Structure, Form, and Architecture: The Synergy
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Lecture - 04
Loads on Structures

Hello everyone. Welcome back to online NPTEL course on Structure Form and Architecture: the Synergy. Today we will cover lecture number 4; that is Loads on Structure, which is very important topic in this course and we will try to understand in a very simplistic manner.

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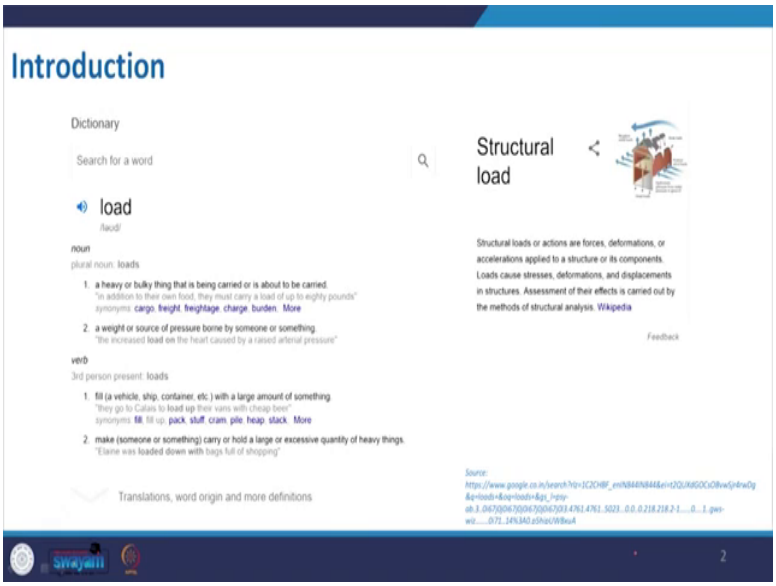

Now, if you see the definition of load, again I am just you know taken the snapshot from the Google search, the first time we search about the load. So, it says about some definition; so,

here the pertinent definition which can be helpful in the context of our course that is the structural load.

So, what is load? So, if you see here a weight or source of pressure borne by someone or something ok; make it very specific to the structural load. But it says structural loads or action other forces deformations or accelerations applied to a structure which will make a result in you know say stresses, then deformation, displacement of object etcetera. So, that is overall idea about the load what we see. But this particular lecture we will talk about the load applied on a structures in reference to building specially.

And sometimes also we will discuss not only the buildings some of other structure element other architectural components. So, let move on.

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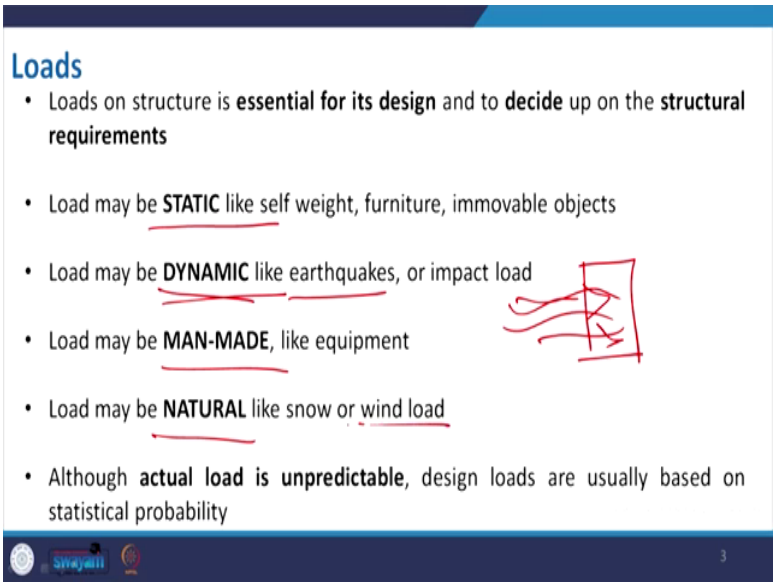

So, in this particular slide we will again you know make it lit bit clear about the loads. Loads on structure is essential for its design. Why all of a sudden we should move about different kind of loads and their property and how they act to a structure, because it will help us to design the structural element. The structural design requires all this calculation of different kind of loads that may act on a building.

The load may be static. Static means, it will not change over time. The other one may be dynamic. So, static weight like static load it include the self weight of the structure suppose our building is made with the concrete, brick steel so it will stand like this. So, that is static. Then the furniture or sometimes like that which will not really change its you know load on structure over time.

The other one is the dynamic which subject to change with respect to time. Say for example the earthquake, we all know the earthquake it is certain jerk which will be random in nature and it will have different frequency. The moment it start and then slow down, and then there will be some you know after shock. So, we will discuss that in upcoming slides. So, this is dynamic in nature

Again if you discuss if you say the example of wind; so, we know that it will not have a constant wind load that is acting on a building that is you know imposing on a building. So, it will have different velocity over time and so, as to with the rain based on his intensity.

And all again load can be classified under the manmade load. Suppose we make equipments like you know in our classroom or so we have benches, then we have other furnitures as well which will put load on the structure. And it may be natural. Natural means, as already mentioned it may be of some disaster or like earthquake or the flood situation or it may be wind load or snow load.

But, one thing we should understand like something like earthquake, flood these are not very much you know here that each day it is occurring; so, it a random event which any occur anytime. So, what we normally do, we cannot actually calculate the load in that precision or

actual load is unpredictable, but what we do is based on the probability that it may occur. So, designing a building, when we design the structure of the building we should take account all possible load that may affect the building design that may deform the building.

So, in order to make your building resistant to all applied load on it anything, starting from the self load to the additional, you know your furniture load, or may be some natural load wind, rain or may be earthquake, flood. So, we should calculate that. So, in such calculation there are different you know handbooks from which different you know input parameter will be taken in to consideration.

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Now, before we really discuss each of that load in detail to get better idea. Let us focus on this image. This is work by student a group of student. So, basically this is a cartoon type image but it says a lot, where it shows different kind of load. So, starting from the sun; so, we

all know that it produce heat. And that definitely cause different you know change in the property like, depending on the material.

So, it will have you know impact by the thermal heat and with heat it may expand, or sometimes in you know winter season it may you know squeeze down. That is creating some thermal load. And, it is also very important that is why you know in the building when a building is you know too lengthy or something sometimes we have to, like we need to give the expansion gap to allow that expansion.

