Maintenance and Repair of Concrete Structures
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Lecture – 25
Waterproofing of Concrete Structures

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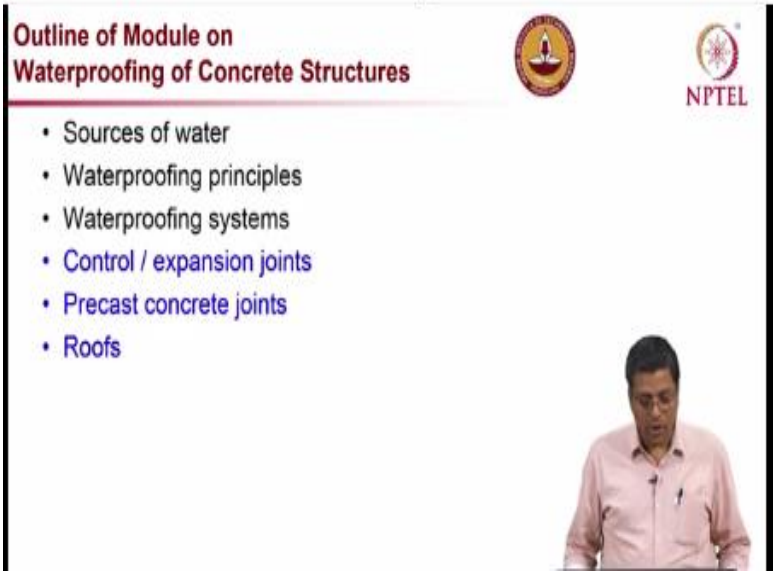

Hi, this is the second lecture on waterproofing of concrete structures. In this lecture we will be looking at control and expansion joints. How do we water proof them and then also for precast joints and also waterproofing of roofs.

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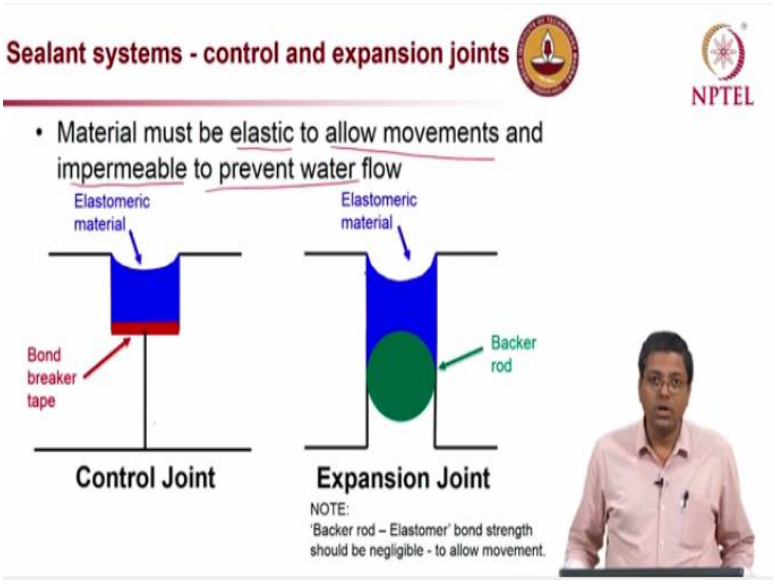

So, first let's look at the sealant systems which are available for control and expansion joints. This is just schematic showing how the sealant systems should be placed in a control joint. On

the left side what you see is a control joint, you can see that black line indicates the control joint and there is no movement allowed.

The sealant material should be detached or there should be no bond between the concrete and sealant, not everywhere but this portion of the concrete (bottom of the sealant). And at the sides of the sealant there should be a good bond. In the case of expansion joint the; as you; as we discussed about the control joint before, the bond breaker instead of providing a tape what we usually provide is a backer rod.

The idea is it facilitates the positioning or placing or pouring of the elastomeric material, whether it is in a liquid form or in a semi solid form. Now, what are the material quality or the essential quality that this elastomeric material should have; it must be elastic why; to allow movements and at the same time, it should be impermeable to prevent the water flow or flow of water through that.

So, the blue region which you see on the screen should be elastic enough, so that they can move or elongate at the same time, they should be impermeable, so that water doesn't get into the joint.

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Let's first look at how the system works or how we do implement this for control joints. So, the tapes; the main idea of using the tape is to prevent the bonding of the sealant to the concrete surface which is the inside surface of the concrete not the side but the bottom level of the concrete joint. And then contain the sealant fluid within the space which you have.

At the same time, it does not allow that elastomeric material to be in contact with this concrete surface (bottom), so that it does not get really bonded. Now, the different type; they come in as caulk injection and at the same time, as a fluid. Bottom left is the caulk injection and on the bottom right side you can see that a person is actually pouring that fluid material into the already prepared joint.

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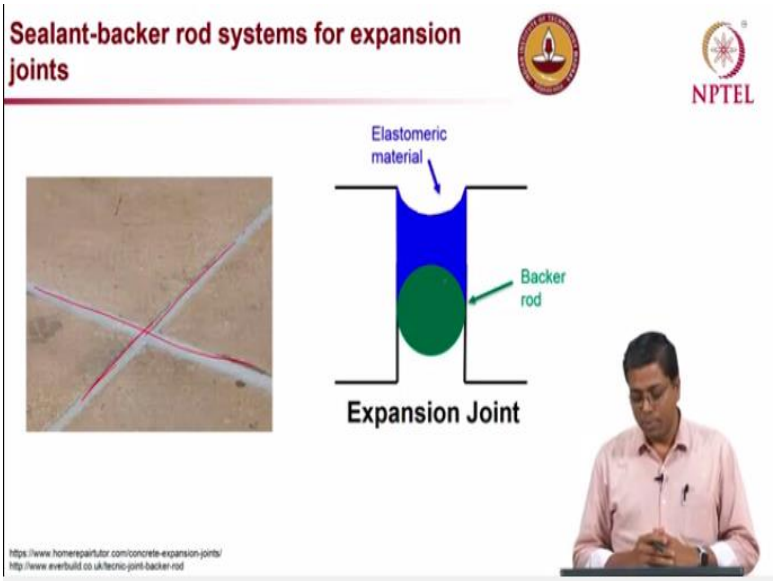

For the expansion joint there is a wider gap and so typically, the backer rod is what is used to create the space for placing the elastomeric material. What you see on the left side of screen is already completed work where you can see this elastomeric material.

