INVESTIGATION OF REUSE AND RECYCLING POTENTIALS OF FIBRECEMENT

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ABSTRACT

In recent years, thanks to technological developments, the variety of building materials used in the building sector is increasing. Increasing the diversity of materials expands the usage areas of new materials in construction activities. Building materials, which are the main source of the building production process, have environmental impacts during in the period from the production stage to the use stage. The greatest damage to the environment by building materials is the generation of construction and demolition(C&D) waste. C&D wastes are composed of building materials and components resulting from construction material production, construction, renovation, repair and demolition activities of buildings. Today, C&D wastes which are one of the most important environmental problems emerge at every stage of the building production process and adversely affect human and environmental health. The providing reuse or recycling of building materials is important in terms of reducing C&D wastes. Material properties should be well known and sustainable building materials with minimum environmental impact should be used in order to reduce environmental problems caused by building production.

In this study; the reuse and recycling potentials of the fibrecement board, which is one of the most frequently used building materials in the building sector recently, have been investigated in the production and construction phases. Within the scope of the study; waste management in the production phase, reuse and recycling of the material has been researched in the fibrecement board production facility. In this context; face to face interviews were made with the facility official about the production process of the material and the production phase was photographed in the production facility. Interviews were held with material sales offices and construction supervisors in order to determine the recovery opportunities

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of the material in the construction phase. According to the study; fibrecement board is a building material that has the potential to reuse and recycling during the production and construction phases. It has been concluded that the fibrecement can be recovered at other stages due to the fact that it has more reuse and recycling opportunities especially in the production process and it is a material that can be used in several parts of building does not harm the environment and human health.

Keywords: Fibrecement, C&D Waste Management, Reuse, Recycling

1. INTRODUCTION

Building materials are among the main components of building production systems. Technological developments and rapid urbanization have changed the points of view towards building materials and traditional building materials have been replaced by modern building materials. Increased diversity of materials allows broadening the usage areas of new materials. Although new material usage creates positive outcomes for the building sector, it also brings about environmental problems. Building materials are in a direct or indirect interaction with the environment through a cycle of process consisting of acquisition of raw materials, production and application on buildings, usage, end of usage and recycling or disposal (Terzi, 2009). Researches point out 10-20% of the negative environmental impacts of buildings during their life cycles come from building materials (Kaya & Türkeri, 2010). The building sector uses 60% of all raw materials extracted in the world as a resource. According to a study by Worldwatch Institute, the quantity of raw materials used in building construction is 40%. Depending on the quantity of raw materials used in the building sector, construction and demolition (C&D) waste is a major problem in the world (Lachimpadi, Mokhtar, Pereira & Taha, 2012). C&D wastes, which constitute a significant part of solid wastes, consume 50% of the resources (Ajayi, 2016). C&D waste is defined as waste consisting of all kinds of building materials and elements that arise for various reasons during the building life cycle (Coşgun & Esin, 2006). C&D wastes consist of building materials and components such as concrete, metal, wood, ceramic and plastic that comes out of processes of building material production and construction, renovation, alteration and demolition of buildings. Uncontrolled release of C&D waste into the environment causes air, water and soil pollution as well as damaging living spaces. In Turkey, various legal regulations have been created to reduce the negative effects of C&D wastes on the environment. The 'Waste Management Directive' that was put into effect by the Ministry of Environment and Urban Planning by publication in the Official Gazette dated 02.04.2015 and numbered 29314 is the most up to date regulation. With this directive, it is aimed to reduce the use of natural resources and provide waste

management through methods such as reduction, reuse, recycling and recovery of wastes (The Official Gazette of TR, 2015). According to the data of 2014, more than about 100 million tons of C&D waste was recovered or disposed in Turkey (National Waste Management Action Plan, 2023).

