Principles of Construction Management
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Lecture – 28
Quality in construction – Welding

[FL] and welcome to this series of lectures on Principles of Construction Management, where we are talking about different aspects related to construction project managements. In the last class we talked about the introduction an introductory aspects of quality in project management, basically construction projects. And today in the first lecture following that we are going to talk about quality in construction as related to welding.

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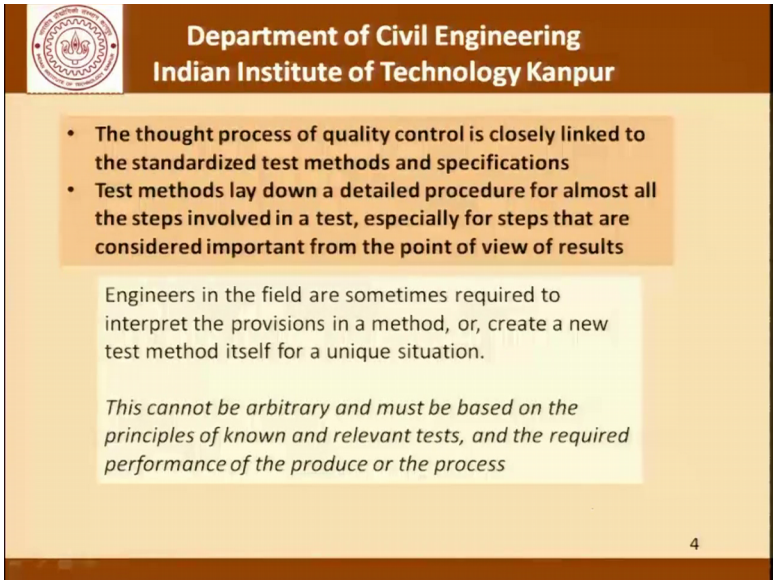

So, what had happened last time was that we had said that the thought process of the quality control is closely linked to standardized test methods and specifications. And test methods lay down a detailed procedure for almost all this steps involved in a test, especially for tests that are considered important from the point of view of results.

We had also said that engineers in the field are sometimes required to interpret the provisions in a method or create a new test method itself for a unique situation at that particular site for that particular material and so on. We would also said that this decision in terms of interpretation of the provisions or when you create a new test method it

cannot be arbitrary and must be based on principles of known and relevant tests, and the required performance of the produce that is the product or the process involved.

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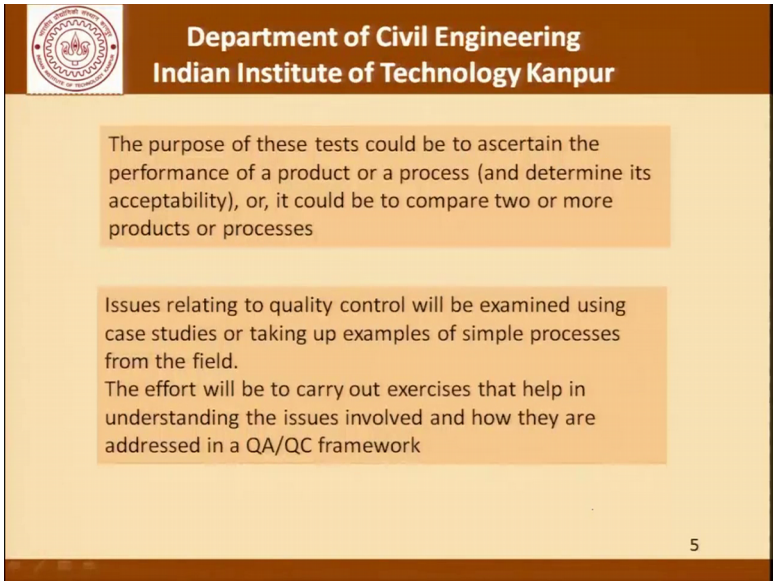

We are also re-iterated that the purpose of these tests could be to ascertain the performance of a product or process, and therefore determine its acceptability or it could be to compare two or more products or processes.

We had clearly stated that issues relating to quality control will be examined using case studies or taking up examples of simple processes from the field. The effort will be to carry out exercises that will help in understanding the issues involved and how they are addressed in a quality assurance quality control kind of a framework.

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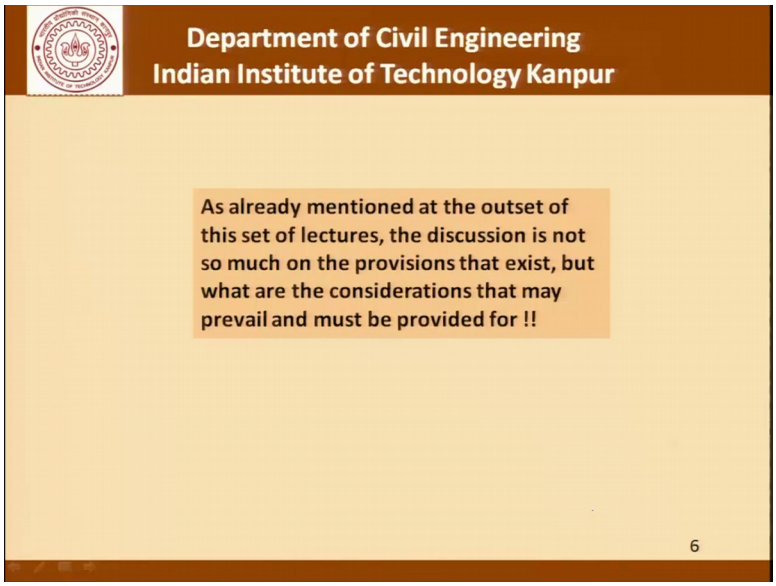

Basically let me remind you that the discussion is not so much about the provision that exists, but what are the considerations that may prevail for those provisions and must be provided for.

So, with this background which is largely a recap of what we have talked about in the last class let us move forward and try to interpret or understand the process of welding, and a issues relating to quality control as far as this very important industrial process is concerned.

Now what is welding?

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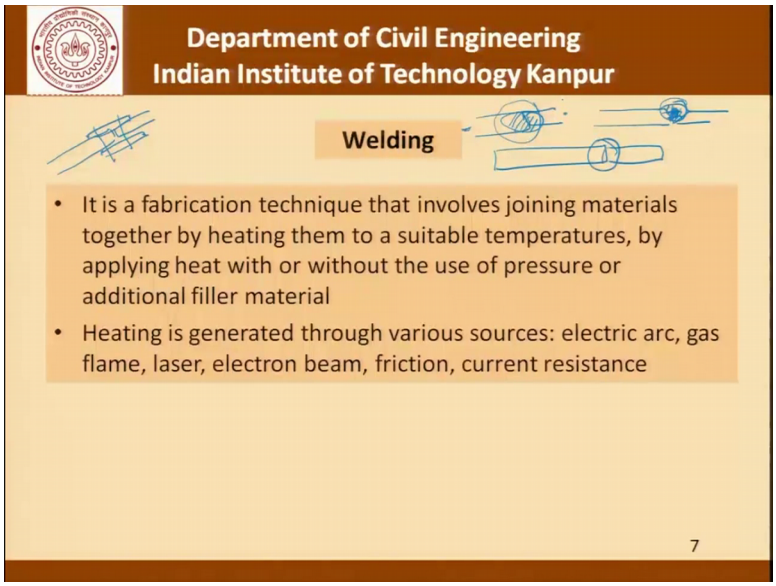

It is a fabrication technique that involves joining materials together by heating them to a suitable temperature by applying heat with or without the use of pressure, and or additional filler material. So, what we are basically doing or what we do in welding is to have these two plates which need to be joined at this place. So, there are different ways of doing it. As far as welding is concerned one of the methods is to create this v here and deposit some material here. And this is basically the welding process.

