The Demand and Requirements of Environment and Resource on the High-Rise Building Structure

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Biography

Dr. Jianguang Shi is Professor of Xiamen University. He has broad interests with outstanding results in the research of a wide variety of civil engineering projects. He mainly carried out the research of high-rise building structure design, durability of concrete structures and building waste recycling and civil engineering projects. In high-rise building structure project design research, the three-level multi-approach method based on structure components, the lateral force mechanism and structure system was proposed. The story element method was provided for the determination of high-rise building structure system. Based on these methods, the software copyright of high-rise building structure project design was obtained. In the aspect of durability of concrete structures, the research of design method, reinforcement corrosion monitoring method and environmental effects classification were carried out. The hierarchical durability design method, the integrated environmental classification method and steel corrosion resistance probe monitoring method were proposed. Monitoring steel corrosion resistance probe technology obtained intellectual property patents. In recycling building waste research, the estimation methods of building waste and concrete waste, recycled concrete aggregate gradation and different aggregate composition, and recycling concrete block were carried out.

Abstract

To meet the social, economic, environment and resource requirements, high performance, low-carbon, energy saving, green, ecological and sustainable design concepts are widely used in high-rise buildings. High-rise building structures design are also from the only focus on the security under natural disasters or the accidents, the applicability of use and comfort, the construction economy to consider the environment and resources in full life cycle. By researching high-performance, low-carbon, energy saving, green, ecological and sustainable concepts to the requirement of high-rise buildings, the requirements of high-rise building structures to resources, environment and the ways to play an active role to meet the increased demand and different requirements of high-rise buildings are explored.

Keyword: High-Rise Building Structure, Environment, Resource, High-Performance, Method
1. Introduction
Currently, the building height, numbers and geographic scope are in rapid increase. High-rise building is at the highest development state (Wood and Oldfield, 2009). A wide range of high-rise building constructions has more and more important influence on the social, economic, environmental and resource. The views of supporting and opposing the high-rise building have been accompanied by a large number of high-rise building constructions (Wood, 2008). To meet the social, economic, environmental and resource requirements, the concept such as low carbon, energy saving, green, ecology and sustainable high-rise buildings is widely used in its construction (Ali MM and Moon, 2007 Al Marashi and Ehnder, 2008, Yeang, 2007, Ali and Armstrong, 2006). Many countries have established their own quantitative evaluation system to promote the green, energy-saving building’s development, such as Green Star of Australia and New Zealand, British Building Research Establishment Environmental Assessment Method (BREEAM), Japanese Comprehensive Assessment System for Building Environmental Efficiency (CASBEE) and the United States, Brazil, Canada and India, using the Leadership in Energy and Environmental Design (LEED) (Candace and Wood, 2008). Since the total environmental load of building structure materials is nearly 60% (Van den Doelsteen and van der Linden, 2002), the full life cycle environmental, resource problems are focused besides the security, suitability, use and comfort, the construction of the economy under a variety of natural disasters or accidents (Grace S. Kang and Aien Kren SE, 2006). In this paper, through exploring the low-carbon, energy saving, green, ecological and sustainable concepts, the approaches of high-rise building structures to play an active role in resources, environment are discussed to meet the increased demand for high-rise buildings or requirements.

2. The environment and resources requirements of high-rise building structures
2.1. Low-carbon and high-rise building structure
Greenhouse gases in the atmosphere are mainly carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF₆) and so on. According to Nicholas Stern report (Sir Nicholas Stern, 2008), 80% lower than current levels of greenhouse gas emissions can be below the earth's natural reduction capacity. Low Carbon building is to reduce greenhouse gas emissions than traditional building. Because the greenhouse gas emissions in building construction, operation and maintenance is about 50% of total global greenhouse gas emissions (Smith 2005). According to Intergovernmental Panel on Climate Change (IPCC, 2007), construction is the best field of cost effective for emission reduction. Therefore, low carbon buildings are of great significance to reduce greenhouse gas emissions. Low carbon buildings mainly emphasized the impact of construction on climate change.
Carbon emissions in building life cycle are mainly involving building construction, fitment, outdoor facility construction, transportation, operation, waste treatment, property management, demolition, and disposal (Chen etc 2011). Carbon emissions in the buildings construction are mainly from building materials production, construction mechanical energy and transportation. The carbon emissions in buildings operation are related to lighting, heating, air conditioning, building electrical use and so on. The carbon emissions in buildings demolition are mainly related to machinery, waste treatment and waste disposal. Considering the full life cycle carbon emissions related to building structural, the type of material and production, the amount of material, local materials use, construction methods, easy to maintaining and alteration, dismantling, recycling, and then easily reuse (Figure 1).

