Offshore structures under special loads including Fire resistance

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Module – 03
Fire Resistance
Lecture – 45
Blast Resistance III

Friends, we will continue discuss about the design procedure for blast resistance. This is a third lecture in blast resistance, lecture title 45, under module 3 which covers details on fire resistance. We are discussing about the design procedure to compute the over pressure.

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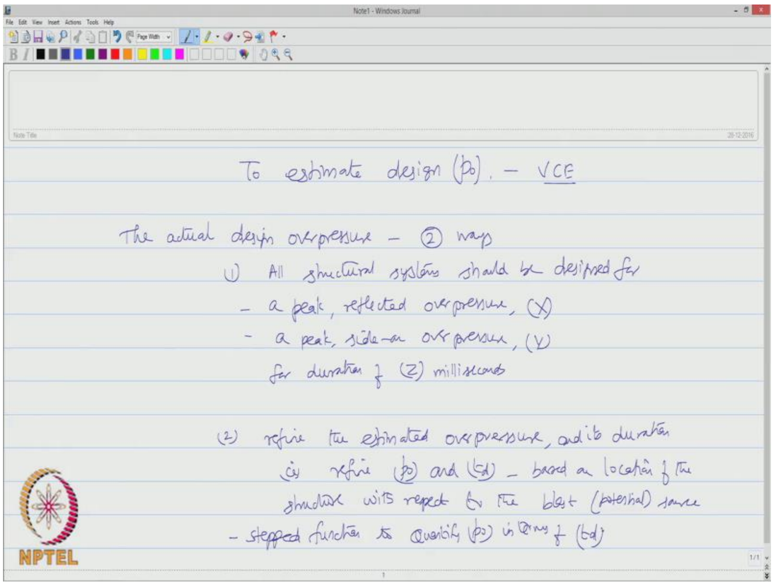

So, we need to estimate the design over pressure p o, we will take up an example of vapor cloud explosion. The actual design over pressure can be estimated by 2 ways. One all structural systems should be designed for a peak reflected over pressure, which we called as let us say X, a peak side on over pressure which called as Y for duration of let say Z milliseconds. So, that is the first way how do you do the design over pressure for a vapor cloud explosion.

The second method refines the estimated over pressure and its duration that is refines p 0 and td based on location of the structure with respect to the blast potential source. One can also use a stepped function to quantify p 0 in terms of td.

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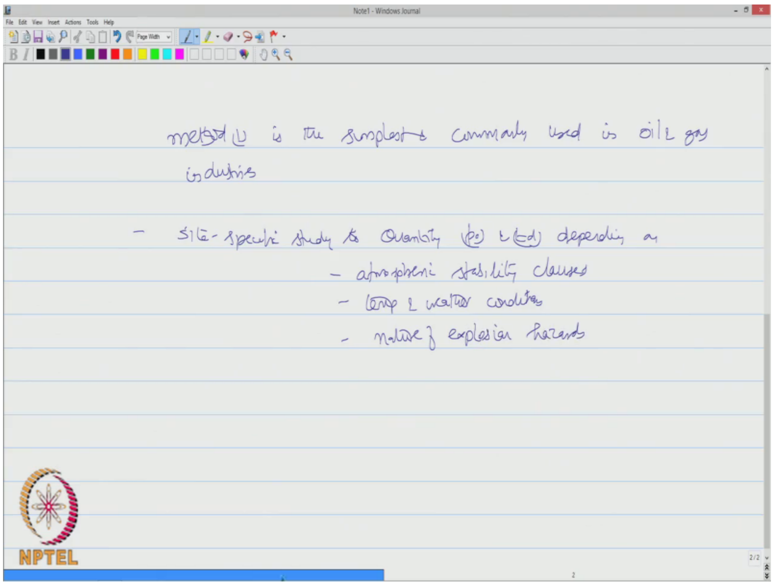

Out of these two, method one is the simplest and commonly used in oil gas industries. One can also conduct a side specific study to quantify p 0 and td depending on the atmospheric stability clause, temperature and weather, conditions and nature of explosion hazards.