The other option could be you take two plates; you put another plate on top, another plate on bottom and try to drive rivets or bolts through these joints. So, there are different methods which are used and we are concentrating on welding. So, in certain cases there is an external material involved that is the deposition of the electrode material as we will see later or it could be a situation where the material in these two plates or reinforcing bars or whatever it is fuses and that of course also implies or requires heating at the joint.

What we have to be obviously careful is- if we apply heating here what are the implications of that heating as far as the main body of the material is concerned. Till what point from the joint is the properties effected. Those are the kind of things that go on in the background in the engineers mind when we decide about what technique to use, what are the kind of quality control procedures we will use and so on.

Continuing further this heating is generated through various sources: electric arc, gas flame, laser, electron beam, friction, current, resistance and so on. These are these are

different technologies that have been developed over the years. And we have methods which are available to us. All of them have their own pluses and minuses as far as heat application at the joint is concerned.

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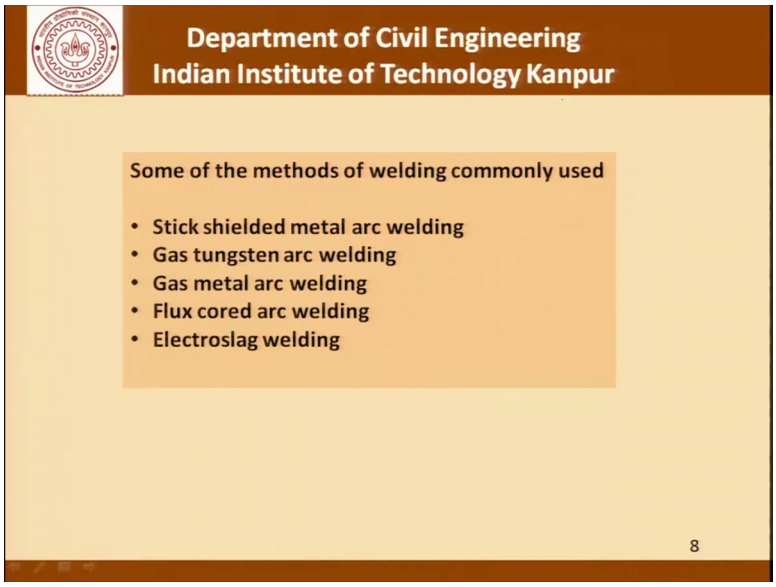

Some of the methods of welding which are commonly used are: stick shielded metal arc welding, gas tungsten arc welding, gas metal arc welding, flux cored arc welding, and electro slag welding.

So, this is of course not a discussion on a not a d type class in welding and we just understand what the physics of the operation is and then move on to quality control issues.

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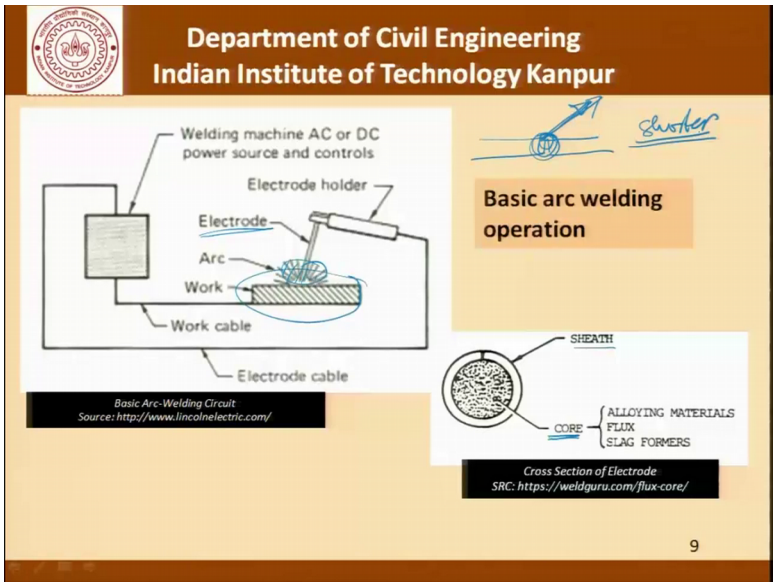

So, this picture here shows the basic arc welding operation. So, as we can see here, this is a work and the way it is shown is that we are trying to do a welding operation let say for these two plates and this joint runs in this direction. This is the region where arc has been generated and heating will take place, and this is the electrode which in detail looks like this. There is a core which is covered by a sheath and this core consists of alloying materials, flux that slag formers and so on. This material from the core gets deposited as we move the arc along the joint.

So now, please remember that is movement along the joint involves the electrode becoming shorter. Basically, what the welder has to ensure is that as he moves the electrode there is a feed that goes in towards the job accounting for the loss of electrode material and it has also to move along the direction of the joint. So, there are two components to the motion of the welder's hand.

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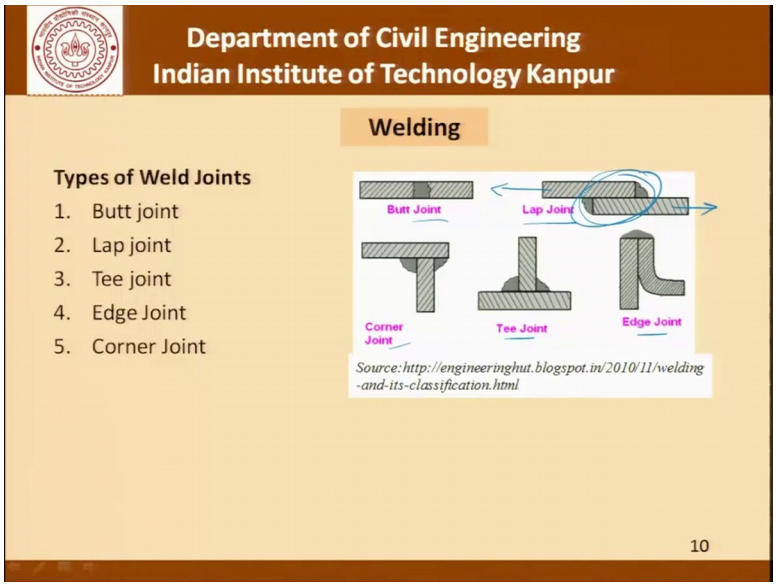

These are some of the common welding types that we use in structure engineering, in civil engineering, butt joints, lap joints, tee joints, edge joints, and corner joints, and you can see how they look like. The butt joint here, it is a lap joint, a tee joint, edge joint, and a corner joint. Of course, as structural engineers we know that if we do joints like this it introduces certain eccentricity as far as a transfer a force is concerned.

So, this portion may or may not remain the way it is and it might deform as far as action of stress is concerned; that is certainly not a major matter of concern as far as we are concerned today.

