Structure, Form, and Architecture: The Synergy

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Lecture – 31
Structure and architectural Forms in Windy Areas

Hi everyone, welcome back again to online NPTEL course on Structure Form and Architecture the Synergy. Today we are at lecture number 31 and as I told in my last lecture that, now we will be discussing some Structure and architectural form for different purposes. And we will start with this particular topic with the Structural Form and Architecture in Windy Area. So, without any further delay let get started.

So, at beginning if I just ask you what is wind, what do you understand by wind. So, wind is basically the bulk of air, but definitely we call it wind when it is in motion.

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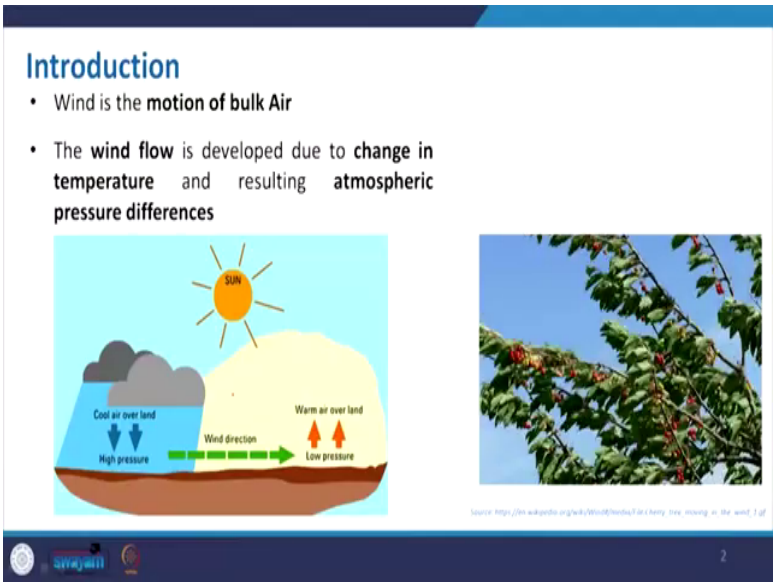

So, in this first slide if you can see the one gif image is showing what exactly the phenomena. So, we can feel it, we can measure it the intensity. So, when there is a blow of wind blow of air, so that we refer to the wind. Now, why this particular motion being created? It is again a very simple thing and I think all of us have read this kind of definition or explanation in our school days.

So, the wind flow is developed due to change in temperature. So, whenever due to the sun your land is getting the heat and then the you know the air in contact to the ground at that lower level also get the heat and become lighter. So, hot air will goes up and that will create empty space. And in order to occupy that empty space, the cool wind on the surrounding will take a motion towards that.

So, here you can see the same due to the sun, then the warm air is basically you know the surface in the you know lower surface whatever the air presence; so they get warmed and then they create a low pressure zone. And the tendency from high pressure to low pressure movement, so cool air will come to this and that will create this particular wind.

Now, each day we feel this wind and if we do not feel it, so we will very much stuffy, ok. But normally before any storm or something, we feel this cool air. So, up to certain level, up to certain velocity of wind we like the wind blow, we enjoy the wind blow. But when the intensity will getting intensified, then probably that will be a threat to us.

Yes so, that will be threat to our building. So, we should know the different phenomena that will occur during this heavy wind blow and how we can really design our building structurally safe and also can raises this kind of wind pressure in case of the emergency.

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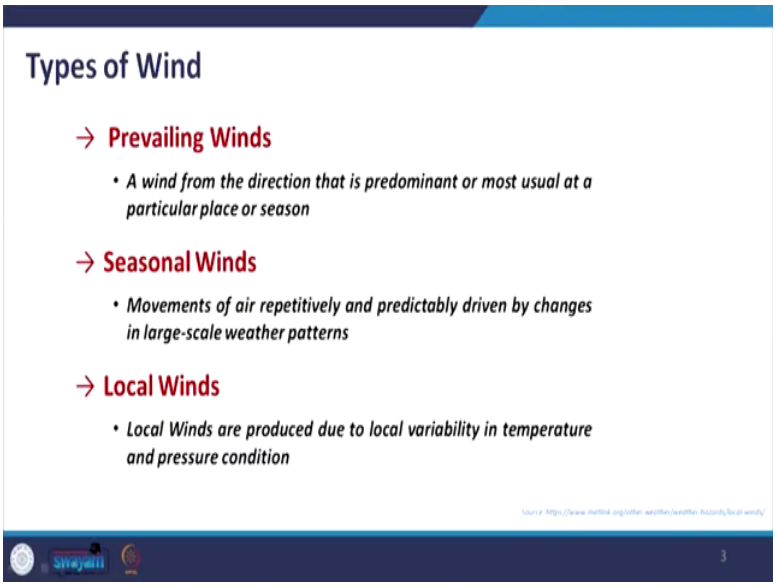

Coming to the types of wind. So, it is again broadly classified into three category; one is your prevailing wind, another one is your seasonal wind and then local winds. So, prevailing winds is basically around the clock over the years. So, there is a specific direction and very predominant direction that most of the cases it is glowing from this side to this side, maybe from south southeast this from with general from southeast direction and move through like this. So, this is the prevailing wind direction.

And based on prevailing wind direction also you know for a region, definitely it will based on the region, it is not uniform for each and every space. So, for a region it will be predictable, it is actually you know similar over the time; and taking this prevailing wind we can also place our building and we can orient our building.

In the second category the seasonal wind, it is something which subject to change when there is change in weather. Say if it is winter, so there is certain temperature, maximum temperature, minimum temperature; if it is summer, then there will be a maximum temperature and

minimum temperature and because of this temperature difference and all, the wind pattern also may change. So, that is the seasonal variation and the seasonal wind. So, during this the summer evening, mostly if you consider the you know southeast part or the east part of India. So, this kind of situation may generate, special in the summer evening. So, we expect some storm, heavy storm or that may also lead to the thunder storm like this.

Now, local wind is basically produced due to the local variability in temperature and pressure condition. So, it is similar to the case where you have a region, where you have water body, you have you know the paved surfaces. So, where it will absorb the heat very quickly and the air in contact of that surface will get the heat and get warm and then that will create a low pressure zone. So, this is very much temporal, very much local in nature where these wind blow form you know form your cool region to the hot region the wind blows that may occur.

This may occur in the two different way; see you have a land, you have some buildings here and then you have some water body and it is consider a sunny day. So, then definitely with this heat from the sun will make this surfaces, drilling surfaces and the adjacent atmosphere very hot. So, the air will get the heat and then go up and form this river which is little bit you know bad conductor of heat and it is not that much warm compare to the land. So, wind will blow from this direction.

Now, consider the same situation at night, the same location; but now you have night situations. So, consider these are the star and all. So, this surface may be concrete or any hard surface; it will get warmer very quickly, at the same time it will get colder very quickly compare to the land.

So, that time the temperature of these particular region near this you know water body or sea, it is basically warmer than this place. So, we get warm air in this part compared to this, and then the movement of wind will then form the land to the water.

So, it is basically depending on the topography, depending on the position like whether it will be near to the water body or maybe sometimes it may be near to the hill. So, based on that, this can change. So, whenever there is a change in temperature and it has relation with the

pressure as well; so then low pressure high pressure will be created. So, when temperature increases, then definitely that will create to the low pressure area, and then from high pressure to low pressure there will be movement.

