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Turkey at the Beginning of the 21st Century:

New Perspectives

Editors
Metin Ayışığı
Recep Efe
Ömer Düzbakar
Mehmet Arslan

Chapter 57

Turkish Waste Blended Cement in 21st Century: A Research in the Context of Industrial Symbiosis

Z. Sevgen PERKER

1. INTRODUCTION

A significant consequence of industrialization activities across the world is the rapidly increasing population of cities, thus increased need for buildings. Efforts to meet such need for buildings in a short period of time have brought concrete, and accordingly cement, to the fore as building material. In our century, Turkish cement industry has a very notable position for Turkish economy as it only uses raw material resources of its own, meets the domestic need, ever increasing exportation, and generates a large employment (Bağrıaçık, Budak, & Laptalı Oral, 2013).

Another consequence of industrialization is the generation of a large volume of industrial waste. In Turkey, industrialization activities that have particularly accelerated in the second half of 20th century have resulted in increased investments in construction in cities, thus increased need for the concrete and cement material, on the other hand a variety of industrial wastes have started to create a significant environmental pollution especially in cities. This has led to investigating properties of industrial wastes and reusing them in various industries.

In 21st century, a variety of research has been conducted in Turkey that holds an important position in construction industry in order to use industrial wastes as additive or substitution material for manufacturing various materials in construction industry in particular, and even to use such industrial wastes alone as a building material. These researches are mainly focused on cement. Such developments have a vital importance to prevent rapid consumption of limited natural resources and minimize environmental issues due to industrial wastes.

2. CEMENT AS A BUILDING MATERIAL AND TURKISH CEMENT INDUSTRY

Cement is a hydraulic binder that is produced by grinding “clinker” with one or more additives which is a semi-finished material obtained by firing raw materials containing silicon, calcium, aluminum and ferric oxide to the sintering degree using technological methods. In the process for manufacturing cement, a variety of raw materials that are exploded and extracted from mines are loaded on vehicles to transport to crushers for crushing process. After crushed by crushers, raw materials are first separately stocked then taken from stocks to be mixed in certain ratios, and grinded by raw mills. The mixture, referred to as raw meal blending, is stocked in the stock of raw mill to be fired, then the raw meal blending is processed by pre-heaters and transferred to a rotary kiln to be kilned at 1400-1450^{0}C. The semi-finished material that is a produced by the rotary kiln as clinker is cooled by the cooler and stocked at the stock corridor of the clinker. It is then grinded by a cement mill with gypsum and additives suitable for the type pf cement to be produced. The cement is stocked in separate silos according to types of cement and put in the market as bagged cement or bulk cement (Kapkaç, 2012; Yalçın & Gürü, 2006).

In the world, the first cement was produced by kilning and grinding the blend of fine-grained limestone and clay in the United Kingdom in. The produced cement was referred to as “Portland Cement” as its properties and color were similar to natural building block that was brought from the island called “Portland”, and in 1845 its properties were improved to achieve a very critical building material that is widely used across the world (Kapkaç, 2012). Initially, while all of the world countries only produced Portland cement, currently there are different types of cements that have gained different properties through a variety of additives in today’s cement industry.

The first Turkish cement plant that had a kiln with capacity of 20.000 ton/year was established in Darıca in 1911. The capacity of this plant was increased to 40.000 ton/year in 1923. By 1950s, Turkey’s annual capacity of cement production reached 370.000 ton in total when 1 plant each was set up in Ankara and Sivas and 2 plants were set up in Istanbul. The period of 1950s was a productive time for institutionalizing of Turkish cement industry, and Turkish Cement Industry T.A.Ş. (ÇİSAN) and Turkish Cement Manufacturers' Association (TÇMB) were established. During this period, although no increase was achieved in production, the cement import was maintained by 1970s because the demand was not sufficiently satisfied (Anonymous 2014). The major cause for this was the increased need for the cement due to increasingly growing urbanization and development activities in Turkey as a result of industrialization of cities in such period. During the years of 1970, the export was improved because the domestic market was not very active for cement industry due to country’s general economic structure. During 1980s, 34 cement plants were installed across the country, and the need for real estate came to the fore again with influence of Mass Housing Law enacted in 1984, which increased the demand for cement, and thus cement production. Although only few cement plants were set up in Turkey in 1990s, during 2000s the requirement for cement was increased more than ever in the country’s history due to economic growth and investments in hosing by the private sector. The cement can therefore be defined as the material of the century (S. İpek & Aydın, 2009; Yeğinobalı, 2003).

