Building Materials and Construction

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Module - 1
Lecture - 1
Functions of Buildings, Role of Construction Materials etc

Welcome to NPTEL project, building materials and construction. This is module one and in the module one we shall be dealing with function of building, requirements of functional requirements of building, types of loads and role of materials. The course is on materials and construction. The first thing we got to understand is the role of materials and to understand the role of materials, it is necessary to understand what are the functions of buildings and structures and that is why, this module includes this four components, okay.

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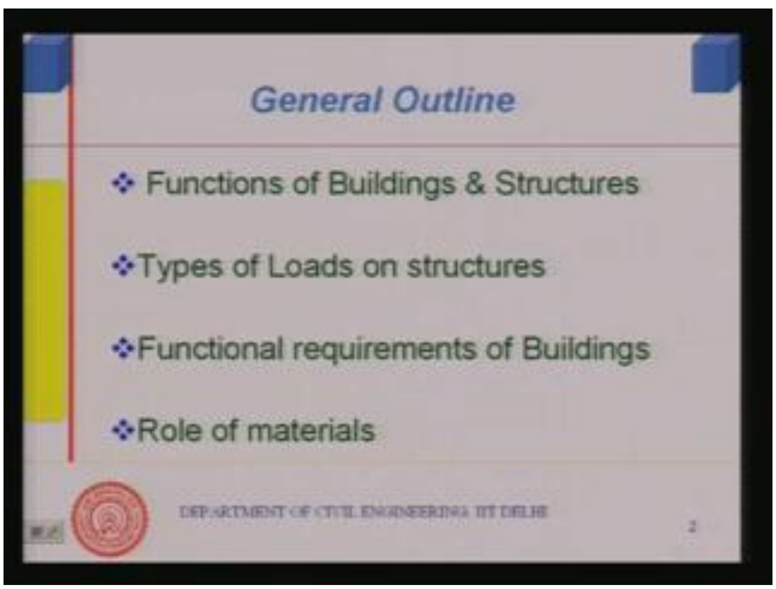

So, general outline of the course, we can look into like functions of buildings and structures, as I mentioned just now, followed by types of loads and structures, then functional requirements of buildings, because load is one issue in case of buildings and structures. But there are functional issues, so we shall be discussing functional requirements of buildings, and then from this it will follow automatically the role of materials. So, starts with function of buildings.

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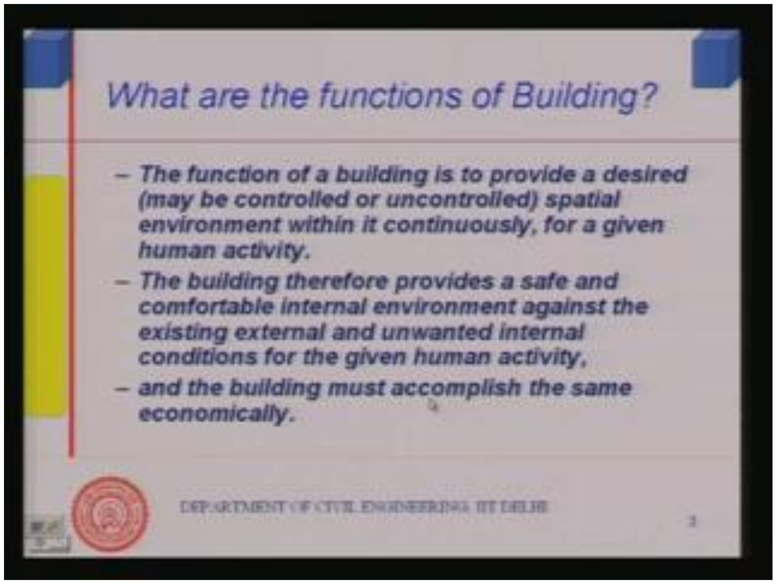

What are the functions of building? Function of building is to provide a desired spatial environment within it continuously for a given human activity. This space may be controlled or uncontrolled. Controlled example is an air conditioned building where the temperature, the relative humidity, etcetera are controlled. Uncontrolled is any ordinary building where no temperature control, no humidity control, etcetera, etcetera. are actually done. So, this is what is the function of the building?

Now, we will, building must provide this environment. After all, building is supposed to provide as a space in which human activity will go on and must provide continuously an environment, which is as we desire. Now, this must be safe.

Safety is the first requirement. It should be safe against all kind of natural forces and also from man-made forces. So, this space, that we are talking of, that is, the building, must be safe and comfortable. It must provide for safe and comfortable internal environments against existing external and unwanted internal conditions for any given human activity.

Now, when you mean human activity, human activity, you mean, for example, in a classroom it is the teaching. So, that is the human activity. In a factory, possibly, production of certain items in a living space living is the human activity and so on. So, human activity, we mean this.

And this must be done quite economically. We cannot go on to do any amount of expenditure we like, to construct such a space. So, we must do it with economy. This is the difference between a monumental structure and modern functional building. Monumental structure like Taj Mahal was constructed by a king and he was not bothered about the monitory implication of such a construction. But modern functional construction must be done economically and also, within a reasonable time. So, both these issues of time and money is important in modern functional buildings.

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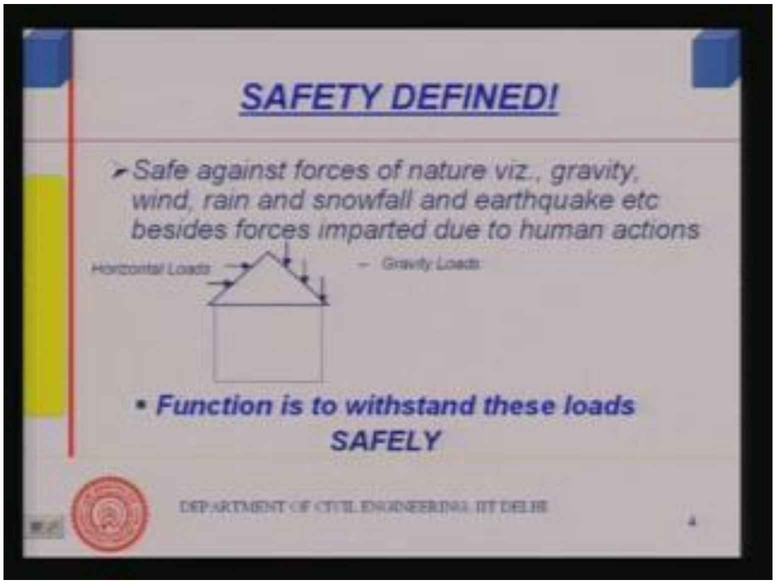

Since we said it must be safe and safety is most important, utmost in buildings or any structure for that matter, since we have said it should be safe, so let us define the safety first. Safe against forces of nature that is what I said safe against forces of nature. For example, well, anything on the earth has the tendency to go down. Therefore, against gravity load, against, you know, that means, for a building or a structure it must stand erect, it must stand erect, should not collapse on its own weight or something like that. Then, it must be safe against wind, safe against rainfall or rain forces, due to rain or snowfall and also against earthquake or such kind of natural forces that exist.

Besides there could be some load due to human actions. There could be some loads due to human actions. For example, if there is the factory and there is continuous impact is imparted onto the floor, then that floor must be safe against such impact, or if you are putting lot of furniture in a space, then it must be, the floor should be able to withstand or hold down to those furniture or human being or and so on. So, these are the loads that are coming from human being.

