**Building Materials and Construction**
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**Module - 2**
**Lecture - 1**
**Role of Materials in Construction**

If you recollect from our last lecture, we actually first looked into what is functional requirements of, you know we looked into what are the functions of buildings, and then we started with types of load and we nearly concluded that. We will just recapitulate a little bit of it right now. And then in today's discussion would be talking about what are the functional requirements of buildings, and lastly we will try to find out what is the role of materials in the whole aspects of building and structure design. So, that is what would be our discussion. So, let us go back a little bit and look into what are the, what did you do in the last class.

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So first we did was, this is what we did. Load type, we looked into special loads. I mentioned, that temperature effects, shrinkage, moisture, hydrostatic and soil pressure, fatigue and fatigue load and also, load during construction, impact and collision, these are special loads. Then, load combinations is one thing, which one has to decide.

Now, just only one point I would like to mention about fatigue load again, which I mentioned in the last class. It is the repetitive load, you know, load reversal structures. So, bridges, structures like bridges, they encounter the fatigue load. So, number of cycles it can withstand, you know, the load, which, that particular load, which you can recycle for infinite number of time, that is what is called as fatigue load, right.

Now, the combination of loads. The important point regarding combination of load is, important point regarding combination of load is, all loads do not act together at their worst condition. For example, when earthquake load is at its peak, maximum, same time the worst wind load will never come. So, the probability of all load at their worst is very, very low.

So, therefore you combine only certain loads together. For example, dead load, imposed load and possibly wind load; dead loads, imposed loads and possibly earthquake load. But you rarely or never possibly will combine dead load, imposed load and earthquake load and wind load together. So, the combinations are also suggested in that particular code, which I mentioned, IS 875 Part 5.

But there is one more important issue is that partial factor of safety against load. So, we have tried to get the load from experienced consensus of experts and so on. But then, still are we sure or else we are not? Since we are not sure about the load and we do not want building to collapse or fail, we add a factor of safety. That means, you multiply this load by some factor, that factor we call as partial factor of safety for load. And using that load as the design load, we do all our calculations. So, I think that concludes our discussion on load type and how we take load into account.

This is relevant from the point of view of material because in construction, because later on, when we are selecting material, load issue is going to come. Properties of the materials, which you are looking for would depend upon the type of load it encounters. So, now we will go back, go to functional requirements of buildings.

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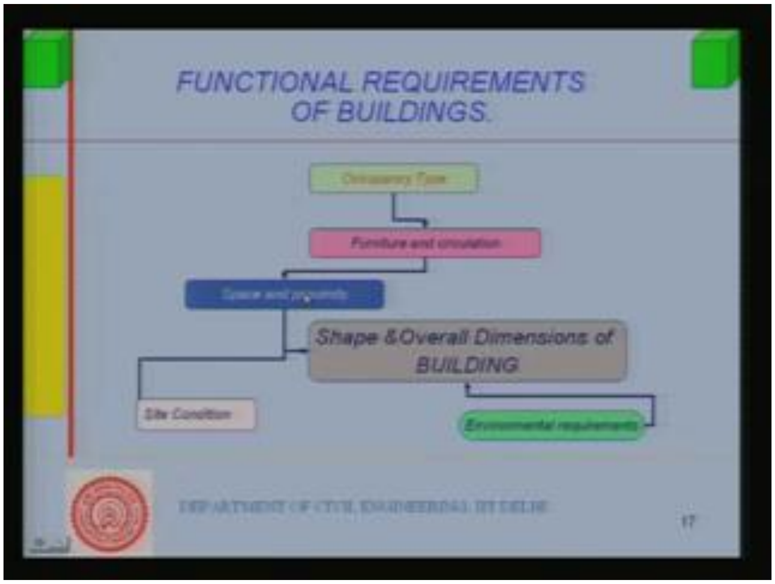


I am talking of functional requirement of building, therefore I must look at the building process. The building process, you see how do we go about it, actually how do we plan and design the building, functional design of the building. I am talking of not structural design, structural design is the second part, so first part is the functional design of the buildings.

Now, the person, the owner or the agency, which is going to use that building or own, you know, that building, they decide what type of building is going to construct, that is, they decide upon what is the occupancy type. I have mentioned occupancy type in the last class, like residential and industrial and so on. So, he decides what type of occupancy he wants to construct, that is his decision what he requires. And then, possibly engages an architect and possibly team of architect engineers and so on.

And then, based on the occupancy type, furniture and what is the circulation space you require, that is decided. I mentioned to you in the function of buildings, the circulation space is an important issue. So, therefore circulation space and furniture are decided based upon the occupancy type followed by what are the spaces required.

For example, in a school you need classroom for so many classes, say class nursery, for preprimary section, nursery and K.G. So, you might have two sections each, therefore four classrooms are required in the preprimary section, then primary section, class one, two class, possibly five or so. You will have as many number of section and number of class. In an engineering institute, like IIT, you will have so many departments and how many number of classrooms you require. Based upon the efficiency of uses of classroom you can find out. So, the planner can find it out how many number of classrooms you require for a particular type of institution or particular type of occupancy.

In a hospital, you will, possibly you will require OPD, out-patient department. Then, there are, may be, department based on diseases, for example, department of ophthalmology and so on. And then, you might have operation theatres and so on.

So, you know, what are the spaces you require, depend upon the, depending upon the occupancy type and the requirement of the occupancy. Once you know that then dimension of the space, for example, classroom, what is the student capacity. If you know the student capacity, the code, in fact there are corresponding IS code also, the codes or practices, various kind of practices, which architects use based on ergonomics, movement of hand, writing, etcetera, etcetera, one can find out how much space is required per person in a classroom.

So, if you know so much area meter square per person per student in a classroom, the size of the classroom you can find.

So, the occupancy type, furniture and requirements of the space decides what would be the space, what is the dimension of the space, what is the area you require. Sometimes height are important, like auditorium, you see, the minimum height is supposed to be so and so for given type of performance, a stage it would require. This kind of heights, you know, heights are again specified in codes. So, depending upon the space itself, its circulation pattern and usage, you find out what is the dimension of the space, the area, some cases height also. So, volume is also important issue.

