Architectural Acoustics
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Lecture - 35
Structure Borne Sound Transmission (Contd.)

So, welcome to the NPTEL certification course on Architectural Acoustics. We are now in the seventh week and this is the last lecture on the seventh week and Structure Borne Sound Transmission two.

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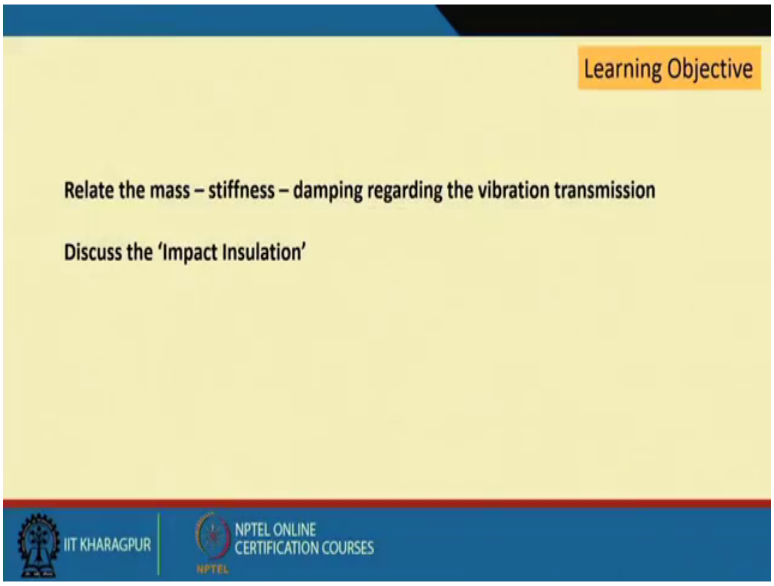

So, in the last lecture we have discussed about the some of the Primary Parameters of a Structure Bond Sound how it is influenced by those parameters. And in this lecture we will have two learning objectives, once again and we will actually be going to relate the mass stiffness and the damping in the vibration transmission point of view. And also we are going to discussed a bit of the impact insulation.

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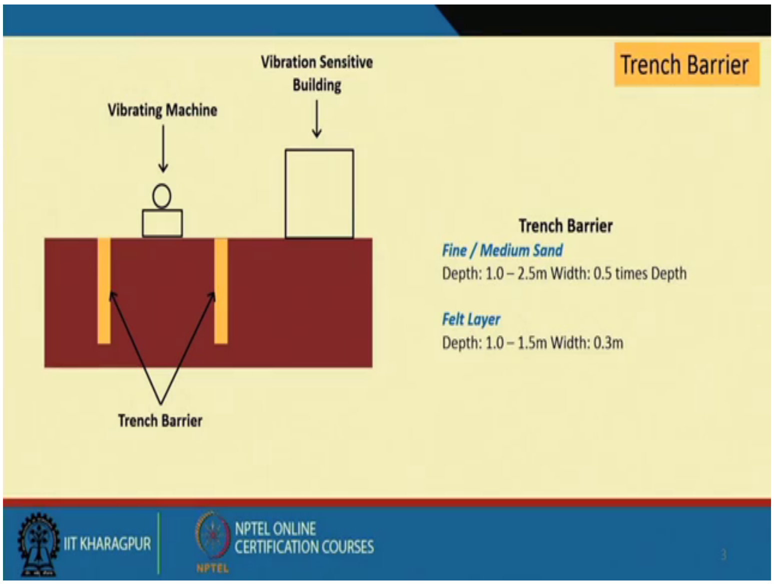

So, before go to this particular the relation between the mass stiffness and the damping. Let us discuss some of the barrier of the trenching. So, if you remember in the last lecture we have talked about there are the source, there are the path, and there is the receiver.

So, sometimes a structural discontinuity in the path keeps you the noise reduction such a bond reduction, sometimes some kind of a mounting in a particular machine will actually stop or reduce the propagation of the sound from the source itself. Sometimes, we can we sometimes have to protect the particular the building or the noise sensitive area by virtue of the sound transmission which can be done through the trench barrier.

In the trench barrier, in the soil itself are in the ground itself to trench has been made and a vibrating machine has been placed. And, because of this trench and this trench may be filled with some kind of the measure the fine or the medium sand or felt layer with these particular dimensions can actually going to reduce the propagation of the sound.

So, here, in this particular zone of the soil or the base there will be an amplitude of the vibration will be very high, but where it crosses 2 there is a damping and due to the damping and the absorption of the sound over here or the vibration or the mechanical energy over here the amplitude will be reduced down. So, by virtue of this trench barrier we can actually protect this particular vibration sensitive buildings also.

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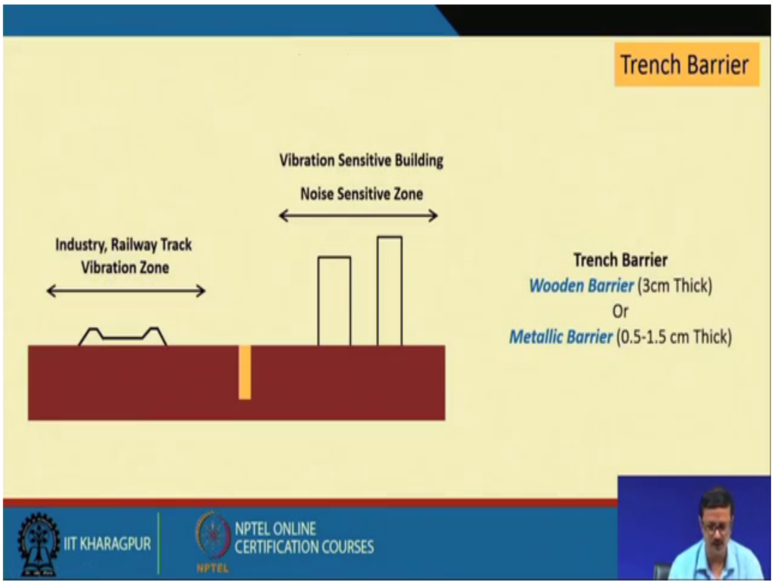

We can also think of this kind of a trench barrier through some kind of a wooden barrier or kind of a metallic barrier where again a railway or an industrial area which is having a vibrating zone search can be self-graded; because vibration propagation of the vibration can be self-girded through this particular trench and this noise sensitive zone; the vibration sensitive building can be taken safeguarded by this trench also.