So, there are, what you have seen, it must be safe against force of nature. One is from gravity that includes all the loads that might come because of human being. An impact is one, which is additional human actions that puts the additional load and wind and earthquake load, etcetera. Two types of load, therefore, vertical load, gravity load is the vertical load, so gravity loads usually and then horizontal loads, which might come from wind as well as earthquake.

Now, there could be other loads and certain inclusion and so on, but generally the natural forces are like this. Natural loads are of this kind, the forces, that you know, natural forces that actually leave load, imparts load to the building or to the structure. So, you call them loads, okay.

And the function of the building or the structure is to withstand these loads safely. It must withstand these loads safely during its designed service period, for example, 50 years or whatever it is for a bridge it may be 100 years. So, it must withstand these loads for its life, designed life, whatever you conceive as a life. So, that is how we define safety.

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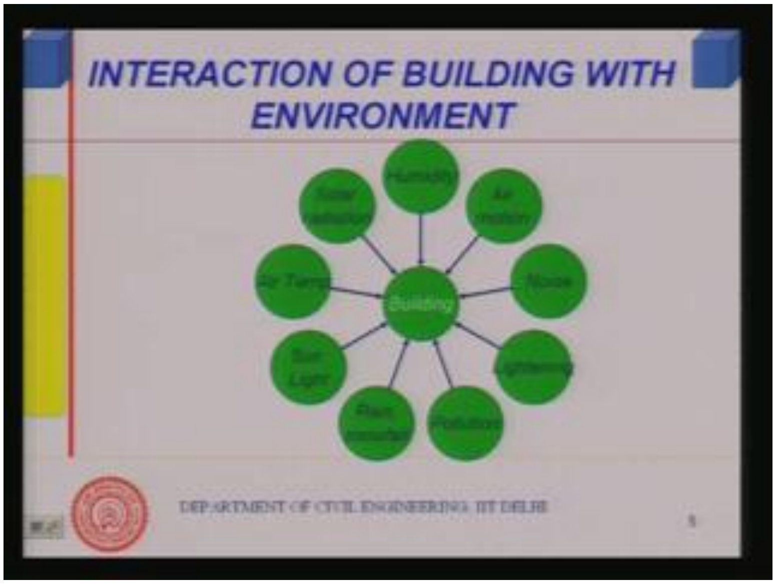

Well the issue of safety we have already talked about, let us see the other issue. We said it must provide for a comfortable environment. Now, comfortable environment, internal environment against, what? Against external environment, and what are the component of external environments? Let us see. For example, humidity is one of them. Then, you have got air motion, air motion; noise, that is of course a human creation as ((Refer Time: 08:35)) come. Then, light hitting this, again the force of nature; pollution, a human creation; rain or snowfall, totally it is known as precipitation; then, sunlight and air temperature; solar radiation. So, the external environment with which the building interacts are these.

Now, some of these ones are desirable. The building must act like a filter. It should allow for some of those desirable aspect of the environment to come in. For example, natural light, sunlight, in a school you like to provide some amount of natural light. Similarly, natural ventilation, air movement. So, you would like to provide some amount of air ventilation, but at the same time you like to cut off some other things such as excess temperature, which can generate heat within the buildings.

Say, in a summer condition in a tropical place, tropical location, the building envelope should provide with kind of a filter such that the heat radiation does not enter into the room. But that sunlight comes in not direct, diffused sunlight, which does not create glare to the eye, should come in, so that you can comfortably see things. So, building acts like a, like a filter. It allows for certain good things to come in, does not allow for certain undesirable thing to come in. So, that is how it interacts with the environment, surrounding environment.

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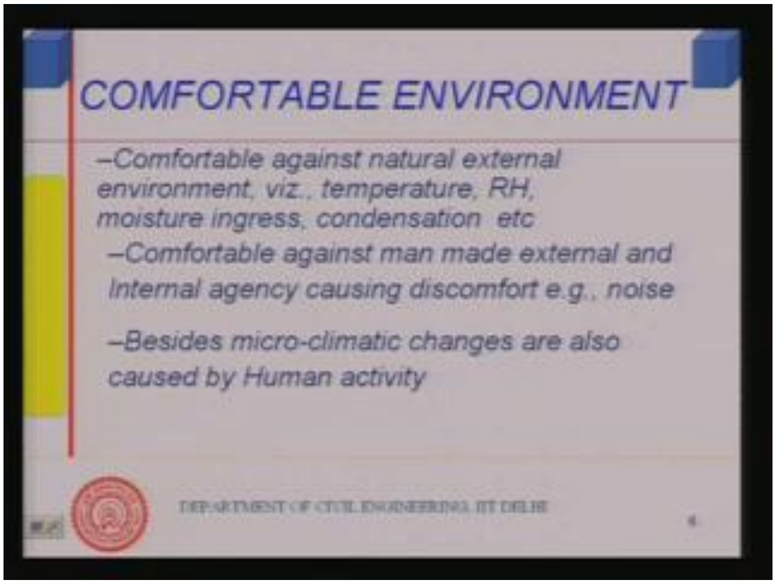

Now, comfortable environment. Therefore, comfortable environment, it must provide this space within the building, must provide for a comfortable environment against natural external environment, like I mentioned just now, temperature, relative humidity, in case of moisture due to rain, condensation, etcetera, etcetera.

Condensation is the phenomena more common in western climate, not in Indian situation, except for possibly Jammu and Kashmir or Ladakh and such areas where temperature within the space is relatively high compared to outside. So, a temperature gradient exists across the wall of the building or the section of an envelope. Envelope is wall roof, etcetera, etcetera, which is cladding, which is the outer shell.

So, temperature gradient may exist between the inside air and the outside air across the wall. And wherever temperature is lowering down, the air, that contains moisture might certainly contain down within the wall. So, that is, the condensation is the phenomena not very common in Indian situation, but moisture ingress is more common that may come because of the rain penetration because of ingress of moisture through seepage or ground water by Kepler reaction or may be due to leakage of pipe etcetera ., etcetera . So, these are some of those external environment.

Some of the man-made environment, like I showed earlier, noise is one of them. The noise is a man creation of industrialization. Well, if you look at it in a very, very rural area, very tranquil rural area, the noise pollution level will be very, very low. Practically, no noise will exist. A lit bit of birds, you know the sound or bird singing and so on. So, it is a tranquil environment in rural area. If you look to an urban area, the noise from traffic, the noise due to industrialization and so on. So, discomfort can arise from such noises. Therefore, the internal space mentioned for specific activity. For example, a classroom, it should be free from external noise.

So, noise is another man-made one and the space within the building must provide for, must provide for, must provide for a comfortable environment against noise or similar other man-made agency, let us say, air pollution. Pollution is, again air pollution from industry or traffic, vehicular pollution and so on. These are again manmade things.

So, the space within the building must provide for comfortable environment as desired, depending upon the activity. For example, you know, just living, you may not require high level of comfort. But if it is an, if it is an industrial situation, for example a factory that is making electronic chips that would require a very high amount of dust, temperature and humidity control, etcetera .

