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NPTEL ONLINE CERTIFICATION COURSE

Refrigeration and Air-conditioning

Lecture-27
Infiltration

With
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I welcome you all in this course on refrigeration and air conditioning today we will discuss the infiltration. This infiltration is the infiltration in a building. In this lecture I will be covering first of all introduce you what is infiltration then driving mechanism of infiltration, how the infiltration takes place, air exchange rate and estimate method of infiltration.

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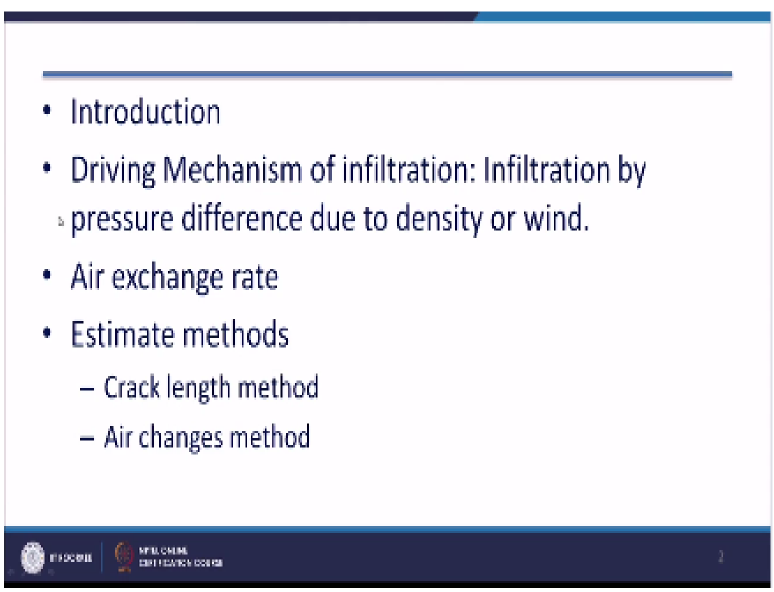

There are two method methods crack length method and air changes method. So we will start with the introduction of infiltration.

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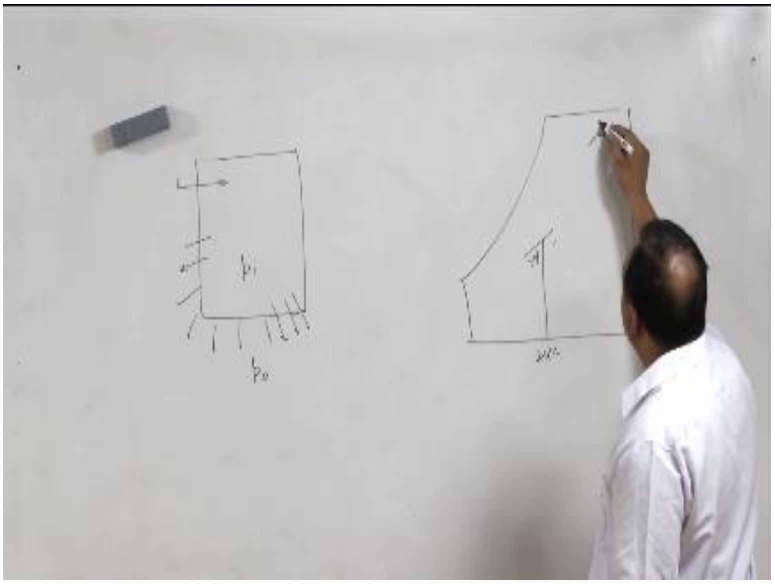

In any confined space for the purpose of air conditioning the air enters in the form of supply air which includes ventilation. This is desired entry of air in the room I mean ventilation is desired and there is infiltration also from different because a room is not a leak-proof entity no building is a leak-proof entity so there is always chances of entering outside air entering into the building and this is known as infiltration.

