Structure, Form, and Architecture: The Synergy

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Lecture – 14
Structural Forms and Shapes

Hello, everyone. Welcome back again to NPTEL online course on Structure, Form and Architecture: The Synergy. Today, we are at lecture number 14 and it is all about the Structural Forms and Shapes and also particularly like it will have relation with the structural efficiency. So, in lecture number 13, that we have seen different kind of structural arrangement like post beam post, like then post slab, then wall slab and also we have seen different kind of elements of that.

Now, those concept the previous lecture concept it will be helpful in this particular lecture. So, we will try to understand in this perspectives. So, we have discussed the structural form or something in relation to architecture earlier, but here it will be something different where we will discussed about the basic shapes determination and the efficiency subject to the load applied onto it. So, let start it.

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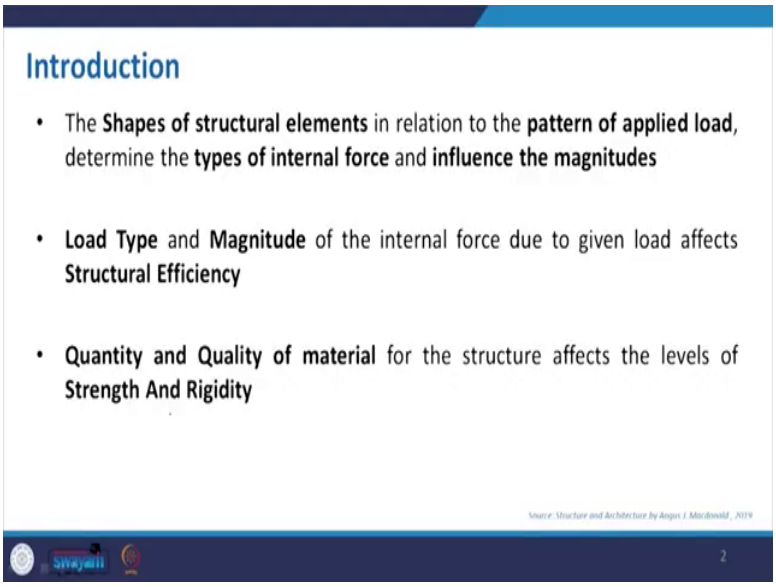

In this particular you know area that we all know the structural form or sometimes we also mention it as a shapes so, that in relation to the pattern of the load it carry the internal load that will give some kind of form. So, the first point that it mentioned that it is basically the shapes of the structural element and the pattern of applied load. So, pattern of applied load means it is we are not talking about dead load or live load, it is basically the force that we talked about in previous lectures like compression, tension, torsion, bending axial load like that and then it will basically determine the type of internal force that the structure that gives.

So, whenever we apply force that we already know that force is always acting in pair so, if there is reaction action then there will be the opposite reaction and also the influence the magnitude. So, this will also depend on the material property like one is the load type compression then what will be the magnitude like how big it will going to make the impact.

Then this load type and magnitude of internal force due to given load affects the structural efficiency. So, now we have to understand like in a structural component whether it is beam or column or whatever the structural element will use to make the arrangement and erect the building as per the design then on applied load how internally those elements are acting and based on the magnitude how we can define the efficiency. So, that if we understand the right shape that we can picked up so, that will make the structure efficient.

So, a many cases just we go for a very heavy mass or huge structures so, indirectly that will add up to dead load. So, we will come to that also how we can think of an what is the logic behind modifying that thing. So, in this lecture we will basically know three different type of structural shapes and then we will discuss about how to improve the say profile or the cross-section of the structural element which will improve the efficiency.

Efficiency means it will not really be compromised the load taking capacity, but as the same time the material reduction are also load reduction indirectly because if you really improve the section instead of solid beam if you can really go for something like with the hollow beam where we can you know in a substantial manner we can reduce the dead load and at the same time we can also carry the load it supposed to take, then that will be efficient.

Then quantity and quality of material will be determined on that. So, if you know that the what will be the load or the type of force will be acting to that element we picked up, then accordingly we can design the you know quantity or materials what kind of composition or maybe also the quality like depending on this your elastic modulus or maybe all other property that we have discussed earlier so, that will be determined to this.

