Effects of Alternative Fuels and Raw Materials in Sustainable Cement Production

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Abstract

As the demand for sustainable materials increases globally, the construction material producers need to supply materials that can be used in environmentally responsible buildings without compromising ecological conditions otherwise they may face with losing their market share. Such projects aim to use eco-friendly materials that encourage the consumption recycled and renewable materials, locally manufactured with less harmful gas emissions with long and durable profiles. Cement is the key material to satisfy housing and modern infrastructure needs. However, cement production has huge impact on the environment while releasing significant amount of harmful gases to the atmosphere. Cement plants account approximately 5 percent of global emissions of carbon dioxide, one of the main causes of global warming. Therefore, the cement industry has developed many opportunities to use alternative fuels and raw materials. Our aims in this paper are expressing the sustainability of building materials in Turkish construction industry through a case study analyzing cement production and emphasizing the effect of using alternative fuels and raw materials (AFR) for sustainable environment. Sustainability of building materials in Turkish construction industry is analyzed through a cement company located in Istanbul.

Keywords: Sustainability, green building, cement, Turkey, AFR

1 Introduction

According to Annual Energy Outlook prepared by U.S. Energy Information Administration (EIA, 2006; EIA, 2008), construction sector is recognized as the largest source of carbon emissions worldwide and impacts of buildings on releasing CO₂ emission is 39%. Negative environmental impacts arise from several construction activities, and building materials manufacturing and transportation consumes energy, generating emissions linked to global warming, acid rain and smog causing negative environmental impacts (Lippiatt, 1999). Due to significant impacts, mitigation efforts have emerged in the past decade. The main objectives of these efforts are to preserve the natural resources as much as possible while providing benefits in environmental, social and economic perspectives. On the other side, construction sustainability performance is indispensable to the attainment of sustainable development (Shen et al., 2007). For this purpose, green building and sustainability concepts are gaining more attention among construction-related societies. Increasing demands for minimizing the consumption of water and energy, considering appropriate materials for more eco-friendly buildings force the companies to improve the aspects of construction phases. It is important to provide more data on the level of emission generated by construction materials so that clients, design consultants, contractors and end-users can make more informed decisions on materials selection (Ng, et al., 2011). With the realization that economic development and the environment are linked, engineers, architects and project managers strive to avoid adverse
 impacts on society and the environment by adopting sustainable development during design and implementation of development projects (Da Silva et al., 2009).

Sustainable buildings use resources such as energy, water, materials and land more efficiently than buildings that are simply built to code (Kubba, 2010). As the interest in green buildings increase globally, the construction industry is becoming more involved in “green” projects and consequently many structures are being constructed in different parts of the world. Today, the public is better informed on sustainability, much more focused on energy and expect to see results (Holland, 2010). According to Kubba (2010), the main benefits of building green include:

- Reducing energy consumption
- Protection of ecosystems
- Improved occupant health

Several certificate systems are established to organize the standards of green construction in various countries. British system which is developed by Building Research Establishment (BRE) is known as BREEAM (Building Research Establishment Environmental Assessment Method), while another system is developed in United States by U.S. Green Building Council (USGBC) and known as LEED (Leadership in Energy and Environmental Design). There are some other certification systems improved in different countries like Japan, Canada and Australia. Turkish certificate system for green construction has not been established yet. However, many efforts have been spent for the past years and are still continuing to form a country-specific rating and certificate system. In the mean time, either BREEAM or LEED is used in the projects that are being designed and constructed with the concepts of green building and sustainability. As of May 2012, 19 buildings are certified by LEED while 60 buildings are in registration process (USGBC, 2012). Also, there are 19 buildings rated by BREEAM certification system (Greenbooklive, 2012).

