Design of Offshore Structures
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Module - 6
Lecture - 8
Design against Accidental Loads VIII

So, yesterday we were looking at the energy absorption by a basically the plastic deformation and the hinge formation all that depends on the plastic capacity plastic capacity depends on the strain and the rotation in a basically if you look at the formula what we got for a simply supported beam with a central point load four m p by l. So, that m p depends on the capacity of the members of basically what we are trying to look at one of the requirement was martial criteria which is empirical trying to limit what could be the maximum rotation possible the second one just need to look at the the geometrically admissible rotation because if the rotation is too much or the delta is too much the beam will already would have broken into two pieces.

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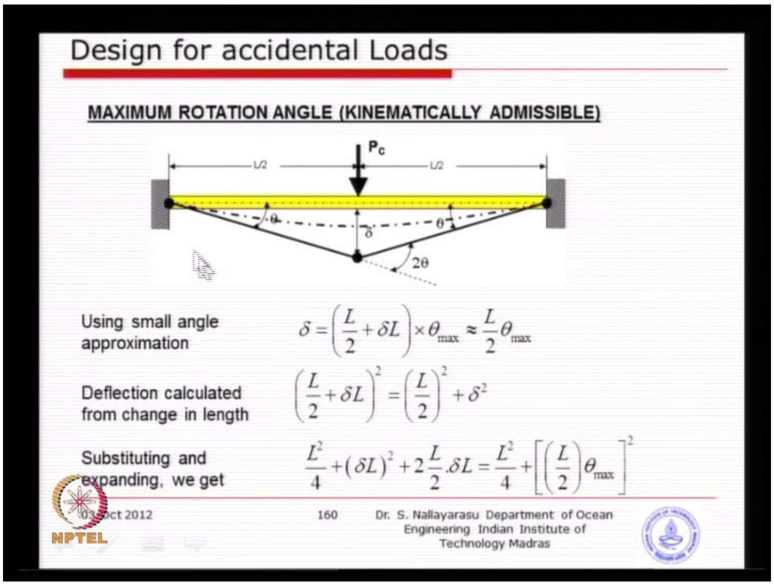

For example you look at this picture you apply a load like this and keep increasing the load when when the delta becomes too large then that cannot exist because you know the length extension or the strain in the beam thus half of the length if it is considerably smaller compared to the displacement the rotation is larger the beam has to break. So, that what we are trying to derive a relationship between the strain and the rotation. So, basically just see here using small angle principal r theta you can find out a relationship between delta and l by two theta and similarly you use theorem to find out the the length extension is dealt l because of the strain in the member and you just expressed in terms of l by two delta l square plus and expand this and basically try to ignore.

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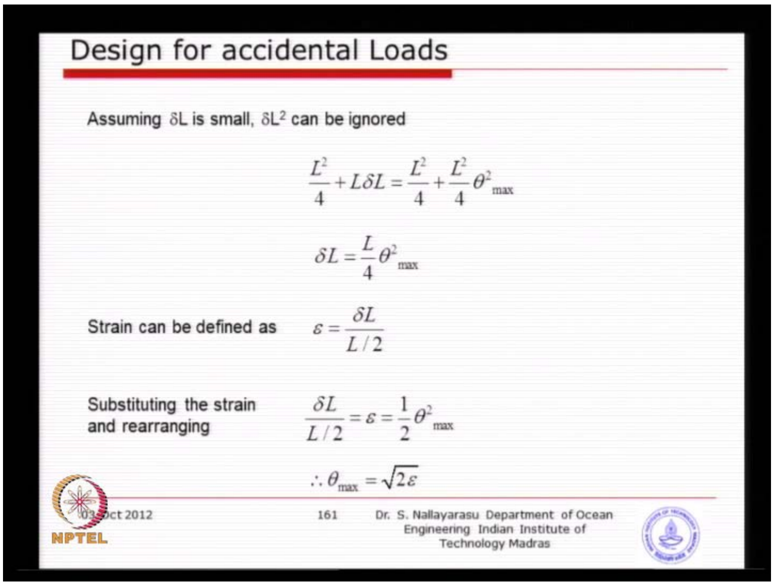

The second-order terms delta l square and delta l and finally, you get a relationship between the delta l and theta basically you get a some relationship and then the strain can be defined as as you know very well change in length over the half length of the member and substituting that you will get a relationship the maximum rotation that can happen if you know what is the strain because the strain is directly proportional to the extension of them half member and that is basically defined as a strain.

So, we can basically look at what will be the allowable strain for example, if it is in a elastic range point two percent then you can find out what is the rotation maximum allowable and if you go into elasto plastic you could allow either two percent or ten percent or fifteen percent. So, depending on what is the strain that you are trying to allow you can relate the indirectly the strain is related to your delta only what we have done is little bit on approximation all this is require only just or get an when you do a non-linear second-order analysis in a computer you do not need to really worry about all this because automatically takes into account here we are trying to derive a kind of relationship between the strain and the rotation because many times you will do a hand calculations simplified hand calculations.

So, what is the marshals criteria which is highly empirical there is on experiments what could be the maximum strain that would like to allow it will produce a corresponding rotation and in here we have just derived geometrically admissible relationship between the rotation and strain and we should actually look at both and whichever gives you the the reduced value which gives that for our calculations simple example.