So, desirable environment is that how, what kind of environment you require for that particular activity. For example, somewhere in a watch repairing area, you might require a very high level of lighting. Visual comfort must be very, very high and so on. So, man-made and external environmental perturbation**,** which are there. The environment within the building must provide for a comfortable environment against such both man-made as well external perturbation or disturbances**.**

Well I must mention here something about micro-climatic changes because these are overall global climatic changes or in an area one can look into, but locally there may be some changes in a particular site. For example, an urban area is always at a much higher temperature than the rural area just because in an urban area there are a lot buildings and these building have their thermal capacity and therefore, they store it. So, the temperature in urban areas is slightly high.

Besides most of the urban areas are piped and in piped areas there is, the moisture does not, moisture does not stick to that place and no evaporative cooling takes place. So, temperature in piped areas, again temperature is higher because surface water will run off. The water will not remain there for evaporation in future and evaporation process, as you know, results in cooling.

So, micro-climatic changes of the, changes, that is caused by the local topographic change that has been brought in by construction of or by human activity. The tall buildings usually obstruct air movement and therefore, they would cause micro-climatic changes. Micro-climatic changes could be there and therefore, while looking at the building, it must provide a comfortable environment against any kind of micro-climatic changes that has been caused by local human construction. So, this is another issue one may look into when thinking of comfortable environment within the space.

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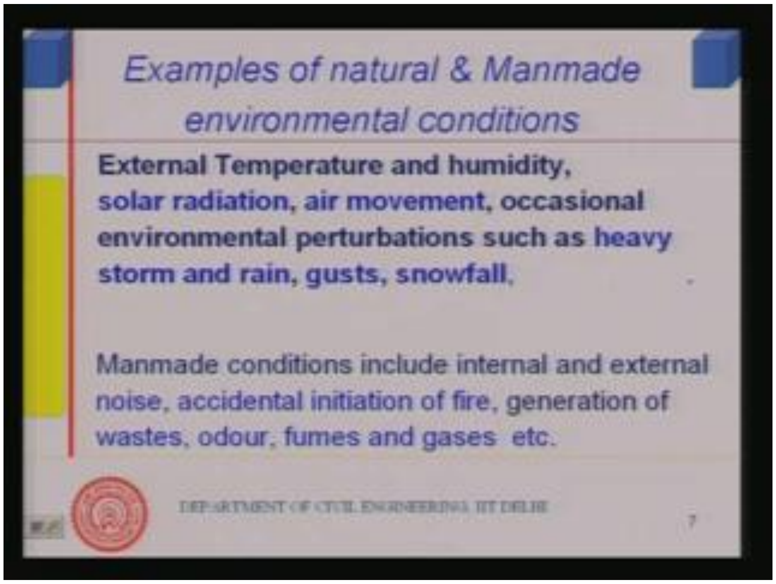

Well, I have already mentioned the examples of man-made and natural, you know, external environmental conditions and these are, say, external temperature, as I mentioned, relative humidity, solar radiation, air movement and heavy storm and rain, gusts, snowfall, etcetera, etcetera .

Temperature, as you know, if it is high temperature, the deep body temperature should be maintain at 37.4 for a comfortable situation. If the temperature is changed very much, let us say small, not very large, let us say a degree or so beyond 37.4 within the body, beyond the limit even it could be fatal, but you start feeling discomfort as the temperature goes higher. And the inside temperature actually depends upon the surrounding temperature, therefore comfort compute condition is the function of the temperature.

It is also a function of relative humidity that you can feel, say, in cities like Chennai, Kolkata or even in Delhi where during July, August, the month of July, August and so on, after the rainfall a lot of humidity outside. So, although temperature might be lower, you still might be feeling discomfort because the relative humidity is very, very high, especially if you are away from the fan or similar sort of places where there are some force cooling takes place.

So, humidity and temperature, together with solar radiation, air movement, etcetera ., etcetera ., are the external environmental conditions against which you must feel the building space must be, within a building, within space a person must feel comfortable.

The man-made, I already mentioned, there is noise, fire, accidental initiation of fire; fire is a very important thing. This is not, this is not necessarily causes discomfort, but it can be related to safety and so on, and waste, odour, fumes, etcetera. These are the examples of man-made and natural environmental conditions against which the space should be comfortable.

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Well, continue with the same. So, desirable internal environment may require when provision of good lighting because lighting was not talked in previous slide, so we just now decided to talk about lighting.

So, lighting is another, another thing, visual comfort. Now, if you are trying to write there is particular amount of lugs or illumination level, you require. If somebody is repairing watch, for such working in small details one requires certain amount of visual comfort and therefore, the illumination level should be accordingly there.

Circulation is the other issue, comfortable movements. So, the space should be such, the building space, the space in the building should be such that there is adequate space for movement of people. If it is movement of material, then there should be adequate space for movement of material or movement of any other equipment and so on. So, therefore circulation is an important issue. Visual comfort is another important issue while dealing with planning of building. We should look into more details into these issues sometime later on in this lecture or in another lecture in the same module.

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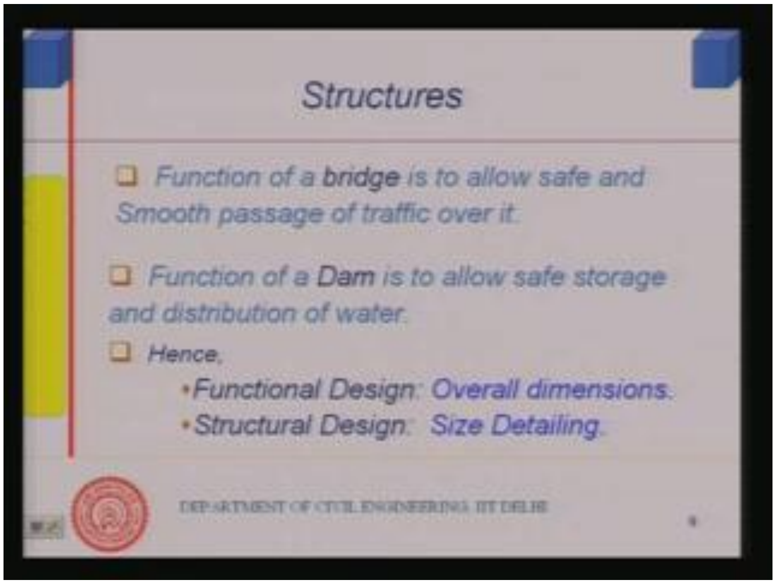

Well, so far I talked mostly about the buildings, but what about other structures like let us say, bridges. Well, function of the bridge is to allow safe and smooth passage of traffic over it, so that is the function of a bridge. So, it must allow for safe and smooth passage of traffic over it. Similarly, if I look at other structure, let us say, dam. Function of a dam is to allow safe storage and distribution of water.

Now, these functions, therefore, dictates what should be the size of the structures, what should be the overall dimension of the structure or building for that matter. We shall look into building planning, as I mentioned a little bit earlier, that we will be looking in details. But for any structure, the functional issues dictate the overall dimensions. So, we get the overall dimension to functional design, right. So, first we do functional design.

And how we get overall dimensions? For example, if it is bridge, suppose, to provide crossing over a river 1 kilometer long, then the bridge length would be dictated by the, you know, width of the river is 1 kilometer. Therefore, accordingly the length of the bridge would be dictated, the width of the bridge will be dictated by the number of lanes you want. These are the issues related to functional design.

