International Journal of Innovation in Agriculture Sciences and Rural Development
Vol.1, NO.1 , P : 4 - 12
Received: 18 Nov 2018
Accepted: 13 Feb 2019

Evaluating the impact of distance from recycling plant on cost and energy consumption during construction and demolition(C&D) waste recycling in Tehran municipality district 15

Nader Lotfi[1]
Head of green space in district 15 of Tehran municipality
Alilotfi1376.al@gmail.com

Shiva Abbaspour
Head of green space research and advice Center in district 15 of Tehran municipality
shabaspour@gmail.com

Zahra Parastar
PhD student of Islamic Azad university, science and research branch
Zahraparastar@gmail.com

Nemat Dindarloo
Master graduated student of soil biology and biotechnology of Tehran university
nematdindarluo@alumni.ut.ac.ir

Abstract

Beside several types of material, construction and demolition waste(C&D waste) waste considered as approximately fifty percent of the entire waste generated. This matter can lead to a major environmental, social and economic problem for human. So it is crucial to have a suitable economic plan to recycle concrete and have a broader insight up to energy consumption during this process. Distance of recycling plant from the jobsite plays an important role in choosing recycling as environmentally friendly activity. Therefore, this research investigates cost and energy consumption for recycling concrete waste in different distance of recycling plant from jobsite and compares it with the case of landfilling concrete waste. For this aim, in one case demolished concrete delivered to a recycling plant and recycled concrete aggregate purchased. In this case the amount of energy and cost investigated in different distance from 10 to 80 kilometers. In the other case, these parameters were calculated when demolished concrete conveyed to the nearest landfill and new virgin aggregate from a concrete plant purchased. The result has shown that, by increasing recycling plant distance up to 60 kilometers, it is not cost-effective to recycling concrete waste and landfilling them is more affordable. Furthermore, the result of energy consumption has shown that it is energy-intensive to build a recycled plant at the location of less than 30 kilometers from jobsite.

Keywords: Construction and Demolition (C&D) waste;

Distance in recycling concrete;
Concrete recycling plant.

Introduction

One of the main building materials used widely all over the world is concrete. In recent years, the environmental impact of concrete usage compels researchers to choose it for further research as a major concern. In order to reduce depletion of natural resources, there has been an increased effort to recycle concrete. It is obvious that construction is known as unique, uncertain, and perplexing industry among all other manufacturing industries (A. Razak et al., 2010). Some of the highlighted can be named as time constrain, limited site space, and high turnover rate. There is a great attention among researchers about recycling demolished waste in order to obtain sustainable concrete due to ever increasing the large amount of construction and demolish waste annually (Á. Salesa et al., 2017 and L.C. Bank, 2016). Due to the fact that the growth of urbanization as well as the number of impermissible dumps have been increased exponentially, there is a dire need of recycling construction and demolished (C & D) waste across the word [A. Yazdanbakhsh]. The notable amount of waste from building sites are generated by the usual pattern of dumping construction materials. Besides, remarkable business via managing demolished waste can be flourished because of the increasing amount of concrete waste as well as reducing the landfill space. According to the previous study, Wang et al. 2008 counted the building industry as an important contributor for generating pollution as well as waste. On the other side, Yuan et al. 2011 reported that C&D waste is known as a significant wastes that could be produced in civil, renovation, demolition, site clearance, and construction. However, the major problem that many large urban centers may be faced every day is the high amount of C&D waste. The exact example is Tehran, the C&D waste were generated roughly 17 million tons annually [Asgari et al. 2017]. Regarding recent study that conducted by Asgari et al. 2017, it became clear that 82,646,051 m3 of construction and demolition waste (average 16,529,210 m3 annually) were generated in Tehran from 2011 to 2016 that is only 26% has been used again as building materials. The high quantity of the C&D waste in Tehran, including mixing sand and cement, concrete, broken bricks and soil with the percentage of 30, 19, 18 and 11% out of the total, respectively [B. Rouhi Broujeni et al. 2016]. Based on these results, in 2025 there is about 2,784,158 tons of the waste will be produced that is about 122% higher than that of 2016. According to the Abdal Industrial Projects Management (MAPSA), roughly 360 personnel were managing the illegal manipulation. However, this number of teams are not sufficient and cannot be efficient in containing the situation due to the huge expansion of Tehran [Asgari et al. 2017]. Based on a research, in many developed countries, construction wastes consisted of about 35% of municipal solid wastes and in developing nations this rate is 50% that are a major amount of MSWs [Najafpoor et al. 2014]. Also, in some countries such as Singapore, the reuse, recycle, and reduce construction waste need to be highlighted due to decreasing the number of landfills as well as rising disposal cost [B.-G. Hwang, Z. Bao Yeo, 2011]. Since it is thought that the price of implementing waste management, weight out the benefits gained, the care to recycle C&D waste has not been received from management [L. Shen, V.W. Tam, 2002]. Currently, all concrete waste in Iran is in landfill areas that will be consumed in the forthcoming age, so reducing the waste production in a tough pressing issue in this region [K. Khodaverdi, 2008]. Embodied energy is defined as the whole energy that is required for inventing and supplying the levels that is appropriate for use of materials, services or products [J.M. Pearce, et al. 2007]. Regarding Salling, 2008, the amount of energy for transporting materials for every 100 km is 265.5kJ/kg and also based on Gloria [T.P. Gloria et al. 2007], the energy that employed for producing the crushed aggregate is 82kJ/kg.

