Sustainable Transportation Systems
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Lecture 10
Impacts of Transportation Systems - V

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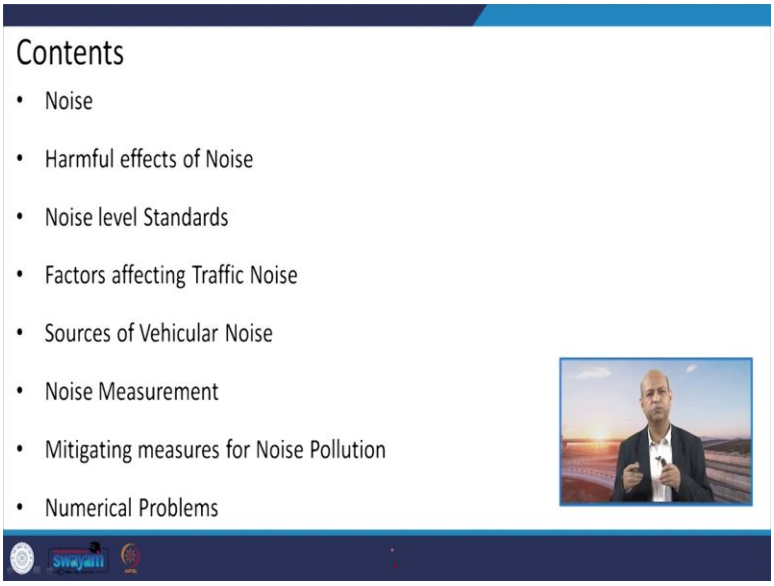

Hi friends, so in the series of impacts of the transportation systems, now we will look into the impact through noise of the transportation activities, that is also one big part of impacts of the traffic and activities of the transportation. So, these are the contents for today's this lecture, we will see what is noise everybody knows, but still we will see how noise is defined and then what are the harmful or negative impacts or effects of the noise.

And what are different standards which we measure that this noise is acceptable and this must is not acceptable and then what are different factors which affect the traffic noise or vehicular noise and how do we measure them or then what are the ways to mitigate or reduce the noise like barriers etc., we will see and a few numerical problems have also been incorporated, I think you will find them interesting to hand to do hands on practice to measure the noise related parameters.

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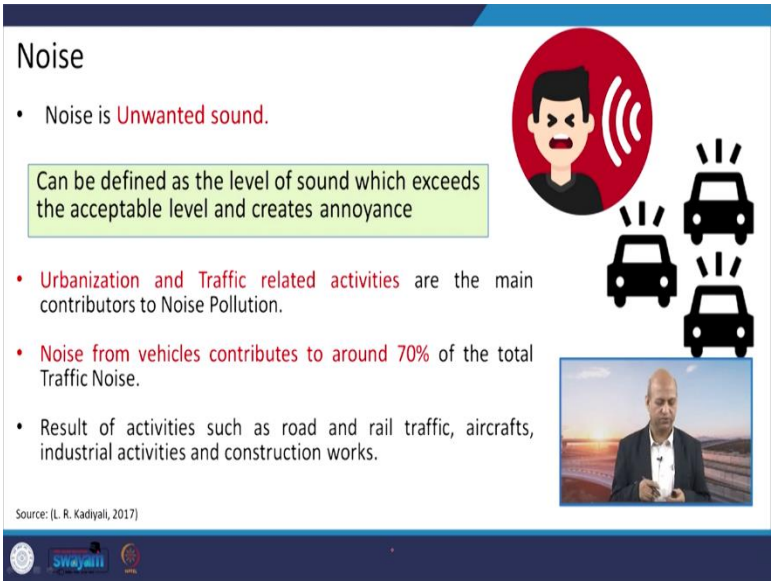

Well, any unwanted sound is noise as it is said, but in old days there was an ad on TV one anecdote I would like to share with you that they used to have this kind of advertisement that owners' pride and neighbour's envy something like that, so noise also is like that sometimes a particular kind of frequency and particular kind of wavelengths of the sound some people enjoy they call it music and for others it may be irritating thing or noise.

So, that way noise definition is also a little bit different, but of course in terms of energy means a beyond a level of some pitch or something which is harmful for our eardrums then whether it is music lover or other that will influence our total system of hearing and feeling.

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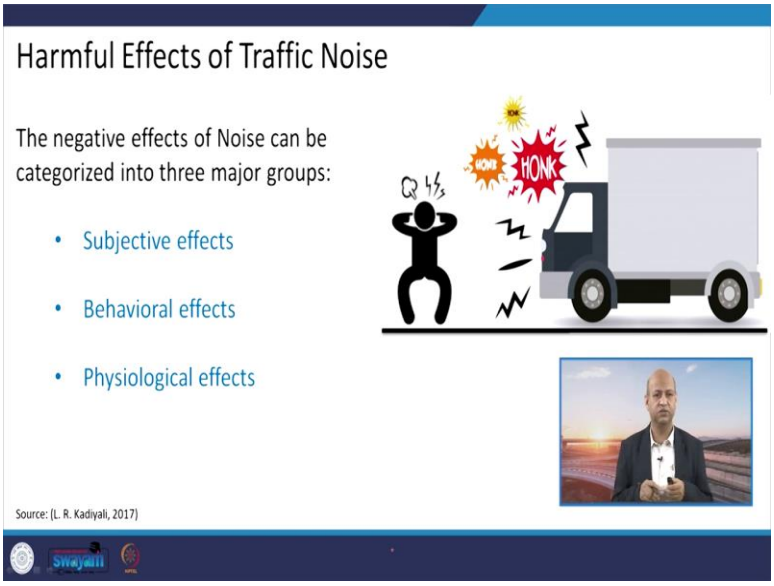

So, there may be effects, symptoms of subjective and behavioral effects also interpersonal behaviour and physiological impacts may be or effects may be there, which damages our certain parts of the body or which creates some sort of diseases or illness. For example, we may not be able to sleep, if there is a lot of noise and when you are not sleeping properly your whole system becomes of very low efficiency.

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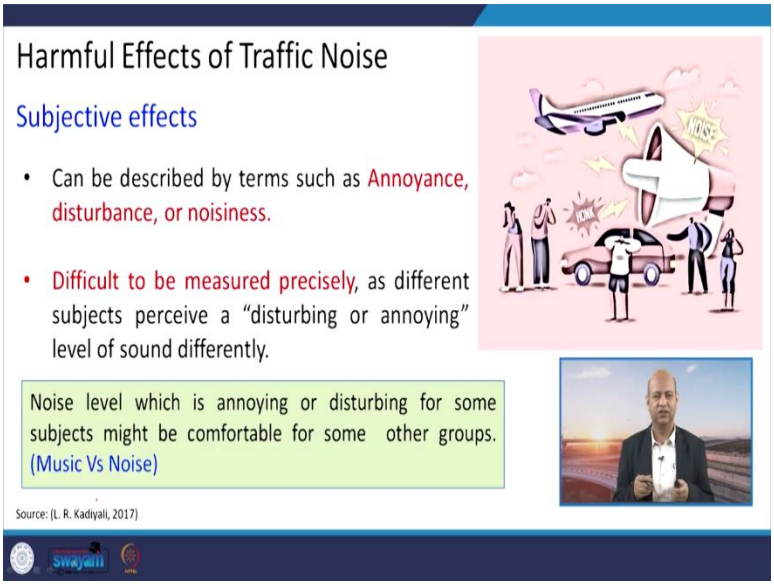

So, the subjective effects are like some sort of annoyance, some sort of disturbances, but it depends on the person to person, so as I wrote here music versus noise means there are certain kinds of

music like rock and lot of drumming and those kinds of things are there, and people enjoy it, but for other people it may be kind of very chaotic situation, they do not like it, they call it, it is not music but noise. So, from person to person, it depends, how do you feel that particular sound note, whether it is rhythmic, or whether it is completely out of beat and it is for your liking or not all those things are subjective.

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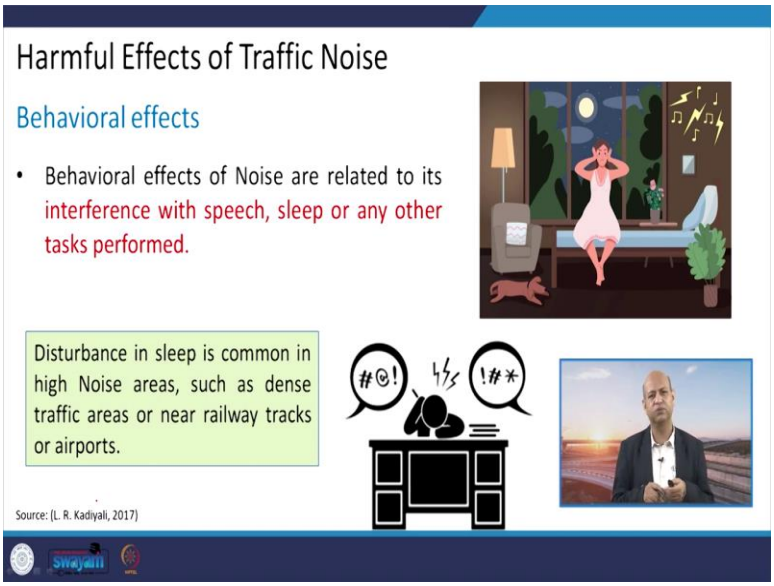

But then behavioral also like we get irritated and if there is a lot of noise in the background we have to shout to communicate our things, so a lot of interference is there in the speech, also like sleeping pattern, our sleeping behaviour can be disturbed by a lot of noise around us, so that is why nowadays people have a good windows which have these insulation effects those kind of glasses people use, and it is otherwise difficult to perform our tasks, for example we are studying or we are doing some other work and irritating noise is there, so we cannot focus on that. So, that is very negative impact, so we do not need the disturbances caused by the noise.

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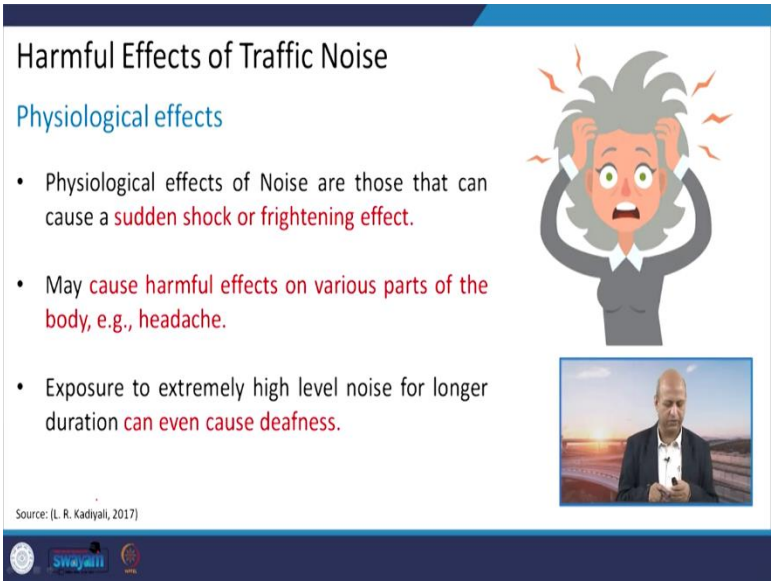

Of course, physiological effects may be there because it can induce or cause the headache or some other problems heartbeats or blood pressure etc., maybe induced by these kinds of environment where lot of noise is there.

