Sustainable Buildings –
The Latest Worldwide Trend in Building Development
持續性建築 – 世界建築發展新趨勢

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ABSTRACT

Sustainable development is an umbrella that attempts to bridge the divide between economic growth and environmental protection, while taking into account other issues traditionally associated with development. It seeks to develop means of supporting economic growth while supporting biodiversity, relieving poverty and without using up natural capital in the short term at the expense of long term development. Sustainable building is the practice of increasing the efficiency with which buildings and their sites use and harvest energy, water, and materials, and reducing building impacts on human health and the environment, through better design, construction, operation, maintenance, and removal — the complete building life cycle.
The world largest Sustainable Building Conference was held in Tokyo in 2005 with significant impact to Sustainable Buildings in concepts, structures, aspects and linkages. Sustainable building focuses on its uniqueness of innovative energy efficiency, alternative energy production solution, building placement, waste management, re-using of materials and structures, new and innovative technologies.

Keywords: sustainable building, innovative technologies, green architecture.

INTRODUCTION

Sustainable Building or Sustainable Architecture, also known as "Green Architecture" or "Green Building," is an approach to architectural design that emphasizes the place of buildings within both local ecosystems and the global environment, according to [1]. Sustainable Buildings include Intelligent Buildings and Energy Efficient Buildings. Sustainable architecture seeks to minimize the negative environmental impact of buildings by enhancing efficiency and moderation in the use of materials, energy, and development space.
The word, Sustainability, is an attempt to provide the best outcomes for the human and natural environments both now and into the indefinite future. It relates to the continuity of economic, social, institutional and environmental aspects of human society, as well as the non-human environment. It is intended to be a means of configuring civilization and human activity so that society, its members and its economies are able to meet their needs and express their greatest potential in the present, while preserving biodiversity and natural ecosystems, and planning and acting for the ability to maintain these ideals in a very long term. Sustainability affects every level of organization, from the local neighborhood to the entire planet.

1. SUSTAINABLE BUILDING CONCEPT

In 2005, the World Sustainable Building Conference was held in Tokyo with great success. It defined the concept and the theme of the SB05 Tokyo. According to [2], this conference slogan recognized that it was the time to move into action towards the common goal of providing buildings and urban context that support sustainable ways of living. Rather than being simply the one-way presentation of ideas between experts, SB05Tokyo collected constructive debates among the participants, including clients and users, to shape positive actions that could be supported and/or shared. A holistic structure (Fig.1) of the sustainable building was examined, according to possible actions along with the design process and to possible objects of related actions. Those actions and objects included not only new buildings but also existing building stock to be maintained, upgraded, re-used or converged, which was widely recognized to be crucial in lowering the environmental load.

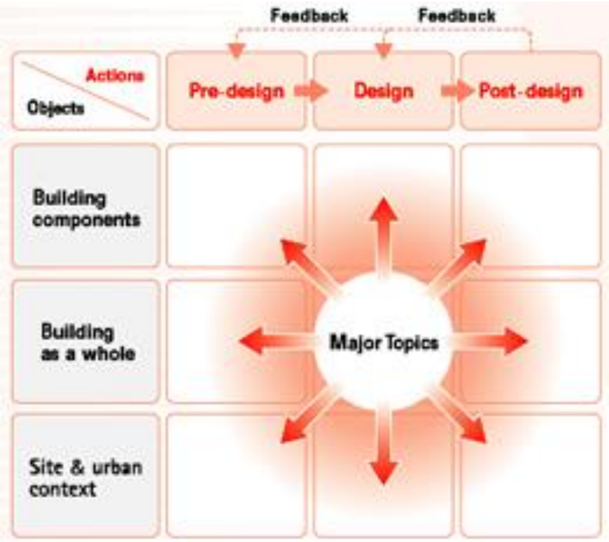

Fig.1 - Holistic Structure of Sustainable Building Development

Per [2], Sustainability has “Environmental”, “Social” and “Economic” aspects (Fig.2). Prior concepts gave priority more or less on scientific and engineering aspects of built-environment. It will turn its eyes to the other strongly related aspects as well, while keeping the original scientific nature. Given this, more holistic approach towards dissemination of the movement could be executed.

