

## A Study on Advanced Design Technologies for the Efficient use of Material Resources in Green Residential Building

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**Abstract** — In this paper, we introduce and analyze a real project to: i) study the guiding design ideas on the utility of material resources and materials efficiency, and ii) explore the design technologies that are feasible in the practices of green residential building. The results aim to: i) improve the technology of the frame system used in designing and constructing green residential buildings, ii) establish the theoretical basis for green residential building design and iii) promote their extensive application.

**Keywords** – design technology; utility of materials resources; materials efficiency; green residential buildings

### I. INTRODUCTION

To carry out and implement the national economical policy of saving resource and protect environment, and promote sustainable development and regulate the criticism of green building, a new criterion named 《The green building evaluation standards》 (GB/T50378-2006) was implemented officially on June 1st, 2006 in China (“evaluation standards” for short as follows). The evaluation system include six kinds of indexes, of which the index of the material efficiency and utilization of material resource is important one.

The construction of residential buildings need massive materials, the healthy of residents will be damaged by the inferior quality of material. In the process of constructing green buildings, the choice of building material, decorative material and elements of buildings are very important. First of all, the 3R material (for short of repeatable, reproducible, recycle) should be advocated to apply. Secondly, it should be applied that the new type building materials which is non-poisonous, innocuous, be beneficial to health of people, which should have the national environmental logo[1].

### II. DESIGN TECHNOLOGIES OF MATERIAL EFFICIENCY AND MATERIAL RESOURCES UTILIZATION

#### A. Saving Material and Material Resources Utilization are Also Closely Related to Building Energy Efficiency and Energy Utilization

The exterior protected construction of building is a complex form which is consisted by all kinds of building materials in accordance with the requirements of construction. Different materials have different thermal conductivity, and the thermal conductivity of building materials reflect the material's ability to transfer heat. So to choose appropriate thermal insulation material, not only it can make the buildings achieve energy saving effect, but also can enhance the ability of against the destruction from other natural factors for buildings and can increase indoor

comfort, prolong the life of buildings [2]. Especially in the northeast cold region, it is significant to apply new technology, new material in the design of external protected construction.

It has been proved by a large number of practices that the external protected construction of building are constructed by block and benzene plate, is the most economical and optimum form in cold region. The external protected construction of high-rise residential building can be constructed by framework with non load-bearing hollow bloc k[3]. It is better for roof to use benzene board or expanded vermiculite as thermal insulation material. In addition, FHP-VC Inorganic composite silicate insulation board has also been the materials for exterior wall and roof with better synthesized performance.

It is also an effective measures of saving materials and materials resources utilization that the controlling of energy-saving design for exteriors wall and doors and windows, that has been mentioned above. Such as using new type of composite wall or single material wall added a layer of expanded perlite insulation mortar, aluminum silicate or stucco gypsum etc., all of above are methods of saving material which are economical and simple. In the design at the condition of providing enough sunshine, day lighting, ventilated and viewing, it should be that the proportion of the area of windows and wall are controlled perfectly, the thermal insulation performance of windows and doors are enhanced, the air tightness from windows and doors is improved and the penetration of cold air is reduced. In the other word, it should be achieved to reduce the area of the exterior windows and doors, improve the insulation performance of the doors and windows themselves, and reduce heat transfer from windows and doors.

#### B. Another effective method of saving material and material resources utilization is the recycling of resources and the reusing of waste material

The building is a creative engineering which comes from nature and returns to nature, so the material applied should not harm human and nature. To achieve the goal of

sustainable development, it have to be restricted to the minimum that the negative influence of materials for environment, and the research of recycling of resources and the reusing of waste material is necessary. Such as industrial waste can be used to produce cement, brick and so on, the waste foamed plastic can be used to produce insulated plank, the wast glass can be used to product cover material and so on[4]. On one side, it can reduce the amount of solid waste and environmental pollution, one the other side it can save raw materials found in nature.