And on the right side you see the green circular region that indicates the backer rod. It essentially provides a back support for the elastomeric material, whether it is a horizontal joint or a vertical joint, these backer rods help very much.

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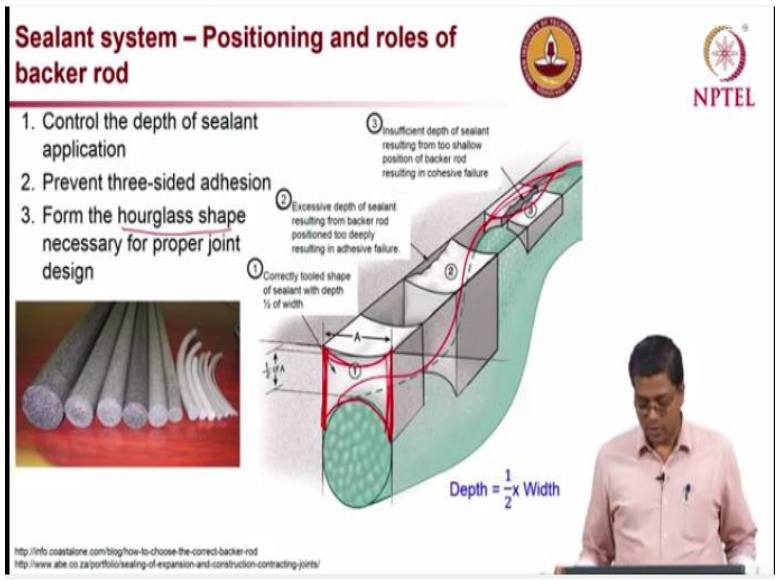

Let's look at how to position these backer rods and what are the different roles of these backer rods. You can see here control the depth of sealant application, so in other words, let me go to the previous one, this depth is what we are talking about, this depth how much, how deep or what should be the thickness of the sealant.

Now, for that different types of backer rods are also available as you see on the picture on the bottom left, different size or depending on the size of the expansion joint or the gap. The dimensions of the gap we can decide what type of or which size of should be selected. Baker rod prevents the 3-sided adhesion.

The bottom side of the sealant does not bond very well with the backer rod, so there is no adhesion between the elastomeric material and the backer rod. So, in other words the red semi-circular region which I just marked semi-circle that is a region without any bond, so in essence the bonded region is only this and this, the 2 vertical phases which I just marked on the screen, that is the bonded region.

So, there is no 3 sides only 2 sides are bonded now, because of the circular shape of the rod it also provides an hourglass shape at the end. So, you can see here also as it was shown in the previous slide, the shape is something like this, so at the center portion you have less thickness as compared to the 2 edges.

Now, what will happen if thickness is different and all that I will cover later more detail but let me briefly explain that here also, typically, depending on the system which you use usually,

manufacturers recommend what should be the thickness of this elastomeric material etc., but what we see usually is that because of use of improper tools or something to insert these backer rods into the expansion joint, it end up having varying depths.

So, let's look at as you see on the picture, the backer rod; the green backer rod you can see that the thickness is varying, there is a varying thickness. so that is not recommended, you should have a uniform thickness.

And case 2 is where you have more thickness than what is recommended and case 3 is where you have very little thickness than what is recommended, it is because the way in which you push these backer rods into the expansion joint. So, what is the problem here; if you see the case 1, everything is perfect, proper joint everything is fine, no problem. In case 2 because you have more thickness, there will be a possibility of this elastomeric material to get detached from the edges or from the concrete surface which is not good.

Now, if the thickness is too little, then what will happen is the failure mode will be something like this, that means it is failing because of the poor cohesion in the case 2, it is mainly the adhesive failure, in the case 3 it is mainly the cohesive failure, I will discuss this more detail later.

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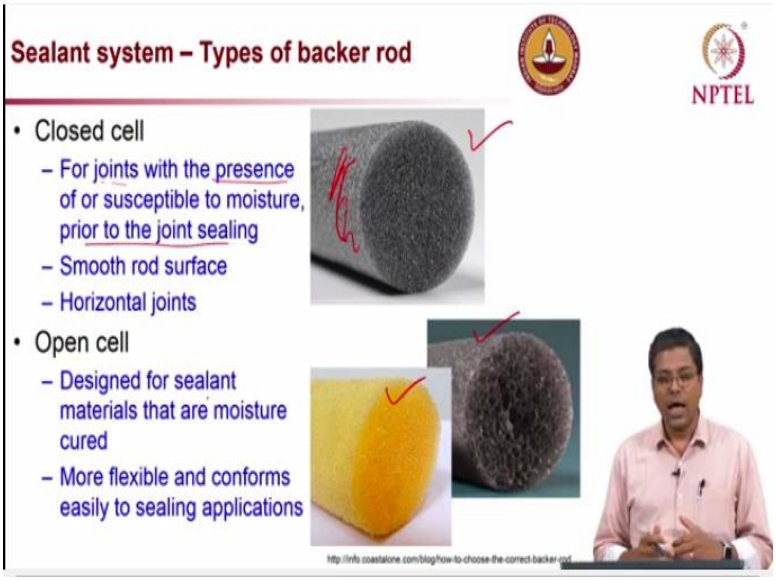

Now, before that let's look at what are the different type of backer rods available, you can see that there are 2 major types; one is closed cell and the other one is open cell. The picture on the top is a closed cell, the picture at the bottom is an open cell, both these are open cell structure.

So, where these can be used? the closed cell ones can be used when if there is a joint with the presence of moisture or if it is susceptible to moisture prior to the sealing process.

