Retrofitting and Rehabilitation of Civil Infrastructure
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Lecture 14
Repair Techniques (Continued)

Hello friends, welcome to the NPTEL online certification course Retrofitting and Rehabilitation of Civil Infrastructure. Today we will discuss module C, the topic for Module C is general repair and retrofitting of concrete structures.

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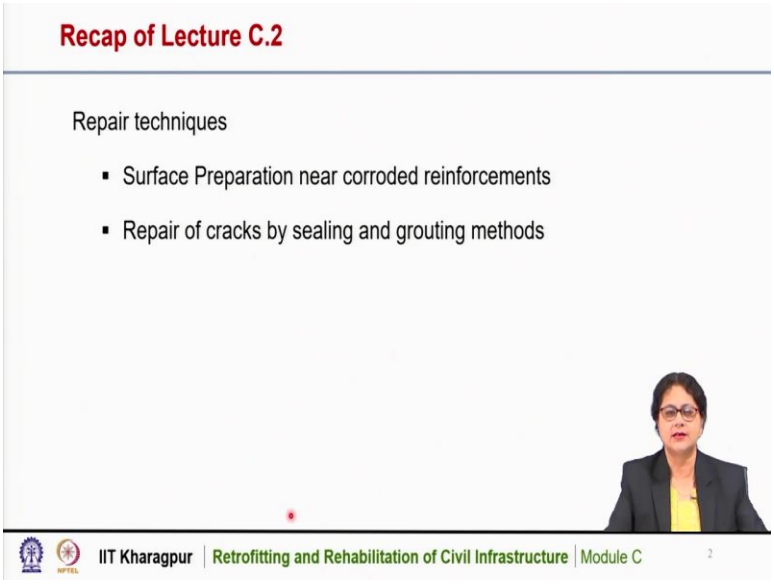

In the previous lecture, we have discussed the surface preparation near corroded reinforcement, and also, we have discussed several sealing and grouting methods as a repair technique of cracks and patches in existing structure.

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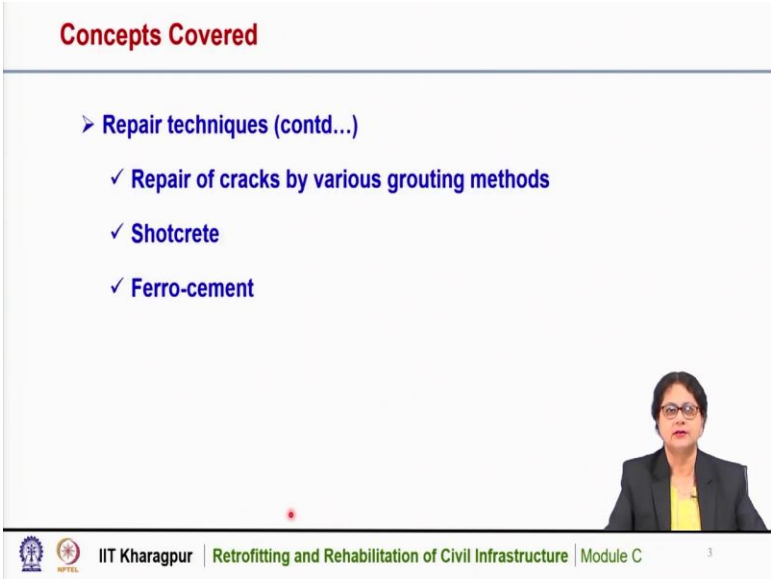

Today, we will continue with the repair techniques of repair of cracks by various other grouting methods, we will also discuss shotcrete and ferro-cement, which are also used for the purpose of repair of existing structures.

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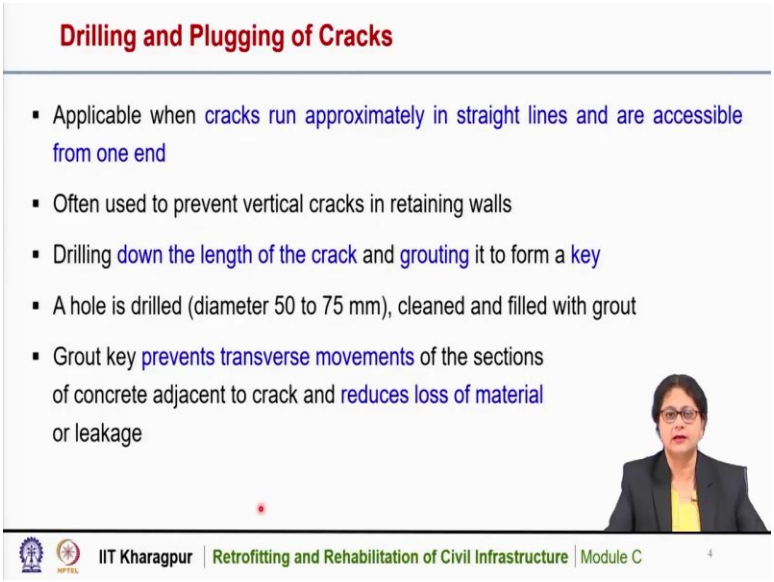

Drilling and plugging of cracks is a method of crack repair of existing structures. The method is applicable when the cracks run perpendicular to the length of the member and is approximately in straight lines and the cracks are accessible from one end, so we cannot access the cracks along

its length, but, from one end, it is accessible only. Often used to prevent the vertical cracks in retaining walls. So, here in this method, drilling down the length of the crack is done.

And in that drilling, a hole is created. The hole is drilled of diameter 50 to 75 millimeters depending on the type of crack and the type of structure and its width and then it is cleaned, the hole is cleaned and then the grout material is inserted into it. The hole is filled with grout and a key is also formed at the mouth of it.

The grout key prevents the transverse movement of the sections of concrete at this into the crack and thus it reduces the loss of material due to leakage. So, drilling and plugging is an effective method of crack repairing, particularly when the crack is long and runs in straight line along the length or height of the member and we can access it from one end and by making a hole by drilling, we can fill that hole by grouting and thus the crack is filled up.

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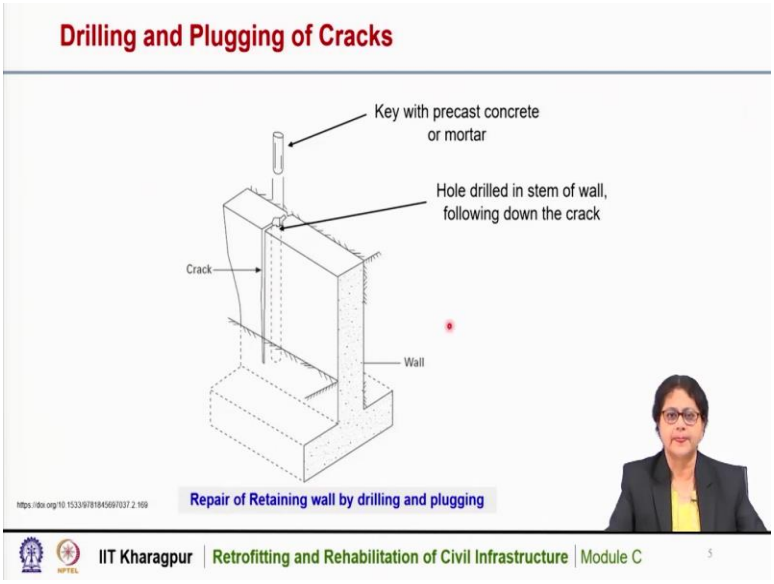

So, here is a schematic diagram of the drilling and plugging method of repair of cracks we can see here it is a typical sketch of a retaining wall which has long cracks you can see here this is the long crack and the top of it we can access and a hole is drilled along the length of the crack.