![Figure 1. Low carbon and high-rise building Structure](image)

The sustainable building assessment DGNB technology system of Germany launched in 2008 contains the building carbon emissions calculation method (Lu, 2010). Comparing the carbon emissions of reinforced concrete structures of low-rise residential in a full cycle at Beijing, the ratio of carbon emissions in construction
phase and the use stage is 3.4. Although the emissions in use stage are large, but aportion to a year, their emissions are relatively small. It is an important aspect for reducing carbon emissions in the construction phase and related industries (Shang and Zhang, 2010). With the rapid increase of material consumption the high-rise building structure is more important for low-carbon requirements.

2.2. Energy-saving and high-rise building structures

In 2006, world energy consumption reached $474 \times 10^{18}$ J, in which the source of fossil fuels is 80% to 90%. China accounted for 18% of energy consumption, was the largest energy consuming country (Statistical Review of World Energy 2009). From 1994 to 2004, building energy consumption in Europe and North America had an annual increase of 1.5% and 1.9% (Pérez-Lombard and Ortiz, 2008). And in China, during the past 20 years, building energy consumption increased by 10% per year, for which most of the current requirements of building energy efficiency are 50% and some individual cities are 85% (Cai and Wu, etc., 2009).

General building energy consumption is about 45.5% of the total national energy consumption. In general building energy consumption, operation energy consumption, building materials energy consumption and indirect energy consumption account for 20%, 15% and 10.5%. Reducing operation energy consumption is the key to building energy efficiency, but reducing the building materials energy consumption has important significance (Li and Jiang, 2006). From the detailed analysis of the life cycle energy consumption of buildings in China, it is found that energy consumption of building energy consumption accounts for 47.24%. The energy consumptions in various stages are: building materials energy consumption accounting for 20.48%, the construction phase energy consumption for 1.86%, building operation phase energy consumption for 24.9%, other building indirect energy consumption for 8.54% (Chen and Luo 2009). The same research also found that the operation phase energy consumption of buildings accounts for 24%, the time of construction and demolition phase is shorter, in the whole building life cycle this part of the energy consumption is the small proportion is about 1.0%~1.6% (Cheng and Shi, 2009). Therefore, from the energy efficiency view, reducing the building operation energy consumption and building materials energy consumption is the key problems.

Through the use of solar energy, geothermal and other non-polluting energy replacing the fossil energy, the office building of Tsinghua University in Beijing can save energy 30% (Ren and Sun, etc., 2008). From the general construction, building materials and indirect energy consumption view, energy consumption related the different parts of the energy consumption reasons (Figure 2). Considering the extensive use of high-rise building structure materials, building materials energy consumption is the focus of building structures.

![Figure 2 Energy-saving and high-rise building structures](image-url)

2.3. Green and high-rise building structures

Green building emphasizes the built environment influence on human health and the natural environment including reducing waste, reducing pollution and preventing environmental degradation (U.S. Environmental Protection Agency, 2009). Person’s physical and mental health is related to the built environment (Shobha and Liam, etc., 2003). Built environment includes building, space and products. Environmental health includes environmental influences on human health (Handy and Boarnet etc. 2002), disease and injury (Rauh and Chew, etc., 2002, Morland and Wing, etc., 2002, Pope and Burnett, etc., 2002, Halpern 1995, Weich and Blanchard, etc., 2002). It can be chemical, physical and biological direct pathological effects, or it could be physical, social environment influences, such as housing, urban development, land use, transportation, industrial and agricultural role. Many countries have established a green building or building energy efficiency standards. Some of the building environmental assessment includes: waste and air pollution, water
pollution, indoor pollution, heat island, storms, noise, human injury, environmental degradation and resource loss. Arising from the concept of green building, high-rise building structure includes the building materials healthy to human and nature, building structure construction, use and removal having the minimized impact on the natural environment (Figure 3).

2.4. Ecology and high-rise building structure
Ecology refers to the natural state of survival and development under some of the biological environment also refers to the biology physiological characteristics and living habits (Modern Chinese Dictionary, 2003). Ecology is the all livings survival state, as well as its relationship between them and their interlocking. Ecological means healthy, beautiful, harmonious things. Ecology building includes three aspects: first, to reduce the load and impact on the earth's resources and environment; second, to create healthy and comfortable living environment; third, to integrate with the natural environment. Ecology building mainly deals with the relationship between people, buildings and nature. It has to create a comfortable space for human, such as health and pleasant temperature, humidity, clean air, good light environment, sound environment and a long effective and more appropriate, flexible open space, etc. in the same time it must protect the surrounding natural environment, such as the request to the nature is small, and the negative impact on the natural environment is smaller (Figure 4).
Ecology building is to make the integration of the built environment and the natural environment (Yeang, 2007). From the principle to minimize the harm to non-renewable natural resources, ecosystems, ecology building design involves the all aspects of construction (Yeang, 2000). Concept of ecology building for high-rise building structure pays attention to the use and conservation of material.

