Studying and Optimizing Sustainable Methods for Buildings

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Abstract

Sustainable buildings are increasingly involved in building design, and many other advanced technology of continuous improvement. Sustainable construction techniques are then introduced from new materials and energy technology to the improvement of envelope thermal performance, construction equipment, and so on.

This paper will focus on how to conduct sustainable design and construction using the following sustainable technologies: construction moisture dehumidification, building heat and ventilation, solar energy utilization, wind energy use, construction of water-resistant, use of local materials and waste management.

This study is not only consistent with the idea of human society as sustainable development, but also provides a grand new starting point for residential construction and design.

Keywords: sustainable design technology; renewable energy; waste management; energy consumption for residential buildings

Contents

1 Introduction

A building is a structure which is designed permanently in the local place for human use. Buildings stand in a variety of shapes and functions, and have been adapted for a wide spread number of factors including available building materials, weather conditions, ground conditions, specific utilizations and aesthetic reasons.

Buildings serve different needs of society, primarily as shelter from weather, living space, privacy, security problems, to reserve belongings, and then to comfortably live and work in. It can be summarized to different species based on their functions including commercial, residential, agricultural, educational, industrial, governmental and so on.

Nowadays, with the continuous increasing of population and development of technology, the need for buildings especially for the residential buildings is becoming far overwhelming. Thus, the building construction and design perform a crucial role in the civil engineering and require for particular attention. One of the most popular tendencies about building construction is sustainable building.

Sustainable building is also called green building (see figure.1), which refers to a structure that is environmentally responsible and resource-efficient throughout a building's life-cycle. Thus, from design to siting, construction, operation, and maintenance, the whole design and process should be sustainable. In other words, sustainable building design involves obtaining balance between home using building and the surrounding environment. This design requires close collaboration of the architects, the design team, the structural engineers, the contractors and the client at all project stages. The sustainable building expands and improves the classical building design from the concerns of durability, economy, serviceability and comfort. How to satisfy all the concerns

simultaneously has becoming the most crucial challenge for structural and construction engineers.

Fig. 1 Sustainable Building (Residential)

Although new technologies have been constantly developing to complement current design in building much greener and more sustainable structures, the general objective is assigned to reduce the overall impact of the built environment on human health and the natural environment that we depend on. Thus, sustainable buildings should be the unavoidable tendency for future residents. The paper is based on the mentioned impact and studied how to create sustainable decisions for new buildings using sustainable construction technology in detail.

2 Sustainable Construction and Design Technologies

The paper will focus on how to meet the sustainability requirements and improve the comfort of the building space associated with the general layout of the local environment for new residential building. The following seven kinds of sustainable technologies will be analyzed: construction moisture dehumidification, building heat and ventilation, solar energy utilization, construction of water-resistant, wind energy use, local materials utilization, and waste management.

2.1 Construction Moisture Dehumidification

The construction effectiveness has been evaluated on its work quality and the ability to complete projects on schedule for a long time. Construction project managers, general contractors, and respective subcontractors who must satisfy tight deadlines and efficiency of the work should feel the most heat. One of the most challenging problems often faced is to deal with a concrete slab with elevated moisture levels.

Frequently, the tight construction schedule will not allow the luxury time of waiting for concrete natural drying process. Concrete curing which includes moisture dehumidification always stands in the critical path. The duration of concrete moisture dehumidification can influence the total project duration directly. As a result, the longer time it takes for concrete slabs to dry, the more delays that would be created. Unless the specifications for moisture content in the concrete have been met, the sealing subcontractors cannot be applied, the flooring procedure can’t be preceded, and manufacturer’s schedule will be delayed instead.

Of all the various available building materials, concrete should be the thorniest resource of moisture. Unless the excess moisture is definitely removed, several serious problems may result.

For example, it will cause migration to of moisture from the core center to the surface, which can result in adhesive failures, discoloration of flooring materials or bubbles in coatings. What's more, it can also create growth of mold in other materials as high ambient moisture remains and poor initial adhesion of flooring installed on the slab.