Now, with that hole, we have to clean the hole and then the grouting material should be inserted with high pressure into it. So, that the cracks are filled up and the monolithic or the strength of

the structure is restored. So, this is a method of repair of typically retaining wall type of structures which has long cracks.

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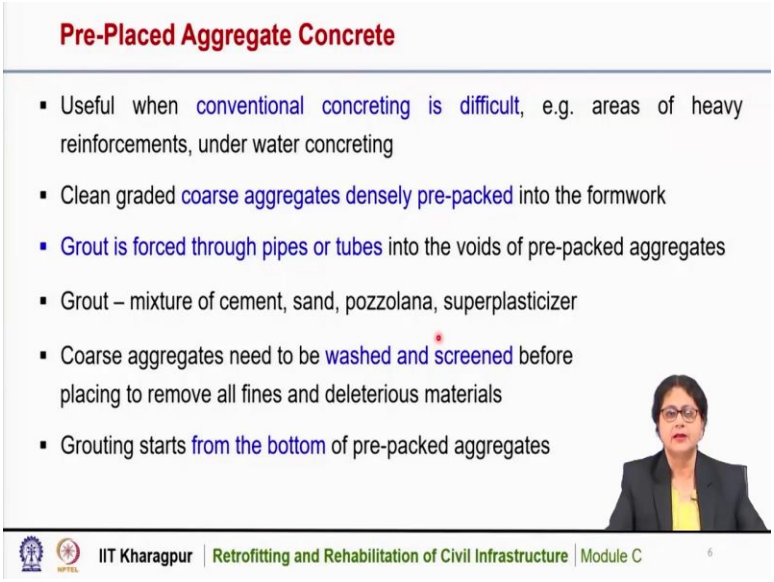

Another type of repairing of cracks or patches on existing structure is preplaced aggregate concrete method. This method is useful when the conventional concreting is difficult, particularly in the areas of high reinforcements or underwater concreting. So, there and it is difficult to have with the conventional formwork. So, here in this case, we can have pre placed aggregate concrete.

So, what we are doing here that clean graded aggregates coarse aggregates are to be densely packed into the formwork. So, formwork is made and we cannot pour directly the concrete mix but we can place the graded aggregates into it and then grout is forced through pipes or tubes into the voids of the pre packed aggregates.

Grout what is to be placed in the pre placed aggregate concrete is the mixture of cement sand and sometimes pozzolana is all mixed around with superplasticizers. The coarse aggregates need to be washed and screened before it is placed into the formwork to remove all fines and deleterious materials. And the pipe is to be inserted into the packed aggregate till its bottom and the grouting starts from the bottom.

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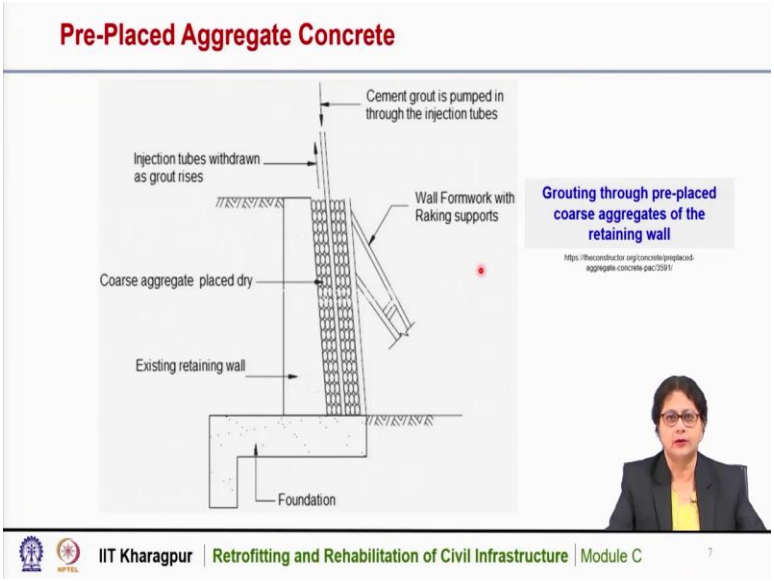

So, here is a typical sketch of a retaining wall type of structure and if the portion of this retaining wall is damaged, then we can repair it by pre placed aggregate concreting method. So, here the formwork is made and we can put the graded aggregates into it and pipe is to be inserted till its end. Now, we have to insert the grouting material with high pressure through these tubes or pipes and when it is filled up, then slowly we can take out the pipe.

So, this way the retain, retaining wall is repaired and it can regain its strength to some extent. So, this is a typical method of repair of retaining type of retaining wall type of structure, where we can go to grouting through pre-placed coarse aggregates of the wall. So, this method is used particularly in this type of structure retaining wall or underwater concreting.

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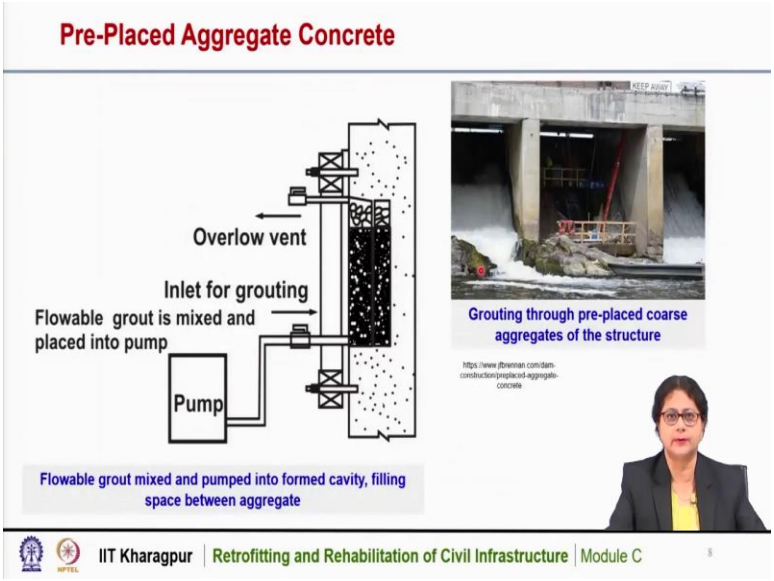

So, here is also a one schematic diagram shown this is also a wall type of structure and this portion is damaged. So, here formwork is made and the graded aggregates need to be placed, the, the grouting material, the cements and grout needs to be pushed into it inserted through force and then it is to be filled up and when the excess grouting material is coming out through this overflow vent then we can understand that the grouting is completed. So, then we can stop it.

Now, after proper curing, the structure can be used again. So, this is also a picture of grouting through pre placed aggregates of the structure. This is near water body, we can see here and the structure is repaired with preplaced aggregate concreting technique.

