Course Name: Building Materials as a Cornerstone to Sustainability

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Lecture 01

Co2 absorbing concrete

Hello students. So today we look at yet another building material. Very interesting. It's the carbon dioxide absorbing concrete. We all know that concrete has very high embodied carbon, very high embodied energy. But that is considered its limitation or its negative aspect.

But imagine having concrete which actually absorbs carbon dioxide. We will be looking at this material today. So, we will look at the introduction to absorbing concrete, its manufacturing and its types, the features, advantages, limitations, what is carbonation process, zeolites in concrete and then we will conclude this lecture. So concrete that absorbs and stores carbon dioxide from the atmosphere is referred to as carbon dioxide absorbing concrete.

It is also called as carbonation enhanced concrete. So, it could be referred by any of these names. We could call it as carbon dioxide absorbing concrete or carbon capture concrete or carbonation enhanced concrete. The manufacturing process of conventional concrete releases carbon dioxide which increases the greenhouse gas emission. But this concrete actually absorbs carbon dioxide and tries to lessen this influence on the environment and thus it becomes more like a green concrete.

Now if we look at the manufacturing and the types of concrete. Typically, carbon dioxide absorbing concrete contains ingredients that have the ability to chemically react with carbon dioxide and absorb it over time or during the curing process. A few methods for obtaining carbon dioxide absorption in concrete, we will now look at those. Now, first is the mineralization. In particular, carbon dioxide absorbing concrete stable carbonates are formed through the reaction of carbon dioxide with specific minerals in the concrete mixture.

Over a period of time, this mechanism could actually help support and aid in the sequestration of carbon. There is also the alkaline activation. In order to improve and enhance carbon dioxide absorption, alkaline materials can be used. Now these are supplemental cementitious ingredients or alkali activated binders. Carbonates are created when these substances combine with carbon dioxide.

There are certain additives and fillers also. Now, in order to minimize the quantity of cement required, certain additives or fillers such as industrial byproducts like fly ash or slag can be mixed into the concrete mixture. This could help with carbon dioxide absorption along with reducing the carbon impact. Bacterial treatment is another way. So adding bacteria to the concrete mixture is one of the more creative methods.

Throughout their metabolic processes, these bacteria have the ability to generate minerals that could absorb carbon dioxide. Now what are the advantages of carbon dioxide absorbing concrete? First is its environmental contribution. So, it is environmentally very sustainable because it actually captures and stores carbon dioxide throughout its life cycle and to lessen the carbon footprint of the construction activities, this material can come a great help. Second is the resource efficiency. It reduces the requirement for the first hand or virgin resources and adds to resource efficiency by using additives and industrial byproducts.

For example, slag. If the mineral slag is not used or fly ash is not used it will be dumped as a waste. But here this concrete it doubles up as a green concrete because these so called waste materials also find a useful place in the manufacture of these concrete. It has potential cost savings So, by using these fillers as we have already seen, it could be construction demolition waste, it could be fly ash, it could be furnace slag, it could be any industrial waste, it could be an agro waste, it could be a hospital waste. When I say hospital waste, I mean the plastic waste from the hospital, sterile plastic waste from the hospital, such as the saline water containers or the syringes and so on.

So, these can be used as fillers and it may be possible to utilize less cement when we use these fillers and this could result in financial savings apart from environmental positiveness. Then these can be also used for climate change mitigation. So by tackling one of the main sources of greenhouse gas emissions in the construction sector, this initiative supports international efforts to mitigate climate change. Let us now look at its limitations or disadvantages. There are certain technical difficulties no doubt.

So consistency and control are two areas where certain procedures particularly those involving bacterial treatment may encounter technical difficulties. There could be endurance concerns. So, research must continue in order to solve potential problems with carbon dioxide absorption concretes, long term endurance and therefore, the longevity of the building. Sometimes initial cost can come as a limitation because the employment of cutting edge materials and technologies could result in higher initial cost and this could prevent widespread adoption. Standardization and certification is another limitation.

The building industry's ability to accept carbon dioxide absorbing concrete more widely may be hampered by the absence or uniform testing and certification process. Considering that the additives could come in various physical properties and strengths, it becomes very important that we have a uniform testing and certification process. There could be problems with scalability. So, increasing manufacturing and implementing carbon dioxide absorbing concrete in major building projects could present a difficulties. Therefore, we need methods or processes for wider adoption of this material and also to popularize these materials various techniques or various strategies must be used.

