Basic construction materials
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Lecture 32
Cement and Concrete 4 - Part 2

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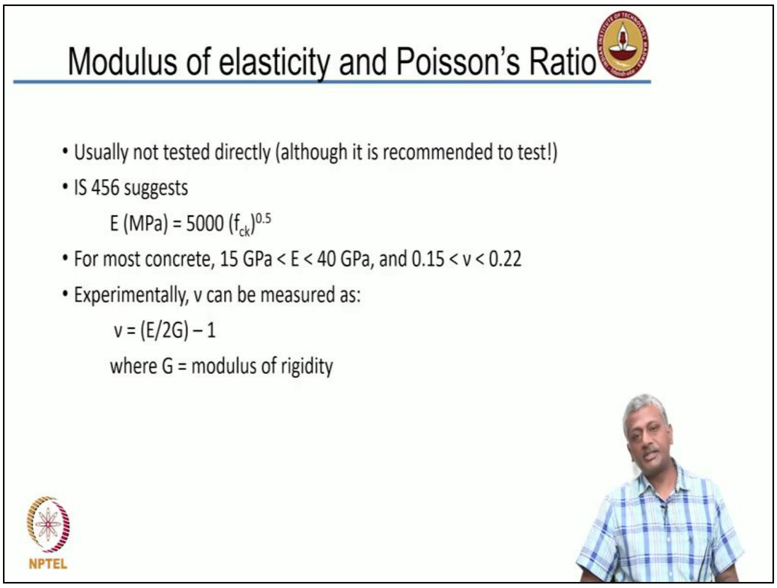

What about other engineering properties? The modulus of elasticity of concrete is also important because it governs the ability of concrete to resist deformation. So usually, it is not tested directly. However, there are test methods, and it is usually recommended to test the modulus every time for any special concrete. Nevertheless, in most cases, we use code prescribed relationships that link the modulus to the compressive strength.

So as per IS 456:2000, which is the code for plane and reinforced concrete construction, our modulus E in Mega Pascal's is given as 5000 $\sqrt{f_{ck}}$ where f_{ck} is the characteristic compressive strength. Remember we talked about the grades M30, M40, etcetera when we say something like that; these 30 and 40 are nothing but characteristic compressive strengths. We discussed and defined what that strength means in terms of specimen size, age, type of curing, and so on, but we did not get into the statistics behind it.

So, there are statistical considerations also behind defining characteristic strength. However, again that is not a subject for us to discuss in this course. In most concrete, our modulus will be between 15 and 40 Giga Pascal's, higher the strength greater the modulus, and our

Poisson's ratio typically will be between 0.15 and 0.22 more or less an average of about 0.18 to 0.2 experimentally we can measure the Poisson's ratio by measuring the elastic modulus and shear modulus and applying this simple elasticity equation.

$$E=2G(1+2\mu)$$

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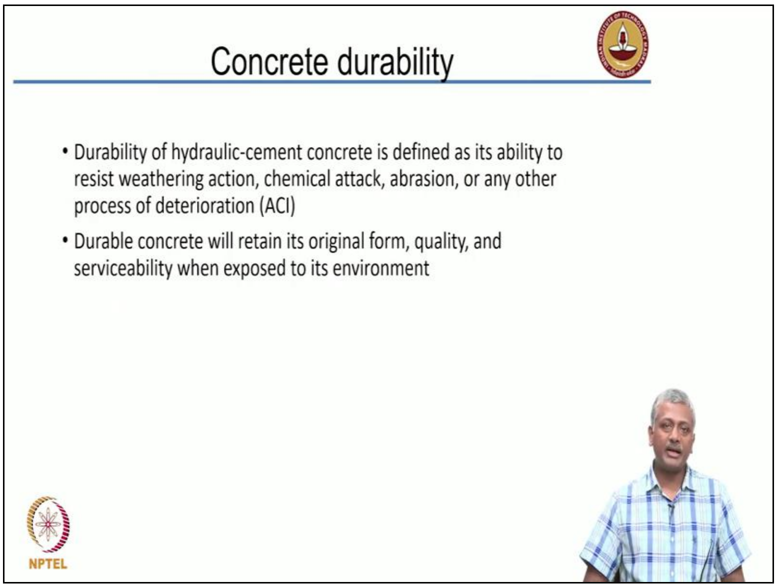

One important aspect that we need to consider beyond the loading criteria is the concrete's ability to withstand its service environment. So concrete has to function very well in the environment of service. If we have a coastal zone, we have chlorides from the marine environment, which may affect the properties of the concrete by corroding the reinforcing steel.

