

# Environmental effects of utilization of sustainable building materials

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## Abstract

Migration is generally defined as a period of time or permanent settlement of people by moving from a place of origin to another place. Throughout history, humanity has migrated due to natural disasters, religion, poverty, wars and this migration has caused urbanization with population growth. With the increase in population, irregular and excessive migration, decrease in resources, unplanned urbanization, infrastructure problems, wastewater lines, drinking water lines, rainwater collection lines, power lines, and natural gas pipelines cannot be delivered to desired places, traffic, and excessive waste generation increased. Therefore environmental pollution and health problems arise in cities. Today, due to the adverse environmental impact of all these, people have become more sensitive and have tended to find solutions to the problem with areas such as sustainable structures, recycling, and reuse of waste. In this study, the studies and gains made with the recycling aggregate used are evaluated in order to produce solutions for environmental pollution caused by the construction sector.

*Keywords:* Migration, Environment pollution, Sustainable structure materials

## 1. Introduction

Migration can be defined as the movement of human or human communities from one place to another. Migrations from the past to the present took place for many reasons such as natural disasters, wars, unproductive lands, famine, poverty and a better living condition. In addition to the economic, cultural, moral and environmental effects of this migration mobility, the impact on urbanization as a result of migration to cities is substantial [1]. With the sudden increase in population in the cities receiving migration, problems occur in housing, health, education, superstructure and infrastructure transportation services. In addition, it causes problems such as increase in air, water, soil pollution, and increase in fuel and garbage waste. This emerges as the main environmental problems such as housing need, increase in construction material production waste, increase in carbon emission and increase in construction demolition wastes. Most of these environmental problems are directly related to the construction industry [1] [2] [3]. Today, energy efficiency and CO<sub>2</sub> emission are of great importance when the environmental impacts of the construction industry are considered. Structures in European Union countries are thought to have a share of 40% in total energy consumption and 36% in total CO<sub>2</sub> emissions. In addition, in the report published by the United Nations Environment Program, it is stated that more than 33% of the world's total energy consumption is spent for the constant needs of buildings (heating, cooling and ventilation, lighting, etc.). Furthermore, it has been stated that the constant energy consumption of the buildings for the production and demolition of construction materials is approximately 10-20%. Moreover, cement which is the main material of the construction industry has a share of 5% of the total CO<sub>2</sub> emission. In order to minimize these negative effects, the concept of sustainability comes to the fore in the construction sector. Although sustainability is defined differently according to science, its lexical meaning is the capacity to continue an event or function in indefinite time. Sustainability has three main components: social, environmental

and economic. Environmental sustainability is effort to improve environmental features while ensuring the continuity and renewal of natural resources. Economic sustainability means providing income and employment for population continuity. Social sustainability is to create an equal and balanced system in health, education, security, welfare and other social issues independent of the individual [5] [6] [7]. In the construction sector, sustainable building is called a system with continuity, without creating a bad or weak feature in the material, without reducing the amount in the material that makes up it. Sustainable building materials are materials that have the least impact on human health and the environment, with minimum energy consumption and CO<sub>2</sub> emission. In addition, it is important that the building material production process is sustainable [7]. Today, more than 6 billion tons of concrete is produced annually in the world. Parallel to this production, the sector has a high impact on the environment due to the consumption of natural resources and high amount of energy. In addition, concrete constitutes approximately 75% of the waste generated at the end of the life of the structure. Therefore, recycled aggregate concrete comes to the fore. The use of recycled aggregate in concrete is thought to be one of the most effective methods that can reduce carbon emissions, ensure the sustainability of natural resources and reduce costs. Therefore, in this study, the effect of using recycled aggregate in concrete on the environmental component of sustainability has been investigated [8].

## 2. Material and method

In choosing the right building material, adding sustainability to safety, economy and aesthetic features is the right approach [8] [9]. Sustainable materials must not contain toxic substances, be suitable for reuse, have no harm to the environment at the end of their life, and must be produced from local sources. The life cycle of sustainable building materials consists of the steps of obtaining raw materials, transportation, storage, use in the building, and recycling at the end of their useful life. If it cannot be recycled, it must be used in addition to different materials or disposed of harmlessly. Life cycle stages for building and building materials are given in Fig. 1.

