international relationships, often overlooked, is information transfer from South to North. Plenty of products with better than average sustainability credentials are already available in the North but remain marginalized: clay reed boards, unfired bricks, hemp lime blocks, and straw or earth buildings to name but a few. A research project on “unburnt dry building products” estimated that these products (bricks, tiles, blocks, boards and plasters) have less than half the overall sustainability credentials are already available in the North but remain marginalized: clay reed boards, unfired bricks, hemp lime blocks, and straw or earth buildings to name but a few. A research project on “unburnt dry building products” estimated that these products (bricks, tiles, blocks, boards and plasters) have less than half the environmental impacts, and the social need for providing quickly constructed, affordable housing solutions on a mass scale. The decision to use different materials will be influenced by a number of factors; for example, M batu (corrugated sheet) roofs are now commonly used across Africa despite the fact that they offer less protection against extreme temperatures than traditional thatch. To illustrate the complexity of the situation, one of the reasons for this choice is that house owners do not have land rights to grow the thatch material. Clearly the most pressing concern in Southern countries must be the achievement of better living conditions. However, an increasing number of solutions for affordable housing are being imported to the South, often with international funding. Work is urgently needed to understand the social, economic and environmental implications of different products and building solutions. The findings should be fed into national housing strategies and those of the lenders and aid providers, in order to plan ahead and ensure that the best overall solutions are provided.

Table 1

<table>
<thead>
<tr>
<th>Country</th>
<th>Programme organizer</th>
<th>LCA schemes for materials and buildings</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH</td>
<td>SIA (Swiss Society of Engineers and Architects)</td>
<td>SIA declaration matrix</td>
<td>1994</td>
</tr>
<tr>
<td>D</td>
<td>Stuttgart University</td>
<td>Ganzehtliche Blauwerssung von Baustoffe und Gebäude (LCA of building materials and buildings)</td>
<td>2000</td>
</tr>
<tr>
<td>D</td>
<td>AUB (Arbeitsgemeinschaft Umweltvertrющее Bauprodukte)</td>
<td>Umweltdeklarationen (environmental declarations) (under development)</td>
<td>2002/2003</td>
</tr>
<tr>
<td>DK</td>
<td>SBI (Danish Building and Urban Research)</td>
<td>MVB (Environmental Product Declaration for Building Products) (under development)</td>
<td>2002 (?)</td>
</tr>
<tr>
<td>F</td>
<td>AIMCC (French Construction Products Association) based on AFNOR (French standardization organization) standards</td>
<td>Experimental standards - Information concerning the environmental characteristics of construction products; XP P 01-010-1: Methodology and model of data declaration; XP P 01-010-2: Guidelines for the application of environmental characteristics to given construction work</td>
<td>2001</td>
</tr>
<tr>
<td>FIN</td>
<td>RTS (Building Information Foundation)</td>
<td>Environmental Product Declaration for building products</td>
<td>2001</td>
</tr>
<tr>
<td>N</td>
<td>NBB (Norwegian Building Research Institute)</td>
<td>Environmental Declaration of building products</td>
<td>1999</td>
</tr>
<tr>
<td>NL</td>
<td>NVTB (Dutch Construction Products Association)</td>
<td>MRPI (Environmentally Relevant Product Information)</td>
<td>2000</td>
</tr>
<tr>
<td>NL</td>
<td>NEN (Dutch standardization organization)</td>
<td>MEPPI (Material Based Environmental Profile for Building) (in development)</td>
<td>2002/2003</td>
</tr>
<tr>
<td>N</td>
<td>Byggfors (Norwegian Building Research Institute)</td>
<td>EcoDec (Mijjadeklarasjoner - Environmental Declaration)</td>
<td>1999</td>
</tr>
<tr>
<td>S</td>
<td>Ecocycle Council for the Building Sector</td>
<td>BBD (Building Product Declarations)</td>
<td>1997</td>
</tr>
<tr>
<td>S</td>
<td>Swedish Environmental Management Council (Svenska Miljödyringsrådet)</td>
<td>Environmental Product Declaration</td>
<td>1997</td>
</tr>
<tr>
<td>UK</td>
<td>BRE (Building Research Establishment)</td>
<td>Environmental Profiles of Construction Materials, Components and Buildings</td>
<td>1999</td>
</tr>
<tr>
<td>US</td>
<td>NIST</td>
<td>BEES Building for Environmental and Economic Sustainability</td>
<td>2002</td>
</tr>
</tbody>
</table>

Driving demand: sustainable construction

Careful selection of construction products is a feature of national green building labels such as BREEM in the UK and LEED in the US. These labels provide an easy way for clients to demand more sustainable construction. Using such methods, construction products are treated as more or less important with respect to issues such as energy and water consumption, health considerations, opportunities to use public transport, and facilities for recycling. In turn, they are part of the wider concept of environmental procurement. The International Council for Local Environmental Initiatives (ICLEI) recently published The World
BuysGreen, an international survey of national green procurement practices (www.iclei.org).