So, we can use some kind of a wooden barrier or the metallic barrier or some kind of the flexible the padding systems over this particular they as a trench.

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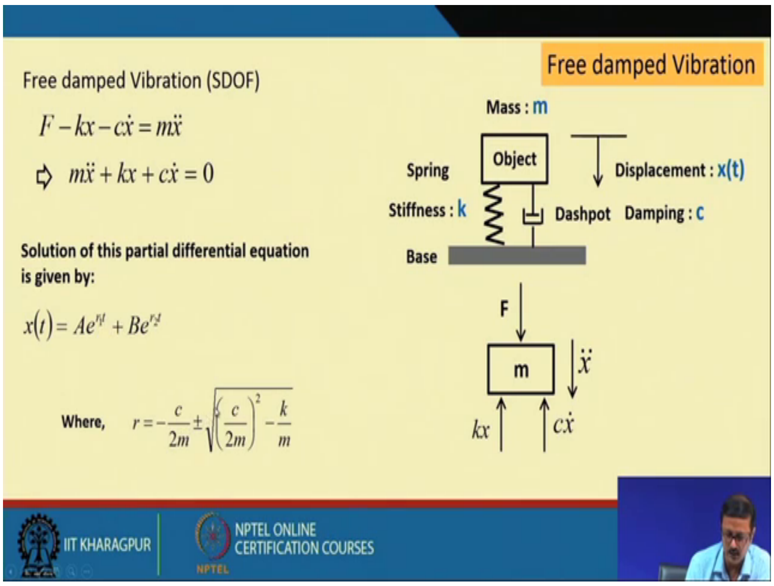

So, next let us go to if we going to this kind of the vibration isolation of course, in case of the object and the machines and the systems with having some kind of a spring and the damping. Then you remember in the last lecture, what we did is that that is a free vibration where, there was no damping a machine is freely vibrated with its own natural frequency.

Here, also it will be going to be vibrated by its own natural frequency the only change is that here there is a damping dashpot is been made. That means, this may the machine is now on kind of a layer which layer is a damping layer and which can be act as a vibration isolators are going to absorb the mechanical energy.

So, what will be the fundamental free body diagram of this particular system a mass is acted by a force and this force is external force or the operating force. And due to this force there is an equal and opposite kind of a force will be developed or the resistive force will be developed one through the systems stiffness which is k into x and one through the damper which we have been introduced over here which is a damping coefficient c into x dot x dot is the d x d t that is the velocity of the particular movement and with that force. Because of this f, and these two forces there it will the mass will be actually having some kind of a result in acceleration and x double dot and m x double dot is your force that is experienced by the mass and this is the resultant force f minus k x minus c x dot

So, if you rearrange the equation will be like that m x double dot plus k x plus c x dot equal to 0. So, this is again a second what order the differential equation and the solution of this differential equation will be like this exponent or in exponent terms and there will be 2 roots r 1 and r 2 can be found out from this equation.

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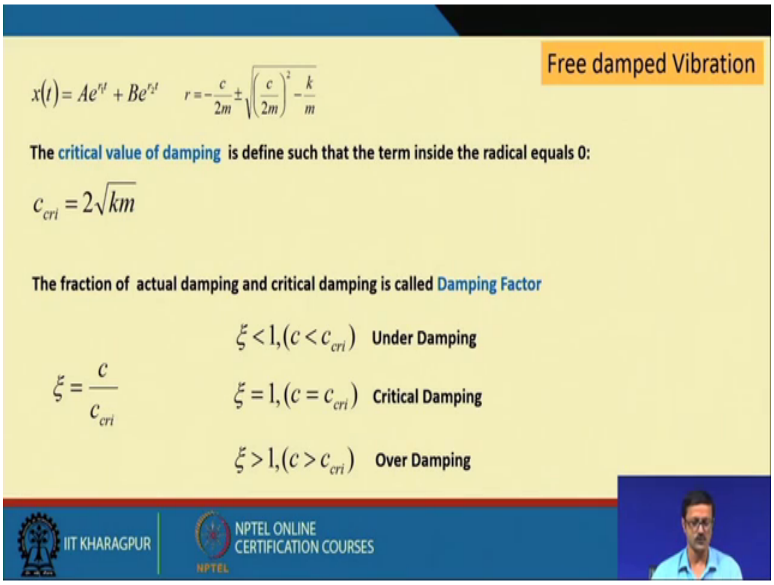

So, by virtue of this damping and this by virtue of these criteria of the damping a critical damping amount of critical damping can be found out with c critical is equal to twice under root k by m. So, what is critical damping is that this much amount of damping if you can provide, that is the fullest amount of damping a particular machine may need, but we can provide over access to that also. Sometimes we can give some kind of under damping case also.

So, a damping has to be provided by virtue of some kind of the layer or some kind of the damper or some kind of a spring or some kind of a flexible padding. So, this damping factor is defined as xi is equal to c by c critical where c critical is your twice of under route k m, and c is the actual value of your that particular damping value of the layers you have you are going to provide.

So please remember, that the c critical is a factor or in the parameter of the c critical is depend upon the mass of the machine which is going to be vibrated and the system stiffness, whereas this c which is the component which is actually going to be provided is comes from the particular layers damping collector.

So, one possibility is that, the c is less than c critical where xi is less than 1 which is the under damping case there can be another possibility as the c is exactly equal to the c critical. So, the xi is equal to 1 that is called the critical damping scenario and there can be another situation where c is more than c critical and the xi is more than 1. So, it is the over damping scenario; so, which one is good and which one will be going to add up we will let us see.

