Course on Design of Steel Structures
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Lecture 04
Module 1
Introduction to Connections

Welcome everybody in today's lecture I will be focusing on connections, various connections are available for joining members in case of RCC structure we connect different members by casting them in (())(0:36) in general, but in case of steel members different type of steel roll sections are available in the market they need to join together and that joining can be done in a various way that means various way means various connections we use, like rivet connections, bolt connections, then weld connections and combination of those two or three.

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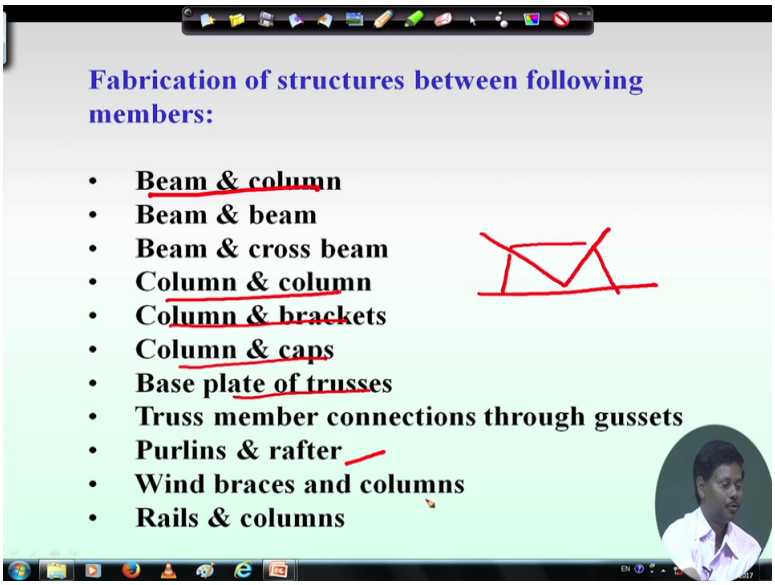

Now when two members like beam and column can be connected together or Beam and beam that means main beam and secondary beam can be connected, main beam and secondary can be connected, beam and column can be connected as I told, column and column means from first floor to second floor, second floor to third floor is columns can be connected, again column and brackets can be connected, column and caps can be connected, base plate or trusses can be connected, again truss member connecting through gussets that means when a member different members are connected at a particular point then that can be connected through gussets member. So when more than two members are joining at a point we need connections.

Now this can be connected through weld or through bold or through erect connection, depending on the requirement we choose the connections. Now purlins and rafters also are connected, then wind braces and columns, rail and columns those things can be connected.

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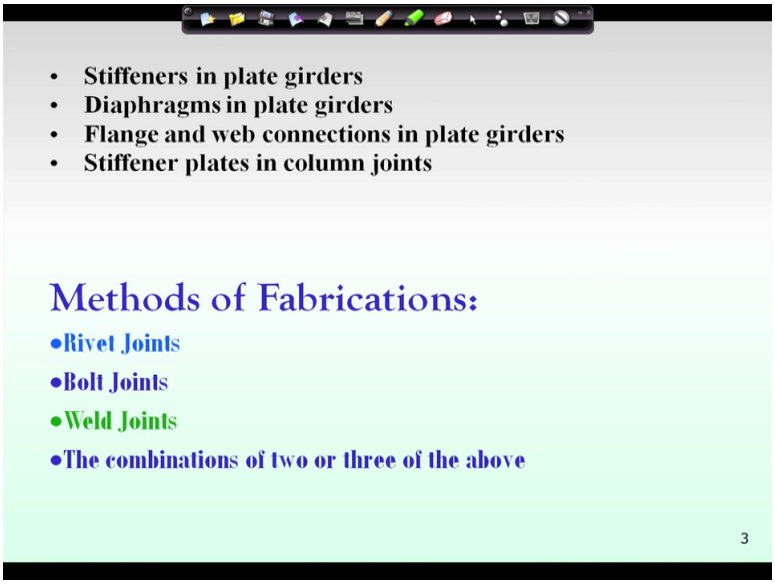

Further stiffeners in plate girders, diaphragms in plate girders, flange and web connections in plate girders, stiffener plates in column joints are also used for connecting different type of members. Now I told method of fabrications are basically three types one is rivet joints, then bolt joints, and then weld joints also we can make combine of two or three of the above means in a particular joint we can make use of rivet and bolt, bolt or weld, or bolt and weld sorry bolt and rivet that can be made. So requirement wise we have to choose.

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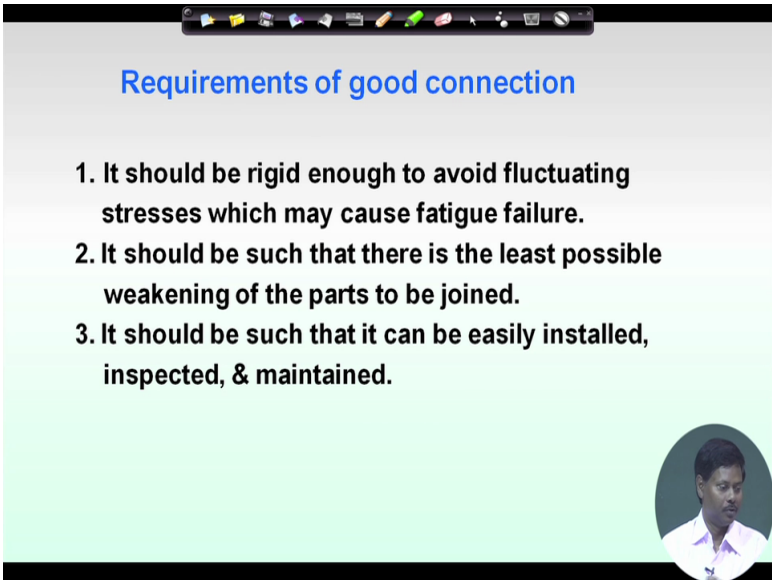

Now let us come to the requirement of good connection, what is good connection basically good connection mean it should be such that it can easily be installed, inspected and maintained that is one thing, then it should be such that there is the least possible weakening of the parts to be joined and it should be rigid enough to avoid fluctuating stresses which may cause fatigue failure. So this thing has to be kept in mind.

