Course on Design of Steel Structures
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Lecture 61
Module 12
Eccentrically Loaded Base Plate

Today we will discuss about the eccentrically loaded base plate. So when the base plates are loaded eccentrically or are subjected to axial load as well as bending moment the pressure distribution from the concrete does not remain uniform. So concentric load is there then only the uniform pressure from the concrete will act on the base plate, so P by A. But here if the load is eccentrically acting or certain moment is acting then the stress in one side it will be tension, in other side it will be compression.

So the stress development will be linearly varying about its neutral axis and the stress will be M by Z where Z is the section modulus. Therefore the stress at two different points means two different extreme ends will be different somewhere it will be P by A plus M by Z, in other direction it will be P by A minus M by Z. Therefore the magnitude of the stress in two direction in two cases two points will be different, therefore we have to design the base plate that means we have to find out the thickness of the base plate on the basis of maximum stress developed on the on the base plate, right due to this not uniform pressure from the concrete block.

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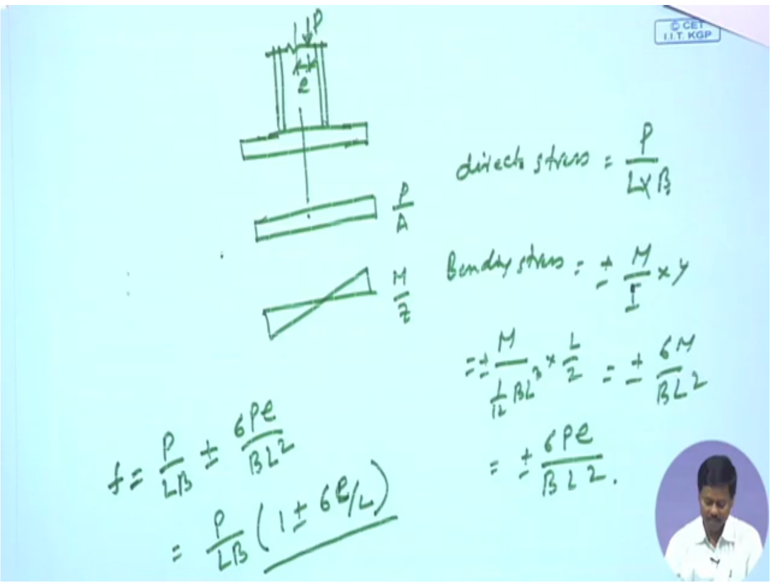

So if we see here that if the column is eccentrically loaded say if this is so if P is here with a distance of e then the load distribution below the column will not be uniform. So one will be due to load P it will be uniform load and another will be this will be P by A and another will be M by Z, okay. So the direct stress we can find out simply from this that P by L into B where L is the length of the base plate and B is the width of the base plate but the bending stress we can find out as plus minus M by Z, M by Z means M by I into Y.

So for rectangular plate this will be M by I means 1 by 12 BL cube into L by 2, so this will become plus minus 6M by BL square or if load is eccentric then I can say 6 M is equal to P into e BL square. So the combined stress due to axial load and bending can be written as P by LB this is the stress due to concentric load and this is stress due to bending or eccentricity, so 6Pe by BL square that means P by LB into 1 plus minus 6e by L, okay. So the combined stress due to axial load and bending we can find out as P by LB into 1 plus minus 6e by L.

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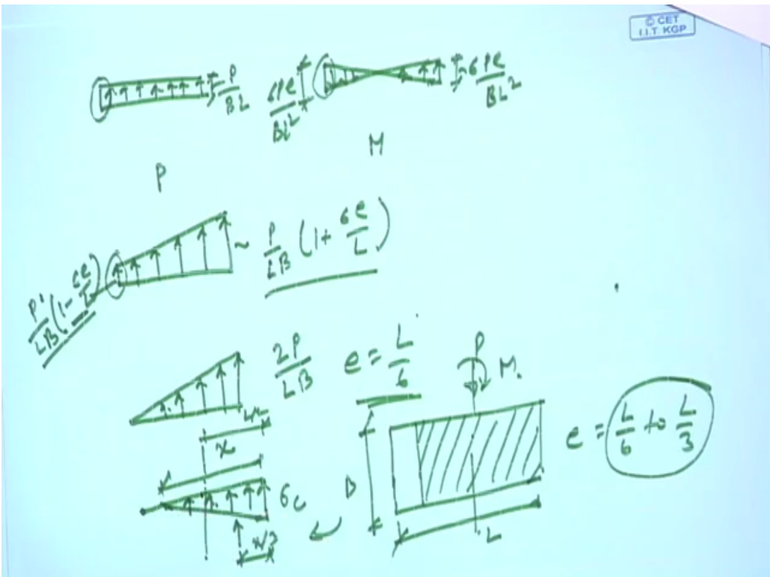