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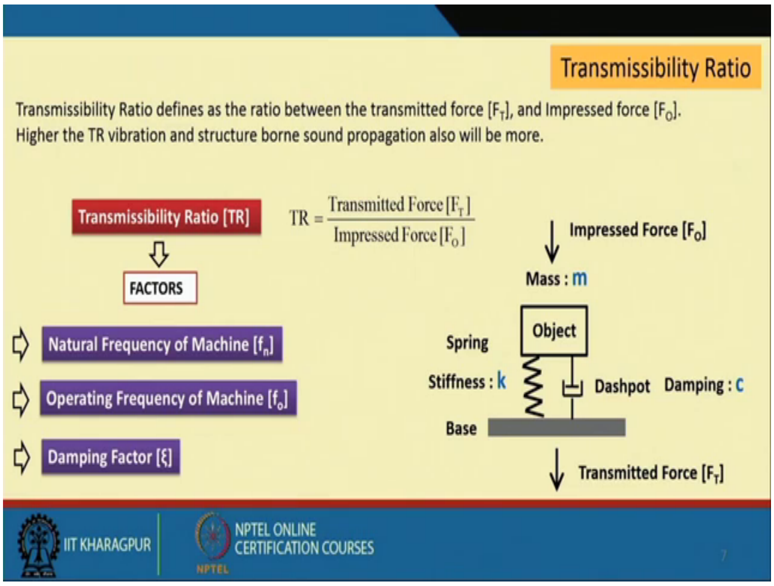

So, suppose there is a mass and this particular the object mass its stiffness and the damping are there; so it a particular vibration scenario.

So, there is a force impressed force, because of the operation which is F naught F o and, because of this force, and because of the all the mechanism happening over here. It has transmitted some kind of a force also F d the ratio of this F t by F o the transmitted force by the impressed force is called transmissibility ratio transmissibility ratio and this transmissibility ratio formula. If you just see, this ratio this TR has to be minimum, why TR has to minimum. Then whatever may be your F naught is F t will be minimum and as F t will be minimum the transmission, due to this vibration will be minimum and my noise propagation also will be minimum.

So, what are the factor actually that will creative payroll; in this particular TR, let us see the first factor is the natural frequency of the machine. Yes, a particular system a particular vibration system has its make the natural frequency by virtue of its mass and stiffness. Next is operating frequency of the machine again, again what is operating frequency; if you start the machine some electricity or some kind of the other energy the machine start vibrating the pump is pumping the water the h u starts sending the air.

So, that particular operation time this operation frequency is actually happened to be there in this particular system. So, operating frequency may not be fixed suppose there is a voltage fluctuations operating frequency may change due to the voltage fluctuation. There are some kinds of a mechanical problem, in the gear or maybe some kind of assembly operating frequency may change due to that.

So, there is kind of a set of operation frequency, because of those kinds everything, but there is a designate frequency operating frequencies there for a particular machine when it is running in a full and the idle condition, what is the third parameter the third parameter is the damping factor.

So, if you use more amount of damping critical damping the over critical damping or the under critical damping. So, because of that your propagation of the sound your transmission transmitted force will be going to change. So, these are three important factors that will play a role in the transmission ratio.

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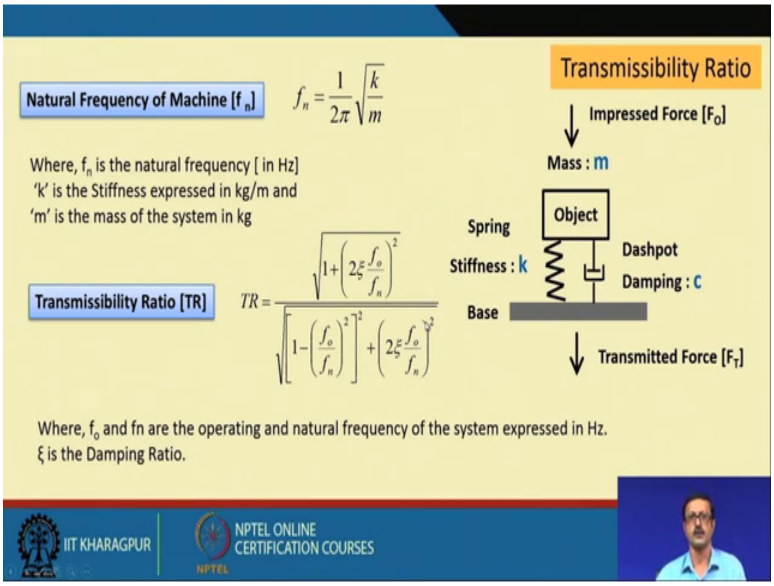

Now, let us see how these three factors can come through equation and I can actually find out the TR the transmissibility ratio if I know F n F o and xi. This is the natural frequency, we have already discussed.

Now, this is the transmissibility ratio equation I am not going to derive this equation any vibration isolation vibration mechanical engineering books you can find out this equation and the derivations on that, but this equation I am going to discuss over here. Because, this is very interesting and being an architect or at least being a technician a particular person who is going to deal with this kind of a noise propagation structure Borne Noise Propagation.

I believe, we should know the ins and outs of this transmissibility ratio equation. This is a big equation no doubt, but if you see there is a very good similarity this I have told you there are three factors only operating frequency natural frequency and the xi; xi what is xi c by c critical that ratio. So, actually if you see this is a ratio format F o and F m this ratio. So, this is unit less and xi is also unit less.

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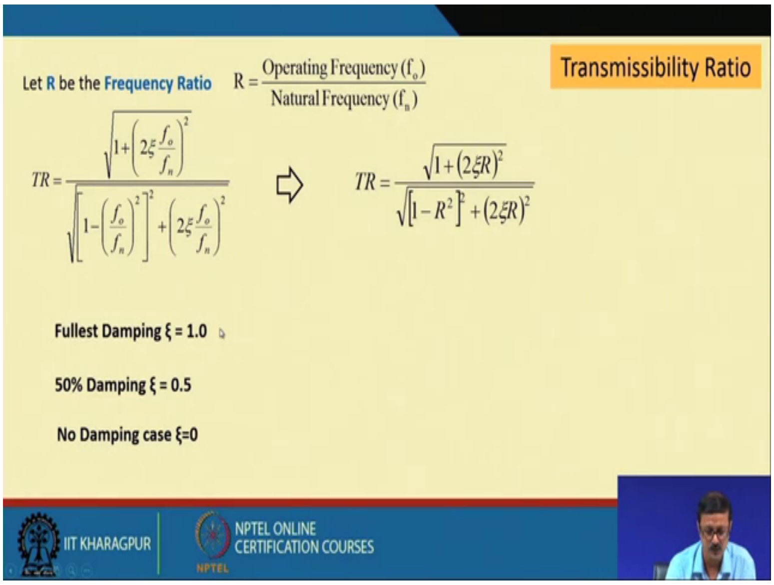

So, this is particularly unit less kind of a character. Now, if I say that this R is a frequency ratio that is f naught by f n. I can reduce this is a big equation to a smaller equation, just I am replacing what I am replacing f f naught by f n by R nothing else.