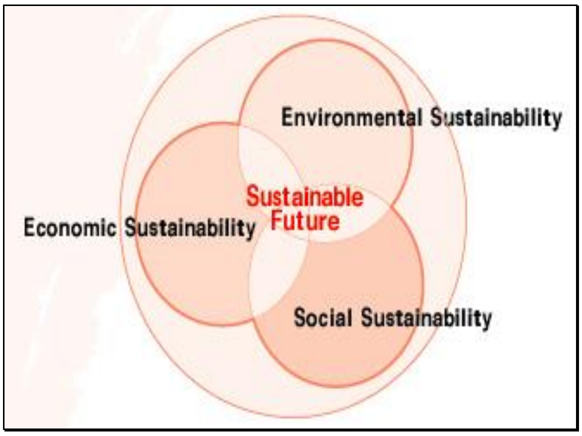

Fig.2 – Aspects of Sustainability

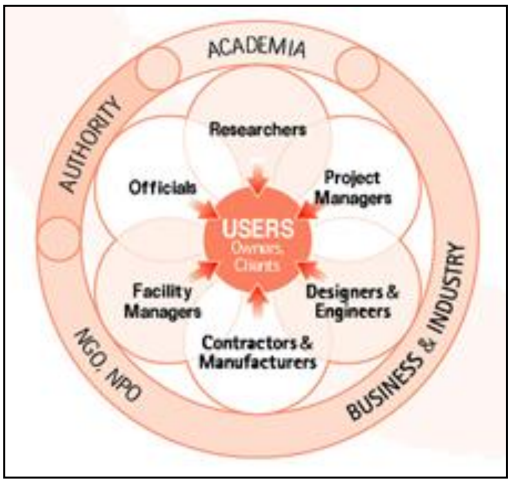

Fig.3 – Linkages between Stakeholders

From [2], it bridges the existing gaps in terms of interests and understanding among the stakeholders of Sustainable Buildings, including clients/users, construction community and planners (Fig.3). Within this stream, the best business practices shall be examined to bridge the gap between high level corporate policy statements and project / investment practice.

2. SUSTAINABLE BUILDING DESIGN AND COMPONENTS

From [1], the practice of green building can lead to benefits including reduced operating costs by increasing productivity and using less energy and water, improved public and occupant health due to improved indoor air quality, and reduced environmental impacts by, for example, by lessening storm water runoff and the heat island effect.

Green building is an essential component of the related concepts of sustainable design, sustainable development and general sustainability.

Practitioners of green building often seek to achieve not only ecological but aesthetic harmony between a structure and its surrounding natural and built environment. The appearance and style of sustainable homes and buildings can be nearly indistinguishable from their less sustainable counter-parts.

Green design often emphasizes taking advantage of renewable resources, e.g., using sunlight through passive solar, active solar, and photovoltaic techniques and using plants and trees through green roofs, rain gardens, and for reduction of rainwater run-off. Many other techniques, such as using packed gravel for parking lots instead of concrete or asphalt to enhance replenishment of ground water, are used as well.

Sustainable Building components include energy efficiency in cooling and heating, alternative energy production in building design, building placement, building materials, waste management, intelligent building management, re-using structures and materials, new sustainable technologies, and social sustainability in architecture.

