Advanced Design of Steel Structures
Dr. Srinivasan Chandrasekaran
Department of Ocean Engineering
Indian Institute of Technology, Madras

Lecture - 60
Blast - resistant design - 3

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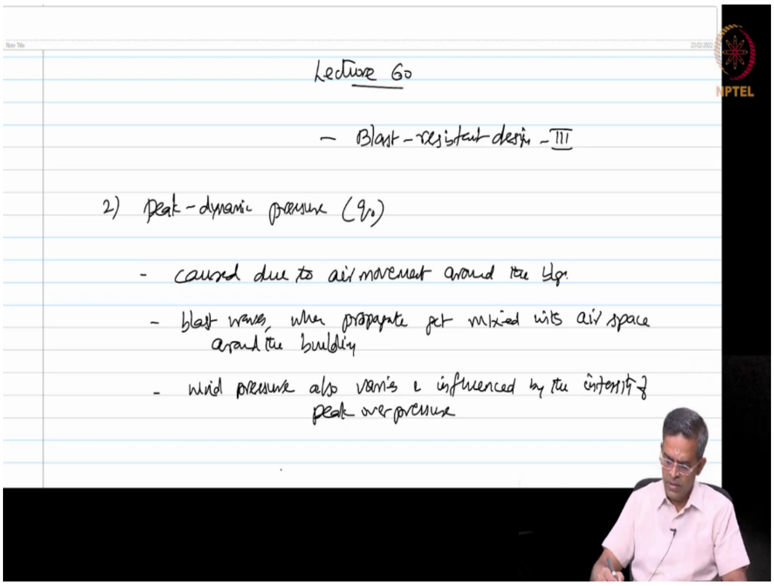

Friends, welcome to lecture 60 of Advanced Steel Design course wherein we are going to discuss about Blast resistant design I put this as lecture-3 in Blast resistant design. We are talking about another parameter which is peak dynamic pressure given as q_o this is essentially caused due to the air movement around the building blast waves when propagate get mixed with airspace around the building and that is resulting in peak dynamic pressure.

Wind pressure also varies and influenced by the intensity of peak over pressure.

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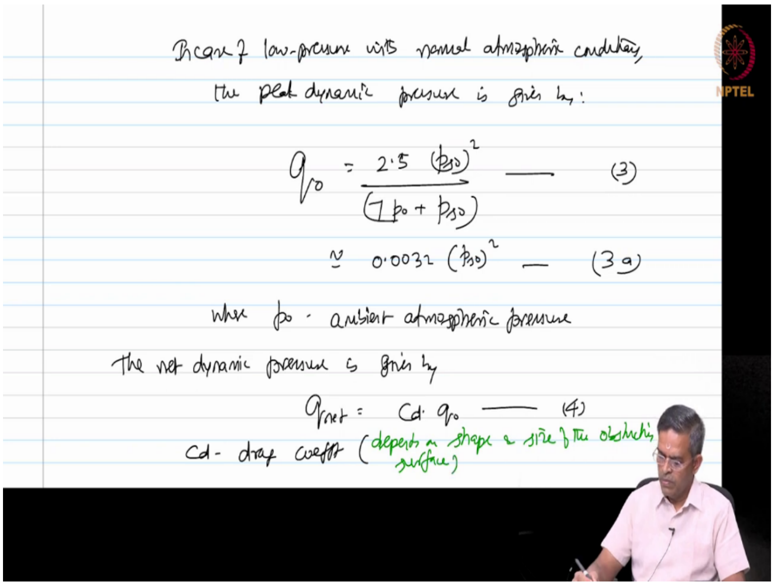

In case of low over pressure range with normal atmospheric conditions, the peak dynamic pressure can be calculated as below.

$$q_o = \frac{2.5\,(pso)^2}{(7po+pso)} \cong 0.0032(pso)^2$$

calls 3 a, where p 0 is called ambient atmospheric pressure.

Having said this the net dynamic pressure is therefore given by

$$q_{net} = C_d . q_o$$

where C_d is called the drag coefficient which is influenced by the wind pressure present around the building. The drag coefficient depends on shape and size of the obstructing surface.

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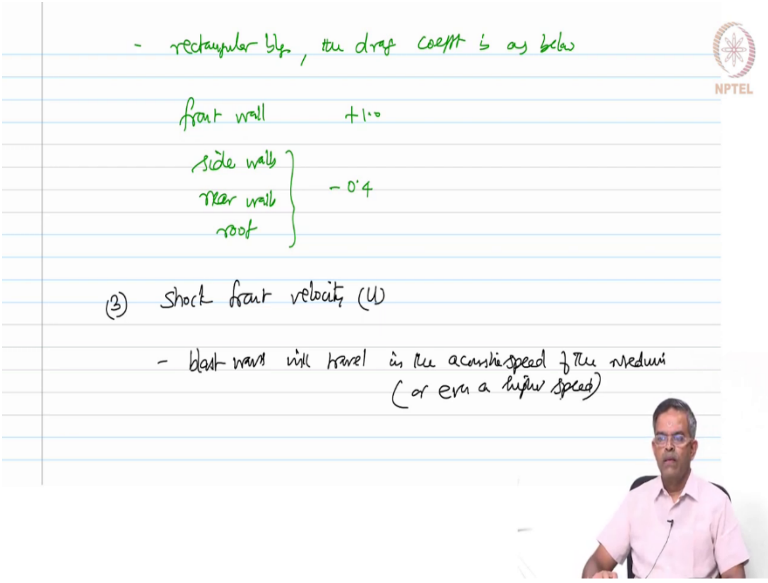