Now let us look at carbonation of concrete. Now concrete carbonation is the result of a chemical process that primarily mainly produces carbonates between carbon dioxide in the air, calcium hydroxide and the hydrated calcium silicate which is found in the concrete. These chemical reactions result in the carbonates that sequester this carbon dioxide permanently. Now you can see in this figure that carbonation takes place in the concrete as a result of the surfaces of the building being exposed to carbon dioxide. Now we have already seen that carbonation is the process by which calcium hydroxide and carbon dioxide in the concrete they combine to form calcium carbonate which is a stable carbonate product.

Now, this has certain properties. Now, it could impact the pH. The carbonation process causes the concrete's pH to drop and increases its acidity. Carbonation can have an impact on durability Because carbonation can cause steel reinforcement to corrode because of its acidity, it can have an impact on how long concrete structures last, particularly where steel reinforcement bars are used. The forming a protective layer This happens and although carbonation can be harmful to steel reinforcement, it leaves a protective coating on the surface of concrete which lessens or reduces permeability and increases resistance to the infiltration of chlorides.

The rate of carbonation can get affected and the concrete mix design, temperature and humidity all have an impact on the rate of carbonation. By nature, carbonation is a natural process that occurs over a period of time in concrete structures which are exposed to the outside or the atmosphere. As a chemical reaction, it involves the reaction between carbon dioxide in the air and the alkalis in hydrated cement paste. Let us look at a small case study of Carbicrete. A Montreal based company Carbicrete has devised a method of sequestering carbon from concrete And this company claims that their product sequesters more carbon than it releases, making it a very green material.

This method allows for the production of regular concrete without the need for calcium based cement, which contributes to about 8% of global carbon dioxide emissions. Though it isn't actively eliminating carbon dioxide from the atmosphere, the process definitely contributes to lowering the amount of additional carbon dioxide that could enter the environment because it depends on emissions from other businesses. However, concrete may begin to contribute to reducing atmospheric carbon concentration. As carbon dioxide absorbed from the sky or atmosphere by direct air capture, these firms like climate works become more reasonably priced. So, this was founded in the year 2016 and Carbicrete licenses its technology to concrete manufacturers so that they could include it in their current precast panel and concrete masonry unit production processes.

Now cement which accounts for about 12% of typical concrete's weight but half of its carbon footprint is no longer necessary when using carbicrete. So, calcium carbonate which is typically found in limestone is heated to 1480 degree Celsius in order to extract calcium oxide which is then used in the manufacturing of cement. Carbon dioxide which makes up 40 percent of the bulk of limestone is released into the atmosphere during this process. Fossil fuels are typically used to power the energy intensive processes which results in extra emissions. By avoiding these emissions, Carbicrete's technology saves about 2 kilograms of carbon dioxide for each concrete masonry unit.

This company also employs slag, a waste by-product of the steel making process that contains calcium oxide. Now they substitute this slag in place of calcium oxide. So when concrete is produced traditionally water is used to cure the cement which causes the calcium to react with carbon dioxide in the air and reconstitute itself as reinforced calcium carbonate. The Japanese building sector is creating a very interesting material I mean interesting use for this material and let us look at the attempt made by Japan. The Japanese building sector is creating a variety of methods to lower carbon dioxide emissions as preventing global warming has made carbon dioxide reduction an international concern including in India.

It is also India's concern and this is where your role as designers and architect becomes very important. Now one of the concerns is the decrease in carbon dioxide emissions related to the manufacture of concrete. Typically to make concrete you need to have cement, water, sand and gravel. Though it produces a lot of carbon dioxide during production, cement is essential because it combines with water to solidify concrete. As a result, the industry is working to lower carbon dioxide emissions by substituting industrial waste from thermal power plants and steel mills such as coal ash and blast furnace slag for cement.

So, you can see the benefit of using this innovative material. Now, in order to have a carbon dioxide absorbing concrete, the admixture which is blast furnace lag, this becomes an industrial waste. By virtue of using this industrial waste, the embodied carbon in the material also gets reduced. This is apart from the unique property of carbon dioxide absorption that the final material has. Coal ash is used from thermal power plant which is also an industrial waste.

