Course on Design of Steel Structures
Prof. Damodar Maity
Department of Civil Engineering
Indian Institute of Technology Kharagpur
Mod 02 Lecture 09
Weld Connection

Hello, in today's lecture am going to discuss about the weld connections, before design of weld connections, I will discuss little bit about the advantages and dis advantages of weld connections, as we have seen, in case of bolt connections, there are certain advantages and disadvantages and according to the requirement of in the filed we have to choose a certain type of connections. Now the design methodology of bolt connections basically two type of bolt. One is bearing type of bolt and another is high friction grip bolt. The two type of bolt has been designed and certain number of examples have been worked out. Now in this lecture will first discuss about the weld connections, weld is basically a process of joining metals, metal pieces by the application of heat and with or without pressure.

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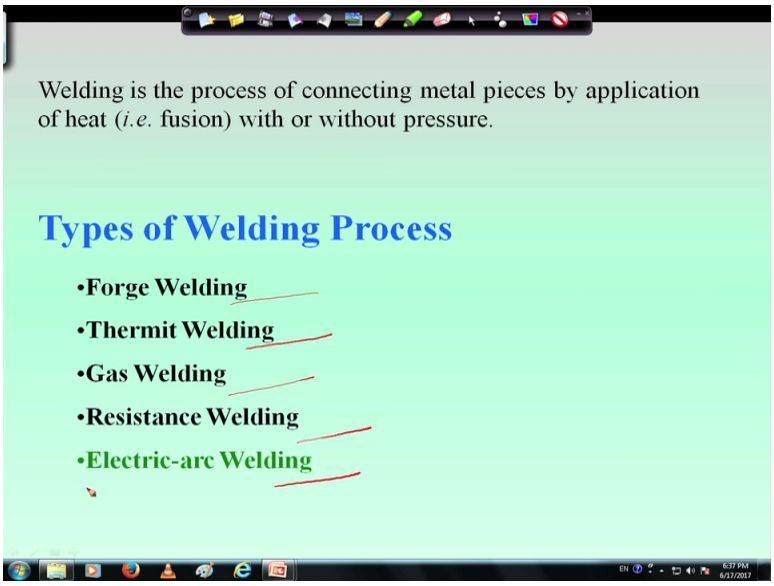

And different process of weld connections are there as we see that is forge welding; one is forge welding, then thermit welding, then gas welding and resistance welding and then electric-arc welding. Nowadays the electric arc welding is a most popular type of welding has been seen in today's market.

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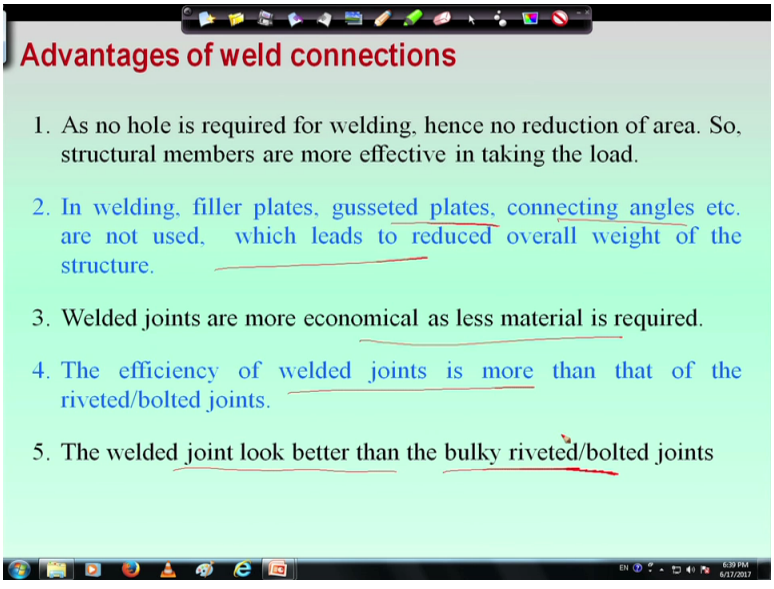

Now coming to weld connections, let us see first the certain type of advantages what we get, first is as weld connection does not need any hole in the plate. So there should not be any reduction of area that means the structure members are will be more effective to take the load. Second is the, in weld connection filler plate, gusset plate, connecting angles etcetera are not used that means

the total weight of the joint will be less in such cases. Now weld joint should be economical as less material are required.

So these are the certain advantages. Another advantages is that efficiency of weld joint is more than that of the riveted or bolted joint, because why is the efficiency is more, because when bolt connection or riveted connections are used we create hole and because of creation of hole the net area, net effective area of the plate is going to be reduced and this area under tension will be less and therefore, the capacity or strength of the bolt joint will be less compared to the weld joint. Therefore, the efficiency of weld joint will be comparatively more than the efficiency of the bolt or rivet joint.

Now another advantage we look that the weld joint look better than the bulky riveted and bolted joint, we have seen that if we want to make a particular shape of the joint we can make by the weld joint, but in case of bolted joint or riveted joint it will look bulky, because of extra bolt and bolt or rivet will be added.

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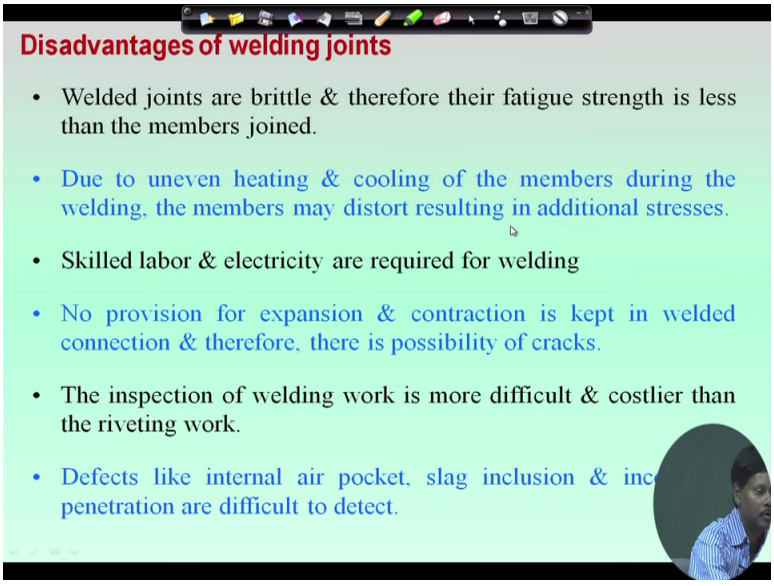

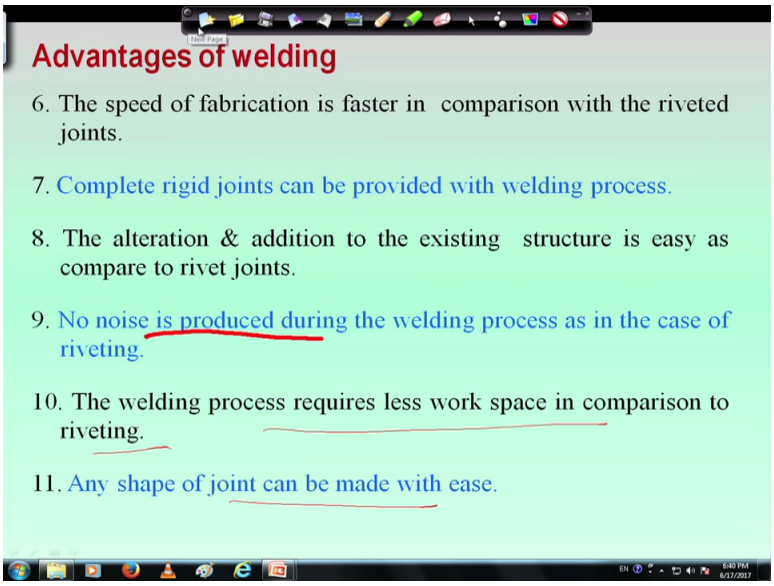

Another advantage is the speed of fabrication. In case of weld joints, speed of fabrication will be much faster than the riveted joint and complete joint means complete rigid joint can be achieved through weld process. In case of bolted joint complete rigid joint we cannot achieve, but in this case we can make it. Then alternation and addition of the existing structure is easy as compared to rivet joint, because rivet joint is permanent in nature, it is difficult to add or alter the existing structure.