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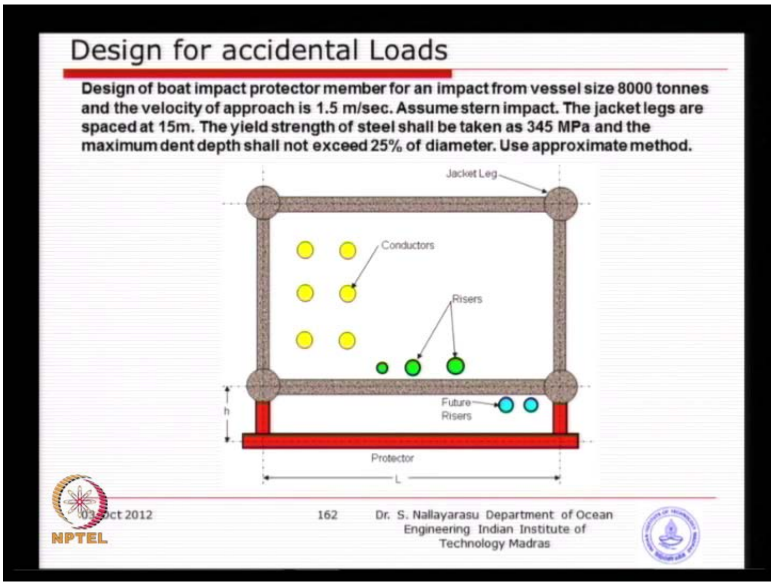

Basically I have given you how do you design a boat impact protector you know you see this picture I think by this time you you know what is the configuration basically a well flat form with four legs and wells are located on the on the inside as you know very well you want to locate the wells inside to protect again any of this kind of impact basically highly dangerous you have wells outside you know what will happen in case of impact the first thing will get damages the well. So, most of the time wells are kept inside for legs with the well protected also the risers you can see in the green color risers means the transportation of will from platform to platform or platform to onshore all of them are kept inside just you know for the reason of safety, but sometimes what happens you plan a platform and then in future you get more oil you would not say I do not have risers I will not take the oil.

So, you need to add additional risers isn't it at that time you add the risers only outside because you cannot go inside and add. So, when such things are planned you have a riser coming in future or maybe unforeseen risers you know several time that was happen you you plan a platform for twenty years, but still oil is still producing you will not stop you will recertify the platform for another five years add another riser add another equipment sometimes happens because the the quantity of oil available could be estimated at the initial stage some accuracy, but not hundred percent correct would be lower or it could be higher.

So, that that scenario you have a additional risers coming outside the legs because you cannot install inside now we need to protect the you see in the red color what I have drawn just a simple frame which will make sure that it is protecting the risers against any impact now you see here there are two connections we have made one to the one left side leg another to the right side like why we did not make a connection here because that member also may not have sufficient capacity to absorb and also if that what deflects what happens it will go and damage the existing risers inside.

So, you have to pick up the correct point in such a way that you do not damage the structure. So, basically that is the idea behind do not want any of this existing facilities to be affected because of the new additions. So, when you see this type of design what we are trying to do is come up with the design in such a way that after impact you do not get damage either to the structure or to the facilities that we are looking at. So, this h will need to be designed in such a way that after impact that deflection does not make the structure to be in contact with that type of facilities that you are adding with a margin probably half a meter of few hundred milli meters.

So, design a boat impact protector for a vessel size of eight thousand tons velocity of approach is one of meter per second and yield said this given and stern impact length of the ah the legs are the length of the member between legs is is fifteen meter and then debt not to exceed twenty-five percent of the diameter and use approximate methods not computer analysis just to arrive at a preliminary dimensions later on you can do all your ah you know computer analysis design, but just to get an idea. So, how do we approach the problem first of all we need to fix of a diameter because diameter also not given no you see there the diameter is not given only the spacing is given. So, we need to come up with an idea.

What could be the potential diameter. So, you need to go back to your basics stand to debt ratio you know basically I think you might have studied in your concrete design steel design simple ideas span versus debt could be in the of ten fifteen twenty isn't it. So, do not keep it hundred it will automatically become a rope isn't it. So, basically span debt ratio is something that all civil engineers should keep in mind. So, that when you start a geometric configuration you're starting in a right direction. So, typically for a supported at both ends spanted debt ratio between fifteen to twenty is a good number is it not? It you start with that.

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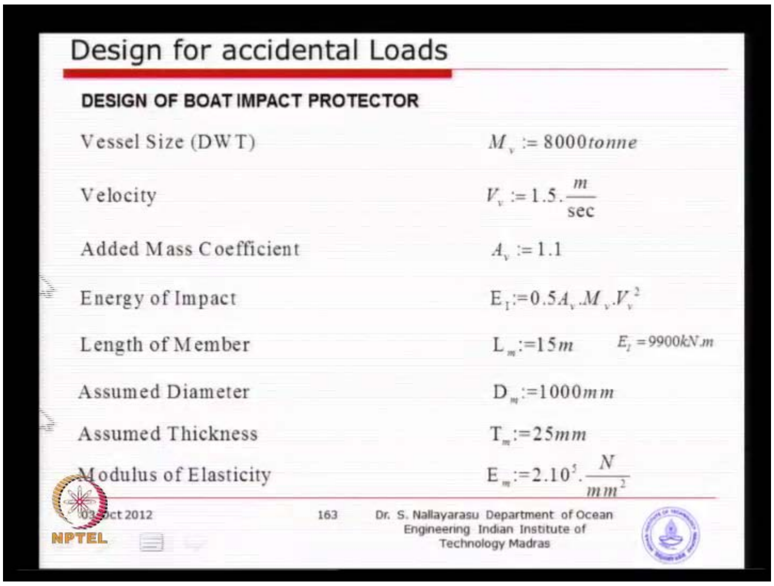

So, based on that I have just assumed a diameter of all the given parameters I just take a diameter of one meter looking at it I would be able to get the fifteen meter means I should start with one meter maybe later if I am not enough I can go for slightly bigger to start with one meter I have just and thickness I have just assumed as twenty five as I mentioned yesterday d by t ratio of about forty you know simply start from there all other parameters are given and basically the energy of impact is calculate and as nine thousand nine hundred kilonewton meter you know basically half m v square everything is given simply calculate and model as a elasticity you should even required for the empirical formula just for a sake up calculations.

