Advanced Topics in Science and Technology of Concrete
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Week - 01
Lecture - 03
An overview of recycled concrete aggregates (RCA): sources and types- Part 1

Hello everyone! Welcome to this next lecture in the series of lectures on recycled concrete aggregate sponsored by SPARC scheme from the department of science and technology. I am Manu Santhanam, Professor from the department of civil engineering at IIT Madras. The collaborators in the SPARC project with IIT Madras are University of Witwatersrand in Johannesburg in South Africa, and University of Cape Town, South Africa. So in this lecture, we will look at sources and types of recycled aggregate. Now let us first take a look at what types of waste are available for people to look at sources of useful materials, including aggregates, of course. So let's take a look at what these sources are.

There are various ways of classifying these wastes, but then what I have picked up is a particular example that is available from the source that has been mentioned at the bottom of your screen. Here, the types of waste are defined based upon where they are collected and what type of waste is being collected. For instance, the construction waste that is collected from buildings is typically classified as bulky waste, and the examples of this include concrete, wood, brick, plaster, roofing materials, wall board, metals, carpet, and insulation. So all of these are available when we, of course, take down a building or when we are even doing new construction. construction much of the time, when we are actually not exactly calculating the quantity of material required, we sometimes have a lot of wastage that comes out of these construction techniques, and this wastage basically can be reutilized in new construction.

Very often, we do not do that; we just simply dump it, so that becomes a waste, and that is related to construction waste arising from a new construction project. And of course, on the other side, you have construction and demolition waste that is coming out of actually taking down a building. Apart from this, you can also get other demolition waste from buildings, which will typically be classified typically as a municipal solid waste. And these include pallets, wood scraps, wall board, siding and roofing scraps, packaging, carpeting, foam padding, and insulation. You know that these are not really going to be useful from the

perspective of utilizing in new concrete construction.

So one has to be very careful that the waste sources are not intermixed; they need to be properly segregated for us to get useful construction materials out of it. You also have land clearing debris, which is also classified as a bulky waste, and this includes tree stumps and tree tops. Then we have highway construction demolition waste. Of course, we are talking about building construction demolition waste, and on the other hand, we have highway construction demolition waste. Again, this can be classified both as bulky waste and a municipal solid waste, depending about the type of material that you are looking at. So you have asphalt, which is obviously part of the bituminous concrete that is going into making the surfacing for roads. You have concrete itself, which is cement concrete, steel in some cases, related construction and demolition waste that comes out of actually removing the concrete and steel, utility poles, you have railroad ties, bricks, blocks, and rocks that are available which have been used in the various layers of your pavements.

So all of these are also are classified in terms of being either a bulky waste or a municipal solid waste, depending upon the type of material that you are looking at. And finally, we have oversized municipal solid waste such as furniture, furnishings, carpeting, and rugs. So when you strip down a building or when you strip down a highway structure, you will get various different types of waste, and you need to ensure that there is a proper segregation for you to actually actively collect the material that is useful and utilise it after suitable processing in new construction. Now this series of lectures is primarily about use of recycled concrete as an aggregate. So let us look primarily at construction and demolition waste.

Now the simple definition obviously is that the waste that is generated during construction, renovation, and demolition activities is termed as construction and demolition waste. Now it turns out that during the construction process, the waste that is generated and during the demolition process, the waste that is generated is significantly different in quantity. The waste generated during demolition is 10 times that during construction. So you can imagine that the amount of material that we are actually obtaining from taking down a structure to rebuild, renovate, or reconstruct all of this material is significantly large in quantity, that can really help us reduce the burden on natural and new materials for new construction. Of course, as I said in the previous slide, C&D waste includes concrete debris, brick masonry debris, reinforcement steel, broken tiles, wood, paper, plastics, electrical wires, sanitary fittings, and

all.

And over 50% of this is basically concrete and masonry debris, and that is the one which we really want to use in new construction. Now why are we interested in reutilizing C&D waste? You must have heard enough about this in the previous lectures, but just to reiterate, because this is a very important thing for us to understand, is that most of this waste that is collected is dumped in landfills or unauthorised places. You may have seen in your own neighbourhood when a building gets taken down. There is a truck that collects all the waste that is generated from the demolition of this building. You must be wondering where it goes. So in the middle of the night, this truck drives over to some location where nobody is watching and simply dumps the material.