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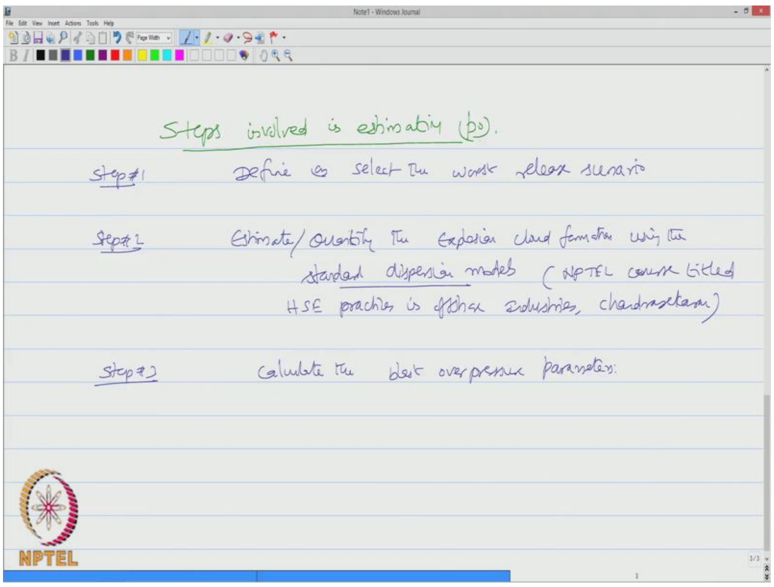

Let us now quickly see what are the steps involved in estimating the design over pressure. First step define or select, the worst release scenario. Step number 2 estimate or quantify the explosion cloud formation using the standard dispersion models. Friends there are various dispersion models available to estimate the propagation of cloud formation in case of such explosions. You can look into a parallel NPTEL course titled HSE practices in offshore industries delivered by me which is available in a free downloadable version from IIT, Madras. So, try to do a parallel capacity building to understand various dispersion models which are very commonly used in oil and gas industries. So, quantify the explosion cloud using the standard dispersion model, after doing this calculate the blast over pressure parameters.

There are different methods to find the blast over pressure p 0.

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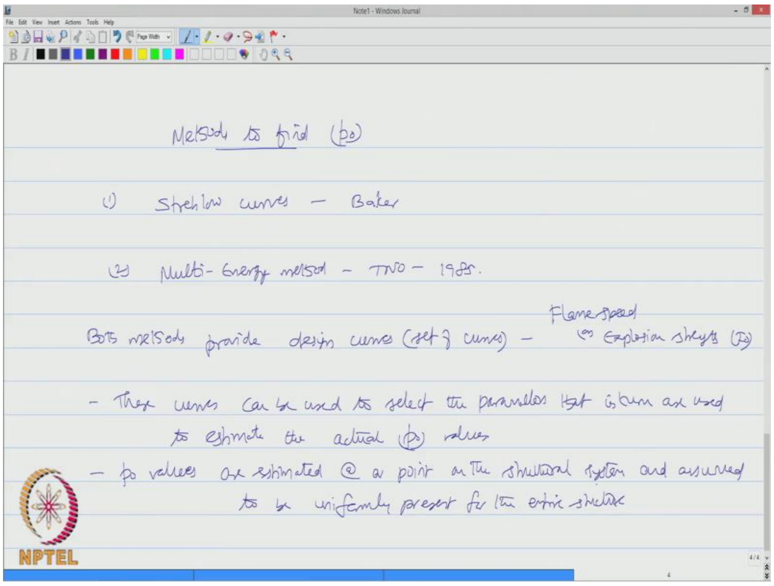

The first method is Strehlow curves which is given by Baker. The second method is Multi-Energy method suggested by TNO in 1985. There are some similarities between both the methods, both methods provide design curves (Refer Time: 08:07) I should say set of curves, based on the flame speed or explosion strength which we say intensity.

So, these curves can be used to select the parameters that in turn are used to estimate the actual over pressure values. Generally over pressure values are estimated at a point, at a point on the structural system and assumed to be uniformly present for the entire structure.

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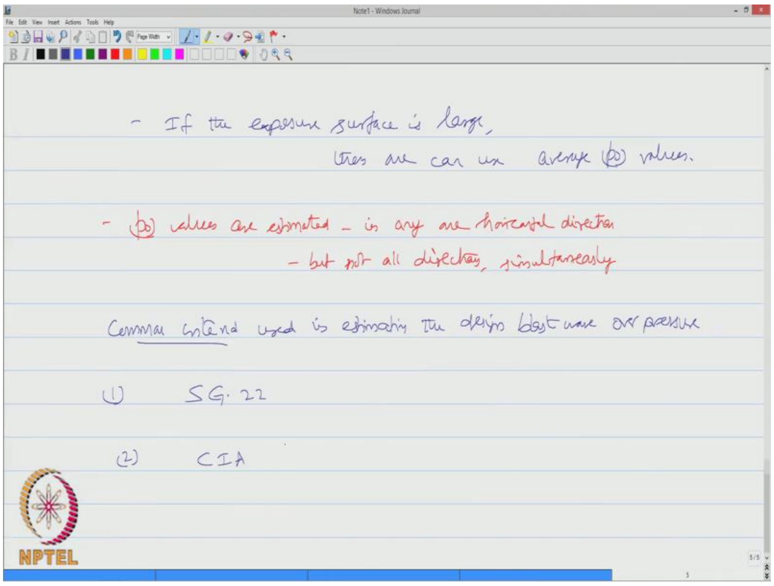

If the exposure surface of the structure is very large then one can use what we call average over pressure values. It is very important to note that over pressure values are estimated in any one horizontal direction, but not on all directions simultaneously. So, one can always try to find out the worst scenario for every direction and take that particular direction as the design estimate. But the design over pressure values are not estimated in all directions simultaneously; however, explosion cloud will spread in all directions from the point of every center simultaneously.

