

RECENT TRENDS AND CHALLENGES OF ENERGY EFFICIENT AND SUSTAINABLE BUILDINGS

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According to several studies (e.g., the Intergovernmental Panel on Climate Change (IPCC, 2014), the US Energy Information Administration (US EIA, 2014), warming of the climate system is unequivocal and mainly derives from greenhouse gas emissions due to human activities. Global Carbon Dioxide (CO₂) emissions from fossil fuels, for example, are estimated to be 29% higher in 2035 than they were in 2012, partly as a consequence of coal use in rapidly growing economies. World total energy consumption, based on (US EIA, 2013), is also expected to grow by 56% between 2012 and 2040.

In the 1970s, the concept of “sustainability” has been firstly proposed to describe an economy “in equilibrium with basic ecological support systems” (Meadows *et al.*, 1972), although the expression “sustainable development” acquired more significance only in 1987 (WCED, 1987). During the last two decades, strategies for sustainable development have been in fact largely supported and promoted; in order to decrease energy consumption, reverse the current loss of natural resources, implement long-term, safe low-carbon and low-input economic policies able to act at the level of several domains such as transportation, ecology and agriculture, industrial development, advances in technology, constructions.

One of the global current challenges for architects, engineers and researchers, in this scenario, is to increase energy efficiency and sustainability of buildings, as well as to improve the actual level of indoor comfort, health and safety for the occupants. Based on recent studies, more than 40% of US (US DOE, 2003) and UK (DCLG, 2014) energy consumption and 24% of global carbon dioxide emissions come in fact from buildings (Howe, 2010). It is consequently clear that a key role is given to combined optimization and calibrated interaction of several aspects, such as technological innovation, materials, insulation techniques, illumination and ventilation.

Recent studies published in the current volume of the American Journal of Engineering and Applied Sciences highlighted, for example, that the application of ventilation control Strategies (e.g., CO₂-Based Demand-Controlled Ventilation (SCV) strategy) and integrated economizers for air source heat pumps in schools, can have important effects in terms of energy balance (Al Raees *et al.*, 2014). Case studies discussed in (Al Raees *et al.*, 2014) for schools of various US locations generally manifested a 19% to 26% energy saving, depending on a combination of building location and occupancy, compared to traditionally ventilated buildings.

Improved energy demand can be achieved also by means of the use of energy saving materials. Research investigations presented by Fadiel *et al.* (2014), for example, emphasized that improved thermal efficiency of cement-based materials can be obtained by use of crumb rubber. During the last two decades, the use of rubber particles in addition to cement paste represented a research topic of large interest for scientists and industries and several States (e.g., the Arizona Department of Transportation (Kaloush *et al.*, 2005) sustained the extended engineering reuse of waste tires in the form of crumb rubber aggregates in Portland cement concrete mixes. Several research studies have been carried out on rubberized concrete compounds, in order to assess the mechanical properties and structural behavior of these “rubcrete” materials (e.g., compressive, tensile and flexural strength; vibration dampening; resistance and behavior at failure under impact; thermal expansion properties; rubber-to-cement adhesion; crack propagation. Segre and Joekes (2000; Siddique and Naik, 2004; Siringi *et al.*, 2013; Segre *et al.*, 2006), as well as to identify the optimal combination between rubber particles (including studies on their size, shape and surface treatment) and the cement matrix in which they are included to partly replace traditional aggregates.

Experiments discussed in (Fadiel *et al.*, 2014), in this sense, show that a 40% content of crumb rubber-although depending on the size of rubber particles-could offer optimized thermal conductivity (up to 28% reduction, compared to conventional mortar) for a rubberized cement mortar. It is thus expected that inclusion of crumb rubber in cement mortar could markedly improve the energy efficiency of whole structural systems.

Although an important energy saving contribution can primarily derive from reduced consumption, however, it is clear that building envelopes (e.g., windows, curtain walls and enclosures) are the first defense line from the environment.

This is the reason why several green building standards (e.g., the International Green Construction Code (ICC, 2012)) currently require windows and cladding walls to behave as energy efficient mechanical systems, able to react to non-continuous, changing external conditions, but at the same time to preserve the thermal and visual comfort of occupants and an appropriate natural daylight.

The International Conference “GlassCon Global-Innovation in Glass Technology” recently hosted in Philadelphia (July 7-10, 2014; www.glassconglobal.com), Pennsylvania, represented an important event in this field. This North America's Premier Technical Conference attended by over 330 leaders in the architectural glass and glazing industry, provided three days of presentations, research and interaction amongst scientists, architectural glass and glazing industry, offering the opportunity to disseminate new technologies and current advancements in glass technology. Specific sessions have been dedicated to the design of complex enclosures, technical details and structural concepts able to simultaneously bind technical energy requirements with aesthetic expression. Attention has been paid also for the implementation of active/passive building energy strategies, as well as for the architectural integration of innovative façades and components into sustainable buildings.

Studies highlighted, for example, that improved thermal capacity of Insulating Glass Units (IGU) could derive from application in buildings of triple-rather than double-IGUs, in conjunction with thermally improved spacers (e.g., “warm edge” space bars) (Elstner, 2014). Indirect effects of triple IGUs would be represented by enhanced sound insulation and solar control, hence high life quality for the occupants.

“Dynamic” fenestrations have been already identified by the US Department of Energy (IPCC, 2014) as a key envelope requirement for (near) zero-energy buildings. EU 2020 green-house energy efficiency targets have been agreed by the whole European Community (EC, 2020). Adaptive façades and multi-functional building envelopes will be the research topic of the starting COST Action TU1403 “Adaptive Facades Network” (COST Action TU1403, 2014), a research network of academics and industrial partners that will generate new ideas and concepts, aiming to provide viable contribution towards the EU2020 targets.

Within the series of Dynamic Glazing systems, both Electro-Chromic Glass (EC) or Thermo-Chromic Glass (TC) solutions and Mechanical Shading (MS) systems have demonstrated high energy efficiency (Culp and Sanders, 2014; Sanders and Podbelski, 2014; Sanders and Hakkarainen, 2014) and increasingly applications in modern buildings. In the first case, EC glass is able to reversibly change its visible light transmission and solar heat gain coefficient in response to sensors (e.g., light, occupancy, temperature), while the typical TC solution, being a passive control system, allows to change the level of light transmission in response to changes in its temperature (e.g., becoming gradually darker as the temperature increases). A TC application usually takes the form of a thermo-chromic PVB® film-laminated glass panel, used as exterior surface of a double IGU.

Presentations given at GlassCon Global also suggested that future trends could consist in technical solutions properly combined with biological systems, such as micro-algae and photo-bioreactors. The project of a Solar Leaf bio-responsive façade (BIQ house in Hamburg, Germany (Wurm, 2014), in this context, represents a recent example of successful and well-promising application of biochemical processes of fast-growing and highly responsive micro-organisms in smart adaptable building envelopes. Although further studies, energy monitoring activities, optimizing processes and developments are required for this pilot project, in conclusion, the BIQ house could represent a further successful advancement within the sphere of highly energy efficient building enclosure techniques.

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