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Reclamation management of construction waste in China: A review

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Abstract: With rapid development of industrialization and urbanization in China, an overwhelming amount of construction waste materials is generated from the large-scale construction activities. Currently, the minimization and reclamation management of construction waste has already been a global environmental issue. However, compared to some developed countries and regions, construction waste recycling in China is still at a lower level, which can be attributed to various aspects. Thus, this paper firstly shows the present status quo of disposal and treatment of construction waste in several advanced economies, mainly including Japan, Germany, Hong Kong, and the United states. Afterwards, the paper highlights the poor management of building-related waste recycling and analyzes its causes. Finally, using the current reclamation management of these developed countries and regions for valuable guidance, this paper has put forward the effective recommendations for better improvements.
Keywords: Construction waste; Reclamation management; China; Recommendations

INTRODUCTION

The construction industry has been well known as the major municipal solid waste generator worldwide, which can contribute to environmental deterioration [1,2]. In the expanding process of industrialization and urbanization over the past decades in China, the amount of construction waste materials has increased significantly and China has been the country with the largest construction waste generation around the world [3,4], due to the accelerated development of large-scale infrastructure and a growing demand for new buildings and demolition. Statistics show that the waste generated by building activities frequently accounts for nearly 40% of the total municipal solid waste received at many landfill sites [5,6]. Moreover, construction industry annually generates approximately 200 million tons, of which 100 million tons is produced from new construction projects [7]. However, nowadays, in China, most of these waste materials is delivered to suburban or rural areas without any pretreatment just by simple disposal of burying or air storage [8]. Along with the speedy increase of construction waste, these simple treatments will no doubt occupy the massive landfill sites, further aggravate land resource shortage, and contaminate the surrounding environment [9].

It has been universally acknowledged that the definition of construction waste is of paramount importance, whereas there has been no clear consensus on defining what is meant by the term in the existing literature. Recent researches have proposed to understand construction waste by tracing to its generation phase. Generally, it has been widely described as the solid waste generated from various building activities like new construction, renovation, and demolition [10,5,11,12,13]. It may also include surplus and damaged products and materials arising in the whole process of construction projects or used temporarily during the course of on-site activities [11]. Approximately 80% of the total accumulation of building-related waste materials is broken concrete, slurry, tiles, part of bricks and blocks, which could actually put to good reuse if applying appropriate recycled technologies [14]. For instance, from a technical perspective, the preparation of recycled aggregate concrete from waste concrete (WC) has been already available, and the relevant applications in the new mixed concrete materials have proved its feasibility and practicability [15].

Obviously, in parallel with the continuous development, China has also witnessed a severe environmental degradation[16]. One of the significant contributors is the tremendous construction waste materials generated from various building activities. Actually, the significant amount of construction waste has already been a worldwide issue. Meanwhile, with the increasing awareness of sustainable development as an important value [17], the reclamation management of construction waste has attracted widespread interests around the globe [18,19,15]. Indeed, construction waste recycling has commonly been perceived as a key strategy in minimization of these waste materials [19].

And at present, the developed countries and regions have attached great importance to reuse construction waste and gained obvious experience in how to recycle waste materials effectively. For example, driven by a shortage of disposal sites, minimization and reclamation management of building-related waste materials at the construction sites have been initiated [20-23]. Furthermore, the application of using recycled aggregate as a sort of building material has been pursued worldwide, with promising results [24-26]. But currently, resources utilization of construction waste is still in the pilot phase of exploration in China, which can be related to the absence of perfect management and regulatory system in waste recycling. As Tab.1 illustrates, only 8% of building-related waste materials in China is reused and recycled, quite lower than the general level of many developed countries, such as Japan, Germany, and the U.S.[27]. Nevertheless, the overseas advanced experience in disposing the construction waste materials can provide some meaningful inspiration and reference for the effective reclamation management of construction waste in China.

The remainder of the paper is mainly divided into four parts. The next section introduces resources utilization management of construction waste in some advanced economies. It is followed by a description of the status quo of building-related waste materials recycling in China. Then it moves on to put forward the corresponding countermeasures for waste reclamation management. Finally it reaches the main conclusions.

ABROAD EXPERIENCE AND ENLIGHTENMENT

Construction waste represents a great deal of construction material, which is actually regarded as one of precious natural resources [28]. Actually, the developed countries, such as the U.S., Germany, and Japan, have made resource utilization of construction waste a strategic plan to achieve sustainable development from the 1990s [29]. In an attempt to protect the environment and to improve sustainability of the construction sectors, many organizations and researchers abroad have developed plenty of initiatives focusing on construction waste materials reuse and recycle with potentials in order to avoid its negative impacts on the natural environment [30-32]. Such efforts mainly include waste reduction, reuse, recycling, and disposal [33]. In the process of practicing those measures, the government has already accumulated lots of practical experience in how to manage construction waste recycling effectively. It would be better for China to directly learn well-rounded waste management experience from these countries.

