Advanced Design of Steel Structures
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Lecture - 59
Blast - resistant design - 2

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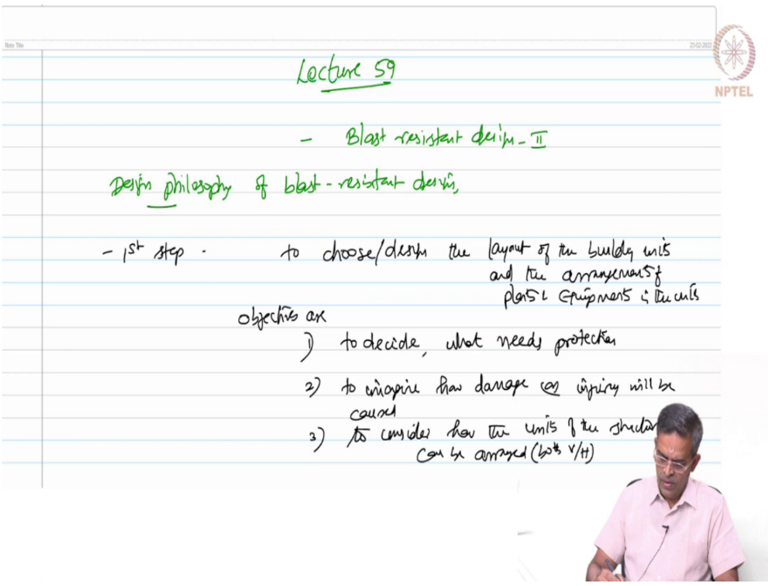

Friends, welcome to the 59th lecture on Advanced Steel Design course. In this lecture, we are going to learn about Blast Resistant Design, let us say 2 because in the earlier lecture we discussed about Blast Loads.

So, when you talk about the design philosophy of blast resistant design, the starting point for the design of a structure of blast test and design is to consider the layout and arrangements. So, the first step is to choose or to design the layout of the building units and the arrangements of plants and equipment's in the unit. That is a first step.

So, there is a specific objective which you have to keep in mind when you choose the layout of the building which you want to design for blast resistance. The objectives are, one need to design what needs protection. One need also imagine how damage or injury will be caused. One need to also consider how the structure can be arranged or I should say how the units of the structure can be arranged both vertically and horizontally to get the best blast resistant protection.

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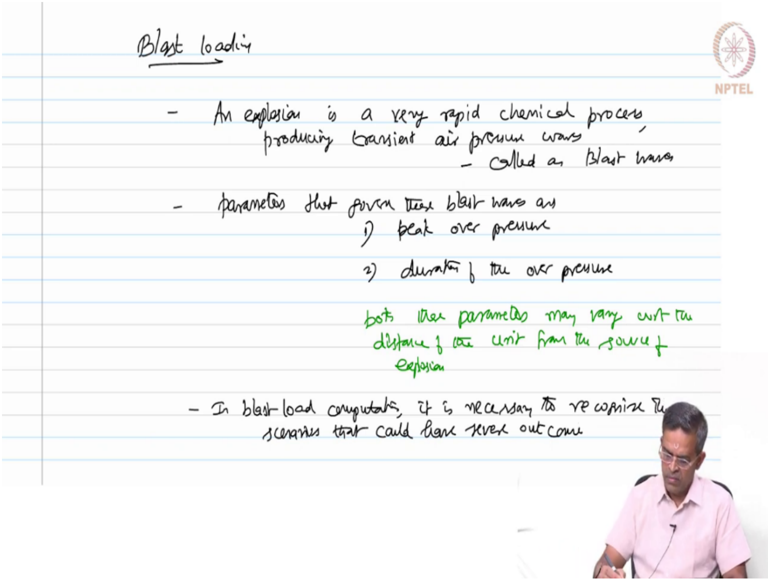

Having said this, when we talk about blast loading, let us define what is a blast load. Blast loading actually is caused by an explosion. An explosion is a very rapid chemical process producing transient air pressure waves. These transient air pressure waves are called as blast waves.