Now, there are three criterias; one is fullest damping I am providing xi equal to 1. And suppose I have providing no damping, this is I equal to 1 is the critical damping I have provide fullest amount of damping the second case I am providing 50 percent of the damping to xi equal to 0.5 and another case I am providing no damping xi equal to 0.

So, just I press the machine on the particular floor itself without any kind of the added the flexible layers. So, let us see; what how and this particular xi values change the TR value.

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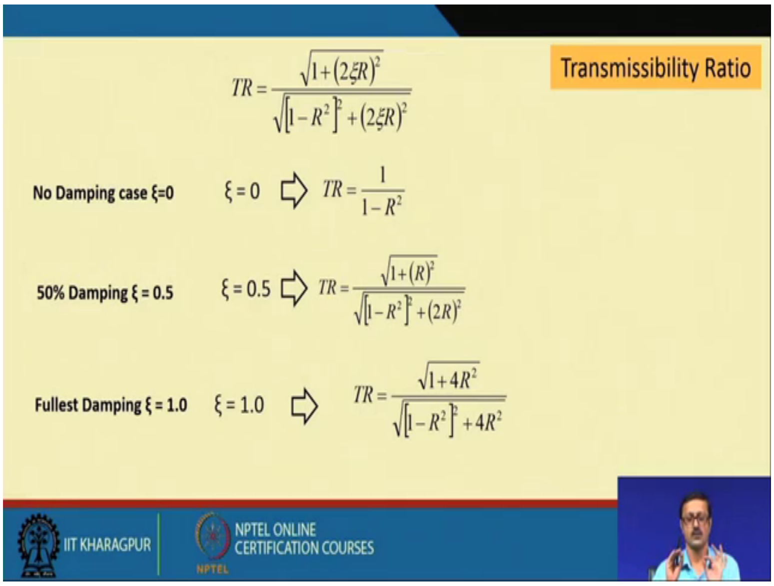

The first case, where this particular xi is equal to 0 or maybe that was the third case, in the last slide no damping is xi equal to 0. So, if I put 0. So, this is 1 and this is also 0. So, and this under root comes out 1 minus R TR equation is now very very simple 1 by 1 minus R square where R is equal to f naught by f n.

Now, if the 50 percent damping is directed this is xi is 0.5. So, put xi equal to 0.5. So, 0.5 into 2 equals to 1.5 into 2 equals to one also here. So, 1 plus R square under root 1 minus R square, whole square plus 2 R square and I think this is slight typological error. This will be only R square and we will rectify it.

So, then next one is if it is a fullest damping. So, the xi is equal to 1 and now if you put the xi equal to 1 you will get this one. So, this is 2 2 square is 4 R square this is also 4 R square and this is remaining as 1 minus R square whole square.

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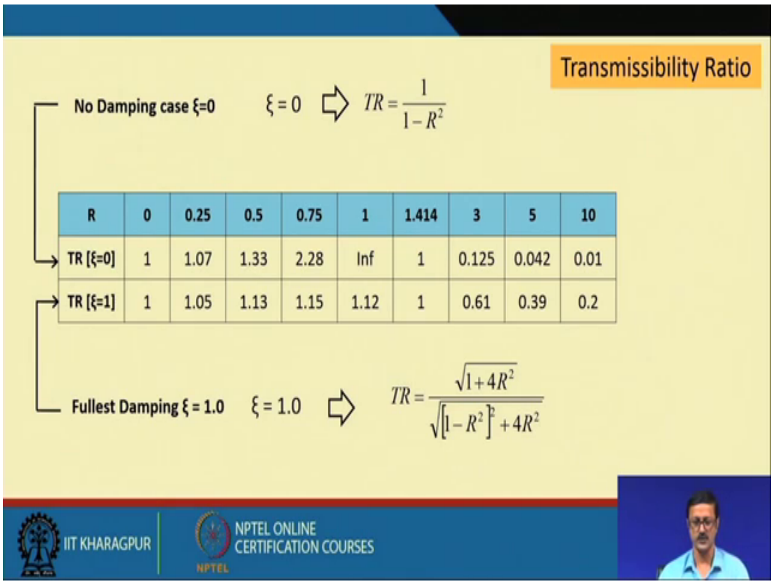

So, these three equations of TR come predominantly far xi equal to 0 xi equals to 0.5 and xi equals to 1. And let us see how it will change its character when I will have different frequency ratio. So, in that you see in this table what I did is that the R is given in the blue this row.

So, R the frequency ratio starts from 0-5 like that0.5, 0.75, 1. This is 1.414 is under root 2 and then3 5 10 like that and we use this equation for xi equal to 0 and xi equal to 1 with this equation and we plotted the thing and you see, if the xi 0 case when there is no damping is provided and if the frequency ratio is 1 that is your operating frequency is equal to your the natural frequency. The TR the transmissibility ratio is infinity; that means, you will be going to propagate the sound will be infinite to be that the transmission force will be infinite.

So, that is the resonance, that is the creation the resonance effect and you are taking no consideration no damping for that. Similarly, if it is 1 in that case, it is going to is equal you have provided fullest amount of damping from infinity to it reduce down to 1.2 and only 12 percent increase in the transmission from the operation free operation operative force also.