Let us quickly see what are the common criteria used in estimating the design over pressure, the design blast wave over pressure. There are two criteria's given - one criteria suggested by SG-22, other criteria suggested by CIA.

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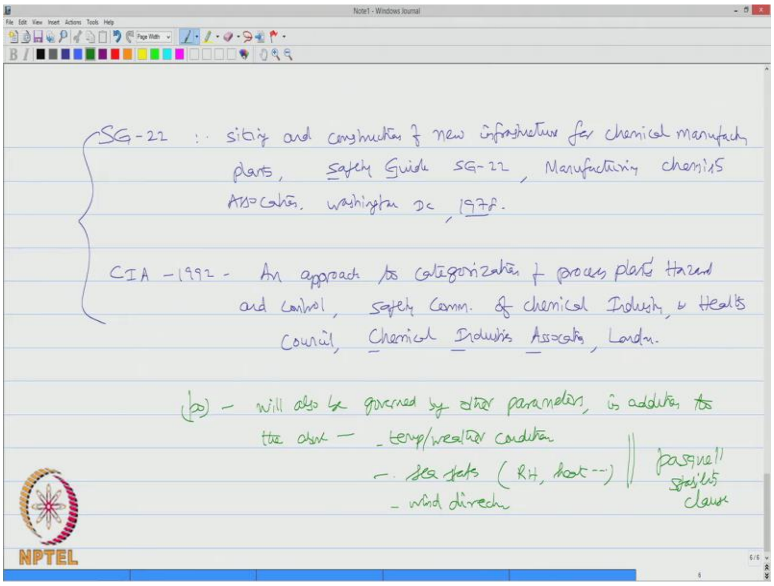

SG-22 is actually siting and construction of new infrastructure for chemical manufacturing plants, Safety Guide SG-22, Manufacturing Chemists Association; Washington Degree Celsius in the year 1978.

The second criteria could be CIA which is in the year 1992 which is an approach to categorization of process plants hazard and control, Safety Committee of Chemical Industry and Health Council, Chemical Industries Association that is CIA, similarly here SG stands for safety guide; Chemical Industries Association, London.

One can very well see here both these standards or norms which are used as common criteria to govern blast resistant design are not directly applicable to offshore structural systems, of course they are applicable to process plants and chemical manufacturing plants we can apply these standards to the process platforms of offshore systems with modifications which can be adapted from the Pasquill stability clause, so that is important.

Design over pressure will also be governed by other parameters in addition to the above for example, temperature and weather conditions, different sea states in terms of relative humidity, heat etcetera, these are available wind direction, wind velocity etcetera available in Pasquill stability clause which are applicable to offshore structures directly. So, there will be some modifications, which are made based upon the recommendations made by either SG-22 or in CIA 1992 to estimate blast wave over pressure on offshore structural systems.

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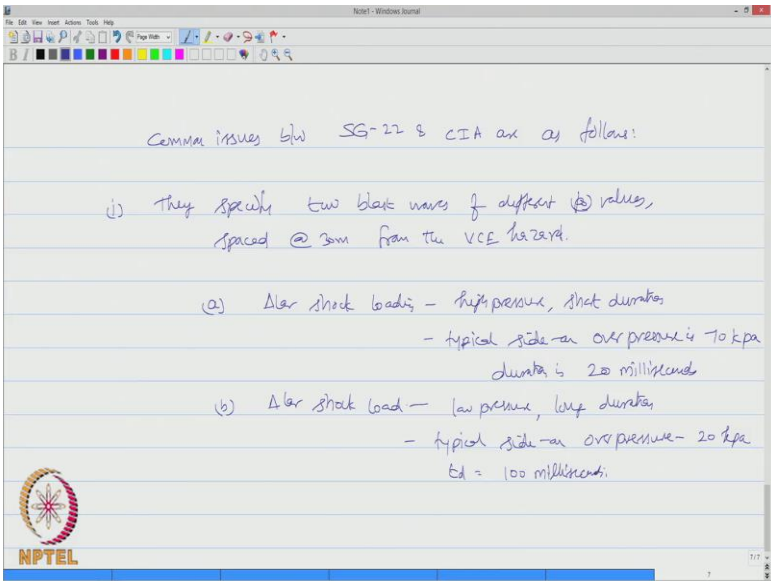

These are commonness between both the common criteria the commonness or the common issues between SG-22 and CIA or as follows - though they differ slightly from estimating blast wave over pressure, but they are based upon certain common factors which we will see now.

