RESEARCH FOR A SUCCESSFUL TRANSFORMATION OF THE BUILT ENVIRONMENT IN SWITZERLAND

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The quality of the built environment is a key factor for a truly sustainable society. This includes high-quality and affordable living and working space, networks for transportation of people and goods and a reliable distribution of energy, water and information. Research at Empa is carried out at different levels starting from the development of new materials to the design of advanced systems and their integration into buildings and structures. Finally, we also look at entire cities and their interaction with the environment. Key issues at all levels are the minimization of the environmental footprint and the enhancement of comfort and safety offered by the built environment to its users. Technology transfer to industry is fostered by large-scale demonstration projects.

The challenges we are facing today can be illustrated by Figures 1 and 2. Figure 1 shows the average energy consumption of residential building in Switzerland as a function of the year of construction and Figure 2 the age of the bridges in the Swiss highway network.

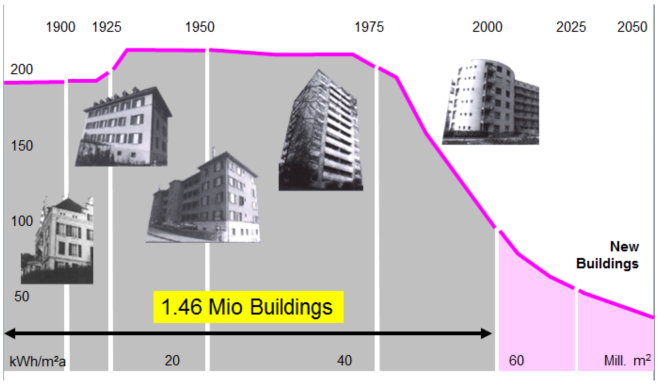

Figure 1: Energy consumption in kWh/m² for residential buildings in Switzerland as a function of the year of construction

Buildings are responsible for 50% of the end energy use in Switzerland and this demand is mainly covered by fossil fuels and therefore is the most important source of green house gas emissions. In order to transform the existing building stock new materials, systems and processes are developed. The energy demand for heating is mainly dependent on the quality of the building envelope. High performance insulation materials play an important role in that respect because it is not always possible to add an additional layer of 30 cm of conventional insulation to an existing façade – either for aesthetic or space reasons. Empa has recently developed an aerogel plaster which has a thermal conductivity of less than 0.025 W/m·K. This plaster is open to water vapour diffusion and can be applied by conventional techniques including spraying. An other important research issue is the seasonal storage of low temperature heat. The idea is to store excess solar heat collected in summer and use it for heating purposes in the winter season. The main issue is of course the minimization of losses during the storage period. One approach is based on sorption and thermo-chemical processes. Currently, two different systems are investigated at Empa: one is based on aqueous sodium hydroxide and a closed sorption process, the other one makes use of the dehydration of ettringite at temperatures between 50-150°C.

At the level of buildings and cities we are developing holistic concepts for the complete renewal of multi-story residential buildings. These concepts include the careful evaluation of the economic, ecological and social consequences of the project and compare the renewal with the option of demolishing the existing building and replace it with a new one. A lot of emphasis is put on the development of prefabricated façade modules which include new windows, piping for controlled ventilation and the needed additional insulation. The viability of the concept was demonstrated in a number of demonstration projects at a 1:1 scale. On the next level, we focus on the adaption of communities towards self-regulating energy systems. In such a system buildings with different characteristic energy demand profiles are connected within a local grid. This grid is connecting decentralized energy supply systems, energy storage systems and users with the goal to make optimal use of the available energy at a local scale.

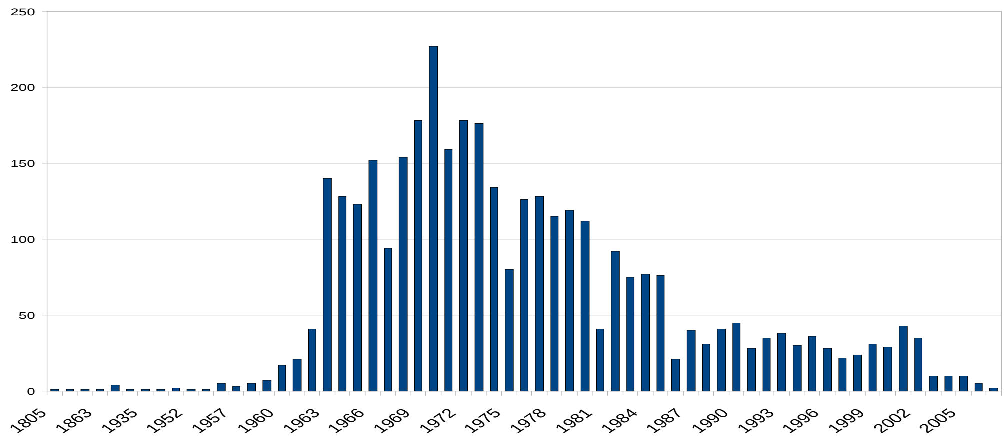

Figure 2: Year of construction of bridges in the Swiss highway network. 40% of all bridges are older than 40 years.

Switzerland has built up an impressive infrastructure over the last decades. Today, we are confronted with the challenge to maintain this infrastructure and to enlarge it at the same time in order to meet the growing demand for mobility and such. Key aspects regarding the existing structures are health monitoring and reinforcement. Wireless sensor networks have a high potential for the instrumentation of existing structures. They are easy to install compared to wired networks but care has to be taken in order to make sure that a reliable operation can be maintained over long periods of time. The key is here again the energy consumption and that is directly related to the transport of information from one node to the next. Therefore, we have developed procedures where the data locally acquired by the sensor is also locally processed and only relevant and needed information is sent over the network. This approach has been successfully demonstrated on a cable stayed bridge over several years.

Additional loads or new requirements regarding earthquakes often cause the post-strengthening of existing structures. Empa has a long tradition in using carbon-fibre reinforced polymers (CFRP's) for this purpose including the application in a prestressed form. An alternative approach is based on a collaboration of materials scientist and structural engineers. The goal is to use so called shape-memory alloys (SMA's) for prestressing existing structures. Preconditions for such a system are low phase transition temperatures of the alloys in order not to damage the concrete and the use of "low"-cost materials. The well-known SMA's based on nickel and titanium would be far too expensive for applications in the construction sector. However, we were able to develop an iron-based alloy with a transition temperature of less than 200°C and a high stress recovery.

In all areas we pay a lot of attention to demonstration projects since this is the most important route for technology transfer in construction. Currently, Empa is developing in collaboration with other academic and industrial partners a new concept: A dynamic, modular research and demonstration platform for advanced and innovative building technologies in the heart of the Empa/Eawag campus. Used as an academic guest house and experimental office space, it will serve as a «Living Lab for Sustainable Construction» that allows novel materials, components and innovative systems to be tested, demonstrated and optimized under real-world conditions.

NEST consists of a central «backbone» for the load-bearing structure and for access to services and media and a basic grid to accommodate about 50 exchangeable living and office modules. Due to its highly flexible design which allows for the exchange of complete living/working units or even entire floors in a «plug-and-play» mode, NEST will constantly change face and tackle the «hot» topics of the time.