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THE EFFECTS OF CONSTRUCTION WASTE ON CLIMATE CHANGE: IS A MORE GREEN CONSTRUCTION INDUSTRY POSSIBLE?

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Keywords

Construction Waste, Climate Change, CO_2 Emissions, Greenhouse Effect.

Abstract

Due to the increasing population, the rapid consumption of natural resources has revealed the necessity of protecting nature from people. Increasing building stock due to population growth has triggered climate change. The energy and natural resources consumed during production in the construction sector have created important environmental problems such as global warming and climate change in the sector. Greenhouse gas emissions caused by construction materials can be considered as one of the main causes of climate change problems and emphasizes the necessity of considering environmental effects. Greenhouse gas is one of the most important factors affecting the ecological environment and climate change, as it is one of the gases with the highest carbon dioxide emission rate. Concrete and steel used in the construction industry are among the materials that have a negative impact on climate change. This study revealed the effects of waste materials used in the construction industry on the problem of climate change and the importance of promoting the efficient use of energy resources for the management of this problem. In addition, this study emphasized the importance of focusing on sustainable structures in order to leave a cleaner and healthier environment for future generations, and that priority should be given to developing environmentally friendly materials.

İNŞAAT ATIKLARININ İKLİM DEĞİŞİKLİĞİ ÜZERİNE ETKİLERİ: DAHA ÇEVRECİ BİR İNŞAAT SEKTÖRÜ MÜMKÜN MÜ?

Anahtar Kelimeler

İnşaat Atıkları, İklim Değişikliği, CO_2 Emisyonu, Sera Gazı Etkisi.

Öz

Artan nüfusa bağlı olarak doğal kaynakların hızlı tüketimi doğayı insanlardan korumak zorunluluğunu ortaya çıkarmıştır. Nüfus artışına bağlı artan yapı stoğu iklim değişikliğini tetiklemiştir. Yapı sektöründe üretim esnasında harcanan enerji ve doğal kaynaklar, sektörde küresel ısınma ve iklim değişikliği gibi önemli çevre sorunları yaratmıştır. İnşaat malzemelerinin ortaya çıkardığı sera gazı emisyonları iklim değişikliği problemlerinin temel nedenlerinden sayılabilmekte ve çevre etkilerini dikkate almamız gerekliliğini vurgulamaktadır. Sera gazı, karbodioksit salınım oranı en yüksek gazlardan biri olması sebebiyle ekolojik çevreye ve iklim değişikliğine etki eden önemli unsurlardandır. İnşaat sektöründe kullanılan beton ve çelik iklim değişikliği üzerinde olumsuz etkiye sahip malzemelerin başında gelmektedir. Bu çalışma, inşaat sektöründe kullanılan atık malzemelerin iklim değişikliği sorunu üzerindeki etkilerini ve bu sorunun yönetimi için enerji kaynaklarının verimli kullanılmasının yaygınlaştırılmasının önemini ortaya çıkarmıştır. Ayrıca bu çalışma ile gelecek nesillere daha temiz ve daha sağlıklı bir çevre bırakmak adına sürdürülebilir yapılara odaklanmanın, bunun için de çevre dostu malzemeler geliştirmeye öncelik verilmesi gerektiğinin önemi vurgulanmıştır.

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1. Introduction

Technological developments and industrialization in parallel with rapid population growth have rapidly increased the impact of human beings on the environment all over the world (Gündüzalp and Güven, 2016). While the increase in production activities in this process has enhanced the rate of use and consumption of natural resources depending on the waste released, which has reached a level that threatens both the environment and human health (Kaçtıoğlu and Şengül, 2010).