For example, in case of a rectangular building, the drag coefficient is given by for front walls it is plus 1.0 for sidewalls rear walls and roof it is given as minus 0.4. Let us talk about the 3rd parameter which is shock front velocity which is indicated as (u). In a free field the blast wave originated from an explosion travel either at the acoustics speed or above the acoustic speed in a propagating medium.

So, in general blast waves will travel the acoustic speed of the medium or sometimes even at a higher speed.

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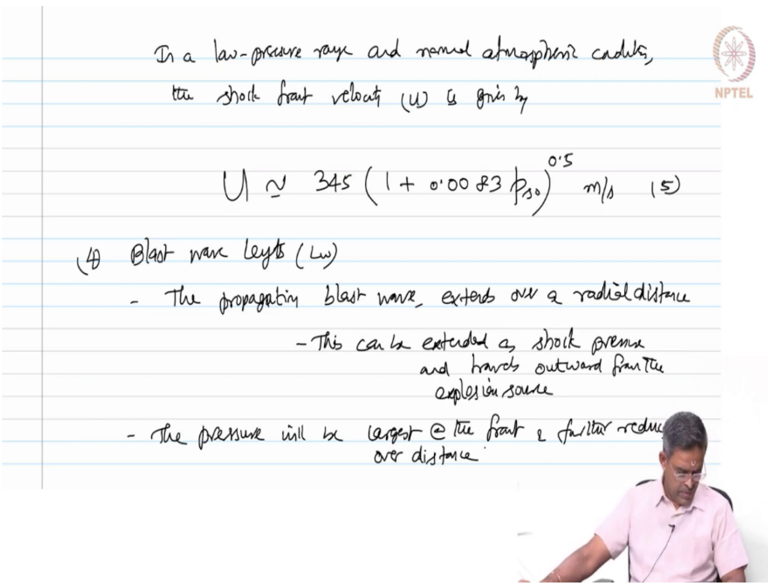

In a low-pressure range and for normal atmospheric conditions the shock front velocity u is given by

$$u \cong 345(1 + 0.0083pso)^{0.5} \frac{m}{s}$$

equation number 5. Let us talk about the 4th parameter which is blast wavelength given by L_w the propagating blast wave at any instant of time extends over a limited radial distance.

This can be extended as shock pressure waves and travels outward from the explosion source. The pressure is largest at the front and reduces over distance.

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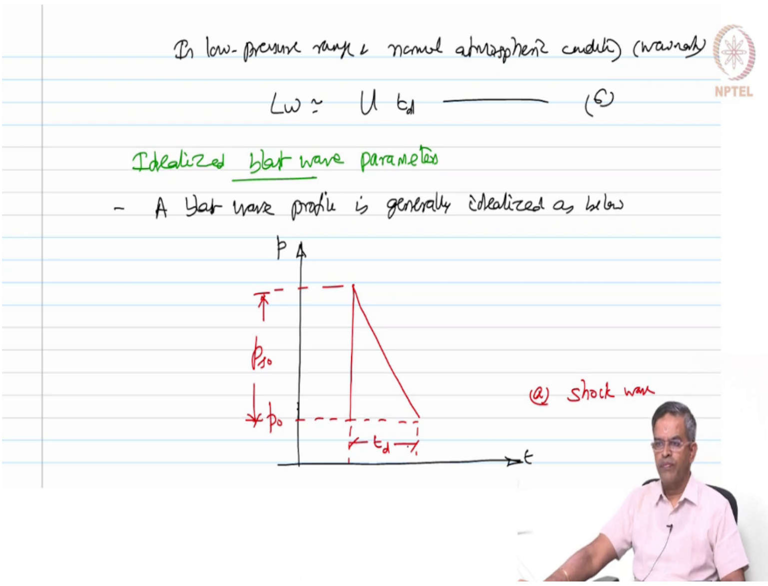

In low pressure range and normal atmospheric conditions as given by Newmark.

$$L_w = u\, t_d$$

Now let us talk about idealized blast wave parameters. A blast wave profile is generally idealized as below to simplify the blast resistant design procedure.

If this is my time axis and this indicates the pressure axis, then idealized shockwave where let me extend this line. This is shockwave. This value is called p_o then this distance is what we call as pso and this duration is t_d. So, an idealized shockwave for design purposes.

