Nature Environment and Pollution Technology
An International Quarterly Scientific Journal

p-ISSN: 0972-6268
e-ISSN: 2395-3454

Vol. 19 | No. 1 | pp. 367-372 | 2020

Original Research Paper | Open Access

Concrete Construction Waste Pollution and Relevant Prefabricated Recycling Measures

Zhang Jie† and Chen Nan
Department of Architectural Engineering, Jiyuan Vocational and Technical College, Jiyuan 459000, China
†Corresponding author: Zhang Jie

Nat. Env. & Poll. Tech.
Website: www.neptjournal.com

Received: 10-12-2019
Accepted: 16-01-2020

Key Words:
Concrete architecture
Construction waste
Waste pollution
Recycling measures

ABSTRACT

Architectural construction has expanded continuously in recent years as a response to China's accelerating urbanization, thus further leading to the dramatic increase of concrete usage. This expansion may cause serious threats to the ecological environment because the production and construction of traditional concrete materials may consume abundant resources, such as coals and limestone, and thus emit air pollutants. Prefabricated concrete building can significantly reduce the use of water, timber, thermal insulation materials, and cement mortar, thereby decreasing construction waste and carbon emissions greatly. Based on the review of the measures for concrete construction waste recycling in developed countries, this study summarized the types of hazards of concrete construction waste pollution, analysed the advantages of prefabricated concrete constructions, and proposed prefabricated recycling measures of concrete construction wastes. Results demonstrate that developed countries have relatively perfect concrete construction waste recycling systems. The hazards of concrete construction wastes are mainly manifested by the embezzlement of lands, water pollution, atmosphere pollution, soil pollution, and damage to physical health. The advantages of prefabricated concrete construction are manifested by high production efficiency, energy conservation, environmental protection, and overall high quality. Finally, several recycling measures were proposed, including strengthened policy support to prefabricated concrete construction; appropriate relevant laws, regulations, and standard systems; improved prefabricated construction enterprises; and enhanced environmental protection in prefabricated construction sites. Research conclusions can serve as reference for understanding the hazards of concrete construction-induced environmental pollution, recognizing the advantages of prefabricated concrete construction mode, increasing prefabricated concrete market shares comprehensively, and alleviating environmental pollutions.

INTRODUCTION

China's construction industry improves residents' quality of life and drives the growth of GDP (Gross Domestic Product). The sustainable, sound development of construction industry is vital to the development of China. Construction waste refers to the waste soil and other materials produced by construction companies and units during new construction, reconstruction, expansion, and demolishment of various buildings, structures, and pipe networks and by residents during home decoration. Currently, the construction wastes in urban areas in China are a major proportion of the total urban waste. If these construction wastes cannot be recycled reasonably, then they would increase continuously, and their proportion in the total urban waste may further increase with the China's continuous urbanization. Muck, waste concrete blocks, waste mortar, brick fragments, cullets, tile fragments, waste asphalt blocks, waste plastics, waste metals, and waste bamboo and timber materials are the major components of construction wastes. Most construction wastes, especially concrete construction wastes from demolishing buildings, can be recycled after screening, deletion, or smashing. Currently, the majority of concrete construction wastes in China are not reused. Instead, concrete construction wastes are transported to suburbs or rural areas and disposed in dump sites or landfills in open spaces, thus causing serious hazards to the ecological environment.

China's construction industry has recently achieved rapid development. Fig. 1 shows that the total output of China's construction industry rose from 6,203.681 billion Yuan in 2008 to 23,508.553 billion Yuan in 2018, showing an annual average growth of 28%. The building area of China's construction industry increased from 5,305,186,300 m^2 in 2008 to 14,089,204,000 m^2 in 2018, showing an annual average growth rate of 17%. These numbers fully reflect the considerable consumption of basic materials, such as concrete, in China's construction industry, resulting in massive amounts of construction wastes. However, the traditional dump sites or landfills of concrete construction wastes may occupy large areas of cultivated land. Moreover, long-term piling or landfills of concrete construction wastes may cause soil, underwater, and atmosphere pollution. In addition, concrete construction wastes are generally transported by open vehicles. Waste leakage, dusts, and lime sands may influence urban appearance and environmental health seriously and bring serious threats to the production and life of residents during transport. To sum up, the existing disposal means of concrete construction wastes cannot satisfy the needs of sustainable urban development, and the recycling of concrete construction wastes is essential in realizing the sustainable development of China's construction industry and a harmonious ecological environment.