According to view of life cycle in a broad sense, the energy consumption of building materials include several aspects as follows: the production of building materials, the operations of building, the disintegration of daily use, the demolition of buildings, the recycling utility of building materials, and so on. Products and materials with more meticulous and complex process, usually consume more energy in the process of production. In general, the better durability of the material, the less indoor pollution caused. Architects often use local materials and reduce the use of metal and concrete which need high degree process and large energy consumption. They should be chosen that materials don't need reprocessing or lead to minimal environmental influence to the external protected construction. Further more, according to the change of function requirement, the restriction of use period and the requirement of the development of city, etc., the demolition or modification of building may be required. If the aspects of demolition had been considered in the process of design, it will be helpful to material's reuse and recycle[4].

The actively use of recycled building materials will reduce the pressure from landfill and save natural resources. It is necessary to make full use of materials from old buildings and use materials which are made of renewable raw materials. The use of materials which are made of renewable raw materials will reduce solid waste and energy consumption in the process of production and save natural resources. It is gradually became popular in the world with the consciousness of environmentally protection. For example buildings made by paper had appeared largely at the world expo in Sevilla of Spai in 1992. It was constructed by prefabricated paper components that the landmark tower at the entrance of the exhibition, which diameter is 13m, the height is up to 33m. Because of the tower can be decomposed so there are no waste of materials after the exhibition. For another example, the processed plastic bottles has been used to the carpet of the headquarter of American Liszt children shop, of which the tiles made of recycling glass bulb are used on the entrance porch. Many countries are working on the technology of modification and regeneration of building waste and the relationship with cost, which will help to save resources and reduce the waste of the globe.

*C. The content of saving material and material resource utilization is focus on the application of the new environmentally friendly building materials.*

As the important material basis of modern construction engineering, the new buildings materials in the world are

called as healthy building materials, green building materials, environmentally friendly materials, ecological building materials, and so on. The environmentally friendly building materials and products include new materials for wall , new material for waterproof sealing , new type materials for thermal insulation, decoration materials and inorganic nonmetal materials, and so on. To contrast with traditional building materials, the production of new type of building materials can not only reduce the consumption of natural resources and energy, but also can give reasonable development and utilization for a large amount of industrial waste. New type of building materials will not pollute the living environment of human beings, it can also improve the function of buildings, and play a role of preventing poisonous gas, sound insulation, heat insulation, sterilization, temperature, humidity, deodorant, anti-static, anti-radiation, and so on.

According to the advice of the world health organization, the healthy housing should be able to make habitats on the better state completely from the physical, mental and social condition. The most important specific indicator should be achieved is the toxic and harmful building decoration materials are not used as much as possible, such as coating containing high volatile organic compounds; plywood, fiberboard, adhesives containing high allergic chemicals such as formaldehyde; high radioactivity of granite, marble, ceramic brick, coal gangue brick; cement products containing fine asbestos fiber, and so on.

The selection of building materials has certain requirements in urban ecological residence of different European countries. For example, aluminum doors and window are not allowed to be used in residential buildings in German Munich, the reason is the process of producing aluminum will consume a large amount of energy and pollute environment. But some kinds of metal can be recycled, so these kinds of materials are adopted by a large number to construct exterior wall, bearing frame and balcony etc. In recent years, the afforestation rate of European countries is very high. The forest is in a virtuous cycle, and wood, ecological building materials, are commonly used in the construction of residential buildings, of which many use wood products as its frame, wall and construction elements. In order to reduce the amount of chemicals, it is general to use metal without coating to construct exterior wall in Germany. At the same time, in the process of construction, it is used that the integrated supporting technology in a wide range, such as the comprehensive use of composite wall insulation, roof insulation, solar energy installation technology, roof vegetation, permeability pools construction technology, and so on.