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Now, we here is basically self-explaining the you know, the you know scale of this kind of storm. So, when it is a very mild very you know low speed wind, so we prefer to enjoy that; but when it is our magnificent scale, then probably you will get this kind of hurricane, this kind of tornado and maybe the sandstone which will be very much vulnerable and threatening to us.

So, type of storm; hail storm we can have normally in the core region we can get this; in thunder storm we all are you know knowing this particular storm,, the heavy storm with the rain and also the lightning. Then the sand storm, then ice storm, tornado, then you also have

heavy snow or blizzard, then derecho storm is again a vulnerable form of this storm; then the tropical storm, normally being observed in the tropical area, and the hurricane.

So, here you can see that how devastating this could be if it passes through urban area; move many settlement, many people will be in threat to encounter that. And the consequences are something like this; I have taken very few examples where like the buildings and the other property got damaged due to this heavy wind blow.

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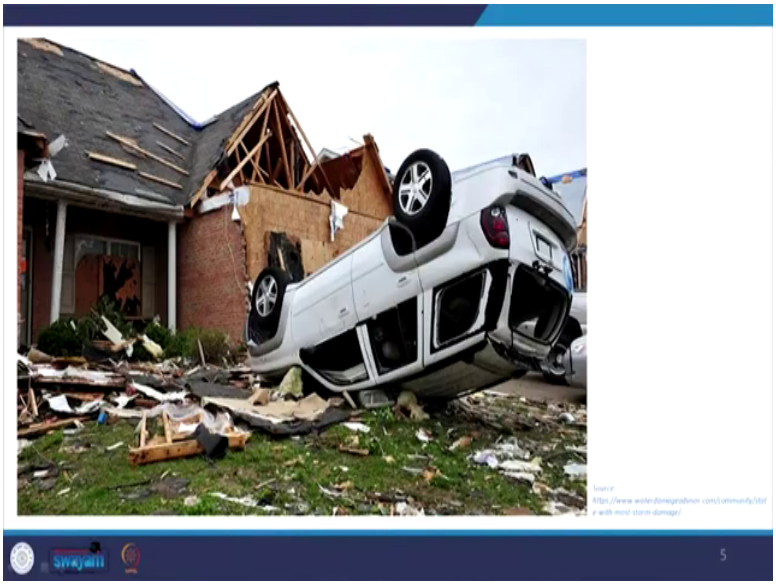

So, here you can see that upliftment of, this is basically upliftment of this car; and even if you see the condition of the roof, it is actually very badly damaged.

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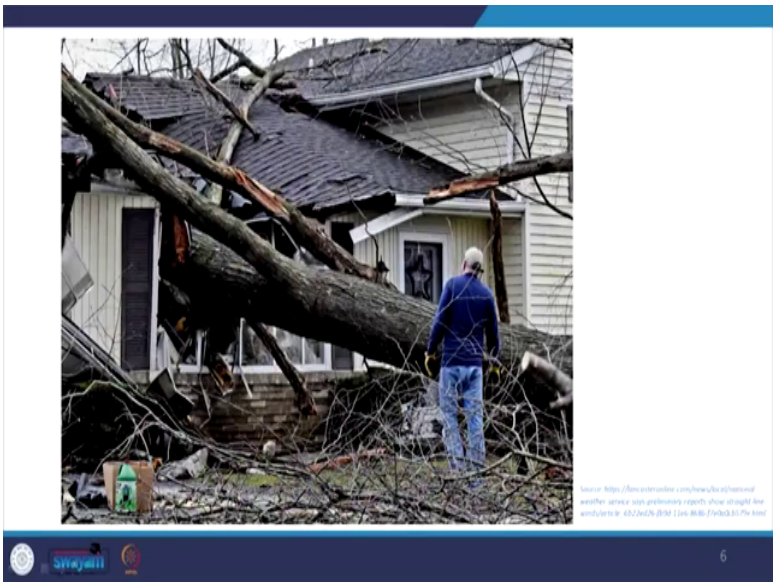

This is another one where not only your building, the surroundings trees will be in a very much threatened and they may also affect your building subsequently.

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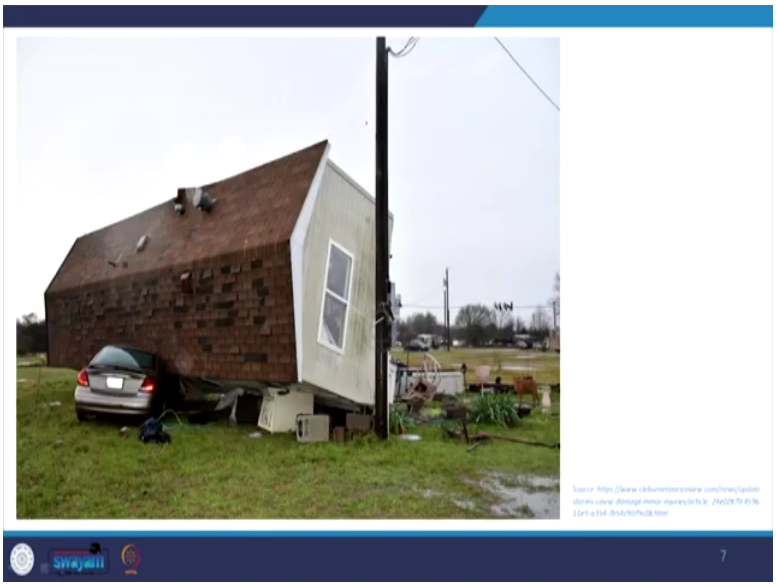

Coming to this example; again this is the turning of the building where you can see that the whole building, though it is very light and temporary shaded, but due to the wind blow, so it is just you know change. So, normally whenever you have this breach roof and all; so it depends on how wind is you know coming that, wind direction will depend like direct that what will be the change, what will be the change in the position of the structure.

So, in this case it is prevailing, like is expected the wind is coming from the that direction; and as because the structure is not well anchored to the foundation, as because it is a temporary setup, maybe for like some settlement. And then if it is not properly anchored, so this will create a thrust tweet and then it will basically tilt. So, this is the result of the same.

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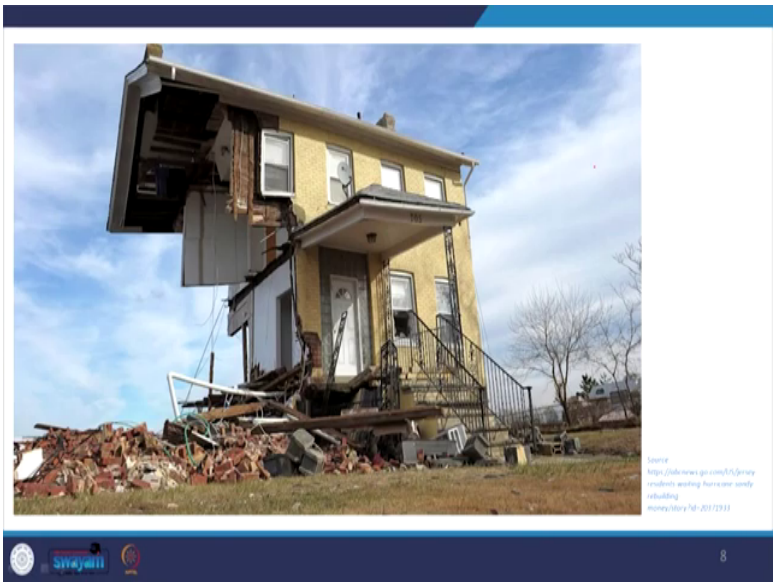

Looking at this example, this is where the portion of the building is totally blown away by the wind and you can see some of the debrises here. So, it is very badly affected. So, it may happen when you have some material that is not that much strong to resist the load or maybe the intensity of the wind is so much that it failed to resist.