Now, once these two factors are known, then you can identify each of the spaces. So, how many number of spaces, that you ((Refer Time: 08:42)). But important issue then also remains, which space should be close to the next space. That means, the relative proximity of the spaces. You first find out the spaces you require, what is their sizes, and then how close, which one should be closed to which one.

For example, if it is a classroom it cannot tolerate noise, so it should not have workshop nearby. They should be away, but in some other cases you would like to have classroom very nearby because you want the students to spend less time in their walking, less time in travelling between two classrooms. This becomes very, very important in hospitals because it can be shown, that in hospital planning if you do a poor planning, you might waste a lot of money in terms of salary of the doctors and nurses if they have to travel a lot.

So, proximity of the spaces, how close they should be, whether they not be at all together is decided again, based on furniture and circulation requirement. You want to minimize the circulation time, you do not want to people to travel too much unnecessarily.

And then, site condition is an important issue. If the site is of the given shape, the building can only follow that shape, it cannot be anything. You do not have a total open scenario unless you are constructing somewhere away from urban area. So, site condition, is a microclimatic issue, which I mentioned earlier. And requirements of the site, local by-laws and things like that, all these decide together with the environmental requirements, decides the shape and overall dimension of the building. As I said earlier, that overall shape in dimension of the building is based upon its functional requirements. This is the process, this is the process, which is shown here.

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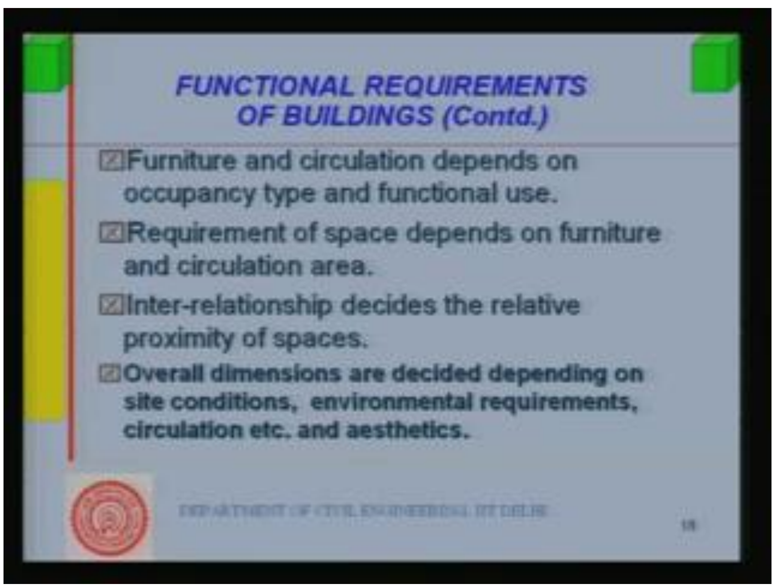


Same thing, I am just repeating, for furniture and circulation depends on occupancy type and functional use. Requirements of space depends upon furniture and circulation area.

Inter-relationship decides the relative proximity of the spaces. Relationship between the spaces, they decide the proximity of the spaces.

Overall dimensions are decided depending on site conditions, environmental requirements, and circulation, also aesthetics.

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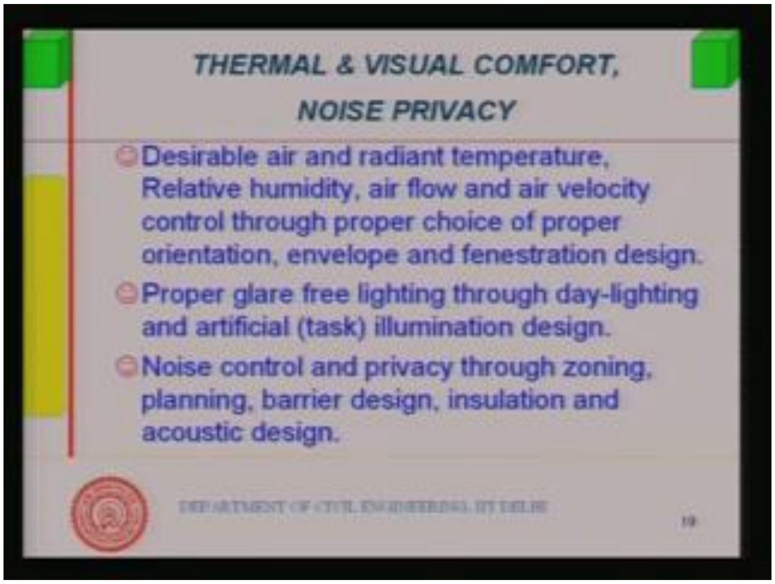


Let us look into some of those, some of those aspects of environmental issues, like thermal comfort. I mentioned earlier, so let us look into some of those aspects of thermal comfort. I have said circulation and furniture proximity of place, spaces, etcetera, that is how we decide. But then, envelopes are essentially can be decided, which may be non-structural. It can be decided on this functional depending upon the functional requirements.

For example, the wall thickness or the material you are likely to use in the wall or the roofing system, except the structural part, the structural part, obviously you will have one. But on top of it, it might have some sort of insulation depending upon the climate you are in. Similarly, if you require noise insulation, the walls and the roof, ceiling, etcetera, etcetera, they would act as noise insulation.

The fenestration, fenestration is a terminology used for opening areas that is kept deliberately, deliberately designed opening spaces, windows and ventilator, which are by design they are left. These spaces are, these openings are left in the wall, so that air can enter, light can enter, so the fenestration design.

These are beside the structural system. These are designed based on functional requirements. So, wall or envelope as a whole, including the fenestration, shading devices and so on, they are decided based on the functional requirements. Other issues of planning from fire consideration, spaces for escape routes and so on, those are again from functional consideration.

Sometime you might do compartmental, compartmental, you known, compartmental, I mean, you can make compartments, fire compartments in the whole building, compartmentalization as it is called from the requirement of spread of fire and so on. So, those are the functional requirements through which we design these aspects. Structural system is designed based on structural requirement, load carrying capacity and so on. Right now we are looking at the functional issues, so let us see thermal and visual, you know, comfort.