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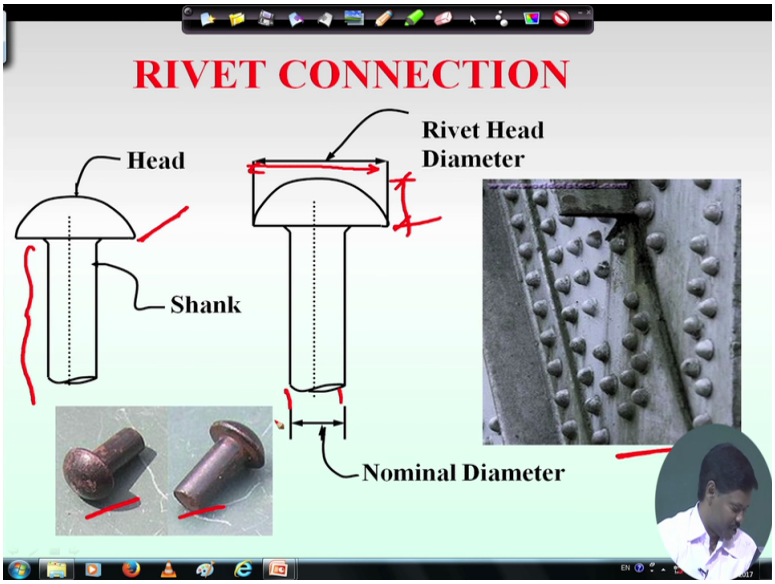

Now coming to Rivet Connections we know rivets are inserted in the plates to join together different plates and by adding heat we can insert the rivet like this so this rivets can be inserted a typical rivet joint is showing here where different members are connected to plate

by riveting and in the parts of rivet which is there is head, this is this part is called head and this part is called shank.

Now shank has particular length depending on the type of means thickness of the plates shank length will be varied and different type of heads are available and according to that different name of the defects are given. Now this rivet head has a particular diameter which is called rivet diameter and sorry rivet head diameter and this is the rivet head height and this is called nominal diameter, rivet diameter that is called that shank diameter is called nominal diameter and depending on the size of nominal diameter the strength of rivet can be calculated on the basis of the type of material used and accordingly we can calculate the rivet strength.

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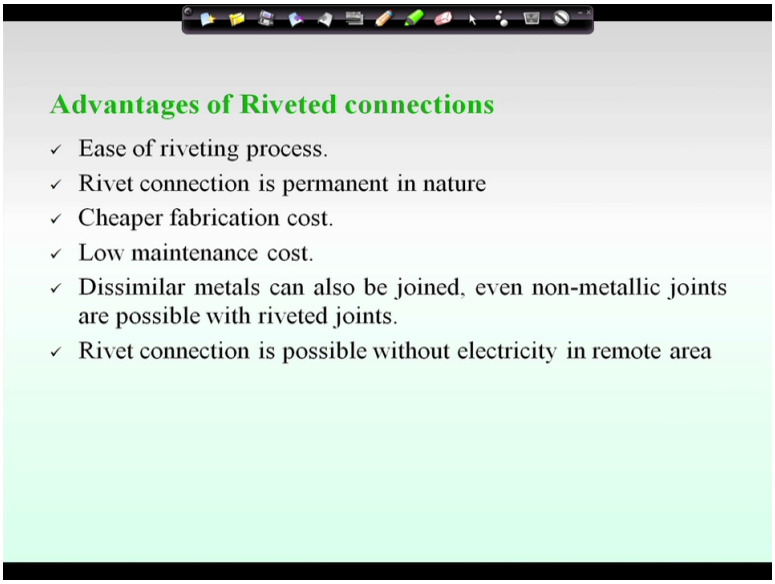

Now before using rivet connections we must know what are the different types of advantages we can achieve through rivet connections, one is the rivet can be used some of the advantages of the rivet connections are sited here like one is ease of riveting process, then cheaper fabrication cost, low maintenance cost and rivet connection is permanent in nature, that means due to vibration and other problems unlike bolt it has it will not loosen so it can be permanent in nature.

Then rivet connection is possible without electricity in remote area unlike welded connection in case of welded connection rivet means in case of welded connection we need electricity otherwise it will be difficult to join the members but in case of rivet connections only

applying through heat through application of heat we can find out. Now dissimilar metal can also joined, even for non-metallic joints rivet joints are possible these are certain advantages.