Now another important advantage we got that no noise is produced during the welding process as in case of riveting process and also, the welding process requires less work space in comprising to rivet and any shape of joint as I told earlier can be made with ease. So these are certain advantages we obtain in weld joint however, it is note that all advantages we will get there is no disadvantages we will get disadvantages also.

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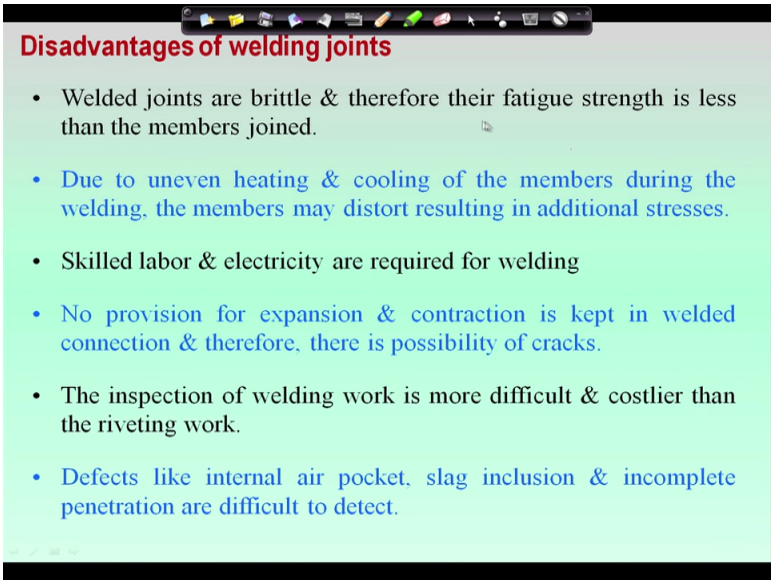

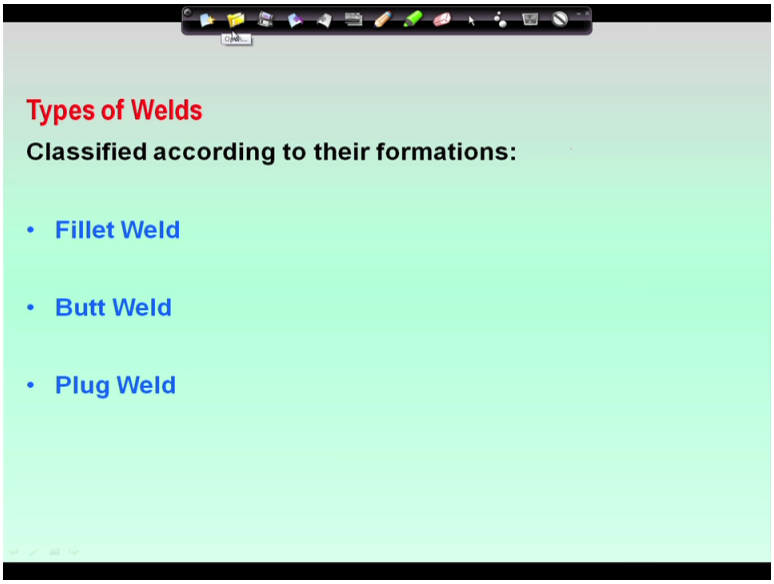

In case of welded joint, these are brittle in nature and as a result the fatigue strength is less fatigue strength is less.

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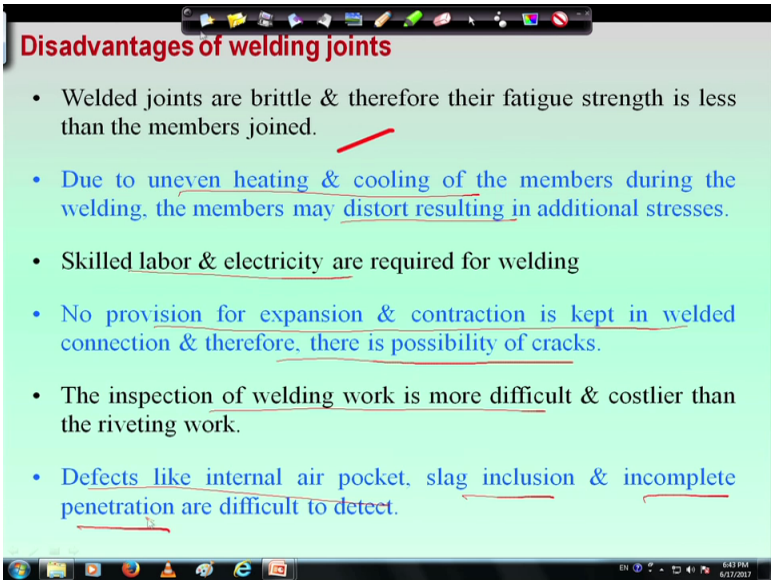

Now let us come to the disadvantages of weld joints. Weld joints are basically brittle in nature and therefore, it is means its fatigue strength will be comparatively less. This is one disadvantages and another disadvantage is that due to uneven heating and cooling of the member during the welding the members may distort resulting additional stresses. So distortion may come and because of distortion the additional stress may come into picture. Then another disadvantage is we need skilled labor and electricity for welding say fore example, if we want to construct a structure at the remote place where electricity is not there, in that case, it would be difficult to go by the weld joint.

So in that case, it will be better if we go for bolted joint etcetera. So this is another disadvantage. Then there is no provision for expansion and contraction is kept in welded connection and therefore, there is a possibility of cracks. So cracks may develop because of this and inspection of weld work is more difficult and costlier than riveting work and another disadvantage is the defects like internal air pockets, slag inclusion, incomplete penetration are difficult to detect.

So while (())(06:40) we are going for maintaining the joint year after year when we go for inspection for weld joint whether is there any defect or not, it is very difficult to detect that, because of presence of internal pocket air pockets and other (())(6:56) etcetera, it will be difficult and therefore, the stress strength of the weld joint will be comparatively less, because of presence of the air pockets. So this is difficult in case of weld joint.

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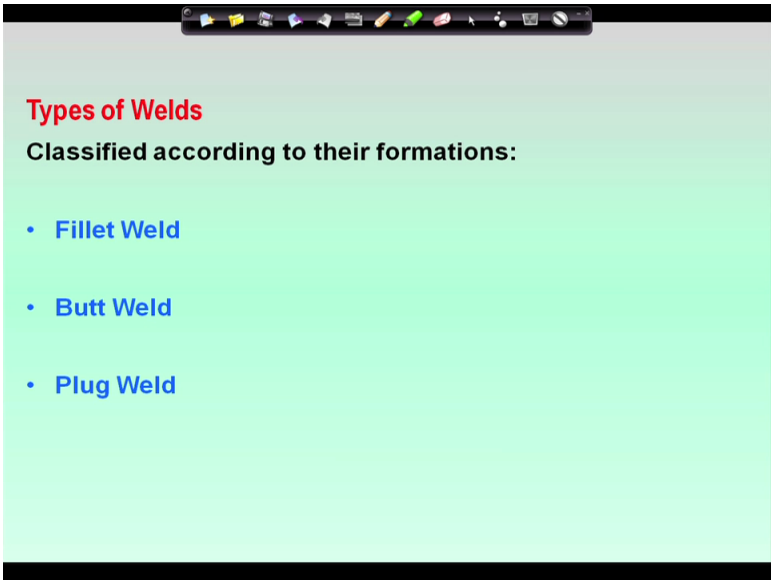

Now coming to type of weld, there are three types of weld we have, one is fillet weld. Fillet weld basically used when 2 members are lapped together.