In such cases, we will use a backer rod with closed cell and also this backer rod typically have a smooth surface, so this curved surface will be relatively smooth, and that also helps in preventing it from getting well bonded with the elastomeric material or the sealant and it is also widely used for horizontal joints. Now, open cell structure; this is designed for materials that are moisture cured.

And at the same time, they are relatively much more flexible and conforms easy to sealing applications. It makes it easy to install but that should not be used when there is a possibility of moisture attack because if that is the case then moisture will penetrate through this open cell structure and then that might come in contact with the sealant which is not preferred but if the sealant itself is cured with the help of moisture, then this is okay.

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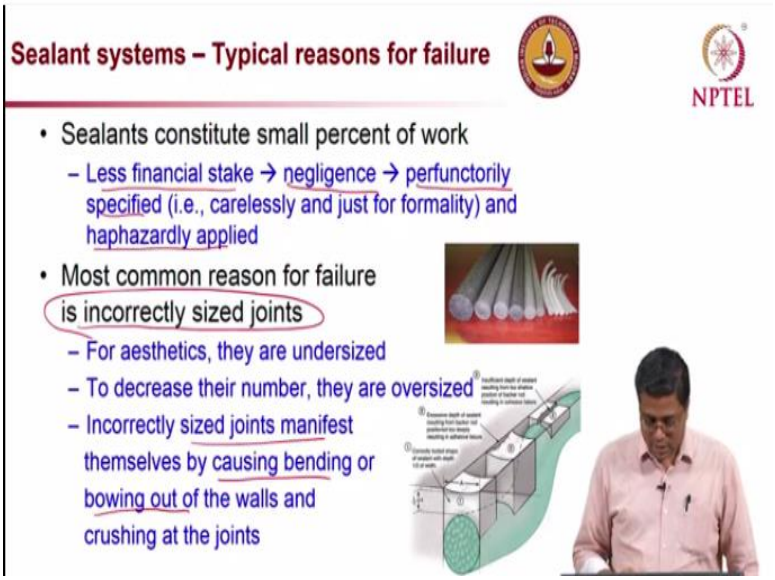

Now, what are the typical reasons for failure? I briefly discuss this earlier but in the 2 slides ago but let me go a little bit more detail into that what is the larger picture of this. First thing is people do not have a big stake on these backer rods, big financial stake because when you look at a project, the cost of these rods or the volume of the material used is relatively much, much smaller, you are only talking about the joints.

But you should remember that these backer rods and the joint sealing systems, if they do not perform well it will really affect the longevity of the structure and then also the comfort inside

the building because water will penetrate through and which is not good and this lack of water tightness of the joints is one of the reasons why precast concrete structures or that technique is not really picking up in India.

It has developed a negative perception because of this but that is where we have to work on by understanding how these systems should work, how these systems work and what are the ways by which we can ensure quality installation. Quality materials and quality installation which will be covered in few slides down the line. So, anyway it constitutes a small percent of work, so there is less financial stake or interest.

And hence there is a negligence to the quality and then the way it is installed all that, so perfunctorily specified in other words, it is not given enough care just it is done for the sake of formality. For example, if I have to have a backer rod there, so I am putting it there, so we normally people do not really look at what is the depth of the backer rod; depth at which the backer rod is placed inside a joint etc.

So haphazardly applied, so these are the concerns; the larger concerns which we have to really work on and most often we see that they are incorrectly sized joints. So for aesthetics they are undersized because people do not want too wide joints.

Now, incorrectly sized joints manifest themselves by causing bending and bowing out of the wall. So as you see here the bottom right picture kind of shows or indicates what can happen, when you do it in an incorrect way. There will be an effort from the workers to somehow get this backer rod into the joint and then it end up in having a poor installation or you will have uneven thickness etc., or non-uniform thickness etc.

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Now, this is a way in which it is usually done. I am trying to use this picture to show that this is not how it should be done. So you can see here this picture itself over here, you can see the thickness is slightly keep varying. So, this is not something which we should be practicing.

We should use proper tools rather than depending on the workers skill level to ensure that there is a uniform thickness. So in this case which you see on the photograph, uniform depth of the backer rod at every point along its length depends on the skill of that individual or the worker.

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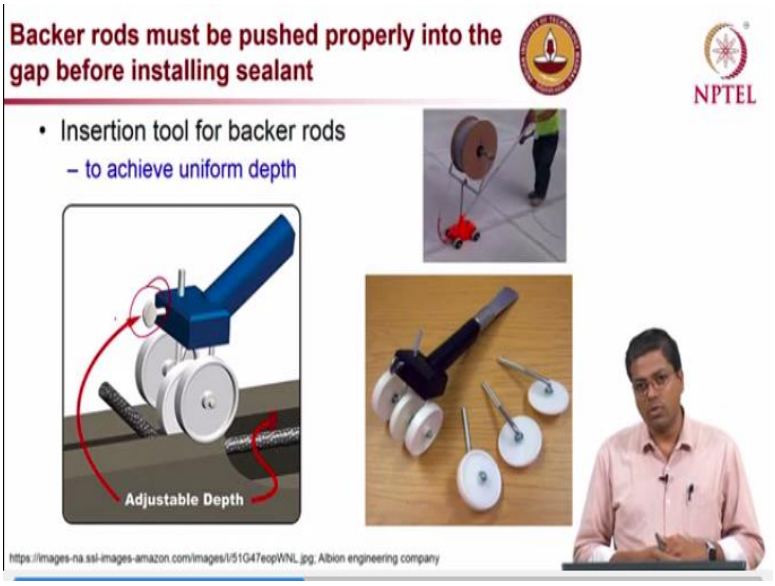

So, there are tools available like this, which can ensure that the depth of the backer rod is uniform throughout its length. So, these kinds of tools must be available and if it is not; I mean must be used then only we will be able to ensure quality performance of the sealant, which you

are going to put above the backer rod. So, you can see here and there are tools available where you can actually even adjust the height whatever you want.

