Recycling of Construction & Demolition Waste (Challenges and Opportunities)

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Abstract

Construction and demolition waste is one of the most important parts of the solid wastes generated in the world where the majority portion is transferred to the landfill sites. Rapid population growth and urbanization have led to dramatic increase in the construction activities and consequently the construction and demolition waste generation and reduction of the landfills capacity. Many researches are working on feasibility of using the construction and demolition wastes in different applications; most of these studies deal with replacing the aggregates and Pozzolanic materials in concrete, mortar and asphalt construction and the obtained results have confirmed the significant potential of these replacements. However, recycling of these wastes in the concrete, mortar and asphalt has had little development due to low government supports, lack of awareness and lack of the required standards in the field of recycling the construction wastes. In this paper, the aim is to present the required standards for recycling the construction and demolition wastes in production of the concrete, mortar and asphalt.

Keywords: Construction & demolition Wastes, Recycling, Standards.

1. Introduction

Waste is defined as a subsidiary product which is produced due to industrial and human activities and is considered useless (Tam & Tam, 2006). Construction industry has a great role in production of municipal solid wastes; construction and demolition wastes are a kind of solid wastes and have a share of *15-30%* in the solid wastes. Per capita production of the construction and demolition wastes is *500-1000 kg*percapita per year in most of the developed countries (Kartam et al., 2004). There are many factors that affect the production process of the construction and demolition wastes including the social- economic situations, the year’s seasons, different municipal zones, population increase and the city development. Improper management of these wastes can lead to harmful effects on the human health and the environment (Past et al., 2017). More construction and demolition wastes are transferred to the landfill sites with increase of the population and the construction projects. This decreases the volume of the landfills and hence, recycling the wastes and using them instead ofthe virgin materials reduce the pressure on the landfills and the demand for the virgin materials’ extraction (Huang et al., 2007).

During the recycling process, the selection between the recycled and virgin materials depends on the cost and quality. As an example, concrete wastes are preferred if the recycled product is much cheaper than the virgin materials and the recycled wastes meet the required characteristics. Some essential requirements that are needed for the successful materials recycling are:

- Shortage of virgin materials as well as shortage of proper saving sites
- Safe supply of the proper recycled materials

- Organized collection and appropriate transfer of these materials
- Precise separation of the construction wastes in the production place or in the recycling place in a way to change these materials to virgin materials or a new product
- Market availability for these produced virgin materials or recycled products
- The recycled products must be competitive in terms of cost and quality

There are some general problems about the construction and demolition wastes including the pollution, collection and transfer, separation, conversion and disposal and finally, lack of essential standards for competition of the recycled materials with the virgin ones (Kartam et al., 2004);these are some factors which prevent extensive use of the construction and demolition wastes in different applications. Therefore, in this paper, present recycling technologies of some common components of the construction and demolition wastes are determined by reviewing different references; then, some required tests are performed on each component before and after using in the recycled product. Finally, the optimal range of each component of the construction and demolition wastes is determined in the considered application to provide the recycled products which are able to compete with the raw material products, in case of providing the necessary standards.

2. Recycling of the Construction & demolition Wastes

Recycling of the construction and demolition wastes was done in Germany for the first time after the World War II and then some researches were studied in some countries to investigate the potential of using these materials (Rao et al., 2007). Recycling of the construction wastes cause:

1. Demand decrease for the virgin materials
2. Cost reduction of the transportation and the production
3. Decrease of the need to the landfill sites
4. Recycling industry development and job creating
5. Reduction of the accumulation pollution of these materials in the environment (Peng et al., 1997)

Major part of the construction and demolition wastes is transferred to the landfill sites; hence, there are many opportunities for industries to minimize the dumping of these wastes, as a result increases the landfill’s life and minimizes the wastes’ transfer and decreases the need to the primary resources, e.g. materials and energy (Tam & Tam, 2006).