And noise privacy, what we do in that case? Well, internal comfort condition depends upon air temperature inside, air temperature, relative humidity, air velocity within the room circulation basically and also radiant temperature. That means, if the surfaces are very hot, all the surfaces are hot, all the surfaces of building are hot, then it would tend to radiate heat into the person. So, radiant temperature, as we said, is related to the radiation from various surfaces. So, through proper choice of orientation of the building, design of the envelope and fenestration design, we take care of thermal comfort.

Proper day-lighting through fenestration and if required by artificial elimination, we provide glare free, glare free visual environment, glare free visual environment. The amount of illumination required is the function of the space itself. Function of the occupancy type depends upon what activity is going on.

For example, corridor, illumination required, required in a corridor will be much less compared to on working table in a classroom or in over a drafting table, drawing board or something of that kind. So, depending upon the visual comfort required, the desirable, you know, the visual level required, contrast required and so on, we design it by providing proper glare free lighting.

Now, what is glare free lighting? Glare comes when too much of light come in to your eyes, light can get scattered into your eyes and your vision can get blurred. For example, if you are looking directly towards the car headlight you get a glare, you do not see anything, you are totally blind for a few, momentarily blind. So, that is called disability glare. But there are something called discomfort glare, which you might have observed sometime sitting in a classroom, at certain angle you cannot see the blackboard. That depends upon the contrast, the angle of viewing and so many other thing. So, glare is a kind of discomfort you cannot see things properly.

So, when I say glare free lighting, I mean, that discomfort should not be there. You should be able to see without discomfort and clearly you are able to see. So, illumination level, contrast level, there should be such that it gives you glare free lighting.

So, by providing glare free lighting, one through the fenestration design by sunlight, you know, sunlight, allowing direct sunlight or day-lighting as it called, providing day light, designing for good day-light that is one thing. Secondly, if it is not adequate because all part of the building, even in deep room you will not get day-light even if you have windows and fenestration designed proper. You have to supplement it by artificial lighting. So, by proper designing of the artificial designing system, fenestration design, etcetera, you can get good visual environment.

Then, comes noise control. Noise control and noise privacy, first of all, you know, first of all, whenever you are doing environmental design, it starts right away from urban design stage itself because if you can, you can control of the site climate itself, then the design is relatively easier, is the site climate itself or the microclimatic modification is very high, then you have to take care of that. So, the first thing is you try to see, that microclimatic modification is relatively less and that is what you can do even in noise control as well by zoning.

Industrial areas are kept away from residential areas, may be buffers are put inside green areas and so on. So, by doing that the noise in the residential areas can be kept low, so that you provide barriers, noise barriers, you know, vertical walls, they serve as the barriers.

Noise barriers, then insulations and little bit of planning within the building, etcetera, etc. By doing that you can actually provide proper noise control and noise free or desirable condition within an environment, which is not too noisy or not discomfort. It does not create discomfort. Noise control and noise privacy through zoning, planning, barrier design, insulation and acoustic design, in general. So, that is how we take care of thermal and visual noise privacy.

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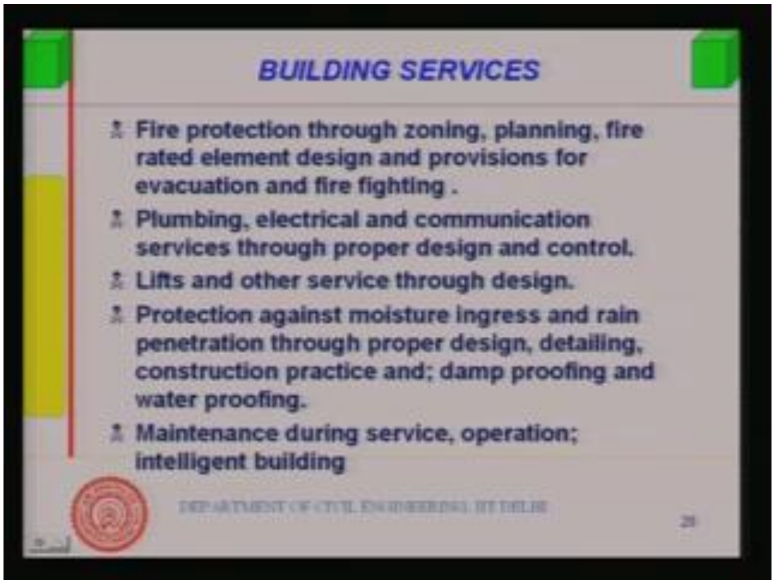


Then, fire protection is a, is one of the most important issue when we are designing buildings for functional requirement. You know, building services, various kind of building services.

Now, fire protection is one of the important issue and fire protection again starts from urban designing, zoning. So, you keep fire generating sources. For example, hazard is one, hazardous occupancy, which stores explosive far away from residential occupancies, which are too sensitive to fire hazard. So, you keep them away, separated, keep them separated might put some sort of buffer. Those, which are not unlikely to be affected and so on. So, first thing is zoning.

Then, by making proper fire protection measures it starts from planning itself, say outside the building. First of all, you leave sufficient space for fire fighting vehicle have sufficient fire separation. For example, a potential source of the fire should be kept away from the building like electric wire or something like that. So, fire separation should be adequate. There should be sufficient space around the building for fire fighting vehicle to move.

You might have fire hydrance, that is, available water sources in piped water sources into the building. Then, you have right kind of space, you know, escape routes well-planned and well, you know, well sort of it should be, one should be readily see it and or you might have an audio-visual system to warn people. So, adequate warning system, visual system signages and so on, so that people can escape and proper planning of escape routes. These are some of those aspects in the planning itself.

Besides that you can compartmentalize the building, so that fire does not go away from one compartment to the other. If it spreads, it does not spread too much. Then, you can design the structural elements for adequate fire resistance. Unit of fire resistance is time, it is time, so we will, we will again discuss when we talk about material role of materials. So, you can design the members, the elements of the building or structure for adequate fire resistance.