PAST STUDIES

With the strengthening of environmental protection and resource saving consciousness, countries worldwide are enhancing the recycling of urban construction wastes. Many studies and applications on recycling technologies for construction wastes have been undertaken. Developed countries, such as US, Germany, and Japan, have achieved high construction waste recycling rates, whereas the recycling rate of construction wastes in China remains low. Hsiao et al. believed that the concrete logistics amount produced by new construction and demolishment projects was increasing dramatically in Taiwan. They simulated concrete wastes in the material flow based on a dynamic model and found that the concrete construction wastes were expected to increase continuously. Concrete construction waste recycling must be increased comprehensively to decrease the environmental pollution in Taiwan (Hsiao et al. 2002). Gotoh et al. analysed the total suspended particulates concentration in regions damaged seriously during the Hanshin Earthquake and found that the elements in the concrete dusts (Ca and S) in construction wastes are similar to those in mortar dust, which is one of the major sources of air pollution (Gotoh et al. 2002). Andersson M. et al. studied polychlorinated biphenyl (PCB) pollution in gypsum on the external building walls in Bergen, Norway and reported that the PCB concentration in soil and plaster of residential buildings and schools was higher than those in office buildings, warehouses, or industrial buildings (Andersson et al. 2004). Lindgren investigated a concrete contamination indoor ammonia event in an office of one airline in Beijing and found that the ammonium hydroxide pollution in the Beijing Office might come from the additives in concretes (Lindgren 2010). Taylor-Lange et al. predicted the specific activity of radium and the probability of radon precipitation through Monte Carlo simulation and estimated the indoor radon concentration and the effective annual dose under two different concrete floors (one has fly ash, whereas the other has no fly ash) in a typical single-family house in the US. Their results show that exposure to radon in concrete buildings could influence human health significantly (Taylor-Lange et al. 2012). Arunvivek et al. believed that commercial concrete industries worldwide are producing abundant wastewater and fresh concrete waste aggregate, which may cause serious environmental pollution upon improper disposal (Arunvivek et al. 2015). Wu et al. believed that the accelerating modern industrialization and urbanization in China might cause construction dust emission. He investigated the current dust control situations in China's construction industry, determined the main sources of construction dust, and proposed a case study to interpret the major dust control measures in construction sites (Wu et al. 2016). With respect to the recycling measures of concrete construction wastes, Eguchi et al. proposed a concrete recycling method that was different from that of

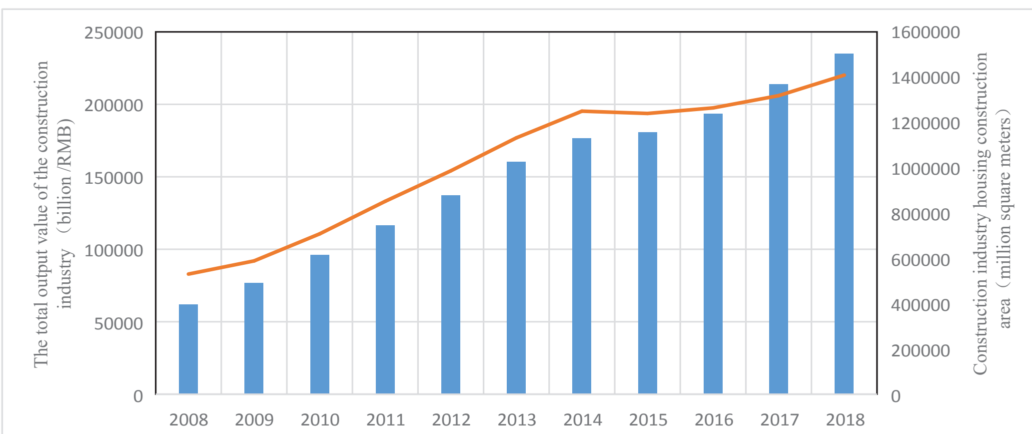

Fig. 1: Total output and building areas of China's construction industry during 2008-2018.
(Data source: China Statistical Yearbook 2009-2019).

