Toward Sustainable Construction: Use of recycled aggregate in concrete in Malaysia

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Abstract

This paper reviews several key issues related to the use of natural aggregate (NA) for concrete production, in view of the high demand for materials to meet the rapid construction development in Malaysia. The current paper aims to discuss the potential of recycling waste concrete to generate recycled aggregates (RA) that may be used as alternative aggregate sources in the production of concrete. Moreover, several major challenges to the use of RA for concrete production are also highlighted. This paper also provides an action plan to encourage the construction industry's wide usage of RA to achieve sustainable construction.

Keywords: construction; recycled aggregate; sustainable; waste concrete

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1.0 Introduction

Malaysia is currently moving from the developing country towards achieving a developed nation status as envisaged by the year 2020. Many of the activities and industrial development are of considerable significance to the realization of this vision. According to plan, the construction sector is predicted to boom and grow rapidly in the coming years, considering the present construction scenario in Malaysia. This liveliness, together with new incentives, were introduced by the Malaysian government in the 10th Malaysia Plan, a leading national structural transformation plan aimed towards achieving a high-income economy covering the period from 2011 to 2015 (Economic Planning Unit, 2010). The Minister of Works in Malaysia (2010) stated that the government is allowed to spend RM230 billion in development allocations for the 10th Malaysia Plan to achieve this target. It was estimated that around 60% (RM138 billion) out of the RM230 billion for development expenditure is budgeted for physical developments to be undertaken by the construction sector. The rapid growth of this sector, in conjunction with economic growth, consequently indirectly requires considerably high amount of production and consumption of construction minerals, such as rock materials (aggregate) and sand. Concrete is the most valuable material in the construction industry. Rock materials and sand are depended upon as a main source of raw construction material. Thus, the mining and quarry industry, should guarantee the adequate and continuous supply of raw materials as a producer of construction minerals to the construction sector to sustain the economic development of the country. The effect of a shortage of these construction materials will result to increased construction cost, and then transferring the burden to the end users (Hamid et al., 2006), which will in turn affect the national development. Although the supply of NA was estimated to be adequate for development in the next few years (Institution of Engineers Malaysia, 2007), the aggressive consumption will reduce the non-renewable aggregate resources if no control measures are to be implemented (Hamid, et al., 2006). Proper planning and prevention are essential to avoid the impact of shortage and address the issues that may affect the supply for future development.

The present paper addresses the issues in the use of natural concrete aggregates in the Malaysian construction industry at present and in the future. This paper reviews published research and development studies from universities, private groups, and government agencies that deal with the use of NA and RA. The potential benefits gained from the use of RA as alternative materials in concrete production as well as the issues and barriers in the limited commercial use of RA in the construction industry are discussed. The necessary proposals to encourage the concrete industry to shift toward maximising the use of RA for construction projects in Malaysia are provided at the end of this paper.

2.0 Sustainable Issues on Natural Aggregate for Concrete

Malaysia is extremely fortunate to have several distributed NA resources, with almost every state carrying out its own quarry and aggregate production activities. Table 1 shows the total production of aggregates from 2005 to 2007 according to states. Among the listed 13 states, Selangor is the greatest producer.

Table 1: The total aggregate production by state for year 2005 to 2007

State	Year		
	2005 (million tonnes)	2006 (million tonnes)	2007 (million tonnes)
Johor	4.1	5.4	5.0
Kedah	3.6	3.2	2.8
Kelantan	1.9	2.4	2.6
Melaka	1.9	1.1	1.4
Negeri Sembilan	2.3	7.1	3.9
Pahang	3.1	3.2	3.1
Perak	10.8	11.6	14.1
Perlis	1.2	0.8	0.9
Pulau Pinang	4.6	3.8	3.2
Sabah	6.4	4.2	3.2
Sarawak	7.9	6.9	6.3
Selangor	12.3	25.5	25.3
Terengganu	2.7	4.5	5.7
TOTAL	62.8	79.9	77.7

(Source: Ismail, 2009)