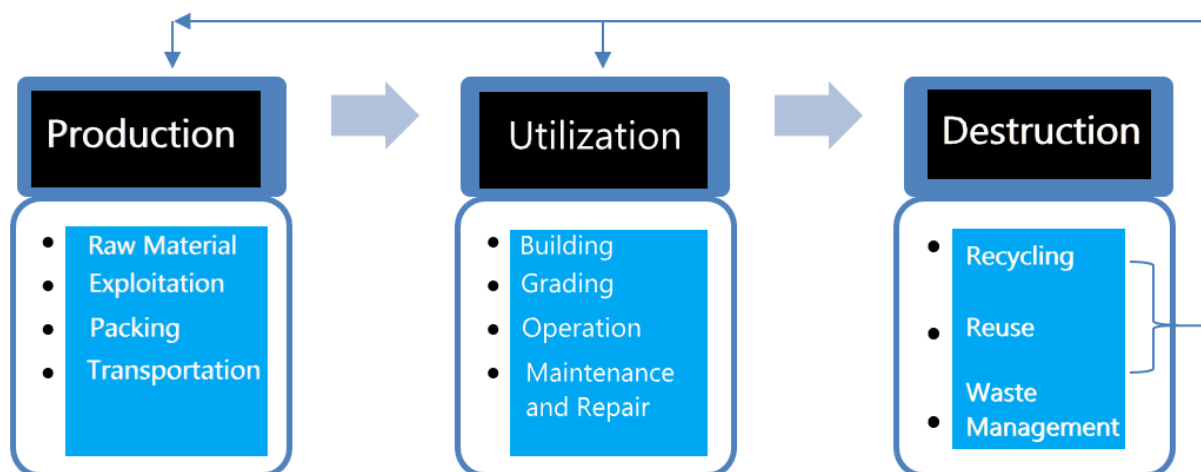


Figure 1. Life cycle stages for building and building materials [10] [11]

Sustainability should aim to reduce the waste of energy and materials used throughout the life cycle of the building material, particularly during the manufacturing phase. Also, waste minimization is important for sustainability. The use of the waste material that occurs at the end of its life cycle in the manufacturing phase effectively reduces the amount of waste.

Today, many studies are carried out for the sustainability of building materials. One of the main measures required to reduce CO<sub>2</sub> emissions in the field of cement production is to increase energy efficiency and use alternative resources. In addition, using waste materials with binding properties and substituted to cement instead of clinker is a very effective method in terms of sustainability [8] [9]. An exemplary application for sustainable building material production is sustainable alkali bricks produced using industrial waste. Portland cementless alkali activated products are known to be sustainable and less costly. Especially geopolymetric bricks are seen as the most advantageous product since they can contain high amount of waste [12]. Agricultural wastes are also actively researched for the manufacture of sustainable building materials. Agricultural wastes are generally non-use materials such as bagasse, rice husk, jute fiber, coconut shell, cotton straw. Re-use of similar

agricultural wastes as a sustainable construction material helps to reduce construction costs as well as reducing environmental pollution and waste amount [13]. Recycled aggregate (RCA) concrete used for sustainability is an important technology in reducing resource-saving environmental burdens by recycling concrete residues as an aggregate. In the studies on sustainability, the rates of construction wastes throughout their lifecycle are given in Fig. 2. It is predicted that the recovery of these wastes is the most effective solution for sustainability and less environmental pollution. In Japan, it has been applied to the superstructure of buildings with concrete produced with recycled aggregate for use in high quality concrete. However, when recycling aggregate is used, it requires more energy in upper building structures as it requires more coarse aggregate. Therefore, while its use in the superstructure is limited, it has been applied especially for pavements, pavement systems, piles and underground structures. However, it is seen that with a better recycling technology, recycling aggregate production can be even more efficient in the superstructure [14].