The whole process of management

As shown in Tab.2, it can thus be concluded that based on further analysis of the whole process of construction waste materials management(generation and collection, transportation, disposal and treatment, and reclamation), some developed countries and regions have strengthened supervision and management towards building waste reuse and recycle.

These regulatory measures throughout the entire process of waste materials generated from building activities indicate that these developed countries and regions make much account of tackling the continuous increasing construction waste accumulation, and the reclamation management problem of these waste materials [34]. Actually, these countries and regions have already implementation that based on making full use of effective market mechanisms, building-produced waste has been separately categorized and then collected for centralized treatment, so that these waste materials can be transformed into new valuable resources with economic worth through different stages of processing, mainly including transporting, cleaning, and recycling [35,36].

Laws and regulations

At the same time, many countries and regions, such as Japan, the U.S., Germany, the U.K., and Hong Kong, has already developed a series of specific laws and regulations into a legal framework focusing on the reuse and recycle of construction waste, which will encourage these waste materials to be properly treated and achieve the better improvements in its disposal and conversion [37,38]. After decades of planning and development, these advanced economies have been formed a comparatively mature regulatory system in minimization and reclamation management of construction waste [39].

As mentioned, these developed countries and regions have obtained significant achievements in how to manage construction waste recycling effectively[34]. As a matter of fact, these achievements is especially pronounced on the increasing improvement and effectiveness of laws, governmental regulations and practices regarding waste reuse and recycling[40]. Besides, these strict laws and regulations currently implemented in these countries and regions emphasize the importance of waste materials reduction at its source, which is in accordance with the basic principle “Polluter pays” that the polluters shall be held responsible for the damage that caused to the natural environment[29].

Table-1: The Recycling Rates Of Construction Waste in Various Countries.

Country	Japan	Germany	Netherlands	Denmark	The U.S.	PR China
Recycling rate	95%	95%	90%	90%	70%	8%

Table-2 : Regulatory measures to manage construction waste recycle in developed countries and regions.

Stage	Country/ Region	Initiative
Generation	Japan	Prior to the construction, the professional construction and demolition enterprises should evaluate the generation and sorted collection of construction waste materials throughout the project, and determine the recycling program.
	Singapore	"The Singapore Green Plan 2012" has been implemented to change the traditional concept of the buildings and design ideas, improve the building techniques, and effectively adopt the prefabricated materials in the process of construction projects.
	Hong Kong	The amount of waste deposited in building landfills is restricted by some administrative rules. Construction waste producers are then encouraged to implement waste classified collection before disposal.
Transportation	Japan	Slip system should be carried out in transportation, which largely prevent illegal dumping activities. It is also helpful for government departments to confirm the amount and type of building-related waste generated, and how to manage it.
	the U.S.	The local government trace the delivery process of construction waste to ensure that it can be put into the designated waste disposal plant.
	Hong Kong	In order to effectively describe the movements of construction waste, delivery record system should be stated in the public sector project contracts.
Treatment and disposal	Japan	Economic incentive policies of construction treatment plant have been established.
	Singapore	Building professionals use construction waste for free.
	the U.K.	Waste producers pay the related taxes and fees when sending the waste materials to recycling facilities.
Reclamation	Japan	Waste recovery logistics system has been built, which is the basic guarantee on construction waste recycling; Policy makers adopt several economic policies to encourage builders and contractors to use renewable materials; The legislation on basic quality standards of recycled materials is promulgated to make it clear to the public that construction waste could be recycled for further utilization.
	Germany	As the world's first nation implemented environmental labeling, the German government certainly prefer to use recycled materials and products.
	Denmark	The revenue earned from construction waste reuse and recycling do not charge taxes.
	Nordic countries	Nordic countries have implemented a common Nordic environmental labeling system in 1989, and have imposed punitive tax burden to illegal dumping waste behaviors.

Table-3 : Laws and regulations to deal with construction waste recycling in different countries.

