Offshore structures under special loads including Fire resistance
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Module – 3
Fire Resistance
Lecture – 46
Blast Resistance IV

Friends welcome to the 46 lecture where we will continue with the Blast Resistance. We will discuss more in detail about the various type of blast loads estimated from over pressure as the blast wave propagates and the structure interferes in the propagation path of a blast wave.

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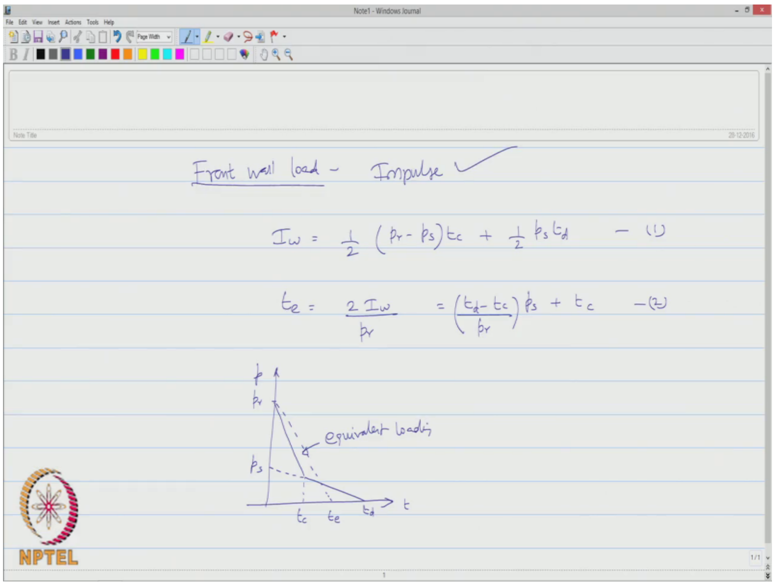

We already said in the last lecture that front wall load depends upon the impulse, where the impulse is given by half p r minus p s of tc, plus half p s of td I call this is equation 1 and say td, where te is the given by 2 I w by p r, which is also equal to td minus tc by p r of s plus tc.

So, we said that in the pressure time curve, if I say this is my p r which has got a loading feature of this nature where we know this going to be tc and this is going to be td, we know that this is my p s, we make an equivalent loading from this bilinear curve I may call this as equivalent period and we call this as equivalent triangular loading, which is going to act on the front wall which is based upon the impulse given by equation one, which we saw in the last lecture.

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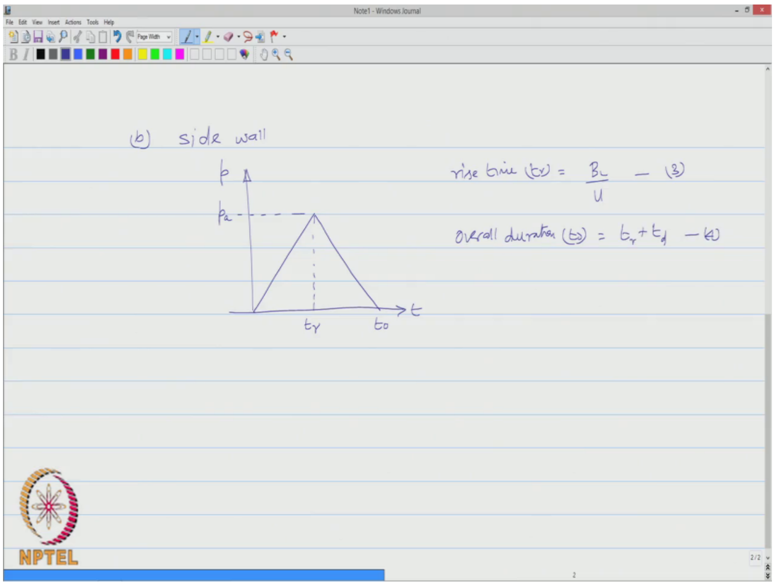

We also said in the side wall because of attenuation effect the over pressure effects will be lesser then that of the front wall and if you look at the pressure time diagram in the side wall loading, you know the pressure will rise go to it is speak which we call as peak pressure then it drops and this time of rise is called tr and of course, this is t 0, where the rise time tr is given by B L by u and the overall duration t o is given by tr plus td.

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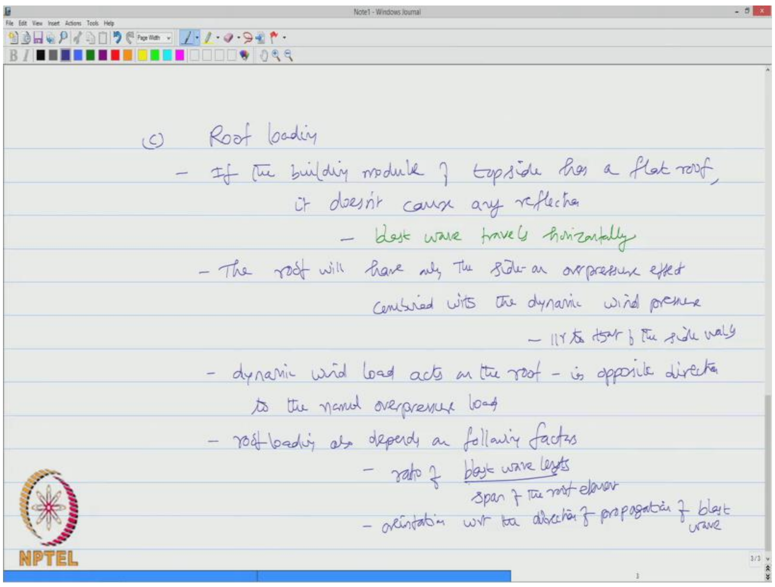

Let us now move on further to find the roof load due to shock wave propagation costing cost from the blast wave; if the building module are any living quarter item on the tops in facility of offshore platform has a flat roof, it does not cause any reflection because essentially blast wave travels horizontally therefore, the roof will effect or feel the roof will have only the side an over pressure effect, which will be now combined with the dynamic wind pressure, this will be more or less similar to that of the side walls.

We all agree that the dynamic wind load acts on the roof which will be in opposite direction to the normal over pressure load; the roof loading also depends on certain factors it depends upon the ratio of blast wave length to the span of the roof member. It also depends upon the orientation with respect to the direction of propagation of blast wave.

