On construction waste disposal in Chongqing

LIAO Qi-yun ¹,†, ZHONG Guo-yi ¹, TAO Yan-yu ², JIA Shun ¹

¹ Faculty of Construction Management and Real Estate, Chongqing University, Chongqing 400045, P. R. China
² Continuing Education College, Chongqing University, Chongqing 400045, P.R. China

Received 7 October 2011; received in revised form 1 May 2012

Abstract: With rapid development of the construction industry in China, lots of construction materials are being widely reused. Meanwhile, more and more materials for building remover or demolition enter into the environment as a result. However, China is facing big building garbage pollution, with simple disposal methods and low efficiency, which urgently needs to be improved. The paper takes Chongqing as an example to illustrate existing problems in this field and then puts forward corresponding countermeasures from the aspects of economy, technology, management and policy, aiming at enhancing the level of construction waste disposal in China.

Keywords: construction waste; countermeasure; Chongqing; disposal

1 Introduction

1.1 Concept of construction wastes

Based on the Regulations of Urban Construction Waste Management issued in China in 2005, construction wastes involve the spoil, disposable materials and other wastes which are generated as a result of site clearance, excavation, construction, refurbishment, renovation, demolition and road works [1].

1.2 Hazard of construction wastes

Construction wastes are characterized by large quantities and varieties of compositions. Construction wastes will cause great harm to the environment without appropriate disposal. Firstly, construction wastes have a great influence on city appearance and environmental sanitation. The phenomenon of construction waste indiscriminate dumping and occupation of roads has serious impacts on the environment. Secondly, building rubbish in the stacking process invades and occupies the land. For example, 10 000 t construction wastes will occupy about 670 m² of land [2]. Lastly, construction wastes will pollute water, air, soil and so on. Rainwater infiltration with strong alkaline leachate generated by building garbage dumps contains heavy metal ion and sulfide. They will affect the survival of aquatic organisms and utilization of water resources and change physical and chemical properties of soil. What’s more, waste gypsum will produce a rotten egg smell of hydrogen sulfide. And waste paper or wood will release volatile organic acids to atmosphere.

2 Status of construction wastes in China

Since the reform and openness, China has made remarkable achievements in economy. The construction industry, as a pillar industry of the
national economy, has developed rapidly in the past 30 a. A lot of building materials are being widely used in construction industry. Meanwhile, more materials from building remover or demolition enter into the environment as a result. Construction wastes account for nearly 40% of municipal solid wastes [3]. Many cities are facing the problem of large quantity of wastes, and the subsequent issues such as land fill and environmental pollution have become increasingly serious. With the exception of Beijing, Shanghai and Guangzhou, the general level of construction waste treatment is very low, which is almost limited to a simple treatment, such as filling holes in the ground or even spreading on land which dramatically destroys the environment.

3 Status of construction wastes in Chongqing

Chongqing is one of the four municipalities of P. R. China and one of the five centre cities. It is located in southwest China and is the economic and financial center of the upper reach region of the Yangtze River. It has the reputation as China’s Chicago.

3.1 Generation of construction wastes in Chongqing

With the support and encouragement of various projects including “Construction of the Three Gorges Project Reservoir Area”, “Western Development”, “Urban and Rural Comprehensive Reform Pilot Area”, and “Two Rivers Area”, the economy in Chongqing has been developing rapidly. However, there also is an urgent need to solve and manage construction wastes.

Construction wastes account for about 30% to 40% of total municipal wastes in Chongqing. Survey reports show that abandoned residential buildings, bricks and rubble are about 45% and concrete blocks about 35%; in deserted industrial plants and office buildings, concrete blocks are about 56%; and in bridges, roads and dams, concrete blocks are about 80% [4]. In different structural forms of construction sites, the composition of construction wastes is different, and the amount of waste varies greatly with construction site management level (Table 1).

According to the Chongqing Municipal Yearbook 2009, the construction area of housing in Chongqing is 164,758.4×10⁶ m² (Table 2) [5]. Every 10⁶ m² construction area will produce 500 t to 600 t construction wastes during the construction process. Therefore, about 9.06×10⁶ t construction wastes will be generated per year. Chongqing removed 4×10⁶ m² dilapidated buildings in 2009 [6], and every 10³ m² demolition of old buildings will produce 7×10³ t to 12×10³ t construction wastes. So about 4×10⁶ t construction wastes were produced. Then a total of 13.06×10⁶ t construction wastes were generated in Chongqing in 2009. Table 3 shows the number of all types of construction wastes and Fig. 1 shows the proportion.