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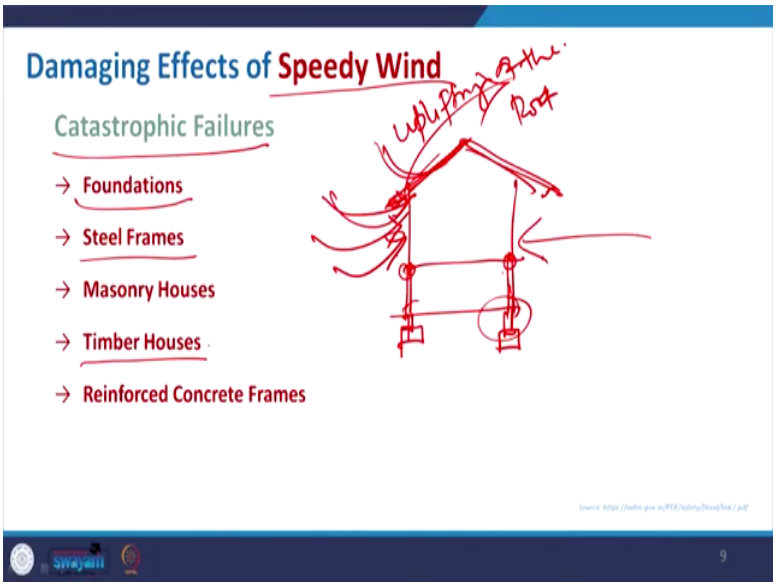

Coming to the damage of a building or any property due to speedy wind or heavy wind; so we can have a catastrophic failure; catastrophic failure means the is the total failure, the dimension, the magnitude of this failure is very large. Where the foundation failure is something, where if your building is like a tilted structure and these joints are not that much strong or this foundation is not anchored with the form of you know footing, this legs are not anchored with the footing. So, due to heavy wind, it may really fail this particular foundation. So, these we have seen in other cases.

In case of steel frame, though it will have a better resistance again that lateral load; but sometimes when you use a glass or some other cladding to the steel frame that may get badly affected for this. And specially the roof; if you just think of the gavel roof or the pitched roof, where normally this you know harry cane and other thing are very much predominant. So,

then that will create thrust, that will create suction and then this particular roof will be blown away. So, up uplifting of the roof is one of the major problems.

Then in case of the masonry houses; if the wall thickness is good enough, then the magnitude of the damage may be somewhat low. But if it is something where you have some old structure and it is not being maintained; so then may be the disaster will be more. Then for the timber houses is very light structure.

Normally sometimes you prefer to build it for just make the temporary structure or maybe where we cannot really resist the heavy wind and we just allow, we just use the basement in the areas where this hurricane and tornado are expected to get. We make the structure in such a manner that during that storm, the hue heavy storm; then we just take ourselves to the basement and we allow wind to blow above ground and that may damage as we have seen in the pictures.

Coming to the reinforced concrete frames. So, in this case reinforced RCC frames will also have; if they are joints are not properly made, so that may get affected. Or else in case of like RCC frame whatever the wall we will use; if use very poor joints or maybe the thickness is very blaze and for the external world, then probably damaged the magnitude of the damage will be more.

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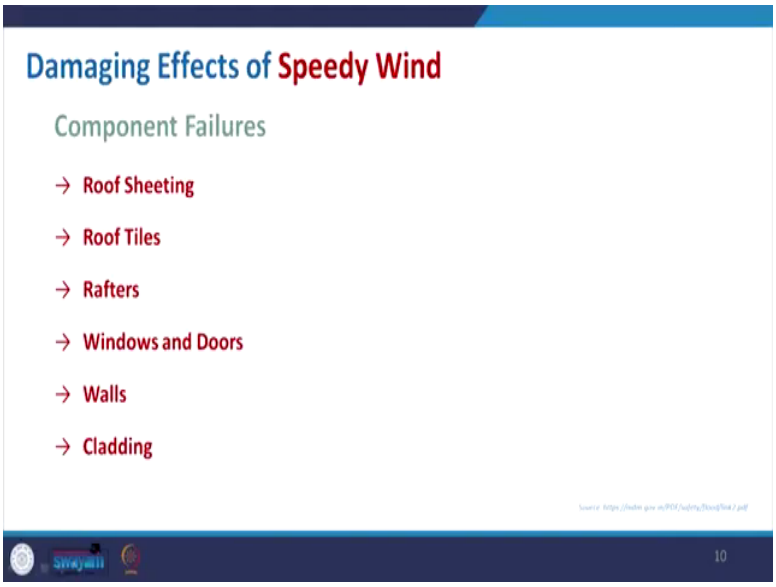

Compared to the catastrophic failure also sometimes it may not be a total failure; but there are some component failure, one is your roof sheeting. So, normally in the village area due to heavy wind; so this particular roof sheeting whatever it is made of asbestos or teen, so they will really create a pressure here. And then if the other part of the building is also have some opening, then that will create a negative drag and these dragging will leave this particular roofing and then it will blow away.

Instead of roof sheeting, sometimes we also use roof tiles with the help of the raptors and the frame and that may also fall into this category. And it has been observed; if we reduce the slope, if we want to make it very flat; then that will be most the more preferred than a very wide angle, because then the upliftment will be really more.

Then door, windows definitely if it is facing the wind direction; suppose this is your building and then here you have your window position and then maybe there is a door. And your if wind is blowing like this, so sometimes this may get badly affected; because with storm that may also carry some other debris from like we have seen in case of the tornado in many instances, you can also browse through intended to see this kind of devastating effect. So, that may damage the windows and doors.

Coming to the walls definitely; if the thickness of the wall is not adequate or it is not properly done with the proper material and the joinery, so that may easily collapse. Then the cladding, whenever you know with the base surface we use for the stone cladding or some terracotta tailing you know cladding, then with this wind pressure it will also peel off. So, many buildings you might have seen in the corners; like if it is properly cladded it with the stone and then all of a sudden you find that the portion that tiles they just are blown away with a window and normally at the corner it happened more.

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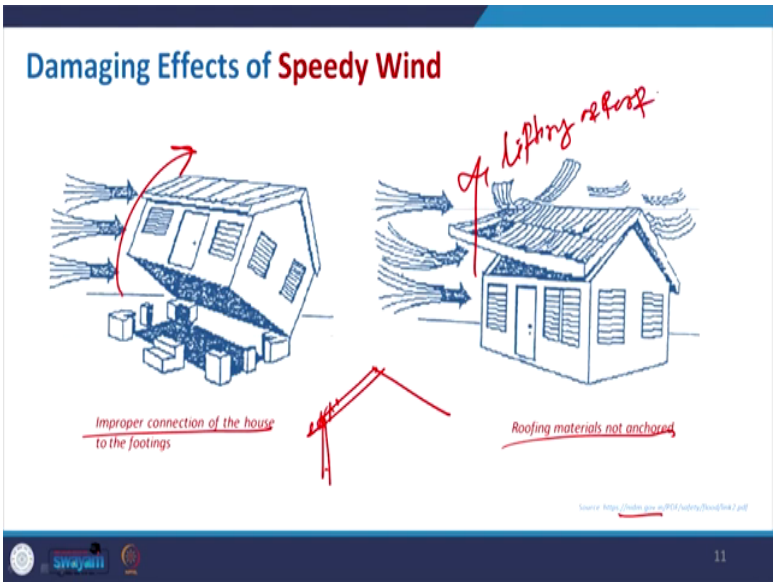

Now, coming to the effects, now whatever we have discussed now let us understand with this images; what I have picked up from a document of your NIDM dot government dot in. So, in this case if your house is not properly connected to the footing. So, it is not having a proper foundation is just some way manage, then it will really turn this building. So, this building can totally turn off and that we have seen in this case. I have shown you this figure, so this is one example of this where the building is not anchored with the foundation.

