Design of offshore structures
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Module - 06
Lecture - 03
Design againts Accidental Loads 3

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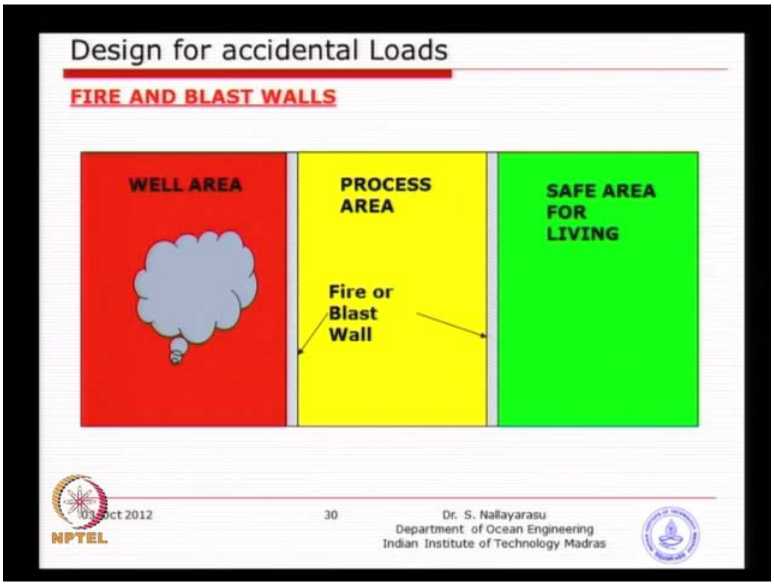

So, today we are going to just continue the session on the firewalls. So, you can see this divisions, basically area wise bifurcation between safe, un so, unsafe and then the process area. Basically, the most critical area is the well by area where, you have high pressure equipment's, especially the fluid coming from underground, under high temperature and also excessively high pressure. If you are talking about the type of magnitude, you know something around 25,000 to 30,000 PSI. So, such type of pressure is equal to almost like a atomic bomb, you know if it explodes you will see in the vicinity, nothing will be able to sustain that kind of loading.

So, that is why the well pressure needs to be regulated and maintained. So, every well I think, I shown you some pictures during the introduction classes that there is a arrangement were its called Christmas tree, where it regulates and reduces the pressure. So, basically though we can do that kind of arrangement, still the potential chance of a spark or a leakage can cause of fire in the vicinity of the well and if the well explodes, it would potentially prove to be a disaster. So, that is why well by area is the most critical in terms of fire and safety and needs to be given most priority, that means it needs to be isolated away from the habitable area.

So, that is why we have seen many occasions, well platform will be separate or if it is not visible, at least kept at one side where the, the, the damages done to that area may not be possess that danger to the other areas like process and the living. So, you see here it is just a nice three rectangles, one is the well by area, central is the process as the decreasing order of, you know the risk and the safe area is given on the right side. So, but you will see in some cases, may be slightly modified like well bay might come in between. Again we need to design these barriers in such a way that, propagation of risk is reduced, not absolutely stopped as we normally think.

We want to have a barrier by which its infinitively stiff, does not actually the form in any case of loading, which is not visible because, the structure which is supporting these barriers may fail before the barrier failed, isn't it? Suppose you want to make a very stiff wall, which is just highly stiff compared to the loading that you are encountering, that may actually performs its duty, but then this, this structure needs to transfer the reaction to the deck structure and the sub structure. They may not to be able to be designed to be taking such high loads, typical example, for example you take the width of the platform is 50 meter, height of the that particular wall is 10 meter, 50 by 10, you take area of 500 square meter typically.

500 square meter with the horizontal loading of say 1 bar, if you apply 1 bar with a 500 square meter loading, I think possibly it will be not there in this location, the platform will fly off to another country. Because, the amount of loading is incomparable to either the wave load or the wind load or other forms of loading which you have designed. Because, if you just calculate the magnitude of loading few 100 tones, few 1000 tones will be the magnitude of loading that you are talking about, may be a 1000 ton is the wave load. Whereas, if you take 500 square meter 1 bar loading, it can just see that it is several times of the wave or the wind loading that we are talking about. That is why we may not able to be design it, though you can design this wall, this wall can be designed for such a loading because, this only a local design just design.

The wall make of very stick steel plates, but the sub structure will not be and that is one of the reasons why we do not want to design for such non flexible walls. So, what if we go in another method where, the wall deforms and absorb energy while actually it is deforming and that is the approach normally adopted for onshore. Whereas, compared to offshore so, basically compare to onshore bunkers, we have always have a very large thickness concrete cell, which is not going to deform when you have such a large loading. Because, you have very good ground conditions where the load can be transferred without much problem.

So, that is why the approach on onshore bunkers versus offshore bunkers is lightly different. Sometimes you, you combine the fire and blast wall together, you also have a fire wall which can take a certain amount of loading, which is just a combined effect. One is the structural requirement, the other one is the performance with regards to temperature. So, that means the external temperature needs to be reduced to certain amount in the inside of the building. For example, if there is a fire here, 900 degrees, you make sure that the insulating material which is part of the fire wall is not transferring or convict, conducting the temperature on the other side, to a higher level. That means reduced it, that, sometimes you will have the same wall designed for certain amount of the pressure due to blast. So, it is a combined fire and blast wall.