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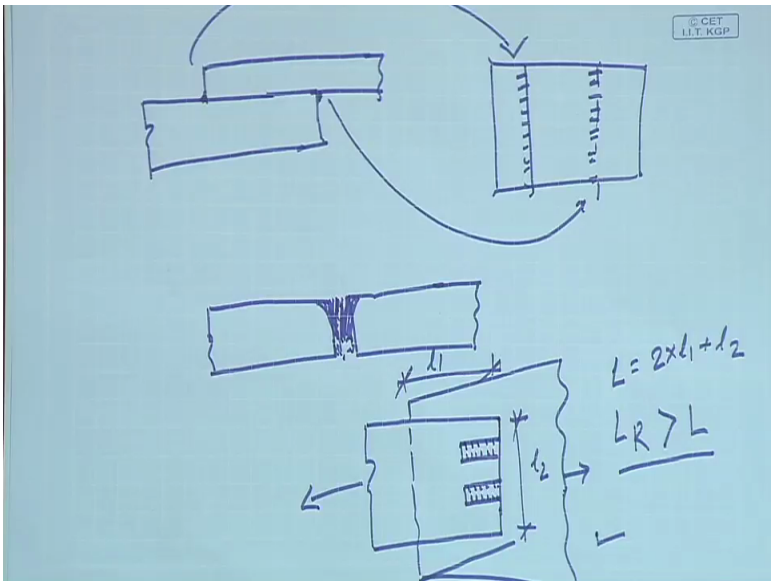
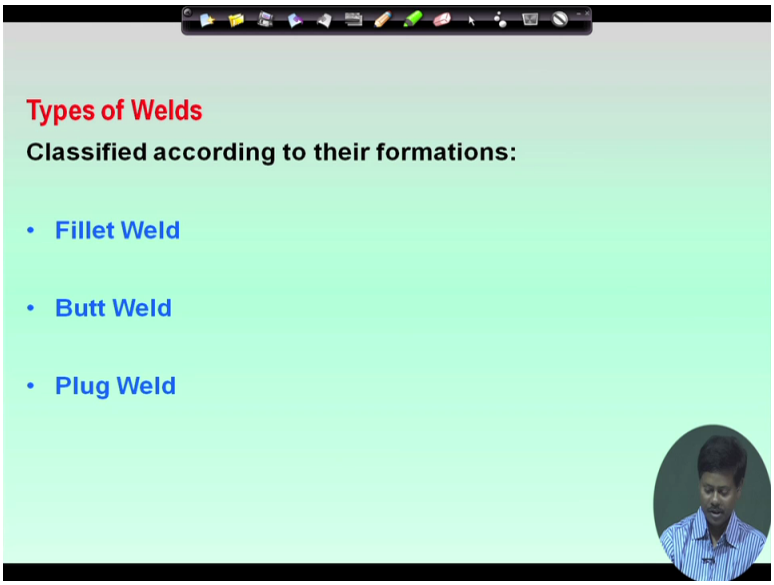


Let us come to here suppose 2 members are there and these are overlapped then when we are going to join this we need to join at the overlap portion and if we see in that plan we will see that these are say, these are welded. So this portion is this and this portion is this. So this type of welding is called fillet weld (())(8:10) means when 2 members are lapped together, 2 members are to be joint, in that case fillet member we can use and in case of fillet weld or I should say that

in case of 2 members joint in a different plane then fillet weld can be used. Butt welds we can use when the 2 members are joint in same plane, suppose this is a member and this is another member we will be joining in same plane.

So in this case we can provide butt weld and we can filled with weld material and it may have complete penetration, it may have incomplete penetration, different type of butt welds are there, I will come in across later and according to the process of penetration the throat thickness of the weld will be defined and the strength will be carried out means strength will be calculated in that way.



Another type of weld is plug weld, the plug weld is required when a plug weld is basically is a type of fillet weld that is necessary when two members are connected together having a limited length of the joint, say suppose one members is like this and another member is connected, right and we have limited length, limited length means here if we see that length is this much say, this is l1 and we will get this is l2, so total length will be available length will be here 2 into l1 plus l2, total length and suppose the force is the force along the joint is so high that the required length LR requirement of length l is much more than the available length. So in this case what will happen?

We have to adjust the total length in between, so what we can do we can make a slot here we can make some sort of slot here and we can provide way. So in this way we can increase the length

of the weld joint by the insertion of slot. So this is how one can make adjustment of the additional length with the insertion of slot. So these are the 3 types of weld we will come across.

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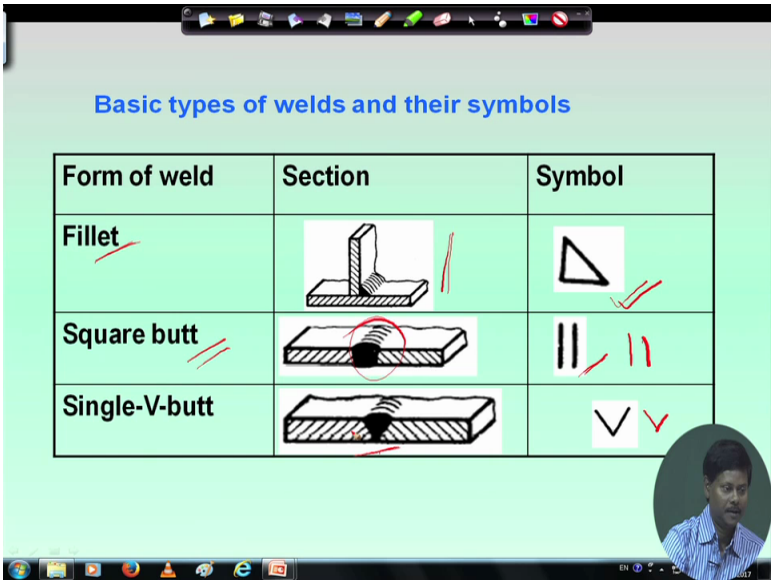

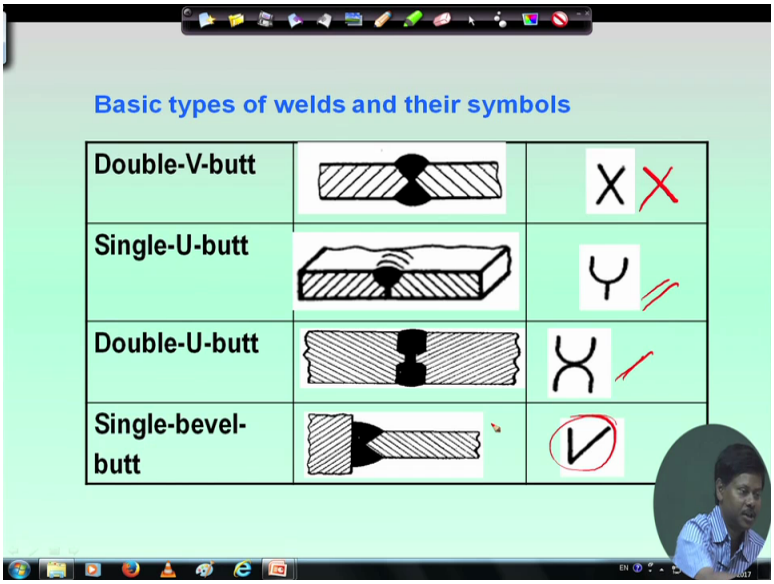

Now I will quickly show some basic type of welds and their symbols, symbols means in drawing we can draw this, we we will to be able to draw this in the drawing, so what we do we use sub-symbol that means if we use certain symbol like this, then it means that this fillet weld. Similarly regarding butt weld if a square but weld is jointed means if a square butt weld is used then in the drawing we use this parallel line 2 parallel line. So that means when parallel line is there that means we understand that this is a square butt.

