Sustainable Materials and Green Buildings
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Lecture 33
Urban Heat Island: Urban Canopy Layer

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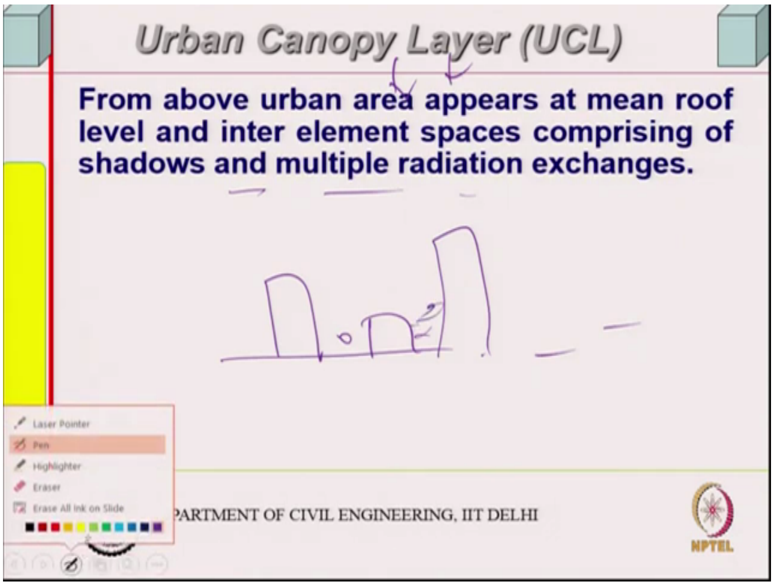

Alright, so continue with urban canopy layer. If I look from top take a top view right, the urban area appears at mean roof level because in an urban area we will have some buildings, some buildings etc etc you know this is, so we look from top somewhere view it from above, I will see the whole thing at an average you know mean roof level and ofcourse the other would be the inter-elemental spaces.

So, you know like from satellite or something one can look into this, comprising of shadows and multiple radiation heat exchanges. Obviously this will have lot of heat exchanges, right.

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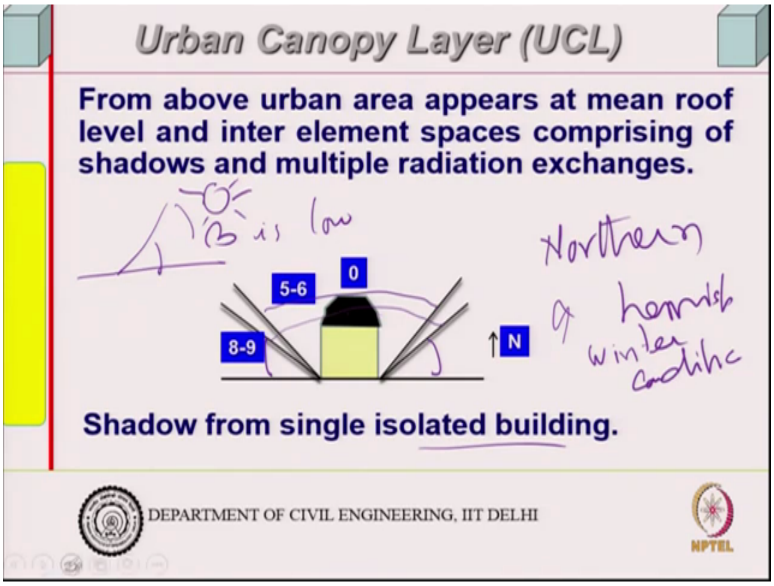

So, for example if I have a single building, for a single building, isolated building, this is the north direction and it is in northern hemisphere, you will find that this is the zone, this zone and this zone you get sunshine hours 8 to 9 hours, right

So if you are seeing from top you will see the you know if there is a single isolated building and nothing else just hypothetical then you will see this area shaded, you know will see sunshine hours less than 8 to 9 hours. For example this zone 5 to 6 hours and this blackened portion it would be shadow for most of the time because sun is this winter condition. So winter condition let us say, winter condition right, top ofcourse will have all the time the sunshine, the sunshine hour complete. But in winter in northern hemisphere altitude angle of the sun is usually low, this beta is usually low. Beta of the sun is low, beta is low.

So sun rays come from the southern directions and it is you know it is in the south, so it goes from east to south to again west and therefore shadow will be something like this, if you are trying to look from top you will see this pattern depending upon the time of the this is just an example for a single building.

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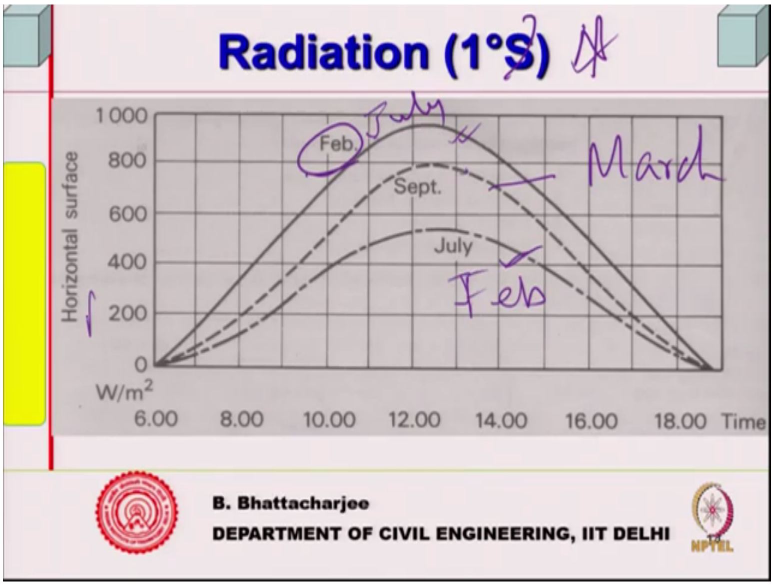

And we know the kind of radiation received, intensity of radiation received on various surfaces this is known to us. Now we are trying to see what causes what you cal first we will define ofcourse what is urban heat island and what causes them, so trying to be built up the background for all this.

So one thing is there is a shadow pattern and a mean you know urban canopy would be the mean roof level. So you will see roof level shadows and sunshine this is a kind of pattern that you will get it and this will vary from time to time of the day and radiation quantity of radiation received is also different depending upon the surface that is there right.

So, if I look at it that says this is radiation of 1 degree south latitude right, so this is in month of July in watt power meter square, month of July because July will be the, July will be actually winter in southern hemisphere. Now if I am I will just make the northern right now here itself I will change it to northern, this is ofcourse September, this is in February, this is the summer, right.

So, southern hemisphere the sun bends on the northern side. Now if I change this to north, this February will become you know if it September okay can be March, September will turn to March, July will be somewhere during January or February and this will be more of July or June, this will be July. So this will change in this manner, so you get lot of radiation during the summer time but in equator this is on horizontal surface, horizontal surface is shifts in this manner right.

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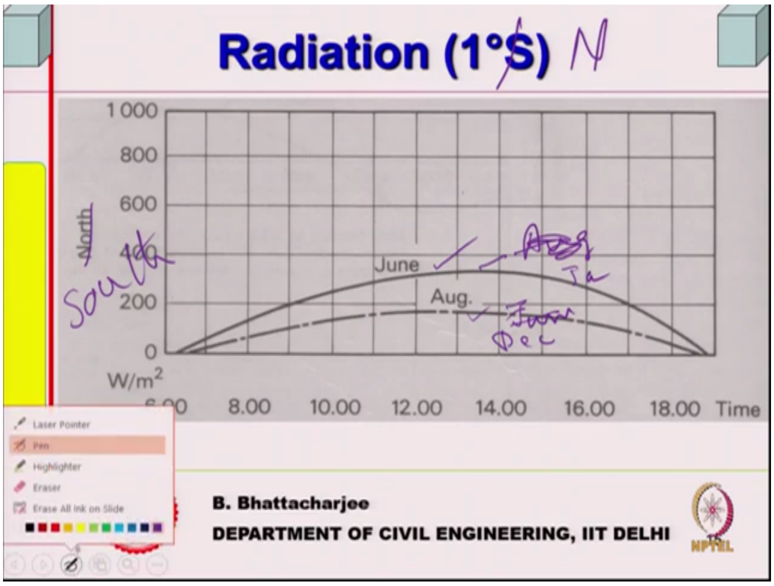

And if I come to on north surface 1 degree south latitude this is your winter and this is the summer. Correspondingly if I take a north right, so this would be basically August and this would be this is 1 degree and this should be south surface now, this would be you know June, sorry this will not be August or June sorry this will be in fact this will be January, this would be December and January summer during you know winter months basically December and January.