Now, these elements will be mostly structural elements, but non-structural elements, walls, etcetera, etcetera, doors and so on. You can have fire doors, so both structural and non-structural elements have taken into account while designing for fire resistance. So, proper fire-fighting provisions may be automatic, fire fighting provisions. Then, you can have wet raiser or dry standpipe, etcetera, etcetera.

Various kinds of building services are provided in order to take care of fire. You can have intelligent system, like automatic fire fighting system. Well, I will just mention about intelligent building little bit later on. So, this is what it is?

Then, providing proper condition, comfort condition, working condition within the structure or within the building through plumbing, electrical and communication services through their proper design and control, lifts and other services. This becomes very important in very, very tall buildings, very tall buildings, multistory buildings, which are, which are like, you know, high rise.

They are, design of building becomes very important issue because one must, should have an efficient traveling system and the space consumed should be less because the number of lifts you may require become too large in case of very tall buildings, something like 20 or 30 or 40 story building. So, you have some lifts, which will excess to, express up to certain floor and then go passenger and so on. Otherwise if it is stopping at every floor, then it consumes a lot of time and a lot of space also. So, life design is the subject and one can design the lift adequately and provide, provide comfortable travel upstairs.

Protection against moisture ingress. This is the very important issue because, this is an important issue in the sense, that it is not only visual comfort, but it has got negative effect, that it may not immediately affect your any component of the structure except that visual part that it lock moisture, but in the long run it can create problem for structural member as well. For example, reinforcement corrosion, it is due to usually moisture ingress, one which triggers off reinforcement corrosion. So, other deterioration processes in structural element and non-structural element can be due to moisture ingress.

So, one has to take care of that but taking care of that is, by design some, certain things can be done. For example, damp proof course into the floor level, in the plinth level, which is provided so that water from the ground does not seep inside. Capillary rise does not take place. Adequate design against rain penetration where rainfall is very, very high. Driving rain against the, driving rain, which is the combination of rain and the wind, so one can do the design for that against that. Then, the leakage of pipes, etc. So, one can ensure adequate quality of construction, so that pipe leakages do not take place.

So, these are the ways how you can, you can do moisture control. In addition to that there are certain amount of detailing, which are required. For example, dripping of water below the sun shade and things like that. So, ((Refer Time: 23:33)) detailing and good practice can give you comfort from moisture condition.

And finally, in the functional requirements one thing is very, very important is, that building requires maintenance. It is not maintenance free. This is what we, you know, tend to believe, that civil engineering structures as if they are maintenance free. You buy any other system, a car, vehicle or anything of that kind or any other electronic systems also, they require maintenance. After certain period of time you have to do car, etcetera, mechanical system you have go to do overhauling.

But it is thought, civil engineering systems, they do not require much maintenance. It is not sure, they require maintenance and proper maintenance and hence, is the trouble free service life because when your cost of maintenance is high, cost is not only the just the repair cost, but it is the disruption cost, your activity, you might stop the function of the building itself.

For example, if it is a classroom and that is not available for classes because the repair is going on, it means, some sort of cost involvement. So, the cost is usually the cost of direct cost of repair plus the cost of disruption and there could be, you know, if you delay it, there could be, it could trigger off further repair and further delay and so on. So, therefore appropriate time maintenance of building should be done, whatever type of maintenance, both structural system, non-structural system.

Maintenance of building system including service. This is very important issue and one may look into, what is called today, life cycle costing. So, life cycle costing is the initial cost plus the maintenance cost and operation cost taken into account in appropriate economic manner. So, this is about maintenance which is also a part, I would say, part of functional requirements.

Lastly, I would like to mention about intelligent building a little bit when I am looking at functional requirements of the building. Now, you see, today as I mentioned in the beginning, I mean, last class I mentioned the beginning something called control environment and uncontrolled environment. A control environment is one where temperature is controlled. Now, there could be a system where temperature fluctuates with certain range whether it is used or not. Similarly, all the lights are on whether it is actually required, you know, is in use or not.

When you have a control system and controlled through a controller, let us say, then feedback is sent from that particular space to the controller and which in turn control environment within the desirable range of temperature, humidity, etcetera, etcetera. This has been used in air conditioning system for long. Similarly, automatic sprinkler system. You have sensors, you know, in case of fire protection you have sensors, which will sense the heat or smoke or the dust or even sometime flame and accordingly ticker off a sprinkler system. So, it is an intelligent system, it can do things on its own.

Intelligent buildings are those buildings where buildings senses or the space itself senses the condition and accordingly, take reaction regarding maintaining it in a desirable condition. For example, it might sense the visual condition, the lux level and accordingly put on the light or put off the light. There could be, there could be the varieties of various version of this. In some cases the moment a person enters into the room, the light becomes on, in a specific area light becomes on.

So, intelligence building system they have become common. They are also called smart building in earlier American terminology. These are ones where fully controlled computer controlled systems, where the services are there at perfect. And envelope design also must be very efficient, otherwise you will be wasting, I mean, first your envelope design must be good, then the intelligent system also better. It is less, it will be more economic and less expensive. So, that is what is all about functional requirements of building.

I think that finishes the part of functional requirements of buildings. Now, we can look into the role of materials in general structural design or construction or in functional design of building. So, that would be our next topic of discussion.

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Well, one point I missed, that is, need for bylaws. Now, when we are doing functional design of building, certain restrictions are required to be put by controlling agencies because as I mentioned, the microclimatic modification is done by, by your construction, new carbon constructions, which we have provided that would change microclimatic conditions.

Similarly, one must leave certain space around the building for fire fighting vehicle to move around or placements of ladder and so on. So, such controls, such controls are provided through various bylaws. Local firefighting machinery that is available, that has to be, you know, that has to be taken into account while doing building design.

So, local municipal authorities of such bodies, they put certain restriction on construction depending upon their ability and necessity because one person, if he builds structure, a building independently, he might disturb the airflow of the house of another person or possibly, obstruct the light entering into the house of another person. So, therefore there is need for bylaws. These needs are now enumerated in this slide.