Similarly, single V butt joint, if we write V that means it is a single V butt joint where joint will be like this, again if we come to double V butt joint it will be like an X when joint is single U butt we will make a symbol like this. So in case of double U butt joint, its symbol will be like this. In case of single V butt joint means its symbol will be this. So different symbols we use for different type of weld in the drawing sheet, so we have to know that what symbol are given in the drawing and what does it mean.

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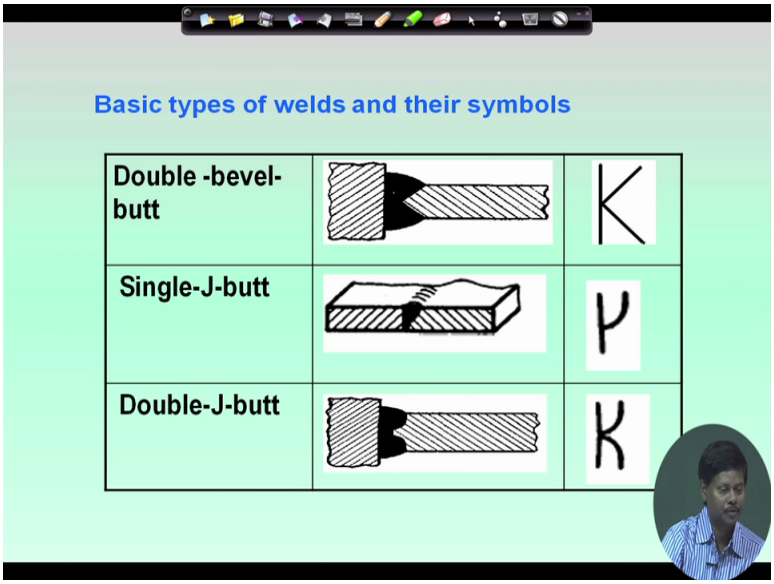

Similarly double V, double-bevel-but joint, single-j-butt joint, double-j-butt joint we can also use in terms of its symbol.

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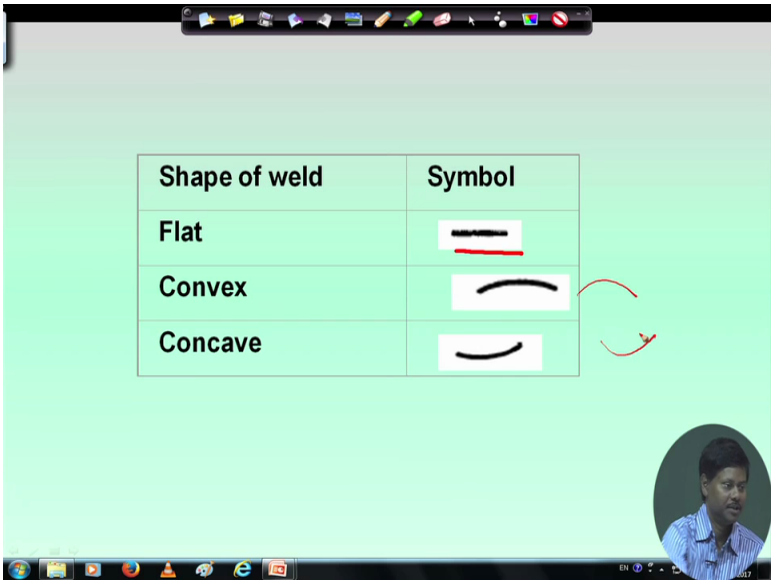

Now shape of the weld when it is flat, its symbol is like this, and when convex, its symbol we use like this and when concave we will use symbol like this.

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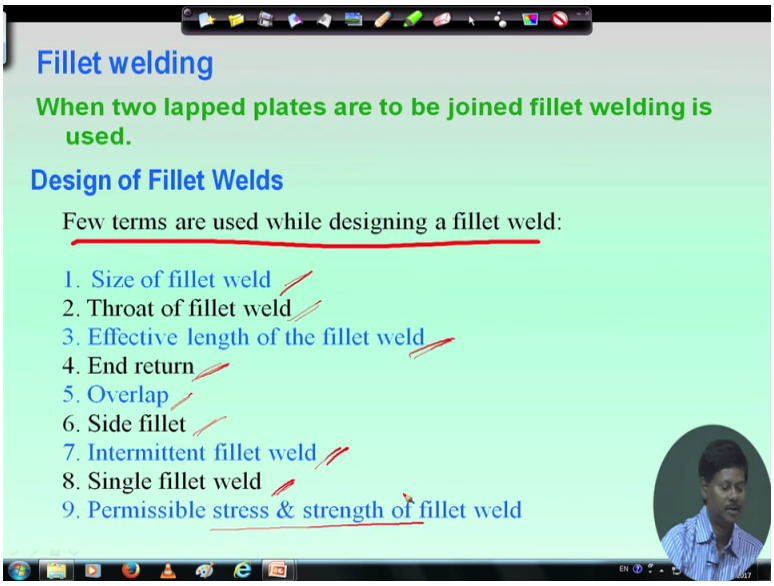

So coming to fillet weld we have seen 3 type of weld, we use, one is fillet weld then butt weld and then slot weld. So first we will discuss the fillet weld, its different parameters then we will see the design methodology for fillet weld joint then we will go for butt weld joint and finally we will go for slot weld joints. So in case of fillet weld as we know that when two lapped plates are to be joined fillet weld is generally and in case of fillet weld we know that this terms will be

used in case of fillet weld. Say what is size of fillet weld? How do we define the size of fillet weld? This we will discuss then what is throat of fillet weld, throat and or throat thickness of that fillet weld, then effective length of fillet weld, we know the length of fillet weld, but what is the effective length?

Then another term we will use end (())(14:17) end return, then overlap, then side fillet, intermittent fillet, single fillet weld and permissible stress and strength of fillet weld we have to find out what is the permissible strength of fillet weld. So these terms we will be frequently used in case of fillet weld design. So we need to know one by one about the term of this means terms of fillet weld different terms of fillet weld.

