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Concrete around us. Building and climate change

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Abstract: Concrete is a valuable material that is widely used by the modern construction industry. It has many valuable advantages and unique properties, hence its widespread use, and not only for the construction of objects. The scale of its use has been the subject of many discussions with regard to the environmental impact and significant CO_2 emissions that accompany its production and subsequent application. The article starts by presenting the scale of production of this material, its advantages and importance for the construction industry. This is followed by an attempt to determine how to optimize its use. Finally, the article raises issues related to the possibility of using alternative solutions to concrete structures and products based on a concrete mix, after which final conclusions are presented.

Keywords: construction, concrete, environmental protection

Introduction

When looking at conteporary buildings, one can get the impression that the ubiquitous concrete dominates modern civil engineering, from construction to land development. Concrete is all around us. Only buildings with a small volume are still built using other materials, mostly ceramics and wood. Concrete is becoming the dominant material in many areas of construction. At the same time, there is an increasing number of opinions about the high price for the natural environment associated with the scale of usage of concrete in construction. The main reason for such concerns is the significant amount of greenhouse gases that are emitted during the production and further use of this material. It is concrete that is blamed as the main culprit for high amounts of CO_2 released into the atmosphere by the construction industry.

Contemporary times need solutions that minimize the degradation of the natural environment, help to protect the climate and, at the same time, enable further economic development. The amount of concrete used in buildings and structures is massive. From concrete frames, nonbuilding structures and roads to elements of finishes, land use, to decorative elements. It is a valuable material, widely used by designers, architects and constructors. Undoubtedly, it offers important and unique advantages. However, like any building material, it also has disadvantages. In addition to the well-known advantages of concrete, such as strength, another important advantage is the possibility to modify or „improve" its basic properties by using various types of additives. This significantly increases the benefits of using this material as well as its scope of application. Architectural concrete, also known as transparent concrete, is a modern material that offers architects new possibilities and creative solutions. In my opinion, the widespread use and popularity of concrete are primarily due to the possibility to create elements of any shape, depending only on the mold in which we place the concrete mix. This enables us to design and build structures and components that have sophisticated, unusual forms. The technology of concrete production allows for the mass production of ready-made elements, i.e. prefabrication of virtually all basic structural components of typical buildings, their production and storage outside the construction site. Building with concrete is quick, permanent and comparatively cheap, if such a term can be used in relation to construction.

Fig. 1. Reinforced concrete structure. Own photo

Assuming that concrete is the „main culprit" behind significant amounts of CO_2 emitted by the construction industry, it seems that the simplest solution is to eliminate concrete from construction in order to reduce the level of these emissions. But can one imagine modern construction without this material or with concrete reduced only to exceptional applications? And is it really easy to eliminate CO_2 from the construction industry?

To what extent can concrete be replaced by other materials that are beneficial to the environment? If we were to adopt a simple principle of replacing the reinforced concrete structure with a wooden one, for example, such an approach would be very naïve and certainly not very rational. Or maybe those popular opinions about the high cost of using concrete for the natural environment are exaggerated and obscure the advantages of this material? These questions do not seem easy to answer. This article makes such an attempt. The result will be an outline of possible vectors of actions that could lead to the rational use of concrete as well as other actions conducive to the overarching goal, i.e. the reduction in the amount of CO_2 emitted into the atmosphere and thus environmental protection.

Environmental impact of concrete

Concrete is not an invention of modern times. Evidence of its use dates back to antiquity and even to the more distant Stone Age [4]. The Romans made it out of water, stone aggregate, gypsum, lime and volcanic ash and one example of how they mastered this material is the dome of the Pantheon with a diameter of over 43 meters. Considering all the processes involved in the construction of buildings and structures, the modern construction industry generates huge amounts of carbon dioxide. According to a study conducted by the Green Building Association, as much as 38% of carbon dioxide emissions in Poland come from the construction sector [5]. This number includes emissions generated by the production of building materials, construction, usage of the building, its demolition and sale. It is possible to reduce these emissions at each of these stages. In terms of the amount of carbon dioxide emitted by the process of manufacturing building materials, concrete, or rather one of its key components, cement, is the leader. Cement production is responsible for 8% of carbon dioxide emissions worldwide [6]. Given the scale of production, i.e. the amount of concrete produced, this is a significant amount but there is also room for reduction of these emissions. Concrete production in 2021 in Poland amounted to approx. 26 million m^3, which consisted of approximately 50 million tons of aggregate and 8 million tons of cement [7]. In most countries, construction is one of the key sectors of the economy and it has a wide impact on other branches of production and services, not only those directly related to construction. Concrete is the most commonly used man-made material, not only in construction. The level of production of this material is an important indicator of the condition of the entire economy [7]. Therefore, when establishing

the lines of action aimed at reducing greenhouse gas emissions, it is important to choose rational actions that lead to positive effects but do not limit the development of the construction industry and thus many other branches of production and services.