ordinary concrete, thus obtaining data needed to determine the mixing ratio design and the quality control method. The economic efficiency and environmental loads of this method were assessed, and the validity of this method was verified (Eguchi et al. 2007). Rao et al. reviewed the international production of C&D wastes and the utilization of recycled aggregates (RAs) and summarized influences of RA use on fresh and hardened concretes' performance (Rao et al. 2007). Tam believed that construction materials were poured to landfills, and abundant wastes might be produced from construction sites. As a method of reducing concrete wastes, using recycled concrete wastes as RA can be an economical and effective method for China's construction industry; this method is also conducive to environmental protection (Tam 2008). Naik believed that Portland cement is an important component of concrete, and abundant greenhouse gas, that is, CO_2, is released during the production of Portland cement. He suggested the construction of a sustainable concrete structure to ensure minimum influence on the environment within its service life (Naik 2008). Khatib et al. suggested the reduction of urban pollution through the innovative use of building materials, the reduction of the dependence on traditional concrete construction, and the effective recycling of concrete construction wastes (Khatib et al. 2018). Xing et al. pointed out that dust pollution is a key problem in the construction process that must be addressed, and the government should assume partial responsibility and reduce dust emission at construction sites for the public. According to data analysis, the preferred technologies and organization measures of the Chinese government, institutional guarantees, and technological innovation are prerequisites of dust-free construction (Xing et al. 2018). Akhtar et al. pointed out that the production of concretes and construction wastes are among the major causes of continuous CO_2 emission in the atmosphere. According to the sorting and critical analysis of information from 40 countries in six continents, he suggested the use of 30%-50% RA-assisted concrete with binding materials to achieve the strength of natural aggregate concrete (Akhtar et al. 2018). Colangelo et al. suggested the use of "green" RA in concrete production to mitigate the potential adverse effects on environment and energy (Colangelo et al. 2018). Based on existing studies, developed countries have relatively perfect recycling systems of concrete construction wastes and carried out abundant studies on waste concrete RA and prepared RA concretes. On the basis of the comprehensive analysis of the pollution hazards of concrete construction wastes, this study analysed the advantages of prefabricated concrete construction and proposed prefabricate construction waste recycling measures to provide references for solving construction waste pollution control problems, standardizing construction waste management, and reducing abundant construction resource wastes.

HAZARDS OF CONCRETE CONSTRUCTION WASTES

Embezzlement of Lands

In China, construction waste results in considerable annual embezzlement of land areas. Moreover, the output of construction wastes will increase continuously as a result of China's economic development, the continuous expansion of the urban construction scale, and the increasing demand for living conditions. The embezzlement of lands will intensify continuously because of the delayed processing and utilization of concrete buildings. Concrete is essential to construction and transportation infrastructure construction. In particular, the demands for concrete will increase greatly with China's continuous urbanization, thus resulting in increased demands for sands and stones, which are used as concrete aggregates. Such huge demands for sands and stones will surely lead to large-scale mountain quarrying and the exploitation of river sands, which will in turn cause serious damages to the ecological environment.

Water Pollution

Concrete in construction waste is rich in water soluble calcium silicate and calcium hydroxide. Waste plaster contains many sulphate ions. Waste metals involves the dissolution of heavy metal ions. Through anaerobic degradation, waste paper plates and timbers may generate lignins and tannin, which are further decomposed into organic acids. Thus, the percolating water of concrete construction waste after immersion in rainwater in landfill is generally strong in alkali and contains heavy metal ions, hydrogen sulphide, and certain amounts of organic matters. If this percolating water is not controlled and flows into rivers and lakes or penetrated underground, then the surface and underground water pollution is intensified accordingly, thus damaging the survival of aquatic organisms and affecting the secondary use of water resources. This phenomenon will cause irreversible damage to the water environment.

