Design of Offshore Structures
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Module - 06
Lecture - 06
Design againts Accidental Loads 6

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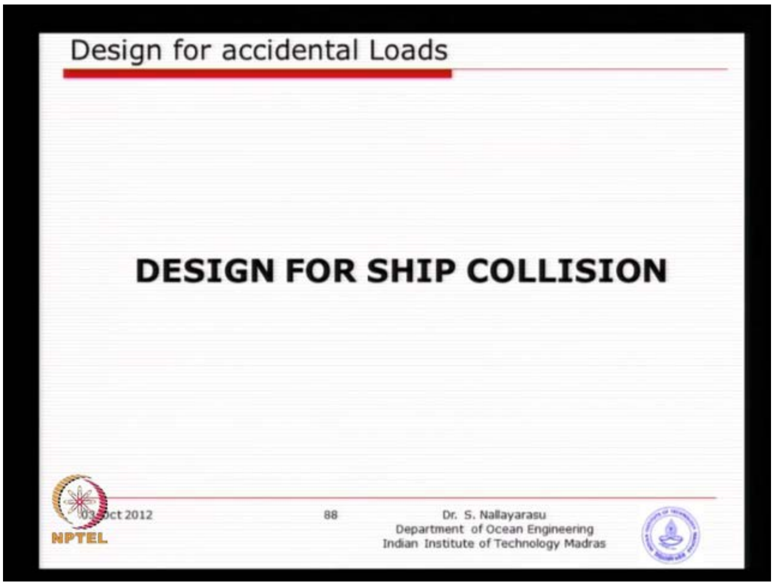

So, today we are going to see the next accidental load arising from a ship collision with the fixed structures. Basically in this case, we are just going to look at the turbulent members, as you know very well predominantly we use turbulent structures for jacket structures. And the ship collision may damage locally or globally depending on the size of the vessel or the boat impacting the structure.

So, we just need to see what we need to consider as a loading case and then, the subsequent damage evaluation and then, the available stresses, again we go back to our designed process. The only difference is the designed method will be slightly different, basically allowable stress method may not be very suitable, as the load is very large and we will be using energy methods and some empirical equations to find out what kind of damage can happen.

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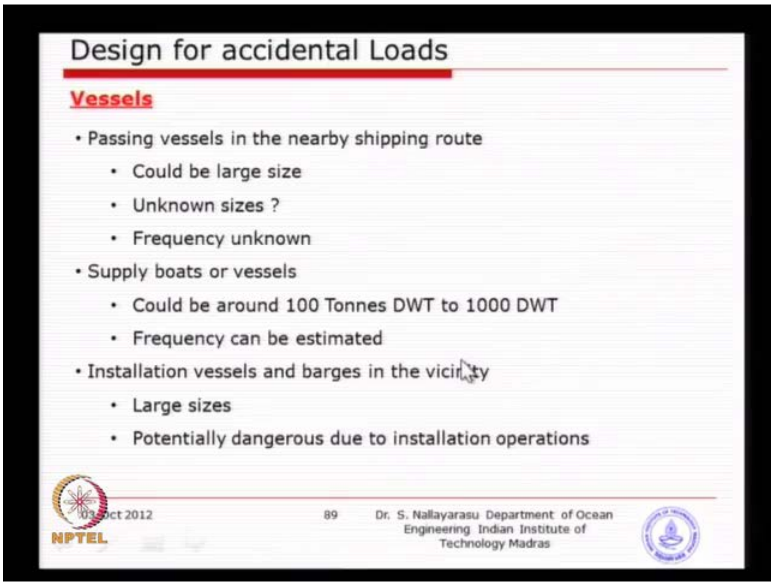

So, we just need to assess our self what type of ship or what type of vessel will be arriving in the vicinity of fixed observe platforms. Normally, when you plan a observe platform location it, it is basically away from the coast for sure, most of the oil and gas field developments are happening quite, substantial distance away from the coast line, number one. Number two, you will not allow commercial vessels to travel in the vicinity of the platforms though, if it is you know for example, oil and gas field is located in the vicinity of the, see the commercial fair way, you may have a restriction on that the vessels may not be permitted to travel.

So, you will reroute to other locations, but still what other ships and vessels can go and arrive in the near vicinity of the platforms, you supply vessels, as you know each platform will require food supply, first of all for the people living in the platform and the spare parts, chemicals required for the processing. So, you will see that several things needs to go and come back and in that case that means, there is a definite possibility that some type of vessel will need to go on a regular basis. It is not that one time it goes in one day and then just. So, you will have periodical intervals every two days, every five days, depending on the supply requirement.

So, such types of vessels have higher risk of hitting the platform, due to various reasons. The reasons could be, many you know it could be a human error, it could be engine failure and we worsening situation of environmental conditions. You know when the boat is starting from the coast, it may be perfectly all right by the time it reaches, you know you might see a different environmental conditions like gusting wind can change, wind direction can change which is definitely a botheration. So, that is why we need to just make sure that, select a suitable boat, you do not select the largest vessel like what we normally do for a live load and other load estimation, we take the highest possible load and then just design for it, which will be the best.

But in this case, if you select the largest ship which may go in the vicinity not even near the platform then, you may not be able to design. So, that is why we need to make sure that the selection of the boat as a loading case needs to be accessed carefully, together with the risk involved. You know if the lower the risk, you will select a smaller vessel size and basically, sorry higher the vessel size and vice versa. So, in this case normally API recommends a 1000 ton vessel typically, most of the platforms used for supply boat. Basically dimension is around 30 to 40 meter or 50 meter long 20, 30 meter wide, a typical ah supply boat. So, 100 ton is not a lot comparing a commercial vessel of few hundred thousand.

You know if you look at a tanker 300000 tanker carrying oil is quite large, when you are imagining to think about designing offshore platform for such a special impact, you may not be able to even design it. So, 1000 tone is quite small, but still there is the damage that could be done by this type of vessel is, substantially large depending on the velocity of approach. If it goes at a higher speed, what will happen? The impact energy will be so large that, it can just destroy the structure instantaneously. So, that is why we just need to do a risk evaluation, what could be potential causes of failure? What could be the potential size of the vessel? What could be the frequency of arrival, you know if it is going to happen one time in a year, the risk is very less.

But every two days if you have a vessel arriving there or leaving there and probably higher risk. So, many times the operators will do a risk assessment and come up with the size, the frequency and the velocity and probably once you have that, then you can find out what is the energy of impact. And some cases, you see the last one, you know you already have a platform and you may actually install another platform in that vicinity. Because, it is not the only one platform there, you may in a progressively develop other fields. So, in that vicinity you will have installation vessels, which are comparatively larger than any of these supplied boats and they can also damage because, they are all going to be there in that vicinity, during the period of installation of the new platforms.

So, that could also potentially prove to be dangerous of course, you will take all necessary precautions to make sure that the installation vessel does not make a case. Most of the time during the design process we do not consider this as a designed case. Because, it is only period, very limited period the installation is happening and also one time during say, one year and the next year you may not actually have the same installation. Because, it is not going to be like every year we are going to install the, you know the new platform. So, normally we do not take the installation vessel as a designed case, but in case if it is required then, you may have to consider that.