In order to balance between the concrete quality and project duration with regarding to construction moisture dehumidification, we can use a processing method for a concrete structure which involves soaking a surface of a concrete structure in treated water containing micro-bubble for a predetermined period (see figure.2). A moisture-drying process is supposed to remove component which contains alkaline such as calcium compound, ammonia, amines and potassium compound in concrete structure by using activated charcoal, zeolite and ion exchange resin. The surface of the concrete structure can be moistened by water aspersion. Thus, by monitoring moisture content, the dehumidification process can be controlled well in a proper limit to ensure the safety and quality.

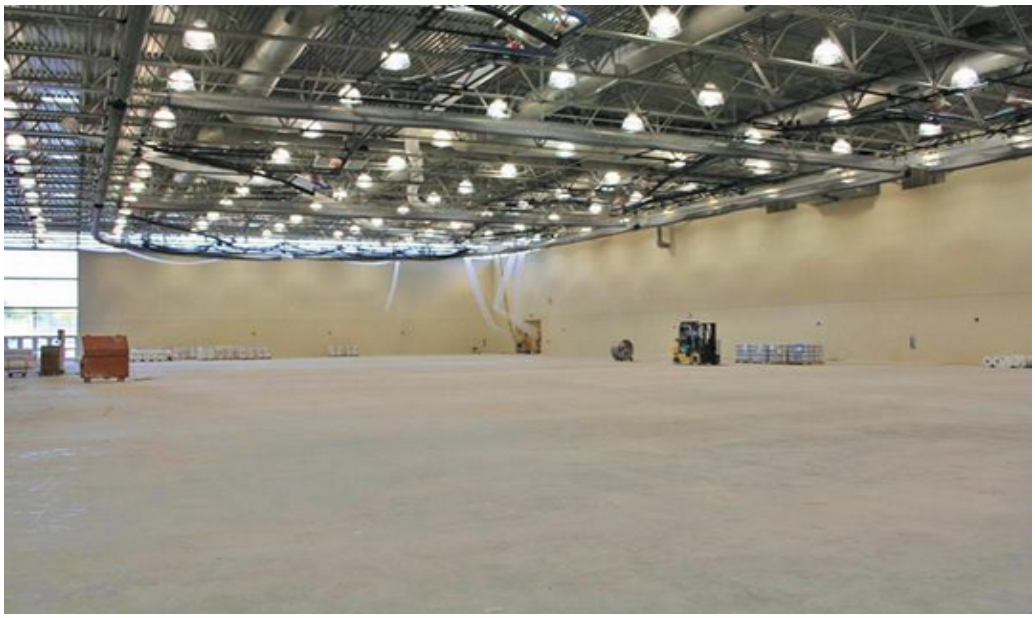

Fig. 2 Concrete Moisture Dehumidification

2.2 Building Heat and Ventilation

For a residential building, the importance for a heating system is obvious. A heating system provides warmth to the whole interior environment of a building to multiple rooms. When heating is combined with other systems in order to control the building climate, the whole system may be an HVAC system (see figure.3).

Building HVAC system serves as the mediator of interior and exterior environment which controls the heat interaction between the building and the nature. Thus, building HVAC system should be constructed not only to satisfy human need but also to create a sustainable cycle for the nature environment as well.

The effective way to solve the problem of optimal joint control of HVAC system during the shut-down stage is studied for balancing of energy saving as well as maintaining indoor thermal comfort. The problem is generated as a set-up optimization problem given the volume of natural ventilation and the statuses of the supplied air as system inputs, the indoor air temperature and moisture contents as system states, the total building energy consumption as the desired optimization objective, and also the comfort requirements of indoor residents as extra constraints.

Thus, a suggested policy that is good-enough to improve this problem can be achieved by using ANN, an index to predict the relationship among various factors including climate parameters, the initial indoor environment conditions, the joint control of HVAC natural ventilation and the optimal shut-down time of HVAC. This policy is proved to have a higher adaptability, generalizability and the allowable accuracy. What's more, the reliability of ANN index can also be further improved by optimizing the problem's configuration. The advanced technology can be

utilized to reduce building energy consumption, which further achieves a 20% reduction of total energy consumption for one hour numerical simulation. If every building can be constructed aiming at achieving lower energy consumption and a more sustainable process, the nature that we depend upon would be a much better and continuous place to live in.

