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STUDY ON A COMPREHENSIVE ASSESSMENT SYSTEM FOR WOOD-FRAME BUILDING ENVIRONMENT

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ABSTRACT

In order to truly understand the impact that wood-frame buildings have on health, ecological environment, and the consumption of resources, promotion and application of modern wood-frame buildings in China should studied. The environment performance of wood-frame building was assessed using literature analysis, questionnaires and depth interviews, and the comprehensive environment assessment system was established. The assessment criteria of wood-frame building environment were divided into three-levels. This study will provide theoretical guidance to environmental performance assessment of our country's wood-frame buildings, and further improve environmental optimization for wood-frame buildings, provide a theoretical basis for building design, and planning of wood-frame building.

KEYWORDS: Wood-frame building, wood-frame living environment, environmental assessment, environmental quality, environmental performance.

INTRODUCTION

Along with the rapid development of science and economy, urban construction has proceeded apace, however, the construction process and related operations have led to pollution and damage to the environment. Building thoroughly formed the fault zone in the present and history, which without the integration with the surrounding environment, as symbol of modern civilization with just using the concrete to stack the tall building. Theories of sustainable development have led to greater reflection on ways of finding harmonious coexistence among humans, the natural environment, and buildings. Thus, issues related to the living environment have come under greater scrutiny.

Many foreign countries all have developed their own green buildings and building

environmental assessment systems. For instance, BREEAM (Building Research Establishment Environmental Assessment Method), LEED (Leadership in Energy and Environmental Design), GB Tool (Green Building Assessment Tool), which can be applied in many different countries, CASBEE (Comprehensive Assessment System for Building Environmental), which the first green building assessment system in Asia, has great significance for our country (Raymond and Cole 1998; Crawley and Aho 1999; Todd et al. 2001; Grace 2008; Li 2010). In recent years, there was a great development about research on green building assessment in our country. Such as CEHRS, Green Olympic Building Assessment System, Evaluation Standard for Green Building, Green Building Assessment System, The Technical Requirement for Environment labeling Products Eco-housing Promulgated and Enacted by Chinese Government, scientific research institutions and designing institution, which provide the basis and theoretical guidance for green ecological building assessment in our country.

Based on the analysis of the sustainable development situation at home and abroad, wood-frame building can protect, enhance and restore the natural environment, has the importance of the full life cycle. There are several steps in wood construction industry, ("wood resource extraction" →requirement of sustainable, green, ecology, energy conservation, and also comply with the living environment and wood architectural conformation. A large number of wood-frame houses were built in North America, Japan and other developed countries each year. In those countries, they have made some achievements on wood construction performance and application research. For instance, the light wood-frame structures house has just appeared recently in China as a new style residential building, but in developed countries it has existed for about one hundred years. With progress in developing better building environments, there have arisen efforts to make more effective use of wood resources. Also, the related research into wood-frame buildings has received growing interest.

China has a very long history of wooden buildings, and the environment-friendly characteristics of wooden structures are highly esteemed. Wood-frame building has its own historical background and cultural features, and it is an important element of the traditional architecture. It also has a close relationship with living environment, life style and working environment. In recent years, with the quick development of construction and living standards in our country, modern wood-frame buildings have also been developed conforming to China's low-carbon economy and sustainable development requirements. Wood-frame buildings offer such advantages as conservation of energy and the environment, though they can incorporate new technology and new ideas. Wood possesses the unique ability to be applied in modern architecture while simultaneously displaying its natural appeal.

It is necessary that wood-frame buildings in China, as a part of the country's intangible cultural heritage, should continue to be constructed. However, they need to keep pace with the times and be employed in pioneering architectural forms and help establish a green architectural environment that is characterized by safety, comfort, health, and sustainable living in the Chinese context. According to one definition of the natural environment (Pearson 1994), buildings should take into account the following five elements: (1) ancestral archetypes; (2) healing architecture; (3) harmony with the land; (4) vernacular wisdom; (5) cultural identity. Today, many residential homes and some light commercial and industrial buildings are constructed using modern wood frames, and in the future it is likely that more people will be interested in various types of construction and transport that employ wood (Wacker 2010). Therefore, the development of wood-frame buildings should exploit the engineering capacity of wood products, enhance the production of wood resources, utilize the environment-friendly characteristics of wood, and support improvements in the wood industry while taking advantage of the fact that the use

of wood helps save resources and promotes environmental protection.