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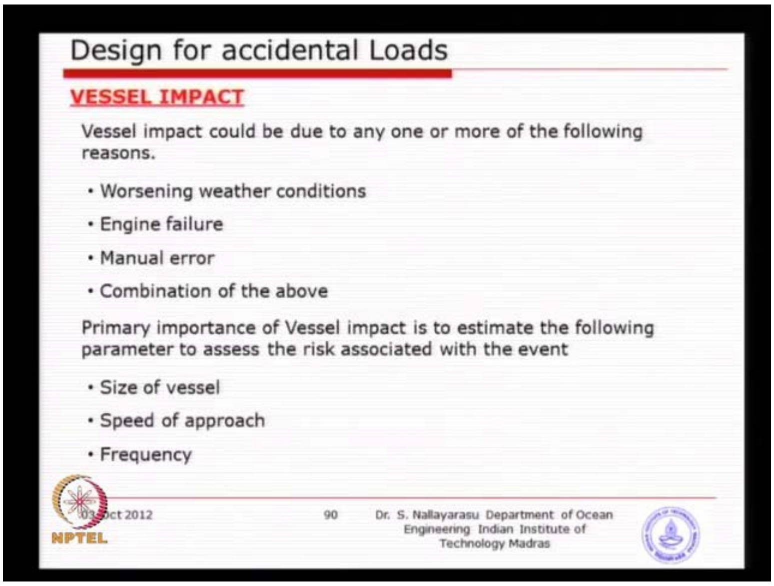

And typically, the vessel impact could be due to various reasons as I mentioned earlier on manual error is really a cause of worry because, many times people misjudge either that distance the speed and the wind conditions. So, it could be definitely a possibility. The other one is the un forcing engine failure, you know you may not have, you know thought about engine will fail at that particular instant of time and probably when the engine is failed, then you are unable to manure or unable to thresh back. Then, it will just automatically drip towards the platform, if it happens to hit then it is a problem. Weather situations normally to be a not so much of problem because, now a days the weather forecasting is available.

So, when you start from the coast you can actually see next three days what kind of weather is there, but still things can change. So, worsening weather conditions while you are in transit or after arrival when you are doing loading unloading process, that time suddenly a gust wind can happen.

So, the ship or the vessel can drip into the platform. What we need to primarily look at is this size or the weight of the ship or the boat, the speed of approach normally, you know you do not go very high speed when you arrive near the platform, you slow down and just go at a very low speed. And basically, human error can make the speed slightly higher than what is permissible in the region and the frequency. So, this is something that we need to evaluate as part of the risk assessment study, you will be given these three numbers so that, you can design the structure.

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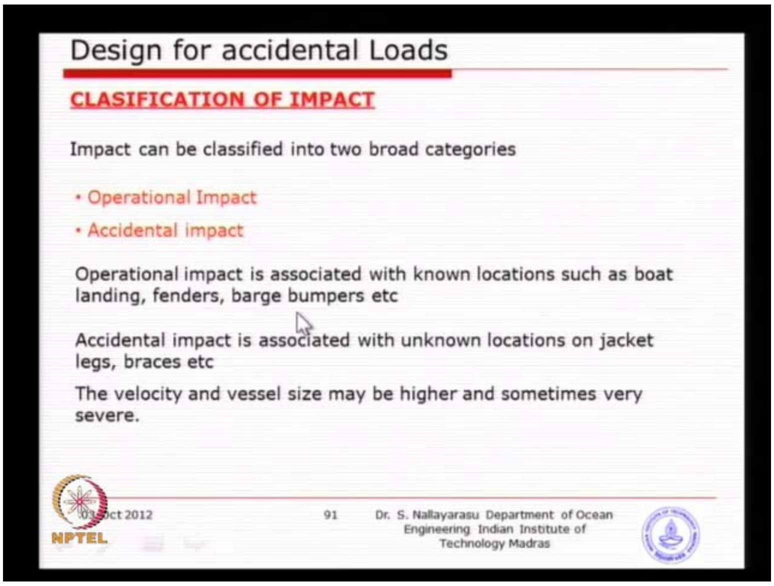

What type of cases we need to consider, there are two cases. One is the you know normally occurring cases where, you plan to actually approach the platform and come in contact. That means, the boat needs to go near the platform and hit the platform, not accidentally, planned operation that means, you just need to control the speed, control the direction, control the orientation of the ship or the boat arriving at the platform because, you need to unload material or may be unload people and vice versa. So, that is basically called operational impact and all the parameters involved is under your control.

For example, the size of the ship is already predetermined that means, you will not allow a bigger ship to go there and berth against, isn't it? And also the velocity at which it is supposed to approach and come in contact will be very much controlled under the captain. And basically then that means, which we have already got these two numbers, you can calculate the energy required to design the structure because, the impact energy is known and you could possibly design it. So, that is called operational impact in this process you do not expect any damage to happen that means after the berthing, the structures would be tact as original design, that means no damage to be expected.

So, you could possibly design without any problem, the accidental impact case is basically a higher velocity because, the speed at which the ship is arriving is not under your control. Because, basically several reasons or the cause of failure could be there and the size of the ship is well determined, basically based on the risk assessment study, but then some cases it may actually go beyond. Because, you have not taken zero risk, you have taken certain risk so, there is always a potential possibility that the size of the ship that you have assumed during your design process may exceed. So, that is something we need to be careful there.

So, this accidental impact, what we are trying to determine is the collapse of the structure should not happen at the at the point of impact or post impact. That means, damage can happen, but then you do not want to design in such a way that even after an accidental impact, the structure should be intact, which if you want to do it you can do it, but at the cost of large structure or may be, may not be able to design it because, the cost will become excessively high.

So, what we are trying to do? We are going to differentiate between the operational impact and the accidental impact. Accidental impact you are allowed to damage part of the structure, not the total, that is what we are trying to define. Whereas the operational impact you need to make sure that the structure is intact because, you are going to redo it again and again because, multiple numbers of times during the period of designed life.

So, what type of impact that may happen, we just need to think about it depending on the type of structure. For example, if you have a mono hull single tubular section installed, in any direction it can come and hit isn't it? Because it is a circular section and what type of impact it can happen is a tubular dent. For example, if you have a circular section, when the ship is hitting against the wall of the cylinder, you may have a local deformation in the form of a dent and it may have also a bending of a beam like a cantilever section. Because, it is fixed at the bottom and just standing above water and also the global deformation of the structure.

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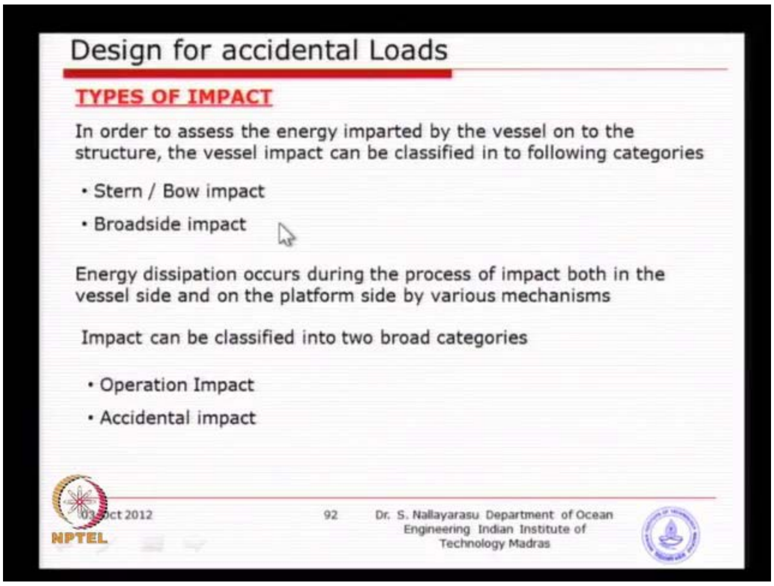

So, basically you need to look at what type of impact that can happen depending on the size of the ship and size of the structure. If it is a very big structure, it may not actually hit at many locations. So, we just need to see those type of impact and evaluate each one of the case and assess the structure for the capacity.