Coming to the second category where foundation is not the problem; but roofing materials are not anchored properly to the building. So, normally for this kind of pitched roof building, we have a series of raptor; and then on top of it we just anchor it. Now, if this anchoring is not properly done, then this kind of upliftment lifting of roof may occur.

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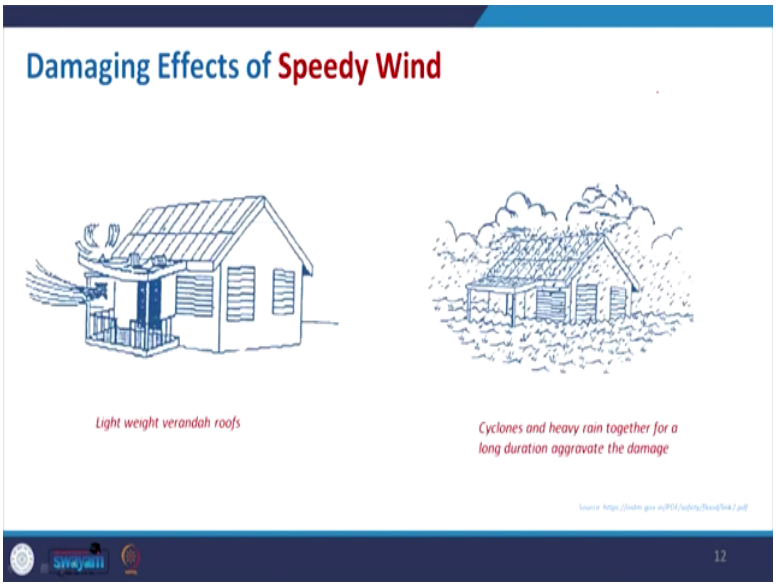

Now, on contrast sometimes if wind pressure is not that much to appealed the main structure; but you have some projection like this verandah. So, then it may also uplift the roof of this verandah or maybe the tailing or something like this; if it is not of that magnitude, it can damage the smalls projection and all. So, we have to as I as suggestion like; what we need to do this projection could we be taken care of and we do not provide such without proper anchoring with the main structure.

Now, this problem with the wind is one and when it will be a thunder storm, so along with a heavy wind and the rain and if it will continue for certain time; so that will also aggravate the damages. So, first of all this wind will make this structure little bit shaky and then there will be some problem of this uplifting of the roof. At the same time with the heavy rain that will be water lock, then if the building material is not that much water foot and all; so that will

become weaker and then the total building may collapse. So, damage will be more, if it is water lock situation, heavy storm and along with heavy rain.

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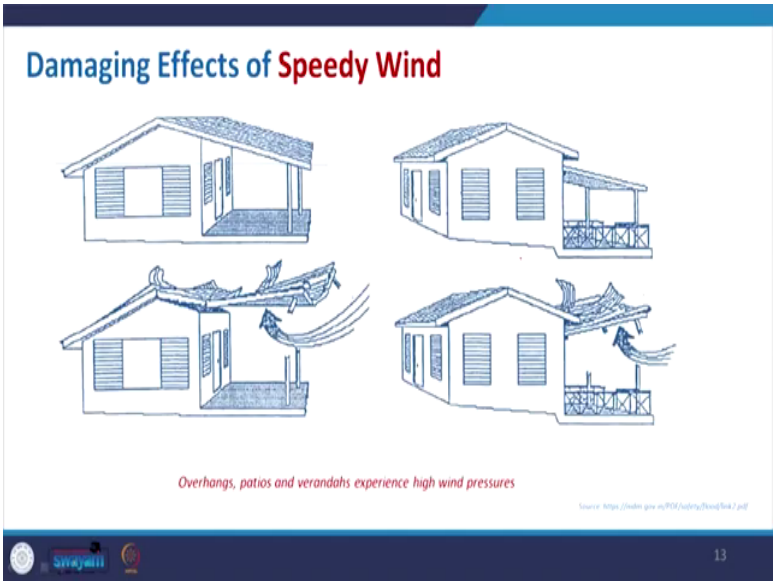

Coming through the speedy wind as we have seen that in this case as well; like when you have a continuous roof for the verandah, so this will create a void and then if the wind direction is from this side, so that will have a really create a pressure at the bottom of the roof and that will really up flipped. So, this is not really recommended.

But at the same time if we just split the main roof and the other roof which is separated and which is not properly anchored to the main structure with proper you know joist and all. So, that may also lead to the uplifting of the roof of this verandah.

So, this projection, whenever we provide the projection, we have to really take care of that. So, that is why the overhangs and the patio and verandahs experience high wind pressure; as because it is directly exposed to the wind and because of this void, it will create this pressure.

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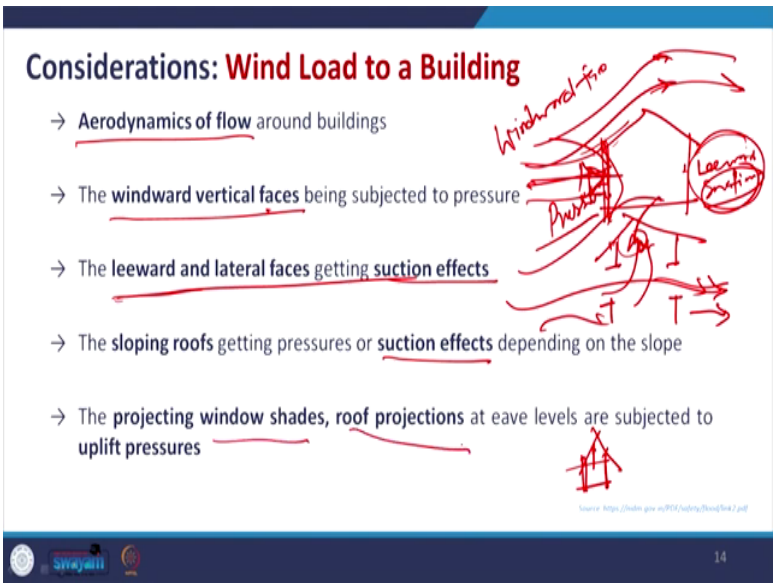

Now, coming to the wind load to a building; so when we consider, when we design a building or decide upon a shape, size of a building and even the structural design, we should take care of few points. And it is start with the aerodynamics of flow around the building; like definitely it will depend on the shape of the building, in it is plan and elevation both, we will come to that again.

The second point is windward vertical faces being subjected to the pressure. So, windward means, in your building there is a prevailing wind direction. So, if wind is coming from this

direction. So, this is called windward face and that is the opposite to that, is basically your leeward.