So different cases will occur here as we told that this is the uniform stress will come from the concrete block to the base plate of P by BL magnitude, right this will be P by BL magnitude. And another stress will be of this magnitude that is M by Z that is 6 Pe by BL square, right this value is 6 Pe by BL square and this value also same 6 Pe by BL square, right. So this is due to bending due to moment and this is due to axial load, right.

So if we combine this what we can see we can see different case may arise one is like this so here what we could see this is becoming P by LB into 1 plus 6e by L and this portion will become P by LB into 1 minus 6e by L, right. So in two extreme end the stresses are different so it is a trapezoidal distribution. Now depending on the magnitude of the compressive load and the compressive axial load and the moment this value may become compression or may become tension, right.

So in other case when this will become 0 that means when the stress due to moment and stress due to axial compression is same then it may become triangular distribution. So this case means it will be simply 2P by LB, okay so its stress will become double, right. Another case may happen that is that some portion may develop tension. So here e is equal to L by 6 for this we could consider but if e is greater than L by 6 then it will develop like this that is here it will be sigma c and if we consider this as neutral axis then this will be x by 3 and this is x if at x distance it starts tension and this is L by 2, okay.

So in this case the tension is developed but amount is less this amount of area is less, so in plan if we see it is something like this so this is the neutral axis. Now some portion it is tension and rest are compression because of the force P and moment M, right so this is B, this is L. So stress distance for small tension will be like this. Now another case may come so here e will be L by 6 to L by 3 with this variation the tension will be less and its diagram will be like this.

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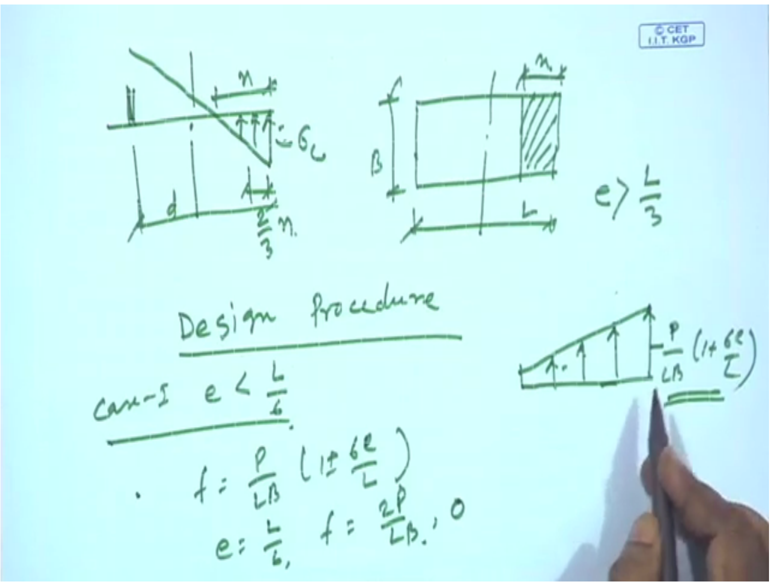

But if e is greater than L by 3 that means when the tension developed is substantial then the stress distribution will be like this so this is the neutral axis so this is this will be like this that means this will be sigma c and the neutral axis depth will be here n and at two third end the cg of this will be there, right and if bolt is provided here say in this position then we can consider this as d so for large tension this will be the stress distribution diagram, right and we will see in plan if we see it will look like this so this portion is only compression rest are in tension, this distance is called n. So this is this happens when e is greater than L by 3, okay.

So we can see three cases when e is less than L by 6, when e is in between L by 6 to L by 3 and when e is greater than L by 3. So for this three cases we will see how to find out the maximum stress on the base plate from the concrete. So once we find out the maximum stress then I can find out the thickness of the base plate, right. So we will see one by one the design procedure.

So for case 1 when e is less than L by 6. So what we can see so here we could see that the stress will develop like this (())(12:11) form, right and this will be P by LB into 1 plus 6e by L, okay and it may become 2P by LB maximum, right and for this we know f is equal to P by LB into 1 plus minus 6e by L, okay. And for e is equal to L by 6 I can find out f is equal to 2P by LB, okay and in other position it is 0, okay. So combined stress should be less than or equal to this 0.456 fck because the bearing strength of the concrete is 0.45 fck.