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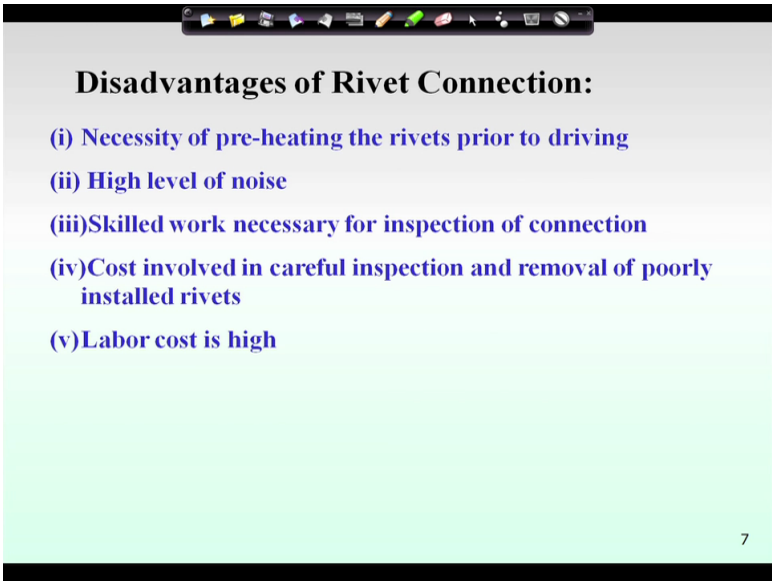

But it has lot of disadvantages also, what are the lot of disadvantages let us see, one is the necessity of pre-heating the rivets prior to driving is required so that is very important, then another thing is that high level of noise is created. So at the site where construction is going on, high level of noise can be created. So generally we nowadays we try to avoid this noise.

Then skilled work necessary for inspection of connection means connection is done completely or not that can be thoroughly checked that is possible if skilled worker available. Then labor cost is high because it takes time that is why riveting process is costly in terms of labor cost. Then cost involved in careful inspection and removal of poorly installed rivets are also there.

So because of certain disadvantages nowadays riveting connections are becoming absolute, mainly because of noise and because of generation of heat and also difficult to change the what you call difficult to change the improper insertion of the rivet, that means if certain rivets are improperly inserted now to change it takes time so it is costly.

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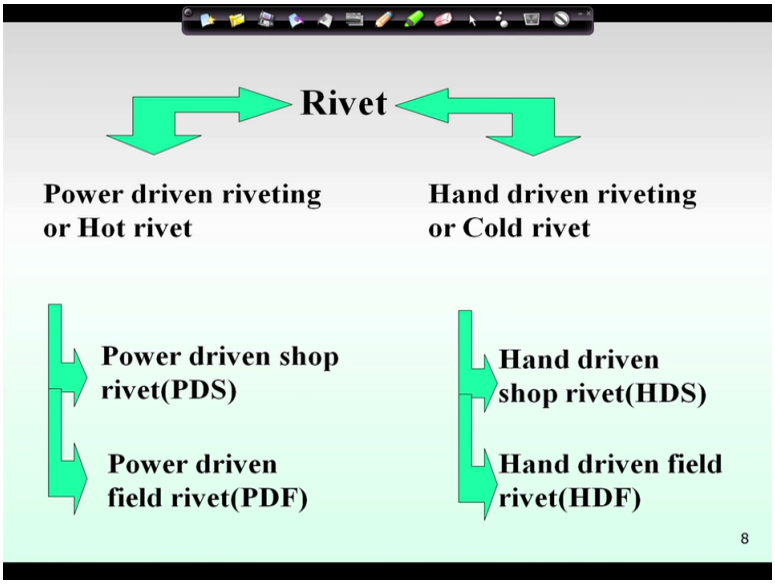

Now coming to different type of rivets we can see that one is power driven rivet another is hand driven rivet, there are two types of rivets. Power driven rivet is called hot rivet and hand driven rivet is called cold rivet, again in power driven rivet we have two types one is called power driven shop rivet, another is called power driven field rivet. And similarly for hand driven rivets hand driven shop rivet and hand driven field rivets are available.

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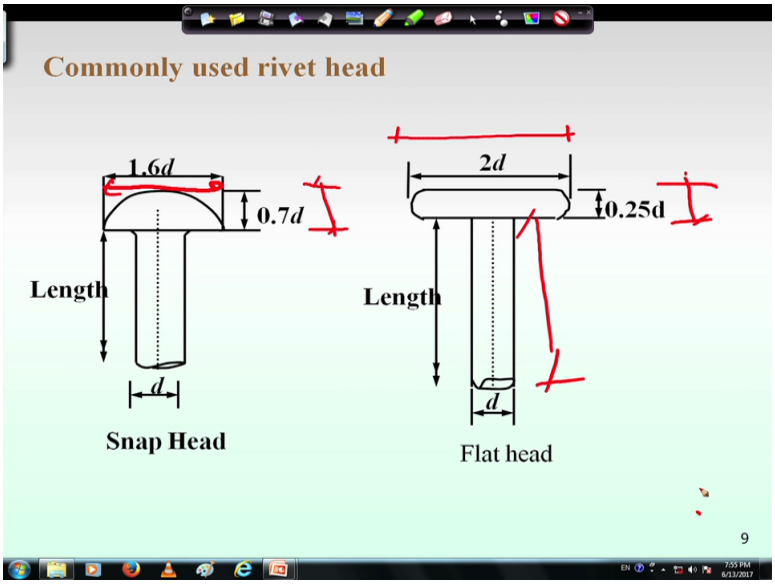

Now commonly used rivets are like snap head snap head where the head dimensions are fixed head dimension means in terms of diameter of the shank if diameter of shank is d then we can consider that that the diameter of rivet head is 1.6d and the height of the rivet head is 0.7d, so with different height and diameter different type of heads are snap means rivet heads are

available and its name are different, I have just given here two type of rivets one is snap head, another is flat head.

In case of flat head the head diameter the head width is 2d and head height is 0.25d and this is length this length is called rivet length and d is the nominal diameter of rivet. In this case we should remember that there is two type of diameter, one is rivet diameter another is whole diameter that means nominal diameter and gross diameter, gross diameter is little higher than the rivet diameter that means nominal diameter, it is sometimes 1.5 or 2 mm more than the actual diameter that means nominal diameter.