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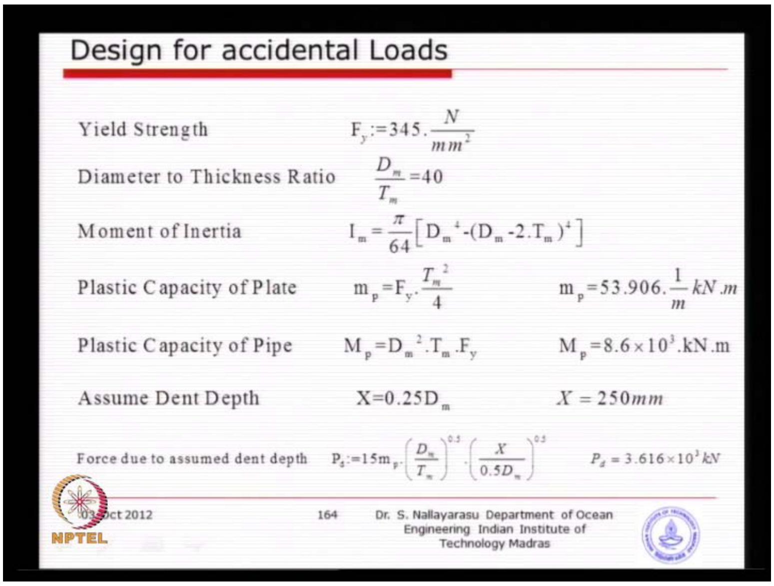

So, diameter through wall thickness moment of inertia and the plastic capacity of the part of the plate you know basically the the the pipe the plate made of the pipe basically that local moment of inertia and then the plastic capacity of the tubular section itself you know as a whole section. So, that is small m p I just to differentiate and then the dent debt is taken as twenty-five percent of the diameter and then force due to dent debt this formula, which I think we were looking at from the a p I recommendations substitute all the parameters you get three thousand six hundred and sixteen kilonewton. So, basically for a twenty-five percent diameter of the dent you get a dent force of something around three thousand six hundred know basically the plastic capacity and plastic movement capacity of the pipe and the plate has to be differentiated both will be used in different places.

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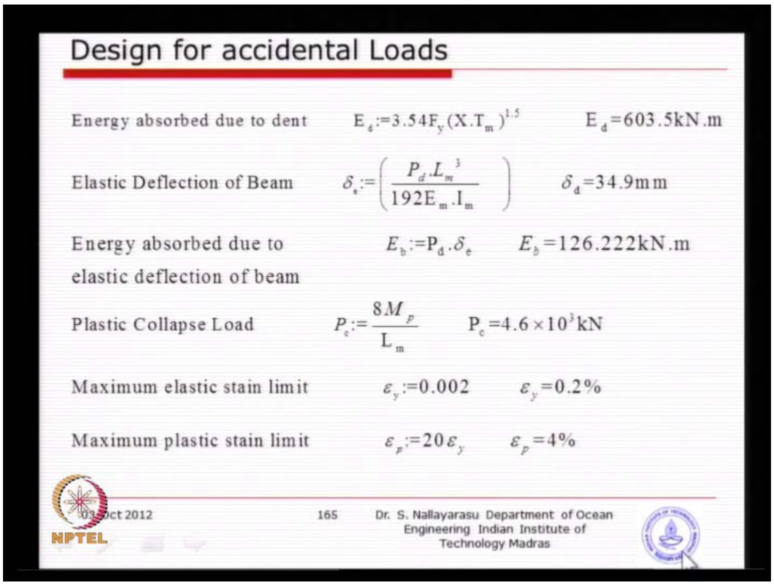

And then you for find out what is the energy absorbed due to dent which is the empirical formula that you have already above six hundred kilo Newton meter and the elastic deflection of the beam you know very well both ends are assumed to be fixed if it is not given if you go back to the configuration you will be able to get fixity. But not hundred percent if it is not given the user hundred percent for examination purpose you may actually give fifty percent or seventy percent, but in this case directly and then energy absorbed due to the elastic deflect now the beam basically the four times displacement and then the plastic collapse load which it derived for a simple point load is for this a fix fixed conditions sorry basically eight m p by l and you get that much of plastic capacity load and then the maximum strain limit you need to calculate for elastic we know very well its point two percent, but for plastic strain is taken as twenty which is what is recommended by Marshall.

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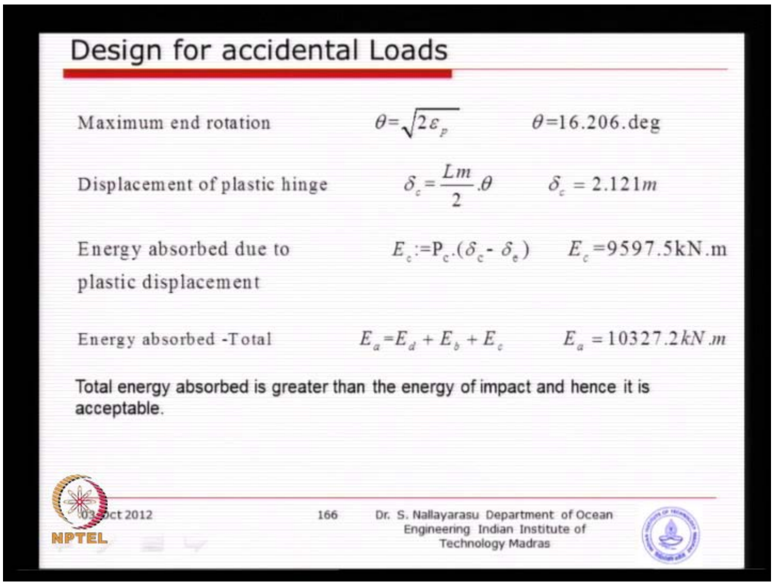

So, you get around four percent and basically the rotation maximum possible which we derived a formula just now at geometrically admissible sixteen degrees and displacement at the plastic is location two point two meter. So, you can see here is just going. So, much and then energy absorbed due to plastic displacement nine thousand. So, you can see the larger energy is being absorbed basically the energy absorbed due to dentist very small about six hundred I think about six hundred and then the elastic is basically about hundred and twenty-six very small, but if you look at the plastic deformation at the at the time; that means, this this protector is going to be sacrificial is going to fail; that means, one-time impact the next time you have to go and the replace.