As opposed to this, well, in case of building also space would be decided by its functional requirements. As opposed to this, the structural design, you know, design of any buildings and structure, we can divide into two parts, one is functional design, another is structural design.

Structural design, essentially, looks into the size detailing because it is mainly against safety, you know, mainly for safety against loads, forces of nature. Therefore, it looks into size detailing. The example of the same bridge if I look into, the length of the bridge, the width of the bridge, these are decided by the functional requirements. Whereas, what should be the size of the or depth of the girders in the beam, that size detailing, what should be the thickness of the deck, that will be decided by structural design.

How many piers you need, it would be decided by economic conditions, besides also whether you need navigation below it or not. If navigation is required in case of bridge, the level of the bridge has to be higher than possibly a bridge, which does not require navigation. So, this is the part of the functional design. What should be the height of the bridge above the highest flood level, highest water level, how many piers should be there because the space between the piers may be dictated by navigational requirement besides of course, economy and soil condition and so on. Those also dictate those. But functional design dictates these issues. The type of bridge then would be selected based on this.

Now, structural design would find out what is the dimensions of each of the component of this bridge structure. So, bridge structure might consist of the piers, so dimension of the piers would be decided upon how much load it is going to carry, that is, by structural design.

The deck system and deck system would again, would depend upon the, depending upon the type of deck systems through structural design, what load it is going to carry. Based on that how much is the thickness of various components of the deck systems that would be designed. So, two types of design when you talk of designs of buildings and structures.

We have two steps in design, one is the functional design and other is the structural design. Functional design deals with overall dimension; structural design deals with size detailing, you see overall these dimension and size detailing. So, that is what is the part of the design?

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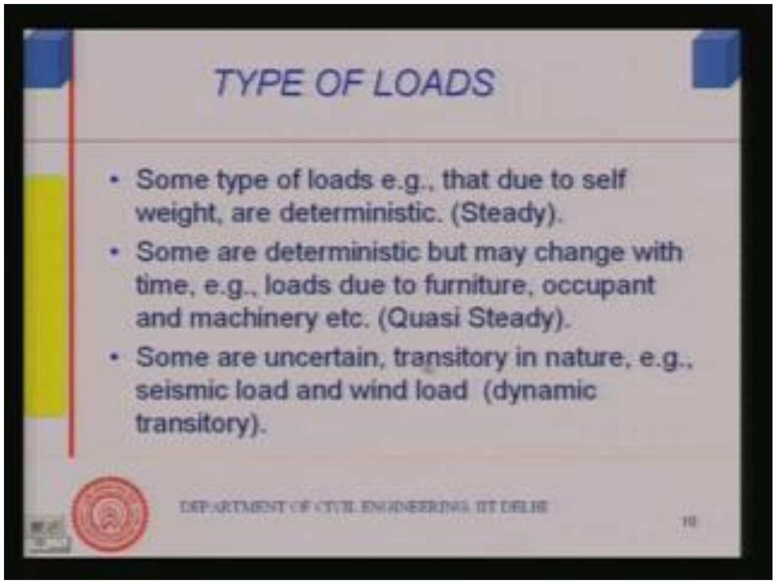

Well, then we can look into the first structural design, the safety, because we said, that safety is more important than the issue of comfort, so you look into the issue of comfort later on. So, in this part of the second part of this lecture let us look into what are the types of loads and safety against loads.

As I said, safety is again various kinds of loads, we call it loads. Loads are basically the forces; loads are generated from the forces. Three type of loads you can define. One is steady, that is, it is there all the time, it does not vary with the time and I can determine it relatively more precisely. So, what we call some loads are steady.

We call some loads are steady, some loads are some type of loads, that is, due to self-weight; it is self-weight. First of all, the structure must bear its own weight. First of all, if, if the structure has to carry some other load, first of all it must be safe itself. It must be able to carry its own load. Now, that kind of load is very much easy determinable. We can find it out, there is no problem about it, because if I know the dimension of the structure, we will be able to find it out.

We will see that somewhat in details and that load do not change with time. We call this load as a steady load. We call this load as steady load because it is steady with time, it is not, it is time invariant.

Now, second type of load is, some are deterministic, but may change with time, say, load is due to furniture occupant or machinery, etcetera . So, in this classroom or in a class, people come and then they go. So, this is not permanent; this is not permanent.

But supposing, you know, this is not permanent, so it is there. It varies over the day or you know, depending upon the human activity cycle within the space it might vary within the day and then go on changing over the, over the day itself. Suppose I change this classroom, after 10, 15 years change it to something else, may be, may be some other space, into a laboratory space. So, it is the loading pattern. People, they were coming, number of people coming would change. So, therefore, its pattern on loading may change with time. It is not steady, changes with the time.

And this load also we can determine, somewhat, somewhat relatively, with relative more uncertainty than the earlier load, which are permanent, but we can still determine them in some manner. There is of course difficulty, as you shall see, but these are not steady with time. They are not same with time, therefore there is quasi steady. Once it is a classroom it will be there. It will be there for it will be the classroom or its function as a classroom will be there for at least 10, 15 years of time, there for a very long period of time and therefore, it is steady for a long period of time. But after that it may change because furniture itself may change, because lifestyle changes.

If you see earlier buildings, very old building, you will see very heavy timber furniture. Today, you come to a classroom, many classroom, you will not find timber, timber furniture. Instead you might find light weight plastic or polymer composite furniture. Therefore, the weights have, because of the change in style, the loads have changed.

So, these loads may change from time to time, so they are not steady. But over a large period of time they are quite steady. We call them quasi steady. We shall see diagrammatically a lit bit later.

A third type of load are totally uncertain. They come suddenly and therefore, very short period of time and then after that they would not be there. So, they act for a very short period of time and that is why, you call them as transitory in nature. They are uncertain because most of the time I will not be able to find out their value precisely. I can find out, make some good guess about them because otherwise, I would not be able to design a structure, but I can make good guesses about them. But they are, there is a lot of certainty in finding out the value precisely, so we call them uncertain. We shall see them some, some, you know, next slide and so on diagrammatically.

For example, as mentioned here, seismic load, that is, the load due to earthquake. So, it is very difficult to, till without current scientific knowledge it is very difficult to predict the earthquake, load the amount, you know, its amplitude or the amount of force that is going to impart to the structure, we can find out with certainty. So, this type of load we call it uncertain. This is uncertain and it is transitory, acts for very, very short period of time. Earthquake acts for a very short period of time, it is not permanent in nature, just there for few minutes or few seconds and that is the end of it. Wind load, heavy wind load, gusts, etcetera, they act for very short period of time.

