Experimental Stress Analysis

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Lecture No. # 29

Calibration of Photoelastic Coatings, Introduction to Brittle Coatings

We have come to the closing part of our discussion on photoelastic coatings; and in the last class, you had a bird's eye view on what type of problems photoelastic coating has been applied successful. Two important issues that you need to look at one were it is applied for a variety of base materials starting from bone to concrete to high strength aluminum (( )). This is one aspect of it. Other aspect of it some of the reason, and most advanced technology where it is employed those problems have been analyzed using photoelastic coatings, inputs from photoelastic coatings was used in refining the design. So, it is more of a current technique, which is very efficiently used in aerospace industries, we are seen quite of few examples from aerospace industry.

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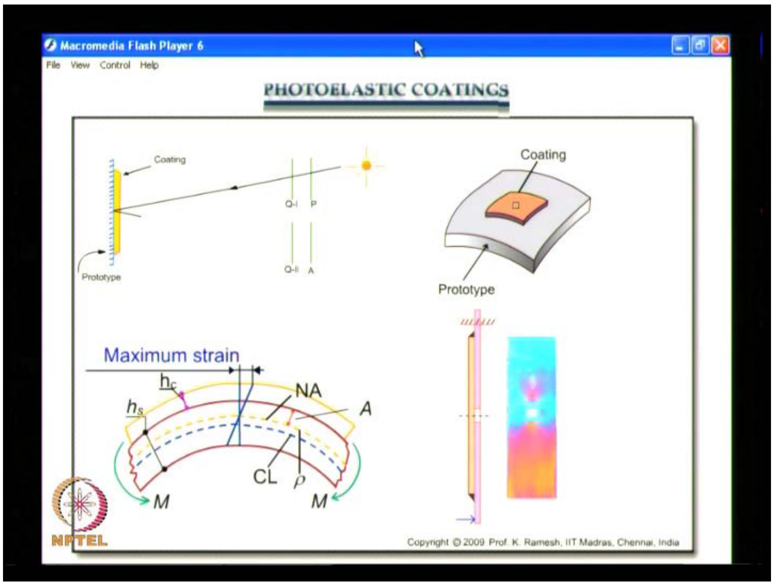

In summary what you can look at is, you have a simple optical arrangement, and then I said for all coating techniques. The coating has to be bounded very carefully on the prototype and we also assume that strains are faithfully transferred from the prototype to the coating. And I said once you come to photoelastic coatings, you have to think of what are known as correction factors that is what is illustrated here.

I have a specimen on which I put coating, when it is subjected to bending, you find there is a strain variation in the thickness of the coating, and you need to account for this variation and bring in correction factors and finally we also saw a simple example, that I have specimen subjected to bending and you see nice set of colors and we had already seen what is the color code in transmission photoelasticity? And whatever the fringe ordering methodologies you learned all those aspects could be applied to photoelastic coating as well and one of the simplest things what you can think of? You look at this optical arrangement; you have the elements shown in this fashion.

I have a polarizer first quarter wave plate, I have a second quarter wave plate and analyzer and we have also look at yesterday, in the last class that a person was inspecting the landing here had this polariscope in his hand. I will just showing the polariscope and you will also appreciate how compact the polariscope it is? You know this is the polariscope you just see how compact it is and now, what I am going to do is?

I am going to attach the light source and we will also see a one example problem how fringes are observed conveniently? Now, I have the light source attached to the polariscope and you can see the whole equipment is so, compact. I can hold it in a hand and what you have here is? I have the light source, I have the polarizer and quarter wave plate combination here and I have the second quarter wave plate and analyzer combination here. So, what I do is light goes through this?

So, you send a polarizer beam of light to the modular concerned and the reflected light is analyze by the second quarter wave plate and analyzer and I would like to show the application of the polariscope for a example problem and what you have here is I have the light system I have the example of a (( )) coupling, which is tighten by 4 holes and this is a complex problem from analytical point of view, because you have assembly stresses developed and I also keep the light source for away from the model what I had there? This is to reduce the angle of oblique.

So, I have the light that impinges on the model and the reflected light is view through the second quarter wave plate and analyzer combination and I see rich fringe contours and for the benefit of the viewers, the human eye is replaced by the electronic camera for you to have a look at the fringe patterns. From a practical point of view these kinds of problems become very important how the bolt is tightened? What is the dark applied they have to be maintained in a particular value. So, that the fringe patterns retains certain level of symmetric and also the sequence of tightening becomes very important in large (( )) couplings. These are all very complex problems from analytical modeling and photoelastic coating can really reveal which information for such complex problems.

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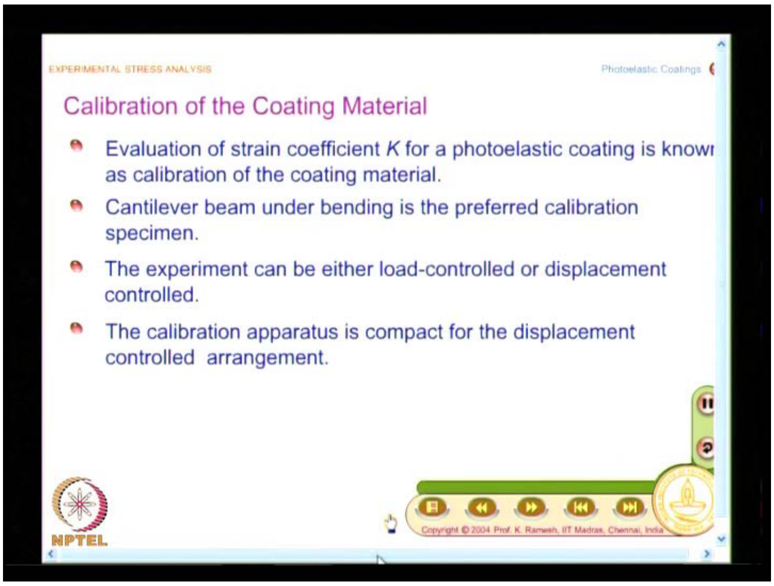

Now, we move on to the important aspect that we have to do as part of a photoelastic coating test is how to calibrate the coating material? And what is the meaning of calibration? Evaluation of strain coefficient K for a photoelastic coating is known as calibration of the coating material. And if you look at what is the most preferred calibration specimen, these a cantilever beam under bending. And if you look at later we are gone to study what is brittle coatings followed by strain gauges and if you look at photoelastic coating brittle coating and strain gauges all of them employee a coating of different kind on the surface and for all these coating techniques, you use calibration specimen as cantilever beam.

