FORUM: Environmental Commission (EC)

QUESTION OF: Assessing the environmental impact of concrete manufacture and application

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INTRODUCTION

Cement is one of the most used substances in the world right after water. From the ancient times, concrete and cement was highly used in regions such as Syria and Jordan, with concrete made from clay and crust limestone to build structures. Knowledge upon the lime-based material travelled through Ancient Egypt and Greece and reached the Romans around 300 BC, where it was used in various cementing properties and on structures that still exist. Such structures are the pantheon and the Colosseum in Rome. Today, the material that we use is called modern concrete, which was birthed after Joseph Aspdin introduced a new and improved cement in 1824 that was made by heating up chalk and clay before grinding it into a fine powder. This invention was named Portland cement, due to the resemblance of portland stone after it hardens.

Although concrete and cement have numerous benefits, there are some severe consequences, and most importantly environmental damage. As in the manufacturing process raw materials are used a big amount of energy is consumed to extract them as well as later on in the heating process where not only a large amount of energy is used a large amount of carbon dioxide emissions are also taken into consideration.

The concrete industry holds about 8% of the responsibility in the carbon dioxide emissions since almost all of the manufacturing process releases into the atmosphere a large

amount of these emissions.During the application and its lifetime concrete is assessed and remains responsible for energy consumption and water pollution.

DEFINITION OF KEY TERMS

Cement

"A powder of alumina, silica, lime, iron oxide, and magnesium oxide burned together in a kiln and finely pulverised and used as an ingredient of mortar and concrete."

Concrete

"A hard strong building material made by mixing a cementing material, such as Portland cement, and a mineral aggregate, such as sand and gravel,with sufficient water to cause the cement to set and bind the entire mass."

Clinker

"A brick that has been burned in the kiln to the point of becoming darkened or deformed."[1] It has a centre role upon concrete production since it is the key product in cement production.

Environmental Sustainability

"Environmental sustainability refers to the responsible management of natural resources to fulfil current needs without compromising the ability of future generations to meet theirs. It aims to balance ecological, economic and social goals, such as reducing carbon emissions, promoting renewable energy and ensuring equitable resource access."[2]

Greenhouse gases

[1] "Clinker Definition & Meaning." Merriam-Webster, https://www.merriam-webster.com/dictionary/clinker#h2. Accessed 21 July 2024.
[2] Patterson, Nicholas. "Examples of Environmental Sustainability." *SNHU*, https://www.snhu.edu/about-us/newsroom/stem/what-is-environmental-sustainability. Accessed 20 July 2024.

"Greenhouse gases (GHGs) trap part of the sun's heat within the Earth's atmosphere. While much of the sun's energy reflects off the Earth's surface and escapes back into space, greenhouse gases effectively capture some of this energy, reflect it, and thereby warm the planet. An excess of greenhouse gases in the atmosphere, driven by human activity since the industrial revolution, has led to rising temperatures and an escalating climate crisis."[3]

Kiln

"An oven, furnace, or heated enclosure used for processing a substance by burning, firing, or drying"[4] .This is used particularly in clay products, as well as in the manufacturing of concrete and cement.

Supplementary Cementitious Materials (SCMs)

"Supplementary Cementitious materials are soluble siliceous, aluminosilicate, or calcium aluminosilicate powders used as partial replacements of clinker in cements or as partial replacements of portland cement in concrete mixtures."[5]

Mortar

"A mixture of sand, water, and cement or lime that is used to fix bricks or stones to each other when building walls"[6]

Portland Cement

"Portland cement, is a binding material in the form of a finely ground powder, usually grey, that is manufactured by burning and grinding a mixture of limestone and clay or limestone and shale. When mixed with water, the anhydrous calcium silicates and other constituents in the Portland cement react chemically with the water, combining with it

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[3] "What are greenhouse gases? - Berlin." *PlanA.Earth*, https://plana.earth/glossary/greenhouse-gases-ghg. Accessed 20 July 2024.
[4] Stamper, Joshua. "Kiln Definition & Meaning." Merriam-Webster, https://www.merriam-webster.com/dictionary/kiln. Accessed 21 July 2024.
[5] Supplementary Cementitious Material Https://www.sciencedirect.com/topics/engineering/supplementary-cementitious-material September 9, 2024
[6] "MORTAR | English meaning - Cambridge Dictionary." Cambridge Dictionary, https://dictionary.cambridge.org/dictionary/english/mortar. Accessed 21 July 2024.