At present, the proportion of new wall materials in building engineering is only 22% in China, but the proportion of it is 80%~90% in developed country. The research, development and implementation of environmentally friendly building materials is earlier than us in developed country, which establish some test methods for organic volatile quantity, some performance criteria of environmentally friendly building materials and begin to

promote the identification of low emission symbol. On the other hand, they develop some new products produced by environmentally friendly building materials. Foreign consumers require high standard of the environmentally friendly degree of building decoration materials. The rate of building materials conformed to the standard have beyond 90% in developed country, such as the USA and Western Europe. Japan has promoted no chemical residential buildings. On the basis of proposal and development of environmentally friendly building materials, model buildings for office and living have been appeared in some countries and have got better social and economic benefits. The experience of the successful are worth learning. Ignoring the environmental value of raw material is one of reasons that building have adversely affect on environment. So in order to protect environment, achieving sustainable building design, it need to be regarded that the influence of raw materials to environment as a part of the value system of evaluating the building.

It is a conception with deep connotation and vast extension that environmentally friendly building materials, which is the basis of the development of ecological building. The innovation of material always cause the innovation of technology. In recent years, they appear that the various of new environmentally friendly building materials which are good for saving energy and environment, such as transparent bubble material, high strength lightweight materials, high insulating glass etc., all of these improve the development of ecological building. It is believed that, the promotion of environmental friendly building materials and the design with modern technology, the sustainable development of residential buildings will gradually become a reality.

In the progress of construction, it is better to use local materials, which can reduce the energy consumption and environmental pollution produced by material transportation. In the case of mature technology and economy allowed, it is better to use new environmentally friendly material and apply new technology to enhance physical properties of residential buildings. To try best to make the structure construction and decoration engineering construction can be completed in a single progress to avoid repeated decoration and material waste.

### III. ANALYSIS OF ENGINEERING PRACTICES FOR SAVING MATERIAL AND RESOURCE UTILIZATION OF RESIDENTIAL BUILDINGS IN CHINA

Taking example of two practical engineering, such as "Shanghai Vanke Langrun District" and "A Quasi Business Building of Shanghai Greenland International Square". It is analyzed that the technology methods, which be used in the design to control the indoor environmental quality, these technologies achieve good effect, so they can be reference of the design in the future.

#### A. *The First Example: Shanghai Vanke Langrun District*

Wall materials of the building: the exterior wall materials of this building is 25mm XPS external thermal insulation system from Owens Corning, equivalent with

40mm EPS insulation board (the heat transfer coefficient of it is  $0.79 \sim 0.94 \text{W/m}^2 \cdot \text{K}$ ), which can meet the requirements of external wall provided by the relevant standard. Brick and coating are used for the external wall decoration, the area of the external thermal insulation system is around  $90,000 \text{m}^2$ .

The node processing: The balcony, awning, parapet wall, roof decoration have all obvious feeling of experience; the air conditioning is not necessary in the daytime of summer and there is no hidden trouble of leakage. It is used for roof that the 25mm XPS external thermal insulation system from Owens Corning and Roof Greening (heat transfer coefficient  $0.7 \text{W/m}^2 \cdot \text{K}$ ).

External window: Aluminum alloy profile with superficial positive oxidation process and double hollow glass is used in the whole area. Insulate aluminum alloy profile and LOW-E glass are used for the windows and doors on the south facade. The value K of normal aluminum alloy profile is  $4.0 \text{W/m}^2 \cdot \text{K}$ , but the it of the windows and doors on the south facade is  $3.0 \text{W/m}^2 \cdot \text{K}$ . By detecting, air tightness and water tightness is level 5, resistant to wind pressure reaches level 3.

Material of construction: The premixed concrete, used in the engineering, can enhance the quality of concrete, ensure the stability of concrete's quality. Bulk cement used completely in the total engineering, as an important part of the green construction, can reduce the wastage of material and the wastage of forest resources from cement packaging bags, protect the ecological environment. Construction practice of the project shows that, the above two technologies can reduce the wastage of material and forest resources and protect the ecological environment.

Refined decoration: In the engineering of Shanghai Vanke Langrun District, it is applied that "the comprehensive household solutions". There are 1090 houses which are refined decorated. All of these houses apply integration of design, supervision, construction and decoration, which can reduce the materials waste caused by secondary decoration, and the decoration quality acquire customer recognition, and the repaired rate is lower than the conventional rough room.