Even that is so true; even our school days we studied that why there is you know some expansion joint given in the railway track. So, this is railway track made up of metal and when we know train just cross then it generate some of you know heat. So, it may expand. So, for that we provide this gap. So, that it can not really bent or there will be some damage in the line.

Now move on to the other one. Not pertinent to the you know in the urban area or may be the area where there is no such snow fall or something, but in some part of the world or even in India some area where we have to take care of this. Because that is additional one, but again it is not very you know permanent ok. Permanent means any particular season will get this additional load, it will accumulate on the roof, and it creates additional load to that; so, as too with the rain. If there is no proper drainage or may be the slope is too narrow or almost flat and there is some problem, so water will accumulate. And that will create some additional load to it and sometimes it may be very much dangerous to a building. I will show you some photographs on that account too.

Now come to the wind. We know that is a lateral force you know acting on a building on a surface. And then we just get two important load: one is your dead load and another is live load. So, if you get the clue from the word dead, means already it is not moveable immovable. And what is live load which is moveable which will change.

Say for example: the you know in this particular room where I stand like the beam columns that were constructed at the beginning and it remains stand. So, it will not move tomorrow.

So, this is basically dead load. So, all building like components like this your beam, or column, walls, roof, different materials, structural material, you know parts they are adding to the dead load of the building.

Now, what is live load which is movable? Say for example myself, like now I am standing in a position in the room so I add load to it, but the moment I just go out from the room so that load will be released. So, I am live load. So, as true with the furnitures because they are moveable, today I like this particular furniture in that manner, but tomorrow I will change it either shift it; so as too with the machinery. So, these are some live load.

And here, you can see that person here, here, or may be the furnitures they are basically live load. And dead loads are these beam columns. Apart from that, due to earthquake there will be some you know wave, there will be some motion on the you know underground and for that the building got affected with this oscillation. So, that is due to the seismic activity or the earthquake. So, that is also referred to earthquake load.

And not only for earthquakes sometimes even if your building is situated in some area where the water table, like round water table is high ground water table is the level of the ground water like we can easily get it. So, nearly like this is the plain near the river or something, where we normally observe the ground water table is high. So, this underground water that may also affect; so, that is your sometimes call is you know hydraulic pressure from below the structure.

Now, before we go further let us just say: we in structure we normally say that one is your foundation and underground structure and then which is above that is basically the super structure. So, many a time I will use this super structure, so I just give it. Apart from that also here its known if you see it clearly there is something dotted some deformation.

So, this is a initial foundation level and here it just went down, because of unequal settlement of the land and sometimes. It may happen due to the compactness of the soil, compactness of

the that particular area. So, it may have unequal settlement. And for that it will also create some load to the building and sometimes it may also you know collapse the building.

Then here if you see that person is drilling something and here is that particular drummer doing something. So, it create something you know some vibration. So, it is also vibration load. And when it actually propagate ok, so that will create resonance. Now suppose with this particular frequency if all structures are acting like that, so it will further propagate and create a resonance.

And sometime it may you know affect the building. So, that is why sometimes we have to look into that you know point and design our structure accordingly. Now, what is late? here in this picture, so you can see a car just this car hit that particular portion of the building and it is all of a sudden load. So, this is refer to a impact load. And it is I can give you another example and I also will show the photograph.

Suppose all of a sudden we start hammering the wall or we just try to nail the wall, so that time it is impact load; all of a sudden load given to that. So, this is overall what we are going to learn from this particular lecture. So, I just give gave the brief about all this through this picture. So, let is move on. Now types of load: there are different way of classifying loads.

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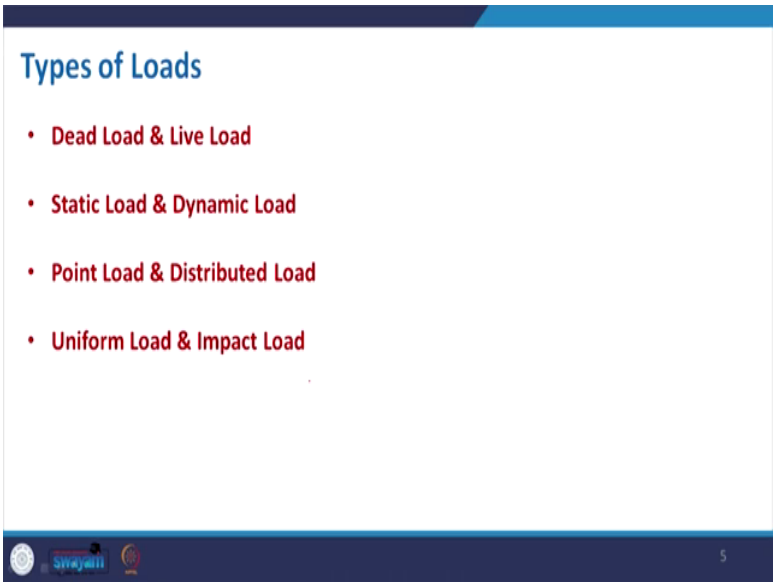

So, these are very common classification. So, one is dead load and live load. Already I mentioned about it and we will also get it more clear with the example. Then it may be static load, it may be dynamic load. It may be point load, it may be distributed load. It may be uniform load, and it also impact load. So, what exactly these are? Let us clear that.

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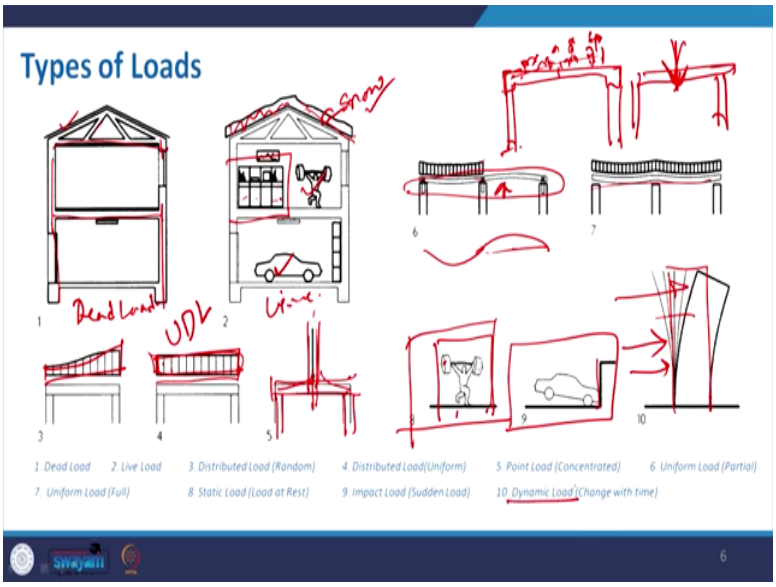

So, here these are tentative diagrams and which I have taken from a book Structure in Architecture. So, here like picture 1 to 10, they are depicting different kind of loads that in the previous slide we had. In this case, if you see that this is showing all these structure component: the column wall, beam, roof, truss, etcetera, so they are actually immovable. They will be same over the time, when it was constructed and now it will be almost same. So, that is why it is called dead load. So, this one is your dead load ok. Is it clear?