Country	The ordinance and its main content
Japan	Use of Recycled Aggregate and Recycled Concrete Specification (1977) was enacted and then built disposal treatment plant which is held responsible for recycling waste concrete as a renewable resource; Reuse of Resources Promotion Act was issued in 1991 and it stipulated that construction waste generated in the process of construction should be disposed by waste recycling facilities; Construction Recycling Law(2002) required that government should set up classification standard, the treatments, recycle system, and zero- discharge technologies of waste treatment.
the U.S.	Superfund was enacted by US Congress in 1980, and this law stipulated that construction waste materials generated must be disposed properly so as not to be dumped illegally at unauthorized areas.
Germany	Application Guide for Usage of the Recycled Aggregate in the Concrete (1998) German Circular Economy Law(1996) was promulgated and the fields and steps of producer responsibility (low waste potential, high recycling potential) applying to waste recycling management were also proposed. The law also stipulated that only waste which cannot be avoided or recycled has to be disposed.
the U.K.	The Site Management Plan Regulations for building projects were promulgated in 2008. Details within the plan included the amount and range of waste materials generated, how the waste is appropriately disposed in accordance with the duty of care provisions, and the prespecified volumes of environmental permissible waste discharge (Government of UK 2010)
Hong Kong	The Hong Kong Government has implemented the Construction Wate Disposal Charging Scheme(CWDCS) since December 2005 and then has provided some financial incentives for construction waste producers to encourage them initiate waste reuse and recycle before being sent for disposal.

STATUS OF CONSTRUCTION WASTE RECYCLING IN CHINA

Legislative and regulatory system

The Chinese governmental departments has recognized the urgent need to promote better reclamation management of construction waste materials since the 1990s and therefore has endeavored to implement various management policies from different respects targeted at reducing construction waste generation and enhancing the degree of building-related waste utilization, mainly including legislations, regulations, and initiatives [40]. As is shown in Tab.3, it is a gradually advanced course to realize and accept that construction projects should manage building-related waste materials in line with the basic principle of sustainable development, namely, “Reduce, Reuse, and Recycle” [41]. These laws and regulations also contain various management practices related to construction waste materials reuse and recycling, such as financial incentive provision and waste disposal charging scheme [42]. More importantly, Urban Construction Waste Management Regulations was issued in 2005, so that to some extent, it promotes the promulgation and implementation of local regulations about construction waste reuse and recycle [43].

However, compared with some advanced economies, it is also found that the current laws and regulatory system in China are by and large identified as poor in promoting the effective reuse and recycle of construction waste materials, and there are still many issues waiting to be addressed [44]. No tangible progress in legislation and regulations of waste reclamation has been made, and shortcomings of the present legal system mainly lie in following two aspects.

Table-4 :Laws and regulations relevant with construction waste in China.

Year	Ordinances	Main contents
1992	Measures for Environment and Sanitation Management	It is not allowed to stack up construction materials in the open air and build temporary structures in public areas, unless it is authorized in advanced by relevant government departments. Regulations involves some rules of managing construction waste generated from new structure, renovation and decoration.
1995	Waste Disposal Ordinance	It is regulated that contractors should be responsible for the sanitation management of construction sites. Waste producers should be imposed waste disposal charging. But such waste-pricing method is unable to cut the construction waste source, and cannot influence the realization of waste reuse and recycle.
2004	Solid Waste Pollution Prevention Law	It specified that waste management at construction sites should be strengthened; Construction builders or contractors should control waste generation at source through the application of low-waste construction technologies; It is also regulated that the relevant regulatory authority is responsible for supervising environmental protection in construction projects.
2005	Regulations of Urban Construction Waste Management	It launched the construction waste disposal scheme, and clear the responsibilities of waste materials transporters and disposal plant; It has tightened the regulations with penalties for illegal waste disposal practices.

Imperfection of relevant laws and regulations

Comprehensive regulations can lay a solid basis for the realization of reclamation management of construction waste materials [40,27,45,46]. But at present, the corresponding laws and governmental regulations aimed to sustained development of construction waste reclamation in China are yet incomplete and not clear [47], and particularly, the existing regulations and schemes are normally limited to cover aspects of construction waste transportation and disposal, but construction waste reuse and recycle are all ignored [48]. In addition, the existing regulations is absence of enforceability. Its merely govern building activities and waste recycling issues just from a extensive perspective, rather than putting emphasis on solving problems pragmatically, for example 'how to regulate illegal waste dumping practices' [49]. This ultimately results in some inevitable difficulties in the implementation process of reclamation management of construction waste in China.

Lack of regulatory mechanism

The absence of an effective regulatory mechanisms is mostly an significant barrier for China to better promote construction waste reuse and recycle [50]. For instance, if governmental supervision for illegal waste dumping behaviors is actually inadequate, most construction waste producers absorbed in short-term economic gains may not transport the collected waste to public landfill sites or make these waste materials recycling, thereby illegal waste dumping exist in wide scopes of inadequately supervised areas [50].