Zoning and land use control. As I said, zoning is required for firefighting, noise control requirement, then unobstructed air movements and sunlight. Control of microclimate and site climate, firefighting provisions, protection against earthquake, in some cases this is required because if you are in extreme zone you cannot construct anything anyway you like.

For example, earthquake zone 5 by Indian Standard Code, yesterday I mentioned the code. I mentioned yesterday, the earthquake zone 5 is the severe most zone. Now, there in such zone, one must construct according to the requirement of, construction must be according to the requirement of earthquake safety. So, any tall building, if you construct a 50 storey building there and soil condition is not good, then it might be susceptible to seismic calamities. So, that is why, sometime restriction are put by the local authorities based on the seismic requirements, protection against the earthquake.

Then, traffic movement and traffic privacy of neighborhood. Now, let me define the neighborhood here. Neighborhood is a space, is the, you know, smallest unit in the urban design, right. Now, such a space, of course, originally when actually conceived in United States of America around 1925, it was thought to be, you know, the population, population, that can be sustained or that can sustain single primary school. So, that was, that was a kind of design.

Anyway, a neighborhood one, is one, which requires traffic privacy. So, within the neighborhood no major ((Refer Time: 31:14)) will pass, no major traffic highways will pass. It will pass through the boundary. So, that was the concept of neighborhood.

So, traffic privacy of the neighborhood, this is important from that point of view. Even bylaws are possibly required. You cannot make any kind of roads. So, for example, through, and through road people will tend to pass through it, but if there are dead end roads or a cul-de-sac culminating into residential areas. Cul-de-sac are circular, circular space into which a roundabout, you know, a vehicle can come and take a round and go back. Now, that becomes fully private, private road from traffic privacy point of view.

So, when I mention traffic privacy, I mean, that actually, that the traffic in a neighborhood would come in only to, only for those people who are residing. No outside thoroughfare will not be allowed in such an area. So, bylaws are also required for that purpose.

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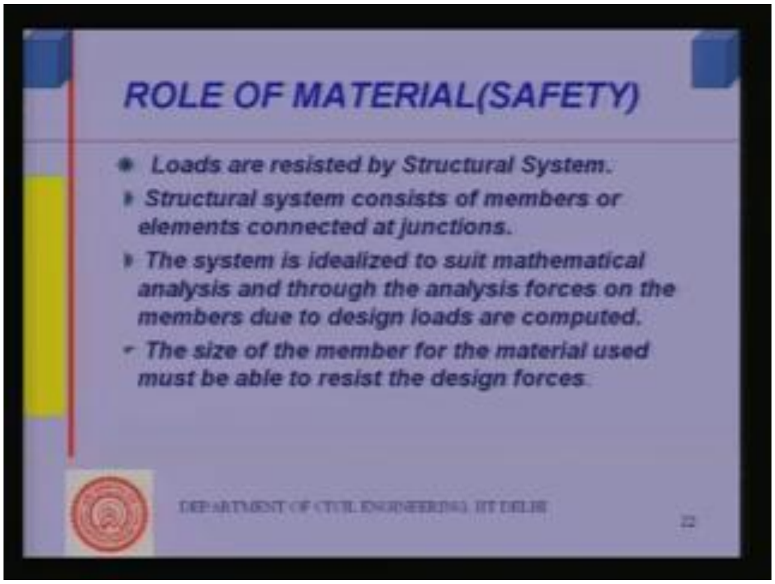


And then think we can look into role of materials. Now, two aspects in role of materials. One, from the point of view of safety that is the first fundamental when we are trying look into role of materials. Two aspects are most important, one is the safety and second is the functional requirement. The most important one is the safety aspects.

So, let us look first aspect of safety, what is the role of material when you are looking at the safety of the structure, and then we look into role of material in functional design. As I mentioned earlier, structural system design, you know, it is the one, which resist the load, what is the structural system. For example, in a framed building, in a framed building, the load, structural load, simply maybe carried by the columns and the beams and the slab and the walls are, may not be load bearing in some case. They will be load bearing, but not necessarily there will be load bearing.

In buildings above four or five storey in Indian condition, the type of brick normally you get, the building are usually non load bearing even up to four storey buildings. In many cases, are, walls are non-load bearing, they do not bear the load.

Structural load is formed by the column beam and slab system and that is called frame system. There are other kind of structures may be something like a dome, something like plate cells, there are varieties of structures.

In a bridge, of course, the non-load bearing structures are very little or such structures, infrastructure project, they are, non-load bearing structures are relatively less. But in a building you can have non-load bearing envelope like walls, right.

So, loads are resisted by only the structural system, which are load bearing. And structural system consist of members, like I said, beam, column and slabs. They are also called elements and they are connected by some means, they are connected in some manner, they are connected in some manner, may be single, you know, joint, what is called monolithically, that is, they are tend to, they are supposed to act as single unit or you might have some sort of connections between these elements or members.

Now, when I do structural design, what I do? I actually consider the elements and the members together and then idealize them as some sort of systems, so that I can apply mathematical treatment.

For example, a column might be thought of, a column is the vertical member. A column is the vertical member, which has got less dimension in x and y direction compared to z, that is, the vertical direction. So, that is, the column usually resist the load, you know, resist the downward load, downward load, that is, gravity load, as it usually resist the gravity load. But whenever any horizontal load is there, even that is component of, some effects come on to it as well. But usually, it is a vertical member, a column is a vertical member and its dimension planar. Dimension, dimension in plane is small compared to its, you know, vertical height, that is the column, a column is the structural element or a member, structural element or a member.

Now, this column loads usually downward onto such kind of column. Beam, on the other hand, usually is the horizontal member and its dimension in the transverse direction, that is, the direction along the span, that is, one long direction, that is called the span. And the dimension along other two directions are very, very small, relatively small.

A slab is a two dimensional member. It has got dimensions both in x as well as in y direction and in the z direction, thickness is relatively less compared to x and y dimensions.

Now, when I am idealizing a structural element, for example a column, I assume as if it is a, as if, you know, its load would be acting downward and its connections are also idealized, so that I can treat it mathematically actual connections, what they are, how they transfer the load from, let us say, beam to the column, that may be slightly different than what we actually design. In design, we conceive or idealizes as, but we got to idealize that because we must make it amenable to mathematical calculations. So, that is what we do.