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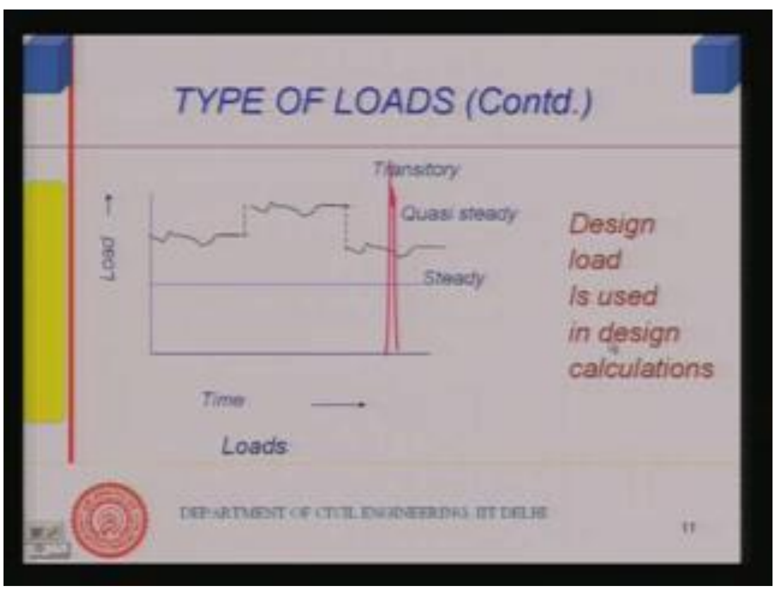

Therefore, these loads are dynamic. They are not steady, they change with time. They are dynamic and in the dynamic also it is actually transitory for a very, very short period of time it is… Diagrammatically, we try to look this load, it will be something like this. With time if I try to see variation of this load, a steady load remains constant. As I said, self-weight, a steady load, it will remain constant throughout the, throughout its life.

So, if this is the design, life of the structure, which is not there in the diagram, it will remain steady all the time. It does not change the weight of the structure, does not change. So long the structure is there, the weight is there, the mass is there. So, therefore this is the steady load.

Quasi steady load, as I said, well there are small perturbation. As you can see, there are small perturbation. You can see over this period, but it is, it is by and large the pattern follows and it is more or less constant. But if the function of the structure change or if the furniture etcetera . change, for example a factory building may be converted into a bank building. There are similar examples, plenty or certain things is not economically viable.

Functional life of a building may change because life of buildings can be defined in, you know, two, three ways. One is physical life, that is, the building or structure, it physically remains, but functional life is when it changes function. For example, many theaters in recent years have converted into shopping Centre. The structure is very much there physically, but its usage has changed, so its functional usage has changed. So, it is being converted into, a theatre being converted into, a cinema being converted into shopping Centre. That is the example of change of functional life. Up to certain years it was a cinema hall, so that is the life as a, functional life as a cinema hall. After that it becomes a shopping center.

So, so its function, now it has got a new function. Now, the furniture would change. The number of people coming in, etcetera, will change and therefore, the load that is semi-temporary, you know, semi-permanent, that would also change. But once it starts, it is therefore some number of years. That is what it has been shown.

This is constant for some number of years and after that it may change or may not change in many cases, but in some cases it may change and it becomes higher. It can be lower also. And for example, in this period it is being lower, these loads are not steady, they are not fully steady, but they are quasi steady, but remain. Therefore, certain period of time and within that period of time also there are small perturbations. For example, people will come and go, so human load. So, that is what these loads are quasi steady load.

And then, the third variety, which I mentioned was transitory. It is over a very, very short period of time, as you can say, and it comes and it is there and just vanishes, and it is dynamic in nature. So, it is, it is, suddenly it comes. It may come once or twice or may be depends upon, depends upon chance. Most of these loads are wind load and earthquake load. This depends upon chance. It may come once in 50 years or a particular load or it may come once in 100 years or may come even twice in 50 years and so on.

Depending upon those it is very, very uncertain because many a times so many factors, which control them, so many factors, which causes them and good lot of it is even unknown today, particularly one related to earthquake. So, that is not even known to us today and therefore, they are quite uncertain. But since we have to design the building, we have to find out the load in some manner or other. We estimate them. So, what you do? We estimate the load

Now, these loads, as you can see, the steady load is constant, constant over time. Steady load is constant over time, as you can, as you can see, steady load is constant over time. This is varying with time within this period also, but the pattern remains same for a long period of time and again changes and this is sudden.

Now, there is no, there is no fixity and there is no fixed value with time. If I take, I have to take all loads into account in some manner. In fact, the summation I should be taking for design of structures, some sort of summation some way although the peak of all the loads do not act together as we understand. But I have got to take account of all these loads in some manner, so how do I do it? Well, in some way I do it and by doing this some, some based on certain some mathematical ways as well as some experience and so on. We take this load into account, and then we find out what is known as design load against which the structure must be safe.

So, design load is that load, which is used in design calculations and it is safe against such a design load. So, long the load is lower than this, it is safe. Well, what happens if it is higher? We will also look into that. We take this value design load in such a manner, we take this design load in such a manner, that during the design period, the life period, the structure remains safe against such design load. So, during this design, load design period, during that service, you know or design period, the load that is likely to come, maximum load that is going to likely to come is design load.

Well, slightly more complex it is than what I am just now saying when you go into the details. But design load is, we can, for the time being the very first lecture we can understand, the design load is that load against which I design the structure, which I used in design calculation. You know, it is used for calculating the, making all design calculations and find out the dimensions of the elements of structure or various components of the structure based on this design load. So, that is one must understand at this point of time.

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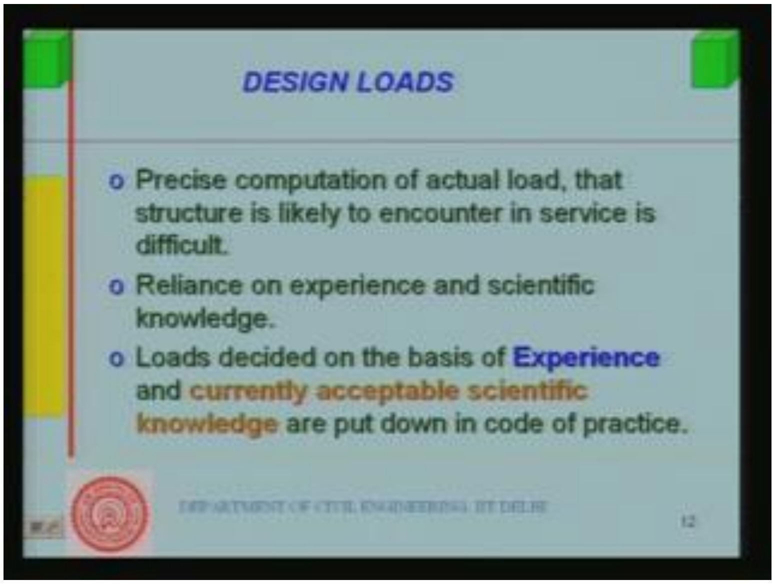

Now, as I said, precise computation of actual load that the structure is likely to encounter in service is difficult. You cannot find out precisely. I can find out possibly steady loads fairly precisely, but when it comes to even quasi steady loads it is not so easy to find them out what should be the design load because it can keep on changing. So, there has to be some way to do that, and when comes to transitory load, extremely more difficult. So, precise computation of such load at any point of time, it is practically not possible. It is practically not possible. So, I should have some way to do that.

So, what we do? Well, we rely on experience and also scientific knowledge. We rely on experience as well as scientific knowledge. It must be understood here, the civil engineering is not totally mathematics based. There is certain amount of experience always is involved because we are dealing by and large with natural system. You are dealing by and large with natural material like soil quite often, or slightly processed materials, let us say, like concrete and sometime, of course, well processed material like steel. Most quite often also we deal with steel or even sometime polymeric materials, polymeric composites and so on.