LEED, one of the most preferred certificate systems in Turkey, involves seven categories: sustainable sites, water efficiency, energy and atmosphere, materials and resources, indoor environment quality, and innovation and design. The categories have different weights and choosing proper materials is important for obtaining higher ratings for the buildings which are evaluated and weighted based on their potential impacts on the environment. The “materials and resources” category accounts for approximately 14% of all points. A correct selection of materials must be done in order to save energy, as well as to reduce CO₂ emissions (Gonzalez and Lacouture et al., 2009). The “materials and resources” category gives credit and encourages the use of recycled materials, rapidly renewable materials, locally manufactured environmentally responsible materials. The major properties of these sustainable materials include zero or low offgassing of harmful air emissions, zero or low toxicity, addition of reused and recycled content, high recyclability, durability, longevity and local production. Such products also promote resource conservation and efficiency (Kubba 2010). For the LEED certificated buildings in Turkey, “materials and resources” category ratings are relatively less than the rates of other categories as Turkish building material industry is just experiencing its baby steps towards sustainability. The main reasons can be listed as follows:

- Some of the criteria in these certification systems are not applicable in Turkey
- Some of them should be adopted based on the local conditions and regulations.

The demand for the assessment of the environmental characteristics of building materials has recently started in Turkey, yet cannot be considered as a big movement. It can rather be accepted as the first step of green approach in construction industry. Some building material producers started implementing this approach in their production processes and certificated their products by different type of labels expressing the environmental attributes of their products.

2 Sustainable Building Materials - Role of Cement in Green Buildings

Production process of one particular building material, which is cement, have a huge impact on the environment because of releasing significant amount of CO₂ emissions. Concrete is by far the World’s most consumed manufactured material. Therefore, cement is considered one of the most important building material since it is mainly used for the production of concrete. Cement plants already account for 5 percent of global emissions of carbon dioxide, one of the main causes of global warming (Rosenthal, 2011; Damineli, 2010). As pointed out in CEMBUREAU Environmental Product Declaration for Cement, 899 kg CO₂ is released during the production of
1000 kg cement (Cembureau, 2008). According to Cement Sustainability Initiative (CSI, 2011), which was established in order to reduce CO₂ emissions from cement production by 23 major cement producers with operations in more than 100 countries, it is estimated that 80% of the future emissions from cement plants will take place in developing economies (CSI, 2011). There is a tendency for decreasing the CO₂ emission of cement production, thus decreasing the environmental impact. CSI members pledged to work with stakeholders to develop a protocol for measuring and reporting CO₂ emissions from cement manufacturing. Working together with European Cement Research Academy (ECRA), The European Cement Association (CEMBUREAU) (2008) completed the Environmental Product Declaration (EPD) for Portland cement (CEM I) and defined their prime purpose is to provide measurable and verifiable input for the environmental assessment of construction works (Cembureau, 2008).

Turkey plays a major role in the production of cement. The production capacity of cement sector in Turkey was merely 20 thousand tons in 1911. In its 100th year, Turkish cement sector has reached a usable production capacity over 80 million tons. Turkey ranks first in Europe and 4th in the world after China, India and USA. (US Geological Survey, 2011). Turkey also holds the first place in exports according to 2010 data (Ignebekcili, 2011). Despite of the increasing cement production within the country, the environmental impacts and sustainability aspects are still less considered.

This study aims to express the sustainability of building materials in Turkish construction industry through a case study analyzing cement production and emphasizing the effect of using alternative fuels and raw materials (AFR) for sustainable environment. Effects of alternative fuels and raw materials in sustainable cement production are analyzed through one of the most prominent case studies handled through other disposal solutions such as landfill, which are less preferable in terms of environmental protection.

### 3 Effects of Alternative Fuels and Raw Materials in Sustainable Cement Production

Large amount of fuels and raw materials are consumed during the production of cement and using alternative fuels and raw materials can help to reduce the CO₂ emissions, thus, supply more sustainable cement production. We have to separate the CO₂ emissions from cement production into two categories: those produced by the combustion of fossil fuel necessary to drive the manufacturing process and those simply derived from carbon compounds in the raw materials that are converted to CO₂ during the manufacturing process (Gartner, 2004).