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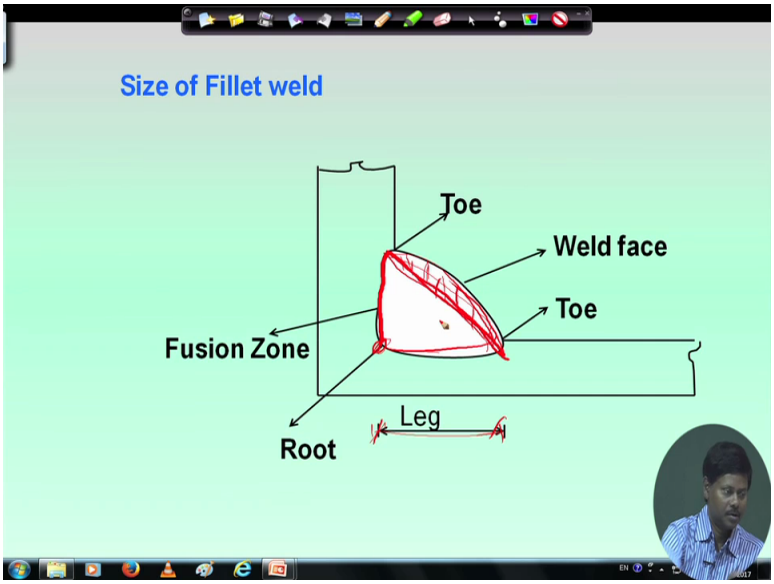

So I was (())(14:52) about to tell that means, I was telling the size of the weld. So if we see here that the two, members are joined together and by the application weld (())(15:07) of it then this will be the fusion zone where the members are joined. Now this is the portion, which is called root. So from root to toe the length is called leg and this will be the size of the weld this leg and this is a weld face and we will see that some extra deposit are there means if we make a straight line from this toe to this (())(15:36), we will see this is the extra deposit which is call enforcement (())(15:41), right.

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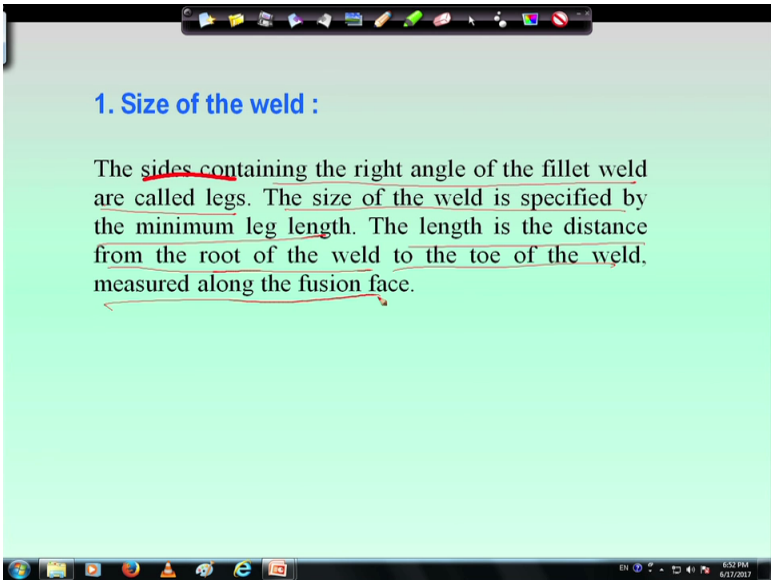

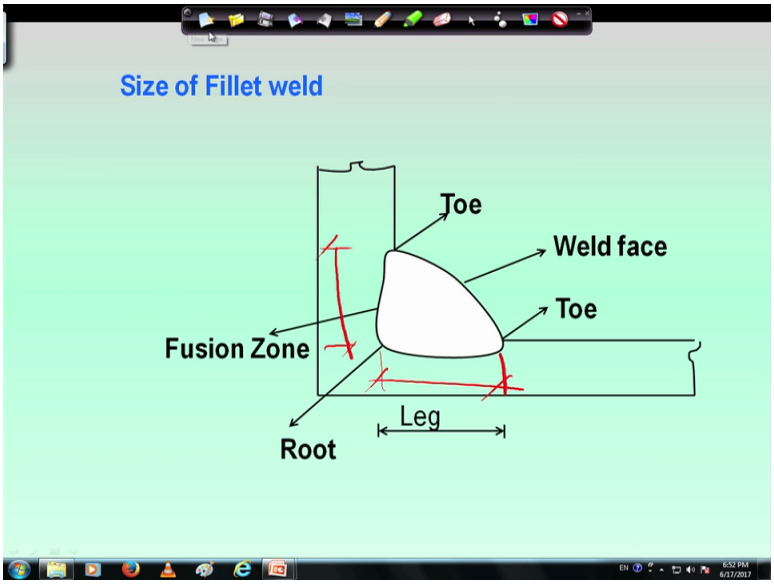

So size of the weld if we define we can say that the size containing the right angle of the fillet weld are called leg, I have shown in the figure, then the size of the weld is specified by the minimum leg length. The length of the is the distance from the root of the weld to the toe of the weld measured along the fusion face. So if we see that the size of the weld, this will be the size of the weld if we see, so there will be length here and they will be another length here. So minimum of these two will be the size of the weld.

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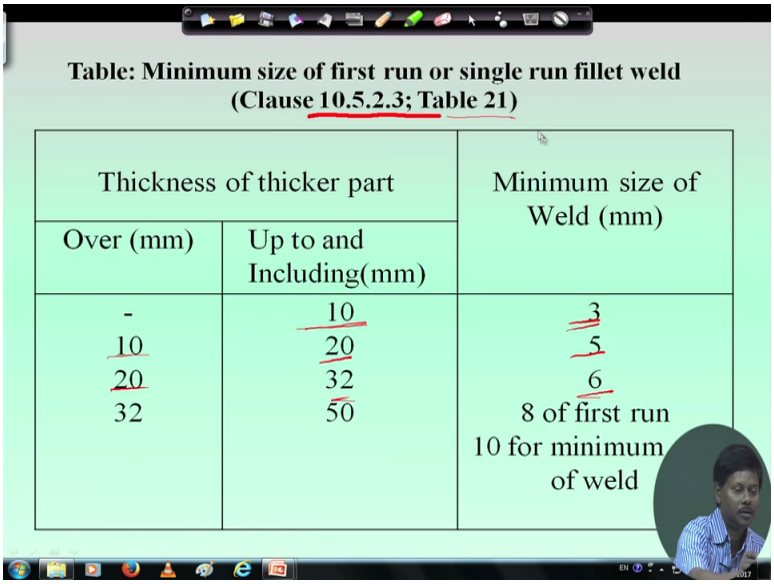

Now minimum size of the weld are given in clause 10.5.2.3 of table 21 of IS 800-2007. So it depends on the thickness of the thicker part of the member thickness of the thicker pat of the member, suppose the 2 members are joined together overlapped. So it may be of same thickness it may be of different thickness. Now minimum size of the weld we can define on this basis that if the thickness of thinner part is up to 10 mm then minimum size of the weld will be 3 mm. Similarly from 10 to 20 mm if thickness of thicker part is existing then minimum size of the weld will be 5 mm. Similarly 20 to 32 it will be 6 mm and so on. So these details are given in table 21 of the IS 800-2007. So we can use that while designing the fillet weld.