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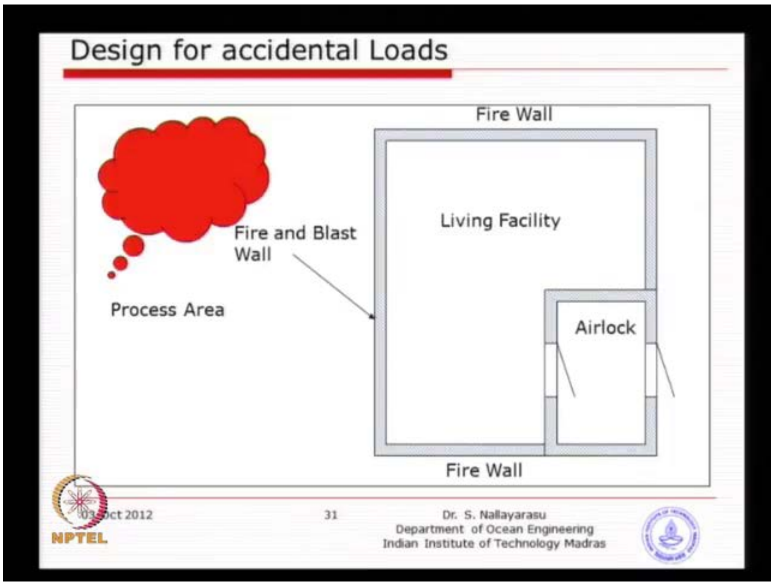

Typically, you will see a living facility will be encompassed by a peripheral fire wall most of the time because, you know basically it does two things. One is, one is the temperature reduction due to fire, the other one is heat loss, you have a air condition space. Basically you do not want that, the too much of heat coming in so that, the energy requirement will be going higher up. So, that means, that is the second purpose of course, is secondary, but the first one is to maintain the temperature within the limits though there is a fire outside. And the other requirement I think you will see in most of the off floor facility is the air lock, which essential path in order to reduce the risk of smoke entering into the facility.

If you have a single door, for sure you will have a smoke increase which will cause tremendous problem to the living facility because, it will get into circulation and everywhere it will pass on and almost all people will be affected because of this. So, that is why you need to create a barrier by which you will have an exhaust, even if the increase of smoke or gas enters into the building, this air lock chamber will evaluate it not allowing the, the same to be entered into the main building. So, that is something very similar to what you see here of course, it is not an air lock. Air lock needs to be pressurized, you need to keep the inside pressure higher than the outside so that, always the increase will be not possible to.

So, you need to pressurize the building in such a way that, you know the increase from outside, unless the pressure outside is so large and normally is an atmospheric pressure outside. So, you may not actually have a, the problem so that means, the inside of the building needs to be pressurized is slightly higher not too high. So, that there is a potential of going out, but not coming in.

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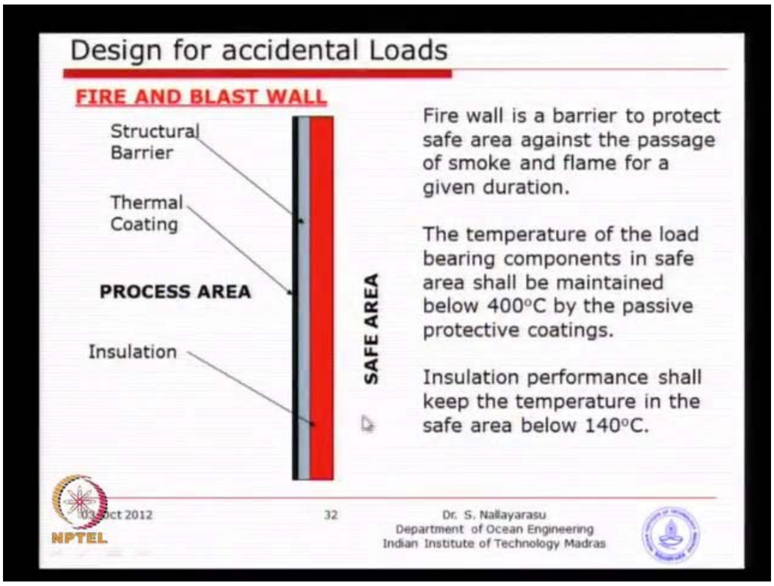

Now you see a typical cross section of a fire and blast wall combined on the left side you see here, the black color is basically the thermal coating, which we talk about there are few types. We have a cement material which is conventional plaster or you have a intimation coating or the other form where, you can use that. So, first one is the thermal coating which reduces the direct fire contact with the structural material, which is steel. And the second one basically the, the gray color which is structural barrier it could be a steel plate of 5 mm, 10 mm or it could be a corrugated plate. We will see the details later on, basically that is the structural material the last one on the right hand side, and you see the insulation.

So, between a thermal coating and on the right hand side is the insulation, in between you have a structural barrier which is going to perform the duty of the blast resistance? That means, when you apply a loading from right side or left side you will see the structure gets the form and when there is a fire, the first thing what you does, you need to perform the structural duty that means, the structure material should be safeguarded from increase the temperature. So, that means the, the thermal coating will reduce the temperature, if it is 1000 the structure will only get reasonably reduced value of say 100, 150, 200. Because, until 400 we can accept because the, quality, basically the material deformation will be limited that means, the stress strain characteristics will be under our control.

The second thing what it does, though this steel is at 400 degrees, we do not want 400 degrees direct contact of occupants of the building because, 400 degrees nobody can take? Because, we all have been living under certain conditions like less than 40 degrees mostly and that means you need to limit the temperature to such type of normal temperature inside so that, they can sustain for a slightly longer time. 400 degrees you can stay there for 2 minutes, 1 minute beyond which you would not able to stay there. But if it is 40 degrees, probably you can stay there for another half an hour before you can get evacuated.

So, that is why this insulation material is placed inside because, this cannot take temperature because, if you keep the insulation material prior to the steel, what will happen? That temperature will actually destroy the insulation itself, that is why the insulation needs to be in a right place, on the right hand side. So, you have several materials for insulators, steel is a very good conductor of heat. So, we need to find a exactly opposite material so, most of the time wool will be used and now a days glass wool is the best material, you might have seen in many places, you know used in most of the air conditioning spaces where, you have the insulation.

So, normally now a days glass wool is preferred and it is easily available. So, you put whatever the thickness, the larger the thickness of the glass wool the reduction in temperature will be higher, but of course, we always look for more space so, typically about 30 mm, 50 mm, 100 mm. So, you have to design looking at the incoming temperature and what is the temperature required, you will design the thickness of the glass wool required. The additional thing what we normally do also, we create a space a between the steel and the glass wool air gap, you know very well that air gap is also a good insulator of sound and temperature.