Now, these blast waves are governed by various parameters, parameters that govern these blast waves are, one, peak over pressure; two, duration of the over pressure. Now, both these parameters may vary with respect to the distance of the unit from the source of explosion. Therefore, in blast load computation, it is important to recognize the scenarios that could have severe outcome and take into account of these in the design. Therefore, friends, the blast pressure waves will also be reflected and refracted by the buildings.

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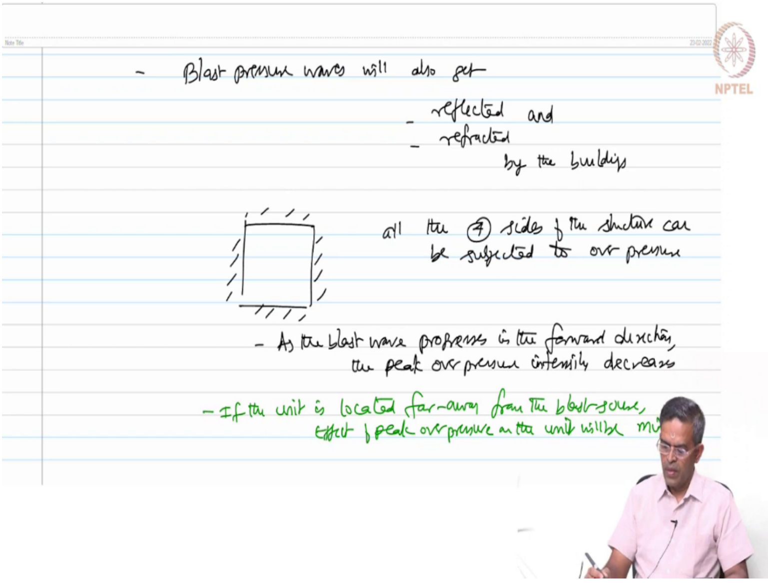

Blast waves are very intrusive and all sides of the structure can be subjected to over pressure. So, if we have a structure, all the 4 sides can be subjected to over pressure. The peak over pressure decreases as the wave moves further. So, as the blast wave progresses in the forward direction, the peak over pressure decreases. Therefore, in simple terms, if the unit is located far away from the blast source effect of peak over pressure on the unit will be minimum.

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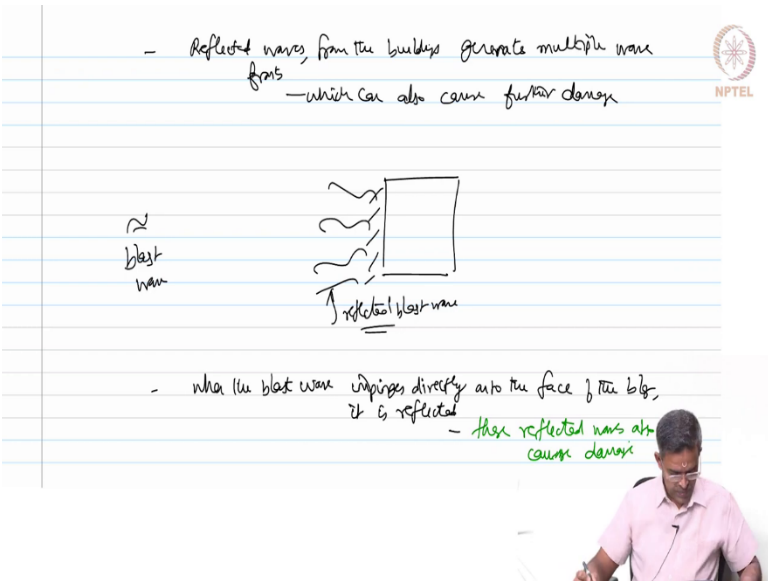

Further, reflection or let us say reflected waves, from the building generates multiple wave fronts which can also cause further damage. So, let us say I have a building, there is a blast wave source, so the fore is affected and there is a reflected wave. Even these waves can also severe effect on the structures.

Further, when the blast wave impinges directly onto the face of the building it is reflected from it. And these reflected waves will also have consequences and they can also cause damage.

