Sustainable Concrete and Its Current Stance in the Construction Industry

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Concrete is currently the second most consumed resource used in the world and the production of this material, mainly the production of cement, contributes to a little over 8% of carbon dioxide emissions globally. The concept of sustainable concrete is rapidly surfacing within the construction industry as environmental issues and concerns like global warming and climate change continue to worsen. Scientists have been and continue to consistently conduct studies to test if sustainable concrete is a possible solution to reducing carbon dioxide and greenhouse gas emissions that come straight from the construction industry. But some construction companies have concerns that changing the composition of the standard concrete could potentially pose risks to the integrity of such an already structurally sound building material. This report will get a gauge on where sustainable concrete stands within the construction industry and attempt to analyze the reasoning as to why this product hasn't been implemented on more projects. Ultimately, sustainable concrete still has a long way to go, but continuing to conduct research and slowly implementing more sustainable methods and kinds of concretes on projects will greatly help to reduce global CO_2 and greenhouse gas emissions.

Keywords: sustainable, concrete, cement, construction, CO_2 emissions

Introduction

Standard concrete is a multi-functional material used on all kinds of different construction projects ranging from custom homes, to civil projects, to commercial buildings. Its durability and strength make it ideal for holding up large structures. Strong in compression, concrete is a universal material that almost every construction company uses. But with the main additive being cement, concrete is one of the biggest producers of carbon dioxide contributing about 8% of the world's carbon dioxide (CO_2) emissions (de Brito & Kurda, 2020). In the United States alone, over 500 million tons of concrete is produced annually (Assi, Carter, Deaver, Anay, & Ziehl, 2018). With the rate in which the population is growing, it is estimated that CO_2 emissions may reach 23% by 2050 solely from the production of concrete (Gupta, Ray, & Labhasetwar, 2021).

Sustainable Concrete

Sustainable concrete is classified as a type of concrete that recent studies have proven to have lower environmental impacts than the standard concrete due to reduced emissions of CO_2 and greenhouse gases (Jin, Chen, & Soboyejo, 2015). New discoveries and information regarding the various sustainable types of concrete are rapidly emerging within the construction industry. Because sustainable concrete is a somewhat new product that hasn't gained much recognition or traction yet, a majority of construction companies have yet to experiment using it on large-scale or commercial projects due to the uncertainty of its properties and capabilities. Scientists and professionals continue to test different types of sustainable concrete to analyze whether these innovations are reliable to use on projects. Sustainable concrete does not classify as one specific kind. Sustainable concrete can mean a multitude of mixtures or material replacements. For example, using recycled materials such as discarded and crushed up concrete to use as aggregate in a new batch of concrete or infusing carbon dioxide into the mixture to prevent CO_2 from releasing during the production process.

Environmental Effects

With concrete consistently remaining one of the most used materials within the construction industry, it is important the industry is aware of the environmental effects concrete has on the environment. CO_2 emissions are detrimental to not only the environment but also to human's overall well-being. As CO_2 enters the atmosphere, it traps the sun's heat and significantly increases the overall global temperature (Osmanski, 2020). In recent years, there has been an influx of deadly wildfires, droughts and other natural disasters that all point to being a suspected result of global warming and climate change caused by these greenhouse gases (Coffetti, et al., 2022). Fortunately, Leadership in Energy and Environmental Design (LEED) and green building are incentivizing projects to head towards a more sustainable future and encouraging companies to seek out and implement more eco-friendly building materials and energy-efficient systems to, "transform the way buildings and communities are designed, built and operated, enabling an environmentally and socially responsible, healthy, and prosperous environment that improves the quality of life" (Leadership in Energy and Environmental Design, n.d.). There are an abundance of businesses creating technologies and innovations like admixtures of ready-mix sustainable concretes and production processes that aim to reduce CO_2 emissions coming directly from the construction industry.