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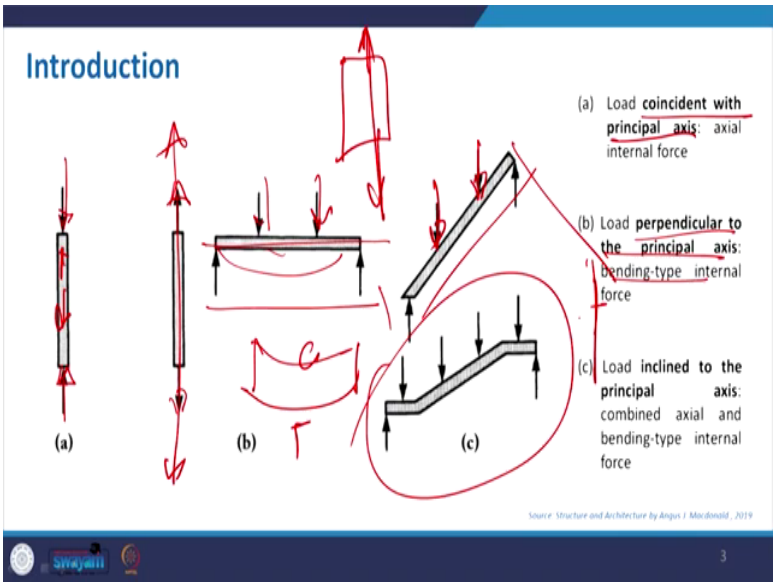

Now, in this case this is also taken from a book structure and architecture by A. J Mac Donald. So, this is another very pictorial and very simple representation and that this lies will be the basis of our further you know discussion in this lecture. So, what is happening in this case? So, we can see this is structural element we can say a column and in this case the load is applied in this fashion.

So, can you say that what kind of you know pressure is being generated in this case? So, this is basically a compressive force that is going to take place where at it is the tension in order to retain it is original position; it will try to resist again that. So, then there will be the opposite reaction so, that will be developed.

Most importantly in this case all this forces they are acting on the same principal axis, same later you know with coincident with the principal axis. So, if this is your object, this is your

principal axis and load is acting on that. So, only in this case either compression or tension will take place. So, this is one.

But, if you make this arrangement like this while load being applied from the top so, in this case basically the bending will come to picture. So, perpendicular to the principal axis; in this case principal axis is this one, the main axis and then bending type internal force will be developed. So, whenever there is a bending so, two kind of you know scenario will see that you know depending on the load if you take the same example. So, compression and then the bottom tension this is second type.

Then come to third type, where it is may be a staircase of the roof it is neither on that you know like coincident with the axis or neither it is perpendicular. So, in that case it will be something really inclined force. So, these are very basic form, but if we just club this together and try to visualize the you know application of this kind of a arrangement we will get many. So, this can be the some column, this is some beam, this is something staircase specially this one and this is may be a part of the roof if we complete the picture and connecting the dots. So, these are the basis.

So, again with that I have again a thermocol just for this time we consider this is the same object. So, if we just really want to see that this is basically the principal axis and when you apply load like this so, either it will have some compression. So, you know this particular internal force will be created and if I want to pull it in the tension. And when you put it like this so, it is more like bending if you apply load on this and when it is slant.

So, then there will be some inclined kind of force acting on that and then we have to go with some vector analysis to find the component acting on you know horizontal and vertical direction that already like we know some of that particular you know calculation that in physics.

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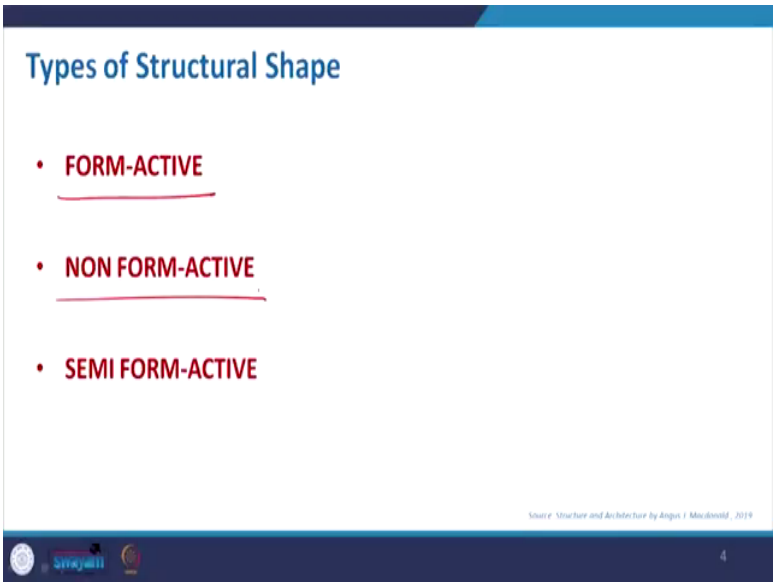

So, based on that you know principle like based on that kind of force that the type of force and then also the magnitude so, we have three category into that one is your form active kind of shape, one is your non form active and the other one is neither active neither non-active, it is somewhat in between semi form active. So, these terminologies are little bit unusual in this case, but I am sure that after this discussion after few slides we will have a better understanding on what exactly they are going to mean.