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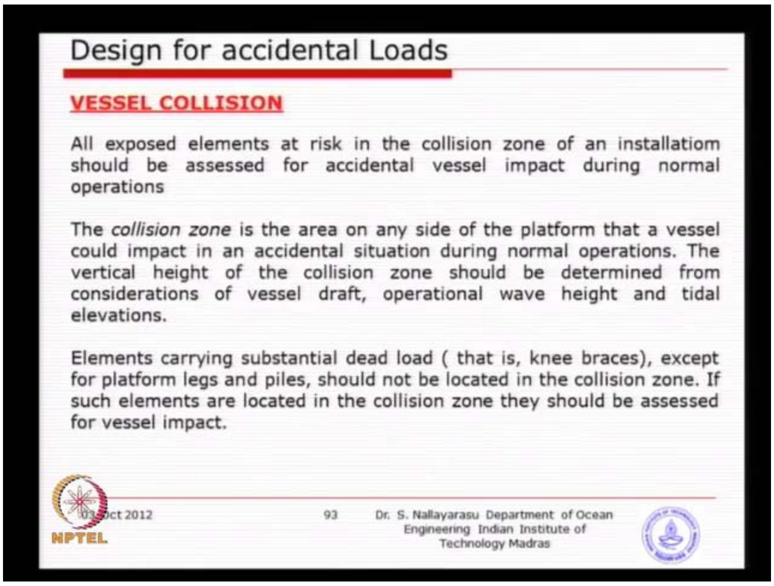

The vessel collision zone is something that we need to carefully evaluate, it is not going to hit the bottom of the structure because, the ship may not be able to go unless you have a submarine coming there. So, basically what we have is a particular zone in the structure near the water line, slightly above slightly below, which we call it, I think we have defined as the splash zone area, the change in tidal levels low tide to high tide.

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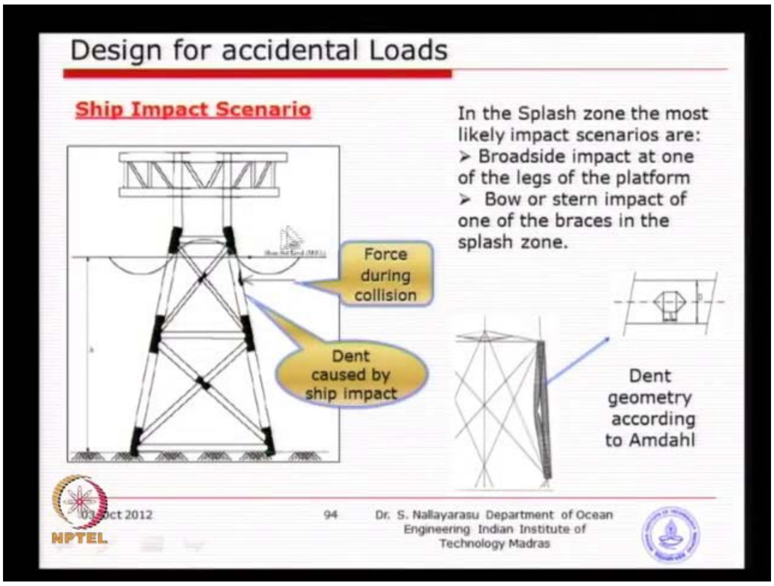

So typically, we see this is the structure that you can see the water line, the mean water line is this and you could see that this, the boat can hit either on this area or just below water line to certain extent. That is what we need to look at and basically evaluate each of the impact because, we do not know a priory that where it will hit. So, we need to assume certain worst scenarios, what if it hits here, what will happen to the member? What will happen to the structure? So, basically we are only trying to assume several cases of impact and that is where you need to make sure there are change in water levels are also taken into account.

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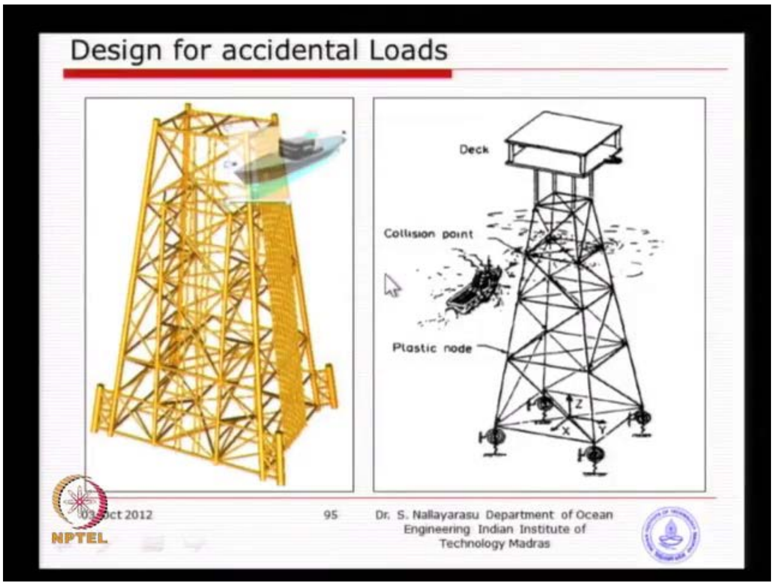

Typically if you see there in this vicinity, the near the water line you may actually see that the high potential of direct impact that means, those members only needs to be designed for such type of impact not the members below. Because, they have no axis through the boat because, the boats cannot get submerge unless, the boat itself is capsizing and then, go and dive downwards which I think it is a different scenario.

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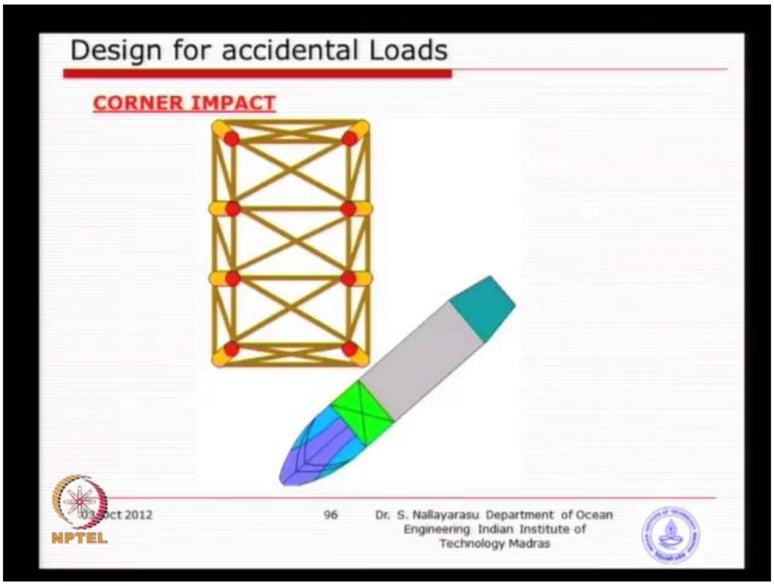

There are two or three types of impacts are expected. For example, you see here drifting vessel, engine failed, environmental conditions are deteriorating and the vessel has no direction and can come and hit in this place and though the engine direction, the basically the, the velocity of the vessel is in this way, when the engine was working. And when the engine is not working and the complete system is going in a different direction, you can get a hit like one corner impact. That means, the leg is getting impacted, that is basically a corner impact that means, what we need to evaluate, when a leg is damaged whether the system will be stable.

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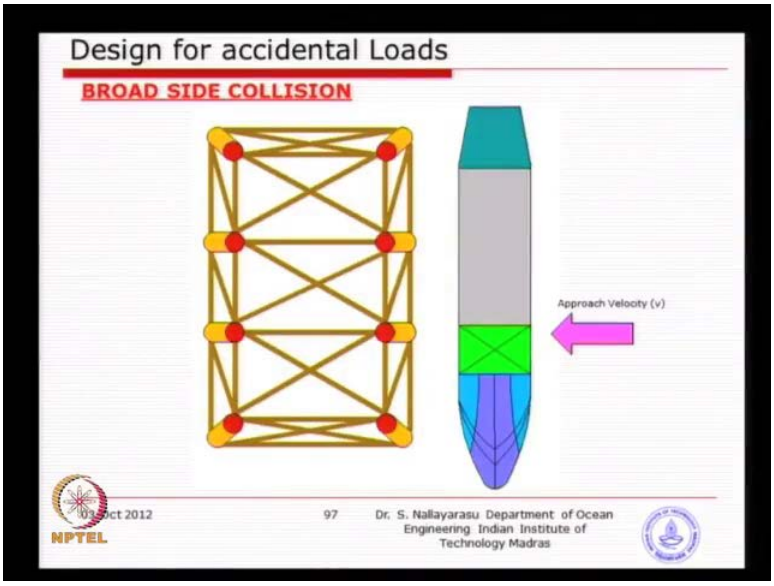

That is the purpose of which is basically to evaluate such a scenario or if it drifts in this phase and comes and get in contact with the structure in a parallel way. That means multiple contacts at simultaneously, which will be not a very a critical case because, so many legs are there, the damage could be lower than the corner impact.