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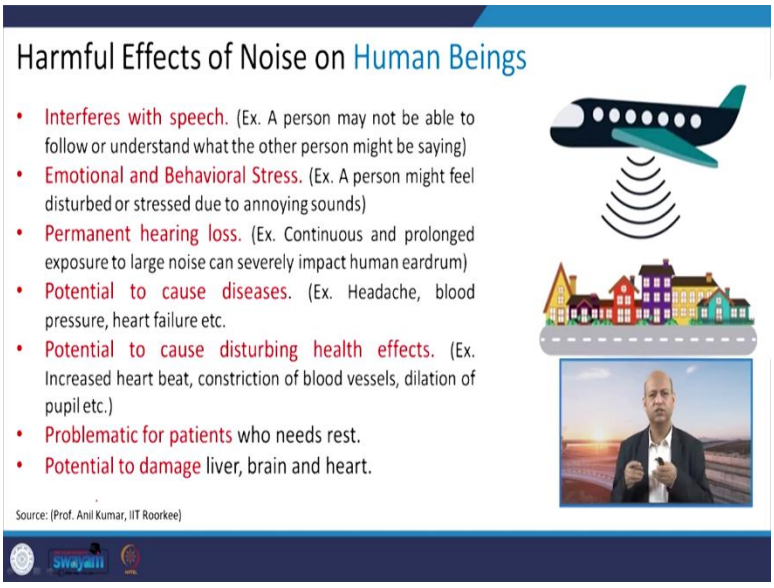

So, in nutshell you can list them like it can interfere with the speeches, because when we are talking to someone then we are not hearing or we are not able to communicate properly and emotional and behavioral stress maybe there, a person might feel disturbed and stressed up due to annoying sounds and or you might be finding that person very polite, but on a particular day you will find

that he is not so in happy mood is, a little bit annoyed, so maybe he is coming from some annoying atmosphere where his mental state has been affected.

So, that way means even permanent hearing loss may be there if you are exposed to very high level of noise continuously, so our drums may be damaged and it may be difficult to regain that kind of stage where you can hear properly, all sorts of those noise or sound related and that spectrum which we are naturally able to listen or hear. So, there may be problems for like patients etc., who are in the need of rest and if there is a noise they cannot rest and then they can also damage our liver or heart or brain depending upon what is our health condition, and how much noise level we are exposed to.

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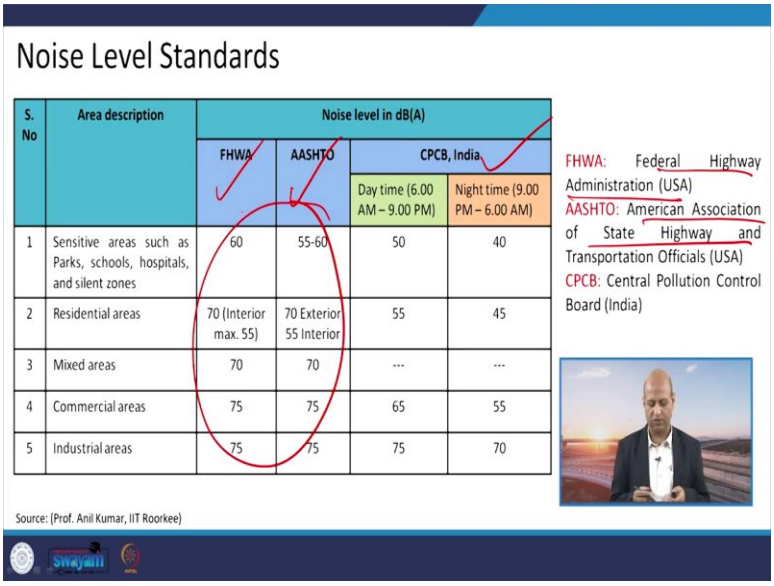

Well, if we compare the standards we in India have very good standards in comparison to other for example one is Federal Highway Administration of USA, this one and another one is American Association of State Highway and Transportation Officials, they also have certain standards, almost it is same basically. But in India, we have better standards means we allow only the lower level, but unfortunately as you know people say that we are very good in having laws, regulations, but implementation is not so good.

So, that is why even at the nights when those hours were noise is not permitted, even by the court's orders but people you know our behaviour is that we sometimes do not care, so that is not good

thing, but this is part of our life and we have to really learn to respect our laws and we should not increase the background noise or in the environment, which is beyond the permissible limits.

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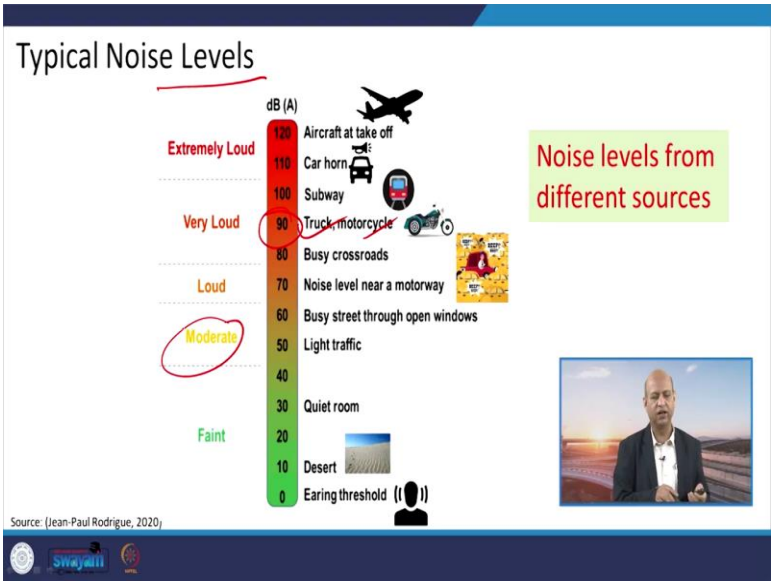

Here are some levels which you can relate with different activities, for example, in our truck or motorcycle when it is going through and making a particular sound level that is known as very loud, it is around 90 decibels, so that is a unit of the noise and the light traffic will cause only moderate quiet room it is very means calm and that is very very nice, so different kind of activities are linked with different levels of sound or noise.

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Then if you want to understand in terms of what are the factors which cause the noise, so the traffic related factors may be there, and this means we are talking about traffic noise, so traffic noise also has different factors, traffic related, then human related factors, than road factors, surface etc., we will see and then vehicle that condition of the vehicle or type of the vehicle those are also the factors, so these four factors will contribute to the traffic noise.

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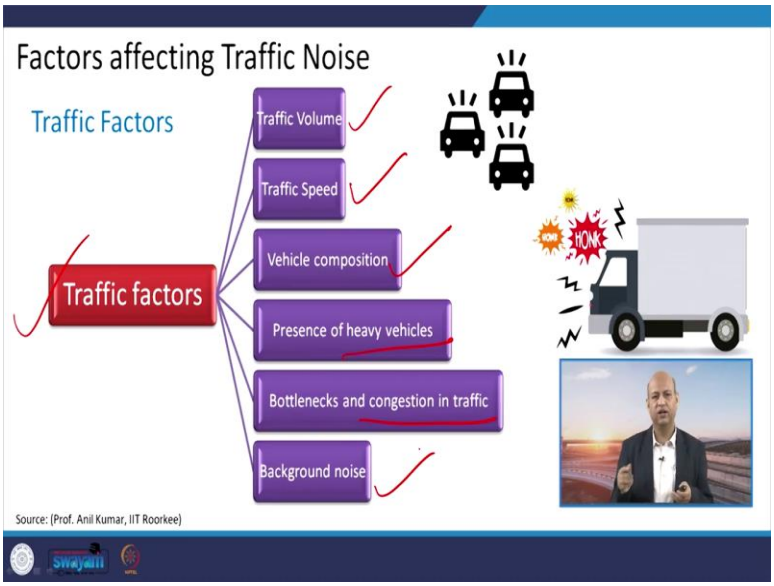

So, if you want to see like traffic factors, so we can further classify them in terms of like traffic volume, if lot of traffic is there and some people are honking or some even you know other noise levels may multiply or it can add into higher level of noise. Similarly, traffic is speed related noise means higher speed, because of certain parts or window vibrations etc., passengers may feel a lot of noise.

Then vehicle composition also can contribute to different types of noises. And also like heavy vehicles' presence or there are congestion, so again a lot of honking and disturbances and also it can add to the background noise. So, if already background noise is there, then the traffic related factors will add into it and the noise level will increase.

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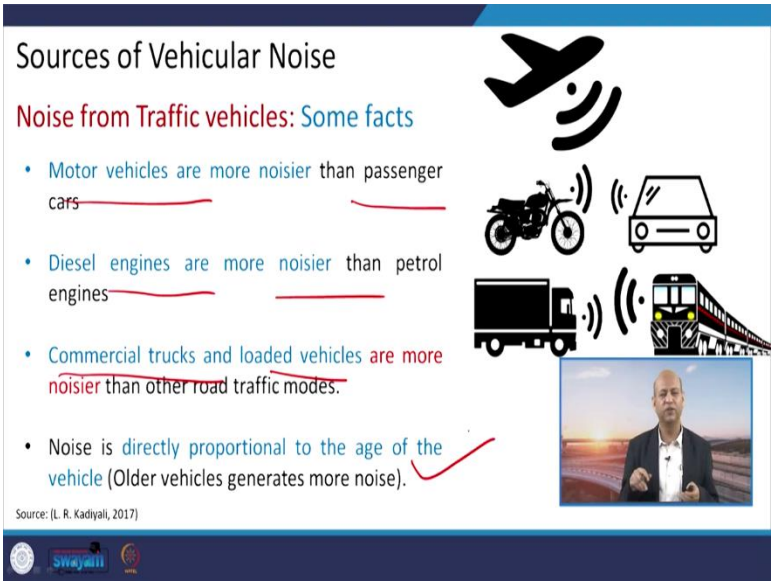

So, these are some facts related to traffic factors. For example, motor vehicles are noisier than passenger cars, diesel engines are more noisier than petrol engines, although a lot of research has gone and even diesel engines nowadays are quite, very calm nowadays, but still means petrol engine and diesel engines working is different and diesel engine makes more noise or more sound. Similarly, commercial trucks, loaded vehicles heavy vehicles, etc., they will make a lot of noise, there will be very high friction between road and tyres, so that contribute to the noise. Similarly, age of the vehicles, when parts are loose, vibrations are more, so again the noise level may increase.