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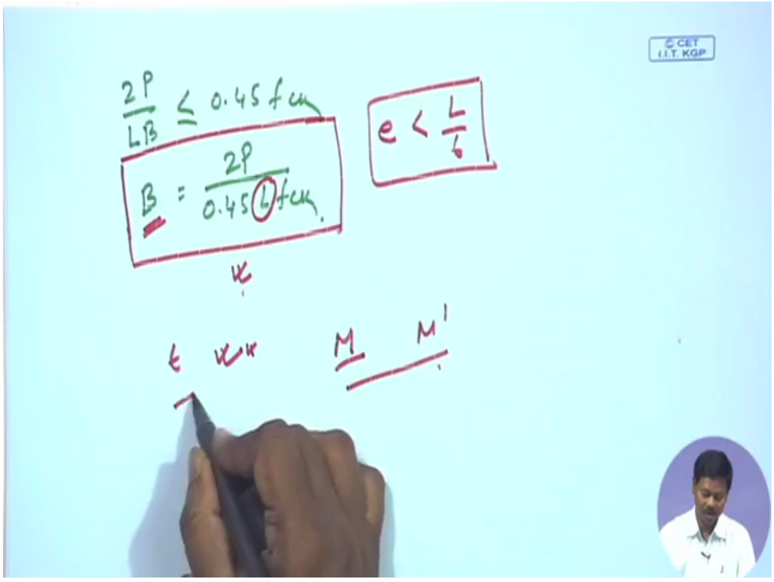

So the combined stress maximum combined stress is 2P by LB it should be less than or equal to 0.45 fck that means B should be equal to 2P by 0.45 L into fck, okay. So in case 1 when e is less than L by 6 what we can do we can find out the width or length of the base plate from this because we do not know what is the length and what will be the width so from the requirements from the dimension of the column we can approximately decide on the length and breadth and then if we decide the length then the required width we can find out and by adjusting length and breadth a suitable dimension of the base plate can be found, right.

So once this is found so this is possible when e is less than L by 6, so for this condition we can make this formula and then we can find out the thickness of the base plate and thickness of the base plate we can find out by computing this stress with the moment carrying capacity of the base plate, okay. So we know what is the moment carrying capacity and from that we can find out the critical stress and then we can make equal with this stress and then find out the thickness, right.

So what we can do that we can find out the moment capacity of the base plate and the moment at the critical section and by equating we can find out the thickness, right.

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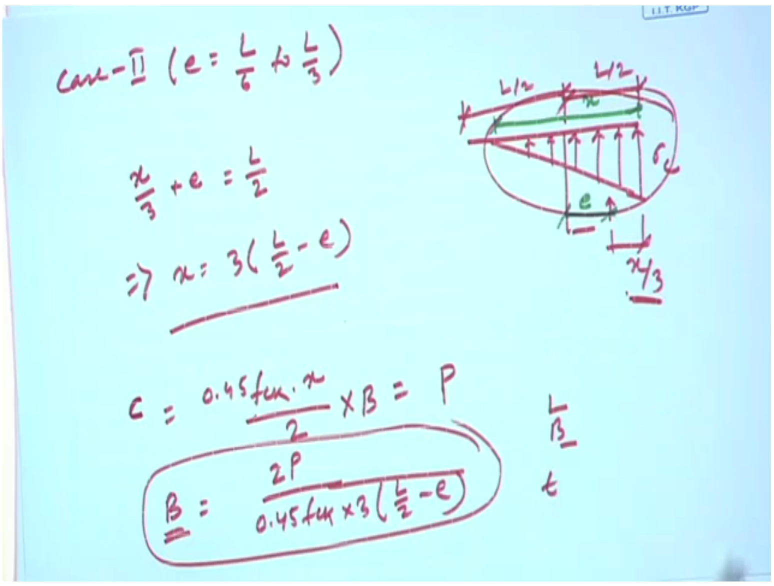

Now we will go to case 2, so case 2 is when e is equal to L by 6 to L by 3, okay. So in this case most part of the base plate is under compression with little or negligible tension on the remaining part. So if we see the diagram of the stress coming means pressure coming from the concrete pedestal to the base plate it looks like this this is sigma c and this is the neutral axis that means this is L by 2 and this is L by 2, right and this is x by 3, if this is x, this is x and this is e, okay.

