Sustainable construction in Finland: approach and best practices

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Abstract
This paper describes:
- the state-of-the-art of construction and environment in Finland
- current status of the national environmental technology program
- selected best practices along sustainable building process
- recommendations to the building sector for the future.

The building sector represents almost half of the primary energy produced in Finland: 34 % is consumed for space and domestic hot water heating and electricity used in households and 10 % for building production. Construction and demolition waste is produced at a rate of 1,5 million tons annually. 20-30 % of the building waste is currently recycled.

Our main ongoing research and development effort is the technology program: Environmental Technology in Construction (1995-1999), coordinated by the Technology Development Centre. It has an estimated budget of 20 million USD, of which industrial cofinancing share is about a half. The program aims at developing methods and technologies for environmentally sound construction to be implemented in enterprises. The program consists of five research and development priority areas: ecobalance and life cycle, design guidelines and procedures, products and production technologies, pilot construction projects and environmental geotechnics.

Different actors within the building process have already established their sustainable best practices. This paper presents selected examples of ecological and energy-conscious buildings, ecological criteria for experimental construction, business based on waste recycling, and electric and district heating energy plant. Finally, the issue of environmental management systems is touched, and recommendations to the building sector are given for the future.
Keywords: building, environment, sustainable construction
1 Construction and environment

The most significant quantifiable environmental impact of the construction sector is emissions due to energy consumption. The building sector in Finland presents 44 % of the total energy consumption: 34 % for heating of buildings and electricity used in households and 10 % for building production (out of which 70 % comes from manufacturing of products and 30 % from transportation and building sites). In addition, 3 % of the total energy is consumed by production of building materials and products for exportation.

Over 80 million tons of building materials and natural resources are used annually in construction in Finland. The amount is fourfold compared to municipal waste. About 7-10 million tons of waste are generated every year at demolition and renovation sites, in new construction, and in civil engineering. The goal is to increase the utilization of construction waste from the current 20-30 % to 70 % by 2005. [1]

In Finland, the availability of free space, and air and water of good quality, is not seen as a problem to be solved and that is not striving us towards environment-saving solutions, like in some other countries. The climatic conditions in the North of Europe are cold stimulating us to energy saving thinking and acting – also because we are depending on imported energy. Sustainable development as a target is accepted and the means for co-operation and large-scale responsibility exist. The starting point for developing and implementing sustainable construction is good for us both within our borders, and abroad.

2 Sustainable construction

Sustainable development is often considered to contain ecological and economical, social, and cultural aspects. In this paper, sustainable construction stands for ecologically sustainable construction, which means essentially management of biodiversity, tolerance of the nature, and saving use of resources. Achievement of ecologically and economically sustainable construction enables socially and culturally sustainable construction.

According to our current definition [2], sustainable construction in its own processes and products during their service life aims at minimizing the use of energy and emissions that are harmful for environment and health, and produces relevant information to customers for their decision making. To building construction this means:

- intensified energy-efficiency and extensive utilization of renewable energy sources
- prolonged service life as a target
- saving of the natural resources and promotion of the use of by-products
- reducing waste and emissions
- recycling of building materials
- supporting the use of local resources
- implementation of quality assurance and environmental management systems.

The desired state prevails environmentally responsible industry and building owners together with environmentally conscious consumers.
3 Environmental technology in construction

Technology programs are an essential part of the Finnish innovation system to encourage the technological development in industry. Environmental Technology in Construction [3] is one of these technology programs coordinated by the Technology Development Centre (Tekes) [4]. It was launched in 1995 to aim at developing environmental-conscious techniques and methods in the field of construction. It has an estimated budget of 20 million USD to be covered by about 50 % by the participating companies.

The program deals with:

- environmental impact assessment methods
- ecological design methods, data bases and programs
- utilization of industrial by-products in construction and geotechnics
- reconditioning of contaminated soil and protection of ground water
- production methods and products that save energy, reduce emissions and make use of recyclable construction materials
- manufacturing equipment, machinery and testing methods for the above.

Alongside this program, the Academy of Finland launched a basic research program for Ecological Construction. Development work for ecological urban construction is carried out in cooperation with the Ministry of Environment and the Finnish Association of Architects, whose ecological urban development is part of this technology program for pilot construction of new solutions.

The ongoing research and development projects are focused to the following five main areas:

- environmental assessment of buildings and building products
- design guidelines
- products and production technologies
- experimental construction
- environmental geotechnics.

The projects within the first area deal with the framework, procedures and methods for the environmental assessment of buildings products together with the structure, format and quality of the environmental information to be used by designers and manufacturers. The second area results in guidelines, methods and tools for clients and designers. International information and technology transfer with organizations, such as CIB, RILEM or Green Building Challenge form part of that work. The third area focuses on improving production processes, waste management, recycling technologies and new products. The fourth area aims at implementing urban environment following the principles of a sustainable future. It consists of experimental construction of new buildings and renovation.