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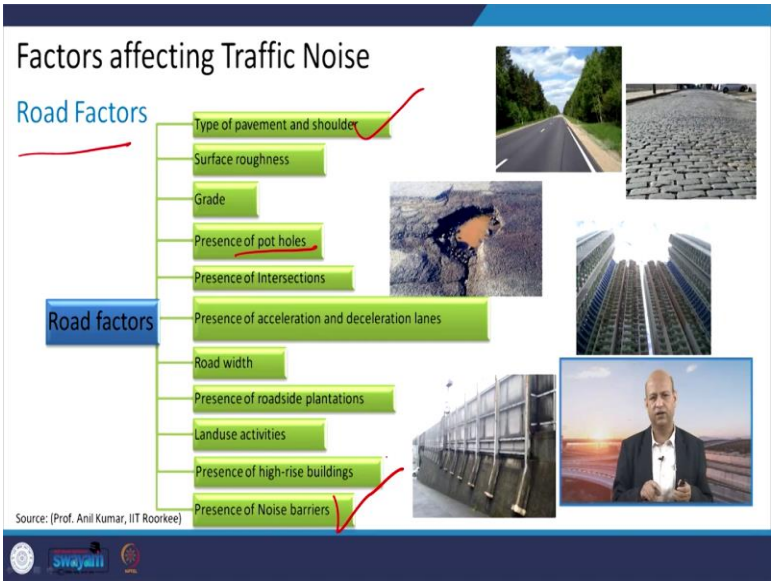

If we talk about the road factors, then again condition of the road, its type of pavement and the shoulders, surface roughness, all these will add into the noise or sound levels, what kind of grade it is and if there are potholes, then there will be jumping and breaks and all those kinds of screeches, they will add to the noise or sound levels. Then if there are intersections, so lot of change in the speed and gear all these activities may contribute to the noise.

How much width of the road is there, so that will decide congestion happens or not and then there are other parts like noise barriers, if there are noise barriers then maybe the people on the other side they may not face a lot of noise because barriers will reduce the noise level. We will see how it is reduced by barrier levels.

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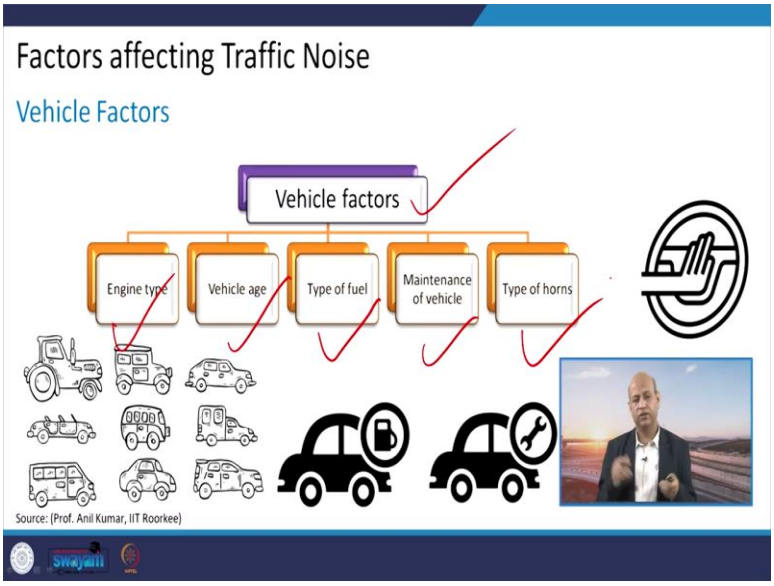

Then there are vehicle factors. So, engine type as we have seen, vehicle age or type of fuel, maintenance of the vehicle, type of horns, some people have very loud horns, so it is quite a very high pitch and high sound and it is very irritating sometimes you know, when you are thinking and walking on the road and some vehicle comes and they push horn very loud level you feel completely shocked what happens what has happened.

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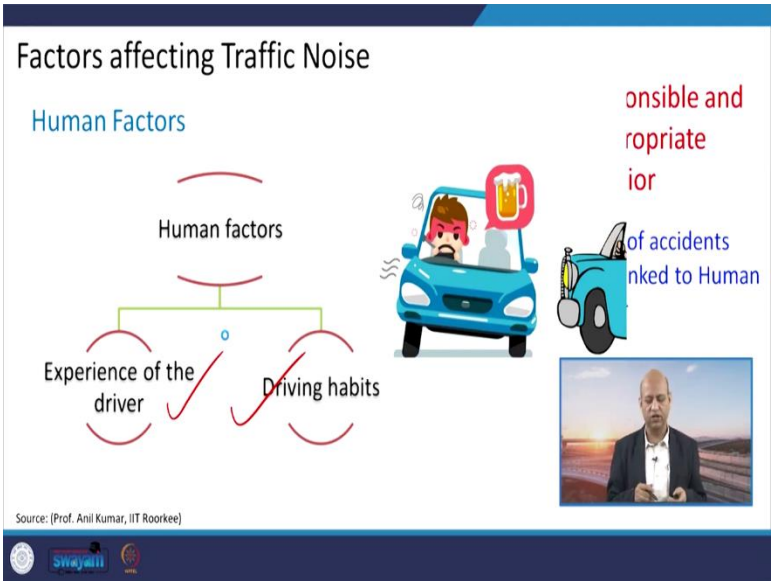

Then human factors like driving habits some people apply brakes very frequently or they have habit of honking although in the European countries or you go developed countries like Germany,

Japan etc., the traffic is calm there you know passengers behaviour is totally different and honking is not allowed and it is assumed as very bad behaviour.

But here our behaviour is quite different and we are habitual of honking and all those things, so they contribute to the noise, and experience of the driver means if driver is very experienced he knows when to apply brake, when to not, when to change the gear etc., so the noise level can be reduced accordingly.

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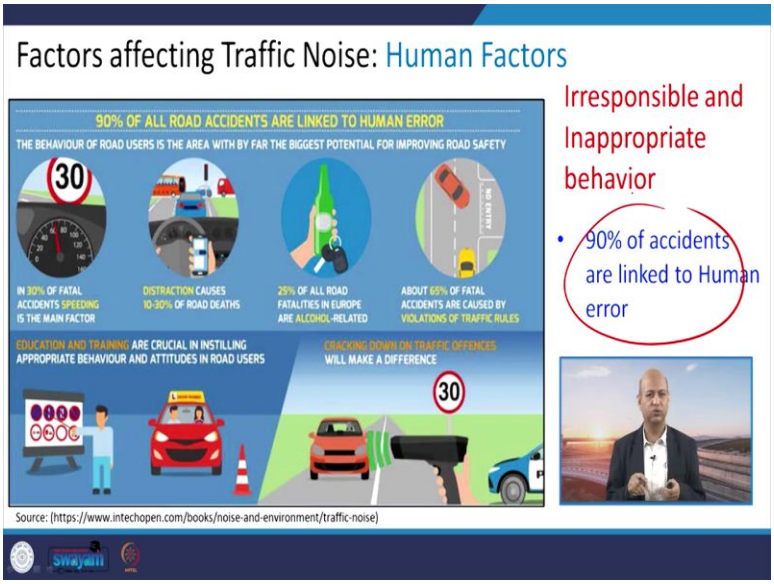

Human factors again like because of these different kinds of behaviour or irresponsible and inappropriate behaviour, they can contribute into accidents. So, the human factor is very, very important because if you are not in a healthy mental framework, and if you are not driving properly, then it can cause accidents, it can harm yourself, it can harm other people.

So, the 90 percent of accidents are linked to human error, means of course there are contributing factors of other things like potholes and bad road or some poor signage etc., but still the human alertness may prevent all those things. So, human error is the predominant factor into causing traffic accidents etc.

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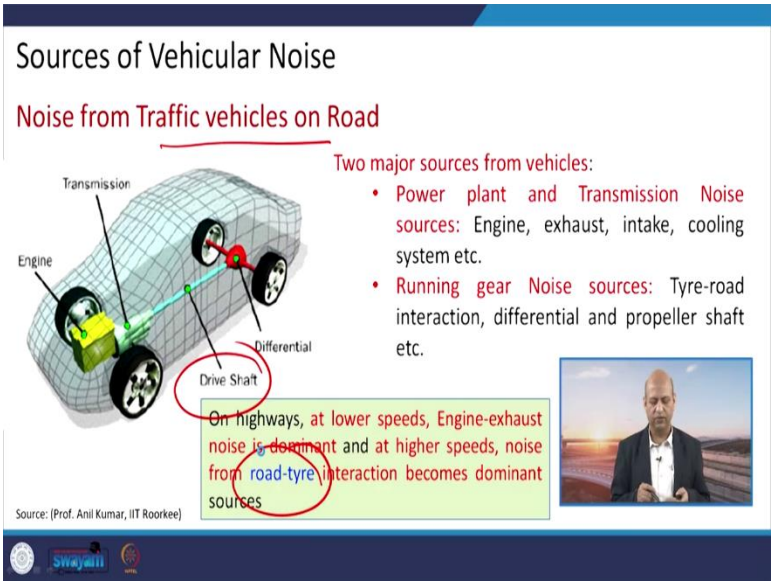

And the noise is one of the important factor to change the human behaviour, because if somebody is not calm and cool irritated by high noise level, so his responses and reflexes will not be proper and that will result into some accidents. And if you see these traffic vehicles on the road how these noise is generated, so you can see this drive shaft, which is rotating and then the gear system, transmission of the energy and the friction with the road of the these tyres etc., and the type of the road tyres interaction, they all contribute to the sound level.

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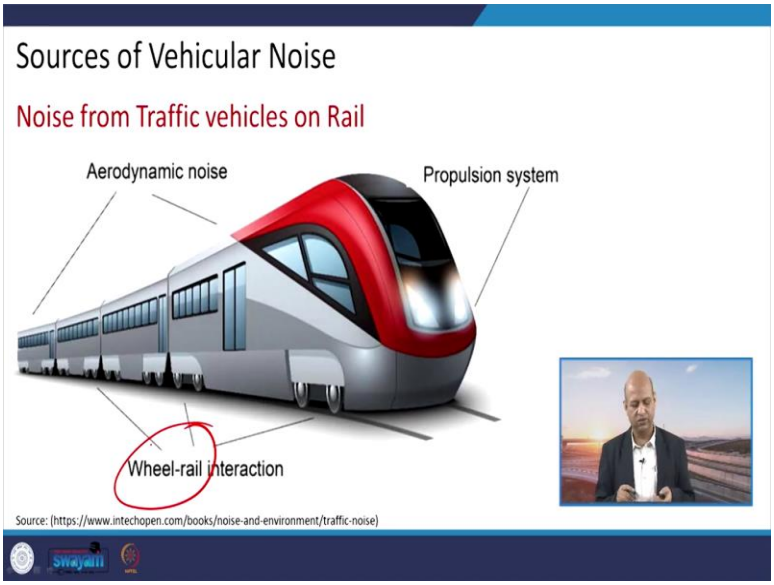

Similarly, like aerodynamics noise because when air is striking or hitting the body and that body also then release some sort of noise, so the propulsion systems and the wheel and road interaction like in case of car or in case of these road vehicles, the interaction of wheel and road is there, so that cause noise, similarly in trains the wheel and rail they also cause, they also produce some sort of noise.