Process of Making Carbon Infused Concrete

The process involved in making any kind of concrete is the most important factor to reduce CO_2 emissions. This is mainly due to the fact that the energy-intensive manufacturing of Portland cement, one of the three main components of concrete, releases an abundance of CO_2 and greenhouse gases (Jin, Chen, & Soboyejo, 2015). Achieving the same durability and strength in sustainable concrete is the biggest concern when making any alteration to concrete (Coffetti, et al., 2022). There are three main components that make up standard concrete: cement, aggregate, and water. The components are mixed together in a concrete mixer truck in which the batch goes through a process called hydration. Hydration is a chemical reaction where, "a node forms on the surface of each cement particle. The node expands until it links up with nodes from other cement particles or adheres to adjacent aggregates" (How Concrete is Made, n.d.). When it comes to sustainable concrete, there are a variety of different kinds with replacements for cement to significantly reduce CO_2 emissions during the concrete-making process. Sustainable concrete ranges from carbon-infused concrete, to geopolymer

concrete, to concrete made of recycled materials, each involving different processes. But the one thing these processes have in common is the ability to reduce the amount of cement needed for the mixture.

CarbonCure is one of the more well-known companies that specialize in the process of carbon-infused concrete that aims to significantly reduce CO_2 emissions. The CarbonCure process begins by injecting recycled carbon dioxide into a batch of fresh concrete as it is being mixed. From here, a chemical reaction takes place where the CO_2 transforms into the mineral, calcium carbonate ($CaCO_3$). $CaCO_3$ actually improves the compressive strength of the concrete (Monkman & MacDonald, 2016). The specific chemical reaction that takes place to create calcium carbonate can be seen in Figure 1.

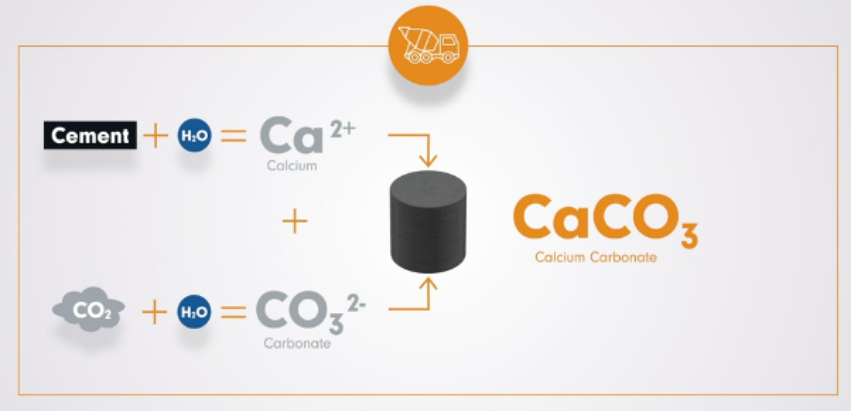

Figure 1: Chemical Reaction that Creates $CaCO_3$
Source: CarbonCure

This additional compressive strength due to the $CaCO_3$ creates an automatic reduction of cement needed in the concrete mix. CarbonCure completed a case study to determine the differences in compressive strength between three different kinds of concrete: standard mix, reduced binder, and reduced binder with CO_2. The concrete mix, reduced binder with CO_2, proved that durability was unaffected, and the carbonate reaction products were homogeneously distributed throughout the mix. An analysis from over a 10-month period using 56,000 cubic yards of carbon-infused concrete resulted in an average of a 5% cement reduction and, "The extended implementation of the technology resulted in 600 tons of cement savings and… 530 tons of avoided CO_2 emissions" (Monkman & MacDonald, 2016).

Cost

Cost is difficult to gauge in means of sustainable concrete mainly because a big part of it depends on the current prices of raw materials. A recent study by Professors in the Department of Civil and Environmental Engineering at the University of South Carolina, mentioned it is very common for the cost of materials to fluctuate depending on the demand for the material and how they are perceived in the marketplace (Assi, Carter, Deaver, Anay, & Ziehl, 2018). One cement replacement or type of aggregate may cost more than the other. In most cases, it is safe to expect that the cost sustainable concrete upfront will be more expensive than standard concrete due to the amount of labor associated with recycling, reusing waste, and even transporting materials (Jin, Chen, & Soboyejo, 2015). For every ton of CO_2 removed from the atmosphere, it can typically cost anywhere from $100 to $300 (Coffetti, et al., 2022). Although this may seem like a lot, the outstanding long-term benefits associated will greatly outweigh the upfront costs.