So how does concrete survive in a given environment? So durability is the term that we use to define that aspect. So again, according to the American Concrete Institute (ACI), the durability of hydraulic cement concrete is defined as its ability to resist weathering action, chemical attack, abrasion, or any other process of deterioration. So again, all non-load-related processes are related to the durability of the concrete.

Again durable concrete will retain its original form quality and serviceability when exposed to the environment. That means all these aspects will be negatively impacted if we have a problem with the durability of concrete.

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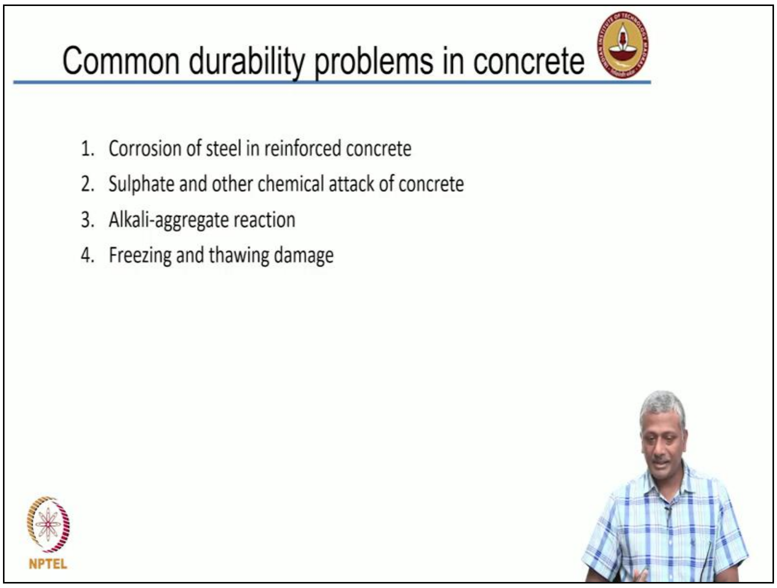

Interestingly all durability problems such as corrosion of steel and reinforced concrete, chemical attack of concrete, alkali-aggregate reaction; remember we talked about this when we talked about the aggregate type and then freezing and thawing damage. When we talked about air entrainment, we talked about freezing and thawing damage. So, all these problems interestingly are related to the presence of water.

If water is present, all these problems will happen. If water is not there, we can avoid many of these problems.

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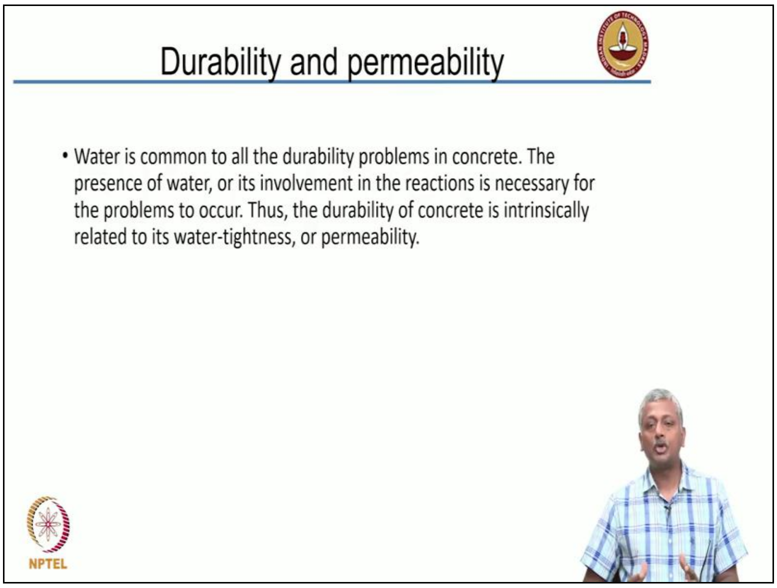

So generally, durability is intrinsically linked to the permeability of the concrete. How easy is for water and other aggressive chemicals to enter the concrete because durability is intrinsically related to the water tightness of the concrete or the permeability of the concrete.

If we can avoid water and other chemicals from getting into the concrete, we will avoid many of the concrete problems.