Now, move to the other one. It is the same type of building, but in this if you see that the building outline is very faint. And there are some object like, a person is lifting weight, then there is image there is a cupboard, then car is parked, rack, and something here basically it referred to the snow. So, these are actually movable. Suppose with increase in temperature

this will be melted and then it will go back to the original shape. So, this is again a moveable one. So, it can come under live load the car. Again it is not permanent.

So, when you go out with your car that place will be free of that load of the car. So, again it is live load. Then the person move out from the room, I have already I mentioned with my example, so this is another one and, here also the furniture because this is movable. You can increase the load, you can move this furniture to the other room. So, these are live load. Now, if you see that picture number 3. So, what exactly it is? It is distributed load.

Distributed load means, when you apply a load to a structure; say for example this is your beam and column someone is standing here; so basically in order. So, at the corner you will have a less load than these particular corners. So, it will form something like this. It is distributed, but random not uniform. But there are cases where it will be done with uniform. So, also we call it in technical term UDL uniformly distributed load. So, UDL uniformly distributed load, so picture four is all about where the load is distributed uniformly.

Now, in contest to that sometimes it may be a point load. Point load is something like you have this surface ok, and some where you just put some load ok. So, that is basically point load. So, here if you see that these two columns they are carrying a load of the beam, and there may be another wall or something, which is a point load to that. Though it will be distributed, but this particular configuration is called point load.

Now, move to the image number or the scheme sketch number 6, again it is UDL but partially. This particular you know arrangement is called continuous beam structure where it is continuing over 3 columns. But load is being given here so for that there is a bending. And to counter it, so there is another type of upward type will bending to this structure. So, this is partial. When you put it continuous or full, so nature will change. So, we will also discuss it when we talk about this you know beam column structures in detail.

Now, move to this one. What exactly the picture number 8? It is the static load. Why it is called static; like here I said that it can be moved and all. So, moveable immovable that is a live and dead load, but here it is static because the movement that person lifted the weight, so

that will be recorded. So, in lifting competition at certain you know category when the load is recorded. So that is a static one, it will not change that will be recorded. So, this load is there.

Now, already I have shown with that this car hitting this particular wall, so it is impact load. And then dynamic load, this was the building initially and with some lateral wind pressures. So, it will bend like this, it will show you like this. So, this is your dynamic load. This is better representation.

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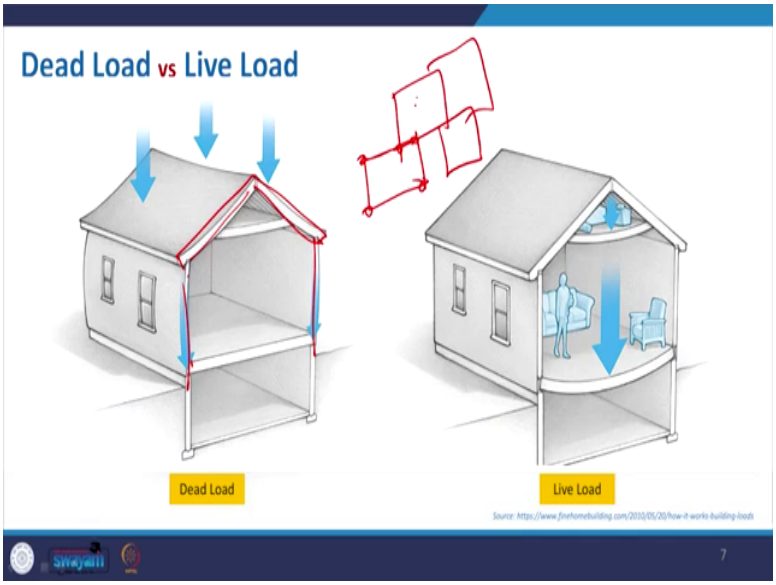

So, now if we, if I ask you this thing like, what is dead load? So, basically the answer is very simple: that all the material all that structural component load of a building is referred as dead load. Whereas, moveable object like furniture, human being, machinery, these are live load. So, both are important in order to design it. So, when we like design a building, based on the requirement we just make the space division and you know create those beautiful spaces.

And then basically in order to make it happen in order to bring it to reality, so we have to design the structure. So, that moment we have to take all these dead load and live load. So, for kitchen it will be something because in kitchen, you know along with a normal furniture and all there will be some permanent furniture. When it is built permanently, even that is in furniture category, but that will be considered as dead load not the live load. So, that we need to understand; suppose you construct a slab or a covered which is permanent made of some you know concrete or brick.

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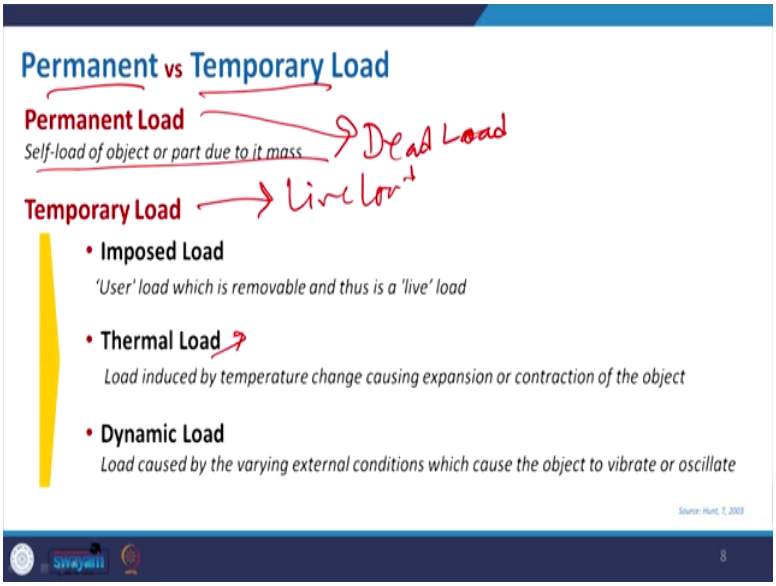

Now, this is another way of looking into this. Like based on the duration like one is permanent and other is temporary. Temporary means, it will not be there after certain time. So, permanent load basically with the self load of the object or part of it and it is basically

leading to dead load ok. And temporary load are basically which are movable and all this is basically the live load.