So, this is what the condition will be given to you whether it is a replaceable protector or permanently the protector should not get damage depending on the situation what you’re given should be able to design it. So, in this particular case it was not mentioned whether boat impact protector member basically have not given whether it should be sacrificial or permanently to be design in such a way that it should not get damage. So, in this particular case what I have done is I have design in such a that way that these are replaceable protector the reason why I decide to do. So, is basically a external member for example, if this is a part of a jacket member and which require for jacket integrity I may not assume that way because once the member get damaged the jacket becomes unsafe whereas, in here is only a peripheral member it does not contribute to the global integrity of the jacket system.

So, I can design if it did get damaged does not matter I will go and replace next time after few days of the damage. So, that is why see here the total energy absorption is ten thousand kilonewton meter. So, I have definitely satisfied the energy absorption criteria basically the energy required and energy absorbed is higher. So, basic idea is the two things to note down we have.

Got all three components one is the elastic dent formation then the elastic deformation and the plastic deformation what is not taken into account is the global jacket displacement which will not be able to calculate by manual calculations. So, what you need is a computer analysis you take this force you have calculator from plastic collapse which is transferred to the jacket legs you will do an analysis of the jacket and then find out what is the displacement and that will be added to the total energy in this particular case we are that is why I have put use approximate method by which I can ignore the global platform deformation.

So, this is a typical example by which you can utilize the design method for dent elastic and plastic deformation of the simple beams whether it is fix or pin pin or other boundary conditions you could the reason why we derived all those formulas give for that one is we derived all the collapse load and then basically these strain and the rotation relationship and basically the relationship between the energy and basic parameter from dent and dent force to the displacement.

So, all those relationships are used just to arrive at the energy absorption versus you know the ah the force introduced the next one what we want to see is you look at this picture then go back to this picture in case if this joint fails before this pinch formation. So, what happens is the energy absorption criteria what we have said e dent plus e elastic plus e plastic may not be able to achieve in case if this joint fails because we have assumed the joint is sixth joint and its going to take that much of reaction whatever the reaction the impact force is p collapse we have calculated half of that is going to go to this joint and that joint needs to take like what we have done for a punching sheer capacity now we need to evaluate the punching shear capacity and make sure the capacity is higher or at least will not fail when the collapse load occurs here. So, that the idea otherwise that collapse load or collapse energy what we have calculated may not be able to achieve because of the joint failure. So, we need to look at the ultimate joint capacity and find out whether we are able to achieve.

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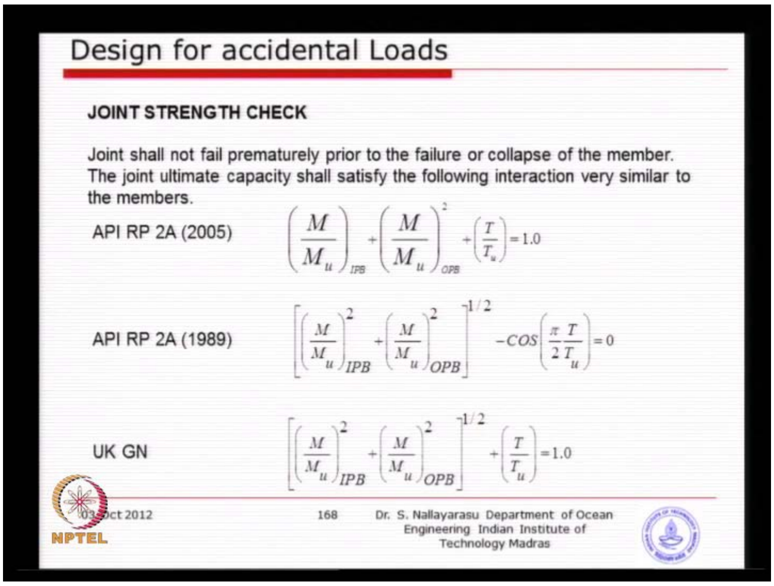

This this as I mentioned earlier on when we were deriving the formulas for joint capacity design all of them are ultimate you you will remember when you're looking at p allowable will be having a f y t square q f q u divided by a factor of safety which is one point six. So, if you remove the one point six that is actually the ultimate capacity of the tubular joint. So, then we can find out at what load that ultimate capacity is achieved. So, if you look at the three formulas which I have just written down here only just a symbol different basically in a p I they put instead of t they have p by p ultimate, you know just notation otherwise this is the formula that previous revision of a p I you could see here which we were trying to derive no relationship between the the moment and the actual load earlier I think yesterday we were trying to do earlier revision of a p I was using this and the reason a p I they have just changed to this and the reason is this is for tubular. In fact, this is the correct methodology. In fact, you will get this term when you derive for circular section whereas, you will get this for the angular section the stress pattern around the brace tubular interface is.

So, complex is not going to be a circular because you will get a elliptical interface you may get a stress variation is not uniform. So, a p I have done a joint study with the industry people in UK and they have come up with the recommendation that we should use this which is going to be conservative in the high moment areas. So, basically this is the one that we are going to evaluate for a joints except that in this case we will remove the because we are looking at the ultimate capacity whereas, the u k they still use the ah combination of this plus this you see here you have got the linear term coming from the first one and the non-linear term coming from the second one.

So, there is a quite a bit of ah different between different codes, but of course, if you look at the I s o codes and the a p I reason one they use this interaction between the actual load and the you will have the evaluate the capacity of the joint make sure that the load at which the collapse occurs will be submitted substituted here, and correspondingly the joints should not when when you just over plot the previous revision of a p i.