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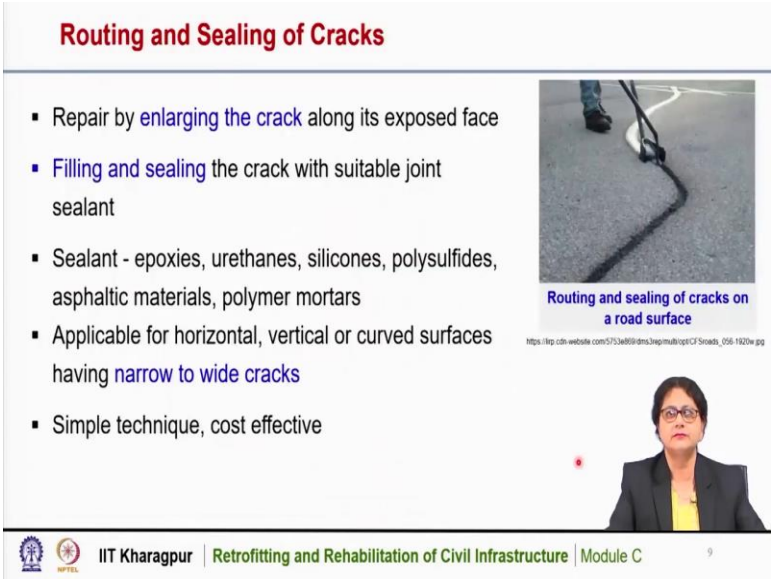

Routing and sealing of cracks are another type of crack repair method this is quite common, particularly when the crack is long and on a large structure like a slab or road surface, we can use routing and ceiling type of technique for crack repairing. The method involves enlarging the crack along its exposed face, then the crack face is filled up and sealed with some suitable sealants.

And we can see here that this is a typical picture of the sealing of cracks, the initially the crack face is to be widened to form a V shaped structure and then it is to be filled up with the sealant. The Sealants are generally epoxies or urethane, silicones, polysulfides, etc. And the method is applicable for horizontal vertical or curved surfaces having narrow to wide cracks. So, this method is quite simple and it is widely used for all types of crack repairs for on existing structures.

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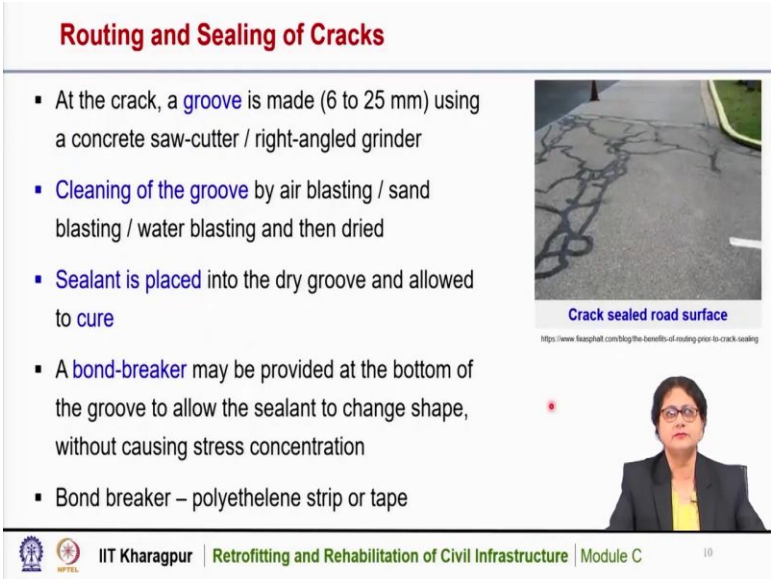

In routing and sealing, the groove is made at the crack phase using a concrete saw-cutter or right-angled grinder. So, we can use a simple saw-cutter or a grinder to have a groove at the face of the crack. And then the groove needs to be cleaned by your blasting or sandblasting or water blasting and it is to be dried up. After drying up the crack we need to place the sealant into the groove and then it is allowed to dry or cure.

A bond breaker may also be used at the bottom of the group to allow the sealant to change shape without causing stress concentration. The bond breaker is useful particularly if there is a possibility of expansion or contraction of the cracks due to thermal changes. So, in that case bond breaker may be useful, the bond breaker may be a polyethylene strip or tape and that can be used at the bottom of the groove and after that the sealant is placed.

So, here you can see a typical road surface and there are cracks on it and the cracks are repaired by sealing. First it is to be routing and with enlarging of its face at the top and then it is filled up with a proper sealant.

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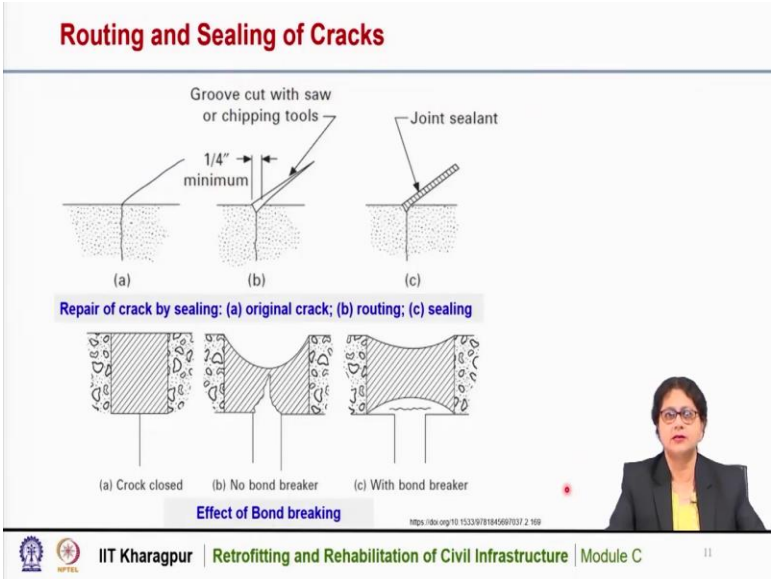

This is the routing and sealing type of repair of cracks shown schematically in this picture. So, you can see here this is the crack it is maybe a fine crack or little wide also and then we can make a groove at the face of it. So, on the surface we can make this type of groove by saw-cutting or chipping. So, that a V shaped formation is there and after that it is to be cleaned and then we can put a sealant. So, this sealant is placed and now, the crack is filled up.

Now, if we use a bond breaker, we can see here in normal condition the crack is filled up, but if a bond breaker is used, then it is helpful in accommodating the thermal expansion or contraction. If there is no bond breaker and there is contraction, then this surface may experience a tensile stress and due to which the sealant may break.

So, there may be crack in the sealant if there is no bond breaker, however, if there is a bond breaker then the sealant may expand and there may be no cracking under sealant. So, it is useful in that way. So, in case when there is thermal expansion or contraction, it is desirable to have a bond breaker at the bottom. So, routing and ceiling type of crack repairing is quite common and is used for all types of crack repair with a proper sealant.

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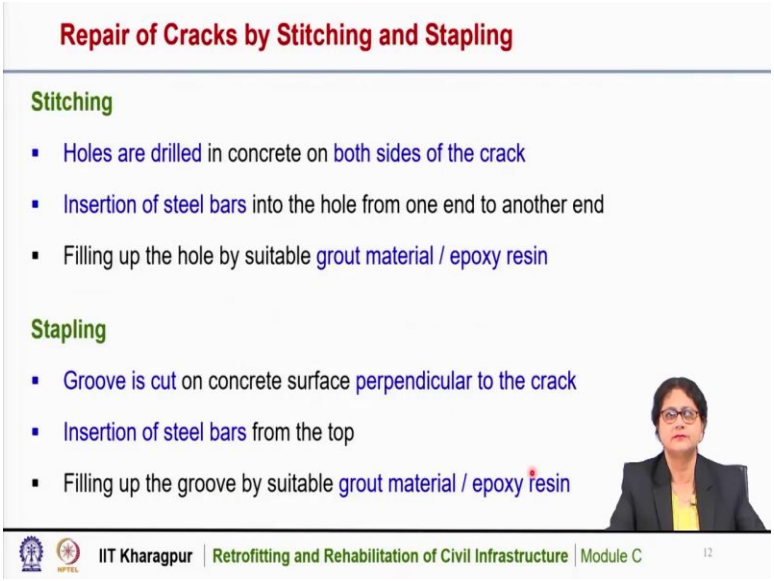

Stitching and stapling are another types of crack repairing and it is widely used particularly for structures which are damaged due to several cracks on it. In stitching holes are drilled on the concrete surface on both sides of a crack. If a crack is quite long, then we have to drill holes on both sides of the crack and that hole should go beyond the crack. Then in that hole, we have to insert steel bars from one end to another end.

