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Research on the Application of Recycled Aggregate Concrete Based on Life Cycle Assessment

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Abstract

In recent years, the majority tend to see construction waste as a significant concern for society. Without any treatment, most of the construction waste is piled up or buried in the open air, causing serious environmental pollution. This essay will focus on the life cycle of the concrete, exploring strategies about the role that recycled aggregate concrete can play in minimising these environmental issues.

Keywords

Recycled aggregate concrete; Life cycle assessment; Construction waste.

1. Introduction

With increased environmental awareness, the issue of construction waste has become a topic of interest. In such a condition, the role of recycled aggregate concrete becomes increasingly important. Recycled concrete refers to the new concrete which is made by crushing, cleaning and grading the abandoned concrete blocks, mixing them in a certain proportion, replacing some or all natural aggregate (mainly coarse aggregate) such as sand and stone, and adding cement, water, etc.

Referring to the cradle-to-cradle theory, the final disposal phase of concrete should be a recycling process. The recycling of construction waste is supposed to be used as an aggregate instead of using natural aggregates which may lead to negative impact on the natural environment due to the mining process. Failure to take appropriate approach to recycle the demolition waste would damage the environment through unnecessary landfill disposal. The application of recycled aggregate concrete appears to be an alternative strategy to achieve a higher level of sustainability due to that it is able to lower consumption and extraction of raw materials, as well as waste dumped to landfill.

2. Life Cycle Assessment of Concrete

Information and data collection are significant in order to make assessment of the materials and building components for their whole life cycle, also the building process should be concerned. In order to make a better decision. Life Cycle Assessment (LCA) is a useful tool to analyse and assess the impacts that buildings and building materials have on the environment. Therefore, employing the LCA approach for concrete and its application is necessary.

In an assumed life span of 50 years, Jonsson et al. (1998) distribute the concrete life cycle into three steps:

(1) Cradle to gate: from raw materials extraction and production phase to building site;

(2) Service life: serves as a building component such as walls;

(3) Demolition and final disposal: dismantling and at last recycling stage.

Marie and Quiasrawi (2012) indicate that in the life cycle of concrete, the first stage (raw material extraction and production phase) and the last phase (disposal and recycling) have the biggest environmental impacts because of a great deal of raw natural materials consumption and waste

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material generation. According to Sjunnesson (2005), the production of the raw material causes almost 85 % of the total global warming potential (GWP), which can be seen as the main contributor to GWP in the life cycle of concrete. Moreover, most of the resources for concrete production from cradle to gate are non-renewable. For the demolition mass, if it was defined as recycling, the environmental impacts from final disposal step will be reduced efficiently and become lower than the impact from earlier stages of the concrete life cycle (Jonsson et al., 1998). Therefore, since the amounts of consumption of natural materials and building waste generation will have negative impact on substantially, the utilization of recycled aggregate concrete could play a constructive role in minimising these environmental influences.

3. The Application of Recycled Aggregate Concrete

3.1 Utilization of Recycled Concrete

Architects and developers are encouraged to use recycled concrete aggregates (RCA) as a construction material in order to alleviate the lack of raw materials. Furthermore, it encourages the construction of infrastructure industries to apply a closed-loop recycling system for resources (Tokushige, 2007).

Due to the durability of concrete, the concrete is often reusable at the end of the building’s life span. According to Sjunnesson (2005), demolished concrete will be sent to a recycling station, the reinforcement bars will be removed and the concrete will be crushed into suitable size for it future use. The recycled concrete can be used as aggregate material in new concrete production or in road construction. Moreover, it also can be used in embankment construction if the piece of concrete is large enough. Reusing concrete results in a reduction of virgin natural resources such as gravel and stone.

3.2 Characteristics of Recycled Concrete

The use of recycled concrete aggregates could be regarded as a promising strategy in terms of waste management. The recycling technology is not difficult to implement, the recycled concrete aggregate can be generated by a range of simple assembled equipment. Before using the aggregate, the quality of recycled aggregates such as the characteristics of structural strength, durability, mechanical performance, fire safety, and workability of the recycled concrete require to be assessed.

According to Eguchi et al. (2007), with the replacement ratio increasing, there will see a decrease in the compressive strength and elastic modulus, however, the drying shrinkage strain will increase. The quality standard of the concrete can be reached by estimating the decrease in properties and adjusting the replacement ratio. For the fire-resistant property and structural performance, studies has shown that recycled concrete aggregates perform at a satisfy quality which is almost equal to the performance of conventional concrete in practical applications. Due to that there are no available existing plants on the market, the on-site mixing method is encouraged to be implemented, since the society has confirmed the effectiveness of the production approach for the recycled aggregate concrete. For the mechanical performance, the recycled aggregate concretes show equal or better results compared to the concrete made with virgin sandstone aggregate (Nagataki et al., 2004). Compared to construction without recycling, a decrease could be seen in the cost and the environmental loads when recycled concrete was implemented in present approach.