So, normally what we do is between the steel and the insulator, you give a 100 mm gap for example. So, it will actually stop the propagation of sound, as well as the temperature. So that may be additional you know precautions. So, you have to come up with the cross section by which you can reduce the temperature, as well as it will take the required design. But one thing very important the sequence for example, before the fire if the blast occurs, what happens? For example, the first is the blast and then followed by a fire, there is a potential chance of the thermal coating, what we call it the material pasted on top of the steel service might actually bull up, exposing the steel directly to a larger temperature.

So, there is a potential danger of such thing happening. So, we need to have sometimes double wall in a basically one barrier sacrificial for only taking the blast, then you will have a fire wall combined with the. So, some of the process facilities they design in such a way that, you have a double fire single fire wall and then followed by in front a blast wall. Again depends on, you know how much risk you would like to take, but there is a potential risk of the blast happening first and then followed by a fire, which actually direct contact of large temperature insured the occupants building. So, basically the idea of a fire and blast wall is nothing but is a bifurcation between processed or unsafe area to a safe area, comprising a structural resistance against blast and a thermal resistance against fire and reduction in temperature, toward desired a level inside the building.

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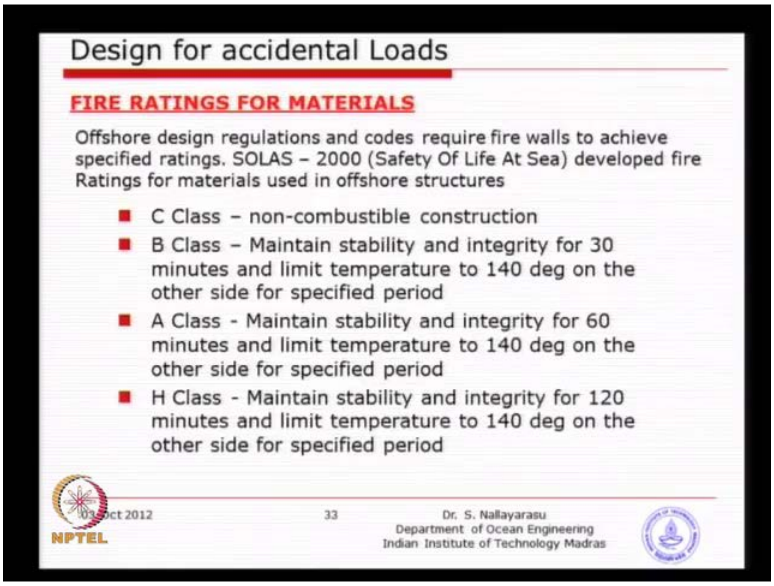

Now fire can be classified into several categories, I think we have discussed about it in the previous sessions, basically the construction material for building bridges, offshore platforms, you could see that various types of material we are using. So, the noncombustible construction is one classical material is this concrete, you know basically is a good material, that is why typically in most of the buildings and civil construction, we use concrete as a material of construction. Basically, if you have this non combustible construction then, it is fire safety is automatic. For example, when you design a residential building, a 230 mm brick wall has 1 hour fire resistance that means, you do not need to really worry about it.

If you have a concrete wall of 300 mm, it has got 2 hour fire resistance concrete wall just reinforce to concrete wall. So, basically most of the buildings constructed of conventional steel concrete or in a, basically with brick wall in fill you will, you will not necessary to design anything special unless, it requires to be a designed for a blast. Because, fire by nature you do not have that much of loading except that it changes the material characteristics. So, non combustible construction basically is good, but unfortunately we cannot use it because, steel gives us the lot of other advantages compare to the concrete, because of the weight.

Now this classification, I just have to be following this particular guide book, you know basically a SOLAS 2000, 2007 also has come, but still we use 2000, some of the guidelines in 2007 is not as strict as the old one. Safety of life at sea so, any installations whether it is you know ship or after platforms, other installations need to follow this particular guideline because, it is coming from IMO and needs to be hundred percent followed. It is not like you can say yes or no, any installation to be certified for occupancy in offshore must have solar certification so that, people are safe. So, this is a guideline, this is a very large book, there is one copy in the central library, in the reference section you may not allowed to borrow and basically can refer to it.

And this gives you the details of various requirements, not only fire and safety, other operational safety and evacuation and basically gives every aspect of safety of life at sea and one of them is, you know the requirements of fire safety. And fire safety what they do is the, classification if you see here, classification is in four categories A B C plus the hydro carbon fire and basic idea is this hydro carbon fire is the most vulnerable because, the temperature rise is very fast, temperature is itself is higher. So, you can see here the h class maintain stability and integrity for 2 hours and limit the temperature to 140 degree c on the safe side of the wall or the barrier.

Whereas, you look at the A class barrier basically, is only 1 hour and 140 degrees. In all three cases, you need to bring the temperature less than 140 degrees, only the time duration H class and A class and B class and C class you can see here. So, when an, when you design a fire wall, you will be given a, you design is A class. So, that means A class means basically 1 hour, you have to maintain the structural stability and the temperature needs to be limited to 140 degrees. So, the thickness of your insulator are insulating material will be decided basically for 140 degrees. So, you can go to the vendor, what thickness is required or you can also calculate because, you know what is the material and the insulating characteristic will be known.

So, the conductance you calculate there is easy to do a 5 minutes, check what temperature is on the upstream and what temperature is on the downstream, but over a time. So, because basically as the time goes by, you will see that the. So, you need 2 hours means you need increase the thickness. So, that is the idea behind. So, H class, A class, B class is only just a matter of the structural stability for half an hour, 1 hour and 2 hours.