So, it is not that for each backer rod size, you have to have a different tool no, it is all adjustable, custom made tools for various applications. Tools definitely play a role on the quality of the end product, it is very, very important. It is like, if you take a nail and you want to hammer it into a wall instead of using a proper hammer, if you use a rock piece or something, it is going to create more trouble.

I am just giving a general example, it is going to be more difficult and at the end also, there is a possibility of the nail getting bend etc., but if you get a hammer, proper hammer with proper head you will be able to drive the nail right into the wall straight without bending, it is possible. So, every time in construction we should try to think what is the influence of the tools on the quality of the end work.

And hence I would suggest that we should enforce the decision makers or whoever is the site in charge etc., to provide proper tools to the workers, so that will make sure that work is also; the quality of the work is also enhanced, at the same time the people will also feel happy. So let's mechanize wherever possible.

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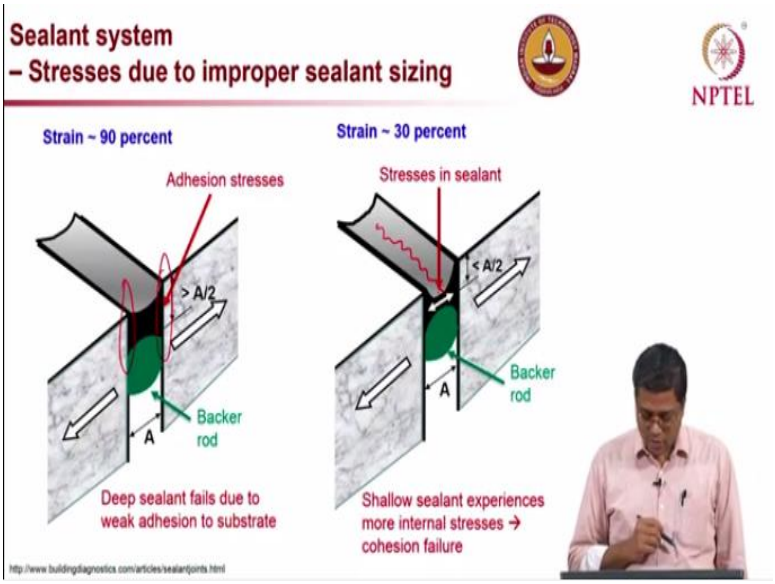

Now, let's look at what are the different stresses that these sealants go through depending on the positioning of the backer rod etc. So, the one on the left side what you see here is this deep

sealant fails due to the weak adhesion to substrate i.e. weak adhesion on the vertical phases which you see on the picture.

So, the green one is the backer rod and so as you see in such cases when the thickness of the sealant is relatively more than half of the diameter of the backer rod, then the chances are high that it will fail because of the adhesion failure between the concrete and the sealant. The one on the right side is mainly looking at when the thickness is less or in other words, the backer rod is not deep enough.

In such case, what will happen is the thickness of the sealant will be relatively much small which will end up in creating more and more stress at the center portion of the sealant and then you will have a cohesive failure. the sealant will kind of crack something like this, that is how that system is going to fail in the second case, cohesion failure.

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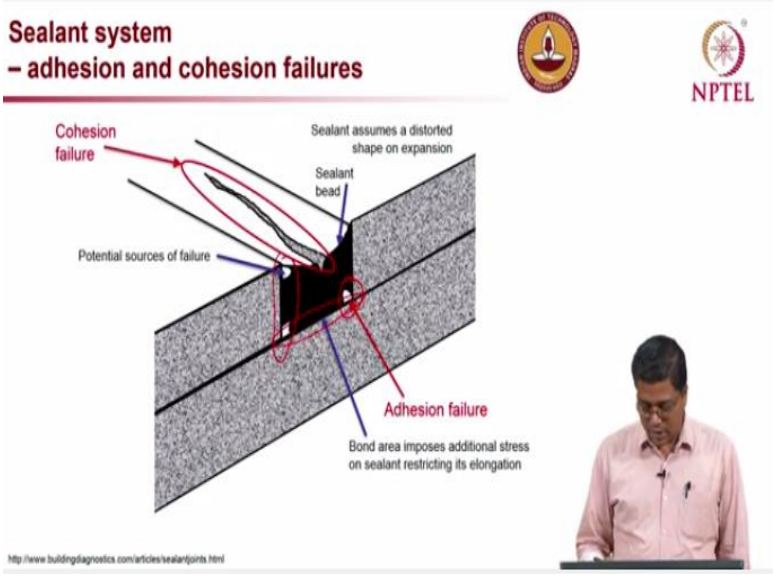

Now, this is a clearer picture about this thing, just another demonstration of the same mechanism but here you can see this is mainly shown for a control joint, there is no de-bonding here but anyway. So let's see here also you can see that this is where the bond failure start on that too, on the corners that is where it starts, if it is a cohesion failure then a crack will develop right at the centre of the sealant.

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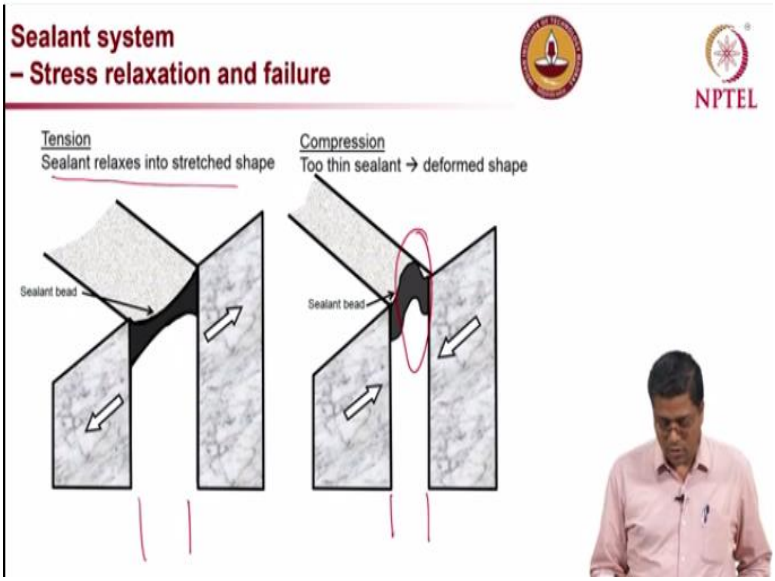

Now, if you look at a time dependent phenomenon like a long term performance say, again you can see that the sealant relaxes into stretched shape, if it is pulled too much. Let's say, there is the expansion joint is expanding or in its expanded form in such case, you can see here, here the gap is more than here. So, in the first case it is in an expanded state or the sealant is experiencing a tension.