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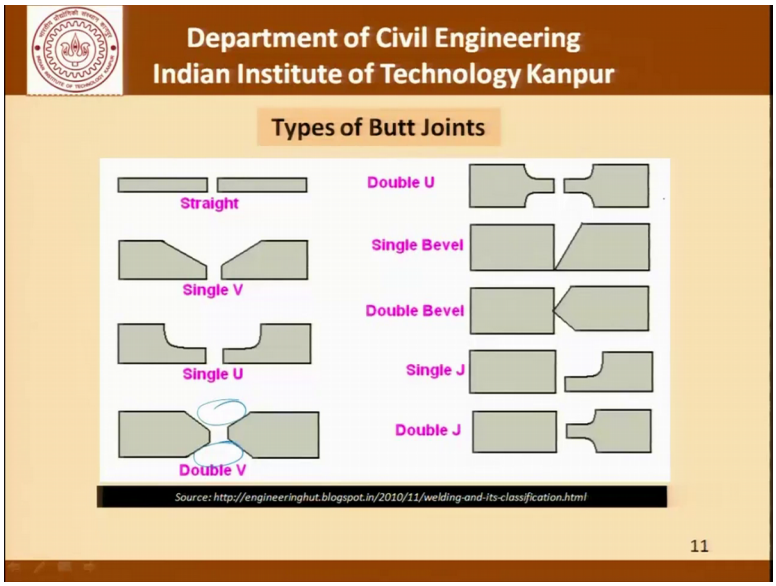

So, moving forwards this picture here gives you the different types of butt joints: single V, single U, double V. So, you can see that we are trying to divide these types of joints depending on how much and where is the material being deposited, and also what kind of edge preparation we do as far as getting the joint ready is concerned.

So, this picture here again on the right hand side shows you the double U, the single bevel, double bevel single j, and double j. And these are used in different forms at different locations depending on whatever structural engineers or whatever designers suggest.

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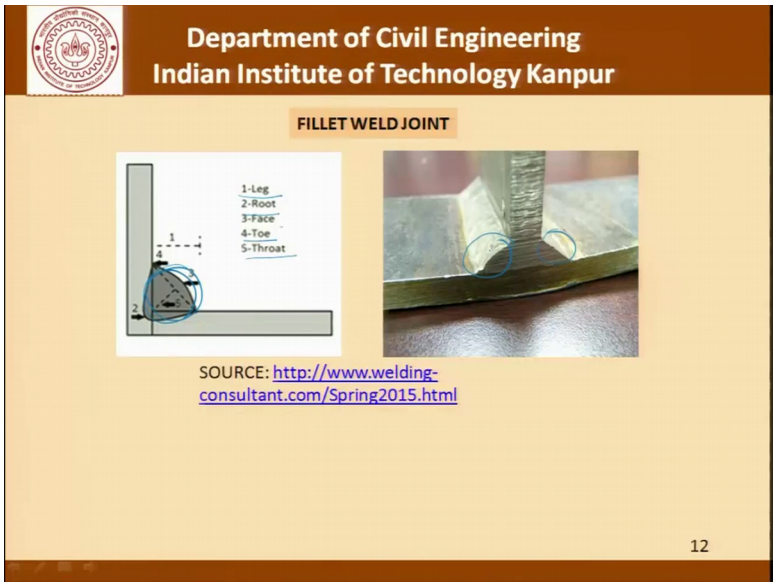

So, this here shows a picture of a fillet weld and we see that this is the material which is been deposited: and in welding terminology we call a leg, root, face, toe, and throat. So, as far as the stress transfer is concerned the structural engineers know as to what kind of stresses act when it comes to a welded area here which will be subjected to shear stresses, and how they are computed, what is the shear strength of the weld, and so on.

So, that is something which is pure structure engineering. But this is something which is important for us to understand even when we go into a quality control issues.

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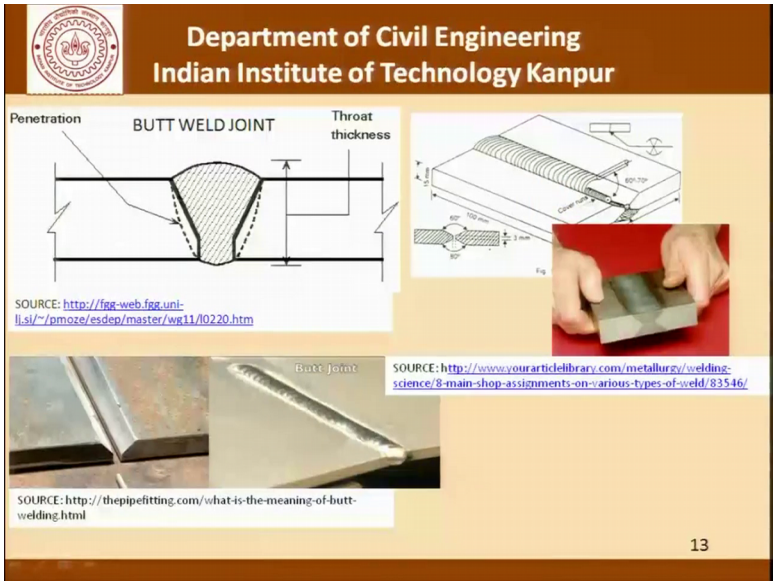

Similarly, there are issues related to the butt welding and this picture here shows a butt welded joint. Similar pictures of butt welded joints are given here.

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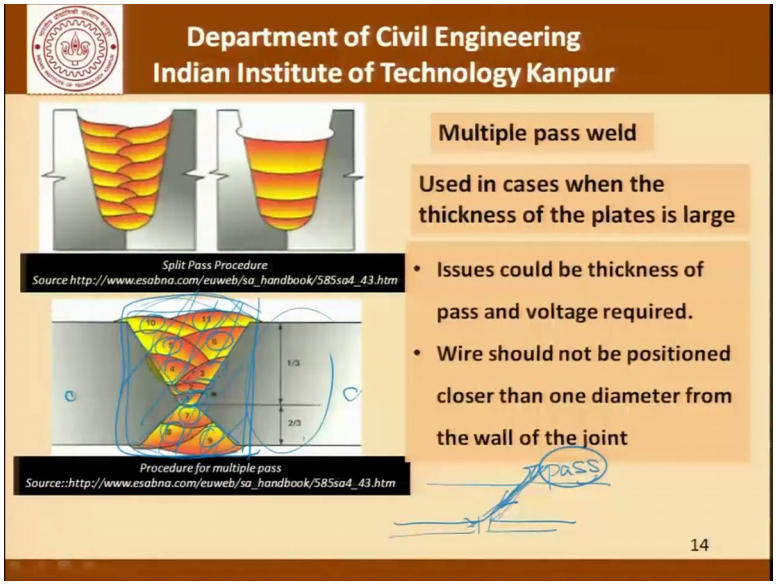

And then I must introduce to you the concept of a multiple pass weld. What this multiple pass weld is it is used in cases when the thickness of the plates is very large and we cannot deposit the material in a single pass.

So if we look at this picture here, we find that I will leave it to you to identify what is the kind of joint that we have proposed here that is we have a joint when the edge preparation has been done like this. And since this thickness is very large the weld material cannot be deposited in a single pass. And therefore, what is being proposed to be done is to deposit material in several passes. What we must remember is- that this picture essentially represents a joint being carried out on a plate which actually looks like this.

So, as we are moving forward this is the kind of edge preparation we have done and we are either going to move this way or we are going to move this way, whichever way is convenient, whichever way it is decided. And as we go in this direction this is what is called a pass. And here what we have is a multiple pass system where the first pass is done, and the second pass is done, the third pass, fourth pass, fifth pass, sixth pass, come back here do the seven eight and nine, then complete the ten and eleven on the top.

