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Ecological Environmental Pollution Caused by Construction Engineering in China and Relevant Energy-Saving and Cost-Reducing Measures

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ABSTRACT

Construction volume has been increasing significantly in the rapid urbanization in China, which causes evident ecological environmental pollution. Moreover, the construction industry is characterized by high energy consumption and high pollution. Therefore, the energy consumption of construction causes a considerably high proportion of the total energy consumption in the industry. Building energy efficiency is also key in the construction industry in China. In this study, ecological environmental pollution caused by construction engineering was further analysed. Results could provide reliable theoretical bases for the government to develop relevant policies on building energy efficiency. First, research on energy-saving and cost-reducing measures of construction engineering in foreign developed countries was reviewed. Second, types of ecological environmental pollution caused by construction engineering were summarized. Factors that could influence energy-saving and cost-reducing processes of construction engineering in China were also discussed. Finally, specific measures for energy-saving and cost-reducing processes of construction engineering were proposed. Results showed that foreign developed countries generally establish energy-saving and cost-reducing measures at the national level, thereby strengthening policy implementation. Ecological environmental pollution caused by construction engineering is caused by the large consumption of energy resources, contamination of urban public environment, occupation of land resources, damages to biodiversity, and influences to the normal living environment of residents. Faulty laws, regulations, and local policies on building energy efficiency; poor promotion and implementation of the government's incentive measures; and lack of evaluation system and inadequate consciousness of building energy efficiency contribute to the energy conservation and cost reduction of construction engineering. This study suggests the development of policies on building energy efficiency, reduction of building energy consumption, promotion of building energy efficiency projects in China, and facilitating of new urbanization.

INTRODUCTION

China's energy supply and resource environment are influenced by the immense demands of building energy consumption, which sets high pressure on construction engineering. Despite the considerable economic values brought by the building industry, no relevant departments are assigned to controlling the high pollution and high energy consumption caused by construction engineering. Therefore, the rapid development of the building industry is achieved, which compromises resource consumption. Resource consumption of the building industry brings not only serious social pressure but also high pollution. Particularly, urbanization rate has been increasing gradually, and building industrialization develops rapidly with the increase of people's living standard (Fig. 1). Developments in the building industry definitely indicate a sharp increase of building energy consumption. Generally, industry and transportation have been large energy consumers, followed by building energy consumption, which becomes the third social industry of energy consumption. With the increasing attention of China on high energy-consuming enterprises, the national government and relevant sectors issue many building energy efficiency policies successively, establish the goal of energy saving and emission reduction in the construction industry, and develop new technologies for environmentally friendly and high-efficiency production throughout the industry. In addition, managing and facilitating green construction is useful in assuring a new development prospect of energy saving and emission reduction in the building industry.

Meanwhile, the rapid economic development and urbanization speed up the construction and reconstruction of infrastructures, urban residential communities, business centres, and factories in China, thereby resulting in high

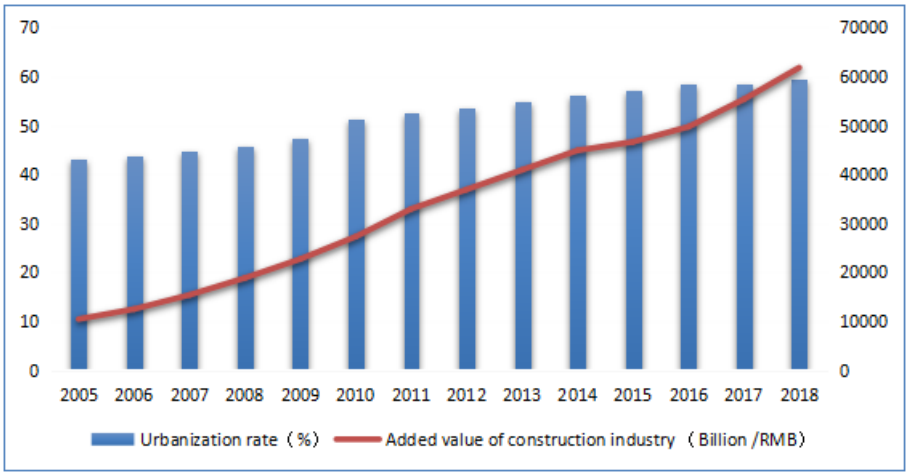

Fig. 1 Urbanization rate and added value of the building industry in China in 2005-2018. (Data source: China Statistical Database (http://data.stats.gov.cn/))