Literature Review

Although sustainable concrete is a fairly new concept to the construction industry, there are many experimental studies that compare and contrast the qualities of standard concrete and sustainable concrete. Questions and concerns may arise due to the fact that sustainable concrete has not been used on many projects before. General contractors, architects, and structural engineers may be turned off from implementing sustainable concrete on projects due to unknown long-term effects and structural capabilities. But how can the industry grow from an environmental standpoint if it is reluctant to stray from the standard building materials? The most important part of combatting this environmental concern is achieving proper strength and durability through these more sustainable practices. The best way of sticking to this goal is by focusing on carbon capture, utilization, and storage techniques (CCUS). A new utilization technique that is making its way into the construction industry is by essentially capturing CO_2 from feedstock mixes and converting it into a mineral through a chemical reaction between CO_2 and alkaline-rich minerals (Coffetti, et al., 2022). The mineralization of CO_2 creates a bond between the aggregates that reduces the need for cement. It has been estimated that this process can prevent 0.36 gigatons (Gt) of CO_2 from entering the atmosphere per year by 2030-2050 (Coffetti, et al., 2022).

The concept of taking recycled materials and turning it into an admixture to mitigate the cement content in concrete is a brilliant way of utilizing existing resources in a more sustainable way. In the recent NRG COSIA Carbon XPRIZE competition, a group of students and faculty from University of California, Los Angeles Samueli School of Engineering produced a new formula for cement that absorbs carbon dioxide rather than release it into the atmosphere. Inspired by seashells and their binding agent, calcium carbonate, UCLA researchers discovered a method in which CO_2 taken from flue gas is absorbed by the portlandite during the concrete curing process. They called this process "CarbonBuilt" (Lee, 2021). Portlandite, also referred to as hydrated lime, acts as a key component in the process of cement hydration as it absorbs CO_2 very quickly (Zheng, et al., 2020). There are several advantages to this new innovation. One being the flue gas used in the CarbonBuilt process is converted right at the source which avoids the hassle of using expensive carbon dioxide capturing procedures. Another advantage being because the CarbonBuilt process can occur at room temperature and normal pressure due to a reduced amount of cement of around 60% to 90%, this concrete has a much smaller carbon footprint. In total, this technology has the ability to consume just about 297 pounds of CO_2 in just 24 hours (Lee, 2021).

Methodology/Results

Survey

The methodology for this research was conducted by creating a quantitative survey to determine where sustainable concrete stands in the construction industry and if industry professionals have had experience using sustainable concrete. The survey was anonymous and had a total of 20 participants. The survey consisted of eight questions that were the same for each participant. The questions can be found in the Appendix at the bottom of this document. The intent of this survey was to determine where the concept of using sustainable concrete stands within the construction industry from an industry professional standpoint.

1. **Have you heard of "green" concrete/sustainable types of concrete?**

More Details

Yes	15
No	5

2. **Have you ever worked or been on a project that used sustainable concrete?**

More Details

Yes	4
No	16

3. If answered yes to question #2, what product was used?

5 Responses

ID ↑	Name	Responses
1	anonymous	Type 1L Limestone Cement, Embodied Carbon Concrete
2	anonymous	Orca aggrigates, Type 1L cement, carbon cure
3	anonymous	Carbon Cure
4	anonymous	Infused Concrete
5	anonymous	N/A

4. Did you notice any extreme differences between the sustainable concrete vs. standard concrete?

8 Responses

ID ↑	Name	Responses
1	anonymous	No
2	anonymous	N/A
3	anonymous	no
4	anonymous	There was significantly more cracking on the slab on grade we poured with carbon cure, we are still figuring out if this was due to the carbon cure or something else
5	anonymous	Unable to answer this.
6	anonymous	Price
7	anonymous	Yes
8	anonymous	N/A

5. **If you have been on a project that has used new types of sustainable concrete (carbon infused concrete, ashcrete, bendable concrete, specific type of ready mix like "Sprague's Ready Mix", etc) would you recommend other projects use it as well?**

More Details

6. **If you have not been on a project that has used a type of sustainable concrete, would you be willing to try it?**

More Details

Written responses to question 7 and 8 are shown below:

	7. **If you have not had experience with sustainable concrete, are there any specific reasons why not? (Pricing, not enough information known about the product, durability/strength concerns, etc.)**
1	Needs to be specified to use on the project
2	Lack of interest
3	Not allowed in specifications
4	Not enough knowledge about its use
5	Pricing, availability
6	Price
7	I usually see admixtures such as fly ash thrown in concrete or better yet on batch plants from concrete demolition of the old building used in the new building
8	Typically is more expensive and not suitable for mass concrete pours from what I understand
9	Concerns about the cost compared to typ concrete
10	Durability and strength concerns – doesn't seem to be trustworthy
11	Never been requested by an owner/seems like it would be more expensive
12	People in the construction industry have heard about it, but people outside may not be familiar hence why they don't request it on certain projects
13	No specific reason has been given to use sustainable concrete
14	Unsure if it would be durable enough
15	Cost

	8. **Any additional comments?**

1	Reduced Carbon Cements, Embodied Carbon additives, etc. are location specific, that is to say what is available in one part of the Country may not be available in another. This must be considered when specifying concrete
2	We are always forced to have the absolute lowest price possible, especially these days. Can't achieve that with carbon friendly concrete.
3	Sustainable concrete may be good for small projects but maybe not large scale/commercial buildings
4	The intention is there, but not enough proof that this kind of material would work on a large scale project
5	I would want to see more large scale projects that have been successful for at least 10 years before considering using this product
6	Feel like this kind of concrete can only be used in smaller does; potentially use it on concrete finishes but not for the actual structure?
7	For environmental reasons, I would definitely be willing to give it a try but with that being said, cost will always be a deciding factor

Analysis/Summarization

After an in-depth analysis of the survey results, it seems as though industry professionals are aware sustainable concrete exists, but do not have much experience using it on projects. From the survey results it seems as though the biggest factors that contributed to the lack of use on projects were the price, sustainable concrete isn't called for in the specifications, and an overall lack of knowledge about the product itself and how it will perform on large-scale projects. It is understandable that companies may be hesitant to use sustainable concrete due to the fear of failure. With building codes and standards that are already set-in stone, it is hard to be open to trying new materials for a building that heavily relies on structural integrity which is generally accomplished with the standard concrete.

With that being said, the four out of 20 responses that have had experience with different types of sustainable concrete all said they would recommend other companies use it on projects. The types that have been used by respondents included: type 1L limestone cement, embodied carbon concrete, orca aggregate, carbon cure, and infused concrete. The two individuals that had used type 1L cement, embodied carbon concrete, orca aggregates, and carbon cure saw no extreme differences. One noticed significantly more cracking but questioned whether it was due to the sustainable concrete or some other factor. It seems as though industry professionals are uncertain whether issues occurring with carbon-infused concrete are from the actual concrete itself. The most common types of sustainable concrete that have been used by industry professionals were from Carbon Cure and carbon-infused concrete. This may be due to the fact that CarbonCure as a company has had multiple success stories using their product and an in-depth analysis of how carbon-infused concrete is made. Participants were asked if they would recommend other projects use sustainable concrete to which all answered yes. 95% of participants answered that they would be willing to try some form of sustainable concrete on a project while 5% answered that they would not be interested in trying this kind of concrete due to concerns regarding durability and strength. The results gave insight as to if an industry professional had used sustainable concrete and the specific kind that had been used as well as any noticeable differences from the standard concrete and if they had not had any experience with this product, then reasoning as to why not.

Discussion/Conclusion

Concrete has been and continues to be the most used construction material on buildings due to its strength, durability, permeability, and workability. This research shows that sustainable concrete is slowly, but surely, integrating its way into the construction industry. The survey results reveal that industry professionals have at least heard about sustainable concrete, but only 20% have actually used it on a project. But the majority of respondents were open to the idea of implementing this product onto a project. The jump towards sustainable concrete does not have to be immediate but moving away from standard concrete just a little at a time could significantly help to reduce CO_2 and greenhouse gas emissions from destroying our planet. A possible solution could be using sustainable concrete on smaller aspects of the buildings like decorative elements. See how sustainable concrete performs as a planter box or a bench. Making the shift to using sustainable concrete has the potential to reduce copious amounts of CO_2 from entering the atmosphere and preserve Earth for longer than currently predicted. With that being said, there is still a long road ahead of the construction industry in terms of determining if sustainable concrete is capable of replacing the standard concrete.

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