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INFLUENCE OF CEMENT INDUSTRY ON GLOBAL CLIMATE CHANGE

Abstract:
The article deals with global climate change for few last decades and establishes relation between co2 concentration and global climate change. Summarized influence of manufacturing of cement and concrete on world's CO2 emission. Effective supplementary cementitious material like fly ash, slag and silica fume were proposed.

Keywords:
Global climate change, cement, fly ash, silica fume

Global climate change is one of the most crucial questions for modern society, 2021 was the sixth-warmest year on record based on NOAA's temperature data (NOAA is National Oceanic and Atmospheric Administration). The nine years from 2013 through 2021 rank among the 10 warmest years on record. Earth's temperature has risen by 0.08° Celsius per decade since 1880, but the rate of warming since 1981 is more than twice that: 0.18° C per decade.

Record-high temperatures over land surfaces were measured across parts of northern Africa, southern Asia, and southern South America in 2021. Record-high sea surface temperatures were observed across parts of the Atlantic and Pacific oceans. However, no land or ocean areas were record cold for the year.

Regionally, the annual average temperature departure for Africa tied with 2019 as the third highest on record, behind 2010 (second-warmest) and 2016 (warmest). North America, South America, Europe, and Asia each had an annual temperature that ranked among the nine warmest on record.

Based on analysis from NOAA's Global Monitoring Lab, global average atmospheric carbon dioxide was 414 parts per million in 2021, setting a new record high despite the continued economic drag from the COVID-19 pandemic. In fact, the jump of 2.58 ppm over 2021 amounts tied for 5th-highest annual increase in NOAA's 63-year record.

One of the most significant questions is that global warming really correlated with increasing of co2 emission? Let's consider figure 1 - diagram of rising of global temperature, which is combined with co2 emission graph [1]. As we can see, there is obvious robust correlation between the rise in carbon emissions and increases in global temperatures. Because of using of fossil fuels, intensify the concentration of carbon dioxide (CO2) in the atmosphere, which peaked at the unprecedented level of 400ppm for the first time in 2014, and is likely to remain above those levels in the foreseeable future.

Carbon dioxide concentrations are rising mostly because of the fossil fuels that people are burning for energy. Fossil fuels like coal, oil and natural gas contain carbon that plants pulled out of the atmosphere for many millions of years. But now, we are returning that carbon to the atmosphere in just a few hundred years. Since the middle of the 20th century, annual emissions from burning fossil fuels have increased every decade, from an average of 3 billion tons of carbon (11 billion tons of carbon dioxide) a year in the 1960s to 9.5 billion tons of carbon (35 billion tons of carbon dioxide) per year in the 2010s, according to the Global Carbon Update 2021.

Carbon cycle experts estimate that natural "sinks"—processes that remove carbon from the atmosphere—on land and in the ocean absorbed the equivalent of about half of the carbon dioxide we emitted each year in the 2011-2020 decade. Because we put more carbon dioxide into the atmosphere than natural processes can remove, the amount of carbon dioxide in the atmosphere increases every year.

The more we overshoot what natural processes can remove in a given year, the faster the atmospheric concentration of carbon dioxide rises. In the 1960s, the global growth rate of atmospheric carbon dioxide was roughly 0.8± 0.1 ppm per year. Over the next half century, the annual growth rate tripled, reaching 2.4 ppm per year during the 2010s. The annual rate of increase of CO_2 over the past 60 years is roughly 100 times faster than previous natural periods, like at the end of last ice age about 15 years ago.