The major contributors for the high production of aggregates in Selangor include the high demand from construction activities because of the increase in building and infrastructure development that supports urbanisation, rapid population growth, and the impact of the good local economic growth in this region (Ismail, 2009). However, the environmental concern is currently rising as one of the main challenging issues affecting the natural concrete aggregate production. The consumption of NA concrete as the largest component material is a key concern because it comprises three-fourths of the ingredient of concrete. The high demand of aggregate for the production of concrete requires massive use of natural stone materials which will destroy the ecological balance of the environment. The impact of the accelerating economic growth, especially in developing areas such as the states of Selangor, Johor, and Pulau Pinang, is reflected in the increasing ongoing development of land for urbanisation and industrialisation use. In addition, communities are projected to grow because of the increase in population. Thus, the competition in land use will start to arise and will require more land for development, and at the same time, will require increased demand for construction minerals needed for infrastructure and building works. Consequently, the rapid growth in the economy and population results in the development and expansion of many residential and urban areas close to the quarries (Institution of Engineers Malaysia, 2007). As a result, the public community will start to complain to stop the quarry activities because of the threat posed by air, noise, and environmental pollution created by quarry operations. Furthermore, several environmental policies and regulations were set up by the Federal and State Governments to control and tighten the operational conditions of quarry activities. These regulations will increase the difficulty in obtaining a licence and/or restrict the operation of a new quarry or mine. Gazetted forest reserve or zoning-sensitive areas, such as Lagong Hill, are protected to some extent from any mineral extraction activities (Er, et al., 2011). The findings of the work conducted by Pereira (2007) on the study concerning the long-term security of the aggregate supply in Selangor, in view of the impending implementation of the Selangor Policy on Environmentally Sensitive Areas (ESAs), was highlighted that the majority of new aggregate resources in this state are located in highly sensitive which categorised as ‘no-go areas’ for quarrying.

Therefore, the effect from the increasing awareness of environmental issues, and the designation, to some extent, of sensitive areas in recent years will contribute to the reduction of production factors in new quarry areas. In the future, the land areas used for mining or quarrying to produce aggregates will no longer be available and will be restricted due to the protection given to the accelerating population growth, as well as to the urbanisation and industrialisation processes. In addition, the sustained use of aggregate will soon deplete the reserves (Abdul Rahman et al., 2009). Accordingly, if aggregate consumption is not controlled and properly planned, Malaysia will face a decline in its supply. Therefore, the concrete industry needs to shift towards the reproduction and use of alternative aggregate by searching and fully utilising the existing potential sources.

3.0 Recycling of Waste Concrete as Aggregate

The impact of a rapidly developing area for construction building includes the use of a high amount of NA and the problem produced by the huge volume of construction and demolition (C&D) waste. At present, C&D waste constitutes a large portion of solid waste in Malaysia (Begum & Pereira, 2007). The sustained growth of the construction industry simultaneously generates substantial construction waste, thus significantly affecting the environment and causing social problems in local communities (Mahayuddin et al., 2008). Presently, a huge amount of waste is generated in construction sites. The estimated total construction waste generated from a project site during the construction of a new building is around 27,068.40 tonnes (Begum et al., 2006). The increasing renovation and demolition works for the upgrade of an existing construction, which have become necessary because of the growing number of old buildings that have deteriorated over the years, outdated building designs, and so on, have also significantly contributed to the solid waste increase. The specific composition of waste generated was determined in the research conducted by Begum, et al. (2006) which showed that concrete and aggregate are the largest component of waste materials generated by construction sites. The amount and composition of construction waste materials are shown in Table 2. The survey on illegal dumpsites conducted by Mahayuddin, et al. (2008) reported similar results and further shows that aggregate and concrete comprise a large proportion of the waste (see Fig. 1). Both findings indicate that the waste levels are high and that a large portion of potentially useful demolition waste, such as concrete waste, is directly disposed in landfill sites without being fully utilised.

Table 2: Estimated amount and composition of construction waste generated at construction sites

Construction waste materials	Amount of waste generated (tonnes)
Soil and sand	7290
Brick and blocks	315
Concrete and aggregate	17820
Wood	1350
Metal products	225
Roofing materials	54
Plastic materials	13.5
Packaging products	0.90
Total	27068.40

(Source: Begum, et al.,2006)

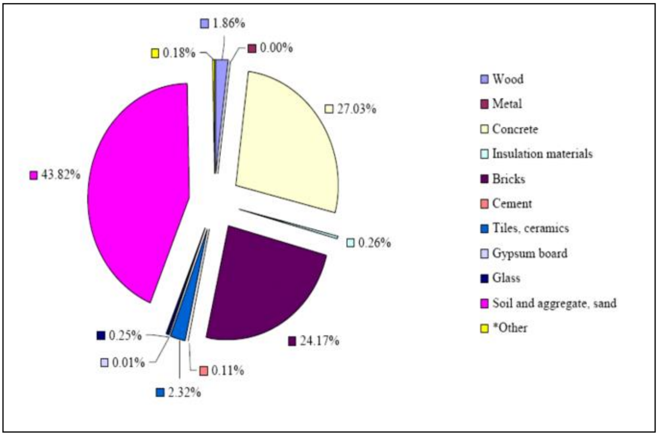

Figure 1: Composition of construction waste materials disposed of at illegal dumpsites
(*Source: Mahayuddin, et al., 2008*)

The availability of waste as a source for recycling has the potential of continuous yield as RA can be a solution to the management of waste disposal problem and at the same time serve as a substitute for NA.