2.1 ENERGY EFFICIENCY

Energy efficiency is perhaps the most important single goal of sustainable architecture. Architects and Engineers use many different techniques to reduce the energy needs of buildings. Heating systems are a primary focus for sustainable architecture because they are typically one of the largest single energy drains in buildings. Passive solar designs allow buildings to harness the energy of the sun efficiently without the use of any active solar mechanisms such as photovoltaic cell solar panels. Typically passive solar building designs incorporate materials with high thermal mass that retain heat effectively and strong insulation that works to prevent heat escape. In addition, low energy buildings typically have a very low surface area to volume ratio to minimize heat loss. Windows are placed to maximize the input of heat-creating light while minimizing the loss of heat through glass (a terrible insulator). In the northern hemisphere this usually involves installing a large number of south facing windows to collect direct sun and severely restricting the number of north facing windows. Certain window types, such as double glazed windows, provide much better insulation than conventional glass windows. Deciduous trees are often planted in front of windows to block excessive sun in summer with their leaves but allow light through in winter when their leaves disappear. Evergreen plants are often planted to the north of buildings to shield against cold north winds.

In warmer climates where cooling is a primary concern passive solar designs can also be very effective. Masonry building materials with high thermal mass are very valuable for retaining the cool temperatures of night throughout the day. In addition builders often opt for sprawling single story structures in order to maximize surface area and heat loss. Buildings are often designed to capture and channel existing winds particularly the especially cool winds coming from nearby bodies of water. Many of these valuable strategies are employed in some way by the traditional architecture of warm regions, such as southwestern mission buildings.

From mechanical and electrical building services design for energy efficiency, there are hundreds of practical solutions. It is the responsibility of building services and energy engineers to design for a suitable system that fits the requirement of an energy efficient building in order to achieve high sustainability.

2.2 ALTERNATIVE ENERGY PRODUCTION

Active solar devices such as photovoltaic solar panels help to provide sustainable electricity for any use. Roofs are often angled toward the sun to allow photovoltaic panels to collect at maximum efficiency, and some buildings even move throughout the day to follow the sun. Undersized wind turbines (normal turbines are often over 250 feet) are becoming increasingly practical for individual consumers and builders. Active solar water heating systems have long provided heating-specific energy in a sustainable manner. Occasionally houses that use a combination of these methods achieve the lofty goal of "zero energy" and can even begin generating excess energy for use in other structures.

2.3 BUILDING PLACEMENT

One central and often ignored aspect of sustainable architecture is building placement. Although many environmentalists envision the ideal home or office structure as an isolated place in the middle of the woods this kind of placement is often detrimental to the environment. First such structures often serve as the unknowing frontlines of suburban sprawl. Second isolated structures usually increase the energy consumption required for transportation and lead to unnecessary auto emissions. Ideally most building should avoid suburban sprawl in favor of the kind of light urban development. Careful mixed use zoning can make commercial, residential, and light industrial areas more accessible for those traveling by foot, bicycle, or public transit.

2.4 WASTE MANAGEMENT

Sustainable architecture focuses on the on-site use of waste, incorporating things such as grey water systems for use on garden beds, and composting toilets to reduce sewage. These methods, when combined with on-site food waste composting and off-site recycling, can reduce wastes to a small amount of packaging waste.

2.5 RE-USING STRUCTURES AND MATERIALS

Some sustainable architecture incorporates recycled or second hand materials. The reduction in use of new materials creates a corresponding reduction in embodied energy (energy used in the production of materials). Often sustainable architects attempt to retro-fit old structures to serve new needs in order to avoid unnecessary development.

3. NEW SUSTAINABLE TECHNOLOGIES

There are new sustainable technologies developed in the recent years and they are implemented world wide.

3.1 PASSIVE HOUSE

The term Passive House refers to the rigorous, voluntary, high standard for energy use in buildings. It results in ultra-low energy buildings that require little energy for space heating. The first Passive buildings were built in Darmstadt, Germany, in 1990, and occupied the following year (Fig.4). In September 1996 the related institute was founded in Darmstadt to promote and control the standard. Since then more than 6,000 passive buildings have been constructed in Europe, most of them in Germany and Austria, with others in various countries world-wide.