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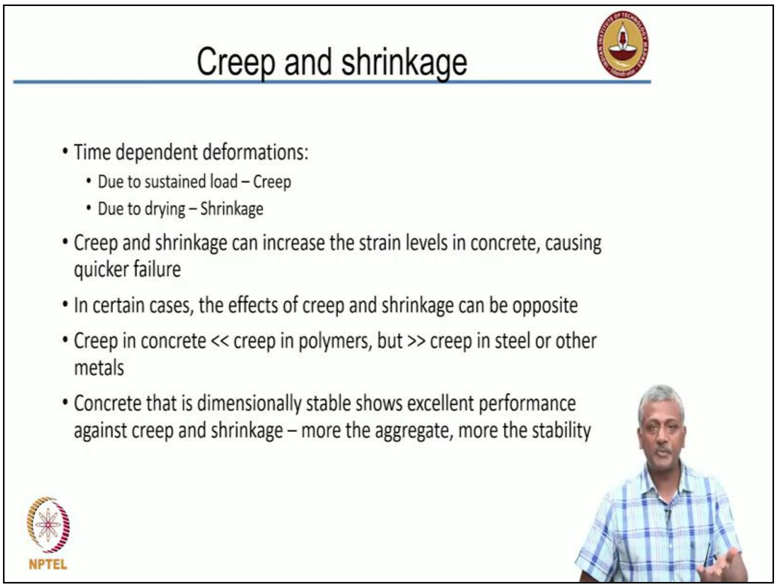

The other aspect that governs the long-term performance of concrete one is the structural aspect of the loading; the second is the durability that is the response to the environment the third is what is called creep and shrinkage. Now please remember that when we do a test in the lab, it is only for a matter of few minutes. However, a concrete standing in a block of structural concrete in a column in a structure is being subjected to load for many years.

Now compare this to ourselves; let us say we lift a bucket and put it down. Second, we lift that same bucket full of water and keep it held up for a very, very long time; what will happen? Obviously, our body will feel the strain of lifting the bucket a lot more than it felt when we just lifted it for an instant and kept it down, that is the response to sustained loading, and we call that as a creep.

Creep in concrete, although it is not as much as polymers that we will talk about in another chapter in this course, but creep can significantly affect concrete properties. When we have creep, it can lead to a faster rate of degradation or deterioration. They can increase the strain levels in the concrete; the other aspect is that concrete has water in it, and this water can dry out of the concrete, causing volumetric contraction, which is called shrinkage.

If we have a piece of concrete floating in space and it is drying, nothing will happen to it, and it will just keep reducing in size. However, the same piece of concrete is held inside a structure, and it wants to shrink the structure will not allow it to shrink because there are restraints to its shrinkage we cause restraint to the movement. And because of that restraint, we will get cracking similar to a slab sitting on the ground.

So if the slab wants to shrink, the ground basically restrains it from moving, and that restraint will cause shrinkage. So restraint causes cracking in the case of shrinkage. In some cases, creep and shrinkage can act in opposite directions, which may offset the damage to some extent. However, we still have to consider and understand the individual effects of these. As I said, creep in concrete is much lower than creep in polymers, but usually, it is much greater than that in metals, especially steel.

So we want our concrete to be strong. Yes, we want our concrete to be durable. We also want our concrete to be dimensionally stable, which means it should not change its volume with time, and this time-dependent change in volume is typically caused by creep and shrinkage. Interestingly, the **factor that affects the creep and shrinkage most is the amount of aggregate**. The more the aggregate, the more the stability.

We took to compare the construction with concrete and construction with stone because we had this magic ingredient: cement paste, which could help mold the concrete in any shape we wanted. However, it turns out the cement paste is the reason why the durability or dimensional stability problems actually occur. The aggregate, for the most part, is inert and does not do anything.

And the more the aggregate that is there in our system, the more stable our system will be. So please keep that in mind when we design concrete, although we want cement paste to be the primary factor governing the behavior of the concrete. We want as much aggregate there as possible that is what we need to consider while designing concrete, and it also makes the concrete more economical that way.