So, whenever wind is you know wind is blowing from this direction and it will come into contact to this surface the first surface; so it will create some pressure, try to deform it at the back side. And then whenever it getting some slope, so it will try to move up. And with this due to this obstruction in this particular space, it create some suction effect.

So, that is why the lateral, the you know leeward and a lateral face getting the suction effect and the vertical one is getting your, windward vertical face is getting your main pressure. So, that we need to take care of that; if intensity is more, so this will create the problem. So, that may damage the building in different way.

Now, in compared to that, if you have a building something like this where the openings are parallel and wind can easily pass through and the openings are quite big enough. So, that we be little bit in a better situation; but that may also lead to get suction at this roof and it is roofed upliftment may occur.

The sloping roof getting pressure or suction effect depending on the slope that, already I mentioned; if we have very you know the angle is more and then you get the suction effect. And again along with the main structure what we also need to look for the projection of window shades and other roof projection in verandah, so that we need to take care.

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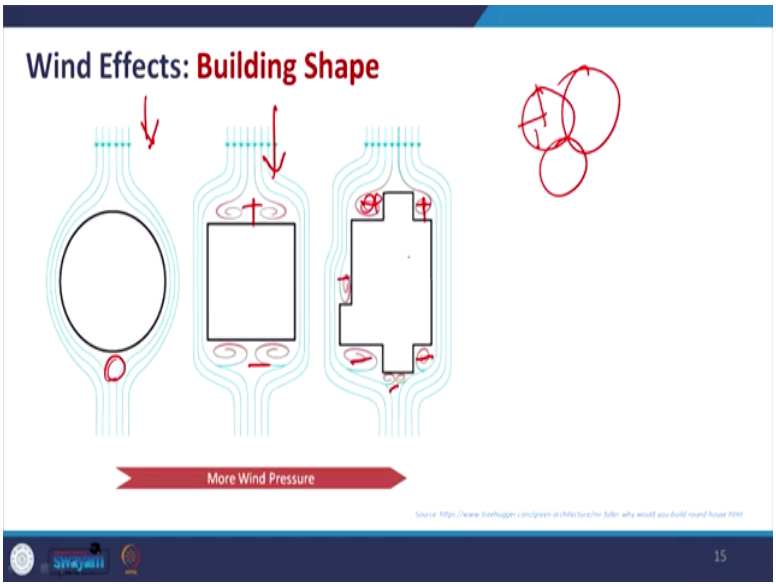

Now, coming to the basic building shape, so what exactly it is happening? If we have a circular one and this is your prevailing wind direction. So, due to this curvature wind is taking the surface and there is no such negative pressure or suction being created at the opponents.

So, this is one of the preferred shape that we can go for the windy area. Now whereas, if you have a squarish plan; then also it will create some kind of suction, it will create some pressure and that may prone to the vulnerability.

But now if we know that circle is a better than these or circular form is better than this rectilinear form; then why we are not going for this kind of solution, as because most of the buildings we see, so they are all of these rectangular form.

The reason is with a rectangular very you know comb the composition of walls with right angle, which provide us to utilize the space in a better way, even the furniture's layout will be easier; and then we can better optimize it. Whereas, if you only have the circle, then you know the division of the internal space will be little bit challenging.

But if square is the plan, then up to that level it is still, ok. But in reality what we found that, is composition of different you know rectangle and then we will get a zig zag form. So, in this irregular form of this rectilinear composition will create some more pressure or sometimes they create more pressure here and also these type of building are more vulnerable to get affected. So, what we can understand from this; if we want to make our structure very simple, very simple geometry, regular geometry, preferably with a curve over all, so that may be helpful for this.

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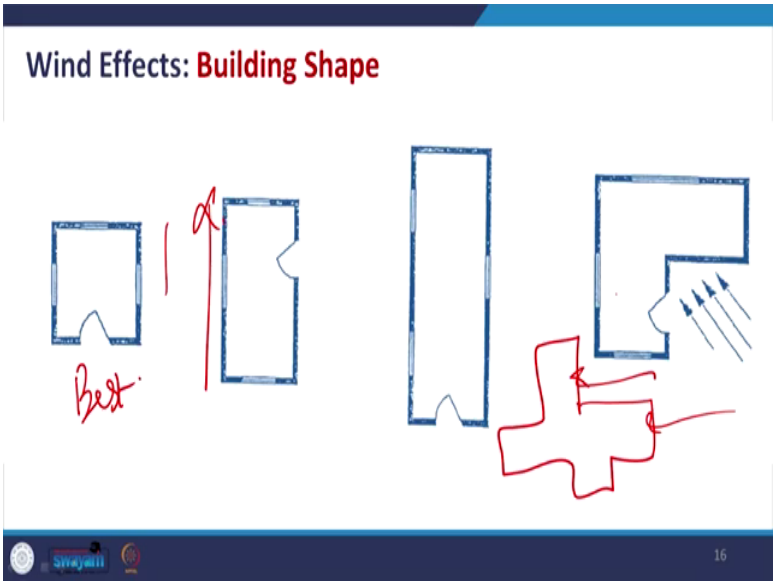

Now, coming to the other wind effect of the building. So, this is considered to be the best out of the given option and whenever we elongate this side, so that will be more risky. And when it is like this, so then it will be even more risky depending on the wind direction. And if we have this l shape or sometimes maybe the shape is something irregular, so that may create some problem. So, due to the unequal sharing of the lateral load due to the wind to the different components will create the problem.

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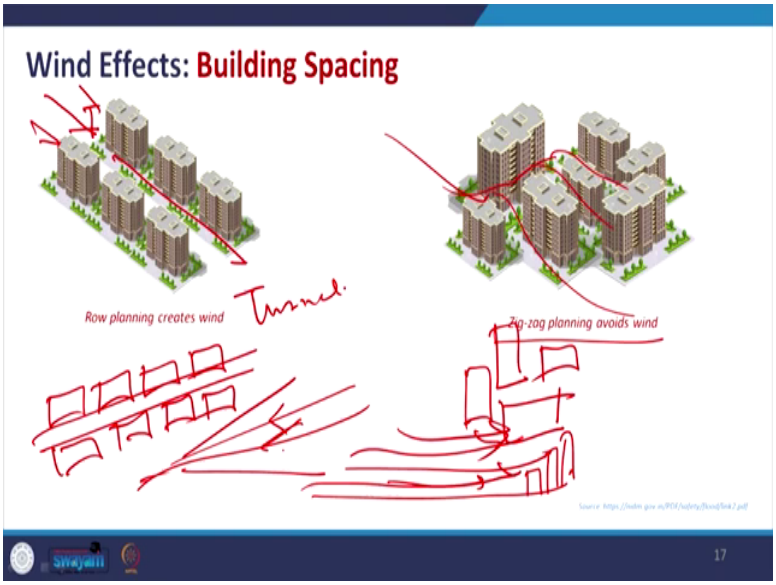

Coming to that, was for a single building single building unit. Now, if you consider the placing of multiple building; if you place building in a very regular form and the wind direction is something from this side, so that will create a tunnel effect ok, which is sometimes not welcoming. So, that will if we will have this arrangement something like this from a high pressure to low pressure. So, wind can really create problem for this region.

Whereas irregular zig zag planning avoid the wind; so prevailing wind may be from these direction, so then they will not gaze get that particular route to get intensified. So, this is sometimes is preferred. So, instead of your row planning ok, so this is not preferred for this; and then we have to make this zig-zag whatever to break the wind pattern or something. So, that will reduce the intensity.