And in such case, if it is tension prevails for long period of time, the material will undergo relaxation and eventually, the once it relaxed in the stress, I mean all the behaviour will also be different, so in other words it won't perform the way as it was expected. Now, if it is experiencing compression for long term, then let's say you have a too thin sealant, then the there might be some kind of buckling which might happen as you see here (2nd picture).

So, it's not popping out but it will buckle, so if it is under compression for long time and that is also it will lead to eventually a permanent deformation also, so that is also a failure case.

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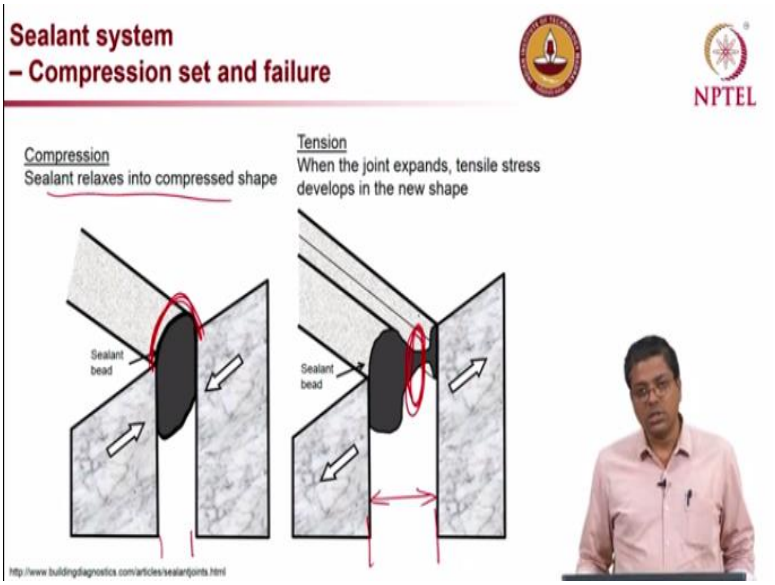

Now, let's look at compression set and failure. On the left side picture, we are talking about a compression and the right-side picture is basically an elongated case. But when if it is at compression for a long time, again the sealant relaxes into compressed shape, so whatever this shape you can see this bulging out and then that shape it will kind of relax and that what does that mean is a permanent deformation might occur.

And after this if it is going back into an expansion, if the joint experiences further expansion then because of this permanent setting or the permanent deformation as shown on the left side. When it starts expanding what will happen is the stress will be generated mainly in this region. So there will be no uniform elongation.

The elongation will concentrate more on the right side or locally there will be a concentration of that elongation or the stress will concentrate over here in long period of time. So, basically the idea here is the elastomeric material we should not allow that material to compress too much or elongate too much beyond its elastic limit that will result in some kind of permanent deformation which will then lead to concentrated stress at different points on the system.

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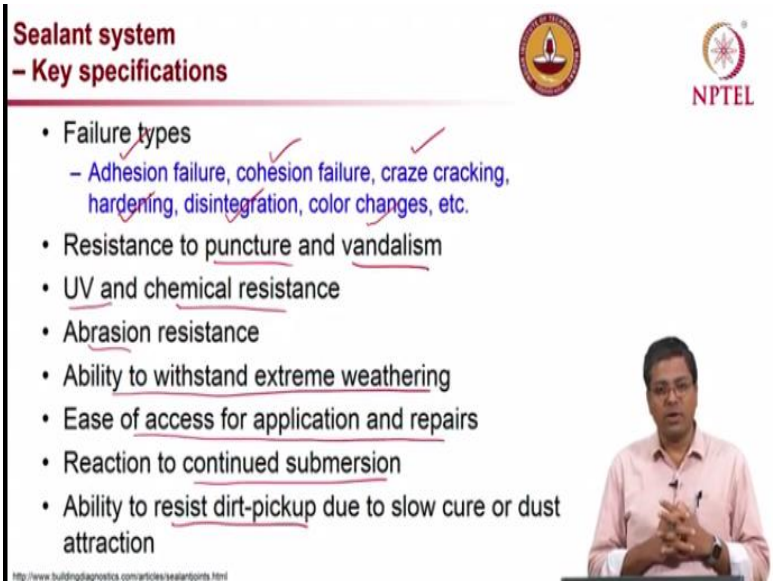

Now, what are the key specifications which we can give when we use the sealant? So first we need to know what are the failure types. We already talked about adhesion failure, cohesion failure, craze cracking, hardening and then disintegration. Also, colour change, I haven't discussed that earlier but sometimes you see that these architects sometimes they prefer a particular colour.

But what you notice is sometimes these materials fade. The colour fades after some time which then leads to poor performance or it does not look as good as it was in the beginning. Now, resistance to puncture and vandalism. This is also very important; puncture I can say it is a technical term. Resistance to vandalism, how do we prevent that something which we have to really look at the managerial part of it or conceal it with something else.

Then UV exposure and chemical resistance, abrasion resistance depending on the type of surface we are talking about, if you are talking about a building façade or something with vertical phase, there abrasion may not be a good or may not be that important but if you are talking about a road surface definitely abrasion resistance is very, very important.

And ability to resist extreme weathering that is also depends on what type of structure you are talking about, if it is an exterior element definitely, this is something important to look at. Now, ease of access for application and repairs, let's say for example if you are talking about a high-rise building, there if it is very difficult to reach there and apply this, then people may not prefer this type of system.