And sometimes the air leaves the room it depends upon the outside atmospheric conditions and inside atmospheric conditions when air comes out of the room that is also not desired movement of the air. And this is known as exfiltration, so there are two things infiltration and exfiltration normally infiltration in the confined space takes place when to ventilation in the room is essential without a ventilation the air-conditioning system will fail, it will become simply a cooling system.

Because through ventilation fresh air enters into the system and this fresh air keeps, this fresh air maintains the quality of air in the room or quality of air which is being circulated in the building. If we reduce this amount of fresh air this is a ventilation air then definitely the load of the cooling coil will reduce because outside air which is fresh air is in somewhere let us say it is available at 40-45ºC.

Instead of using this air if I use return air which is coming from the roof it is at 27ºC. So definitely if I do 100% recirculation 100% of the circulation of air the load of the air conditioning coil or system will be less, but and at the same time I will be losing the quality of air inside the room. And quality of air the main problem will come with the scarcity of oxygen and excess of carbon dioxide both have very harmful effect on the human health.

Normally it is witnessed especially where the population density is high like schools or theaters though the temperature and humidity is maintained, but the level of carbon dioxide is very high. Normally it is recommended that carbon dioxide should be around 400ppm and level of carbon dioxide in the occupancy should not be more than 300 of this may be let us it can go up to 700ppm.

But not in any case more than 1000ppm and that is alarming situation when it exceeds 1000ppm then its effect on the health are visible, people have headache first of all headache starts you will find many people who are sitting in a sea environment they have headache due to this axis of carbon-dioxide the feeling of nausea, cramps pain in the legs that is due to the axis of carbon dioxide.

And it has witnessed that in many of the places like schools or computer labs the level of the carbon dioxide is up to 2400ppm that is very alarming. So that is why ventilation in any building is very important. Now let us talk about infiltration regarding infiltration it is undesired flow of air in the building and because as without temperature difference bulk of the heat cannot move sorry the heat cannot transfer without temperature difference.

Similarly bulk of the fluid cannot transmit transfer without pressure difference, so there has to be a pressure difference inside pressure if pressure and outside pressure there has to be some pressure difference which will act as a driving force for the movement of air inside the building or take away here from the building to the surroundings.

Now how this pressure difference is generated, that is one issue and how we can prevent the infiltration of, infiltration of this air into the building, because infiltration brings the load on the cooling coil also. For example, inside the room suppose the coil room temperature is maintained let us say 24ºC and outside air is 42ºC this is 24 50% and this has some humidity let us say 6%.

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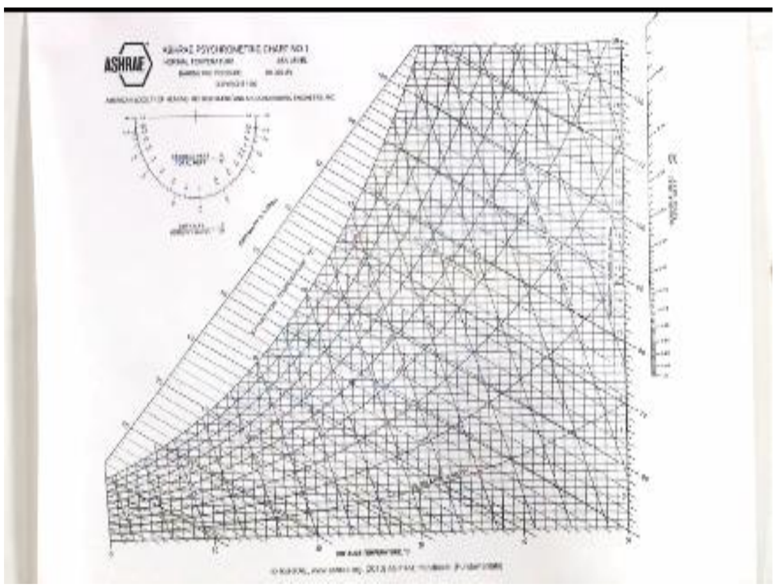

Let me take psychometric chart now here suppose this is inside condition not the air supply condition this is inside condition and outside air is available let us say 40ºC and 50% delayed or let us say this one or this one 50% relative humidity this is outside air. Now air available here enters the room it enters the room and after entering the room this air will bring energy to the room and this energy, suppose this is the final state this is supply state.