When do construction products contribute to more sustainable construction?

It is important to consider context: many products which are not in themselves particularly “environmentally friendly” could be exactly the right products for reducing a building’s environmental impact. A particular window may not have a lower environmental impact, but the way it is used could maximize collection of low winter sunlight and block the summer sun. Creating a low environmental impact building means matching products to the specific design and site in order to optimize overall environmental impact.

We should not allow ourselves to be wooed by the idea of “green material” as the only solution to sustainability. After all, timber accredited by the Forest Stewardship Council produces just as much methane in landfills as uncertified timber. The key to greener material use is to use the material in a way that changes the “one-way trip” mentality inherent in so many applications of construction products.

The challenge is how best to measure and to manage the impact of construction products. By evaluating the performance of products against specific environmental parameters, it is possible for the specifier to select products and components on the basis of personal, organizational or independently chosen preferences or priorities.

A common approach to measuring the environmental impact of construction products is life-cycle assessment. How this can be applied to construction products is described below, together with a closer look at some of the most prevalent indicators currently measured – embodied energy and “recyclability”.

What is clear from taking a life-cycle thinking approach is that it is not only the type of product used that is important, but how it is produced (with clear links to environmental management systems) and even more importantly how it is used (and treated when its first life is over). As well as the tools described below, this leads to concepts like “design for adaptability” and “design for deconstruction”. In the modern city environment, where building functions and fashions change so often, it may also challenge the assumption that durability and sustainability always go hand in hand.

Life-cycle assessment

The data needed to measure the lifetime environmental impacts of any product or system, including construction products, can be generated using life-cycle assessment (LCA). LCA is a method for evaluating the environmental impacts of a system by taking into account its full life cycle from cradle to grave. This means consideration of all the impacts associated with production and use of a system, from the first time man has an impact on the environment till the last. This concept is expressed in Figure 1.

If we take the manufacture and use of a brick wall as an example, then using LCA we would typically consider the environmental impacts associated with:

- extraction and transport of clay to the brickworks;
- manufacture and transport of ancillary materials;
- extraction and distribution of natural gas for the brick kiln;
- mining and transport of fuels to generate electricity for use in the factory;
- production and transport of raw materials for packaging;
- manufacture and transport of packaging for bricks;
- manufacture of brick in the brickworks;
- transport of bricks to the building site;
- extraction of sand and production of cement for the mortar;
- building of the brick wall;
- maintenance of the wall, such as painting or repointing;
- demolition of the wall;
- the fate of the products after demolition.

LCA must be carried out in accordance with a detailed LCA methodology (in other words, a description of rules that need to be followed). This ensures that the LCA is fair and that the results can be used comparatively. ISO standards 14040 to 14043 have been developed to standardize and define the manner in which LCAs should be undertaken. However, more precise rules are required to enable like-with-like comparisons using an LCA. Many LCA programmes have been developed to create environmental product declarations (EPD) schemes, and a number of national approaches for construction products currently exist (Table 1). There is no single harmonized approach (see below).

Making fair comparisons

One of the most important aspects of an LCA is to ensure that comparisons are made on a like-for-like basis. For example, let us say we wanted to compare the environmental impacts of two internal walls for a building – one made of aerated blockwork and one of timber studwork with timber paneling. We might well find a database that could provide us with the environmental impacts associated with production of a tonne of aerated blockwork and a tonne of kiln dried softwood. However, the comparison of the two internal walls cannot be made merely on the basis of these two profiles. A tonne of each product would produce very different areas of wall. Instead, we need to define a “functional unit” that will enable us to compare the two internal walls.

A typical functional unit would be one square metre of internal wall over a particular building year, lifecycle. Included would be assumptions about repair and maintenance over the 60-year life, and about the dismantling/demolition of the wall at the end of its life.

