Advanced Topics in Science and Technology of Concrete
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Utilisation of recycled concrete fines

Until now, we were focusing on high-value application where we try to learn what are the available treatment methods which could help us to turn this recycled concrete fines into reactive material. So it can be utilized as supplementary cementitious binders. From now, we will be focusing on high-volume application where we try to use lot of this material or high amount of this recycled concrete fines into this application. So the application here focused is granulated lightweight aggregate. Most of this work is done in our lab as a part of a PhD thesis of Kalle Kursula. So what we used here is a high shear granulator.

Usually this granulator is used in medical applications where it is tried to make some pellets for medication. However, granulation is not as such new for our applications in construction industry. We have lightweight granules for producing lightweight concrete. Mostly they are manufactured from clay material.

Here we are trying to use fine concrete powder with a high shear granulator to produce such granulated concrete powder based artificial aggregates. Let's see one by one what we have done in the study. Before moving on to the results, let's see how this is done practically. Before going to the actual results, let's see what has been done in this project.

So what we did is we used this recycled concrete material to mill them into finer fraction to simulate the property of this fines from the crusher or the recycled concrete production. We also try to crush all the fractions including both the cement and the mortar assuming a low quality fine that also crushes the aggregate together. So we didn't do careful separation of the aggregate from the fines. After producing this powder, we added that into the shear granulator like you see here. This is part of a project called DECONCRETE which is about recycling the concrete as demolished material and also as an object that can be recovered from the demolition site and used for the new concrete. So these are the granules that is produced after the granulation.

These are separated in three different containers to cure them in different ways. One is in the oven. Another one in the carbonation chamber. And the third one in the humidity chamber with the 20 degrees of temperature and 100% relative humidity. So this is after curing for 24 hours.

Then we try to measure the strength of the granules. So for that we measure the dimension of the granules in different direction because it's not exactly spherical. And then we measure the crushing value for at least 10 granules for each mix composition. This is after crushing the granules. So with this background idea, let's go now to the actual study that has been done.

We have used three different types of concrete or recycled concrete material for this study. One is from ready mix concrete plan which is relatively fresh. And the other one is precast sludge. You know in precast industry they cut the precast panel and wash the fine material so it will be ended up as a sludge or a cement sludge material. And the third one is geopolymer fines wherein we used the geopolymer produced from our own lab to crush and recycle it to see the future recycling process for this geopolymer material.

So here you see the ready mix concrete fines as case study one. So like I said this is relatively fresh so they still had the reactivity there and it can be easily used as a supplementary cement. Water was used as a binding agent in this granulation. We did not go for any special grinding aid or granulation liquid because this material itself was reactive so we just need to add some water there. The granules were made in a diameter of 5 to 8 mm.

And ladle slag which is a type of by-product from steel industry has been added as co-binder. So the idea is to improve the carbon capturing capacity of this material because ladle slag had higher carbon capturing capacity compared to this ready mix concrete fines. So we tried carbonation in this study. So like you have seen in the video there was normal curing, curing in high humidity chamber, curing in carbonation chamber. So when you see the results of the crushing force you see that the strength is high with the humidity chamber one when the ladle slag is increased compared to even CO_2 curing.

This is assumed that the CO_2 curing tries to carbonate the ladle slag on the surface of the granules and once the pores were closed by calcium carbonate products there may not be carbonation happening after there is no porosity anymore on the surfaces. So still the interior part of the granules are not accessible by the CO_2 after once the porosity is saturated or the pores are closed by the carbonation products whereas humidity is not happening in that way and the crushing force decreased up to 20% and then increased at 30% maybe because of the particle packing efficiency. Now it is also studied in several cases that if you add particles of different size in the right proportion without even any reactivity of this material the filler effect also will give you some positive impact on the strength improvement of these materials. Talking about carbon sequestration you can see that CO_2 sequestration efficiency improved with the addition of ladle slag in this material but then it is not so much seen from these values which is from thermogravimetry analysis so it is showing percentage of CO_2 that is captured in different composition. And it was obviously seen that with the CO_2 curing there is improvement in the microstructure there is less pores especially on the surface layer compared to the interior.