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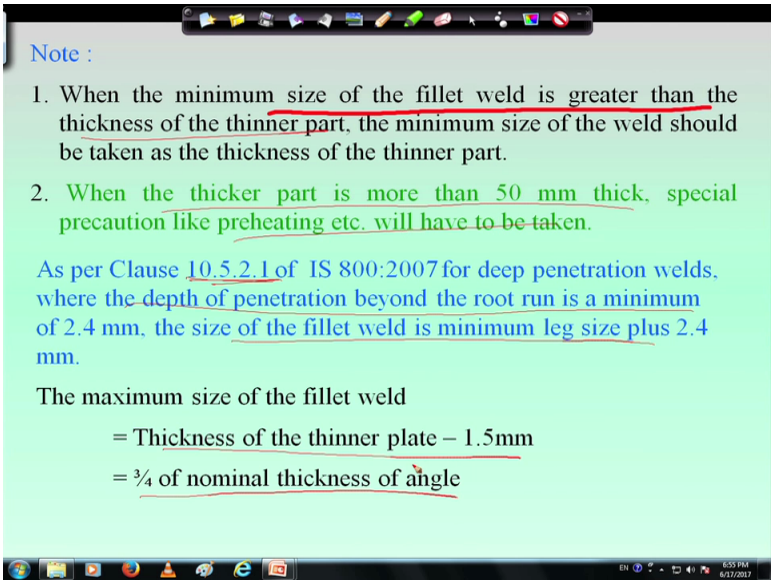

Now few things we have to remember like when the minimum size of the fillet weld is greater than the thickness of the thinner particularly, the minimum size of the weld should be taken as the thickness of the thinner part. So minimum size cannot become more than the thickness of the thinner part. Then when the thicker part is more than 50 mm thick special precaution like preheating etcetera, will be taken case and as per clause 10.5.2.1, for deep penetration weld where the depth of penetration beyond the root run is minimum of 2.4 mm, the size of the filet weld is minimum leg size plus 2.4 mm and this is about the minimum size of the fillet weld.

Now the maximum size maximum size also defined in the code that is the thickness of the thinner part minus 1.5mm, it can go up to that that means the thickness of the thinner part we know and the maximum size we can become that thickness of the thinner part minus 1.5 mm. Similarly, in case of angle the maximum size of the fillet weld be 3 fourth of the nominal thickness of the angle.

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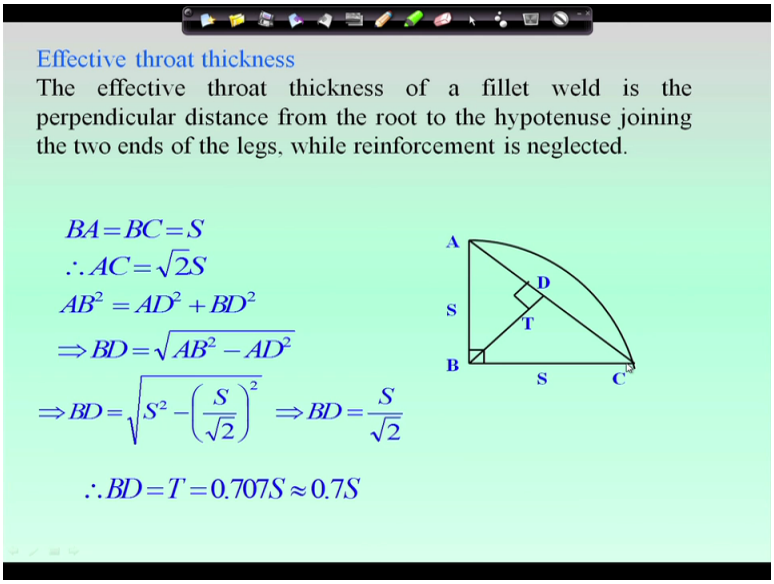

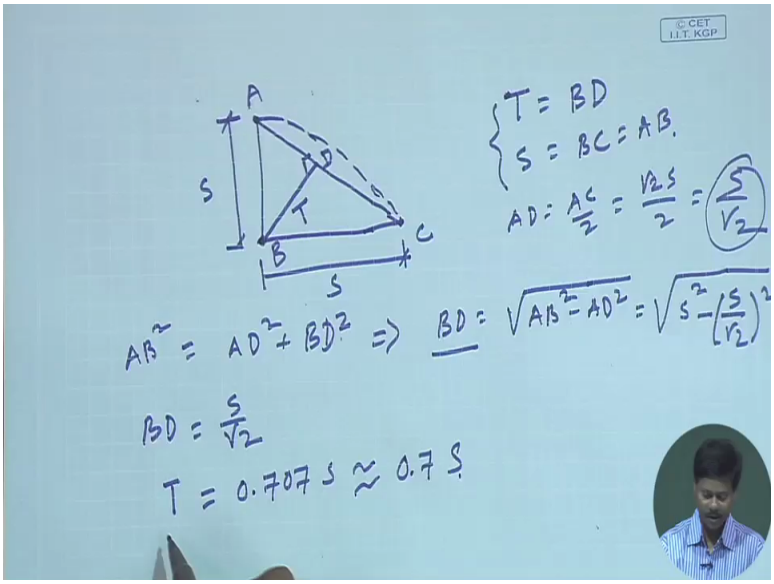

Now, (I will come to) now I will discuss about the effective throat thickness, as I told one is size of the weld. So if we see if we make a diagram that this is a size of the weld and (this the) this is root and from root to toe is a size of the weld and if size of the weld in different direction is same then we can write S or the minimum of that. Now extra deposits happens here, which is called enforcement and this extra deposit we provide to increase the efficiency of the joint.

Now if we give a name say suppose A, B, C. Now from root to perpendicular distance to the hypogenous will be the thickness of the weld. So if this is D then the thickness of the weld the throat thickness will be BD where the size will be BC or AB. Now how to find out the relation

between T and S. So we can see here that, in triangle ABC we can write that AB square no no, in triangle ABD, if we write in triangle ABD, AB square will be AD square plus BD square. So from this we can find out BD is equal to root over AB square minus AD square, right.

So now AB is nothing but AB we can write as S, so this is S square minus AD, AD is AC by 2, right. So we can write, AD as S by root 2, right because AD is AC by 2, AC means square root of AB square plus AC square that means S square plus S square means root 2S by 2 that means S by root 2. So AD we know S by root 2, so from this we can find out the value of BD. So if we see, so finally we can find out the value of BD as S by root 2, right that means the throat thickness T can be met S by root 2 that means 0.707S or we can write 0.7S. So we can find out in this way, the relation between the throat thickness and the size of the weld, if the size of the weld is S then the throat thickness will be the 0.707S.

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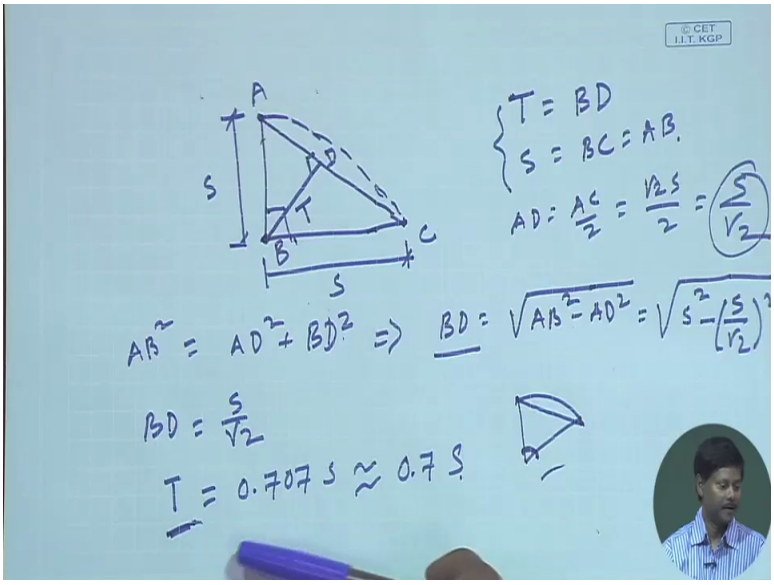