(Refer Slide Time: 07:23)

Now we will draw a horizontal and vertical line and we will get A state A this will be in the form of sensible heat and latent heat. So air which is coming into the room shall bring energy in the form of sensible heat and this is latent heat and this is sensible heat addition by the air. Now if I calculate these values, now from here then this enthalpy head of the air which is at 40ºC temperature and 50% relative humidity is approximately 110kj/kg.

And at this point the enthalpy is 48kj/kg so this is the difference 110 and 48 it is going to be 62kj/kg this much of energy will be entering the system. Suppose infiltration rate is 1kg/sec so 62kw is quite high 62kw is tens of tons and from this we can also find what is the sensible heat addition what is the latent heat addition. So sensible heat addition if you are able to find the enthalpy at A and that is 60, 70, 80 sorry 60, 62, 64, 65 approximately 65kj/kg. Now these information are helpful when we do load calculation in the system.

Because when we design an air conditioner for a building or a house in that case infiltration is also taken into account and this infiltration is the load due to this infiltration is also added in the total load of the building. Now the problem is how to estimate the infiltration in the building.

Now before we do the estimation of infiltration in the building let us understand the driving mechanism of infiltration in the building.

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Now let us talk about a high-rise building of five stories or ten stories or may be low rising building also. It is not totally air tight it has certain height and for example, in case let us take example of winters. So in winters outside temperature, inside temperature is we are maintaining inside temperature 24ºC right outside temperature is let us say 5ºC. Now what is going to happen in this case.

In this case at the bottom of the building outside temperature will be greater outside pressure will be greater than inside pressure, this building will behave like a chimney you must have a studied the movement of the fluid in the chimney same way the movement of the fluid will take place here, here outside pressure is greater than this pressure inside pressure, so air will move in from the bottom.

And this you must have realized also during the winters there is a lot of infiltration in your house from the bottom of the door or from the bottom of the windows this is due to this pressure difference only. And the pressure when we are going up the pressure in the building will reduce, pressure outside will also reduce. Since the density of air is higher in this case because density is P by sorry, PV=MRT.

So density is P/RT, so density of the air is equal to pressure divided by R temperature. So the moment the temperature is reduced the density will increase. So definitely a lower temperature of fluids have higher density. So density is high that is why the fall in the pressure of air because when we are moving up the pressure will reduce here also the pressure will reduce, but the fall in this case the fall in the pressure will be larger.

And it is possible that this fall in pressure is such that it always happens, not possible it always happens then here the pressure, outside pressure this is P2 let us say this is P1 so here at the exit P1 is greater than P2 and here P1 is less than P2. If I draw a diagram between the falling pressure with height of the building it is going to be like this, this is pressure and this is height or it is denoted by H in the buildings.

Now in the case of outside pressure it is going to be like this, this is outside pressure and this is building pressure, pressure of the building inside and this is pressure outside. And this is the fall in the pressure with height of the building and we get a place or a points where both sides the pressure is same this is known as MPL neutral pressure level at this point, there will not be any movement of the fluid otherwise from the bottom in the winters from the bottom air will enter the building and it will leave from the top.

In summer definitely the scene is going to be different, in summer the air will enter because outside temperature will have that inside, inside temperature let us say 24ºC outside temperature maybe 45ºC so situation will reverse, air will enter from the top and leave from the bottom infiltration here. This property was also used this movement of the fluid was also used for the cooling of the building you must have observed in the old buildings they were ventilators.