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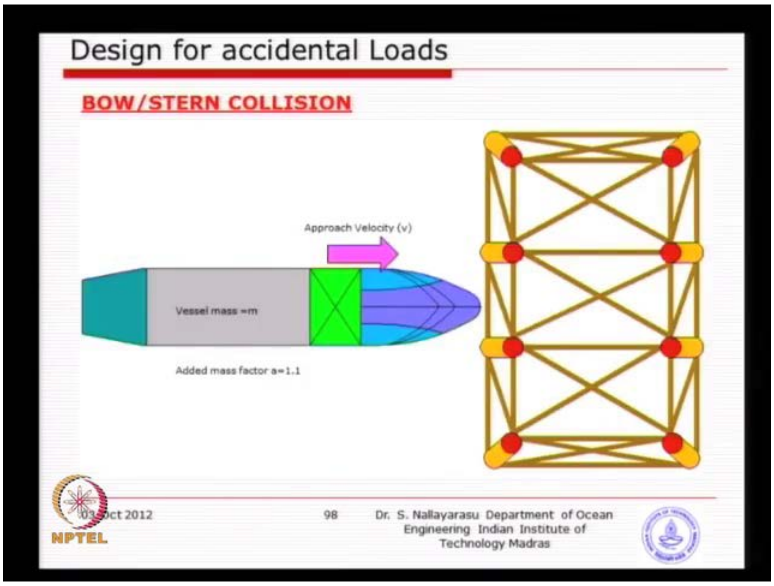

Or you may have a arriving vessel, unexpectedly higher speed just re pop the structure across through. So, this is one of the dangerous situation when bow or stern collision happen, you may see that the velocity is 100 percent that means, the engine direction is this way and basically can hit. So, what we are looking at is that coefficient of added mass, I think all of you are studying aerodynamics floating bodies, the most important one for the floating structures come in contact with the fixed structure, the added mass of the fluid that it carries, when it is moving from stationary to another location. Basically this will have increased added mass, compared to the added mass for a stern or bow impact, here it is 1.1, the other one is 1.4, 1.5 depending on a type of vessel and ship.

So, that is where we need to evaluate the impact of the direction of impact and basically the weight of the ship plus the added mass of the fluid, I think I hope all of you understand, what is added mass. Added mass is the fluid surrounding the structure or the floating body moves together with the body itself, which contributes to the, the dynamics of the system, which increases the impact energy, which is what is important for us.

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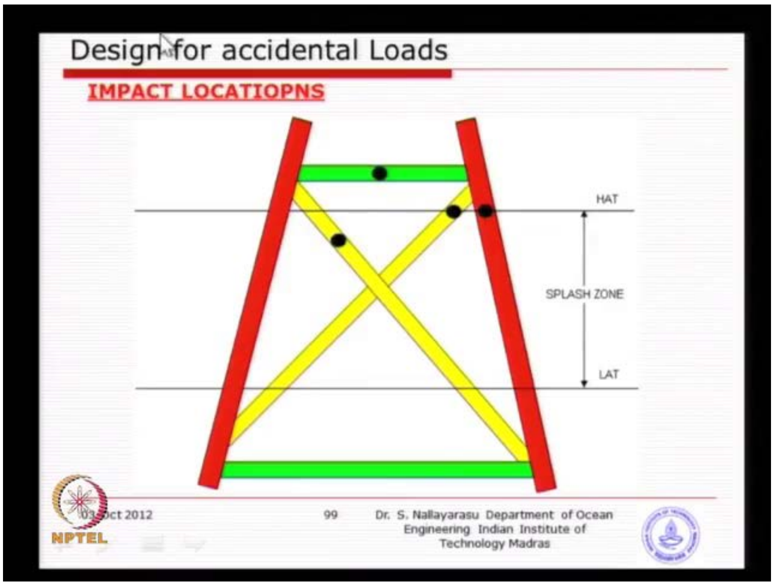

So, basically 1.1 and 1.4 that location of collision as you can see, as I mentioned on will be in the joules of changing water levels, it could hit anywhere in the horizontal braise. But why I have highlighted only at the center, for purpose of evaluation, you know basically the center impact could produce larger moment, isn't it? Simply, I have just chosen, but it is not the only case that you need to evaluate, you may evaluate another case where, the impact could be very close to the support location. So, what will happen? The shear could be maximum so, basically as an engineer we need to just start thinking, what will happen if I keep on changing the location of impact because, nobody knows where it will hit.

So, what we are trying to do is get back all the scenarios and only select the critical ones and try to evaluate the structural strength in terms of energy of absorption. And basically not enough, the structure will fail, what will happen if the structure fails? That means that if this braise gets damaged that means, that the braise is no more in the system, whether the jacket will be stable or it will become unstable, that is what we are trying to evaluate. So, if you look at the next braise basically, you can see here also can happen anywhere between this water line to this water line. In case of a low water, you can have a hit somewhere here, when it is high water you may actually, all depends on the draft of the ship or the boat that is arriving here.

So, if it hits at this location and basically this part of the member gets damaged or may be broken, then what happens if the load transfer whatever was coming through this right side leg, have to find the alternative way or redistribution should happen. And that is exactly why, you provide most of the time the braces in like a criss cross bracing, if another bracing is not there for example, this is not there, only one bracing was provided for some reason, what will happen? It becomes a portal frame which becomes less redundant and may not take the loads actually designed for.

So, that is why it has got a larger you know basically thinking. Because, you need to arrange the system in a such a way that, even if one of the member at any one time is failed because of the impact still the structure will be having sufficient redundancy so that, it does not collapse immediately after the failure of that particular member, that is the intention.

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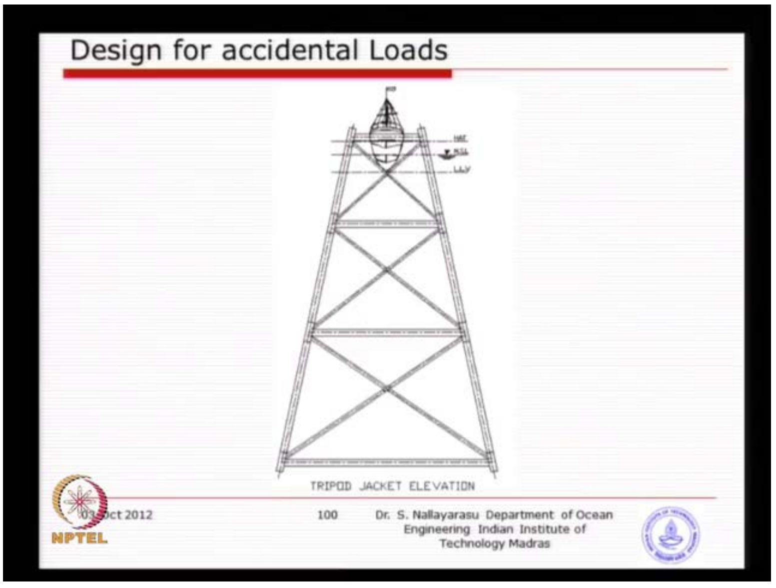

Another picture showing you know, basically can just go directly across the cross bracing.