Or sometimes they say that they take it to low-lying areas. Now sometimes these low-lying areas are water bodies and channels which do not have access to that water, and because of this, flooding also gets created in cities. In some cases, there are genuinely landfills that take this construction and demolition waste, but the problem is that they are available in a mixed condition because all the other municipal solid waste garbage that is collected everything gets piled up in the same location. So instead of being utilised, dumping all this material means we are actually wasting a lot of valuable resources. Some examples of the kind of dumps that are quite easily seen in locations close to urban areas are: for instance, look at this pile of dumps that is there, which is basically a complete mix of different types of waste.

Here, mainly, it is a construction demolition waste, as you can see, because you do not really have too much intermixed garbage in it, but still, there is a significantly large amount of material that is dumped outside of cities. I do not know how many of you are aware that in Delhi there is a dump called the Ghazipur dump which is extremely large. It is like a mountain of debris and other municipal solid waste. In fact, it also has some waste that continues to burn. So for a long time, environmentalists and civil engineers have tried to figure out ways in which they can minimise the impact of this dump and somehow get some strategies worked out to reutilize some of the useful material that is present in this dump.

Now the other reason why we really want to utilise waste is that it is occupying a lot of our area. I mean, imagine if you could save the amount of land area that you are dumping your waste on; it could really lead to a lot of gainful utilisation of that area for other purposes.

Getting mixed with municipal solid waste it makes the recyclability quite difficult. If you are mixing up the garbage that is collected from homes with the construction and demolition debris, you are obviously going to have a lot of issues. And finally, of course, we are very interested in getting CND waste reutilized because we can save our natural resources.

We can ensure that less of natural resources are utilized for new construction, and that way we can reduce the burden on the earth. Now you must have also heard of many different stories from across your neighbourhoods from major cities where construction and demolition waste are simply choking our cities. There are a lot of examples, such as in New Delhi, in Pune, and in Chennai. So all of these are creating a major problem in urban areas. I am not saying that CND waste is not a problem in rural areas.

Even their useful farmland can sometimes be taken up to dump all this material, and because of this, our potential for useful agriculture also comes down. In cities, land is already at a premium. We want to resettle as many people as we can, and if we are not making efforts to actually keep this land free and not really dump all this garbage in there, then we are really going to be having a lot of problems. Just to give you some statistics from across the world, I have not included India here because we do not really have a very clear strategy of collecting information on the amount of waste that is generated and utilized. Slowly, we are trying to gain some ground in assessing the extent of waste and utilisation, but a lot of the countries which are already on the path of major utilisation, I have presented the data from some of these countries.

As you can see in the Netherlands, for instance, more than 90 percent of the waste that is generated is being reutilized, and that is something which is very interesting to note because you have a situation where you are actually saving a lot of the waste from simply going to the dumps. Just other popular countries, like in Japan, for instance, 80 percent, the USA is just above 80 percent, and Taiwan is nearly 90 percent. These are countries that are doing really well with respect to the utilisation of the waste. Now compare this with some of the other countries where a lot of waste is simply not getting utilised and is available for new construction, but there has been no real effort to reutilize this material. For instance, in India, we have a lot of issues with how this waste can be reutilized, and a lot of it is getting dumped in areas where we could actually have much better uses for the land.

Just to give you some ideas about C&D waste recycling that is available in India, as you can see from the map of India, there are only a handful of locations where C&D waste plants have been located. The installed C&D waste recycling capacity in India is estimated to be only about 2.5 percent of the total waste generation. So you can imagine that our potential to recycle itself is restricted to 2.

5. So that means we have a long way to go with respect to our ability to recycle the construction and demolition waste. Out of these waste recycling facilities, many are located in Delhi. There are about three in Delhi: one in Ahmedabad, one in Mumbai, one in Thane, one in Surat, one in Indore, one in Vijaywada, and one in Bangalore. So what this tells you is there is tonnes of potential for actually creating the facilities for reutilizing this waste, and we really need to make a major effort in order to get there; otherwise, we will be looking at a condition where natural resources are going to get depleted. There will be increasing environmental constraints from actually extracting material from natural resources, and we have to increasingly utilise construction and demolition waste.