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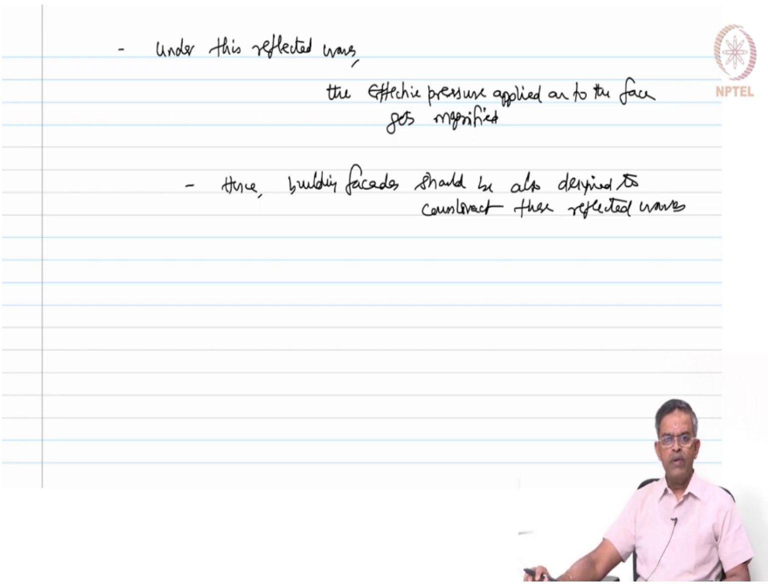

The effective pressure applied on to the face of the building is magnified when this occurs. Under this reflected wave, the effective pressure applied on to the surface gets magnified. If the facade is to survive without breaching, it must be designed to resist this pressure. So, therefore, building facades should be also designed to counteract these reflected waves.

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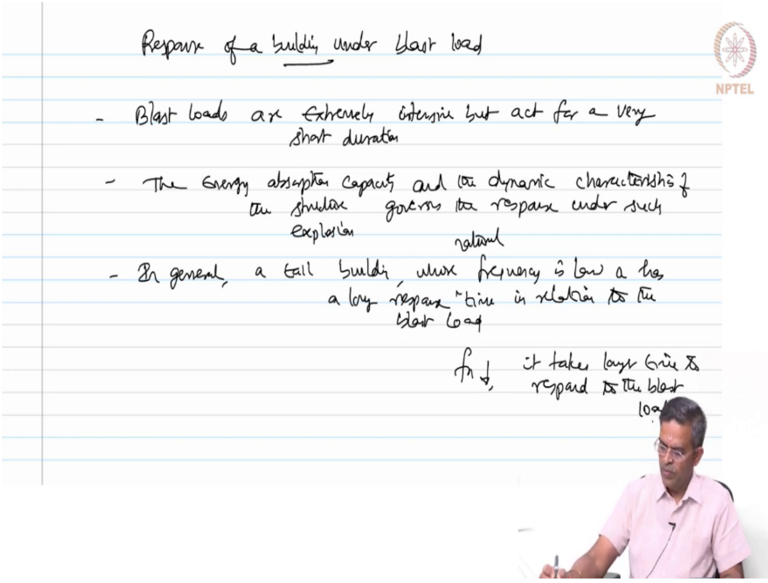

Let us quickly see qualitatively how the estimate the response of a building to a blast load. So, blast loads are extremely intense, but acts for a very short duration. The energy absorption capacity and the dynamic characteristics of the structure governs the response of the structure under such explosions.

In general, a tall building, whose frequency or let us say natural frequency is low and has a long response time in relation to the load. So, if the frequency is low as in the case of tall buildings, it takes longer time to respond to the blast load.

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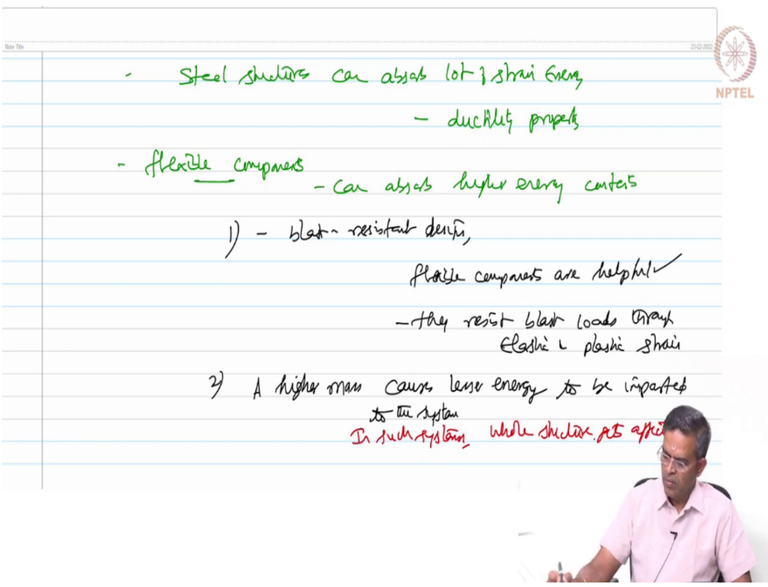