(hydration) and decomposing in it (hydrolysis) and hardening and developing strength, creating what is called concrete."[7]

BACKGROUND INFORMATION

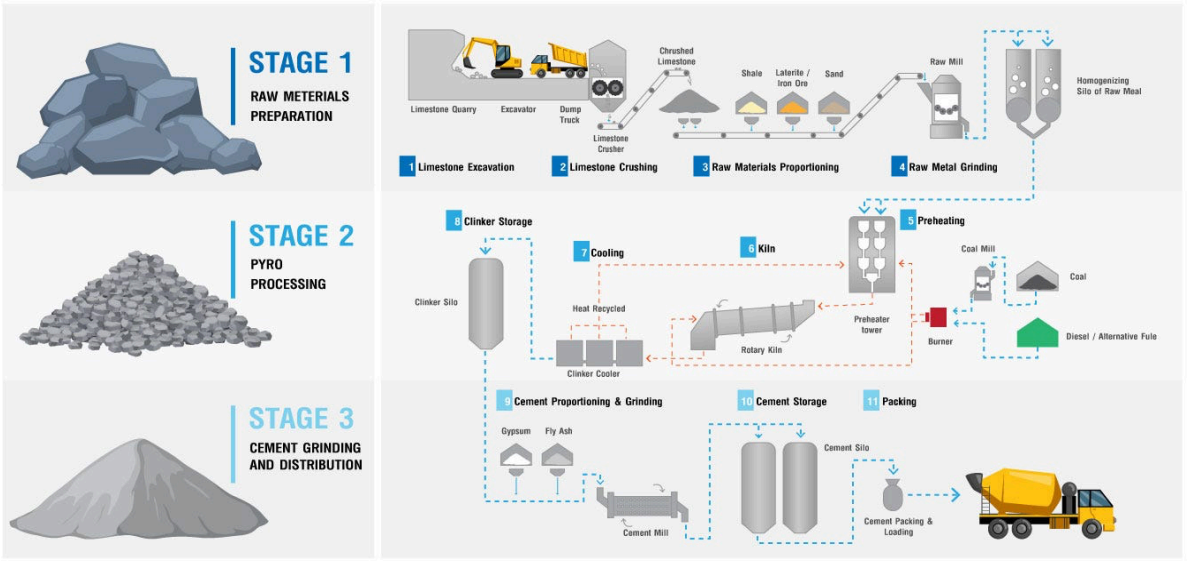
Concrete and Cement production

Concrete and cement are used in a variety of places due to their versatility and durability. It is a material that we interact with every day and more than 70% of the world's population lives in a structure that is made of concrete. This building material has the unique ability to be shaped to any structure, reaching from basic foundations and exterior surfaces to roads and bridges. It is preferred in the majority of the work done upon construction needs since it is characterised by its strength and durability combined with its cost effectiveness. Once it is installed, there is minimal work that is required in order to maintain it and it is generally less expensive than other building materials.

The process behind the cement production is very complex. To begin, the raw material needs to be extracted from the ground. These materials include limestone, clay, and sand, as well as alternative raw materials, such as fly ash, blast furnace slag, which are raw substances that contribute to a circular economy. After the quarrying process, the fragments are broken into ball-sized pieces, and they are sent to the laboratory for analysis in order to ensure their quality and efficiency. These rock pieces are ground finely and combined with ingredients such as chalk and shale, and later on blended to achieve a consistent composition, creating a mixture called raw meal. The raw meal goes through the preheating process, which includes travelling throughout a preheater tower so chemical reactions between the components begin, thus making the next step much more efficient. The finely ground material enters the higher end of a kiln and reaches the lower end, which has a flame, heating the materials to about 1,400 degrees Celsius. As this procedure partially molten the substance, a series of reactions take place creating the clinker, a new substance that occurs after adding a small amount of gypsum. The clinker finishes with the heating part

[7] "Portland cement | Manufacturing, Composition, Uses." Britannica, 21 June 2024, https://www.britannica.com/technology/portland-cement. Accessed 21 July 2024.

and later on it is quickly cooled down by some coolers. Emissions controlled devices are also used in this process implementing carbon capture and storage technology, preventing any major environmental impact.



[8]

The manufacturing process behind concrete is based on the production of cement since the main component is cement. In order to create concrete a combination of about 10-15% Portland cement and about 15-20% of water is blended and formed into a paste.This paste is combined with aggregates, such as sand, gravel or crushed stone, which constitute 65-75% of the mixture. Upon mixing the water and cement, they bind together, forming a solid mass[9].