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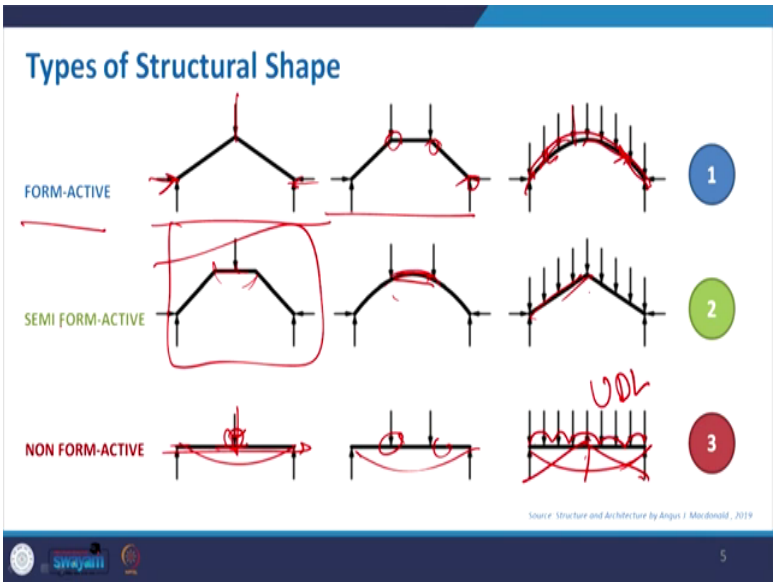

So, before I go to you know discuss each of them with some you know specific example, let us focus on this slide which is very important slide where we can see three types. Now, looking at this you have to get the idea like where they are different. The first one to get form-active. So, the purpose that you know the internal force that created in the structural element should have either compression or tension and it act with that axis, it may be inclined when it is pitch loop or else it is a simple one. So, in this case it is basically the same.

So, here if you see that it is this portion will have like this particular you know way of acting the force whereas, in this again this form we have those you know elements where we can only have this compression or tension that is also in the truss we can get it. And, this is another arch where it is again a compression where all this load will be transferred to that particular support.

Now, come to non form-active as we mention that in this case we will basically see that it is a bending in nature. When your forces is acting just perpendicular to your principal axis of the structural element and different magnitude when you can make it flat so, again it is a bending. And, again you can see that depending this may be a point load this is 2.1 and this is a regular point load that sometimes it may be like uniformly distributed load.

Now, in between these two that is semi-active so, where in that case the load being applied so, it not at the point. So, it is at the middle so, it is like a flat. So, this portion will have some bending so, it is a combination in between. In this case in state of making this like umm very pointed so, here also we can get some curvature. So, this portion will have some bending and again it is in between. So, if I just fold it, so, we will improve it to towards the form semi form-active. So, it will come in a resultant of semi form active- form. So, it will be clear more clear once we just see some of the examples of this category.

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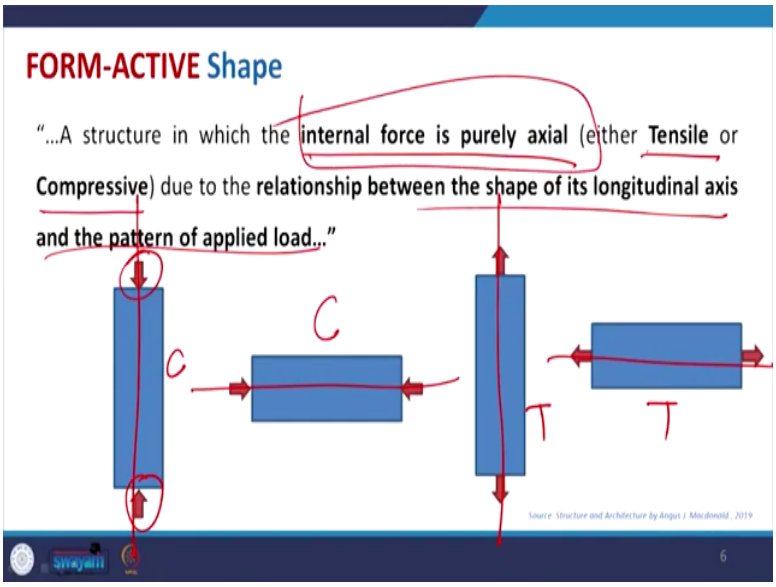

So, what exactly form say form-active shape? So, this is structure in which the internal force is purely axial; that means, either tensile in nature or compressive in nature and it has relation. It has relation with the shape and its longitudinal axis and pattern of the load. So, in this case axis is this one, in this case axis this one, this is also axis, this is this axis, but this composition looks very similar, but if you see carefully the applied load is something like that.

So, in this case compression, in this case compression, this is tension this is tension. So, this kind of element the form we select is basically a form active. So, criteria to say a form like a structural shape whether it is form-active or not is basically the internal force is purely axial either tension or compression.

