Admixtures And Special Concretes

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Lecture -72

Special concretes - Concrete for 3D printing - Introduction, classification, printing process

Concrete for 3D Printing

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Okay, in this last chapter, we will look at concrete for 3D printing. We have already talked a lot about rheology earlier and you saw how that rheology was applied to the design of self-compacting concrete. Now in this context, 3D printed concrete is also a special rheology-controlled concrete where a lot of the functionalities of this material deal with the fundamental rheological characteristics. So that is why your understanding of rheology will also make a difference with respect to understanding the content for 3D printing. Now in IIT Madras, we created this Imprint or IIT Madras Printability Lab which has IITM and Tvasta as one of the partners.

Tvasta is a 3D printing manufacturer or 3D printing company that makes its own 3D printers and executes projects with concrete 3D printing. So, they originally started as a start-up from 2016 IIT Madras graduates, none of them are civil engineers by the way. They set up this company in Bangalore and initially, they were involved with 3D printing as it is applied to the manufacturing industry and for the product industry, essentially plastics and metal. Later, they started looking at concrete because of a workshop that we had conducted here in 2016 where we invited top experts from around the world to talk about 3D printing.

We created a working group from this and then from then on, we have come quite some distance with Tvasta. So Tvasta today is probably one of the leading 3D printing companies of course in India and if possible, we can think about that in the world also because of the speed at which they have come up to this level. Their construction arm is based in Chennai.

Introduction- Types of Manufacturing Technique

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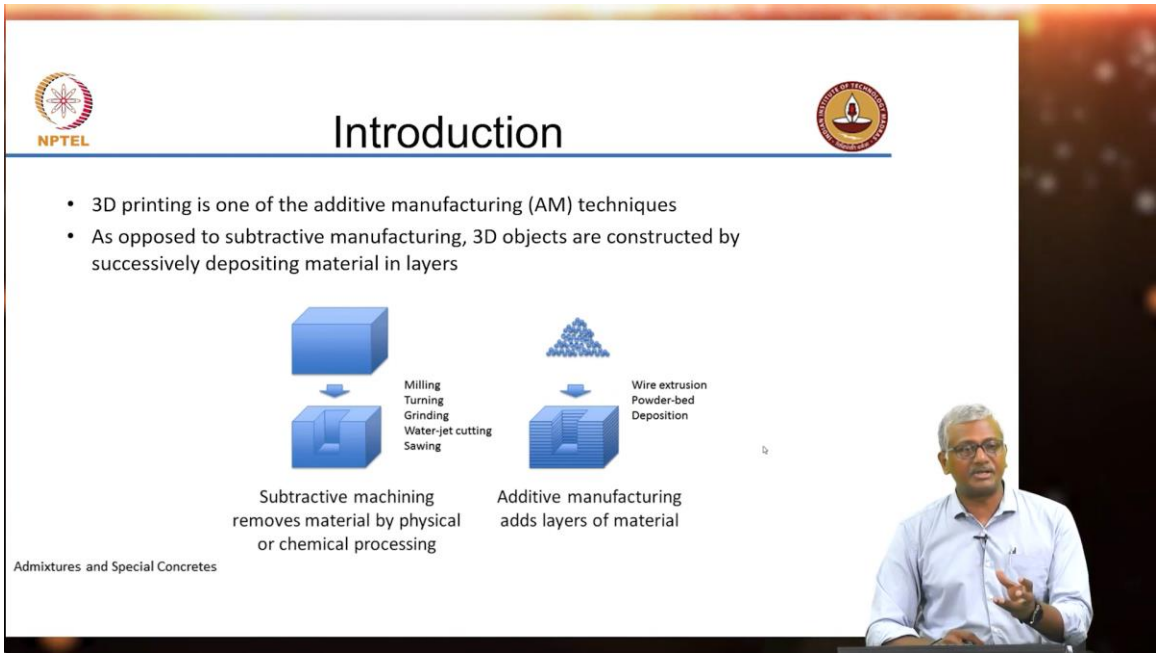

So, 3D printing is one of the additive manufacturing techniques. We are typically used to subtractive manufacturing.