Environmental Impact

Even though concrete and cement are highly used due to their benefits, they have severe environmental impacts, both upon their manufacturing and in their application. In the production process of cement, an important step takes place, which is controlling the

[8] Cement Production Technology. Introduction | by Suppawat Boonrach ...

[9]Etler, Sarah. "What Is Concrete Made Of?" A1concrete.com, 20 June 2024, www.a1concrete.com/concrete-repair-learning-center/what-is-concrete-made-of. Accessed 15 Sept. 2024.

emissions. This step is of paramount importance but not all concrete and cement producers follow it. As cement is one of the most widely used materials after water, all of the carbon dioxide emissions have a severe impact on the planet since it is responsible for 8-9% of them.

Manufacturing and Application of Concrete and Cement

The environmental impact of concrete goes beyond the manufacturing process. It continues to have environmental consequences even after the construction, particularly throughout its lifespan. Some of the impacts associated with concrete manufacturing as well as its application,are the following:

Carbon Dioxide Emissions

In order to produce concrete, the process of manufacturing cement takes place. When making one kilogram of cement,one kilogram of carbon dioxide is released into the atmosphere and as cement is one of the most consumed materials, on an average more than 4 billion tonnes are produced annually, releasing more than 4 billion tons of carbon dioxide in the atmosphere. During the manufacturing process, there are two main origins of which carbon emissions can occur. First, the combustion of fossil fuels used to power the rotary kiln are a main contributor since they release about ¾ of ton of carbon dioxide.The second source is “the chemical process of turning limestone into lime in the cement kiln”that also produces a large amount of CO2, which in combination with the burning fuels makes 1.25 tons of carbon. In addition, the high temperatures of the kilns also allow burning hazardous waste, such as tires, reducing the need to burn coal, which is one of the major sources of carbon emissions.

Energy Consumption

Besides the large amount of carbon dioxide released into the atmosphere, a large environmental concern is the energy consumption that happens during the concrete and cement production.The majority of the energy is used to operate the rotary kilns transport the raw materials, and the fuel for the extraction of these material, which all takes about 1,758 kWh per each cement ton.In the past, wet-process kilns were mostly used, needing 50% more energy to remove the moisture,than the modern dey-process kilns . In contrast

with cement production, concrete manufacturing requires less energy consumption since the other main components, such as sand, gravel and water, are not as energy intensive.

Water Pollution

Another important environmental concern regarding the manufacturing process of cement and concrete is the water pollution. As water has a critical part in the cement manufacturing process,such as being used for cooling and cleaning the machinery, it is very common to generate wastewater that if not handled properly pollutants can be released into water sources near the site. Substances such as these are heavy metals like chlorine and high levels of pH.As a result, it can disrupt ecosystems and the wildlife while also endangering human health.

Assessment of the Environmental Damage

Acknowledging the severe impact of concrete production and application, the cement industry has taken active measures in order to assure that the impact is limited and controlled. Firstly, there is the Life Circle Assessment (LCA) that is responsible for controlling the environmental damage from the early stages of the raw material extraction, through the production, reaching its application and disposal. Another method is controlling the amount of resources that are used in order to produce the cement. Particularly, the amount of raw material extracted is taken into consideration and later on assessed to see the type of damage it can cause. Measures such as these, also leave room for improvement making the industry more sustainable.

Mitigation

Even though this is an outstanding issue, attempts to solve it in a more innovative way have been made and tried in various different regions.For instance, the replacement of fossil fuel to biomass fuel, where instead of using fossil fuels, which are play a big role on the greenhouse gas emissions, they now use biomass fuels that utilise the waste and is a renewable source. Carbon Capture and storage (CCS) are able to reduce greenhouse gas emissions by capturing the carbon dioxide underground.

MAJOR COUNTRIES AND ORGANISATIONS INVOLVED

China

As the People's Republic of China is the largest cement producer worldwide, they are actively conducting research in order to achieve " a peak in carbon emissions by 2030 and neutrality by 2060".For that reason, China is also a country that has suffered concrete and cements most dangerous consequences, encouraging them to take action into the environmental impact.In order to cut down on its emissions, Anhui Conch, one of the largest cement manufacturers in the mainland of China, by limiting the coal and electricity per tonne of cement usage.In this process they changed from fossil fuel to biomass fuel, finding ways to capture carbon dioxide and reuse the waste heat to generate electricity. With this manufacturing corporation set as an example, other chinese companies start to adapt to these changes, assisting in reducing the carbon footprint in the cement industry. In addition, China's government has prioritised energy efficiency in the industry by constantly encouraging the modern, dry-process kilns, which are equipped with preheaters that use waste heat during the production. Lastly, in effort to change the traditional cement based construction, research has been conducted upon using steel structures to reduce environmental impact.