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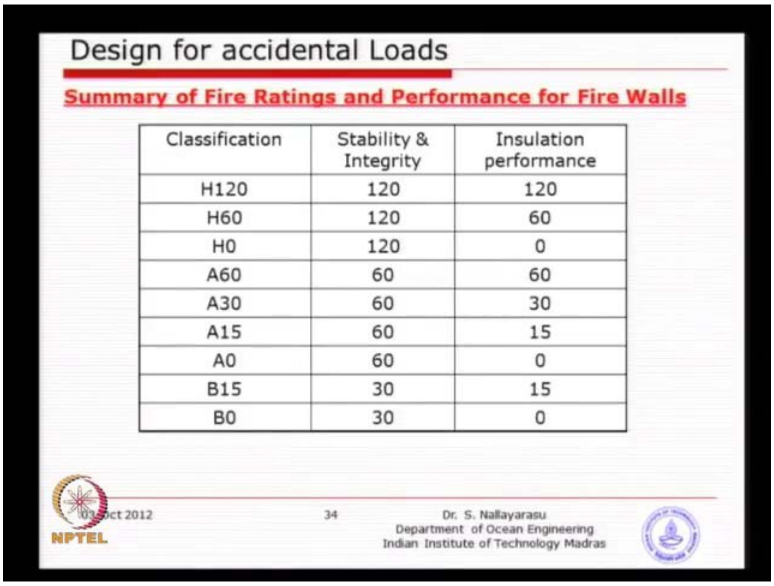

Classification	Stability & Integrity	Insulation performance
H120	120	120
H60	120	60
H0	120	0
A60	60	60
A30	60	30
A15	60	15
A0	60	0
B15	30	15
B0	30	0

So, if you just look at the table, this is how you define the basically the firewall characteristics. So, starting from H 120, H 120 means is 2 hours of stability and then insulation performance is also 120. Whereas, H 60 means H class is always 2 hours of stability and strength. Whereas, the 60, the number indicates the insulation performance, basically on the right hand side you have a insulator, which needs to be giving the temperature less than 140 degrees for 1 hour, that is basically H 60. H 120 means H itself is 120 minutes of stability and strength and in addition, you have an insulation characteristic of basically 2 hours.

So that, you have to little bit careful there, this 120 versus 60 this H means is stability and strength is for 2 hours, A class is 1 hour and the B class is half an hour, that is what you are seeing from the first column. And the second column is the subscript for that, if it is 120 it is insulation performance, 60 0 and basically gives you the thickness of insulator required. So, basically that is the idea and this is how you just need to. So, if you are asked to find out the thickness of H 60 insulating material, you basically need to work out 60 minutes what will be the thickness? If I have a temperature 900 degrees on the upstream to limit the temperature to 140 degrees, we need to do calculations.

So, structural response to a fire basically what we, what we need to just look at it, even if the fire occurs large deformation, basically because of the material characters change. I think you might have seen in many occasions, when you want to deform a steel plate what you normally do is, you just heat it because, if you try it to bend it in a cold form, what happens? The effort require is more. So, if you go to go to a blacksmith shop, normally you just heat it and you can change it to any shape, easy to malleable. So, that is exactly what normally happens when you have a fire, the material gets easy to change it shape under forms of loading.

For example, fire followed by a loading already exist, for example, gravity loading is already there, this structure may be already subjected to compression loading due to its own sulphate also a super impose loading. So, when you heat a column what will happen? Easy to deform and docile by failure. So, basically the large deformation needs to be looked at for the whole structure and we need to understand the characteristics by which we want to design. In this particular case, just now we were talking about the low transfer to the support system. So, if you have a dedicated wall not carrying any loading for example, you have a wall designed only for the purpose of taking the load from fire and blast.

But connected to the support structure in such a way that does not carry the existing gravity loads. For example, I have two columns on either side, I have a beam connecting these two columns, taking all the loads to the columns, but this wall is fitted in such a way that, it does not carry any of the loads coming up from the previous floor. And then, then basically that means I can allow the wall to deform under that conditions. Because, I am not depend on this wall to transfer the load to the sub structure, compare to the, you know the buildings that we normally construct, most of the load barring walls are carrying the loads. So, if you actually allow the wall to deform, what will happen? The whole structure will fail.

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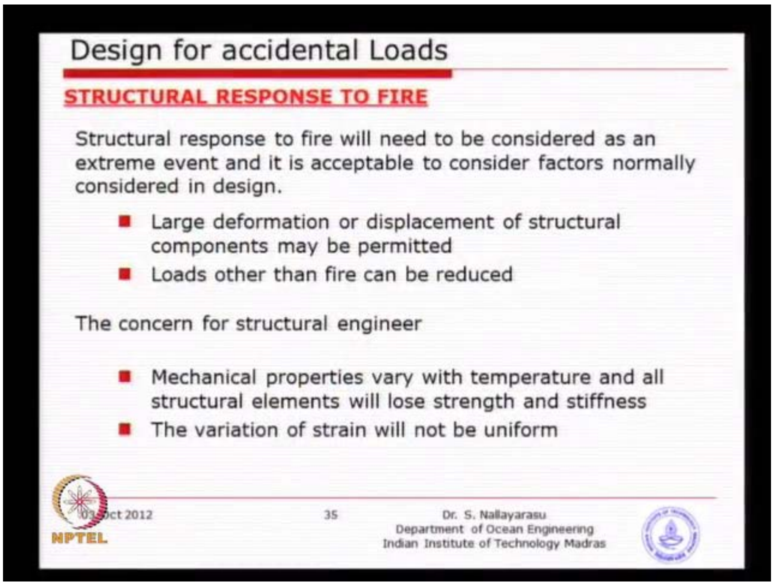

So, when we design a fire wall, we need to design in such a way that we introduce smaller reaction to the structure, by allowing the deformation to happen and that allowing deformation means basically energy absorption or work done. Basically if you have a firewall of certain size, load applied is and the deformation is a half a meter and the load multiplied by a half a meter displacement is the amount of energy observed by the wall, during the process of this incident happening. The larger the energy absorption is better because, then this structure will not fail. If you make that same wall as rigid, it is good, it is actually good, wall does not deform, wall is staying in the same location, deformation is very small.

But what happens, the structure with to which this wall is attached, what will happen? Will actually receive too much of a support reaction, by which the supports will fly off or fail and basically structure will collapse. Compared to a situation where the same barrier is supported on a very strong ground, no restriction on support conditions, then it is fine and that is where we have to just design just exactly opposite. But not to the extent that the deformation go and actually create problem to the other facilities. For example, I have an equipment half a meter away, when a fire wall or a blast deforms go and hit that equipment creating a chain reaction of subsequent fire and blast.

So, what we need to do is evaluation of this deformation is permitted, provided it is not harmful to subsequent events. Loads other than fire can also be reduced, in case if you have a such a wall designed, in such a way that no loads can be. So, you need to come up with the connection, it can be transferring loads from the wall to the beam, but not from the beam to the wall.