So, this is the method by which multiple pass welds are done. And this joint becomes a

monolithic joint for two plates which are shown here. Where the issues involved n this kind of a welding process could be the thickness of the pass; obviously there is a pass thickness which is involved and the voltage required. Depending on the kind of welding that is being done or the kind of conditions under which the welding is being done the welder may choose to set the voltage of the machine. Similarly, the wire should not be positioned closer to one diameter from the wall of the joint.

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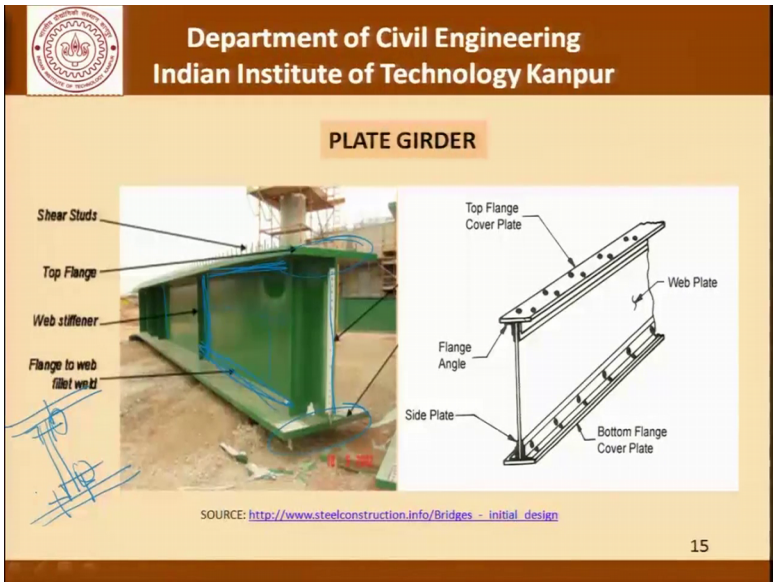

This picture here is that of a plate girder which is very commonly used as far as civil engineering is concerned. We have the bottom flange, the top flange, and the web. And these are stiffeners that we know about that could be a horizontal stiffener here somewhere, but the important this as far as welding is concerned is that the web and the flange are connected through a weld here, the stiffener is connected to the web through a weld here and the top flange is connected to the web plate through a weld here. Of course, if we are not doing a welded connection then we will have to use the web plate like this, your flange is like this and you will have to go through angles to connect the flanges in the web.

So, we are talking about welding is an option. And we will see that remove these connecting members connecting angles also tends to also helps us reduce the dead weight of the structure. Having seen a civil engineering example let see in pipe lines.

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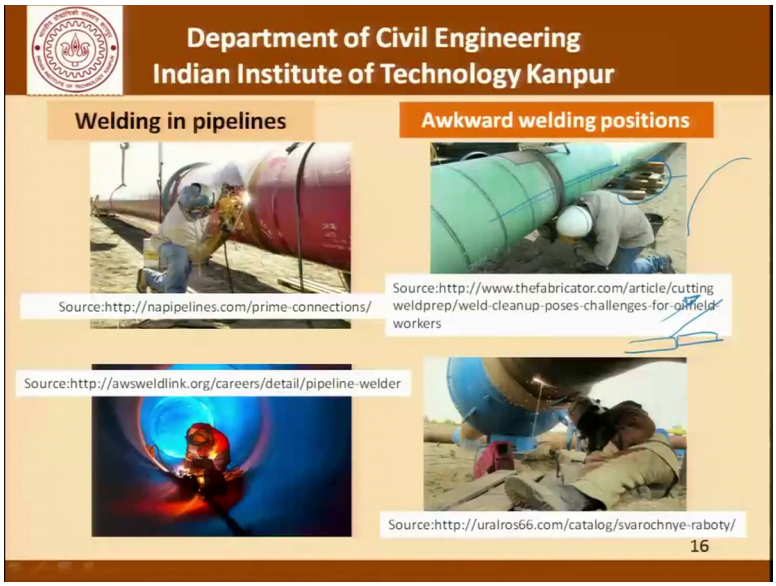

This picture here is one of those examples where a pipeline is being welded. Similarly here the welding is being done inside the pipe; that is the welder is basically working under fairly confined spaces. Continuing this is another picture of a pipe line and we can see these kinds of filler material which is being used or which has been put in place to keep the alignment of the two pipes at a desired level. So, this is something which is very very important to ensure that after the welding has been done there are no residual stresses arising out of misalignment. Continuing with this we have a position here; the welder has to lay down below the pipe and do the welding.

I hope it is clear to you that these welding positions pose a very difficult challenge and call for extra expertise on part of the welder. So, the position of welding is a very very important aspect of the entire welding operation. These are very awkward welding positions. But from an engineering point of view what has to be done, going back to the discussion as far as the feed is concerned you can imagine that in this case the feed has also to incorporate the curvature of the joint; when we are joining plates it is a horizontal plate being joined.

We have talked about this jointing of plates enough and we know that when plates are been joined, basically we are having a pass in this direction, but there is no change in the position of the plate. But in this case the feed has to incorporate not only the consumption of the electrode, but also the change in the curvature of the pipe.

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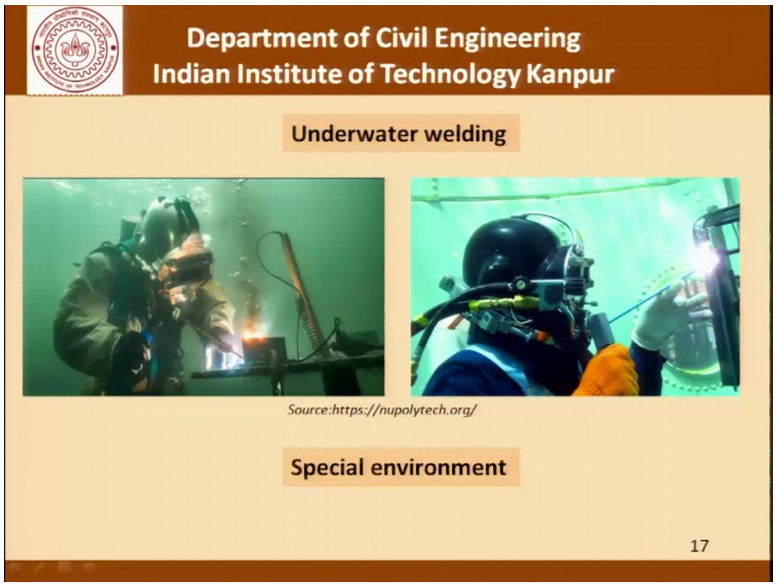

Continuing further, there are very special environments such as under water where sometimes welding has to be carried out.

Please remember that we have talked about the fact that construction operations are not necessarily carried out in green field environment; that is not something which is new. At times construction operations involve repair and rehabilitation of the structures and installations, and in that case work has to be done under very challenging conditions. And this is one of those situations where we are talking about under water welding.

So, it is the technology is already available the technology is not the subject of discussion; the point is to understand and appreciate that what standards we should use, what will be the methods of quality control, we can draw inspiration from environmental welding that is welding carried out under normal conditions and then drop (Refer Time: 14:49) specifications as far as under water is concerned.

I do not mean to say that there are more specifications that exist for quality control of underwater welding. But the subject of discussion today is to create awareness in you on understanding what goes on when creating those specifications or test methods; you should understand the environment, you should understand the conditions, and then try to ensure that in your protocol of doing things all those things are adequately addressed.

Now obviously, quality control has a very important component in non-destructive

testing.