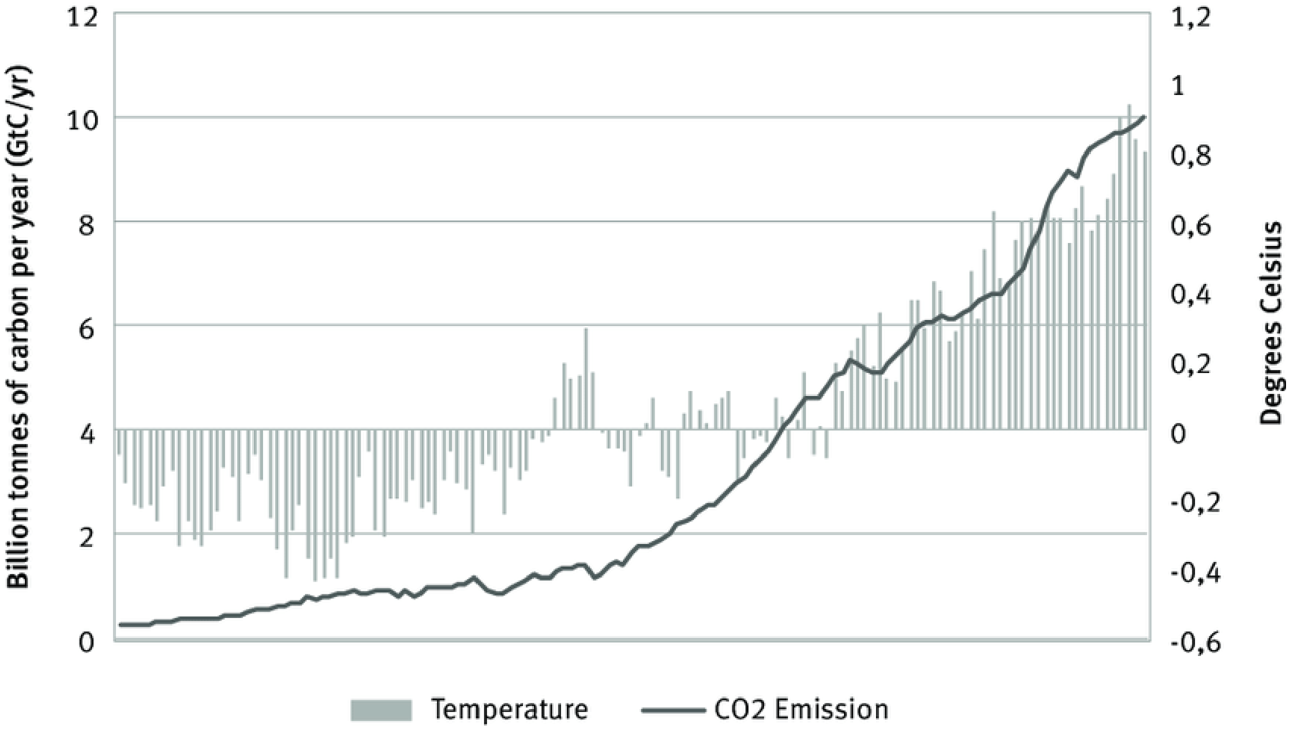

Figure 1 – Global warming and CO2 emissions 1880-2015

The modern record of atmospheric CO_2 levels began with observations recorded at Mauna Loa Observatory in Hawaii. Figure 2 shows the station's monthly average carbon dioxide measurements since 1960 in parts per million (ppm). The seasonal cycle of maximum and minimum values (small oscillating) is driven by summertime growth and winter decay of Northern Hemisphere vegetation. The long-term trend of rising carbon dioxide levels, undoubtly, is driven by human activities.