The major types of cements currently produced in Turkey include Portland cement, blended cement, high early-strength cement, slag cement, sulfate-resistant cement, trass cement, white Portland cement, fly ash cement, super sulfate cement, Portland slag cement, Portland silica fume cement, Portland-limestone cement, Portland composite cement, pozzolana cement, and composite cement (Yeğinobalı, 2003).

3. INDUSTRIAL SYMBIOSIS AND USE OF WASTE MATERIALS IN CEMENT

In today’s world, on one hand rapidly depleted natural resources and energy resources and on the other hand ever-increasing environmental problems have forces us to question whether sustainable industrial production and growth are actually possible. The concern of all of the world countries for sustainable development has paved the way for putting the concept of industrial ecology on the agenda, thus for creating an approach for industrial symbiosis. One of the most significant indicators of industrial ecology is the industrial symbiosis, thus the industrial ecology is aimed at creating industrial added value through a holistic perspective including environmental, economic and social aspects. As known, symbiosis is defined as the ability of different species to live together under certain conditions. Co-existing species gain mutual benefits from each other's existence. Industrial symbiosis means adaptation of this collaboration existing in the nature to industrial entities, of productivity of natural ecosystems to industrial systems. In other words, establishment of partnerships by industrial entities to have mutual benefits is referred to as industrial symbiosis. As part of industrial symbiosis, resources such as energy, logistics, human resources, investment, water, etc. are jointly used by different industrial entities, and the most important collaboration on this is to reuse industrial wasteS (Demirer, 2011, URL-1).

With industrial symbiosis, industrial wastes and by-products can be recovered, use of resources and environmental pollution can be reduced, and raw materials and energy can be efficiently used (URL-1). In this respect, the major issue that needs to be questioned is the compatibility of different industries in terms of material input and output. The cement is a building material that has a high potential for reusing industrial wastes (Ulutaş, 2013). Industrial wastes that can be used for production of cement include fly ash, bottom ash, silica fume, blast furnace slag, marble, ceramic wastes, gypsum waste, boron-containing wastes, soda and beer wastes, waste tire dusts, and rice-husk ash.

3.1. Fly Ash and Bottom Ash as Cement Additive

The fly ash is a waste product that is produced by burning coal at thermal power plants operated by coal. The burning coal produces flue gasses, fly ashes and flue bottom ash that has coarser grain than them. Fly ashes are stored with other ashes, causing a waste problem that needs to be solved. There are many Turkish investigations and studies on reusing fly ash as industrial waste. One of the most important of these is to use fly ash as cement additive. Reusing fly ash for industrial applications, on one hand, means to seamlessly dispose of an industrial waste that is generated in considerable amount, and it is ecologically important. On the other hand, the use of fly ash within the cement and thus providing economic benefits for production would make substantial contributions to building industry that is one of the leading sector of this period (Çivici, 2012).

A study performed in 2007 reported that production of fly ash was approximately 15 million ton per year in Turkey (Başyiğit, Kılınçarslan, & Beycioğlu, 2007). Keeping fly ash in flues partly prevents environmental pollution, a vital problem of today, on the other hand, depositing on an area or disposing results in environmental pollution. Fly ash causes a variety of environmental issues such as dusting, damage to agricultural products, rain splash erosion and wind erosion, infiltration in the soil and thus transportation of toxic substances, and radiation. To prevent such problems, fly ash should be reused in various areas of application to bring it into national economy. The primary industry where fly ash can be made use of is the cement industry (Beycioğlu, Başyiğit, & Subaşı, 2008).