2.1. Recycling of the Construction & demolition Wastes in Concrete

Concrete is one of the most commonly used materials in the construction process. From the perspective of environmental preservation, it is worth studying the concrete’s production and consumption,its balance with the environment during its life span and finally its destruction and return of the resulted materials to the nature (Maleki and Pykanpour, 2015).The most usual method for recycling the concrete wastes is their direct using in production of new concretes as replacement of the natural aggregates. However, the concrete quality made with the recycled aggregates is the same as the concrete quality made with the natural aggregates. Hence, the concrete having the recycled aggregates is preferred if the recycled aggregates are much cheaper than the natural ones (Kartam et al., 2004).In fact, the aggregates occupy *70-80%* of the concrete volume, and their characteristics and strength have great effect on the concrete specifications (Kesegic et al., 2008). Therefore, the recycled aggregates must pass the same tests which are performed on the natural aggregates (Shams et al., 2016). The most important characteristics of the recycled aggregates before using in the new concrete are:

- **Particles Size:** the primary and secondary grinding are done by using a crusher. In the primary grinding, the concrete wastes are split into *50 mm* parts and the wastes’ metals are removed by using magnets. Then, the second crusher is applied to reduce the particles size to the range of *14-20 mm* (Rao et al., 2007).

- **Water Absorption and Specific gravity:** water absorption of the recycled concrete aggregates is *3-12%* for the coarse and fine aggregates. These values are much higher than the natural aggregates values which are *0.5-1%* (Rao et al., 2007). The recycled concrete aggregates have higher water absorption while they have lower special gravity than the natural aggregates; the reason is the mortar stick to the recycled aggregates which has a porous structure (Topcu & Sengel, 2007) and affects the concrete's efficacy and characteristics (Rao et al., 2007). Lower special gravity of the recycled aggregates provides more efficiency in comparison to the natural aggregates (more volume for the same weight) and can be interesting economically for the contractors (Shams et al., 2016).
- **Abrasion Resistance:** recycled concrete aggregates have higher abrasion strength and crushing value than the usual aggregates (Topcu & Sengel, 2007). Using the recycled aggregates as the subbase material in the flexible pavement has provided promising results. The recycled aggregates are used in the concrete production of the hard pavements and are applied extensively as the new materials in the hard pavements in the countries like the United States and Britain (Rao et al., 2007).

Recycling of the construction concrete needs more attention due to the pollutions like plaster, soil, wood, plastic and rubber. Generally, the pollution is not a problem for the recycled aggregates which are used in the roadbed construction; however, more control is needed for the recycled aggregates which are used in the concrete. The pollution level can be controlled by inspecting the incoming trucks to the aggregates production manufactory; this can be done by having information about the shipping place of the crushed concrete. With decrease of the natural sources, thedemands for the concrete recycling and use of the recycled aggregates, instead of the natural aggregates, have been increased, which would be economical and prevent the environmental damages (Shams et al., 2016). Table (1) demonstrates the essential tests after production of the concrete samples by using the recycled aggregates.

Table (1) essential tests after production of the concrete samples containing the recycled concrete wastes (Rao et al., 2007)

<table>
<tr><th>Tests of the Concrete Durability</th><th>Tests on the Hardened Concrete</th><th>Tests on the Fresh Concrete</th></tr>
<tr><td>Carbonation</td><td>Compressive Strength</td><td>Workability</td></tr>
<tr><td rowspan="5">Freezing and Thawing Resistance</td><td>Flexural Strength</td><td>Air Content</td></tr>
<tr><td>Tensile Strength</td><td rowspan="4">Bulk Density</td></tr>
<tr><td>Bond Strength</td></tr>
<tr><td>Modulus of Elasticity</td></tr>
<tr><td>Creep & Shrinkage</td></tr>
</table>

Recent researches confirm good quality of the produced concrete containing the recycled aggregates up to *30%* (Tam & Tam, 2006). This may be the simplest, the most economic and the least controversial method of extensive use of the recycled concrete aggregates in production of the new concrete (Shams et al., 2016).