So, whatever repair system which we adopt we should also look at constructability and how easy it is to implement. Otherwise, eventually somehow people will get things done but it may not be of good quality. Now, reaction to continued submersion. If it is exposed to lot of water for long period of time, then how the material will behave, so water resistance to moisture attack that is something important to look at.

And ability to resist dirt pickup, this is something which is an important feature when we look at dusty environment. Typically, in a construction site you will have a lot of dust flying around, so this material or the sealant material which you apply should not attract dust and keep it on the surface which might affect the surface texture a little bit. These are all the different features that you can specify when we talk about selection of these materials, technical specifications.

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If you see the picture on the top left, if I have to repair it there might be a tendency that just get a new material and then just fill it up, instead of removing the existing sealant material which is already damaged and cracked.

So, this material is what I am talking, already damaged and cracked. We should remove the existing elastomeric material completely and then replace that with a new material. So, old sealant between the concrete expansion joint need to be removed and replaced and use a grinder or to make sure that it is completely removed.

Why I am saying this complete removal is important is we should avoid the presence of any of the old or damaged sealant which is not good anymore, there should not be any residue of that

sealant on the concrete surface. If you have some residue of this, let's say you just pull out these sealant material, there may be still some residue left on this.

And that will prevent the new material which you are going to inject or which you are going to place there from getting well bonded with the concrete, when you place the new material all these have to be removed, this should be completely removed, so the concrete surface should be very clean.

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Now, let's look at something about water proofing of the roofs. This is something which we usually see how people do water proofing. Typically, this brick-bat coba is used but ideally, it should be brick jelly and lime mixed together. That is how in olden time where people used to do but nowadays, there is this trend of just laying the brick on top of a mortar layer and then sometimes even more than one layer we have seen.

And then expecting that to provide good resistance against water proof against water. Now it is believed to give proper insulation from water and heat; heat maybe we can agree there is no issue with that but water is not always correct. Especially, when the performance of this thing depends on many factors such as cracks etc., I will show you that in the next slide.

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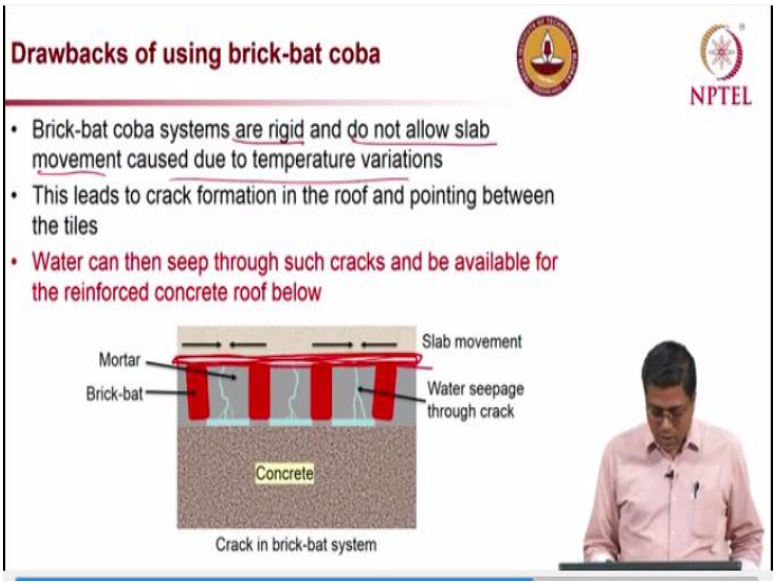

So, they are rigid system, very rigid not a flexible system and they do not allow the slab movement caused due to temperature variations. So, when you have this brick bat or a brick layer, I am going to call it brick layer, and then you have concrete at the bottom and so when there is temperature changes and there will be a possibility of cracks formation.

Once the cracks are formed in the brick layer, then rainwater or something that can easily penetrate through these cracks and then reach the concrete below.

Usually, we will also have a tile or something on top, terracotta tile or cotta stone something we provide on the roof top, so that we can walk easily. Now, on the tile also you will have some joints between the tile that will also crack over a period of time. now all these will let the water to enter the brick layer but it finds it very difficult to evaporate. So that is the major problem.

It is not only just entering but it stays there for long period of time, it does not evaporate that fast, so that is our major problem.

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Now, here I am going to show a video which clearly demonstrates, this is not a video just made for the purpose of this class but this is something which happened in a building. So, you can see this video, you will see the brick layer is there, you can see here brick layer.

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And you can see water gushing into this opening, so this is something you can see the amount of water which is collected inside that brick layer on top of a roof.

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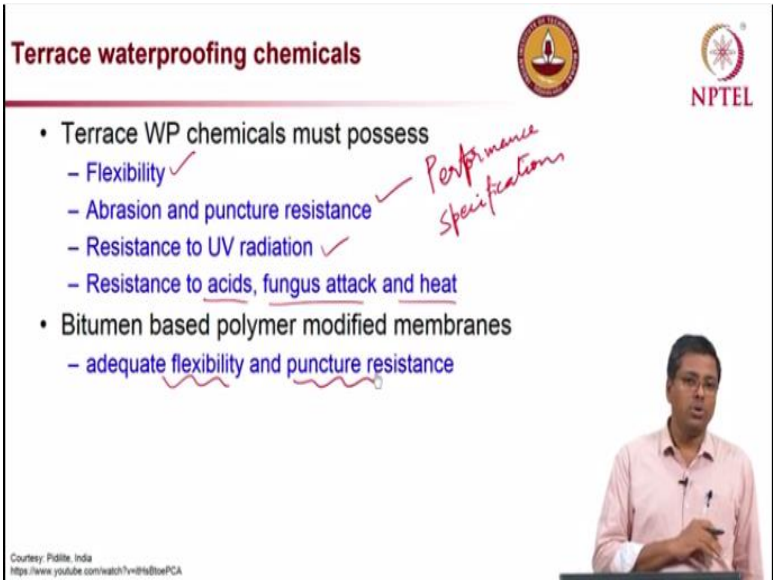

So, very, very important thing to think about. Let's stop using this is my opinion, others might disagree but my opinion is that let's stop using this brick layer unless we are also providing systems which will prevent the entry of water into the brick layer. So, I think the better way of going ahead is that making sure that we can provide some thin layers waterproofing chemicals are available or some layers which will ensure that water does not enter into or no water is available for the reinforced concrete slabs below.