After inserting the steel bar, the holes need to be filled up with suitable grouting materials or epoxy resin. So, in stitching like we are doing it includes, so here also on the surface of the concrete, we can stitch it with steel bars. So, the holes are created in staggered way and it should go beyond the crack and then through that hole we can insert steel bars, so that it can reach to the other end and after inserting the steel bar the holes need to be filled up with suitable grouting material or epoxy resin.

In case of stapling, the groove is cut on the surface perpendicular to the crack here we are not making holes through the crack, but we are cutting a groove perpendicular to the crack on the surface of the concrete. Now, in that groove, we need to insert steel bar like we do it in stapling. So, here also we are doing stapling on the concrete and on that groove, we need to insert a steel bar from the top.

After inserting the steel bar, the groove needs to be filled up with proper grouting material or epoxy resin. So, stitching and stapling are quite effective in arresting the cracks for further

progressing and they are used particularly in structures which are quite long in slabs are in roads and they are quite effective in crack repairing.

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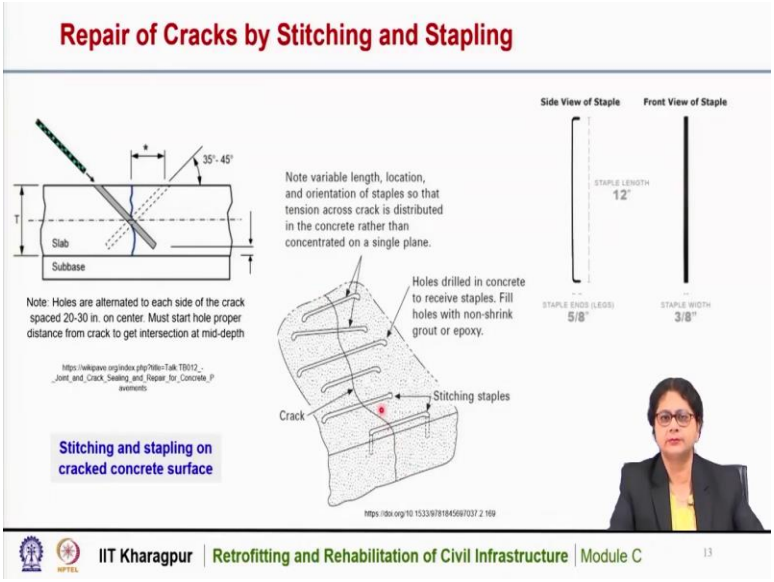

Here are the schematic diagrams of stitching and stapling, we can see here this is a concrete slab, you can see here it is a slab on great, this is the subbase, so the concrete road and this is the crack. So, a hole is made on this side and it is extending up to this beyond the crack. Then the next hole is in this side in staggered position and then it is also extending like this and through this hole we are inserting the steel bar, straight steel bars need to be inserted and that goes beyond the crack.

So, alternatively left side and right side of the crack the steel bars are inserted and then it is filled up with grouting material or epoxy resin and with that the crack is arrested. So, this is stitching of the cracks. This is stapling. So, here the grooves are cut on the surface up to a certain depth a small depth and then stapling bar is to be placed on it. So, this is a typical staple steel bar which is to be used for this purpose we can see here this is a typical staple bar with like a C shaped and this is to be inserted into the groove.

Now after inserting the steel bar, a proper grouting material is to be filled up on this groove and after curing, it is ready for its operation. So, in stapling also the crack is arrested and it is quite effective on repair of cracks on the roads or slabs, etc. Stitching and stapling on concrete surfaces are quite useful and effective in crack repairing and they are widely used also.

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These are some of the pictures of stitching and stapling of concrete roads, here you can see this is the crack and this is the groove which is made for stapling purpose. Here is, this is the crack along the length of the road and these are the holes for stitching. So, after stitching the holes are filled up with epoxy resin and we can see here, alternating holes have been created on this both sides of the crack and steel bars are inserted and it is then filled up with grout or epoxy.

This is a picture of stapling; this is a long crack on the road surface and these are the grooves which are made and on that groove steel bars are inserted, the staples and then it is filled up with cement grout or epoxy material. So, this is stabling and the road surface after stitching or stabling looks like this. So, this also is a surface this is undergoing the stitching or stapling type of crack repairing and this way we can repair the cracks on the road surface. So, these are quite effective method of repair of cracks.

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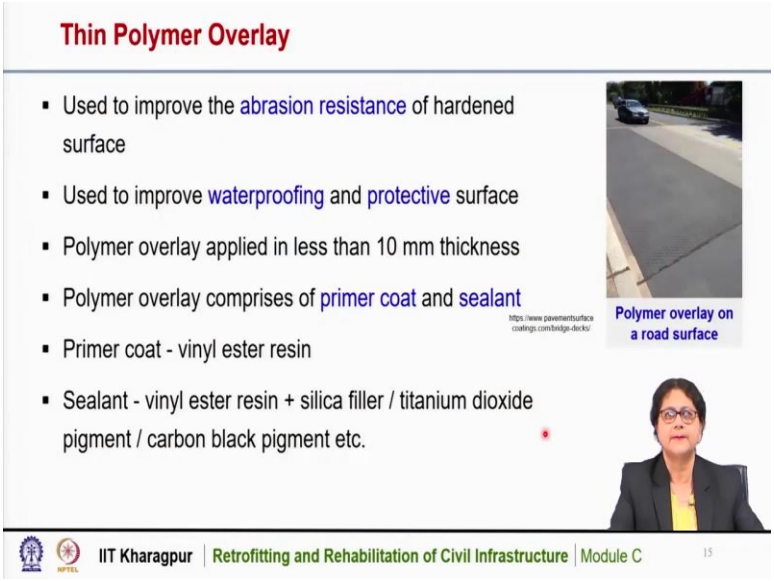

Sometimes we can also use overlay to repair the cracks. Thin polymer overlay is used to improve the abrasion resistance of hardened surface. The overlay is also used to improve the waterproofing and also to protect the existing surface, the polymer overlays applied in less than 10-millimeter thickness and it comprises of a primer coat and a sealant.

The primer coat may be vinyl ester resin and the sealant may be different types of resin like vinyl ester resin and with that silica filler or titanium dioxide pigment, carbon black pigment, etc. may also be used. So, a thin polymer overlay may also be used as a protective layer to cover the irregularities and to improve the abrasion resistance of the existing surface.

So, this is a typical picture of polymer overlay on a road surface. So, the entire road surface is protected with this type of polymer overlay.