4 Best practices

The following examples are presented to illustrate how different aspects of sustainable construction have been implemented into practice:

- environment-conscious buildings
• criteria for ecological neighbourhood
• business based on waste recycling
• sustainable electric and district heating energy plant.

4.1 Environment-conscious buildings

An ecological single-family house was developed and built to disturb the processes of nature during its life cycle as little as possible, e.g. to exist in harmony with nature. The house should be a simple and cheap basic house for everyone, still having good architectural quality and providing occupants good quality and flexible living spaces.

The Marjala house [5] is built largely of wood and wood products. Other keywords are local products, simple technical solutions, repetition of same details and components, thus decreasing the number of different components. The inner surfaces are coated with so called ecological materials from nature, such as wall paper, paintings and waxes. The outer paints are cooked on site or made of skimmed milk as a base material. It gets its energy for heating and hot water from firewood and sun. There’s one stove in the house and 10 m² solar heating panels on the roof. Heat from firewood and sun is collected and stored in a 1.500 liter hot water tank. Standby heating is provided by a 6 kW electric heater at the bottom of the tank.

The heating energy of the Marjala house is 42-50 % of that of eight reference houses. It is supplied with an owner’s manual and service instructions for the next 50 years.

Another sustainable building example is an energy-conscious dwelling. The purpose there was to find out the actual influence of structural and technical systems on construction costs and comfortable dwelling when ecological alternatives are favored. The goal was a 30 per cent reduction of annual heating energy without significantly increasing construction costs. First, performance and costs of various exterior walls and windows were calculated. A trade-off comparison between a better thermal insulation of exterior walls and windows and, on the other hand, building costs and dwelling comfort was performed.

The results indicated the fact that a better insulation gives an opportunity of using floor and air heating based on low temperature technique. An experimental apartment was constructed, based on the results obtained. This was a block of flats containing 15 apartments in Helsinki. Eleven of the apartments were equipped with air heating and four with floor heating. All of them had individual ventilation and a heat recovery unit. In humid rooms there was an additional floor heating facility (integrated in the heating system).

Room temperatures and dwelling comfort were studied in two air heated and two floor heated apartments. Energy consumption was measured from November 1995 to October 1996. The results were reassuring: The energy consumption of the heating system was 59,1 % lower than in the reference building and 30,4 % lower than the original goal. The energy consumption (hot water included) of the experimental building was 49,7 % lower than in the reference building. The annual temperature efficiency of the heat recovery systems was 42,7 % in air heated apartments and 40,8 % in floor heated apartments.

Due to the good indoor climate the apartments are suitable for allergic persons. Some additional research on air conditioning and water systems is still needed.
4.2 Criteria for ecological neighbourhood

The City of Helsinki and the Eco-Community Project organized a design competition for experimental building in a rural area including ecologically sensitive and valuable protected waterfronts at Viikki near the centre of Helsinki [6]. The competition aimed to save nature and natural resources, to have a high quality with regards to their architecture and functionality of the dwellings, and to be feasible to construct. The competition also was a means for a search for solutions which follow the principles of sustainable development and which could be more generally applicable. A group of building consultants devised a tool for the ecological assessment of building plans.

Viikki’s ecological criteria for ecological construction [7] is a method that defines minimum ecological levels for building and estimates the ecological degree of various development projects. Minimum ecological levels for building have been dimensioned to enable their implementation in residential construction to be carried out at a reasonable additional cost. The fulfilling of ecological criteria will also achieve cost savings during the use period. These criteria, whose purpose is to serve as a guide for design and implementation, shall be appended to regulations concerning building practices at city cites. In Viikki, increasingly ecologically conscious building will progress as a four-step process: a minimum level of ecological criteria applied to all projects, supportive PIMWAG points for significant trial projects with a high expectation value, experimental image buildings representing radical ecological construction, and follow-up studies for mapping information about projects under construction. Examples of the required minimum levels are as follows (difference from reference building):

- CO₂ 3,200 kg/yr², 50 years (- 20 %)
- waste water 125 l/resident/day (- 22 %)
- construction site waste from building 18 kg/yr² (- 10 %)
- waste produced by residents 160 kg/residence/year (- 20 %).

4.3 Business based on waste recycling

The annual steel production in the world equals ca. 700 million tons. At the same time the steel industry produces approximately 400 million tons of by-products, solid residues and sludge. In addition to the reduction of waste and emissions, the effort towards a waste-free steel industry has created business activities based on the useful application of by-products. Recycling in the steel industry means primarily either returning by-products into metallurgical processes or utilization of the by-products elsewhere.

In Finland there are two steelworks based on blast furnace hot metal production and two steelworks with electric arc furnace technology. The integrated steelworks in Raahe and Koverhar produced 2.6 million tons of steel, and 0.8 million tons of blast furnace and steel slag. Besides this, approximately 0.15 million tons of dust and mill scale were formed as by-products of the process. In Tornio approximately 0.3 million tons of Ferro chromium slag and 0.16 million tons of electric arc furnace slag were formed.