So the calculation of the length of the plate under compression we can find out that is x by 3 plus e is equal to L by 2, e plus x by 3 is equal to L by 2. So from this I can find out x is equal to 3 into L by 2 minus e, right. So length of the plate under compression can be found from this. So once we find the length of the plate under compression then we can find out the width.

So width of the base plate now I can find out so for that first we have to find out what is the total compressive strength coming from this means what will be the area of this, okay. So total compressive strength will be 0.45 fck into x because sigma c is 0.45 fck maximum bearing strength of the concrete consider into 2 so half into sigma c into x this is the area into in another direction B so this will be the total compressive force in concrete. So total compressive force in concrete we have calculated from the area of the stress triangle into width which is equal to P the total load.

So from this I can find out the value of B so value of B we can find as 2P by 0.45 fck into 3 into L by 2 minus e, okay. So the width of the base plate now can be found from this formula, right. So length is known, width is known now thickness of the base plate can be computed by equating the moment capacity of the base plate to the moment at the critical section, right. Then we can find out the thickness, okay.

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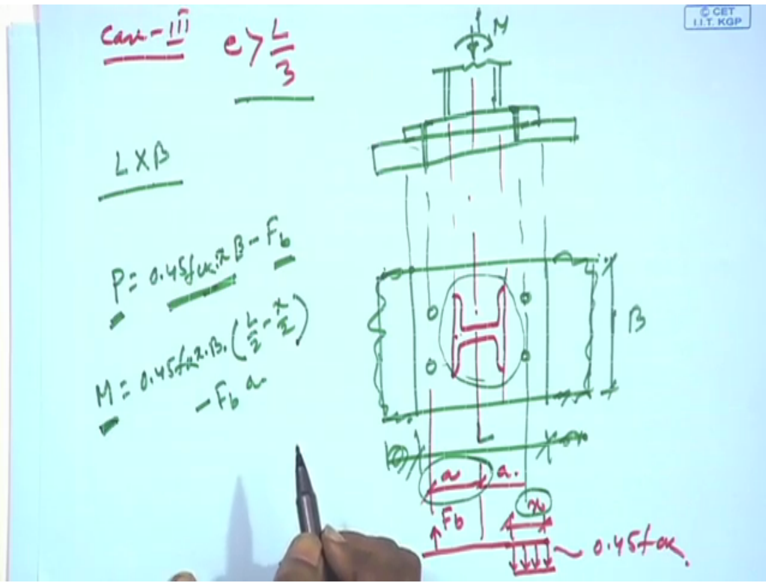

So next we will go to the third case, case 3 where e is greater than L by 3. So in third case if we see the diagram say this this is a column which is under axial compression and moment, okay. Now this is connected with base plate and then again with the concrete block, okay and this is connected with bolt anchor bolt here, right. So now if we see the plan this is the base plate length sorry width B and this is the sorry it will be from here so not this one, so this is the length and this is the width and here there will be bolt and if this is the column line then I can provide the column here so and this is the cg, right.

Now this distance is a, okay and this distance is here also we can provide bolt so this distance is also a. So with this if we draw stress diagram it will be like this this is the force on bolt and in some portion the compressive stress will develop say for this portion 0.45 fck, right and this is a and this is x, right. So for e is less than L by 3 the design what we can do we can first assume certain size of L by B, okay we will assume certain size of L by B before calculation, okay. So this L by B can be found from this dimension approximately from this dimension we can found a suitable size of L by B.

Then from the equilibrium of forces we can find out P is equal to 0.45 fck into x into B minus Fb, right 0.45 fck is the stress into x upto x it is developed the compressive force and into B is the width of the base plate minus Fb, Fb is the tensile force in the bolt. So here the P is the axial compressive force and a is the a I am coming later. So the axial compressive force P can be equate with 0.45 fck into x into B minus Fb and similarly the moment can be equate as 0.45 fck into x into B into L by 2 minus x by 2, right minus Fb into a, so this will be the moment where a is the distance of line of anchor bolts from cg of the column this is a.

So from cg of the column to the line of the anchor bolt. So moment I can find out from here. So from these two I can find out the value of x, okay.