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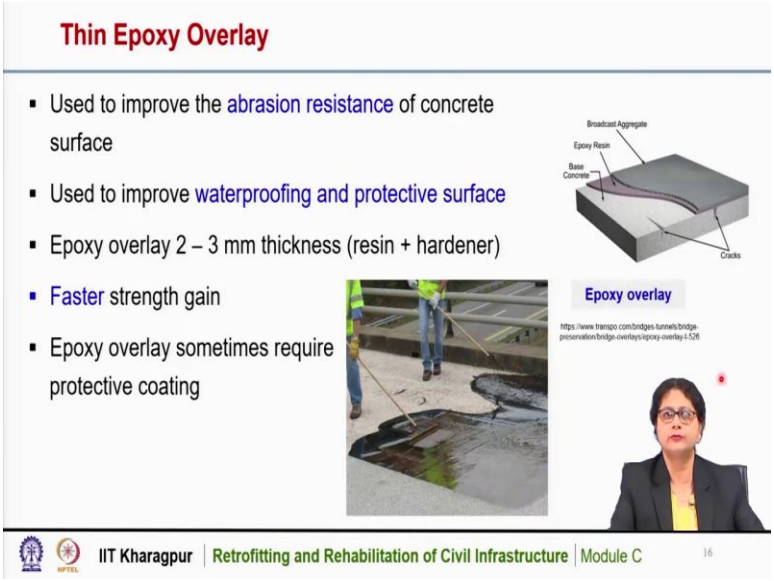

Overlay can also be by thin epoxy layers. So, this type of overlay is used to improve the abrasion resistance of the existing concrete surface and also to improve the waterproofing characteristics and to protect the existing surface. So, this is a typical picture of epoxy layer which is placed on the existing surface as an overlay, the thickness is much less in case of epoxy overlay as compared to the polymer overlay, it is in the range of 2 to 3 millimeter.

And of course, it is resin plus hardener, in all cases it is the resin and the hardener is to be mixed in different proportions and then it is to be applied on the surface. The epoxy overlay is quite effective and it is easy to apply, the strength gain is faster but sometimes it requires a protective coating. So, here we can see also that the existing surface, it is a typical schematically shown and epoxy overlay is placed and over that a protective layer can also be placed.

So, polymer overlay or thin overlay are also quite effective particularly for road surfaces to improve the abrasion resistance and also to improve the waterproofing characteristics and also as a protective membrane or layer.

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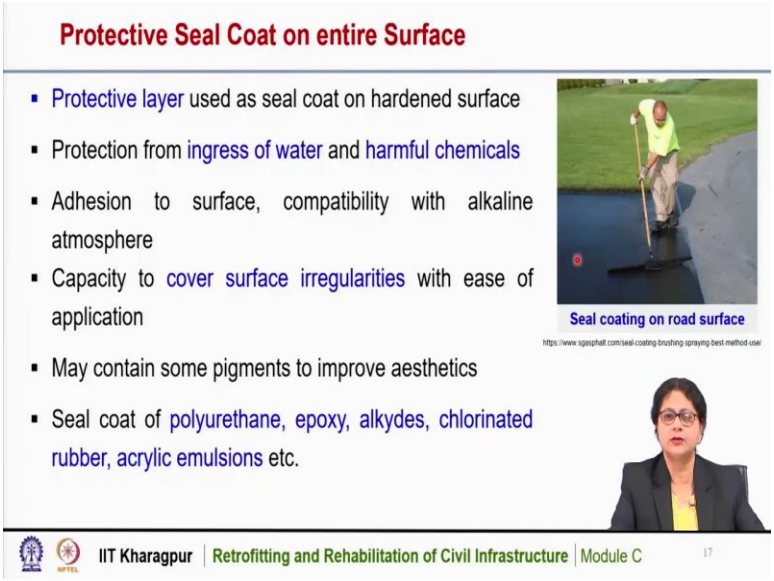

Protective seal coat on entire surface. So, here this also can be used on road surfaces which are maybe irregular and have surface irregularities. So, this type of protective seal coat is used on existing surface, particularly to seal the surface from the ingress of water and other harmful chemicals.

Addition to surface compatibility with alkaline atmosphere has to be considered while selecting a proper seal coat. And we provide the seal coat particularly to cover the surface irregularities or to improve the writing quality and it should be applied on the entire surface to protect the surface from ingress of water and any other harmful chemicals.

The seal coat may contain some pigments also to improve the aesthetics and the seal coat is are generally epoxy type of material or polyurethane, alkydes, chlorinated rubber, etc. So, this is a typical picture of the application of seal coat on an existing road surface to improve the surface quality and also to improve the waterproofing nature of the surface.

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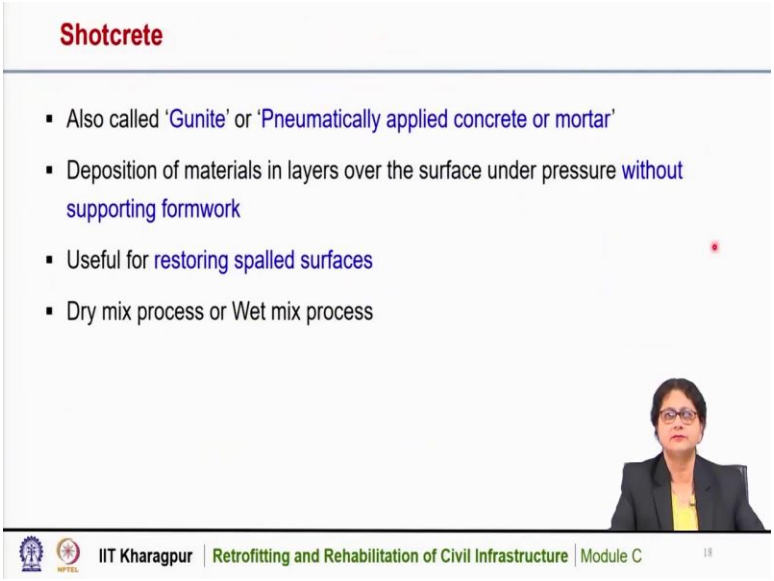

Shotcreate or Guniting is also a common repair method. This is also called gunite or pneumatically applied concrete or mortar. Shotcreting is the method of deposition of materials in layer over the surface under pressure without supporting formwork.

So, this is quite advantageous because in this method, we are applying the repair material without any supporting formwork and it is useful for restoring the spalled surfaces, when the surface is damaged and it could be vertical surface or horizontal surface or even a curved surface, we can use shotcreting organizing to restore its surface.

And this is quite effective method because it does not require any formwork for this and with this, we can repair the damaged surface. The shotcreting can be of two types; dry mix process and wet mix process. In two ways we can apply the shotcreting so that we will see.

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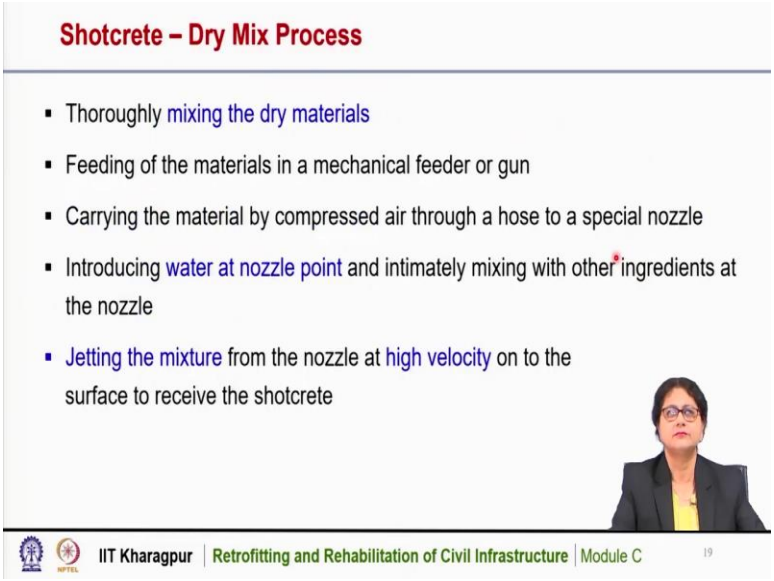

In dry mix process of shotcreting the materials are mixed in dry, that means all the ingredients they are mixed in the feeder in dry condition and then it is feeded into the mechanical feeder or gun. Now the dry mix is carried into the equipment and it is then carried by compressed air through a hose to a special nozzle.