Population growth and economic developments in the world have occurred the condition of expanding living spaces. Depending on this, urban and industrial areas are expanding and the natural environment is affected by this with the construction of living spaces (Kartal, 2018). Today, increasing construction activities cause high energy and natural resource consumption. Environmental problems arise as a result of the building storage that is occurred by using materials containing a large number of harmful substances. Considering that the urban population will increase in the following years, the concept of the sustainable and environmentally-related building has come into question to reduce negative environmental impacts. In recent years, many types of research on ecological structure production have been carried out and new approaches have been brought to this subject. Accordingly, the main features that we encounter are that the energy consumed during the building production is at a minimum level and meanwhile the waste generation is low, the materials used do not contain harmful properties and contribute to the circulation of natural resources. In this study, the effects of waste materials used in the construction and building sector on climate change and depending on this, the dissemination of the efficient consumption of energy resources is examined. During the production of cement, which is the binder material of concrete used in the construction industry, greenhouse gas is released. Approximately 5-8% of the total CO_2 emissions worldwide occur during cement production at the end of clinker processes (Alsubari et al. 2016, Maraghechi et al., 2017). The CO_2 emission released at the end of these processes raises the importance of waste minimization, which consumes less energy during production and provides the sustainability of the construction site by using recycled construction materials (Teixeira et al., 2016). One of the most suitable processes to reduce the CO_2 footprint of concrete, which is a construction material, is to use the raw materials used in clinker, especially fly ash, blast furnace slag, silica fume, etc. with industrial by-products instead of natural resources, or to substitute recycled materials such as waste glass and plastic (Berndt, 2009, Meyer, 2009).

Climate change which is caused by greenhouse gas emissions that is created by human beings is one of the biggest problems that the world has faced recently. Greenhouse gases are one of the most harmful gases due to the high emission rate of CO_2. In addition to the energy and greenhouse gases that are accumulated in construction materials, a very large amount of environmental waste occurs during the production and consumption of these materials. These emitted gases have a devastating impact on the environment and cause ecological problems such as climate change. In general, while using materials for buildings, the energy to be consumed during the construction of the building should be considered in the material selection as they affect the ecology. Since the overuse of modern building materials causes high carbon emissions, it brings about the ecological balance to deteriorate (Coşkun, 2013). The selection of materials, which provides low energy consumption, reduces the effects of buildings on the environment (Zinzade, 2010).

Sustainability, a term that has been widely used in the construction industry recently, is to meet the needs of human beings by protecting nature, achieving a high level of harmony with nature in a balance. In sustainable building design, all conditions must be taken into account in order to minimize adverse environmental conditions and to obtain a spatially comfortable and high-quality architectural design. The use of daylight quality has positive effects on the concept of sustainability. The efficient use of daylight reduces energy consumption in buildings and contributes to energy savings. As a result, CO_2 absorption, the formation of toxic gases and global warming are reduced (Tatar, 2013). There are some methods for the environmental assessment of the constructed buildings. The Breeam (The Building Research Establishment's Environmental Assessment Method) certification system, which was first developed in England in 1990, is the first environmental assessment method in the world. The subject of this study and one of Breeam's goals is to reduce the impact of the buildings on the environment in the life cycle (Anbarcı et al., 2012). Supplying raw materials for building materials, their transportation, processing, assembly and processing causes CO_2 production and triggers global warming (Breeam, 1993). Buildings are also responsible for ozone layer depletion and climate change. The most important reason for this is chlorofluorocarbons (CFC) (Dorbek, 2007). For instance, in 1986, buildings, refrigerants used in air-conditioning

systems and foam materials used in insulation accounted for 7.5% of the UK's annual CFC use and this ratio has exceeded 15%, not only because buildings emit more CFCs, but also because of the emergence of new usage areas such as propellants in aerosol sprays (Dorbek, 2007). As a result of all harmful effects, it underlines the effects of waste materials on climate change in the design of buildings and the need for efficient consumption of energy resources. In addition, the energy consumed during the production of building materials, the amount of CO_2 released, and the waste generated should be kept to a minimum.

2. Climate Change

The climate system has naturally changed on all time scales throughout the Earth's approximately 4.5 billion-year history (Türkeş et al., 2000). The problems and damages that are caused by global warming and climate change are the environmental issues at the forefront that threaten the world (Doğan and Tüzer, 2011). The current effects of climate change; will increase agriculture, water resources, sea level, energy, human health and biodiversity. Although climate change has not been experienced all over the world, it will cause successive impacts in terms of economic, social and ecological aspects and will make it necessary to take measures against climate change. At the same time, all of the states in the world must take the necessary precautions by showing a common determination. The main causes of climate change are; the increase in the current temperature on earth as a result of the emission of naturally occurring greenhouse gases to the atmosphere and fossil fuels burned to generate energy from additional greenhouse gases, cutting down the rainforests, improper agricultural and livestock practices, chemical production, and human acquisitions.