4.0 The Benefits of Using Recycled Aggregate

The impacts and benefits gained from the use of RA are discussed as follows.

4.1 Reduction of space required for landfill

A conventional method for solid waste management, which involves the dumping of waste into landfill area, is commonly practised in Malaysia (Mahayuddin, et al., 2008). However, the increasing waste generation requires new landfills to be built because landfills have limited space and capacity. On the other hand, recycling has the potential to reduce the amount of C&D wastes disposed in landfills and consequently help extend the useful life of landfills .

4.2 Recovery and protection of the environment and its natural resources

A lot of negative impacts arising from mining and quarrying aggregates, such as the destruction of ecosystems, which are the natural habitats of flora and fauna, and damage to the existing stream flow and water resources. In addition, air pollution resulting from dusts created from quarry areas has become a social issue for nearby communities. The use of RA can at least reduce the dependence of the industry on NA, and thus can maintain aggregate security and still ensure sustainable development (Pereira, 2007; Surya et al., 2013).

4.3 Cost reduction

Recycling C&D wastes for the production of RA can result in immense savings. The RA is considerably cheaper than the NA in terms of price. The availability of RA as an alternative can provide balance and control of the price of aggregate in the market, which has continued to increase due the depletion of the NA supply. The use of RA can also reduce the total life construction cost of structures (Aqil et al., 2005). Recycling can cut the costs of managing waste disposal, such as a reduction of transportation cost, to bring wastes to landfills and reduction of fees or charges for dumping waste at landfills. Furthermore, recycling can also reduce the cost for importing aggregates.

4.4 Benefit to industry and economy

RA can contribute to the reduction of the cost of material in the production of concrete, thus lowering the prices of construction materials, which would translate to more profit to the industry. In addition, the production of RA from waste will create new businesses in the recycling process, thus consequently providing new jobs to the people.

5.0 Main Challenges for Using Recycled Aggregate

Japan and other developed countries in Europe pioneered the use of RA after the Second World War. In the annual report of the European Aggregates Association (UEPG) shown in Table 3, the overview of the 2010 statistical estimates shows extensive production of RA in several European countries.

Table 3: Summarised estimates of recycled aggregates by several Europe countries for 2010

Countries	Recycled Aggregates (millions tonnes)
Austria	4
Belgium	15
Denmark	1
Finland	1
France	17
Germany	60
Hungary	3
Netherlands	20
Poland	9
Sweden	1
Switzerland	5
UK	49

(Source: European Aggregates Association, 2012)

Table 3 shows that Germany has the highest recycling rate of aggregates with a production of approximately 60 million tones, followed by (in descending order) the UK, the Netherlands, France, and others countries. These countries indicate their experience in advanced research and technology as well as in the code of practice in the method of use and production of RA. However, the situation is different in Malaysia, where the use of aggregate produced from recycling waste, such as RA for concrete material, is still not commonly practiced (Abdul Rahman, et al., 2009). Several factors have been found to influence the formation of the barrier, which limits the practice to utilise RA in concrete production in Malaysia.

5.1 No signs of NA depletion crisis

Abdul Rahman, et al. (2009) reported that signs of a serious crisis, such as shortage of NA in Malaysia are still not felt at present. The available aggregate supply and reserve encourages the construction industry not to really focus on the use of RA. Majority of the states in Malaysia are estimated to have their own quarry activities, which contributed to aggregate production.

5.2 Lack of recycling plant and facilities

Compared to other waste recycling, such scrap metal, plastic, and others, there is a lack of business that offers recycling plant and facilities to encourage the collection and reprocessing of concrete waste to commercially produce RA. The abundance of NA in the market could be a reason that RA did not pick up its value. In addition, the lack of demand from the industry in the use of RA makes this kind of business non-attractive and uncompetitive. The effect of inadequate business that offers recycling plant and facilities is also one of the reasons that the construction waste is disposed off to dumpsites (Mahayuddin, et al., 2008).

