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Reclamation chain of waste concrete: A case study of Shanghai

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ABSTRACT

A mass of construction and demolition (C&D) waste are generated in Shanghai every year, and it has become a serious environment problem. Reclaiming the waste concrete to produce recycled aggregate (RA) and recycled aggregate concrete (RAC) is an effective method to reduce the C&D waste. This paper develops a reclamation chain of waste concrete based on the researches and practices in Shanghai. C&D waste management, waste concrete disposition, RA production and RAC preparation are discussed respectively. In addition, technical suggestions are also given according to the findings in practical engineering, which aims to optimize the reclamation chain. The results show that the properties of RA and RAC can well meet the requirement of design and practical application through a series of technical measures. The reclamation chain of waste concrete is necessary and appropriate for Shanghai, which provides more opportunities for the wider application of RA and RAC, and it shows a favorable environmental benefit.

1. Introduction

With the rapid development of construction industry, the construction and demolition (C&D) waste has been dramatically increased in the last decade, and the C&D waste has become a serious environmental problem in many countries throughout the world (Chung and Lo, 2003; Begum et al., 2006; Duran et al., 2006; Yuan and Shen, 2011). Large amount of C&D waste gradually becomes the burden of urban development and environment, which should be considered carefully. For the traditional disposal of C&D waste, it is often transported to the landfill as the way of municipal solid waste. As a result, negative impacts on the environment, the high cost of transport and disposition are inevitably considerable (Wu et al., 2014). Furthermore, the traditional disposal of C&D waste requires more land occupation, which is not economical obviously, especially for the metropolises like Shanghai. As mentioned above, proposing an appropriate method of C&D waste management is necessary. Since the waste concrete can be recycled as secondary materials, reclaiming waste concrete provides an effective way to reduce the C&D waste, which allows us to save the natural resources and energy at the same time (Zega and Di Maio, 2011). Many studies were carried out on the recycling of waste concrete in recent years. The successful example is the application of recycled aggregate (RA) to mix new concrete which is often termed as recycled aggregate concrete (RAC).

For the utilization of RA and RAC in civil engineering, many scholars have carried out related investigations (Poon and Chan, 2006; Jurič et al., 2006; Wong et al., 2007). However, most of the researches were based on the experimental results under the laboratory condition. Some scholars aimed to study the properties of RA and RAC (Katz, 2003; Xiao et al., 2005; Etxeberria et al., 2007), and some other scholars mainly investigated on the application of the RA and RAC (Kikuchi et al., 1998; Eguchi et al., 2007). Although the previous studies provided the theoretical basis for the application of RA and RAC, the large-scale applications of RA and RAC will still be restricted, if without an entire reclamation chain. An integral consideration is urgently needed, for the wider application of RA and RAC in practical engineering.

This paper is developed to propose the reclamation chain of waste concrete in Shanghai, based on the researches and practices. The reclamation chain of waste concrete includes the C&D waste management, waste concrete disposition, RA production and RAC preparing. Moreover, the technological suggestions on the application of RA and RAC are also given according to the findings in practical engineering. Through investigating the reclamation chain of waste concrete in Shanghai, an appropriate method of waste concrete management is presented. As Shanghai is a modern metropolis, the experience of waste concrete management could be seen as a relative representative case, and it can also be used as a reference for similar cities throughout the world.

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2. The current situation of C&D waste generation in Shanghai

Attributing to the fast economic development in PR China, construction industry has also enjoyed a high speed growth. More and more buildings and large-scale infrastructures have been built in PR China in recent years. Meanwhile, the quantities of demolition waste are very huge due to the frequent change of urban planning or earthquake disasters. China has been the country with the largest production of C&D waste in the world (Xiao et al., 2012). The urban C&D waste has reached 30–40% of the total urban waste generation, due to the large-scale C&D activities resulted from the accelerated urbanization and city rebuilding in the mainland of China (Zhao et al., 2010).

Shanghai acts as the financial center of PR China and is an international metropolis. Large-scale C&D projects will still be continued because of the requirement of urban development, and the quantities of C&D waste are also considerable with the increase of C&D activities in Shanghai. For example, according to the specified data from the Shanghai Municipal Waste Management Authority which is responsible for the management of C&D waste in Shanghai, the demolition activity in Shang Gang Fourteen Area has produced approximately 250,000 m^3 of waste concrete until 2015. The demolition project of Pudong Avenue has produced about 200,000 tons of waste concrete until 2014. Additionally, the demolition project of Jinqiao Overpass has produced approximately 129,000 tons of waste concrete until 2014.