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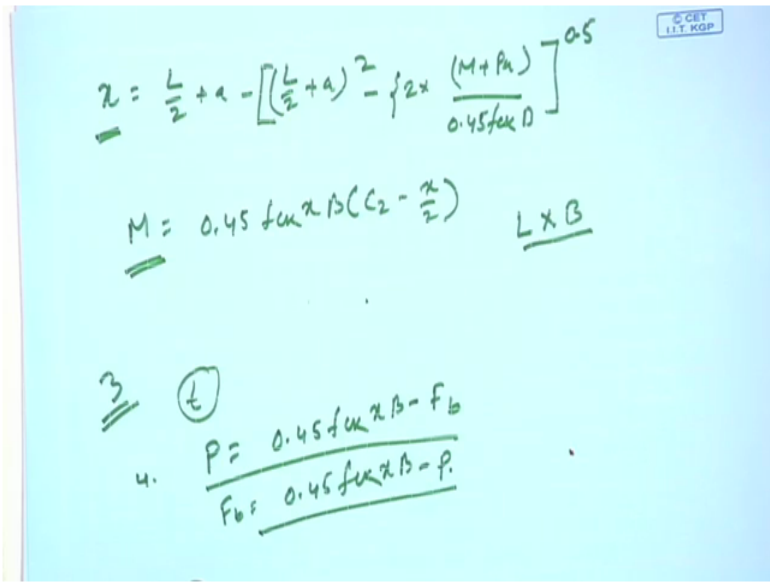

Now from these two if we calculate we can find out the value of x as this L by 2 plus a minus L by 2 plus a whole square minus 2 into M plus Pa by by 0.45 fck into B into whole to the power 0.5. So using those two force equation I can find out the value of x as this, right.

And the maximum moment can be determined at the critical section as M is equal to 0.45 fck x B into C2 minus x by 2, okay where C2 is the outstanding outstand of base plate from the column flange. So C2 is the outstand of base plate from the column flange. So from this we can find out the value of M. Now then the third step what we can do we can find out the thickness so once we find out the length and breadth of the base plate we can find out the thickness of the base plate by equating the moment capacity of the base plate to the moment at the critical section, moment capacity of the base plate means that is 1.2 Zefy by gamma m0, right. So from that we can equate and we can find out the thickness so this is how one can find out the size of the base plate, right.

Now in this case we need to carry another step that is to find out the design tensile force in the bolt because we do not know the design tensile force in the bolt. So that can be find out from this equation that is P is equal to 0.45 fck into x B minus Fb we know this equation, right. So here Fb is nothing but 0.45 fck x B minus P, right. So from this we can find out the Fb as this.

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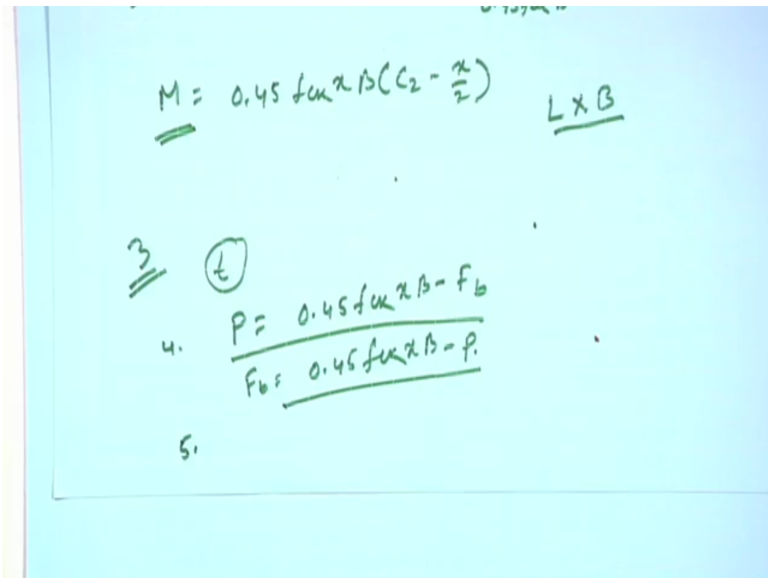

Now after this what we can do next step is step 5 that is weld connection which need to be design to join the column section with the base for the maximum tension in the column flange due to the applied moment so the weld connection again has to be done. So it is a Tds process but if we know the formulas then we can directly find out the L, B and T the length, width and thickness of the base plate otherwise you can derive from this basic equation and then we can find out the length, breadth and thickness of the base plate, this is how one can design a base plate when it is eccentrically loaded loaded eccentrically or loaded with moment, right.

So this is whole about the eccentrically loaded base plate and the slab base with these three lecture we have covered in next we will go to the gusset base where we will see when the moment is also coming into picture then how to design the gusset base gusset base design means one is design of the base plate and another is the design of the angle which is connected to the base plate or gusset base base plate with the column. So there the critical will be the design of the angle section which is joining two members that we will see how to do it in next class, okay. So I conclude this lecture here, thank you.