As shown in Table 1, global climate change has effects on agriculture, vegetation, forest, water resources, sea level, energy, human health, and biodiversity. It is inevitable that climate change will have some impacts on social and economic life.

Table 1. Potential Impacts of Global Climate Change (Doğan and Tüzüner, 2011)

Sea Level Rise and Coastal Areas	Energy	Human Health	Agriculture	Natural Environment and Species	Water Resources	Forests
Coastal Erosion	Change in Energy Policies	Climate-Related Deaths	Product Losses	Losses in Natural Habitats	Decrease in Water Supply	Forest Composition
Floods and Overflows	Change in Energy Consumption	Epidemics	Irrigation Problems	Decrease in Species Diversity	The decline in Water Quality	Change in the Geographical Distribution of Forests
Costs of Protecting Resident Coastal Communities	Change in Energy Costs	The decline in Air Quality	Change in agricultural fields	-	Competition for Water Resources	The decline in Forest Health and Productivity

2.1 Nature Climate Change

The climate balance in the world has been changing since human beings settled down. As well as climate change in the world can change from natural causes, today's anthropogenic effects also contribute to this (Aksay et al., 2005). External factors, which can cause climate change, mainly include plate movements in the earth's crust, changes in solar activities and astronomical relations between the earth and the sun (Türkeş, 2008). Astronomical relationships include a series of periodic changes and provide important evidence for long-term climate changes. Major astronomical relationships to global climate change include; the “changes in shape (E) of the earth's orbit around the sun (eccentricity more rounded or more elliptical) and changes in the earth's axial tilt (T) and precession (P) (direction of the rotation axis)" (Figure 1) (Türkeş, 2008).

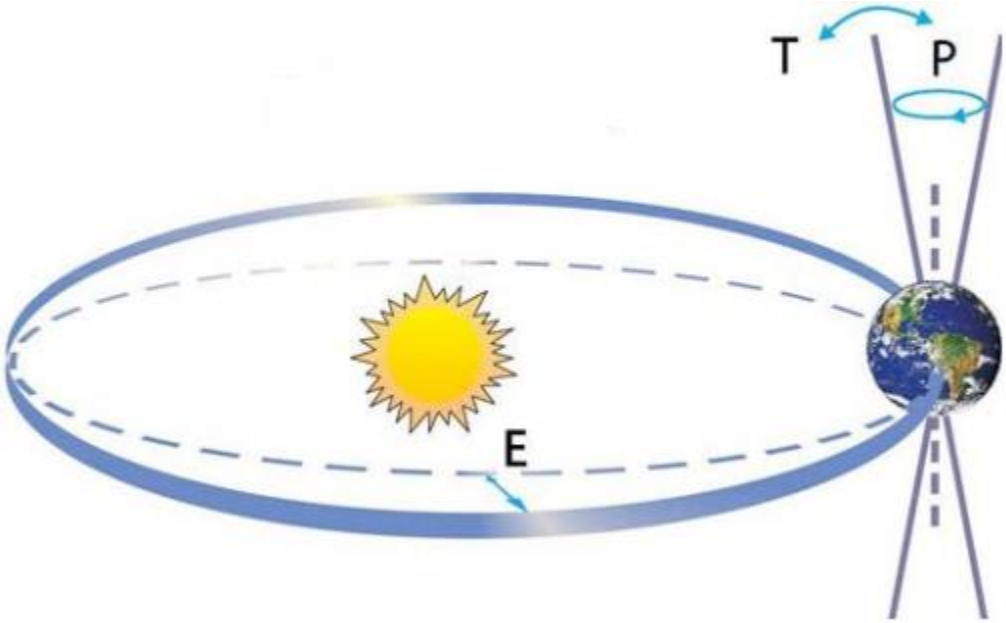

Figure 1. Simplified Roadblocks Of Milankovitch Cycles [2]: (E) Changes in The Shape of The Earth's Orbit, (T) Axial Tilt, and (P) Precession (Türkeş, 2008)