For an external wall or roof, the functional unit also takes into account the thermal resistance of the construction to ensure that all the specifications are compared on a like-for-like basis. Some specifications may use less insulation product (and therefore have a lower initial environmental impact). However, they will also allow much greater heat loss (i.e., operational environmental impact) over the building’s lifetime.

LCA design tools for buildings

This interaction between the environmental impact of the products and the overall impact of the building has prompted the development of integrated environmental design tools for build-
The importance of different elements

BRE calculated the embodied environmental impacts relating to a typical UK office building and broke them down into constituent elements. The contribution of each building element is shown in Figure 2. This includes all the elements of the building, including substructure and superstructure, and covers the maintenance and replacement of elements over the 60-year life.

Floor finishes contribute the largest impact because they are typically fossil fuel intensive and replaced frequently. Choosing lower impact products can significantly reduce a building's overall lifetime impact. In addition, raised access floors offer flexibility while floor surfaces contribute the third most significant embodied impact.

Of the major design elements, windows have the lowest impact (only 3% of the building total). For a building with higher glazing ratios, the impact of windows will increase as the impact of the external walls reduces.

The choice of structure makes very little difference to the overall impacts of the building since both cement and steel account for around 2% of the total.

Green procurement

Two important decisions affect procurement of building products and its impact on the environment: what to buy (i.e. the product type) and from whom to buy it.

General LCA information provides assistance to specifiers on what to buy. Deciding from whom to buy can be determined in a variety of ways. Clients might use certification to ISO 14001 or an EMAS environmental management system as an indicator of good performance by a supplier. Alternatively, specific measures such as use of local or low-impact raw materials or low-emission technologies may also be useful.

Neither an Environmental Management System nor evidence of a “single issue” approach to environmental impact help clients to decide how a particular manufacturer’s product compares to the typical product across the wide range of issues that need to be considered. Many manufacturers are therefore now turning to LCA in the form of environmental product declarations (EPDs) to communicate their own environmental performance to their customers.

The ISO 14025 Technical Report: Environmental Labels and Declarations – Type III Environmental Declarations gives guidance on how a producer can provide quantified environmental life-cycle product information. The information is presented across a range of indices relevant to the product category. The objective of such a declaration is “to encourage the demand for, and supply of, those products and services that cause less stress on the environment, thereby stimulating the potential for market driven continuous environmental improvement” (ISO 14020). The relationship between LCA and EPD’s is illustrated in Figure 3.

Specifiers can ask their suppliers for environmental product declarations to satisfy themselves that the company they are using takes a responsi-
Sustainable building and construction

Life-cycle thinking made simple:
The Green Guide to Specification

Towards harmonization
M any companies manufacture in several countries. They therefore wish to see the range of schemes listed in Table 1 harmonized in order to allow more economic use of LCA and environmental product declarations across their business.

The International Organization for Standardization Committee on Sustainability in Building Construction (ISO/TC 59/SC 17) is working to create, inter alia, an international standard for environmental declarations for building products parallel to the more general activity on EPDs of a separate committee (ISO/TC 207/SC 3/WG 4). The European Commission published a comprehensive report in 2002 which described the different schemes currently in operation and considered opportunities for harmonization. SETAC (the Society of Environmental Toxicology and Chemistry) has produced a state of the art report that is helpful in demonstrating the basis on which harmonization can be achieved.

Conclusions
The overall performance of the building is the most important consideration in achieving more sustainable construction. Construction products must be chosen in this context. The most successful approach to specification is one in which underlying objectives and priorities are clearly established at the early stages of a project, as this can then help determine the appropriate balance between environmental and technical requirements. Taking a life-cycle approach is a significant and very positive step in the right direction.

Notes
3. Tables 1 and 2 are adapted from DG Enterprise, European Commission and PricewaterhouseCoopers, Comparative study of national schemes aiming to analyze the problems of LCA tools and the environmental aspects in harmonised standards, 2002 (http://europa.eu.int/comm/environment/lcarep/lcafinrep.htm).
4. See note 3
After several important technical improvements, concrete made with Portland cement is probably the world's most used man-made material. Global cement production in 1997 was 1.57 billion tonnes (Humphreys and M. Ahsan, 2002). That much cement, mixed with water, gravel and other substances, equals some 1.05 billion tonnes of building material to produce houses, office buildings, sewage pipes, dams, concrete roads, etc.

Cement production is widespread: plants are found in 150 countries (Marland et al., 2002), with China being responsible for roughly one third of the total. Global cement production is increasing as consumption in developing countries rises: between 1990 and 2000, production grew 55% in developing countries and 31% in the developed ones. Cement demand in 2020 is expected to be 120-180% higher than in 1990, with most of the growth in developing countries (Humphreys and M. Ahsan, 2002).