Much more C&D waste was produced with the rapid development of urban construction in Shanghai. Ding and Xiao have given the trend of C&D waste generated in Shanghai from 2000 to 2012 (Ding and Xiao, 2014). It is found that the C&D wastes annual generated in Shanghai were above 10 million tons from 2000 to 2012, and the total C&D waste generated in Shanghai was 13.71 million tons in 2012. The C&D waste generated in Shanghai kept a relatively high level compared with the other regions that similar to Shanghai, e.g. Hong Kong, Greece and Florida, US (Poon et al., 2001; Fatta et al., 2003; Cochran et al., 2007). A mass of C&D waste generation provides an opportunity to establish a reclamation chain of RA and RAC to civil engineering in Shanghai.

Because of the compositions of C&D waste are quite different in various regions (Wu et al., 2014; Pasandín and Pérez, 2015), investigating the compositions for C&D waste is necessary for the waste management. According to the previous investigation (Ding and Xiao, 2014), the percentages of material compositions for C&D waste by weight for Shanghai in 2012 are presented in Fig. 1, and the percentages in other years are similar to that in 2012. It is revealed that the waste concrete, brick and block are the primary source of RA, and the waste concrete shares a relatively high proportion among the C&D waste; consequently, disposing the waste concrete properly is beneficial to reclaim the C&D waste (Poon et al., 2002; Paranavithana and Mohajerani, 2006; Li et al., 2014). In Shanghai, recycling the waste concrete as the RA and RAC is an effective method, and the integrated reclamation chain of waste concrete has been established in Shanghai. Each link in the reclamation chain is respectively discussed in this paper.

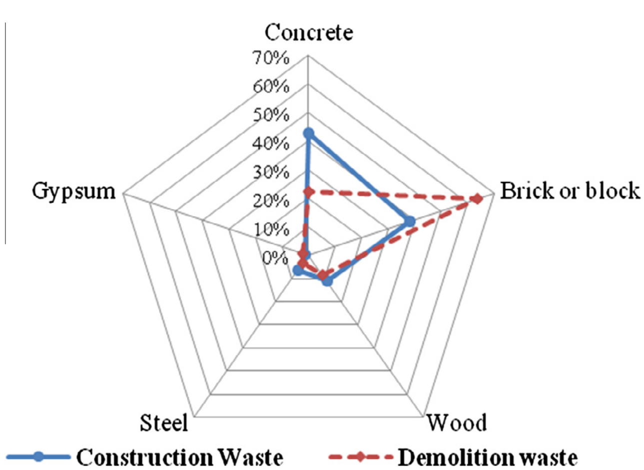

Fig. 1. Material compositions for C&D waste in Shanghai (2012).

3. Research and development on the reclamation chain in Shanghai

Industrial production of RA and RAC provides an effective and appropriate way to reclaim the waste concrete. As shown in Fig. 2, an integrated flow diagram of the reclamation chain of waste concrete in Shanghai is presented. The first step is the C&D waste management, and the waste concrete is collected after separation. Subsequently, the RA and RAC are produced through a series of processing technologies, and then the properties of RA and RAC are measured. Finally, the technical suggestions of RA and RAC are given according to the information feedback and findings in practical engineering, which aims to optimize the reclamation chain of waste concrete. In addition to evaluate the performance of each step in the reclamation, the related testing programs are also presented in this section. Through the introduction of the reclamation chain, the experience of waste concrete reclaim in Shanghai is shared.

3.1. Waste concrete – the source of recycled aggregate

As an example, waste concrete is collected in Shang Gang Fourteen Area in Shanghai, and the specific location is shown in Fig. 3. The waste concrete is obtained from the demolition of concrete pavement that was ever used as a container terminal. There is approximately 250,000 m^3 waste concrete, and about 360,000 tons RA can be produced in this area. The RA production factory is close to the production origin of waste concrete, which aims to reduce the transport cost and improve the production efficiency. Approximately 800 tons RA is produced in this factory every day.

In order to insure the quality of RA in a stable state, the waste concrete used in RA preparing should be controlled well and possess a fine mechanical property and durability performance. The compressive strength and carbonation depth are respectively determined to evaluate the properties of waste concrete, and the results are listed in Table 1. Nine core samples of waste concrete are obtained from the three spots, and the three spots are uniformly distributed on the concrete pavement, as shown in Fig. 3. The core sample used in testing compressive strength of waste concrete is a cylinder with 75 mm diameter and height, and the compressive strength was determined to evaluate the mechanical property of waste concrete. The average value of compressive strength is 42.32 MPa, and it demonstrates the waste concrete possesses a relative high strength grade. Carbonation depth was also measured to evaluate the durability of waste concrete, and the average carbonation depth is 2.67 mm, which proves the waste concrete has a good resistance to carbonation. Consequently, the waste concrete holds a favorable mechanical property and durability, and it is feasible to produce RA.

3.2. Recycled aggregate

The properties of RA have a significant influence on the behavior of RAC. This part aims to evaluate the properties of RA used in mixing RAC. The production, properties and the improving technology of RA are discussed, respectively.

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