And at the point of the nozzle water is introduced and at that point it is thoroughly mixed with water with the dry ingredients and after mixing the water with the dry ingredients, then the mixture is applied on the surface with high pressure then jetting the mixture from the nozzle at a high velocity on to the surface to receive the shotcrete.

So, here in the dry mix process all the ingredients it is generally the concrete or cement sand material that is first mixed in dry condition and then it is feeded into the mechanical feeder and which is carried by compressed air up to the special nozzle. And the point of the special nozzle water is added and then the water and the dry ingredients are mixed thoroughly and after that it is inserted or it is applied on the surface to be repaired.

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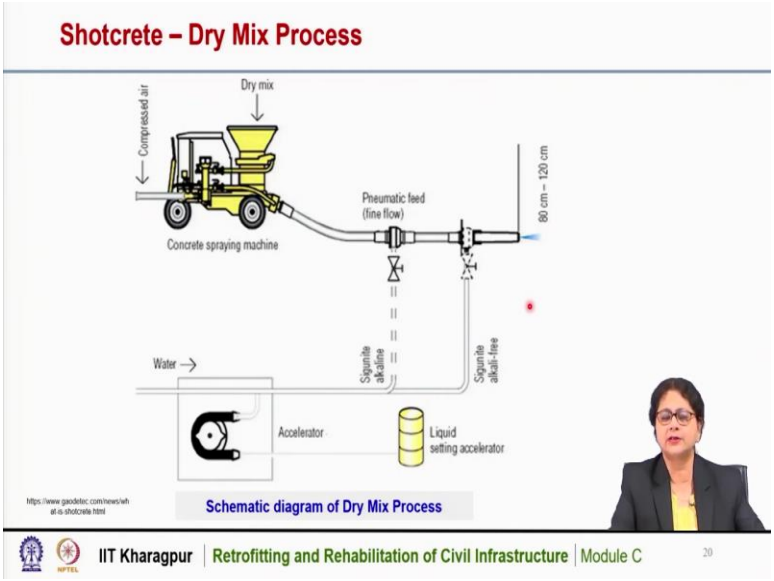

So, here is the schematic diagram of the dry mix process, we can see here this is the spraying machine where the all the ingredients are mixed in dry condition and compressed air is applied and through it, pneumatically you can see here it is coming to the nozzle. Now, in the nozzle at this point water is added. It will also contain some accelerators and that is mixed.

So, all the mixing materials that are here and all the ingredients are mixed thoroughly with water and admixtures, if there is any and then it is pumped and applied onto the surface with high velocity. So, this is the process of dry mixing shotcreting and with that initially the all the materials are mixed in dry condition and water is added at a later stage and then after adding water or with some other accelerators or admixtures, it is applied on the damaged surface.

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So, here is one picture, that dry mix shotcrete applied on a curved surface, you can see here no formwork is required and the mixing material is applied with high pressure onto the surface and the surface is prepared. So, this is dry mix shotcreting.

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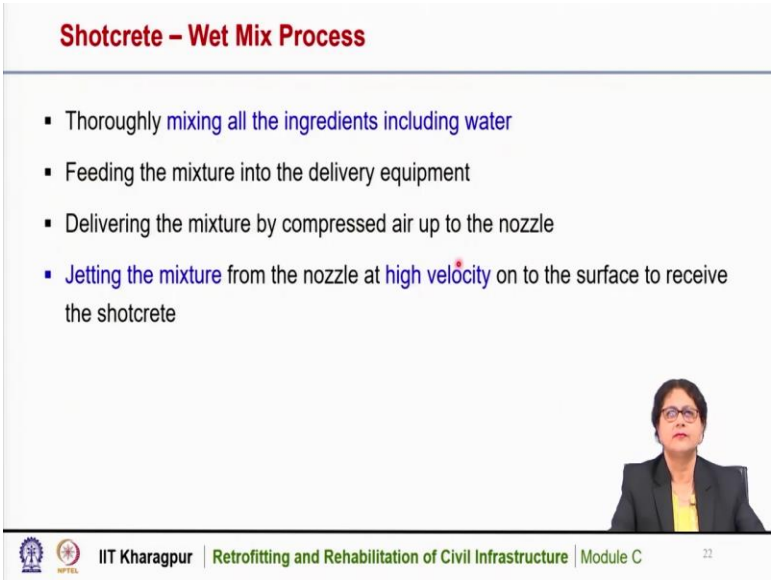

In wet mix process, all the ingredients including the water are mixed thoroughly at the beginning only. So, thoroughly mixing of all the ingredients including water, and then feeding the mixture into the delivery equipment. Now, delivering the mixture by compressed air up to the nozzle.

So, here the difference is we are mixing all the ingredients including water and also some admixtures if it is there at the very beginning and then it is delivered by compressed air up to the nozzle and then getting the mixture from the nozzle at high velocity onto the surface to be repaired. So, here the mixing is done along with water and then it is taken and then after that the jetting of the mixture at high velocity onto the surface to be repaired.

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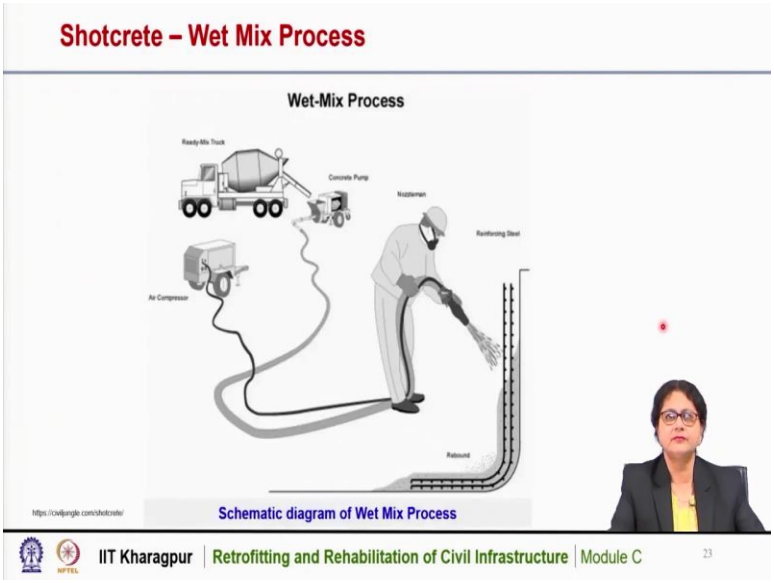

So, here is the schematic diagram of wet mix process, we can see here this is the mixer, where all the ingredients including the water is mixed thoroughly and then by the air compressor it is pumped and then it is applied on the surface to be repaired. So, here the shotcreting material is applied with high pressure onto the surface. So, this is the schematic diagram of wet mix process.