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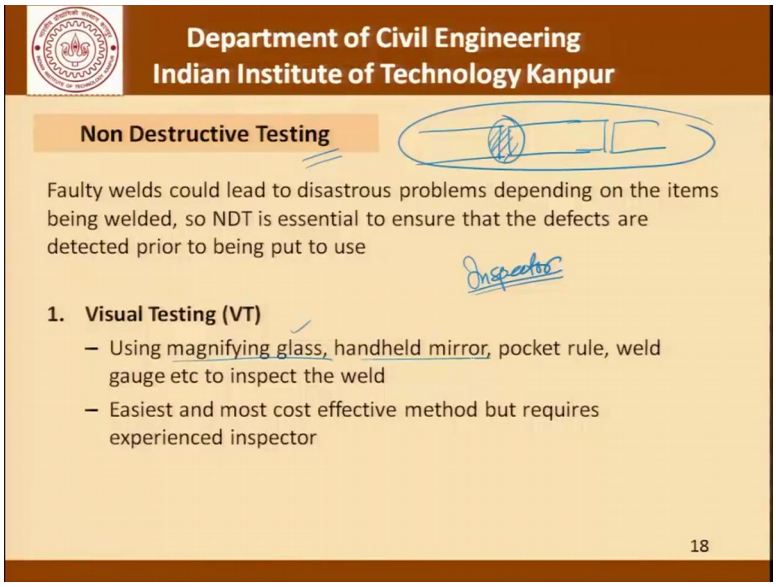

So, even though that is not our subject primarily, but it is interesting and it is important for us to know some of the tests which are commonly used for non-destructive testing of welds. Faulty welds could lead to disastrous problems depending on the items being welded, so non-destructive testing is essential to ensure that the defects are detected prior to the system being putting used.

We must remember that quality control and quality assurance of a larger project has several steps. So, we can talk in terms of a pipeline saying that this is a pipeline saying that this is the pipeline which has these joints. And the first step would be to ensure that this is welded properly. The next step would be that well we will have a pipeline which has let us say several of these joints, and we will test this pipe line as a system as part of our quality control procedures.

So, we will probably talk about another example of pipelines and how we must drop a proper protocol for quality control of a pipeline project, but for the time being let us move on and try to see the different methods which are available.

So, visual testing is one of the most simple and the most common thing that comes to our mind. Using magnifying glass, handheld mirror, pocket rule, weld gauge etcetera to inspect the weld. I would like to draw your attention to using the magnifying glass and a

handheld mirror.

Please remember that this testing is carried out by an inspector. So, the inspector goes to the site to inspect the welds. And this inspection is part of a non-destructive testing protocol. So, what does this inspector do and what are the kind of tools that he has been used to look at the welds. He could use a magnifying glass to see there are any obvious abrasions on the surface and so on.

Then there is a mirror, because sometimes as we have seen when the welder was doing the operation the weld may not be visible to the inspector so easily. So, he has to use a mirror at different places to see the weld. So, there is something like if you see certain security protocols you will realize that if you look at into a car sometimes the bottom of the car is inspected using a mirror which is inserted through a very strange looking contraption under the car.

So, that is how we do visual testing. Continuing with this easiest and most effective method, but requires a very experienced operator.

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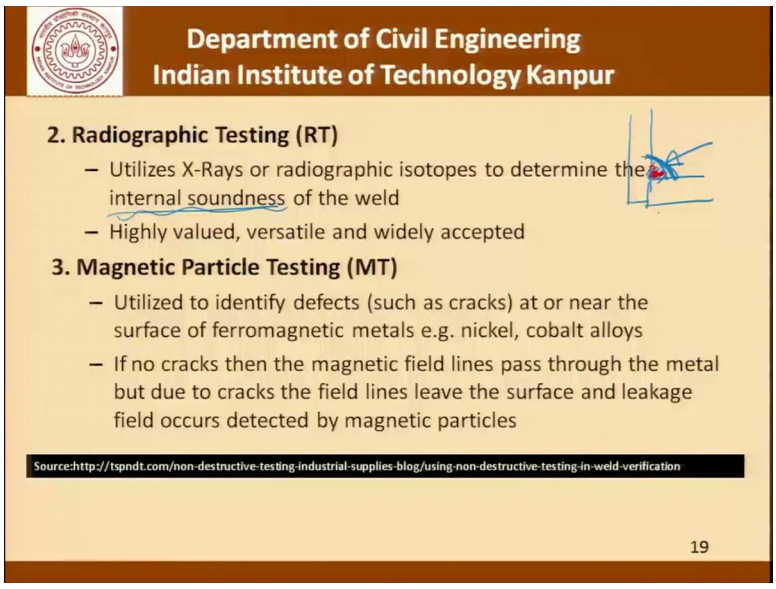

Coming to the radiographic testing which is the next step utilizes X-Rays and radiographic isotopes to determine the internal soundness of the weld. Now here we are talking about internal soundness which is simply not possible to inspect through a visual inspection. If we recall the picture of a fillet weld for example or it could be any other

weld what we have is a deposit of material here. Now visual inspection can help us do any kind o inspection on the surface. When it comes to internal soundness whether there are some defects or voids which have been trapped inside the weld which is quite possible in the case of multi pass welding that requires something like a radiographic testing.

There is highly valued versatile and widely accepted as the test method in welding. Magnetic particle testing is another method and it is utilized to identify defects, such as cracks at or near the surface of ferromagnetic materials, like nickel, cobalt, alloys. If there no cracks then the magnetic lines pass through the metal, but due to cracks the field lines leave the surface and the leakage field occurs and that is detected by magnetic particles.

So, these references that are given at the end of this slide; those of you are more interested to go to some of these references and try to understand the physics, and how these methods actually operate.

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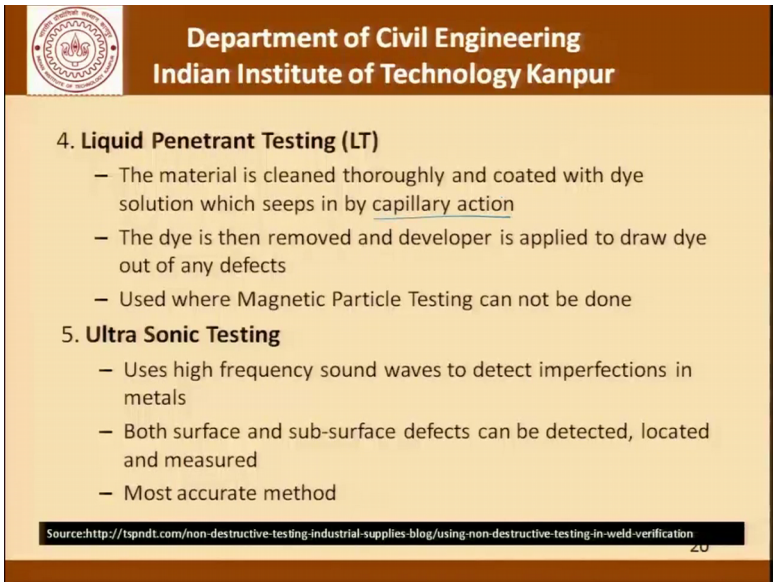

Next in the line of testing of welds is liquid penetrate testing which is called LT. The material is cleaned thoroughly and coated with dye solution which seeps in by capillary action. Here again we are trying to understand if here is any capillary action as a result of pores or defects in the weld. The dye is then removed and a developer is applied to draw the dye out of any defects and used where magnetic particle testing cannot be done.