The main parameters in this study are the cost and energy consumption in both landfilling concrete waste and recycling concrete in different distance of the recycling plant. The cost is just the overall cost of production and transportation of recycled concrete aggregate and virgin aggregate. To estimate the total energy consumption, all stages in the life of concrete have to be considered, which includes the energy consumption for production, construction, life cycle and demolition. However, this study only considers the total energy required for production and transportation of recycled concrete and virgin aggregate. In terms of production, recycled concrete includes the crushing of demolished concrete in a concrete crusher, whereas, for virgin aggregate, this process includes mining and crushing. In terms of transportation, recycled concrete involves the transportation from the demolition site to the recycling plant and then from the recycling plant to the construction site, while for land filling transportation is delivering concrete waste to a landfilling site and then transferring new aggregate from quarry pit. In some case, the cost and embodied energy for recycled concrete are more than for virgin aggregate. This matter largely depends on the transportation distances for concrete. In these situations, the transportation distance between the construction site and the source of virgin aggregate is closer than that of recycled aggregate which involves transportation between the demolition site, recycling plant, and the construction site. This study will compare the cost and embodied energy for production and transportation of virgin aggregate and recycled aggregate by giving different values for the transportation distances.

MATERIAL AND METHODS

The aim of this research was to compare the cost and energy required for landfilling concrete waste and recycling concrete in different distance of recycled plant. A case was therefore created in which a four-story concrete structures are demolished. After calculating the energy and price needs for recycling concrete, the result compared to find the best distance of concrete recycled plant which is both cost-effective and energy-intensive.

A. Costs related to recycle or landfilling concrete

The overall amount of concrete that has to be processed or new aggregate purchased is 5675 metric tons. The price was based on price quotes from local aggregate suppliers. In one way, the cost involves the cost of throwing out the demolished concrete waste at the landfill and buying new virgin aggregate. The landfill that was seen in the survey was the Northern C & D landfill located in Paradise, Tehran, at a length of 35.6 kilometers from the job site. The cost of landfilling was $6.0771 for every metric ton of concrete waste. This overall cost of landfilling includes the cost for loading/unloading and transit. The virgin aggregate was bought from Lime rock industries Inc, which is located in North Tehran, at a length of 43.72 kilometers from the job site. In the one case, the price of buying virgin aggregate was $11.0375 for every metric ton, and this price includes the cost of fabric and the cost of preserving. The virgin aggregate required for this situation is 5675 metric tons. For the other case the cost involves for delivering the concrete waste at the recycling plant, and the price of buying recycled concrete aggregate from the same recycling plant. The recycling plant distance in this case is changed from 10 to 80 kilometers. A tax of $6.75 was charged for the overall cost of the activities in all the cases.

B. The energy required to recycle or landfilling concrete

The two major arenas in which energy use was calculated were for crushing and transportation. The energy use of production and transformation was calculated based on Building for Environmental and Economic Sustainability Technical Manual and User Guide [T.P. Gloria et al. 2007]. According to BEES 4.0 [T.P. Gloria et al. 2007], the energy applied in the production of crushed aggregate is 82 KJ/kg, and according to Salling, 2008, the energy required for the transit of material for every 100 kilometers is 265.5 KJ/kg.

