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Identification of Waste Sources in Ready-Mixed Concrete Plants

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Abstract

In today's highly industrialized world, an enormous amount of wastes is originated from the construction industry. This type of wastes conversely affects both macro-economic conditions and environment of a country or a region. Therefore, waste management is an important aspect of project management. Although there is a wide variety of construction materials, concrete is still the mostly used one in the construction industry and thus has a big impact on the amount of construction-based wastes. Reducing such wastes is among the objectives of the waste management issue in construction projects. Accordingly, the determination of waste sources is the first step to deal with them. Based on these arguments, the current paper presents a study that aims to identify the sources of fresh concrete wastes in ready-mixed concrete (RMC) plants as a part of an on-going research project. Toward this aim, production and delivery processes of RMC were reported and discussed in a detailed manner from the perspective of waste management. As a result, four sources were identified for such wastes. It was also found out that only two types of these sources (i.e., over-order and residual RMC in the truck-mixer drum) are quantifiable.

Key words

Construction waste, Fresh concrete waste, Ready-mixed concrete, Waste sources

1. INTRODUCTION

Today, construction wastes constitute approximately 20–40% of the area occupied by wastes in a country ([16], [5], [10]). Construction wastes produced per year in England [8] and US [20] are estimated as 91 and 164 million tons, respectively. Especially in developing countries such as Turkey where the construction industry is in a rapid development process (Figure 1), the rate of construction wastes is expected to be higher [19]. Therefore, minimizing or recycling construction wastes is a crucial activity for using the limited natural resources efficiently for a long term.

Although there are different construction systems, reinforced-concrete structures are still common. Easy supply and low cost of raw materials, easy forming, and low know-how requirement in the production process are main reasons of using concrete in construction projects. In a concrete building, the cost of concrete may rise up to 10% of the total project cost [3]. In addition, according to Turkish Ready Mixed Concrete Association [18], Turkey has an annual ready-mixed concrete (RMC) production amount of 102 million m^3 (Figure 2).

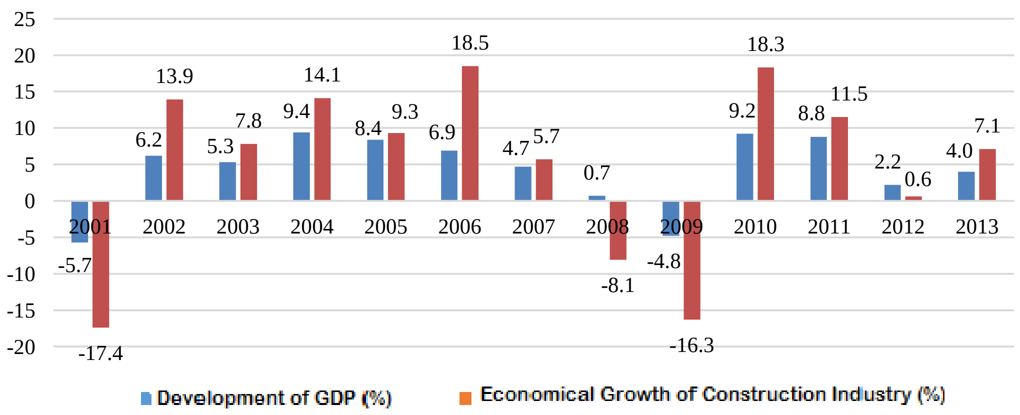

Figure 1. Comparison of the economic role of the construction industry with the development of GDP in Turkey

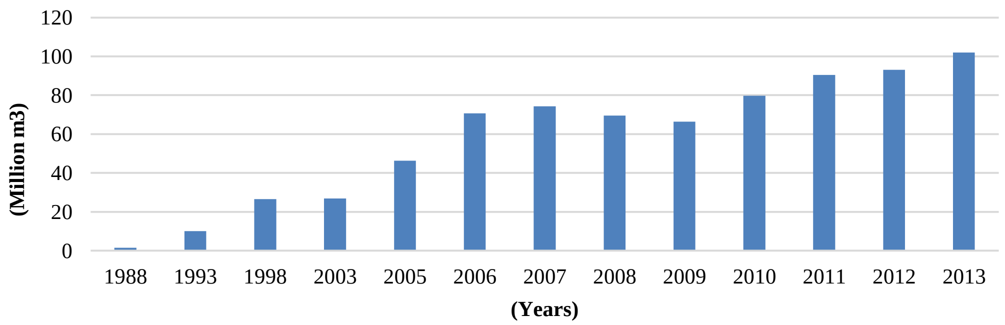

Figure 2. The annual production amount of RMC

This production amount places Turkey in the first rank in Europe and the third rank in the world (Table 1). Therefore, it can be argued that concrete wastes have a big impact on construction-based wastes, and reducing them will improve both macro-economic conditions and the built environment in Turkey.