You do not select disc and diametral compression; you take a cantilever beam and then evaluate the pertinent properties for a fringe in coating for a brittle coating and also the gauge factor in the case of strain gauge. And the experiment can be either load controlled or displacement controlled and you would see the displacement controlled, experiment arrangement is very compact compare to a load controlled arrangement.

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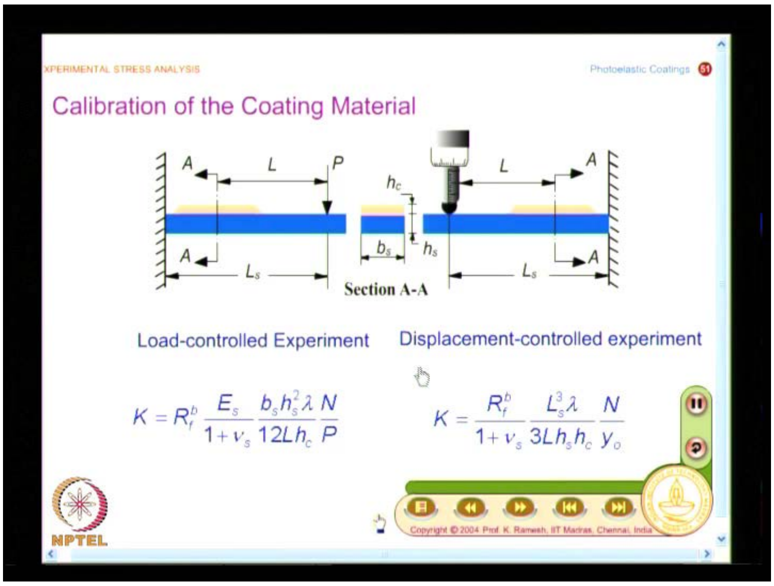

And this is how the specimen is loaded? And you need to make a these in h of it is very simple and what I have here is? A cantilever beam on which the coating is pasted and if you watch carefully I have a (( )) edge here. This is made of the adhesive whatever you do there and another advantage of an approach like this is. The coating material is very precious. So, you put only a portion of the cantilever beam on the top is pasted with the coating there by you safe the amount of coating material.

So, you have the length of the beam length at which you are making the measurement, you have the measurement light what is the thickness of the specimen and thickness of the coating? And this is the load controlled arrangement. You also have a displacement controlled arrangement instance of applying the load here; you have a micrometer which provides the necessary and deflection.

And what you have here is? When I have a load controlled experiment, I the expression for K is very conveniently given, in terms of the parameters of the experiment and you should notice that I have to use the reinforcement factor for bending. If I do not use this my estimation of K would be (( )) and what you do from the experiment is?

I have to find out the fringe order and the corresponding load. I need essentially the ratio N by P for a load controlled experiment from conducting the experiment apart from the geometric details, I need to supply the value of N by P. On the other hand when I come to displacement controlled experiment, the expression is recast and you have N divided by y 0 and y 0 is the deflection at the load at the displacement controlled point.

Whatever the displacement I introduced, which is taken as length L s for that distance what is the displacement that is being used. So, what I have here is? In load controlled experiment I get the strain coefficient K as R f b young's modulus of the specimen divided by 1 plus nu x B s h s square into lambda, which is the wave length of the light used divided by 12 L h c and N by P, which has to be determine from the experiment. And displacement controlled experiment I get strain coefficient K as R f b divided by 1 plus nu x L x cube lambda divided by 3 L h x h c multiplied by N by Y 0.

This shows the overall view of a displacement controlled apparatus for loading a cantilever beam and this is the fixed end and you can apply the displacement at this end by moving the micrometer appropriately and you could rotated at apply the load, apply the desired displacement, you can also note down the level of displacement that is introduced and what you have here is, I have the specimen tilted for your benefit to show that you have a coating pasted and what you can also notice is? On either side the glow is applied in a manner, that you have a rivaled edge for smooth transfer of strain from the specimen to the coating. The whole apparatus is very compact and that is the greatest advantage and all the coating techniques by brittle coating or strain gauges, the use only a cantilever for the measurement of pertinent parameters.

In this case you want use this to find out the strain coefficient K and advantages, you also use only a small coating material to safe the precious coating material. You do not need to apply for the entire cantilever beam; you applied only in a region where you want to have sufficient level of stress to reveal the fringe pattern.

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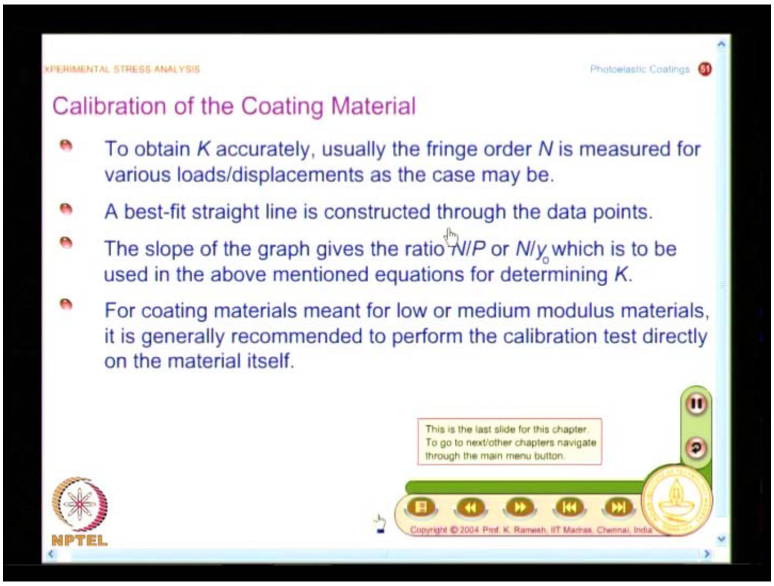

And you know I have been saying that in photoelastic analysis, the calibration constants have to be determined as accurately as possible. The same rule applies to evaluating K as well; it has to be obtaining as accurately as possible. So, for this you need to find the fringe order correctly. And you do not just make one measurement you make various for various loads and displacements find out the fringe order and do a graphical least square analysis what you do is? You fit a best fit straight line through the data points collected. So, from the graph you get the ratio of N/ P, if we are doing a load controlled experiment or N/Y0, if we are doing a displacement controlled experiment.