It doesn't have a scientific and accurate definition about roles and development regularity of different structural factors and characteristic parameters of wood-frame building environment for the comfortableness, habitability and health of human life, and people's cognition about wood-frame building. The studies involving the whole environmental characteristics and residential properties of wood-frame building are less. Therefore, efforts to develop wood-frame buildings using ecological designs in terms of sustainable development have to take into consideration physical, psychological, and human physiological factors. In this regard, it is necessary to study indoor and outdoor environments and the use of natural energy sources so as to find a proper balance among the quality of indoor environments, energy consumption, and environmental protection (Li 2010). It is important that wood-frame buildings are able to satisfy people's practical and spiritual requirements, and such structures should incorporate human-oriented design concepts to embody the human caring. Thus, the core values of wood-frame ecological buildings are low consumption of energy and resources, no environmental pollution, good-quality indoor living environment, and ensuring that the buildings meets the psychological, physiological and social requirements of the people who use the structures. Assessment and analysis for the comfortable livable environment of wood-frame building, which enrich assessment system of wood-frame building and residential properties, have specific theory significance and application value with the development of wood-frame building, and meet the people's the growing environmental protection needs and create more comfortable, healthy living environment.

METHODS

Wood as a building material possesses the environmental benefits. It is not only our most widely used building material, but also one with environment-friendly characteristics that make it suitable for a wide range of applications. Wood as raw materials are produced and used in a sustainable fashion. One of the greatest attributes of wood is that it is a renewable resource. If sustainable forest management, plantations resource and harvesting practices are followed, our wood resource will be available indefinitely. Most of the focus of wood-frame construction as green building is on reducing building's energy consumption (Robert 2010).

The environment of a wood-frame building amounts to a small ecological system centered on the people that use the structure. People's perceptions of the building include an objective assessment of the physical environment as well as subjective feelings with respect to the psychological environment. Therefore, living environment characteristics and significance of wood-frame building are explained and evaluated by comprehensive natural science and the humanities, which make this kind of green ecological building more suitable for living, and through promoting the green ecological building to realize the strategic objectives of sustainable development. Field investigations into the use of wood-frame buildings involve going out and obtaining practical information about the way in which such structures are employed. The use of wood-frame buildings can also be carried out by means of questionnaires and depth interviews. This study used document analysis, depth interviews, and questionnaires to obtain a comprehensive assessment system for wood-frame buildings.

Literature analysis

The human living in a comfortable, healthy environment has placed greater emphasis on methods of evaluating both homes and residential areas. Such evaluations can be conducted by

Tab. 1: International comparison of typical building environmental assessment systems (Shuzo Murakami et al. 2002, Tian 2009, Todd et al. 2001.)

Assessment tools		BREEAM	LEED	GBTooL	CASBEE	CEHRS	GOBAS	ESGB
Applications		Britain	Multinational	International	Japan	China	China	China
Development time		1990	1998	1998	2002	2001	2003	2006
Level of assessment	Society	√	√	√	√	√	√	
	Economy		√					
	Ecological	√	√	√	√	√	√	√
Assessment content		1.Management 2.Energy 3.Health 4.Pollution 5.Transport 6.Land Use 7.Ecology 8.Materials 9.Water resources	1.Sustainable sites 2.Water efficiency 3.Energy and atmosphere 4.Materials and resources 5.Quality of indoor environment 6.Innovation and design	1.Resource consumption 2.Environmental loading 3.Indoor environment 4.Service quality 5.Economics 6.Management 7.Communication	1.Energy efficiency 2.Resource efficiency 3.Local environment 4.Indoor environment	1.Residential environmental plan and design 2.Energy and environment 3.Quality of indoor environment 4.Residential water environment 5.Materials and resources	1.Environment 2. Energy 3.Water resources 4.Materials and resources 5.Quality of indoor environment	1.Land Conservation and outdoor environment 2.Energy conservation and utilization 3.Water Conservation and utilization of water resources 4. Material Conservation and utilization of material resources 5.Quality of indoor environment 6.Operation management (Residential housing); Comprehensive performance of life cycle (Public building)

means of a literature analysis of studies related to the environmental performance of wood-frame buildings, and these studies differ in such areas as research background, theoretical development and specific study direction. This analysis of the literature provided us with the basis to draw up a questionnaire relating to a comprehensive environmental assessment for wood-frame buildings.