We take a large component, we mill it, we cut it, and so on, and build the component or part that we desire. This is basically from a manufacturing technology segment. You would have done a workshop in your college or even carpentry where you take a large block of wood then you cut it to the right size. In the fitting workshop, you would have

taken a large block of metal done cutting and filing and grinding and everything, and then made it to the right size. That is called subtractive manufacturing.

But additive manufacturing is the other way you create a 3D image of the object and then you deposit material to create the object so that you can minimize the wastage and digitize the process to control the process more digitally.

Subtractive and Additive Manufacturing

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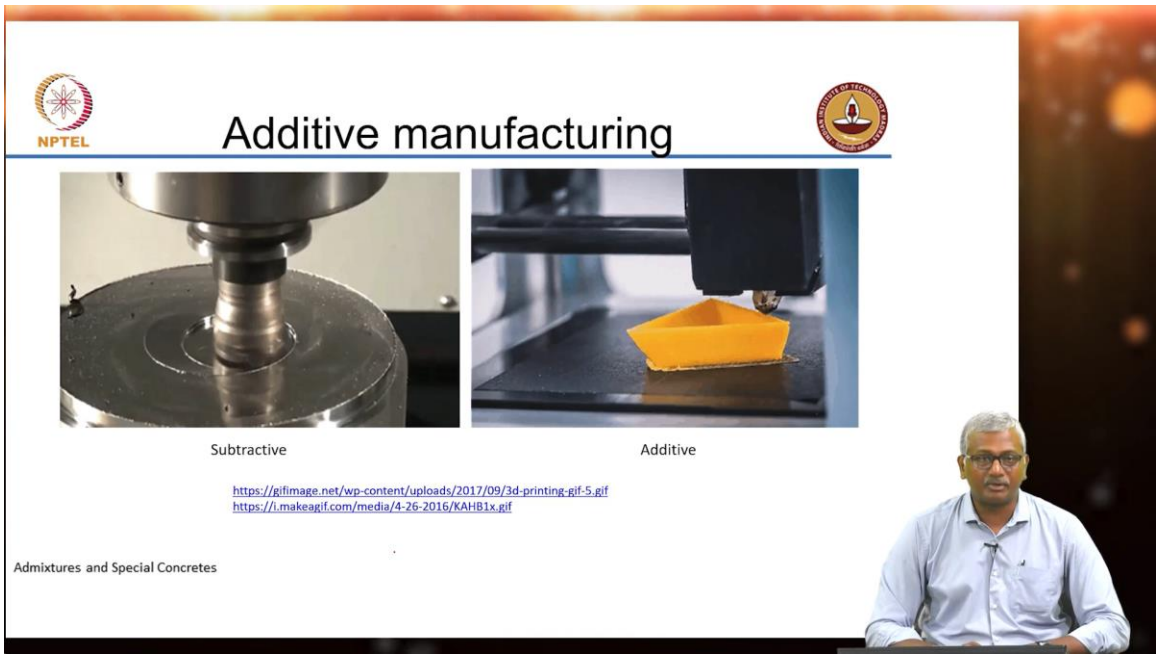

So, this is a simple example of subtractive and additive manufacturing. So, (refer to the left picture) milling is being done on a large metal piece, and additive manufacturing of plastic is being done (refer to the right picture). So, you have layers that are getting deposited. Plastic is quite easy in this way because when you heat plastic it flows, when it cools down to room temperature it sets and hardens. So, it is quite easy to do 3D printing with plastic.