2.5. Sustainable development and the high-rise building structure
Sustainable development is the development not only meeting the current needs and without compromising the needs of future generations to meet their capacity. They are an inseparable system, it is necessary to achieve the purpose of economic development, but also protect the atmosphere, fresh water, oceans, land, forests and other natural resources and environment of human survival so that future generations can live and work. The concept of sustainable building is the pursuit of reduced environmental load, dovetailing with the environment, and is conducive to occupant health. The aim is reducing energy consumption, water conservation, pollution reduction, environmental protection, ecological protection, protection of health, increasing productivity, conducive to future generations. World Organization for Economic Cooperation and Development proposed the four sustainable construction principles and an assessment, first is the principle of resources efficiency, the second is the principle of energy efficiency, third is principle to prevent pollution, including indoor air quality and carbon dioxide emissions, fourth is the principle of environmental harmony.
(Zhang and Xu, 2009). The sustainability of the building can be measured from the environment, resources, social and economic aspects (Figure 5) (Guthrie, 2008). Due to the huge materials used and potential energy, the sustainable construction, green technology, energy, fire and building safety has an important role in high-rise building (Beedle and Armstrong, 2007).

![Figure 5. Concept of sustainable development and high-rise building](image)

2.6. high-performance and high-rise building structure
High performance means more green, energy-efficient, environmentally friendly, sustainable, able to withstand the occasional accident, zero-energy, good return on investment and best meet the owners needs. High performance requirements of building or high-rise buildings involve more extensive and specific targets, such as facility requirements, environmental and economic, energy and resource conservation, reducing waste, increasing the comfort and health (the High Performance Building Guidelines, 1999). When in evaluating the world's best high-rise buildings of CTBUH association, the established standard requires the building form, structure, building system, sustainable strategies and integrated security as a whole, showing a wide range of sustainability, such as through a suitable site, new materials, energy conservation and alternative energy, reduced emissions and water consumption allowing minimal environmental impact, help to improve people’s quality of life, to meet future development needs of society, economy to investors, owners and community, high standards of quality and performance, enrich and improve the surrounding environment. Therefore, high-performance building is the people’s understanding, needs and social requirements put forward a more general requirement or standard. High-performance building structure corresponding to high-performance building is to meet the targets embodied in the structure field. From such comprehensive quality considerations, the energy, environment, security, defense, durability, convenience, cost effectiveness, productivity, sustainability, functionality and operation of high-performance buildings throughout the life cycle, high-performance structural must meet the requirement of energy, resources, environment and other more extensive properties under the base properties of economic, rational, durability and security (Energy Independence and Security Act of 2007). From the entire life cycle study, the higher the performance index, the higher initial investment, but will reduce the total cost of the life cycle (Figure 6). So from an economic study, there is a reasonable range of performance indicators.

![Figure 6. The relationship of performance and economic](image)

3. the resources and environment requirements of high-rise building structure
From the concepts of low-carbon, energy saving, green, ecology, sustainable and high performance, the common requirement summed up for high-rise building structure to implement these ideas is mainly in the resources and the environment (Figure 7). Resource requirement is mainly reflected in reduced consumption of resources, using renewable resources, resource recycling and resource efficiency. Environmental requirements are mainly reflected in reducing environmental impact, the use of environmentally friendly materials and focus on environmental adaptability. To meet the Resources and environmental requirements of high-rise building structures, the minimal environmental pollution and the maximum utilization of resources should be as the goal for structural design. For the maximum utilization of resources of building structures, the material-saving design strategies (Kyoung, 2008), the stiffness-based methodology (Kyoung, 2010) and multidisciplinary design optimization (Philipp,
2009) have been proposed. For the minimal environmental pollution of building carbon emissions calculation method (Lu, 2010), the whole life cycle assessment, energy-saving design, etc. have been suggested (Candace and Wood, 2008, Ren and Sun etc. 2008) (Figure 8). Also the comprehensive evaluation of the sustainable design from the environment, resources, social and economic aspects has been established (Guthrie, 2008).