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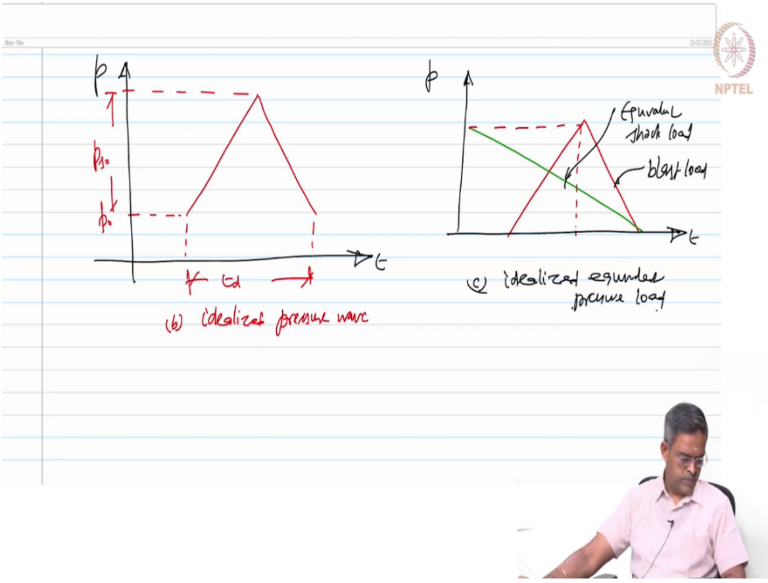

When you talk about the pressure wave time scale and pressure, so, again called as t_d this is p_o and this is called pso and this is idealized pressure wave. A pressure is also simplified using equivalent shock load. So, let us do that. We know idealized pressure wave and looking at this peak and considering this value an equivalent load is established and this is shifted at this junction.

This is the blast load the equivalent shock load. So, this is what we say as idealized equivalent pressure load. Now, let us talk about determination of vapor cloud design over pressures.

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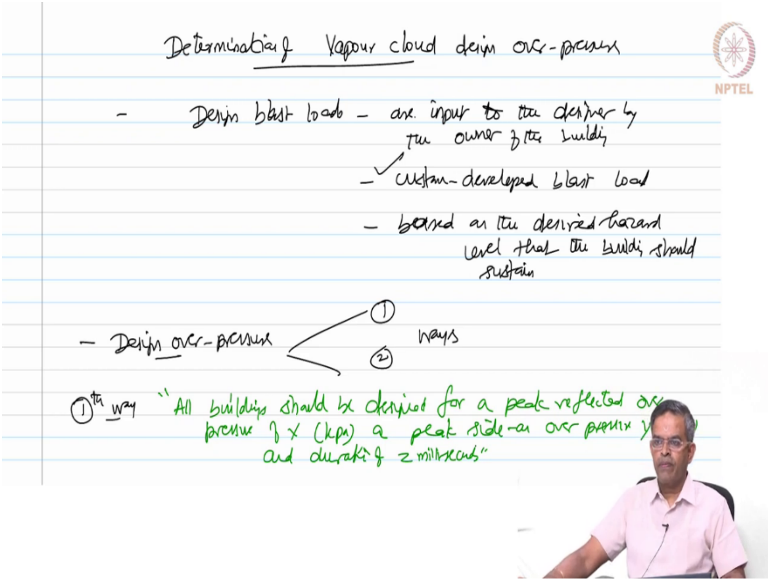

Design blast loads are usually supplied by the owner input to the designer by the owner of the building. It is custom designed or custom developed blast load. It is based on the desired hazard level that the building should sustain. These hazard levels depend upon the material and the process used for the purpose. So, let us talk about what is design over pressure.

The design over pressure can be stated in two ways. The simplest is all buildings should be designed for a peak reflected over pressure which is over pressure of x kilo pascal a peak side on over pressure y intensity in kilo pascal and for a duration of z milliseconds. It is a general statement is one way of prescribing the design over pressure.

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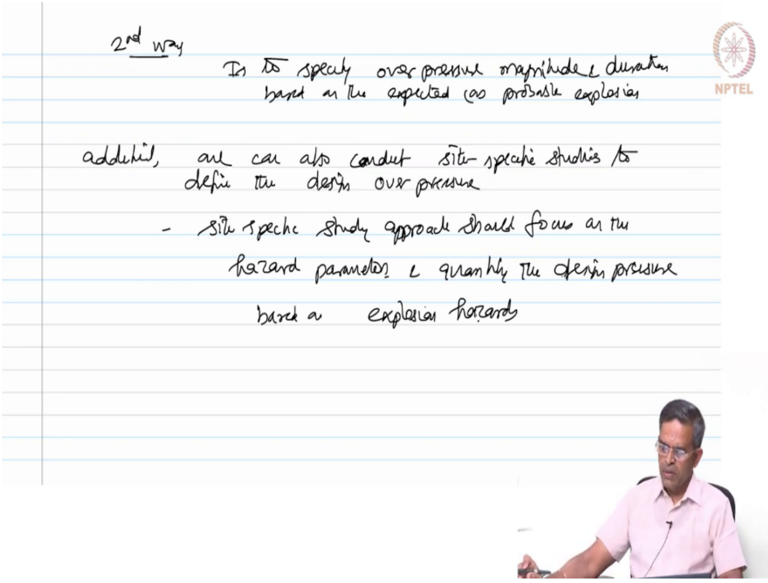