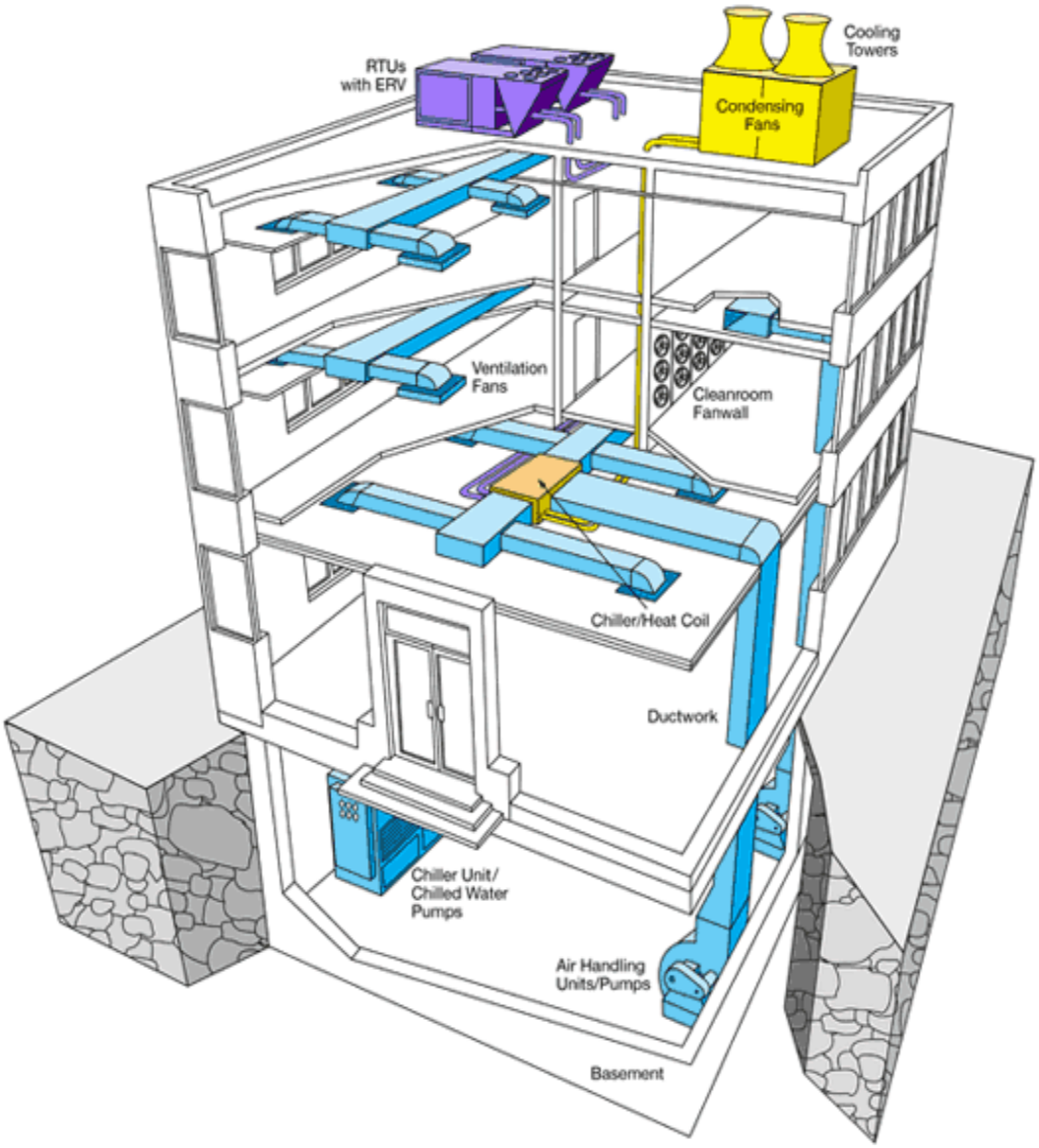

Fig.3 HVAC System for a Building

2.3 Solar Energy Utilization

Building energy consumption indicates that there exists a sharp upward tendency of total construction rising and living comfort upgrading. To realize the sustainable development of national economy, resource-efficient and energy-effective construction should be nothing but imminent and imperative. Currently, with ever increasing need of building construction, the energy waste problem is negligible, and the growth rate of building energy consumption exceeds far beyond that of energy production. If these high-energy buildings are continuing to be developed, the national or even the international energy production would be difficult to meet the tight demand.