3.2 Status of construction waste disposal in Chongqing

Similar to most cities in China, construction waste disposal methods in Chongqing are traditional and simple. Currently, although Chongqing has 16 relatively standard construction waste disposal areas [7], wastes are dumped in a random fashion and secondary pollution is widespread. What’s worse, because of the remote distance, limited capacity and lack of effective treatment, only about 6% construction wastes will eventually be put into landfill sites. Others are used for construction backfill, mixed with solid waste disposal, and even dumped illegally. Recycle rate of construction wastes in Chongqing is about 5% [8], which is far below the world average.

<table>
<thead>
<tr>
<th>Structure type</th>
<th>Waste composition%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Block/Brick</td>
</tr>
<tr>
<td>Brick structure</td>
<td>30 to 50</td>
</tr>
<tr>
<td>Framework structure</td>
<td>15 to 30</td>
</tr>
<tr>
<td>Frame-shear-wall structure</td>
<td>10 to 20</td>
</tr>
</tbody>
</table>
Table 2 Building area completed by construction enterprises in 2008 and 2009

<table>
<thead>
<tr>
<th>Year</th>
<th>Building area/10^6 m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>156.1893</td>
</tr>
<tr>
<td>2009</td>
<td>164.7584</td>
</tr>
</tbody>
</table>

Table 3 Composition and quantity of construction wastes in Chongqing in 2009

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity/10^6 t</th>
<th>Proportion/%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building materials industry</td>
<td>1.06</td>
<td>8</td>
</tr>
<tr>
<td>Construction site</td>
<td>3.26</td>
<td>25</td>
</tr>
<tr>
<td>Demolition of old buildings</td>
<td>4.00</td>
<td>31</td>
</tr>
<tr>
<td>Architectural decoration</td>
<td>3.90</td>
<td>30</td>
</tr>
<tr>
<td>Others</td>
<td>0.84</td>
<td>6</td>
</tr>
</tbody>
</table>

Fig. 1 Composition and proportion of construction wastes

4 Comparison

4.1 America

The United States is one of the first countries to advocate environment verification. The Comprehensive Environmental Response, Compensation, and liability Act (CERCLA), otherwise known as Superfund, was enacted by Congress on December 11, 1980. This law provides a Federal “Superfund” to clean up uncontrolled or abandoned hazardous-waste sites as well as accidents, spills, and other emergency releases of pollutants and contaminants into the environment. Through CERCLA, the Environmental Protection Agency (EPA) of the U.S.A. was empowered to seek out those parties responsible for any release and assure their cooperation in the cleanup [9].

4.2 Japan

From the late 60s last century, Japan has developed a series of laws, regulations and policy measures to promote the construction of waste disposal and conversion, such as Waste Disposal Act (1970), Use of Recycled Aggregate and Recycled Concrete Specification (1977), Reuse of Resources Promotion Act (1991), Recycling Law (1991), The Outlines for Promoting the Correct Handling of By-Product of the Architectures (1998), and Construction Recycling Law (2002). According to the statistics from Japan’s Construction Ministry, in 1995, the Japan waste concrete recycling rate had reached 65% and 90% by 2000 [10].

Japanese Guidelines for Construction waste disposal are 1) discharge as much as possible from the construction site; and 2) reuse as much as possible.

4.3 Countries in Europe

Germany is the first country to implement environmental labeling, which has also created laws and regulations, such as Circular Economy and Waste Disposal Act (1994), and Recycling Economy and Waste Disposal Act (1996). To 2002, Germany has distributed 2290 recycled aggregate processing plants [11]. Besides, Germany Reinforced Commission proposed “Application Guide for Usage of the Recycled Aggregate in the Concrete” in August 1998. France has produced a concrete block masonry with the broken concrete and bricks, complying with the relevant NBNB21-001 (1988) Standard. The United Kingdom has developed a wash machine, which was specifically designed for recycling the wet mortars and concretes. Nordic countries such as Denmark, Finland, Iceland, Norway, and Sweden have implemented a common Nordic environmental label in 1989.