Since the recycled aggregates concrete is a sustainable material, the characteristics associated with its advantages includes:

(1) Reducing the mining of raw materials and their transport and manufacture, as well as environmental impacts produced by other processes;

(2) Creating more employment opportunities;

(3) Reducing energy consumption and the greenhouse gas emissions;

(4) Reducing the cost of the construction such as the expenses for waste disposal and tax for purchasing new materials.

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3.3 Risks and Opportunities

The properties of recycled concrete aggregates such as workability, absorption, as well as strengths have been studied, which shows that the use of RCA will lower the concrete workability and both the compressive and tensile strength. This problem can be better alleviated by the use of R-RCA (the second generation), in general, second generation performs better than the first generation RCA (Marie & Quiasrawi, 2012).

Another limitation over the project life cycle is the non-renewability. However, at least some percentage of nonrenewable resources are able to be turned into a renewable one by advances in recycling (Blengini et al., 2012).

In addition, the irregular surface of the recycled concrete aggregates would lead to negative impact on the workability of concrete. A specific type of superplasticizers can be used depending on the reduced workability. Another solution can alleviate this issue is controlling the proportion of the recycled concrete aggregate to make it acquire better property (Batayneh et al., 2007). In general, the increase of RCA proportion will get better property.

4. Case Study

The concrete waste disposal problem has raised wide environmental concerns because of large amounts of waste generation. Many countries have high awareness about concrete recycling and contribute to reduce waste creation. However, there are some differences between each country in terms of the situation of concrete recycling. This part will provide some case studies by outlining comparing the concrete waste recycling practices in Japan, UK, Hong Kong and Australia.

Japan is a leading country which plays a key role in minimising and recycling concrete waste. In 1992, the former Ministry of Construction (MOC) established the “Recycle 21” program, which set a number of targets for the recycling of construction by-products (Kawano, 2002). Along with a range of recycling law such as “Recycle 21” over the past few decades, the recycling ratio increased from just 48% in 1990 to almost 96% in 2000, most of the materials were reused in road construction as sub-base. Although many countries are active to promote the use of recycled concrete aggregate, the quality of their recycled aggregate would be unstable due to the limited current concrete recycling technology, which limits its applications in road, pavement and drainage construction. However, the recycled concrete aggregates produced in Japan can be employed for high-grade concrete applications for the reason that Japan is implementing advanced technologies nowadays in order to improve the quality of recycled concrete aggregates (Tam, 2009).

According to Rao (2007), England consumed 220 million tonnes of aggregates in 2001 but just a quarter of which were recycled materials. Therefore, the importance of Construction and demolition (C&D) waste has been recognised by the Scottish Executive Development Department (SEDD). In order to reduce the C&D waste, a research program commissioned by SEDD has been presented to gather information on the level of use of recycled aggregates and seek the opportunities to reuse and recycle the mixed construction and demolition waste.

In Hong Kong, a pilot facility for C&D materials recycling was established in 2002, there is a handling capacity of 2400 tonnes every day to produce recycled aggregates and use them in government projects. This facility mainly produces material for rockfill and recycled aggregates. In the year of 2003, more than 22,700m3 of concrete using recycled aggregates involved in over 10 projects, including reinforced pile caps, ground slabs, external building and retaining walls, beams and parameter walls, and mass concrete (Fong, 2004).

In Australia, one of the most important steps in promoting the implement of recycled aggregate in concrete materials has been initiated by the Commonwealth Scientific and Industrial Research Organization (CSIRO): “Guidance on the preparation of non-structural concrete made from recycled concrete aggregate’’ established in 1998 and ‘‘Guide to the use of recycled concrete and masonry materials’’ in 2002 (Tam, 2009). The major benefits associated with recycled aggregate in Australia

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include the reduction of the need for new landfills and the use of non-renewable natural materials. However, the overall recycling rate is still not high enough in practice. To keep promoting the use of recycled materials, the standardized policies and classification systems for concrete waste and financial support from the government are needed.

5. Conclusion

In conclusion, evidences have shown that the closed-loop recycling system plays a key role in preserving non-renewable resources and maintaining the healthy built environment. Given that the concrete production needs continuous exploitation of natural sand and stone, consuming huge energy resources for transportation. Indicating that the application of recycled aggregate concrete appears to be one of the viable alleviation strategies. To summary, the recycled aggregate concrete can be used to reduce the negative environmental impact and the consumption of energy, providing social, economic and environmental benefits to urban areas.

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