So, you have the readymade expression available, which can be used find out what is the value of K? So, for many of the high modulus coating materials and also medium modulus coating materials probably you could use simple cantilever beam put the coating and evaluate either by a load controlled or displacement controlled. I said displacement controlled, the loading arrangement is very compact that is the very popular loading arrangement supplied by the manufacturer also. Suppose, I want do it for the coating materials, which are meant for a specimen like rubber.

So, I will have a very low young’s modulus value of the coating material rather than putting it on a specimen and then do a photoelastic coating test. It is the advisable, you make a tension specimen out of it, stretch it find out F sigma and from your identity between F sigma and F epsilon, which you are seen earlier determine F epsilon, then your K and that is what summarized here.

For coating materials meant for low or medium modulus materials, it is generally recommended to perform the calibration test directly on the material itself. So, what you do is you essentially take a tension specimen and perform the test and get the value of F sigma, from F sigma go and find out F epsilon and finally, determine K. So, with this we have covered all aspects of how to do a photoelastic coating test like in transmission photoelasticity. You have to find out f sigma in reflection photoelasticity, you have to find out K. K will also this applied by the manufacturer, but if the manufacturer the whatever that you got you have doing it the test after long time, then it is better that you recalibrate find out what is the strain coefficient K and then perform the test.

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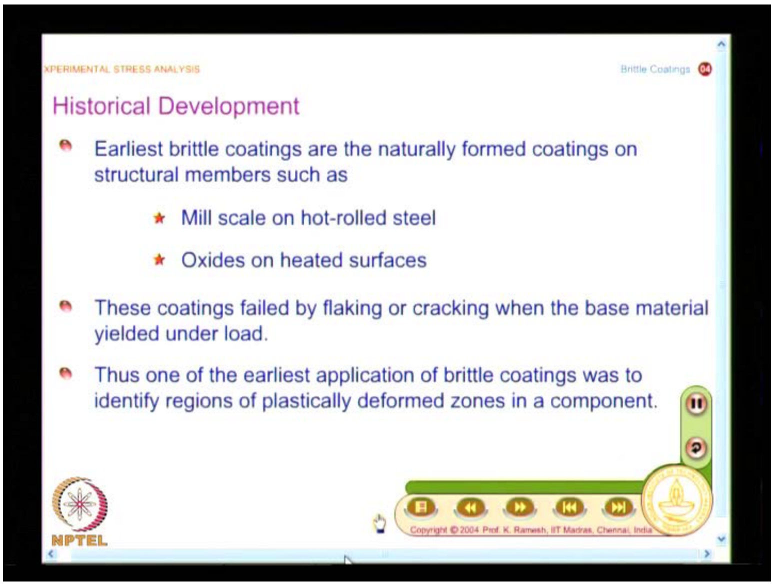

Now, we move onto brittle coatings and we have already had bird's eye view of what brittle coating is, in one of the initial lectures, you know very well that you have a coating that is put on the specimen, which is brittle in nature and this coating is allowed to fail under the application of the load and we also look at was what are isostatic and isoentatic. We will see that in more detail and if you really look at what was the first application of brittle coatings? It was applied to find out, then the material has yield and this was seen on mill scale on hot-rolled steel. The coatings are naturally formed on structural members when we do a hot rolling process, you will have a mill scale on the hot rolled steel and you also had formation of oxides on heated surfaces.

So, the initial coatings swap naturally formed coatings and what was the focus? I said each of the technique operates well in a particular range and if we look at the first application of brittle coating was to find out, whether there was plastic deformation; that means, you are talking of very large strains.

So, when these coatings failed by flaking or cracking when the base material yielded under load, the focus was to indentify yielded. Thus one of the earliest applications of brittle coatings was to identify regions of plastically deformed zones in a component; that means, you are talking of a very high value of strain close to 2000 microstrain. The difficulty comes when you want applied to elastic problems and we are also seen that properties of the coating dictate the accuracy of the technique.

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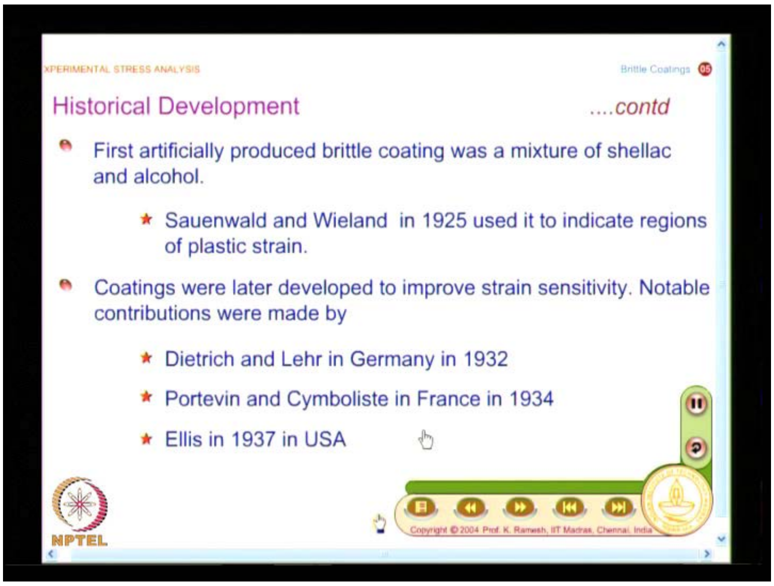

And it is desirable look at what are the contributions by various scientists? And it is also interesting to see, what was the first artificially produced brittle coating? We had seen naturally formed coatings earlier. The first artificially produced brittle coating was a mixture of shellac and alcohol and this was used by sauenwald and wieland in 1925 to indicate regions of plastic strain.

And I said that when you are talking about plastic strain, you are talking of very high value of strain. Coatings were later developed to improve strain sensitivity improve strain sensitivity in the sense, the coating should fail at a lower strain. This is what we are looking at? And I am always said any advancement in science or technology material research as always propelled the direction of technology.

So, without advancement in material research you cannot see advancement in science or engineering, the same applies to development of brittle coatings 2. So, when you develop better materials, I can bring down the strain level for the coating to break and again this not done by one individual, there are all coats of researches to contribute the five. You had people from Germany contributed in 1932 and you had people from France in 1934 and also contributions from USA notably by Ellis in 1937. So, what you will have to look at is? Any development is not individual centric you know a team of people across the world (( )) and the present day coatings fail much below the plastic strain.