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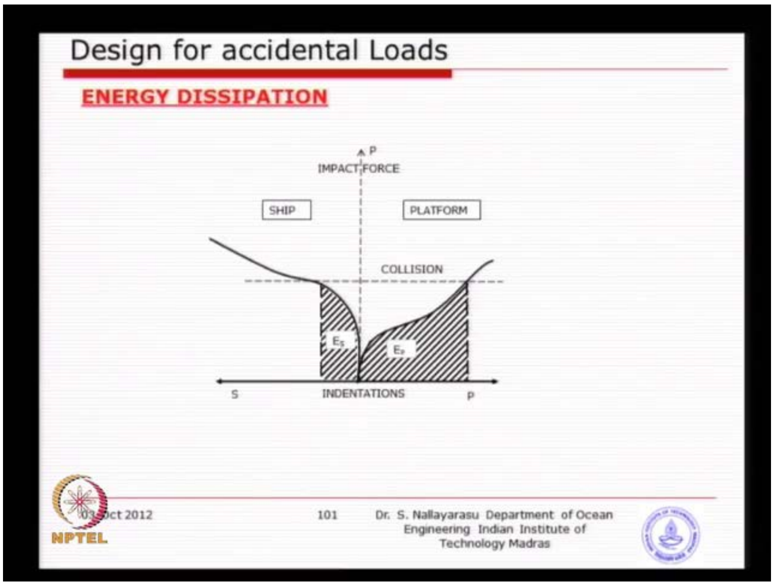

So, when the impact happens this is picture you need to remember basically, what really happens to the process? You could usually see when two cars are colliding each other, what happens? It is not that only one car is getting damaged, the other one is, no damage happens. Basically, in this case you have a moving vessel a fixed structure and basically the structure is not infinitely stiff for example, you make instead of a structure, a barrier which is highly stiff. And basically the damage may only happen to the ship, but in this case we have a structure which has got hollow sections, they are not solid sections. And also they have flexibility in the vertical or horizontal direction that means, the cantilever structure.

So, that it will also absorb certain amount of the energy during the process of collision, during the process of collision the ship also goes through a similar damage. Because, the ship also made of steel and hallow constructions and basically the local valve will get deformation, also bent, also made a contribution towards absorbing energy. So, that means if you look at ship and the platform at certain percentage of energy absorbed by dent and the damage happen to the ship side and also to the structure side. Unfortunately, the problem with the evaluation of ship energy absorption is so complex because, there is not only single type of ship or a hull available all over the world. You have several types of configurations, this will be very difficult to, for a structural engineer to incorporate the amount of energy taken by ship.

So, what DNV specified basically this graph is taken from a DNV code, you know you assume that the 100 percent energy is absorbed by the structure part and not the other, basically that is exactly the idea behind. And we are going to concentrate on the amount of energy absorbed only on the structure side and not on the ship side. But in reality there is a certain percentage of energy is absorbed by the damage and indentation happening on the ship side. So, you see here in this picture the horizontal axis, basically the indentation or the dent or deformation on the vertical axis is your, the amount of force excited on to the structure during the process of collision. So, basically that is the idea behind and which we need to work out, how to get this p value for a given dent.

So, you take a piece plate, you try to impact if you deform by certain an amount of you now deformation, what will be the impact force? Because is not a static force like, unlike you think about simple beam deformation put a load there, find out the delta by means of elastic beam theory. Because, that is a static load in this case we have a dynamic load the load is moving at the certain velocity and we need to find out what could be the impact force at that time of contact. So, which is you could find out by several means, what we are going to use here in this particular case the structure is not such a simple plate. We have a circular section, hallow section several experiments are been done in the past, in fact DNV has conducted several experiments in house.

They have come up with the relations ship, which is a empirical it means, if you are having the energy of impact at the time of contact that means, you will have the weight of the ship, you will have the velocity, you have the added mask, you calculate the energy. And then, using the energy you can find out what could be a potential amount of impact force excreted on to the structure, to generate a dent. So, that empirical question we will try to use to arrive at that force because, unless we know the force we cannot design a platform. For example, if you take a rubber you know simple rubber disk and apply a load you can actually dip, measure the deformation at certain load and increase the load until the rubber fails.

So, you can establish the load displacement relationship. Similarly, you can establish for a simple scheme of structure like a rode or a plate, but for such complex structures like a jacket, no one has done a full scale testing. So, basically scale model testing plus if you analysis DNV and the other people those who have gone research have come up with several empirical equations, we will see that. And we will try to use one of them basically we will use one from API.

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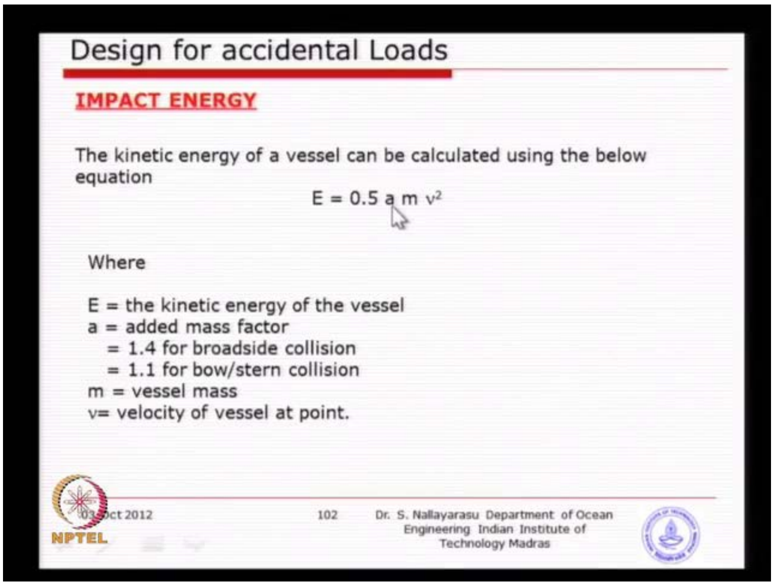

How to calculate the impact energy basically is kinetic energy formula basically half m v square, what has been added here is basically the added mask which is basically for floating structure moving in water. So, added mass coefficient for board side collision and I think you have seen the picture earlier on. So, basically half m v square, v is the velocity of you know the ship or the boat arriving and basically, the m is the mass of the ship, a is the other mass factor and e is the kinetic energy at the time of impact. So, once you know this then, we can move forward. So, basically mass of the ship can be obtained by the weight divided by gravitational acceleration.

Most of the time, you know the boats and ships they give in terms of dead weight tonnage plus the payload, I think those who are studying naval architecture you will know very well, it is called dead weight tonnage, DWT and basically displacement of the vessel. So, if know the weight of the ship plus the cargo, hold everything together divided by g, you will get the total mass and you can find out the kinetic energy of impact or energy of the impact.

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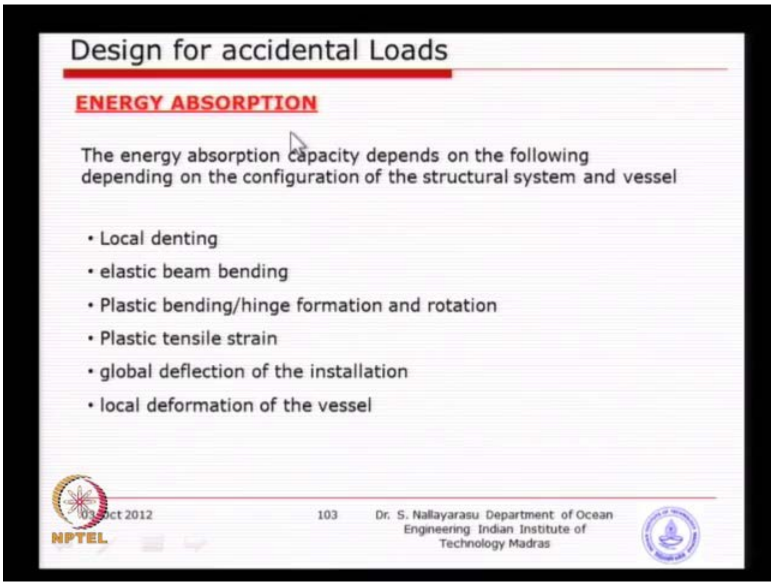

Energy absorption during the process of dent or the damage happening in various sequences as you can see here, the first one is a local dent basically the deformation of the wall of the tubular section, which is part of the structure. Then, the second one is the elastic beam bending basically, the horizontal member or inclined member, you have made a dent in the structure by means of impact. And that they, during the process of denting you have introduced a force on the structure, which is making the member to deflect either horizontally or the other means. And basically during the process, it has ha global deformation to the member that means, the member deflects by say delta, which also absorbs the energy and after that, that reaction from the beam goes to the structure, may be the columns or the legs and the overall structure gets deflected.