Now in temporary load, there are certain way of defining it: one is your imposed load, second is the thermal load, and third is dynamic load. So, what is imposed load? Basically the user define load. So, it includes everything, like from human being to furnitures or all machinery that we use. Thermal load relate to the heat you know due to change in temperature what load will be applied to a structural component or building. Dynamic load: load caused by varying external condition ok. So, it may be due to rain, it may be due to flood, it may be due to snow, may be for the wind, or may be it is for the earthquake. So, all these oscillation, vibration that you know creating the load is under this dynamic load. So, let us understand these is further detail. So, that will have a better idea about it.

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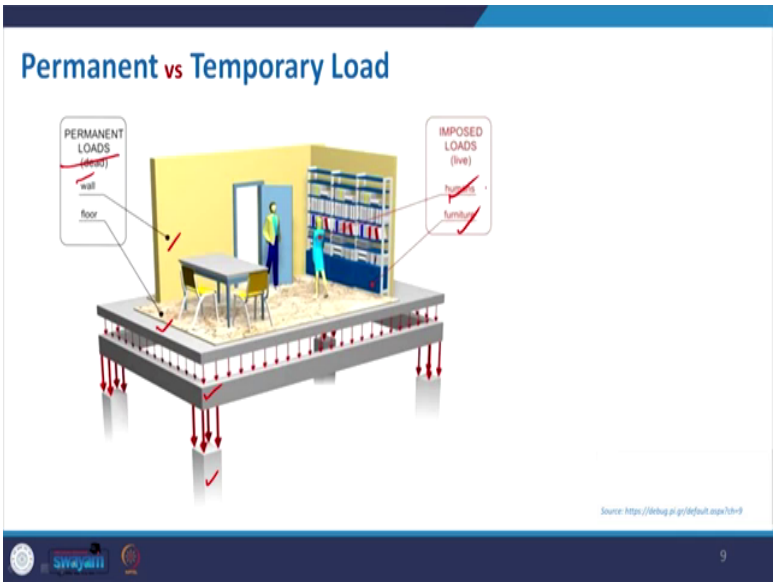

So, this is another image schematic image where you can see that wall, then your floor, then floor is transferring load to the beam, beam is transferring to column, and finally it will transfer to the foundation, and foundation will transfer load to the soil is anchored with. So, these are permanent load or dead load. Now, what is imposed load the human being and the furniture? Already I mentioned it, now this also you know helpful to clear it in a better way.

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Now, this is example of permanent load. This is a building under construction building. Here we can see that you know all these you know structural element, beam, columns and other things which are made of concrete or a sometimes after certain times it will covered with the brick then other any you know structural material which will make this in closer livable. So, these are permanent load. So, material load and equipment load.

But, one thing very interesting to looking into this; as because it is under construction, so this is being supported with some you know shattering a scaffolding or sometime this you know this props which will hold this. So, these are very temporary structure. So, in this image will only consider this particular you know the main structural component beam column not this, these are again temporary structure.

This you may say equivalent to the furniture. So, once it is get the you know final setting, when it is stable enough full remove this shattering ok. So, this pictures those shuttering and props ok, these are not permanent load. Permanent load is only the material load or any equipment that is permanently built.

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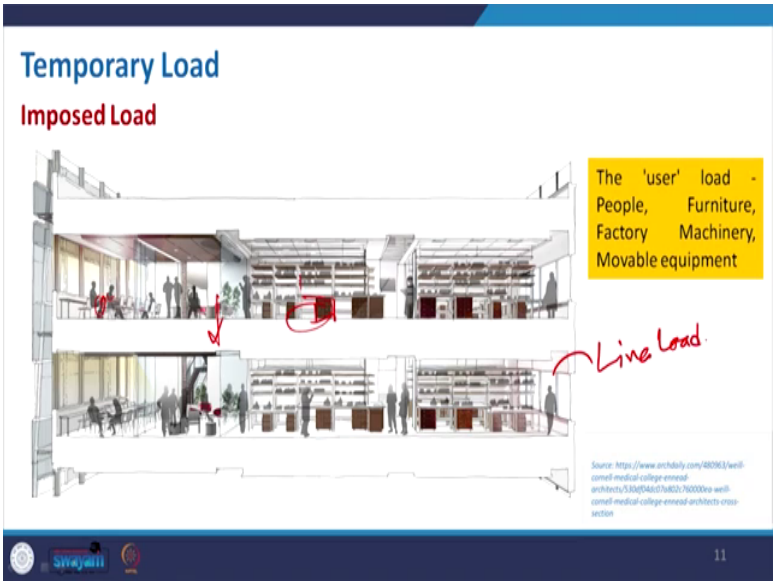

Again this is a schematic one the imposed load, where we already mention that it is the load you know by the people human being or the furnitures and etcetera. So, here you can see the

cross section this is all schematic formal lab. So, where this is a seating area, this is the lab area, so including all these like even those lab equipments, furnitures, everything will add to the imposed load. And they are again as we discussed that live load.