In this study, we compared typical building environmental assessment systems used in China and other countries. The methods of assessment comprise a variety of concepts which have already been applied all over the word as a means of environmentally-conscious protection goal (Murakami et al. 2002). As it was indicated in Tab. 1, these assessment systems reflect different degrees of concern in various countries.

Questionnaire

The literature analysis and information from field investigations, which included responses to a questionnaire and obtaining opinions from specialists in the field of wood-frame buildings, provided the basis for evaluating these structures in the present study. An objective expert questionnaire investigation method was used to collect reliable and effective data.

The questionnaire primarily consisted of the following three parts: (1) basic information relating to the respondents, which was filled in anonymously; (2) establishing and categorizing items for assessing the comfortable livable environment of wood-frame buildings; (3) receiving advice and recommendations from building experts relating to assessment of the comfortable livable environment of wood-frame building. Following the expert advice, three assessment items were added to the questionnaire and three assessment items were modified.

Depth interviews

The depth interviews used in this study were mainly conducted among experts, scholars, and researchers in the field of wood-frame buildings as well as wood science research institutes of colleges and university scientific research institutes and enterprise in China. From a review of the related literature, very few depth interviews have been conducted in China method with respect to environmental assessment of wood-frame buildings.

RESULTS AND DISCUSSION

Sustainability and ecology of wood-frame building

Wood is natural renewable, easily machining and non-toxic. The sustainable performance of wood also lies in easy degradable properties, which can reduce environmental pollution by non-decomposition products, promote the virtuous circle of ecological system. As a renewable resource, the main attribute is that it absorbs and reduces the amount of CO_2 in the atmosphere. In essence every cubic meter of wood used in place of other building materials saves the release of 0.8 t of CO_2. Considering an average detached wood-frame house, this equates to around 4 to 5 tonnes of CO_2 (Harris 2005). The trees in the Sustainable management can be realized the best advantage for the wood, carbon and energy, and using wood in building can be achieved long-term carbon storage. So, the wooden building materials are chosen to replace emissions intensive manufacturing materials, such as steel, cement and other materials. It is important to fully realize the difference between embodied energy and emissions for better making recovery and utilization of wood waste energy.

The wood-frame industry has endorsed partnering arrangements with both the private and

public sector, and the construction process has improved making it faster and more efficient than other forms (Hairstans et al. 2007). Wood-frame structure can be enclosed within a short time on site using factory-made panelized systems. Wood- frame building systems have development potential in the market, which indicates that it is possible to reduce the cost of low-to-medium rise buildings significantly by using lightweight building systems based on wood products. Wood-frame building can store carbon, realize the alternative income, improve carbon-intensity of landscape level, and make contributions to mitigation of climate change. Today, a large number of wood-frame buildings have distinct structure characteristics and environmental protection consciousness appeared constantly, and they have put into use.

Building ecological must be established on the basis of material ecological. Wood comes from forest with resources of sustainable utilization. Environmental burden of the development and utilization of wood is far less than steel, cement and plastic. China is the biggest construction market in the world, and the construction has long been using traditional building materials with reinforced concrete. Not only the energy and resource consumption is serious but also the environment load is heavy, so there is an urgent need to promote development of new building system for energy saving and emission reduction.

Therefore, wood-frame building with advantages of energy saving and emission reduction used in China's urban, no matter from energy, materials or cost will be efficient. The safety, durability and normative of wood-frame were especially suitable for the seismic zones. Wood-frame building is like a natural air conditioner having the real "warm in winter and cool in summer". Wood-frame building makes people closer to nature, pro-and natural, can harmony with the environment, and gives a person with simple natural beauty.

Selecting indicators for living environmental quality of wood-frame building

Wood-frame building environmental quality influences on consumers of building interior environment including indoor environment and outdoor environment, and whole system of wood-frame building itself effects on consumers with work and life in safety, healthy, convenience, agreeableness, and so on. Human's cognitive and requirements of building environmental quality is not immutable, which has link relationship with their social economy, construction industry development. So that Architecture deals with the practical necessities of life and work. Thus, it is essential that building design should take into account such factors as comfort, habitability, health, and sustainability as well as overall satisfaction and safety—all of which allow the people who use the building to live in a quality environment. The present study was based on the research methods outlined in section 2, and it aimed to identify the main factors that affect the environmental quality of wood-frame buildings. The selection of those factors embodied the following aspects:

1) Analysis and comparison of typical means of assessing green buildings and related factors in countries other than China.
2) Study of green building assessment and related factors in China.
3) Implementation of national standards and assessment of other norms presently adopted by the construction industry in China with regard to the environmental quality of buildings.
4) Using information from research institutes, companies involved in the construction of wood-frame buildings, and other related associations and organizations to establish the current situation with respect to green buildings.
5) Obtaining views and proposals from various experts so as to ensure the implementation of relevant factors.