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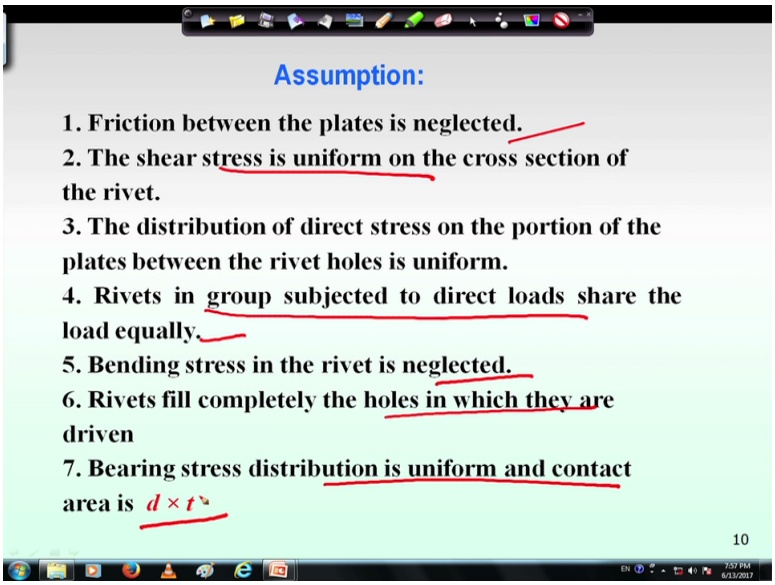

Now while designing the rivet joint we have certain assumptions we have to make on the basis of which we can design a rivet joint. First is friction between the plates are neglected, when joining the rivets we are neglecting friction between the plates. Then shear stress is uniform on the cross section of the rivet that means over the cross section the shear stress distribution has been consider as uniform, this is uniform.

Then distribution of direct stress on the portion of the plates between the rivet holes in uniform that is also uniform and rivet group subjected to direct loads share the equal load, that means if we have n number of rivets and if we have total load p then each rivet is withstanding load of p by n, that means equally sharing the load.

Then bending stress in the rivet is neglected and we consider rivet fills completely the holes in which they are driven that means though rivet hole diameter and rivet diameter is slightly

different that means 1.5mm to 2mm larger in case of hole diameter but while designing the rivet we assume that it is completely completely filling the hole.

Then bearing stress distribution is uniform and its contact area is d into t, where d is the nominal diameter and t is the thickness of the plate. So bearing stress distribution when we will be calculating will calculate the contact area as d into t.

Now as I told that rivet connection is becoming absolute nowadays therefore in new code in IS:800-2007 details of rivet design is not given in Limit State Method details are not given however in case of bolt and weld explicitly it has been described.

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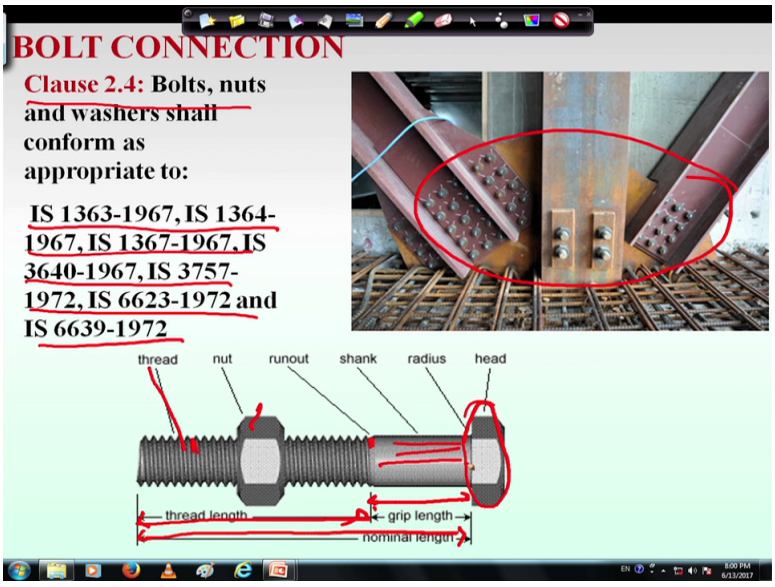

So when we will be going to bolt connections we will see the codal provisions and then as per code what are the requirements, what are the types of failures of bold at coming in to picture that we will see and we will try to design the bolt apparently.

So in clause 2.4 of IS 800 sorry in clause 2.4 of IS: 800-2007 it says that bolts, nuts and washers are confirmed as to appropriate to these codes. So in these codes the bolt properties are given in these codes. In this IS code bold properties, their dimension, their strength, different type of strength, different type of bolt these are given in these codes, which is mentioned in IS:800-2007 in clause 2.4.

Now coming to bolt see here the numbers of members are joined together at a particular point and bolts are used for joining these. Now I we come to the parts of bolts we will see bolt has a head, this is called head and this is called shank this area is called shank, right and this is

called runout and this is called thread this is called thread and this is called nut. So nuts are tightened over the plate to connect different plates at a particular point then this is thread length from here to here is thread length and this is the grip length this portion is called grip length and total length is called nominal length.

So bolt has different parts like head, nut, shank, thread, thread length, grip length and nominal length which will be required for our design, when we will be going for design of different type of bolt we will see these parameters are required, these dimension different dimension like what is the nominal diameter of bolt, what is the gross diameter or whole diameter or bolt, what is the type of head whether it is hexagonal or square, like this we will come across.