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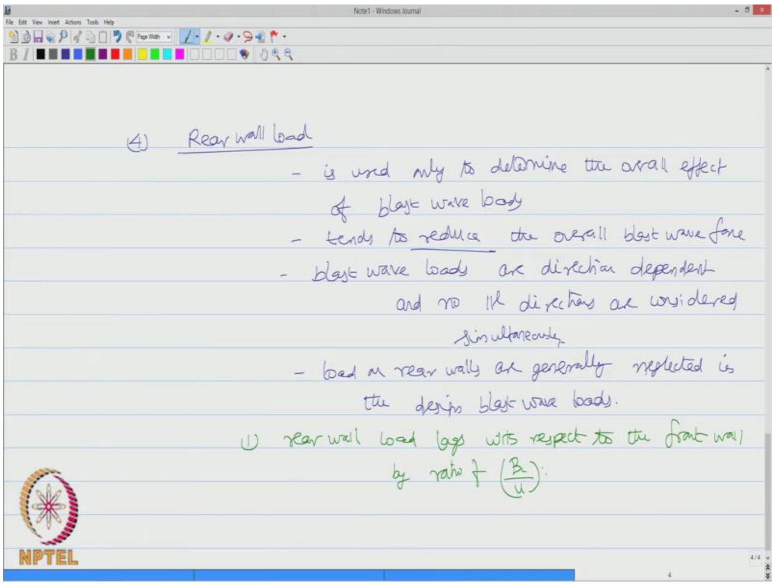

The fourth element is a rear wall; the rear wall load is generally used only to determine the overall effect of the blast wave loads. Actually the rear wall load tends to reduce the overall blast force, it is important to note that blast wave loads or direction dependent and no parallel directions are considered simultaneously, in that case we agree that load on rear walls are generally neglected in the design blast wave loads. The primary reason is rear wall load lags with respect to the front wall by ratio of B L by u; we know that B L by u is actually the rise time when you calculated for the side walls.

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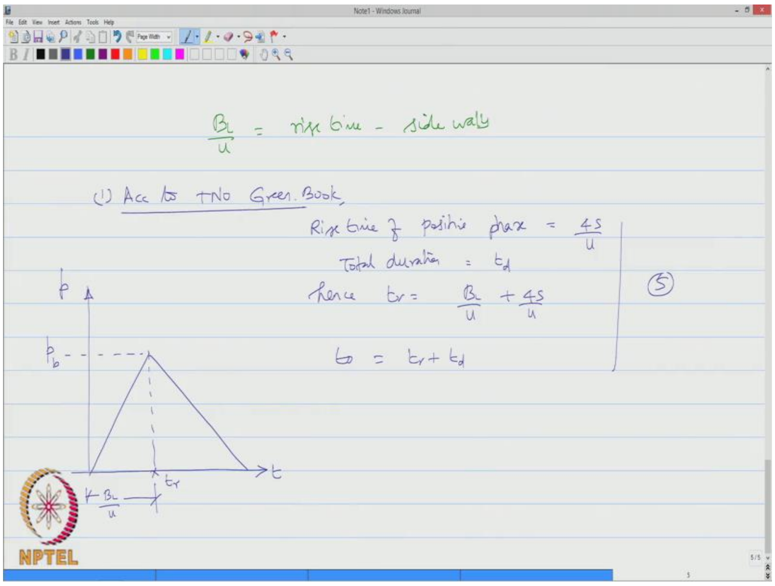

So, according to TNO green book; the rise time of the positive phase will be 4 s by u, the total duration will be consider as td and hence tr is actually B L by u plus 4 s by u, and t 0 will be tr plus td I call this is equation number 5. So, if you look them graphically in the pressure time representation, the pressure rises then it drops we call of course, this as rise time and we know this is going to be equal to B L by u we already said that. So, this is tr and of course, in this case this is going to be P b, I am talking about the rear load. This is according to TNO green book; alternatively we can also estimate this load using UFC 3-340-02.

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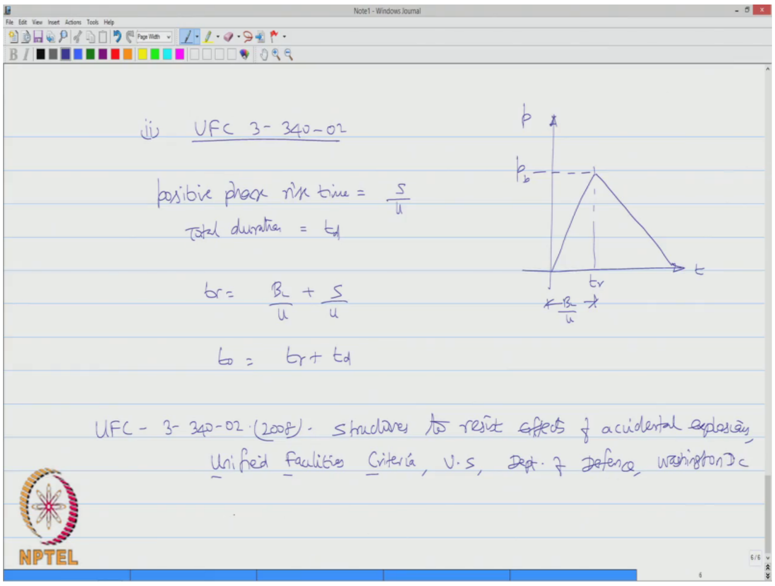

According to this the graphical representation of the load in pressure time curve, will have rise period and the drop in of course, we know this is tr and this is given by B L by u and this is P b and in this case the positive phase rise time is actually only s by u, the total duration is td and the rise time is B L plus u by s by u and overall time is rise time plus duration td. So, you have seen 3-340-02 2008 structures to resist effects of accidental explosions, unified facilities criteria UFC, United States department of defence Washington D C year 2008.

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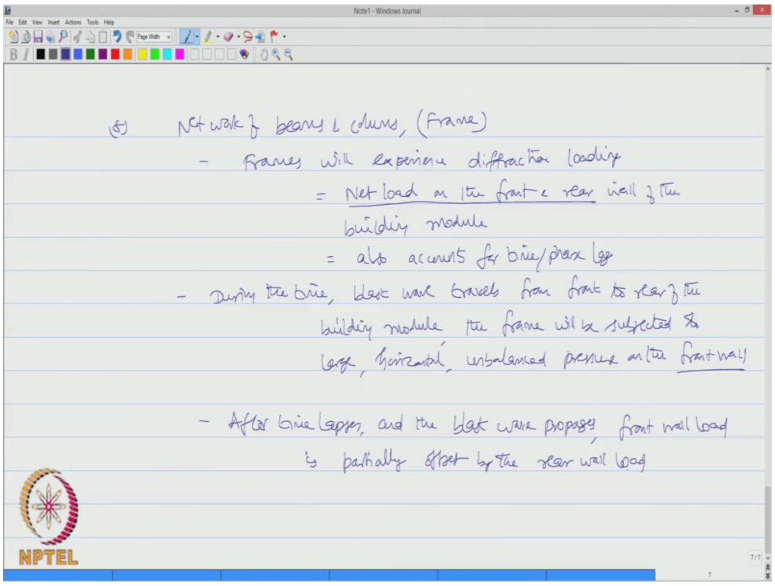

If the system is network of beams and columns, what we call as a frame building; then frame will experience diffraction loading, which will be actually equal to net load that occur on the front and the real wall of the building module.

So, this net load also accounts for the time of the phase lag; during the time when the blast wave travels from front to real of the building module, the frame will be subjected to large horizontal unbalanced pressure on the front wall and we agree that the load on the frame will be actually the net load on the front and rear, after time lapses and the blast wave propagates front wall load is partially of set by the rear wall loading.