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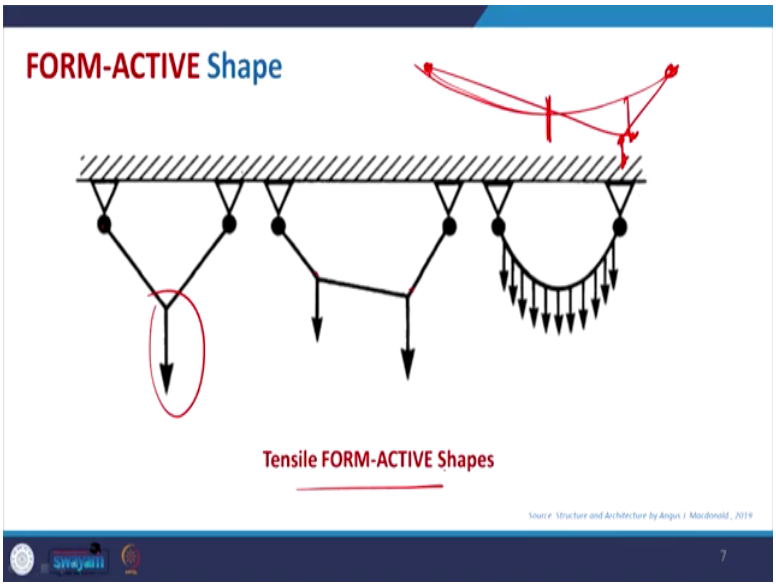

Now, take this picture as example. So, what exactly. So, you consider this as a rope. So, you just fix two points and just put rope like this. Now, if you just let it be like this then probably it will take a symmetry depending on the self weight and you get some point like this the curvature is same. But, at the same time you just apply load to this so, probably it will readjust to the point and you get something. This is the you know first option.

This is the second option. So, it will adjust its shape and where either it will of tension these are of tensile form active shapes that we also say in suspension bridges or you know cable suspended structures. So, there we can get this kind of form active. So, where it is basically showing the tensile nature of the internal force been created.

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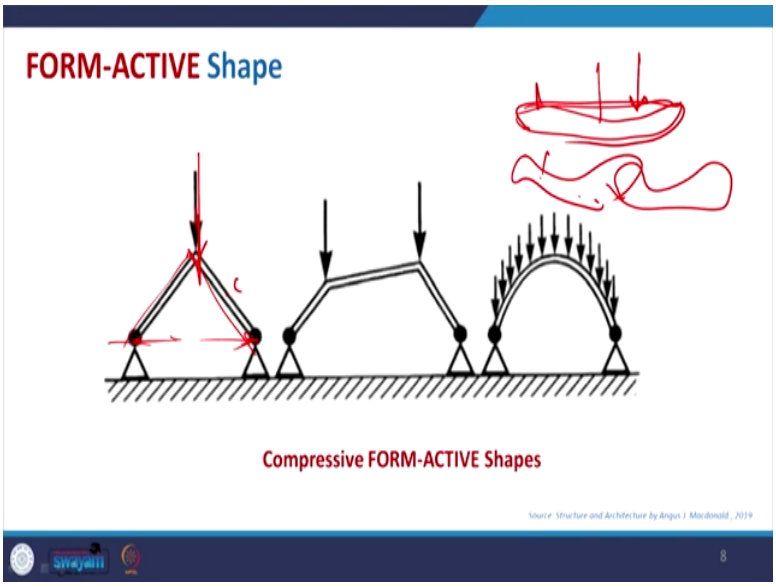

You just make the mirror image of that so, it will be the compression very interesting and in this representation this is a pitch roof and also in the earlier picture we have seen like here it will be developed so, it will put some pressure on that so, it will try to go apart from this so tension here in this case we will try to compress it. So, in this portion we will get compression in the system. It is just with the two point load and this is something with some arch. So, that also we can really get it.

The adjustment can be done not only limited to this you know suspension bridge or may be of these kind of arches, it may also be extended to the cell structure some pneumatic structure where it can be adjusted. Say for example, this is just you know air packet that normally we used to get when you know order something or when you pack something for the delivered to for safety of the product. So, it is full of air, but the main reason I just want to show that in

this case if I put pressure. So, accordingly it getting adjusted so, this portion the compression been created. So, if I put it here, accordingly the profile got changed.

So, if I just want to draw the same thing like when it is just a packet is something like that I put the pressure so, it will take the form like this; if I put it there so, it will be something like this, if I put the pressure so, it will be something like this. So, whatever may be that pneumatic form this is also called a pneumatic form we can create with this form active shapes. So, this is one kind of shapes and if we want to know the efficiency so, these are the form where will have maximum efficiency because that in this case only one will be taken care of and it will have this adjustment.