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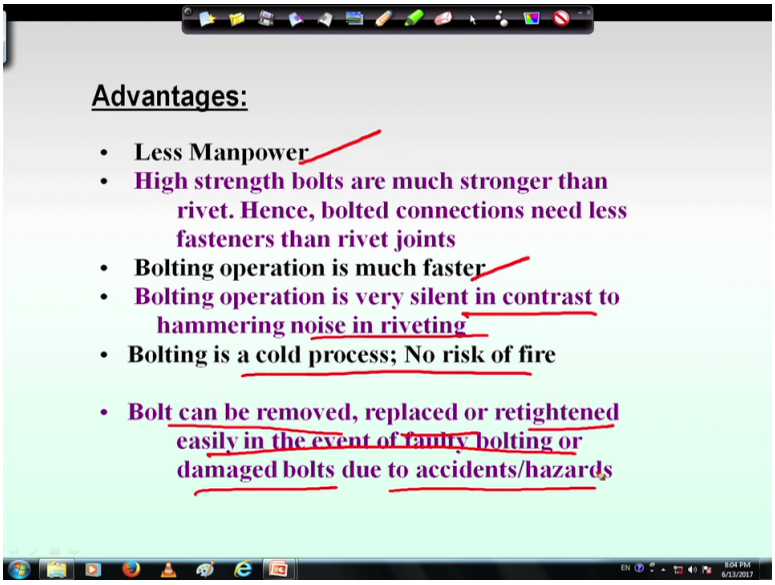

Now before going to use bolts we will see what are the advantages and disadvantages of bolts. As I told there are three types of joints one is bolt joint, one is rivet joint, another is hole joint, every joint has certain advantages and disadvantages. So we have to look into the advantages and we have to see what are the disadvantages and for a particular case where we are going to joining certain member, we have to know what type of design we are going to look for, means what type of connections we are looking for means what type of connections will be useful for joining those elements.

So first let us see what are the advantages of bolt, one is less manpower unlike rivet connection here manpower is quite less just to tighten the nuts and get connected, then another advantage is high strength bolts are much stronger than rivet. So number of bolt

required will be less. In case of rivet number of rivet required will be more and in that case the number of bolts to be created on the plates is more as a result the strength of the plate after insertion of hole will be quite less in case of rivet in comparison to bolt.

Number of bolt if it is less means generally it comes less compare to the rivet then what we see that number of holes required will be less and net effective area will be high as compared to rivet that is why strength will be high as compared to rivet in case of bolt connections.

Then bolting operation is very fast unlike rivet or rivet or weld, bolting operation here is very fast because you just go and tighten the nuts then bolting operation is very silent in contrast to hammering noise in riveting. In rivet in case of welding joint also noise is produced but in case of bolting there is no noise and this is a cold process so there is no risk of fire unlike riveting or welding case, in case of welding also heat is generated so there is no risk of fire.

And another enormous advantage we can found from bolt connection is that this bolt can be removed, replaced, or retightened easily in the event of faulty bolting or damaged bolts due to accidents or hazards, unlike rivet connection or weld connection in case of bolted connection if we find that something goes wrong in the connection we can remove the connection, we can replace the bolt or we can retightened the bolt, then we can find out the means we can find out the actual strength, right.

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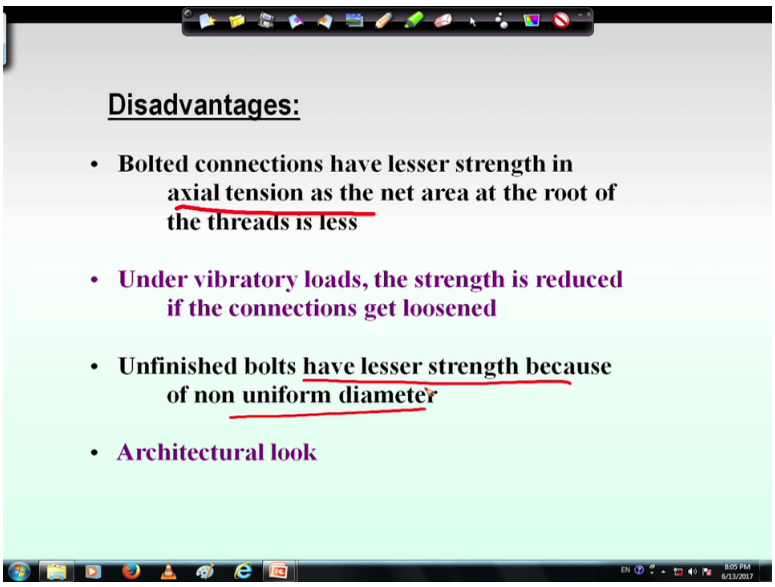

Now certainly it has certain disadvantages what are those let us see one is architectural look in case of of course rivet connections are also architectural look wise it is not recommendable because it looks balky. So in case of architectural look we may have to think while

connection sometimes so there is a disadvantage in case of bolt connection and bolt connections have lesser strength and bolt connections have lesser strength in axial tension as the net area of the root of the thread is less, because net area is becoming less.

Then under vibratory loads, the strength is reduced if the connections get loosened. So in case of bolt connection this is a big disadvantage that is under vibratory load the nut get loosened and because of that the strength is going to be loosed. Unfinished bolts have lesser strength because of non-uniform diameter, ok this is another disadvantage that in case of unfinished bolt it has lesser strength, so we need more number of bolts and more number of bolts means more number of holes and more number of holes mean lesser strength of the plate because of the insertion of hole. So in tension the plate will be net area of the plate will be reduced so strength of the plate will become less.