Notably, reclamation management of construction waste is a complex systematic engineering and a dynamic process, which involves many elements [51]. It not only contains various processes, but also involves different government departments, typically including the construction committee, the planning department, and the environmental protection bureaus, etc. But for now, the functions among these different departments involved do unclear, disconnected, and repeated, basically caused by the vagueness and uncertainty of responsibility allocation and lack of collaboration between these departments [33,52].

The main problems

As previously mentioned, most waste in China has been disposed by means of stacking in the open air or the landfill [8]. On the whole, the actual development of waste reclamation in construction sectors is still at the exploratory stage and yet too mature to effectively alleviate the environmental pressure [22]. One of the significant reasons behind this phenomena lies in the low management level of construction waste recycling [53]. Meanwhile, its poor management can be attributed to the following several aspects.

Absence of policy support

Being lack of preferential policies, promotion mechanism and incentive system, construction waste recycling has been arduous in China [33]. For example, there are no standard construction waste classification norms, which can contribute to a low level of waste collection and sorting [54]. Besides, the policies designed to support construction waste plant to establish waste reuse and recycle practices are still lacking [27]. Furthermore, the local authorities do not launch long-term concrete solutions concerning construction waste reduction and reclamation especially for landfill planning and construction issues [27,55].

Lack awareness of construction waste recycling

The implementation of construction waste recycling is a systematic project, to large extent, which relies on the joint participation of the government, enterprises and the general public [56,57]. The fact has been universally acknowledged that building professionals' consciousness of reclamation management of waste materials on-side is crucial to the development of waste recycling [58]. However in China, on the one hand, on-site construction managers and engineers are lack of universal awareness about waste reduce and recycle. Most of Chinese construction projects do not have detailed waste reduction and reclamation management plans. On account of low waste disposal fees and high transportation costs, most contractors would rather dispose the construction waste as garbage than increase their investment on waste reduce and recycle. On the other hand, the general public and construction contractors all lack the sufficient knowledge on quality and feasibility of recycled materials. So now, promotion of construction waste reclamation is totally up to the efforts made by governmental departments.

Insufficient attention to on-site waste sorting

On-site sorting separates construction waste according to its characteristics so that some valuable waste can be picked up for reuse and recycle, whereas the rest can be deposited at landfills [59,60]. But in China, only waste materials with short-term economic benefits(such as concrete, bricks, and timber etc)which can be used directly in subsequent construction is reused and recycled on-site, while other mixed waste without being separated at source generally ended at landfills or directly disposed of at unauthorized areas[61]. Besides, building professionals are unwilling to carry out on-site construction waste sorting due to miscellaneous obstacles in despite of its perceptible advantages [60,42]. However, if the generated construction waste materials can be sorted on-site and then transported out of construction sites by type, the high proportion of waste reuse and recycle would be achieved, since waste sorting and separation on-site can prevent the generation of construction waste, and reduce the cost for waste materials transportation and disposal [59].

MANAGEMENT STRATEGIES

Based on the above findings and discussions, all these management problems demonstrate a pressing appeal for the need to improve current construction waste recycle practices in China [33]. Currently, the volume of construction waste generated is increasing rapidly and almost all of the waste materials can be largely predicted and recycled [31]. However, it is reported that only about 8% of construction waste had been recycled and the remainder was disposed in landfills. These enormous quantities of construction waste, if it is appropriately reused and recycled, many remarkable economic benefits and social environmental benefits can be obtained [31]. Meanwhile, strengthening minimization and reclamation management of construction waste materials is not only a management and technical work, but also a complicated system engineering which requires the common participation and full support from the whole society [62,34]. In this regard, it is advisable to make the following recommendations to improve the current situation in construction waste recycling.

To perfect government legislation

Compared with those developed countries, there is a lack of precise and detailed legislation and governmental regulations related to reclamation management of construction waste in China. Hence, to overcome such obstacles and advance a harmonious recycling society better, the comprehensive management legislation about construction waste recycling should be promulgated. More importantly, a legal system covering a much broader range of dimensions, such as construction waste sorting, transport, disposal, reuse, and recycling, should be developed [42].

Meanwhile, the corresponding impartial standards and specifications of production quantity, discharge amount and disposal of construction waste accumulation should also be strengthened, which is regarded as an important criteria of the construction enterprise management and technology.

To determine the function of various departments

In China, an mechanism in which the responsibility of each department involved is clearly defined is lacking. Therefore, it is the inevitable urge to establish an effective mechanism to clearly coordinate these departments involved and properly allocate their responsibilities pushing for more necessary regulation. For example, in order to coordinate the relationship among various departments, it is essential to establish an independent regulatory agency whose role is to supervise the reclamation management practices of construction waste materials, and continuously optimize and reorganize the responsible agencies.

