LifeCycle Tower – the Natural Change in Urban Architecture

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Summary

More than 50% of the world's population today lives in cities with more than 1 million inhabitants - and the trend is increasing. 40% of today's energy, CO2 and resource consumption and 40% of waste production are accounted by the global construction industry. In the past, urban architecture has been based predominantly on conventionally produced prototypes with long, complex and resource-intensive construction work. A situation which the Cree GmbH, a subsidiary of the Austrian Rhomberg Group, intends to change with a hybrid construction system for multi-story buildings with up to 100 m height and 30 stories. The project is based predominantly on a renewable raw material - wood.

The goal of the project LifeCycle Tower was to develop a flexible, prefabricated, construction system as a new, independent product, which meets all technical and economical requirements of modern real estate markets. Additional emphasis was placed on the systematically improved resource- and energy efficiency. An integrated planning process was applied to the entire project. This means that representatives of all areas of knowledge (architecture, static, facility management, building technology, etc.) had worked jointly through the essential tasks in their entirety. Another central element was carrying out theoretical simulations, which were checked and confirmed with real trials (e. g. fire tests).

The result of the Project is a flexible “new to the world product”:
- for timber based multi-story buildings up to 100 m and 30 storeys
- for multiple uses such as office, apartment and/or hotel
- with a positive energy balance
- with an unmatched ecological footprint
- which is prefabricated and independent from manufacturers or geographical locations

Now, the theoretical development became reality. A prototype, LCT ONE, with eight stories was built in Dornbirn, Austria.

Impact on business & ecological environment
- up to 90% improved CO2 - balance
- 50% improved resource efficiency
- Construction times cut by half
- Regional value added by local production possible
- Flexible usage and conversion of building

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1. Global challenge for the building industry

Processes of cultural, ecological and economic change observed around the world are leading to an altered frame of reference for and different demands on the building industry.

1.1 Urban growth

The urbanization of the world presents an enormous challenge to the future of mankind. Even today, 50% of the world's population lives in cities of more than a million inhabitants. Experts believe that this could rise to 75% within 30 years. Over the same period the world's population is expected to rise by 78 million people per year – roughly the population of Germany (United Nations 2008).

The countries that profit from an economic upswing strive to transform their cities into better places to live.

Buildings will have to reach greater heights to keep pace with the rising requirement for space. Accordingly the future activity of the global building industry will become concentrated in urban areas and on the construction of multi-story buildings.

1.2 Scarce resources

If present-day methods of using the world’s resources were maintained, then 2.5 planets would be required to satisfy the future demand for resources. For Europe in particular, where 90% of all raw materials have to be imported, guaranteeing the fulfilment of that need for resources will be an essential precondition for prosperity and social harmony.

Construction worldwide is responsible for around 40% of today's consumption of resources and energy as well as 40% of global CO_2 emissions (United Nations Environment Programme 2009). It is clear that efficient use of resources and energy, and a reduction in CO_2 emissions will be considerable factors in successfully addressing these issues. One of the consequences will be an increase in the statutory provisions and targets relating to energy and resource efficiency applicable in many countries.

1.3 Conventional construction

Up to now, urban development has been based mainly on conventionally built prototypes of complex construction. This entails high construction costs, long erection times and elevated design and construction risks.

Systematization and industrialization of the building production process, such as emerged decades ago in the automotive industry, has so far not been seen in the construction industry.

2. Integrated research – high-rise buildings in wood

The changing global construction scene was the trigger that spawned a research project over several years. An international interdisciplinary team of experts led by Cree GmbH has developed a new type of **wood-hybrid construction system for buildings up to 100 m high** (30 stories). The special feature of the research process was the integrated interplay of knowledge leaders from all the professions in the building industry, such as architecture, structural engineering, building physics, building services, process management, marketing etc.

Three main objectives were pursued:

2.1 Large-volume building

As a result of the global trend towards urbanisation, efforts were made to develop a solution for use in an urban context. The objective was the development of a multi-story building solution capable of reaching up to 30 stories or 100 m in height (Cree GmbH 2010).