2.2 Human-induced Climate Change

Gases other than industrial gases are found in the atmosphere and account for 1% of it. The percentages of these gases in the atmosphere are sufficient for the formation of the natural greenhouse effect. Thus, our world has a warmer temperature of up to 30°C (UNEP, 2001). Recently, the human-induced formation of greenhouse gases has been the main focus of the global climate change issue. With the increasing population, human activities in the fields of energy, industry, agriculture and transportation increase; thus, greenhouse gas emissions rise. As a result, an increase in world temperature occurs (Figure 2). This increasing temperature also affects climate change. Especially in the 20th century, an increase in greenhouse gas emissions is observed.

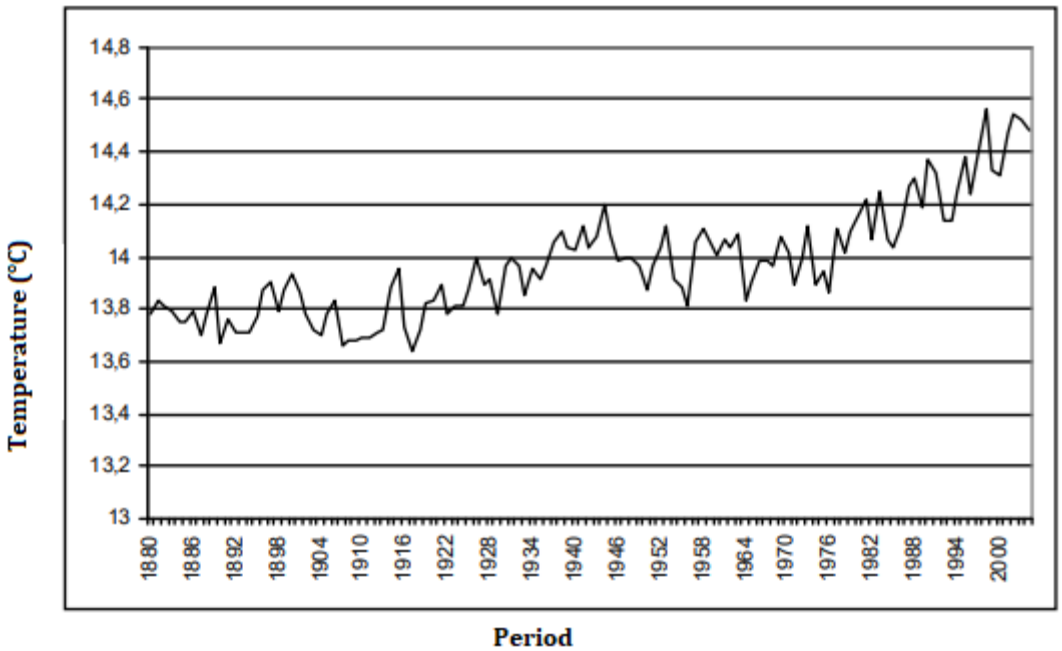

Figure 2. Earth's Surface Temperature (°C) in the Period 1880-2004 (Doğan and Tüzer, 2011)

Human impacts are not only greenhouse gases but also aerosols and volcanic eruptions. These are among the main human factors that can cause climate change though their duration of action varies. Unlike the gases, which come out as a result of the combustion of coal, oil, and organic materials and create a greenhouse effect, aerosols reflect the sunlight that reaches the atmosphere back into space (Doğan and Tüzer, 2011). Aerosols have cooling effects and although their lifespan is shorter than greenhouse gases, their effects are more local. Aerosols cause acid rain

and deterioration in air quality (URL 1: Date accessed: 29.04.2021).

3. Waste

Any substance to be disposed of can be defined as waste (Ağaçayak, 2019). According to the environmental law, it is defined as "Harmful substances thrown or released into the environment as a result of any activity" (Çevre Kanunu, 1983). In other words, according to the United Nations Environment Programme (UNEP), the concept of solid waste is defined as "Substances that the owner does not want, does not need, does not use, and needs to be treated and disposed of" (Öztürk, 2010).