Now it is only a matter of time before policies are made in that direction, and our group here at IIT Madras is ensuring that we do all the background work to make those policies possible in the future. Now, just to give you an example from Chennai itself, there are a couple of landfills that we collected some information from. So we have C&D waste from various places that have been taken in Chennai are transported to two primary dump yards. One is a Perangudi dump yard, and there is a Kodungayur dump yard. So what we did was we assessed the composition of the C&D waste that was getting dumped by inspecting 10 randomly selected trucks carrying C&D waste for 5 days each in both the dumping grounds.

The total quantity of C&D waste being dumped in these places for a period of one year were also collected from the Weybridge database. Of course, Weybridge is where the trucks get weighed to estimate the quantity of material that they are carrying. You may have seen these in highways and in several other locations. So that is what we also did to try and collect this data and understand how much is the waste that is just getting dumped in two of the dump yards in the city. Interestingly, if you look at the composition, as I had talked about earlier, most of the waste is masonry and concrete waste; more than 50 percent of the waste is actually masonry and concrete.

Of course, apart from this, you still have materials that could find its way in construction, like tiles and stones. There are fine materials, which could be a mixed type of waste, and there are other things which are collected from your construction demolition waste. The total quantity of C&D waste is about 1.14 million tonnes per annum. Significant quantity considering that these are only two dump yards.

Demolition, and these are demolition wastes that have been legally taken to these locations. You can imagine how much of the demolition waste in the city would be illegally being taken to other locations and getting dumped. We do not have any ways of actually quantifying that information. One needs to actually start developing strategies to quantify this information. Demolition debris alone is about 0.

94 million tonnes per annum. Other things are additional waste. About 500 tonnes per day of C&D waste is being dumped in each of the two landfills in Chennai city. You can imagine the scale of this problem. Two landfills, 500 tons per day of C&D waste. Now we are foolish for not really being able to utilise this material in new construction.

We need to put in place all the policies necessary to ensure that we are doing a good job of utilising these materials. Now, of course, I am just reiterating what would have already been covered in the basic lectures. But let us then get on to what type of waste is being collected and what would be the characteristics of this type of waste. So, first of all, we need to classify the different types of recycled aggregate that are typically collected. So, recycled aggregates are those produced by crushing and processing any kind of construction and demolition waste.

So, you can classify these into different types. One is the most important for us is the recycled concrete aggregate RCA, which is obtained by crushing concrete. Then you have recycled masonry aggregate obtained by crushing masonry units, which include brick or block along with plaster. Then you have recycled ceramic aggregate, which is crushed by crushing waste ceramic tiles and sanitary ware. Now of course, sometimes the sanitary ware can be extremely hard to crush.

So, the amount of energy that you spend in crushing sanitary ware may sometimes not really be worth the effort that you are putting in because you are wasting a lot of energy in trying to

crush this extremely hard material. You may want to find some other ways of reutilization rather than crushing it to an aggregate size. Now glass is much easier to crush and forms recycled grass aggregate. So, waste glass is mainly intended to replace fine fraction of materials in the concrete. You may have seen several pieces of literature that talks about the utilisation of fine glass as a replacement for the fine aggregate in concrete or sometimes as a filler.

So, why cannot glass be recycled? Because in many instances, you may have seen that you just need to remelt the glass and reform the new glass. The problem is that when glass is available as a waste, it is basically mixed glass. Different types of glass get mixed together. Colours: different colours of glass get mixed together, and recycling this to form new glass is out of the question. So, what we need to do is find other means of utilising the glass.

In India, of course, you are well aware from your local neighbourhoods that we do not waste too much material. There are people who actually collect the waste and find some useful ways to get something out of it. For instance, we call them the kabadi, or kabadiwala. So, we are used to actually reutilizing a lot of material anyway. Unfortunately, the same cannot be said about construction and demolition waste, because if you really want to reutilize such material, you need to be able to have processing facilities that are much larger than what these small-scale scrap dealers have.

Nevertheless, in a construction demolition waste, the steel that is generated obviously has a lot of value because steel can be easily recycled. So, steel can also be easily separated by magnetic methods, and because of this, steel removal from construction demolition waste is not really a big problem. Steel gets recycled. It is the concrete, the masonry, and the masonry and the sanitary ware part that get mostly dumped, and that is what creates a major problem in most of these dump yards. So, just to take a look at different types of recycled aggregate, as I talked about earlier, you have RCA, or recycled concrete aggregate, that is obtained by crushing concrete.