United States of America

The United States of America is currently working on new and innovative technologies to ensure that the cement and concrete industry are reducing the environmental impact. Since the U.S has recognized the issue at hand, and as they are not able to achieve zero-emissions yet but still work upon projects regarding this topic , they have worked on different decarbonization technologies. One of the fastest and inexpensive ways to control and reduce the emissions is by using blended cements. Particularly " incorporate substitute materials, called supplementary cementitious materials to make blended cement". Various corporations have worked with this strategy and the Roanoke Cement Cement Company in Virginia estimates to reduce emissions by 85%. Another technique to avoid emitting carbon dioxide is Carbon Capture and Storage (CCS). With this way, the carbon is captured and permanently placed into a suitable geological underground formation.

India

India is one of the most rapid-growing producers of cement, making the member state highly aware of the environmental damage this industry can cause. The region has also imposed some of the best national initiatives with programs such as the Perform, Achieve and Trade (PAT), that promotes energy efficiency and was launched under National Mission for Enhanced Energy Efficiency (NMEEE). India's Ministry of Environment, forest and Climate Change forced cement manufacturers to conduct Environmental Impact Assessments in large constructions. This program assesses the air quality, the water resources, the biodiversity, the land use and soil, and the noise pollution.

Environmental Impact Assessment (EIA)

Although it's not a part of the United Nations (UN), the Environmental Impact Assessment follows various UN frameworks and principles that are aiming to tackle the environmental impact of concrete and cement manufacturing and application. As EIA is aware of all the consequences associated with concrete and cement they strongly recommend mitigation measures to control the issue. Adopting new technologies and improving energy efficiency as well as optimising the use of supplementary cementitious materials (SCMs) are able to reduce a large amount of carbon footprint.The United Nations Environment Programme (UNEP) also provides guidance upon the EIA and encourages innovation and improvement through research and new technologies.

World Cement Association (WCA)

The World Cement Association (WCA) “supports the full decarbonisation of the cement industry”[10]. It is recommended that the use of synthetic fuels in carbon capture and the usage of biomass can decrease emissions. The WCA also supports research in technologies that can reduce the environmental impact of cement manufacturing, technologies such as alternative fuels and raw materials as well as enhancing energy

[10] “WCA - Who We Are.” *World Cement Association: WCA*, www.worldcementassociation.org.

efficiency. Lastly, it aims to drive positive change and assist the cement sector in becoming more responsible and aware of the practices.

International Energy Agency (IEA)

During the manufacturing process of cement, a large amount of energy is used and that is the reason that most efforts to reduce environmental impact is energy efficiency. The International Energy Agency (IEA) provides energy efficiency roadmaps and strategies to assist in reducing reliance on fossil fuels and replacing them with renewable alternatives in the cement industry. In addition, they provide guidance to regulate some rules and frameworks in order to encourage energy efficiency and low carbon technologies, and special approaches are made in countries with a large amount of cement producers.

TIMELINE OF EVENTS

Date	Description of Event
6500 BC	The earliest recordings of concrete structures by the Nabataea traders in the region of Jordan and Syria, creating concrete floors, housing structures, and underground cisterns.
3000 BC	Egyptians tended to use mud mixed with straw to create dried bricks, gypsum mortars and mortars of lime in the pyramids. For the construction of the Great Pyramids at Giza, the Egyptians used about 500,000 tons of mortar[11]

[11] "The History of Concrete: Evolution and Technological Milestones." Giatec Scientific Inc., https://www.giatecscientific.com/education/the-history-of-concrete/. Accessed 21 July 2024.

UN INVOLVEMENT: RELEVANT RESOLUTIONS, TREATIES AND EVENTS

Memorandum of Understanding (MoU)

The Memorandum of Understanding is a formal agreement aimed to decarbonise cement and concrete production throughout the world. It was signed between the United Nations Industrial Development Organization (UNIDO) and the Global Cement and Concrete Association (GCCA). The key reasons behind this partnership are reducing the environmental impact, advancing the industry practices and supporting the achievement of the Sustainable Development Goals (SDG's). In addition, the agreement fully supports the industries commitment in order to achieve carbon neutrality by 2050, which perfectly aligns with the goals of the paris agreement.