Especially, steel structures can absorb lot of strain energy. This is because of its ductility property. Further, flexible components can absorb higher energy contents. So, friends, in blast resistant design, flexible components are helpful because they resist blast loads through elastic and plastic strain. Further, this is the first point we have. The second point, a higher mass causes less energy to be imparted to the system.

In case of larger explosions, the structure as a whole becomes affected by the blast waves. So, in such systems, the whole structure gets affected by the blast waves. In blast resistant design, we have a concept called protected space. Let us see what is that.

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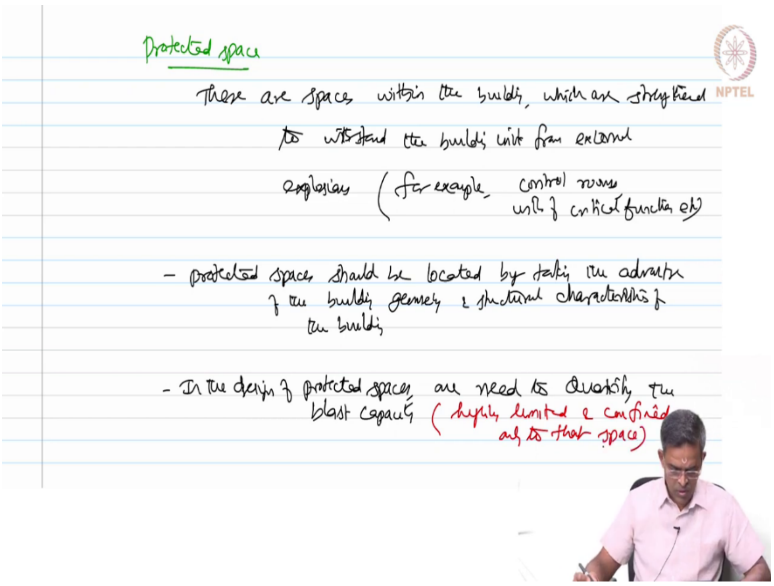

What do we understand by protected space? Protected spaces or areas within the structure which are hardened to protect the occupants and equipment's against the effect of external explosion. So, these are spaces within the building which are strengthened to withstand the building unit from external explosions. For example, protected spaces could be control rooms, units of critical functioning, etcetera.

Protected spaces should be located utilize the benefit offended by the offer with geometry. So, protected spaces should be located by taking care or taking the advantage of the building geometry and structural characteristics of the building. Having said this, in the design of protected spaces, one need to quantify the blast capacity. But please note, the blast capacity of protected spaces is highly limited and confined only to that space, not for the entire building. That is important to remember.

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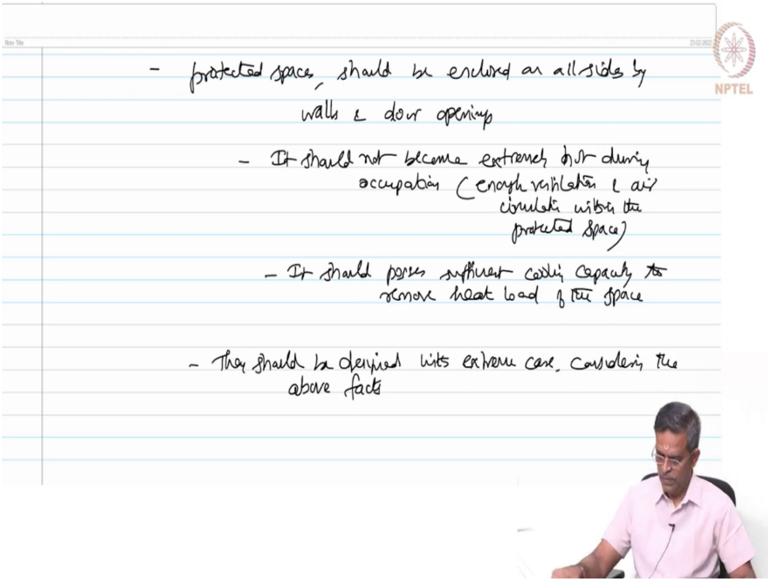

So, protected spaces therefore, should be enclosed on all sides by walls and door openings. It should not become extensively hot during occupation. So, there should be enough ventilation and air circulation within the space.