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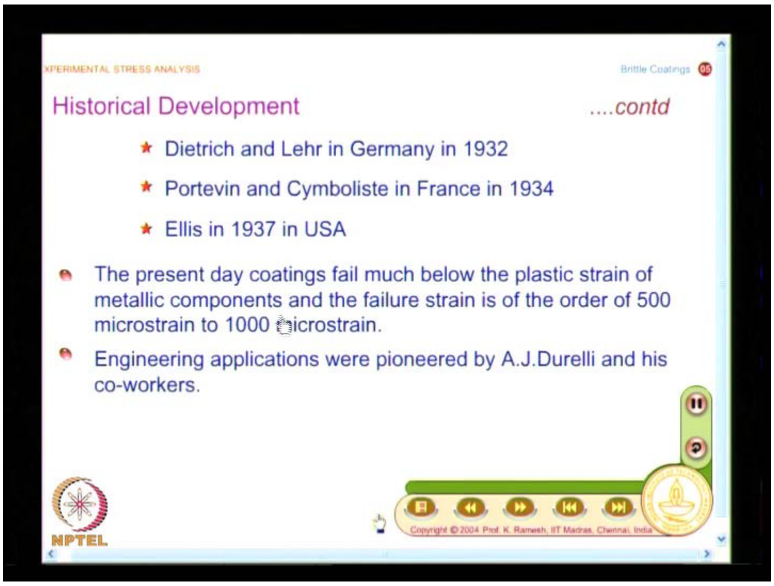

That is what you have to look at? It is started with identifying zones of plasticity in model and failure strain is of the order of 500 to 1000 micro strains even less now, people say even 3000 micro strain is possible. So, you have material research contributed to development of better coating materials, which have more sensitivity for failure here the coating has to fail.

The coating has to fail by 500 micro strain and now, you will also have coatings below 300 strain and many engineering applications were pioneered by A. J. Dureli and his co-workers say, I said when I talk about photoelastic coatings, I said (( )). (( )) was the keep person who develops the contourable plastic and also develop correction factors and you have to remember his contribution, if we go to transmission photoelasticity frank was considered as father of photoelasticity.

So, here made significant contributions. Similarly, when you come to brittle coatings the name that you cannot forget is A. J. Dureli, we have done several industrial problems.

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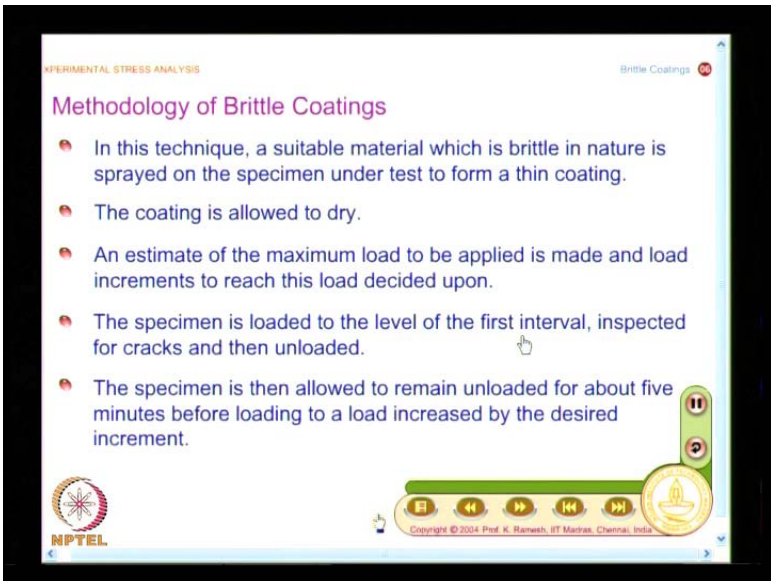

And what is the methodology of brittle coatings? This you already know we have only going to refresh our old memories and in a very formal sense. So, what I have is, in this technique a suitable material which is brittle in nature; that is a key point and what way it is bounded? It is sprayed on the specimen under test to form a thin coating. So, this simplifies your specimen preparation, because I can cover large areas by a spray gun and I have already set brittle coating is a useful technique for solving industrial problems, which are very large in size and your focus is to identify zones of stress concentration for further study. So, you have to cover large areas. So, in such a situation a spraying technique definitely helps.

You allow the coating to dry and then how do you load the specimen. Here the loading of the specimen is very interesting. An estimate of the maximum load to be applied is made and load increments to reach this load decided upon. This is the peculiarity of the technique, which I have mentioned earlier to in many problems, you find out for a given operational load what are the stress is developed? Here, you incrementally load the specimen at every stage you go and observe for cracks. So, it is very peculiar from performing the experiment.

So, I need to find out the maximum load and also decide what are the load increments? Then what I do is, I load the specimen to the level of the first interval, then go and inspected for cracks and then unloaded. Either unload or keep increasing in the load I could do any one of these approaches. So, what you will have to look at is after the first interval you have to inspect for cracks and the cracks what you see carry information and we were already noted that gives you principle stress direction. When you call those patterns as isostatics will again see with an example, will also label it we also show another set of contours call isoentatic. So, the experimental approach is peculiar, estimate the maximum load, and determine the load increment and you incrementally load after the first interval look for cracks.

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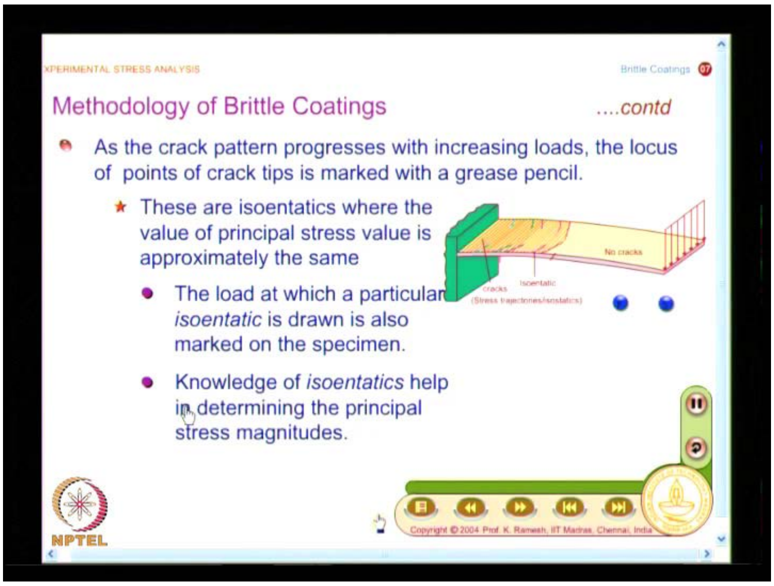

And what you have is, the crack pattern progresses with increasing loads, the locus of points of crack tips is marked with a grease pencil. We will see that this example and what you have here is, I have a cantilever beam, which is subjected to end load and if you watch very carefully the color of this loading will change for each increment and the same color is also used to mark the ends of the cracks.