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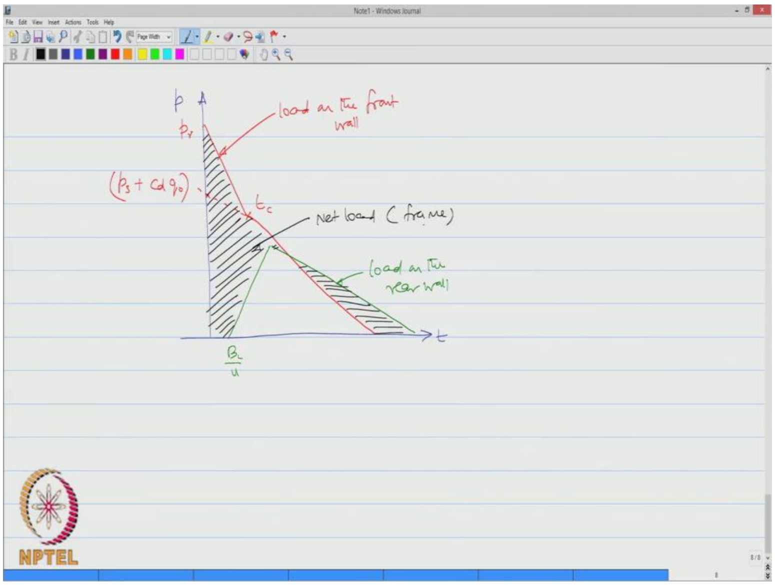

So graphically if you try to plot in the pressure time plot of this variation, let say load on the front wall is plotted like this in red colour let say this indicates load on the front wall and of course, this value is p r and this is indicated as tc, let us extend this and this value is p s plus C d of q 0, which we already explained further let us try to see the load on the rear surface. So, this will have a magnitude which will be indicated in green colour.

So, this is load on the real wall we know the net effect of these 2 is what we are looking at as the load on the frame we know that this value is BL value. So, we have now looking for a net loading, which is indicated by the hatch the portion. So, this is the net load which is acting on the fluid.

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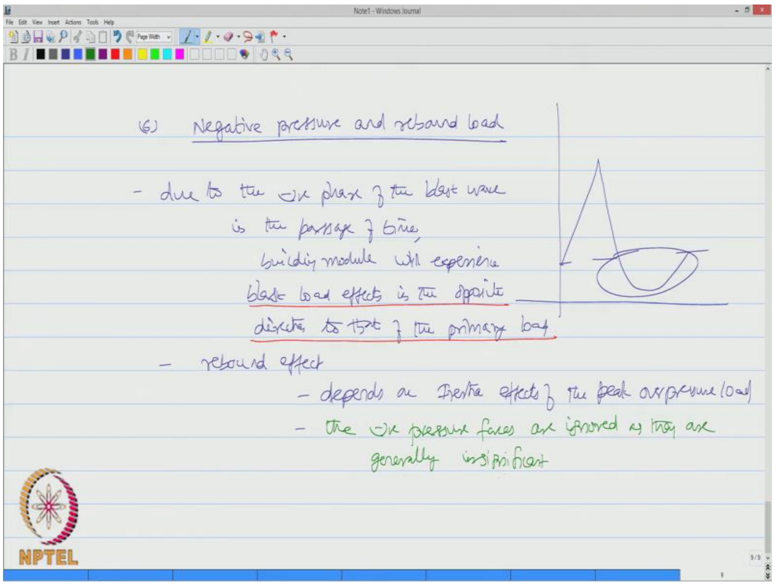

The next factor is the negative pressure because we know as the blast wave propagates; it reaches the peak then drips and then comes to normal. So, there is negatives are pressure it is call the section pressure and this will have a rebound loading. Due to negative phase of the blast wave propagation in passage of time, the building module will experience blast load effects in the opposite direction to that of the primary load that is very important, it experience blast load effects in the opposite direction to that of the primary load.

This is what we call as rebound effect. This will be dependent on the inertia effects of the peak over pressure load, fortunately the negative pressure forces are ignored as they are generally insignificant.

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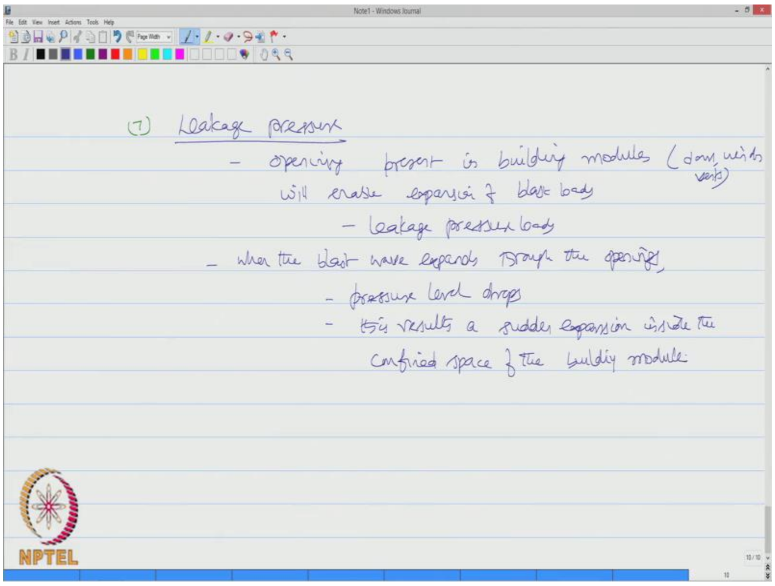

The next effect what we have is leakage pressure; opening present is building modules like doors, windows, wends etcetera will enable expansion of blast loads; this is what we call as leakage pressure loads. When the blast wave expands through the openings, pressure level drops this results a sudden expansion inside the confined space of the building module.

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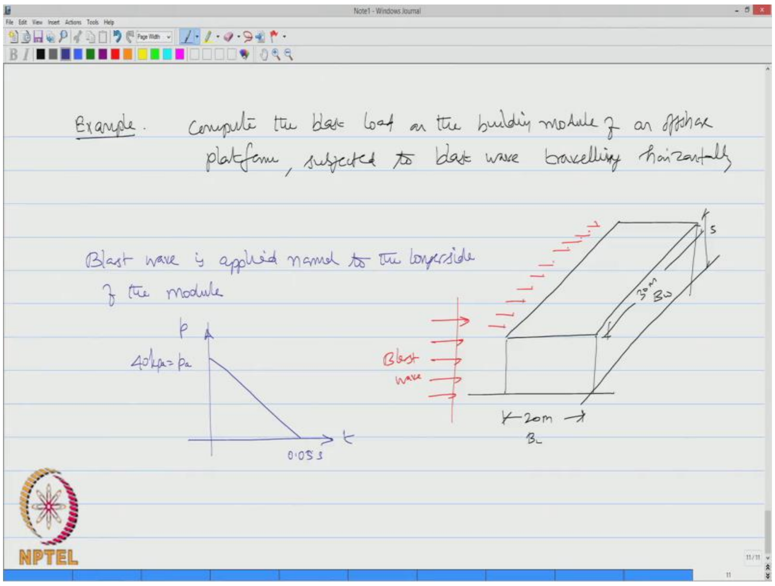

Let us taken example on try to work it out, the designed blast wave. So, let us say compute the blast load on the building module of an offshore platform, subjected to blast wave travelling horizontal.