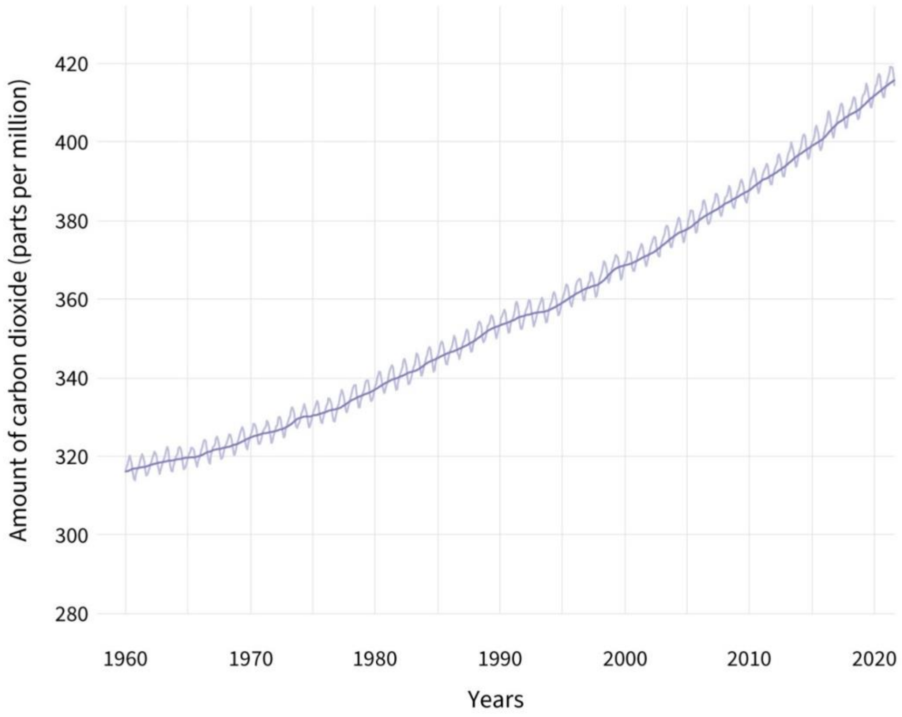

Figure 2 - Atmospheric carbon dioxide concentration

Of course, we have to admit, that greenhouse gases are not only carbon dioxide, but, at the same time, currently, it is CO_2, which is the main factor of global warming. On the other hand, some experts declare doubts, that significant rising of CO_2 concentration is caused of human effecting, as they say rise of co2 concentration can be caused very natural reasons instead human industries – volcanic activities, for example.

One of the most representative ways to evaluate emission of CO_2, as known, caused by different kinds of human activities, as you know, is a value of carbon footprint. A carbon footprint is the total amount of greenhouse gases (including carbon dioxide and methane) that are generated by our actions.

The most tremendous amount of emission of CO_2 corresponds to few most well-developed countries, like the USA, China, Russia, and India. Main impact to our nature is doing by US and China, but this fact couldn't calm down specialists from other countries. Next tremendous questions - why do we pay attention to production of concrete? Does really cement have tremendous carbon footprint?

Manufacturing of cement involves various raw materials and processes. Each process is explained chemical reactions for manufacture of Portland Cement. Cement is a greenish grey colored powder, made of calcined mixtures of clay and limestone. When it mixed with water becomes a hard and strong artificial material. The manufacture procedures of Portland cement include next stages: mixing of raw materials, burning, grinding, storage and packaging. The major raw materials used in the manufacture of cement are Calcium, Silicon, Iron and Aluminum. These minerals are used in different form as per the availability of the minerals.

Let's have a look at chemical formula of cement manufacturing. As we can see, this is chemical reaction, which leads to significant carbon dioxide emission. Of course, heating of raw materials requires tremendous amount of energy and, also gives us co2 emission at the same time, but chemical dividing of lime stone gives us the biggest part of carbon dioxide releasing. For approximate estimation we can state, that production of 1 ton of cement leads to emission of 1 ton of carbon dioxide.

As you can see, concrete production is one of the most tremendous parts of global commodities manufacture. Total volume of concrete production archives 14 billion of cubic meters per year, since density of concrete is roughly 2.2 ton per cubic meter, total concrete manufacture is about 30 billion tons, that is much, much bigger than production of crude oil or steel. As you, probably, remember each cubic meter of concrete includes about 300 kg of cement, and here, we can find out, that global production of cement is about 4.4 billion tons per annually, which is insignificantly less than crude oil production.

It is shown in table 1, the biggest manufacturer of cement is China, and total amount of Chinese cement is over 2200 million metric tons per annum. It is overwhelming, but every year China produces much cement, then the USA overall 20th century. The second biggest manufacturer is India, which produces 320 million metric tons per annum. Cement manufacture of Russia is about 60 million tons per year.