Since the raw materials that are used in the cement are contained in the fly ash, fly ash can be used as a cement additive. In addition, because fly ash displays pozzolanic effect, it can be substituted with cement in the concrete grout. The literature has a large number of studies reporting that fly ash can be used as cement additive (Akkaya, 2013; Alkaya, Çobanoğlu, & Boz, 2008; Atakay, 2006; K. Çelik, 2005; Ö. Çelik; Erdoğmuş, 2006; Gündeşli, 2008; Güvercin, 2002; G. Kaya, 2010; Kibici, 2008; Nas, 2012; Özmal, 2005; Sevimli, 2004; İ. B. Topçu & Karakurt, 2008; Zaimoğlu, 2003)

The bottom ash can be defined as a type of fly ash that has a grain size greater than fly ash. The literature has various researches that bottom ash can also be used as mineral additive for production of cement (A. İ. Kaya, 2010; Kaya, 2005; Özmal, 2005; İ.B. Topçu & Karakurt, 2008).

3.2. Silica Fume as Cement Additive

Silica fume is an industrial waste that is produced during production of silica metal and some metallic alloys. Its amorphous and very fine-grained structure gives silica fume a very favorable pozzolanic character. Increased environmental pollution and improved awareness of reusing industrial wastes have led to investigating different properties of silica fume. It is known that the first study on making use of silica fume to protect environment was performed in Norway in 1950s, and relevant studies were gradually improved and continued by 1980s in Scandinavian countries in particular. Silica fume is currently chosen as both cement and concrete additive in different countries (Çivici, 2012; İ. B. Topçu & Uğurlu, 2007).

The pozzolanic effect of silica fume plays an important role in strengthening the contact surface of aggregate – cement grout that is known to be the weakest point of the concrete. Furthermore, the concrete that is produced by silica fume cement is known to enhance the compressive strength if appropriate mixture is provided. It is possible that concrete surfaces decompose, crack and break into pieces, or become damaged in the form of cavity or through erosion caused by impact of streams under certain conditions of use and traffic loads. However, because the silica fume in the cement increases the resistance of both the paste and interfacial strength of paste-aggregate, it also increases the resistance of concrete against mentioned abrasive impacts. The literature has a wide range of researches that indicate silica fume is appropriate for use as cement additive (Ö. Çelik; Dur, 2003; Gündeşli, 2008; Güvercin, 2002; İ. B. Topçu & Uğurlu, 2007; Zaimoğlu, 2003).

3.3. Blast Furnace Slag as Cement Additive

The process for deriving iron is performed by a specific furnace that is called “blast furnace”. The iron ore needs to be heated up to 1600^0C in a blast furnace in order to derive pig iron from the iron ore. During the process for heating up the ore, the blast furnace slag remains on the crude iron that has an amorphous structure and is lighter than the iron. Because pozzolanic character of blast furnace slag is increased when it is grinded, it become very suitable for use as cement or concrete additive. The slag cement is known to be first used in Germany in 1982, then in the USA in 1896 (Çivici, 2012). The concrete that is produced by cement made of blast furnace slag has improved property for processing. When an appropriate mixture is established, concrete containing slag cement is known to have rather lower resistance in early ages and higher resistance in later ages as compared to concrete containing normal Portland cement; furthermore its tensile strength is higher than that of concrete containing normal Portland cement. The use of cement with blast furnace slag in concrete has somewhat an advantage in abrasion resistance over concrete containing Portland cement provided that appropriate and adequate concrete cure is used. Concrete containing cement with grinded granulated blast furnace slag is considered to be more resistant to sulfate attacks as compared to concrete that only contains Portland cement. The literature has many researches that indicate blast furnace slag is appropriate for use as cement additive (Alpaslan, 2012; Bilim, 2006; Çavuş, 2008; K. Çelik, 2005; Erdoğmuş, 2006; Gündeşli, 2008; Güvercin, 2002).