In order to meet the ever increasing need for energy, an important source of renewable energy is solar energy and its technologies are broadly utilized for buildings (see figure.4). By using solar energy as a new energy source, the energy consumption can be reduced to really low and can be controlled under the limit. Thus, we can adopt passive solar building design, which does not involve the use of mechanical and electrical devices.

In passive solar building design, roofs, walls, and windows are supposed to gather, store, and distribute solar energy in the form of heat in the winter and reject as much solar heat as possible in hot summer. However, the key point of designing a passive solar building is to take most advantage of the local climate and atmosphere. Elements to be considered should include location and size of windows, thermal insulation, glazing technology, thermal mass, and shading percentage.

For new buildings, passive solar design techniques can be easily applied, but for existing buildings it can be only adapted or adjusted to make full advantage of solar energy. Reasonable passive design strategies can not only reduce the disastrous impact on natural environment, but also can minimize the total building energy consumption. Therefore, the efficiency of passive building energy technology plays an important role in carrying out the responsibility of sustainable development, reducing greenhouse emission, and at the same time realizing the energy conservation plan.

Thus, in the building construction, solar energy facilities should be taken serious consideration of and combined with construction process to achieve sustainable energy usage and consumption.

Fig.4 Solar Energy Utilization for Residential Buildings

2.4 Construction of Water-Resistant

Buildings, especially residential building which is a reliable place for humans should be able to provide a respectively safe and comfort shelter with regard to winds, rains, snows and other

natural phenomenon. Thus, it requires being water resistant. Water-resistant describes the ability to object water relatively unaffected or resisting the permeation of water under specified conditions such as wet environments. This is mainly realized be the utilization of plywood (see figure.5).

Fig.5 Water Resistant Plywood for Buildings

Learnt from the team project, the construction of plywood always stands in the critical path. The quality and duration of plywood have crucial influence on the reliability and efficiency of whole project. Thus, how to choose a proper and economic material for plywood and how to monitor the quality of plywood construction become key factors for building water resistance.

Wood is a primary and important construction material which is ecological sustainable and flexible in usage. However, as a bio-material, moisture crisis can decrease its physical property, mechanical quality and biological serviceability and durability. It is thus crucial to understand moisture dynamics in wood to make optimal usage of it. The movement process of water through

wood is complicated by the physical fact that the coarse capillary system inside the wood is interconnected.

Wood is easy to get as a resource, but how to balance between the wood quality as water resistant material and the economy of cost is the problem we need to figure. All the materials should be adjusted to local conditions and measured to be suitable.

To improve water resistance of plywood, an advanced technology called neutron radiography and X-ray CT can be used to monitor water transportation in the internal micro-structure respectively. The factors we need to take into considerations include water uptake and release of plywood which would be influenced by veneer checks and gaps, the type of adhesive and grain direction of veneers. By analyzing the influential factors and monitoring with existed properties, we may produce more water resistant plywood to protect us from storms and heavy snows effectively.

2.5 Wind Energy Use

Currently, a large majority of energy that has been used in the world still mainly derives from fossil fuels such as coal, natural gas and petroleum. Thus, we are changing towards to other alternatives and there is then negligible and tremendous growth in renewable energy technologies. Alternative energy refers to those energy not came from traditional fossil fuel sources through conventional processes. Wind Energy is another alternative resource besides solar energy that discussed above (see figure.6).

Wind energy is the energy extracted from wind by wind turbines to transfer wind power and produce electrical power instead. It is clean, plentiful, renewable and widely distributed. It produces almost no greenhouse gas emissions during general operation. The most obvious

advantage is that the effects on the environment are generally less problematic than those from traditional power resources.

However, wind energy utilization is limited by the local climate and environment and is mostly used on prairie which has a great access to wind easily. Thus, this method can be only effective for the windy areas such as Chicago and coastal cities. If we master the technology to combine the power generation system with the construction of the building, we can utilize wind as a sustainable energy resource in an incredible efficiency, especially for high-rise buildings. Additionally, weather forecasting permits the wind-electricity network to be predicted and readied for the possible variations in production that will occur.