Nowadays, the importance of using sustainable building materials is increasing in the building production process. Sustainable building materials are materials that are sensitive to the environment and the limits of exhaustible resources in production, using raw materials effectively and having the least harmful effects on the natural environment by the life cycle assessment. Usage of these materials has a positive impact on the environment and human health by preventing the decrease in raw material resources and increasing energy consumption. Regarding the environmental impacts of building materials, there are the ISO 14001 Environmental Management System and TS EN ISO 14040 Environmental Management – Life-Long Assessment standards. The TS EN ISO 14040 standard; covers assessment of possible environmental impacts through the life cycle including processes such as raw material supply, production, usage and recycling or disposal after usage. 'Sustainable Use of Natural Resources' was added to the obligatory conditions required for building materials in the 'Building Materials Directive' (305/2011/AB) that put into effect by the Ministry of Environment and Urban Planning by publication in the Official Gazette dated 10.07.2013 and numbered 28703. Sustainability of the use of natural resources depends on whether the building materials can be reused or recycled after demolition, the use of environmentally friendly raw materials and secondary materials in the building and the durability of the building (The Official Gazette of TR, 2013). In the 10th Development Plan of the Ministry of Development (2014-2018), an environment protection policy was determined to increase environmental sensitivity and quality of life in cities by practices such as waste and emission reduction, energy, water and resource efficiency, recovery, noise and visual pollution prevention and usage of eco-friendly materials.

The main building materials that are used in building production are concrete, wood, plastic, stone, bricks, iron and glass. These materials are recovered in various methods such as reuse or as the raw material for another material in the process from production to construction, usage and demolition. In the world, especially in the EU countries, the reuse/recycling rates of building materials are above 70% in the Netherlands, Denmark, Estonia, Germany and Ireland; between 50% and 70% in Belgium, the United Kingdom, France, Norway, Lithuania and Austria; between 30% and 50% in Latvia; between 10% and 30% in Poland, Finland, Czechia, Hungary and Spain (Tojo &Fischer, 2011). Precise data about the rate of reuse/recycling of building materials in Turkey cannot be reached.

In this study; fibrecement board is investigated which are prevalently used in the building sector today. Fibrecement is a general term used for composite materials that are formed by mixing Portland cement, inert/mineral filling materials and various organic fibers (Schoon et al., 2012). Fibercement boards are obtained by turning materials such as cellulose fiber, quartz sand and cement into boards by processing in specialized machines and autoclaving them (Erdem, 2015).

The aim of this study is to investigate the waste management practices in the fibrecement board production and research of reuse and recycling potentials of the material in the production and construction phases. The study is limited to the production and construction phases of the material in the life cycle. Two methods are used as literature and field study in the study. Within the scope of the study; a literature review was carried out on the material; as a field study; interviews were held with an official of a production facility in Sakarya for the production phase, with material sales offices and site supervisors for the construction phase in Sakarya -Turkey. As the field study; the production process stages of the material were photographed, and the works on waste management, reuse and recycling of the material in the facility were evaluated in the production facility.

2. LIFE CYCLE OF BUILDING MATERIALS AND WASTE MANAGEMENT

Building materials have an effect on the environment throughout every stage of the life cycle. In order to reduce the negative effects of building materials on the environment, usage of sustainable construction materials comes to the fore. In sustainable building material selection, attention should be paid to what the environmental effects of the material are, how its use affects the environment and how these effects may be prevented. It is important that building materials protect natural resources by reducing the need for new raw materials and create a healthy environment by forming minimum wastes.

2.1. Life Cycle of Building Materials

The production, use in building, and recycling or disposal of building materials constitutes the life cycle of the material. In the life cycle, with the approach of 'from the cradle to the grave', the environmental impacts and outcomes of all processes from acquisition of resources to their return to their place in nature are considered (Sev, 2009). The life cycle of a material consists of the processes of raw material acquisition, material production, material packaging and distribution, material implementation, usage of material, maintenance and repair, recycling or disposal (Tuna Taygun, 2005). In order to reduce the negative effects of building materials on the environment; one needs to minimize the resources that are used, energy that is consumed and waste that is formed in the processes of raw

material acquisition, production, construction-installation-usage during the life cycle (Sev, 2009).