SKJ Companies, a subsidiary of the Finnish steel group, Rautaruukki Oy, is responsible for utilizing the by-products of steel industry. Activities cover the whole range of the by-product business from by-product treatment to product development,
marketing and export. SKJ has developed into products and is marketing approximately 90% of the above mentioned by-products of Finnish steel industry totaling about 1.4 million tons. Slag, that is the largest product group by volume, is marketed to road construction, agriculture and the building materials industry. SKJ companies have activities in the fields of by-product treatment, product development and technology know-how. With regard to the technology know-how SKJ also has activities within export. The primary export countries have been Russia and East European countries.

4.4 Sustainable electric and district heating energy plant
The new energy plant of Helsinki City uses natural gas as its fuel and produces a nominal electric power of 450 MW. The fuel is fossil, but offers the advantage of practically no particle and sulfur emissions. The NO\textsubscript{2} emissions are low: for NO\textsubscript{2} only 35 mg/MJ of fuel. In comparison, modern coal-fueled plants emit ca. 50 mg/MJ, and 10 years ago typical emissions for coal were above 200 mg/MJ. Also carbon dioxide emissions are low, only 56 g/MJ (more than 90 g/MJ for coal).

The power plant produces both electric energy and district heating energy. The electric energy is produced in two stages by gas and steam turbines. The remaining useful energy (about half of the yield) is then available for district heating. The amount of unused heat (e.g. outside the heating period) is cooled by seawater. When all available energy is used the total efficiency of the plant is about 90 per cent. About 50% of district heat is used in the densely built area of Helsinki. The heat from the energy plant is lead outside of this area, to North and East parts of the city, via a new 20 km long district heat tunnel (an investment of ca. 500 million FIM). About 90% of the building volume in Helsinki is covered by district heating.

5 Considerations for the future

One of the concrete measures towards sustainable construction is the development and implementation of environmental management systems. The basic idea there is continuous environmental improvement of activities with the help of measurable targets. By means of an environmental management system, it is also possible to benchmark the environmental level of an enterprise to others. The building up of the environmental management systems is increasing in Finland.

Consequences of sustainable development on the construction industry by the year 2010 were studied in a CIBW82 project Sustainable development and the Future of Construction [8],[9]. That project resulted in the following recommendations to the Finnish building sector [2]:

- Building owners:
  - to set concrete environmental demands to the parties involved in the design process, as well as to the final product, during the initial design phase
  - to set concrete goals regarding building maintenance that are based on environmentally friendly methods and include these goals in, for example, the building maintenance agreements
• assure of the productivity of one’s own business by emphasizing environmental issues, quality and preservation of property values.

Building users:
• to act as a demanding customer when selecting spaces and considering the environmental qualities of the building over its life span as one selection criteria
• to see the environmental issues as one aspect of comfort and consequently as one factor that affects the productivity of the use of the spaces
• to develop one’s own activities to be more environmentally friendly in the occupied building.

Clients:
• to inform and analyze the owner’s environmental demands regarding the construction project, as well as make sure they are adhered to
• to select the parties involved in the building project based on their expertise on environmental issues
• make sure that environmental goals are part of the owner’s demands and implementation plans and, if needed, set them together with the owner.

Designers:
• to consider the environmental qualities of construction materials as a starting point of the design and to develop design solutions from the point of view of environmental goals of the final product
• (one can also set goals, even if the owner is not yet doing it)
• to develop the design process together with other professionals in order to achieve the optimal situation
• to develop methods and tools which will enable the designers to control not just the statics and cost but many other variables, such as life span and maintenance intervals, pollutants and health factors, heating and moisture technology etc.

Manufacturers of building products:
• to see the life cycle considerations (environmental impact, life span) as the basis of product development
• to explain in the product information the environmental qualities based on life cycle analysis, together with information regarding use and conditions of use, recycling and – and bear responsibility of that information
• to minimize actively the environmental harms of one’s own production processes.

Contractors:
• to see environmental consciousness as a factor of competitiveness and to develop one’s own services to be environmentally sound
• to reduce the environmental impact of one’s own business processes regarding, for example site operations, logistics and material selections
• to require readiness from the other parties (sub-contractors, material and product suppliers) to work in cooperation towards environmentally sound goals.

Building maintenance organizations:
• to see environmental consciousness as a factor of competitiveness and to develop one’s own services to be environmentally sound
• to correct one’s own processes so that they are based on sound environmental thinking, show initiative and give feedback to the building owners regarding environmental issues
to expect cooperation from suppliers and partners regarding environmental issues.

Officials:
- to confirm the creation and existence of mechanisms that lead to life cycle thinking
- to consider environmentally sound construction as one criteria in all building
- to use appropriate guidance (regulations, supervision and sanctions) in order to achieve environmental goals.

Researchers:
- to produce, together with other parties in the construction business, environmental qualities for entire buildings and building parts as well as methods and means to calculate them, to be used by owners, builders, designers and contractors
- to aim in one’s own activities to introduce life cycle thinking as the guiding principle of design and construction process and actively implement research results in, for example, experimental construction projects
- to produce research based information to contribute to the ethical discussion on environmentally sound construction.

6 References