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Now, in this case if you see this is one suspension bridge in New Zealand where you can see this particular you know beautiful structure been created like again a rope. So, it is fixed up

fixed in two points and then it is getting adjusted whenever it is required. And, sometimes even for temporary bridge we also make with thread like rope and some you know wooden materials. So, this is one example of form active shape.

Now, come to the other one like this one basically it is representing this tensile type that we have seen in this particular picture. So, we just represent it with the case like case study on that.

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And, then this one is just the other one that the compressive arch. So, here you can see this particular form being created very beautifully. So, see this particular efficiency. In this case this is another example where you can see the very minimal thickness and all it is giving tent kind of shapes. So, again it is a form active shape. So, this kind of shell structure or something which will help us to go for form active and that can be also created with membrane.

So, the next example already I have shown you this picture in some other context, but here we are discussing with the form active.

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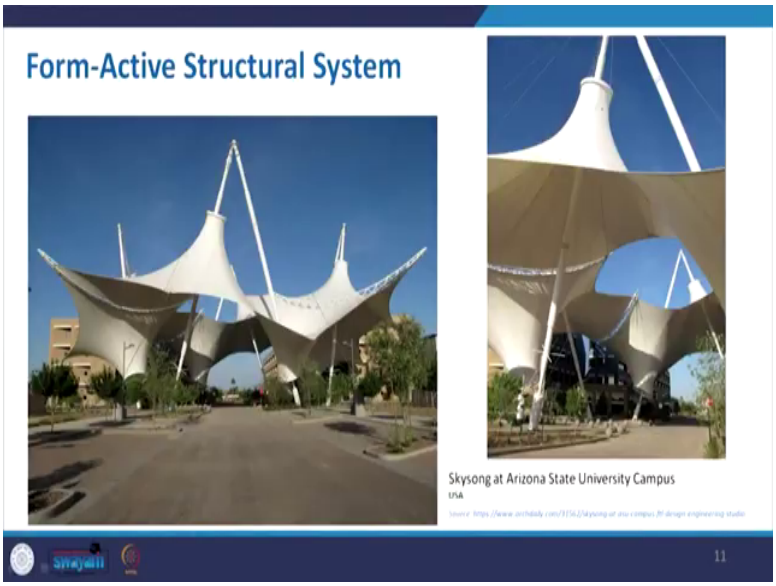

So, here again basically in this you know membrane the tension is developed and only when the member is consider this post this is a compression. So, again it is form active and you can see the efficiency like definitely the thickness and other thing will be really helpful. So, kind of stadium design kind of you know some you know arch design where we can really go for this kind of form.

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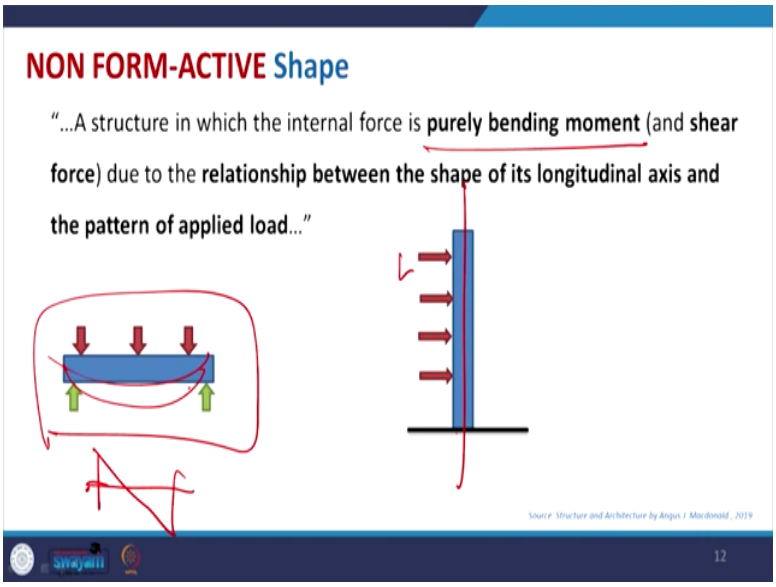

Now, come to the non form-active shape. In that picture we have seen that in this case like the relation is like it is perpendicular the load applied on the element is perpendicular to the it is longitudinal axis or the principal axis and in that case purely bending moment and shear force that is the main you know internal force that being created due to the you know relationship between the form that is when placed like the element being placed and the applied load on to it.

So, this is the case where you can see that this is something like a beam supported and then the load applied. So, it will have the bending and then the shear we will get it some bending moment and then you have some shear force diagram to this if it is something like two end supported. And, this is another one where it is representation of a tall structure where lateral

will place. So, this is your principal axis and then it is acting perpendicular to it. So, again it is something which is non form-active so, where bending will take place in this case.