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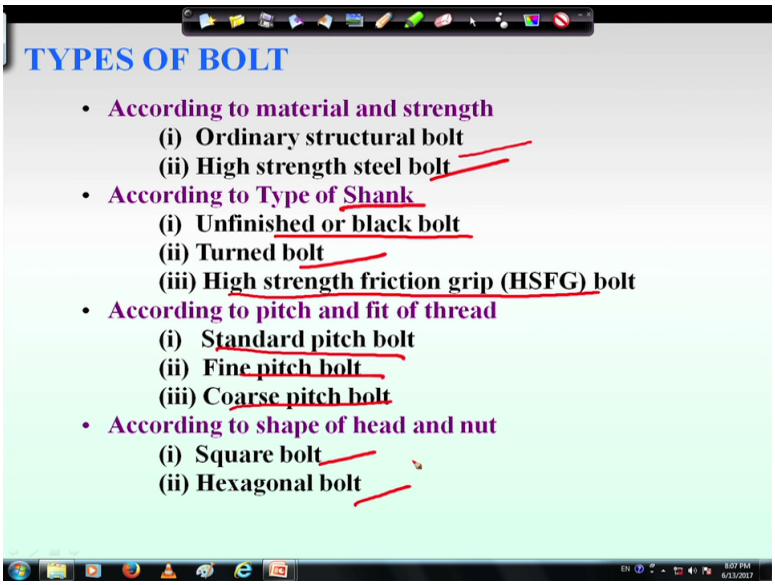

Now coming to types of bolt, what are the types of bolt, we can classify the bolts in different way, one is according to the material and strength according to material and strength we can classify this as ordinary structural bolt and high strength steel bolt, this two type we can make.

But according to type of shank according to type of shank we can make three types of bolt means you can categorize into three type of bolt one is unfinished or black bolt, another is turned bolt and another is high strength friction grip bolt. This is very important high strength friction grip bolt generally use in case of high load and if we need less number of hole, less number of bolt then we have to go for HSFG bolt.

Then according to pitch and fit of thread we can use standard pitch bolt, fine pitch bolt and coarse pitch bolt, these three type of bolt means pitch can be categorized. Then according to shape of head and nut we can make as square bolt or hexagonal bolt. Square bolt means if head is square and hexagonal bolt means if head is hexagonal.

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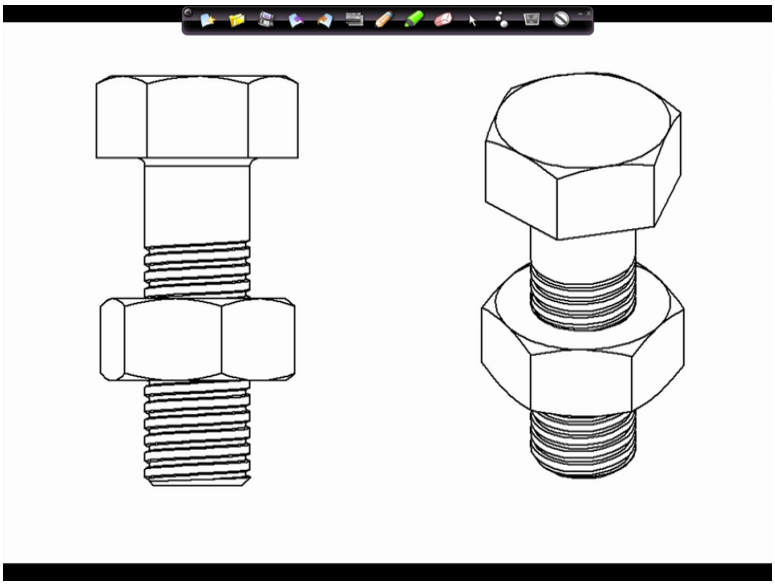

This is a typical example of hexagonal bolt. If we see here we will see that it has it has number of sites are six in this case.

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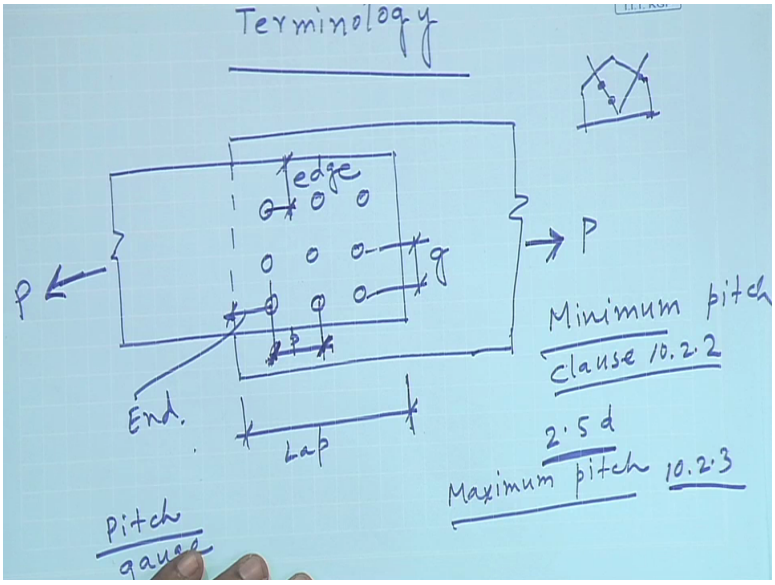

Now before designing the bolt connections we have to come through some terminology. So let us see, ok just this slide I do not want to show please remove this one. So we will go for

some terminology. We need to know certain terminology before going to use design procedure of bolt connections, like in case of rivet and bolt some terms are used like pitch distance, gauge distance, edge distance, end distance, bolt hole, gross diameter, nominal diameter so those things will come into picture. So we will see what are those.