Figure 1 shows the CO2 released in limestone decomposition during cement production, selected regions, 1920-2020. The basic way to make Portland cement is to heat a mixture of limestone and clay – two largely available, natural, non-renewable materials – in a kiln at about 1500°C to produce cement “clinker”. After cooling, the clinker is finely ground and mixed with gypsum and, frequently, other finely ground materials such as fly ash and blast furnace slag to produce various commercial varieties of cement.

**Cement production and the environment**

The major global impact of cement production is global warming. Humphreys and M. Ahsan (2002) estimate that the cement industry is responsible for 3% of global anthropogenic greenhouse gas emissions and 5% of global anthropogenic CO2 emissions. About half the CO2 is released by limestone decomposition in the kiln – “cement process CO2” (Humphreys and M. Ahsan, 2002; Gale and Freund, 2000) – and the other half is due mainly to fuel burning (Figure 1).

CO2 release rates differ among countries, depending on a) production process, b) clinker content, c) energy efficiency in the calcination phase, which is responsible for 90% of energy consumption (Gale and Freund, 2000), and d) differences in fossil fuels’ carbon content. Old cement plants are less energy efficient and sometimes still use the wet process, which consumes 20-40% more energy (Gale and Freund, 2000).

Cement production also generates emissions of NOx, SOx, dust, dioxins, etc.

**Blending materials**

Mixing clinker with other materials, a process called “blending”, reduces CO2 emissions and increases energy efficiency during cement production.

Table 1 presents the most common blending materials. Fly ash (including from cement-making itself) and blast furnace slag are the types of waste most used in blending. Their use could be greatly increased except where local shortages exist.

Table 2 presents the most common blending materials used in cement production.

**Concrete and the environment**

Concrete typically contains 8-15% cement, 2-5% water, about 80% aggregates (e.g. gravel, sand, limestone filler) and less than 0.1% chemical admixtures.

Despite its size, the 80% share of natural or recycled aggregates causes less than 3% of total emissions and energy use in concrete production (Vares and H. Akkink, 1998). Hence cement content and composition, as determined by engineers and architects, determine the concrete’s environmental load.

For a constant set of materials, the cement content is a function of the desired mechanical strength, production variability, service life requirement and concrete workability, along with the nature of the admixtures used. Chemical admixtures can reduce the cement consumed for a given strength, or increase concrete workability, without increasing cement consumption. A modern concrete mix design, combining several aggregate grades with admixtures, produces a more eco-efficient concrete.
ing concrete production variability by using adequately trained personnel, carefully selected raw materials and more sophisticated proportioning and mixing equipment, as most ready-mix companies today can do, is also an effective way to reduce concrete's environmental impact.

When concrete is made on site by do-it-yourself home builders or small contractors, the above approaches are not viable. In Brazil, for instance, 68% of the cement sold is bought by building material dealers and used with little or no controls.

A large share of concrete used worldwide is reinforced with steel. In Brazil most steel rebars are made by recycling steel scrap in electric mini-mills. In countries where the steel for concrete reinforcement is often made from virgin pig iron, the environmental impact is higher. Steel's contribution to the environmental load of reinforced concrete is greater than that of the aggregates, but much less than that of the cement.

Service life
Increasing the service life of concrete structures is a very efficient way to improve the eco-efficiency of the global economy. Service life can be dramatically extended with little or no increase in or even a reduction of the environmental load. Doubling the thickness of the concrete over the steel rebar from 10 mm to 20 mm, for instance, quadruples the service life of reinforced concrete, defined as the time it takes carbonation reach the rebar, but increases concrete consumption by only 5-10% (Helene, 1993). In marine environments, a high blast furnace slag or fly ash content can increase service life and decrease the environmental load.

At the end of its service life, most concrete can be recycled as aggregate or even in cement production. But because natural aggregate is usually cheap, concrete is not extensively recycled except in a few European countries (e.g., the Netherlands). In Brazil, as in most developing countries, only local authorities run recycling plants processing concrete and other construction and demolition waste, and the resulting aggregate is generally used as road base. Additional recycling opportunities for such waste need to be investigated.

Making concrete a more sustainable material
Aside from some specialized applications such as the use of chalk or glue as mortar, there are currently no viable alternatives to clinker-based cement and concrete, and despite intensive research, it will probably take decades to develop any. And while the technical options mentioned above, along with other technologies, can increase the sustainability of concrete and are available on markets worldwide, they are not always explored.