The energy consumption for landfilling concrete waste implies the energy consumed in transmitting the waste concrete from the jobsite to the landfill, energy consumed in transporting the virgin aggregate from the recycling plant to the landfill, and the energy eaten up in crushing for the production of virgin aggregate. In the one case, the space between the jobsite and the quarry pit was 43.72 km and the length between the jobsite and the landfill was 35.6 kilometers. Using these values, the total energy consumption in this case was forecast. In the other case, the energy consumption of recycling concrete involves the energy consumed in transmitting the waste concrete from the jobsite to the recycling plant, energy consumed in transporting the recycled concrete aggregate from the recycling plant to the job site, and energy consumed in crushing the demolished concrete at the recycling plant. The length between the jobsite and the recycling plant is changed every 10 kilometers to reach to 80 kilometers.

RESULT AND DISCUSSION

a. Cost and energy consumption in landfilling construction and demolition waste

The cost incurred in the landfilling concrete waste involves the throwing away of the crushed concrete and buying new virgin aggregate. The cost for landfill was $6.0771 per metric ton, which amounted to $34487.68 for 5675 metric tons. The price of buying virgin aggregate was $11.0375 per metric ton, which amounted to $62637. 67 for 5675 metric tons. Thus, the total cost incurred in this case, including the taxes, amounted to $104409. 75 (Table 1).

Table 1. Cost calculations for landfilling concrete waste

Factors	Value	Unite
Cost for landfill demolished concrete per ton	$6.0771	/Ton
Quantity of demolished Concrete	5675	Ton
Cost to landfill demolished concrete	$34487.68	
Cost for buying Virgin aggregate per ton	$11.0375	/Ton
Quantity of virgin aggregate needed	5675	Ton
Cost for buying Virgin aggregate	$62637.67	
Total cost	$97125.35	
Tax 6.75%	$7284.40	
Total cost	$104,409.75	

The energy required to reuse the concrete is 82 KJ/kg [20], and the energy needed to send material for every 100 kilometers is 265.5 KJ/kg [T.P. Gloria et al. 2007]. The energy required to transport the demolished concrete from the jobsite to the landfill equals 549950062.5 KJ. The energy needed to produce 5675000 kg of virgin aggregate equals 465350000 KJ, and the energy needed to transport virgin aggregate from the quarry pit to the job site is 658734705 KJ. Thus, the overall energy consumption in this case is 1674.035GJ (Table 2).

Table 2. Energy calculations for landfilling concrete waste

Factor	Value	Unit
Energy required to produce virgin aggregate	465,350,000	KJ
Distance from the jobsite to the landfill	35.6	Kilometers
Energy required to transport demolished concrete to landfill	549,950,062.5	KJ
Distance from the quarry pit to the jobsite	43.72	Kilometers
The energy required to transport VA from the quarry pit to the jobsite	658,734,705	KJ
Total Energy	1674034768	KJ
	Or 1,674,035	GJ

Kg: kilogram KJ: kilojoule GJ: gigajoule VA: Virgin aggregate

b. Cost and energy consumption in recycling concrete waste

In this case the cost for disposing concrete at the recycling plant per ton is $3.566 to $6.527 depends on the distance and the cost of buying RCA per ton is 9.252 to 12.222 upon the distance of 10 to 80 kilometers. Further result is shown in Table 3. The energy for transportation and production of recycling concrete waste involves the energy needed to transport the demolished concrete from the jobsite to the recycling plant, the energy required to reuse the concrete at the recycling plant and the energy needed to transport the recycled concrete aggregate from the recycling plant to the job site. The result of this case is shown in Table 3. It is obvious that by increasing the distance of the recycling plant, the cost increased.