2.2. Recycling of the Construction & demolition Wastes in Asphalt

Waste asphalts can be applied in the new asphalt production as the recycled aggregates and filler. In Netherlands, *50%* of the asphalt wastes are used for the asphalt production which contains *10-15%* of the recycled asphalt added to the new asphalt (Tam & Tam, 2006).Glass wastes can be used as the aggregates in the asphalt production. Proper asphalt mixtures should contain *10-15%* glass wastes in the surface layer and the maximum acceptable size of the glass wastes is *4.75 mm*. More contents and bigger glass pieces in the asphalt lead to problems like improper friction and negative effect on the bond connection and are good for lower layers. Generally, glass wastes can be replaced as the aggregates in the asphalt in the range of *10-30%*. Furthermore, rubber and plastic wastes can be used as the aggregates in the asphalt or as the modifier of the bitumen specifications. Rubber wastes of *0.15-0.16 mm* in size at *18-22%* of the bitumen weight can be applied as the bitumen specifications modifier which increase the bitumen viscosity and improve its durability (such as strength against moisture, oxidation and fatigue); moreover, rubber wastes of *0.85-6.4 mm* can be used during the dry process as the aggregates at *1-3%* in the asphalt type A. In Britain, rubber wastes are used at *1-3%* as the aggregates in the asphalt production and at *8%* by weight in the bitumen. In general, rubber using in the asphalt production leads to fraction reduction, durability improvement and noise decrease (Huang et al., 2007). Actually, the requirements and the design methods, used in the asphalt production with the recycled aggregates, are the ones which are applied for the asphalt production with the virgin aggregates (Azizian et al., 2003). Table (2) illustrates the required tests on the recycled aggregates and on the asphalt samples which contain the recycled aggregates.

Table (2) required characteristics and tests for the recycled aggregates and the produced asphalt in the surface layer

Tests after producing the asphalt samples with the recycled aggregates	**Tests before producing the asphalt samples with the recycled aggregates**Huang et al (2007)
Bulk specific gravity	Grading, fines content, flakiness index
Marshall stability and flow	Resistance to fragmentation, polished stone value (PSV), aggregate abrasion value (AAV)
%Air voids, % voids in mineral aggregates, % voids filled with asphalt	Leaching
Moisture susceptibility	Water absorption, magnesium sulphate value

Moreover, the asphalt wastes can be used as the landfill cover in large quantities when they have no recycling potential (Ryan, 2011).

2.3. Construction & demolition Wastes Recycling as the Replacement of Pozzolanic Materials

By reviewing various sources, Zimbili et al. (2014) expressed that in case of replacing *11-14%* of the ceramic wastes, the cement mixture would have proper performance; in this case, the new produced cement will pass all the cement technical standards and can be used as the Portland cement. The important parameters for studying the feasibility of this replacement (replacement of ceramic wastes with the Portland cement) are:

1. Pozzolinic properties of the ceramic waste
2. X-Ray diffraction
3. Setting time
4. Particle size
5. Specific surface area
6. Volume stability
7. Density
8. Strength of cement

The brick wastes, in the powder form, can be used as an effective Pozzolinic material in production of the cement as a replacement for a part of the mortar and concrete. According to the research results of Lin et al. (2010), Naceri & Hamina (2009), Cheng et al. (2014) and Nigri et al. (2017), mechanical strength of the concrete and mortar can be improved by replacing the brick wastes, up to *10%*, in the cement. Replacement of *10-15%* of the brick wastes in *90* and *180*-days samples improved the mortar strength however, use of the brick wastes over *10%* has negative effect on the mortar stability (Demir et al., 2011). In case of adding the super plasticizer at maximum *2%* and replacement of brick powder wastes with cement at maximum *15%* in the concrete mixture provide proper and effective results in production of the concrete blocks.Moreover, it was stated that the brick wastes can be used as the cement replacement at *15%*(Sharma et al., 2014).Based on the obtained results, it seems that using the brick powder at *10-15%* can be effectively applied as a replacement of cement in the concrete and mortar production. Table (3) presents the required tests on the Pozzolinic materials and the mortar samples containing the brick wastes.

Table (3) required tests on the Pozzolinic materials of the brick and the mortar containing the Pozzolinic wastes of the brick

Tests after mortar production contacting brick wastes as the Pozzolan (Naceri & Hamina, 2009)	**Tests on the Pozzolinic materials of the brick** (Tavakoli et al., 2014)
X-Ray Diffraction	X-Ray Diffraction
SEM	Water Absorption
Laser Granulometry	Unit Weight

Besides the mentioned tests in Table (3), after production of the mortar and concrete samples with the brick wastes as replacement of a part of the Pozzolinic material, other common tests must be performed on the samples containing these wastes to better study the characteristics and performance of the produced samples.