There is an ultrasonic method for testing of welds; and uses high frequency sound waves to detect imperfections in the metals, and both the surface and subsurface defects can be detected located and measured and it is a fairly accurate method. This again is the reference which has been used to put this material together on these testing methods.

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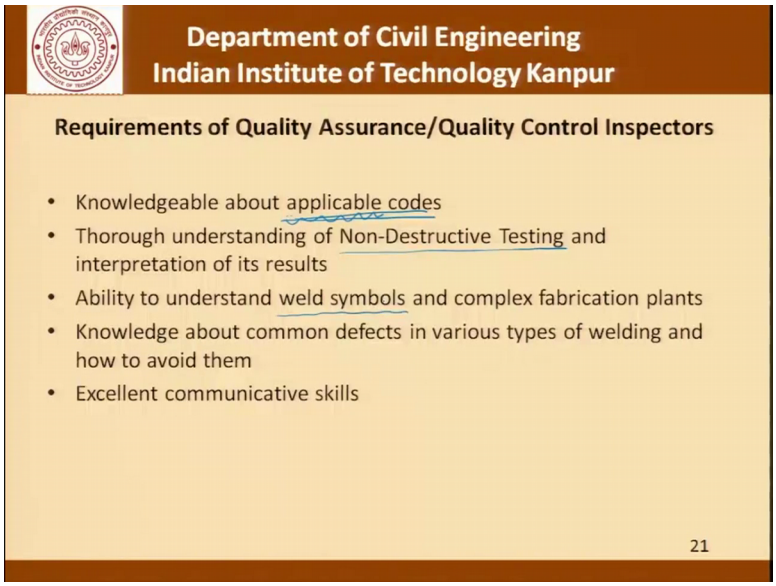

And now, I think we have prepared enough ground to understand the requirements of quality assurance, quality control inspectors. What is the background that the instructor must have in wanted to be able to carry out a fair and a thorough inspection of welding works? Obviously, knowledgeable about applicable codes: it is obvious that there are applicable codes or there will be applicable codes what we have insisted in doing today is to not go into the coral provisions. If you in fact go through this discussion that we are having today and then read the codes you will find that the codes actually address some or all of those issues which are being talked about.

So, an inspector must know what codes are applicable in a particular case. He should have a thorough understanding of the non-destructive testing and interpretation of its results. Non-destructive testing is like a pathological tests and it is the physician who has to interpret it. Somebody who carries out the test is carrying out the test as given by the manufacturer of that testing equipment.

What are the limitations of that test? How the test should be actually interpreted is being left to the inspector; and that something which the inspector and the engineer must really

understand. Ability to understand weld symbols and complex fabrication plants; we did not get into it, but there are all kinds of symbols which are available which are used in drawings to indicate the different kind of welds.

And the first thing that has to be seen is whether the welding has been done as prescribed by the designer or as required by the designer and given on the drawing. So in fact, the drawing itself also gives a very important clue as far as the quality of design that has gone on as far as welding is concerned. Knowledge about common defects in various types of welding and how to avoid them: so the inspectors job is also sometimes to educate the welders and tell them what kind of precautions can be taken so that a particular defect is avoided. An excellent communicative skills: is just a soft skill which all inspectors must have as a matter of a all engineers must have.

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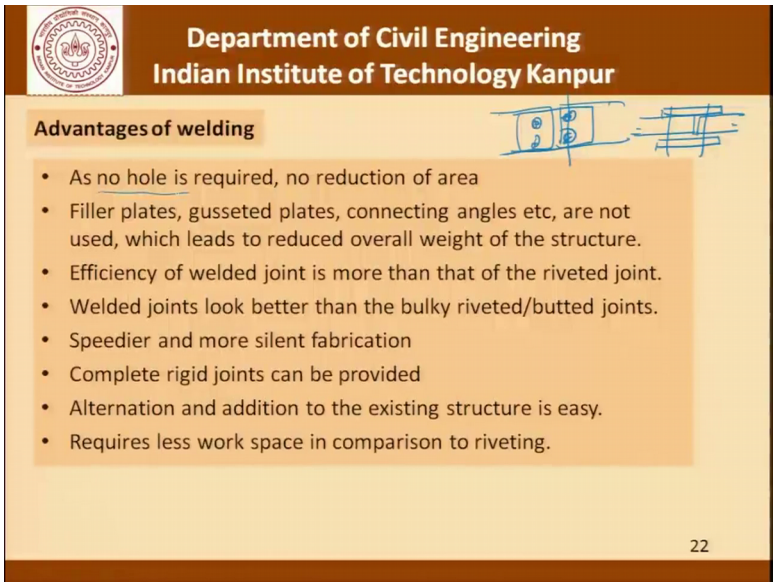

Now, before we go into the disadvantages let us first go through the advantages of welding which will put a lot of our discussion in prospective.

As no hole is required there is no reduction in area. We talked about the fact that we want to join two plates and we make wholes in these plates in order to put a plate and then we are going to use rivets or bolts. What I am trying to show you is a situation something like this, where there are these two plates being jointed through rivet or bolts. These holes reduce the cross sectional area of this plate and that is what is something which a structural engineers are not happy about, they would like to avoid that. And therefore,

welding comes to a rescue and we can make do without any hole been drilled into the plates.

Filler plates, gusted plates, and connecting angles are not used, and that leads to a reduced overall weight of the structure. The efficiency of a welded joint is more than that of a riveted joint. Welded joints look better than the bulky riveted or butted joints. Speedier and more silent fabrication; those of you had some experience with realize that riveting and bolting is a very noisy operation sometimes and welding is relatively more silent and of course it is faster.

Complete rigid joints can be provided, alterations and additions to existing structures are easy, and required less work space in comparison to riveting.

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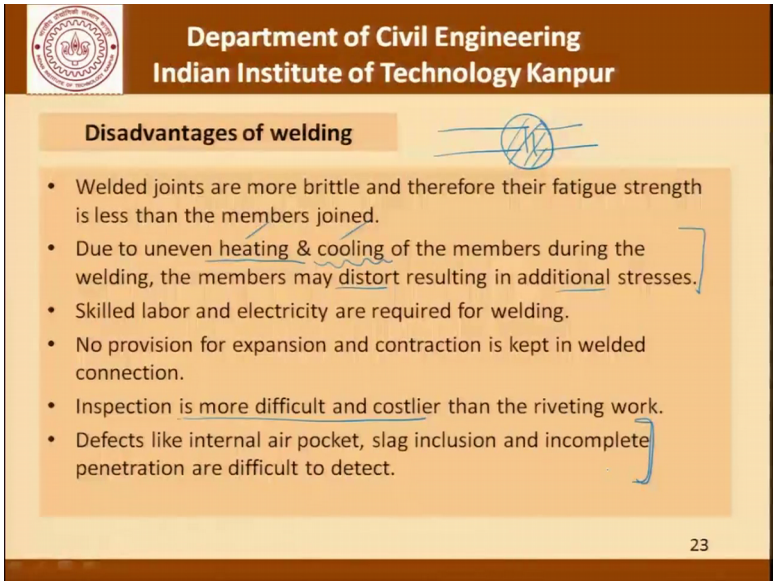

Now, having said that; what are the disadvantage. Welded joints are more brittle and therefore their fatigue strengths is less than the members jointed, and that something which we are aware of and the designers keep that in mind when they prescribe welding.