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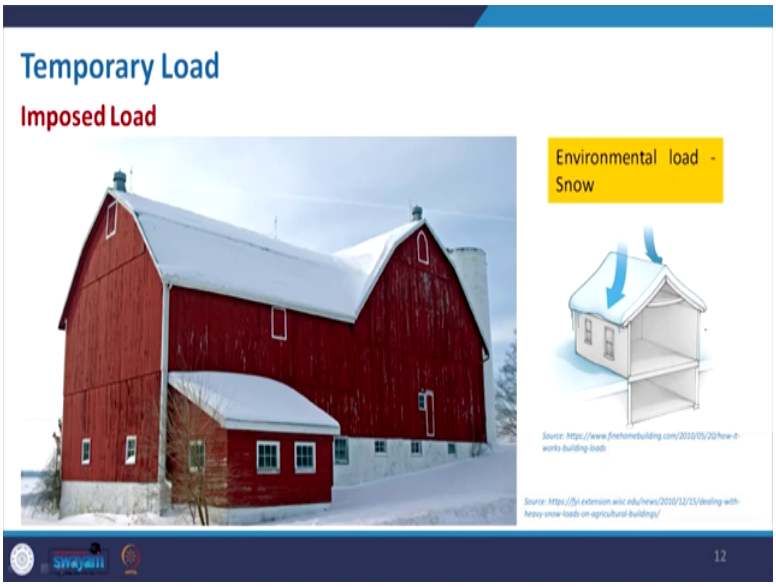

Imposed load it may be something from the nature. So, again this is already we mention that snow load. So over the period, like once it get the temperature it will be melt it, but it is some additional load. So, you can see in this building and this thickness may vary. If there is like a continuous activity, snowfall over a time so it may create a huge load. And sometimes you know for that reason when you design this kind of roof, so there will be some mechanism to you know remove this in periodical manner. So, that it will not really damage the building.

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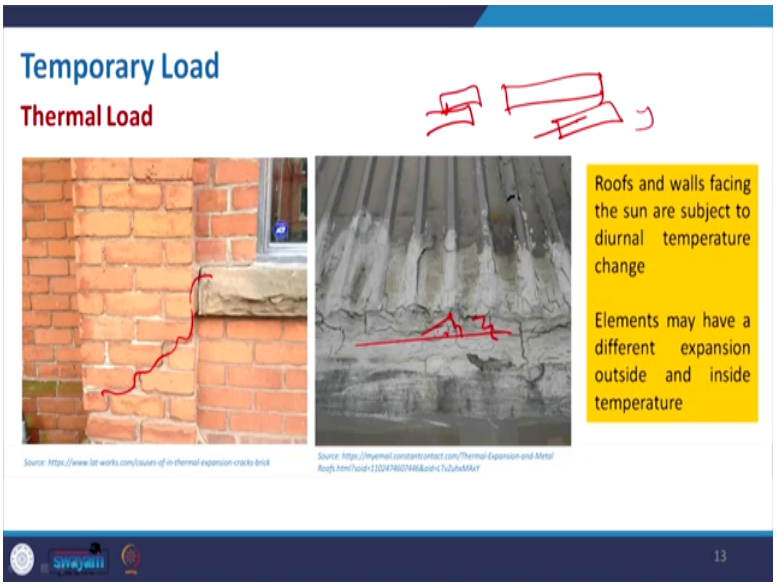

Now, come to the thermal load. So, it is basically due to the change in temperature. So, sometimes object will expand, sometimes that will actually you know do the reverse it will just compact, it will contract in that sense. And due to the change in this temperature there will be some you know development of crack. And it will only develop when we use different materials. Because you know in you know school science we have studied the Young's modular, so that is like based on that like if you know that modulus it will be different for like concrete it will be then steel.

So, steel will expand more than concrete and in concrete whether it is plain concrete or RCC; so RCC means reinforce cement concrete, which also you know which is also having steel as reinforcement. So, whenever we have different kind of material, say for example here bricks and motor. So, two different materials they expand differently, in different manner, their

explanation will be different in some you know temperature difference and it will develop crack.

So, this is for the brick and this is roof (Refer Time: 27:32) based and there is some putty which was fixed initially and due to different expansion with you know heat, so here we see the cracks. So, purpose is not fulfilled here, because if we develop crack so sometime it may also we prom to the water leakage and then your building will kept damp and all.

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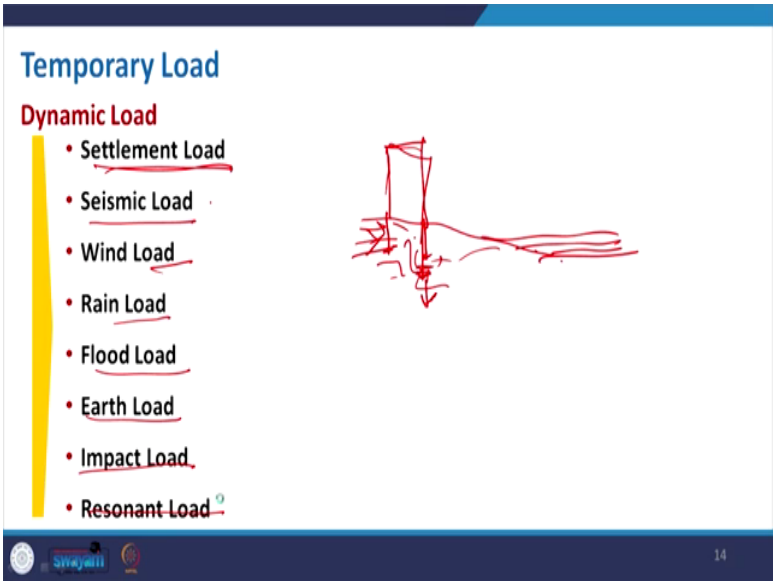

Now, come to the dynamic load. There are lots of load they are in this category, so we will discuss one by one. So, settlement load at already I mentioned, so what exactly it is? So say for example, your building is here and you have this foundation right. And this area is having some water body and ground water table or so sometimes this particular land seem little bit down.

So, this self weight the dead load will try to deep it down, so for that the building may tilt. So, due to settlement of the soil below the structure, below the ground may cause some damage. So, that load is actually do the damaging is called settlement load. Then seismic load due to earthquake, wind load due to wind, rain load, flood load, then earth load. Earth load is basically the lateral soil pressure ok. Impact load all of a sudden load and resonant load will create resonance. So, let us see one by one.