2030 Agenda for Sustainable Development

The 2030 Agenda for Sustainable Development was adopted by all of the United Nations Member States in 2015 and it was a call of action to "end poverty,protect the planet, and ensure that by 2030 all people enjoy peace and prosperity" through 17 goals.Goal 9 " Industry, Innovation and Infrastructure" promotes sustainable industrialization which is a priority to the concrete industry. Goal 12 "responsible consumption and production" encourages sustainable practices in production and resource efficiency. It aims to reduce waste, by recycling and reusing concrete waste as aggregate in new concrete or in other construction applications. Lastly Goal 13"climate action" mitigates climate change as well as its impacts, linking it directly to reducing the carbon footprint in the concrete industry.

Paris Agreement

"The Paris Agreement is a legally binding international treaty on climate change"[12]. This treaty brings attention to the carbon emissions from industrial projects, including

[12] unfccc.int https://unfccc.int/process-and-meetings/the-paris-agreement,September 10, 2024

cement production. As a result, the member states that signed needed to formulate and impediment emissions reduction strategies leading to tighter regulations on carbon emissions from cement plants. The key goals of the treaty are to limit global warming, keeping the temperature under 2 degrees Celsius , climate finance, Net-Zero emissions, and global stocktake.

PREVIOUS ATTEMPTS TO SOLVE THE ISSUE

Green Concrete

Instead of using the traditional cement and concrete in order to construct a structure, green concrete was introduced. Green concrete is an environmentally friendly version of normal concrete just with recycled material including industrial material, such as fly ash, slag and recycled aggregates instead of using limestone and clay.It is the future of the industrial sector, with numerous sustainability benefits. Reduced carbon footprint is one of the main benefits since the cement will be replaced with other byproducts that are more sustainable. In addition, green concrete is energy efficient due to the fact that the majority of the products are recycled and a small amount of cement will be added.Unfortunately, one of the biggest concerns regarding green concrete is the performance and durability. The inconsistent quality of recycled materials may have residual impurities that don't allow us to understand the quality and thus if it will be as firm as concrete itself. Even though green concrete is a great solution not everyone has access to it and as it is able to work on only on smaller constructions it is not a permanent solution.

World Business Council for Sustainable Development (WBCSD) - Cement Sustainability Initiative (CSI)

The World Business Council for Sustainable development (WBCSD) - Cement Sustainability Initiative (CSI) was active from 1999 to 2018, bringing together global cement companies to address the different environmental and social challenges, while focusing on reducing carbon dioxide emissions. Seeing as reducing carbon dioxide emissions was one of the main goals, CSI promoted the best practices to all of the manufacturers. Some of these

practices were, energy efficiency improvement, alternative fuels and the development of low carbon cements. CSI continued to promote sustainable resources, and biodiversity and land stewardship until it was incorporated in the Global Concrete and Cement Association (GCCA) which continued to do the work. This occurred due to the very slow progress upon the co2 reduction as well as the dependency on coal and fossil fuels after the encouragement to use alternative fuels.

POSSIBLE SOLUTIONS

Carbon-Neutral Concrete

The research and development of carbon neutral concrete that is able to absorb the carbon dioxide in its application process or through its lifetime. Different member states can work together in order to develop a more stable and reassuring green concrete without the past concerns. When in the chemical process carbon capture and utilisation (CCU) will occur. During the mixing process the particles of carbon dioxide will have turned into calcium that can be used to stabilise the raw meal. Since this would be a more sustainable way to include cement in the construction sites, all the manufacturers would prefer it rather than removing the cement use indefinitely.

The use of Alternative Products

Knowing that fossil fuels and energy are highly consumed during the concrete production and application all the member states would use alternative products. Instead of relying on coal and other traditional fossil fuels, biomass industrial waste and renewable resources would be used.By promoting the new initiatives it will be essential by manufacturers to adopt more energy efficient and low-carbon technologies, with partnerships forming to ensure sustainability to this sector. Unlike the past attempt, the introduction to the alternative products would be slower, allowing all manufacturers to adopt the new techniques and have more time to experience it.

International collaboration

Collaboration between large and smaller manufacturing corporations to ensure that all of them are following a similar plan to remain as sustainable as possible. With this collaboration when different techniques are introduced corporations will try them, sharing their progress and mistakes to ensure that no one else will make them. The process will be tracked and the correct amount of changes will be made once the new product is done testing. The product could be a new alternative or a new device that will assist them all.

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