They specify two blast waves of different over pressure values spaced at 30 meters from the vapor cloud explosion hazard location. One can be a triangular shock wave which has got high pressure, short duration, the typical side on pressure is about 70 kilo pascals and the duration is about 20 milliseconds. The second wave which is spaced at 30 meters spacious interval is also a triangular shock load with low pressure long duration, a typical side on over pressure is about 20 kilo pascal and the typical duration is about 100 milliseconds.

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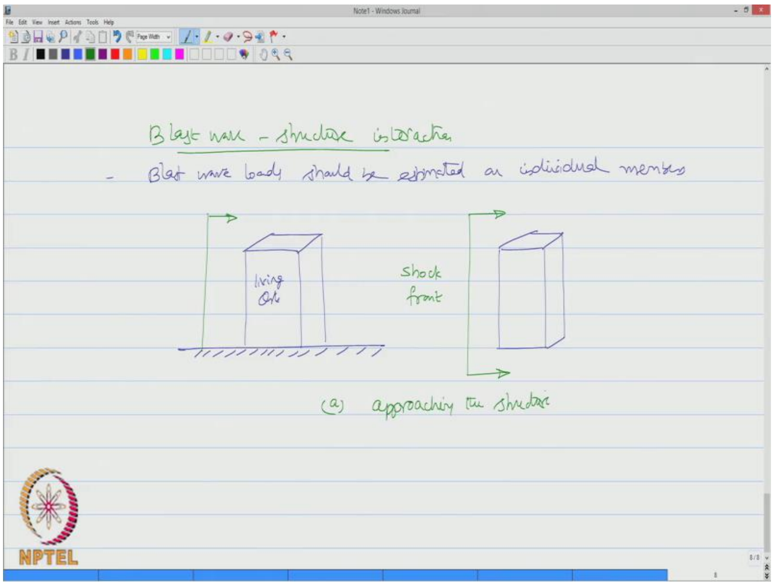

Let us talk about blast wave structure interaction. Blast wave loads should be estimated on individual members. The blast wave structure interaction can be explained interestingly by the graphical wave.

Let say I have some infrastructure may be a living quarters I am marking it fixed in sense they are located on the top side of the platform, let say this is living quarters. The shock wave happens to act on the module, when it is abstracted by the module then it attempts to pass through the wave. So, we call this as shock front. Once a shock front approach the structure, so I should say approaching the structure once it approach the structure the shock wave is reflected from the front surface it is reflected from the front surface whereas, the shock wave originally is located somewhere here.

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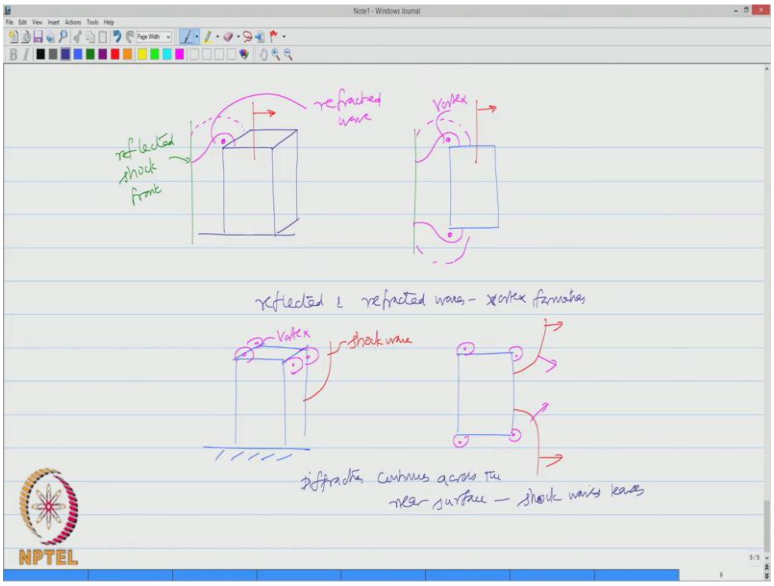

This is the original shock front this is reflected shock front. This reflection will also cause a refraction wave, this is what we call as refracted wave this refracted wave will induce vortices this will cause vortex whereas, the shock wave front this number here.