According to the IPCC, wastes are classified as household waste, industrial waste and other wastes (IPCC, 2006). Household, commercial or industrial wastes are expressed as the loss of usefulness after consumption of raw materials, fuel or water, and therefore loss of material value for the person (Read, 1999). Large wastes in urban areas are defined as household waste. Household wastes consist of food wastes, garden and park wastes, cardboard, wood, plastic, metal, glass, and other wastes and most of them are recyclable and reusable materials. The separate collection of all these wastes that will participate in recycling is of great importance for the reduction of greenhouse gas emissions.

3.1 Types of Waste

Solid wastes are divided into seven groups regarding their origin; household solid wastes, industrial wastes, hazardous wastes, special wastes, medical wastes, agricultural and garden wastes, construction and demolition wastes (Gündüzalp and Güven, 2016).

Household Wastes;

These are the wastes that can be transported with the services of municipalities, destroyed in household waste landfills, recovered by separation and incineration. Kitchen garbage, packaging wastes, office wastes can be given as examples (Sayar, 2012).

Hazardous Wastes;

"Substances or preparations that are explosive, oxidizing, highly flammable, irritating, harmful, carcinogenic, corrosive, infective, fertile, mutagenic, which, in contact with air, water or an acid, release toxic or very toxic gases and substances and preparations produced during the disposal of wastes with any of these listed characteristics are ecotoxic wastes" (Atık Yönetimi Genel Esasları Yönetmeliği, 2008).

Industrial Wastes;

These are the wastes that are generated as a result of industrial studies.

Agricultural and Garden Wastes;

These are the wastes that are generated as a result of the processing of animal and herbal products. The solid wastes produced are affected by the social and economic situation of the society, dietary habits, and different conditions such as climate and geography (Palabıyık and Altunbaş, 2004).

Medical Wastes;

According to the Regulation on Control of Medical Wastes No. 27555, it refers to the *"Infectious, pathological and penetrating wastes originating from the units"* (Tıbbi Atıkların Kontrolü Yönetmeliği, 2005).

Construction and Demolition Wastes;

They are the type of waste that is released as a result of the construction and demolition of buildings.

Other than solid wastes, there are also liquid, gas and packaging waste in the world. Blood from hospital waste, washing water used in dental treatment applications, dialysis machine water, cleaning water, sewage water wastes, etc. refer to household wastes; nuclear power plants, industrial plant chimneys, incineration plants, the use of fossil fuels for energy purposes, garbage storage, and composting areas refer to gaseous wastes (Karasu, 2013).

3.2. Construction Wastes

3.2.1 Construction and Demolition Wastes

Construction activities such as buildings, bridges, roads, tunnels, subways and canals affect the environment to a certain extent. When considering a large-scale construction project, it is necessary to prepare an Environmental Impact Assessment (EIA) report that covers all impacts since it will affect the soil, water and air environments before proceeding to the construction phase (Erdin et al., 2004).

Before a construction project is undertaken, all elements that will adversely affect the environment must be eliminated. As soon as the first scoop hits the ground, wastes that need to be disposed of such as excavated ground and construction rubble will be generated. Recycling is seen as a very useful process in the destruction of construction waste and rubble.

In the report prepared by the European Commission in 1999, it is stated that an average of 180 million tons of construction and demolition waste is generated every year for 15 member countries (Ölmez and Yıldız, 2008). 78% of waste is stored and approximately 28% is recycled. The amount of construction and rubble waste that is generated in Germany, England, France, Italy, and Spain from 15 member countries is 80% of the amount of waste that is generated in European Union member countries. The Netherlands, Belgium and Denmark are countries that have achieved great success in the recycling of construction and rubble wastes. As it is demonstrated in Table 2, construction and demolition wastes that are generated after construction activities are divided into 4 categories.