It is difficult to make a direct comparison of the assessment system with respect to wood-frame buildings in different countries. Thus, any assessment system of modern wood-frame building has to take into account the particular conditions that exist in each country.

Establishing a comprehensive assessment system of the environmental performance of wood-frame building

These important factors were building techniques, performance and space artistic image of wood-frame building, but the ultimate goal is to provide the place of human activities that fully embodies its functionality. Based on the selection principles outlined in the previous section, we attempted to create the assessment items in an objective and systematic fashion. For the wood-frame building to have a low carbon footprint, it is necessary to consider carbon emissions. Furthermore, it is necessary to reduce the loading and influence on resources and the environment.

Tab. 2: Comprehensive assessment system for living environment of wood-frame building.

Comfortable living environment for wood-frame buildings (A)	Environmental quality of wood-frame buildings (B_1)	Indoor environment (C_1)	Indoor sound environment (D_1) Indoor light environment (D_2) Indoor thermal environment (D_3) Indoor air quality (D_4) Indoor vibrations (D_5) Green building design(D_6)
		Outdoor environment (C_2)	Outdoor sound environment (D_7) Outdoor light environment (D_8) Outdoor thermal environment (D_9) Landscape and greening (D_{10}) Regional infrastructure (D_{11})
		Quality of service (C_3)	Durability (D_{12}) Security and adaptability (D_{13}) Sanitation (D_{14}) Culture and entertainment (D_{15}) Tracking and maintenance System (D_{16})
	Environmental performance of wood-frame buildings (B_2)	Materials and resources (C_4)	Water resources (D_{17}) Land resources (D_{18}) Low environmental load (D_{19}) Productivity (D_{20}) Carbon emissions (D_{21})
		Energy consumption (C_5)	Efficiency of building equipment systems (D_{22}) Renewable energy utilization (D_{23}) Building intelligence (D_{24})
		Livability (C_6)	Environment construction (in keeping with psychological and physiological needs) (D_{25}) Environmental management (D_{26}) Healthy (D_{27}) Comfort (D_{28}) Economy (D_{29}) Social function (D_{30})

It makes sense that the wood-frame building created wooden environment only through people activity, and have to consider psychological interactive relationship of between people and the environment. The building of healthy human settlement environment can be evaluated from mental and physical health of residents. It needs to be accommodating healthy, comfortable, safe, ecological and environmental protective for improving living environment quality. It is also necessary to be friendly to natural environment in order to achieve the sustainability live goal.

So as to establish a healthy, comfortable, safe living environment that is in harmony with the natural environment so as to achieve the goal of sustainable living. This paper takes into consideration such aspects as the natural environment, the physical environment, the psychological environment, social adaptability and cultural factors, and economic factors in framing comprehensive measures to make an environmental assessment of wood-frame building items. In terms of operational effectiveness, we divided the assessment into three levels, as shown in Tab. 2: Level 1 assessment items (two types); level 2 assessment items (six types); and level 3 assessment item (30 types). "A" signifies the comfortable livable environment for wood-frame buildings, which is the main object of this assessment. "B" represents level-1 assessment items, which is divided into two types. "C" constitutes secondary assessment items and is separate into six types of indexes and factors. "D" signifies the level-3 assessment items and is divided into 30 types, being made up of subdivisions of level-2 items. These indexes and factors cover the four main areas of ecology, energy conservation, waste reduction, and health. The next step in this study was field testing of the assessment index and factors, which consisted of evaluation and analysis combined with quantitative and qualitative analysis to assess the environmental advantages of wood-frame buildings.