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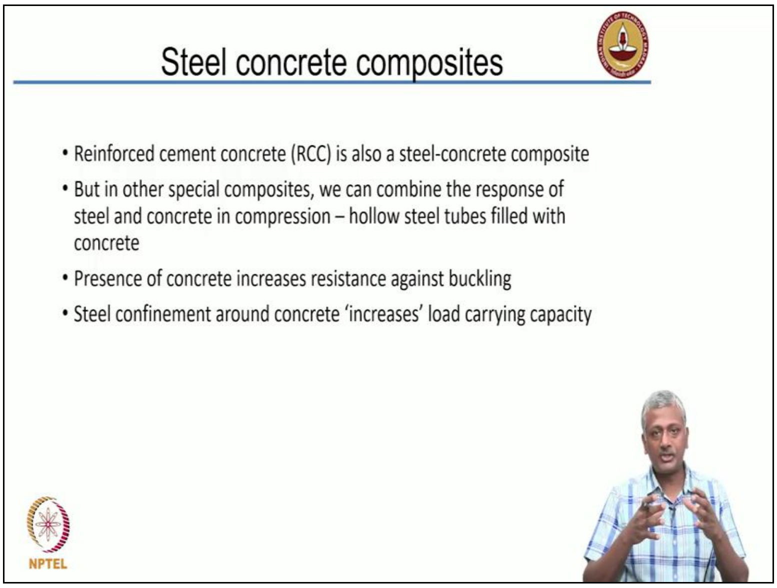

Now we talked about concrete separately. In another chapter, my colleague professor, Pillai, talked about reinforcing steel or will be talking about reinforcing steel. But let us talk a bit of steel-concrete composites. Of course, reinforced concrete itself is a composite because it has steel reinforcement inside a concrete structure, but we can also have special composites of concrete and steel like hollow steel tubes filled with concrete.

There are special advantages there because when we fill up concrete inside hollow steel tubes, we save a lot on steel as far as compression members are concerned. Secondly, the concrete prevents the steel wall, which is thin, from buckling, and third the steel which is confining the concrete inside increases the load-carrying ability of the concrete. Remember, we talked about the fact that we are basically causing it to bulge outwards when we compress a cube. So if we have concrete that is confined in the steel tube, the concrete's compression will be resisted by the tube and which will cause the confinement, and that confinement increases the load-carrying capacity. So these are called hollow steel tubes filled with concrete. So that is one way of establishing another composite relationship that is much better than what we would have if we just had a concrete column or a steel column.

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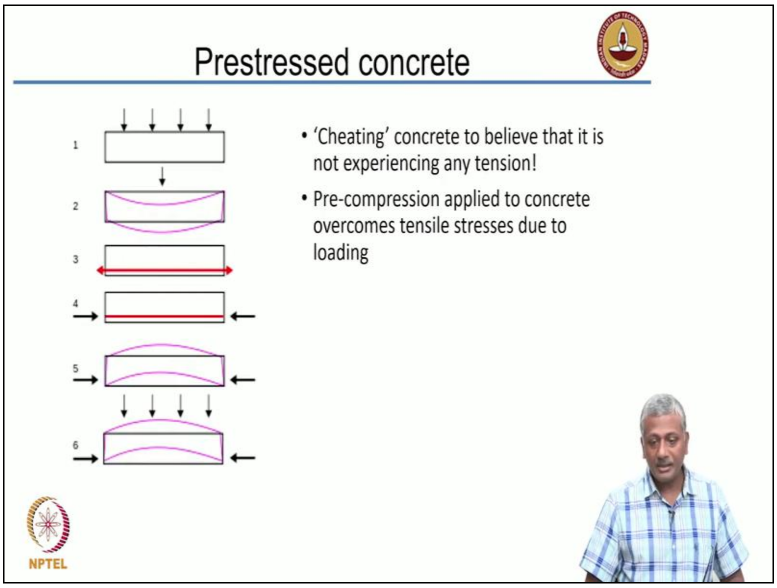

The other way to use steel-concrete composites is what we call pre-stressing. Now again, just taking the simple example of a beam here. So we have this beam loaded from the top and that top loading results in a deflected shape like this. Beam deflects, and while it is deflecting, there is tension at the bottom and compression at the top. So the concrete will fail because of this tension.

Now, what do we do? We put reinforcing steel to take care of this tension. However, can we do something else and that is the essence of pre-stressing. So what we do here is we put a steel rod inside, which is of very high strength. We pull the steel rod; while we pull the steel rod, we apply a compression reaction to the concrete. So we hold against the concrete and pull the steel rod.

So we are applying a reaction to the concrete. So the tensile force that we apply in the steel rod is balanced by the compressive reaction in the concrete. So we are causing compression of the concrete. Pre-compression is being caused to the concrete. So when we have the steel rod below the concrete's central axis, we are applying this tension to the steel rod and compressing the concrete.