So, you need to come up with a such a nice connection, that it cannot take other forms of loading. Mechanical properties basically, what is our concern is basically how the variation of the steel properties during the temperature rise and then the steady state. So, what we need to look at is the stress strain characteristics like, how it changes that means modulus of elasticity and also the yield strength reduction, during the process that means, corresponding strength loss and stiffness loss.

The stiffness reduction means large deformation may happen. So, as long as you can quantify it then you can limit the deformation to how much amount. The variation of strain will not be uniform, this is exactly is the problem, across the thickness, across the length is going to be varying. So, simulation become quite difficult, especially you have a three dimensional fire scenario and look at the beam length or the wall length across the thickness, you will see that the strain will be according to the temperature. And the temperature is not constant across the cross section. So, there will be a higher this side smaller this side. So, behavior becomes little bit difficult to predict so, most of the time we end up doing a non-linear geometric analysis, to account for a variations.

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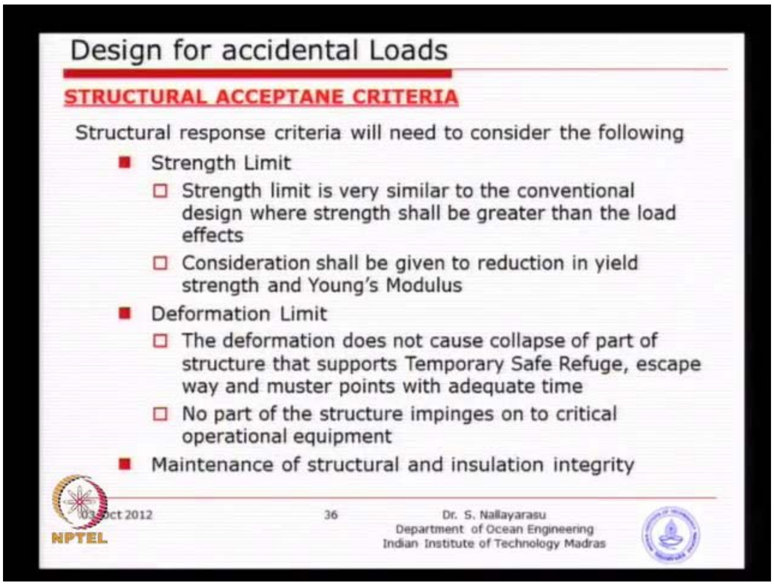

So, what could be our acceptance criteria, we need to look at as usual the two things. One is the structural strength limit, that means there is no disintegration should happen, the wall stood should still stick to the wherever it is attached. And deformation limit basically, to make sure that the large deformation does not go and affect the neighboring structures are the facilities. So, strength limit is basically design as per our conventional idea, design capacity versus the load effects, but how we deal with it whether it is going to be a allowable stress design or it is going to be LRFD or is it going to be something different needs to be decided by us.

Most of the time in 70's and 80's we used to go for conventional allowable stress design, you know you just take the pressure due to blast and design as per conventional allowable stress analysis and just limit it, the structure become too big. That means, the thickness is very high, the span is limited or you will stiffen it with lot of beams and columns. So, you made it so strong that the, under the blast it is still strong enough to take the load, but not considering the supports and that is where several of the structures especially, the onshore structures have failed terribly because, you design the firewall for the requirements, but not the system and the foundations.

So, you have to little bit careful in selection of the method by which you will do the design, we will just look at the three of the options. Sometimes still a people do this, what if you actually design a firewall in such a way that, it just blows off when the critical limit is reached. Typically for a example, you have a firewall or a blast wall sustainable to certain load because, you do not want to break the structure in case if the firewall capacity is exceeded in a case for example. Something very similar to a exit or a window, you have a window designed for a particular pressure, you do not want the window or a barrier to be stronger than the subsequent structures which are attached.

So, in that case it just blow off and many cases, now a day's vendors have come up with a design ware it will take particular design load beyond which, it will actually break away to safeguard the main structure you know. But it is not advisable because, if the people have not evacuated on the other side, it may become potentially problem. So, actually this is a little bit difficult to design according to the structural systems. Consideration shall be given to what happens to the material, when you look at steel whether how much reduction to yield strength and how much reduction to modulus and how much is the ratio between the reduction in yield and reduction in modulus of elasticity.

So, we just need to quickly look at how much, which I have taken some examples from one of the guide book, you will see that it will be similar. Deformation limit basically, this is what we were talking about, how much we can permit inside or increase into the safe area, also into the escape way or the roots along which the people are running away. No path of the structure in basis on critical equipment on the opposite side for example, you have a well by area and you have a process area, process area you will have a several process equipments, pressure vessels.

So, if you go and hit that so, we need to make sure that either the equipment is located away or the deformation is limited. So, that is why most of the time when you design a fire wall, you must make sure that no equipments are placed within the vicinity, probably about a meter. And then, maintenance of structural and insulation integrity, basically we need to see these three categories.

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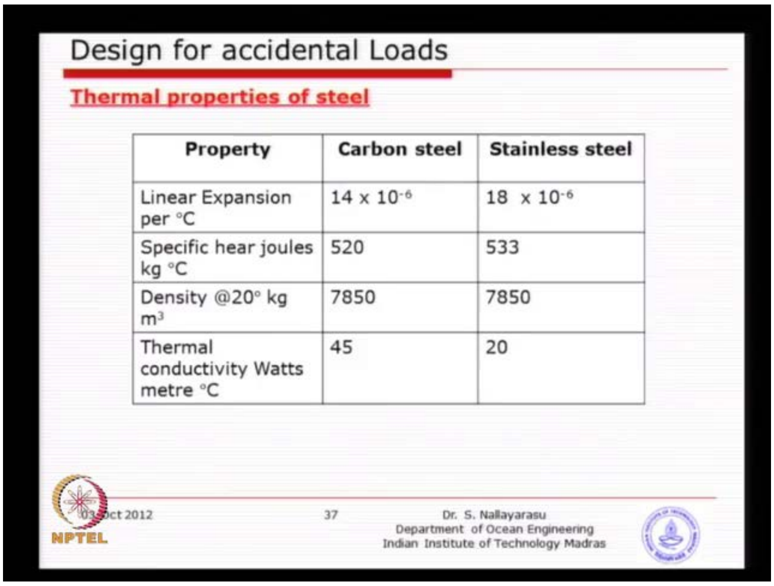

Typical and thermal properties of steel and I think you might have seen.