In general, issues to be resolved for disposal construction wastes in Chongqing are as follows: 1) a huge production of construction wastes; 2) low recycling rate of construction wastes; 3) few methods for construction waste disposal; 4) lack of management and supervision of construction waste disposal, relevant laws and regulations are still inadequate, enforcement is not valid, and the management system is not perfect; 5) lack of promotion mechanism about construction waste recycling. Construction waste management has not kept pace with the development of the construction industry, the chain of construction waste recycling industry is not perfect, the price system of construction waste management is disorganized, and the policies to support the industrialization of construction waste management are lacking.
5 A hypothetical economic model

China lacks construction waste disposal management and supervision. On one hand, relevant laws and regulations are still inadequate, enforcement is not valid, and the management system is not perfect. On the other hand, awareness of the construction waste recycle and recycle technologies urgently needs to be improved. The government should take some encouragement and punishment measures. In China, the government has absolute discretion to regulate the construction market and promote the construction waste recycle industry. The government develops standards and norms to govern construction waste recycling industry, land use planning, and environmental controls on processing activities related to those standards and norms.

In Chongqing, it is not compulsive for site managers to recycle construction wastes. Actually potential benefit is available for site managers to reuse construction wastes.

\[ E_{(s)} = E_{(i)} + E_{(x_1)} + \cdots + E_{(u)} + \cdots + E_{(p)} \]

where \( E_{(i)} \) is the waste management benefit, \( E_{(i)} \) and \( E_{(x_1)} \) is the first and the second kind of waste utilization benefit, \( E_{(u)} \) is the \( i \)th kind of waste utilization benefit, and \( E_{(p)} \) is the government subsidies or the amount of punishment.

\[ E_{(u)} = R C_{(p)} + T_n + E_{(u)} - Q_{(m)} - T_w \]

where \( R C_{(p)} \) is the price of other one kind of recycled product at the recycling center gate, \( T_n \) is the cost of transport from recycling center to site, \( E_{(u)} \) is the any extra costs of other one kind of recycled product created, \( Q_{(m)} \) is the price of other one kind of newly quarried product in the manufacturer, and \( T_w \) is the cost of transport from manufacturer to site.

If \( E_{(s)} > 0 \), site managers can make use of the recycling of construction wastes.

6 Countermeasures and suggestions

6.1 Principle

The utilization principle of construction wastes is reduction, recycling and innocent treatment. The government is exploring various methods to reduce construction wastes and promote recycling.

Construction without any disposal of wastes is not an environment-friendly activity. The hierarchy of disposal options categorizes environmental impacts into five levels (Fig. 2). The top position of the strategy means the most desirable action to be taken.

![Fig. 2 Stratagy levels for construction waste disposal](image)

6.2 Technology

The wastes can be recycled and used as building materials. Feasible methods can be used including balance of cut and fill design. To recycle the building materials such as the waste concrete blocks, bricks, mortar and rubble in construction wastes, the particle sizes are graded by screens to be separated into coarse and fine aggregates. The coarse aggregates can be directly used as foundation reinforcement and bed cushion of roads, runways, and indoor floors. The fine aggregates can take place of cement and sand as a concrete added material. For example, rubble can be made into bricks; waste brick, mortar and cement mixture, if combined with the fresh additional materials, can produce light blocks; waste concrete, brick, stone, and sand can be made into hollow blocks, solid bricks, square bricks, and concrete bricks after some post treatment.

Materials prior to disposal should be classified and recycled in a proper place. Public filling shall be delivered to public filling facilities and remaining building waste should be shipped to landfills for disposal [12].

Fig. 3 shows the construction waste treatment process.

Before demolition and successive crushing, a building should be stripped from useful and hazardous materials. The procedure is as follows.
1) The building is carefully inventoried for the presence of hazardous materials. These items are then removed and handled by professionals.
2) After that, less dangerous materials are removed.
3) Products that are suitable for reuse are removed.
4) After that, the interior is stripped from the concrete until it is clean.
5) Finally, the building is demolished. Concrete is crushed and steel rods are separated.

Lots of methods are available for recycling construction wastes. The most common one is to crush stone aggregate, metal, glass, and plastic, which can be applied to new construction projects after recycling processing transformation. Table 4 shows specific common recyclable materials and application.

6.3 Policies

To establish relevant laws and regulations and strengthen the comprehensive management legislation of construction wastes \(^{[13]}\), the legislative work of construction waste resources should be strengthened and a reasonable standard for construction waste disposal should be established. “Urban Construction Waste Management Regulations”, enacted on March 1, 2005, has achieved effect from June 1, 2005. It promotes construction waste management and plays a positive role in the environmental management of Chongqing.

To promote actively the industrialization of construction waste management, a new environmental protection industry for construction waste should be established by charging waste disposal fees for businesses and residents. The government should vigorously support the environmental protection industry and strengthen the intensity of incentive policies by adopting forms of cost subsidies, grants or interest-free loans, tax concessions, and other means to promote the industrialization of construction wastes and set out a comprehensive system including research and development companies, demolition companies, professional construction waste recycling companies, prefabrication plants and other products. The government should also develop a strategy to encourage the recycling industry. Finally, the cost of comprehensive construction waste management should be reasonable and organized to ensure that recycling can be economically carried out.