And the function of ventilators was just to ensure this movement of air from top to bottom position in the summer season right. So that proper ventilation in the building is maintained.

Now we are talking about the infiltration, suppose because air is not come, air is also moving with certain velocity. Suppose on the building air moves across the building, building acts as a bluff body building acts as a bluff body but definitely at all the points there is going to be a positive pressure.

So this is building on the both sides if I show the pressure of air it is going to be inside and leeward side and this is negative pressure and air will be flowing out of the building right from the top to bottom. So air movement in infiltration is also important we cannot always say that the movement of the air will be like this. Suppose the wind velocity is high then here will enter from all the point possible points in the building.

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Now after this we will take up how to quantify the infiltration how to calculate the amount of air which is getting into the building before that I would like to explain air exchange rate. So in air conditioning we never say that the flow of air in the building is $5m^3/h$ or $8m^3/h$ or $5m^3/h$ or let us say 1000, 10,000 CFM it is always expressed in terms of CFM or 20,000 or CFM the issue is this is only flow rate it depends what is the size of the building.

In a building 1,000 CFM may be very high in a small house of two rooms, suppose there is a two room set in a two room set 1,000 CFM may be very high, but in a multi-story building of three-story or four story this may be negligible. That is why air movement in the building is always normalized with the volume of the building or the volume of the occupancy and that is known as air change rate, it is equal to volumetric flow in the room, volumetric flow in the A of air in the room divided by volume of the room.

It means the movement of air in the room in the unit of volume of the room if I say air change rate is 1, air change rate is 1 means in 1 hour time is volumetric per hour. So volume of the flow of air in the room per hour divided by the volume of the room, that means suppose the volume of the room is, volume of the building is $100m^3$ right and the airflow in the building is $500m^3/h$ we will say that the air for in the building is 5 air changes per hour.

So it is expressed in terms of air change rate per hour SACH and five SACH means per hour the flow of the air in the room is five times the volume of the room or volume of the building. Normally for air conditioning purpose it is a thumb rule that normally 5 to 7 air changes per hours are maintained in the building, if it is evaporative cooling like desert cooler is used we can go up to 12 or 15 year changes per hour. But 12 and 15 year changes per hour is a very high flow of rate in occupancy.

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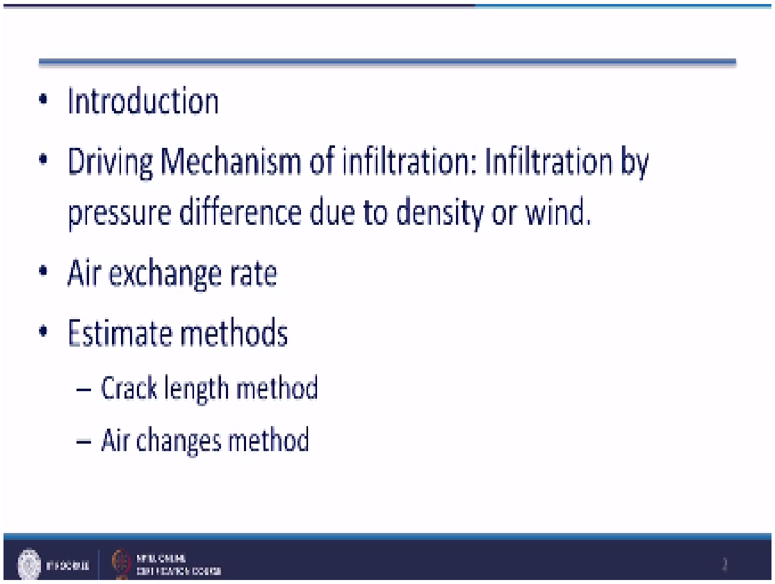

So after the air changes per hour or air exchange rate will go for estimate method for infiltration so there are two methods one is crack length method other is air change method, crack length method is more scientific I mean some calculations have to be made in this crack length method but air changes method is very practical normally it is used by the practicing engineers for the air tightness of the building.