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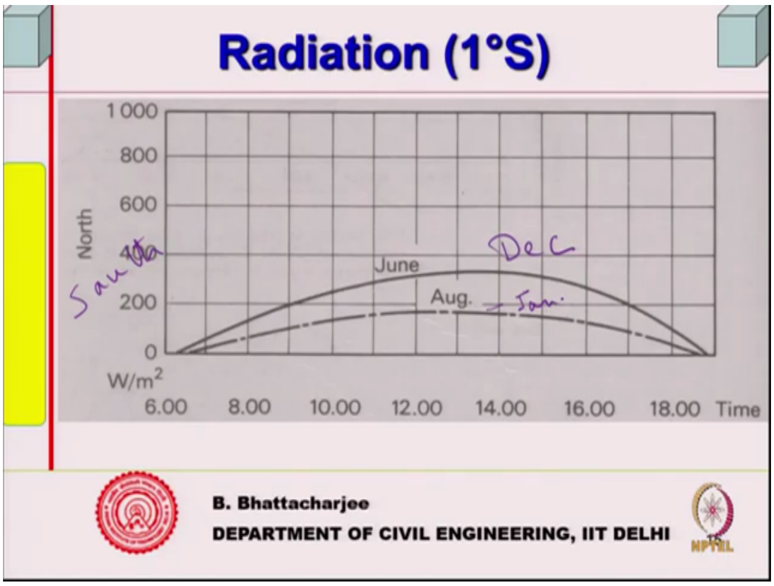

So it would change to this, so this would be south first of all and south will receive more radiation during the this will receive you know this is December in fact and this would be sometime in January or so, so you would actually you will get more radiation on the southern surfaces in the winter, right and that is how it is.

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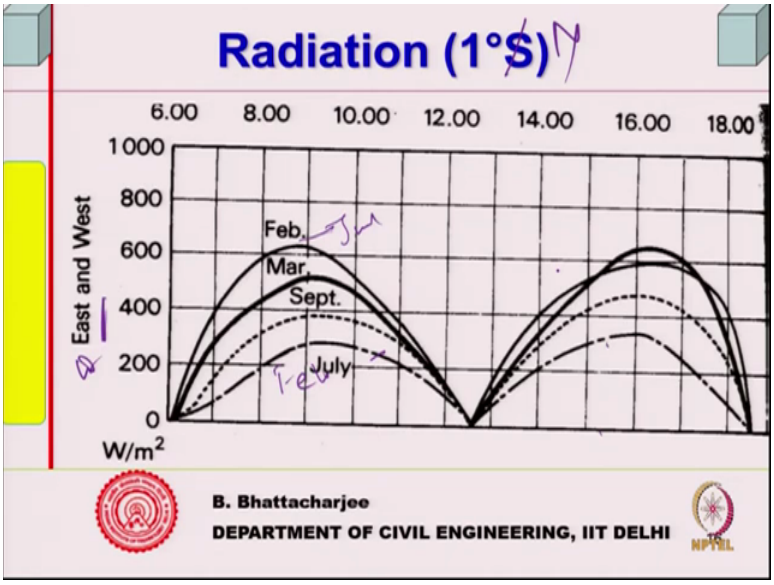

Now, east and west surface this will just get change to west for east and west in morning you get it always, so this you get in the July, this in the February for 1 degree south. If I make it 1 degree north this month will change, this will become February, this will become July and this surface still east and west it will remain same, west will remain same but only months will change. So, you see know close to the equator you get a radiation pattern.

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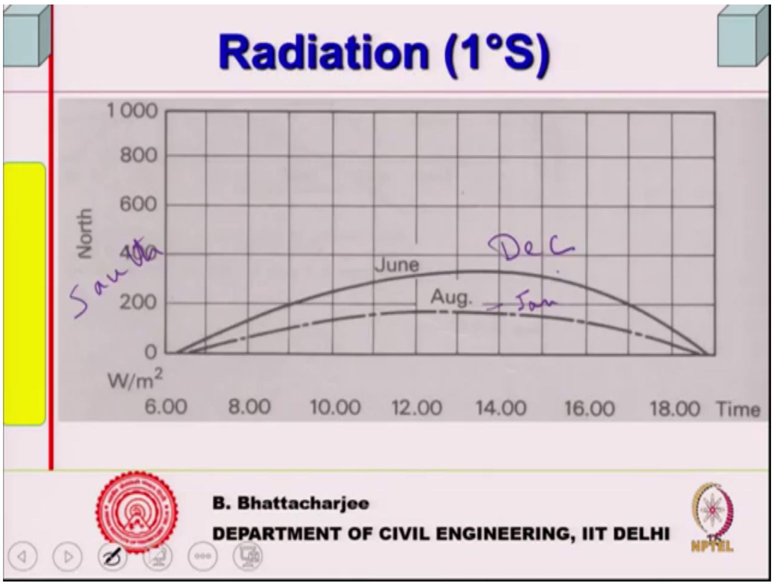

Which is not to far different in the surface which receives sunlight, it is not to far different in you know it does not vary too much, if you are close to the equator.

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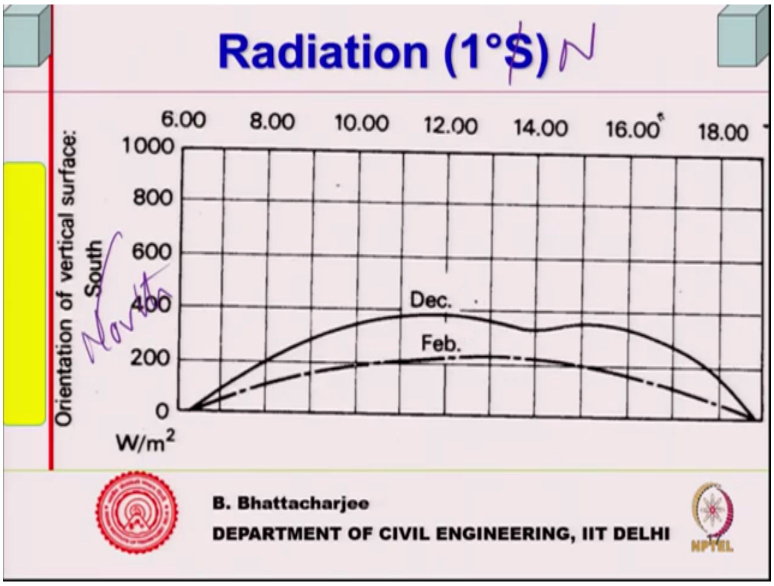

But if you go away from equator let say same one you know this was a ofcourse south surface, so this is north surface in northern hemisphere 1 degree north, this will become February, this is December months will also change accordingly. So, if close to equator north and south surface both gives us the radiation and winter as well as summer some radiation and east west both gets radiation.