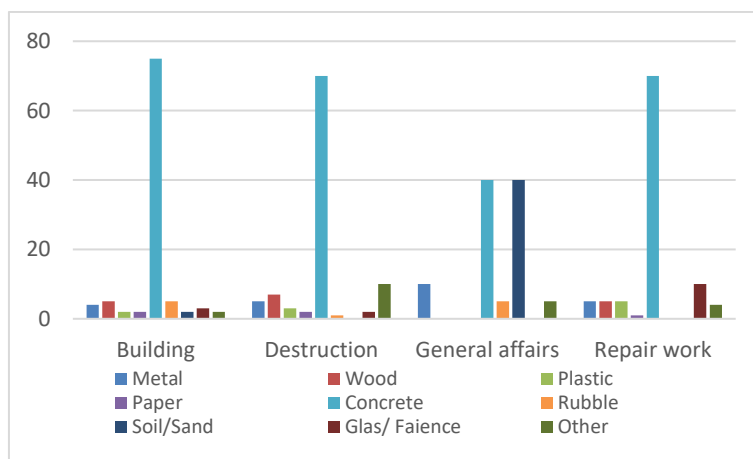


Figure 2. Proportions of construction waste over the lifetime [15]

Aggregates are the basic material of highway pavement. However, it is used only on sub-coating surfaces. The widespread use of aggregate in highway pavements shows that the use of recycled aggregate is very important for sustainability [7]. In Fig. 3, concrete mixture amounts of the materials according to the use of NA and RCA-NA are given.

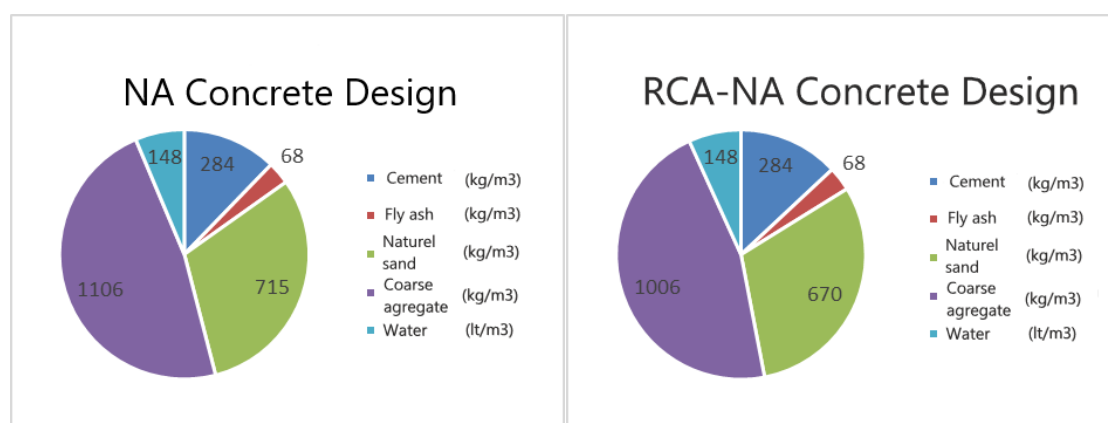


Figure 3. Concrete mixture amounts of materials according to NA and RCA-NA usage [16]

In this study on sustainable highway pavement, the environmental and economic sustainability of the recycled aggregate (RCA) and normal aggregate (NA) concrete used throughout its life cycle was evaluated [16]. It is seen that concrete pavement manufactured with RCA-NA reduces the social and environmental burden, but creates an increase in cost. RCA-NA coating 0.11% increase in total cost, 0.29% less energy consumption, 0.26% less air pollution and 0.07% less greenhouse gas 0.30% less land, 0.44% it has been found to provide less toxic substance production, 0.01% less transportation and 0.42% water savings. It turns out that the use of RCA on the basis of manufacturing, recycling and transportation provides more savings. Evaluations are made

on the road example applied in the study. However, more effective results are predicted when the use of SEE is considered from a sustainability perspective throughout its lifetime and when considered universally [16]. In a building life cycle analysis study conducted in Singapore, the environmental impacts of local recycling aggregate manufacturing, material shipping and importation were examined. In the analyzes made for three different scenarios, S1 is where all resources are produced locally, S2 is where all materials are imported and S3 is 100% RCA is used instead of imported aggregates in S2. Impact assessment for the whole structure is given in Fig. 4. In this evaluation, it has been observed that material import and transportation processes show significant differences in terms of environmental pollution. It was stated that the use of recycled aggregates would be beneficial in Singapore to reduce the potential environmental burden and to ensure sustainable construction [17].