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Now, if you take this example this is just a bridge and this a random example I have taken from internet, but you can see such many where it is more predominant of this non form-active shape that been used in various structure even in the building as well where is basically for the bending and shear force will be the prime you know consideration and the form and it is shape will go with that relation.

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This is from the building where again it is something like you know you have series of columns and you have this beam. So, it is post beam structure, but again in this particular phase we are now considering the purely bending and other thing into consideration. So, again, it is non form like non form-active shape kind of relationship.

So, now we know two type of let say one is active form active another is non-active. So, in active what is the reason I am just repeating it. So, there basically you will have pure axial internal force that is either on tension or compression and we have seen the example of your suspension bridge as well as this arch, we can also have some membrane structures and cell structure. In non form-active is purely a bending and shear force that too is most commonly being used in the building or in the fly over where those beams post a kind of structure is being placed. So, post beam post and you can more often it is basically non form active shape.

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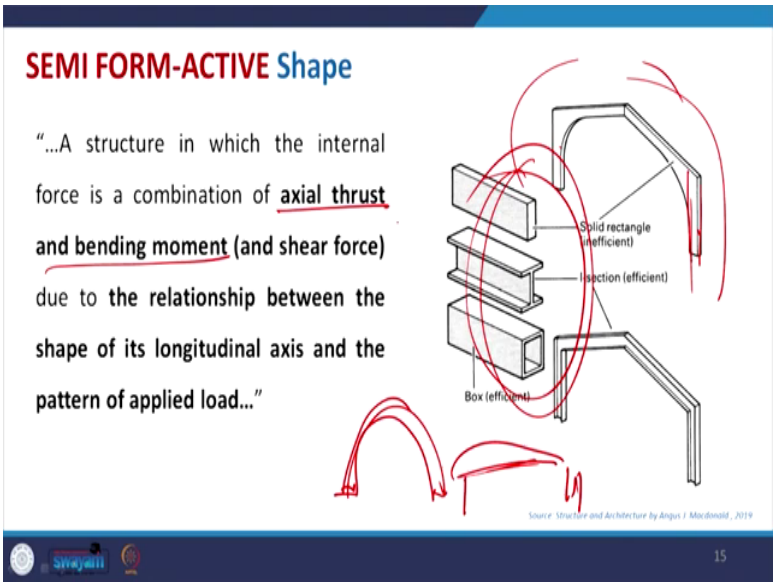

Now, semi form active shape is in between form active and non form active. So, it is basically a combination of both axial thrust and the bending moment shear force. So, you combine all together. So, in this case what is happening like definitely we have some kind of you know this particular form where this is a separate post and this is a post how they are connected to make this particular arch.

Now, in this case what is happening how it is in between because if you go separately with this post and all so, it will give you some of you know I mean making one member of this arch and all it will give you the form active shape. But, at the same time if you just make it flat with this giving a support so, it will give you the non form active, but in this case we are very much choosy about selecting the material like whether we go with the solid rectangle cross-section of that or instead of I section or maybe a box section.

So, the reason is we can build with anything because it will have some purpose to carry some load, but in this three cases things will differ we will come to that, but for this time being it is in between.

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Now, if you see this structure this is the same example maybe like replica of this kind of structure that I have picked up so, where this is basically showing us semi form-active structural system.

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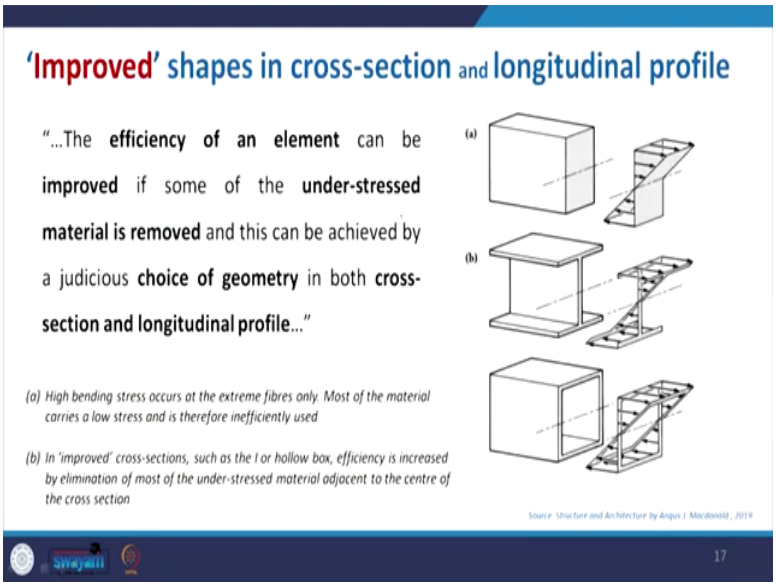

Now, how to improve the efficiency? When definitely we talked about the efficiency, then the form active will have the maximum and when you go from non-form active it will not that efficient.