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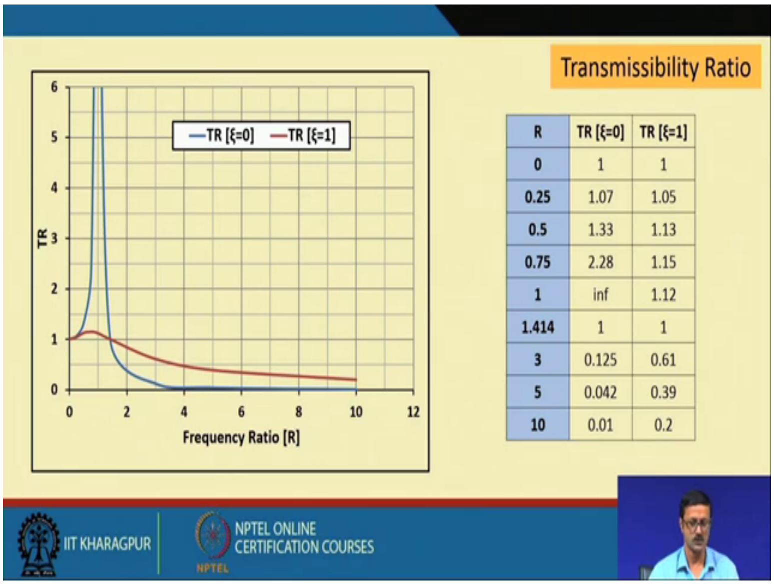

So, with this two data set of data, you can draw a graph I have, this is the y axis is the transmissibility ratio and x axis is the frequency ratio.

So, it is always going to be better if the transmissibility ratio is less than 1 and then only I can say that what, what may be the operating force my transmission force is less than that, but this see this blue line is what xi equal to 0 its infinity when it is one and this is one it is infinity. And then it is gradually decrease down, but this red line is for the fullest amount of damping your TR is under very controlled way I mean it is following a very controlled manner.

So, definitely the fullest amount of damping is going to help it will reduce down your amount of vibration or the force propagation due to the vibration.

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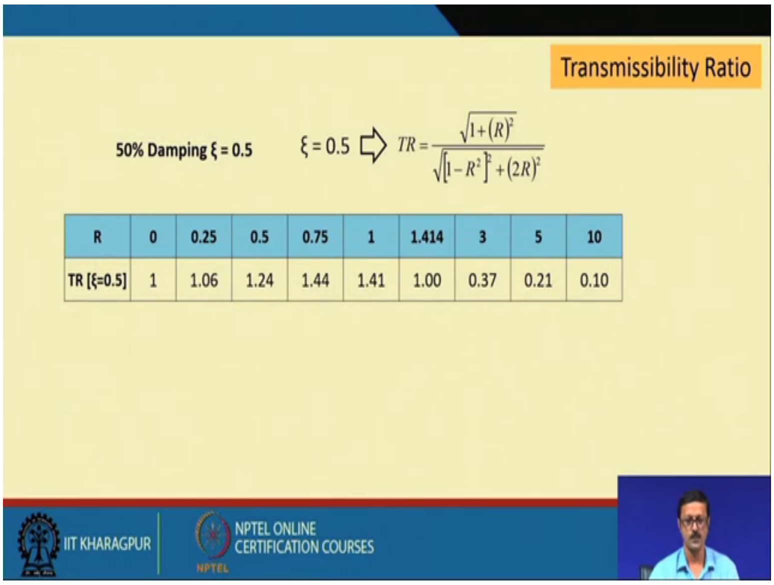

So, let us do this for the 50 percent of the damping also I am sorry this is again, a typological error where this two has to be eliminated. In the PowerPoint slide I will change it and I will upload it this R is here and for this t values this is the particular damping value. This particular damping value is this and for that we can also now, draw a graph another graph which is a black colour one which is for TR equal to 0.5. So, even if you give a 50 percent of the damping. Yes, it is it increased with respect to the fullest damping, but still it is under control still it is under control.

So, we can think of some kind of the damper in a particular machine below the machine to reduce the propagation of the sound, but my dear this is not.

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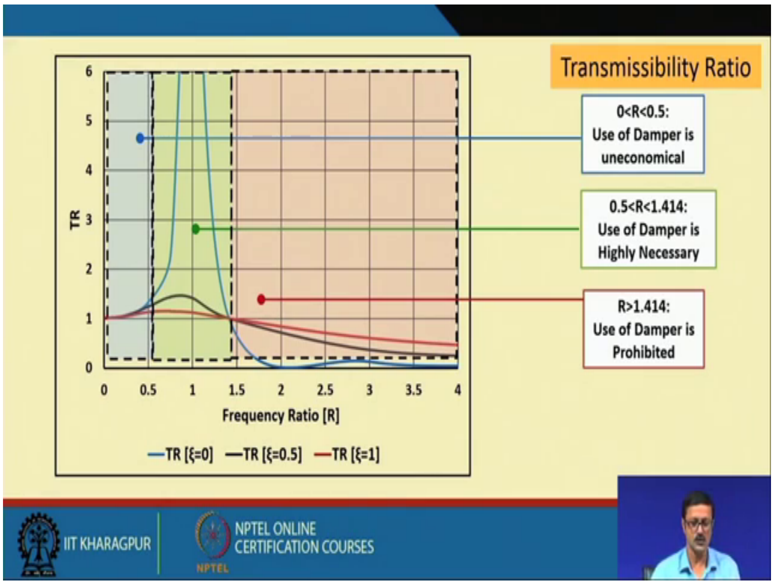

So, easy if you see this particular transmissibility ratio curve or the set of curves I can see there are three typical zone. The first zone I see this particular first zone where this frequency ratio is point sorry for 0 to 0.5 or. So, where it if you give damping or if you do not give damping or if you give list amount of damping all are flying from 1 and very gradually it is increasing.

So, I have written that if your frequency ratio is in between this your natural frequency and operation operative frequency ratio is in between 0 to 0.5 you can give damper, but that is very-very uneconomical, because if you see here what is the distance or the damping;; if you do not give and if you give 100 percent this is negligible, negligible amount of change will occur if I go back if you give 0.25, if you do not give anything it is 1.07 if you give fullest amount of damping it is 1.05. See the change you giving nothing is 1.07 and giving 100 percent is 1.05 only 0.02 fraction of change.

If you give fullest amount of damping that is why I have written over here this is zone 1.0 to 0.05, use of damper is uneconomical you can give, but it is slight change will be occur. The next shown is this shown where 0.5 to 1.4, 14 root 2. In this zone, if you see if you do not give it will fly away the TR is very very high infinite. In fact, for 1 and if you give then this is reducing and reducing by maybe less than 0.1, 0.5 or.