3. Conclusion

Until now, various kinds of the construction and demolition wastes' components are studied for producing different products. Based on reviewing different references in the field of mortar, concrete and asphalt production by using the construction and demolition wastes, satisfactory results are obtained. By using the optimal values of the construction and demolition wastes in different applications, their competition with the raw materials products becomes possible and hence, low life problem of the landfill sites will be solved and the demand for the raw materials will be reduced.

References

Azizian MF, Nelson PO, Thayumanavan P, Williamson KJ. Environmental impacts of highway construction and repair materials on surface and ground waters: case study: crumb rubber asphalt concrete. Waste Manage 2003; 23:719–28.

Cheng H. Reuse research progress waste clay brick.Procedia Environmental Sciences. 2016; 31: 218 – 226.

Demir I, Yaprak H, Simsek O. Performance of cement mortars replaced by ground waste brick in different aggressive conditions. Ceramics – Silikáty. 2011; 55 (3) 268-275.

Huang Y, N.B R, Heidrich o. A review of the use of recycled solid waste materials in asphalt pavements. Resources, Conservation & Recycling. 2007; 52:58-73.

Kartam N, Al-Mutairi N, Al-Ghusain I, Al-Humoud J. Environmental management of construction and demolition waste in Kuwait. 2004; 24:1049-1059.

Kesegić I, Netinger I, Bjegović D. Recycled clay brick as an aggregate for concrete: overview. Technical Gazette 15(2008)3, 35-40.

Letelier V, Tarela E, Moriconi G. Mechanical properties of concretes with recycled aggregates and waste brick powder as cement replacement. Procedia Engineering. 2017; 171: 627 – 632.

Lin KL, Wu HH, Shie JL, Hwang CL, An Cheng.Recycling waste brick from construction and demolition of buildings as pozzolanic materials. waste management & research. 2010;28(7):653-9.

Maleki F, Pykanpour P. Environmental impacts of the concrete industry and its recycling role in the environment. International Conference on science & Engineering. 2015

Naceri A, Hamina MC. Use of waste brick as a partial replacement of cement in mortar. Waste Management, 2009, 29(8): 2378-2384.

Nigri G, Cherait Y, Nigri S. Characterization of eco-substituted cement containing waste ground calcined clay brick. *Canadian Journal of Civil Engineering*, 2017, 44(11): 956-961.

Past V, Yaghmaeian K, NabizadehNodehi R, Dehghani1 MH, Momeni M, Naderi M. Selection of the best management method for construction and demolition waste disposal in Tehran with the view of sustainable development based on Analytical Hierarchy Process (AHP). Health & Environment2017; 10(2):259-270. (In Persian).

Peng C H L, E.Scorpio D, J. Kibert C H. Strategies for successful construction and demolition waste recycling operations Construction Management and Economics, 1997, 15(1): 49-58.

Rao A, N.Jha K, Misra S. Use of aggregates from recycled construction and demolition waste in concrete. Conservation & Recycling. 2007; 50:71-81.

Ryan M. Guidelines for Waste Asphalt Reuse in New Pavement or in Roadbed Construction of Paved Roads; and/or Storage and Final Disposal. 2011.

Shams A.Z, Roshankar S, FaghieMohammadi A, Ziya Shams A. Use of recycled aggregates concrete instead of natural aggregates and comparing compressive strength of recycled concrete with conventional concrete. First National Civil Engineering Conference of Bandar Anzali. 2016 (In Persian).

Sharma S, Mall R, Raza K. Effect of waste brick kiln dust with partial replacement of cement with adding superplasticizer in construction of Paver Blocks. International Journal of Science, Engineering and Technology Research.2014. Volume 3, Issue 9.

Tavakoli D, Heidari A, HayatiPilehrood S. Properties of Concrete made with Waste Clay Brick as Sand Incorporating Nano SiO_2. Indian Journal of Science and Technology.2014; 7(12): 1899–1905.

Tam V W.Y, Tam C.M. A review on the viable technology for construction waste recycling. Resources, Conservation & Recycling. 2006; 47:209-227.

Topcu I B, Sengel S. Properties of concretes produced with waste concrete aggregate. Cement and Concrete Research. 2004; 34: 1307–1312.

Zimbili O, Salim W, Ndambuki M. A Review on the Usage of Ceramic Wastes in Concrete Production.

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