Table 1 – The world's biggest manufactures of cement

Country	Production (in MTPA)
China	2200
India	320
Vietnam	95
USA	89
Egypt	76
Indonesia	74
Russia	57
Korea	55
Japan	54
Turkey	51

There are many ways to reduce CO2 emission from concrete and cement industry, like that:

- Using different admixtures instead of part of cement in concrete,
- Using of high performance concrete, and, of course, ultra high performance concrete, that allows reduce total amount of concrete and cement since dimensions of elements become less,
- Increasing of durability of concrete and reducing of volume of new buildings.

Let's consider carbon footprint of ordinary cement and some different types of binders in more details.

As we can see from the current table 2, fly ash, slag and silica fume have very small carbon footprint compare to ordinary cement. But, what is the reason of that? I state, those material are the by-products of different human industries, and their carbon footprint was accounted there. Thus, using those types of admixtures, we twice help environment: very first time when we use by-products, which is waste in other case, and, second time when we reduce required cement amount.

Table 2 – CO2 equivalent factor of some cementitious material

Binder	CO2 equivalent factor
Ordinary portland cement	0.92
Portland limestone cement	0.85
Slag	0.15
Fly ash	0.06
Silica fume	0.06

Fly Ash

Fly ash, the most widely used SCM (supplementary cementitious material) in concrete [2], is a byproduct of the combustion of pulverized coal in electric power generating plants. During combustion, the coal's mineral impurities (such as clay, feldspar, quartz, and shale) fuse in suspension and are carried away from the combustion chamber by the exhaust gases. In the process, the fused material cools and solidifies into glassy particles called fly ash. The fly ash is then collected from the exhaust gases by electrostatic precipitators or bag filters as a finely divided powder [2, Figure 4-2].

Fly ash is used in more than 50% of ready mixed concrete (PCA2000). Class F fly ash is often used at dosages of 15% to 25% by mass of cementitious material and Class C fly ash is used at dosages of 15% to 40% by mass of cementitious material.

Slag

Slag cement is the glassy material formed from molten slag produced in blast kilns as a byproduct from the production of iron and steel making. The molten slag is shaped as the ingredients used to make iron melt at a temperature of about 1500°C and float above the denser molten iron. In order to transform the molten slag into a cementitious material, it is rapidly quenched in water to shape a glassy-like, granulated material, then dried and ground into a quite fine powder [2, Figure 4-4]. If slag is allowed to cool slowly in air, it will form crystalline products that have no cementitious properties. None systematically cooled slag is inert material, and is used for other applications, such as aggregate for backfill in civil, industrial and infrastructure buildings [2, Chapter 6].

Slag cement, when used in general purpose concrete, commonly constitutes between 30% and 50% of the cementitious material in the mixture.

Silica fume

Silica fume is the ultrafine non-crystalline silica produced in electric-arc furnaces as an industrial byproduct of the production of silicon metals and ferrosilicon alloys. Silica fume is also known as condensed silica fume, or microsilica. Silica fume rises as an oxidized vapor from the 2000°C furnaces. When silica fume cools it condenses and is collected in special bag filters. The condensed silica fume is then processed to remove impurities.

Silica fume is typically used in amounts between 5% and 10% by mass of the total cementitious material. It is used in applications where a high degree of impermeability is needed and also in high-strength concrete.

PLC

Portland-limestone cement is engineered with a higher limestone content. PLC (Type IL) gives specifiers, architects, engineers, producers, and designers a greener way to execute any structure, paving, or geotech project, with virtually no modifications to mix design or placing procedures. All while maintaining the resilience and sustainability you've come to expect from portland cement concrete.

Experts say, that when addition amount of limestone is quite small, strength of concrete is increased, but when containing of limestone achieves about 4%, strength of concrete start to decrease.

In other worlds, we can replace about 10% of ordinary portland cement without decreasing of total strength of concrete [3].

Summarize, production of concrete and cement is extremely significant – concrete is second most popular commodity in the world after water. And production of cement impact on environment becomes bigger from year to year.

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