So, I should say reflected and refracted waves will result in vortex formation. Then subsequently the shock wave will leave the structure, as passes as propagates it will leave the structure. So, the shock wave leaves the structure, while leaving, so this is the shock wave while leaving again it causes vortex. So, ultimately when it leaves the infrastructure and propagates further it will cause vortices at all corners and they will propagate in this direction.

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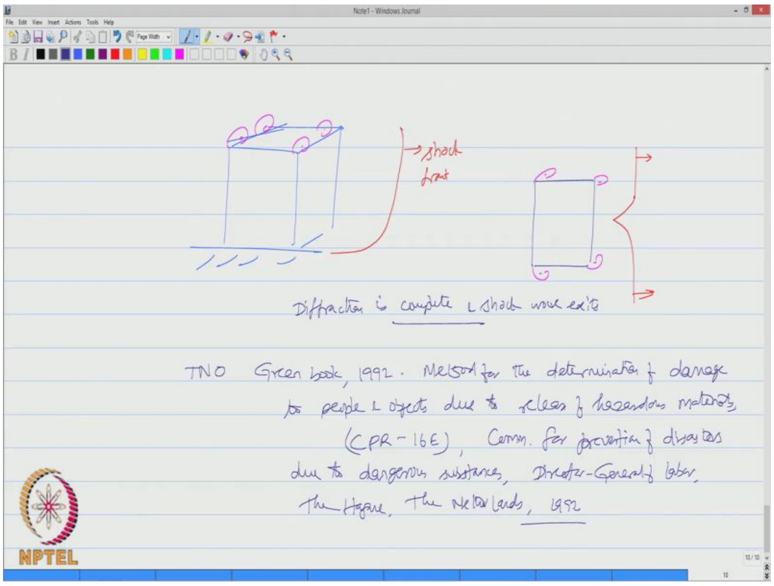

So, I should say here the diffraction continues across the near surface as the shock wave leaves the building then subsequently the vortices will be formed and the shock wave will completely leaving the building, it means the shock wave completely leaves and heat causes vortices. So, I should say here that the diffraction is complete and shock wave exceeds.

So, one can say that blast wave structure interaction is given very clearly illustratively in TNO green book, which is talking about the method of preparation method for the determination of possible damage to people and objects due to release of hazardous materials that is CPR-16E which is prepared by committee for prevention of disasters due to dangerous substances and directive general of labor, Hague, Netherlands scheduled released in 1992.

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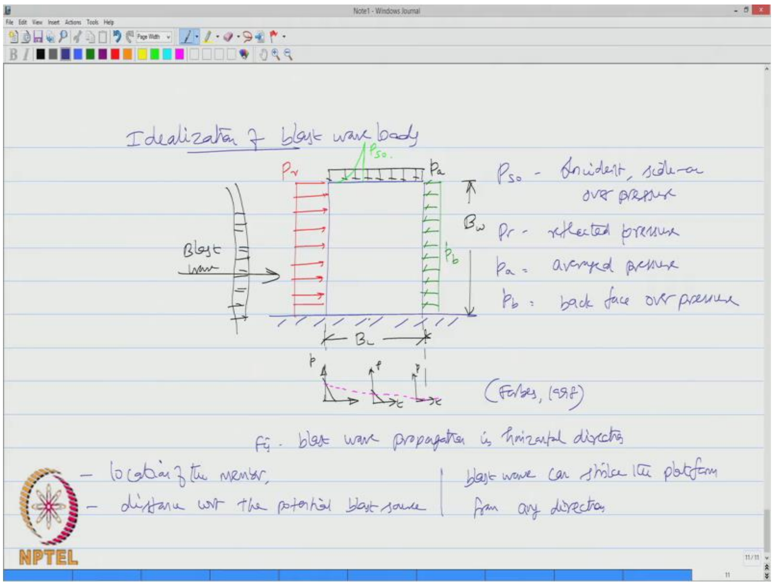

So, we need to idealize this blast wave loads for the purpose of design let us talk about how they are idealized. Let us say if I have any infrastructure of abstracting the flow in the field of shock wave propagation.

The shock wave front hits the infrastructure which we called as p r the refracted one and further it also has active pressure acting on this side by call this as p a and back phase over pressure will be acting on this side we call this as p b and the typical side over pressure is marked like this, it goes in picture the peak value and the peak value is P so.

So, now P so is the incident side on over pressure which is caused by the blast wave loads, p r is the reflected pressure, p a is the averaged pressure because the dimension of the structure can be very large compared to the flow propagation direction and p b is the back face over pressure. These all true when the blast waves of closure structure this is the blast wave which is approaching the structure.