Wind power generation techniques must take the following factors into consideration: enough capacity of storage; geographically distributed turbines; dispatchable backp sources; the ability of exporting and importing power to neighboring areas; the responsibility to reduce demand when wind production is low. By figuring the mentioned problems out for building, not only residential ones, we can reduce energy consumption to an incredible extent and create a much more sustainable planet to live in than we've ever imagined. The spread tendency of wind power should govern sustainable market and turn out to be effective way to improve energy crisis.

Fig.6 Wind Energy Use for Residential Buildings

2.6 Use of Local Materials

Conventional building materials are tightly associated with international market forces which often render housing becoming much more unaffordable to low-income families. In addition, some of conventional materials are climatically inappropriate especially in hot arid regions such as Africa. Traditional materials sometimes also have bare resistance to erosion, are inclined to insect infestations, or have poor structural properties causing multi-story construction impossible. Therefore, the housing cost in those areas is becoming more expensive. One way to reduce the housing cost is wisely using local materials which are much more economic and easier to access.

We use local materials available near the construction site including not only stone, granite and wood, but also mud or clay or cement dust to improve internal resistance to erosion and enhance structural properties for construction (see Figure.7).

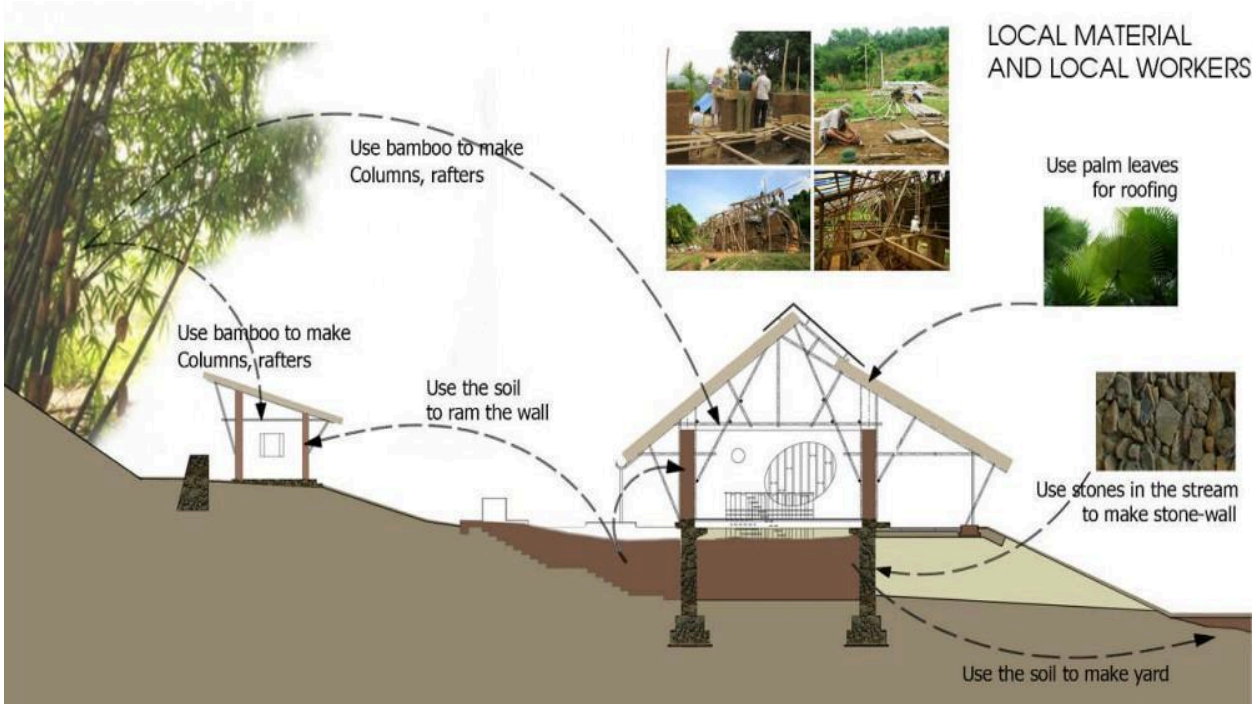

Fig.7 Local Material for Building Construction

New material designs should be approved by relevant regulations or authorities. That combined with the revival traditional construction techniques in producing and building with those materials allows communities more independence of constructing their own much more affordable houses. At minimum, they save transportation fees of material costs, and reduce the overhead for the contractors or subcontractors, which can be gained as taught in class lectures.