Now we have to quantify the air tightness of the building, because no building is absolutely airtight we can always say that it is I mean it is very good air tightness is very good or it is fair, or it is poor, or it is excellent a blower door test is done on the building.

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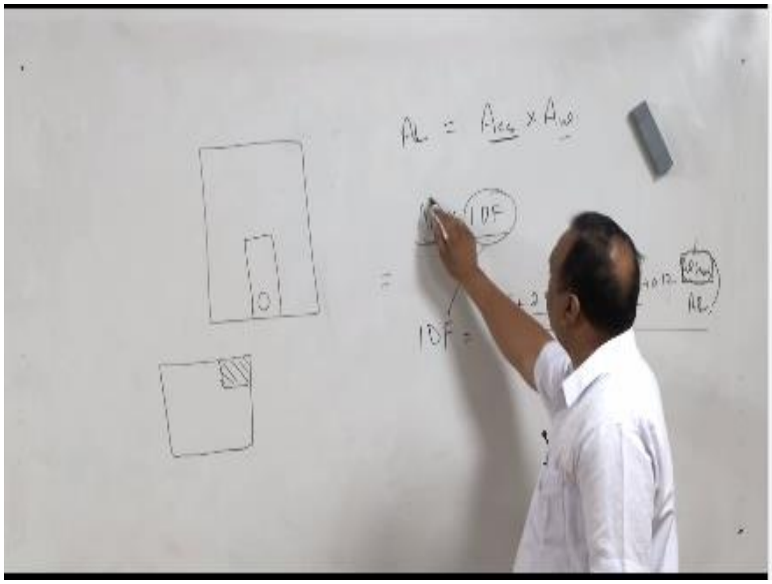

In a blower door test there is a I mean a air tightness stress of the building on a door a blower is fixed all the windows and doors of the buildings are closed a blower is fixed and certain amount of pressure is maintained in the building right. And when this certain amount of pressure is maintained in the building it is noted what is the flow rate of this blower in order to maintain that pressure and we will get one point.

And now we will keep on changing the pressure, pressure above the atmospheric pressure and we will be getting different points for different pressures when the pressure is high flow rate will be high when the pressure is low definitely flow rate will be low. And variation of pressure I will tell you the range it is between 4 Pascal to let us say 25 or 30 Pascal 4 Pascal 25, 30 Pascal and you get a curve like this.

Similarly we start creating vacuum in the building also and we get another curve. So here let us say this is zero pressure and zero flow and this is positive pressure positive flow Q and this is positive pressure this is a negative pressure and this is suction from the building. Now this curve has relationship as ΔP is equal to some constant sorry Q is equal to some constant ΔP^n.

So for the particular pressure difference, the pressure difference can always measure inside and outside pressure difference we can always measure we can find how much air is flowing into the building. Now this value of infiltration in the building is divided by the exposed area of the building and we get a certain value and this value is used for this a generalized value and this value is used for calculating the infiltration in the building.

I will give you an example of residential building where air leakage area has to be calculated. Now air leakage area is exposed area into unit leakage area this method is used for residential building only it is not for commercial building. So unit leakage area we get from a chart where it says that the tight building is it is a tight building where unit area is $0.7C^2/m^2$ and it is good then it is $1.4C^2/m^2$ and this average 2.8 leaky 5.6 very leaky 10.4 and so on.

Now this unit leakage area is multiplied by this exposed area of the building. Now exposed area of the building is the area of the wall I am showing you the plan of the building area of the wall plus area of the roof excluding area result for the garage. So this is exposed area of the building and then we get a leakage area and this leakage area is multiplied by infiltration driving force IDF and we get total infiltration in the building.