2.2. Construction & Demolition Waste Management

Waste, which is one of the most important environmental problems today, is formed as a result of unconscious use of resources. C&D wastes constitute a large part of solid wastes. C&D wastes with different properties and qualities are formed at each stage of the building production process. The most important factor in waste generation is the type and construction technique of the building material. In order to reduce the environmental impacts of building materials in the life cycle, waste management needs to be implemented. C&D waste management is a method that involves many stages, achieves more efficient utilization of C&D wastes and may be used for management of area, construction, repair, disaster, disassembly and demolition wastes that emerge out of building practices (Ustaoğlu, 2014). The effective C&D waste management will help reduce the need for natural resources and energy by minimizing waste generation.

The waste management hierarchy provides evaluation of wastes by determining suitable methods for the qualities of wastes. The types, quantities and usage areas of materials in buildings are important in terms of with which method recycling can be achieved. Waste management consists of the stages of prevention, reduction, reuse, recycling, recovery (raw material/energy) and disposal (storage/combustion). Providing reuse or recycling of building materials are important in terms of reducing wastes. In order to reduce environmental problems caused by building production; material properties should be very well-known and sustainable building materials with minimum environmental impacts should be used.

3. FIBRECEMENT BOARD AS BUILDING MATERIAL

Cement-based boards are one of the composite building materials that enable usage of existing materials in various forms by development of production techniques through technology. Fibrecement board, which is one of the cement based boards, is a preferred building material in the building sector in terms of technical properties in the historical process.

3.1. Definition and History

Cement-based boards are composite building materials with high specific weight and smooth surface that are created by combining certain ratios of wood chippings or agricultural plants, cement, water and several chemical substances (Arslan, 2018). These materials have the lightness, elasticity and workability of

wood and the water and moisture resistance of cement, and its resistance against burning and corrosion (Yapı Katalogu, 2019). Fibrecement board is a general name given to fiber-reinforced cement boards among cement-based boards (Hekim Yapı, 2019). Fibercement boards are cement-based boards that are used in all types of interior and exterior facade applications, are hardened by autoclaving and have a flat or wood patterned surface appearance with natural fiber added (Erdem, 2015).

The first example of cement-based particle board in the world emerged as a result of production of thick boards named Mevrit by mixing cement and waste wood particles that are formed as a result of producing wooden shoes worn by villagers in the Netherlands with the initiative of Mijnheer Muiselaar and Mijnheer de Vries in the late 1930s (Tepe Betopan Fibrecement Guide, 2013). The first cement-based board production facility was established in 1967 in Switzerland, and serial production started in 1970. Board production facilities were established in Germany and Hungary between 1977 and 1978 (Arslan, 2018). As a result of using asbestos in cement-based boards in 1970s, health problems emerged. After the prohibition of the usage of asbestos in building materials, cellulose which is a sustainable and harmless fibre type was started to be used as an alternative to asbestos in fibrecement production. Today, it is estimated that the number of facilities producing fibrecement is around 1100 to 1500. Fibrecement board production and usage is highly prevalent in the Northern part of the Americas, Spain in Europe and especially South Korea in Asia (Erdem, 2015).

In Turkey, fiber-added cement-based boards produced in the 1950s started to be used in industrial buildings (Erdem, 2015). For fibrecement boards, Tepe Group started trial production in 1984, and production continued in the 2000s with a mechanical spreading system. The annual production capacity of the facility is 67,500 m^3 (Tepe Betopan Practical Guide, 2018). Hekim Yapı Industry established its production facility in 2001 and started production in 2004. The production capacity of the facility for 2014 was 125,000 m^3 (Hekim Yapı, 2019). The annual production capacity of Vefa Holding's Ekobord Facility is 24.00 m^3 (Ekobord April Catalog, 2016). In Turkey, fibrecement is a building material that has been used actively especially after the 2000s and included in the sector with the names of the firms that take part in its production.