The first reason seems to be lack of knowledge awareness on the part of professionals and authorities. With few exceptions, there is almost no technical reason to use cement with high clinker content, but many engineers and architects still prefer it. Designing reinforced concrete structures for an extended service life is a relatively new, often unfamiliar concept that needs to be refined and has not yet been incorporated into concrete design codes and standards, which sometimes set a minimum of cement consumption in structural concrete. Much effort is needed in the technical and environmental education of civil engineers and architects, and to change design codes and create incentives to use blended cement.

Other barriers are market based. Old, inefficient cement plants may still be competitive. Advanced admixtures can be expensive. Ready-mix concrete sometimes costs more than concrete produced at the building site, so DIY builders and small contractors often prefer the latter option. Here the need is to balance social sustainability with environmental sustainability.

Finally, concrete's sustainability must be judged in real situations. A generic life-cycle assessment approach that may work for more standardized materials, like plastics and metals, will seldom be adequate to evaluate concrete. There is a great need for more accurate and independent data about life-cycle loads of cement and other building materials—especially in developing countries.

References


Bamboo in construction: status and potential

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Bamboo is a well established cultural feature in many regions of the world. Its diversity and versatility are well documented. Some 1250 species and 1500 traditional applications have been identified. The main users are the rural poor, and it is perhaps for this reason that bamboo has largely been taken for granted by the wider community. As a material resource, bamboo has not received the mainstream recognition it deserves.

Bamboo is the fastest growing woody plant on the planet. However, it actually belongs to the grass family. Most species produce mature fibre in about three years, much more rapidly than any tree species. Some species grow by up to one metre a day, and the majority reach a height of 30 metres or more.

Bamboo has exemplary “green” credentials. It is adaptable to most climatic conditions and soil types, acts as an effective carbon sink and helps counter the greenhouse effect. It is being used increasingly in land stabilization to check erosion and conserve soil. It can be grown quickly and easily, even on degraded land, and harvested sustainably on three- to five-year rotation. Bamboo is a truly renewable, environmentally friendly material.

The bulk of bamboo is gathered from the wild or rural environment, but in many areas bamboo resources have dwindled due to overexploitation and poor management. This issue needs to be addressed through well organized and managed cultivation if bamboo utilization is to develop on a sustainable basis. Plantations are already being raised in China and India to support the pulp and paper industry.

A billion people worldwide live in bamboo houses. For the most part they are low-grade, impermanent buildings, belying the material properties of bamboo and doing little to promote its image as a viable construction material. At little extra cost these buildings can be upgraded to provide safe, secure and durable shelter, benefiting the most vulnerable members of society.

Possibly the major factor contributing to the view of bamboo as a temporary material is its lack of natural durability. It is susceptible to attack by insects and fungi. Its service life may be as low as one year when in ground contact. However, the durability of bamboo can be greatly enhanced by appropriate specification and design and by careful use of safe and environmentally friendly preservatives such as boron.

The main structural advantages of bamboo - its strength and light weight - mean that properly constructed bamboo buildings are inherently resistant to wind and earthquake. These properties can be effectively exploited through careful yet simple design and detailing.

Even when issues of durability and strength are resolved, the question of acceptability remains. A bamboo building need not look “low-cost” or even necessarily look like bamboo! Imaginative design and the use of other locally available materials within the cultural context can make the building desirable rather than just acceptable.

Bamboo: the international view

Bamboo has a long history as a building material. It is widely used in construction throughout the world’s tropical and sub-tropical regions, with a range of applications to match or even exceed those of timber. Bamboo buildings of every description can be found in Central and South America, from low-grade temporary shanties to exclusive, architect-designed mansions.

Bamboo products for use in construction are increasing in availability. They range from bamboo mat boards (flat and corrugated), to more sophisticated panel products such as fibreboard, “plyboo” and flooring, to large laminated sections (now under development) for use in external joinery. Bamboo products for use in construction are increasing in availability. They range from bamboo mat boards (flat and corrugated), to more sophisticated panel products such as fibreboard, “plyboo” and flooring, to large laminated sections (now under development) for use in external joinery. Bamboo will therefore find a market where timber is in short supply, or where it is specified for architectural reasons. In Europe there is a small but flourishing market in bamboo for internal applications (e.g. flooring) but not as yet for structural ones.