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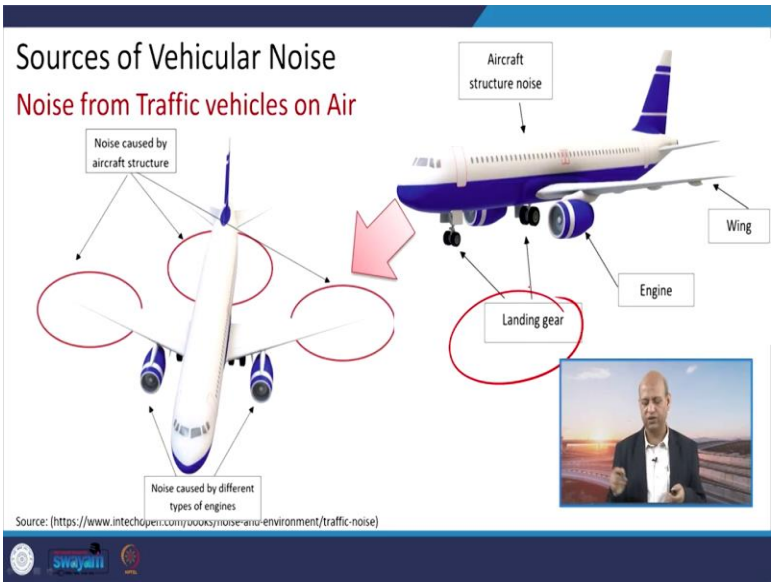

In air traffic also again engines and then these landing gears all lot of noise is produced because of jet engines, it is very high noisy environment outside.

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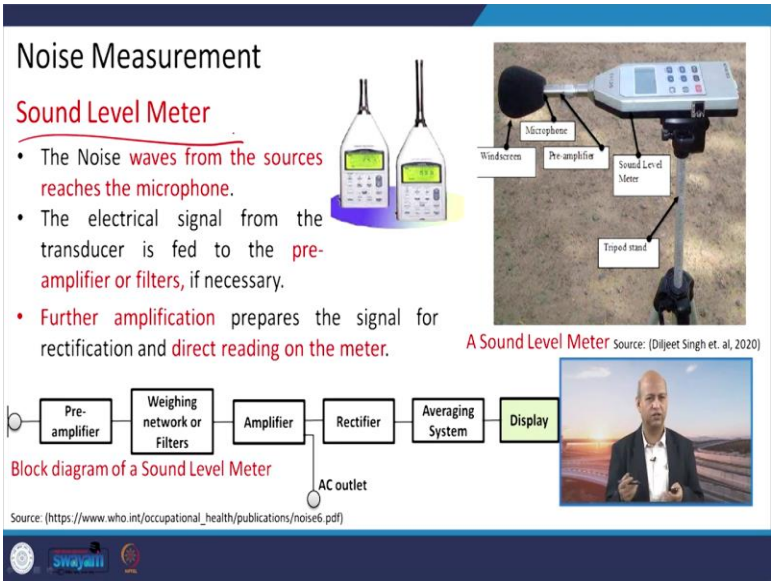

And that is why sometimes near airports or aerodromes the property rates are not so high, some people do not want to live there, because of this noise and they do not find as a healthy condition to live. So, all these things sometimes increase or decrease the property prices depending upon what kind of facilities we are having around us.

Well, then how to measure the noise because when we want to reduce the noise, then we should measure it first and compare with the standards, so there are instruments they like sound level meters, they can measure the noise and there are different units of the noise measurement, we will see in later slides.

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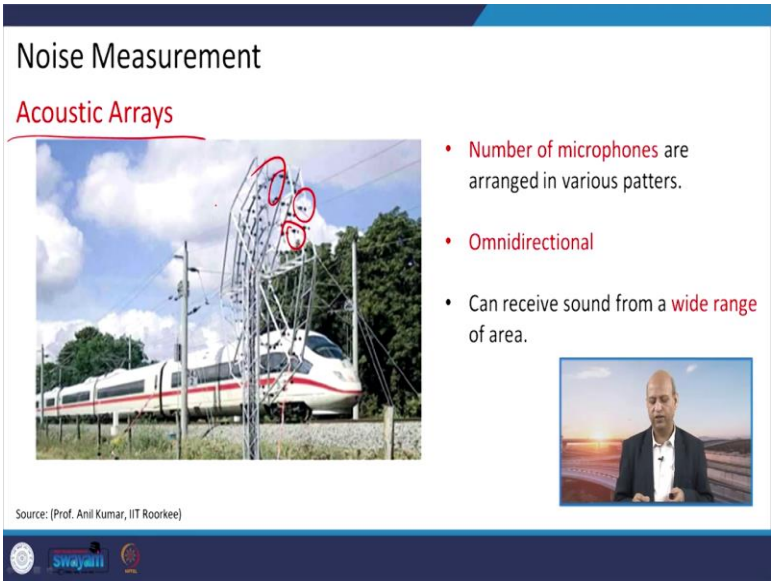

Then these kind of acoustic arrays are used for capturing the noise in and around of a particular site location, so these kind of several sensors can be used for catching the sound, a wide range of a spectrum of the sound.

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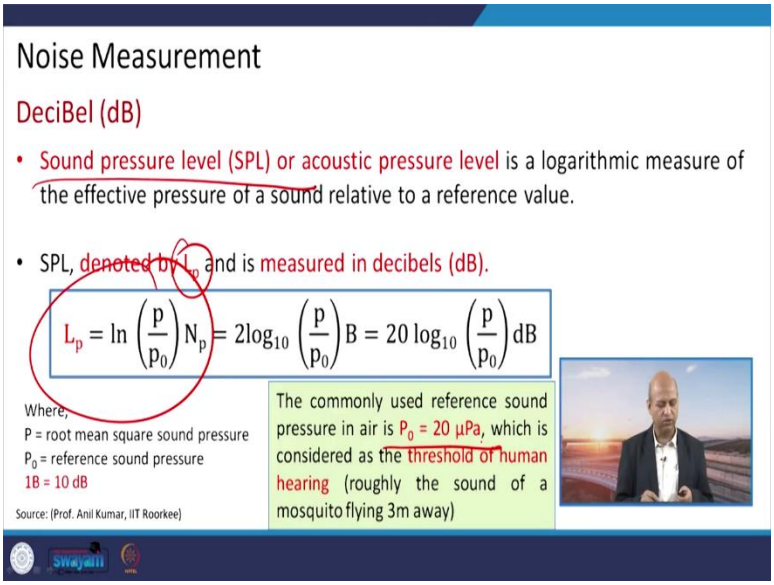

As you know, decibel is the unit and then if you want to convert the sound pressure level, the sound pressure level, so you can this SPL can be measured or denoted by Lp and Lp can be represented by the ratio of the this square sound pressure and reference sound pressure.

$$L_p = \ln\frac{p}{p_0} N_p = 2log_{10}\frac{p}{p_0} B = 20\ log_{10}\frac{p}{p_0} dB$$

So, root mean square of the sound pressure of different ranges and then the reference sound pressure means a reference sound pressure is also there like here this 20 micro Pascal, so, that ratio will decide how much this SPL value is there.

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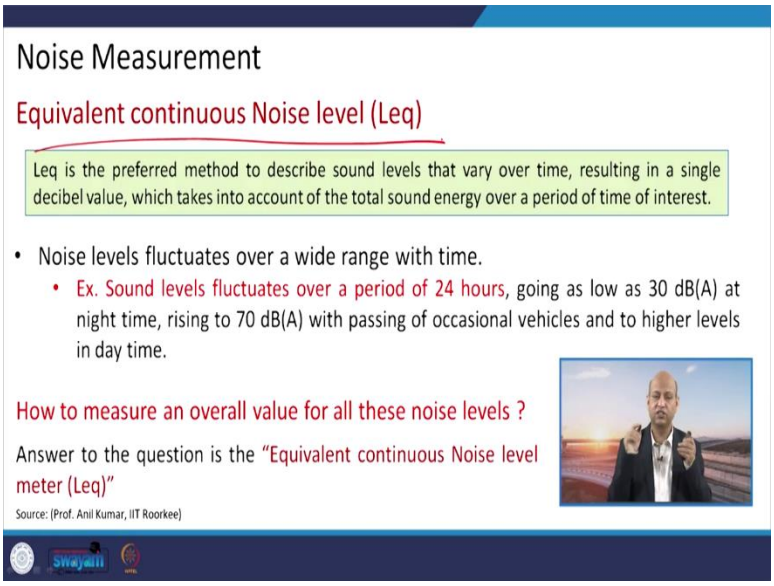

Then we also convert it into some other units like Leq equivalent continuous noise level, because noise fluctuates from one level to another like wind direction fluctuates or wind velocity fluctuates similarly this noise is also one energy and this energy fluctuates from low to high middle something like that. So, some of them average them out not automatically very simply average that is logarithmic and then sum them up as equivalent noise means, like fluctuating noise is there for let us say one hour and if you measure a Leq means if that level of noise is for one hour, then the same energy is there.

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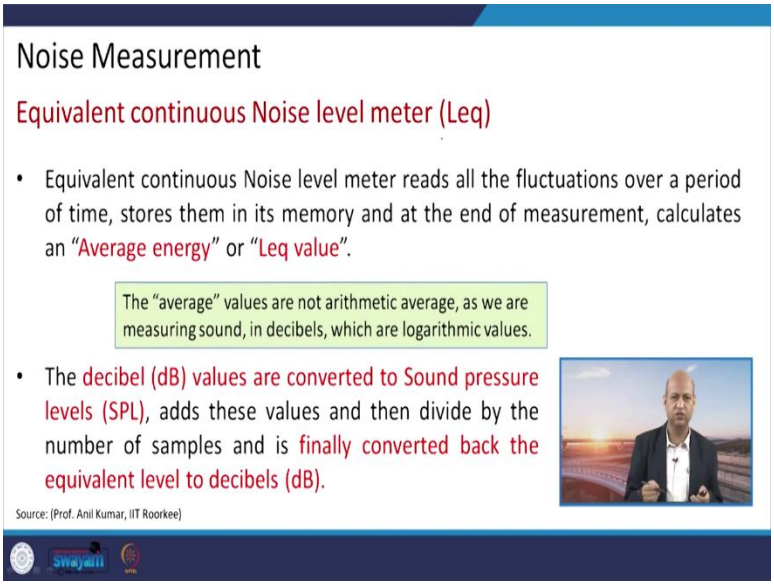

So, this is basically the representation of the equivalence of the energy level.