3.2. Material Properties

Fibercement board is produced by using organic or inorganic fibers and mineral filling materials (quartz or silica) where the binding element is cement. By adding various reinforcement minerals into the formulation based on the usage purpose of boards, improvement can be provided in thermal isolation, electrical

resistance, lightness and fire resistance (Hekim Yapı Fibrecement Board Practical Guide, 2013). Fibrecement board production takes place with two different methods as air-curing and autoclaving. Air-cured products have similar formulas and contain synthetic reinforcement fibers (polyvinyl alcohol and polypropylene), cellulose, Portland cement, pozzolanic and inert filling. Autoclaved products mainly contain cellulose, cellulose-added fibers, Portland cement, quartz sand and stabilizing materials (Schoon et al., 2012).

Fibercement board has many properties. It is produced from natural materials that contain no substances harmful to the environment and human health. It is an A1 class of fire-proof building material according to EN 13501-1. It has no emission of any gasses that are harmful to human health or the environment during a fire. It is very resistant to atmospheric conditions and is not affected by water and ultraviolet rays. It has good sound and thermal insulation. It is resistant against animal wastes, chemical substances, crashes and impacts. It is lightweight, easily portable, and can be processed and mounted with suitable tools. It does not rot, has a long lifespan, and does not require special care. It can be painted many times with interior and exterior paint (Hekim Yapı Product Catalog, 2015).

Fibrecement boards are divided into 3 groups as smooth, grooved and textured boards. The standard dimensions of boards are 1250 x 2500 mm and 1250 x 3000 mm; thickness 6-20 mm and 8-12 mm. Fibrecement boards are applied to the various parts of buildings such as wall, flooring and roof. The boards are used in all types of buildings as interior and exterior coating material, cross partition wall material, support material under roof coating materials, under-eaves coating material, under-ceramic material in wet volumes, undercoat upholstery material in multi-story buildings with pre-production, concrete mold material, frames around windows/doors in outer facades and decorative coating elements in interior spaces (Hekim Yapı Product Catalog, 2015).

4. REUSE AND RECYCLING POTENTIALS OF FIBRECEMENT

In the scope of this study, waste management in the production phase and the reuse and recycling potentials in the process from production to construction of fibrecement board is examined. On-site observation was made at a fibrecement production facility in Sakarya. In order to examine the reuse and recycling potentials of the material in construction phase, interviews were held with material sales offices and site supervisors in Sakarya.

4.1. Production Phase

The production process of the material was investigated by interviewing a facility official of a firm that produces fibrecement boards in Turkey. The firm examined

in the study is a production facility that was established in 2001 in Sakarya - Hendek 2nd Organized Industrial Zone on a land of 111 acres on a 20.000 m^2 closed area. The facility has an annual capacity of 80,000 m^3 fibrecement board. The production capacity of the facility was 125,000 m^3 as of the end of 2015 (Hekim Yapı Product Catalog, 2017).

Supply of Raw Materials: The raw materials of the fibrecement board are Portland cement, cellulose fiber and micronized milled silica. Portland cement; is stored in cement silos after purchased from cement plants. Groundwater is used as water source. The water is stored in clean water and filtered water silos (Fig. 1). Cellulose fiber is imported from abroad. Packaged cellulose stacked at the factory entrance is transported to closed storage areas by material transport vehicles (Fig. 2). Cellulose is made ready for production by passing through grinding machine in open area (Fig. 3). Quartz; is extracted from the mine in a land very close to the production facility and processed in the facility. Silica sand is obtained by grinding the quartz mine stored in the open area in a stone grinding machine (Fig. 4). The milled silica sand is stored in open and semi-open areas (Figs. 5 and 6). The aim of the facility is to reduce the use of raw materials and to protect natural resources by using appropriate technologies that harm the environment at least within the framework of technical and economic opportunities.

Figure 1.Cement and Water Silos (Author[1], H. Bozkurt Archive, 2013)

Figure 2.Transport of Cellulose (Author[1], H. Bozkurt Archive, 2013)

Figure 3.Grinding of Cellulose (Author[1], H. Bozkurt Archive, 2013)

Figure 4.Stone Grinding Machine (Author[1], H. Bozkurt Archive, 2013)

Figure 5 - Figure 6. Milled Silica Storage Area (Author[1], H. Bozkurt Archive, 2013)

Processing of Raw Materials: At the first stage of board production, the raw materials, which are cement, cellulose and silica, are processed by special processes and turned into process sludge. The sludge sized as a raw sheet on the 'Hatscheck' machine is stacked between steel sheet molds and kept in the curing room for setting the cement. After the waiting period, the boards are made resistant to climatic conditions by autoclaving at high pressure and temperature (Figs. 7 and 8).