Table 2. Categories of Construction and Demolition Waste (Ölmez and Yıldız, 2008)

Categories	Types of Waste
Road Construction and Maintenance Materials	Asphalt, concrete, cover soil
Excavation Materials	Soil, stone, hardcore
Building Debris Waste	Concrete, mixed rubble, steel, brick, iron, timber
Building Renovation and Work Zone Materials	Wood, roofing material, pipe, carpet, plastic, glass, metal, insulation material,

3.2.2 Wastes Resulting from Natural Disaster

Disasters continue their negative effects on people and the environment from past to present (Güler, 2018). Wastes that result from disasters can be; herbal wastes, soil and rock wastes, household wastes, damaged buildings and infrastructure, recyclable wastes, electronic, white goods wastes and living corpses (Brown et al., 2011). The wastes that are generated as a result of natural disasters are construction and demolition wastes. Asbestos and arsenic-treated woods in waste cause health problems (Dubey et al., 2007). During the post-disaster period, wastes such as food and beverage wastes used medical wastes, and packaging wastes continue to occur (Luther, 2008). A lot of work has been done to reveal the wastes that are released at the end of disasters (Brown et al., 2011). The types of waste that are generated in different disaster situations within the scope of these studies are given in Table 3.

Table 3. Types Of Waste That is Generated In Different Types Of Disasters (FEMA, 2007)

		Types of Waste Generated								
		Herbal waste	Construction/ rubber waste	Personal waste	Hazardous waste	Household hazardous waste	White goods	Solid/ mud	Tools	Rotten waste
Types of Disasters	Hurricane / typhoon	*	*	*	*	*	*	*	*	*
	Tsunami	*	*	*	*	*	*	*	*	*
	Tornado	*	*	*	*	*	*		*	*
	Floods	*	*	*	*	*	*	*	*	*
	Earthquakes		*	*		*	*	*		
	Forest fires	*		*		*	*	*		
	Ice storms	*				*				

Disasters will continue to maintain their devastating effects in the process from the past to the present. Due to the collapsed buildings and infrastructure after disasters, a large amount of waste such as concrete, brick and wood emerges.

3.3 Greenhouse Gas Emissions Caused by Construction Wastes and Their Impact on Climate Change

Greenhouse gases are compounds in the atmosphere that have the most heat retention feature and prevent the sun's rays from overheating and cooling the earth. Thanks to the ability of the atmosphere to transmit light and retain heat, the temperatures of the soil and water remain in balance. The world becomes overheated due to the increase in the amount of heat retained in the atmosphere because of the overproduction of greenhouse gases (Kartal, 2018). The gases causing the greenhouse effect in the world are 36-70% water vapour (H_2O), 9-26% carbon dioxide (CO_2), 4-9% methane (CH_4) and 3-7% ozone (O_3). Among these gases, especially CO_2 is released more in industrialized countries and this is also called carbon emission. CO_2 emission is mostly seen as a result of fuel consumption. In addition, carbon emissions increase significantly as a result of increasing industrial activities. Carbon emissions are the most important cause of climate change.

A high amount of carbon emissions occur during the production of cement and steel, which are frequently used building materials in the construction industry. The production of these building materials is carried out at high temperatures and fossil fuels are used for this. With the increasing industrialization and urbanization, the use of these raw materials and depending on the amount of carbon that is released into the air is increasing day by day.

The amount of carbon emissions in various building materials in the construction industry is demonstrated in Table 4. The amount of carbon sequestration seen in the table is a situation-specific to wood material, as it is a situation related to the material's ability to contain carbon (Kartal, 2018). Since the wood from which the wood material is obtained is organic, it has the property of retaining carbon and is the construction material that contributes the least to carbon emissions.