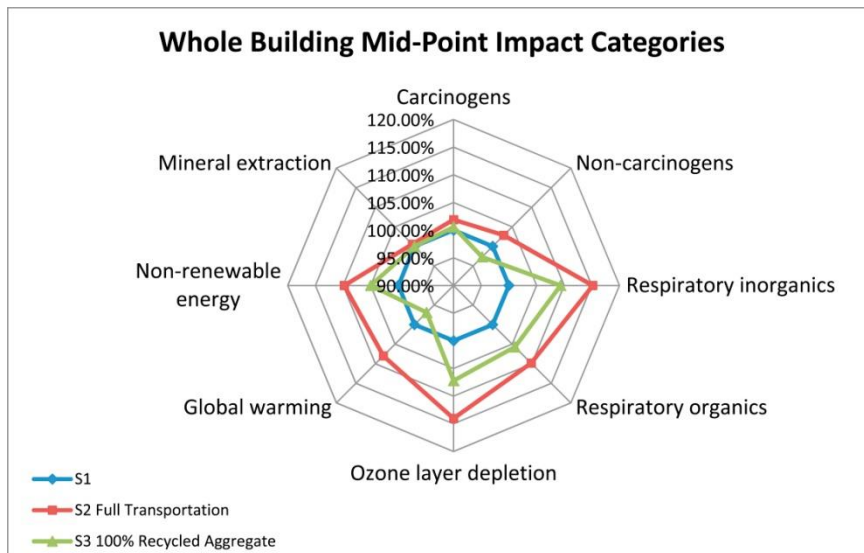


Figure 4. Impact assessment for the entire structure [17]

Life cycle impact analyzes have been conducted for the optimum environmental and economic benefit of concrete production stages using NA and RCA in Europe. The European life cycle database was used for maintenance work and areas where company data could not be collected. The environmental and economic impacts of raw material supply (A1), transportation (A2) and production (A3) stages of the building life cycle, which are only the production process, have been investigated [18].

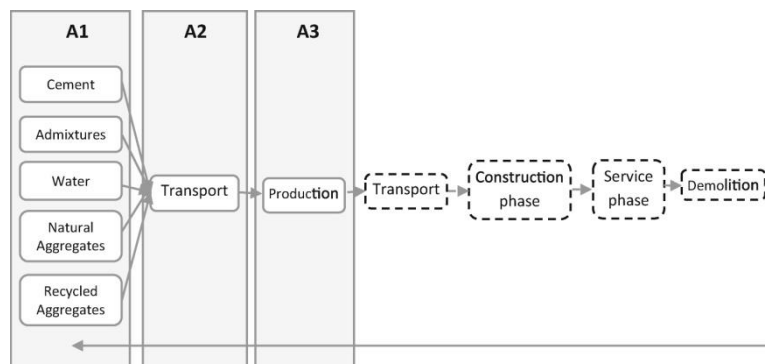


Figure 5. Concrete production process and life cycle [18]

When the mechanical, environmental and economic aspects of the manufactured concrete are examined, it has been observed that reducing environmental effects does not increase the cost. It has been determined that using CEM II type cement instead of CEM I reduces the cost and environmental impact. When the environmental and economic effects of the material are examined, it is seen that the use of recycled aggregate has significant environmental and economic benefits in the concrete production process [18].

The possibility of RCA being replaced by NA in concrete was also investigated. In a study using different waste aggregates, cement dosage, plasticizer usage and silica fume effect on samples were investigated. As a result of

the mechanical tests, it was observed that the use of 100% waste aggregate in concrete caused a decrease in strength, while the use of 75% NA and 25% RCA gave values close to the strength control samples [19].