energy consumption and environmental degradation of the building industry in the country. Specific project construction activities (e.g., construction organization, project implementation, and project closeout) may affect the environment along the construction line and within a certain region to some extent. Construction engineering may cause adverse effects on surrounding environment, manifested by environmental pollution in the construction site, water and soil loss surrounding the construction areas, and vegetation deterioration. Moreover, construction engineering may destroy surrounding cultural relics and cause loss of cultivated lands along the construction line.

STATE OF THE ART

Many studies have indicated that building energy consumption is the primary social industry among the three energy consumption industries in many developing countries, which is determined by various social problems, such as energy crisis, environmental pollution and population growth. Several studies on ecological environmental pollution caused by construction engineering and relevant energy-saving and cost-reducing measures have been reported. Given the ecological environmental pollution caused by construction engineering, Gangemi et al. (2000) believed that ecological problems in the architect's design with the aid of an environmental consultant can mitigate environmental pollution effectively to some extent. Morledge et al. (2001) stated that the building industry is the major source of environmental pollution, and a close relationship between water environmental pollution and construction is observed. Tam et al. (2004) proposed a "green construction assessment (GCA)" system to construction engineering, including management and operation performance assessments. This GCA system was further used to analyse the degree of environmental pollution of construction projects. Cheng et al. (2006) analysed the effects of construction engineering's abundant pollutants on the economic benefits of other industries. Gangolells et al. (2009) believed that construction engineering mainly results in water pollution, wastes, soil pollution, resource consumption, local issues, traffic problems, and influences on biodiversity. Wu et al. (2015) studied dust pollution caused by construction engineering, investigated the current status of dust control in the building industry in China, and proposed insights on mitigating this type of pollution. Liu et al. (2017) regarded construction engineering as the common environmental noise source in China and many other developing countries worldwide. They also investigated noise pollution caused by construction engineering in three central cities in Zhejiang Province, China. With respect to energy conservation and cost reduction of construction engineering, Lee et al. (2004) studied supervision and voluntary policies on energy saving of buildings and discussed how the government attains full use of measures on mitigating the energy consumption of buildings. McWhinney et al. (2005) believed that the fiscal and tax preference policies of the government can guide private sectors with regard to investment decision making in the construction market. These policies can also aid private sectors adopt actual measures to some extent. Li (2008) analysed barriers against comprehensive implementation of building energy efficiency policies and deemed that control over carbon emission price was the best method for increasing building energy efficiency. Kim et al. (2013) believed that the government shall develop coherent and incentive fiscal taxation policies to address environmental pollution problems caused by construction engineering. Li

et al. (2015) suggested the expansion of the range of building energy-saving policies in China in achieving multiple goals. Moreover, social, economic, and environmental factors must be considered to accelerate innovations. Finally, the authors discussed policy design and proposed measures for further modification and improvement. Azzouz et al. (2017) conducted a life cycle analysis on energy conservation measures in a high-rise office building in downtown of London, United Kingdom and concluded that life cycle assessment is significant to early architectural design decision. Poddar et al. (2017) implemented a simulation analysis on cold and heat load shedding potential of energy-saving measures of buildings for research, dormitory, and administrative purposes. Yang et al. (2018) evaluated the effects of energy-saving policies and carbon emission reduction measures on decreasing health damages, which had been ignored for a long time in China's building industry. The results demonstrated that energy-saving measures are important in reducing health damages of national and provincial building industries. On the basis of these aforementioned studies, environmental pollution caused by construction engineering is serious. However, the pollution degree is related to the energy-saving and emission reduction measures at the state, regional, and city levels. The range of research objects of energy-saving policies of the building industry in foreign developed countries is large. Most associated studies have focused on the implementation and prediction of national energy-saving policies and relevant input cost and policy mechanism. In the present study, new concrete energy-saving and cost-reducing measures for the building industry were proposed on the basis of the analysis of ecological pollution caused by construction engineering in China. Implementation methods and effects of these measures were assessed. Conclusions of this study provide a scientific method for improving policies regarding building energy efficiency and providing certain references to promote effective sound development of energy-saving construction engineering.