2.2 Resource efficiency

The shortage of resources and the associated rising prices of raw materials turn the intelligent use of material goods into an enormous competitive advantage for the building industry. Therefore timber, a renewable and local resource, was chosen as the basis for the development of the new building system. Its reduced "ecological backpack" is only half that of conventional buildings (Manstein C & Reisinger H 2010). Most products we create from the resources of the earth contain far more material by virtue of their extraction, transport and processing than their self-weight alone would suggest. According to the renowned chemist and environmental researcher Prof. Friedrich Schmidt-Bleek all goods have an ecological backpack. To produce a kilogram of steel takes on average 8 kg of mineral ore and fossil fuels, a kilo of copper 348 kg, while a kilo of aluminium "actually" weighs 37 kg. Wood has an ecological rucksack of 1.2 kg. Moreover, wood as a material has the potential to improve the CO_2 balance by 90% (Braune A & Benter M 2010) and reduce the weight of the building by 50 % (Cree GmbH 2010).

2.3 System building

A further objective of the research was to develop a standardised universally usable modular system containing a significant proportion of building technical services (heating, cooling, ventilation,…). The individual elements should, as in the automotive industry, be capable of being prefabricated in a factory and modular to the extent required by the client. The concept of serial off-site production was intended to ensure economies of scale, consistently high quality and rapid erection of the building on site.

The **first research project "8+"** investigated the technical feasibility of buildings in wood construction. The results showed that it was technically feasible (from a structural engineering point of view) to erect buildings 80 m or more in height. The research did not consider the commercial marketability or the likelihood of obtaining statutory construction approval of the final concept. It was therefore not possible to construct a building based on principles of the "8+" research project.

The **second "LifeCycle Tower" research project** extended the findings of the "8+" project and developed a new building system modified to suit the requirements of the modern real estate market. Industrial prefabrication and special consideration of fire safety in the design led to the new product becoming ready for the market.

From research project to built property: with the "**LCT ONE"** the developed concept was transformed into reality in the form of an eight-story demonstration building.

3. The LifeCycle Tower – innovative building system for urban, sustainable architecture

3.1 Architecture

The system can be divided into three main components: core, hybrid slab and façade columns.

3.1.1 Access core

For the LifeCycle Tower research project, a rectangular core was adopted as the basic structure to ensure that the nodes in the stiffening components would be as few and as simple as possible and compatibility maintained with every available facade system. The core is erected in two sections, each 32 m high, in order to maximize stiffness and ductility while being economically competitive with conventional building systems. The reduction to two horizontal interfaces secures not only structural and economic benefits; it also permits a high degree of prefabrication and shortens the construction time. The central core for this project was selected primarily for its structural properties; however this arrangement also has disadvantages when it comes to efficient use of floor area, as incorporating the second escape route inevitably results in a less favourable rentable space ratio. In general, individual stories and their technical services can be accessed via one or several centralized or decentralized be used. The options are available depending on regional building regulations for tall access cores. The cores serve as the stiffening element of the building. While wood is the optimal choice as a material for the access cores, concrete and other non-combustible building materials can also buildings.