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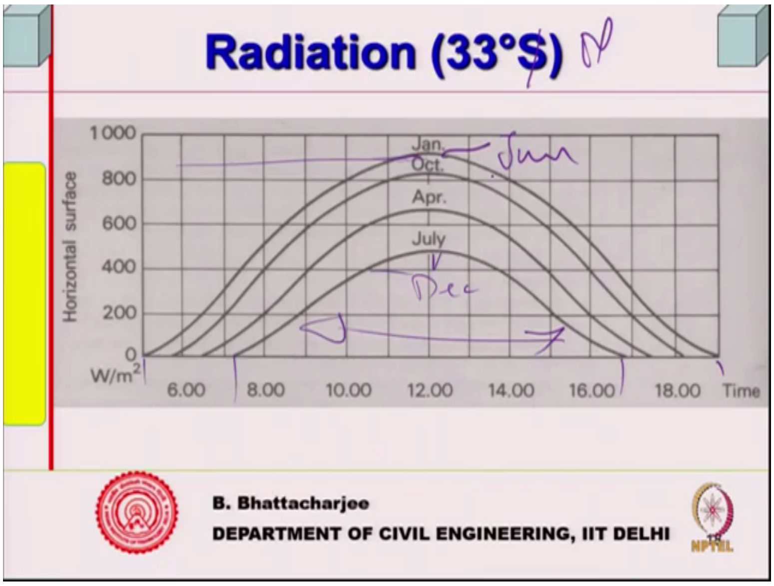

But if you come to radiation for 33 degrees south, compare to that on horizontal surface this January will ofcourse corresponds to now June for north and this would be for December right. So what happens is winter you receives much less you will have much less sunshine hour and much less intensity of radiation as well. In summer the sunshine hour is longer and you know sunshine hour is longer and radiation intensity is high.

Now 33 degrees south in India of course Indian subcontinent or northern hemisphere will corresponds to in India it will be summer corresponds to Srinagar or some such place, 32 degree is Srinagar so around that zone, so Leh or similar sort of places, so where you get lot of radiation in summer. So this is for horizontal surface.

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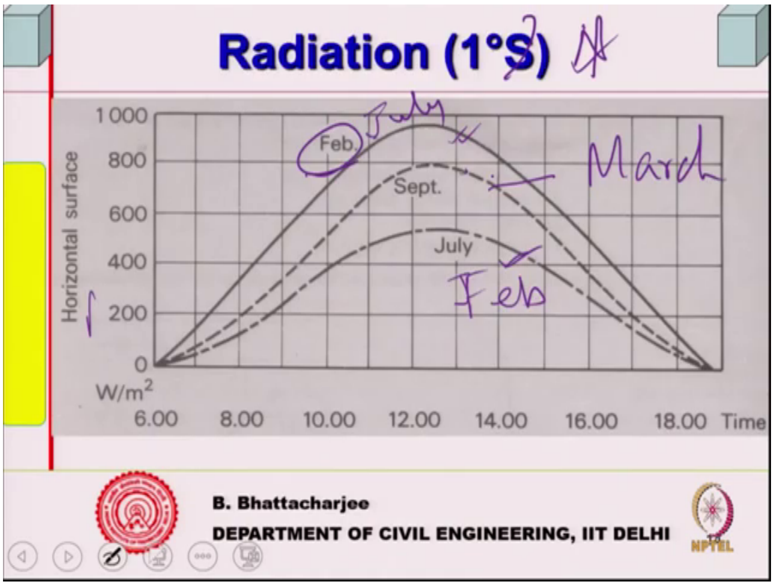

Well this was almost uniform in 1 degree, in 1 degree it was almost uniform not very different you know in horizontal surface sunshine hours are more or less similar right.

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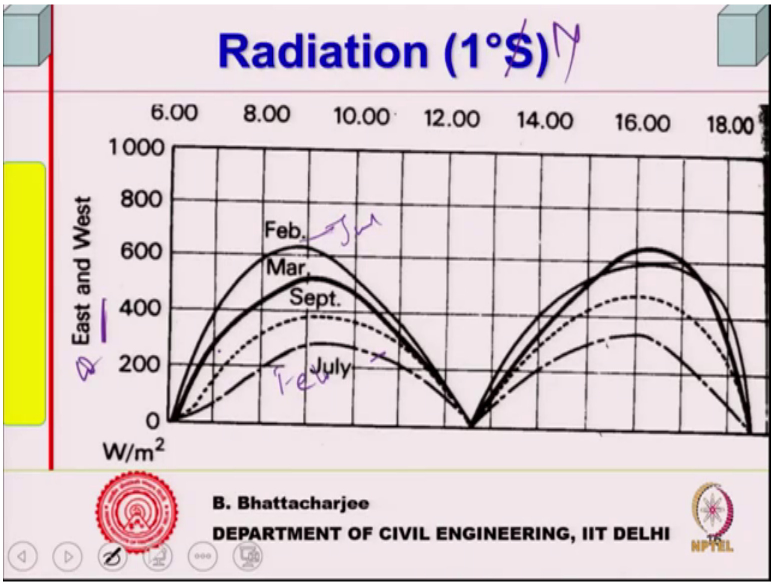

And away from equator at latitudes away from equator you find radiation pattern changing, summer you receive more radiation, winter you receive less.

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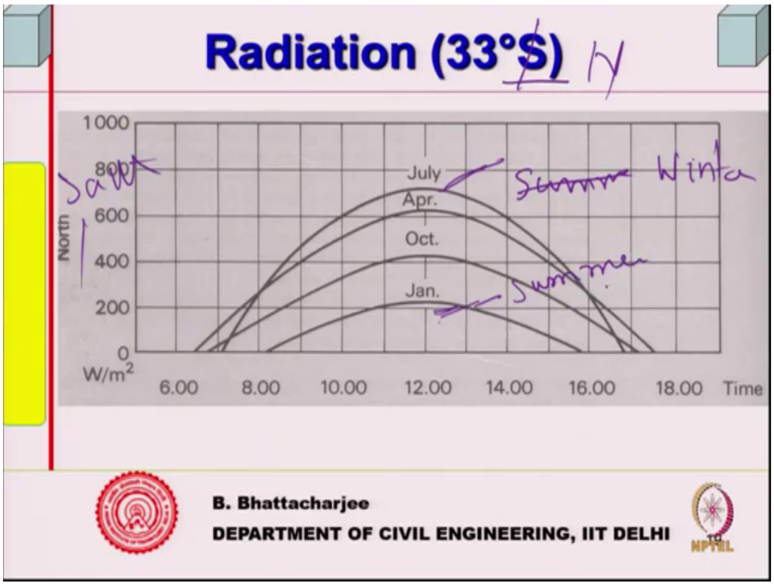

And on north surface in case of 33 degrees south is you see the it receives maximum radiation during their winter and minimum during summer and if I change this to north this will change to south and this month will (change) you know this will change to summer month, this will go to, sorry winter month this will go to winter and this will be summer months. So, somehow you receive south surface receive radiation during winter maximum, so this is a radiation pattern.

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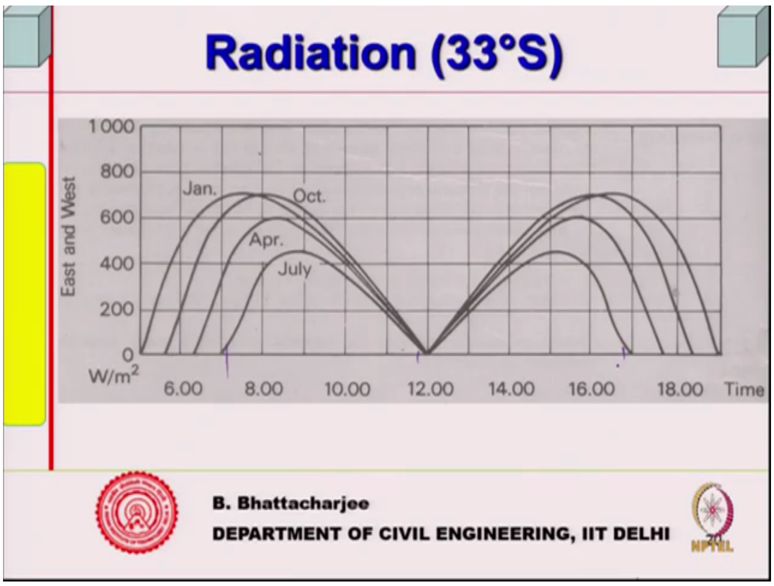

And east west ofcourse will be similar but hour should definitely get reduced because sun rises later, sets earlier in winter.