So, if your frequency ratio is in between 0.5 to 1.5 use of damper is highly necessary you have to give the damper, otherwise, it will propagate the sound or the vibration like anything. Again, if I go back to this particular table, this is in this zone. So, if you suppose 0.75 if you give if you do not give it is 2.28 if you give full then it is 1.15 or if you give 50 percent is 1.0.

So, you have to give the damping over that if it is one it is obvious infinite and it is reduced down to like that, but in case of point sorry root 2 all are equal. Now this is the second zone. So, you have to have, give the damper for those zones if your frequency ratio comes in between 0.5 to 1.5. Now, there is a third zone also. The third zone is when your frequency ratio is greater than 1.414 or root 2 see what happened, if you do not give follow this blue line do not give after the root 2 line this is here, if you give full amount of damping you are above.

So, what does it mean? If you give the full amount of damping and your frequency ratio is it the higher than 1.414 root 2 you are enlarging your TR value you are enlarging your TR value by putting the, this damper. So, use of damper is prohibited you should not use the damper if the frequency ratio is more than root 2. If you see the table one again, suppose it is your frequency ratio is more than root 2, that is your suppose 0.5 sorry 5. If you do not give any kind of damper it is 0.042 if you give full amount of damping your TR value is 0.39.

So, why should I give that, why should I give even 50 percent of the damping also, because it is give me 0.21 it is 0.04. So, below this below point root 2: those area or maybe in another one. Another way if the ratio is more than root 2 better to not to provide the damping. So, that is why I have written this is the red zone the third zone when the R is more than root 2 use of damper is prohibited do not use the damper.

So, by virtue of this particular equation I have told you this equation is very tough to derive very much very much I mean the mathematically very tough to derive, but it has a very interesting role to play in the vibration transmission. It suggested that, just closing my eye and putting some kind of a damper in a particular machine is not going to actually going to happen not going to help me I have to first find out the what is the operating frequency what is the natural frequency I should know the what is a ratio between them if the ratio is in the first zone its uneconomical.

If it is the second zone I have to have provide the damper and if it is in the third zone you should not we should not use the damper, because if I use a damper the TR will be much more the higher and the it will actually propagate much high amount of vibration.

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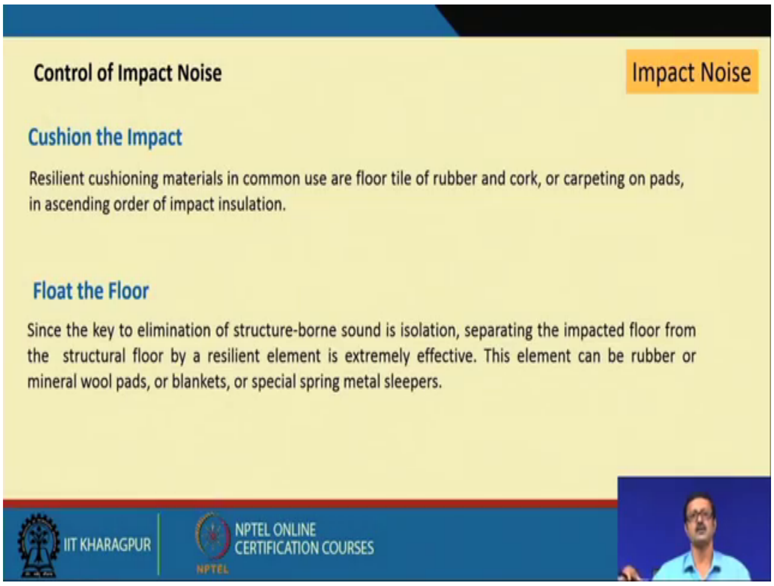

So, next let us go to the impact noise the impact noise is noise that made by some kind of a sound in a particular horizontal floor, by some kind of impact maybe the footstep maybe is some kind of a machine tapping on the particular floor or maybe sometimes its maybe a dance floor or some kind of aerobic activities or so for that also sometimes it is happened. So, the noise will propagate from the upper flow to the lower four, because of this impact.

So, there are various way to control the first one is the cushion is the best one is the cushion for this particular impact control. We can create some kind of a float of the floor the floating floor where you can use the some kind of an arrangement where the particular floor is floated over the structural flow.

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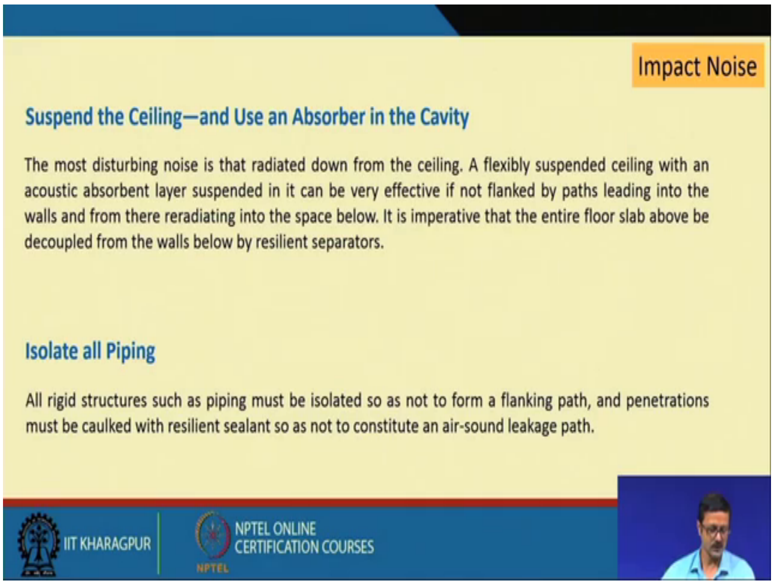

We can also use kind of a suspended ceiling system and use some kind of a absorber; and the cavity kind of an attachment below the structural for to avoid the propagation of the noise from the floor above to the below. And also we can we can use some kind of isolate all kind of a piping and all those kind of the work which is actually propagating some kind of fluid. And then, because of that some kind of a vibration and we can isolate that one to reduce, the only impact bond sound or so.