So, now let us mark the dimensions of these, we call these dimension as B L building length, and we call this dimension as B w this being the blast wave propagation direction, and p a average could be essentially let say this point it can be this is t and this is p and it can be varying this way. Similarly at another point somewhere here we can give again t versus p it can be lower and another point again here p versus t can be further lower. If you try to plot these points, that is how the variation happens. We have a very interesting reference for this Forbes, 1998. So, this is a picture which shows the blast wave propagation in horizontal direction that is the figure.

However, depending upon the location of the member, depending upon the distance with respect to the potential blast source, blast wave can strike the platform from any direction. So, one should estimate the forces or the blast wave loads in all directions and take the maximum or an average value as a design blast wave over pressure for designed considerations.

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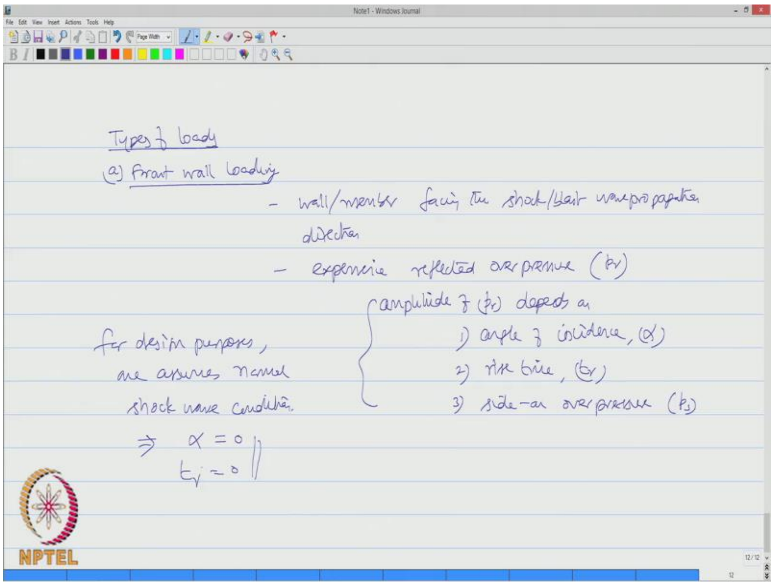

Let us talk about different kinds of loads to estimate the designed blast wave over pressure. First is the front wall loading, front wall loading in sense the wall or the member facing the shock wave or the blast wave propagation direction is considered as the front wall. This will experience reflected over pressure which we can ask p r, the amplitude of p r depends on the angle of incidence alpha, the rise time of peak over pressure p r and side on over pressure value p s.

Generally for design purposes one assumes normal shock wave condition. Normal shock wave condition means alpha is 0 and tr is 0.

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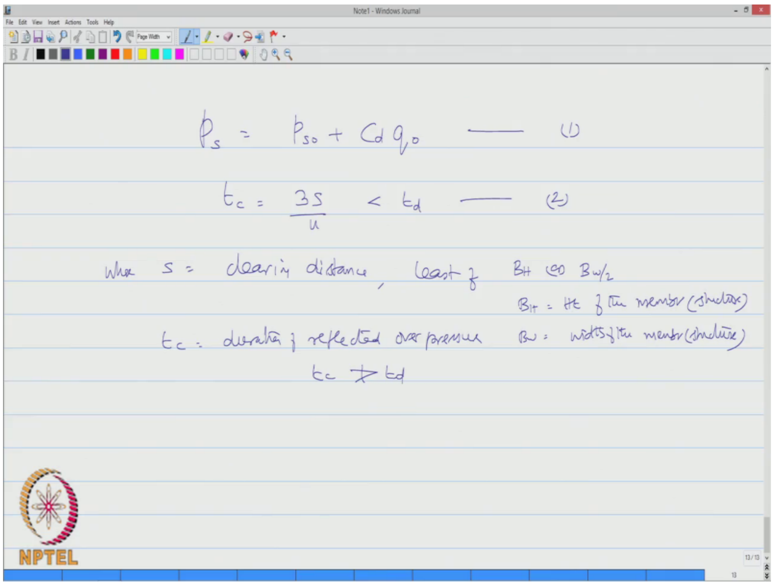

So, in that situation one can calculate p s as p so plus c d q 0 and tc as 3s by u which should be less than td. Where s is the clearing distance which is the least of B H or B w by 2, where B H is height of the member and B w is width of the member or the structure the bluff body.

One can estimate the loads on the bluff body completely and distributed for every member as designed blast wave loads. It is interesting that the duration of the tc is duration of reflected over pressure. Reflected over pressure duration cannot be more than the duration of the shock wave itself; that is over pressure.