ECOLOGICAL ENVIRONMENTAL POLLUTION CAUSED BY CONSTRUCTION ENGINEERING

Large consumption of energy resources: Resources mainly include water, land, animal, plant, and mineral. Construction engineering primarily consumes water, land, wood, sand, and mineral resources and is one of the productive activities that claim high energy resources. With the continuous increase of construction projects and requirements on construction quality in China, building energy consumption increases gradually and accounts for nearly 50% of the total energy consumption of the society. The construction industry ranks as top among all industries in term of resource demands. In China, construction engineering has a large consumption of three major building materials, namely, cement, steel, and wood. Moreover, construction engineering consumes substantial net water, land resources, wood, and materials but has a low recycling rate of building wastes. More than 50% of cities in China have problems with regard to water supply shortage, which is intensified by the increasing water consumption of construction engineering in urban areas. The increasing occupation of the cultivated land by construction engineering further exacerbates the reduction of cultivated land area in China.

Pollution of urban public environment: Construction activities that break rules and regulations cause serious environmental pollution. Noise, dust, and wastewater produced by construction constitute a high proportion in the total waste emission in cities, thereby significantly affecting physical health and daily life of urban residents. The annual wastewater emission from construction engineering is considerable, which causes increasingly serious water pollution. Air, waste, light, and electromagnetic pollution in construction engineering constitute a high proportion in the total extent of environmental pollution. The construction and operation stages of the entire construction engineering may destroy natural ecological environment along the construction line. In other words, construction engineering causes air, water, waste, noise, light, and other pollutions.

Occupation of land resources: Land resource is an important component of natural environmental resources and is irreplaceable. The construction project must expropriate and destroy a large area of land and deteriorate ecological environment continuously, thereby intensifying water and soil loss. Water and soil loss refers to the entire process of corrosion, transportation, and sedimentation of excellent soils under the effect of water current. Non-standard and protection-free soil and rock constructions, such as excavation or filling of subgrade engineering, may result in changes of local landform and vegetation damages. New slopes in construction engineering are not protected during the construction period, and these slopes are exposed to the surface. Surface will be impacted by rain washing, which results in local water and soil loss. Construction engineering occupies land resources permanently and destroys surface vegetation along the construction line. Temporary occupation of lands, soil construction, and waste discharge may destroy the original surface vegetation seriously. During the construction, poor civilized construction trampled by material transportation, mechanical grinding, and construction workers may destroy cultivated lands surrounding the construction regions randomly.

Damage of biodiversity: Construction engineering may

destroy biodiversity in addition to the damages to surface vegetation and occupation of abundant land resources. It not only occupies many land resources but also covers some ecological sensitive regions. These regions have single ecology, which is easy to be destroyed but difficult to be protected. Moreover, the single ecology division of growth regions of animals and plants destroy their original habitats, thereby reducing biological resources. Moreover, this ecology division will produce considerable water and soil loss and modify watercourse of rivers or hydrological conditions, thereby changing the survival environment and causing disappearance of some biology. The construction wastes can destroy animal and plant habitats at two sides of the construction sites.

Influences on residents' living environment: Currently, many construction projects have not solved wastewater, waste gas, and waste problems properly after completing the project, thereby further causing serious pollution and damages to surrounding environment. For example, some municipal projects discharge construction wastes randomly, which affects the appearance of a city and even blocks municipal pipes. Generally, construction engineering can be found in downtown areas with dense population. Noise pollution caused by construction cannot also be ignored. This type of pollution not only causes hearing loss of people but also many unrevealed diseases. Construction during night is the major noise pollution source that disturbs normal rest of surrounding residents. Construction vehicles can also affect daily life of these residents. If these problems cannot be solved effectively, then the dispute between local residents and construction units becomes increasingly serious. Meanwhile, construction process can influence existing traffic environment. For example, the passage of many construction vehicles during the construction period increases traffic flow along the construction line and thus interferes traffic order in these regions.