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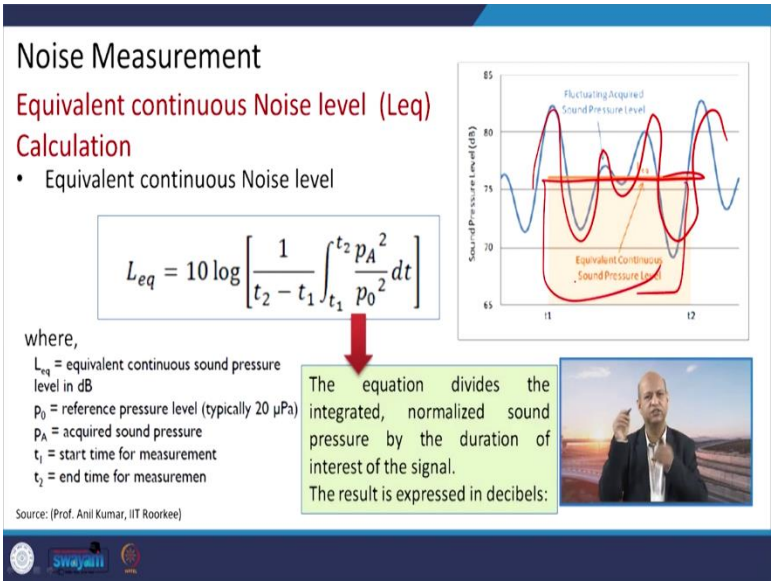

And here it is very nicely represented.

$$L_{eq} = 10 \log[\frac{1}{t_2 - t_1}\int_{t1}^{t2} \frac{p_A^2}{p_0^2} dt]$$

Like it is these kind of noise levels are fluctuating and we if you calculate this Leq, so, this much of energy is equivalent to that energy which is being given by fluctuation of the sound.

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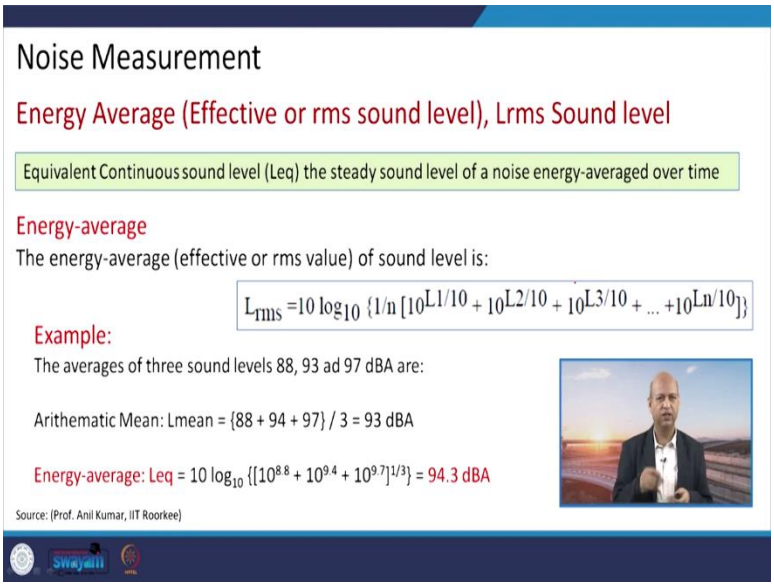

And you can see some examples like you can try them at leisure, so very simple numerical problems are there for energy average means you convert the sound level into energy and then

back energy to the sound level, then you can get what is this decibels, how much decibels are there because of contribution from one source to another.

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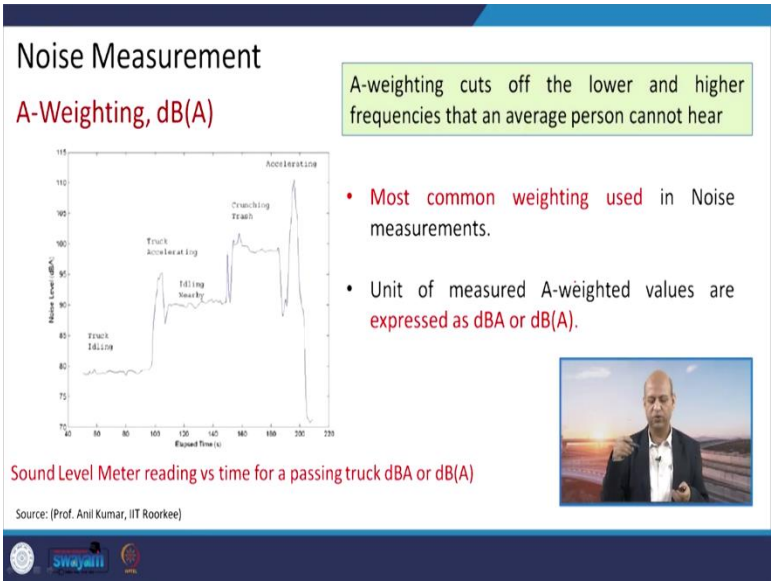

Similarly, A-weighting is very important because beyond a limit we do not hear and those kind of cut off sound levels are removed and A-weighting is done.

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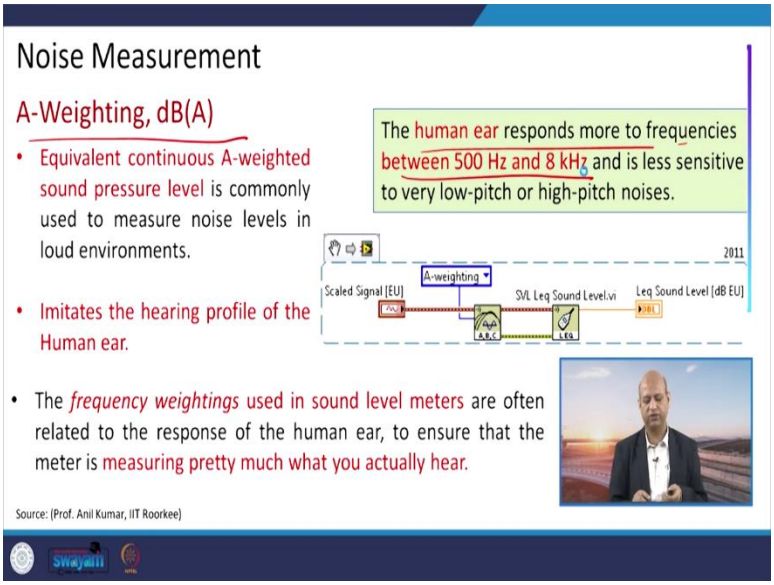

So, this dB(A) is also one way of representing the sound pressure levels from our human ear response viewpoint, because between this only we hear here 500 hertz to 8 kilohertz.

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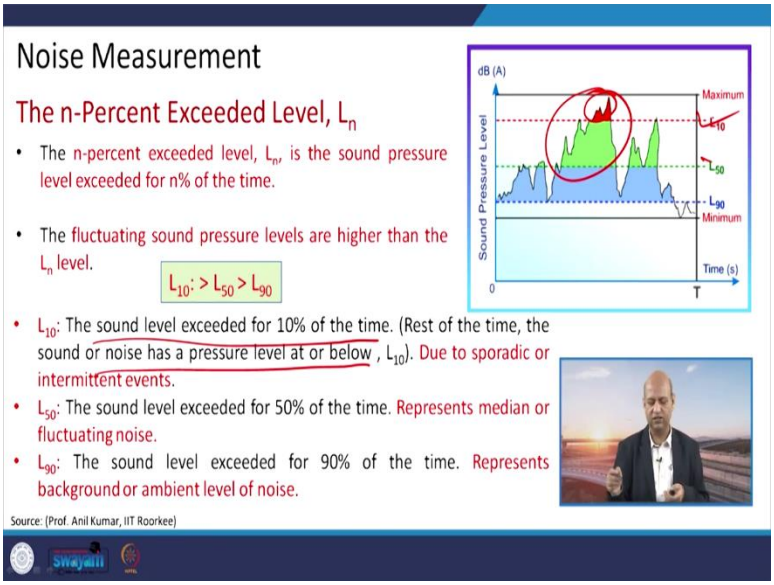

Then n percent exceeded level like Ln means, this much percent is exceeding that particular level is exceeding, so many times or so many percentage, for example this much is L10 means only 10 percent time this much of noise will be available in that particular measurement series. So, this is known as the L10 because the sound level exceeded for 10 percent of the time only.

So rest of the time the sound or noise has pressure level at or below that L10, so this is L10. Similarly, L50 means 50 percent of the time this is exceeding, so L90 is 90 percent of time. So, basically that is you can see background noise, because all the time that this much of level will be present, so L90 is less than L50 and L10 is highest one.

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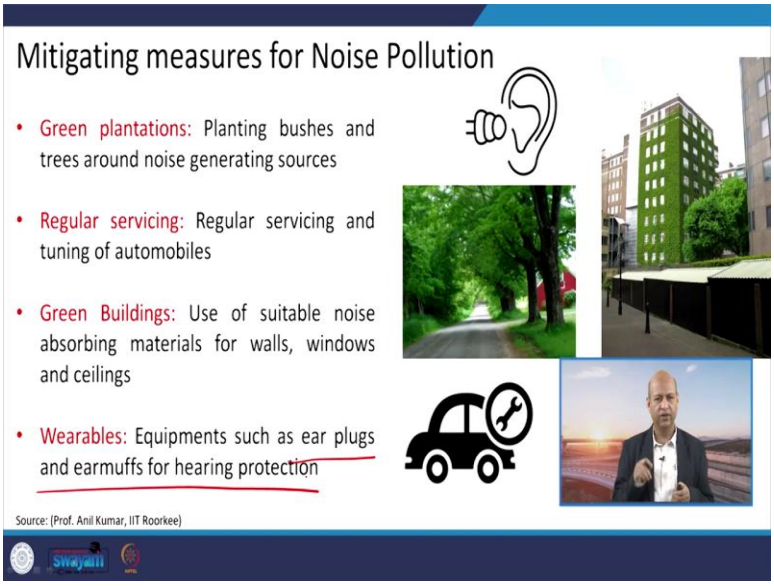

When we want to talk about mitigating noise pollution then we also should learn about different materials or different infrastructures which adds into reducing the noise like green plantation that is good for the environment as well as they also absorb the noise or they reduce the noise. Then regular servicing of the automobiles, because if you are not maintaining it properly, then some loose end parts will create the noise and engine or braking system etc.

Green buildings having suitable absorbing material for the noise on the walls and windows they are also in nowadays and wearables equipments like if you are working in a very noisy environment then better you apply some earplugs, otherwise you will be exposed to high level of noise and it will harm your physiological balances.