To enact public policy support

In present situation, most on-site managers and workers still have limited awareness of construction waste reuse and recycle, and they don't regard waste materials as renewable resources [26,63,64]. Therefore, in order to encourage construction waste recycle and change waste materials into renewable resources, the Chinese government should make further efforts to raise on-site managers and workers' awareness of material recycling through benefit-drived mechanism, such as raise construction waste disposal fees and

explore the establishment of rewarding and punishing mechanism and supervising mechanism to effectively encourage associated stakeholders to initiate means to minimize waste generation and regard waste recycling as an essential part of the whole construction process [8,65,66].

Besides, although the Chinese government has established some pilot projects in applying recycled construction waste materials, the coverage area of these projects is normally confined to a few governmental investment construction programs [33,52]. Indeed, pilot projects could be expanded further to all building programs in China [33]. Furthermore, the government should establish appropriate evaluation index system to periodically assess pilot projects performance [66]. These projects with better performance will be rewarded, which could be an effective incentive mechanism to make recycled construction materials more acceptable [45].

In addition, the Chinese government should vigorously support the establishment of construction waste treatment plants based on turning construction waste into valuable materials, and enhance the guidance over industrial incentive policies. For example, the government could take some steps like expenditure subsidies, interest subsidies or zero-interest loans, preferential taxation and others [67-69].

To strengthen the whole-processing management

In order to reduce waste generation amount, make the waste materials harmless and reuse them as valuable resources, reclamation management of construction waste should be extended to the whole life cycle of the waste materials [22,70]. Actually, through its entire life cycle from waste generation to final disposal [71], reclamation management should encompass production, transportation, disposal and recycle of waste materials [72- 73]. In terms of waste production, waste generation control at source has been considered as a key strategy for effective waste recycling, due to its benefits in reducing construction waste transportation costs and saving waste disposal fees [74,75,27]. And construction waste generation should be made classified on-site, which can avoid the difficulties to follow-up reclamation disposal. As for waste transportation, it is essential to methodically determine and optimize the overall spatial layout of construction waste recycling treatment facilities based on transport distances from building sites to these recycle facilities in each region across the country. Moreover, construction waste recycling can decrease the demand for new building materials, cut down resources consumption, and ultimately achieve an improvement in environmental quality [76-78].

Change perspective, construction waste is generated throughout all stages of the entire project life cycle, involving planning, design, construction, operation, maintenance, and demolition stage [79-81,22]. These stages including design, maintenance and demolition could also cause numerous construction waste generation waiting to be disposed. For example, it appears to be a general consensus that projects design changes have remarkable influence on the increased volume of construction waste [83,84,82]. In fact, each stage contributes directly or indirectly to overall efficiency of reclamation management of construction waste materials [82,75]. Hence, the current reclamation management of construction waste in China, which focuses primarily on the construction stage, should be extended futher to cover the scope of design, maintenance, and demolition stages of building projects [85].

CONCLUSION

The large-scale construction activities has generated annually substantial amount of construction waste materials in China. Actually, at least half of the significant accumulation of waste could be reused or recycled through appropriate recycling measures and technology. But for now, how to promote reclamation management of construction waste is one of the most difficult social problems. This paper will improve the understanding of resources management of construction waste and the conclusions can be drawn as follows:

First, although the Chinese government has implemented some schemes targeted to encourage construction waste recycling, which are clear indications that government is determined to address waste disposal issues, reclamation management of construction waste is still in its nascent phase and is rather immature to effectively help ameliorate the pressure of the resources and environment [22].

Second, the poor management of construction waste recycling in China could be attributed to various aspects, mainly including shortcoming of existing laws and regulations system, absence of policy support, lack of awareness of construction waste reclamation, and insufficient attention to waste collection and sorting.

Finally, this paper explicates the fact that some management measures and experience among relevant governmental departments and construction professionals in construction waste reuse and recycle have not been implemented. Hence, there is an acute need to carry out effective measures and an integrated management system to overcome the current difficulties in construction waste materials recycling. Measures for better improvement for waste reuse and recycle has been proposed, mainly including perfecting

corresponding legislation, determining the function between various governmental departments, enacting some public policy support, reinforcing the whole-processing management.

As regards the current recycle situation of construction waste materials of some developed countries and regions (like Japan, Hong Kong, Singapore, China, Germany, the U.S., and the U.K.), China's waste recycle development is lagging significantly behind these advanced economies. Therefore, learning the successful experience in managing waste recycle from these countries and regions is of vital importance to strengthen its further management reclamation of construction waste at a strategic level for China.

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