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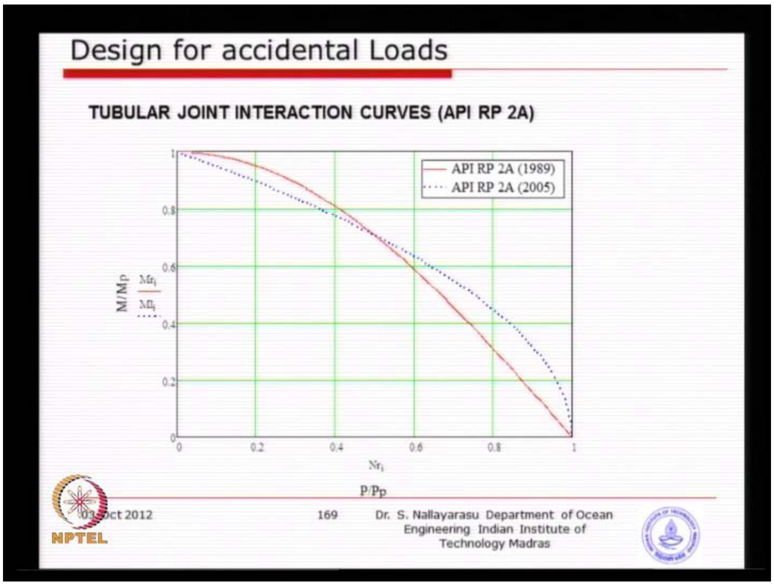

And then the new version of a p I see a difference between some areas you see the red color is the the old a p I and the dotted blue color is basically the the new a revised some areas the new equations are actually under predicting and basically not. So, good, but still you back to if you look at this one this is even verse. So, that is why the u k guidance notes has been withdrawn now no more valid because all the u k codes and standard we are going back to I s o codes in fact most of the british codes are now with is getting one by one drawn because is getting replaced by the I s o codes.

So, maybe you do not need to say this the next one what we are just going to look at see what we did was the impact and local member local joint and then we just look at the global behavior what happens is when the jacket is getting fit by a a boat or a ship we need to look at whether any reserve capacity available and that is some time we call it reserve strength or reserve strength ratio. So, how do we get this basically we said that design requirement first adequate initial breast capacity would be available adequate joint capacity which is what we were discussing just.

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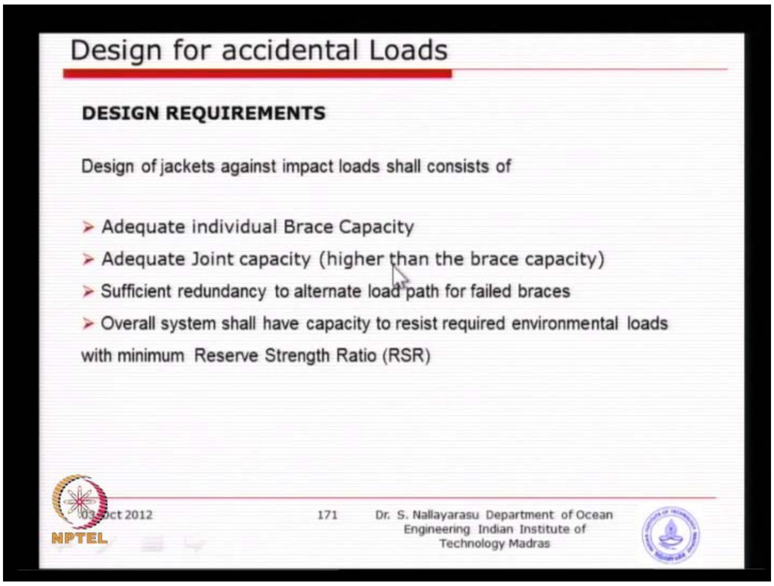

Now, sufficient redundancy to at alternate load path were failed braces its very important I think the typical example will be the leg brace if we have a single braze and basically if the braces is failed because of the impact we do not have way alternative load path and that is were many of the places you should insist that at least the first of two levels between you should provide a leg brace over all system capacity basically nothing, but reserve strength ratio of the jacket before and after the damage you know.

So, basically you find out what is the strength original what is the strength after damage and if the reserve strength is in terms of ratio if it is more than one you are safe for example, you have a jacket you apply a environmental loads of one year or hundred-year whichever the case we would like to like evaluate and find out at what maximum load the jacket fails; that means, collapses and then do the same thing after one of the member is removed because the impact damage remember and then make the jacket to fail at what load it fails then you compare these two numbers is these two numbers are substantial differences exactly the ratio will give you the reserve strength available and that normally should be greater than one and if it is one one point one one one point two you are safe. So, that is what we’re trying to evaluate which is quite important in case of a accidental loads.

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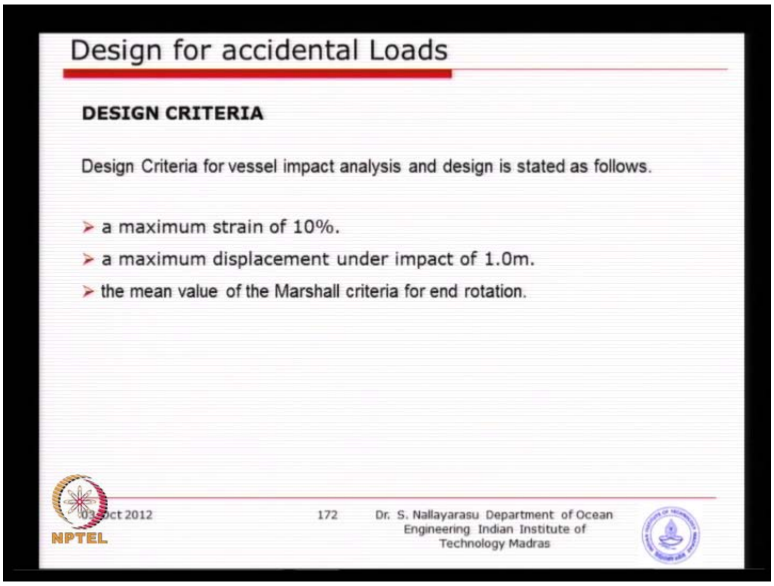

What will be the design criteria for a finally, recommended by a p I is basically maximum strain of ten percent this is what we are looking at earlier on four percent was their maximum displacement under impact is one meter and mean value of martial criteria for the rotation you know basically calculate. So, use maximum strain of ten percent calculate the strain by using the jaw metrically admissible relationship with is equal to summation of two epsilon and find out what will be the the martial criteria limitation I think two thousand five hundred d by t squire. So, you find out whichever gives you the the reduced rotation use that and with limiting displacement of one meter. So, that will be the criteria acceptable by a p I as well as most of the industry companies which I think just now we were trying to explain all these four parameters basically kinematic ally admissible shall not exceed martial criteria.