Due to uneven heating and cooling of the members during welding, the members may distort resulting in additional stresses. There is heating of the joint. So, if you have this plate being joint with this plate we have already talked about the fact that this area will get heated; now obviously, if there is a heating the joint will also cool. And this heating and cooling at this location could result in distortions and additional stresses. Both these

aspects heating and cooling in certain cases need to be addressed through pre heating of the joints and ensuring that the cooling happens at a certain rate.

A skilled labor and electricity are required for welding. No provisions for expansion and contraction is kept in welded connections. Inspection is more difficult and costlier than that of riveting works. This is actually the bottom line as far as quality control and quality assurance procedures in welding is concerned. Defects like internal air pockets, slag inclusion, and incomplete penetration are difficult to detect. And that is why we need very very thorough inspection procedures which are the only way to ensure good quality construction.

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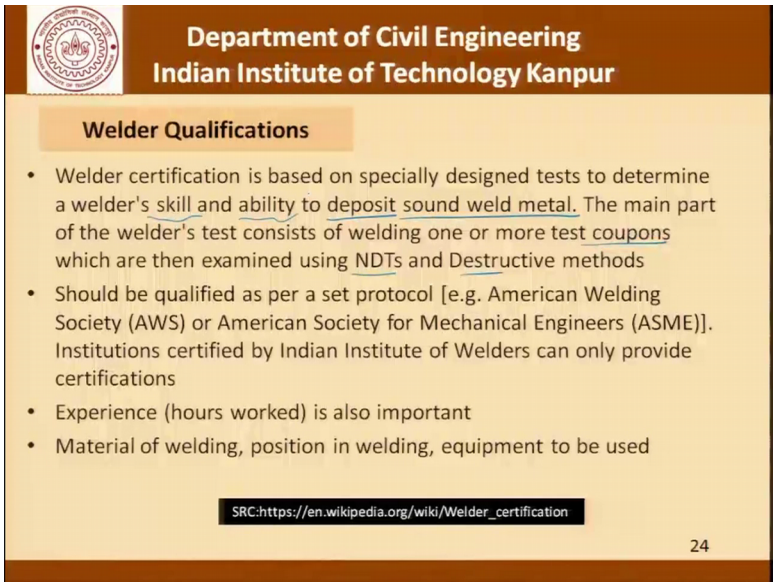

Now, the first thing that I would like to take up from the point of view of quality control is give you an insight on welder qualification. Welder certification is based on specially designed tests to determine a welders skill and ability to deposit sound weld metal. The main part of the welders test consists of welding one or more test coupons which are then examined using non-destructive tests and destructive methods. So, there are coupons and there are tests non-destructive and destructive to make sure that the welder has indeed deposited sound weld metal in the joint as was required. And this is the test for the welder's skill and ability.

The welder used at site should be qualified as per a set protocol. I have listed American Welding Society the AWS or the American Society for Mechanical Engineers which is

ASME, but it need not be American society it could be any society which is acceptable to the clients. But the idea is that not everyone should be allowed to weld, a site is not a training place when you come to the site it is a professional job the training has to happen somewhere else and you should have or the welder should have a proper certification which has been issued or which has been granted by a authority or an institution which is mandated for that purpose. It could be a certificate issued by the Indian Institute of Welders or any such professional organization.

Experience in hours is also very important. One might require that in this particular job we would like to have experienced welders, it is like having experienced pilots. So, once you move from one category to another you have to put in certain hours of flying. In the same way here we have to put in a certain amount of hours of welding before you can say that yes I am an experienced welder and I can do more challenging job. The welder should understand the material of welding, position in welding, and the equipment to be used.

We can talk about horizontal, vertical, curved surfaces, over head and so on. So, the welder has to be competent to be able to do these things. There is of course the possibility that a welder is not qualified for over head welding, but is good enough for horizontal and vertical welding. So, be it the certificate should. So, it is like the driving license you may be able to drive a two wheeler, but not a four wheeler; a normal light vehicle, but not a heavy vehicle. So, your license or your certification should clearly say what are the conditions in which you have been tested, what are the kind of jobs that you are qualified to do.

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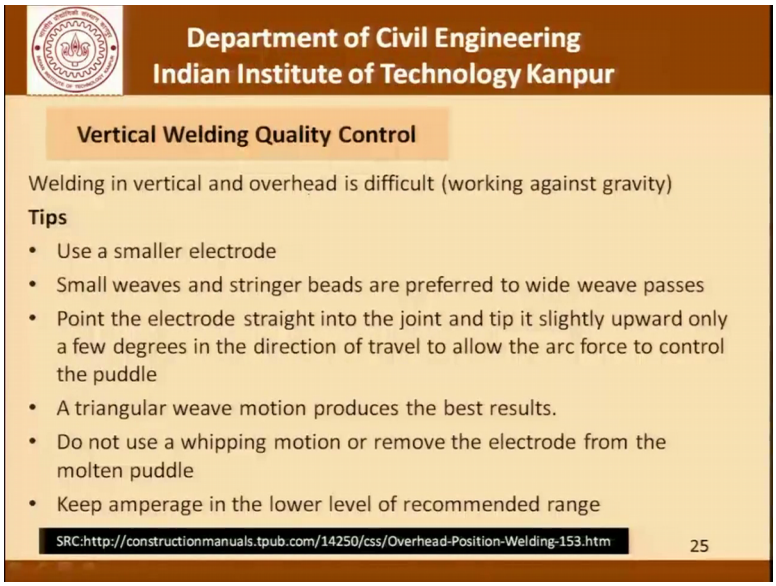

Now, a few tips on vertical welding quality control. Vertical and overhead is difficult because we are working against gravity. So, some of the tips that experienced welders tell us is use a smaller electrode. Small weaves and stringer beads are preferred to wide weave passes. Point the electrode straight into the joint and tip it slightly upwards only a few degrees n the direction of travel to allow the arc force to control the puddle. A triangular weave motion produces the best results. Do not use a whipping motion or remove the electrode from the molten puddle. And keep amperage in the lower level of recommended range.

So, these are some of the tips which are available as far as experienced welding is concerned.

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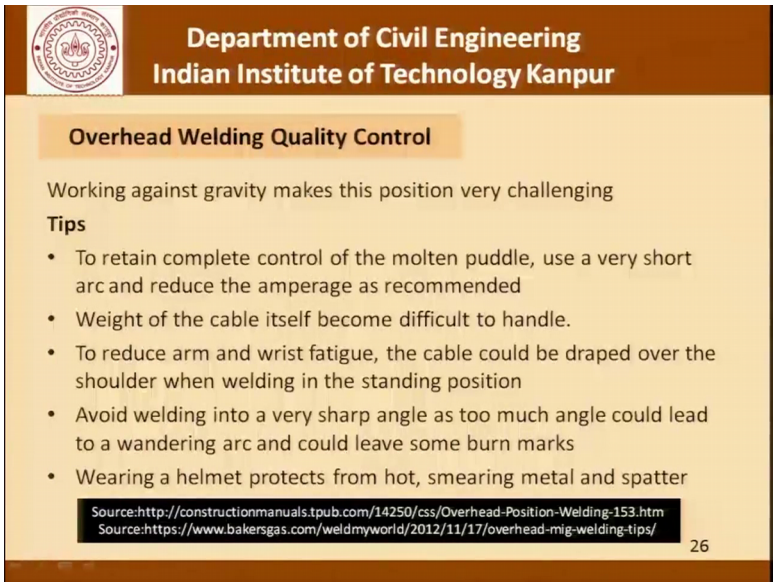

Going forward with over head welding quality control it again is one of the most challenging positions working against gravity. And here the tips are more less similar to retain a complete control of the molten puddle, use a very short arc and reduce the amperage as recommended. The weight of the cable itself could become difficult to handle; if you are doing overhead welding and to reduce arm and wrist fatigue he cable could be draped over the shoulder when welding in a standing position. Avoid welding into very sharp angle as too much angle could lead to a wondering arc and could leave some burn marks wear a helmet because that is the way your head is protected against any smearing metal or spatter.