3.4. Marble Wastes as Cement Additive

Production wastes from marble plants are usually not reused, resulting in problems for environmental pollution. Average 1.750.000 tone of marble is processed a year across Turkey, and wastes in the form of dust and debris produced during processing marbles ay plants account for 30% of processed marbles (M. İpek, İyiliksever, & Yılmaz, 2014). The use of such potential for industrial purposes, on one hand, will provide considerable benefits to national economy, on the other hand, will make major contributions to preventing environmental pollution. The literature has many studies on reusing both marble dust and wastes for a large number of industries including ceramic, cement, paint, glass, and building material but relevant applications are not common as it is expected (Beycioğlu *et al.*, 2008). Some research in the literature on using marble wastes as cement additive indicate that the use of marble wastes for producing refractory cement in particular ensure refractory cement to meet expected standard values (Kavas, 2003). In addition, the relevant literature has studies reporting that marble dust can be used with silica fume and phospho-gypsum as cement additive (Sağlam, 2012).

3.5. Ceramic Wastes as Cement Additive

Ceramic can be defined as a product that is derived by phases including blending of raw materials, namely clay, feldspar and quartz, and forming and kilning. Because ceramic holds a very important position in terms of production volume in the building industry of current Turkey, there are a wide range of plants that produce ceramic. The pieces of wall tile and floor tile are generated as waste product during production at such plants. Although the literature does not include many studies, there are some studies that the use of such ceramic wastes as cement additive meets the required standards for cement (Toker, 2013).

3.6. Gypsum Wastes / Phospho-Gypsum as Cement Additive

As is known, the gypsum is a building material that is produced by slightly kilning and grinding of limestone. In addition to natural gypsum, it is possible to produce a type of gypsum that is called chemical (synthetic) gypsum from various industrial waste materials. The synthetic gypsum, which contains several foreign substances in its chemical composition, is known not to have same properties as natural gypsum. To substitute natural gypsum with chemical gypsum, these foreign substances need to be neutralized. Synthetic raw gypsum, the product referred to as phosphatic gypsum or phospho-gypsum, is a waste product resulting from reaction of phosphate stone with sulfuric acid in the production of phosphoric acid that is used for production of phosphatic fertilizer. 5 ton of phospho-gypsum are generated from production of 1 ton of phosphoric acid. In Turkey, 3 million tone of wastes are created by this way (Sağlam, 2012). Therefore, it is very important to reuse of this waste. The literature has various studies suggesting that when an appropriate mixture is ensured, phospho-gypsum is successful as retarder in the cement, improves the processability of mortar, and provides more favorable results for effects of sulfate (Değirmenci & Okucu, 2002; Okucu, 2006).

3.7. Boron-Containing Wastes as Cement Additive

Boron minerals and compounds are currently used to produce different products and materials in a variety of industries. Turkey has plenty of colemanite in particular that is one of the boron minerals and can be used as cement additive. Boron-containing cement is produced by using colemanite, an important boron mineral, for boric acid and using the remaining part in the cement. Boron-containing cement is known to have higher resistance values in the long term than those of normal Portland cement when an appropriate mixing ratio is ensured; and concrete made of boron-containing cement is known to have higher resistance and durability as it has less cavities. Boron-containing cement also substantially prevents formation of thermal cracks in the concrete as well as permeability of water and chemicals, thus reduced permeability allows avoiding corrosion problems to a large extent. The literature has a great number of academic studies showing that boron wastes can be used in the cement, and physical, chemical and mechanical properties of boron waste-containing cement comply with applicable standards (Akbulut, 2009; Altınköprü, 2010; Erdoğmuş, 2006; Okucu, 2006; Özmal, 2005; Sümer, Sağlık, Tunç, Kocabeyler, & Çelik, 2008; Taban, Gökçe, & Abama, 2012; Targan, Erdoğan, Olgun, Zeybek, & Sevinç; Uğurlu, 2009)