Atmospheric Pollution

Waste plaster in concrete construction waste contains abundant sulphate ions, which are transformed to hydrogen sulphide and volatile organic acids under anaerobic conditions. These harmful gases cause atmospheric pollution once emitted to the air. Resource reserves and output, such as natural sands and stones, are decreasing annually due to exploitation. Particularly, natural river sands cannot satisfy the demands, a shortcoming that is worsened by the increasing supply–demand contradictions. Resource shortage is particularly serious in certain big cities. Thus, finding alternative resources is an urgent concern. Many artificial sands have been put into use. In coastal regions with relatively high economic development, sea sands are applied to prepare concretes by taking advantage of geology. However, sea sands have a relatively high Cl-content. The illegal or unreasonable use of sea sands can easily cause the corrosion of reinforcement in concrete, eventually bringing potential safety risks in architectural structures.

Soil Pollution

Harmful substances in construction wastes and their percolating water cause soil pollution, which is manifested in changes in physical structures and in the chemical properties of soil. Soil pollution influences the nutrient adsorption and growth of plants and the activity of microorganisms in soils, breaks the ecological balance in soils, and promotes the accumulation of harmful substances in soils. Consequently, the harmful substances in soils exceed the standards, thus inhibiting plant growth and even causing plant death. In addition, harmful substances may be transferred to fruits through plant adsorption and further influence the physical health of humans and animals through the food chain.

Threats to Physical Health

Concrete construction wastes, which are piled up randomly without processing, produce harmful substances that may enter the atmosphere, water, and soil. Subsequently, these harmful substances may enter the human body through various ways, thus resulting in poisoning. Many toxic and harmful components in concrete construction wastes enter the food chain through animals and plants, which further lead to lesions and affect the physical health of humans. During respiration, harmful dusts from concrete construction wastes may enter the human body through the respiratory tract and diffuse in the circulatory system, thus causing substantial damage to the human body.

ADVANTAGES OF PREFABRICATED CONCRETE CONSTRUCTION

High Production Efficiency

The prefabricated parts of prefabricated concrete construction are manufactured through assembly lines in factories and then transported to construction sites for mechanical hoisting assembly. This path not only saves in labour force and materials significantly but also increases concrete construction efficiency. Furthermore, the convenience and efficiency of construction work is increased. Thus, planned tasks can be accomplished in a short period, which is desirable. The construction of prefabricated buildings is affected slightly by severe weather conditions. Therefore, prefabricated concrete construction significantly increases production efficiency and shortens construction period in comparison with traditional construction means.

Coexistence of Energy Saving and Environmental Protection

Traditional architectural construction requires the frequent casting-in-situ of concretes, which may cause serious dust and wastewater pollution as well as noise pollution in construction sites. On the contrary, prefabricated concrete construction can decrease casting-in-situ significantly. The direct assembly and installation of prefabricated components not only save in field wetting operation to a large extent but also decrease dust and wastewater pollution and the production of construction wastes. They result in a green construction environment. During the production of prefabricated components, reusing moulds and assembly line-based production can maximize resources. Mechanical hoisting assembly is basically applied in installing parts, which decreases the use of many scaffolds and templates and promotes resource saving and environmental protection.

Guarantee of Overall High Quality

Prefabricated components are manufactured through standard production line. Improving production technologies and the standardized production procedure can guarantee the satisfactory quality of prefabricated components. Components, such as prefabricated external wall panels, can maintain the stability of walls, while water-proofing, heat insulation, and thermal insulation are considered. This strategy decreases field construction and promotes quality components. The manufacturing of prefabricated components in factories plays an important role in effectively controlling architectural quality.