Basically, that is going for the last one, but in between what happens is basically the interesting thing. For example, you have a dent load which is substantially smaller that means, the dent may not happen. For example, you have very thick tube and you just take a small hammer, you try to impact what will happen? The local, local strength of the tube is so large that, the dent may not even happen, but if you have a dent is larger that means, it may keep on increasing the dent level absorb more energy. But if the dent so large, that it actually can just pierce off or break the member into two halves. So, that means the relative stiffness of the member is also important, in addition to the local stiffness of the ((Refer time: 26:01)) section.

So, what are the things involved? d by d ratio, which makes the local you know the strength higher and the l by d ratio, the longer length and smaller diameter. So, you see that the diameter, the span and the thickness and the end conditions, you know if you have a pin condition, it may deflect more. If you have a fix condition, it may not deflect more. So, you see here the relative dimensions are the member in question is very important. So, the local denting and elastic beam bending is definitely going to happen, but what we are looking at, what happens after that? You know if the cellar, if the impact process so large, the stresses are going behind yield, you know at the extreme ends. You take a simple fix beam and the bending movements at the point of impact are going to be same as the end, you know basically w l by 4, which we you have derived the last time.

And once the bending movement is so large and the yield stresses, the stresses at the support points are going higher than yield, what will happen? Redistribution may happen from a triangle distribution to rectangle distribution, I think we derived it. So, once you have a huge formation happens, then what will happen? The beam may go through further deformation, because of plastic beam bending, which we call it the collapse load, but once it reaches the collapse load what will happen? The member will break away and that means, local denting elastic beam bending and then the plastic deformation.

So, these three things go into form a major part of energy absorption process and lastly, we have a global deformation. In addition to it, sometimes what happens is the tensile stain basically you take a long member and try to deflect more, there will be a actual force introduced on the member. I think you can easily understand, you take a string of flexible string, hold on to it on both ends very firmly and try to make a large force, what will happen? The string will try to slip away from your hands, which is basically a tensile sail induced by large deformation bending, which is also going to contribute because, larger the tensile strain, what will happen? It will not allow the member to deflect any further.

So, that is one of the studies which mean necessity, necessarily not take large amount, but will contribute to certain amount of additional energy absorption. And the last one is the local deformational of the vessel, as I mentioned earlier and we normally keep it a side and not add part of our design process, because of the complicity, because of the unknown types of ships and variety of hull forms, we normally do not include in the design of structures, which is conservative. Because, you are assuming the, that part of the energy also taken by structure, which is a reasonable. Typically, API gives you an idea because, many times mandatory requirements are supposed to be full filled.

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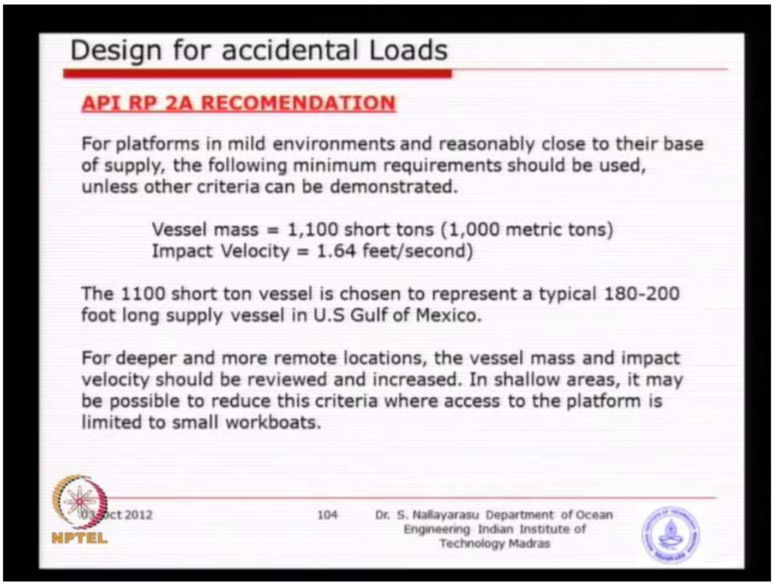

So, if you have are designing a platform in gulf of Mexico, you have to mandatory design for 1000 tons, but elsewhere if you come around like for example, ONGC platforms they do not design for 1000 tons, they design for a much smaller size vessel. Because, it has got a definitive impact on the design sizes, the larger the size that you design for, your leg size will increase, bray sizes will increase, you may have lot of other members. So, that is why API requirements are not mandatory for platforms elsewhere, but some clients they follow someone keep the vessel size slightly lower. In this case, I think they are using about 600 or 700 tons, but if you go to elsewhere like north, North Sea platforms it is they are designing for even larger size vessels. Because, the both boats or the ships arriving there in a bigger size.

So, you may design for 5000 tons, some of the platforms that design for 10000 tons shifts, boats arriving there. Again in depends on the, the risk level the, the oil companies want to take. In fact in this particular case, I would mention one of the case where two years back, when we design the platform the client was talking about no ships will come to my platform. Basically, he was assuming he wants to take such a risk that no ships will come because, he is a unmanned platform. Of course, yes it is a completely unmanned platform, no necessity of people going there because, it is remotely controlled from another platform.

But unfortunately what happened, one year later after the insulation is over and basically a boat hit the platform and completely damage the front two braises. And it was not noticed by the owner himself because, there was nobody on the platform number one it is remotely controlled from another platform. The damage happened such that, it did not disturb any other facilities everything was intact. So, how did they find later on in a basically when they were monitoring the flow in pipes, flow in the equipments, there was a sudden jerkin the flow levels or liquid levels in one of the equipment.

So, then they investigated then, they visited the platform, they found that the braise is completely ripped off and basically it is an accidental case and they could not locate who was the owner of the boat. In basic that can also happen and lucky in that platform those braises where actually broken, but no damage to the structure was done and still it is intact. But later it was, you know replaced to the different arrangement to protect against. So, you could see that when you take such a high risk, you know they have taken a risk, but they have made more money than, actually if you have designed for you know that is exactly the behind.

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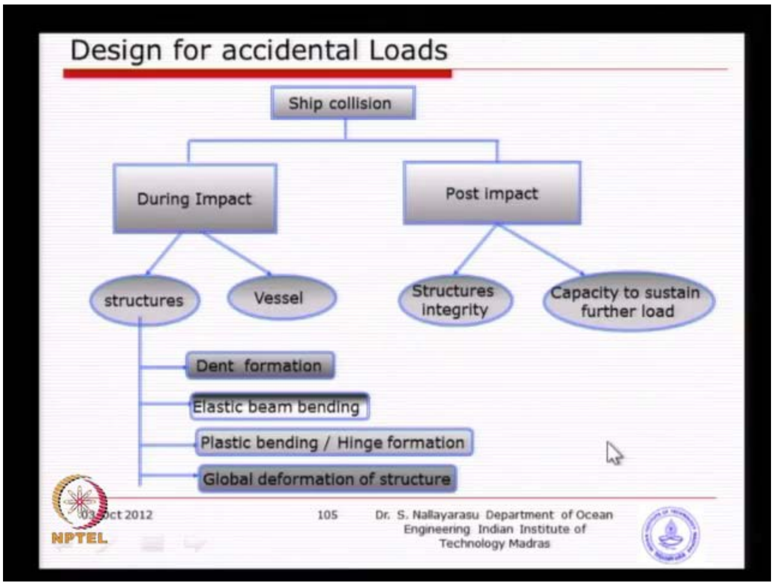

So, just a complete picture of what really you needs to be verified in the design process basically, one is during the impact which is very essential. What we do not want is the capacity of the structure is lesser than the energy of impact that means, progressively it will make the structure to collapse. So, that means during the process of impact what we want is to take sure that, the energy of impact can be absorbed by the energy available from the various forms of energy absorption mechanism, in the structure. I think the most one is the dent elastic beam bending and the plastic deformation and the last one is global deformation of the vessel. So, basically these four we need to find ways and means of calculations.