Packing of Materials: Fibrecement boards are palletized to be sent to the stock area after production. The pallets are transported to the storage area by material transport vehicles (Fig. 9). The packed boards are stacked on top of each other and stored in a closed area for protection (Fig. 10). Attention is paid to the storage conditions determined by the Quality Management Department in writing in the facility.

Transportation of Materials: The packaged boards are delivered to the sales and application offices via covered vehicles (Fig.11).

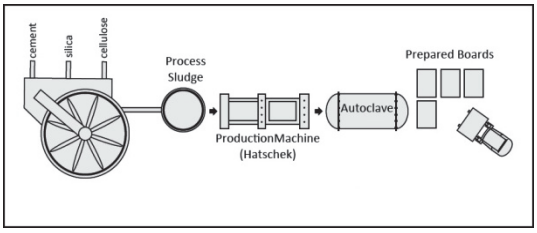

Figure 7.Fibrecement Production Facility (Author[1], H. Bozkurt Archive, 2013)

Figure 8.Fibrecement Board Production (Hekim Yapı Fibrecement Practical Guide, 2013)

Figure 9.Transport of Pallets (Author[1], H. Bozkurt Archive, 2013)

Figure 10.Storage of Fibrecement Boards (Author[1], H. Bozkurt Archive, 2013)

Figure 11.Packed Boards (Author[1], H. Bozkurt Archive, 2013)

4.1.1. Investigation of Waste Management in Fibrecement Production

A field study was carried out to examine waste management in the process of producing fibrecement boards. In this context, a questionnaire was applied to an official of the facility, information was obtained about the production process of the material and the operations carried out in the facility were supported with photographs. The information obtained as a result of the examination in the study is summarized below:

- The facility has a waste management plan, and the wastes that are generated in the facility are categorized according to their types and sent to recycling through licensed firms.
- The Environmental Management Unit in the facility that has TSE EN ISO 14001 Environmental Management System and TSE EN ISO 9001 Quality Management System certificates works on the directives published by the Ministry of Environment.
- Environmental impacts are kept in consideration during raw material processing. According to the Hazardous Chemicals Directive, the boards that are produced do not contain harmful materials such as asbestos. There is no harmful gas emission during production, and the CO_2 emission caused by production in the steam chimneys in boiler rooms is being controlled.
- The water that is necessary in the separation facility for the cement to enter into a reaction is reused by constantly being cycled with a cycling system (Fig. 12). The process water is sorted after being stored in the balancing tank. Cement and sand particles that are mixed in the process water are precipitated in sedimentation tanks and sent back to production in the form of sludge (Fig. 13). The decomposed water is reused in the production phase after waiting in the settling ponds (Fig. 14).
- The material wastes that are generated in the production phase are reutilized in new material production. The edge cut parts of the boards can be included in the production process by turning them into by products out of paste. The defective products are stored in an open space (Figs.15 and 16).

Figure 12. Decomposition Plant (Author[1], H. Bozkurt Archive, 2013)
Figure 13. Sludge in Sedimentation Tank (Author[1], H. Bozkurt Archive, 2013)
Figure 14. Separation Water Recreation Pool (Author[1], H. Bozkurt Archive, 2013)

Figure 15-Figure 16. Defective Materials (Author[1], H. Bozkurt Archive, 2013)

The precautions are taken to prevent any negative effects on the environment and human health in the production process of fibrecement boards. Necessary precautions have been taken for employees during dust output from the dry sizing facility of the material. Trainings are organized for employees to act with environmental consciousness and the production areas to be clean and tidy. Certificated branch-foreman trainings are provided for the correct implementation of the material and taking the necessary precautions. Sales and application dealers are also informed about how to dispose of the material.