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And this is a picture of wet mix shotcreting applied on the surface. You can see here this is a surface a typical concrete surface and the surface is damaged. So, to restore the surface, we can use the wet mix process.

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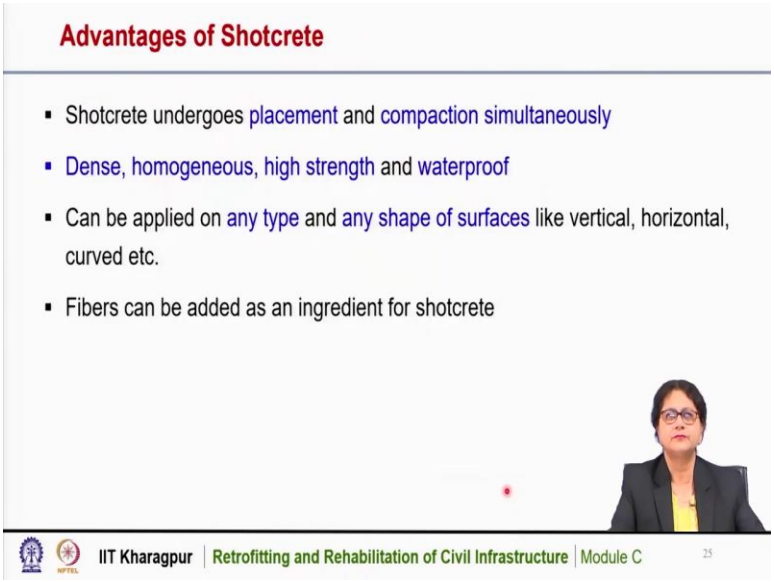

The advantages of shotcrete are several. That shotcrete undergoes placement and compaction simultaneously. We do not require any formwork or any other vibrator for the concrete to be applied. So, it undergoes placement and compaction simultaneously. We get a dense homogeneous, high strength and waterproof material through shotcreting. So, that is why it is

quite effective and popular also, for repair of structures. Can be applied on any type of structure of any shape or surface, whether it is horizontal, vertical or curved, we can apply the shotcreting.

And fibers can also be added as an ingredient for shotcreting. So, microfibers if it is required to for arresting the shrinkage type of cracks that also can be applied and fibers can also be added into the ingredient for shotcreting. So, shotcreting is quite popular both wet mix and dry mix and we can use either wet mix or dry mix type of shotcreting depending on the type of structure and its location. If the ingredients are to be taken at a large distance, then the dry mix process is more beneficial because of the workability issue.

So, in that case, we can take the dry mix and near to the site and then water is added and then it is applied, but if the site is nearby, then wet mix process is desirable, because we can mix all the ingredients including the water thoroughly and then we can directly apply it on the damaged surface. So, depending on the type of structure and its location, we can use dry mix process or wet mix process of shotcreting.

Shotcreting is quite popular and effective for repair of existing structures particularly large structures and it does not require much formwork or compaction and so, that is why it is quite advantageous and we get a dense, homogeneous and high strength material and which is waterproof also with shotcreting.

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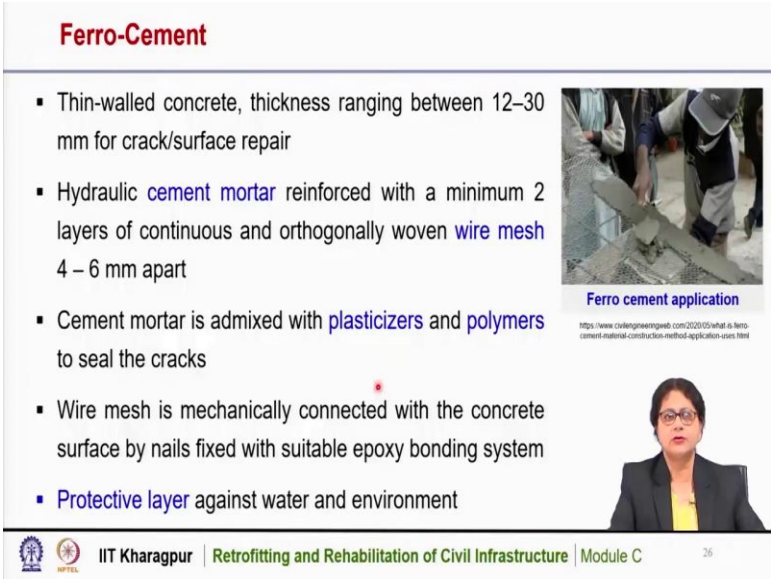

Ferro-Cement is another type of concrete, which is used for repair purpose as well. Ferro-Cement is thin-walled concrete the thickness ranging between 12 to 30 millimeter for crack or surface repair. Here the hydraulic cement mortar reinforced with a minimum two layers of continuous and orthogonally woven wire mesh 4 to 6 millimeter apart is used. We can see here, it is a typical Ferro-Cement application with wire mesh and that is why this is called Ferro-Cement.

Because wire mesh or fine steel wires are used. The cement mortar is mixed with plasticizers and polymers to seal the cracks. The wire mesh is mechanically connected with the concrete surface by nails fixed with suitable epoxy bonding system and it is a protective layer against water and environment. So, Ferro-Cement is also used widely and it is also quite effective for repair of damaged surface.

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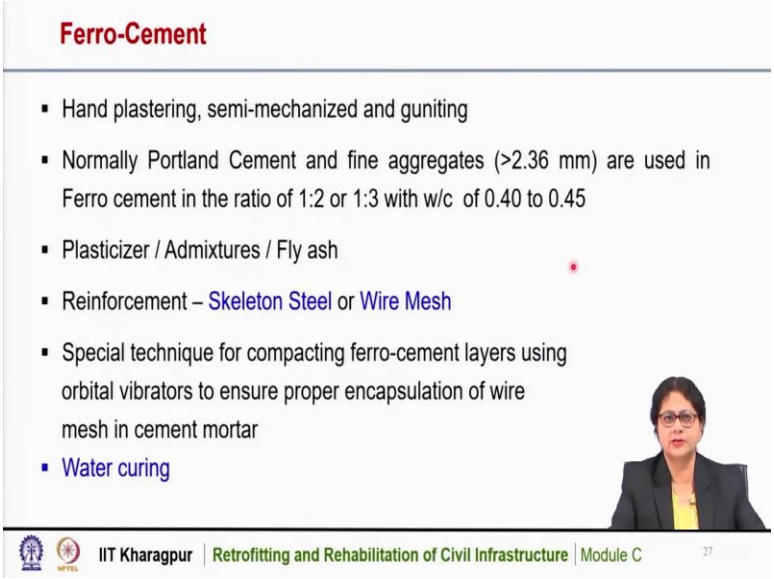

Ferro-Cement is semi mechanized. It can be applied manually by hand plastering or by a semi mechanized system or by guniting also. It is the normally Portland Cement and fine aggregates are used in Ferro-Cement in the ratio of 1:2 or 1:3 with water cement ratio ranging from 0.4 to 0.45. Plasticizers are also used, admixtures are also used, flyash or other supplementary materials can also be used in Ferro-Cement.

And the reinforcement which is used is skeleton steel or wire mesh of very fine steel wires are used. There is a special technique for compacting the Ferro-Cement layers using orbital vibrators to ensure proper encapsulation of wire mesh in cement mortar, because we cannot use the

conventional vibrators for this. So, a special technique using orbital vibrators are used to ensure proper compaction of the Ferro-Cement with wire mesh and it requires water curing like the conventional concrete.