The 2nd way of prescribing design over pressure is to specify over pressure intensity and duration based on the expected or probable explosion that could occur in the structure from the potential source. Additionally, one can also conduct site specific studies to define the design over pressure then if you ask me a question what should be the basis for developing such site-specific studies, what should be the steps involved in developing such approach.

The site-specific study approach should focus on the hazard parameters and quantify the design pressure based on explosion hazards. There are various steps involved in this.

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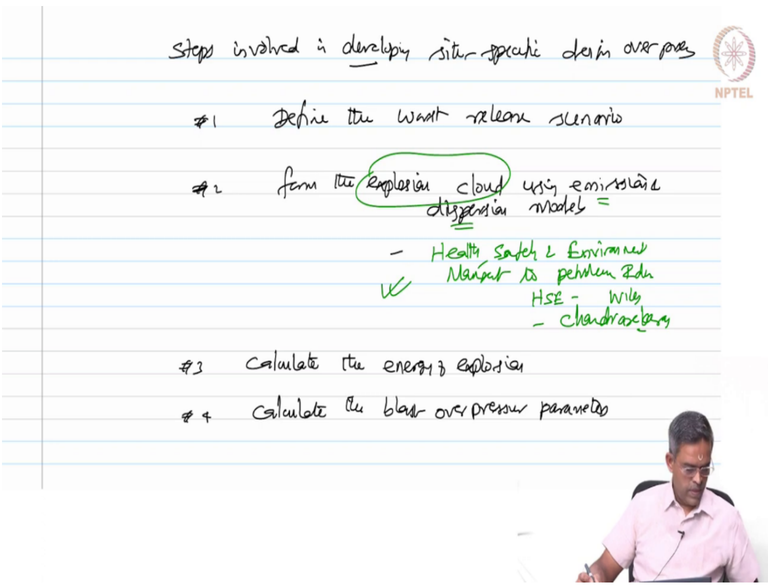

Let us see what are the steps involved in developing site specific design over pressure. Define the worst release scenario that is step number 1 based on that form the explosion cloud using emission models and dispersion models. Friends, there are different models available to define the explosion cloud. Please see the book written by me on Health Safety and Environmental Management to Petroleum Industries.

So, HSE book by Wiley and authored by me. You can have more details about the book in a home page. This will give you more information about various emission and its dispersion models that can be helpful to define the explosion cloud. In step number 3 calculate the amount of energy contributing to explosion. In step number 4 calculate the blast overpressure parameters.

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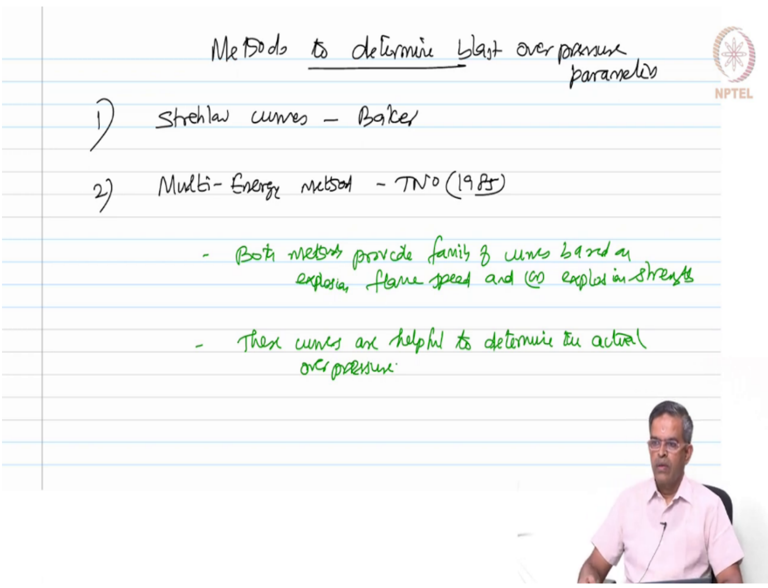

Having said this, let us talk about the methods to find the blast over pressure parameters. There are two methods. One is the Strehlow curves suggested by Baker. The second one is multi-energy method based on TNO 1985. Both methods provide family of curves based on the explosion strength, the flame speed and r explosion strength. These curves are used to select the dimensionless parameters which are then unscaled to determine the actual over pressure.

So, these curves are helpful to determine the actual over pressure.