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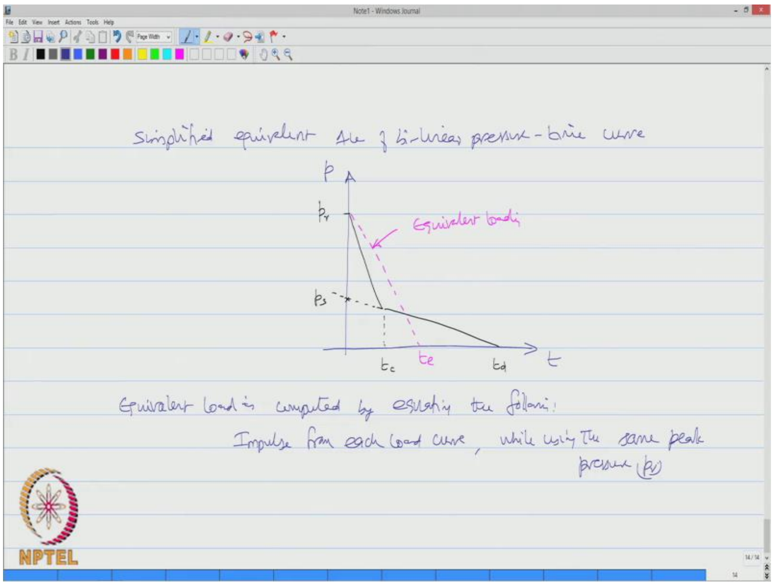

So, graphically a simplified equivalent triangle of bilinear pressure distribution curve, pressure time curve will explain this let say this t pressure versus time plot, this is the actual loading. So, this is my td and this is my tc, the reflected over pressure duration and extend is this is my p s and of course, this is my p r. The equivalent loading can be taken as, we call this as te this is the equivalent loads which has the component of p r and p s both as a modified measure.

The equivalent load is computed by equating the following impulse from each load curve while using the same peak pressure p r.

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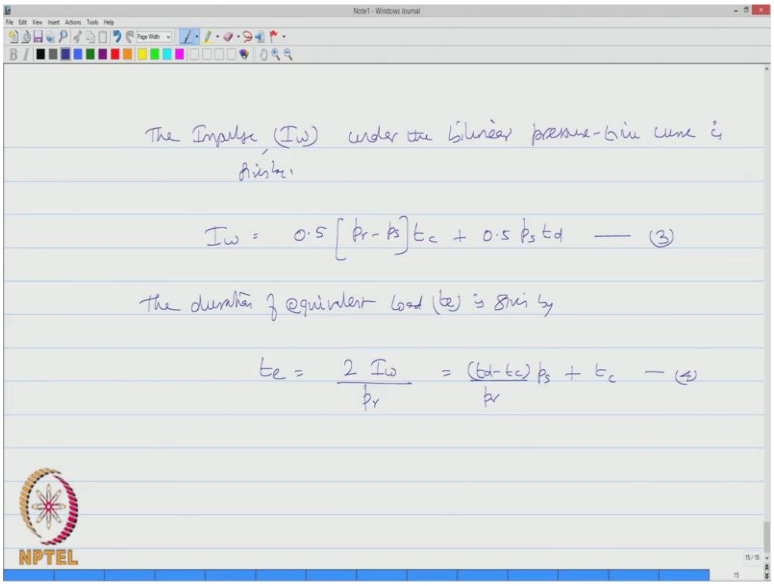

So, let us write the impulse I w under the bilinear curve, bilinear pressure time curve is given by I w is half p r minus p s into tc plus half p s into td - equation number 3. The duration of the equivalent load that is te is given by te is equal to twice of I w by p r which can be simplified by substitution whereas I w is available there, which can be td minus tc by p r into p s plus tc - equation number 4. So, that is the estimate for front wall loading.

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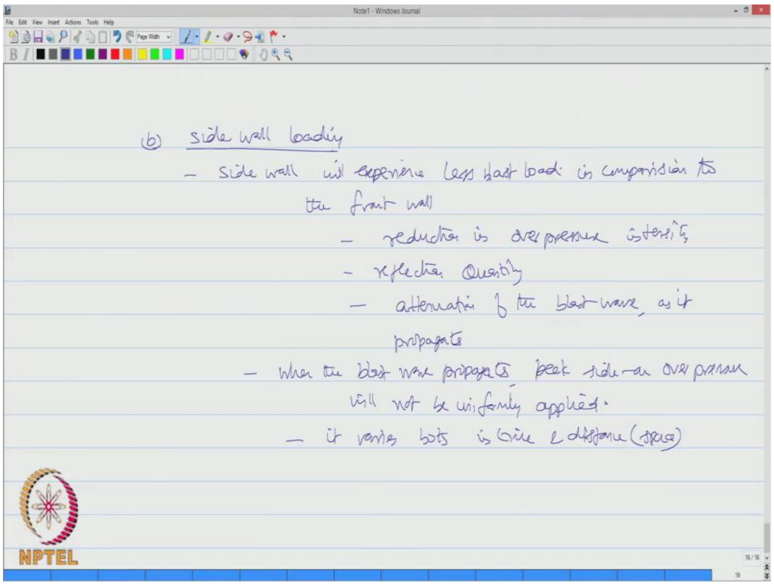