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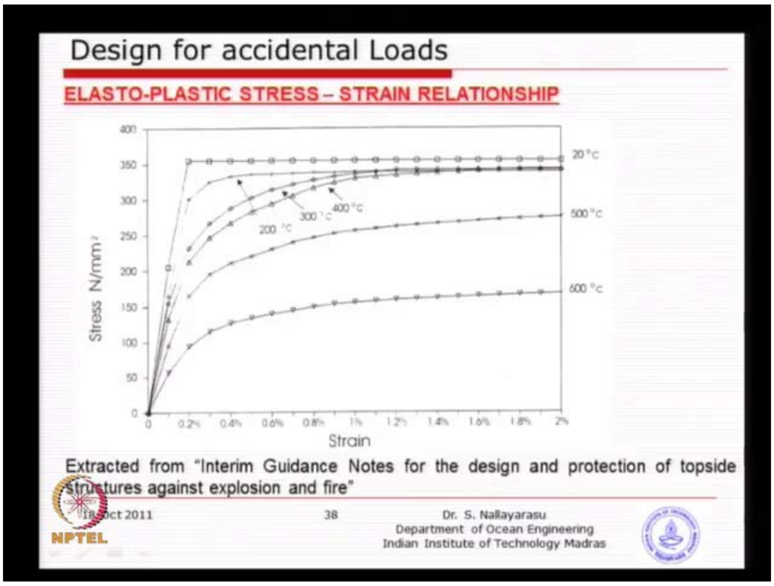

A graph which you has taken from this interim guidance notes, which is basically a joint industry project in Europe, by several oil companies together. They have made a prototype structures both for blast and fire and have tested and one of the testing is just you can see here is a typical stress strain diagram showing a different temperature, how the behavior is. So, you can see the first one the 20 degrees is the perfectly elastic and plastic material just you see a one straight line and just perfectly a plastic horizontal line.

At 20 degrees is a high stent steels with this 350 mega Pascal steel, 50 guy is material. So, basically the slope of this line of the initial line will give you the, what? Modulus of elasticity.

So, you could just see the stress versus strain ratio 350 versus about 0.2 percent, which is a typical elastic strain, I think most of you will remember. So, if you look at the other graphs it just subsequently as it increase the temperatures, the slope starts to decrease, I will come down. Modulus of elasticity is expected to decrease, the indication is no good the stiffness reduces. So, basically and you can also can see the, there is no clear demarcation point between elastic and plastic, basically it becomes non-linear from starting rather than, a linear I have to certain limit, typically about 0.2 percent and becomes perfectly plastic.

And this has become almost like a highly non-linear material from start, something very similar to rubber, I think if you look at a rubber material you start making a testing, you will see that it never forms any part of the initial stage linear. It is always going to be a continuously non-linear changes occur and that is what has happened we have, we have heated the material, we have heated the steel and becomes easy to deform. So, that means when you are designing a structure at say 500 degrees, we need to look at not only the yield strength and also the slope of the initial, that sometime we call it as a initial modulus, sometime we take the tangent modulus depending on what strain you are following.

For example, when you are allowable stress design when you are doing design most of our cases we take strain as 0.2 percent, if you look at yield point is corresponding to 0.2 percent. Now if you look at this 0.2 percent, it just go around project this at say 500 degrees, somewhere here the yield strength is around 160, 170, but if you decide to allow one percent strain, somewhere around here, you can go up to 240. So, all depends on what is the strain you are allowing, that means strain means corresponding deformation, if you are allowing large deformation of the wall, what will happen? 1 meter. If you calculate the strain at the ends of the beam, you will see that there is a no more 0.2 percent, it is going to be surely more than 0.2 percent.

So, that means the selection of yield point, selection of modulus of elasticity because, when you allow up to 1 percent, the modulus of elasticity is even worse. Because, it has become almost flat, that tangent modulus I think you, hope you understand the difference between the initial modulus and the tangent modulus. Basically, the tangent modulus is the tangent taken at the point of the intersection between the line and the intersection coming from the previous step. Typically we take at the point of into interest. So, if you look at initial modulus its quite good, almost all of them are in the very close range, as you propagate further higher strain, you will see the tangent modulus become very small, almost becomes 0.

So, if you look at this one, the first one is actually a is 0. So, basic idea is the strain limits need to be fixed according to the deformation limit, whether you want to allow 50 mm deformation or 1 meter deformation. So, this gives you an idea that three parameters of elasticity, one is a modulus of elasticity, strain and yield strength must be taken as a parameter for design. As long as you know this, then we can decide the, which method of design that we can look at. So, this interim guidance notes gives all the design procedure in fact most of the lecture notes I am following is based on that. Of course, again this has been taken by API, API has just fully absorbed this report as a design procedure.

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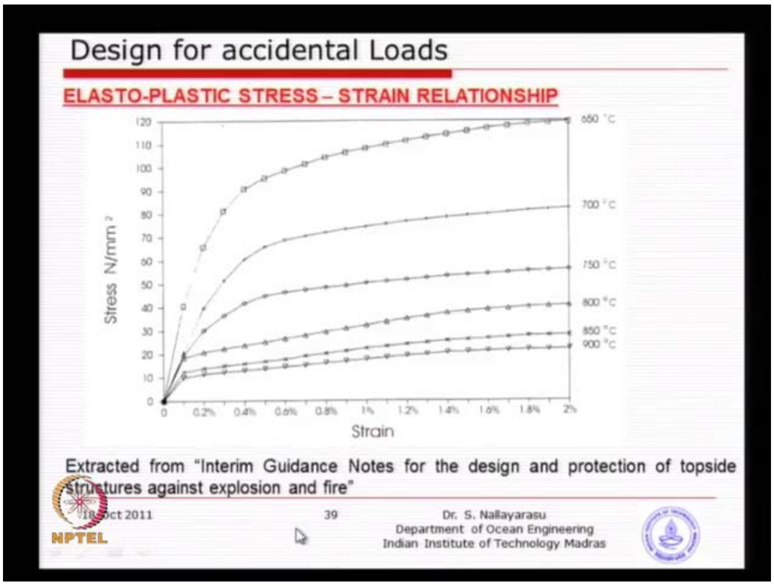