It should possess sufficient cooling capacity to remove the heat loads of the space. So, one should be able to maintain both the temperature and the humidity conditions of this protected space. So, protected spaces should be designed by the extreme care considering the whole facts. Having said this, let us see what are the principal parameters which will govern the blast resistant design.

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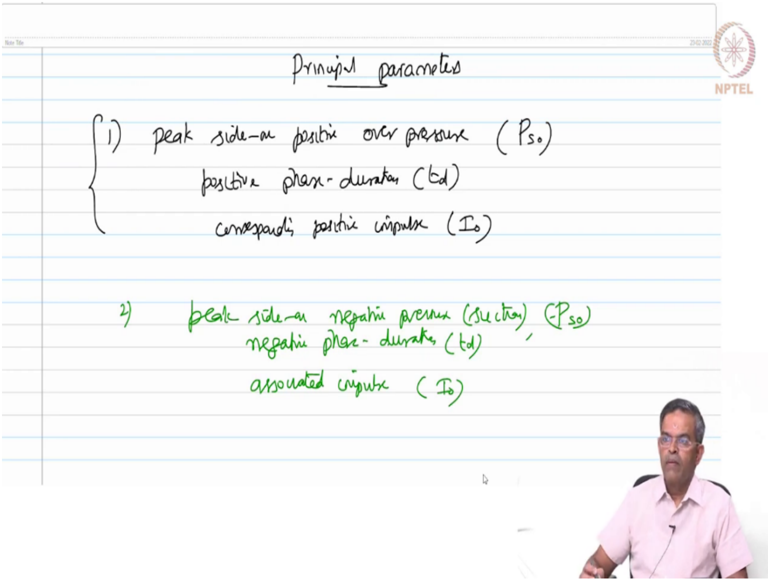

The principal parameters to be defined for blast resistant design are as follows. One is peak side-on positive over pressure, indicated as P_{so}. So, the second is positive phase-duration indicated as t_d and the corresponding positive impulse indicated as I_o. This is one set of data.

The second set of data is peak side-on negative pressure, which is suction pressure which is called as again P_{so} with a negative sign. Negative phase duration is also the t_d and the associated impulse which is also I_o. In addition, other parameters also important.

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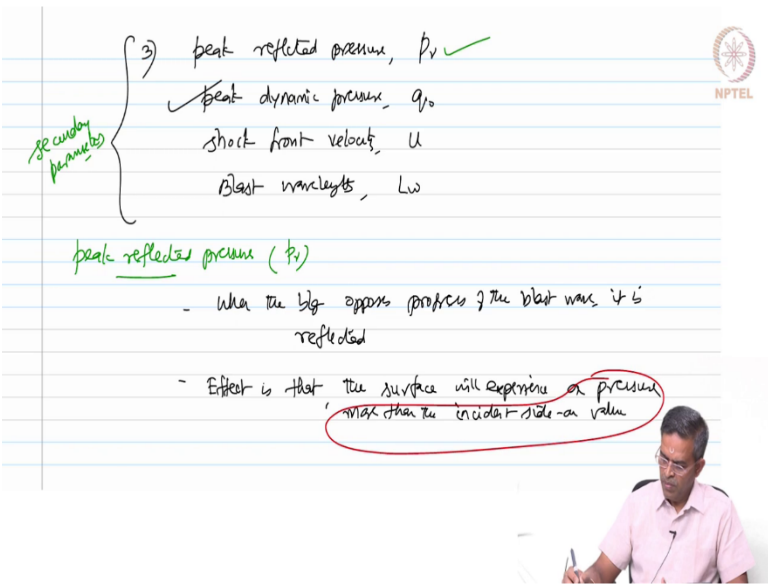

The third set of parameters is peak reflected pressure called as p_r, then peak dynamic pressure called as q_o, shock front velocity which is u, and blast wave length which is L_w. The secondary parameters can be always derived from the primary blast wave parameter. So, these are called as secondary parameters.