Now for calculating IDF in a residential building for the cooling purpose it is going to be equal to 25 + 2.5 module of ΔT 0.38+0.12L/L/1000. Now ΔT is the temperature difference inside outside temperature difference L flu leakage area of flu if there is a shaft normally in our country we do not have lives or such an opening in the houses. So this can be neglected and we can take up to here and this will give us the infiltration driving force estimate of infiltration driving force.

And if the provisions of flu, flu or fireplaces is there then we can take AL flu also and this infiltration driving force when it is multiplied by the leakage area that will give infiltration in the house, but this is strictly for residential buildings.

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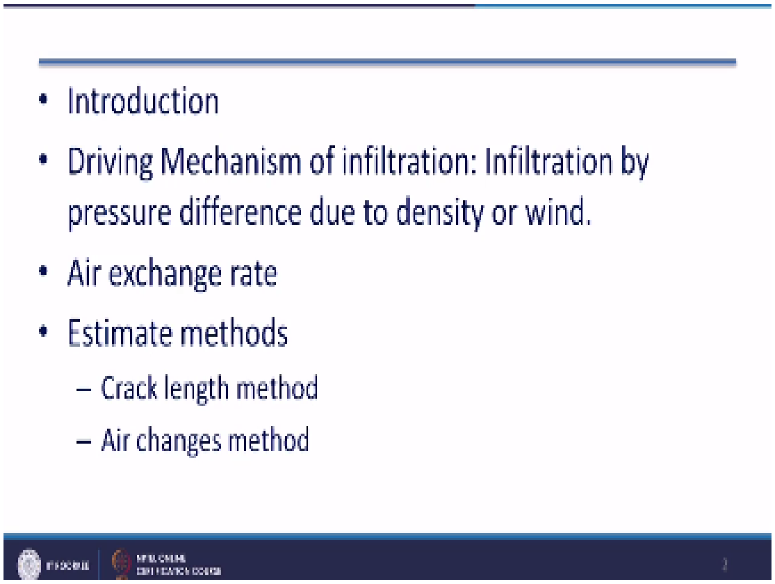

Now air change method now air change method it is normally it is it is very popular with the practicing engineers.

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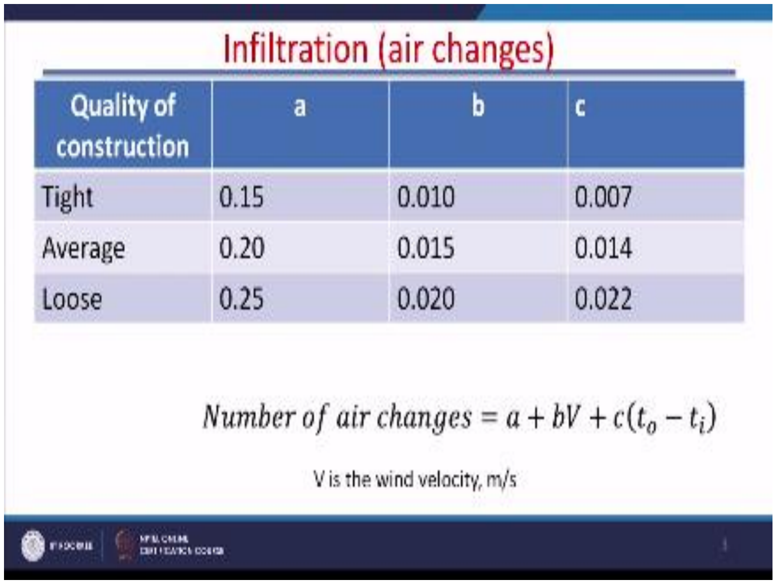

Infiltration (air changes)

Quality of construction	a	b	c
Tight	0.15	0.010	0.007
Average	0.20	0.015	0.014
Loose	0.25	0.020	0.022

$$Number\ of\ air\ changes = a + bV + c(t_o - t_i)$$

V is the wind velocity, m/s

In air change method quality of construction is estimated tight average or loose that is it, it has three classifications.