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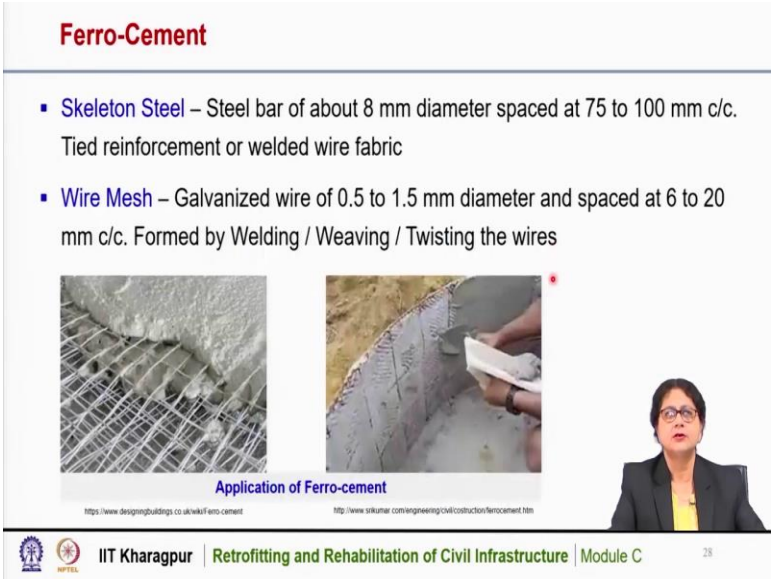

So, in Ferro-Cement as we have mentioned that either we can use wire mesh or skeleton steel. In skeleton steel, we can use a small diameter steel bars of about 8-millimeter diameter and it is spaced approximately 75 to 100 millimeters center to center and tied reinforcement or welded wire fabric. So here we can see a typical skeleton steel is used for the Ferro-Cement and then the cement mortar is applied on it.

And in case of wire mesh it is the galvanized wire or very fine diameter of the range of 0.5 to 1.5 millimeter in diameter, which are spaced at 6 to 20 millimeters center to center. And it is formed by welding or weaving or twisting the wire. So, here in this picture you can see that this is the wire mesh and over it the Ferro-Cement is applied. So, this is the application of Ferro-Cement with skeleton steel and also with wire mesh.

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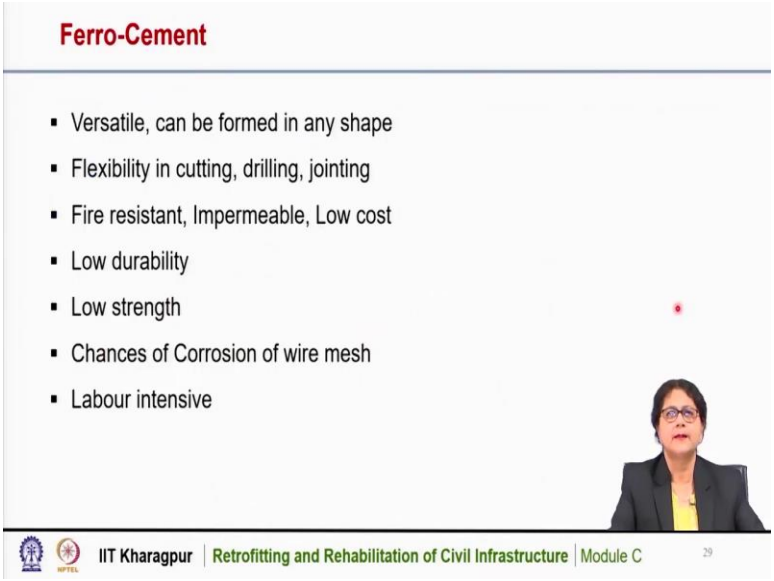

The Ferro-Cement is quite versatile and can be formed in any shape because we are using the wire mesh or the skeleton steel a very small diameter. So, it can be formed into any shape. So, it can be applied for curved surfaces as well or any other horizontal or vertical surfaces as well. So, that way it is quite versatile, it is flexible in cutting, drilling and jointing. Because, the steel is not very of large diameter or it is a wire mesh. So, cutting, drilling or jointing is quite easy. And by manually also we can do it.

So, in that way it is quite low cost and it is fire resistant, impermeable, it is semi mechanized, so, it is low cost. However, Ferro-Cement does not give a high strength. So, it gives us a low strength, the durability is also low because of the low strength and the mechanism and we are using the wire mesh or the skeleton steel. So, there is a chance of corrosion also of the wire mesh. So, in that way it is not lasting long and it is labor intensive. So, these are some of the advantages and limitations of Ferro-Cement.

Ferro-Cement is quite easy to apply, it is only by hand or by manually we can do it or semi mechanized and it is it requires only wire mesh which can be formed into any shape. So, that way it is quite flexible and we can cut it really to a joint it quite easily. So, that way it is Ferro-Cement is versatile and it is applicable for repair of structures, existing surfaces. It is fire resistant, impermeable and also low cost. So, it does not require any high-end equipment for its application or so.

So, it is quite easy to apply that way, but it does not give us high strength, because of its low strength, it is also low durable, and the chances of corrosion are there because we are using wire mesh and also it requires labor. So it is labor intensive technique. However, Ferro-Cement is used widely for a low cost application in several existing structures.

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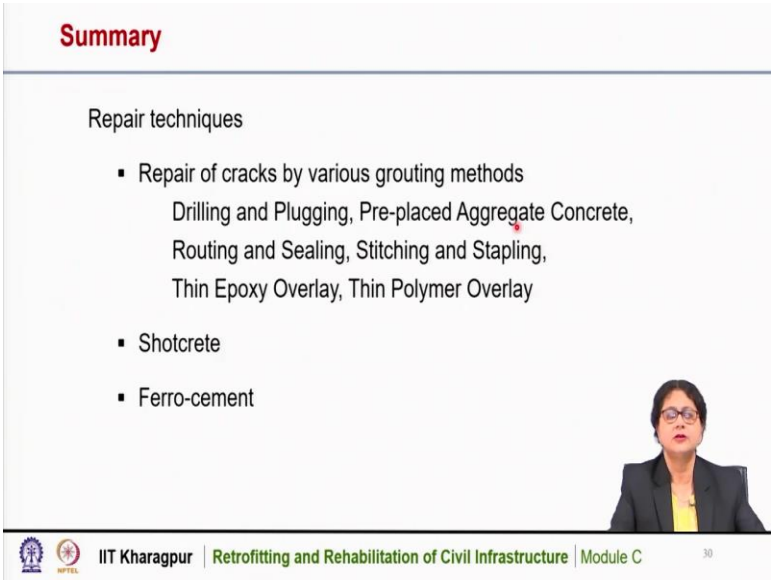

So, to summarize, we have discussed several repair techniques of cracks and patches on existing concrete structures. We have discussed earlier other methods; today we have discussed several grouting methods like drilling and plugging type of method, pre-placed aggregate concreting, routing and sealing of crack repair.

We have also discussed stitching and stapling, which are used widely for the crack repair particularly on concrete roads, thin epoxy overlay or thin polymer overlay also we have discussed to cover up or to improve the surface irregularities and waterproofing. We have discussed shotcreting and Ferro-Cement. These are also quite popular and effective methods of crack and patch repairing and that is why these methods are used widely for improving the surface and to repair the cracks and patches of existing structures. Thank you.