PREFABRICATED RECYCLING OF CONCRETE CONSTRUCTION WASTES

Strengthen Policy Supports to Prefabricated Concrete Construction

The guidance and support of governments provide a development direction for prefabrication construction and guarantee benefits for prefabricated construction enterprises. The reasonable management by the government determines the development of prefabricated construction. The development of prefabricated construction realizes the philosophy of China's green energy-saving push. China should increase its investment on prefabricated construction development; formulate various supporting policies that provide capital subsidies, preference policies for land bidding, loans with discounted interests, and preferences to economic technological indexes (like plot ratio and building area); set up a special promotion department for the large-scale propaganda of the advantages of prefabricated construction; formulate an excitation mechanism; and develop the guidance of government. To provide reliable guarantees to real estate developers and construction units, the government of China can apply special funds for prefabricated construction, formulate preference policies to attract foreign investment, and increase marketing efforts. Moreover, the Chinese government should set up a series of special key subjects of prefabricated construction in colleges and universities, offer financial assistance to relevant experiments and practices in universities, train talented individuals with technological and management skills, and establish key technology R&D funds to promote R&D and the innovation of structure and technological systems for prefabricated construction.

Perfect Laws and Regulations of Prefabricated Concrete Construction

Currently, the prefabricated component manufacturing market in China is chaotic. Owing to the lack of production standards and norms, the component cost remains high, thereby restricting the expansion of prefabricated component manufacturing. Provinces and cities have released relevant laws and regulations, and some standards have been formed in local regions. However, these laws, regulations, and standards are independent from one another and are lacking in authority and universality, thus resulting in diversity and chaotic national industrial standards. China has published the industrial standards of Technical Regulations on Prefabricated Concrete Structure several years ago. The standards propose explicit technical regulations in different links of the entire process, and they restrict construction chaos to a certain extent. Thus, relevant departments of China should concentrate their industrial powers to formulate China's standards or norms, implement specific rules, realize standardized production, expand the manufacturing scale of prefabricated components, and decrease the production cost of single components, thereby lowering the engineering cost and facilitating the industrialized development of construction. In addition, the formulation and further perfection of universal standard atlas or technical design scheme must be accelerated; unique, standardized, systematic, and supporting technical standard systems must be formed; the requirements of different provinces and cities for building functions and performances should be met; laws for reference throughout the prefabricated construction process must be offered; and technical foundations for expanding the prefabricated construction scale must be laid out.

Improve Levels of Prefabricated Construction Enterprises

The prefabricated construction industry is developing slowly in China and remains in the initial stage. China has successively released many supporting policies and incentive measures to guide the sound development of prefabricated construction. Owing to hindering factors, such as excessively high investment, prefabricated component manufacturers are few and are lacking enthusiasm to scale up. Thus, prefabricated component manufacturers are costly, which further restricts scale expansion. Therefore, different provinces and cities of China should perfect supporting policies, implement specific rules, provide certain guarantee, stimulate the enthusiasm of manufacturers, introduce benefits to manufacturers, expand market demands, improve the productivity, and form scale benefits. Additionally, local governments should improve the professional quality of workers in prefabricated component manufacturers and train professional technicians and managers through regular professional trainings to improve the production efficiency and professional degree of enterprises and bring them additional benefits. To encourage prefabricated construction industrial development, the provinces and cities of China launched many pilot projects. Through these pilot projects, China should integrate resources effectively, increase the R&D of key technologies and talent training, and accelerate the training of professional production and construction and leading enterprises that integrate the design, production, and construction of prefabricated components.

Strengthen Environment Protection at Prefabricated Construction Site

Enterprises should pay attention to the environmental management of construction sites. Enterprise protection is an important factor in modern construction industry. The management level of enterprises determines the construction schedule and level. Therefore, managers with rich management experiences and strong coordination ability should be selected for construction site management. Additionally, several management measures should be adopted to increase the management level and decrease unnecessary expenditures. The construction schedule should be planned reasonably to control the construction period, and the use of expensive heavy hoisting equipment should be minimized. Moreover, construction sites should be managed through an environmental protection method that includes material wastes reduction, reasonable arrangement of construction order, and slowdown phenomenon prevention.

The assembly efficiency should be improved to increase the components produced in factories, decrease the field management of components, increase the construction efficiency, and save cost.