Let us talk about peak reflected pressure, indicated as p_r. When the blast wave hits the surface, it is reflected back because the building is causing obstruction for progress of the blast wave. So, when the building opposes progress of the blast wave, it is reflected.

The effect of this reflection is that the surface will experience a pressure more than the incident side-on value. So, the pressure will now increase. The pressure intensity will be more.

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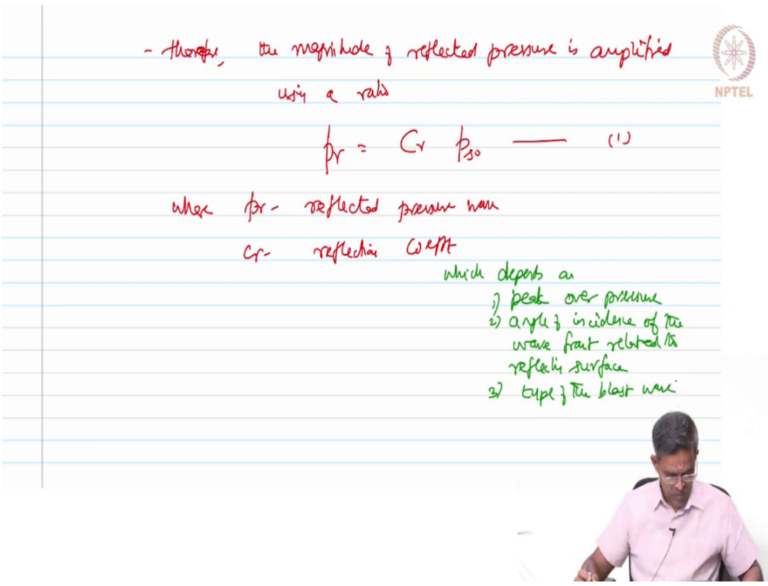

So, therefore, the magnitude of reflected pressure is amplified using a ratio. So, we should say the reflected pressure is given by reflection coefficient of p_{so}. Let us say equation 2.

$$p_r = C_r p_{so}$$

Let us say equation 1, no problem, equation 1. Where, p_r is reflected pressure wave, C_r is the reflection coefficient.

Which depends on, which depends on the peak over pressure and angle of incidence of the wave front related to the reflecting surface. It also depends on the type of the blast wave.

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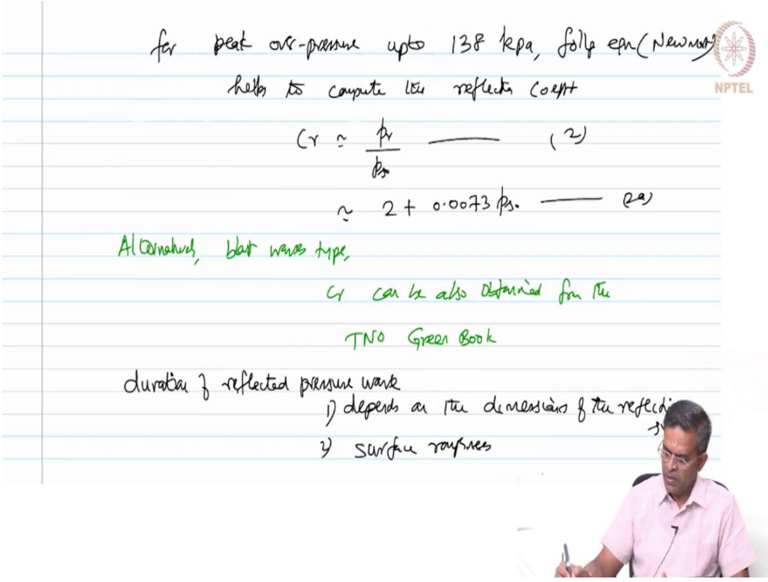

$$C_r \cong \frac{p_r}{p_{so}}$$

Having said this, let us say for peak over pressure up to 138 kilopascal following equation provided by Newmark helps to compute the reflection coefficient. So, C_r is given by p_r by p so, is approximately equal to, you can see from this equation, will call say equation number 2, which is equation 2 (a).

$$C_r \cong 2 + 0.0073 p_{so}$$

Alternatively, for different type of blast waves C_r can be also obtained from the TNO Green Book. The duration of the reflected pressure depends on, the dimensions of the reflecting surface, surface roughness, up to a maximum time approximately equal to the positive phase duration of the wave.