If two plates are joined together, say for example this is one plate and this is another plate are connected. Now these are connected either by bolt or rivet, so maybe this is connected like this, these are bolt position and we will come across that bolt positions are either regular or zigzag according to that we can make means we can name as zig-zag bolting or plane bolting or chain bolting (())(23:14) sometimes diamond bolting also used, so we will come across.

Now the overlapping portion of these two plates, this distance is called lap distance, here if you have a force P and if you have a force P then this distance is called the overlapping distance is called lap distance. Now pitch what is pitch, pitch is the center to center distance of adjacent bolt that means center to center distance of adjacent bolt or rivets measure in the direction of stress.

That means in this direction forces are there, so in this direction this distance is called pitch p, right. Similarly the perpendicular to the direction of stress, this distance is called gauge distance gauge, right.

Now there is a difference between pitch and gauge, pitch distance is distance between two consecutive rivet or bolt along the direction of stress and gauge distance is gauge distance is distance between center to center distance between two rivet or bolt perpendicular to the stress, right.

Now this distance is called End distance end and this distance is called edge that means that means parallel to the direction of stress the outermost rivet center and the edge of the plate, the distance between these two is called end distance and the perpendicular to the stress, the distance if we consider this is called edge distance, right.

Now so what will be the pitch distance and edge distance, so we have to see what is the minimum pitch distance, this is expressed means discussed in clause 10.2.2 of IS: 800-2007, 10.2.2, in clause 10.2.2 the minimum pitch is defined minimum pitch, that is how much that is 2.5d, 2.5 times nominal diameter of the rivet or bolt, 2.5 times the nominal diameter of the rivet or bolt that is the minimum pitch.

Why this minimum pitch is required because we need sufficient space between this rivet or bolt to tightened so that it does not overlap, right. So minimum pitch is required to tighten the bolts properly and to prevent the bearing failure between two bolts if it is very closer than a bearing failure may occur, so to prevent this bearing failure we need to specify a minimum pitch and code has specified this 2.5d.

Then let us come to maximum pitch, what is maximum pitch and that is necessary. Maximum pitch is desirable to place bolt sufficiently close because to reduce the length of connection and gusset plate that means if we have different members connecting at a point as I shown if we have pitch distance more than the gusset plate will be require more. So the amount of material for gusset will be more that we do not want, that is why we will try to make pitch distance as less as possible but not less than minimum pitch. So this maximum pitch that also is defined in code that is given in clause 10.2.3 in this clause the maximum pitch what should be is defined there.

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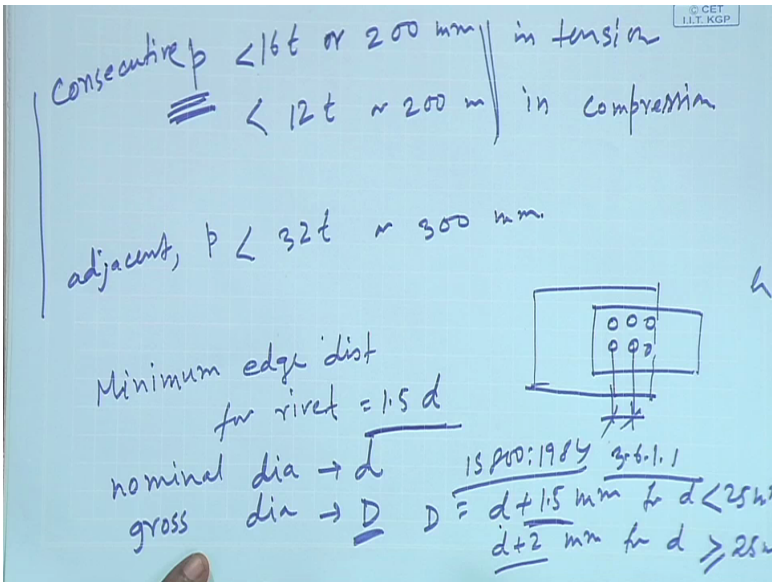

So this maximum pitch is defined in code which is written that that it should be 16t or 200 mm in tension that pitch should be 16t or 200 mm in tension and it should be less than 12t or 200 mm in compression.

This is the pitch this is the distance between two conjugative bolts distance between two conjugative bolts but distance between two adjacent bolts in this case, this is conjugative bolt and distance between two adjacent bolt adjacent bolt pitch would be less than 32t or 300 whichever is less, alright whichever is less. So pitch has to be decided in this way.

So while designing a member, say in case of a lap joint we need to provide bolts in such a way that it follows the codal provision that means the limit of maximum pitch and minimum pitch has to be maintained.

Next minimum edge distance minimum edge for rivet now I will come for rivet and then later I will come for bolt this is true for bolt. So minimum edge distance for rivet that is given 1.5d, where d is the nominal diameter of the rivet, right and gross diameter as I told rivet has nominal diameter nominal diameter is termed as small d and gross diameter which is the hole diameter actually in case of rivet that is termed as capital D and this capital D will be d plus 1.5 for d is less than 25 mm and it will be d plus 2 mm for d is greater or equal to 25 mm.

This is given in IS 800: 1984 in the earlier code, in clause 3.6.1.1, remember when earlier codes were available that means 1984 which was based on Working Stress Method at that time the code has provided the gross diameter as nominal diameter plus 1.5 for nominal diameter less than 25 and if it is more than 25 mm than it is d plus 2, that means clearance has been taken as 2 mm.