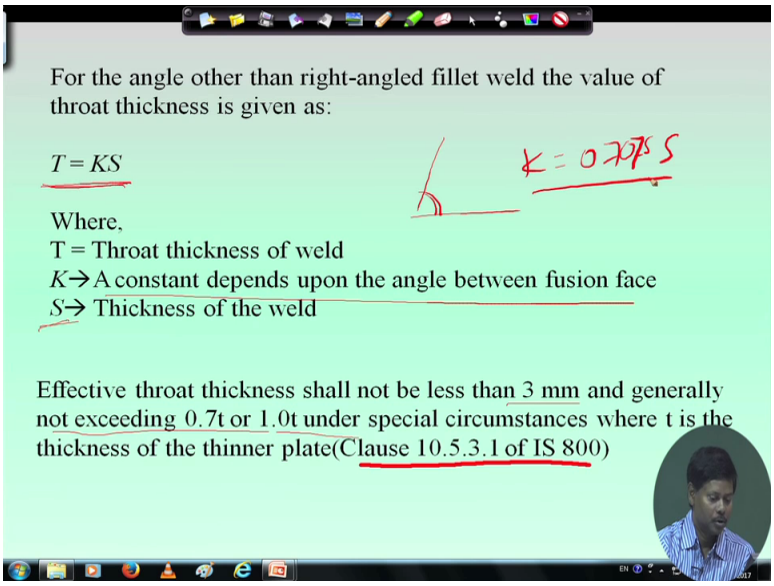

Now this is true for right angle triangle if it is right angle then fine we can find out this (()) (23:24) but what will happen about different angle means if it is joined like this, it is not right angle, right. So in this case what will happen, so that is defined in code that is in clause 10.5.3.1 of IS 800, it is told that the throat thickness will not be less than 3 mm and generally not exceeding 0.7t or 1t under special circumstances where t is the thickness of thinner plate?

This is about the throat thickness, but what I was telling I will here that the T throat thickness will be with some constant into S that means throat thickness if T is the throat thickness and S is the thickness of the weld means size of the weld then K and K is the constant depends upon the angle between fusion face that means if fusion face is like this then this K cannot become 0. 707 S, right. So what will be this value that is given in the IS 800 in a tabular form it is given which I am showing here.

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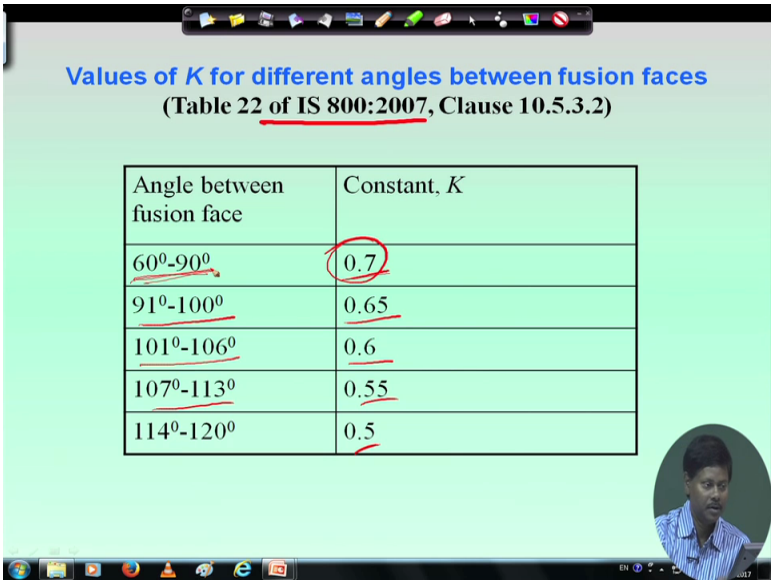

In table 22 of IS 800-2007. So in clause 10.5.3.2 we will see that the value of K will be 0.7 angles between fusion face is 60 to 90 degree. Similarly for 91 to 100 degree the value of K will be 0.65, 101 to 106 degree it is 0.6 like this 0.55 and 0.5 that means the maximum value is 0.7. So maximum value of K is 0.7, which is which becomes when angle between fusion face is 60 to 90 degree. If it is more than that then the value of K will be reduced. So we have to take the value of K from this table.

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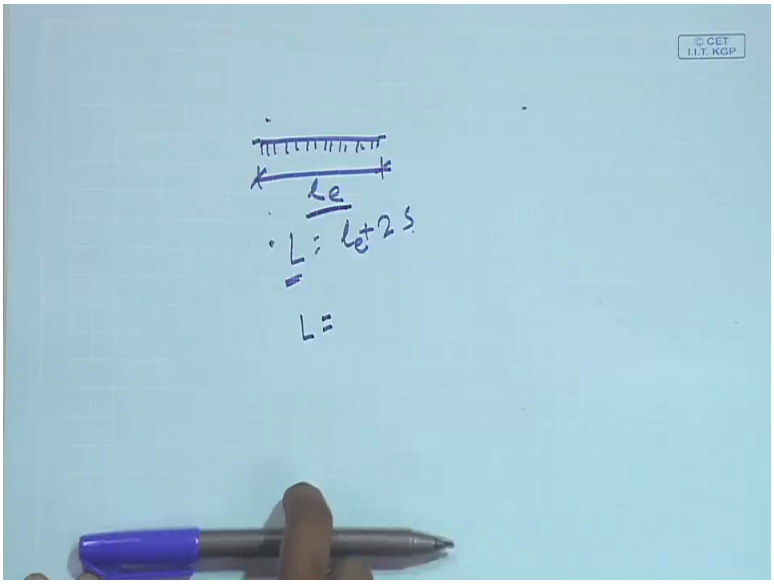

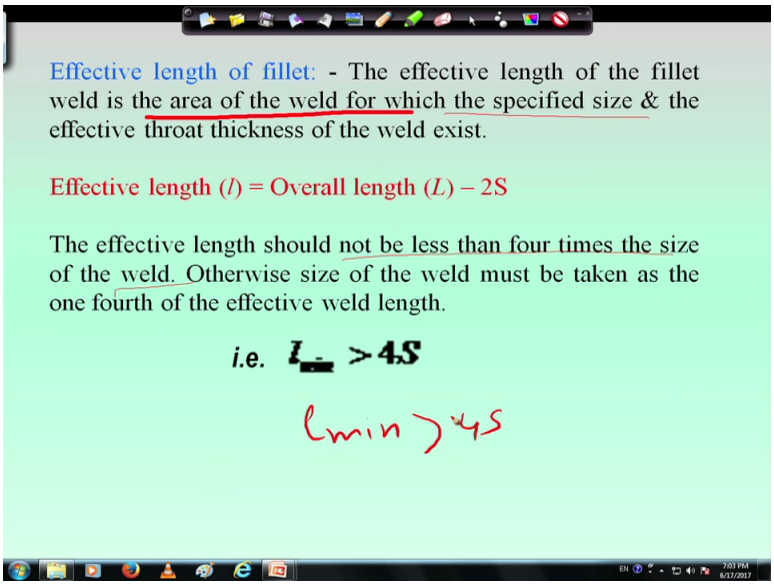

Now coming to effective length. So effective length can be find out from the area of the weld for which specified size of the effective throat thickness of the weld exist. So effective weld effective length we can calculate means when we are going to make welding say, suppose we have a length this much then if we say, this is effective length then total length will be l plus 2S, total length and if it is effective length. So why 2S means we assume that means we consider that the strength will be carried out by the length which is called effective length, but we have to provide little more into 2 side to make sure the strength is being carried out by this le. So the total length we will make little higher, right and this effective length should not be less than four times the size of the weld that means minimum effective length should be this l minimum has to be written 4S where S is the size of the weld. So this we have to follow.