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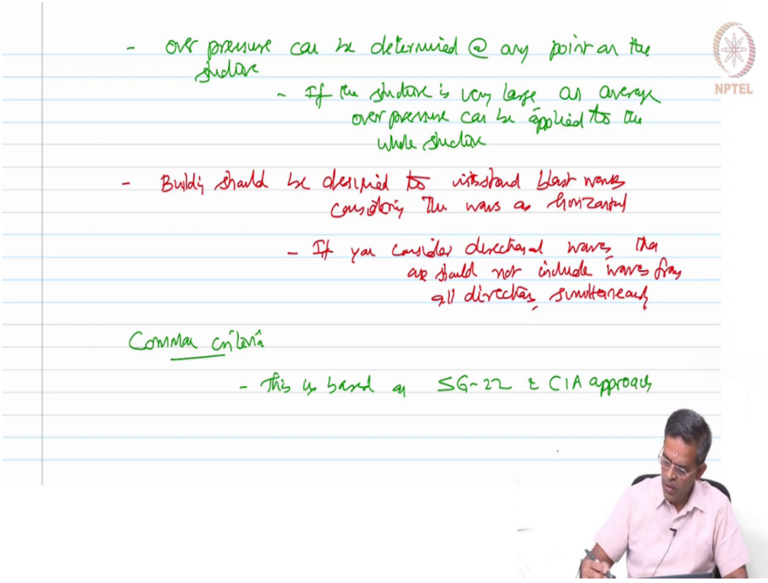

Over pressure can be determined at any point on the structure on the structure based on its distance from the source and then can be applied to the entire structure. The structure is very large an average over pressure can be applied to the surface. Normally a building should be designed considering the potential blast waves from any horizontal direction but not all directions simultaneously. Please understand that. Building should be designed to withstand blast waves considering the waves as horizontal.

If you consider directional waves then one should not include waves from all directions simultaneously that is the point, one at a time. There is something called a common criterion which is helpful to determine this over pressure. Commonly used criteria are actually based on SG-22 and CIA approach. I will give you this reference for the benefit of the learners.

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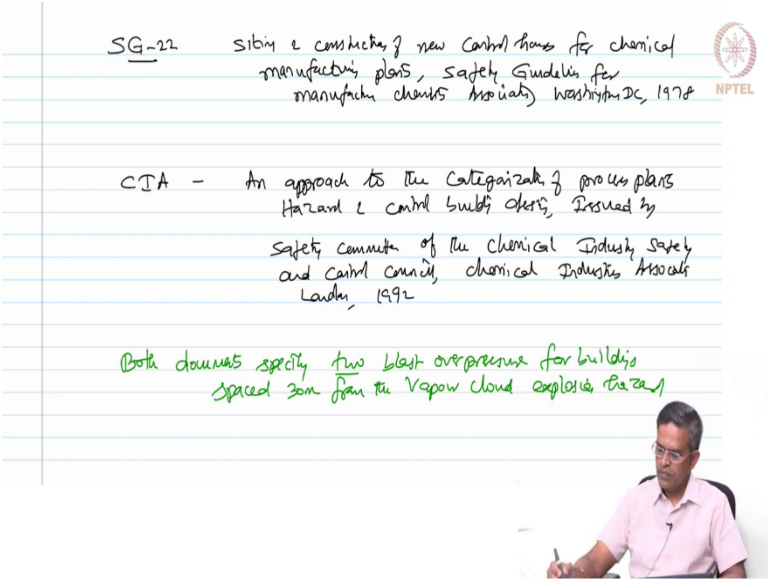

SG-22 is siting and construction of new control houses for chemical manufacturing plants, Safety guideline Manufacturing Chemists Association Washington DC 1978. The second could be CIA approach which is an approach to the categorization of process plants hazard and control building design published by Safety Committee of the Chemical Industry Safety and Control Council, Chemical Industries Association London, 1992.

Both documents specify at least two blast over pressures for the buildings spaced at 30 meters from the vapour cloud.