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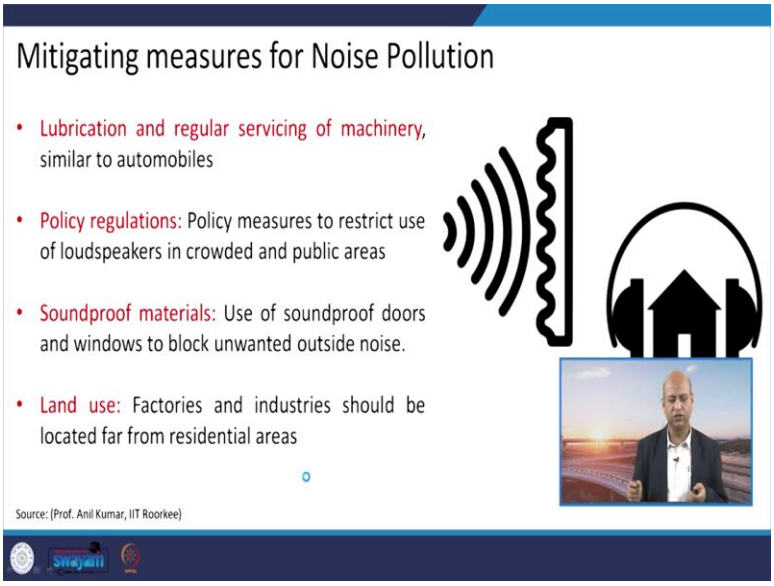

Also, we should apply lubrication and regular servicing of our vehicles or machinery and some policy regulations which are like loudspeakers, so if there is a law that beyond 10pm we should not use the loudspeakers, then we should use that policy and we should follow that law. If we are not following then we are basically adding to the noise level to other people also. And soundproof materials can be used, like as I said there are new windows which have very good material which absorbs a lot of sound and they do not allow to sound enter into the indoor environment.

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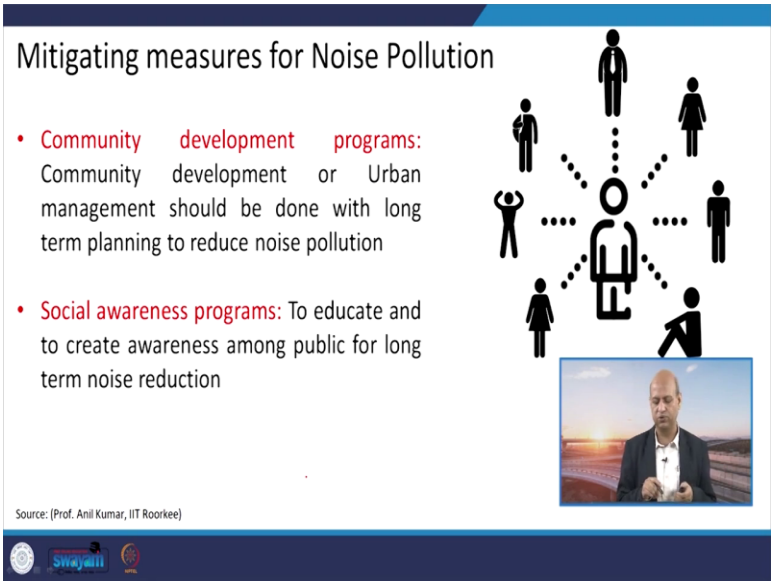

And land use planning is also important because you should not plan any noisy activity near to like schools or hospitals, means sensitive communities, they should be kept off switch off these kind of noisy activities and there must be proper signage, so that people become alert and they should not use any honking kind of horns etc.

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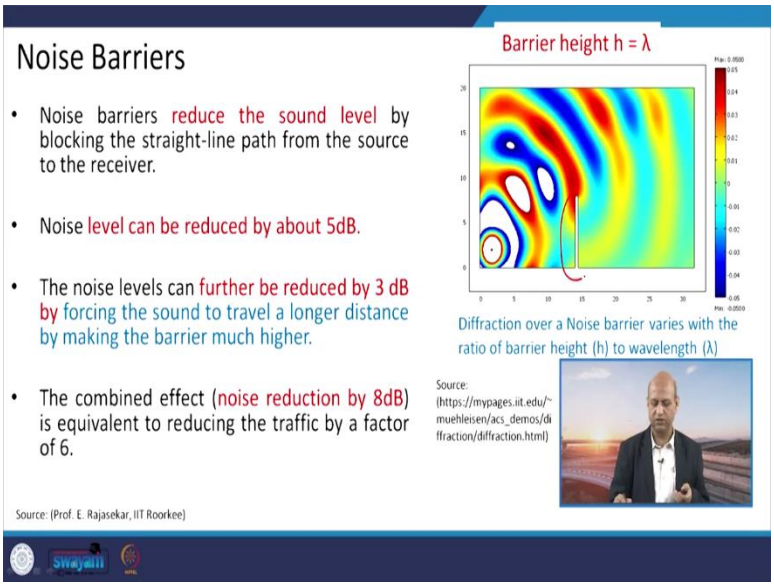

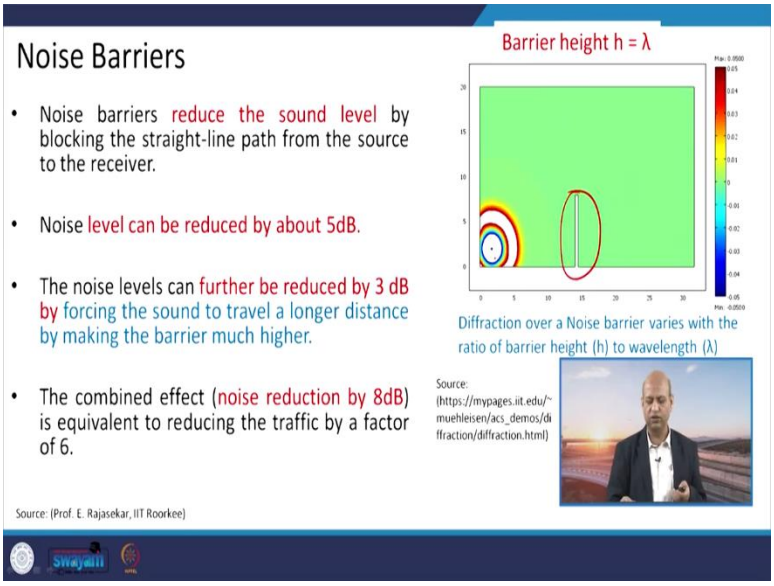

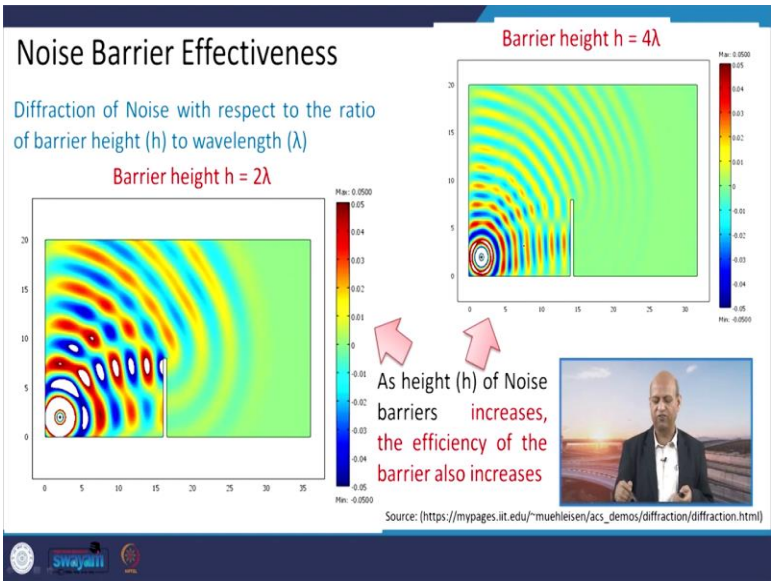

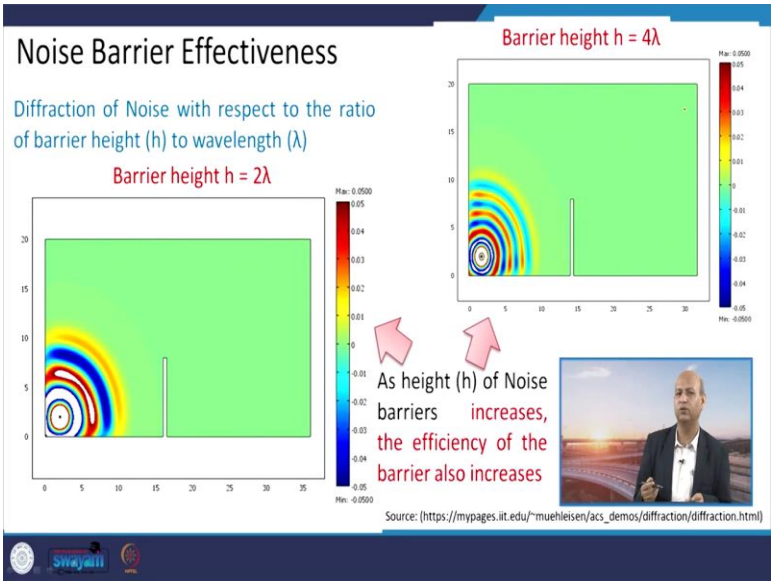

Well, this is like one barrier means barrier how to use the barrier, for example this is the barrier here and as noise is going to this side, so it loses its energy because of barrier height and in next slide you will see that we increase the height of the barrier from this must to four times then how this energy level reduces because of different heights.

So, very low energy remains after a certain distance, so barriers contribute a lot of in reducing the noise and there is particular exercise of designing barriers depending upon the traffic noise level and traffic activity, frequency those kind of things.

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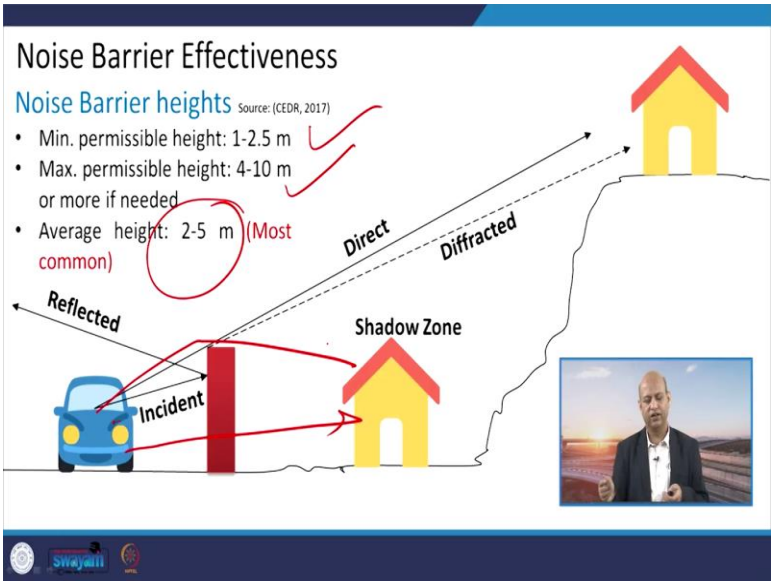

So, average height of the barriers is 2 to 5, but minimums generally 1 to 2.5 and maximum is 4 to 10 meter depending upon as like in cities on the highway, expressway or simple roads etc., you can see and if there is hospitals, then you need to have a very good barrier and there must be some signage that people should not honk there.