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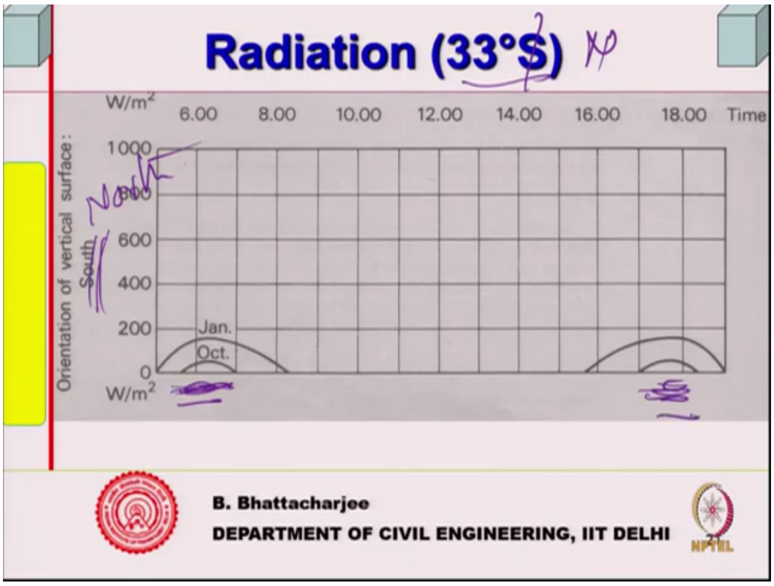

So, that is how the radiation pattern on east and west and north surface I means south surface in 33 degrees south receives only small amount of radiation during summer period because days long, so sun rises slightly beyond east that is some of little bit on the south in case of southern hemisphere, in northern hemisphere slightly in the north.

So actually sun rise it will not be 12 hours but sunshine period is more than 12 hours. So therefore north gets receives a little bit of sunshine in the summer period and I means we east gets it and west as well you know known I means sorry not in north. In case of northern hemisphere it will receive something in the morning and something in the afternoon in summer time.

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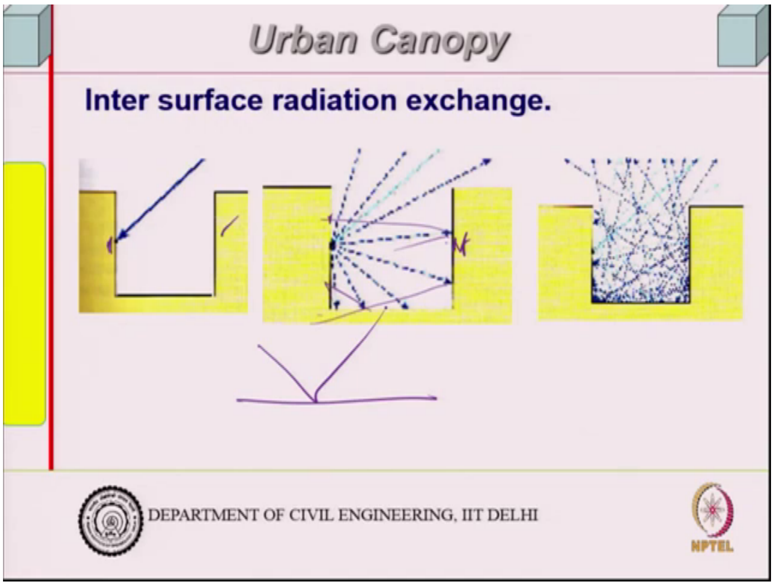

So, this is how radiation patterns it is, so we see that radiation intensity varies depending upon latitude although I am not going to calculations but we can actually calculate the out and depends upon what you called day of the year or month or whenever it is present in day in the month but it varies and also varies its latitude, varies upon its latitude the orientation of the surface and so on.

So, actually if I look at it I will have surfaces like this right, so sun's beams radiation is following like this. Now this radiation will then reflects supposing I have another building here, I looked at single building earlier. Now if I look at 2 multiple many surfaces I have now it will get reflected here and actually it will have large numbers of inter reflection. Because this reflection will be again depending upon the angle of incidence will go here, this will go there and there will be infinite number of reflections.

So, this energy in a way in every time it reaches here, some of it will be absorbed by this material, first directly this will absorb and after first reflection and the second reflection this will be absorbing this and the third reflection again this will be absorbing this, fourth reflection this will be absorbing this. So all the you know it almost get contained into the surface. Supposing it was a horizontal surface it would have gone in reflected and in an urban area you have got large number of buildings therefore inter reflected radiations, reflected inter reflected energy that literally some of it gets absorbed or trapped into the urban area itself, trapped into the urban area itself right.

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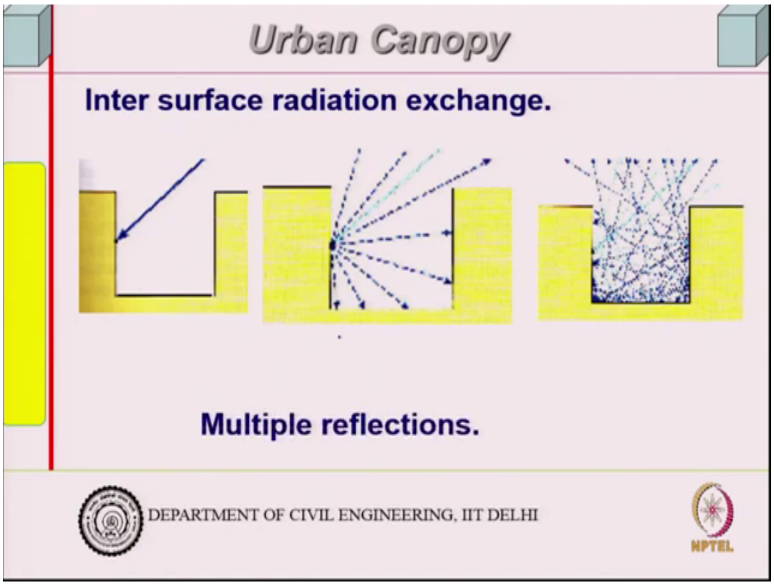

So, although its quantity etc so varies, so depending up which orientation it is facing what is the h by w ratio? It will depend up on that and one can model this, but I am not interested in modeling the same thing, here I am introducing this subject to you. So multiple reflections occurs so that traps the energy right, so you know so that is what it is.

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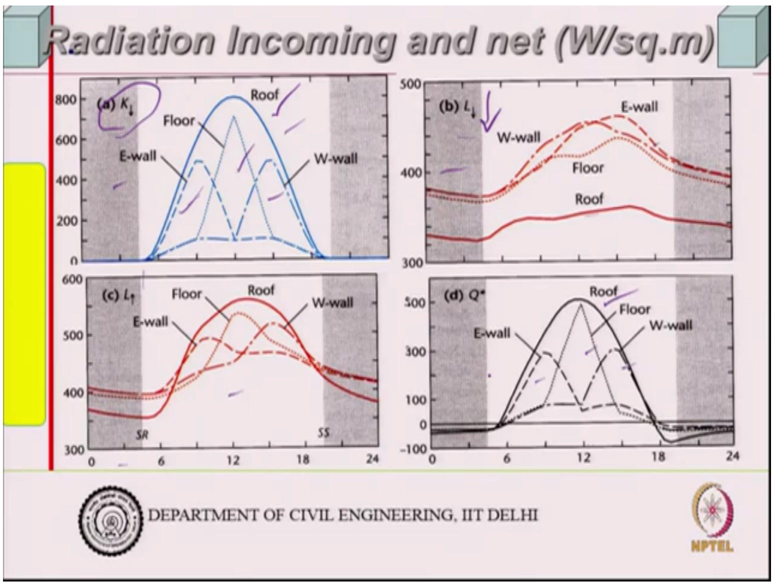

So, incoming short wave radiation if you recollect, we had the roof this is for northern hemisphere, west wall, east wall, floor this is what the short wave radiation incoming short wave radiation would be. Incoming long wave radiation because whatever coming from the wall, whatever is coming from the wall from a taller building to a nearby building right on a horizontal surface or roof you know it will come some of it and it might come from east wall, so typically on an average this is the long wave radiation which will be received by surfaces as well.