3.8. Soda and Beer Wastes as Cement Additive

The soda waste generated by production of soda ash and the beer waste generated by beer filtration process are significant local wastes in Turkey and in many different countries. The quality of such wastes, particularly their fineness, allows using them as additive regulating viscosity for self-compacting concrete. Therefore, it is important to use it as additive in the cement to be put in the mortar of self-compacting concrete. The literature has various studies suggesting these wastes to be used as cement additive (Alam, 2009; Güneş, 2010).

3.9. Waste Tire Dust as Cement Additive

The number of vehicles on the road increases in parallel with increased quality of life in the cities across the world. Vehicles have a large number of tires with expired useful life, and these tires pause a threat to environment and human health. Stocking conditions and complex structure of gradually increasing waste tires make difficult to control and recover them (Alpaslan, 2012; Beycioğlu *et al.*, 2008; Koçak & Alpaslan, 2011). To prevent tires from occupying a large area in the storing area, they are incinerated and disposed of, which in turn results in release of various toxic gasses and air pollution. If tire wastes are not stored separately from other wastes, then they create a risk of fire. The fire causes air pollution on one hand, and waste tire oil to be transmitted in the soil and from there to underground water during incineration. Furthermore, the pile of tires creates an ideal environment for mosquitos and rodents to breed. The literature has various studies suggesting that waste tire dust can be used with fly ash or blast furnace slag as cement additive (Alpaslan, 2012; Beycioğlu *et al.,* 2008; Koçak & Alpaslan, 2011).

3.10. Rice-Husk Ash as Cement Additive

One of the wastes that cause a global environmental issue is the rice husk that is a by-product of industrial production and results from production of rice. Approximately 100 million tone of rise husk is generated a year across the world, and approximately 20 million tone of rise husk ash is generated a year from incinerating of risk husk. In this sense, a substantial amount of waste is produced in Turkey. This high amount of waste has led to consider the usability of rise husk ash in the cement industry that is very active in Turkey, so a variety of studies have been performed in this regard. Such studies have showed that if an appropriate mixture is achieved in the rice husk ash substituted cement, the compressive strength is low in the early period, but values of compressive strength of the mortar increases in the late period depending on the successful pozzolanic activity of rice husk ash. In addition, the results of these studies suggest that the rice husk ash reduces the concrete permeability through high filling effect of rice husk ash and contained silica, resulting in favorable effect on the concrete resistance. The literature has several studies indicating that rice husk ash can be used as cement additive (İşbilir, 2012).

4. RESEARCH ON INDUSTRIAL WASTE ADDITIVE IN TURKISH CEMENT

This section of the study includes postgraduate dissertation studies performed since 2000 on industrial waste additive in Turkish cement in the context of industrial symbiosis.