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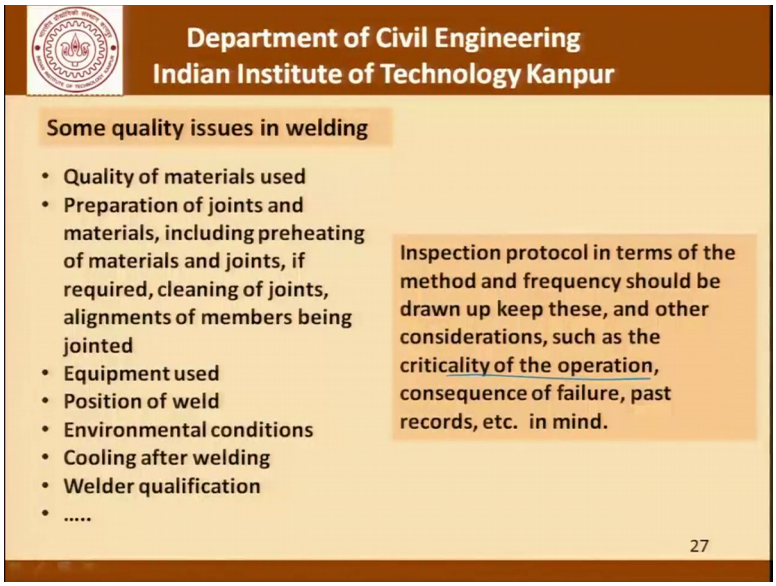

What are the quality issues in welding? Quality of the materials used, whether it is a electrode or their job. Preparation of joints and materials including pre heating of materials in joint if required, cleaning of joints, alignment of members being jointed. Equipment used for the purpose, position of the weld environmental conditions, cooling after welding if required welder qualification and so on.

And all this has to be kept in mind when we are developing an inspection protocol in terms of the method and frequency. Also other considerations such as the criticality of the operation, consequences of failure, past record etcetera should be kept in mind. We must also keep a meticulous record of all welding operation at site; that becomes very very handy in case of any referral which is required after the operation has been carried out.

The records must clearly indicate the number of the weld, the welder who carried it out, what were the qualifications of that welder who carried it out, what were the conditions that were prevailing when the welding was carried out, and what if any for the test that were carried out at that particular joint.

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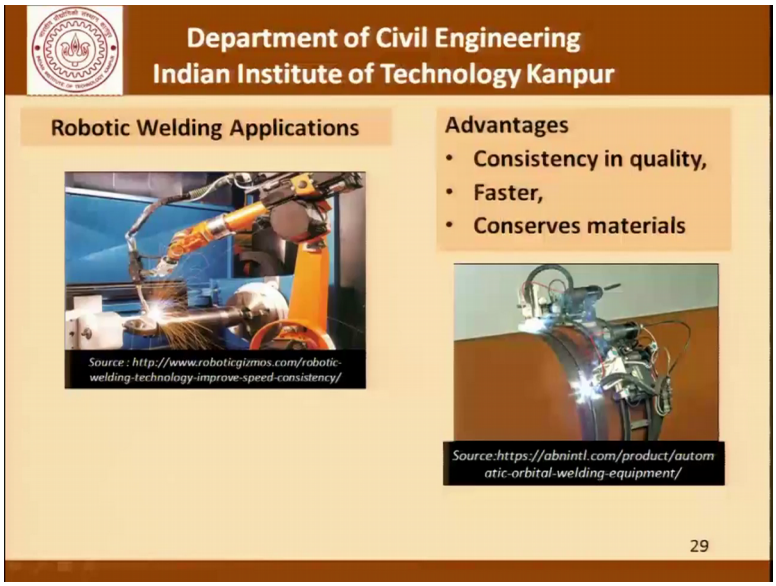

So now, before I conclude the discussion today on this welding let me also show you some pictures of robotic welding applications were we have basically eliminated the use of a welder. The human intervention has been removed, and that gives us consistency in quality, faster, and it conserves material.

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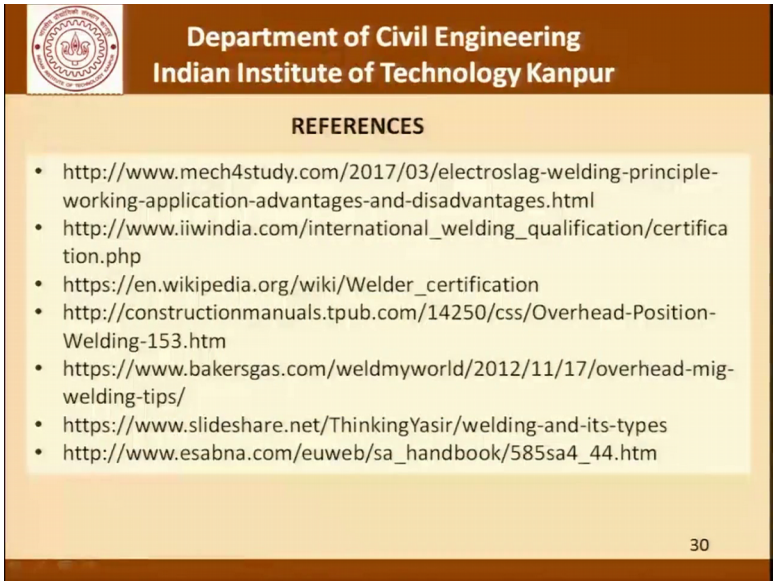

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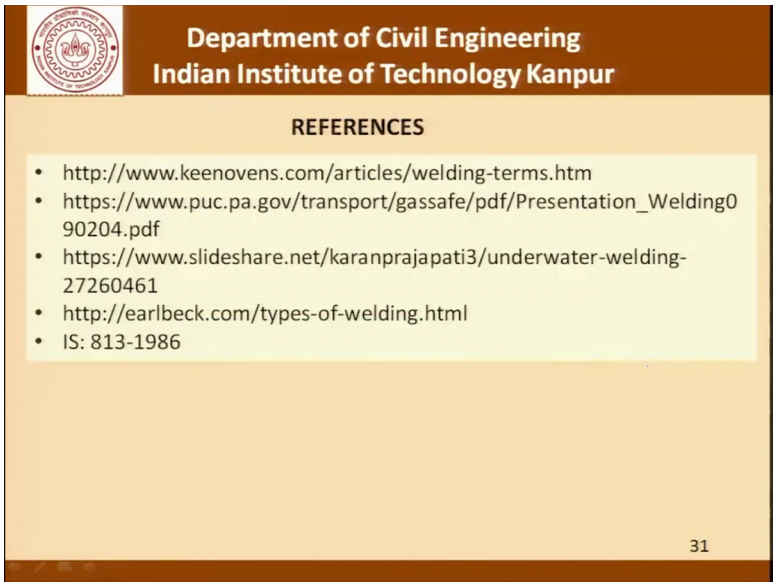

With this let me give you a list of references, which I have used and you may find relevant to understand the whole operation a little better. And I look forward to seeing you in another case study on quality operations in construction projects.

Thank you.