So, normally in urban area that is why we get this kind of you know situation, where different alignment will not allow wind to really take the intensity. Whereas, in you must have seen in a countryside or maybe in the case of western, example western country example. So, you have a field, agriculture field and then you have some settlement and then when wind is coming from this direction, it is getting the strength and definitely it is more devastating.

Even the recent times in India few of such cyclone that has come. So, definitely when it is moving through the empty area or over the sea, so the intensity is quite high from know, when it is created. And this basically very much devastating; but when it enters, when it heat the land and then penetrate to the front you know buildings and also it is getting it is losing its power and that is why I like in urban area this kind of pattern is a preferable.

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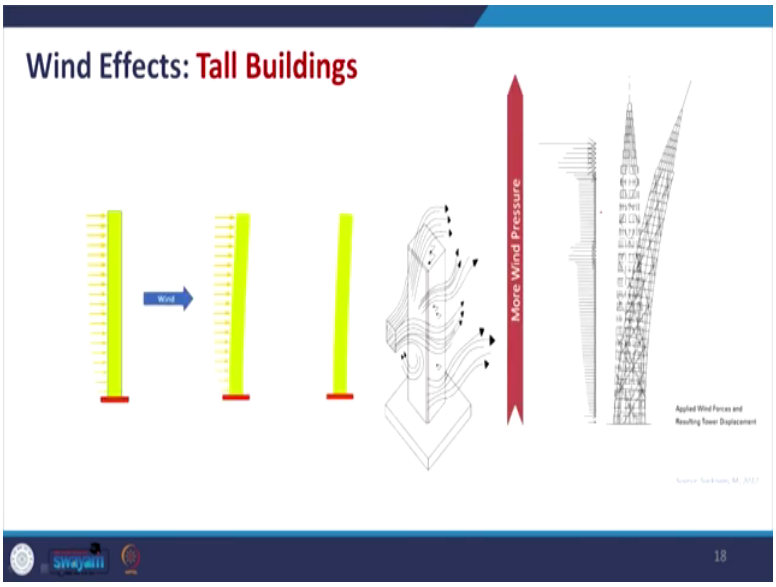

Now, coming to the tall buildings that we have discussed this previously when we discuss about different you know effect of wind and as because with the height; increase in height this particular sway, lateral sway is actually very much high. And that is why like you can feel the building's sway like this. And if we do not adopt such a high rise structures component, then probably this will be a catastrophe.

So, we cannot really increase the height of the building and that is why like when we will be discussing maybe in upcoming lectures on a high rise structure, will touch this again; where we will say the different kind of coarse structure, different kind of tube structure that will help to make this high rise to protect against this lateral load especially with the wind. For them definitely earthquake will play a different role to that; but along with that, with the increase in

height, wind is one of the major factor to be considered for high rise building design. So, here like this phenomena is there.

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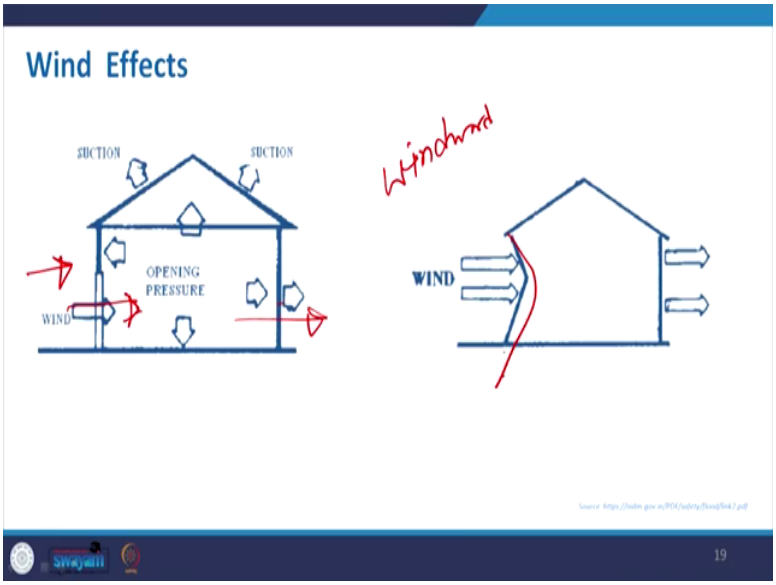

Now, coming to the wind effect and different options, so if we see this; then wind direction is from this side and then basically it can enter through this particular space and then it will create suction to up flip the roof and also a if we have another opening it can go outside. But if it is restricted by a vertical wall or what we have mentioned there that is the windward wall vertical wall, so that will try to bend and then it will collapse.

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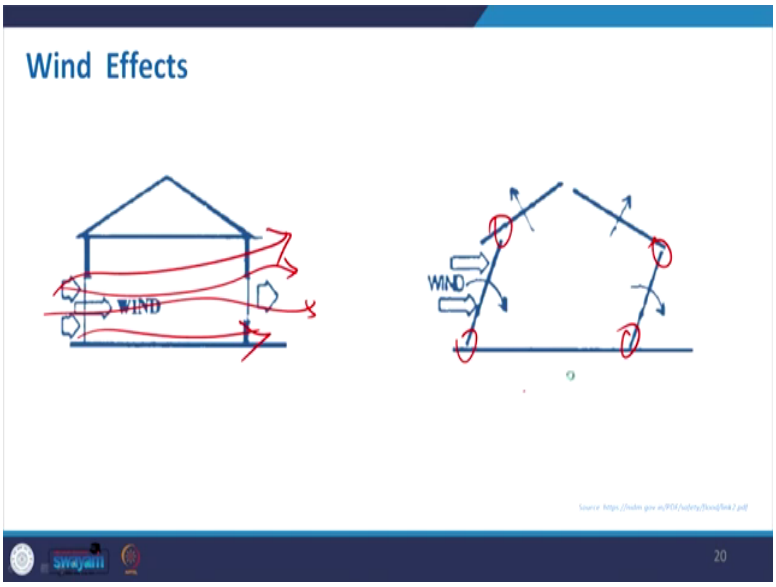

Coming to this option, as I mentioned that there is no suction being created; as because wind can easily pass. So, this is very important to know that, if we want to stop the wind it will create problem more, ok. More problem will be created, so it is better if we can pass, allow or wind to pass with a design, then it will be safe.

Now, if in this case like wind is being obstructed; like in this case this wall is very weak, but the foundation is strong, that is why it can get a deformation. But in this case the whole joints, like different joints from your foundation, then your roof to the wall is very weak and then that will have a total collapse.

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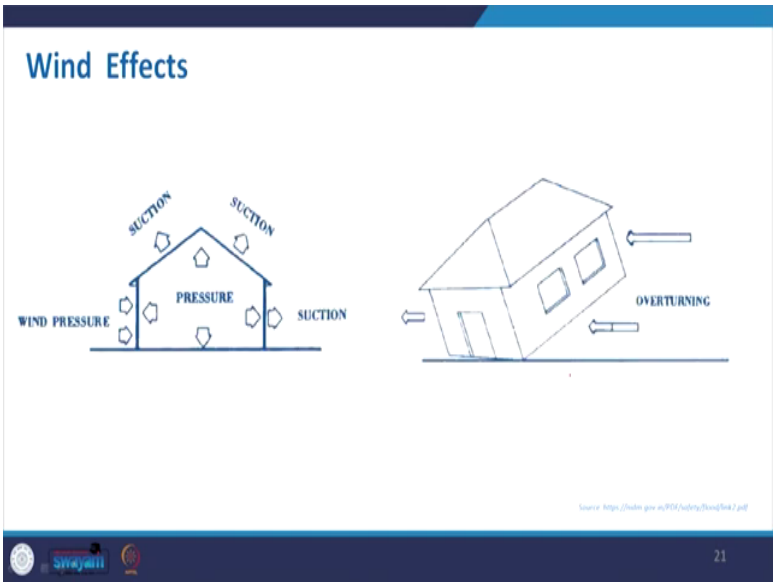

Coming to the other portions where like you will get this particular wind pressure in this direction and there is a pressure difference from inside outside; so that will create a suction and then basically this overturning may occur.