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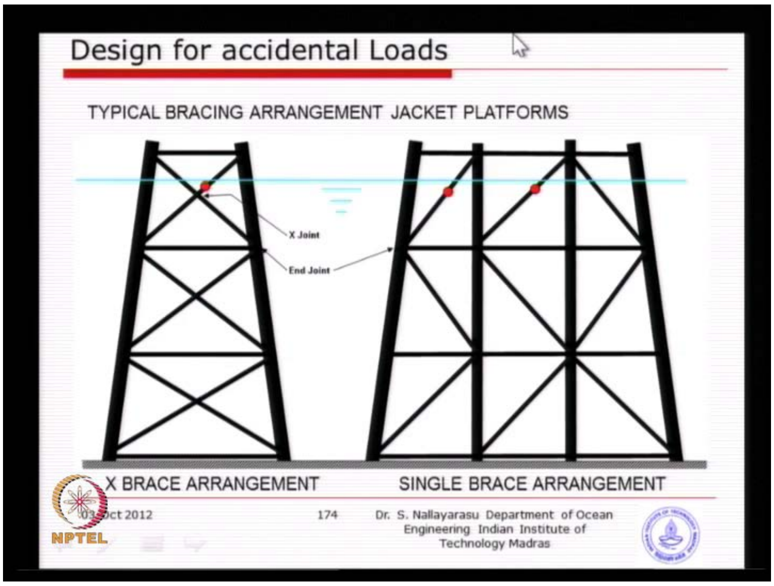

Typical. In fact, locations, so you see here this is basically an x brace this is a non redundant single bracing system. So, if one impact happens their basically what will happen the brace becomes unstable and fail the system becomes portal. So, there will not be any redistribution possible especially the horizontal loads vertical loads anyway go through all the legs because its carried by the leg system whereas, the horizontal system or horizontal load will have sufficient over stressing of legs. So, that is why in this area if you provide a x brace is reasonably producing additional redundancy in the system which will give you higher ratio when you apply the same load next after this damage you will be apply the first thing what will happen the legs will fail; that means, before achieving a a higher load if the legs fail the platform will definitely collapse.

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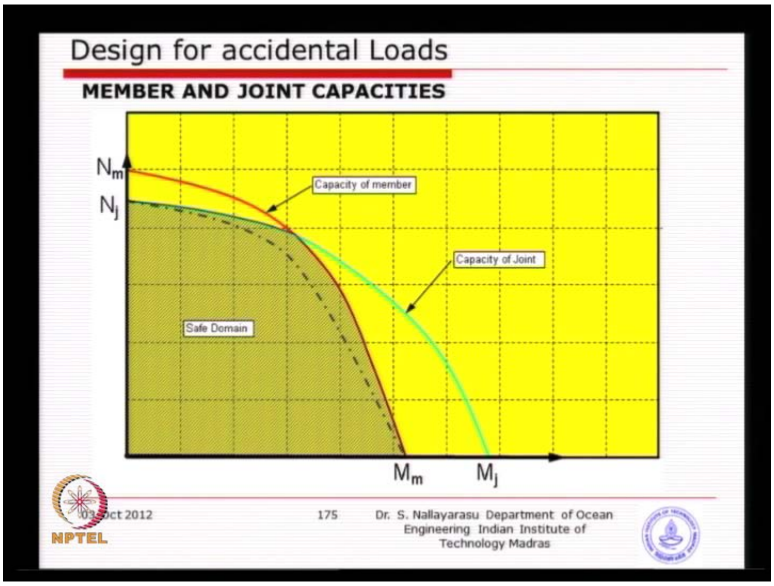

So, in here I have just given you a chart were in the capacity of the member versus capacity of joint when you design overall system you need to make sure that there is no member or a joint isolated basically should have capacity lesser than what is the minimum capacity required. So, the overlapping zone is the shape do mine of the capacitor or a members not one member all the members and capacity of joints put together some of the soft ways like for example, d n v system software has the capability to plot all the joints and members together to come up with the safe load that you can apply, but if we want to do it by manually you’ll take a longer time because each one you have to bring in to the chart the allowable movement and the allowable actual load.

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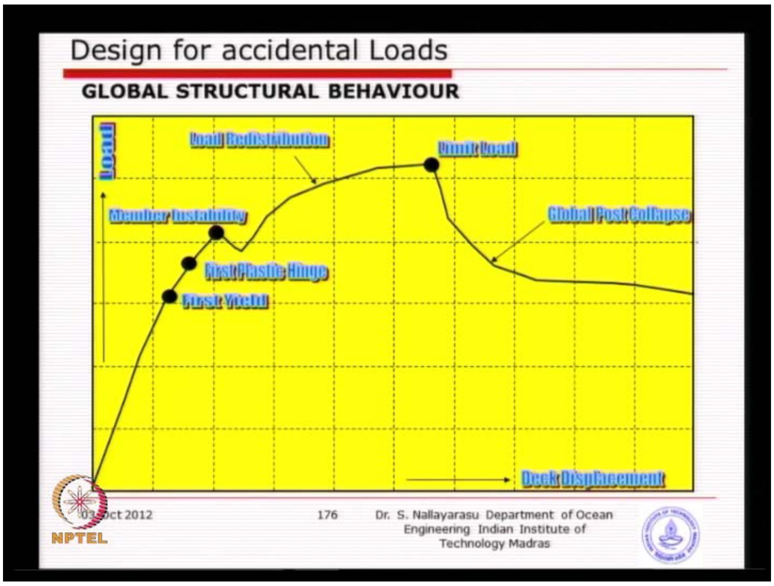

Basically when you look at the global structural behavior of a system first will I think which we were looking at earlier on last time when we were looking at a joint you know basic load deformation curve and first yield first crack and then ultimate failure a similar idea only thing is here is a multiple members multiple joints. So, when you look at the first yield of a one particular joint or a remember does not mean that the system is going to collapse because when you look at the overall system bending movement may be maximum at one point elsewhere bending movement is very very less.