What we will end up doing is causing the concrete beam to bend upwards. So this downward bending is called sagging. This upward bending is called hogging. So now what will happen? Even before it is actually loaded into the structure, this concrete beam has now bent slightly upwards. Now when we take this and put it in the structure and subject it to load coming from the top, what will happen?

The net result of this deflected shape that is upwards and the deflected shade expected from the loading that will be downwards will be zero. So our net deflected shape will be perfect our net deflected shape or net deflection will be zero. So what we are doing is we are cheating the concrete into believing that it is not experiencing any tension right by causing it to compress before it is getting loaded.

So we have a pre-compression that causes compressive stress throughout the concrete then we have the loading in the structure, which causes tension at the bottom. So the compression because of pre-compression and tension because of loading cancel each other out. So pre-compression is applied to concrete to overcome tensile stresses due to loading.

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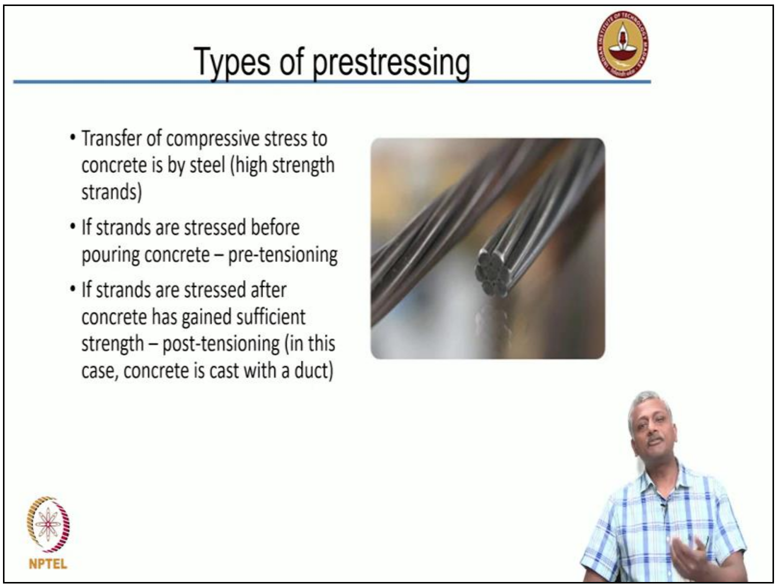

There are different types of pre-stressing; it depends on when we apply this stress to the steel; of course, the steel which is used in this case is not the same as reinforcing steel. I am sure that you will learn more about it in your steel chapter with Dr. Pillai. These are called high-strength strands. So we have individual strands here we can see, and usually, we have high-strength wires which are bundled together to make a stand. So this is a seven-wire strand that is bundled together, and then we produce a certain length of this steel.

So these strands are the ones that are going to be stretched in a pre-stressed concrete member. So if the strands are stressed before we pour the concrete, we call it pre-tensioning; I will come to an explanation in just a minute.

However, if we prepare the concrete that hardens, and then we prepare some sort of a cavity inside and then push the strand inside and pull it to cause compression, in the concrete, that is called post-tensioning. In pre-tensioning, we have the strand sitting inside fresh concrete, and concrete hardens around it. Post-tensioning means that the steel is actually embedded only after the concrete hardens. So how does this works?

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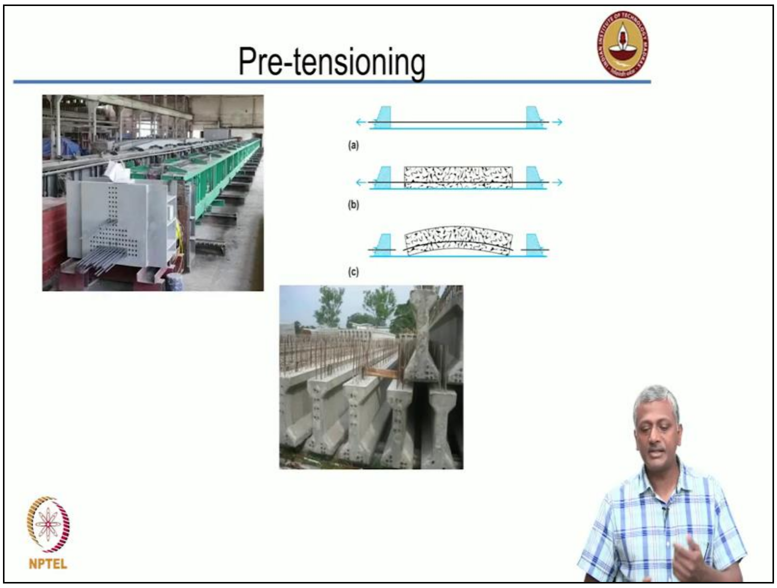