Figure 7 the resources and environment requirements of high-rise building structure

Figure 8 Resources and Environment design method of high-rise building structure

The maximum utilization of resources or the minimum resource usage of the building structure material is to provide a design means to compare or select a specific building structure. The least environmental pollution or environmental evaluation method provides the comparative method to quantify the effect after the technical measures. To achieve the design target of the minimum environmental pollution and maximum resource utilization to high-rise building structure, all possible technical approach needs to be employed. Based on the review and development of high-rise building structure the environmental and resource benefits technology is of great significance.

4. The resources and environmental benefits technical approach of high-rise building structure

As the support skeleton of high-rise buildings, high-rise building structure includes four aspects, structure system, floor structure, and component layout and component size. Under meeting the performance requirements, to explore the minimum environmental pollution, resource-efficient technologies way is the main tasks to realize the resources and environmental benefits in high-rise building structure. The technical approaches being taken are mainly summed as the high-rise building structure design technology, the unity of high-rise building structure with the architectural form and function, high-performance materials and material selection, 3R technology, new structure technology, prefabricated construction technology (Figure 9).

4.1. High-rise building structure design technology

For high-rise buildings structure, the use of resisting or reducing wind, seismic structural system and shape will reduce the structural materials demand, improve the structural performance, and exert material properties (Peter and John etc. 2008, Peter, 2009, Case Study, 2008). At the same time the development of new innovative structural system and structural elements to meet the different requirements of high-rise buildings form a more effective structural resistance system (Evelyn, 2006, O-14 Tower Dubai, 2006). Rational structural component layout to form an effective structure is a powerful way to the conservation of resources

![Diagram](image)

Figure 9. High-rise building means to achieve resources and environmental benefits

4.2. The unity with architectural style and function

High-rise building form and function layout has significant impact on the suffered wind, earthquake force and renewable energy use and building energy consumption. High-rise building structure unity with architectural style and function is an important way conducive to renewable energy and reasonable performance to obtain environmental benefits of high-rise buildings (Peter, 2008, Mahjoub and Praima, 2008). New network tube structural system, not only meets the needs of the building shape changes, also plays effective material properties, is the structural measures to make the whole structure to meet the resource efficiency and environmental benefits (Kyoung, 2008). Structure integrates with maintenance, insulation and other building need, such as shear walls sandwich. High-rise building structure integrates with decoration, such as water concrete.

4.3. High-performance material and selection

High-performance concrete and high-performance steel and reinforced not only have high strength and durability, but also have high impermeability, frost resistance and other performance. If these materials are used, building can reduce the size of structural components, material quantities, resource consumption, pollutant and emissions in the production process. And the service life of engineering structures can be extended. It is conducive to structural system innovation. This is the basic technical approach for high-rise building structure to obtain the resources and environmental benefits (Ye and Lu et al. 2006, Ishii and Fujisawa, 2009, Fang and Froese, 1999, Flaga, 2000, Sungho and Cheonghoon, 2011). Different building materials and structures for resources and environmental benefits have different effects (Liu and Hu, 2005). The best is wood, steel is more energy (Dias and Pooleyadda, 2004). Sulfoaluminate cement is the least environmental pollution cement (Amina and Adelaid, 2007).

4.4. 3R technology of Reduce, Reuse, Recycle

High-rise building structures needs a mass of material with increased height. It is extremely important to use the 3R technology of Reduce, Reuse, and Recycle to the resources and environment. Reduction is mainly behaved in structural system innovation, choice or optimization, floor layout optimization and components types and optimization. Reuse is mainly rest with the structure which can be demolished, broken down, the parts which can be refurbished, reused. The Recycle can employ the technologies of eco-cement, recycled concrete and other renewable technologies. Eco-cement is the cement which the city's garbage gray mud from sewage sludge or sewage treatment plants and other industrial waste materials used as cement manufacturing material. Recycled concrete is the concrete which the broken concrete waste used as concrete aggregates, such as "recycled concrete application of technical regulations" DGTJ08-2018-2007, etc (Xiao and Li, 2003).

4.5. New structure technology

A novel new structure technology development direction is the combination of energy efficiency and structure to form a new structural system. These new structural system includes the Insulated Concrete Forms (ICFs), DIPY construction formwork wall, superimposed structural system (DB34 810:2008), fiber cement whole grouting wall structure, cast-in-situ RC grillage shear wall with lightweight insulation hollow blocks (DBJ01—620—2004 ), Multi-ribbed Structure System autoclaved aerated concrete (ALC) slab and steel or concrete structural system (GB1 5762-1995 ).
4.6. Prefabricated construction technology
Use of prefabricated or prestressed construction techniques to reduce the environmental and resources impact of is very effective structure techniques (Lara and Poon, 2009, Andrew and Poon etc. 2009), such as the concrete structures with precast components (SJG18-2009), and the CL integral assembly or in-situ whole structure made from the whole cast, the compound wall, solid wall, the integral assembly or in-situ floor, after pouring edge component.
The different technical structure approaches have different connotations, different techniques responsibility (Table 1). The technical indicators or strategies is must help to promote the choice of these technical methods and the enthusiasm or sense of mission for responsibility.