A study by Kula performed in 2000 investigated the effects of fly ash and bottom ash additives on the setting time of cement, expansion in volume, compressive strength, and grinding time. Physical and mechanical properties of cement mixtures were determined in accordance with Turkish standards, and compliance of physical, chemical and mechanical properties of cement mixtures with fly ash and bottom ash with applicable standards was investigated (Kula, 2000). The study performed by Sevimli in 2004 investigated the resistance of fly ash cement and concrete against normal and sulfated water and sea water (Sevimli, 2004). The study performed by Özmal in 2005 aimed at saving energy in production of cement and eliminating the damage to environment that may be caused by waste materials. In the same study, bottom ash and fly ash were added in the cement mixture in different ratios to identify the effects of these additives on the physical and mechanical properties such as setting time of concrete, expansion in volume and compressive strength (Özmal, 2005). The study by Kaya performed in 2005 investigated the usability of waste bottom slag in the cement industry (Kaya, 2005). The study by Atakay performed in 2006 addressed using fly ash for production of blended cement and examined the effects of fineness of ash and amount of additive on the cement properties (Atakay, 2006). The study conducted by Duru in 2006 focused on the resistance of blended cement containing fly ash and natural pozzuolana against the sulfate, and the results were interpreted by comparing additive-free Portland cement and sulfate-resistant cements (Duru, 2006). The study by Kibici conducted in 2008 tests were performed on the samples of fly ash cement of various amounts for viscosity, setting, resistance and shrinkage to identify the changes; and the results of these tests were discussed for properties provided above as well as cost (Kibici, 2008). The study conducted by Kaya in 2010 aimed at investigating resistance characteristics of cement mortar made of fly as additive (G. Kaya, 2010). The study carried out by Nas in 2012 addressed the physical, chemical, mineralogical and mechanical properties of Portland cement containing fly ash (Nas, 2012). The study by Akkaya in 2013 discussed the use of fly ash as cement additive (Akkaya, 2013).

The study performed by Çelik in 2005 focused on the effects of type and ratio of additives in the cement mortar composed of fly ash and blast furnace slag on the resistance and durability properties of pozzolanic cement under different environmental conditions (K. Çelik, 2005). The study performed by Bilim in 2006 investigated the effects of grinded granulated blast furnace slag on the cement mortar and concrete properties. The properties of cement slurry and concrete that were prepared with variable ratios of water/binder and slag were compared with the control mortar and concrete mixtures produced by additive-free Portland cement to determine their resistance and durability properties (Bilim, 2006). The study by Erdoğmuş in 2006 aimed for evaluating addition of fly ash and blast furnace slag in the cement as additives. This study examined the effects of these additives on the mechanical properties of the cement, setting time, volume expansion, compressive strength, and the time for grinding. The most significant aspect of the same study was addition of previously untried binary mixtures of iron dross that Turkey has abundantly as waste material and in the amount that may cause environmental issues and of colemanite concentrator that contains high amount of boron, and to investigate the effects of these additives on the mechanical properties of the cement (Erdoğmuş, 2006). The study performed by Çavuş in 2008 investigated the effects of blast furnace slag on the compressive strength of cement (Çavuş, 2008). The study conducted by Kaya in 2010 underlined the importance of producing blended cement using materials as a substitution of cement such as fly ash, grinded furnace slag and natural pozzolana to reduce energy consumption and ecological problems. The objective of the same study was to assess in-vitro performance of blended cement produced by using fly ash and bottom ash (A. İ. Kaya, 2010). Studies performed by Delibaş in 2012 and Toker in 2013 addressed the effects of blast furnace slag on the properties of the cement (Delibaş, 2012; Toker, 2013). The study conducted by Talefırouz in 2013 identified and interpreted the physical and mechanical properties of the mortar created using fly ash, granulated blast furnace slag, lime and steel slag as cement additive (Talefırouz, 2013).

The study by Dur in 2003 investigated the properties of silica fume cements (Dur, 2003). The study conducted by Zaimoğlu in 2003 determined and interpreted physical and mechanical strength of fly ash and silica fume cement using experimental methods (Zaimoğlu, 2003). The study performed by Güvercin in 2002 aimed to find the effects of silica fume, fly ash and blast furnace slag on the cement (Güvercin, 2002). The study conducted by Gündeşli in 2008 reviewed the sources to investigate the positive and adverse effects of wastes such as fly ash, silica fume and blast furnace slag on the concrete when they were used as concrete and cement additives, and also what sort of results would be obtained when the ratio of substitution was changed (Gündeşli, 2008).