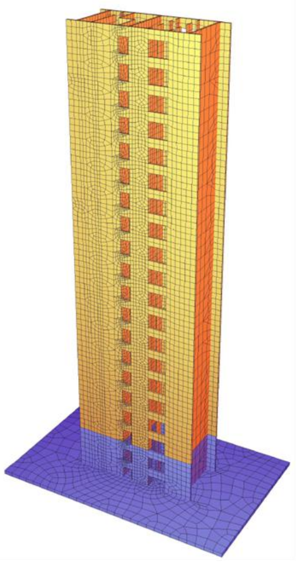

Fig.1: Core

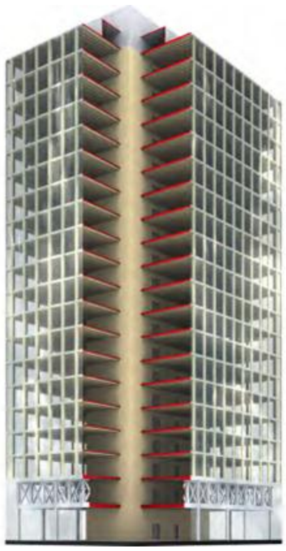

Fig. 2: Shell & Core

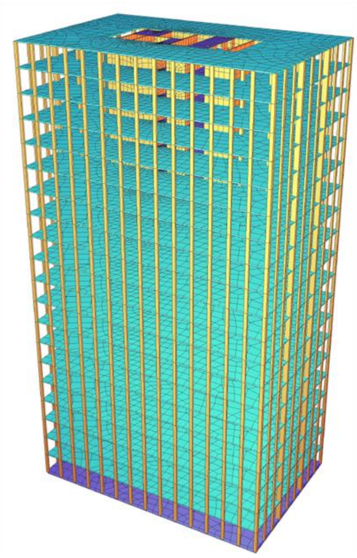

Fig.3: Shell & Core

3.1.2 Hybrid slab

A wood-concrete composite rib construction was chosen for the slab. This fulfils several functions: First, it enables the floor plan to be arranged freely thanks to its long span (<9.45 m) and secondly it guarantees the separation of the stories in the building from each other, as required by fire protection regulations. The space between the ribs allows the building services to be installed within the thickness of the slab. The system also increases the resistance to the spread of fire at the deck soffit. Suspended ceilings are not envisaged. The wood should be left visible for the room users to enjoy, as at the facade supports.

Fig.4: Hybrid slabs

3.1.3 Facade columns

Double columns, designed to provide the required fire resistance, transfer the facade forces directly to the slab, avoiding transverse compressive stresses, and then directly into the column pair below. The pull out or lateral forces, between the double columns and the hybrid slabs, are prevented from separating by strong, but simple, mortise and tenon joints. Wooden frames link several pairs of columns into one unit that can be installed together with the façade. The combined installation of primary and secondary facade elements allows site work to progress more quickly compared with conventional systems as this is a completely dry method in which no curing times are involved.

Fig.5: Loadbearing system

3.2 Modular construction

Prefabricated construction elements with consistent, standard solutions reduce the need for one-off designs. Construction details have already been incorporated and the components only have to be put together on site. Subsequent work involving non-prefabricated components, such as separate fire protection cladding, is kept to a minimum. The elemental approach avoids the need to construct complex details on site, which is difficult to ensure is done properly in such environments.

Fig.6: Construction phases

3.3 Energy design

A clever, highly energy-efficient building services concept was developed for the LifeCycle Tower, which can be built to low-energy, passive house or plus-energy standard. The qualities of the respective location are utilized optimally for the building. Priority is given to the use of renewable energy sources in the energy planning of the building, sources such as geothermal energy, for example, that can be used for both heating and cooling the building. The distribution and delivery system is adjusted to the respective system temperatures. Combined heating-cooling ceiling elements have been developed for space heating and cooling.

The lighting, a comfort ventilation system as well as smoke detectors and sprinklers are all integrated between the ceiling elements. Other possible elements focusing on the use of regenerative energy include solar thermal systems for hot water, regenerative fuel plants where high water temperatures are required and photovoltaic systems integrated in the facade. Despite sun protection measures, the demands on room temperatures in summer (comfort criteria and workplace guidelines) make the use of passive cooling ceilings to cool the building inevitable. However, the higher energy expense that this involves can be reduced by an intelligent control concept (exterior shading controls, automatic night cooling, occupancy sensors) and correct user behaviour.

3.4 Fire safety

Fire protection is an important aspect in obtaining approval to construct multi-story buildings. In the last 20 years, modern timber construction has experienced enormous growth both in terms of technology and in economic efficiency, which is also reflected in the continuous amendments to the statutory regulations. Significant differences within national and regional statutory regulations continue to mean that generally applicable statements about the likelihood of construction approval being granted for multi-story buildings cannot be made, all the more so because approval is very dependent on the proposed building use (hotel, office, residential).

A detailed analysis of the possibilities offered by timber construction and consideration of the risk of the spread of fire posed by the combustibility of wood led to the development of a certified fire protection concept. A number of large-scale fire tests have been carried out in Europe for the floor slab elements of the building system. These tests show the technology is able to withstand up to a two hour fire test. Based on the results of these tests, the components have been optimized leading to a reduction in the amount of concrete used, and the granting of the required REI 120 certificate.

4. Commercial considerations

Construction costs for a system-built LifeCycle Tower are fully comparable with those of a conventionally constructed building. A comparative analysis for the two building types found that the additional initial investment cost for the LifeCycle Tower was only 2%. The objective of the further research is to achieve cost leadership in the area of resource & energy-efficient large-volume buildings.