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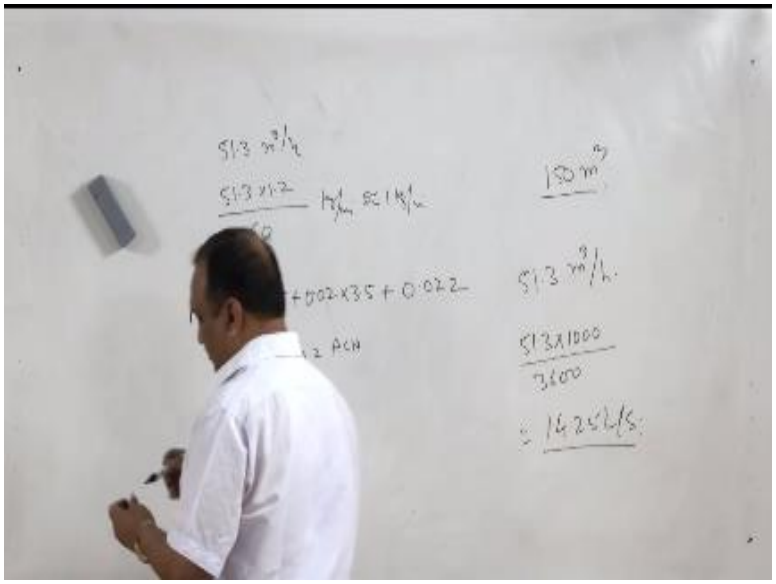

And the equation for number of changes, number of air changes air changes per hour is equal to let us compare with the tight with the loose, suppose the building is tight construction then A=0.15 plus B=0.01 multiplied by the velocity, velocity we can say 30km/h if we assume normal velocity nowadays here is 13km/h will give approximately three points in let us say 3.5, 3.5m/sec, I have taken 30km/h as velocity, 30 km/h that is 13x5/18.

So that is approximately 3.m/sec and the third one is 0.07. Now if I solve this then I will be getting the value 0.15 +0.1x3.5 +0.192 air changes per hour okay. Now if I take a loose building in loose building air changes per hour is going to be 0.25 + 0.02 x by 3.5 air velocity is 3.5+0.022. Now if I solve this 0.25+0.02 3.5 this is going to be 0.342 air changes per hour. Now you can see this is 0.342 and this is 0.192 the air changes per hour.

In the loose building is approximately 78 or 80% more. Now suppose I have a house of which is having a I mean the volume inside volume it has let us say house volume is $150m^3$ it is not very higher side. So air changes per hour is point so suppose the building is loosed at 0.342, so 0.342 multiplied by 150 will give $51.3m^3/h$ of air circulation in the house. Now 51.3m3/h is going to be I mean 51.3 x 1000 it will give liters divided by 3600.

So 51.3/3.6 it is going to be 14.25l/sec so this is going to be the movement of air in the house. Now this infiltration in the house 14.25l/sec now if the density of air I assume 1.2, if I assume 1.2 then 14.25x1.2 around 17kg/sec it is very high the velocity this meters no sorry, it is m^3 1.2m^3 sorry. It is 51.2 21.3x1.2/3600 60 it is 1kg/min approximately 1kg/min the infiltration in the house from here I will get this 51.3m^3/h or 51/3x1.2 I have consider the density of air divided by 60 this will give us kg/min.

And that is approximately 1kg/min, so that is on that is quite considerable. So infiltration brings the load on the cooling coil, infiltration brings the load on the cooling coil and this causes unnecessary expenditure of energy in cooling the air. So and so the infiltration is an undesired phenomena in a building, but it cannot be completely avoided but it can be reduced to a certain extent.

So that the cooling load on the cooling coil is minimum. Now in the next lecture here I conclude this lecture in the next lecture we will take up the design conditions in the building. Thank you, very much.

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