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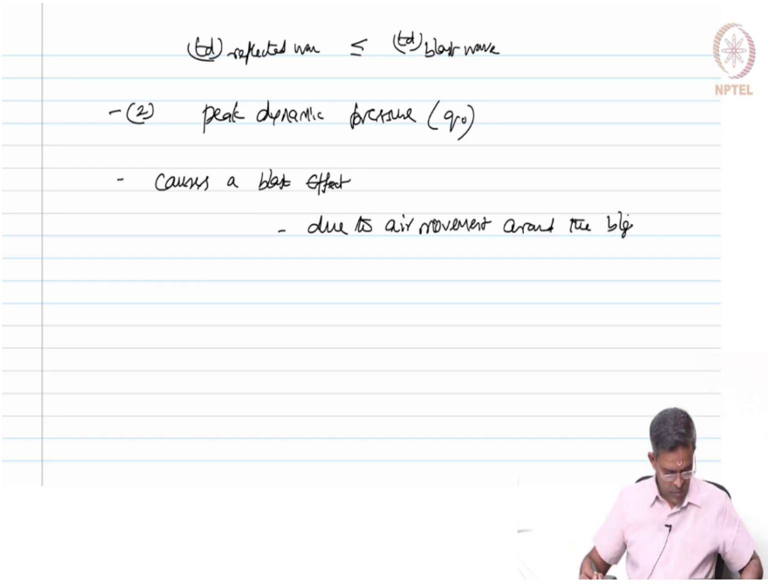

So, therefore, we can say time duration of the reflected wave is less than equal to time duration of the blast wave, and depends on the O parameters. Upper limit of this corresponds to total reflection of the entire blast wave without any diffraction.

Let us talk about the next parameter which is peak dynamic pressure, talk about this parameter peak dynamic pressure which is given as q_o. The peak dynamic pressure causes a blast effect, and it is caused due to the air movement around the building.

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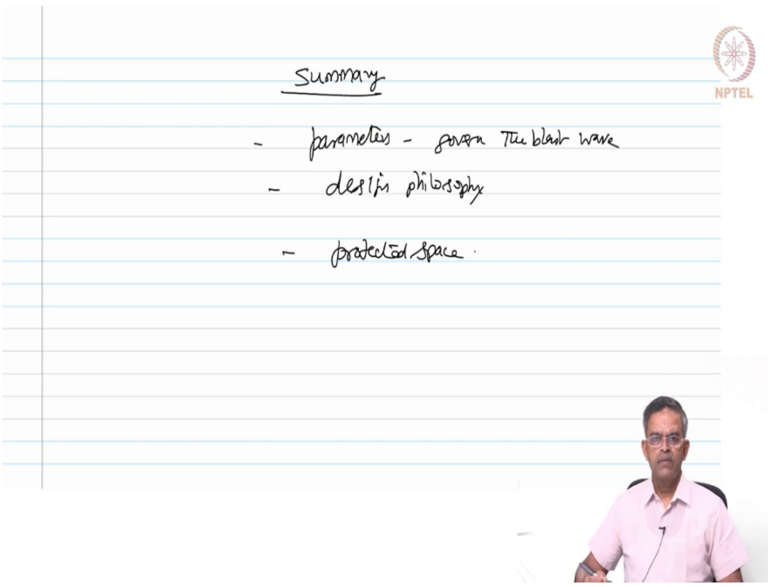

Friends, in this lecture, we learned about various parameters that govern the blast wave characteristics. We also learned about the design philosophy of blast resistant design and how the flexible units are better. We have also learnt something called protected space, and where and how a protected space should be used in a blast resistant design structure.

We will see further details in the next lecture about the Blast Resistant Design.

Thank you very much. And have a good day.