So; that means, one point may actually get in to a the first yielding stresses what elsewhere whole system you may have less stresses lesser than the yield point and continuous increase of load what will happen you will see that anyone of the point along the structure several thousand members are there you may form a inch and that is the point that we need to know down because from there the system will start to behave unstable you know one of the member this inch formation is there, but reminder is still intact, but in another few hundred tone loads what will happen is that that member will become unstable if that member becomes completely unstable then the load from that member needs to be distributed to the neighboring members or neighboring joints and that is the time basically will start relieving if there is no redundant system path for example, if you do not have a express there is no redistribution going to happen one of the joints may get overstressed.

So, that is the time you see here the load will the capacity may actually drop down, but once that members overstressed you make it slightly increased redistribution because of the local member in that vicinity, but ultimately the system will start failing when you have a few more members get you know the plastic inch formation; that means, one member to member three-member at some stage the system will be just unable to take any more load because it is unstable and that is the load that we are looking at which we call it a total collapse load of the system or a jacket. So, that is if you know that and basically the ratio of the same load before and after damage can be evaluated in the next picture

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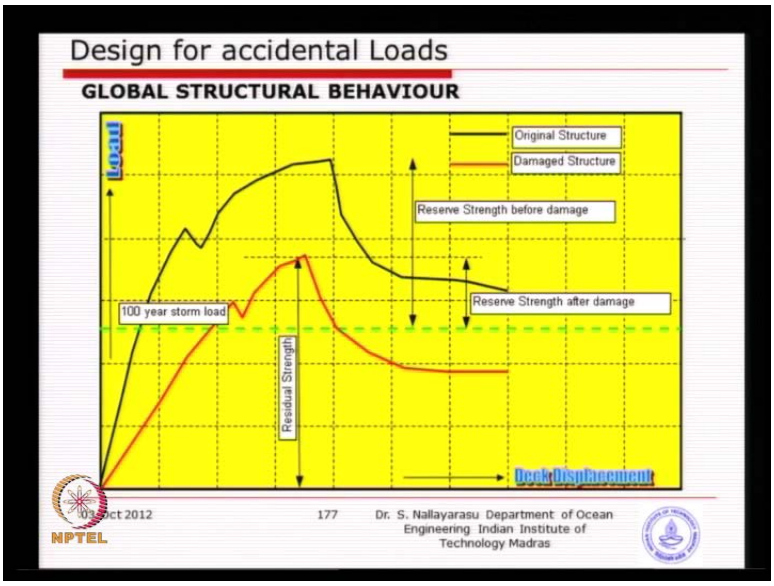

That's exactly what I have just detected in red color and the the black color original structure versus the damage the structure and that ratio will be your reserve strength ratio depending on what is your load capacity whether you are looking at one year or hundred year. So, in this particular case hundred-year term is taken as the reference load and the applied a horizontal load hundred years term load keep increasing with a factor of one one point one one point two one point three for both the structures. So, original and damaged the differences give you the strength available against damage all the time we were looking at the horizontal axis as a deflection you know basically the deck placement what is the maximum amount that you can permit.

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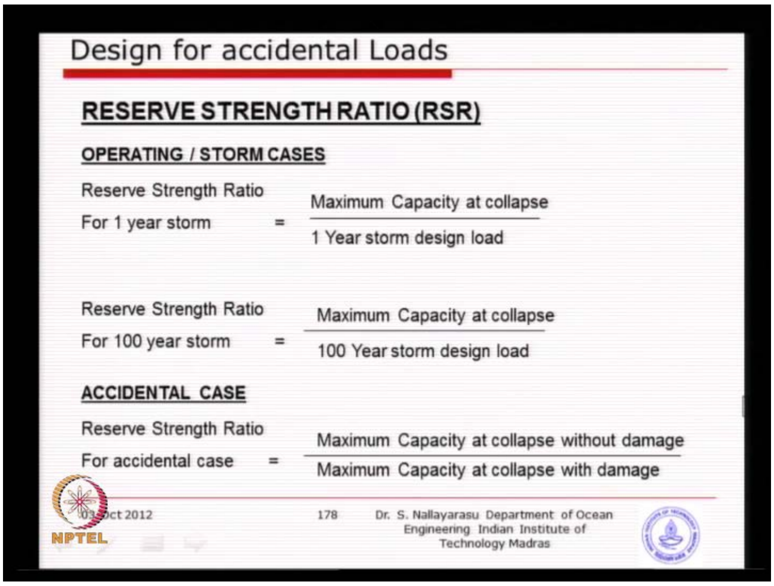

The results and ratio can be just defined as three cases one is operating and other one is storm the third one is just an accidental case this is what we were looking that just now and these normally is used for recertification for platforms there is no damage there is no damage, but still we want to calculate the reserve strength ratio because the platform has been serving beyond the design life for example, originally serving for twenty five years, but I want to operate for thirty years now that last five years you know basically several things have changed environmental conditions have changed when I want to recertify I do not want to design the platform based on allowable stress method s because this surely going to fail because all the design conditions are different old design conditions is completely different from now and members are corroded.

So, I cannot design and verify the same platform which was design twenty five years back using the new design court made that. So, what we normally do is for recertification of the platforms we use at the ultimate design principle because it only for a duration of time next five years maybe next two years. So, that time and we look at the collapse capacity and compare it with the design requirement and that will be design defined as a reserve strength ratio all of you remember recertification cannot be done using normal design principles which we are using is because for sure they will not able to take the loads because the design requirement twenty five years back is very less stringent number one the design courses are less stringent and over the period of time design requirements how been increased for example, typically the live load requirements the sea state conditions several years back we might have been using a smaller sea state, but because more and more information we have now the designs states are slightly high year or well you know basically informed decisions are taken now because we have lot of information earlier not much data was there simply assume same maybe sixteen meter seventeen meter.

Now, it is. In fact, nineteen meter and we have got global warming water depth changes. So, you can see by effects of all this design and requirements you have come higher. So, if you use the design requirements to verify the the existing platform against allowable stress method surely none of the platforms designed life could be extended, but then the question will come should be shut down the platform yes you do not want to do the certification using the ultimate design principles of what is the owners worry whether we can operate the platform whether it is going to collapse whether it is going to fail during the operation. So, that is the question will be asked. So, you ascertain the safety we want to make sure that the platform is over stress for sure everybody knows, but will not collapse in case if you operate that is what we idea behind.