So, what we do, we try to first idealize the structure and once the structure is idealized, then we try to find out how much the force an element will have to bear under desired load condition. So, I know the design load condition, and then mathematically I find out from basic principles of mechanics, which you might be studying somewhere else in a mechanic course. So, using basic principles of mechanics we find out how much is the load the column will have to bear or the beam will have to bear. That is what we do through structural analysis. We call it as structural analysis through which find out the courses and these are computed.

Then, size of the member for the material used must be able to resist the design load. So, design force, that has come on to it from the design load, which I have taken, load may not directly onto the column.

In a beam, column, slab system, frame system, the load will first come onto the slab, then from that slab it will be transferred to the beam and then to the column. So, the amount of load, that is coming to the column, that we try to compute through structural analysis, and then find out the size of the column, which is sufficient to withstand the load for the kind of material I am using the column. So, therefore material is an important issue. What material I am using, that will dictate what size of it, what would be the size of the column or what would be the size, you remember, right, what would be the size, you remember.

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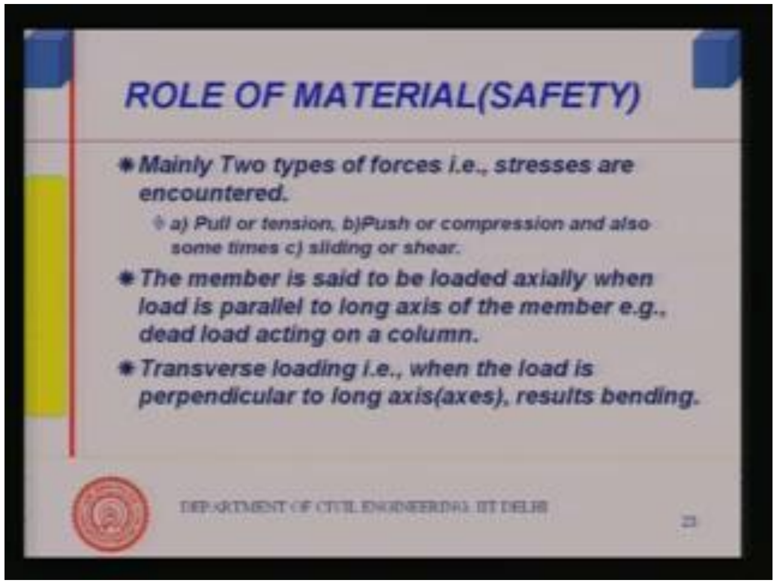


Two types of forces, there are mainly two types of forces or stresses, I would say, in case of such structural members. A pull that is, we call tension or a push, which is compression. Well, we have shear, which is sliding, which is sliding. Now, many times shears, complementary shears can be resolved into a pull and a push, combination of pull and push. However, shear is the other kind of stress that the element has to the member has to withstand. So, these three types of stresses, pull is tension, push or compression and sliding or shear. These are three types of forces mainly it encounters. Some other cases, shear would come, shear may come from bending or come from various sources, but this is the kind of forces one encounters**.**

Then, the member must be able to resist this kind of forces. So, it should have low strengths sufficient, we will look into it. Now, the member is said to be loaded axially, when load is parallel to its long axis. When load is parallel to its long axis, a member is said to be loaded axially, like a column. Column, as I said the load usually withstand downward load. Therefore, it is usually axially loaded. There may be some eccentricity, but axial load will definitely be there.

If there is horizontal load at the top of the column, it is not axial, but then it can cause some sort of bending. But axial load is always there in a column because its self-weight would be definitely. On the other hand, a beam, its self-weight acts in the downward direction, whereas its length span is in the horizontal direction.

So, the load is acting transverse to the, transverse to its axis, long axis. Load is acting transverse to its long axis, so that is transverse loading. So, when load is perpendicular to the long axis and that is usually results in bending, that is usually results in bending, that is usually results in bending, you see. So, axially loaded member and then bending and there can be combinations, there can be combination of the both.

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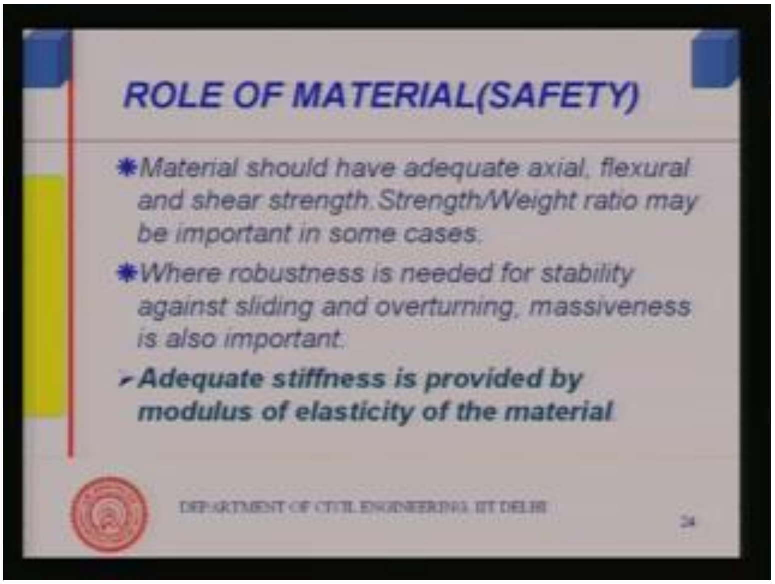


Now, therefore material should have adequate axial resistance against, axial loading against bending. Now, this bending is also called flexural resistance, flexural, it is called flexural resistance and must have good shear strength.

Since it is likely to face axial stress, that is, either tension or compression. In case of column, it is mostly axial compression, and then flexural strength. That means, resistance against bending and sometimes shear strength. So, the flexural strength can both be compression and tension.

Some cases, in multistory buildings the structural elements, their strength and weight ratio is very, very important. Strength to weight ratio is important in some structures, in tall buildings because more the weight of the structure itself, it is likely to cause, you know, more load will be actually imposed on the lower storey. So, you like to have things lightweight as much as possible.