The carbon footprint determines the total amount of greenhouse gas emissions during the full life cycle of a product. It is expressed as carbon dioxide equivalent per functional unit of the product. The carbon footprint includes emissions of CO_2, methane, nitrous oxide and other greenhouse gases [8]. The carbon footprint applies to all production, including other building materials, not just concrete. Preparation of an ordinary concrete mix causes atmospheric pollution of approx. 140–310 kg CO_2 eq/t. On its own, this amount is smaller than in the case of steel production (approx. 1900 kg CO_2 eq/t). However, given the quantitative scale of concrete production, the resulting pollution of the Earth's atmosphere is significant [1]. The calculation of the carbon footprint of concrete is most often based on its life cycle and includes activities related to the extraction and preparation of raw materials, transport, preparation of the mix and transport to the construction site. However, one should also take into account the period of operation and the time after demolition, i.e. the so-called „second life" of concrete[1].

An analysis of the amount of CO_2 emitted by the processes of obtaining raw materials for the production of concrete shows that cement production has the largest influence on this amount. A side effect of the calcium carbonate firing process, in addition to calcium oxide, is CO_2. The production of Portland cement releases approx. 700 kg of CO_2/t of cement and requires a large amount of energy

Lines of action

Considering the goal set out in the Paris Agreement of 2015, i.e. to achieve climate neutrality by 2050, numerous actions and initiatives are undertaken, also by cement and concrete manufacturers, which are to designed to bring about a gradual reduction of greenhouse gas emissions and thus to „save" the climate of our planet. Taking into account the entire „life-cycle" of a building, from the production of materials, to construction, service life and finally its demolition, the scope of operations is considerable. This not only pertains to buildings, but also includes everything that is related to the areas around buildings, such as squares, communication routes and other elements of land development.

The simplest solution seems to be a significant reduction in the use of concrete in the construction industry. On the other hand, from a practical standpoint, concrete is so useful and sometimes virtually impossible to replace that it is very difficult to stop using this material.

Concrete surfaces made of various types of slabs in urban squares, parking spaces and areas around buildings are a very common solution. Squares and communication routes with too much concrete are comfortable to use, durable and easy to clean, but they generate more and more opposition and awaken a yearning for natural and ecological spaces. This is especially true in highly urbanized areas, where even the smallest „patches" of greenery are extremely valuable. In the social space, the term „concreteosis" was coined for the excessive use of concrete in public areas. What could singnificantly change this situation is a different approach to designing and an understanding among investors of the need to introduce other, ecological solutions.

If we reduce the amount of cement in the concrete mix by partially substituting it with fly ash, multi-furnace slag, or micro silica, we could attain a substantial, linear decrease in the amount of CO_2 released into the atmosphere. This seems to be a beneficial solution, even at the price of lowering the strength of concrete, wherever possible.

These substitutes are waste products in various types of combustion and smelting processes, and the only emissions of CO_2 in this case are generated by their transport to concrete plants [1].

An alternative to traditional concrete is organic concrete, i.e. a concrete mix composed of fibrous waste materials from plants, such as reed, instead of aggregate. Hempcrete, in turn, is a mixture of cut up woody pieces of hemp stalks with a lime-based binder. Such „alternative concretes" with a much lower density than traditional concrete will not replace concrete in traditional reinforced concrete structures, but they can be used for other applications, such as infill walls in a structural frame. The main advantage of such conglomerates is that they are much more „environmentally friendly" materials. The amount of CO_2 absorbed during hemp growth

exceeds the amount of carbon dioxide generated in the production of concrete, which ultimately makes such a mixture carbon negative.

The widespread use and promotion of such concrete-based conglomerates makes it possible to implement a „more environmentally-friendly concrete" wherever such materials are suitable.

Hempcrete was discovered in the 80s. of the XX century. In Poland, building houses in hemp concrete technology is gaining more and more supporters. In 2012, the first such experimental building was built at the Institute of Natural Fibers and Medicinal Plants in Poznań. In 2016, the first year-round house in Poland was built, completely insulated with hemp concrete [10].