Publicity and education should be strengthened and people’s environmental awareness should be raised. The strength and breadth of publicity and education must be increased. In addition, the latest technologies and methods for utilization of construction wastes should be introduced to construction industry.
Table 4 Application of recyclable materials

<table>
<thead>
<tr>
<th>Recyclable material</th>
<th>Application</th>
<th>Case</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crushed stone aggregate</td>
<td>Primary materials of Kin Road, scrap of foundation works, primary packing of drainage works, crushed stone aggregate for concrete required, and the extensive use of the general packing</td>
<td>Pilot study of the Public Works department</td>
</tr>
<tr>
<td>Asphalt Excavated material</td>
<td>Aggregate and grass-roots fill Fillers</td>
<td>Municipal departments are studied Construction projects</td>
</tr>
<tr>
<td>Coal ash</td>
<td>Manufacture of concrete products for filling and reclamation, construction of roads, manufacturing reinforced grouting structures</td>
<td>Jiangbei Airport Construction; Foundation construction</td>
</tr>
<tr>
<td>Metal</td>
<td>Make new metal products</td>
<td>Construction industry commonly used method</td>
</tr>
<tr>
<td>Glass</td>
<td>Pipe bedding material (instead of sand and aggregate), wall building with gravel backfill, gravel paving, filler and bedding</td>
<td>Under study</td>
</tr>
<tr>
<td>Plastic</td>
<td>Synthetic plastic wood, used for landscaping, gardening and hydraulic engineering</td>
<td>Some public facilities in fitness and entertainment facilities, such as garden equipment</td>
</tr>
<tr>
<td>Rubber</td>
<td>Laying the roof with rubber plate, sports/playground floor pad</td>
<td>Some public facilities in fitness and entertainment facilities, such as playground floor pad</td>
</tr>
<tr>
<td>Foam/Foam rubber</td>
<td>Preparation of non structural engineering with the lightweight concrete</td>
<td>Housing department of building engineering</td>
</tr>
</tbody>
</table>

6.4 Management

To supervise the construction wastes, Chongqing will develop a responsibility system of construction waste tracing, which ensures that the amount of construction wastes generated on the construction site is registered and recorded. It is strongly recommended that some foreign verification systems can be used, such as LEED, which will help to deal with construction wastes. The vehicles that remove and transport construction wastes will be installed with GPS systems to monitor effectively the final destination of the construction wastes.

The government should establish relevant laws and regulations and strengthen the comprehensive management legislation of construction waste. The government should take some encouragement or punishment measures to guide people’s behaviors and increase propagandist strength to enhance the enterprise and the public awareness of environment protection. Enterprises should actively improve the efficiency of waste recycling by technological innovation. People should support the related policies. Fig. 4 shows the relationship of the government, enterprises, and the public.

A whole processing mode of construction wastes should be established. To eventually achieve the principles of reducing the quantity and environmental impact from construction wastes, a whole-processing procedure for construction wastes was introduced, which considered the original source, transit, transportation, treatment, and disposal as a system. A brief description about the procedure is as follows.

1) Reduce construction wastes fundamentally by improving the planning, design, and construction management. For example, green building materials with good environmental compatibility can be used in the design and light materials can be used to reduce the weight of buildings.

2) Analyze the transportation cost of building wastes. Handling, loading and transportation of the building garbage affect this stage.
3) Analyze the treatment and disposal processing mode. The recycling treatment of construction wastes can be divided into three types: the first is “low use”, such as separating the brick, asphalt, concrete, metal, and wood from the hazardous wastes and general backfilling; the second is “intermediate use”, such as processing into aggregate production of new wall materials; and the third is “high use”, such as the reduction of waste into concrete and asphalt for recycling.

7 Conclusion

With the rapid development of construction industry, construction wastes have been produced continually. Too many wastes have caused serious pollution to air and water resources. Based on the analysis and research on the status and construction waste disposal in Chongqing, P. R. China, the paper makes a comprehensive analysis of construction wastes from generation to final disposal from the systematic perspective and puts forward a macro economic model of the construction trash recycle to promote its marketization. Meanwhile, the paper also presents some research results of handling process and proposed suggestions to improve the level of construction waste disposal in Chongqing and promote sustainable development of Chongqing construction industry compared with some developed countries.

References


Edited by XUE Jing-yuan