#### 3.1 Alternative Fuels

In Turkey, the energy consumption in 2005 is supplied mainly by petroleum, coal and natural gas. (33%, 28% and 27% respectively). The structure of energy resources heavily rely on fossil fuels (Ministry of Energy and Natural Resources General Directory of Energy Affair, 2006). Lignite or petroleum cokes are the primary fuels used in cement kilns. The replacement of these fossil fuels with wastes and industrial by-products (alternative fuels) can contribute to sustainable development while lowering the CO₂ emissions and reducing the cost of production. By far the largest proportion of energy consumed in cement manufacture consists of fuel that is used to heat the kiln. Therefore the greatest gain in reducing energy input may come from improved fuel efficiency (Hendriks et al., 2003). 40% of the total CO₂ emission in cement production is caused by consuming fuels (Akcansa, 2009); use of alternative fuels plays a significant role in overall emission reduction, although care should be taken for high volatile elements as mercury and thallium (Hendriks et al., 2003).

The share of the total CO₂ emissions of Turkey represented by the cement industry is 10% (Akcansa, 2009). This is higher than the world average which is accepted as 6% (McCaffrey, 2002). This illustrates the importance of using alternative fuels in order to reduce CO₂ emissions in Turkey. Alternative fuels can be used in cement kilns instead of carbon based fossil fuels such as lignite or petroleum coke. Thus, the energy requirement can be met by using wastes as an alternative to fossil fuels in cement kilns, and therefore reducing the amounts that need to be handled through other disposal solutions such as landfill, which are less preferable in terms of environmental protection.

The cement company establishing waste acceptance procedures and including waste and industrial by-products properly into the fuel system are the main steps of AFR (alternative fuels and raw materials) management system. Additionally, the physical and chemical properties of the waste sample are checked to ensure the waste’s compliance with legal limits and specifications. Another major advantage of burning waste materials in cement kilns is that no residues are generated, since the ash is completely incorporated in the clinker (Damtoft, 2008).
The alternative fuels consumed in one of the largest plants of the Company are used-tyres, refuse derived fuel (RDF) plastic, contaminated waste (Fig. 1), waste oil, scrap paper, waste soil, husk, tank bottom sludge, sewage sludge and scrap rolling soap. In 2011, the Company has used 68,500 ton of alternative fuels thus saved 36,000 tons of coal. This amount gives a 4.58% calorific substitution rate, while 29% is targeted for 2020. According to the measurements obtained from several tests in their laboratory, consumed alternative fuels and supplied energy by these products are shown in Table 1.

![Image of contaminated waste](image.png)

**Figure 1.** Contaminated waste as an alternative fuel source

**Table 1.** Wastes used for alternative fuel sources and their energy (Akcansa, 2010)

<table>
<thead>
<tr>
<th>Wastes</th>
<th>Energy (kcal/kg) (Petcoke ~7500)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Used tyre</td>
<td>5500</td>
</tr>
<tr>
<td>Industrial Plastic</td>
<td>4350</td>
</tr>
<tr>
<td>Scrap Rolling</td>
<td>3500</td>
</tr>
<tr>
<td>Waste Oil</td>
<td>3500</td>
</tr>
<tr>
<td>Scrap Paper</td>
<td>3400</td>
</tr>
<tr>
<td>Contaminated Waste</td>
<td>3400</td>
</tr>
<tr>
<td>Husk</td>
<td>4760</td>
</tr>
<tr>
<td>RDF plastic</td>
<td>2800</td>
</tr>
<tr>
<td>Sewage sludge</td>
<td>2000</td>
</tr>
</tbody>
</table>

Beside the advantages of using alternative fuels in cement kilns, their use can lead to some operational challenges. Therefore some improvements and provisions should be considered to minimize the possible problems such as plugging in cyclones, fluctuation in cement quality and higher maintenance requirement and operational costs (MVW, 2010).

Alternative fuels that have high amount of chloride like PVC should be used in limited amounts, because it is known that chloride presence in cement are limited by standards. Therefore fuel mix optimization is very critical in terms of sufficient heat value in kiln and cement quality.