Let say I have a building module which is 20 meter y and 30 meter long, what about 5 meter high; see this is 5 meter high, this is 20 meter and of course, this 30 meter. So, I call this as B w, this as B L and the blast wave is heating the system from this direction travelling horizontal. So, it is very clear that from this figure please note blast wave is applied normal to the longer side of the building and the peak over pressure with duration is actually 40 kilo pascal, the duration is 0.05 seconds.

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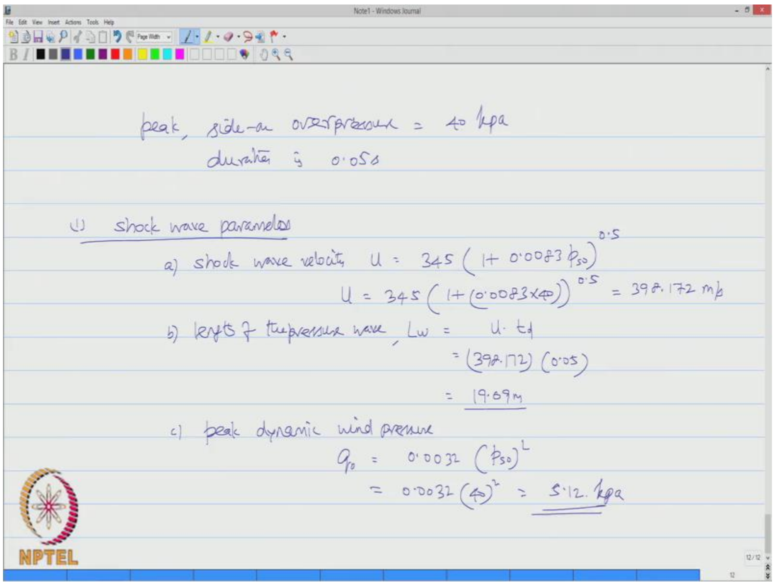

So, the peak side on over pressure is 40 kilo pascal and the duration is 0.05 seconds.

So, let us say shock wave parameters; shock wave velocity U is given by 345, 1 plus 0.0083 Pso rise to the power of 0.5. So, U is 345, 1 plus 0.0083 into 40 rises to the power of 0.5, which is 398.172 meter per second. Once I know this I can find length of the pressure, wave which is L w, which is given by U into td which is 398.172 into 0.05, which is 19.09 meters. A peak dynamic wind pressure is q naught given by 0.0032 of p so square, 0.0032 of 40 square which is 5.12 kilo pascal.

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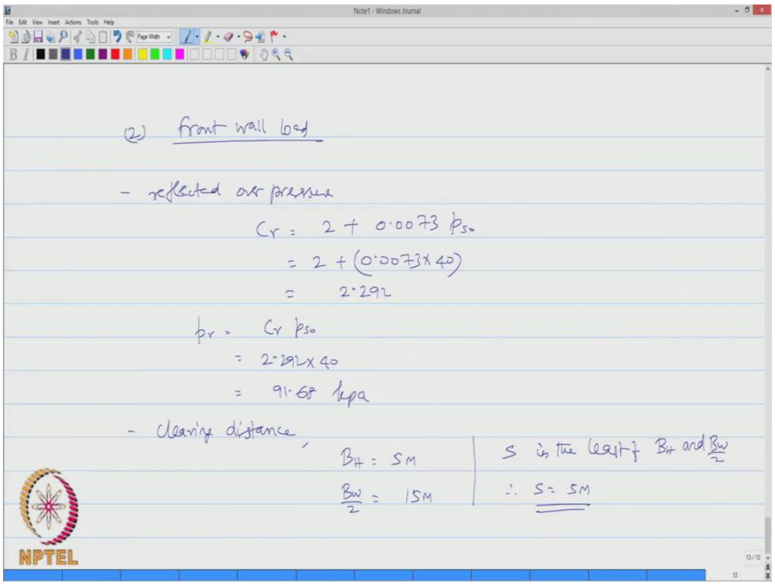

The second one is to compute the front wall load; to compute that let us first find the reflected over pressure which is controlled by a coefficient C r, which we know is given by 2 plus 0.0073P s o. So, this compute that by multiplying the known p so value for the given case, now the coefficient to be multiply is 2.292 therefore, p r is C r into p so which is 2.292 into 40, which is 91.68 kilo pascal. Let say the clearing distance the clearing distance, we need to calculate for which B H height of the module is 5 meter and B w by 2 is 15 meter. We know that the clearing distance S is the least of B H and B w by 2. So therefore, S is 5 meters.

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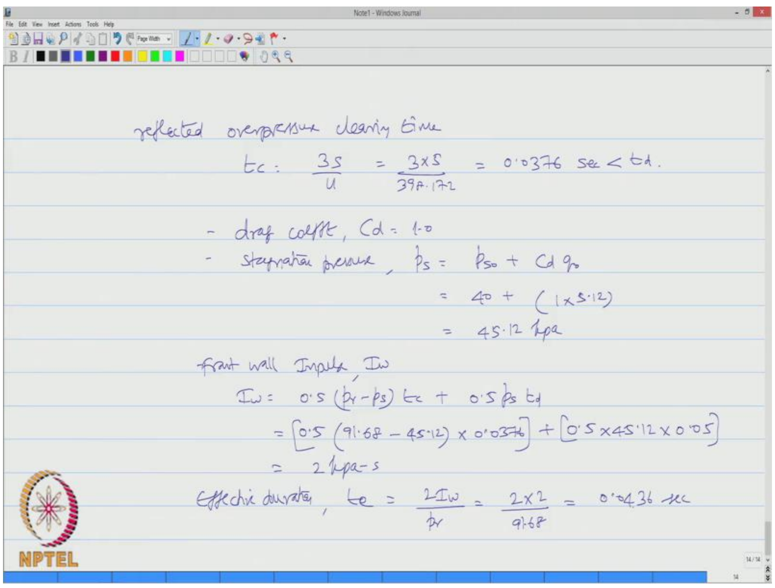

Now, I can find the reflected over pressure clearing time; which is tc which is 3 S by U, which is 3 into 5 by 398.172, which is 0.0376 S, which is less then td. The drag coefficient we take it as 1.0 in this case and the stagnation pressure is given by p s is equal to p so plus C d into q 0; in my case it is 40 plus 1 into 5.12, which is 45.12 kilo pascals.