Table 3. cost and energy consumed for recycling concrete in different distance of recycling plant from jobsite

Items	unit	Distance 10	20	30	40	50	60	70	80
Cost for disposing concrete at the recycling plant per ton	$	3.566	3.989	4.412	4.835	5.258	5.681	6.104	6.527
Total Cost for disposing 5675 ton concrete at the recycling plant	$	20,237.05	22,637.58	25,038.1	27,439.63	29,839.15	32,239.68	34,640.2	37,040.73
Cost for buying RCA per ton	$	9.252	9.675	10.098	10.521	10.944	11.376	11.799	12.222
Total Cost for buying 5675 ton RCA	$	52,505.1	54,905.63	57,306.15	59,706.68	62,107.2	64,558.8	66,959.33	69,359.85
Total Cost with 6.75 % tax	$	77,522.5	82,777.37	87,902.49	93,028.68	98,152.73	103,332.4	108,457.5	113,582.6
Energy required to recycle the concrete per ton	GJ	465,350	465,350	465,350	465,350	465,350	465,350	465,350	465,350
Energy to transport demolished concrete to the recycling plant	GJ	150,671	301,343	452,014	602,685	753,356	904,027	1,054,699	1,205,370

Energy to transport RCA to the jobsite	GJ	150,671	301,343	452,685	602,685	753,356	904,027	1,054,699	1,205,370
Total Energy	GJ	766,692	1,068,036	1,370,049	1,670,720	1,972,062	2,273,404	2,574,748	2,876,090

GJ= Giga Joel

a. Impact of transportation on Cost and Energy

The results show that the cost and energy consumption during the concrete recycling are much lower and more favorable compared to landfilling them. Therefore, to test the impact of transportation distance on cost, energy consumption, and particulate emissions, the distance between the jobsite and the recycling plant was changed at the increment of every 10 km from 10 km to 80 km. Results show that when the distance between the jobsite and recycling plant becomes more than 60km, then the use of virgin aggregate becomes a more cost-effective option than using recycled concrete aggregate (RCA). On the other hand the results show that when the distance between the jobsite and the recycling plant become more than 30km, then the total energy consumed for using a recycled concrete aggregate becomes more than using a virgin aggregate (figure1). At this point, the use of virgin aggregate is a more energy efficient option than RCA.

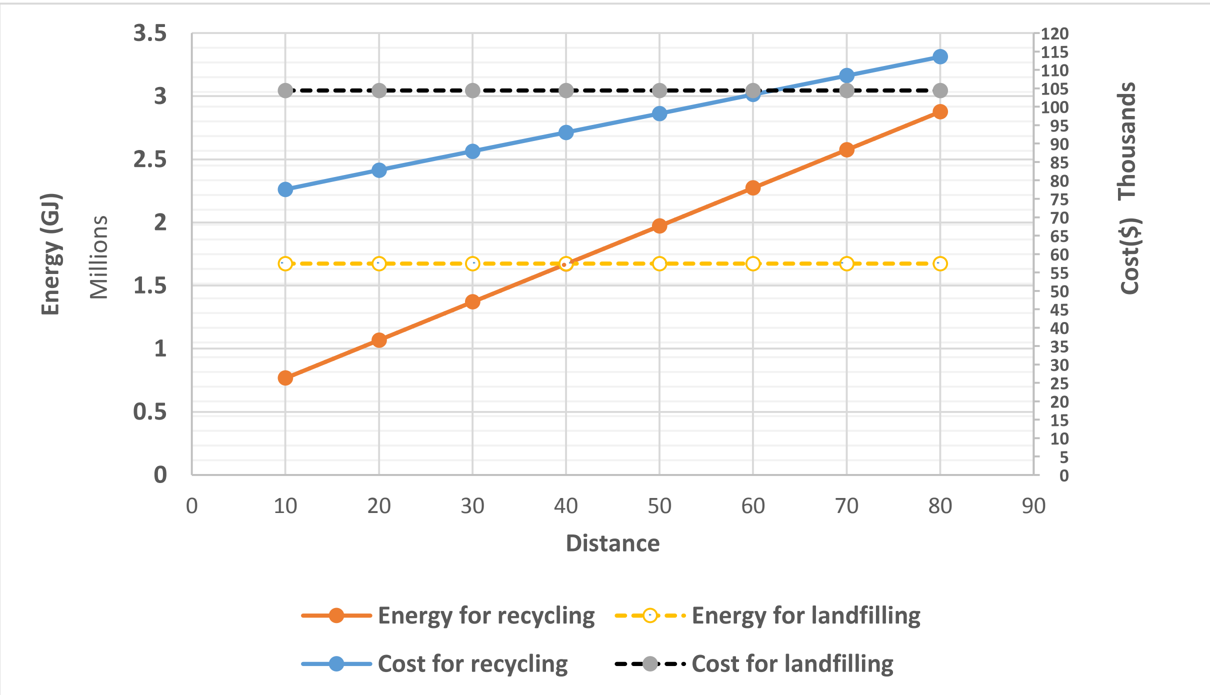

Figure 1. Cost and energy consumed for using and recycling concrete in different distance of recycling plant from jobsite