So, if you can increase the distance between the source of the sound and the receptor, so even naturally when the sound energy is traveling to it, it gets dissipated and it will reach in a very low value or low energy, so means it directly goes without barrier then for example this much is the distance, but if you are having this barrier then this will travel like this, so the total distance increases and the sound dissipation occurs more.

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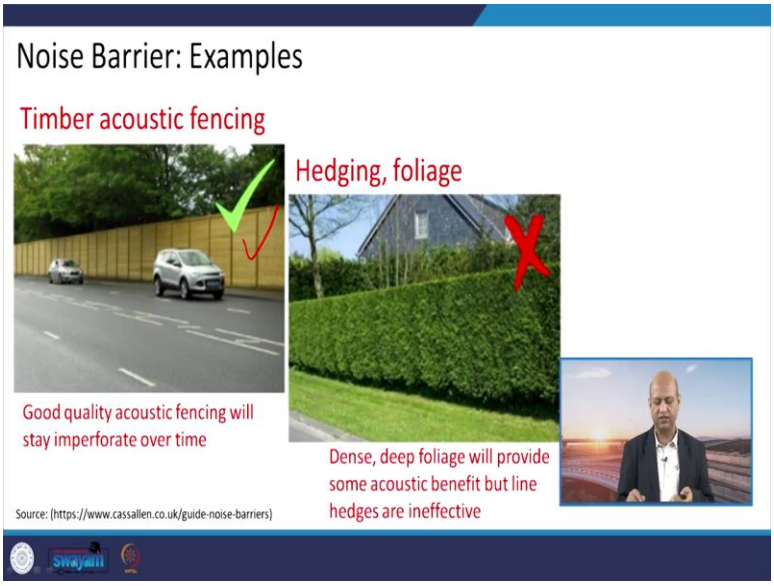

Similarly, the material also has important role for example, these hedges etc., they are porous and they are not able to reduce noise, so effectively and these kind of good quality acoustic fencing may be better rather than these simple hedges.

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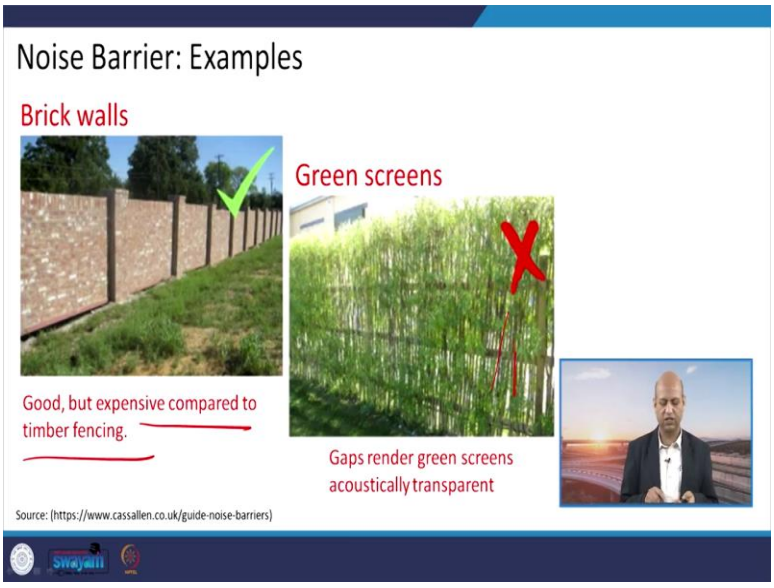

Similarly, these timber fencing is good, but if there are gaps then again because these rendered green screens they look nice, but they are not good in protecting yourself from noise.

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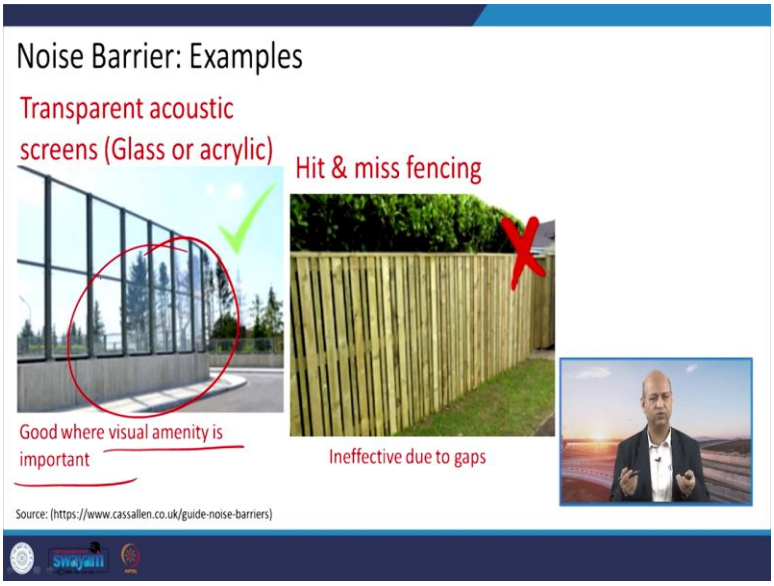

Similarly, because of gaps these hit and miss fencing is not so good, but if you have like visual kind of some screen of the glass or some acrylic or there are so many metal nowadays, they can even, you know do not stop this beauty of the surrounding area, so aesthetic value is also there and also you can reduce the sound levels.

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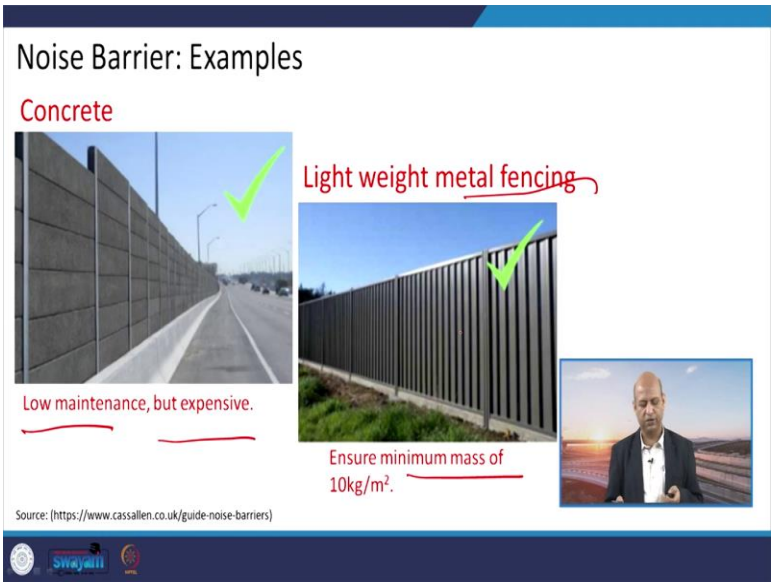

Well concrete structures maybe good in low maintenance kind of but they are expensive when we are constructing and I mean it is difficult to afterwards when if you want to change the location

then it is very difficult. Some kind of lightweight metal fencing can also be there which can be used depending upon the seriousness of the site.

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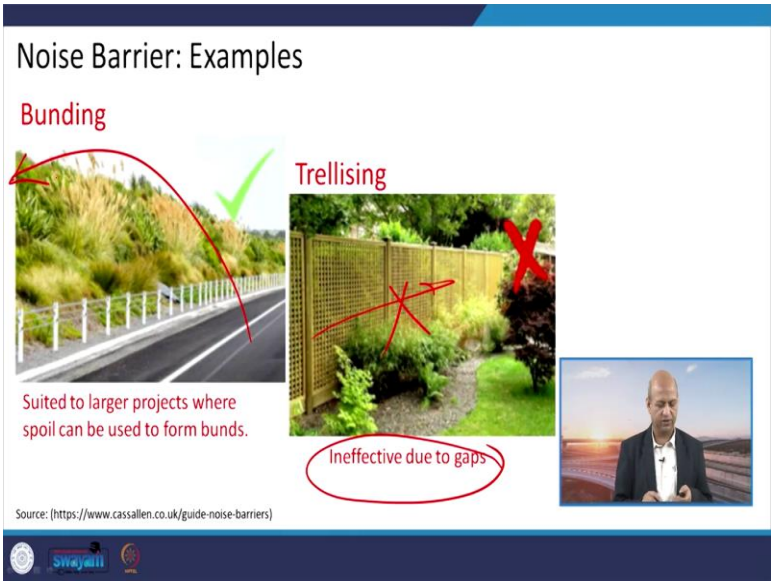

But as because of due gaps these kinds of infrastructures are not good and but if there are kind of very high bendings and slopes, so again the distance will increase, so the very less noise will go to that side where people may be walking or cycling etc.

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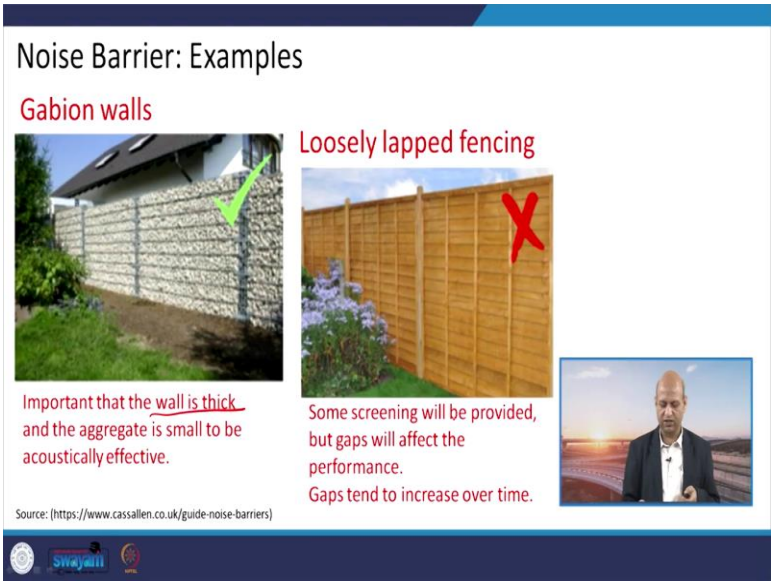

Similarly, again this wall thickness is good and that is a good solid wall with aggregate etc., that will prevent you from the noise, but these kind of screening with gaps will not help as we have seen.

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Similarly, these kind of structures are suitable and these slatted fencing are not suitable.