So this is one example of granulation and carbonation that has been tried in the recycled concrete fines especially from the ready mix concrete. Next case study is about precast concrete waste sludge. This is a concrete sludge that is obtained from Norwegian industry. As you see the precast concrete industry cuts this concrete panel and washes it away so it is all the time in the water so it has been already hydrated and there is no any reactivity left out so ideally it can be used as a filler it is a very fine material. So in this experimentation we try to use different co-binders in a synergy that it would help us to produce an alkali activated granules which is why we wanted to supply some silica alumina and also some of the activators there.

So we used blast furnace slag, paper mill ash and biomass fly ash which are local industrial site streams as a strategy to produce co-binders for alkali activation. So you see these are added in different percentages here for this study. So 12 different mixes were granulated with an 8M molar sodium hydroxide solution. So there is no sodium silicate added here which is termed to be highly non-environmental friendly activator so we avoided the sodium silicate and after granulation these materials are cured in oven at 60 degree Celsius. Room temperature we tried but it did not work with this material so we went for 60 degree Celsius oven curing and in all the mixes the amount of concrete sludge was maintained as 10 to 50 percent sorry there is a mistake here so 10 indicates 10 percentage of the concrete sludge and then 30 indicates 30 percent and 50 indicates the 50 percent of the sludge.

Among co-binders this is the percentage of co-binders that has been added. So 30 percent FA means 30 percent of fly ash, 30 percent PMA means 30 percent of paper mill ash and the remaining co-binder is blast furnace slag. So you see so

this 10, 30 and 50 are co-binder content. So when you see the granules with 70 percent blast furnace slag and 30 percent of fly ash performed better with the strength property. This is co-binder mean the percentage of different co-binders in the total amount of co-binder.

So anyway 50 percent of recycled concrete fine from the precast industry with 50 percent of co-binder and in the 50 percent 70 percent is slag and 30 percent is biomass fly ash. So you see that the crushing force went up to 80 newtons which is well above the crushing strength of available lightweight aggregate granule which we also tested it is around like 50 newton normally. So that is one of the case study and the third one is about geopolymer concrete fines which I said is mainly taken from the geopolymer material that is from our own lab. So we granulated the waste geopolymer powder or the geopolymer that has been crushed in the lab. So five different milling times were used.

Here our aim is to understand if we produce this fines in different particle size distribution how that could affect the strength of these granules. So we mill it in different timing and we used some blast furnace slag and sodium silicate very little amount of sodium silicate and the co-binder. So blast furnace slag 90 percent and 10 percent sodium silicate is used as co-binder in a proportion of 10 percent 20 and 30 percent together with the geopolymer concrete fines. You see the D50 value is different based on the milling time. So it was interesting to observe that the crushing force for one minute is higher compared to even five minutes and 10 minutes or 10 seconds and 30 seconds.

So there is an optimum crushing force sorry optimum particle size or the milling time that is one minute below which or above which it is not of perfect time range to produce granules of high crushing force. This is because of the particle packing effect. So at this one minute grinded sample the particle packing or the particle size distribution was perfect to produce better packing or compact packing that gives you the higher crushing force. So recycled geopolymer granules like I said gave the best crushing force of 107 Newton at one minute. And the density seems to be very high to be used as a lightweight aggregate in this case and the results were satisfactory to be used as a lightweight or a regular weight aggregate concrete for construction.

So with this studies we also try to understand how this different materials and different processing would affect the life cycle or the environmental impact of this material based on what we have done in the lab scale. Because our ultimate aim is like we are using some waste material into an application and we should know what is actually the impact that we are creating. Because we are also using other processes to improve its properties in the new application. So we need to know like are we really helping it or what is the actual impact. So now you see that we had three different types of materials we produced.

One is from ready mix fines. Let's name it manufactured aggregate one with 70% fine concrete waste. Then precast fines manufactured aggregate two with 50% fine concrete waste and geopolymer fines that is manufactured aggregate three with 70% fine concrete waste. In this granulation of MA1 we used ladle slag of 30% as co-binder and we just used water and humidity chamfer. I mean it is also there are possibility to use carbonation chamfer which will improve the environmental impact positively. And in this precast fines we used 50% co-binder of which 30% is fly ash and 70% is blast furnace slag.