So, what you have is, you have cracks, these are called as stress trajectories or isostatics and you know in the case of a beam. The end is heavily loaded the free end is not loaded that is why you do not see cracks in the in this region and I will repeat the animation and what I do is, at every increment of the load I mark the isoentatic and isoentatic is drawn like this, because you know I have this end effects. It is slightly exhaustrated and you know you have a uniaxial state of stress in the case of beam.

So, essentially you will get cracks parallel like this that is what you have to anticipate the crack, because you have the bending stress in this direction. It is perpendicular and you will have lines parallel like this that is how you anticipate the cracks. Now, I repeat the animation has the model is loaded for each load. The color changes the same color is used for mark the ends and this is just exhaustrated you know it may not be exactly horizontal near the free edge, to indicate that these kinds of lines are put. I repeat the animation again that tells you how you go about in doing the experiment.

So, for each increment of the load you find additional cracks are getting formed, which cracks are very important. What is the sensitivity of the technique? Where you have to be very careful, if I keep increasing the load I will keep looking at cracks more and more cracks will get formed what is important here? You should be careful to identify the first increment, it is should be as known as possible to detect the first on set of cracks, because we have a stress concentration zone.

The stress concentration zone is the one, which is going to give you first set of cracks. So, it is the first set of cracks that are very critical in these techniques. So, you have to be very careful in deciding the first load increment should not be very high, then you mix which is the high stress concentration zone. So, what you do is, as the crack pattern progresses with increasing loads, the locus of points of crack tips is marked with a grease pencil.

These are isoentatics where the value of principal stress is approximately the same and you can see this. See this animation again you have this as the model is loaded incrementally at every stage you have cracks formed an isoentatics are mark. The load at which a particular isoentatic is drawn is also marked on the specimen that is why you perform the experiment?

Here a not label the load, but what I have done in the animation is, whatever the color that I used for the end load, the same color is use to draw the isoentatic and if I have a record of isoentatics this helps in determining the principal stress magnitudes. You know it decidable to see this isoentatic very closely; I will repeat the animation and then take a closer look at it, I have this and I also zoom it further. So, what you have here is, the isostatics are parallel like this and you see isoentatics of different colors, which is for different loops and what is important is? Then do the first set of cracks form that is very important I have to be careful in deciding my load increments So, in this experiment you see isostatics as well as isoentatic.

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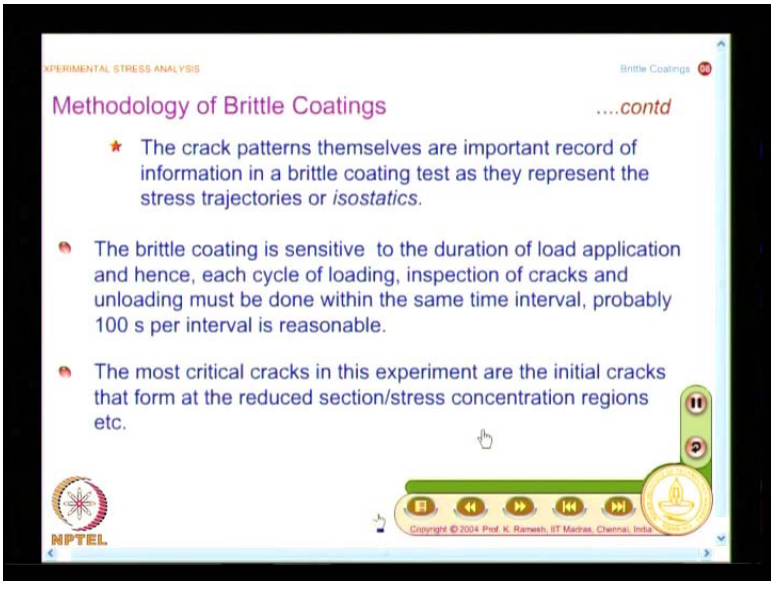

And this is what I when emphasize it again and again. The cracks patterns themselves are important record of information in a brittle coating test, they are represented and they represent the stress trajectories or isostatics. So, you people have developed methodologies to inspect for appearance of cracks. They have very elaborate methods, they are several methods are available. So, that you do not mix any zone where cracks have been formed. So, that itself is a separate branch where you have several methods.

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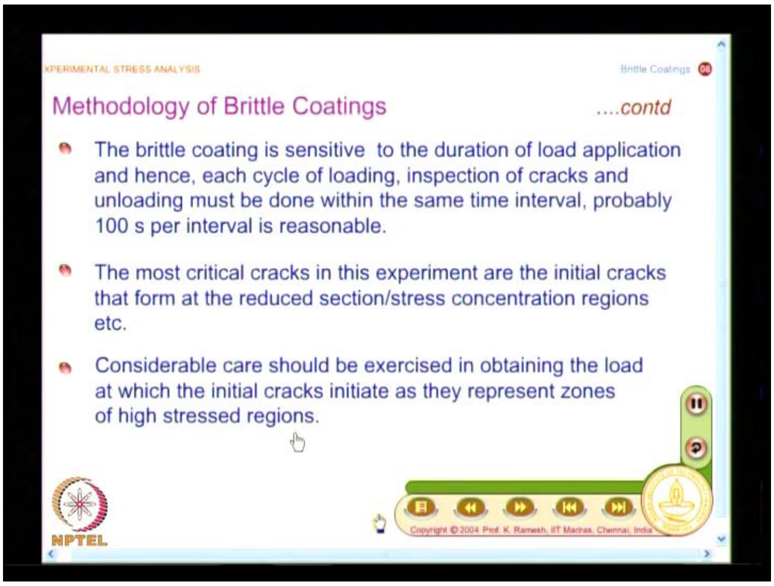

And another aspect, which will have to keep in mind, is the brittle coating is sensitive to the duration of load application. So, you have to have a particular cycle to follow for each cycle of loading, inspection of cracks and unloading must be done within the same time interval and this varies depending on the coatings, it probably something like hundred second per interval is reasonable people also code five minutes.