Therefore, the front wall impulse I w is given by 0.5 of p r minus p s of tc, plus 0.5 of p s into td which is 0.5, 91.68 that is my p r and p s is 45.12 tc, which is 0.0376, plus 0.5 into 45.12 into 0.05. Which tells me the impulse is 2 kilo pascal second, so many seconds and the effective duration, te is given by 2 I w by p r. So, in this case it is 2 into 2 by 91.68 which is 0.0436 seconds.

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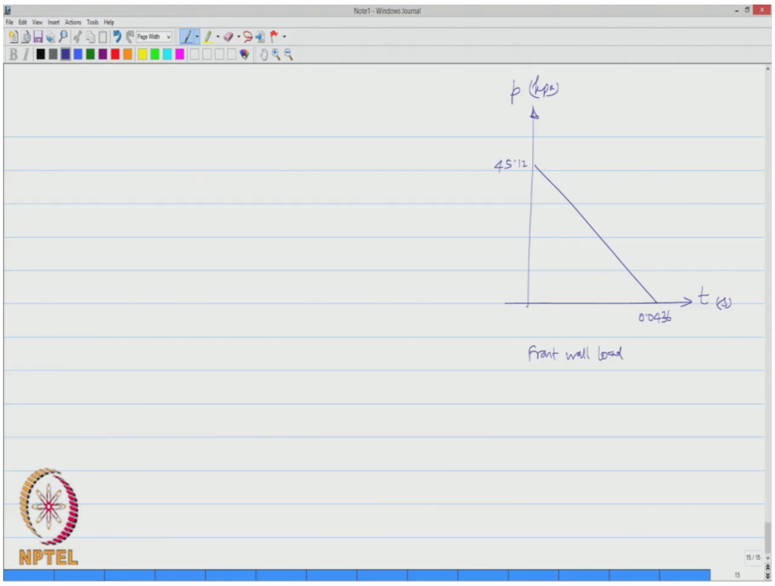

So, I can write to plot this on the pressure time graph, this is my time they pressure in kilo pascal and time in seconds in a plot and this is my 45.12, this is my 0.0436, this is for the front wall loading.

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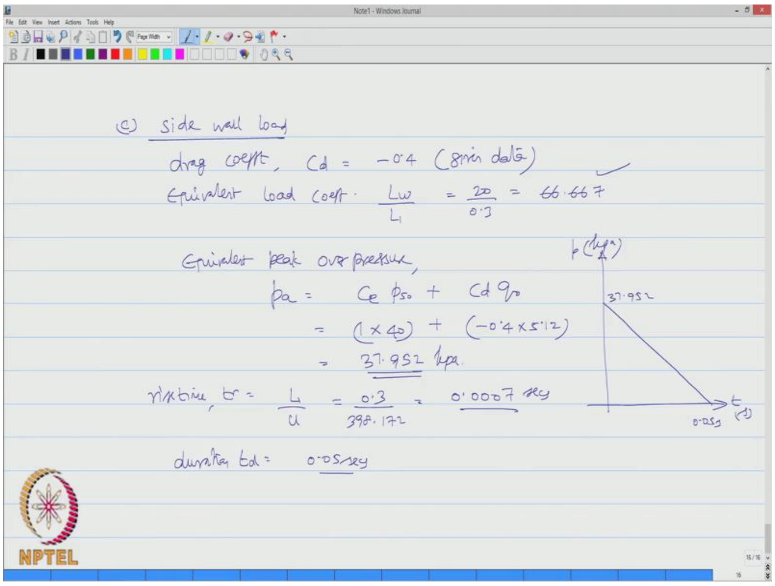

Let us talk about the side wall loading; for the side wall drag coefficient C d is minus 0.4 is a given data, the equivalent load coefficient for the side wall is actually dependent on Lw by L1, which is 20 by 0.3, which is 66.667. So, the equivalent peak over pressure for the side wall which is p a is given by C e into p so plus C d into q 0.

So, equivalents in this case is going to be 1 because of the ratio, plus C d is minus 0.4 into q 0 is 5.12, we know that the side wall lesser effect than different wall which is going to be 37.952 kilo pascals. Now let us compute the rise time, which is tr which is L1 by U, which is 0.3 by 398.172, which is 0.0007 seconds and the duration td is actually 0.05 seconds let us try to plot this in the pressure time scale, we know that this is going to be 37.952, as you see here and this value is going to be 0.05 seconds, this is for the side wall.

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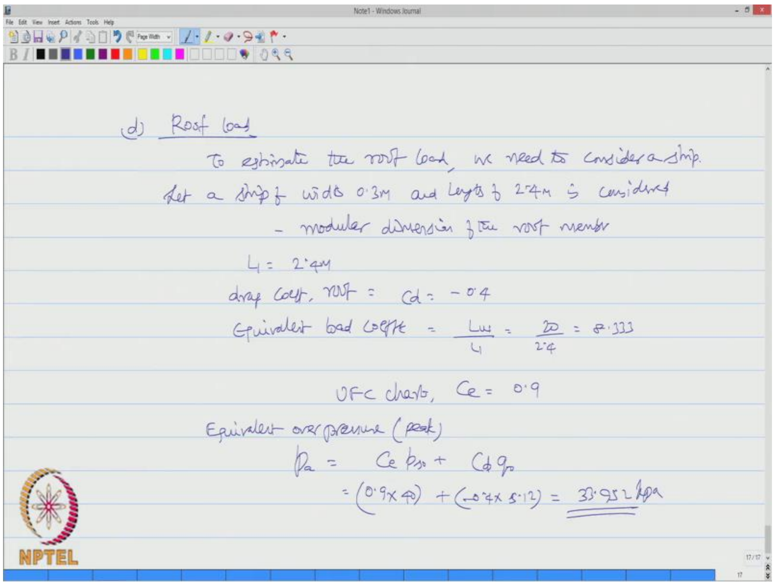

Let us work out for the roof load; to estimate the roof load we need to consider a strip, let a strip of width 0.3 meter and length of 2.4 meter is considered because that is going to be the modular dimension of the roof member. So, now, in this case L1 is going to be 2.4 meter and drag coefficient for the roof is C d is minus 0.4, equivalent load coefficient is actually the ratio of Lw by L1, which is 20 by 2.4 depends on this ratio which is 8.333, for this ratio you can refer to the UFC chart, one can find the equivalent coefficient as 0.9. So, therefore, equivalent over pressure that is peak over pressure is p a, which is can be C e into p so plus C d into q o.

C e in this case is 0.9, p so is of course, forty C d is minus 0.4 and q 0 is already estimated as 5.12, which gives me 33.952 kilo pascal which is much lower than the pressure on the front wall.