Of course, it is quite simple and basically that previous one gives from 20 degrees to 600 degrees. So, you can even see further from 600 degrees to 900 degrees. So, if you look at one of them 900 degrees, almost it has become no strength 10 mega Pascal and just the curve goes almost flat. So, that indicates that the material would have already melted down, basically is no most strength. That is why most of the walls, we would like to design less than 500 or any steel that you need to design for fire, you should make sure that you have residual strength, which is possible to sustain.

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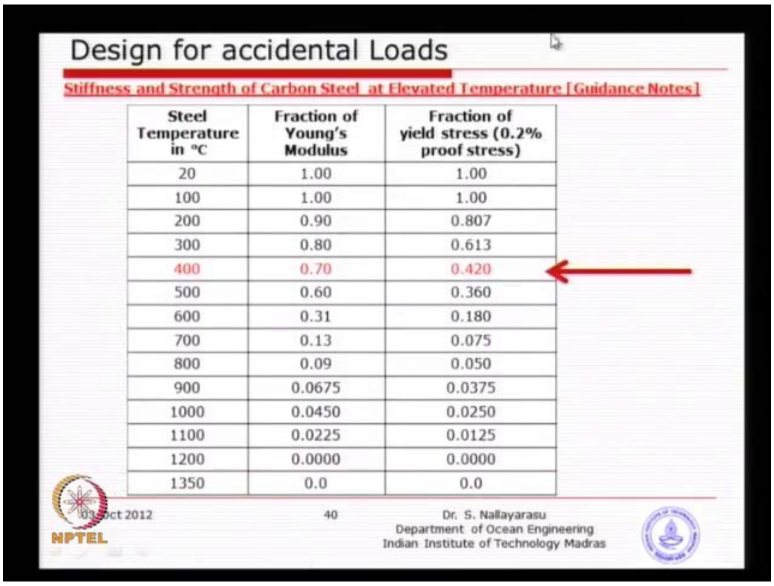

Steel Temperature in °C	Fraction of Young's Modulus	Fraction of yield stress (0.2% proof stress)
20	1.00	1.00
100	1.00	1.00
200	0.90	0.807
300	0.80	0.613
400	0.70	0.420
500	0.60	0.360
600	0.31	0.180
700	0.13	0.075
800	0.09	0.050
900	0.0675	0.0375
1000	0.0450	0.0250
1100	0.0225	0.0125
1200	0.0000	0.0000
1350	0.0	0.0

Based on the guidance notes, I have just taken some of the values of modulus of elasticity and the yield strength at 0.2 percent strain. Basically you see here, 20 degrees mod no reduction to modulus of elasticity, no reduction to yield strength that means conventional operating conditions. Even at 100 degrees, not much reductions see seems to happen, in a basically still under the same 100 percent strength you can utilize. So, as long as you have the temperature less than 100 degrees, probably not a big problem of course, when it is at 100 degrees, the deformation is within the limits of standard design procedure. But then the reaction introduced by these steel beam structures at 100 degrees needs to be taken into account, that is why some of the structures when we design.

For example, when you design a pipeline in a hot area like middle east, 50 degrees, 60 degrees, we need to design for 60 degrees, normal sun temperature reaches there almost during summer time around 60 to 65 degrees. So, imagine in the winter time it goes to 5 degrees, 10 degrees. So, the difference in temperature causes huge amount of axial force on the pipe line, which could cause potential problem to support structures or could cause problem to the equipment to which these pipes are connected. For example, you have equipment one, equipment two on either side of the pipeline and when the pipeline expands 50 degrees, you could imagine the amount of force introduced will be very very large. Because, the pipeline is restricted by connecting to the.

So, that is why the several structures design you need to take into account the effect of temperature. Now if you have 400 degrees, you could see here the modulus of elasticity reduced by 30 percent. So, whatever the value you have 2 into 10 power 5 is it just multiplied by 0.7 as the reduction factor. So, these numbers are given by these guidance notes of course, if you look at the API slightly different. In fact modulus of elasticity value reduction is not given in API, we still have to follow this interim guidance notes The reason it is called the guidance notes, the interim the final report has not been issued yet, 2005 was the interim guidance, still further subsequent results is happening.

So, final report has not come yet and look if you at the same temperature for the yield stress, it goes as much as 50 percent, in fact 58 percent reduction only remaining is 42 percent. So, below which if you look at any temperature, the material become no strength, you know basically that is impossible to design because, when you design for example, 800 degrees you are only left with 5 percent of the yield strength. That means, your structural requirement will be so large for example, thickness is originally at 100 percent here may be 20 mm, at 5 percent yield you may require a thickness of 100 mm, which you may not be able to design at all. So, that is why we need to limit the temperature, most of the guidance requirements needs to be around 400 degrees.