Table 1 the different connotations and techniques responsibility for resources and environment benefits

<table>
<thead>
<tr>
<th>resources benefits</th>
<th>high-rise building structure design technology</th>
<th>structural materials savings</th>
<th>architectural style and decoration materials savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>environment benefits</td>
<td>high-performance material and selection</td>
<td>improve material efficiency</td>
<td>reduce resource consumption</td>
</tr>
<tr>
<td>techniques responsibility</td>
<td>reduction, reuse, recycling of the 3R technology</td>
<td>saving insulation materials</td>
<td>reduce construction waste</td>
</tr>
<tr>
<td>structural engineers</td>
<td>Prefabricated construction technology</td>
<td>reduce construction waste</td>
<td>reduce construction pollution and energy consumption</td>
</tr>
<tr>
<td>architect structural engineers</td>
<td>architect structural engineers</td>
<td>architect structural engineers</td>
<td>structural engineers</td>
</tr>
</tbody>
</table>

5. the resources and environment benefits method of high-rise building structure
The resources and environmental benefits technical approaches of high-rise building structure should be encouraged and become the developing direction. Comparing the design methods or means of resources and environmental benefits with these technologies, it is found that the multi-disciplinary design optimization, carbon emissions calculations method and full life cycle assessment is a more suitable method (Table 2). The specific indicators of resources and environmental performance must be proposed when the multidisciplinary design optimization, carbon emissions calculations and full life cycle assessment is applied to high-rise building structure design.

Table 2 the relationship of the design methods and structure technology approach

<table>
<thead>
<tr>
<th>The material-saving design strategies</th>
<th>high-rise building structure design technology</th>
<th>the unity with architectural style and function</th>
<th>high-performance material and selection</th>
<th>reduction, reuse, recycling of the 3R technology</th>
<th>new structure technology</th>
<th>Prefabricated construction technology</th>
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<tbody>
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<td>The stiffness-based methodology</td>
<td>high-rise building structure design technology</td>
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<td>new structure technology</td>
<td>Prefabricated construction technology</td>
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</table>
High-rise building structure must meet the safety, suitability, comfort, durability, integrity and fire and other basic performance requirements. Improving these performance indicators not only meet the social and economic development needs, but also help resource and environmental performance improvement. The high-rise building sited natural environment determines the structure needs to withstand the wind, the earthquake intensity and site conditions, and determine the advantage of wind, solar, geothermal and other renewable energy and water, temperature, humidity and other environmental conditions. Therefore, the natural environment both affect the performance of the structure itself, but also affect the architectural design. These parameters, such as building function, number of storey, the main building height, plane shape, vertical shape, space separating, length width ratio, height and width ratio, the storey height and the spatial distribution of these factors, not only provide the request for the building structure, but also coordinate the building performance and structural constraints. Therefore, high-rise building structure design is to searching the best structure system, floor structure, component layout and components, etc. having good resources and environmental benefits under the condition of the sited natural environment, architectural parameters, and social development and economic conditions to meet the safety, suitability, comfort, durability, integrity and fire resistance and other performance requirements, full use of the resources and environmental benefits technical approach (Figure 10). Multi-disciplinary design optimization, the calculation of carbon emissions and the whole life cycle assessment and other methods is to be able to complete this mission.

![Figure 10: The framework of high-rise building of resources and environment benefits](image)

6. Summary
The proposed high-rise buildings design concepts, such as high-performance, low-carbon, energy saving, green, ecological and sustainable, emphasizes the environmental and resource performance of high-rise building structure. By exploring high-performance, low-carbon, energy saving, green, ecological and sustainable design concepts to the requirement of high-rise building, high-rise building structure technical approach is summed up which play a role in the resource and environment benefits. These technical approaches includes high-rise building structure design technology, architectural unity of form and function, high performance material and selection, reduction, reuse, recycling of 3R technology, new structure technology, prefabricated construction technology and other technical means. Comparing the design methods and means of resources and environmental benefits with these technologies, it is found that multi-disciplinary
design optimization, the calculation of carbon emissions and life-cycle assessment is a more suitable method. Resources and environmental performance and indicators is provided for to high-rise building structures to encourage and promote high-rise building resources and environment benefits continues to increase.

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