Waste management encompasses preventing, collecting, transporting, and disposal of wastes. Main principles of waste management are reducing, reusing, and recycling of wastes. Therefore, for an effective waste management procedure in a construction site, it is important to determine which kinds of wastes can be reduced, reused, or recycled. Concrete wastes appear in two ways during the whole lifecycle of a construction project: (i) as the fresh concrete waste during the implementation phase and (ii) as the demolition waste during the destruction of the structure.

Demolition wastes are generated as hardened concrete after the building completes its economic life. Therefore, reducing demolition wastes or recycling them to their raw materials seems impossible in the current technological conditions. However, reusing crushed demolition wastes as filling materials or aggregate for fresh concrete are common practices in the construction industry ([1], [11], [14], [15], [21], [2], [6], [13]).

Fresh concrete wastes occur both in construction sites and in RMC plants at the start of the economic life of a project before concrete gets hardened. There are recycling facilities which separate the fresh concrete to its raw materials. Therefore, identifying the sources of fresh concrete wastes can be helpful both for determining preventive measures and for calculating the amount of this waste that can be recycled. In this context, the current paper presents a study that aims to identify the sources of fresh concrete wastes in RMC plants as a part of an on-going research project.

Table 1. The RMC production amount of ERMCO countries in 2013

Country	Amount of Production (million m^3)	RMC per Person (m^3/person)
Spain	16.3	0.3
İtaly	31.7	0.5
Turkey (2013)	*102*	*1.3*
Germany	45.6	0.6
France	38.6	0.6
England (UK)	19.6	0.3
Portugal	2.7	0.3
Belgium	12.5	1.1
Poland	18	0.5
İreland	2.4	0.5
Netherland	6.6	0.4
Norway	3.8	0.8
Sweden	3.3	0.3
Total of Europe	218.1	0.5
Russia	44	0.3
USA	230	0.8
Japan	99	0.8

2. LIFECYCLE OF THE FRESH CONCRETE

Concrete is mainly used to produce the bearing elements of a structure. Therefore, the quality of the fresh concrete has a big impact on the strength of a structure. This quality depends on the mixing ratios of raw materials used in the fresh concrete production. For example, an increase of 20% and 30% of the water content will decrease the strength of concrete by %30 and 50%, respectively [17]. Although the concrete quality is determined by internationally and nationally accepted standards, the fresh concrete produced in site by unskilled workers will likely have a high risk for quality. In addition, since the amount of concrete produced in site is limited, every production may also have different qualities. In order to overcome these problems, the fresh concrete is produced in RCM plants where the production is supported by automation systems and the product is transported by truck mixers to construction sites.

The production process in RMC plants starts with laboratory tests. In these tests, the quality of raw materials and their compatibilities are evaluated. In fact, these tests are conducted when new raw materials arrive to the batching plant. Therefore, each RMC plant has also a quality control department. After these tests are completed, for each concrete class a specific mixing ratio is determined and saved into the automation system.

In RMC plants, concrete is produced in two ways: (i) dry system and (ii) wet system (Figure 3). In the dry system, cement and aggregate are mixed in truck mixers without adding water and admixture. The water and admixture are added at the construction site before concrete is poured. Nevertheless, this system seems to be logical when the transport distance is too long. If the transport time exceeds two hours, there will be some quality problems. If the moisture content of the truck mixer is too high, the chemical reaction between cement and aggregate will start before the necessary water is added. In addition, admixtures and water may be added by unskilled workers in site and the necessary mixing for a homogenous concrete production may not be waited. Therefore, in RMC plants, the wet system is more common than the dry system. In the wet system, all of raw materials stored in different places are weighed separately and put into the mixing drum of the plant by means of the automation system. Since over-mixing will lead to segregation in the fresh concrete, the mixing process is continued for a specific duration in mixing drums, and then, the mixed concrete is poured into truck mixers where the mixing process will continue until it arrives to the construction site [9]. Finally, in construction sites, the fresh concrete transported by truck mixers is poured into formworks by concrete pumps, and residual concrete is transported back to RMC plants.

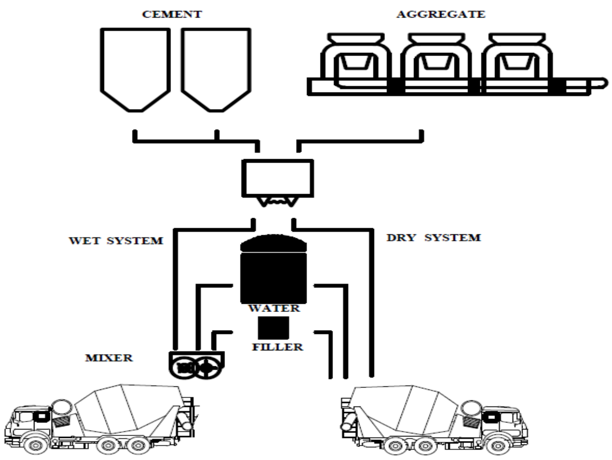

Figure 3. The operation schema of RMC plants

3. SOURCES OF FRESH CONCRETE WASTES

In order to identify the sources of fresh concrete wastes, three different RMC plants operating in different cities in Turkey were investigated as a part of an on-going research project. Each RMC plant was visited once a week for 12 months. After detailed observations, four sources for fresh concrete wastes were identified as follows.