Classification of Additive Manufacturing Technology

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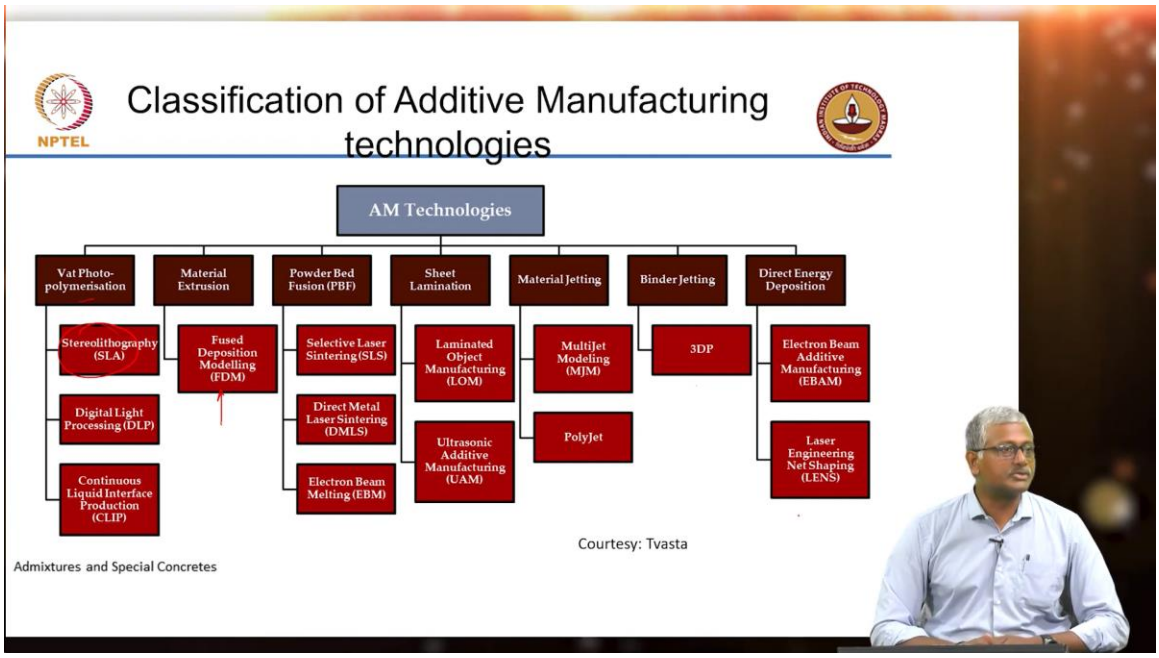

There are various types of additive manufacturing technologies, of course, we will not go through entirely everything. But just for your understanding, there are a lot of ways in which you can do additive manufacturing. This is photopolymerization. One of the leading research segments today is stereolithography.

There are much more sophisticated techniques with additive manufacturing available in the electronics manufacturing industry. Today even medical 3D printing is being done. Material extrusion is what we are mostly concerned with. In the case of metal or the case of plastics, it used to be called fused deposition modeling. But in concrete, we just call it concrete extrusion 3D printing.

There are powder bed fusion techniques, sheet lamination techniques, and material jetting techniques. In the material jetting technique, the ink or the binder is jetted onto a bed that contains the aggregate, and that ensures that the aggregate can be encapsulated in the correct location. Then you have binder jetting which is more or less the same as material jetting. And then direct energy deposition like electron beam additive manufacturing and laser engineering. So many technologies today are available in this segment of manufacturing. The idea of digitization of construction is to see a way in which we can employ manufacturing techniques in construction.

Why? Because construction as such does not have the kind of productivity that manufacturing does. If we start digitizing construction it can reach levels of productivity equivalent to manufacturing. Precast concreting is one way of digitizing or making construction more like a manufacturing scheme. But again in all these cases whether it is 3D printing or precast, if it is done in a factory there is some assembly involved on site

which involves skilled people to do it. So, skill levels must be upgraded when you start dealing with new technologies. We cannot work the way that we have been working before.