And we also used 12 molar sodium hydroxide liquid and cured at 60 degree Celsius. And in the third one for the geopolymer fines we again alkali activated with 30% of blast furnace slag and 3% of sodium silicate and cured at ambient temperature. So by using life cycle analysis we try to understand what kind of impact we created in these materials. You see when we compared different cases with the available commercial aggregate in most cases the crushing force are higher than the commercial aggregate. However, the density also was way higher compared to the commercial aggregate.

So the water absorption reduced and the specific gravity is higher. However according to the ASTM standards the maximum dry loose bulk density for a lightweight aggregate is termed 880 kg per meter cube. And we could produce one of the aggregate in that range that is MA2 with the precast fines with 50% of this recycled fine material. So when we did LCA to understand the carbon emission in this process of making this aggregate you can see that MA2 is not a good way of production process compared to even the commercially available aggregate which is using high temperature sintering process actually. So what was the main problem of MA2 is oven curing one of the thing because we left it at 160 degree for 24 hours and we used the energy of laboratory grade oven.

So this may have some impact when we are going for industrial scale processing. We also used sodium hydroxide as the granulation liquid in this case which could also add to the emission for this production process. However when you think about the 70% utilization of ready mix concrete fines and also geo polymer concrete fines for the methods that we used here as production technology is way below what we could expect from the commercial aggregates. However impact is not just about the carbon emission. We should also consider other factors.

For example in Finland if we consider 13.7 million tons of construction and demolition waste was generated in 2019. Let us assume among that about 10% of the total generated waste will be recycled as manufactured aggregate in future. And you assume that of different types of manufactured aggregate because it may not be the same type of concrete that is produced. So based on that and based on the available methodology to calculate how much of land we will conserve by using this into the manufactured aggregate.

Because when I said about avoiding landfilling mostly the coarser fraction goes to earth construction whereas the finer fraction ends up in the landfill even today because there is no particular application for this finer fraction. So when we think about using this in the manufactured aggregate we conserve like 10 hectares of land to 13 hectares of land that is otherwise used as a landfill area. And we will avoid quarrying of new aggregates which is a very good impact that we can consider about conserving environment. We can conserve like 37 hectares of quarrying operations that could happen otherwise if we are not producing this manufactured aggregate. So the impact is also created in this way which causes positive environmental production.

So I mentioned that let us discuss a bit about what needs to be done in the future. So we have to create tools to support uptake of this technology. So what is hindering the uptake of this technology? The first one is change of legislation. Change of legislation is important and this should also can be done by the push to industry. Wherein there is lack of competence even if there is a change of legislation industry is very conservative to accept that changes to certain level.

So we should also work on that part. An increase of fee for unsustainable handling of waste material. So there is a factor called gate fee here in Europe where if you want to landfill your waste you have to pay the gate fee to dump your material. So this will change the habits. So if you increase the fee so the disposal of this waste material in the nature would be avoided. Help with identification of material treatment and disposal.

So this will help in avoiding wrong handling of material which will also help in smarter and profitable choices to the industries which will also encourage the industries to go for these non-conventional materials for the profit basis. Requirements on SRM integration in new structures. Like we have to integrate, now we are talking about digital transition and more information like material passport. So it will help us to identify what type of material are there and how they could be recycled. Maybe even when we produce the concrete we can already give the options of recycling once it reaches its end of life.

So these are something we have to think for future. So adaptation of new practices and mandates the knowledge competence that will help in handling our material better in the future. So with these insights and overall picture of what is recycling concrete be like and what is the present situation in the research field and also some new insights of using recycled concrete fines based on the current work happening. We also see some needs for the future. So I hope you enjoyed this lecture and would come up with so many interesting questions.

I would be happy to answer you. You can contact me in my email. I would like to acknowledge the project partners who helped us to do this research on recycling concrete fines in high volume application and also to do a life cycle analysis to understand the actual impact we are creating by doing this application. And here you can see my email address and my group members here. So thank you for listening and happy to be helpful if you need some if you want to interact with me in future.