5.3 Poor quality properties of RA

There are considerable differences between the properties of RA and NA. Physically, RA is composed of original aggregates with remains of a certain amount of mortar (cement paste) adhering to the aggregate particles. The presence of adhered mortar is relatively more porous and thus make the properties of RA has higher water absorption and lower strength characteristic compare to NA (Ismail & Ramli, 2014; Padmini et al., 2009; Surya, et al., 2013). Consequently, the incorporation of RA in concrete mixes can crucially affect on the concrete performance. Although there are available studies providing methods to produce a quality RA i.e., (Shima et al., 2005; Ismail & Ramli, 2013), the inferior quality of RA properties compared with the NA still give negative image perception and make the industry hesitate because of the lack of confidence in use of RA as material for concrete production. In addition, there is a variation in the quality of RA due to various sources of demolished concrete, which requires frequent quality control, testing, and proper segregation and classification.

5.4 Lack of knowledge and experience

Another barrier limiting the application RA, as reviewed by Adnan, et al. (2008), is caused by the lack of knowledge on the performance of RA in concrete production. One main reason attributed to this lack of knowledge and experience in handling RA is that the availability of the existing NA, which is the commonly practiced materials used in concrete production, makes the aggregate produced from recycling waste unattractive. As a result, there is a lack of adequate experimental data and information to study the performance characteristics of RA used for new concrete works, or to serve as an exposure to share and educate the public, especially the professionals involved in the construction area.

5.5 Unavailability of policy, standards or specification

Malaysia still does not have a clear and strict policy that imposes manufacturers, contractors, or designers to use RA in construction projects or to add/produce construction materials such as concrete. Several countries have developed their respective legislations and policies to encourage a more extensive use of RA. For example, European countries such as Sweden, Denmark, and the UK have implemented the Aggregates Levy in the construction industry as a way to conserve NA resources and to promote the maximum use of secondary and RAs (Söderholm, 2011). By the end of 2005, the Hong Kong government introduced the "Construction Waste Disposal Charging Scheme," which was intended to encourage contractors to recycle and to reuse C&D waste as well as simultaneously to reduce the disposal of construction waste to landfill (Yu et al., 2013). Moreover, there is an unavailability of standards or specification for the development and the conduct of use for RA, such as for structural or non-structural concrete production. For instance, Japan has setup its own Standardisation Committee to formulate the Japanese Industrial Standard (JIS), which has developed specification to classify the quality of RA in three grades: Classes H (high quality), M (medium quality), and L (low quality) (Watanabe et al., 2007). The development of relevant standards in the use of RA is essential to provide the manufacturer an easy way with information and the reference specification required for RA properties to produce what is required to achieve a specific concrete in certain performance desired.

5.6 Other factors

The availability of landfill for the disposal of C&D waste, which is relatively cheap to dispose, the negative perception of people on product recycling, and the lack of awareness on waste recycling are other factors that may be attributed as a barrier on the wide acceptance and usage of RA in Malaysia.

6.0 Conclusion

The time is now appropriate for the Malaysian construction industry to move toward a more extensive use of sustainable building materials through recycling. The following are several actions to promote and encourage the Malaysian construction industry to shift toward the use of RA.

The government needs to develop an appropriate policy and regulation that requires the stakeholders involved in the construction industry to adopt recycling activities. The government should play a role to promote the use of concrete products made with RA. For instance, the government can encourage the designer/manufacturer to use RA in the production of precast concrete for Industrial Building System projects.

The government should encourage more new entrepreneurs to venture into creating many businesses that offer services to collect and process the concrete waste materials to produce the RA. This can be done with the government becoming a partner to inject a fund, and make an investment to buy new technology of recycling plant and facilities from abroad to be run in Malaysia.

The government and private sector should provide funds or grants for researchers to create more innovative research and development about improving the technologies and product related to enhance the quality of RA produced for effective application in the construction industry.

The government has to setup one standardisation committee, which consists of professionals in the construction industry and academicians, to develop their own standards and specifications on the processing and use of aggregate products from recycled C&D waste intended for Malaysian construction projects.

The government should also provide special rewards or intensive support for contractors/manufacturers that use RA in construction projects or as new building material products.

As a final point, to enhance the awareness of the Malaysian populace through the educational system concerning the importance of recycling, sustainable development concept should be practiced in Malaysia.

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