Let us do it for side wall loading. Similarly, the side wall will experience lesser blast loading in comparison to the front wall, this is mainly due to reduction in over pressure intensity, reflection quantity and attenuation of the blast wave as it propagates. It is also important to note that when the blast wave propagates the peak side over pressure will not be uniformed or I should say will not be uniformly applied. It varies both in time and distance that is space.

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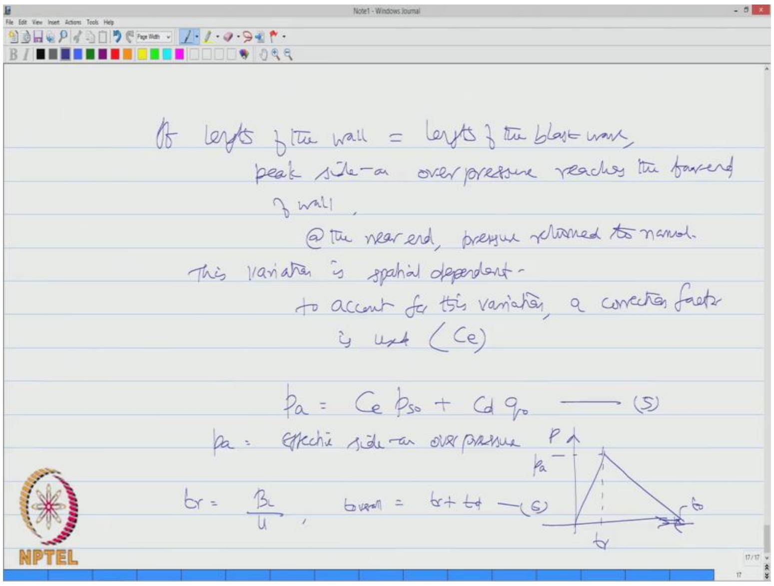

Interestingly if length of the wall is equal to the length of the blast wave, then in that case the peak side on over pressure reaches the far end of the wall whereas, at the near end the pressure returned to normal. So, this variation is spatial dependent, now to account for this variation a correction factor is used which we call as c e.

So, therefore, the peak over pressure on the side wall could be c e times of p so plus c d of q naught where p a is the effective side on over pressure, graphically we try to plot this in the pressure time domain this is what we called as tr, this is this value is my t 0 and this value is my p a. Whereas tr in this case is going to be B L by u and the overall duration t overall will be tr plus td, I put this as equation number 6.

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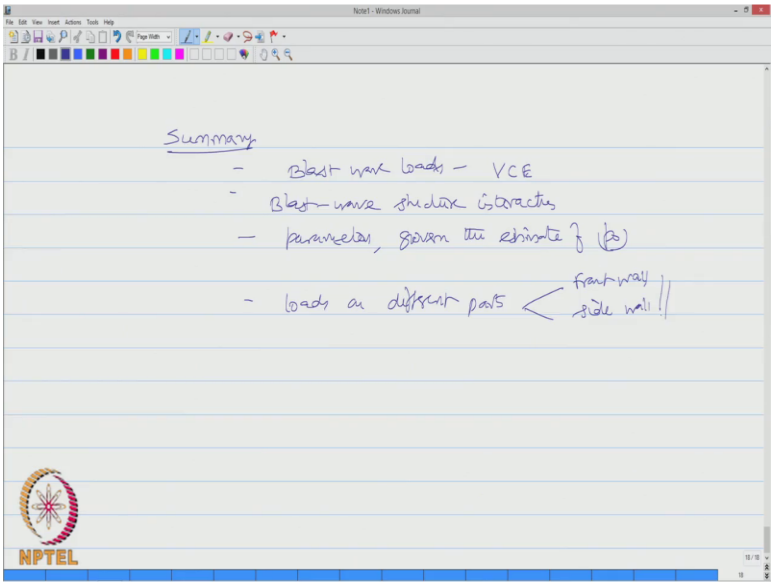

So friends, in this lecture we started understanding the design blast wave loads based on one specific application which is vapor cloud explosion, we understood the blast wave structure interaction, we also understood different parameters which govern the estimate of design over pressure of a blast waves. We are working out the design loads on different parts of the structure like front wall, side wall etcetera. We will continue this in the next lecture as well.

Thank you.