So this is time of the day, this is actually time of the day starting from 0 to 24 hours you know I mean not in between only it is there, so this will show you 0 to 24 hours right and we can typically we can look into the amount of long wave energy that goes out. So this is short wave received and long wave energy but whatever will be given is long wave because earth cannot either reflects or radiate short wave radiation at its temperature of 288 Kelvin.

So, it will give away, so this is what is long wave radiation received, this is also short wave radiation received, this is what it will give away typically this can show roof receives maximum obviously at the roof level or an average basis, walls that is west wall, east wall and this is the floor right, this is the floor because floor will gets some radiation may be coming through windows or whatever it is, so that is how the radiation received will be.

So that is why we you know previously as we said we found that different surfaces at different latitude receives different kind of radiation, this is ofcourse on an average basis anywhere typically right and there will be so short wave radiation it will be receiving and whatever it will give away is all long wave radiation depending up on its temperature right. So, roof will give you a some radiations and so on, and net effect therefore is something like this, net effect is something like this, So roof receives radiation, floor receive some radiation, west wall and east wall receives radiation this is our all in northern hemisphere.

So, net Q that we have talking about, so this is K which I defined earlier, L coming in, L going out etc-etc, on an average basis without going into the details and one can actually estimate this out, you can calculate this out based on heat transfer only I have given you the basic fundamental equations and that is all if you know average (())(15:35) and all that specific building one can model it very easily.

But when you want to do for a larger area it becomes things will become complicated or atleast computational time required will be very-very large, so you have to actually handle it in such a manner that it is actually you can do that but one can arrive at this kind of (()) (15:53).

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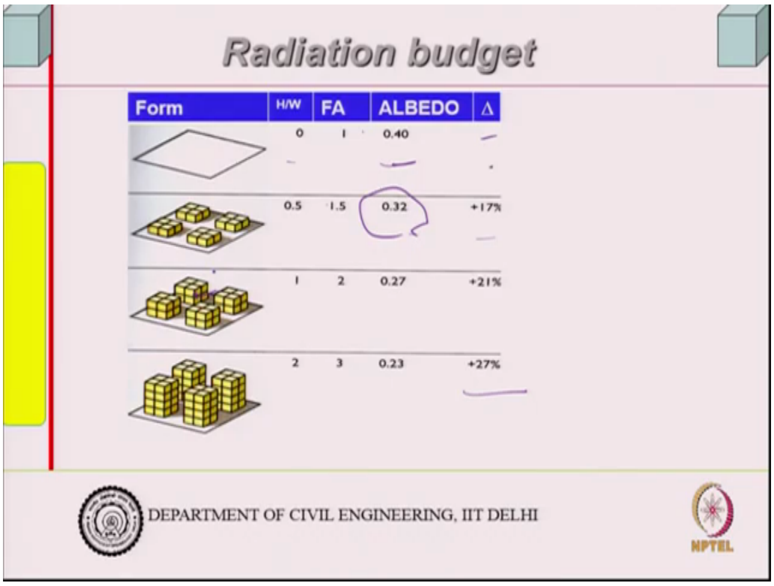

So, from you know this kind of if I have now urban pattern if I look at it form, this is a flat surface, this will ALBEDO could be 0.4 soil etc we talked about. But if I have this kind of surfaces you know this 1.5 percent is the total surface area now right and ALBEDO will now reduce, ALBEDO will reduced because good lot of it will get absorbed amount going out will be reduced some 70 percent reduction delta change and if you have more buildings there will be more absorptions further absorbtions.

So that is how urban area tends to absorbed the heat. Now this if you can understand that what we talked about because suns radiation receiving here, here of course it shows shadow so sun's radiation received here will be reflected there you know reflected back mutual reflection and all that long wave radiation, so net effect wil be something. Of this kind, right. Net effect will be something of this kiind

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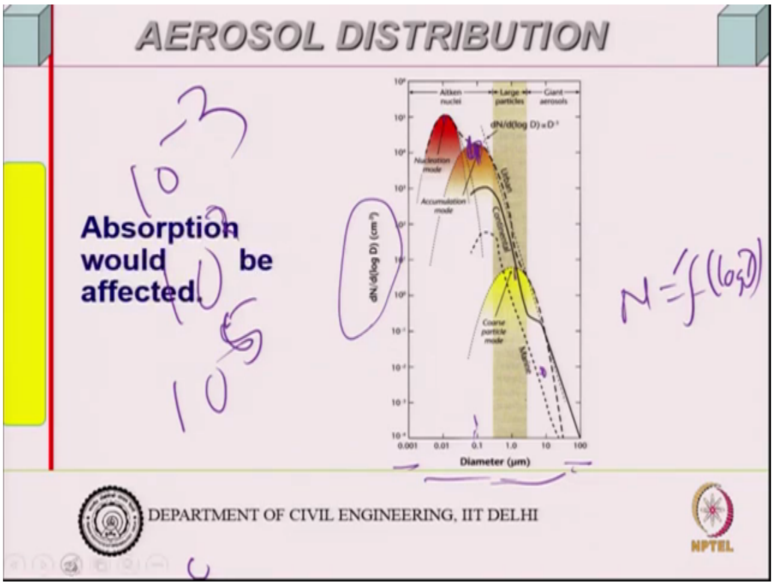

AEROSOL concentration if you look at it, this is diameter versus number of particle, usually particles size generally they vary from if you look at from 001 to 100 in micron or whatever you need to you take, so it is actually 10 to the power you know variation is 10 to the power minus 3 to 10 to the power plus 3 or you know so something like 10 to the power 5 or 6 it will vary 5 or 6.

So it is not worth wile plotting in linear scale, it is more convenient to take them in log scale. So this in log scale, semi log graph and you see DND log diameter one can (())(17:51) so is a peak, so maximum number of particle will be here because you know N as a function of, function of log D, so DND log D where it is 0 the peak, that is the maximum number of maximum particulate would be there, so you can see urban area AEROSOL is very much here, nucleation mode is ofcourse is somwhere there and its particles size is somewhere there and variant condition is this Cos particle is this, continental and so on.

So you have urban condition is somewhere there right, so AEROSOLs concentration of this sizes are very high and that is why absorptions would be you know absorption there would absorb as well, so this will affect the absorption.

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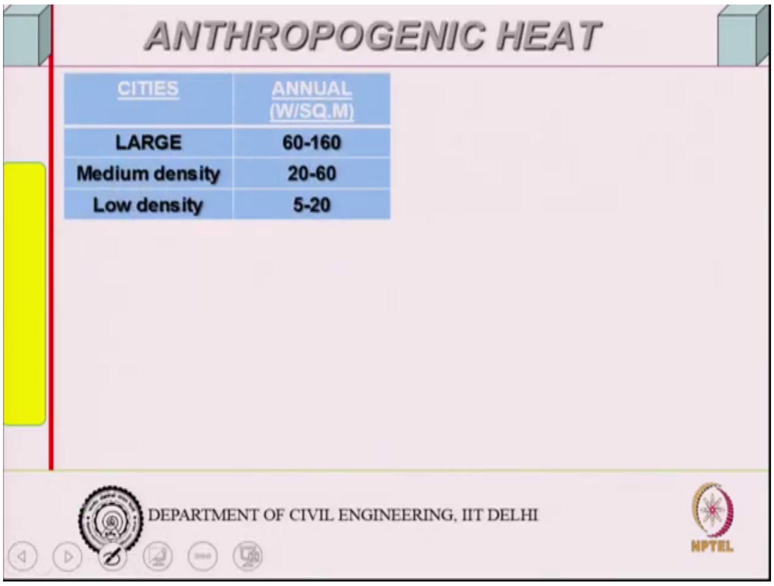

Now next issue is besides this radiation that we get it we also generates some heat.