I think elastic beam bending is very simple, all of you are very very well familiar with the simple beam bending equations for point load at various locations, in a beam with either fix condition or partially fix condition isn't it? So, it is a basically elastic beam theory you have for example, the deflection calculations for most of the cases available in the text books. Dent formation we are going to have a look at some of the empirical formulas developed by various agencies, which will give you the energy absorption and the impact force, it is an empirical formula.

The third one is the plastic beam bending, which also have been introduced to you few classes back. Basically at collapse, what could be the deflection at the point of load, depending on the strain that you allow, I think this where we need to discuss little be more. Larger the strain you want to allow, more the deformation can happen and at the point of collapse plastic hinges may form and that time, the structure will come unstable. The last one cannot be completed by manual calculations, you need a help of computer because the structure is so complex, you will use the computer simulation. The only thing is the calculated dent force from here, will be applied to the structure and find out the global deformation of the total system.

So, when you add all the energy absorption by all these four mechanisms is greater than, the energy of impact which we just know calculated 0.5 m b square into ((Refer time: 34:22)) coefficient. Then, that means you can finally conclude that the impact energy is fully absorbed by the structure that means, the structure will still stand there. Though, important thing is this, if during the process of this energy absorption, one of the members has been completely broken or hinge formation happened. So, that this one thing we need to be very careful, if it is an operational impact we do not permit this, but if it is an accidental impact we do permit, but then the next stage will be post impact.

If you have actually made one of the member to achieve or reach collapse stage, one of the member not the whole structure, but the structure is still in tied because, the energy of impact is smaller than energy absorption. But then what happens, one member is gone the purpose for which you have put that member, there must be certain reason, why you have made that member inside the structure. So, once that member becomes inactive what happens to the reminder of the structure, that is called a the post impact. So, you need to evaluate what once the impact is happening, energy is absorbed, one of the members is dented and also plastic deformation has happened.

That means, it may become unusable and that that stage whether the structure can still stand, number one how long it can stand? That is a main thing, whether it can sustain eddy additional forces or not. For example, at that time of impact you have the dead load, you may also have the wind load, the wave load and in future you may also have a storm load, we do not know. But normally we do not assume at the time of impact another foam is hitting, which is two disasters together. So, normally we assume one you know accidental case had one time.

So, at that time of impact we assume that the gravity loads do exist and no environmental loads, but post impact once that impact is over, you are looking at your say the repair scheme. But you cannot take a infant amount of time to repair it because, in future you do not whether the storm is coming next month or next year. So, you need to find out that time duration, if you can make repair quickly, but you need to make sure that during this period of time whether, the structure is stable and not over stressed. That means, if you apply a smaller storm condition for example, normal operating condition 10 meter width, still okay.

Then, you have got one year to repair suppose, if you have 100 year storm coming, within that one year then, the structure will become unsafe. So, that is what the purpose of, the post impact analysis is to make sure that you get enough time to repair. So, when you are designing the structure you take one member out, still it can take operationally impact or operational storm loads then, it is fine. And if it is, if it can take 100 years storm also without that member, that means your design is slightly over design or may be better design. In fact that was a, that was the case in that particular structure which I was mentioning even without that x braise, the structure be stand 100 years storm.

So, the owner was extremely happy because, they do not need do repair in the near future, but in case they did the repair within one year, but he was so happy that the structure still can stand without any problem. So, that is exactly the idea, the basically during impact we need to make sure the energy is absorbed, post impact structure is stable and able to take the gravity loads plus certain amount of environmental loads. And that certain amount depends on the duration, which you would like to spend on your repair work. If you have one year storm designed then that means, you can designed repaired work within a year so that, you can do the replacement. So, basically the design against boat impact is all these scenarios needs to be worked out.

So, one is the size of the vessel, velocity and the frequency and basically then the energy absorption scheme, which I think we will just go through quickly and the post impact analysis. This post impact analysis is basically a global structural analysis, which I do not think we will be able to demonstrate in the classroom, basically structural analysis like any other schemes. So, basic idea is that input for this will be coming from the dent model, this particular model. So, basically you allows say 10 percent dent take that force apply to the structure, together with gravity loads and analyze the structure.

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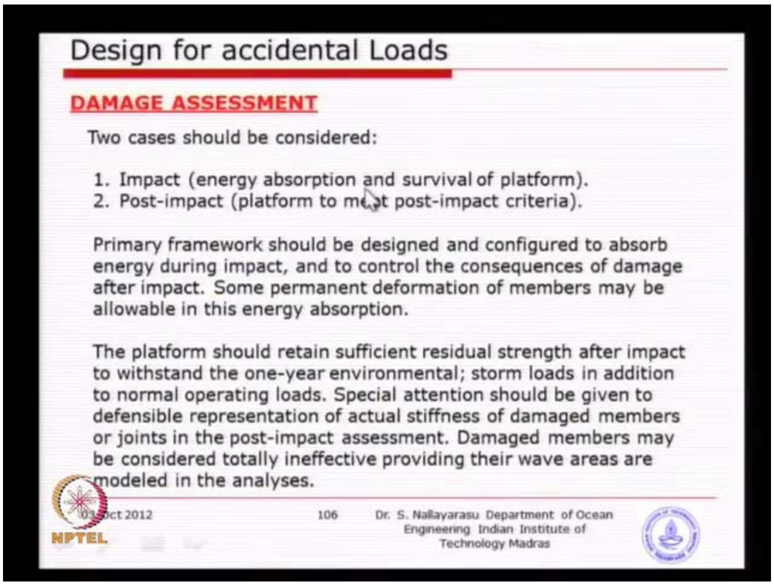

Damage assessment basic idea is the energy absorption and survival of the platform that means, you do not allow the structure to fully collapse during the process of impact. Post impact, just to make sure that you are able to a repair it during the shortest possible duration.

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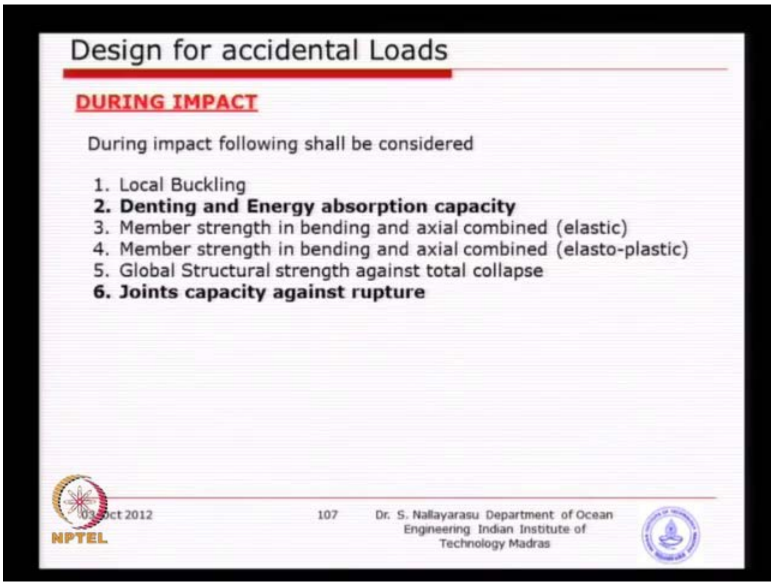

So, one by one we will just look at the scenario, in this process what we do not want is the local buckling and I think we have learn enough about it during our member design. The d by t ratio plays the major role, if you have the d by t ratio selected so large, that it cannot even take a dent, at the point of impact it will buckle straight away. So, that is basically one of the area we must make sure that the selected members in the area of impact needs to have no local bulking cases. That means need to have sufficient wall thickness and making too bigger wall thickness also is a worry because, the dent will not happen.