So, if wind is coming from this direction, so your building is supposed to tilt like this. So, something like this overturning will take place, where if you have rigid connection. But if there is some kind of poor joints; so first your roof will be blown away and then there will be damage to the wall as well.

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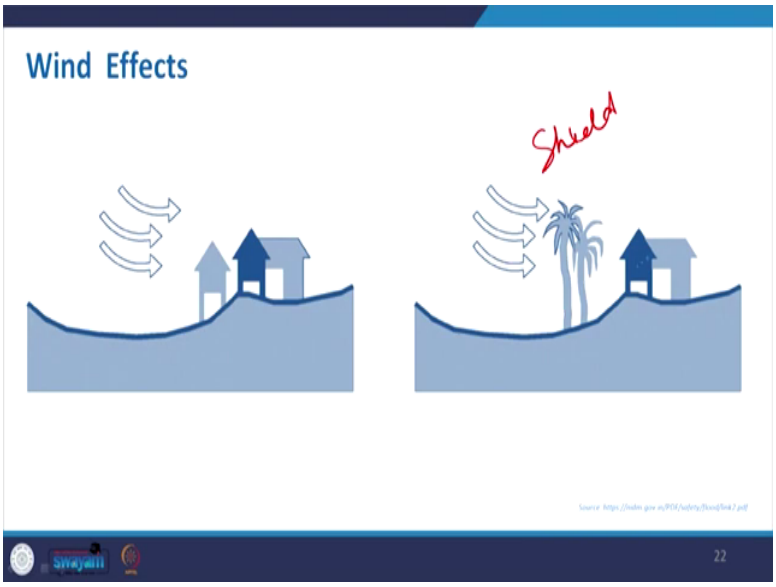

Coming to the wind effect minimization. So, in this case where you can just expose your buildings direct to the wind or else sometimes you can create a buffer or we can provide a shield with some tree which is very strong to you know resist against the wind, so that can also reduce the pressure and the damage will be less.

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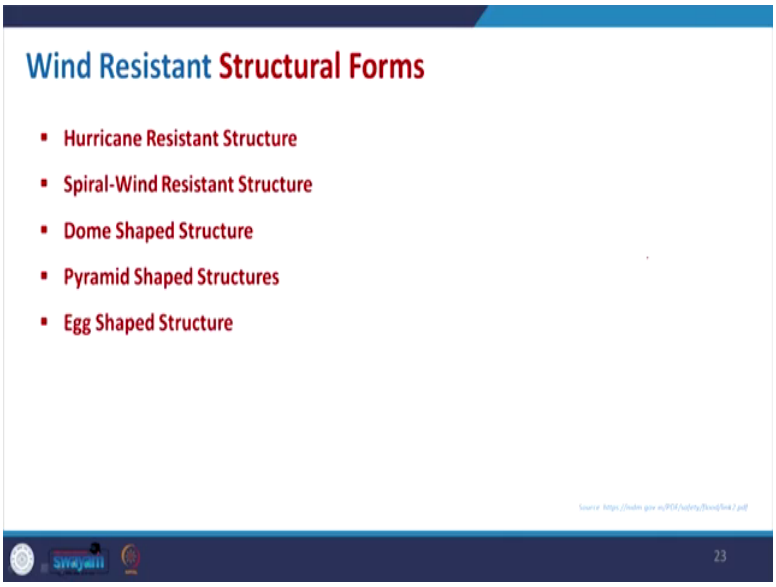

Now, based on this we understand that the form regular form that we want, the basic shape should be very much you know squarish or maybe circularly possible. And again with the height we have to really think of the aerodynamics and then we can you know make design for stall structure with such structural system, which can resist the lateral load due to the wind.

So, here I have just listed few types of a structural form pertaining to the hurricane resistant structure, spiral wind resistant structure; dome shape structure is another good structural form that will do very good with aerodynamic property, then pyramid shaped structure and the egg shaped structure. So, here I will I picked up one example; and again like my previous lectures as I mentioned that, you should also search for more example under this category and will exchange the idea, so that will be clear about what exactly the structure and for what it is.

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So, this is for the hurricane resistant structure and this is again a dome shape. So, it will really give a you know 360 degree wind for wherever the prevailing direction, so that can pass through. But more importantly this component, so this punctures been created where like if wind can pass through; so that will not recreate the negative drag pressure of the drag effect.

The backward portion of the opposite to the wind direction like it is compared to the leeward facet of the building. So, here it is circular, so this can be used or instead of that, we can have a roof something like this which is tilted, so wind can pass through and this particular roof can also help to wind to easily pass on this surface.

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Coming to the spider wind resistance, where it is basically the tornado; in this picture we have seen that it started with this and then it is basically making a spiral and it is aggravated. So, taking the shape, the aerodynamic shape can be taken up.

So, there is a building of your; in this case this is the shanghai tower. So, there this particular philosophy has been taken to that minimize this particular wind load with the shape, so that may really you know reduce that damage and can protect the building from the lateral force.

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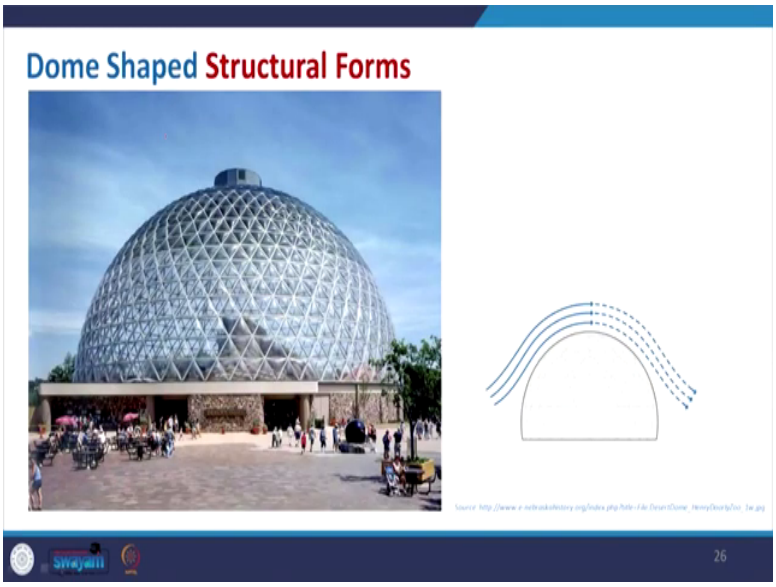

Coming to the dome shaped, it is always preferred for the windy area where you can have this kind of movement; where the wind from this direction can easily pass through and that will not create much thrust on the structure. So, this is one of the form architectural form that we can apply for the area where the wind is a problem and we can have a heavy wind special in the coastal region or something. Somewhere occasionally not every time or not throughout the year; maybe a particular time, where we can expect this hurricane or tornado, so this kind of structure may also help.