Turkey is a developing country and there is a high consumption of materials and resources. Although the legal authorities are promoting the use of waste materials by cement companies through strategy papers and regulations, it is still hard to reach alternative fuels (Republic of Turkey Ministry of Forestry and Water Affairs, 2010) The company mentioned in this paper has a promising capacity to use alternative fuels but the main difficulty is to obtain alternative fuels in desired amounts. The main reason is that there is a deficiency in waste collection and recycling systems. It should be noted that cooperation with municipalities in sourcing alternative fuels and reuse/recycling of waste is of vital importance. The company strives to create cooperation opportunities with municipalities to obtain refuse derive fuel and sewage sludge to use as a source of fuel. A campaign is also announced on the internet to collect waste for this purpose (Akcansa, 2012).
3.1.1 Refuse Derived Fuel (RDF)

Using RDF as a supplemental fuel in cement production is an economically viable option to reduce fuel costs and landfill disposals. However, its effect is changing with the cost of capital, coal and landfill disposal prices. There are also several advantages of RDF such as decreasing CO₂ emission and ash residue, producing more homogeneous fuel, having a higher calorific value content and a lower moisture content, etc. (Kara et al., 2008) The company has cooperated with The Scientific and Technological Research Council of Turkey (Tubitak) and Istac Co. to investigate the potential of alternative fuels derived from municipal solid waste. The industrial plastic pretreatment facility is established to disintegrate and transform the nonhazardous and inert material into RDF (Fig. 2). In this facility, nonhazardous waste from various industries is handled. RDF manufacturing process can be seen in Table 2.

**Table 2. RDF manufacturing flow diagram**

<table>
<thead>
<tr>
<th>Waste</th>
<th>Acceptance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Primary Shredding</td>
</tr>
<tr>
<td></td>
<td>Metal Separating</td>
</tr>
<tr>
<td></td>
<td>Secondary Shredding</td>
</tr>
<tr>
<td></td>
<td>Separation/Drying</td>
</tr>
<tr>
<td></td>
<td>Refuse Derived Fuel (RDF)</td>
</tr>
</tbody>
</table>

**Figure 2. Using refuse derived fuel plastics in RDF Plant**

3.1.2 Tyre Derived Fuel (TDF)

Three tyre feeding systems in three kilns of the company have disposed 12.2 millions of scrap tyres within last 7 years (Fig. 3). The environmental benefits of utilizing scrap tyres as a supplemental fuel in the portland cement
manufacturing process are multifold. When whole tyres are combusted in cement kilns, the steel belting becomes a component of the clinker, replacing some or all of the iron required by the manufacturing process (Epa, 2008).

However, none of the differences in the emission data sets between tyre derived fuel (TDF) versus non-TDF firing kilns for sulfur dioxide, nitrogen oxides, total hydrocarbons, carbon monoxide, and metals were statistically significant. Separate studies conducted by governmental agencies and engineering consulting firms have also indicated that TDF firing either reduces or does not significantly affect emissions of various contaminants from cement kilns (Epa, 2008).

Figure 3. Used tyres as an alternative fuel source

3.1.3 Sewage Sludge

The disposal of sewage sludge (Fig. 4) generated for sewage treatment plants is causing an important waste management problem. Cement companies are able to use sewage sludge with calorific energy potential as one of the alternative fuel sources. The Company within the licence of “using waste as an alternative fuel” from Ministry of Environment. Thus, dried sludge are also used as alternative fuel in its rotary kilns. Accordingly, a cooperation has been started between the Company and the operators of Istanbul Water and Sewarage Administration (ISKI) Ataköy Waste Water Treatment Plant to supply 45,000 tons of sewage sludge annually. In order to feed rotary kilns with dried sludge that are transported by silobuses from Ataköy Waste Water Treatment Plant, essential storage and feeding systems were constructed inside the plant. Mentioned system consists of storage of waste in closed silos and conveying to rotary kilns through feeding units. The facility is in compliance with environmental, health and safety regulations. The use of sewage sludge does not generate additional emissions, also of all proven technologies, the co-processing of sewage sludge in a cement kiln offers the largest reduction of CO₂ equivalents per ton of dry sludge (Theulen and Szabó, 2010).