Trees, like all plants, absorb and accumulate significant amounts of CO_2 during their growth cycle, which, combined with the unique properties of wood, make it a very popular building material.

However it would be difficult and unrealistic to use wood instead of concrete in building structures and finishes where concrete is used on a large scale. Thanks to modern technologies that process and produce entire systems of elements for erecting buildings, the use of timber in construction is developing rapidly but it cannot eliminate or replace concrete in all areas of construction. Timber as a building material has been used for centuries. You can see how it differs from concrete „at first glance". This material has been used for a long time to build various structures, including rural cottages, palaces and manors, and religious and defensive buildings. Thanks to modern technologies we can use this material in a very well-planned and effective manner.

Fig. 2. Building in a wooden structure. Own photo

However, one must realize that it takes many years for a small seedling to grow into a large tree which can later be used for construction purposes. In addition, each tree is extremely valuable for our environment. They are an irreplaceable source of oxygen. One hectare of a deciduous forest produces about 700 kg of oxygen per day and retains huge amounts of toxic substances contained in the air (carbon dioxide, sulfur dioxide and heavy metals) [9]. Forests have a huge impact on the earth's climate. They protect against soil erosion, mitigate the effects of hurricanes, and finally have a soothing effect on our nervous system. All this points to the inescapable conclusion that forest resources must be managed carefully, also in terms of their use in construction. It would be highly undesirable if our attempts to replace concrete with wood in order to reduce CO_2 emissions and protect the climate led to irreversible damage and destruction to the environment.

With respect to concrete, CO_2 emissions can be reduced during the building use phase as well as by limiting the amount of demolitions and thus avoiding problems with the recycling and reuse of materials. Instead of demolishing a building and erecting a new one from scratch, we could, at least to a certain extent, modernize and adapt existing buildings, including those with frames and individual elements made of concrete. In many

places, especially villages, there are abandoned buildings, sometimes in ruin, which, at least in part, could be saved. Such renovations are becoming increasingly popular, but perhaps the scale of these projects is still too small. Old buildings receive a „second life", which sometimes differes from their original function. Such projects most often use ecological materials and technologies, natural materials, and reclaimed materials, which are environmentally friendly [2][3]. These types of activities can even serve as „manifestations" of ecological attitudes and behaviors among people and circles for whom environmental protection is one of the most important values in their way of life.

Conclusions

Concrete is a valuable material that is widely used by the modern construction industry. It has many advantages and valuable properties and in many respects it is a unique material.

Many of its applications are difficult to replace. If, motivated by the desire to reduce CO_2 emissions, we take actions only aimed at limiting the use of concrete, without considering the consequences of such decisions, we are only addressing the superficial problem. A rational approach to designing and erecting new facilities, combined with the use of existing building resources, can help to significantly reduce the emissions of CO_2 into the atmosphere, which are the main reason why concrete evokes negative connotations. The following list includes such actions in many areas related to construction and not only limited to concrete:

1. Limitation on the excessive use of concrete in buildings and land-use elements.
2. Rational replacement of concrete and reinforced concrete elements and structures with other alternative materials, where possible.
3. Popularization of a concrete mix that uses ingredients whose production eliminates or significantly reduces the amount of CO_2 emitted into the atmosphere.
4. Rational and well-planned development of timber constructions.
5. Promotion of green building and building solutions, including the use of existing buildings.

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Beton wokół nas. Budownictwo a zmiany klimatyczne

Streszczenie: Beton jest materiałem budowlanym szeroko stosowanym we współczesnym budownictwie. Ma wiele cennych zalet i wyjątkowych właściwości, stąd jego powszechne wykorzystanie i to nie tylko do wykonywania konstrukcji obiektów. Skala jego wykorzystania staje się przedmiotem co raz szerszych dyskusji w aspekcie wpływu na środowisko naturalne i znacznej emisją CO_2, która towarzyszy jego produkcji oraz późniejszemu zastosowaniu. W artykule przedstawione skalę produkcji tego materiału, jego zalety i znaczenie w budownictwie. W dalszej części podjęto próbę , określenia optymalnego sposobu jego wykorzystania. Poruszono kwestie dotyczące możliwości zastosowania alternatywnych rozwiązań w stosunku do konstrukcji betonowych oraz produktów opartych o mieszankę betonową W podsumowaniu części przedstawiono wnioski końcowe.

Słowa kluczowe: budownictwo, beton, ochrona środowiska