But we, quite often we deal with natural materials such as soil or slightly processed materials as I call it, relatively more processed, but not as processed as steel, man-made material although it is, but processed, less processed than steel, so that is concrete. So, when you are dealing with such material and then you want this material to perform against natural forces, which are not known to us, not within our control, so we cannot rely totally on scientific knowledge. The experience is an integral part of civil engineering design or on the standing level.

Experience of people accumulated over years that is used in civil engineering design. For example, you know, whether it is Egyptian pyramid or Qutub Minar, Taj Mahal or similar other temples of south India and so on, these were built even before modern scientific knowledge was available. By empirical observation and by simple experience people have built those structures. So, this experience earlier were never recorded in systematic manner, but these days we have systematic way of recording those experiences. And therefore, in civil engineering design and practices you will find out, that all the time something called code of practices referred to, code of practice.

And there are organization or institutions, which actually maintains those code of practice. Say, for example, Indian standard code of practice is developed and maintained by Board of Indian Standard. Since there are a lot of experience is involved, therefore it has to be written down somewhere for anybody to use. And by consensus of people come out, come to in a large number of gather together or committees are formed. They put down the experience of other people and their own into booklet. Those are known as code of practice.

So, loads are based on, loads are decided on the basis of experience and therefore, loads are decided on the basis of experience and therefore, they are put down into the code of practice. And also, currently acceptable scientific knowledge, wherever we can add scientific knowledge we add that. Based on scientific knowledge plus the experience of people that is codified, that is put into practice and we write it down in books called Codes of Practice.

So, how to find out design load? We can do into codes, which are available. In India, of course, we look into Indian Standard Codes, as they called, and it is maintained by Board of Indian Standard, the Government of India body.

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And it defines different types of loads, the classification of loads as per Indian Standard. I will just mention now one by one. Dead load is the first one. It is one load I will define what it is. And the corresponding code is IS 875 Part 1. So, these are, they have got number. IS stands for Indian Standard and they have got numbers 875 Part 1 is deals with dead loads.

Then, there are some other load called imposed loads. I have mentioned it earlier there are three types of loads, but for practical usage while finding out how much is the load I should use in design, it is more possibly just by defining loads, their steady, quasi steady and you know, transitory is not sufficient. Possibly, because each of the type of load I must determine the design loads, I must determine separately.

And therefore, from that point of view the classification of the loads are: dead load, imposed load, then wind load, snow loads, earthquake load, special load and load combinations. And the corresponding codes are shown by the side of it. For example, IS 875 Part 1 deals with dead load. What is dead load, I will just mention. Imposed load is IS 875 Part 2. IS 875 Part 3 deals with wind loads and IS 875 Part 4 deals with snow load.

Earthquake loads is dealt specially, because it is special in nature because of its uncertainty and also the importance it is given to because calamities failure due to earthquake or even fatalities due to earthquake is much more. Then, seismic load, I mean, that is same as the earthquake load. Then, special loads, now loads like fire, temperature, etcetera ., etcetera . these are encountered in special loads.

So, question is now, of course, what is, how do we define what is dead load, and so on. We will come into come to it. Dead load is the load that is permanent to the structures; dead load is the load that is permanent to the structure that is given in IS 875 Part 1, as I just mentioned. So, dead load is the load, that is permanent to the structure, therefore it would include the self-load of the structure itself.

Load of all finishing, which remains there in the structure all the time, does not go away, so it is a steady load. So, this is what is called dead load, dead, you know, it is not alive. Alive load is, on the other end is the one, which can change, but dead load does not change and therefore, we call it dead load. How do we determine it? Well, we will see in the next slide how do we determine it. It is very simple because if I know the dimension of the structure, then I can find it out very easily.

Imposed load is, on the other end, is imposed over the structure itself. It is not permanent, but it is on those, those kind of loads, which is quasi steady. You know, it is that load, which is quasi steady. So, imposed load is that load, which is quasi steady, which comes into the structure. So, includes the loads from the furniture, loads from human being, load from any other thing. So, imposed load would come from what has been imposed over it by human being for its, for its activity and so on. So, this is what we call as imposed loads.

Wind load is very simple, it is coming from the wind and I shall, I shall mention something more about it, how we find out in the next slide. Snow loads are coming from the snow, as the name suggests. Earthquake loads coming from the earthquake and special loads and load combinations. One thing is load combination. I said, special load includes load from, let us say, temperature because of temperature changes.

And you know, you know, in tropical country like India we have some portions, which are desert, dry desert in the western, north-western part of the country places like Jaisalmer, Jodhpur, Bikaner and so on, those are hot dry desert sort of climate. So, temperature variation during the day and night is very large; over 24 hour duration cycle, the temperature variation is very, very large. And you know, it can vary from, let us say, 48, 49 to about 25. So, about 25, 30 degree centigrade diurnal variation, as we call it, may be there.

Also, there is a large season of variation. If I see the yearly cycle, in winter lowest temperature is fairly low in such places, could go as low as about 2, 3 degrees or you know, of that order. So, maximum temperature is 50, minimum is about 2, 3 degree centigrade and on top of it, the structure might receive direct solar radiation. So, temperature fluctuations could be very large. So, when such large fluctuations are there, the material expansion ((Refer Time: 43:06)). And if the material is not allowed to expand or contract, there is a restraint to its movement. Then, this induce some amount of loads. So, temperature load is one of the special loads.

Fire can cause some certain amount of load, so these are other ones. So, such special load is coming from, let us say, soil or similar, you know, in a retaining wall load coming from soil and so on. So, those are special loads, but besides that something called, something called load combination is also an important issue.

How do you combine all these loads to calculate out the design load because all loads are not going to act together? And especially, they will not act together at their maximum big value, so all loads do not act together especially to the big value. Therefore, how do I combine these loads? So, these are dealt in with a special, you know, especially in this,

this particular code IS 875 Part 5. So, IS 875 Part 5 deals with this and this is how, you know, combine these loads. That is what we talked about in this particular code and we will see how it is done little bit later.

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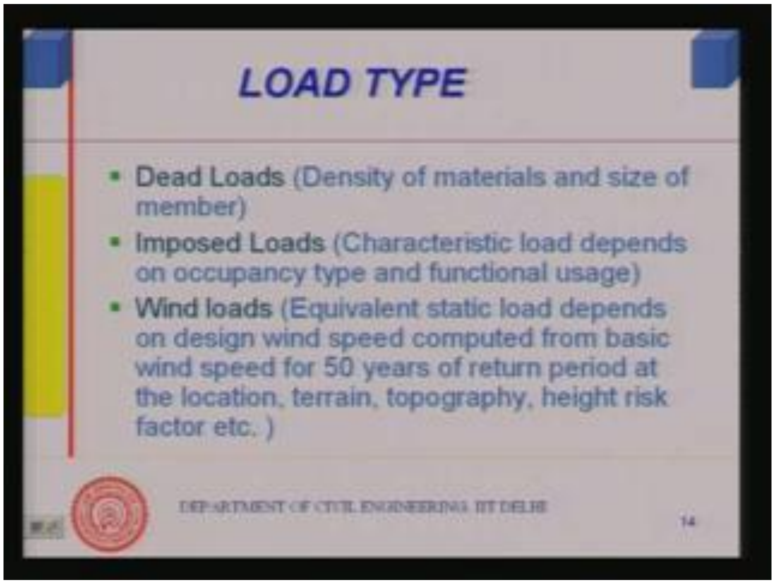

Well, calculation of dead load is pretty simple, as I said, because it is deterministic, I can determine it, number one, and it is constant with time. So, there is no much variability. Once I calculate out its value, that is my design load. How do I calculate out since it is permanent feature of the structures, size of the structure itself, its self-weight that contribute to the dead load? So, I got to know its dimension. If I know its dimension, what is the sizes, length, breadth, width?