Figure 4. Sewage sludge
3.2 Alternative Raw Materials

The rising prices and depletion of raw materials and growing concerns about sustainable environment caused an increasing interest in the recovery of materials and using industrial wastes and by-products for cement manufacture. Such alternative materials may partially replace fuel, conventional raw materials (limestone, clay, etc.) and clinker in the final composition of cement (Puertas et al., 2008). The amount of clinker needed to produce a given amount of cement can be reduced by the use of supplementary cementitious materials such as fly ash, slag, microsilica and natural pozzolans. The replacement of these materials with clinker not only reduces the amount of clinker required per ton of cement produced, but also reduces the amount of wastes and landfill materials caused by industrial by-products. Therefore environmental impacts and costs of cement may be reduced.

In cement production, the company substitutes natural raw materials with alternative raw materials, wastes and industrial by-products. Grid has the largest share in the use of alternative raw materials in the company. Grid is followed by pyrite ash, excavation soil and the blast furnace slag derived from iron–steel production, respectively. Marble wastes containing minerals such as aluminum and iron as well as other wastes such as foundry sand, iron powder, scales, plaster chipping, bypass powder, volatile ash and iron dross are also utilized in the cement production process. Also phosphogypsum, which is a pollutant residue obtained from the production of phosphoric acid in the phosphate fertilizers industry, is used as an alternative of gypsum. By using these industrial wastes the need to extract natural raw materials is reduced. This action contributes not only to the protection of natural resources and consequently the environment but also to the reduction of cost. Depending on the used ingredients, total CO₂ emission during the production of cement can be reduced by using less clinker as seen in Figure 5. In addition, total energy consumption can be reduced from 121 kWh to 98 kWh for producing Blended Cements, resulting with approximately 20% energy saving. The company also produces ground granulated blast furnace slag (ggbfs) and CEM III type cement. The other cement factories of the company use ggbfs in producing blended cements. Ggbfs is also used as a minor additive in cement production and as a mineral additive in concrete production.

![Figure 5. CO₂ emissions during the production processes of Ordinary Portland Cement and Blended Cement (Hoenig and Schneider, 2002)](image_url)

4 Summary

As a result, with the concepts of green design and sustainability with widely accepted application of certificate systems, companies producing building materials need to supply materials that can be used in environmentally responsible buildings without compromising ecological conditions. Green building certification systems require materials to possess green properties which are manufactured with respect to sustainability perspective. The green buildings in Turkey are mostly constructed based on LEED and BREEAM requirements. Correct choice or substitution of materials in these projects is helping to obtain higher ratings for these certificates as well as reducing the environmental footprint. The companies producing the materials for constructions need to focus on sustainable development and produce more eco-friendly materials.

The major objective of this study is to investigate using alternative fuels and raw materials by a Turkish cement manufacturing company. The sustainability report of the selected company is analyzed to understand what kind
of efforts and process improvements are needed in Turkey to contribute to minimization of negative environmental impacts. The investigated company operates 3 cement plants, 5 cement terminals, 38 ready mixed concrete plants and 4 aggregate plants. Declaring its products’ properties in terms of sustainability, the company recycles the residual concrete of building sites, separates and disposes the wastes (other than process wastes) in accordance with the legal legislation. Taking into consideration of “materials and resources” category in the certification systems, the company aims to contribute higher ratings from this part. Using alternative fuels and raw materials at the production of cement is the main part to improve the sustainability approach of the company. Their methods such as using alternative fuels and raw materials in cement production are helpful for obtaining following environmental benefits which are also emphasized in green building certifications:

- Protection of natural resources by using alternative fuels and materials
- Reduction in CO₂ emission
- Providing post incineration zero waste
- Obtaining energy efficiency
- Reducing the rate of clinker usage in cement

The awareness of sustainability and green buildings is becoming prevalent in Turkish construction industry and material producing companies. This would eventually lead to implementing pertinent procedures during manufacturing processes of the construction materials.

References