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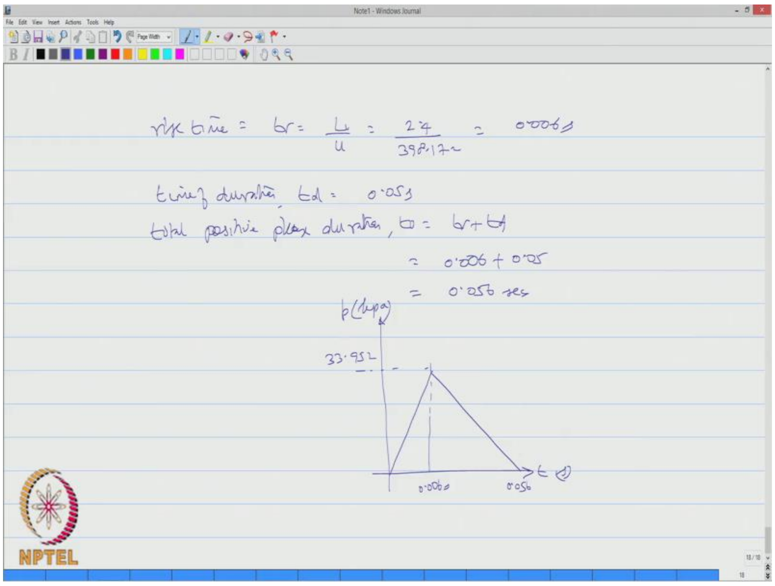

So, the rise time for this case is going to be tr which is L1 by u, which is 2.4 by 398.172 which gives me 0.006 seconds. Time of duration of the loading which we call as td is 0.05 seconds. So, therefore, the total positive phase duration, which I call t 0 is tr plus td which is 0.006 plus 0.05002C which is going to be 0.056 seconds; let us try to plot this on a pleasure time curve. So, the value it is rises at 0.006 seconds and the value is about 33.952 which you can see from here.

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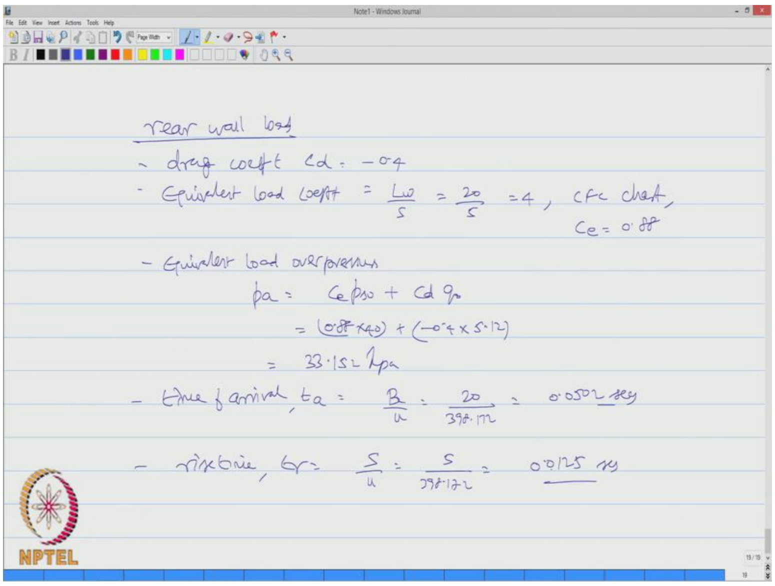

And then it drops of and that become 0.056 seconds; let us talk about the rear wall, for the rear wall drag coefficient C d is taken as minus 0.4 and the equivalent load coefficient depends on L w by S in this case is 20 by 5, which is 4, for which from the CFC chat one can find C e as 0.88. So, I can now work out equivalent load over pressure, which is given by C e of p so plus C d of q 0, c e is 0.88 and p so is 40, plus, minus 0.4 into 5.12 which gives 33.152 kilo pascal and time of arrival because the rear wall will have a time lag with that of the front wall therefore, we call this as time of arrival which is B L by u which is in this case 20 by 398.172 which is 0.0502 seconds.

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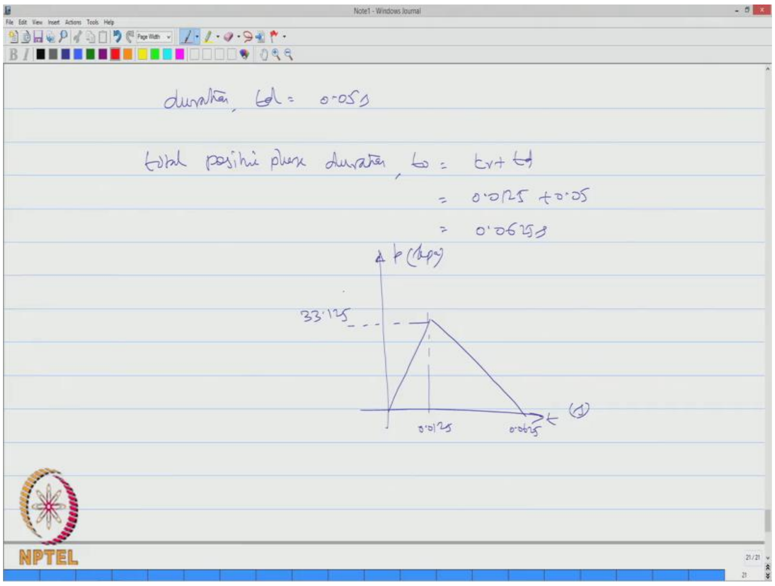

Once it arise you rises therefore, time rise tr is actually S by u, which is 5 398.172, which is 0.0125 seconds and duration td is 0.05 seconds. Therefore, total positive phase duration t 0 is tr plus td 0.0125 plus 0.05, which is 0.0625 seconds, let us try to plot this on the pressure and time scale and we know that it rises at about 0.0125 and then completes at 0.0625 and the pressure raised was actually equal to 33.125 which you see from here. So, that is of the load can be calculated on different phases of a building module in offshore platform, whose dimensions are taken as a dimension of a bluff body.

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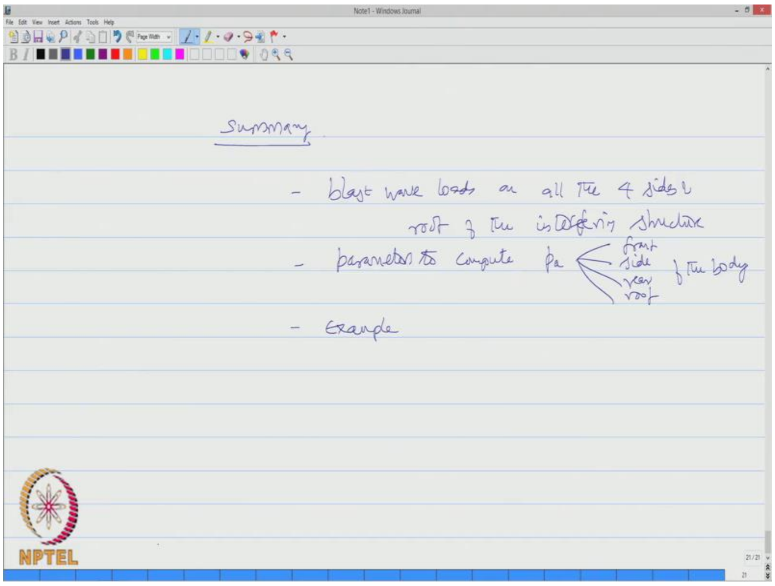

So, friends in this lecture we understood how to compute the blast wave loads on all the 4 sides and roof of the interfering structure, we have understood the governing equations and the parameters to compute the peak over pressure on all the sides, front side, rear wall and roof of the body, we have also worked out in example to estimate the loads on different phases, different sides of a building module.