Now, what are the qualities of this waterproofing chemicals; they should be flexible so that even if there are movements, they do not tear or no cracks are formed and they should also be abrasion and puncture resistance because while we walk also, if the material or the if the top layer is not abrasion resistant, then it will have wear and tear in very short period of time.

And also these are all exterior elements we will keep many things on the rooftop which might have sharp edges etc., that is a simple example if you put a furniture on the rooftop you will drag the table etc., so all these can lead to damages through which water can enter the roof, so abrasion and puncture resistance are very, very important parameters and also they should be resistant to UV.

This is one of the main problem with most of the water proofing chemicals is that they tend to degrade over a period of time because of the exposure to sunlight but now there are chemicals available which are UV resistant, sometimes even chemicals with about 10 year guarantee etc., are available, so but point is you should specify these things when asking asking for good quality durable waterproofing chemical.

So, resistance to UV radiation is very important. Resistance to acid, fungus attack and heat all these are specific cases. So depending on what type of application you are talking about you have to include these specifics into the technical or tender documents because if you just ask for a waterproofing chemical you will get some chemical which may work for some short period of time but may not really last for long period of time.

And also include another specification which can be like, you should check the performance after a rainy season or just after a rainy season and then only like, if you give some conditions like this which are performance specifications, then I think this is really a good thing which must be done instead of just asking for something you should come up with these are the exposure conditions which the waterproofing layer can experience.

And hence, I need these tests and you can also mention that I will wait for a rainy season to complete the testing because sometimes people also do ponding tests but that again limited time. So again all these case to case basis you have to decide but it is all these one engineer I mean, once you know that these are the different ways by which the system can fail, then you can devise specifications to go around it or to resist such failures not going around.

Now, bitumen based polymer modified membranes are also available, really flexible and puncture resistance also. Because it is flexible, it allows the movement on the slabs or whatever the structure you are talking, they do not tend to tear so easily.

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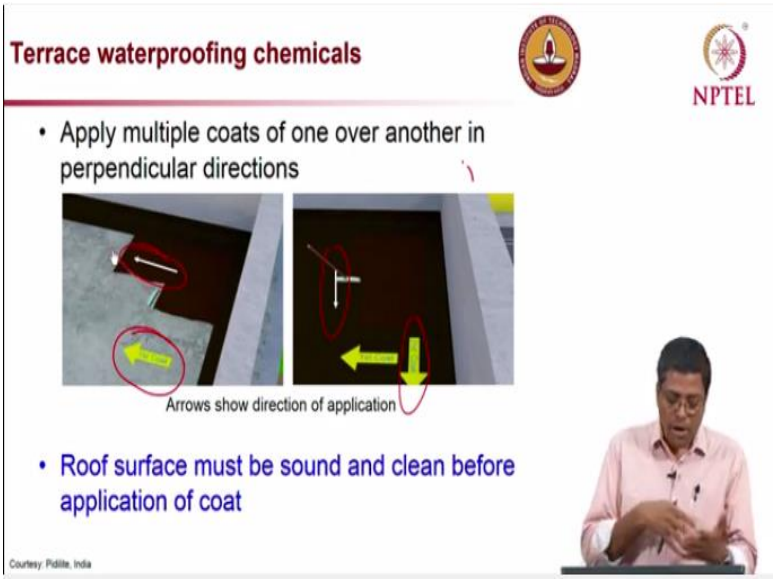

Now, when you apply these kind of waterproofing chemicals or coatings, one main thing to look at is the multiple coating layers to be applied in perpendicular direction. So that there is a very good filling happening in a microstructure or even let's say, in millimeter scale or in a sub millimeter scale.

When you have these multiple layers applied, then definitely it enhances the quality of the waterproofing layer or it enhances the impermeability, it makes it more and more impermeable as opposed to multiple layers applied in the same direction.

So, the brush should move in perpendicular direction then it will kind of fill up very thoroughly and then you will get better performance. Now, at the same time the roof surface must be sound and clean before the application of the coating.

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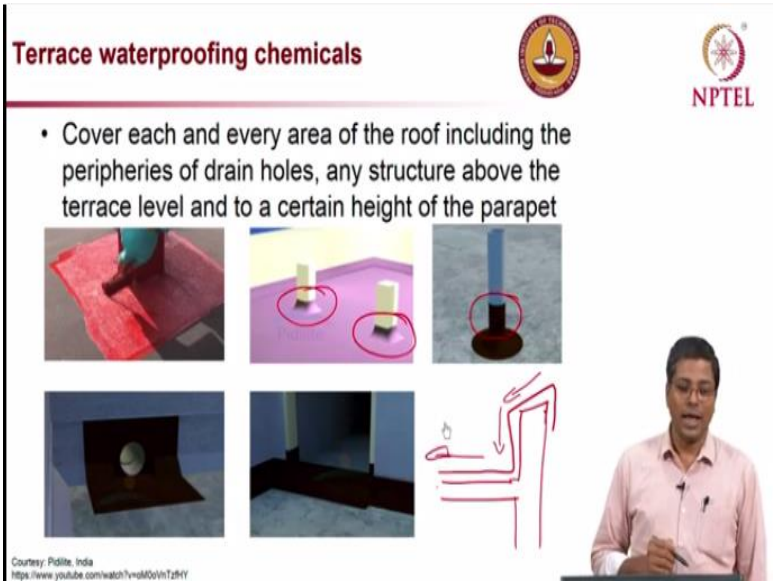

Now, another thing is when we talk about waterproofing, it is not just a small area we should focus on, it is not only the horizontal surface that we should focus on as you generally watch these images, you can see that every image there is a little height also. It is not just the area where we want but we look at the possibility of water entering into the system.