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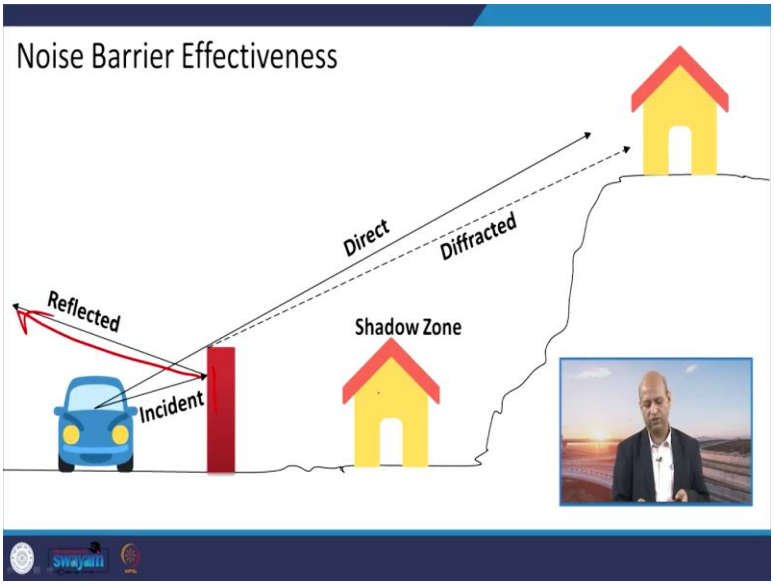

So, again that effect as I know these reflectors these barriers also reflect the sound, so lot of sound goes away and only remaining one goes to the receptor. So, this is again we are showing to you.

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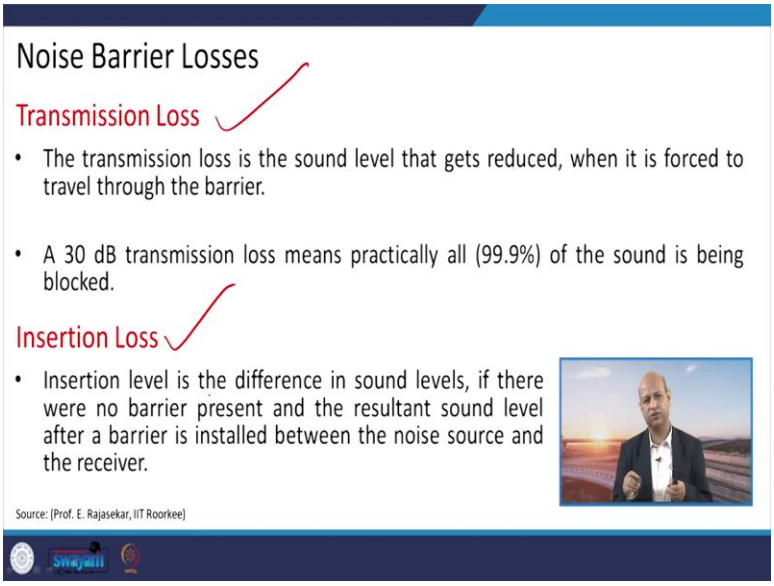

Well, noise barriers losses are there two types like transmission losses because of distance etc., it loses, sound loses the energy and this insertion losses, which are depending upon the initial sound and the sound which is reaching there, so that because of barrier presence that lot of difference is there, which is known as the insertion losses. So, these losses sum up and we get the net result of low sound.

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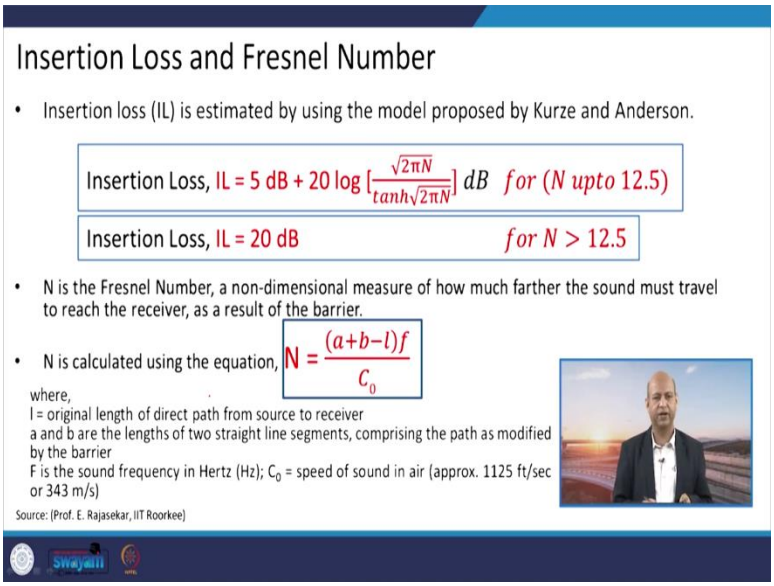

Again how to calculate these insertion losses? So, a very simple empirical formulation is there, which you can use and you can practice at leisure.

Insertion loss, $IL = 5\ dB + 20 \log[\frac{\sqrt{2\pi N}}{\tanh \sqrt{2\pi N}}]\ dB\ for\ (N\ upto\ 1.25)$

Insertion loss, IL = 20 dB, for N>12.5

N = $\frac{(a+b-l)f}{C_0}$

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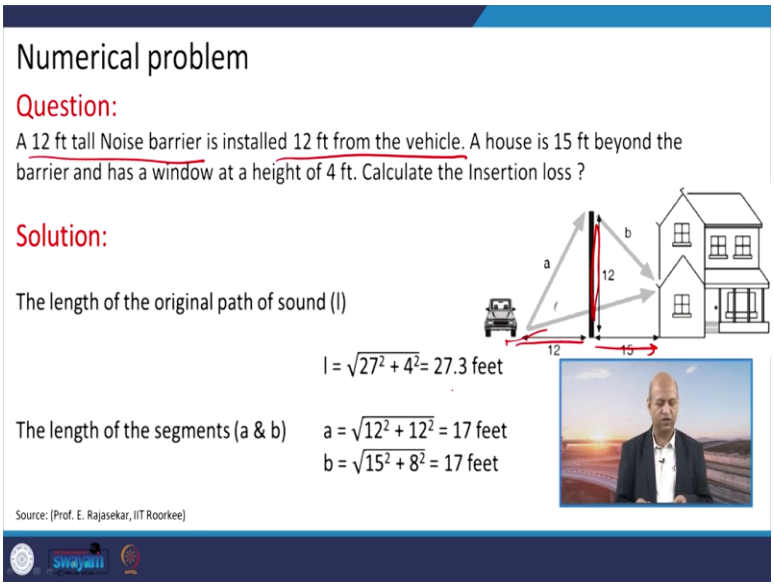

It is very interesting to see that like 12 feet tall noise barrier is there installed, 12 feet from the vehicle, so this is the barrier 12 feet high, 12 feet away from the vehicle, 15 feet from the house, so how much energy losses will be there, and there is like a window of 4 feet height, so all these parameters you can use to calculate the total path length.

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Numerical problem

Solution (cont'd):

Fresnel number, $N = \frac{(a+b-l)f}{C_0}$

Hence,

$(a + b - l) = 34\text{-}27.3 = 6.7$ feet

At f = 100 Hz, the Fresnel number, N is;

$$N = \frac{6.7 \times 100}{1100} = 0.61$$

The Insertion loss (IL) can be calculated by:

$$IL = 5 + 20 \log \left[\frac{\sqrt{2\pi \times 0.61}}{tanh\sqrt{2\pi \times 0.61}}\right] \approx 10 \text{ dB}$$

Source: (Prof. E. Rajasekar, IIT Roorkee)

And then how much energy losses will be there. So, this is kind of your homework.

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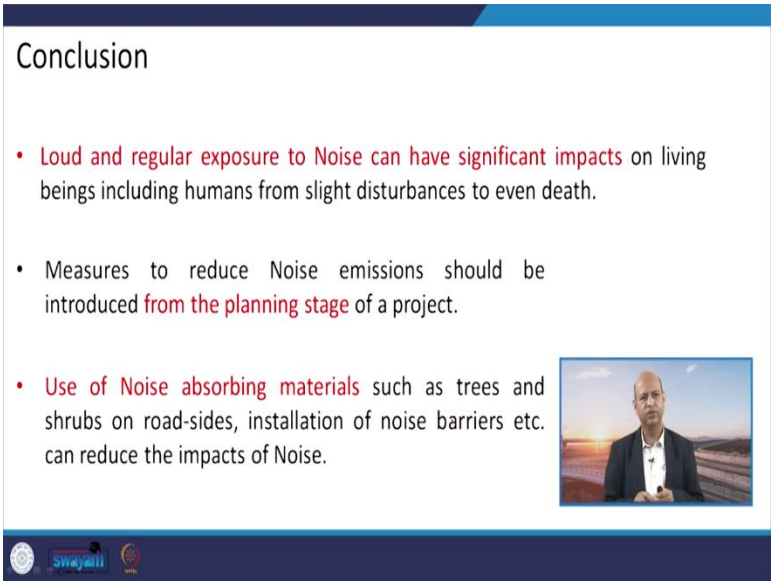

And at last we conclude that these loud and regular exposure of loud noise to people working people, they can reduce your efficiency, they can make negative changes in the physiology, they can irritate us, they can change our behaviour and they can damage our health also. So, we should not allow noise levels very high in our surrounding.

And these noise emissions should be kept minimum as well as from the planning stage itself, we should be proactive in terms of using certain materials, which reduces the noise and maybe we can use some structures and barriers, we can design them according to the need of the that location and we can make the surrounding much noise free or calm and good location, where you can enjoy your other activities.

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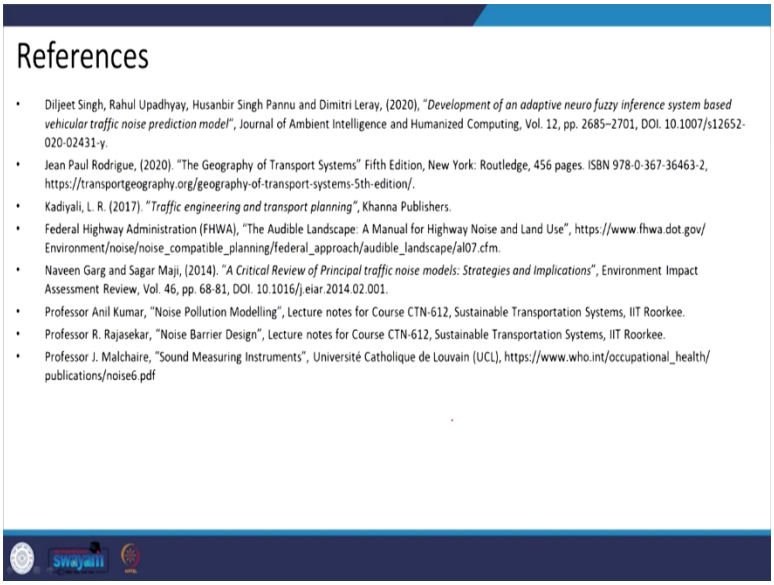

So, references are there for again to have additional knowledge about different numerical problems or design parameters and all those things if you want to know more about. So, again thank you. So, this is all for impacts of the transportation sector on the environment, human beings and other activities.

Now, we will see like environmental impact assessment, because the impact is there, so we should assess it, otherwise how would we plan to reduce the impact. So, there are techniques which are used for environmental impact assessment of different activities and the transportation sector is one of the important activity, which also influence the environment, so we should know the EIA or environmentally impact assessment techniques and procedures. So, in next lecture we will see that. Thank you again for your kind attention and see you again.