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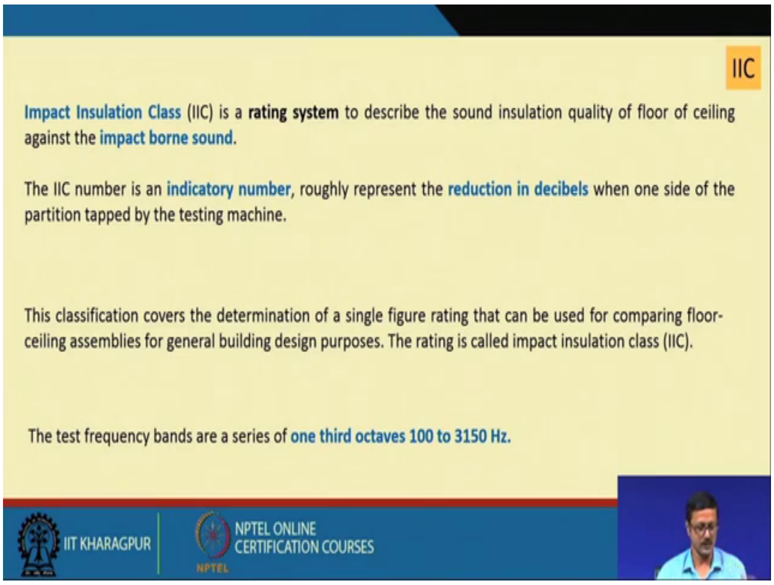

So, very similar to the STC that is the sound transmission class there is also impact insulation class or IIC rating system is also available for the any kind of those kind of a floors where again, the one third octave band from 1000 to 3150 those 16 one-third octave band is actually taken at a particular single number is try to find out a indicatory number which will be give you some kind of a sense of reduction of the dB from the source to the receiver the area.

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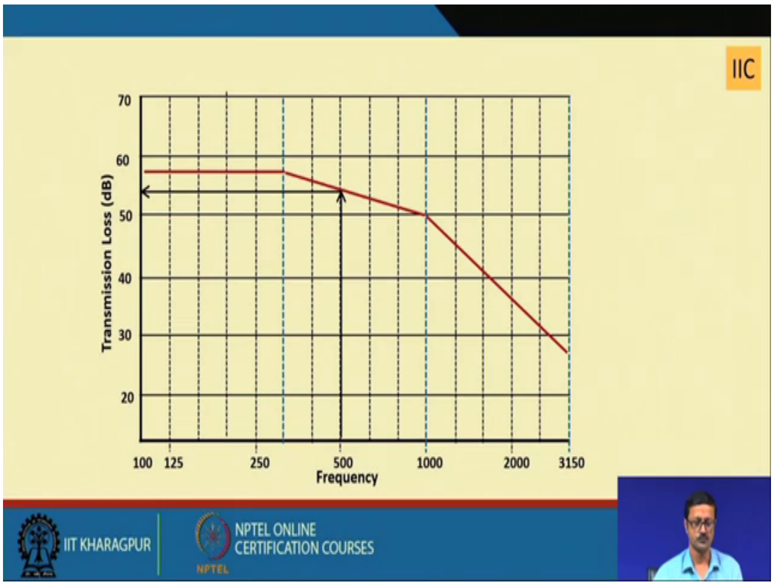

So again, it has to be done like this it is the 16 frequencies and you test each frequency and see the what is the reduction in the dB and this will be plotted oppositely on the way we did in case of the STC the same procedure we can follow. If you remember we take the first six frequency take the average draw a straight line then decrease by the 5 dB within this 5 dB zone and then again decrease by 15 dB within that 15 dB zone we get a, the contour.

In this contour, in that case, it was called the STC contour. In this case it is called the IIC contour, and if you see remember this is the other way around the STC contour was something like this is going like this. This is other way around and similar to the STC contour the corresponding to the 500 frequency sound the when it is striking this. This contour and horizontal and this particular value in the transmission loss case will be the IIC value of this particular material or particular floor.

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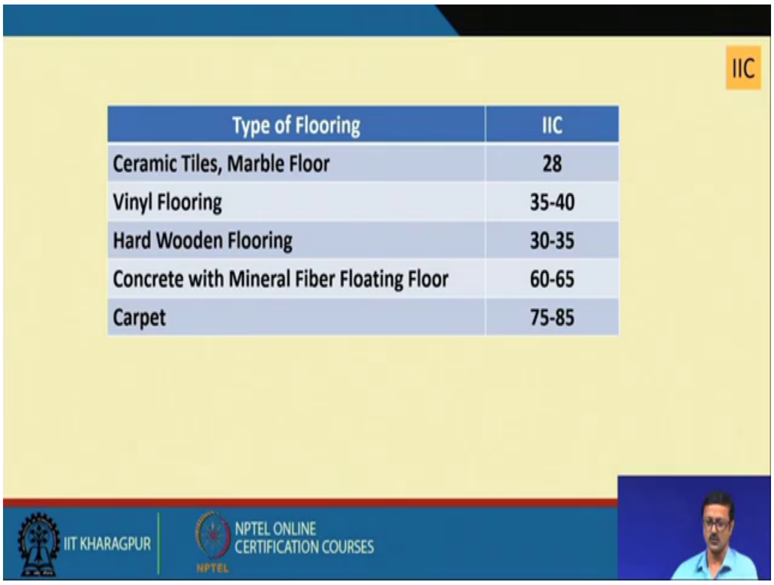

So, they are typical I have listed down some typical floor or typical material which actually used for any kind of a floor and the corresponding IIC value ceramic tiles is less the vinyl flooring is also very less, but if you go for the carpet or any kind of the floating floor with the concrete and the mineral fibbers all it will be very high. So, I have sketched also some of the cases if you want to have a kind of a floating floor.