The quality of aggregates is also important in concretes produced using waste aggregate. In order to increase the quality of waste aggregates, the aggregates are kept in acetic acid solution and the surface is purified. It has been determined that the use of 25% waste aggregate in the samples produced gives positive results. In addition, it has been revealed that the waste aggregate has a lower water absorption rate as a result of its processing [20]. The coarse natural aggregate has been completely replaced by RCA. As a result, an increase of 6-10% has been observed for energy consumption, global warming, eutrophication, acidification and photochemical ozone formation. However, waste generation was reduced by 35% and abiotic consumption by 50% [21].

The potential environmental impact of coarse RCA for concrete production in China has been studied. Life cycle analysis was conducted for the environmental impact of waste storage areas resulting from cement contents, aggregate replacement, transportation, production and concrete production. It has been observed that the GDA concretes have a beneficial effect on the environment during the transportation phase, but the increase in cement dosage in GDA concretes has the most impact and increases the environmental impact. Despite the environmental impact in the construction industry in China, it has been suggested that the use of SEE will have a positive effect on resource depletion and that new techniques should be developed [22].

Life cycle assessment was conducted for 624 recycled aggregate concrete mix, consisting of 61 separate studies, to measure the CO<sub>2</sub> emission of GDA concrete. Based on large scale life cycle assessment, emission factors for GDA concrete have been defined. Overall, similar emission results were obtained as a result of an extended functional analysis including volume, strength and durability. However, it has been suggested that RCA may be preferred to be used as a filling due to its high carbonation [23].

Mix design method of GDA concrete, selection of functional units, transport distance of recycled aggregate, allocation of material and CO<sub>2</sub> parameters were evaluated in the province. A relationship has been established between the total environmental impact of concrete and the LDA transport distance. It was emphasized that the effect of mechanical property variability of concrete on the environmental impact of LDA should be taken into account. In addition, it is suggested to use a Geographical Information System (GIS) based method to determine the transportation distance and give the most appropriate transportation plan [24].

An extensive experimental study was conducted to understand the mechanical behavior, environmental impact and resource utilization of concrete mixtures with high amounts of fly ash (UK) and GDA. In addition, the environmental impact of the manufactured concretes was also examined. According to the results of this study, although the transport distance was relatively short according to NA, the environmental impacts of including GDA and UK in the mixtures did not significantly affect [25].

### 3. Conclusion

Today, different waste uses are seen in cement and concrete production. These wastes can be by-products that are generated as a result of production or used directly, as well as the number of wastes used by processing is quite high. Six hundred million tons of construction waste is expected in Istanbul alone in the next ten years in our country. In addition, the environmental burden of the construction sector should be minimized by recycling or reuse of construction wastes from urban transformation projects. Waste management and reuse will become a necessity for our country.

It is seen that the use of recycled aggregate reduces global warming, air acidification and toxic air for human health and especially the reduction is more effective in virgin aggregate production and transportation. However, environmental impacts increase due to the production energy in concrete, where GDA is completely used. For this reason, useful solutions should be produced for both mechanical properties and environmental effects of concretes to be manufactured with the optimization of GDA and NA.

Since the use of GDA completely requires more energy, it is not recommended in high-rise buildings, but it is important to use it especially in projects such as infrastructure and filling. Where a number of transport activities in Turkey during this period should *yönelim* RCA technology, so there should be benefits for both environmental and economic development.

Replacing NA with RCA is a technically feasible option in terms of reducing natural resource consumption and waste generation. However, before claiming an improvement in sustainability, the environmental impact needs to be thoroughly analyzed. Currently, studies are continuing due to the fact that the use of RCA does not have an extreme environmental benefit, but it significantly reduces the consumption of natural resources.

The raw material problem, which occurs with the decrease of natural resources and the increase in the population, can be minimized by re-utilizing the waste materials. While the use of waste materials contributes to the search for raw materials, CO<sub>2</sub> emission in production can be prevented.

Sustainable building materials will gain more importance in the construction sector due to the decrease in resources, transportation costs and construction waste disposal. The necessity of leaving enough resources for the future generations to be sufficient for themselves can only be realized with correct and environmentally conscious projects.

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