CONCLUSIONS

The output of construction wastes in China is increasing annually, resulting in the increasingly prominent problem of construction waste pollution control. Construction wastes not only occupy large-scale land resources but also cause substantial damage to soil, air, and water environments. Moreover, China has failed in recycling construction wastes. With continuous urbanization, the volume of construction waste may increase, and its proportion in total urban wastes may increase further. This study reviewed the recycling measures of concrete construction wastes in developed countries, summarized the types of hazards of concrete construction waste pollutions, and analysed the advantages of prefabricated concrete construction. Results demonstrate that developed countries have relatively perfect recycling systems for concrete construction wastes. The embezzlement of lands, water pollution, atmospheric pollution, soil pollution, and threats to physical health are the five types of concrete construction waste hazards. Prefabricated concrete construction has several major advantages, such as high production efficiency, energy saving and environmental protection, and overall high quality. Certain measures can be adopted to decrease the environmental pollutions from concrete construction wastes, including the strengthening of policy supports for prefabricated concrete construction, appropriate relevant laws, regulations and standard systems, improving the levels of prefabricated construction enterprises, and enhancing the environmental protection of prefabricated construction sites. Intensive studies on concrete construction waste recycling systems, information disclosure systems that connect different stages of concrete waste disposal, comprehensive evaluation of prefabricated concrete construction quality, and environmental pollution control at prefabricated concrete construction sites must be continued.

REFERENCES

Akhtar, A. and Sarmah, A. K. 2018. Construction and demolition waste generation and properties of recycled aggregate concrete: A global perspective. Journal of Cleaner Production, 186: 262-281.

Arunvivek, G. K., Maheswaran, G. and Senthil Kumar, S. 2015. Eco-friendly solution to mitigate the toxic effects of hazardous construction industry waste by reusing in concrete for pollution control. Nature Environment & Pollution Technology, 14(4): 963-966.

Andersson, M., Ottesen, R. T. and Volden, T. 2004. Building materials as a source of PCB pollution in Bergen, Norway. Science of the Total Environment, 325(1-3): 139-144.

Colangelo, F., Forcina, A., Farina, I. and Petrillo, A. 2018. Life cycle assessment (LCA) of different kinds of concrete containing waste for sustainable construction. Buildings, 8(5): 70.

Eguchi, K., Teranishi, K., Nakagome, A., Kishimoto, H., Shinozaki, K. and Narikawa, M. 2007. Application of recycled coarse aggregate by mixture to concrete construction. Construction and Building Materials, 21(7): 1542-1551.

Gotoh, T., Nishimura, T., Nakata, M. and Nakaguchi, Y. 2002. Air pollution by concrete dust from the great hanshin earthquake. Journal of Environmental Quality, 31(3): 718-723.

Hsiao, T. Y., Huang, Y. T., Yu, Y. H. and Wernick, I. K. 2002. Modeling materials flow of waste concrete from construction and demolition wastes in Taiwan. Resources Policy, 28(1-2): 39-47.

Khatib, J. M., Elkordi, A. A. and Saleh, Z. A. 2018. Mitigating Urban Pollution through Innovative use of construction materials. Urban Pollution: Science and Management, pp. 235-247.

Lindgren, T. 2010. A case of indoor air pollution of ammonia emitted from concrete in a newly built office in Beijing. Building and Environment, 45(3): 596-600.

Naik, T.R. 2008. Sustainability of concrete construction. Practice Periodical on Structural Design and Construction, 13(2): 98-103.

Rao, A., Jha, K. N. and Misra, S. 2007. Use of aggregates from recycled construction and demolition waste in concrete. Resources, conservation and Recycling, 50(1): 71-81.

Taylor-Lange, S. C., Stewart, J. G., Juenger, M. C. G. and Siegel, J. A. 2012. The contribution of fly ash toward indoor radon pollution from concrete. Building and Environment, 56: 276-282.

Tam, V. W. Y. 2008. Economic comparison of concrete recycling: A case study approach. Resources, conservation and recycling, Resources, Conservation and Recycling, 52(5): 821-828.

Wu, Z., Zhang, X. and Wu, M. 2016. Mitigating construction dust pollution: State of the art and the way forward. Journal of Cleaner Production, 112: 1658-1666.

Xing, J., Ye, K., Zuo, J. and Jiang, W. 2018. Control dust pollution on construction sites: What governments do in China? Sustainability, 10(8): 2945.