Fig.4 - One of the original Passive Houses at Darmstadt, Germany

Despite the name, the standard is not confined only to houses. Several office buildings, schools and supermarkets have also been constructed to the standard. Although it is mostly applied to new buildings, it has also been used for refurbishments.

The Passive standard requires that the building is within the following limits:

- The building must not use more than ≤ 15 kWh/m²a (4,755 Btu/ft²/yr) in heating energy
- The specific heat load for the heating source at design temperature must be less than 10 W/m²
- With the building pressurized to 50Pa by a blower door, the building must not leak more air than 0.6 times the house volume per hour (n50 ≤ 0.6/h).
- Total primary energy consumption (primary energy for heating, hot water and electricity) must not be more than 120 kWh/(m²a) (38,039 Btu/ft²/yr)

These standards are much higher than houses built to most normal building codes.

These buildings take a lot of high technology applications such as super-insulation, advanced window technology, passive solar design, air tightness design, heat recovery ventilation, energy efficient equipment in heating, cooling and lighting.

3.2 ZERO ENERGY BUILDING

A zero energy building (ZEB) is a term applied to a building with a net energy consumption of zero over a typical year. In other words, the energy provided by on-site renewable energy sources is equal to the energy used.

A building approaching zero energy use may be termed a near zero energy building or ultra-low energy building. Those that produce a surplus of energy may be known as energy-plus buildings.

Although zero energy buildings remain uncommon in developed countries, they are gaining in importance and popularity. The zero-energy approach is seen to be a potential solution to a range of social and environmental issues, including reducing carbon emissions, reducing dependence on nuclear power, fuel imports, and the use of fossil fuels in general, and providing a measure of protection against increased future energy prices. One typical example is the BedZEB zero energy housing in the UK (Fig.5).

Fig.5 – BedZED zero energy housing in the UK

In the case of individual houses, various micro-generation technologies may be used to provide heat and electricity to the building, perhaps using solar cells or wind turbines for electricity, and biofuels, or solar collectors linked to seasonal thermal stores, for space heating. To cope with fluctuations in demand, zero energy buildings are frequently connected to the electricity grid, and may export electricity to it when there is a surplus. Others may be fully autonomous (off-grid) buildings.

There are potential advantages of ZEB:

- it appears to isolate the buildings' occupant(s) from energy price increases
- buildings built using ZEB concepts tend to be more comfortable due to more uniform interior temperatures

- it is substantially less expensive to improve energy efficiency during initial design and construction than it is to do so through a retrofit
- higher resale value
- the value of a ZEB building relative to similar conventional building increases as energy costs increase

3.3 SUPER-INSULATION

Super-insulation is an approach to building design, construction, and retrofitting. A super-insulated house is intended to be heated predominantly by intrinsic heat sources (waste heat generated by appliances and the body heat of the occupants), without passive solar or large amounts of thermal mass, and with very small amounts of backup heat. This has been demonstrated to work in very cold climates but requires close attention to construction details in addition to the insulation.

Some may consider that super-insulation is an alternative to passive solar (although many building designs include features of both with special attention to preventing summer overheating). Super-insulation is one of the ancestors of the passive house approach. A related approach to efficient building design may be zero energy building.

There is no set definition of super-insulation, but super-insulated buildings typically include:

- Very thick insulation (typically R40 walls and R60 roof)
- Detailed insulation where walls meet roofs, foundations, and other walls
- Airtight construction, especially around doors and windows
- a heat recovery ventilator to provide fresh air
- No large N-facing windows (or s-facing in the Southern Hemisphere)
- No large amounts of thermal mass
- No active or passive solar heat (but may have solar water heating)
- No conventional heating system, just a small backup heater

3.4 GREEN ROOF

A green roof is a roof of a building that is partially or completely covered with vegetation and soil, or a growing medium, planted over a waterproofing membrane. The term does not include roofs which are merely colored green, as with green shingles. It may also include additional layers such as a root barrier and drainage and irrigation systems. Container gardens on roofs, where plants are maintained in pots, are not included in this discussion, as they are not considered true green roofs.