You can see here that most of these are basically pristine aggregate that was used in the concrete, but with a little bit of cement paste or mortar attached to the surface. Depending on the extent of crushing and processing, you can restrict the amount of mortar or paste that is attached to the aggregate surface. Now, this is recycled masonry aggregate. You can see that

there is a lot of different mixed things here because there is plaster, there is brick, there is block, and so on and so forth, and because of which you get a complete mixture. You know very well that bricks are quite weak as compared to concrete, and because of that such aggregate, recycled masonry aggregate would have only limited uses in new concrete construction because you cannot really satisfy the water absorption demands of this kind of aggregate because brick is extremely absorptive.

It is going to absorb a lot of moisture, and such aggregate will not classify for good quality aggregate as per the Indian standards, for instance, IS 383. Then we have recycled ceramic aggregate. These are the tiles and the ceramic sanitary ware that is leading to the crushing of these ceramic materials. And as I had discussed earlier, ceramic materials are very difficult to grind because they are extremely hard as compared to regular cement, concrete, or brick. In such cases, you can only do a limited level of crushing.

It is best to think about other beneficial ways of utilising the full-sized ceramic blocks or sanitary ware rather than actually trying to crush them into very small sizes. Why am I saying this? Because very often we think about reutilization and reutilization in new construction. In such cases, it is very important for us to think about ways of crushing the material into sizes that are suitable for new construction. We know that typically we use about 20 millimetres of aggregate. Imagine crushing sanitary ware into 20-millimetre pieces. You may not be able to do that quite easily because of the hardness of the material.

And the amount of energy that you input into this process may be much more than what you can actually save by not using natural materials. So, you have to make your decision very carefully; for that, you need to actually do a proper calculation or quantification of the energy and CO_2 emissions associated with each of these processes. And that is something that will be covered in a later lecture by one of my colleagues. Now, recycled glass aggregates, as you can see here, basically broken pieces of glass, crushing glass and when you crush glass, it makes into a very fine powder, and that fine powder can be used to replace the fine fraction that is used in concrete. Now, in IS 383, those is the Indian standards for concrete aggregate.

Similar to that, there will be standards in EN, in ASTM, and so on and so forth. These standards basically talk about the types and properties of the aggregates that are permissible for use in new concrete construction. So, in IS 383, there is a specific table that tells you

about how much of recycled aggregate can be used, what type of recycle aggregate can be used. So, I am just here talking about the types of aggregate. One is your recycled aggregate, which could be complete mixture of everything from masonry to concrete and all. You have recycled concrete aggregate only from concrete waste.

Then you have iron and steel slag, which is basically aggregate that is manufactured from the slag that is generated during the iron and steel manufacturing process. So, you have to you must have heard about the iron and steel manufacture process, where you have slag that comes out of the different types of furnaces, like blast furnaces, electric arc furnaces, ladle slag, and so on. So, this slag that comes out is cooled slowly to make it into a hard, rocky material, and then it has to be crushed to a size that is suitable for use in concrete. Again, the difficulty there is there is a lot of iron present in the slag. So, crushing the slag to a size that is capable of being used in concrete can involve a lot of energy input.

Similarly, from copper factories, you can get copper slag. Copper slag is basically iron silicate. These are iron silicates again, very hard materials, but also they are very dense materials; they increase the density of your concrete. So, you have to also compensate for the density increase and ensure that you are taking care of that while doing your concrete mix design. So, these are some types of manufactured aggregate that are allowed by IS 383.

Then of course, there is the fine recycled concrete aggregate. Now, in the previous picture, I showed you coarse recycled concrete aggregate. In this picture, I am showing you fine recycled concrete aggregate. So, you can see that this fine recycled concrete aggregate, or FRCA, can be further subdivided into extremely fine powder, which is less than 300 microns. So, this is an extremely fine powder; some of it can be finer than 150 microns also. In which case, technically, it forms a part of your paste fraction in concrete.

Now, there are also adhered mortar pieces and sand particles between 600 microns and 1.18 millimetres, and then there are more coarser particles, which could be the crushed rock, crushed coarse aggregate, or simply sand particles, which are of the size of 2 to 4 millimetres. So, these are the various compositions that you find in a typical recycled fine aggregate. Basically, you are crushing the concrete into a size that is smaller than 4.75 mm, and that is your fine recycled concrete aggregate. So, these are the different types of aggregate that you can actually get from the construction demolition waste. The extent of usage, or the amount

that can be used, is again defined by IS-383. We will quickly take a recap of this in a later part of this lecture.