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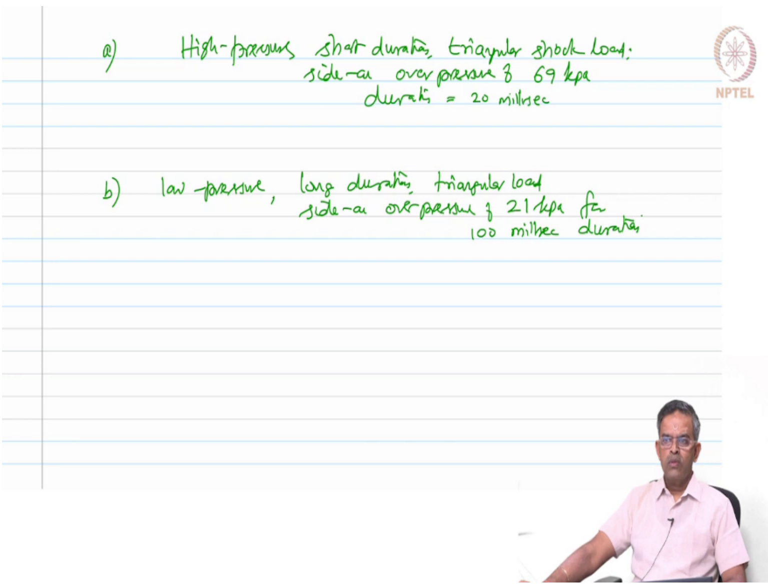
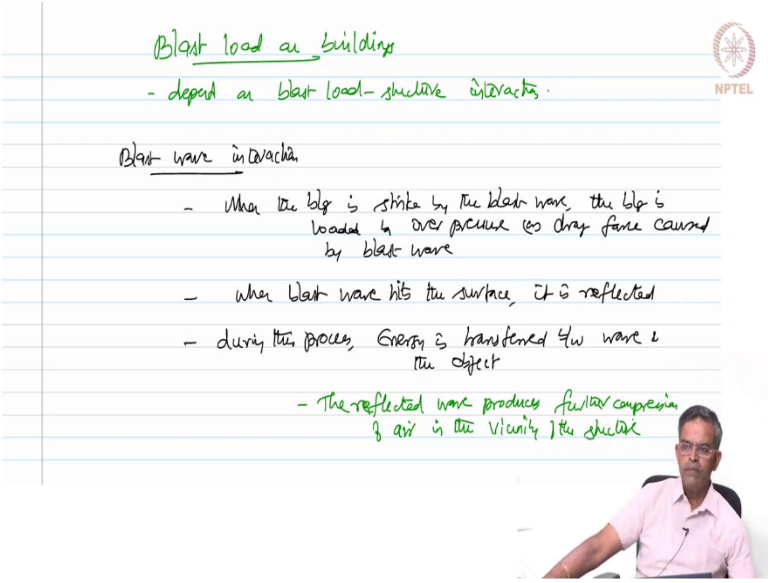


It says that high pressure, short duration, triangular shock loading side on over pressure of 69 kilo pascal and duration 20 milliseconds. As far as low pressure is concerned it says a low pressure, wave of long duration, triangular loading side on over pressure of 21 kilo pascal for 100 milliseconds duration. (Refer Slide Time: 35:04)



Let us now talk about blast loads on buildings. To design the blast resistant building loads on the building as a whole or on individual elements should determine. So, therefore, we need to understand the blast wave interaction to obtain these loads. So, blast load on buildings depends on blast load structure interaction. Now let us talk about blast wave interaction. When a blast wave strikes the building, the building is loaded by over pressure or drag forces by the blast load.

So, let us say when the building is strike by the blast wave the building is loaded by over pressure or drag forces caused by the blast wave. The interaction between the wave and the structure is quite complex. When the blast wave encounters a solid surface, it starts reflecting from the surface and as we discussed this reflecting wave depends on the geometry of the structure, shape and size and the diffraction surface and it diffracts around the building.

Further so, when blast wave hits the surface, it is reflected. During the process of reflection energy is transferred between the wave and the object. The incident blast wave is reflected from the building and it starts producing further compression of air in the vicinity of the structure on the structure. On a molecular level the surface applies an external force to each air molecule which is sufficient to give it equal momentum in the opposite direction. Therefore, there applies the same external force to the surface.

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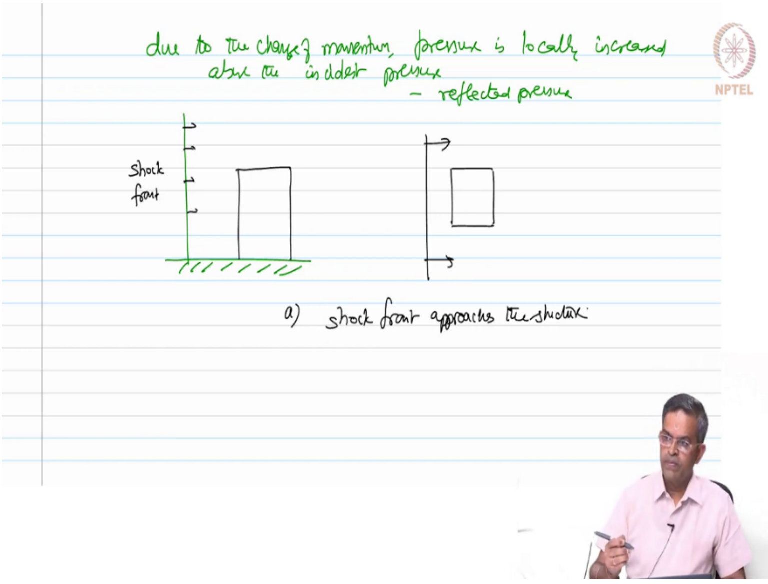

Due to the change of momentum, pressure is locally increased above the incident pressure. This is termed as reflected pressure. Diagrammatically let us say if this is my shock front which is approaching the structure, it passes around the structure. So, the shock front approaches the structure that is the first step we have. So, what happens is after it approaches let us copy this figure, put it here.