Now, the reason. Now this slide is very important like in the previous example when we started this lecture so, we can have this three type of cross-section can be used for this structural arrangement. Now, what is happening here? In this case if you go for a solid section so, based on this particular you know shear force what is happening this case that whole portion will have see at the you know outer fibre will have the maximum force. So, that means, in this case high bending stress occurs at the extreme fibres only and most of the internal component ok. So, they will have something which we can say that they are under stress ok.

So, basically most of the material carries a low stress and therefore, inefficiently used, now we just remove it. If we change this solid section to I section what is happening still at this stage we can have the similar kind of you know behavior structural behavior, but at the same time we can reduce it and when you go for a box section again we do the same.

So, if you see this particular you know efficiency; if you go with this kind of thing like the reduction of the material because some of the part is not really very much responsible for you know bearing this particular stress and all. So, they are having they are caring less stress and that is why that can be removed ok, logically so that we can get a better profile which can be used.

So, that is increasing the efficiency. Now, efficiency in terms of we are reducing the material; that means, direct implication that we can say that there will be reduction in cost of the material, but in other direction that will also reduce the dead load. So, we will have some reductional load, but again we are not compromising the you know capacity the bearing capacity of the member because that is being selected based on you know proper analysis that you know element selection that we have discussed in you know last to last class that when you select the cross section we go through that how it will behave against the applied load on to it.

So, the improved cross section like I section or a hollow box efficiency is increased by eliminating most of the under stressed material and we create it hollow. So, this is one approach by which you can improve the shape of the cross section.

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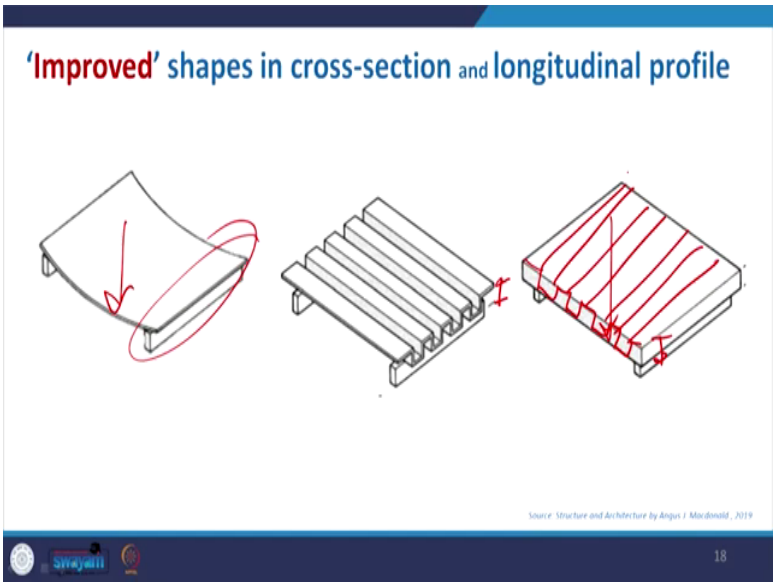

Take other example. In this case it is a you know you just very thin plywood in this case it will have this particular bent. So, whenever this is having the bent so, at this stage it is basically non form active and to give support we could have two options. We increase the thickness like this which can really know hateful to make it stable, but here what we had done increase in cost of the material as well as we have increase the you know what we say the dead load.

But, compared to that if you go for something like folded plate then basically the thickness remains same, but we can substantially reduce the material because which are not really needed because of the most of the you know important portion of the you know element where you know it will take the essential stress to make your structure stable and safe. So, some of the portions can be removed easily.

So, if you compare this thickness and this thickness is same, but you can easily compare how much reduction being you know taken care of how much material we have reduced from this particular block. So, this is very useful to make your structure efficient. So, these are something where improvement can take place and we can convert it to some kind of you know from purely non active form to semi active or something like that.

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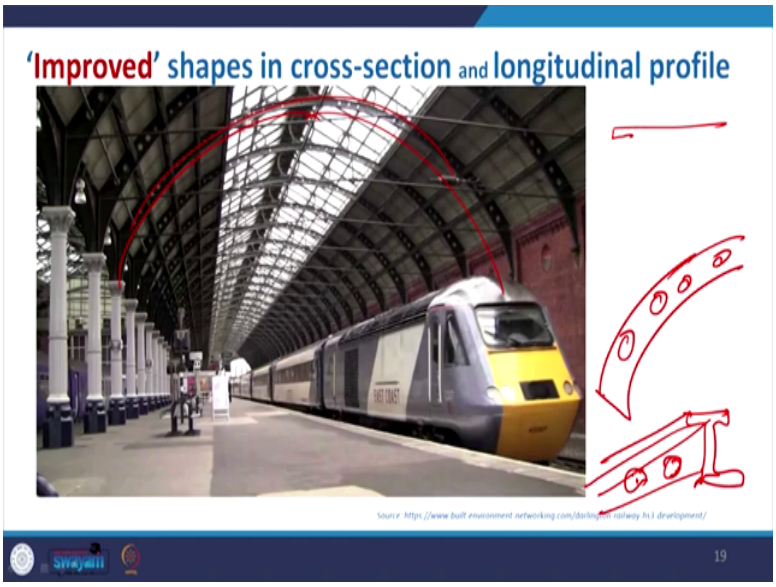