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Coming to the pyramid shape again; as because the wind is increasing, the pressure is increasing with the height, so if you reduce the mass at the top and then we just create this particular pyramid shaped structure. So, wherever wind will you know contact this particular aligned surface, so that will lift up and it will act like a mountain.

So, then that will not really create the problem with a plane surface. So, this is important parameters. So, where pyramid shaped structural form can also be used.

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Coming to the egg shaped formed. So, again it is a variant of the dome shape. So, where also taking this, so this is basically London city all, you can see the London Bridge here and then in this form this particular water body. So, whatever the wind will come, so that will take this particular aerodynamic shape.

And to explain that aerodynamic shape it is basically; if you see that, you know the profile of a plane, so basically the cockpit of the aeroplane. So, this is basically making this particular safe of with a curve where lies it can easily drag through, so that will not create much thrust on the surface. So, taking this similar concept of this linear you know, the propeller and then this curvature; so this kind of egg shaped, oval shape or the domical structure is preferred in windy area.

Now, coming to the end of this lecture what we understand from this discussion that, yes wind with a certain acceptable intensity or the velocity that is enjoyable or that will also help us for the better ventilation. But when it is beyond certain limit, it will be threat to the human settlement; and for that definitely depending on the structural form, structurally elevation, structural arrangement, it will affect, like it will decide the damage magnitude.

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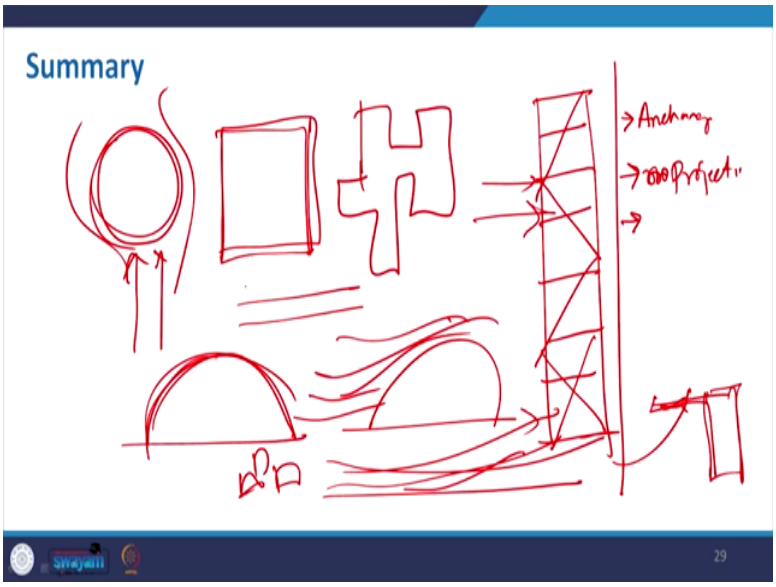

And for that, definitely it is prefer to have a plan like circle, where you do not have that much negative pressure been created. If not, try to make building symmetrical no or squarish form; not really very irregular or zig zag pattern that may be more prone to the vulnerable situation with the heavy load.

In case of the elevation, it is preferred to have a you know aerodynamic shapes which may be domical semi-circular shape or it may be egg shaped depending on the prevailing wind

direction, so this may done. And whenever we consider it for the high rise structure and we will discuss that in detail; so then along with your regular member, so what we need to add some diagonal bracing which will make the structure more, adding more stiffness and then that will also resist again the lateral load created by the wind.

And we have seen some of the examples of for the building form, which we can apply for different purposes or make that you know resistant against the hurricane, again the spiral wind resistant structure that we have seen in the shanghai tower.

And then a few things we have to remember, that is you have to maintain the good anchoring of all the structural component; specially for the pitched roof, roof to wall, wall to foundation that anchoring should be proper. Then they are not and then the projection; projection we have to take care, if there is a projection which is not properly designed or not properly anchored, So that may create some problem.

And then again the material that we select that also depends like that, also will determine that how devastating the outcome will be with the globe wind, high speed wind. So, the proper material to be taken whether it is RCC or whether it is a steel frame, so that cladding should be done in a proper manner.

With that we can make our building structure more resistant again the wind like as much as possible. And also what we have seen in normally wherever you have the plane land or you know empty land, the wind can easily get the density; but whereas, in zig zag pattern of a building in a very close urban area, so wind will not really get the path and then it is will not really, zig zag pattern will not really allow wind to increase the pressure. And then where is row pattern is basically increases the wind and it creates the tunnel effect.

So, these are something where the individual level or at the arrangement of the building level we can think of and we definitely should follow some guidelines; already available in Indian standard or maybe other guidelines which are available. So, what I suggest that, with this basic information you just go through the link and there are few guidelines provided by different you

know state level government disasters, you know risk, deduction and department they have publish some of the reports.

And then from those reports guidelines, definitely we all will get benefitted and we can apply that knowledge wherever we will design something for a area, where the wind is definitely a issue; not even if it is not for throughout the year, maybe in particular season maybe in between summer and your rainy season.

So, with that I conclude this lecture and like this we will be continuing with the next topic that is your structure and architecture form in seismic area, where the earthquake will be taken as the parameter and then how like what are the effects of the earthquake. And then how we can make our structure earthquake resistance for a normal structure, low height structure as well as the tall buildings.

And to be specific to the tall buildings, we will have different discussion; we will have some lectures which is upcoming, where we will discuss about different high rise structural system. There we will also touch upon the advantages and disadvantages. But prevailing the next lecture, we will focus on the seismic effect on the building design, building form.

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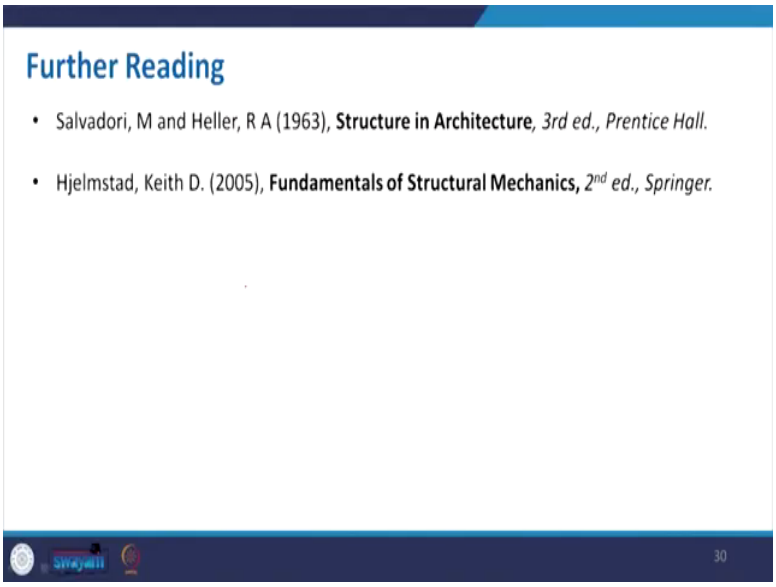

And these are the study material and also not restricted to this two reference; I have given the link where from I have collected some information, you can always browse through that to get more to that and you can get some more insight from those document. So, with that I would like to thank you to take part in this course and we will be waiting for you for the next lecture.

Thank you very much.