3.1. During the Filling Process of Truck Mixers

Since the hopper of a truck mixer is at the back side, truck mixers have to draw close backwards to the mixing drum's discharging part. In this situation, depending on drivers' abilities, sometimes the hopper and discharging parts do not match exactly, and as a result, some fresh concrete is unintentionally poured outside of the truck mixer. In addition, if the production stops for a while or the concrete class changes, then the mixing drums should be washed up. In this process, some fresh concrete waste is generated. Although the amount of waste generated by each filling or washing up effort seems to be negligible, the sum of this waste in RMC plants with high production amounts becomes remarkable. For example, the waste amount shown in Figure 4 was produced within two hours in an RMC plant with an average daily concrete production of 750 m^3. However, it is very difficult to measure the amount of this waste due to the intensive vehicle traffic. In practice, when the production stops, this waste is collected and stored by loaders in the debris area.

3.2. Quality Control Laboratory

In RMC plants, besides the quality control of raw materials, the quality of the fresh concrete has to be controlled. In practice, for this purpose, some fresh concrete from each production is taken and filled up into cube formworks in the laboratory of the RMC plant. In general, this exceeds the needed amount, and hence, some fresh concrete waste is also generated in this process.

3.3. The Adhesive Concrete in a Truck Mixer's Drum

Although truck mixers try to pour all of the fresh concrete content in construction sites, there always remains some adhesive concrete in their drums. Therefore, after truck mixers return to RMC plants, their drums are washed up by adding about 200-300 liter water. In the context of the ongoing research project, in each visit of RMC plants, 10 truck mixers were washed and the waste content was measured. The preliminary statistical analysis revealed that approximately 500 kg aggregate comes out as waste in the 100 m^3 fresh concrete production.

Figure 4. The waste generation during the filling process

3.4. The Over-Order Concrete

In construction projects, wastes are inevitable. Therefore, the planned material amount rarely matches with the actual material need. Especially in concreting works, this difference can be observed more clearly due to some reasons such as the content of filler blocks and reinforcement and poor workmanship. In order to overcome this problem, many planning engineers have the tendency of over-ordering materials. For this purpose, they determine a coefficient based on their own personal experience and multiply it with the planned amount [[12], [7], [4]). Nevertheless, since these coefficients are based on experience and are not exact values, almost in every order the residual fresh concrete occurs because of over ordering. However, in practice, this residual concrete is not stored in the debris area. Instead, if the transport duration does not exceed two hours, it is mixed with lower class concrete of another order and used in other projects. For example, if the residual concrete class is C30, it is mixed with C25. Therefore, this type of wastes is mostly encountered at the end of the working day. Since this type of wastes is documented, the amount is measurable.

The aforementioned types of wastes are a part of the production and are inevitable. In addition to these waste sources, it was also observed that fresh concrete wastes are also generated from a problem in production, such as the breakdown of some machines. Although the amount of this waste can be huge when compared with other types of concrete wastes, it occurs rarely and randomly. For example, during on-plant observations, 3 m^3 fresh concrete was produced only once.

Similar to other enterprises, the aim of RMC plants is to make some profits. In this respect, many RMC plants neglect the environmental impact of fresh concrete wastes and do not strive to reduce or recycle these wastes. Interviews with plant managers revealed that the low cost and easy supply of raw materials are main obstacles for taking countermeasures.

4. CONCLUSIONS

In today's highly industrialized world, an enormous amount of wastes is originated from the construction industry. Since wastes are unused materials that do not have an economic value, they conversely affect both macro-economic conditions and the built environment of a country or a region. In this context, waste management becomes an important aspect of project management.

For an effective waste management procedure, it is important to determine which kinds of wastes can be reduced, reused, or recycled. In this regard, the first step of waste management should be the determination of waste sources. In this study, it was aimed to identify the sources of fresh concrete wastes in RMC plants. Toward this aim, three different RMC plants were observed in every week for a year. The results revealed that fresh concrete wastes are generated in four different sources in an RMC plant (i.e., during the filling process of truck mixers, quality control laboratory, the adhesive concrete in the truck mixer's drum, and overordering). Because of the operation process of the batching plants, only adhesive concrete in the truck mixer's drum and the over-order concrete are quantifiable.

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