Wood-frame building environmental comprehensive assessment method

As seen in Tab. 2, wood-frame building environmental comprehensive assessment item is divided into three levels, and it was applied the fuzzy theory and multi-grade fuzzy comprehensive appraisement means. Considering the influence of many index and factors, use fuzzy mathematics tool to make comprehensive assessment for wood-frame building environment. According to the fuzzy mathematical theory that converts the qualitative evaluation to quantitative evaluation, the fuzziness of things can be solved and various uncertainties can be analyzed. The mathematical model is conveniently applied to comprehensive evaluation of complicated problems with multiple factors and multi-level. Assessment steps as follows:

1) Make sure assessment objects: wood-frame building environmental
2) Make sure influencing factors set of wood-frame building environmental, that is
   $U=\{u_1,u_2,u_3,\ldots,u6\}$
   Each factor includes many sub-indexes, that is
   $u_i=\{u_{i1},u_{i2},\ldots,u_{in}\}(i=1,2,3,\ldots,6)$
3) Make sure comment set, methods that use five levels score for wood-frame building environmental assessment, that is
   $V=\{v_1,v_2,v_3,v_4,v_5\}$={excellent, good, fair, qualified, substandard}
   Grade assign to comment set V, that is
   $E=(E_1, E_2, \ldots,E_n)_T$
   It showed standard score of each element in comment set.
4) Find the weight vector, make sure the importance of factors to the wood-frame building environment, that is
   $A_i=\{a_{i1},a_{i2}, \ldots,a_{in}\}(i=1,2, \ldots,6)$
5) Make sure fuzzy evaluation matrix, that is

$R=(r_{ij})_{m\times n}$

6) Choose an appropriate synthesis algorithm, through compound operation and get fuzzy synthesize assessment result, that is
$B=AR$
7) Calculates the comprehensive score of the assessment index, that is
$Z=BE$

So that, (U, V, R) constitute a mathematical model on fuzzy comprehensive assessment. This mathematical model converted fuzzy vector A in U to one of the fuzzy subset B in comment set V by fuzzy matrix R, and get to the B is fuzzy comprehensive evaluation for wood-frame building environment.

Using the comprehensive assessment system for the environmental performance of wood-frame building

State and government departments seek to establish policies and guidelines to protect and improve the environment and the quality of life, and building environments play a decisive role in the development of society. Wood-frame buildings are typified by green, low-carbon construction standards, and so assessing the environmental quality and performance of modern wood-frame buildings is particularly important. In keeping with the particular conditions that exist in China, scientific theories and methods can be applied to develop low-carbon, green, modern wood-frame buildings.

Using the comprehensive assessment system for the environmental performance of wood-frame building, the following was found:

1) Designers should use assessment tools to obtain feedback from residents and make more targeted decisions for their projects;
2) Using the assessment tools, residents can build up knowledge and awareness of the building's environment from a scientific perspective, and this will better serve their own requirements;
3) It is necessary to establish a star rating system for wood-frame building and promote the assessment of green buildings;
4) It is necessary to develop a database for the comprehensive assessment system of wood-frame building;
5) Construction planning theory development can be used to enhance the designs of wood-frame building;
6) Improvement in wood-frame building can be achieved through the establishment of guides, norms, and standards;
7) It is help to take shape cyclic wood-frame building environmental management mechanism;
8) Sustainable development in the construction industry can be achieved by means of green low-carbon building.

CONCLUSIONS

The use of wood in construction can realize long-term carbon storage in buildings, and the use of wood-frame buildings has very important practical significance for energy conservation, pollution reduction and tackling climate change. We want to better promote wood-frame building technology and industry development based on the conditions unique to China, and improve social awareness of wood-frame building. Therefore, we should establish a comprehensive assessment system for the environmental quality of life in wood-frame buildings to promote the

sustainability of wood-frame building, provide a theoretical basis for overall evaluation, approval and scientific assessment of wood-frame building environments.

We believe that an advanced wood-frame building performance and assessment system will help to improve the environments in which many people live. A comprehensive assessment system for wood-frame building environments will provide useful information for building owners, designers, and users, and will promote development of high-quality, sustainable architecture. And it can also guide the construction market in the environment friendly direction, and encourage the construction project carried on innovation in the respect of improving an environment and promoting construction market reforms. Thus, the establishment of such a comprehensive assessment system of wood-frame building environment should effectively promote the development of sustainable architecture.

In future research, further research and collection of experimental data, along with continued tracking and study of advanced methods for comprehensive assessment, is needed to promote development of a comprehensive system for assessing the environments in wood-frame buildings. Concurrently, constant updates of technological development are needed to supplement and complete the assessment system. This will allow wider, deeper interdisciplinary research into comprehensive assessment of wood-frame building environments, leading to the development of theoretical systems that can effect real transformation, leading to practical application that will conform to market needs.

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