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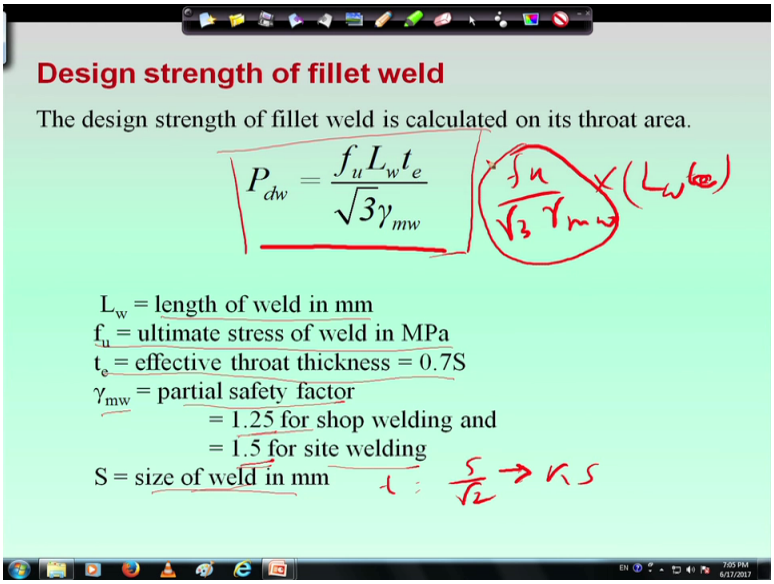

Now coming to the design strength of fillet weld. When we are going to calculate the strength of the fillet weld join we have to find out what is the permissible strength of the join and permissible strength, permissible stress into the effective area will be the permissible strength or permissible force of that joint. So that can be calculate from this formula which is given in the IS 800 that is, Pdw is equal to fu Lw te by root 3 gamma mw where Pdw is a design strength of fillet weld and fu is the ultimate stress of weld fu, Lw is the length of the weld which is called effective length not the total length and te is a effective throat thickness which is 0.7S effective throat thickness.

Now gamma mw is a partial safety factor, this may be 1.25 for shop welding and we can consider 1.5 for site welding gamma mw, gamma mw is a partial safety factor for weld connection and this value can be taken as 1.25 for shop welding and 1.5 for site welding then S is the size of weld S is a size of weld that S, we can find out means t can be find out from S by root 2 or K into S, value of K can be found from the table as given in the code. So we can calculate the design strength of fillet weld from this formula Pdw is equal to fu Lw te by root 3 gamma mw, basically fu by root 3 gamma mw is a permissible stress in the weld into area, area is Lw into te. This is the effective area right and this is a permissible stress in the weld fu by root 3 gamma mw.

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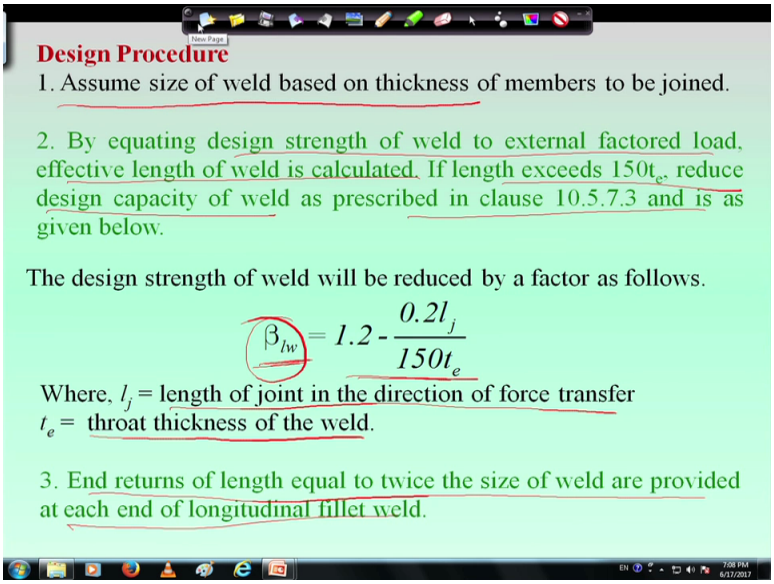

Now if we go to the design procedure we will see that first what we have to do? We have to assume a size of the weld, suppose we are going to design a weld joint, we have been given a particular load then what we can do? Either if we see that the length is constant means we have a certain length then we can find out the what will be the throat thickness of the weld and size of the weld, in other way also we can do, we can fix the size of the weld from the maximum and minimum criteria and the we can find out the effective length Lw and then the total length, right.

So one way we can do that first we can make, we can assume size of the weld based on thickness of the member then by equating the design strength of weld to external factor load the formula which I have given in last slide the effective length of weld is calculated. If length exceeds 150te then we have to reduce the design capacity of the weld as prescribed in clause 10.50.7.3 and is as given below, right. So that reduction factor will be beta Lw that is given by this formula that is 1.2 minus 0.2 lj by 150 into te where lj is the length of joint in direction of force transfer length of joint in direction of force transfer and te is a throat thickness of the weld.

So from this we can find out the reduction factor beta Lw and if the length of joint exceeds 150te then we have to multiply this factor to find out the actual strength. Then another thing is end returns of length equal to twice the size of the weld are provided at each end of the longitudinal fillet weld what is that?

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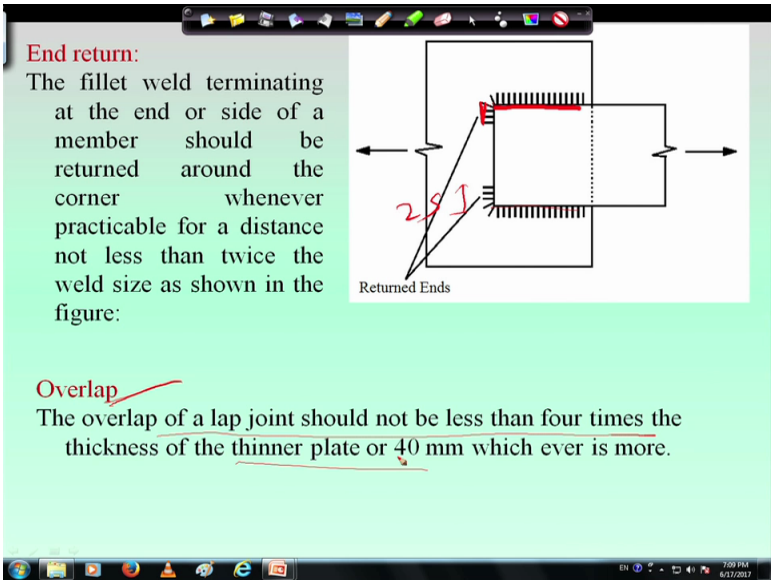

Let us come to that slide, this is called end return that means when the length of joint **is** is this then we have to provide a end return of this value and that is 2S. So this return, this is 2S, right. So if we provide here, the weld in this direction and this direction and if it is extended up to the corner then we have to extend up to 2S more, which is called end return and another thing we have to remember that is overlap.

The overlap of lap joints should not be less than four times the thickness of the thinner plate or 40 mm whichever is less, this also we have to keep in mind while going to design. So this is all about the calculation of design strength of fillet weld we have seen that how to find out the design strength of fillet weld Pdw which is basically fub by root 3 gamma mw into Lw into te, fu by gamma mw into root 3 is basically, the permissible stress of the weld while fu is the ultimate stress of the weld metal and Lw is the effective length not the total length and te is the effective throat thickness that means size divided by root 2 or K into S means depending on the angle of fusion K value can be calculated from the table and from that we can provide the K value. So this is how we can find out the design strength of weld connection, thank you.