For example, you make it solid no dent, no dent means basically large impact force because, the dent, the energy is not absorbed. Large impact force is not good for structure because, this, the, the beam may be very good, but the introduced reaction forces on to the other part of the structure may actually, the structure will collapse instantaneously, you understand the idea know? So, you do not want to have a very large stiffness also. So, you need to play a little tricky role in making sure that, the dent also happens, but not too big because, if it is too big what will happen? The member becomes two parts. So, this design is little bit tricky and we need to look at all these cases, I think first we will try to solve for denting model so that, we can get the reaction forces.

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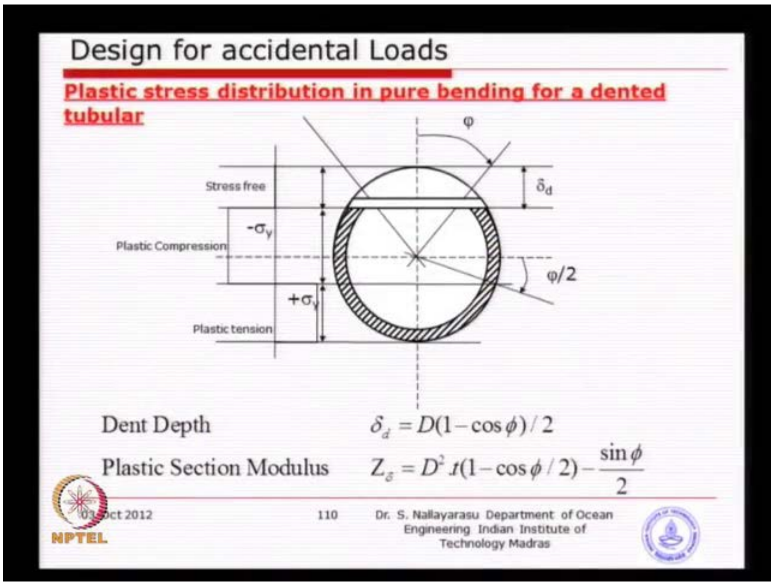

So, if you look at one of these cross section, you could see from here the dent of a circulars section, as you keep on increasing this depth of dent. See here delta t or delta d, the larger it goes this two things happen, one is the cross sectional area gets reduced as you can see from the picture and the section modulus, which going to give you the strength against bending also reduces. So, as long as the delta d is more, we get two things delta d more, you will actually have energy absorption higher because, it is internal work done is more. But at the same time the cross sectional area is reduces substantially and moment of inertia comes down global or the beam bending will be becoming weaker, it cannot take too much of load.

So, it may actually break away or it may go from elastic to elastic to elastoplastic and fail. A simple geometric relationship describing the delta d with the respect to that angle and the plastic section modulus, which I think we derived for the case of a circulars section, I think and expressed in terms of this reduced section is shown here.

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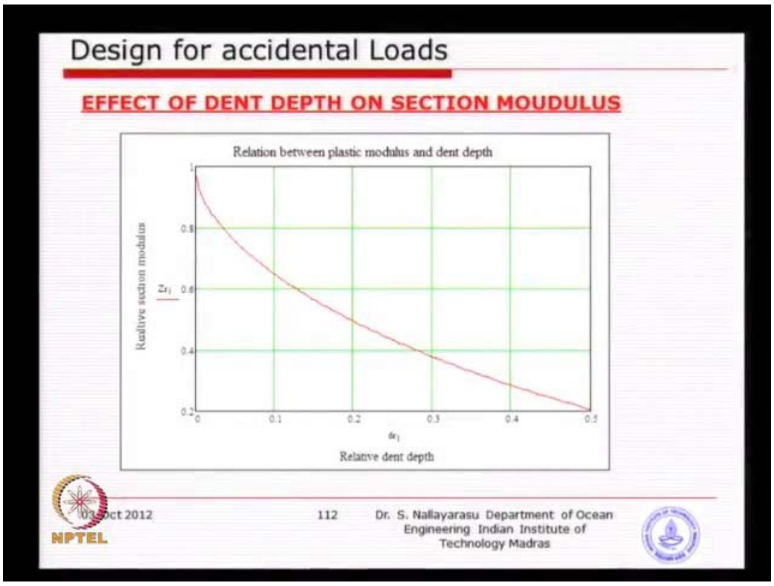

So, if you plot these two together in a graphical form, the reactive dent depth is basically the, the delta d divided by d, which is just a ratio normalized with respect to basically the relative section modulus. Section modulus with respect to the original circulars section, you could see here that the, you know the dent depth is 0 is full section modulus is available. As you keep on increasing the dent, you can see here at 50 percent dent you only have less than 20 percent section modulus, isn't it? So, is only just becoming so, you expect, you want to have a larger dent absorb more energy, but unfortunately what will happen?

It has got no sectional area, it has got no section modulus, that beam may fail. That means, it will not go further to the next stages of energy absorption, which not very good. So, we need to limit in the d by t ratio in such way that, the dent is only certain depth then, after that the, the beam reflection happens. Because, we want to have no global failures so that is the idea behind you need to work out. So, this equation is just a geometrical relationship between the section modulus and delta d.

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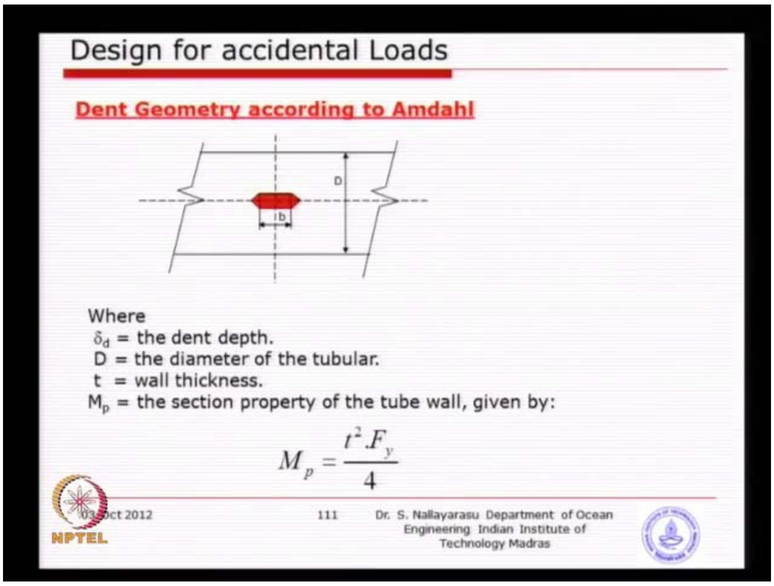

A simple pictures showing dent geometry, you can see here in red color is a local deformation. If it is a flat plate for example like this, when somebody is poking with a sharp object, you may find greater type of local deformation. But in this case it is not a sharp object basically, a ship of any type of bow or stern, you know shapes it can hit in any direction. So, people have assumed is something like this, you know basically a two way deformation, but at this edge is a sharp corner and basically, the moment capacity is not the tubular moment capacity, in this case is a local plate moment capacity.

I think t square by 4 is the plastic capacity of a flat plate, t square by 6 is the moment capacity of elastic moment capacity t square by 4 is plastic moment capacity. So, basically multiplied by f y is just treated as a flat plate because, it is only a local. So, do not, do not substitute here your plastic capacity of the circulars section because, this deformation is local to the surface of the plate. So, just that is why I have just put this formula so that you can use it.