4.2. Construction Phase

The fibrecement boards are applied to cutting, screwing and dying processes during the construction phase. In order to apply the fibercement board as coating material on a wall, the wall is coated with insulation plates and anchored. The insulation plate is covered with protective membrane. Vertical and horizontal profiles are mounted onto the wall for board placement, and boards that are cut based on the wall dimensions are screwed onto the profiles. The screw holes on the boards are closed with paste, and the boards are dyed (Fig. 17).

The reuse and recycling opportunities of the fibrecement board during construction are limited. In the scope of the study, information has been reached that the large-scale boards that are left during construction are sent back to sales branches and reused for various applications (Figs. 18 and 19).

Small-sized materials are disposed of as waste in the construction site. It was determined that the producing firm does not have any implementation related to collecting and recycling the waste materials that are generated during construction. The reuse potential of the material may be increased by reducing material losses with designs made based on the dimensions of the material, correct practices and labor utilization.

Figure 17. Fibrecement Board Construction (Hekimboard Application Movie, 2013)

Figure 18- Figure 19. Storage of Remanent Materials
(Author[1], H. Bozkurt Archive, 2013)

5. CONCLUSION

In order to reduce the negative effects of buildings against human health and the environment, it is important that the building material that composes the building is being sustainable. In this context, the harm to the natural environment will be minimized thanks to the minimum level of waste generation in the life cycle of building materials and the possibility of reuse / recycling. In the scope of the study; the reuse and recycling potentials of fibrecement board in production and construction phases are investigated. Based on the data obtained in the study, the following conclusions are reached:

- The waste management plan created by the 'Environmental Management Unit' minimizes negative impacts on the environment by preventing/reducing wastes at the fibrecement production facility. In the firm's environmental policy, the wastes such as packaging, paper and metal that are formed in the facility are categorized based on their types and collected; they are sent for recycling through licensed firms.
- The presence of a separate production area for quartz mine in the facility shows that the facility uses its own means to meet the raw material needs. In addition to this, it also reduces the amount of energy consumed for obtaining raw materials.
- It has been determined that the wastes generated during the production of the material are recovered by inclusion in the production process. The reuse

of the water that is used in production by cleaning through a sorting system shows that natural resources are minimally consumed and polluted. The reuse the sludge that is obtained during separation of the process water back for production reduces the amount of raw material needed for producing new material.

- The inclusion of the material wastes and defective materials that emerge during the cutting process back in production shows that fibrecement board is a recyclable building material during the production process.
- The forestation in the production facility area leads the environment to look better. The organization of various information seminars on environmental issues for employees shows that the facility has an environmentally sensitive approach.
- Although fibrecement boards have the potential of reuse during the construction phase, no studying is carried out for recycling of the material. The waste materials in the construction site are sorted out according to size and while large boards are stored for reuse, small boards are thrown out. The material dimensions need to be taken into consideration in the design process in order to provide maximum usage and minimum waste generation during construction process.
- As fibrecement board is a building material that can be installed and removed, damaged parts during usage can be replaced. It is thought that fibrecement board will not have negative effects in terms of human and environmental health in terms of disposal as it is building material that does not contain any harmful materials such as asbestos.

Consequently; fibrecement board examined in the study is a building material that has the potential to reuse and recycling in the production and construction phases within its life cycle. In the production facility of the material; importance is given to waste management practices and works are carried out towards considering the environmental impacts in recycling, reuse or disposal of waste in the facility. While boards can be reused by evaluating according to the material dimensions, there is no study on recycling during the construction phase. In this context; the reuse and recycling potential of fibrecement board during the production phase is better and higher than the construction phase. Fibrecement board is a building material used in buildings especially recently and it is not yet possible to determine reuse or recycling of the material in the use and demolition phases. It is thought that the material can be used as a raw material of a different building material after various processes are performed in order to increase the reuse and recycling potential of the fibrecement. The facts that the

usage rates of fibrecement board are increasingly higher in recent years, it does not harm the environment and human health, and the evaluation of wastes generated in the life cycle shows that it is a building material that can be recovered in terms of reuse and recycling potentials.

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