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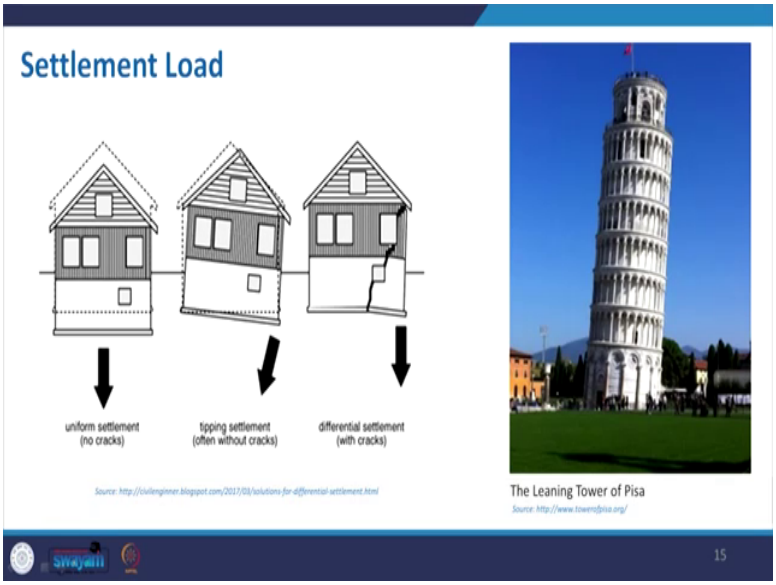

So, this is a settlement load. So, as I mentioned that if it is uniform settlement. So, your building will settle and all building the settle very slowly if the soil is not compact, so no damage. But when it is a tipping settlement then building will tilt. But at the same time if your building is having differential settlement, like there is no fixed settlements so it will

crack. So, tipping settlement example is here the Leaning Tower of Pisa. Come to seismic load or earthquake load.

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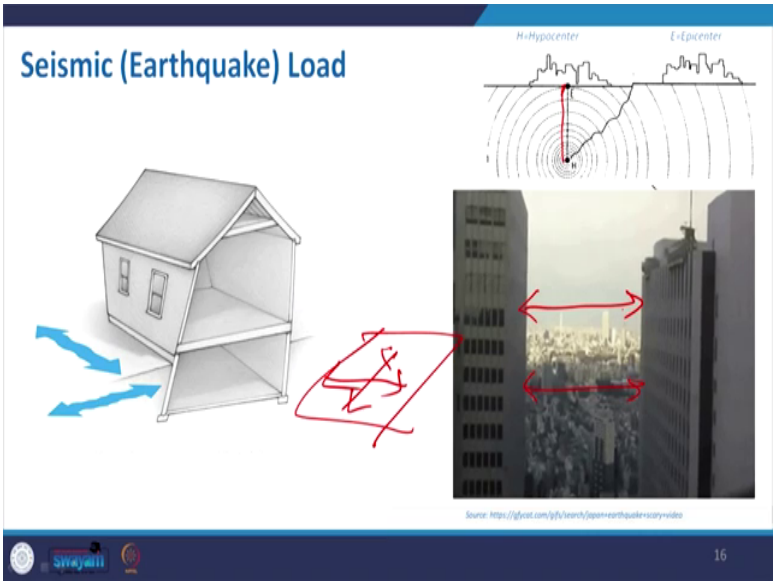

So, in earthquake what you can see that it generates below the earth. So, that is called hypocenter and that above point is called epicenter. So, it is a movement of land in both the direction ok. So say for example, I have this building this is you know grounded like this. So, during the earthquake it is the jerk, random jerk with different intensity so that will try to move. But the thing is the heavy structure that will have a inertia, so it will try to you know stay in its origin position.

So, if you do it so that will lead to sway. And the moment the you know surface showing this direction this will stay in original position and this will create huge sway at larger height. So, it will be vulnerable for collapse. If you see in this is a GIF image. So, by which you can

understand that how its collapse, you can observe with this length. This is the earthquake load and it is very dangerous. Recently we observed in India in 2015 we had experienced it and in the area Taiwan, Japan, or in China, Indonesia. So, it is very common in nature.

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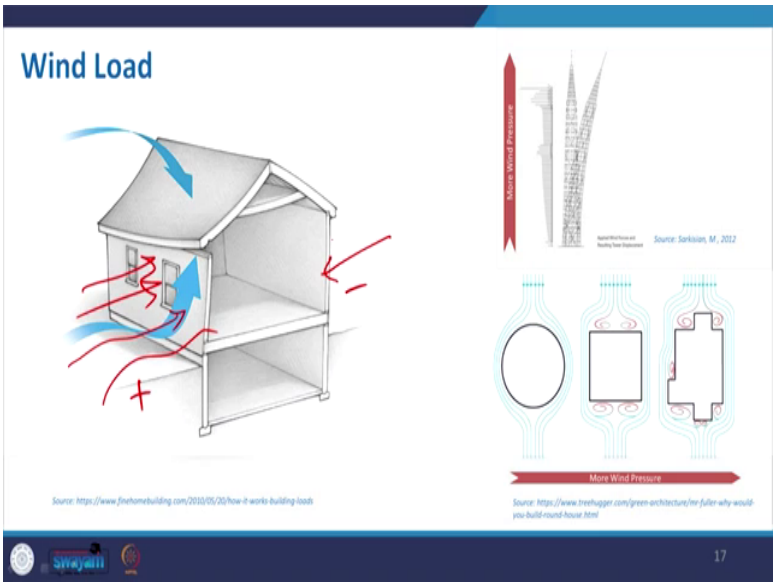

Now, come to the wind load. Here actually it is due to the wind ok. So, wind will create some thrust on this wall and then at the back yet it will create suction. So, this is called positive negative. So, that will also create the sway of the building. And actually the velocity of wind, if this is your height and this is your velocity of the wind, so it will increase if your height increases.

And there are some basic forms which will actually you know minimize the wind load on this. If your surface is having larger area complicated area so that will create more problem

due to the wind pressure. So, we should design in that manner. But for height as building wind load is very vital along with all other self load and other live load

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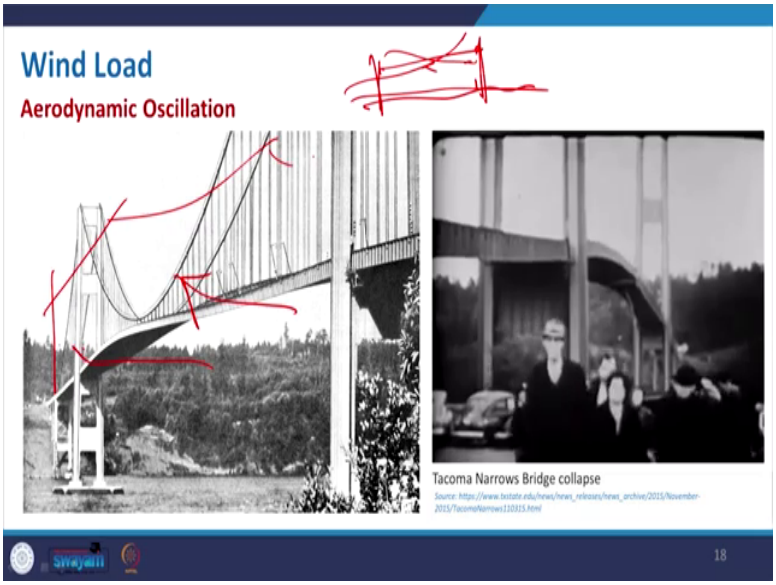