Table 4. Carbon Emission Values of Commonly Used Materials in Construction (Kartal, 2018)

Material types	Carbon footprint amount (CO_2eg/kg)	Carbon sequestration amount (CO_2 g/kg)	Origin of material
Polyurethane	4200	-	Polymer
Stainless steel	3778	-	Metal
Polystyrene	3300	-	Polymer
Glass wool	3148	-	Glass
Aluminium plaque	2980	-	Metal
Aluminium profile	2264	-	Metal
Polyethylene	2130	-	Polymer
Plasterboard	1967	-	Natural stone
Float glass	1230	-	Glass
Copper pipe	981	-	Metal
Copper plate	973	-	Metal
Plywood	718	1188	Wooden
HDF	661	1436	Wooden
MDF	652	1417	Wooden
Ceramic tile	613	-	Soil
Autoclaved aerated concrete	442	-	Cement, mortar, concrete
Fiberboard	425	1531	Wooden
Hardboard	409	1564	Wooden
Plaster	243	-	Natural stone
Lightweight concrete	240	-	Cement, mortar, concrete
OSB	208	1692	Wooden
Dried wood (leafy tree)	167	1636	Wooden
Wood fibre/ Fibre sized wood	152	1638	Wooden
Precast concrete	121		Cement, mortar, concrete
Dried wood (coniferous tree)	119	1637	Wooden
Laminated wood	109	1730	Wooden
Freshly cut wood	49	1182	Wooden
Hardcore	14	-	Natural stone
Gravel	3	-	Natural stone
Gypsum	3	-	Natural stone
Sand	2	-	Natural stone

It is seen that the carbon emission of metal, glass and polymer-containing materials is quite high while the carbon emission of terracotta, autoclaved aerated concrete, processed natural stone and composite wood materials is at a moderate level.

4. The Importance of Sustainability and Waste Management In The Constructıon Sector A More Environmental Approach

The construction sector holds many sectors in its own market and benefits from this sector from the construction to the end of the construction process in the construction sector (Pamuk and Kuruoğlu, 2016). While words such as clean and green are not used together with the construction industry, it has now become possible with the developing technology and environmentally friendly designs.

The increase in the damage of the construction sector to human health and the environment day by day, as a result of this, the sustainability of the sector and its environmentalist approach have also been brought up. It is known that buildings consume 30% of material resources and 40% of energy resources in the construction sector, and 35% of the CO_2 emissions that cause global warming and climate change originate from the construction sector and it has been emphasized that new practices should be mentioned to reduce the rates of construction waste (Çekirge and Çubukçuoğlu, 2017).

In the future, it will gain importance for the construction industry to design structures that will increase energy efficiency and reduce CO_2 emissions. Many laws have been made to increase energy efficiency and reduce CO_2 emissions in European Union countries, England and China (Candemir et al., 2012). For instance, the "Climate Change Act" in the UK aims to reduce CO_2 emissions in buildings by 26% until 2020 and by 80% in 2050 (Candemir et al., 2012). In the light of these aims, it is mentioned that the buildings to be built in the world must be built on the basis of zero-carbon.

5. Conclusion and Suggestions

In recent years, when natural resources have been rapidly depleted, the increase in population and industrial activities has increased the amount of energy used. This situation has brought up taking precautions to protect the environment as a result of the deterioration of the ecosystem balance. Energy efficiency has been brought up using materials that are less harmful to nature and the balanced consumption of natural resources.

The increase in energy consumption, the increase in the greenhouse effect with the use of some materials in the construction field, and the increase in carbon emissions depending on this brought up the constructions to be done according to some environmental criteria on the agenda. There are some certificate systems (Leed and Bream) that are used by many countries in this field. These certificate systems have some main criteria and include topics such as sustainable land, usage of water and material resources, energy and atmosphere use, and indoor air quality.

Thus, by giving importance to the concept of energy conservation of the building in the construction sector, the energy performance, carbon emission values and reusability or recycling properties of materials gain importance.

It is observed that greenhouse gases, which are generated as a result of construction activities, have a negative impact on climate change. Depending on this, it is underlined that energy ought to be used effectively and carbon emissions should be kept at a minimum level. It is known that glass, metal and polymer-based materials have quite deep impacts on the environment. Although the embedded energies of polymer-based materials are low, the fact that they have high carbon emissions, create hazardous wastes when they are used and disposed of.

It is required to take necessary precautions to use energy effectively in the production of materials that are used in the construction industry (especially in cement production), to reduce consumption and to reduce their effects on climate change, and improvement activities should be traceable and sustainable.

Conflict of Interest

No conflict of interest was declared by the authors.

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