CONCLUSION

The recycling system of concrete is now being significantly improved under enhanced awareness of the environment and advocate request for recycling along with the Iranian standard of recycled aggregate for far-reaching use. Recycling of concrete demolition waste can provide chances for saving resources, energy, time, and money. The results from this study show how the distance from the source of concrete material plays a huge role in selecting recycling as an environmentally friendly and economic process. The major energy consumption involved in the process of obtaining recycled concrete aggregate is the energy required for the crushing and screening demolished concrete, as well as the energy required for the transportation of the concrete material from the source to the jobsite. At some point as the distance between the jobsite and recycling plant increases, virgin aggregate becomes a more favorable option in terms of cost and energy consumption than using a recycled concrete aggregate from a recycling plant. Therefore, it is cost-effective and energy-intensive to build a concrete recycling plant in less distance of 60 and 30 kilometers from the jobsite, respectively.

REFERENCES

[1] Asgari, A., Bagheri, A., Mahvi, A. H., Dadashzadeh, D., Khalili, F., Raei, M., ... & Ghorbanian, T. (2017). Quality and quantity of construction and demolition waste in Tehran. Journal of Environmental Health Science and Engineering, 15(1), 14.

[2] Broujeni, B. R., Omrani, G. A., Naghavi, R., & Afraseyabi, S. S. (2016). Construction and Demolition Waste Management (Tehran Case Study). Engineering, Technology & Applied Science Research, 6(6), 1249-1252.

[3] Gloria, T. P., Lippiatt, B. C., & Cooper, J. (2007). Life cycle impact assessment weights to support environmentally preferable purchasing in the United States. Environmental science & technology, 41(21), 7551-7557.

[4] Hwang, B. G., & Bao Yeo, Z. (2011). Perception on benefits of construction waste management in the Singapore construction industry. Engineering, Construction and Architectural Management, 18(4), 394-406.

[5] Khodaverdi, K., Faghih, A., & Eslami, E. (2008). A Fuzzy Analytic Network Process Approach to Evaluate Concrete Waste Management Options. USA: University Columbia.

[6] Najafpoor, A. A., Zarei, A., Jamali-Behnam, F., Vahedian-Shahroudi, M., & Zarei, A. (2014). A Study Identifying Causes of Construction Waste Production and Applying Safety Management on Construction Site. Iranian Journal of Health Sciences, 2(3), 49-54.

[7] Pearce, J. M., Johnson, S. J., & Grant, G. B. (2007). 3D-mapping optimization of embodied energy of transportation. Resources, conservation and recycling, 51(2), 435-453.

[8] Razak Bin Ibrahim, A., Roy, M. H., Ahmed, Z. U., & Imtiaz, G. (2010). Analyzing the dynamics of the global construction industry: past, present and future. Benchmarking: An International Journal, 17(2), 232-252.

[9] Salesa, Á., Pérez-Benedicto, J. A., Colorado-Aranguren, D., López-Julián, P. L., Esteban, L. M., Sanz-Baldúz, L. J., ... & Olivares, D. (2017). Physico–mechanical properties of multi–recycled concrete from precast concrete industry. Journal of Cleaner Production, 141, 248-255.

[10] Salling, K. (2008). Energy consumption and truck freight transport demand: is Denmark a special case?.
[11] Shen, L. Y., & Tam, V. W. (2002). Implementation of environmental management in the Hong Kong construction industry. International Journal of Project Management, 20(7), 535-543.
[12] Wang, J. Y., Kang, X. P., & Wing-Yan Tam, V. (2008). An investigation of construction wastes: an empirical study in Shenzhen. Journal of Engineering, Design and Technology, 6(3), 227-236.
[13] Yazdanbakhsh, A., & Bank, L. C. (2016). The effect of shear strength on load capacity of FRP strengthened beams with recycled concrete aggregate. Construction and Building Materials, 102, 133-140.
[14] Yuan, H., Shen, L., & Wang, J. (2011). Major obstacles to improving the performance of waste management in China's construction industry. Facilities, 29(5/6), 224-242.