So, this is one example of like wind load and that actually collapsed that Tacoma Narrow Bridge in 1940. So, what happened exactly? When you have this particular bridge over you know (Refer Time: 32:38) wind is predominant, so it will create pressure. So, it will actually make it twist it and it will create a vibration. So, definitely it will be a periodic vibration until it collapse.

So, for that it is very vital. And that is why for those bridge construction normal we give some counter weight. Say for example, in Howrah Bridge and all heavy counter weight is given to protect against the wind load. So, this is also important. This is one example from the bridge

category, but that has affect for the high rise building. So, we should know this. So, this is due to wind.

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Come to the rain load. Again accumulated rain will add extra load to the supporting structure and this may collapse. So, here fall ceiling or something it was some damage due to rain you can see the water here and all. So, that should be also taken into consideration.

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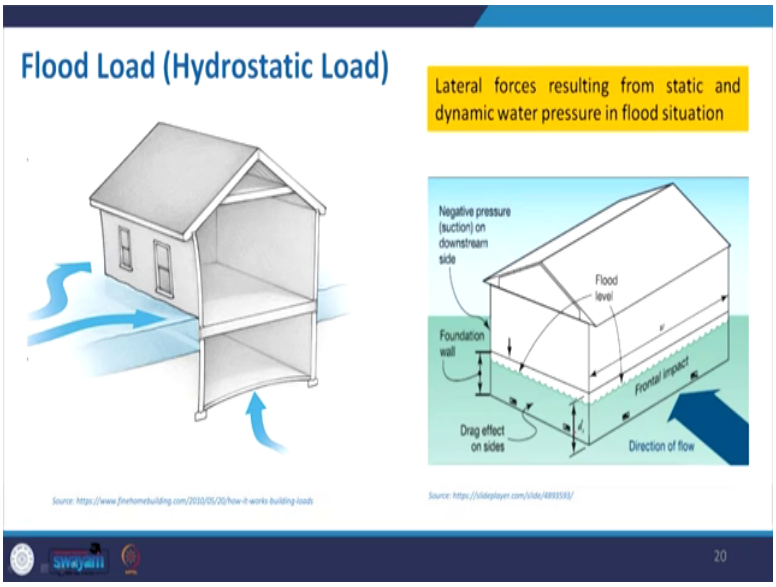

The flood load is hydrostatic load. Again it will create pressure, so in on the direction of flow that will also create the drag effects from the side and that will create negative pressure or suction at the back. So, that will also create some problem to the building. And if your building may material is weak or that particular pressure and it also depends on the volume of the flood. So, this volume of the flood or the height of this particular level will also affect the you know damage. So, let us see the next GIF image.

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So, you can see that due to flood what is the situation the building is totally collapsed. And recently in India, Uttarakhand we have also experienced similar kind of thing due to the heavy unprecedented rain and flood the situation many building collapsed.

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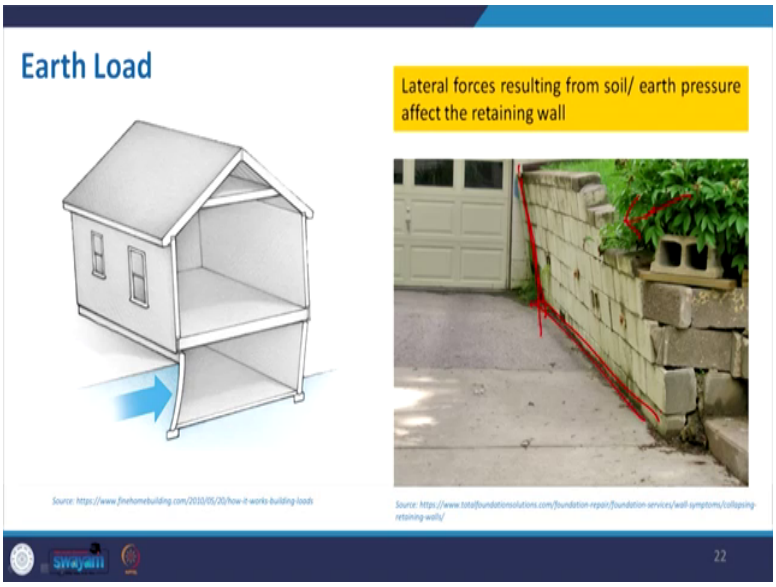

This is the earth load. So, basically lateral forces resulting from soil or earth pressure that may sometime damages. So, you can see this is retaining wall or the boundary wall and this earth is actually you know creating pressure to this, and it is not in a safe condition. So, sometimes it is also very vital to know. So, this is earth load.

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Impact load, already I have given the explanation that nailing a you know nailing with a hammer or may be a car just you know hit a building all of a sudden that create the impact. So, it is also sometimes important. So, if your building is vulnerable to this kind of things, so you have to take into consideration. And if your structure is weak sometimes you know putting a nail also damage your building, it will also create you know disturb the equilibrium of your structure.

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Now, this one is the last one where it is called resonant load. So, what is resonance? When you a wave generates and over the period it will actually propagate, so it will create resonance. And sometimes you know we experience this with the this Mexican wave for you know you know very two great team are playing football or cricket in the stadium. So, people they are creating in a rhythmic manner. So, when that wave created wave and the supporting structure the vibration is accumulating they are actually synchronizing each other.

So, that will propagate the wave and that may create the resonance. So, which may collapse. So, this is another example where it was your control demolition and it was collapsed due to the resonant frequency of the wave. So, helping taking that as a advantage that was a control demolition. So, that the this particular demolition will not affect the surrounding area. So, here we actually summarize everything. So, what we learn?