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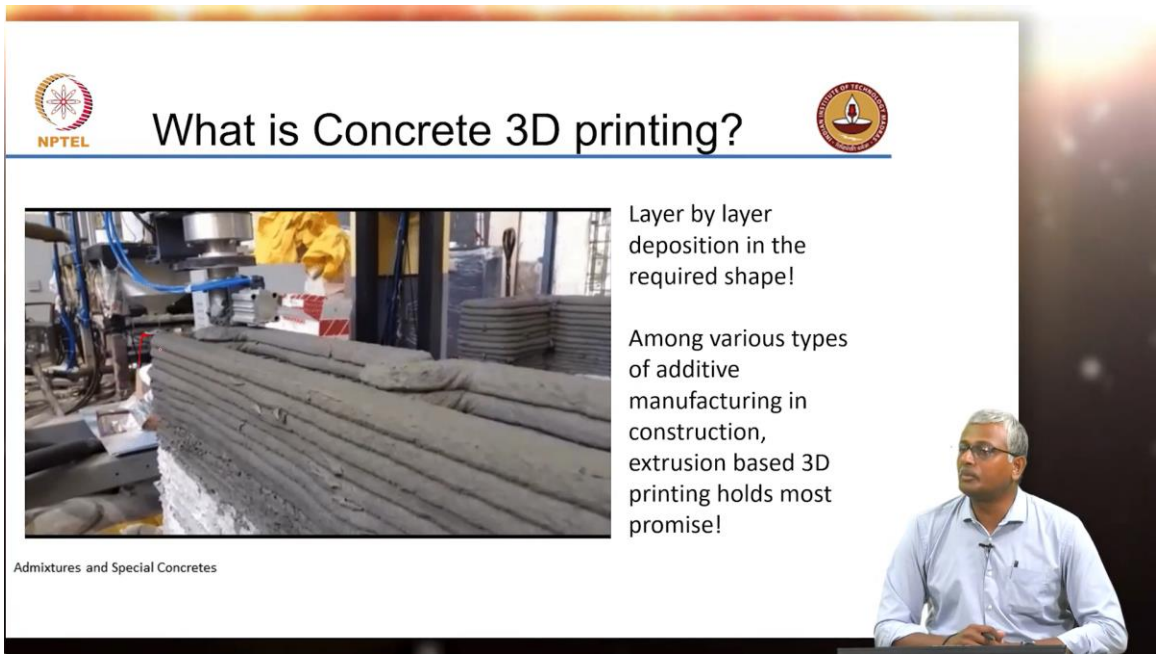

So concrete 3D printing is a layer-by-layer deposition in the required shape. You can see the printer depositing the material. And here what you are essentially ending up with is creating complicated shapes without formwork. These shapes cannot be easily achieved in normal concrete because you must prepare formwork specifically for each shape which will be an expensive affair. And if you are not going to be able to reuse the formwork then economically it cannot be justified easily. So, 3D printing can be made use of wherever you need some flexibility in your design.