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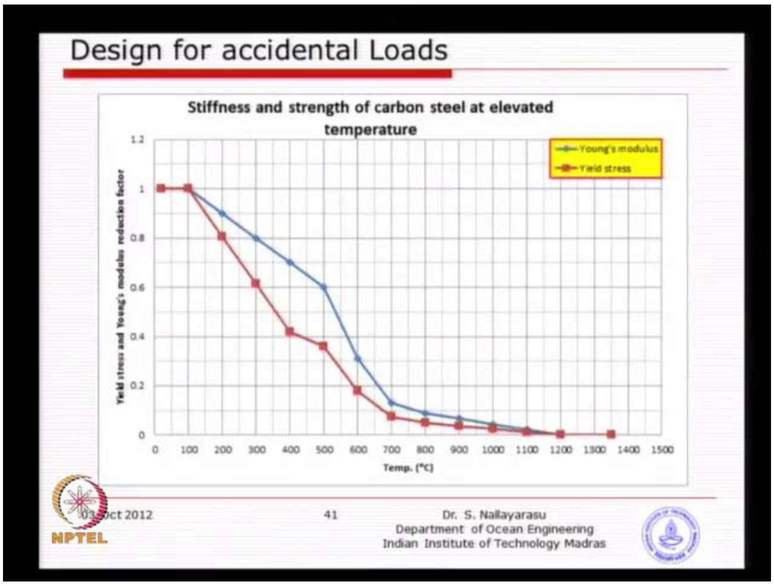

Basically, this is the same thing expressed as a, as a graph, you can see here it is not very straight lines, basically this data is obtained from experiments. So, that is why you would not see a straight line joining some values to other values. So, basic idea is, this is also not same as value for both modulus of elasticity and yield, they are two different values. So, do not get that the idea that slope and the yield strength reduction will be same, it will be same provided this graph follows the single line like this, but unfortunately the strain value changes every time when you increase the temperature because, the demarcation is not going to be a single point. So, that is why you have a different value for strength reduction, different value for yield strength and the modulus elasticity.

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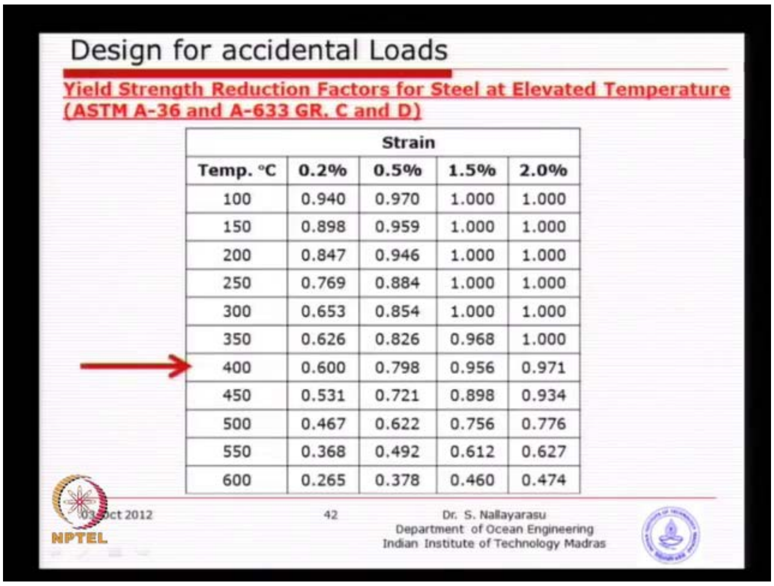

So, that is gives an idea about the reductions that you will apply for the design procedure. Now API has also given a comparative table at different yield limits instead of 0.2 percent, I think most of you are familiar with elastic stress design, where we use the yield strength according to 0.2 percent strain limit. Whereas, when you go for a higher deformation, we are going to increase the strain limits to higher values. So, you can see here 0.5 percent, 1.5 percent and 2 percent sometimes, we go even three percent strain limits. So, you can see here the values of yield strength reduction at 0.2 percent versus the 2 percent.

Now if you allow larger deformation to happen so, you can still reach, that is what I was highlighting in this particular one. If you go here or in even the previous one, if you allow the 0.2 percent strain for example, let me go to this graph, I can make maximum allow 100 mega Pascal. Whereas, if I go to 2 percent I can allow almost, I can allow almost 150, 150 mega Pascal, the yield strength. So, basically the larger the deformation that I will allow, I can have a higher yield strength used in the design. So, that is where you can see here this table will give you an idea that you limit the strain because, after all is the relationship between strain and the stress.

So, basic idea is the larger deformation means you can have no reduction to the yield strength whereas, if you limit your strain to 0.2 percent then, you will need to reduce by 6 percent which is 094. Correspondingly, if you come to 400 degrees, what happens is 0.6. So, there is a difference between the guidance notes that is what I wanted to highlight, guidance notes says is only 42 percent strength. Whereas, API with their own research has gone to 0.6. So, there is a little discrepancy so, you have to little bit careful if you are designing to API it takes 0.6, but unfortunately API does not give you the, any recommendation for modulus of elasticity.

So, we will still go back to this table, we will use a 70 percent reduction for modulus of elasticity based on guidance notes and API you will take a 60 percent that means, 40 percent reduction for yield strength at 0.2 percent. So, what we will need to do is, first we need to define and accept what is the strain limit and then subsequently you will decide, what is the reduction for yield strength? What is the reduction for modulus of elasticity?

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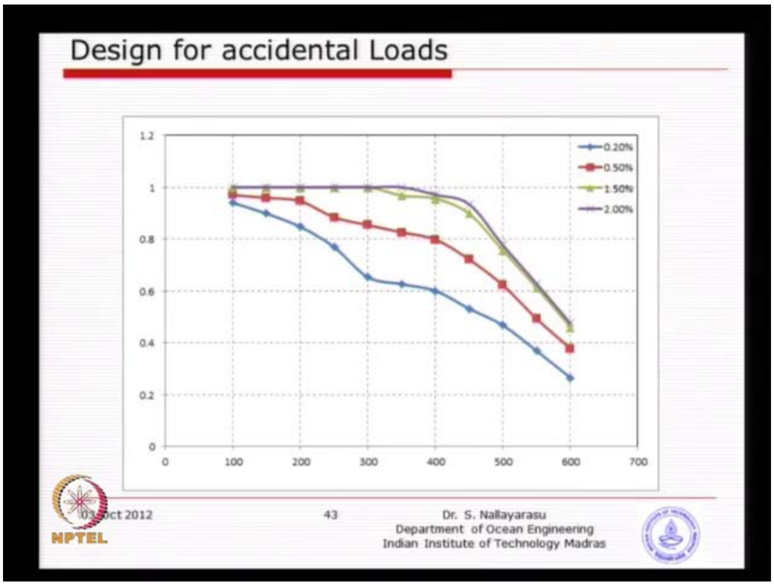

All, for them just for comparison purpose, plotted in a terms of graphical display so that, you can understand easily.