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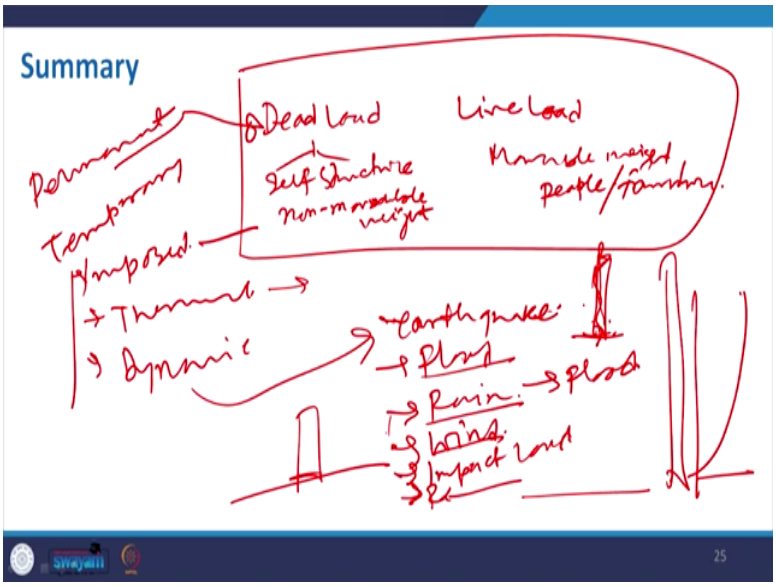

So, basically two type of load: dead load and live load. So, what is dead load? This is basically the self weight of the structure and non-movable weight. And live load is actually movable weight example: like people, furniture, and other. Then also we have discuss it in terms of permanent and temporary. So, what is permanent? Basically refer to dead load and temporary which is which will be varying with time.

So, it has first the imposed load: user load and furniture load, and then we also discuss the thermal which will not be a constant expansion contraction over the years. So, in certain season it will expand sometimes it will contracts. So, based on that, this is taken into consideration.

And then you have there is you know dynamic load; under dynamic load. So, the load caused by earthquake; the motion on the ground which create the, you know disturb the equilibrium

of the structure and your building start showing and when it is beyond that particular resistance it will collapse. Then it may be due to flood, it may be your rain, unprecedented rain and causing through flood. Then wind is very vital specially for the building we construct near the coastal area where wind pressure is really considerably high or may be the high rise.

And in wind and for earthquake both the cases the problem is with the high rise. So, the moment you go up, so wind velocity will be more that we discussed. And apart from that we also discussed the impact load. So, all of a sudden you just you know throw heavy bag on the floor or something some equipment you just throw it out so that will create some impact on the floor or the wall. And then we also discussed with the resonant load, and which actually you know also very vital when we have such gathering. So, a music when it synchronize the waves, multiple waves they synchronize each other and propagate and create huge load on the structure.

So, all these load that we discussed today it actually it will help us to design. Like we have to consider all the loads, which are pertinent to that particular type of building. And in order to make your structure resistant enough to tackle all this load all this factors we will discuss in the course, in some of the module we will discuss it. So, in order to make your structure earthquake resistant what type of structure is good and all?

And the challenges to make this resistance table from this particular you know all this loads along with you know, without compromising any purpose that that is for that building was designed.

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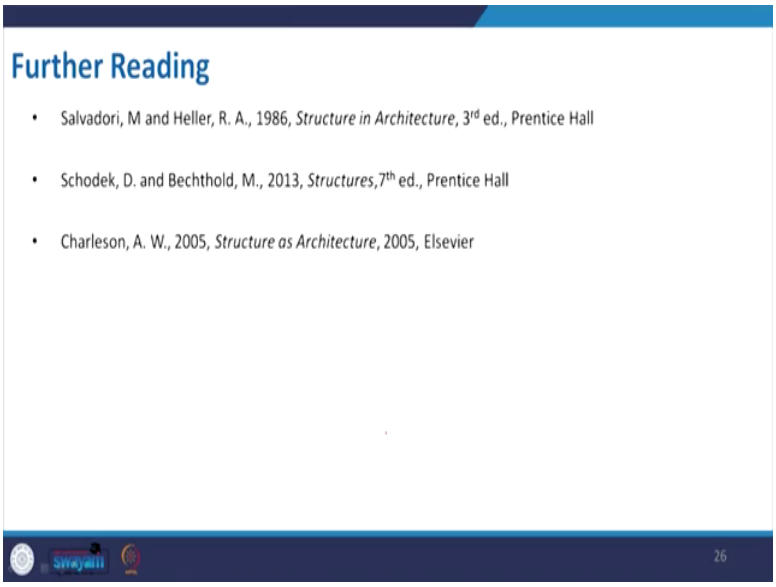

So, with this I just conclude this particular lecture. And these are the books already I mentioned in earlier lectures. So, you can go through it to get more information about all this we discussed.

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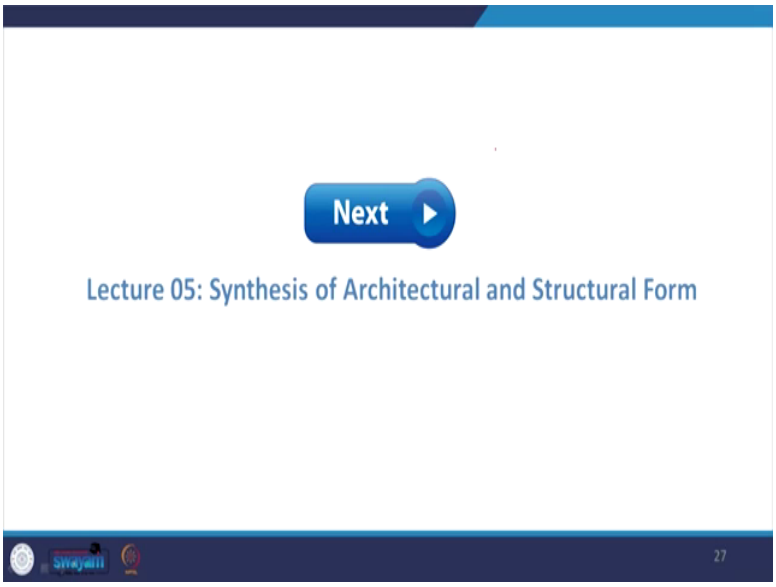

And, in the next lecture we will discuss the synthesis of architectural and structural form, which will be another interesting topic to know about.

Thank you for the day.