If you do not use these two blast furnace slag plus coal ash what happens is, this will get dumped somewhere as landfill. At least now it has a use in a particular material which is carbon dioxide absorbing material and by virtue of using these two there is reduction in cement amount in the concrete. So, these two material replace a small part of cement. Apart from this there is cement which is used and a special admixture which is actually a company secret and it is very difficult to get that information. All this results in carbon dioxide capturing and ultimately a unique building material.

So, the first concrete type in the world which is carbon dioxide SUICOM was created by Japan and it virtually eliminates carbon dioxide emissions throughout the manufacturing process. carbon dioxide storage utilization for infrastructure by concrete materials is referred to as carbon dioxide SUICOM. By both absorbing and lowering carbon dioxide, carbon dioxide SUICOM reduces 306 kg of carbon dioxide per cubic meter during manufacture as against the regular concrete which emits 288 kg. Put in another words, the manufacture of concrete will emit almost no carbon dioxide and the more carbon dioxide suicom that is produced, the less carbon dioxide that is released into the atmosphere. So, if you see standard concrete, it emits approximately 288 kilogram per meter cube.

What happens is carbon dioxide emissions are cut when we start using cement substitutes and that could get cut by 197 kg per meter cube. Now this carbon dioxide because by virtue of being captured could again reduce it to minus 109 kg per meter cube resulting in a material which is actually carbon negative by minus 18 kg per meter cube and thus I feel this is a wonder material in a way. Now, this y-C2S is a powdered material composed of calcium hydroxide So, it has calcium hydroxide plus silica. Now this hardens when it reacts with carbon dioxide. Now stated otherwise y-C2S is a substance that performs the same function as cement in hardening concrete plus it also has the ability to absorb carbon dioxide.

Now, the Japanese company used y-C2S to absorb carbon dioxide in order to create a commercial version of long life concrete in the year 2006. Subsequent research led to develop CO2 Suicom, an entirely new kind of concrete that uses industrial waste from steel works and thermal power plants as well as y-C2S as the primary components to absorb and harden massive volumes of CO2. The amount of cement used in CO2 Suicom concrete is half that of a normal concrete. Furthermore, CO2 Suicom helps to lower carbon dioxide since it fixes CO_2 when it hardens. The company has also successfully fixed exhaust gas from a thermal power plant as a proof of concept demonstrating that CO_2 in exhaust gases may be directly captured and reduced.

Let us look at the applications of CO_2 Suicom. Now, currently carbon dioxide Suicom is utilized in river embankment blocks. Then in road pavement blocks, it is also used as a boundary block that separate sidewalks from roadways. So, they could be used as a boundary block. As you can see here, there are huge large boundary blocks which are used here.

They could also be used as road pavement blocks as shown in this figure. Now international interest in high particularly from western businesses that are well versed in global warming mitigation strategies. A number of businesses have shown interest in bringing these items to market and making a sales out of it. Let us look at the future of this building material. Until now, carbon dioxide Suicom has only been used on small scale, that too with unreinforced precast products.

This is because of the widespread belief that early corrosion would occur from using steel rebars as reinforcement in concrete that turns neutral due to the carbonation reactions. Prefabricated concrete without reinforcing is important. So, if we have reinforcement then it is difficult to predict the longevity of the building when this material is used. Due to the very small market carbon dioxide reductions would only be possible for a few hundred 1000 tons annually. Using the knowledge we have gathered by studying carbonation curing for more than 50 years on a NEDO commission, work is currently being done to broaden the scope of carbon dioxide Suicom use.

For all cast in place and reinforced concrete which produces several tens of millions of tons of carbon dioxide. If we could absorb carbon dioxide by employing CO_2 Suicom, it will be great towards a carbon neutral society. And therefore this building material becomes a very important building material. By using carbon dioxide absorbing concrete, we are actually doing two favors to ourselves. First one is the amount of cement that is used in this concrete gets reduced because we are actually using an additive which is an industrial waste.

It could be any- normally slag or fly ashes used. With further research maybe some new material may be introduced. And the second is, this material actually absorbs atmospheric carbon making it an extremely low carbon building material. And using low carbon building material is a very important aspect of sustainability. So we will stop today's class with this thought and in the next class we will handle another new building material. Thank you.