So, interestingly friends we are now able to understand how the blast loads can be computed on bluff body or body interfering with the shock wave propagation, when the shock wave propagates on the horizontal direction the propagation takes place of course, in multi directions, but will try to work out one direction at a time and we then take the optimistic value for the design purposes.

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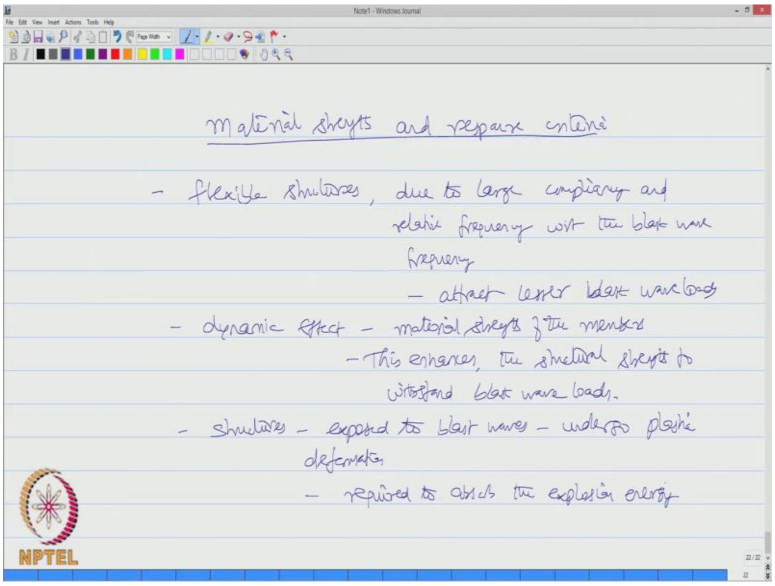

Further, in the continuation will talk about the material strength and the response criteria of building modules, when the interfere the shock wave propagation; we know that flexible structures due to large compliancy and relative frequency with respect to the blast wave frequency will attract lesser blast wave loads. So, the dynamic effect plays a very important role on the material strength of the members. So, this enhances rather the structural strength to with stand blast wave loads; structures are building modules exposed to blast waves, undergo plastic deformation because that is required to absorb the explosion energy.

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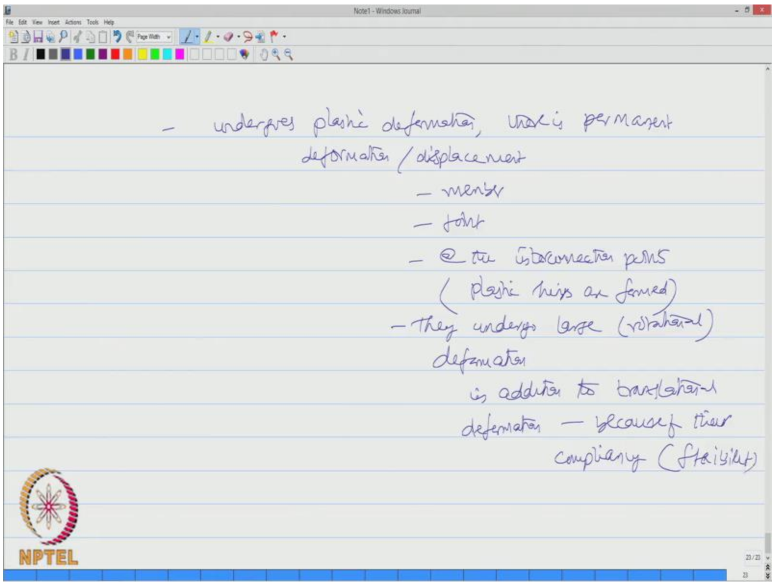

And we do agree that when a building module under goes plastic deformation, there is a permanent deformation or displacement cost on the member on the joint or at the inter connection points, where tentatively plastic hinges are formed.

So, they undergo large rotational deformation in addition to the translational deformation, which is essentially caused because of their compliancy or I should say flexible.

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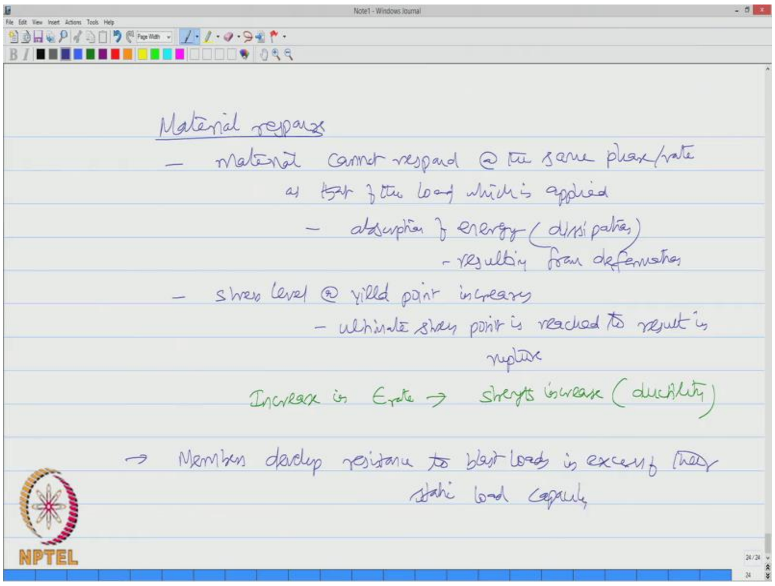

If you look at the material response, material cannot respond at the same phase or same rate as that of the load which is applied because there is absorption of energy, which we call dissipation resulting from deformation. So, there is always a variation between the rate at which the material response compare to that of the load applied rate. So, result of which stress level at the yield point increases and ultimate stress point is reached to result in rupture.

So, interestingly increase in strange rate leads to strength increase because of ductility. So, it means that members develop resistance to the applied blast loads in excess of their static load capacity.