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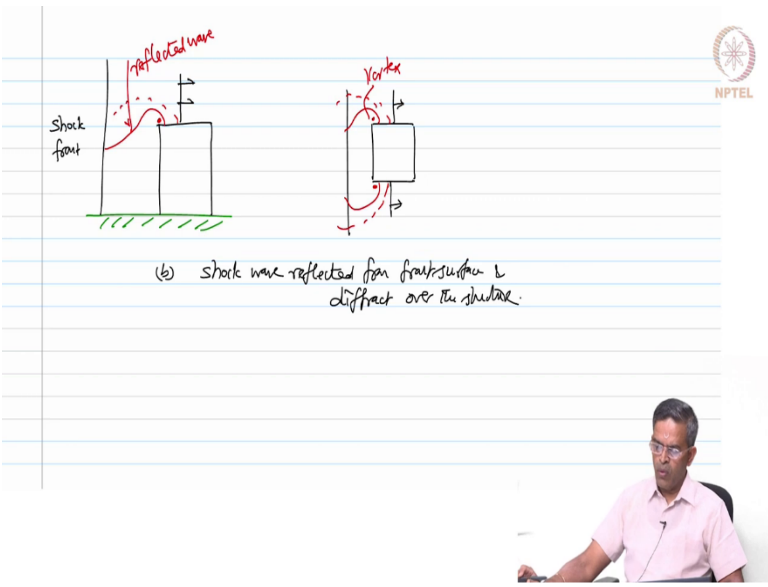

After it approaches it moves ahead, but it reflects, its reflected wave. Similarly, around the building it moves ahead, but I will remove this because this is moved. So, I will remove this there is only a wall the source this arrow is removed. It reflects and it creates a vertex. So, this picture depicts shockwave reflected from the front surface and diffract over the structure.

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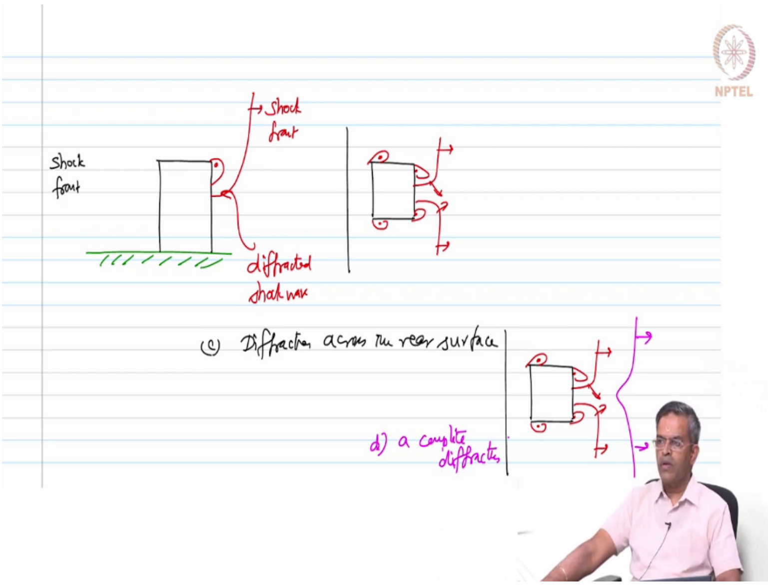

As the wave progresses further let us copy this figure. As the wave progresses further remove this it creates vertex and the shock wave becomes here. We call this as diffracted shock wave. Similarly in this case vertex will be created. So, this figure indicates diffraction across the rear surface.

Now once the shockwave moves further when the diffraction is complete, I will just copy this figure and put it here. The diffraction is complete. I should say this figure indicates a complete diffraction. So, the whole set of figures a, b, c, d indicate shockwave propagating over the structure. So, this is available at TNO Green Book.

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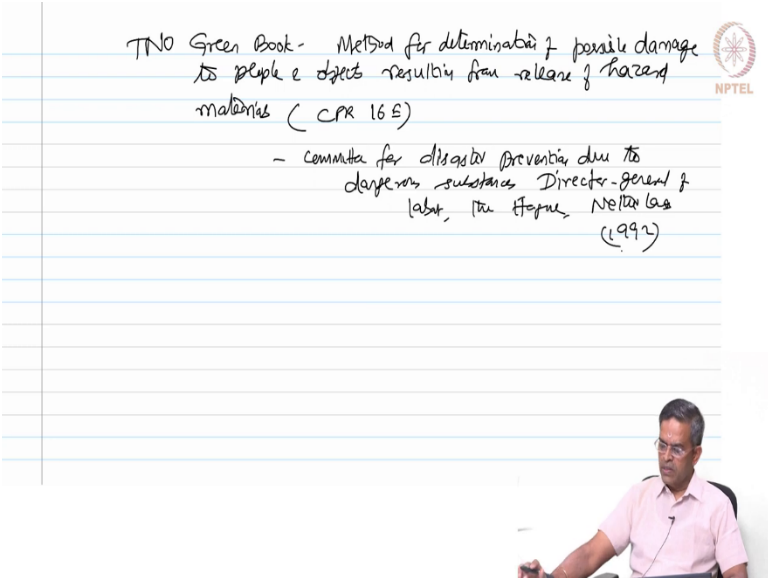