But it is more important in aircraft and such structures, strength to weight ratio. Civil engineering structures in some cases, not always, but some cases in civil engineering structure you might require robustness, that is, massivity, sometime robustness. I refer here is massivity.

For example, a dam, in a dam the water is on one side, which might push it due to hydrostatic pressure. Now, it must have adequate resistance against sliding. It should not slide against water pressure, should not slide, dam as a whole should not slide. It should be stable against sliding and therefore, it should be robust that can come from its massivity.

Similarly, many walls, walls under horizontal loading, it should not topple, that is, the overturning, it should not overturn. So, this is stability against overturning, against sliding and this stability against sliding and overturning, that comes when you have heavy mass. You cannot slide a mass nor you can overturn it easily, so that is robustness.

In civil engineering structures, sometime you might require robustness, that is, the massivity. So, you need weight, a lot of weight and therefore, your material, if it is heavy, that is fine. But in many other cases you would like to minimize the use of material because that costs, that cost your money.

Less material, cheap material, that would be cheapest situation, so robustness is also required in civil engineering in some cases. Well, you need adequate stiffness; adequate stiffness. For example, it should not bend too much, it should be stiff. If it is a building frame, a beam is bending too much and you can feel it. Then, you will feel uncomfortable. It may not fail, but it should not deflect too much. Deflection, you might feel uncomfortable, so should have adequate stiffness and this stiffness comes from a property called elasticity, modulus of elasticity. You should have come across these terminologies in physics and mechanics, strength of materials and so on.

So, modulus of elasticity is the important property, which will give you stiffness. So, as we are looking at role of the material, first of all the most important role of the material is to provide adequate strength, axial under, against flexural, axial under axial loading, that is, axial compression or axial tension. Then, flexural tension or flexural compression should have flexural tensile strength, good flexural compression strength. If it is required, should have good axial tensile strength, should have good axial compression strength, should have good shear strength. And then, sometime you might need strength to weight ratio, sometimes you might need robustness, and then stiffness is very, very important.

So, therefore modulus of velocity, it should have good modulus of velocity or high modulus of velocity as required. So, whatever is required, high or low that has to be decided by design, by thought, by pre-thought only, and the material has to provide that. So, you select a material based on whatever is their requirement. This is the first mechanical property. Let us see something more towards the mechanical properties.

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This is an important issue, post elastic ductility, post elastic ductility is an important issue. What is ductility? It is the capability of deformation. Prior to failure a formal definition would be given a little bit later on, but why do we need this? Adequate warning through large deformation prior to failure is required. I must know, that failure is, you know, I must get a warning for impending failure, so that I can do evacuation or whatever it is.

Now, I can give you an example in case of earthquake design. You see, since we are very uncertain about the extent or you know, the intensity of the earthquake, which I am likely to encounter. It is very difficult to predict, very, very difficult to predict in the life of the structure what is the intensity, maximum intensity earthquake it is likely to face. That is very difficult to predict.

So, the strategy for earthquake design is like this. If it is an, if it is a small earthquake, normal, not very, not very, you know, not very unexceptional or something like that, not very, I mean, sorry, not very exceptional earthquake, so what will happen in such situation? Nothing should happen to the structure. It should stand erect, every component of it, including all the non-structural members.

But if you have moderate earthquake, the earthquake and their intensities are classified into low, moderate and you know, high. So, moderate earthquake, well, structural element should remain intact without any damage, but some of the non-structural elements may fail. Non-structural elements failing does not cause really any danger because it can, local danger, danger is there and people can take protection. So, nonstructural elements can fail.

But in case of high intensity exceptional earthquake, which you know, which we never envisage if the structural elements can get damaged, may be it will break some places, but complete collapse should not take place. So, how can I, it can break, but still should not collapse. That means, you should allow for large deformation. In beam-column junctions, there should be sufficient rotation capacity. It can, you know, it can tilt or do something, but ((Refer Time: 47:34)) should not collapse.

So, that is what necessitates. That is what, you know, requires for such kind of action that it should deform a lot. It should tilt, but should not fail, should not fail without going into, showing lot of deformation, lot of tilt**,** lot of rotation, so on.

Lot of crack development, that property will come if I have good ductility of the material. So, sometime it is required, that material should have adequate ductility, that is, should have sufficient deformation before failure.

Another important aspect is endurance limit against fatigue. I mentioned fatigue, fatigue is nothing but reversal of stresses or repetitive loading like a vehicle comes over the bridge and then it goes away. So, that actually imposes repetitive load, right. There is a stress is applied and then withdrawn, stress is applied and withdrawn, applied and withdrawn, and that cycle continues.

So, the load, which it can withstand after, you know, at infinite cycle because static loading, where it fails. If I go on increasing the load, at some load it will fail, that is only one cycle, that static monotonic loading failure. Static strength, actually a fatigue strength, is much lower than this, which I can reverse, do, do the reversal of that particular load, apply or release the load, apply and release the load for infinite number of cycles. So, that is the endurance limit.

Let us define the endurance limit. Well, infinite number of cycles we actually restrict to 10 to the power 6 cycles, million cycles. The load reversal, which the structure can withstand for 1 million cycle, we call that as endurance limit. So, where fatigue load is important, I told you about bridge or may be of store structures where the tide will come hit it and then again it will go back, so there is a reversal of stresses. Such places where there are reversal of stresses, fatigue is an important issue and the endurance limit is the property.

So, I might require endurance from the material where fatigue is concerned, not all places, everything will be my concern. Some places I might require, I demand from the materials, that it should have good endurance limit. I select the materials accordingly, right, okay.

And then, impact toughness, some cases I like to have good impact resistance, where say, supposing I have forge hammer foundation, foundation of a forge hammer, you know, forge hammer is used for smithy, okay. So, quite industrial situation, one may produce some material mechanical industries through a forge hammer and such a forge hammer, actually, impart large amount of impact onto the foundation. So, foundation should be in a materials, which I am putting into the foundation should be able to withstand that impact.