Classification of Additive Manufacturing Technology in Construction Industry

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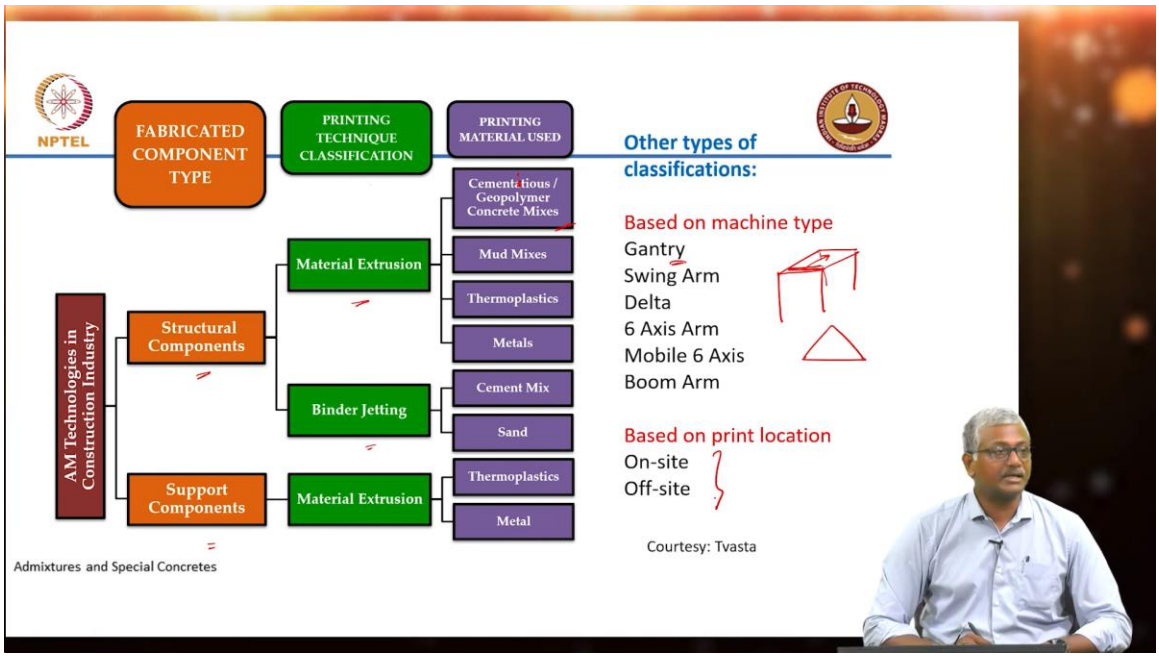

Fabricated component type:

So again, concerning 3D printing itself you can either fabricate structural components like walls or columns or beams or whatever and support components. Support components are those which are like let us say you are printing a formwork. Or you are putting together a material that can act as a base or a support or a mold for other concrete that you are going to be placing on top of it.

Printing Technique Classification:

Now in terms of the technique of printing, you have either material extrusion or binder jetting as popular choices for printing structural components. As we will see later, binder jetting is not something that can be done for large-scale components. It is more suitable whenever you need to produce something very intricate but at a much smaller scale. Now extrusion-based 3D printing is commonly used.

Printing Materials:

Extrusion-based printing can involve cementitious mixes. Geopolymer concrete mixes could also be used for 3D printing with material extrusion. Mud or clay can also be 3D printed. Thermoplastics and metals are being done already. We are not dealing with those as far as construction is concerned but that can also be done.

Types of Printing Machines:

There are different types of printing machines that can execute these prints. The machine type could be a gantry. Gantry means you have a frame and your machine can move along

the portal. A swing arm printer where you have a centralized pole and then the arm swings around and prints. The delta is a frame that is not rectangular but is triangular. You have a 6-axis arm, a mobile 6-axis arm, or a boom arm. Various types of machines can be used.

Classification based on location:

printing also can be done either onsite or offsite. Onsite means you bring the printer to the site and do the printing. Offsite is like a precast operation. You print in a factory then you take it to the site.