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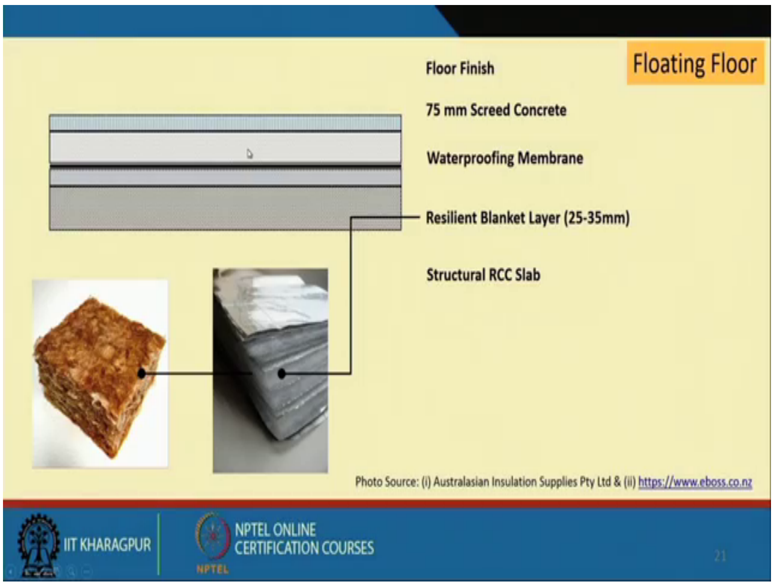

So, this is your the structural slab this is your structural slab first layer got the bottom most layer. We can prove some kind of a blanket this is the second one is the blanket or the resilient blanket which is something like this a blanket you put. And then you put some kind of this black colour thick line is the waterproofing membrane and over that you put 75 mm script concrete and the over and above.

This is your desired floor finish is a compacted kind of a the floating floor; cover construction where each and every layer the structural the layer structural slab and the top floor finish and the screed concrete layer is sandwiched with a, the waterproofing membrane and the resilient blanket. We can also float the floor it a little high you see what we did is that, there is a structural slab which is this and over that there is a the some kind of a resilient blanket layer it is may be through layer or maybe just below this 50 by 50 mm wooden plank.

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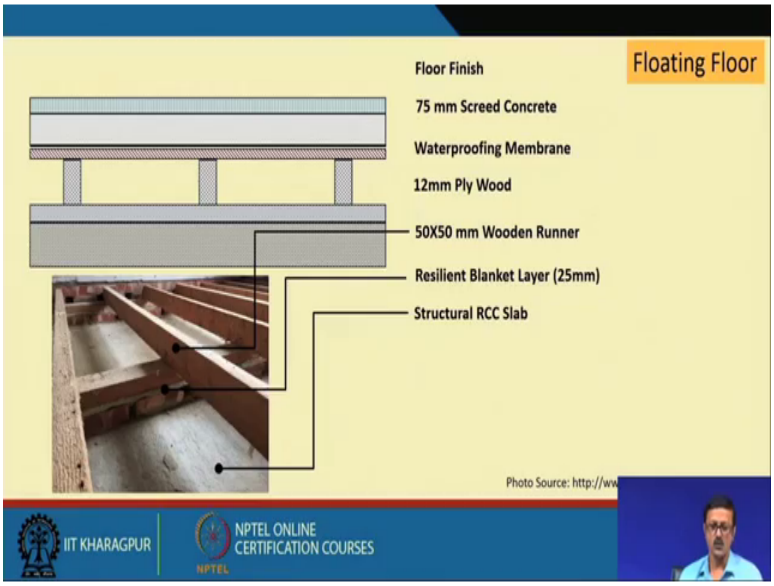

So, this is that resilient layer over that this wooden plank runners are run. This is the runner and over that which is not shown in this particular photograph we may place a 12 mm ply and over the 12 mm ply. Again, you put that waterproofing membrane and after this waterproofing membrane you put your script concrete and the desirable floor finish.

So, here what happened is that this structural slab is isolated from the above floor by virtue of this wooden membrane and some air gap in between. And also it having some kind of a soft resilient blanket layer which will definitely going to absorb the foot borne a footstep noise or the impact bond noise also.

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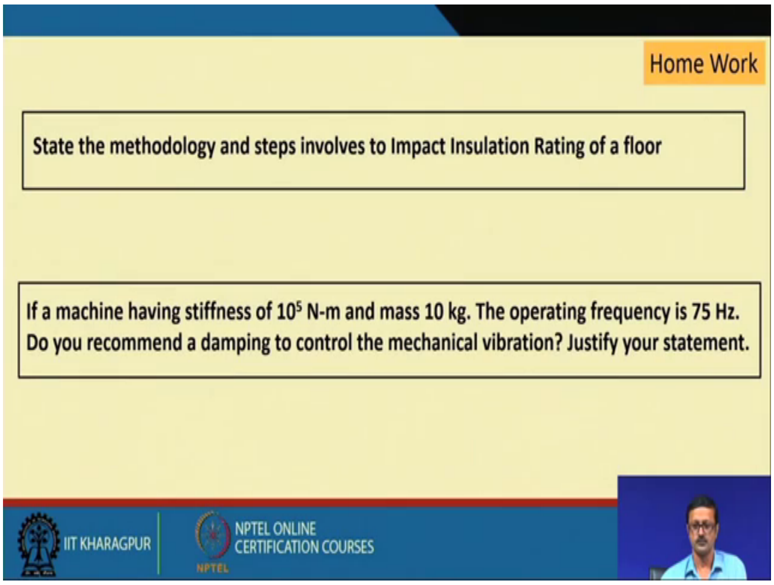

So, that is going to be the end of the weeks lecture this seventh week lecture. And this fifth lecture of the seven weeks as usual I have some homework for you the first one is the theoretical. You have to state the methodology and step involves to impact insulation rating of the floor. Please remember this is very similar to the high STC I have described the STC in a fullest way in the lecture number I think 33 and the impact insulation rating is almost similar to that.

So, you have to find the steps and methodology by yourself. And another one is mathematical suppose a machine is having its stiffness of 10 to the power 5 Newton meter and mass is 10 kg and the operating frequency is suppose 75 hertz. So, this stiffness and mass will give you the natural frequency and operating frequency is 75 hertz. Now I my question is do you recommend any kind of damping solution damper to control this mechanical vibration do you and if you say: yes, why if you say no why.

So, you have to give your justification of your statement. So, these are two homework for you. And in the next lecture next week will go to the environmental noise control and that will be the last week of this program.

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So, I have taken help of these four books for this particular lecture number 35 on Structure Bond Sound Transmission 2.

Thank you for hearing me.