So let us take the example of pre-tensioning, so these are the end blocks through which our steel is stretched in tension. Steel is getting stretched in tension through the end blocks. Now we pour the concrete. So concrete is poured, the steel will not transfer any stress to the concrete if it is in the same stretched state. However, what happens if we cut the steel here That is what is done here. If we cut the steel here, the elastic steel will want to go back to its original dimension. So when it wants to go back to the original dimension, it conveys a compression to the concrete and results in this sort of a shape that we call hogging shape. So that is called pre-tensioning. So we can see here, this is the end block; this is a steel bar that has been stretched through the end block; this is the formwork.

And the concrete is poured inside and after the concrete attains some level of strength because if the concrete is fresh and then we cut the steel, nothing will happen. It is not going to transfer any stress; the concrete has to gain some strength. Concrete poured and then gained some strength, and then we cut the strands; when we cut the strands, it transfers the compression to the concrete.

Moreover, with this, we usually make many beams for bridges like the ones which are shown here; these are called girders, and we can see these are the steel strands that are running through the concrete that has been cut and that has transferred pre-compression to the concrete.

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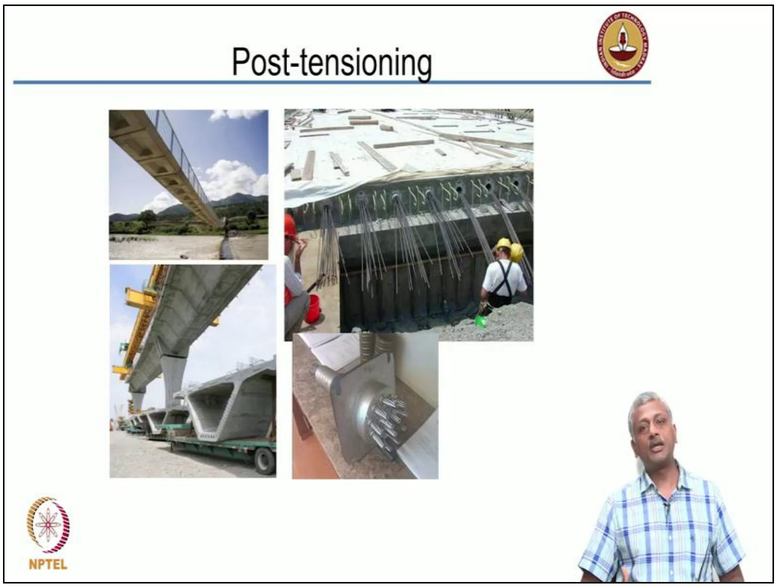

What about post tensioning post-tensioning is what we see commonly in your segmental bridges I have shown an example in the first part of the concrete lecture. So our segmental bridges are here. So these segments are transported to the site after casting at the factory and then stitched together; it is almost like stringing beads.

We take beads and put them in the string and strength and tighten the beads against each other that is what we are trying to do here, so we have several of these segments which are put against each other we push the pre-stressing strand through it and then stretch the strand passing the compression onto the pre-stress members, and that is what is shown here this is again an end block showing where the strands are coming out just like what is here.

It is a magnified view of what we see there. So we cast the concrete with a duct inside the concrete. So that we can push the steel through this duct easily, the problem is after the pre-stressing has been done and the compression has been transferred to the concrete the steel is freely sitting inside the duct. If we leave it like that, it will corrode with time, and corrosion obviously will lead to a rapid loss in its stencil capacity.

So what we need to do is fill up the duct filled with grout after completion of work; after completion of stressing, the duct is filled with grout, which causes the steel to be protected against corrosion. So here is a case where they are post-tensioning slabs, and if we go to many of the multi-story buildings today to avoid too many columns and have extensive open floor areas, they go for post-tension slabs.