There may be many, many other situations where impacts are important, blast could be important. In blast resistant structure, therefore I should have my material, which should be able to withstand this blast. The property that is important in such situation is called impact toughness, that is, the energy it can withstand before actually failure, you know, at, under impact, failure under impact. So, that is called impact toughness. So, this is important.

Then, industrial flooring abrasion resistance might be important because that might be rubbing lot of or pulling certain materials. So, there is the separation. Even bridge wearing coat where the vehicles move the wearing coat, top that is, that should have good abrasion resistance. So, pavement should have good abrasion resistance. So, materials should not go away under impression.

Railway sleepers, they require resilience. Resilience is the property, is the amount of energy it can withstand up to elastic limit, you know, wire stress elastic limit is that point up to which if you apply the stress and release, the stress will come back to its original position. That you know already, must be from some strength of materials course.

So, the energy up to elastic limit, half stress into strain up to elastic limit, it is called resilience. Some cases you might require good resilience of the material. It should be able to strain good resilience. Railway sleeper is one such example. It should actually withstand a lot of energy when under, I mean, the vehicle, I mean, train wheel has or train has come and when it goes away, it should come back to its original position, it should have resilience property.

Some vibration control system or isolators should have good damping properties. That means, it can dissipate a lot of energy under vibration. So, some cases you might demand a bridge bearing. For example, ((Refer Time: 52:20)) bearings, which are used commonly in bridges, they are the ones where possibly you require good damping properties of the material.

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And the next one is functional. These are, so far what I talked about was related to safety, the next one would be related to functional requirements, what you demand, what is the role of material in functional design of building or you know, in functional requirements of building. So, that is what we are trying to look into now.

When I am looking into role of the material in functional aspects, the functional design, functional requirements of buildings, we have seen, that there are thermal requirements.

Now, if thermal requirements, the material should have right kind of insulation properties, that is, it should have low thermal conductivity or proper thermal conductivity. I did not say low, but it should have required thermal property, thermal conductivity.

Then, thermal diffusivity, which is the derived property from specific density and thermal conductivity, essentially it means, the ratio of conduction to the storage in the material. So, that is thermal diffusivity. It should have a proper thermal diffusivity that means, specific heat should be also appropriate.

Then, thermal expansion, coefficient of thermal expansion. That is not really from the environmental point of view, but thermal expansion is related to temperature loading. So, therefore it should have thermal, proper thermal coefficient of thermal expansion. These are the properties, which are important from thermal point of view for materials.

But then, surfaces, for the surfaces the important ones are, for example, external surface. You know, white wash surfaces are supposed to be good because they have high long wave emissivity and low short wave absorptivity. So, accepting the radiation or you know, refusing the radiation, that property is important for the surface material.

Sun’s radiation is the short wave radiation. So, we do not want the heat radiation from the sun come into the building or not into the structure. So, it should have low short wave radiation absorptivity, should absorb less short wave radiation. But then, when get, when it is heated up eventually, although it receives some amount, it will radiate this heat to the environment to the outside sky in the night when, you know, cool sky in the night, and it must radiate as much as possible.

So, it should have high long wave emissivity. So, this emissivity and absorptivity property of surfaces are important. So, that is what has been mentioned here, you know, long wave emissivity and short wave, I mean, short wave emissivity and long wave, short wave absorptivity and long wave emissivity. These are also important aspect.

Then, in case of sound transmission loss, quality of wall, that dictates insulation. And if you are trying to control against ((Refer Time: 55:46)), then transmissibility of the wall against structure ((Refer Time: 55:50)) is also important.

Some you put mounting, so this property of mounting, damping properties of mounting, mounting is the small element put between vibrating machine and the floor. So, properties, damping properties or transmissibility of this mounting, they are important. Sometime you might demand from material to give right kind of property. For example, the corkboard, this should have good damping properties.

Absorption coefficients of materials, they are required in acoustic design of auditorium. So, this is again the properties of the element, constructional element altogether including its surface, not of a material, but the whole construction as a whole.

Fire resistance of elements, fire resistance of elements are expressed in time. It is the time up to which it can withstand the fire without losing its integrity, insulation quality and should remain stable, should not collapse. So, fire resistance is in terms of time. So, materials, you might demand a good fire resistance of material. Well, I am not going to discuss in detail what is fire resistance and things like that, but you might demand the material may be required or the construction, not material as a whole, but the construction may be demanded to provide adequate fire resistance.

Hydraulic diffusivity, permeability and vapour transmission coefficients or transfer coefficients, these are required against moisture ingress or moisture migration. These are required against moisture ingress or moisture migration, hydraulic diffusivity. So, you might demand from the material these properties if you do not, you know, proper blocking of moisture. Reflectivity of surfaces are important from lighting point of view, alright. I think we have nearly finished our discussion of role of materials except for one slide, which is related to some specific material.

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Durability, of course, is one of the most important issue related to all materials. It might, it might have good strength, but if it is chemically attacked by external agencies, external agencies, then its durability is not good. It should be durable, it should last long without getting degraded. So, this is the property, which we demand from all materials all the time.

For example, some surfaces might deteriorate under ultraviolet radiation, when exposed to ultraviolet radiation. Concrete may deteriorate when in presence of sulphate. So, have to look into these issues and we might demand good durability from the material, right.

And a special case, some material, which are mouldable material, like concrete, it is mouldable material, plastics are also mouldable material. But from civil engineering point of view, concrete is an important aspect**,** so their properties in fresh state would like to also look into, you know, their properties in the fresh state is an important issue.

So, materials plays an important role in its fresh state. And then, when it is formed during its service life, it should have adequate strength and other functional properties, what we demand from material as well.

To summarize what we have seen so far in this module of two lectures, what we have seen is, we look into, we looked into types of loads that encounters. One of the function is the, main function of course providing safe environment. And from safety point of view we looked into what are the types of loads it can encounter. Then, we have seen what are the functional requirements of the building? The second aspect, the functional, first is the load type, then the functional requirements, right. First is the load safety requirements, then is functional requirements. So, we looked into functional requirements, and then we tried to look into role of materials. In the next module we look into the materials themselves. We start with some of the materials, notably concrete and so on.

Thank you very much.