Bamboo use is not restricted to building. Bamboo has been used as concrete reinforcement, and development work is continuing in this field. Bamboo is used for light traffic bridges, and the feasibility of constructing large span bridges carrying vehicular traffic has recently been demonstrat-
ed in Colombia. Bamboo as scaffolding is well known (40-storey construction not uncommon in the Far East), and its use is set to increase as a result of the development of a design and erection guide in Hong Kong.

Other construction applications include ground stabilization, through the use of retaining walls and piling, and coastal protection (recently trialled in Sri Lanka).

**TRADA’s experience**

TRADA (the Timber Research and Development Association) is an internationally renowned centre for forest product engineering and technology. Its origins can be traced to 1934. TRADA is based in the UK, with operations worldwide.

TRADA has recently completed the first phase of a project in India to develop and promote a cost-effective bamboo based building system. This project is designed to provide safe, secure and durable shelter at a cost that is within reach of even the poorest communities in developing countries. It has demonstrated that with careful specification, detailing and environment-friendly preservation, the life of bamboo can be extended to match that of other building materials.

Prototype testing provided an effective visual demonstration of the performance and strength of components and assemblies, as well as of the resistance of walls and roofs to wind, earthquakes and impacts. The building system costs around half that of traditional brick, block or reinforced concrete construction. It is one of the cheapest permanent methods of building yet developed. It is also sustainable, simple to erect, strong and durable, incorporating all the essential requirements for affordable shelter. Moreover, the basic system can be enhanced through improved use of shape, space and colour at little or no cost. Overall, the system effectively demonstrates that desirability and quality are fully compatible with affordability.

In its second phase (2000-05) the project will be extended to Bangladesh and Sri Lanka. The technology will be applied in the development of large community buildings such as schools and health clinics. Use of bamboo for construction of footbridges in rural areas will also be investigated, with the development and testing of prototypes.

**Bamboo’s potential**

Taking into account all that bamboo has to offer, it is well placed to address four major global challenges:

- Shelter security through provision of safe, secure, durable, affordable housing and community buildings;
- Livelihood security through generation of employment in planting, primary and secondary processing, construction, furniture and manufacture of high value-added products;
- Ecological security through conservation of natural forests by substitution of primary timber species, as an efficient carbon sink, and as an alternative to non-biodegradable and high-embodied energy materials such as plastics and metals;
- Sustainable food security through agro-forestry systems, by maintaining the fertility of adjoining agricultural lands, controlling erosion. Bamboo is also a direct food source.

The challenge now is how to share this knowledge to bring it to the attention of a wider audience and demonstrate that the new technologies are equally viable in areas which have not had exposure to the “new thinking” and, above all, to deliver the benefits it promises to the poorest members of society.

**Future requirements**

**Sustainable supply**

A policy of organized planting, careful management of plantations and natural stands, and appropriate regulation of supply are prerequisites for any other interventions aimed at promoting bamboo as a building material.

**Standardization**

Lack of guidance on use of bamboo in building has been a major obstacle to its wider adoption. Draft international standards ISO 22156 and 22157 represent the first step towards addressing this problem. New or amended national regulatory instruments such as manuals, codes of practice, specifications, building regulations and standards are now required.

**Research and extension activities**

These will exist at government level to explore the potential of alternative materials, and to put in place the resources and mechanisms to carry out necessary material developments and evaluations. Where this capacity already exists, it is often necessary to reorient the approach of research institutions to link them directly with the building industry, together with their government and private sector clients.

**Training**

Curriculum revision is required to give greater emphasis to the new technologies. This would apply to institutions training high-level artisans or technicians for the construction industry, as well as professionals such as architects, building technologists, civil, structural and mechanical engineers, and quantity surveyors.

**Fiscal policy**

Financial incentives are required in order to encourage the establishment and support of industries involved with the new technologies. In addition, the widespread policy which limits the advance of bank loans and mortgages on “bamboo” houses must be reviewed.

**Demonstration and quality**

Effective dissemination aimed at popularizing the new technologies is vital, considering the negative perceptions held by many about bamboo in building. Even when issues of durability and strength are resolved, the question of acceptability remains. Construction of model buildings is therefore essential to overcome prejudice and boost the confidence of specifiers (e.g. architects, engineers, builders) and users. In this regard the quality must be the highest achievable, since any shortcomings in the standard of construction, detailing and finish will be reflected, unfairly, on the building system as a whole.

1. Draft documents prepared by the University of Hong Kong.