Companies/ technologies in 3D Concrete Printing Space

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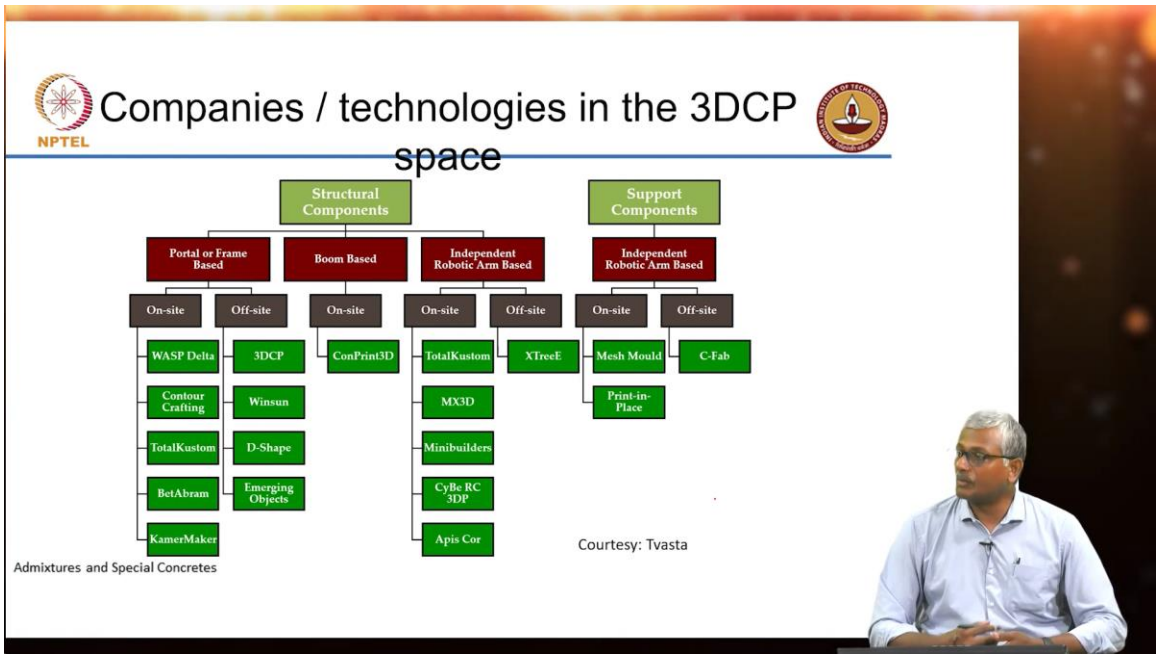

There are several companies, and everything will not be gone through here but you will find most of these companies having their videos on YouTube. There is some news or the other that keeps coming out about many of these different companies about what they have accomplished with 3D printing. Sometimes they print very fast, sometimes they print components that are previously unseen, and so on. There are a lot of examples on YouTube where you can see the videos of printing.

3D Printing Process- Steps involved:

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1. **DESIGN**

One is obviously to create the model using CAD software, a 3D modeling software. Revit can also be used to do a 3D model. But the problem next is how do you convert this 3D model into a 2-dimensional print. When you give a regular print command on your computer that is only 2 dimensional. All the ink gets deposited in the shapes that you are having your letters in on top of the paper like an inkjet printer sprays the ink. So, a laser printer has a slightly different technology but the idea is the same that you are putting ink where it needs to be put.

2. **SLICING**

For 3D printing, the design that you have in a 3D-printed model must be sliced to convert that into 2D. Now if you think of this as a reverse of your computerized axial tomography scan. Suppose you have a fracture in your arm you put the X-ray source on this side you have a film on the other side. Same radiation shielding right? The segments in your hand that are denser, the bones will shield more X-rays. That image will be captured on the photographic film on the other side.

Now when you do a CAT scan of the same arm you are taking images completely around the arm so 360-degree images are being taken. And then you have an algorithm that puts these images together and recreates the three-dimensional shape. That is what is a computerized axial tomography scan. So, there you are having slices that are put together to make a 3D object. Here you want to do just the opposite. From a 3D object, you want to slice it in such a way that it is possible to execute by a printer. So the CAD model is

broken into layers and converted into what we call STL or AMF files which are then executable by a printer.

Now these conversions, the slicing software is freely available on the internet. It is a shared open-source code. So, you can get this freely from several groups that are working around the world. In this case, Tvasta created their own but then this can be done by most people who are savvy with how these things are done.

3. PRINTING

The next thing is telling the printer to print in those layers. So, let us say you had a box. If you want to print a box then you will be breaking it up into slices and then asking the printer to execute the box. It will just print rectangles or squares one on top of the other until you have the complete box right. This involves file transfer, positioning, and printing of the design layer by layer. So essentially a printer is going to wherever the material is required, extruding the material, and placing it there.

4. POST PROCESSING

And we know that in concrete we need to do post-processing like curing. Or if we want a specific surface finish, we must do the finishing also. Curing and finishing are important for concrete and then you get your final product.