There are some new houses called collective housing. They incorporate appropriate elements of local building materials for social and climatic design primarily and now is spontaneously imitated by local communities in many regions of Unites States. This methodology is potentially

applicable wherever affordable and viable house cannot obtained from conventional building materials.

2.7 Waste Management

Nowadays, responsible waste management is one of the most essential aspects of sustainable building, which is second only to energy efficiency referred by building professionals. Actually, an increasing number of residents and contractors are inspired to strive for innovative and impactful waste management and trying to adopt environmental strategies. All those strategies as well as advanced technologies begin from the design phase of a project, and then extend into construction and throughout operation and maintenance period. Therefore, how to ensure the feasibility of the measures comes first for our consideration.

Waste management generally includes garbage collection, waste treatment and recycling materials. First, we should make clear classification of waste according to their materials, different functions and recyclability. Then, appropriate measures can be adopted to deal with every kind individually and respectively. In this context, the process of managing waste means eliminating waste where possible; minimizing waste where feasible; and recycling or reusing materials which reasonable. Current waste management practices have identified those processes as imperial procedure for sustainable resources management.

Effective management of building-related waste requires close coordination and cooperation of governments, communities, and professional groups. It can be divided into the following aspects: Eliminating waste, Minimize waste, Reusing materials.

2.7.1 Eliminating Waste

Some waste generated in the process of construction can be eliminated. For example, durable metal such as steel and aluminum in concrete construction may be selected on the basis of being readily reusable for other projects such as reinforcement for bridges. Thus, eliminating other material waste such as wood waste which is associated with formwork fabricated of plywood might be effective for reducing waste for the whole building project. In a word, elimination of waste can be beneficial to reduce impacts on human health and the environment at the same time.

2.7.2 Minimize Waste

Other building-related waste can be minimized. For example, different construction products can be designed based on its original manufacture and assigned to be transported with minimal packaging and cost. In addition, we can also consider that proper selection and utilization of recyclable materials provides unbelievable potential to minimize waste during the construction period.

2.7.3 Reusing Materials

Unlike other two kinds, some materials can be reused. For example, even after a collapse of a house, if the doors and windows are in good conditions, they can instead substitute for new products, be sold to reduce cost or be used on another project. They are all beneficial forms of material reuse.

Fig.8 Waste Management

There are also some materials which cannot efficiently and effectively be eliminated, minimized or reused. The optimal solution for them is ultimately collection, or managed disposal at the lowest cost suggested by professionals. Nevertheless, in many areas, disposal fees are really expensive. Thus, we need to make wise choice according to local policy and try to obtain a sustainable balance between cost and local environment.

3 Conclusion

Sustainable construction of buildings primarily aims at reducing the environmental impact of a building through the entire life-cycle, optimizing its economic serviceability and achieving the comfort and safety for the residents simultaneously.

While normal building is guided by the short term economic concerns, sustainable construction is emphasized on long term economy, quality and efficiency. At each building stage of the life cycle, it decreases harmful environmental influences and enhanced the economic sustainability of the building. A sustainable design and construction of a building should take the use of water, raw materials, energy and land into serious consideration over its whole life cycle.

In order to achieve a new and more global approach for People-Planet-Prosperity, the paper discussed seven methods to improve sustainable design and construction for buildings, especially for residential buildings. The methods covers from basic materials to renewable resources to energy consumption reduction and then to waste management. Most suggested measures combine the current tendency with most advanced technology to achieve a much more sustainable house.

However, unavoidably, the housing cost would be increasing due to the high technology or extra consideration introduced in the paper and the construction process can also be limited by local conditions or other factors. Thus, we need to use the method we learned from the class such as time cost control and time-cost trade-off analysis to balance between the resources, cost and time to obtain an optimal solution for building construction.

Thus, with sustainable construction and design of new buildings, our planet will increasingly develop as a green place to live in.

Fig. 9 Combined Sustainable Building under Construction

Fig. 10 Green Planet- Sustainable Objective

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