PT slabs are very commonly seen in many of our construction sites today. Post-tension slabs are commonly used today. However, mostly we will see post-tensioning applied extensively in bridges today, like the pedestrian bridge shown here or the metro rail bridge shown here; this is a Chennai metro rail construction project where they have these segments launched and sitting against each other.

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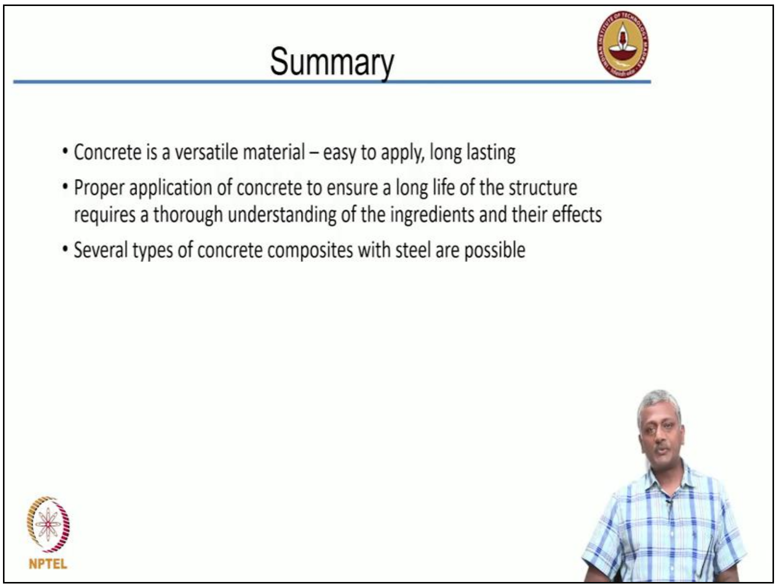

So with this, we come to the end of the chapter on concrete or cement and concrete; throughout this chapter, one thing that would have come across very clearly is that concrete is a very versatile material. It is easy to apply and is long-lasting. Provided we do an excellent job of the construction. It is critical to properly do concrete construction to ensure that we get the best effects or best results out of it.

Proper application of the concrete ensures a long life of the structure. And that requires a thorough understanding of the ingredients and their effects. And as I said, apart from the structural engineer, apart from the contractor, the site engineer, and so on, we need a concrete technologist who is a specialist who understands the properties of concrete well on the job site to ensure that the concrete is used properly.

Furthermore, today we are increasingly dealing with special composites of concrete with steel, one of which is the pre-stressed concrete. Moreover, without pre-stressed concrete, many of our structures would have been challenging to make with just reinforced concrete. So we need to remember that concrete advancements deal with applying new and different types of composites that can be made with steel and concrete.

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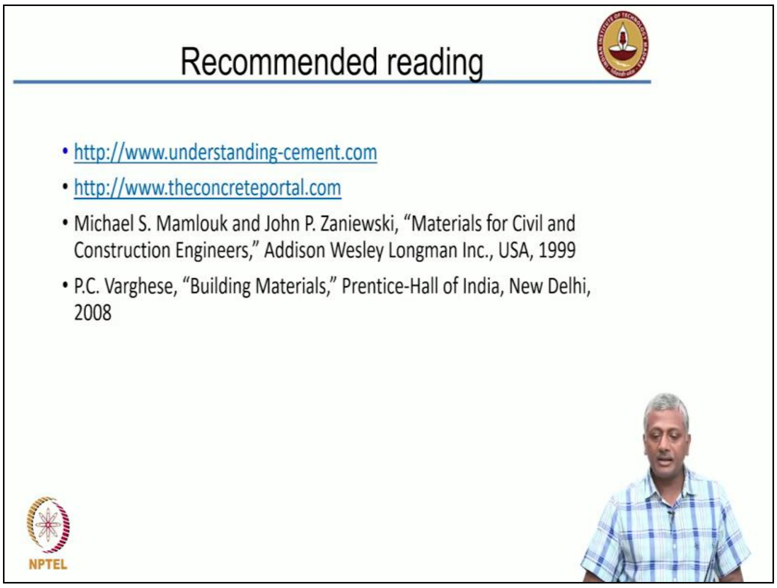

So with that we come to an end there are several websites which have information regarding concrete https://www.understanding-cement.com/ is a very useful website this website is my own that is www.theconcreteportal.com, but of course, much of the information that is presented here has much detail about concrete we do not need to get to that to this course. For these course textbooks you can refer to Mamlouk And Zaniewski and PC. Varghese.