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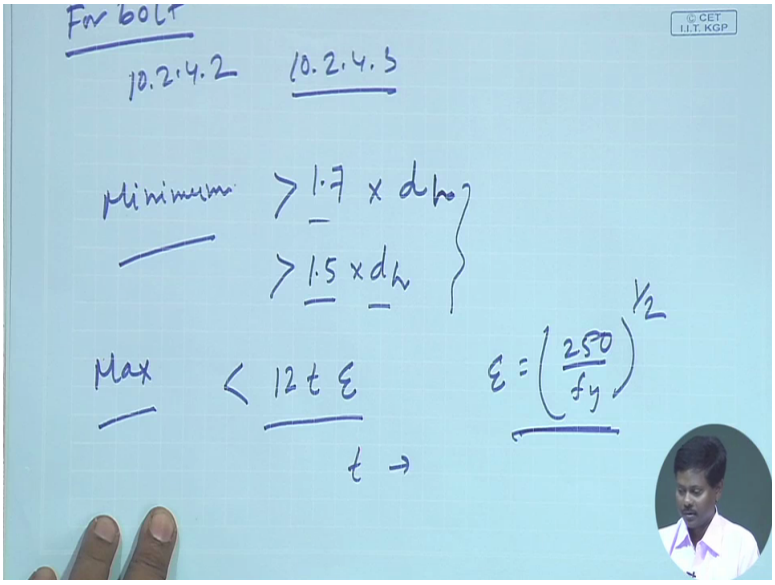

Now for bolt, in case of bolt the minimum and maximum edge distance and end distance are given in clause 10.2.4.2 and 10.2.4.3, minimum and maximum edge distance and end distance has been given clause 10.2.4.2 and 10.2.4.3.

Now what is stress here is states that minimum edge or end distance that should be greater than 1.7 times the hole diameter d hole, dh is diameter of hole, 1.7 times the hole diameter and this is in case of shear or hand frame cartages this is in case of shear or hand frame

cartages and it should be greater than 1.5 times the hole diameter in case of rolled machine flame (())(33:37).

So for different cases the minimum edge distance are defined either 1.7 times the dh or 1.5 times dh and maximum edge distance maximum edge distance is defined it should be less than 12 t into epsilon, where epsilon is 250 by fy into whole to the power half, t is thickness of the thinner part t is thickness of the thinner part and maximum edge distance should not exceed this 12 t into epsilon and epsilon can be calculated from the steel property, right.

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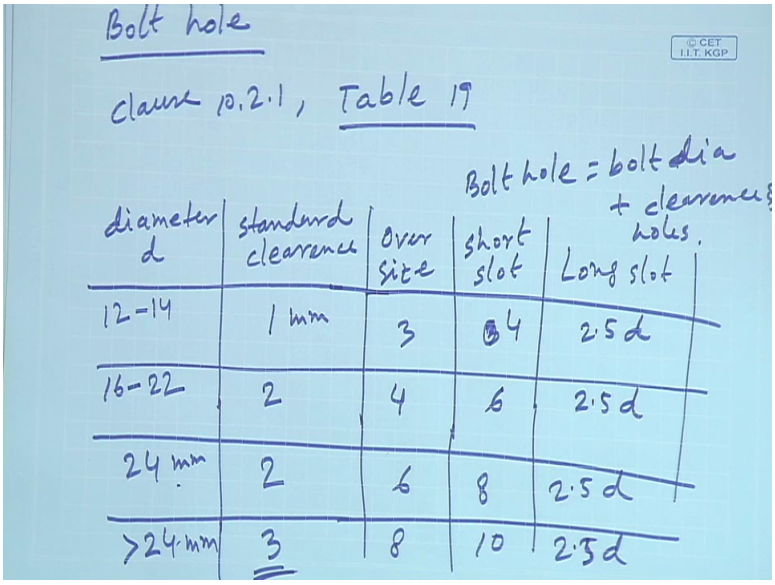

Now another term which we have already used that will come into discussion that is bolt hole bolt hole means that is required to fascinate the insertion of bolts to make the connection between steel members and this bolt hole details are given in clause 10.2.1, table 19 the bolt hole has been given that means it depends on the diameter of the shank that means bolt diameter the nominal diameter if this is d then if nominal diameter is 12 to 14 then standard clearance means hole will be standard clearance will be 1 mm, right (())(35:46) millimeter, that means bolt hole is bolt diameter plus clearance clearance of holes.

You can refer to the code where very meticulously this table has been described means have been elaborately given. Now for different cases this hole clearance will be different, like for standard clearance it is 1 mm, for over site it is 3 mm, for short slot it is (3 mm) 4 mm and for long slot it is 2.5 times d, where d is the diameter of the bolt.

Similarly in case of bolt diameter from 16 to 22 this standard clearance is 2 mm, over site is 4 mm, short slot in case of that it is 6 mm and for all the cases it is 2.5d for long slot. Then for

24 mm diameter of bolt the standard clearance is considered 2, this is 6 and for short slot it is 8 and for long slot 2.5d and if the diameter is greater than 24 mm then it is 3 the standard clearance is considered 3 that means the whole diameter for standard is will be 24 plus 3 times it is 27. Similarly for over site it is 8, for short slot it will be 10 and for long slot it will be 2.5d. So this is how the bolt hole will be calculated.

So these details is necessary for calculating the bolt strength, while calculating the bolt strength we will see what are the type of failure is coming into picture and for different type of failure this pitch distance, edge distance, bolt whole, bolt diameter, etc will be required. So before going to start those things we should be aware of these terminologies. So with this I conclude this lecture, thank you.