Environmental friendly building materials: Decorate building materials is with good quality, first-class green building materials products conform to the requirements of all kinds of national environmental standards. The whole house with decoration also ensure the quality of indoor air exceeds the secondary standard of the "indoor environment quality evaluation" issued by national EPA.

Waste material recycling: With ecological concept, about 400,000 old bricks and tiles removed, which rest of the original site, are reused in the landscape, such as building exterior wall edge, road of district, and so on. It can save building materials and play a role in propaganda of environmental protection.

#### B. *The Second Example: Shanghai Greenland International Square*

The reuse of 3R material:

Renewable material circulation: In the partition wall of this building, it is used that light steel keel gypsum board to divide space flexibly, in this way it can be avoid that repeated material waste produced by multiple decoration from the change of the layout of space, the damage of building component and saving material. The area of light steel keel gypsum board used is about 411m<sup>3</sup>. The external facade use the insulate aluminum alloy profile, the total area is about 65% of the external facade of saving material , and renewable material is about 22%.

The using of waste and scrape materials: The waste and scrape materials, such as steel, steel products, aluminum, plastic and fiber, and so on, are transformed to various of useful article and art works for decoration. It is transformed to public recreational chair by crushing, compression and suppression that the remaining scraps of wood of decoration. To transform the remaining concrete of decoration to works art by transparent resin casting. Using old steel and new type material of silk screen printing to produce indicator map and landscape. (As shown in Fig. 1)



Fig. 1. The example of reforming and using waste material

#### IV. CONCLUSIONS

It can be seen from the above analysis, they are complement each other that saving material, material resources utilization, building energy efficiency, material recycling, waste material modification and the using of environmental friendly building materials, etc., according to the present development situation, the practical techniques can be summarized as the following aspects:

Choose suitable thermal insulation material, especially in the northeast cold region. It is significant to apply new technology, new material, new craft in external protected construction. To strengthen the control of energy saving and design of exterior door and window is that, in the process of

design, under the condition of assurance requirements of sunshine, day lighting, ventilated and viewing, controlling the the proportion of window to wall in residence, improving the performance of heat preservation of doors and windows, improving the air tightness of exterior doors and windows, reducing the infiltration of cold air. In other words, reducing the area of exterior doors and windows is also a effective measure to save material, and utilize material resources.

Actively using recycled construction materials can reduce the pressure of waste landfill and saving natural resources, to make full use of materials from old buildings, and actively use recycled construction materials, use local materials, reduce the using of metal, concrete and some kinds of materials which process difficultly and consume a large amount of energy, to redevelop the short-lived material. The materials be selected that will product minimal environmental impact to exterior protected construction or materials with less secondary processing (paint, reprocessing, waterproof and fireproof treatment).

Focus on the using of environmental protection building materials, which include new wall materials, new heat preservation and heat insulation materials, new waterproof sealing materials, new decoration materials and inorganic non-metallic materials. It will gradually become a reality to promote environmental protection building materials, apply modern high-technology in design, the sustainable development of residence. In the process of construction, it is used that the integrated supporting technology such as the comprehensive use of composite wall insulation, roof insulation, solar installation technology, roof vegetation, permeability pools construction technology.

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#### REFERENCES

- [1] Rong Fang, Qiang ji, Simple analysis 9 parts of design of green resident. 《The theory of building and programming》, 2007.2, pp15-16
- [2] Qian Yongmei, Jin Y.J., Wang R.Z., Research on Applying the Reborn Resource and New Materials for Energy Saving and Protecting Environment in the Design of Green Ecological Residential Building Design at the Super Cold District, Applied Mechanics and Materials, 2012.1, pp826-834
- [3] Chen fang, The appeal of environmental friendly building material and promote the sustainable development of resident building, 《The modernization of building management》, 2004.3
- [4] Wentu Su, Zhibin She, The construction and management of green building, 《Resource and living environment》, 2006.12, pp60-6