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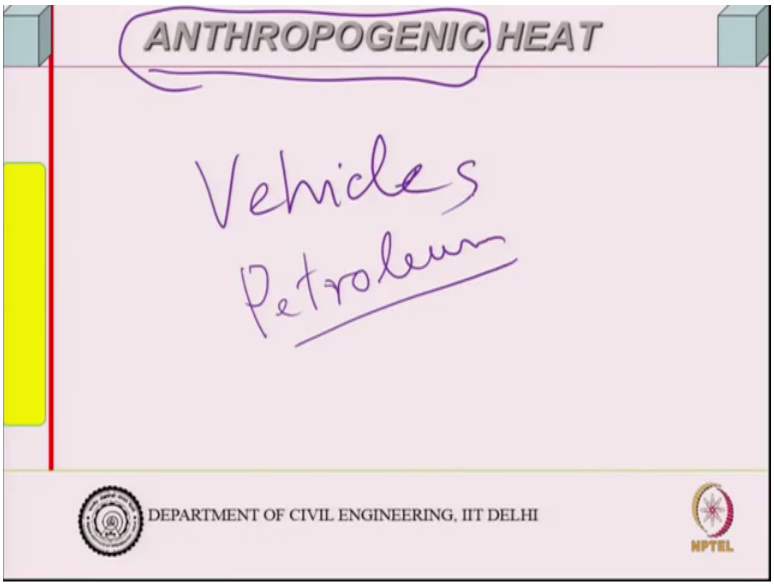

Vehicular traffic, our appliances, so this are called Anthropogenic, the one generated by human being.So in addition to whatever radiation I am receiving there is Anthropogenic heat generation as well. So both together causes increase in the temperature or delta T so you know this is also, this is a further addition of heat that is on.

Now this one can actually get some idea about them because we know for each type of fuel for example you know petrol, you know petroleum, petroleum, petrol, petroleum or diesel or hydrogen, how much energy they generate fuel value etc are known to us some idea one can get it, but I am not interested giving you in detail one can estimate it.

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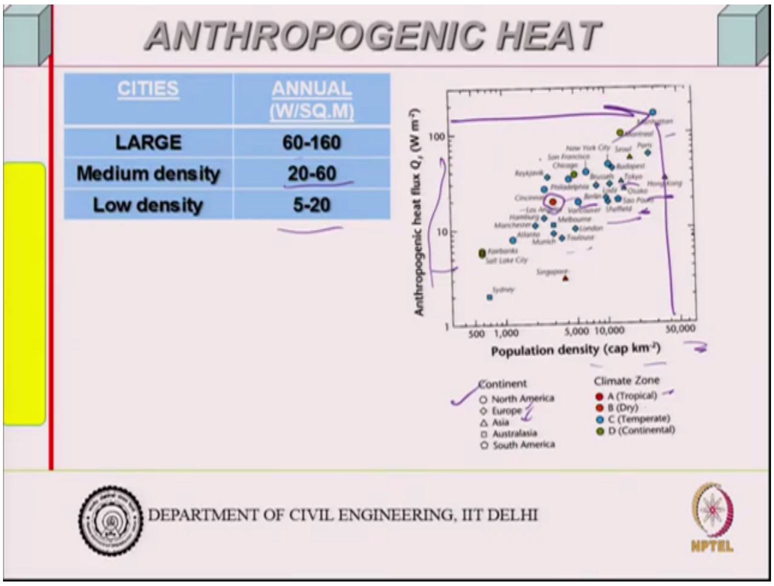

But typically large cities 60 to 160, what per square meter annually. It will vary from summer to winter because depending up on the location latitude or social condition also so it will vary from country to country. In case of tropical countries possibly where the lot of air condition if it is used, you know the country where relatively more developed or area city which is using a lot of air condition units some are Anthropogenic heat generation might be very high, compared to winter because air condition should generate that heat and medium cities density medium, density medium density population 20 to 60, low density 5 to 20 watt power square meter.

So it varies, the values of course is density depends up on the population density and a society, kind of society as well, but you generate some. So this is typically per capital per kilometer square population density in terms of person per kilometer square and if you have high population density Anthropogenic heat flux, so this is somewhat for the American case they had the data available right may not match with the Indian scenario of the values because we do not use that many numbers of vehicles as they do.

But you can see where the population density is high, this value is also high. Well this pattern would be true, pattern would be true in any place where it will also depend upon kind of income of the people expenditure capability of the people.

So you can see that this is some them are European, Berlin for example this is a south pole or Latin American Philadelphia Sin scenerty Los Angles I am trying to see if there summations there will be 1 or 2 may be London, Melbourne, Australia, Hong Kong yeah so Tokyo, so these are you know wherever data is available. So generally ten to worldwide it tend to show an increase this is north America, this one Europe is the triangular ones, Asia is sorry Asia is triangle, Europe is the square once, Tokyo and this is tropical this is tropical Los Angles, A is tropical, B is dry so this climatic zones also they have given.

So it will depend upon that one can get that one can get that you know one can get some estimate of this from budgeting actually you know how much energy you are consuming whole year electricity consumption from. So those kind of data one can generate but the idea is right where you have higher population density were likely to have more Anthropogenic heat together with what we have seen naturally coming.

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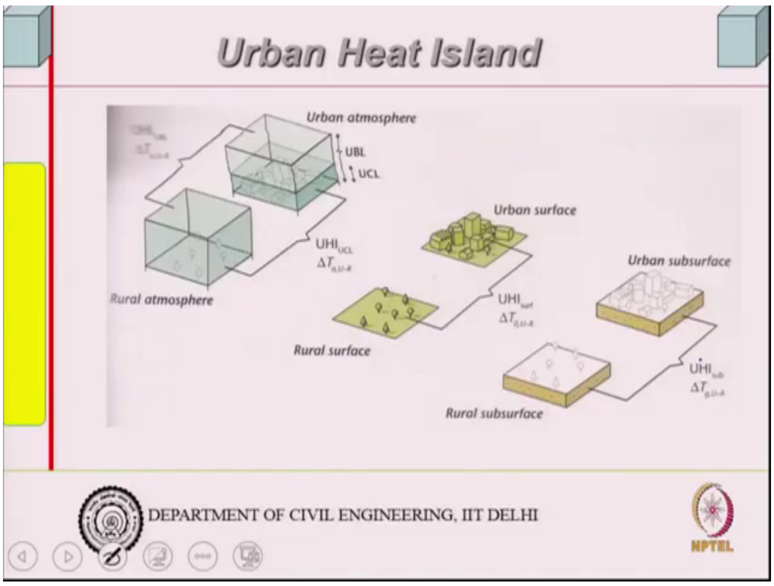

So therefore this results in what you call urban heat island, right.

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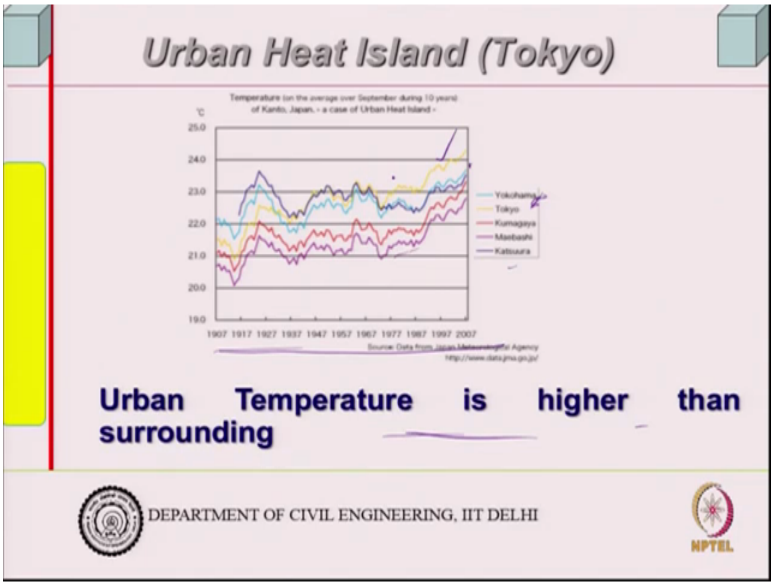

Okay let me see if I have a definition, urban temperature is higher than surrounding. We have seen that sometime earlier we have talked about micro climatic effect, there are several other effects ofcourse that can affect your wind moment and so on which I did not discuss today but this heat issue that we are looking at.