So, it is the function of the coating that you employee and you will have to again remember the most critical cracks in this experiment are the initial cracks that form at the reduced section/stress concentration regions. So, this is the most critical aspect of it and another aspect is at every increment of load you must make and develop the skill to identify crack at all regions you do not mix the region. This has to be done very systematically.

So, I essentially get isostatics and then I get isoentatic for every increment of the load.

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So, that is what again emphasized you need to exercise considerable care in obtaining the load at which the initial cracks initiate as they represent zones of high stressed regions, see the methodology like this. The coating is design to fail at a particular strain level, if the crack as formed at a given load what it indicate is the strain level is at least this it could be more than that also. So, that is the reason why you have to select the initial loads small enough. So, that only localized region have crack formation.

Suppose, I apply a very high load I would have lot of cracks formed that is not the issue, you have to sequentially record the formation of cracks as a function of load. So, I want to see only few cracks at a time. So, that is the success when I have the load increment appropriately decided upon and I also said experimentally anticipate results before perform an experiment. So, you have done some calculations, it is not that closing your eyes go and apply the load and then react to whatever the pattern that you see. You anticipate in a particular fashion and that has to be look at very carefully.

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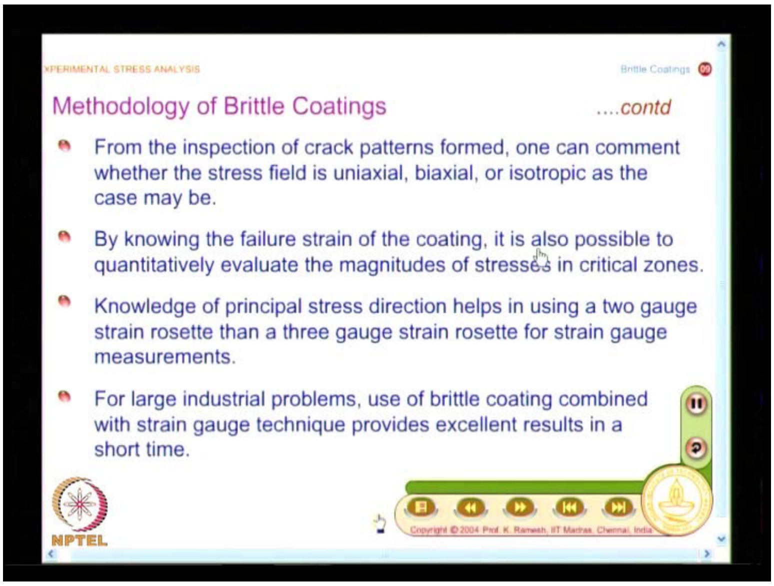

And what is the important is like in optical techniques; here also I see whole field information by looking at the crack patterns formed one can comment whether the stress field is uniaxial, biaxial or isotropic. In fact, in some of the earlier studies even to identify zones of uniaxial, biaxial and then isotopic was an issue, it was large problems. Suppose, I know in a particular region I have only uniaxial state of stress, then I can reduced a strain gauge channel that is the advantage.

Here, we are not talking about you know laboratory size problems; you are talking about industrial problems which are very large in size. And by knowing the failure strain of the coating, it is also possible to quantitatively evaluate the magnitudes of stresses in critical zones. See this is the possibility, but whether we want use it of a experimental is you have to take a local decision based on your requirement and time availability.

I am always said, as experimental is people develop very complicated methodologies to extract as much as possible from a experiment, but from a user point of view you will have to find out to what extent you want use the experiment detail? My recommendation would be brittle coating is an ideal technique where you can use the isostatic could decide how to paste strain gauge in a complex structure? If I am able to reduced one channel per point a great (( )).

And that what is summarized here, you have if you have the knowledge of principal stress direction using a two gauge strain rosette than a three gauge strain rosette is possible, if I know the principal stress direction instead of a three gauge strain rosette I can go for a two gauge strain rosette. So, I reduced one strain gauge per point and the great success of brittle coating is in conjunction with strain gauge technique. The combination provides excellent results in a short time for industrial problem, this is the key issue. So, that is what I always mixing industrial when it approaches you, it wants result yesterday. They want thickness in finding out the source of error and in such applications combination of brittle coating and strain gauges definitely helps.

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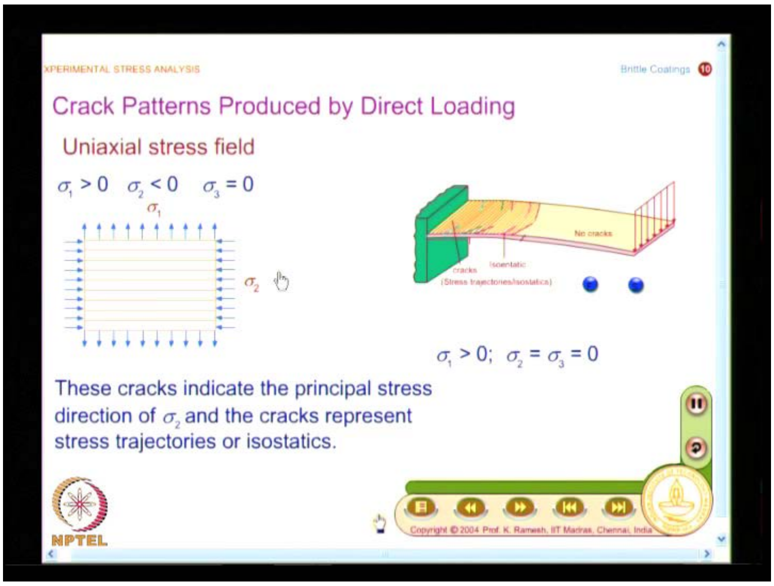

And now, we look at what kind of a crack patterns formed by directed way and what is shown here? Suppose, I have sigma 1 is greater than 0 and sigma 2 is less than 0 and sigma 3 equal to 0. I have essentially biaxial loading situation and sigma 1 is greater than 0 so, you have cracks formed perpendicular to the direction.