4.1 Industrial series production

Industrial prefabrication of standardized components will exploit the economic advantages of scale and learning curve effects. Factory quality assurance will also lead to minimisation of errors and consistently high quality of construction on site.

4.2 Supply chain management

Cree is not a manufacturer. The independence of contractors and subcontractors means that the best bids out of the local market suppliers can be accepted for production and erection. Capacity bottlenecks or overproduction can be evened out by flexible integration of the producing firms.

4.3 Life cycle-oriented design

The cost of erecting a building is responsible for only 20% of the total cost of the building over its entire life cycle. The concept of the LifeCycle Tower incorporated extensive considerations of cost-effective use, reuse and demolition of the building. One of the consequences of this is the absence of loadbearing partition walls in the structural frame, which allows room sizes to be freely varied in the future. A high energy standard ensures low operating costs and the wood can be used for energy generation following the cascading use principle at the end of the building's life cycle.

5. Implementation concept

5.1 Formation of Cree GmbH

A dedicated company with a present staff of 15 was set up in 2010 to further develop and market the findings of the research. The partners are Rhomberg Holding GmbH, Signa Holding and RIMO Privatstiftung. The development of the LifeCycle Tower and Cree has been met with acclaim and interest from all over the world, presented at international conferences and cited as a pioneering project in innovative timber construction by leading experts.

5.2 Proof of concept

5.2.1 Eight-story prototype LCT ONE

The design conclusions drawn from the research project were implemented in an eight-story (27 m) demonstration building built in Dornbirn, Austria. Based on this prototype, the advantages of the building concept (including resource and energy efficiency, up to 90% improved CO_2 balance, 50% shorter construction time, series production) are reported on a public stage. The project serves as an exemplary model for modern sustainable building and point the way ahead for the future development of this sector of the construction industry.

Fig.7: LCT ONE outside

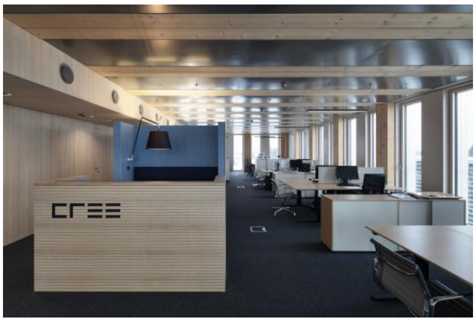

Fig.8: Cree office

Fig.9: LCT ONE at night

5.2.2 First customer project IZM (Illwerke Center Montafon)

The first commissioned project is a large building (120 m) with about 10.000 m² floor area being built in Vandans, Austria. The technical and economic advantages of the proposed LifeCycle Tower wood-hybrid building system were decisive in the commissioning. Verifiable compliance with the fire safety requirements and the ecological advantages of the system were further important factors in the acceptance of the tender by the client.

Fig.10: IZM building phase

Fig.11: IZM

5.3 International marketing

The building system in its finally developed form will be marketed internationally using LCT ONE and IZM as reference projects. Potential target markets will be analysed in parallel with the international positioning of the Cree brand.

5.4 Country-specific construction approval

The engineering feasibility of the tower based on its current stage of development can be confirmed. Construction approval of actual projects still has to be obtained from the competent authorities in each future location. A strategy of sequentially increasing the maximum permissible building height will be adopted to ensure future construction approval. Cumulative experience (construction approvals, fire safety concepts, certifications, testing,…) grows with every completed project and serves as the basis of discussions for obtaining approval of the next higher building class.

6. Conclusions

The concept offers enormous opportunities – for the local timber construction industry as well as housing component manufacturers, contractors and suppliers. The uniqueness of using wood as a visible and sensual construction material for high-rise buildings will lead to new modern perception of nature's building material.

In terms of its export potential, the LifeCycle Tower provides an opportunity for local skills to develop international connections and to strengthen the economy and research locations. It allows small and medium enterprises (SMEs) to benefit, above all those which in isolation are considered not to possess the necessary prerequisites for strategic internationalisation. The implementation and international marketing of the developed modular system opens the way for SMEs to international know-how transfer and real export opportunities.

Wood as local renewable construction material will become increasingly important: it secures regional or national independence interms of raw material supplies and protects against high prices.The propagation of the LifeCycle Tower concept in regions in which timber is of high importance therefore strengthens their economies and independence.

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