There are various benefits of a green roof:

- Provide amenity space for building users — in effect replacing a yard or patio
- Grow fruits, vegetables, and flowers
- Reduce heating (by adding mass and thermal resistance value) and cooling (by evaporative cooling) loads on a building — especially if it is glassed in so as to act as a terrarium and passive solar heat reservoir
- Reduce the urban heat island effect
- Increase roof life span
- Reduce storm water run off
- Filter pollutants and CO_2 out of the air

- Filter pollutants and heavy metals out of rainwater
- Increase wildlife habitat in built up areas

Fig.6 - An intensive roof garden in Manhattan, New York, USA

3.5 WIND CATCHER

A windcatcher is a traditional Persian architectural device used for many centuries to create natural ventilation in buildings. It is not known who first invented the windcatcher, but it still can be seen in many countries today. Windcatchers come in various designs, such as the uni-directional, bi-directional, and multi-directional. It is believed that the windcatcher functions based on the difference of height between base and tip. The height difference creates a slight pressure gradient between the base (which is inside the house) and the tip of the windcatcher's column whenever a breeze or wind passes through the tip of the windcatcher (that is not felt at the base). The pressure gradient then helps suck out the warmer air inside the house up through the column leaving the denser cooler air behind. The cumulative effect over a 24 hour period is quite noticeable.

When coupled with thick adobe that exhibits high heat transmission resistance qualities (R-value), the windcatcher is able to chill lower level spaces in mosques and houses (e.g. shabestan) in the middle of the day to frigid temperatures.

Fig. 7 – Windcatcher (Left) and Wind Tower (Right)

A Wind Tower is a structure seen on ancient buildings of the Middle East, particularly Bahrain. This acted like a natural air conditioner creating a soothing effect in the harsh conditions of the desert.

3.6 SOLAR CHIMNEY

A solar chimney often referred to as thermal chimney is a way of improving the natural ventilation of buildings by using convection of air heated by passive solar energy.

Air conditioning and mechanical ventilation have been for decades the standard method of environmental control in many building types especially offices. Global warming, pollution and dwindling energy supplies have lead to a new environmental approach in building design. Innovative technologies along with bioclimatic principles and traditional design strategies are often combined to create new and potentially successful design solutions. The solar chimney is one of these concepts currently explored by scientists as well as designers, mostly through research and experimentation.

A Solar chimney can serve many purposes (Fig.8). Direct gain warms air inside the chimney causing it to rise out the top and drawing air in from the bottom. This drawing of air can be used to ventilate a home or office, to draw air through a geothermal heat exchange, or to ventilate only a specific area such as a composting toilet.

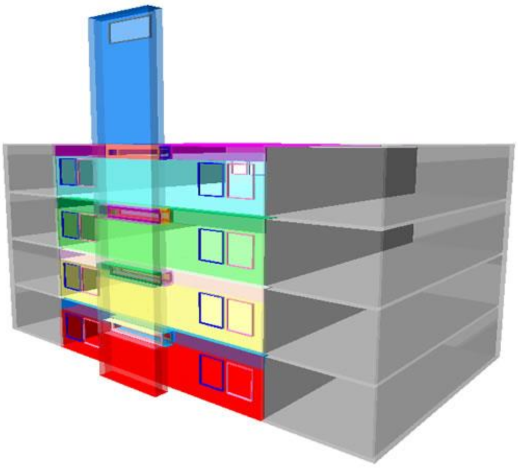

Fig. 8 - CAD(TAS) Solar Chimney model

Natural ventilation can be created by providing vents in the upper level of a building to allow warm air to rise by convection and escape to the outside. At the same time cooler air can be drawn in through vents at the lower level. Trees may be planted on that side of the building to provide shade for cooler outside air.