INFLUENCING FACTORS OF ENERGY-SAVING AND COST-REDUCING PROCESSES OF CONSTRUCTION ENGINEERING

Faulty laws, regulations, and local policies regarding laws and regulations of building energy efficiency: China has issued several energy-saving laws and regulations. However, most of them emphasize on industrial energy saving. The energy-saving design system for building energy efficiency is currently faulty, accompanied by relatively backward supervision and implementation and incomplete punishments to violations. These factors all contribute to the implementation and outcome of building energy-saving policies. Moreover, building energy efficiency is an extensive concept that covers each stage in the full life cycle of buildings. However, existing building energy-saving policies are still under design, and these policies have difficulty receiving responses during late construction. Therefore, building energy efficiency is simply a concept that has not been implemented thoroughly.

Poor promotion and implementation of the government's incentive measures: Foreign countries have implemented a series of relevant policies and financial incentive programs to facilitate implementation of energy saving. These measures have received good response in foreign countries and stimulated enthusiasm of developers to apply green building energy-saving technologies, popularize the knowledge of green buildings, and provoke public consciousness on energy conservation. Corresponding market demand to promote the development of building energy efficiency is unavailable due to the long payback period of investment to building energy efficiency. Without promotion and guidance of the government, building energy efficiency is difficult to be implemented. The government shall adopt some financial incentive measures while complying to market rules and regulations, such as providing preferential policies (e.g., loans and tax exemptions) of developers who apply building energy-saving technological measures positively and subsidies for buyers of green buildings. China lacks experiences in the implementation of awards for energy-saving policies, which inhibits development of building energy efficiency in the country.

Lack of building energy consumption assessment system: The construction market often calls for green buildings. However, owners cannot assess the energy-saving performance, which includes energy efficiency and energy-saving effects from technological professionals, thereby limiting the promotion of building energy efficiency. With scientific progress, a series of energy consumption simulation software have been developed to assess energy consumption in early construction period. China lacks sufficient data regarding energy consumption. Thus, providing corresponding energy consumption indexes and setting up a complete evaluation system of building energy efficiency are impossible. Therefore, establishing and improving a building energy consumption index system and assessment method to promote standardization of building energy efficiency and provide consumers an explicit and intuitive understanding on energy consumption and economic benefits of green buildings is necessary. Moreover, this method can facilitate promotions of energy-saving and popularization of energy-saving consciousness.

Inadequate consciousness of building energy efficiency: Although China pays high attention on building energy efficiency and advocates all related organizations to increase

input and improve understanding on the importance of building energy efficiency, it fails to achieve the expected effect at present. In view of developers, only large units and enterprises with strong capitals pay attention to and use energy-saving technologies and new materials. By contrast, most middle- and small-sized construction enterprises step back for incremental investment and economic risks in construction of green buildings. Moreover, although consumers consider elevated location, appearance, and greening of buildings in the community when purchasing houses, they pay little attention to building energy efficiency. People have poor consciousness of energy saving. Without sufficient knowledge on the economic benefits of building energy efficiency in full life cycle and its positive effect on the environment, people are less willing to assume expenses of green buildings. As a result, the development of energy-saving buildings is inhibited due to the lack of supply-demand market.

ENERGY-SAVING AND COST-REDUCING MEASURES FOR CONSTRUCTION ENGINEERING

Improve policies and systems for building energy efficiency: For the benign development of building energy efficiency services, the government has to develop relevant policies and regulations, establish and improve a complete system to constrain all relevant stakeholders, establish a good market atmosphere, provide relevant supporting policies, and facilitate building energy efficiency services. Moreover, the government shall improve a detection, approval, and assessment system of energy efficiency, update relevant standards in time to meet the requirements on building energy efficiency services, and facilitate development of public building energy efficiency services. Standardizing market competition can be realized from market access mechanism and professional qualification certification system. The qualification authentication system for building energy efficiency services is included into the work plan of the government. The government is suggested to establish and improve the energy efficiency auditing and marking system for different building types. Moreover, it shall set up an effective collaborative mechanism based on practical situations of building energy efficiency. The government shall also train a good market to facilitate development of building energy efficiency services from multiple aspects.