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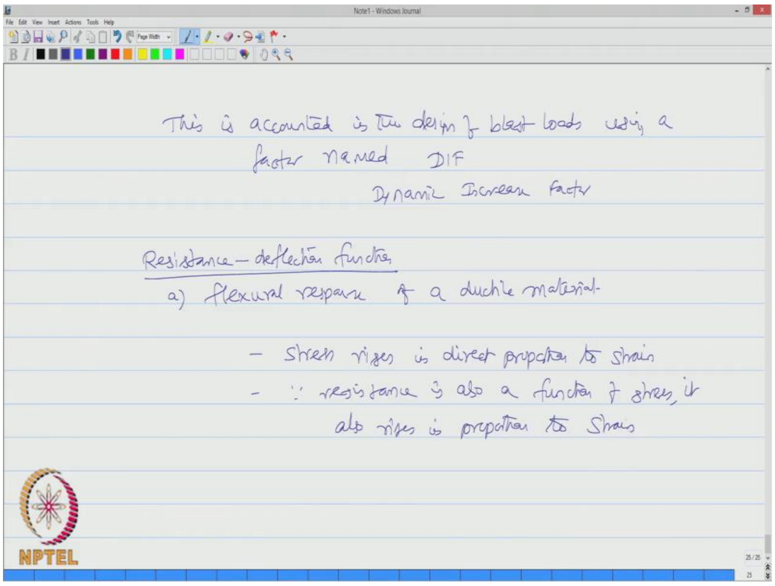

So, this is accounted in the design of blast loads using a factor called DLF, dynamic increase factor. Let us try to look at the Resistance-deflation function of the material, in general consider the flexural response of a ductile material, we know that stress rises in direct proportion to strain, since resistance is also a function of stress, it also rises in proportion to strain, if the extreme fibre in the cross section reaches the yield value then the stress strain relationship becomes non-linear.

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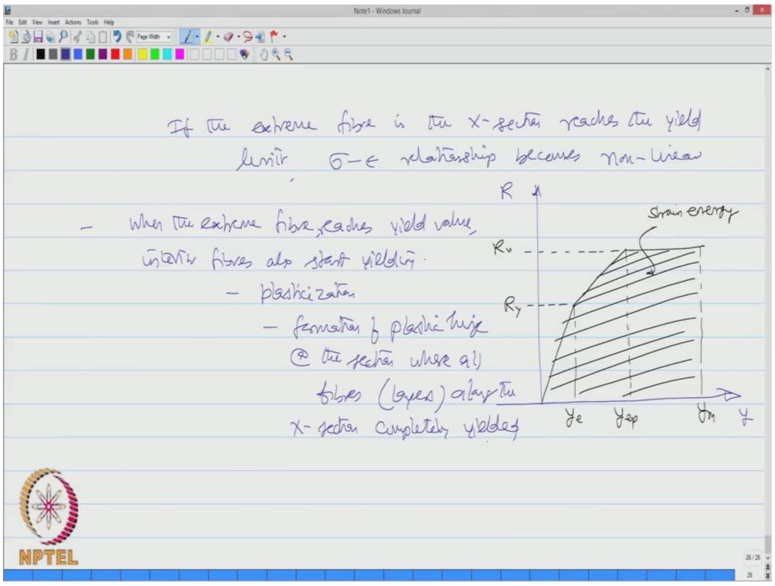

On the other hand, if you try to plot the variation, I call this as the deformation and resistance; let say initially it is linear then it is more with large deformation and then it is having infinite deformation. So, we agree that this is my yield strength and this is my resistance of yield and I can say now this is my ultimate strength or resistance and this value is my yield point and that is my maximum value y m and strain energy of course, the area of is called this gives me strain energy. So, when the extreme fibre reaches yield value, interior sections or interior fibres also start yielding we call this as section plasticization; this will result in formation of plastic hinge, at the sections where all fibres or all layers along the section completely yielded.

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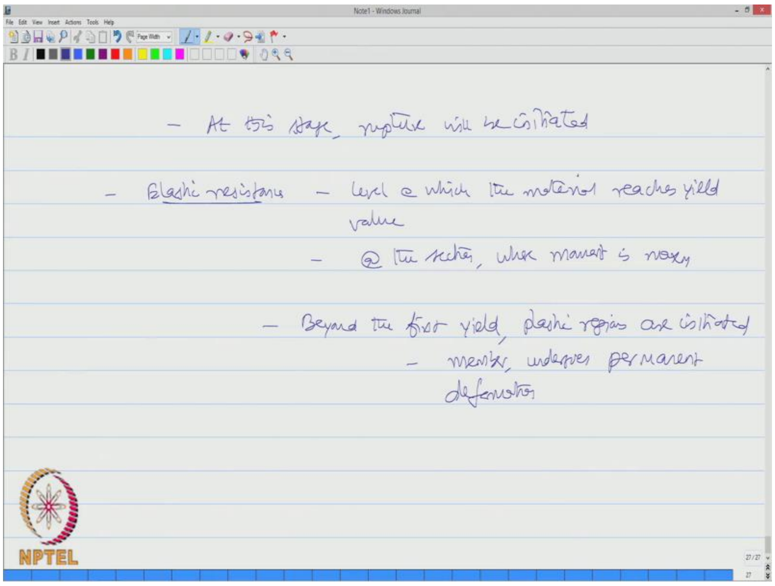

At this stage rupture will be initiated; if you look at the elastic resistance this is the level at which the material reaches yield value and is generally occurs at the location or at the section where moment is maximum. Beyond the first yield plastic regions or initiated and the member under goes or permanent deformation.

So, friends this characteristic changes with respect to the yield property of the material behaviour under this kind of loads and the rate of loading and the strain rate or not similar because of the delay taken by the material, which depends on it is energy absorption capacity, which we actually call the plastic resistance capacity of the section, we will discuss them in detail as we keep on proceeding with different kinds of load resistant analysis.

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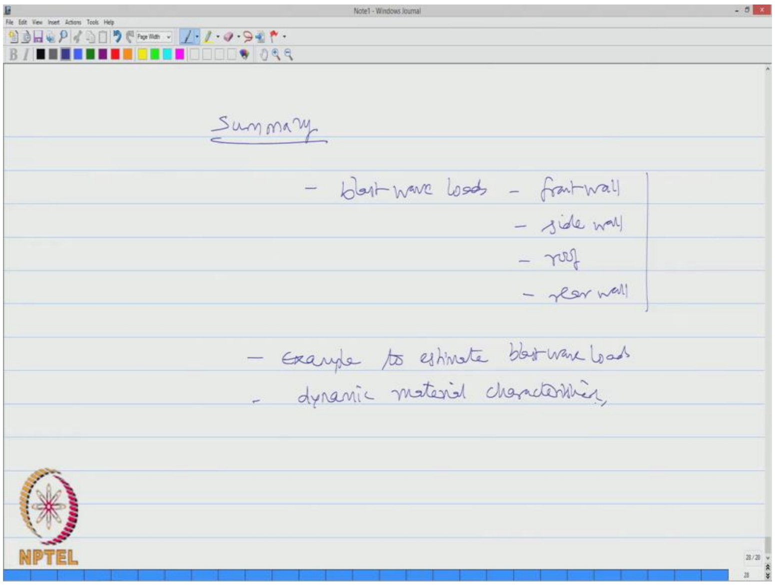

So friends, in this lecture we worked out the blast wave loads on different parts like the front wall, the side wall, the roof and the rear wall; we also solved an example to estimate the blast wave loads on a building module, we also understood the dynamic material characteristics which enables the material to resists the blast wave propagation in terms of energy dissipation. And we also understood that the strain rate happens in the material is not at the same level as that of the rate of loading occurring because of the blast wave.

Thank you very much.