This natural ventilation process can be augmented by a solar chimney. The chimney has to be higher than the roof level, and has to be constructed on the wall facing the direction of the sun. Absorption of heat from the sun can be increased by using a glazed surface on the side facing the sun. Heat absorbing material can be used on the opposing side. The size of the heat-absorbing surface is more important than the diameter of the chimney. A large surface area allows for more effective heat exchange with the air necessary for heating by solar radiation. Heating of the air within the chimney will enhance convection, and hence airflow through the chimney.

Openings of the vents in the chimney should face away from the direction of the prevailing wind.

The use of a solar chimney may benefit natural ventilation and passive cooling strategies of buildings thus help reduce energy use, CO_2 emissions and pollution in general. Potential benefits regarding natural ventilation and use of solar chimneys are:

- Improved ventilation rates on still, hot days
- Reduced reliance to wind and wind driven ventilation
- Improved control of air flow though a building
- Greater choice of air intake (i.e. leeward side of building)
- Improved air quality and reduced noise levels in urban areas
- Increased night time ventilation rates
- Allow ventilation of narrow, small spaces with minimal exposure to external elements

3.7 THE LATEST "NEW"

From Professional Engineering September 2006 [3] issue, UK building designers found an answer to global warming. They revised building regulations to incorporate an innovative "Wind Turbines" into tall buildings (Fig.9). Designers have incorporated three 30m-diameter wind-turbines into the design of the Bahrain World Trade Centre.

Fig.9 – Wind Turbines in Tall Building

From Apple Daily on 29 October 2006 [4], it reports that UK plans to build its first green and environmental city in East London of size 3 hectares land as the first of its kind in the country (Fig.10). It will consist of 230 houses, self produced energy and with almost zero CO2 emission. The energy source will be wind and solar.

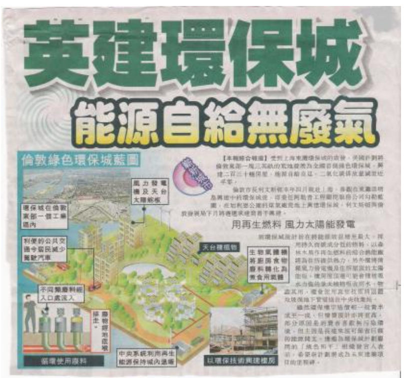

Fig. 10 – UK's first Green City in East London

4. CONCLUSION

In the recent years, sustainable development has been recognized of its importance to everybody in the modern world nowadays. The significant advantages and the trend of moving forward will definitely be adopted in pace by many countries in the coming years. In the long term, the promotion for sustainability development is an everlasting and process.

5. AUTHORS

Dr Leonard Chow is the Vice-chairman of HKAEE and he was the immediate past chairman of Asian Institute of Intelligent Buildings. He achieved the title of Certified Energy Manager (CEM) in 2005 and the Certified Building Commissioning Professional (CBCP) in 2006 granted by the Association of Energy Engineers (USA). He was graduated at the Mechanical Engineering Department with First Class Honours at the Imperial College of Science and Technology, University of London, U.K. He practices as a Mechanical and Building Services Engineer for over 20 years. Subsequently, he obtained his Master MSc and PhD degree in Engineering at the University of Hong Kong and University of Western Australia. Dr Chow is currently a chartered engineer in UK, a registered professional engineer in Hong Kong and a chartered professional engineer in Australia. He establishes his own company ISPL Consulting Ltd in the mid 1995 and celebrates the 10th year anniversary in 2005. His company is the consultants in Mechanical, Structure, Safety and Environmental (Energy & IAQ) aspects with about 25 employees. Dr. Chow is actively involved in professional institution contributions. He wrote over 30 technical papers, guidelines, manuals and conducted over 20 technical seminars in Hong Kong, Tokyo, Beijing, Xian, Shanghai and Singapore in the recent years.

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