Implement fiscal and financial incentive policies: The development of building energy efficiency services is dominated by government guidance and assisted by policy incentives. However, it has not been transformed from government to market. In view of constraints and incentives, the government develops policies and combines them flexibly to guide all involved parties to fulfil their responsibilities in the development of building energy efficiency services positively under government supervision. Mandatory policies can propose requirements to construction companies through labelling, rating, and application of energy consumption, which can stimulate market demands for building energy efficiency services. For energy consumption rating, provinces shall implement the quota system for public building energy consumption in accordance with local situations. Meanwhile, a public building energy consumption monitoring platform shall be constructed as an assisting measure. Incentive policy meets the demands of related stakeholders in building energy efficiency services through economic subsidies, including fiscal subsidies and tax exemption.

Establish a third-party energy-saving and cost-reducing assessment organization: Market demands determine the development of building energy efficiency services. Attention shall be paid to market regulation, and the enthusiasm of related stakeholders must be stimulated. However, consumers have poor enthusiasm toward building energy efficiency services, which is mainly caused by failures in determining the amount of energy saving in buildings and a reasonable assessment of building energy efficiency services. Establishing a third-party organization for energy-saving detection, auditing, and assessment through market strength is suggested. The third-party organization must be independent from the government and building energy efficiency service companies. However, establishing the third-party organization needs support from the government through relevant award policies. Moreover, the government shall not only train relevant staff to produce fair detection, auditing, and assessment but also strengthen the cooperation of the third-party organization with universities and scientific research institutes. The professional ability of staff in the organization must also be improved.

Strengthen publicity of energy-saving and cost-reducing policies of construction engineering: Enhancing publicity to increase public consciousness of building energy efficiency is suggested. Energy conservation cannot be implemented without public participation. In addition, energy-saving behaviour of the public is conducive to reduce the energy consumption of buildings. In energy-saving technological updating and coordinated economic development environment, guiding the energy-saving behaviours of the public is essential in the long run. Policy publicity departments at all levels shall use information awareness tools in the era of media effectively, form an extensive and lasting energy-saving consciousness in the society, perform multiple education and training activities on scientific knowl-

edge of building energy efficiency services, and organize the public to participate in exhibition of energy-saving benefits and demonstration buildings (communities). Moreover, an energy-saving building information website shall be set up to collect and publish relevant technologies and policy information in foreign countries regularly.

CONCLUSIONS

With the progress in urbanization and industrialization in China, energy consumption of buildings is increasing continuously. To obtain energy-saving and sound development, building energy efficiency shall be the main priority. Building energy efficiency plays an important role in stabilizing economic development, reducing environmental pollution, and improving people's living comfort. On the basis of the literature review regarding energy-saving and cost-reducing measures for construction engineering in foreign developed countries, the types of ecological environment pollution were summarized, and relevant influencing factors were recognized. Research results demonstrated that ecological environmental pollution caused by construction engineering is manifested by large consumption of energy resources, public urban environmental pollutions, occupation of land resources, damages of biodiversity, and influences of residents' living environment. Faulty laws, regulations, and local policies on building energy efficiency, poor promotion and implementation of the government's incentive measures, lack of evaluation system of building energy efficiency, and inadequate consciousness of building energy efficiency are the major factors that influence energy conservation and cost reduction of construction engineering. Finally, concrete countermeasures are proposed from perspectives of improving policies and systems of building energy efficiency, implementing fiscal and financial incentive policies, establishing a third-party energy-saving and cost-reducing assessment organization, and strengthening publicity of energy-saving and cost-reducing measures of construction engineering. Future studies on the analysis of the influencing factors of building energy efficiency, standardized management of green construction, estimation of regional differences in building energy efficiency, and updating and optimization of energy-saving and cost-reducing standards of buildings are needed.

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