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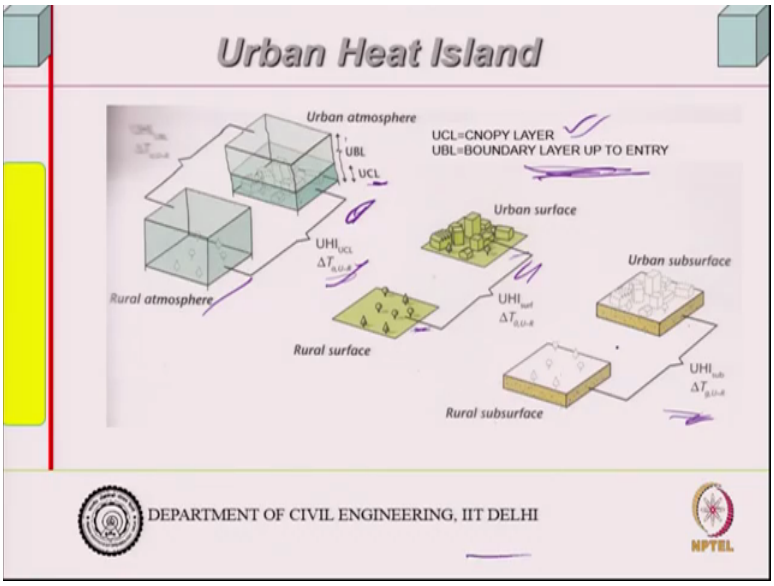

So usually delta T is the temperature, this is the rural atmosphere, this is the urban atmosphere. Now UCL is the canopy layer, this is the boundary layer and entry of the layer that if you consider a layer or a volume around the urban area the bottom layer is up to the roof level you know canopy layer is up to the mean roof level or possibly at the roof level and if you consider a layer above where it enters into the common atmosphere that should be boundary layer up to the entry point right where you know you can ensure you can consider the atmospheric boundary of that urban area.

So this is UBL and rural and this there is a difference between the delta T so temperature difference between urban and rural will exist. Here you will have you know so urban heat island surface also there will be there is vegetation, here you have buildings and sub-surface also there will be a difference in temperature urban minus rural because there will be you know moisture you would have taken out and so on so rural sub surface, so there is a difference between surface, sub-surface and the atmospheric condition as well.

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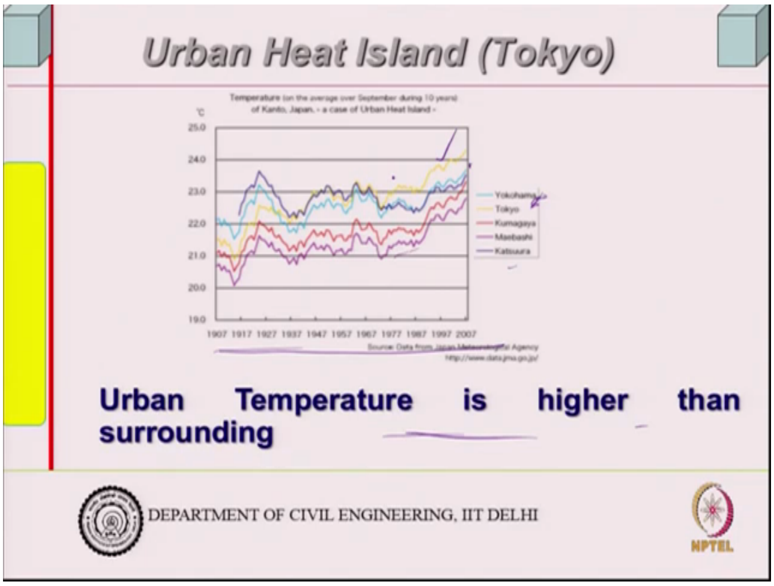

And this for example a data for Tokyo and its surrounding is available, temperature is higher, so this is Tokyo the yellow one this are its surrounding right, so this are the surroundings areas in fact this is also some (())(25:03) so this is nearby and surrounding have got similar pattern from 1907 to 2007 average temperature, right. Now this measurement data should be available and it shows that there is a temperature difference of the urban area and that is we realize also, depending up on depending up on the situation if you, you know the temperature in a urban area is much usually higher 78 degrees higher that times, so this is what is urban heat island concept, this is what is urban heat island concept.

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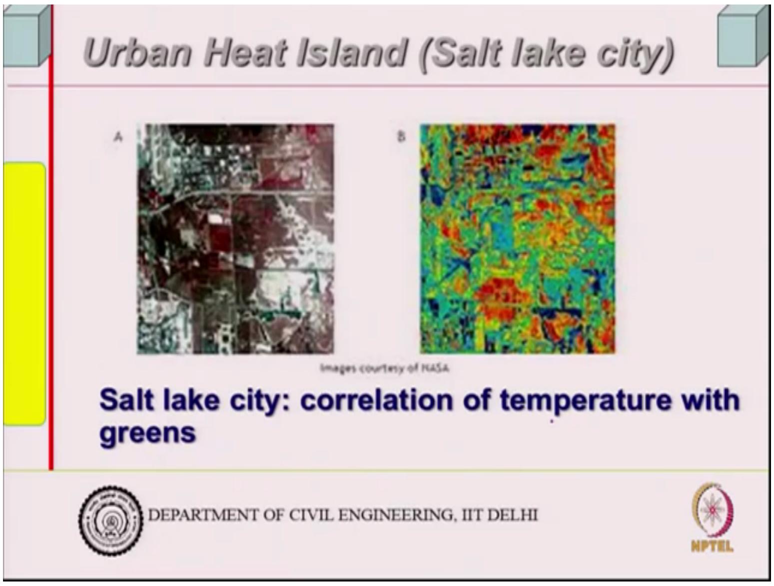

Now this is been also proved by you know salt lake city for NASA, so from satellite picture you can get ideas of temperature, the green ones show the vegetation, the red one are the warmest one which are the built up areas, so correlation with temperature with greens are easily possible from satellite data, so that gives you the idea.

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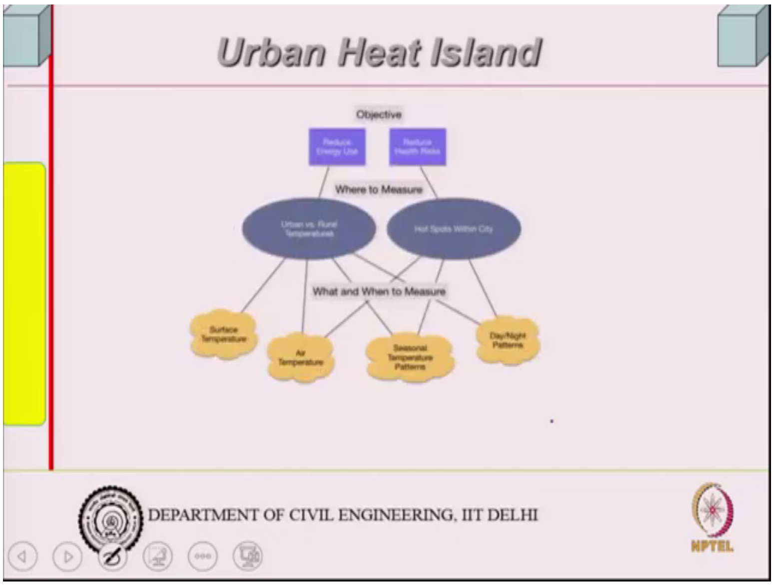

So there is a you know there is there is urban heat island. So how to reduce this if you want to reduce this?