So, you can see for additional reading. Please see TNO Green Book which talks about method for determination of possible damage to people and objects resulting from release of hazard materials which is CPR 16 E, committee for disaster prevention due to dangerous substances, the Director General of Labor, the Hague Netherlands published in the year 1992. Now, for design purposes we idealize this blast waves.

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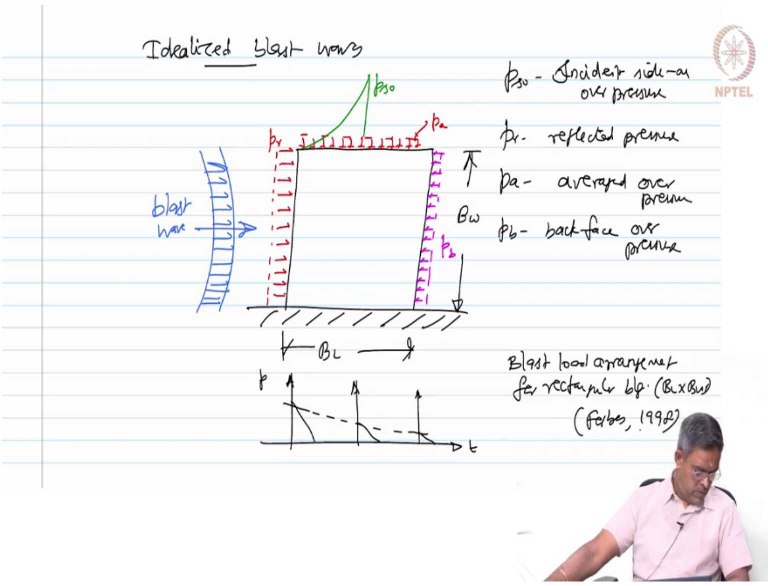

We are now talking about idealized blast waves. So, if you have a building, this is the elevation. The building is subjected to some blast wave. Now, the blast wave will have three components. One will be in the fore side, other will be on the rear side and one will be in the top. In addition, this follows pso distribution.

So, this is what I call as p_r, this is p_b and this is pso where pso is the incident side on over pressure, p_r is the reflected pressure, p_a is the average over pressure which is indicated here and p_b is the back face over pressure. So, the building is receiving pressure from all the sides.

So, these can be also marked as B_w and B_L where B_w and B_L are physical dimensions of the building in the direction of propagation of the wave. So, one can see as time progresses, the pressure intensity keeps on decreasing. With respect to time the peak over pressure intensity keeps on decreasing. This is blast loading arrangement for rectangular building of size B_L by B_w given by Forbes in 1998.

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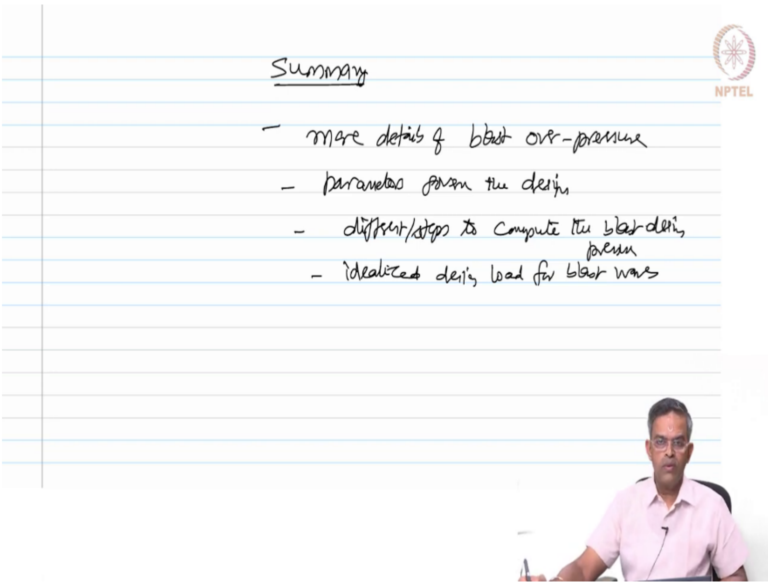

So, friends, in this lecture we learned more details of blast over pressure. Parameters used that govern the design and different ways or different steps to compute the blast design pressure. We have also learnt the idealized design load for blast waves. We will see more details in the next lecture and work out couple of examples to estimate the blast load on buildings using these calculated values.

Thank you very much and have a good day, bye.