So, by looking at the cracks formed, I can comment that this is the combination of uniaxial stress either I can have uniaxial stress or you have a tension compression and you have already seen an example, of a cantilever beam. So, by looking at the cracks what you get? These cracks indicate the principal stress direction of sigma 2 and the cracks represent stress trajectories or isostatics. Here, it is shown for a tension compression whereas, here whatever the cantilever example, which you had see earlier essentially gives a uniaxial state of stress sigma 1 is greater than 0; sigma 2 and sigma 3 are 0.

So, by looking at the crack pattern I can comment whether it is a uniaxial stress field, see we actually go around and look at you have this white wash that is put on buildings and white wash is actually a brittle coating. So, by looking at the crack pattern on the wall you can comment whether I have a uniaxial loading, there whether I have biaxial loading or whether principal stress direction is same at all directions, all those kind of comments you can make.

So, from that point of view also looking at the crack pattern, gives you an inside without solving the problem what is a nature of stress field?

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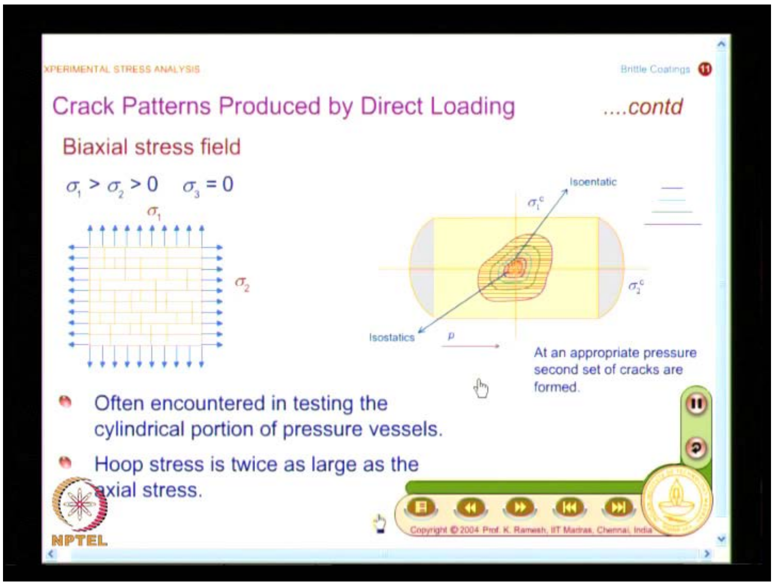

Suppose, I have tension tension combination what happens? And where they have the tension tension combination in your engineering, see engineers always deal with pressure vessels and once you go to the pressure vessels you have hoop stress as well as longitudinal stress. This is the very nice example; where tension tension combination exist not only this… you know hoop stress is much larger than the longitudinal stress.

So, only when the pressure is sufficiently increased suppose for a particular pressure p for the hoop stress you have cracks form. The second set of cracks will from only later, because longitudinal stress is much lower than the hoop stress only when it is double you will have in an ideal situation only when the loading is double, you will have second set of cracks get formed.

So, what you have here is, when sigma 1 and sigma 2 both are greater than 0 and this is the situation where sigma 1 was much larger than sigma 2. So, you have 2 set of cracks formed, I have cracks perpendicular to sigma 2 as well as perpendicular to sigma 1. The mathematical analysis would become very complex, when I have biaxial loading the mathematical and applying failure analysis becomes difficult, but this gives an indication that you have a biaxial tension. I have knowledge from the crack pattern that I have a biaxial tension and this you had already seen in the earlier discussion on brittle coating. A famous example, of pressure vessels we had look at and mind you this is not an ideal pressure vessel that is why you have cracks formed like this.

It is not perfectly cylindrical you have welding, you have a that kind of practical issues considered for a illustration; otherwise you will you will have cracks all over the pressure vessel it is localize mainly, because you have a some short of stress concentration there. So, this kind of a biaxial stress field is often encountered in testing the cylindrical portion of pressure vessels.

So, it is of practical importance and this is what I had mentioned that hoop stress is twice as large as the axial stress. So, first set of cracks formed horizontally like this, then after increase of pressure you have second set of cracks formed and that is what is shown here. You had already seen this in one of the earlier classes and probably we could also see the brittle closely. So, I have this second set of cracks formed at a particular value of pressure.

And these are all the rays that you get the cracks formed, then you have the isoentatic drawn and the experiment produced like this for another pressure you have this and you draw the isoentatic and so on. And what happens if principal stress direction is same, which you call it as isotropic field sigma 1 equal to sigma 2 and both are greater than 0. So, you have a random crack patterns.

So, if we come across in your buildings random crack patterns, if you watch the white wash and you find that you have random crack patterns, you can immediately conclude that principal stress direction is same in an every direction in this zone of the building. Which you can notice, if we go and watch your house very carefully the white wash what you have, because the building gets stressed and you can find out by looking at the crack patterns, comment whether it is uniaxial stress field or biaxial stress field or where sigma 1 equal to sigma 2 and you also have a nice example, that is shown as part of it.

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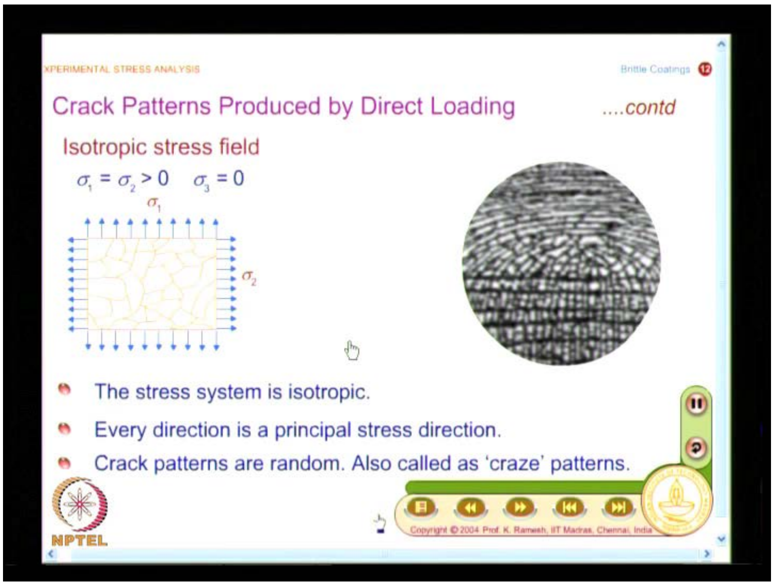

So, that is what is taken by a very special process for the case of ring and diametral compression, we are seen 0 the fringe order that is what shown here and you see very clearly, very random patterns here. This is the isotropic point and these are all the isoentatic with the think lines are isoentaic and the thin lines are the isostatics. This is the isoentatic, this is the isostatic and you see a random pattern here. A random pattern indicates that you have an isotropic stress field. So, the stress system is a isotropic every direction is a principal stress direction, because every direction is a principal stress direction you have cracks on all the possible directions crack patterns are random and these are also called as craze patterns.