Then, I can find out its volume and volume multiplied by the density of that particular materials that has gone in for making. For example, if it is steel, simply 7850 kg per meter cube is the density, that is known to us, multiplied by the dimension of the structure, dimension of the structure itself. That will give me the dead load that is supposed to carry. I might express this load in terms of kg per meter length of the material. So, it is the, in that case, it will be the area multiplied by 1 meter length, that gives me the volume multiplied by the density.

I am not going to detail calculation, so I am not really going into how detail, you know, detail calculations are done, but I am trying to give you an idea what is dead load. So, dead load and how easily it is, you know, why we separate dead load out from the rest because it is very easily calculable.

Thickness of the finishing if I know, I have structure made of concrete, then I know its density is 2500 kg per meter cube, the dimension is not, is known, then that dimension will give me the volume multiplied by the density, that will give me the weight that it has to extent from its self-load over the thickness of any finishing item I have used. For example, the flooring in a floor. So, if I know what is the thickness of the flooring and the density of the flooring material, I can find out easily.

Now, this particular code, which I mentioned earlier, that is 875 Part 1, it gives you density of varieties of types of materials, which are used for construction, so that you know because steel, there is quite a bit of certainty, density quite a bit of certainty. But concrete, its density is not as certain as steel because it might vary a little bit, plus minus 50 kg per meter cube from 2400 or 2500 kg per meter cube. So, what value I should take? I might take 2400 and student like you might take to be 2500 and some of my colleague might take it to be 2600. So, then it becomes problematic thing. 100 kg per meter cube difference and multiplied by the volume, it can lead to all sort of variations.

So, codes gives you the value that should be used. So, density of the, density of the concrete is given in the code, so the value is specified in the code and therefore, as a practice you use that value because it has come through wisdom of many people who have designed this code or written down this code. So, wisdom of people are actually, actually written down and codified in codes. And therefore, what should be the density of the particular material you should use?

Concrete is relatively more easily, more widely used, therefore it is known, but many finishing materials, their densities, are not so well known, readily not available in anybody's minds. So, you can refer to such a code and get that density values and use the dimension to find out the ((Refer Time: 47:31)).

Next is, of course, the imposed loads. Now, imposed loads, I said that it is a quasi-steady load and it comes from furniture, human being, etcetera, etcetera, therefore imposed load desired in on building depends upon the type of the building and this type of building is classified in what is known as occupancy classification. Occupancy classification, for example, this occupancy classification, you know, depending upon what kind of activity would go on, depends based on that the occupancy classification has been defined and this is given in national building code of India.

It is another code, national building code of India, NBC, and in that buildings has been classified into let us say, residential, then industrial, institutional. It is very simply understood, load would vary upon whether it is residential, the number of person per unit area in a floor is the function of type of occupancy.

If it is residential, you will have possibly, may be, 1 or 2 person come. But if it is the classroom, then, then the number of person sitting within 1 meter square area could be relatively more or total area in a, say 20 meter square or 30 meter square area, number of persons would be occupying the space at certain point of time would be much larger than possibly, residential area.

In an industry, of course, the machine might come, so the flooring has to be designed for such machine loading. Therefore, depending upon the occupancy the impose load has been given in the code for various types of room that is possible in such a occupancy. For example, in an industry, industrial flooring, the impact also to be taken into account. So, what should be the load for such impact? How much percentage increase you should have? If you want to consider the impact load as an equivalent static load, etcetera, etcetera are given.

So, as I mentioned, in a classroom, what should be the load in an institutional building? You will have classroom, the residential occupancy will not have a classroom. So, in institutional building what are the possible rooms that are given? And corresponding loads are given in the code 875 Part 2. And imposed loads are based on experience of people because you cannot, weight of mass of person or student would vary, mass of furniture would vary. So, many variabilities are there.

How much load do I take, such loads have been actually, such loads have been actually arrived at what should be the design load by consensus, by experience of people and then by committee sitting or large committee sitting, different countries, and then you know, the varieties. For example, in India, there is a committee in Indian Standard Board of Indian Standard has a committee for deciding upon the load. They look into the other codes of other country say Canadian code or American code, American concrete institute code or British code and so on. Their experience are also taken in and put together with our own experience and this load is decided because I cannot find out precisely. So, by consensus these loads have been arrived at.

Now, one more important point I would like to mention here is characteristic load. Now, the load I should design, I should use in design it should be such, that by and large, this load should not be exceeded during the service life of the structure. This load I call as characteristic load.

A characteristic load is that load, which will not be exceeded more than 5 percent of the time, 95 percent of the time the load would be lower than this load. Only 5 percent of the time load can be exceeded. You see, it comes from statistic. The 5 percent of the chance you can take, otherwise the load that would be taking is very, very large. So, characteristic load, as we call it, it is that load, which will be exceeded only 5 percent of the time, 95 percent of the time load is not exceeded. And how much this load I should take, that is codified.

And how did it come into the code? Experts sitting together, by consensus they arrived at this load. In many countries these loads are there and for various codes, there are worldwide different codes, there are international codes also, but various codes are there and they are experienced of all the people, experts all over the world. They are taken into account deciding upon the load that is to be taken in a given country. So, in our IS code also it has been formulated similarly. And these values have been decided. 5 percent of the risk you take, and then of course, that is not the end of it. I do not design only for that, but I multiply this by factor called factor of safety, which I shall discuss sometime later on. So, imposed loads are decided like that.

Then, it comes to wind load. Well, when it comes to wind load, we design mostly, most commonly, you design it taking it as an equivalent static load, static force, horizontal force. I mentioned horizontal loads earlier. So, horizontal equivalent horizontal force if I consider and which is static, which is acting all the time because it is, it is, it is relatively mathematically slightly more difficult to handle dynamic load, which is changing continuously. But today, it is all possible and also dynamic analysis of structures are done. I will just mention this later on, but this is not purpose of my lecture.

Anyway, I just want to tell you what are the types of load and how one arrives at design load, a little bit introduction to it because this course is more on construction, on the material and we are trying to look at the role of material. There are courses on design of structures where loads, detailed estimation of loads have been taught, higher level courses are there.

So, wind load, first of all we found out equivalent static load and that depends upon design wind speed. You see, from basic fluid mechanics you can find out there is the force or the pressure that would come in, is a function of the velocity square density and velocity square half rho v square, that is what, you know, I can show that pressure is equal to this, that would come from basic fluid mechanics. Well, I am not going into details of this. So, it depends upon the velocity, it depends upon equivalent static load, depends upon basic wind speed.

Now, basic wind speed at a given location I got to find it out and that comes from metrological data. Data on wind speed at particular height, usually at 10 meter height, this has been collected all metrological stations all over the country and 50 years data, you know, last year, many years data is taken into account. And the wind that would be coming, probability of wind coming in given year, 0.02. Well, some basic statistical statistics are taken in account and the basic wind speed with 50 years of return period. This 50 years of return period is, that is, probability of finding, that wind speed once in 50 years that is taken into account and that particular wind speed is recorded down again in the code. The code gives you basic wind speed values.