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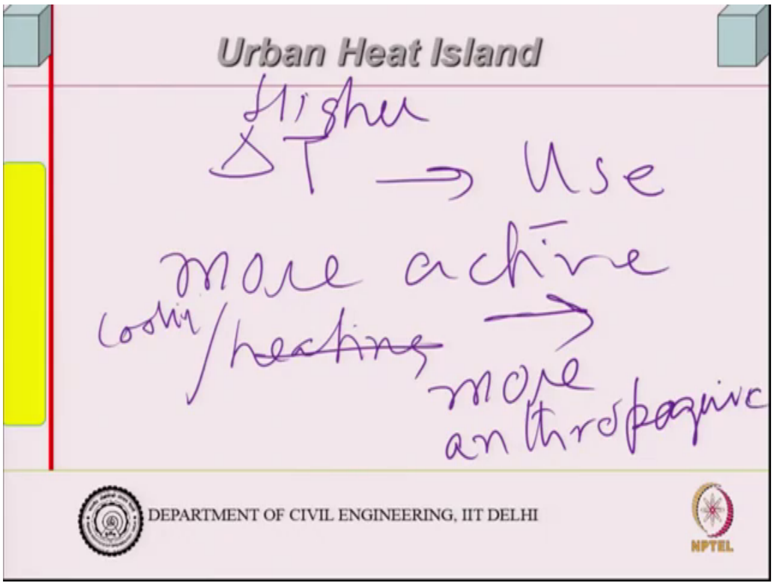

Because it has got a this has got an cascading effect, higher the delta T, higher delta T you would possibly try to you know make it use more use more active system heating or cooling system I mean cooling ofcourse not heating, cooling because high at temperature, so more active cooling system you would like to more active cooling system you would like to utilized right more active cooling system we would like to handle.

So therefore cascading effect mans the more active cooling system means the more Anthropogenic heat will generate, so more active more Anthropogenic and therefore it will have a tendency to increase it even more. So therefore we should we look into some sort of reducing this from overall urban point of view, individual building point of view we have looked into energy consumption and so on although we did not look into modeling but we have looked into some ideas related to that.

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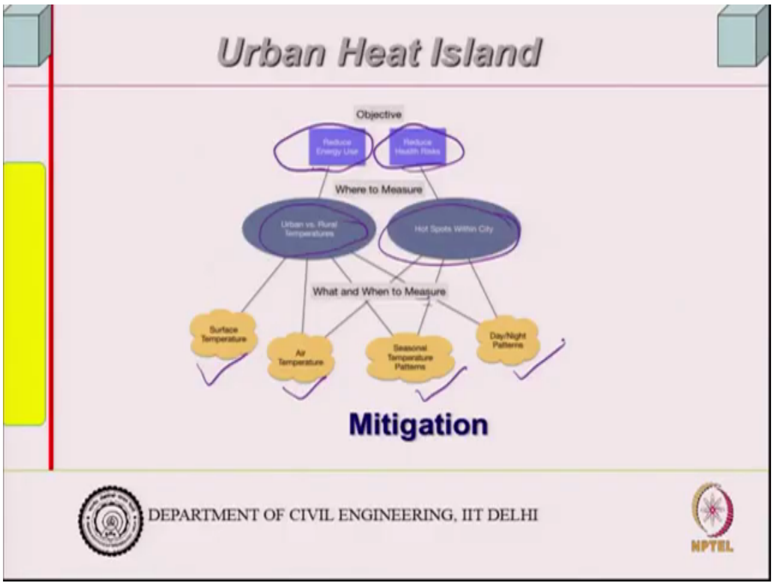

So basically objective is to reduce energy use, reduce health risk ofcourse right, so urban and rural temperature you can measure hotspot within the city you can measure, which has got highest temperature within the city itself. Then okay you measure air temperature, surface temperature, seasonal temperature, seasonal temperature pattern, day and night temperature pattern, so one can measure this if one is looking at it basically if you know that then you can reduced the energy consumption and all, right.

So mitigation is required I mean that would be good idea and mitigation strategy could be tree cell vegetation, how does tree does that that will see in the next discussion.

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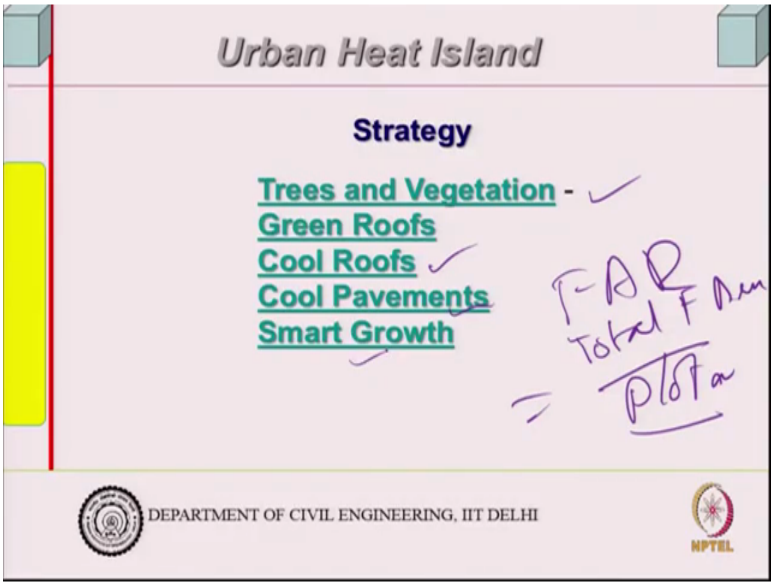

Trees and vegetation, well green roofs also one can concieve but there are problems with the green roofs, you have to through water proofing your construction system of the roofing system right, in a good quality construction, cool roofs you can have different types of passive concepts but some of them are not so easily, easily achievable then it lot of engineering or science or technology into it. But this can be easily looked into, so in the urban planning stage or urban you know urban not only planning stage at the urban you know if you are changing any urban pattern taking decision related to urban.

For example, decision related to change of floor area ratio in a city. The moment you change the floor area ratio as you can see now from our discussion you know you are making building taller if you increase the floor area ratio, what is floor area ratio? Floor area ratio of total floor area, floor area divided by plot area, so if I increase the floor area ratio in fact I am allowing taller building to come on the same plot population density will increase and not only that population density will increase and it will also affect the you know all kind of temperature rise and things like that, so urban heat island effect

Cool pavements, this can be done easily, relatively cooler pavement in the sense that you do not have everything concrete surface, where there will be a lot of run of you know and smart growth.

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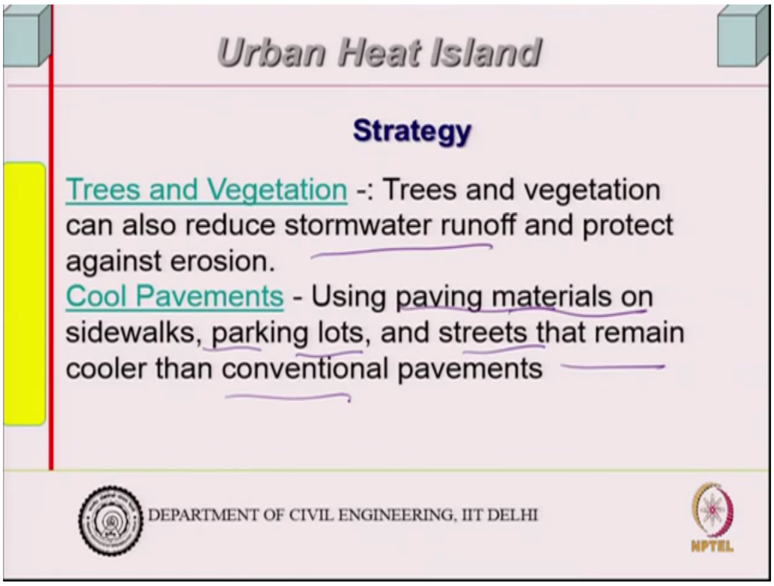

So, we look into some of that quickly one or two will look into trees and vegetation, trees and vegetation can also reduce storm water runoff and protect against erosion besides keeping it cool. Because we have seen from that temperature is directly related to vegetation growth NASA photograph that I showed you and cool pavements using paying materials on sidewalks you know.

Now pavements quite often people makes sidewalks even concrete pavement that is not the right thing to do, possibly if you do not want ofcourse the urban heat island affect and paving materials on sidewalks, parking lots, percolated concrete there are several options available that remain cooler than conventional pavements, so this is the mitigation strategy, I think with this we will close.