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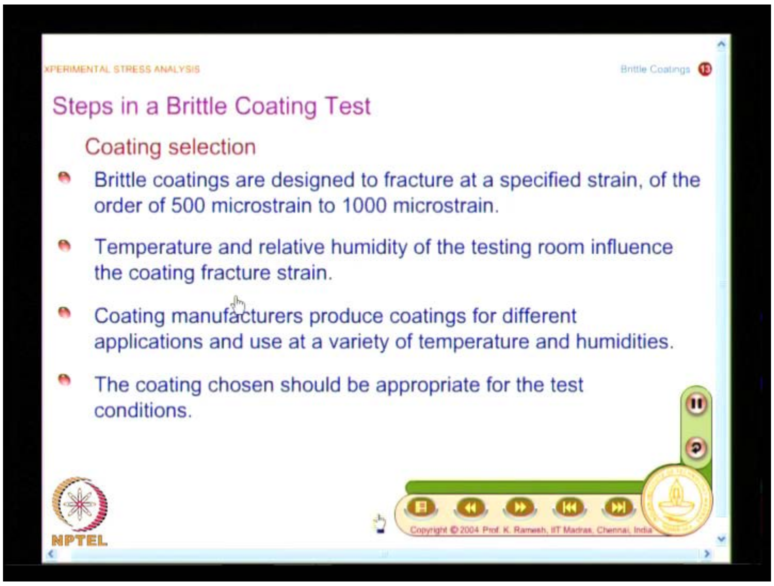

And you know once you come to a brittle coating test, the first step that you need to do is you have to select a coating and if you look at any brittle coating test any supplier whose supplies coating, he gives a different set of coatings for a variety of temperature and humidities.

So, depending on your test conditions, you have to choose a coating that is appropriate for the test conditions and I said the environment is very, very sensitivity. So, the temperature and relative humidity of the testing room or the test places, because it is also an outdoor techniques. So, you have to measure the temperature and relative humidity that influence the fracture strain of the coating, because all your calculation depends on what is the fracture strain based on that when you make and it is an approximate technique. It is a applicable for a very large structure and the technique as such in is approximated that is good enough for industry problems, when you want to have quick answers this kind of an approach is good enough.

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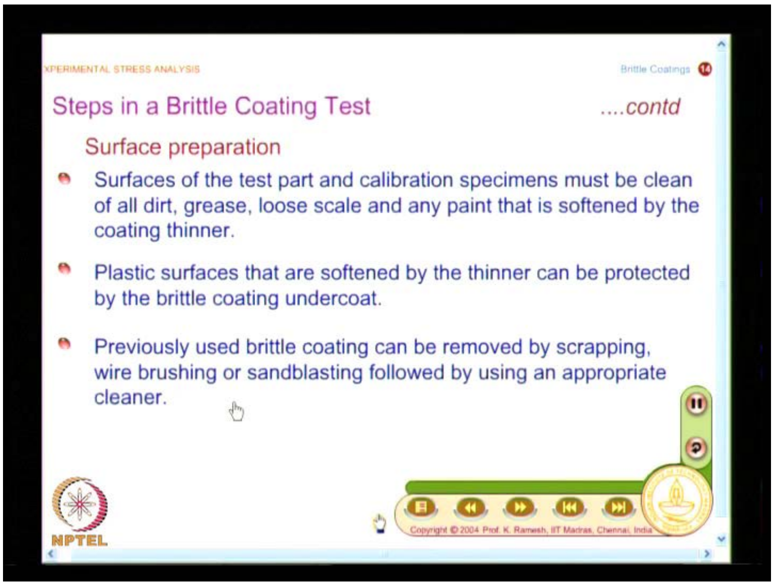

So, the first step is we have to select the coating and other next step is what in all the coating techniques surface preparation assumes importance. These are all very generic you can actually abbreviate this under write it rather than writing full sentences like what I had here? And when I have to want on coating the surface must be clean of all dirt, grease, loose scale and any paint that is softened by the coating thinner.

So, that has to be done, and then what you have is? You have plastic surfaces you can also applied on plastic surfaces that are softened by the thinner can be protected by the brittle coating undercoat. So, you need to put an undercoat and then only start using the… you apply the actual coating and then do the analysis and you also have occasion where you need to remove the earlier coating by scrapping wire brushing or sandblasting followed by using an appropriate cleaner.

See you may also come across problems where there is a tension compression combination and if you want to reveal the compressive stresses you have to remove the earlier coating, then recoat it at the maximum load then release the load. So, you have a direct loading approach and also a relaxation approach.

We will develop the mathematics for direct loading, and then extra plot it for relaxation. So, you will have occasion not only to clean the surface to apply the coating, but you also have an occasion to remove the brittle coating that is applied, which can also be done by scraping wire brushing sandblasting etcetera.

So, in this class what we had looked at was? We look at how to calibrate the photoelastic coating I said you have to use a cantilever beam as the model for finding out the pertinent parameters and I also mention for all the coating techniques like brittle coating as well as strain gauges you evaluate the relevant parameters, using cantilever beam as the model. So all the coating techniques cantilever beam is a very ideal model for you to do the test.

Then we started of a discussion on brittle coatings and I said it is useful for industrial problems for large industrial problems though you can also find out quantitatively, the value of the stress magnitudes mostly desirable to use to find out the principal stress direction and the point of interest. So, that in strain gauge instrumentation I minimize the number of strain gauges to be pasted at a point of interest. Even if minimize reduced by one strain gauge I say well lot in my strain gauge instrumentation and we will look at some details of the test. We also look at by looking at the crack pattern you can identify whether there is a uniaxial stress, biaxial stress or isotropic stress field, and we will continued the discussion in the next class. Thank you.