So, called the collapse analysis, but we do not want to have a distribution where the ratio between the required collapse capacity and the collapse capacity of the structures should be having the margin and that is why it is called the result strength ratio which is absolute strength because this is not something similar to our working stress factor of safety is one point six one point six seven here if you exit it will fail whereas, then available stress that will still heavily not fail because only working within the elastic limit. So, basically in the operating strong cases this will be used for most of the time recertification of platform for accidental this case this is just get a time frame for repair work.

You know if you have a reserve strength ratio damage the structure versus and structures how much time we can permit basically depending on what will be the storm condition is going to allow for example, I allow only a one-year storm condition in a valuation of damage case than within one year I have two repair it bring biases structures to undamaged condition. So, this reserve strength ratio is important para meters of a comparison of ultimate strength of full system either before damage to after damage and or comparing with the storm condition where one year and hundred year the other thing that I just want to review an idea is how do we are observed the energy in addition to structural members you know there is several ways of doing it even in jackets we provide this for example, we just now design the protecting member one horizontal device just a structure with it observes by denting observes deflection both the elastic and plastic imagine if we can in corporate mechanism by which I do not want to damage the members, but somehow I can observe more and more energy by means of a device which is implanted into the system are implanted into the structure which will be good. So, that I do not want to replace every time isn’t it I can make that structure rigid, but by impact structure is able to take more or observe more energy.

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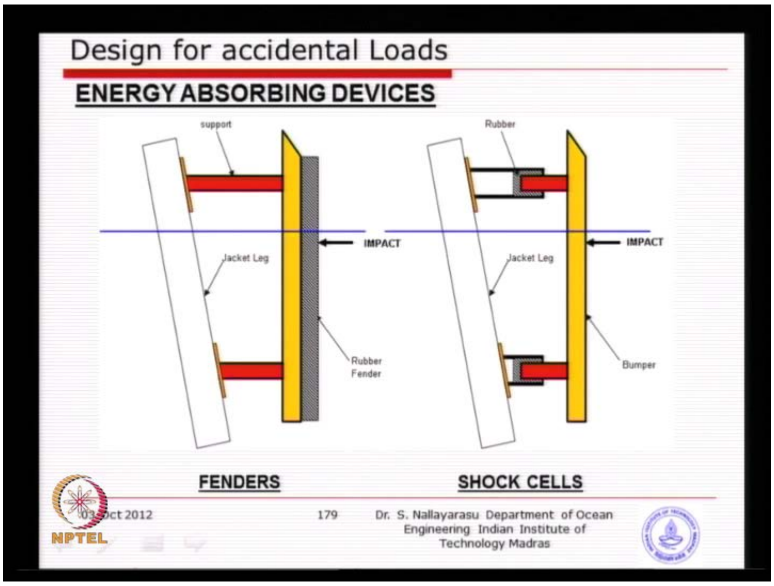

So, you see first thing on the right side that will be interested to see a structural connection between member that is taken directly the impact and the structure which is basically the jacket leg. So, in between we introduced as you pipe in pipe. So, you have outer pipe I have inner pipe both pipe’s are basically that together with the rubber element the here in the arch down there.

So, when an impact occurs is the rubber will allow the movement of the inner pipe into the which is the outer pipe basically trying to do some work by deflection of the rubber element very simple idea only thing is need to be design appropriately that it will not fail or it will not be too stiff that is where the idea is to stiff no deflection will happen if it is very flexible and by impact it will definitely damage. So, basically for required rapacity these rubber elements can be designed appropriately and molded together and supplied.

By several specialist venders available in large capacity like one thousand ton and two thousand ton capacity only thing these when you have such a element incorporated here the jacket leg should have sufficient capacity to receive such a loads. So, you need to design for it. So, this will call it shock cells is nothing, but rubber element observing energy by means of deflection. So, this is normally used for almost every jacket because you will provide detection on all eight directions diagonal four orthogonal. So, that no damage will happen to the jacket legs because we know very well if you jacket leg is damage what to happen the jacket is gone and to protect against that it provides shock cells and you see on the left side instead of spending like that is actually bringing.

The rubber element in the front this is basically conventional way of fendering you provide fender rubber element. So, the ship will come into contact with the rubber and the rubber will deflect and the energy observed only the residual energy will be observed by this structural member and the load transfers will happen either way of course, energy absorption by these rubber will be very very small compared to this type of focused shock cells depending on the design can select anyone them mostly we use this type of design for port land harbor structures you know you will see you go to the chennai port or any port see lot of rubber fenders hanging around you know. So, that the ships can common, but against whereas, in the case of of a of a jacket structures you provide this protection for of coursing jacket also we do provide this type of fendering for bringing the boards closers you know you will see several rubber fenders hanging around.

So, that you can bring the boards closers. So, the people can gets transfers from board to offshore platform. So, in summary basically a designed against impact with a simple exercise a times first three stages distribute done by calculation dent elastic and plastic deformation the last one is the the global platforms deformation and a we have just look at a some devices to take an additional energy of shock cells writing that you can complete the design against the accidental load two types of problem we have solved I think one is on the you know the design of protected other day we were looking at the one more problem for ship impact.

So, and on the fire and glass wall design though I have given you example you could expect a simple design of being a plate know basically against increase the temperature are a blast pressure you know you’ll be given a load you can come up with the thickness of the plates different boundary conditions. So, in here what will be the will learned a a slightly different design principle in comparison to what your being to members and the tubular joint where factor of safety is used of course, if you umpire the members and joined their itself there is a difference in members we limit the designed to elastic joints we do not limit the designed to elastic we go beyond elastic, but before first crack the capacity divided by a factor of safety whereas, in case of accidental loads have gone behind elastic gone up to the ultimate strength and then give a larger factor of safety here the allowable stresses can be increased by seventy percent. So, you will see that all three three three things you need to remember and select a suitable method for a suitable situation I thing with this we have completed five models.