And how they enter, if there is a little flood or not necessarily flood but let's say you have a heavy rain there could be easily a couple of centimeters of water on the rooftop in such cases. Also, you should not have water getting in between the waterproofing layer and the concrete below. So, any small opening anywhere on the system will end up in the failure of the system.

Because these membranes are not like breathable membranes. Once water gets in they do not allow them to evaporate, so that is the danger of this, or that is how the system should be also. If you have a parapet which I do not have a picture here yeah the one on the bottom left is slightly okay but let me just draw a parapet wall here.

If you have a roof element like this and on the right side, you can see the parapet. So if we have to waterproof this, instead of just waterproofing on this bottom or the roof top, we should also go around this and then put it like this. So in that way what happens is even if there is some water on the top of the parapet right here, it will just try to flow, there is no possibility of this water getting in between the horizontal layer and the horizontal roof slab.

And also if possible provide a slope for the parapet, at the top of the parapet we should provide a slope, so that water will easily flow like this and then you can take it to wherever the drain is.

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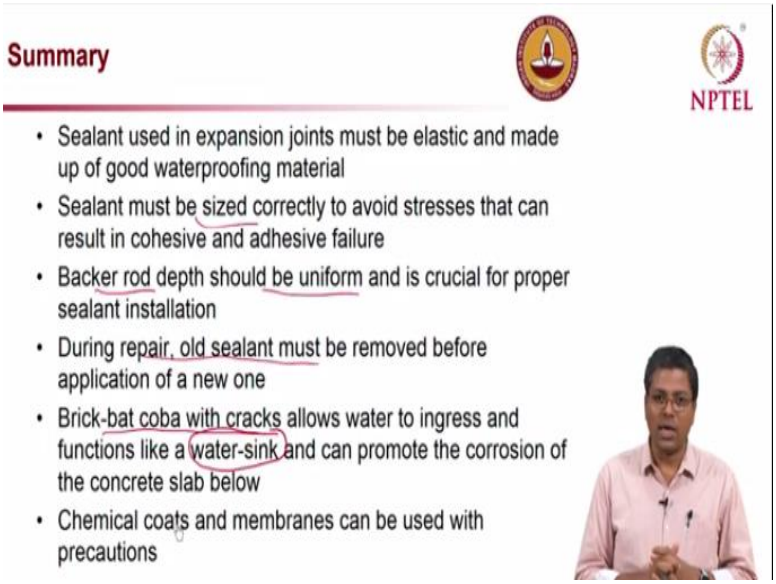

With that we will summarize this, so we talked about sealants used in expansion joints and what are the properties of that they should be elastic, made of highly impermeable material and also the size of the sealant is very, very important. Because the failure mechanism will depend on the thickness of the sealant and the backer rod. We discussed in detail, how important they are in ensuring that the sealant actually performs very well.

So, they should be inserted in a uniform manner, uniform depth. During repair old sealant must be completely removed and the concrete surface should be ground, so that the new sealant will

bond very well with the concrete surface inside the joint. And brick bat coba, we looked at what are the failure mechanism, so how the cracks can get initiated in the brick layer.

And which will lead to the entry of moisture into the brick layer but at the same time it does not allow it to evaporate that fast because of which the concrete roof below might have significant amount of water, might get exposed to moisture for long period of time. So, in other words they function like a water sink, the brick layer so it is better to avoid such systems.

And also, these brick layers and I did not tell this earlier but they also add a lot of weight to the structure. Imagine that brick bat coba will be about 6 inches or at least and they also add a lot of weight to the structure. So, if we go for a very thin waterproofing chemicals or a thin membrane, then we can actually have a thin structure which also have sufficient insulation both from water and heat.

So, such products are available, look for such products but at the same time make sure that the technical specifications which you provide are equally strong enough to reject the poor quality materials. We should always think about the life of these products and how long they will last. So think about what are the failure mechanisms and then write specifications individual line items in the specific tender documents, so that the quality of the entire waterproofing system can be enhanced.

So, individual specification to address the different failure mechanism must be included in the tender specifications and instead of just saying high, low we should just come up with some kind of numbers also. So if you really look into the market look at various product, compare how different properties are listed and then see whether, sometimes you also see that there are products which has so many properties which you really do not need for the specific applications.

So, when we make tender specifications we should think about the specific application and look at the possible failure mechanisms, not only in short term but also in the long term failure mechanism and then write technical specifications for addressing all those.

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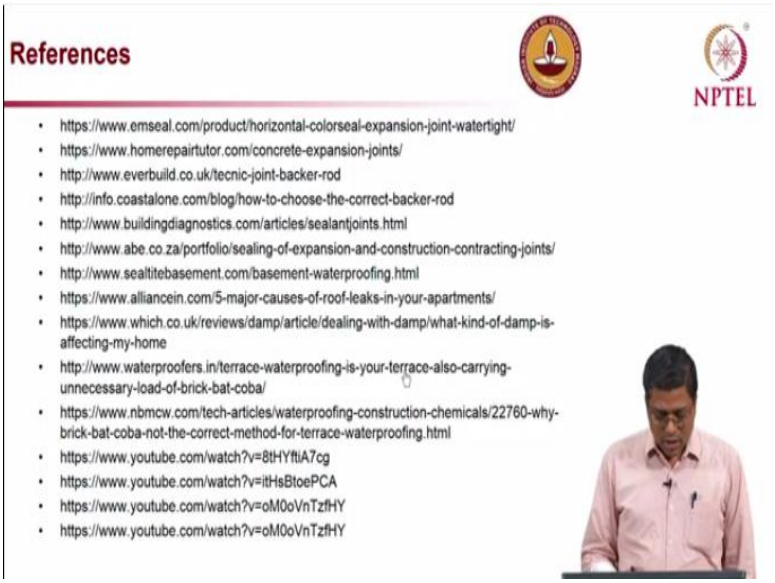

These are the references, took a lot of images etc., from the internet. Thank you.