The study performed by Kavas in 2003 emphasized that main raw materials used for producing refractory cement needed to be very clean and very poor in iron and alkali in particular, and he indicated that there were therefore only limited number of raw material deposits. He drew attention that the reserve of existing clean deposits was reduced day by day, or more number of production processes were needed for clean raw materials, thus costs for production were increased. In the same study, the use of marble wastes in the cement as clean raw material was studied. That study compared, and interpreted the results, properties and cost of refractory cement produced by marble wastes with the properties and cost of additive-free cement (Kavas, 2003). The study carried out by Sağlam in 2012 questioned the usability of waste marble dust, silica fume and lime waste to produce cement (Sağlam, 2012). the study by Alişer in 2013 assessed the resistance of cement mortar containing marble dust and glass fiber against sulfate (Alişer, 2013). The study by Gökçer in 2013 investigated abrasion, high temperature and frosting – melting behavior of cement mortars containing marble dust and glass fiber (Gökçer, 2013). The study performed by Kırgız in 2007 examined the possibility of using wastes of marble and brick industry as mineralogical additive in production of cement (Kırgız, 2007). The study conducted by Çiftci in 2004 investigated the usability of brick dust as pozzolanic additive in the cement mortar (Çiftci, 2004).

The study performed by Akbulut in 2009 examined the usability of clay wastes containing boron as additive in the Portland cement (Akbulut, 2009). The study conducted by Uğurlu in 2009 addressed using solid wastes from production of borax with fly ash and volcanic tuff in the cement as additives (Uğurlu, 2009). The study carried out by Altınköprü in 2010 investigated the setting time, volume expansion, compressive strength and grinding time of the cement containing industrial wastes with boron (Altınköprü, 2010).

The study performed by Alam in 2009 underlined that soda and beer wastes were locally produced wastes in Turkey and in many different countries. The same study suggested that fineness of additives was the reason for choosing them in production of concrete, and drew attention on using of these additives as additive regulating viscosity for self-compacting concrete would be appropriate. In the same study, properties of the mortar and concrete made by substituting cement or aggregate with these additives in different ratios were discussed (Alam, 2009). The study performed by Güneş in 2010 aimed to study use of soda solid waste as cement additive (Güneş, 2010).

In the study conducted by Alpaslan in 2012, they performed some tests on the samples of cement paste containing tire dust and blast furnace slag to identify physical and mechanical properties, and interpreted the results (Alpaslan, 2012).

The study performed by İşbilir in 2012 underlined that a large amount of rice husk waste was generated by production of rice. The same study suggested that because the rice husk ash generated by incinerating the rice husk contains high amount of silica, it would have favorable effects on the cement mortar and thus on the resistance properties of the concrete. The authors performed physical and mechanical tests on the samples of cement prepared with rice husk ash and interpreted the test results (İşbilir, 2012).

5. CONCLUSIONS AND RECOMMENDATIONS

As is seen, a large number of postgraduate studies have been performed on the use of industrial wastes in Turkish cement industry from 2000 to the present day, and these are guiding, comprehensive and rich studies for implementation of industrial symbiosis to be performed. On the other hand, Turkish literature has a great number of research projects, articles and reports as well as postgraduate dissertation studies on using industrial wastes as cement additive / substitution.

As a result of review performed for the present research, the number of studies that investigated fly ash, blast furnace slag and silica fume respectively, which were industrial wastes used as cement additive / substitution was higher than studies on the other wastes. This suggests that the number of studies on other wastes should be increased for implementation of industrial symbiosis.

As a result of review performed as part of this study, we determined that technical research infrastructure has been established, which is critically important for implementation of industrial symbiosis in Turkey in the 21st century. It is very important to raise awareness of industrial manufacturers and consumers to implement this infrastructure, therefore while academic research is maintained, consciousness-raising studies on industrial symbiosis need to be performed. There are number of applications implemented for various industries in Turkey regarding industrial symbiosis in the 21st century, however, implementations of cement industry need to be increased considering the amount of wastes produced (URL-2). For this purpose, it is believed that introduction of technical research and existing applications would be beneficial and guiding.

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