If you are studying a course on design against wind load, then details of these would be told you at that point of time, but for the moment we can understand, that wind load is calculated based on basic statistical that are available to us for last so many years. And taking that in account, the wind load that would be exceeded once in 50 years, that is, with 15 years, 50 years of return period is taken as basic wind speed. This basic wind speed is used together with terrain topography.

If it is undulated ground, the forces would be one kind, what is the height of the structure; that is another issue. If the height of the structure is more, the velocity would be different and therefore, the equivalent static pressure or equivalent static load is calculated based on basic wind speed location, terrain topography, height and risk factor of the structure, etcetera ., etcetera . More details I think is unnecessary for this course. So, this is how the wind load is calculated.

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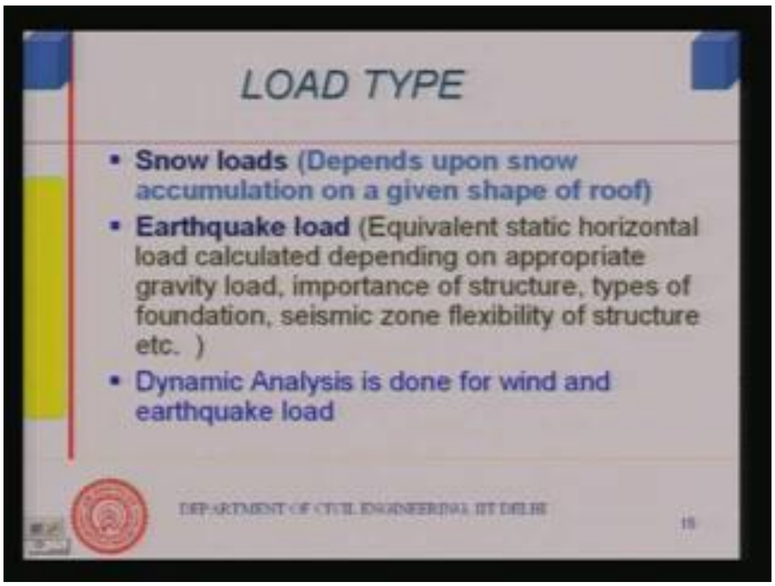

Snow loads depends upon, well just going back a little bit and this, how you calculate the wind load that is given in code 875 Part 3. So, the formula, equations, etcetera ., is given there, right. And snow load, that is given in Part 4 of the code I mentioned earlier, that depends upon how much snow is likely to accumulate over the given surface.

What is the slope of the surface? If it is the flat surface you will have more, you know, snow load on to it compared to possibly inclined surface. So, based upon inclination of the surface, shape of the roof that is what I mentioned, shape of the roof and amount of snow accumulation in a particular location. One can calculate snow load and that is what is given in the particular code, right.

Where it is do not available, where the data for a particular location is not available, one can approach appropriate body, appropriate government organization, which keeps this data. Code gives you the values wherever is available; wherever is not available, it also suggests, that you can approach the appropriate body. So, snow load is calculated on this basis.

Earthquake load is more complex to calculate and it is much more complicated. In fact, well, again it is conventional design based on calculating an equivalent horizontal load. You know, earthquake is nothing but ground motion, both are horizontal and there could be vertical component also. It, in, in fact it is random motion. I am not again going into details of this, but then, one can calculate out an equivalent horizontal load for design purposes and that was also done earlier in course and even now this is allowed to be done.

But how much is the equivalent horizontal load? That depends upon importance of the structure types of foundation, which is zone, whether it is earthquake prone zone or not. For example, this country has been divided into part five earthquake zones, zone 1 to zone 5 and zone 5 is the most seismic prone. So, based on those flexibility of the structure, etcetera, you can calculate earthquake.

Dynamic analysis is done for wind and earthquake load. So, you can do dynamic analysis to find out what is the, how much is the wind and earthquake load. That means, you can take into time variant and nature of the earthquake motion, its down motion, exact more details you can calculate out today with the advent of computer and so on, and modern mathematical tools those are available.

So, experts on earthquake engineering, they do this job. And if you take course on that subject, designing a earthquake load, then you will be coming closer. But this particular code, 1893 tells you how to take an equivalent static load and a little bit of some sort of, you know, the process that is involved in it and the factors that are involved in earthquake load calculation.

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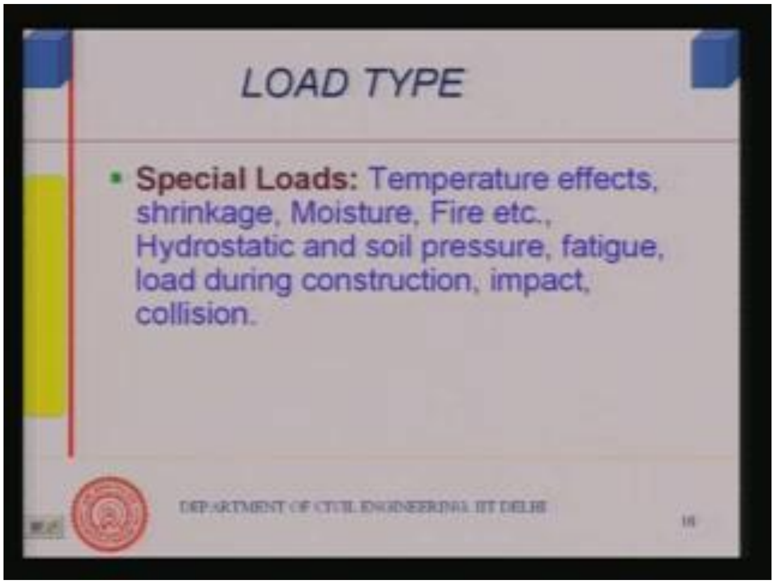

Well, lastly in the load type, special load, I mentioned the temperature is one of the special load because diurnal variation can be very large, seasonal variation can be very large, that can cause expansion of the construction of the material. And if the material is not allowed to expand and contract, then it can result in temperature load. So, how do we take this into account that is given in type 5 of the code 875.

Then, you know, material like concrete, the string there is shrinkage. So, those shrinkage loads, moisture, fire, etcetera, hydrostatic pressure due to water, soil pressure and those are given.

Fatigue is one thing, which I mentioned. Fatigue comes from repetitive loading. You might have experienced, you might have seen, if you take a small wire and turn it, bend it like this, after sometimes it breaks, although you have not applied very high load, but it has broken in fatigue. So, that is called fatigue load. These are special loads. In the bridge there is always a reversal of stresses because a vehicle comes, then it goes away in very quick short succession. So, always there is reversal of stresses. The structure goes down and comes up, so that is called fatigue. So, these are special loads.

How you take account of fatigue load, how you take load during construction or impact of collision, you know, because of certain situations. So, those are taken into account in this particular code. This is the special load and these are taken into account in, in the last code, you know, how you take into account. These are given in the code 875 Part 5.

Load combination, as I said, all loads do not act together and therefore, how do I combine this load to find out design load that is also given in this particular. So, I think, this we will conclude this lecture. In the next lecture, additional aspects of load and load type, we will mention whatever was left, and then we will follow up the other aspects of functional requirements of building and role of materials, which is part of this module in the next lecture.

Thank you.