So, let us take this example this is one railway station I have picked up. So, if you see this particular you know members this particular truss so, it could have a very solid profile right, but essentially if you see carefully that it has some punctures to that can be developed. From I section also you know like if I just want to reduce it. So, in that case we can have some of the punctures in between.

So, basically and that cannot be just like in order to reduce the weight or something to look very interesting in terms of design that has to be done with proper justification and we have to select that logically with calculation. So, that there will be no such compromisation on like your you know carrying capacity or the bearing capacity of the element which will be used as a supporting structure.

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This is another one where this is now being common where we have seen to create large span in state of a heavy beam we can go with very simple space frame. So, compared to a section solid section so, a truss can give you more efficiency to come up with the solution and this space frame is another where we connect the truss in 3D.

So that it can really solve the purpose that is reduction on the self weight and you can see the span also this being used normally for the airport, public station and it is possible like you

know the purpose here is not to really have the floor on top of it or heavy load. So, it just a cover so that we can go a for a light roof structure. So, this kind of arrangement can give you the efficiency.

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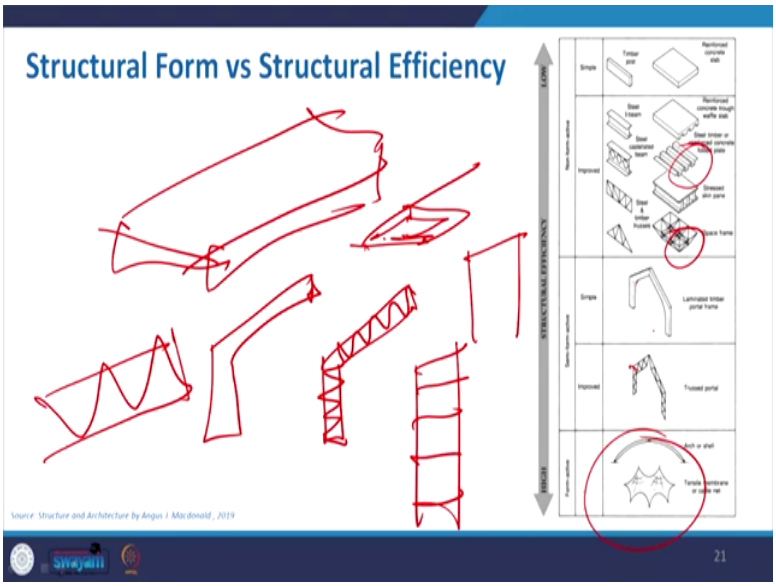

Now, if you see that we summarized here in this case like we start with the frame like form active shape like your tensile membrane structure that we have seen in the sky some structure in Arizona or maybe some arch that we have seen. So, these are much more efficient on because that we will handle it very carefully.

Now, when you go for the semi from-active so, it is in between, but we still have some chances to improve the cross sections in state of a solid hollow beam here only that truss portal being used. So, earlier it was just a solid member and now, we just transfer this thing in

truss. So, there is reduction in the cross section, reduction in the material and so, true with the reduction in the weight.

Now, come to the non form active where it is basically your post beam kind of structure something about post, then the slab and in that case instead of you know huge slab and thickness we can have waffle slab where we you know from you know inside you can see that it is giving you know you know adequate strength we can reduce the material wherever the portion or of that element is under you know under stress or not really carrying this you know critical stress and other things.

So, folded plate can be one of the option to transfer it and then we can also go for the space frame structure to again create the volume. So, wherever we want this thickness we can have, but depending on the calculation and proper selection. So, it needs very careful analysis to select the element cross-section and without compromising the desired stress level that it should take when load is applied on to it and we can reduce it or the cross section material in you know in many purposes one to reduce your the material use and that related to the cost and as well as the dead load. So, we can optimize this thing with some improved cross section.

And, if you know see now in this direction so, if you go for a normal frame structure with the beam column that is not as much efficient than if you go for some cell structure and membrane structure but, we cannot create this all the time because of some other purposes because when you go for the high rise building so, floors are there on top, so, we cannot.

But, wherever there is a chance that we can create this kind of structure to create the span or something like that we can really go for this form active space and wherever is possible we can really improve the cross section to be used as element. So, this is the overall discussion that we have.

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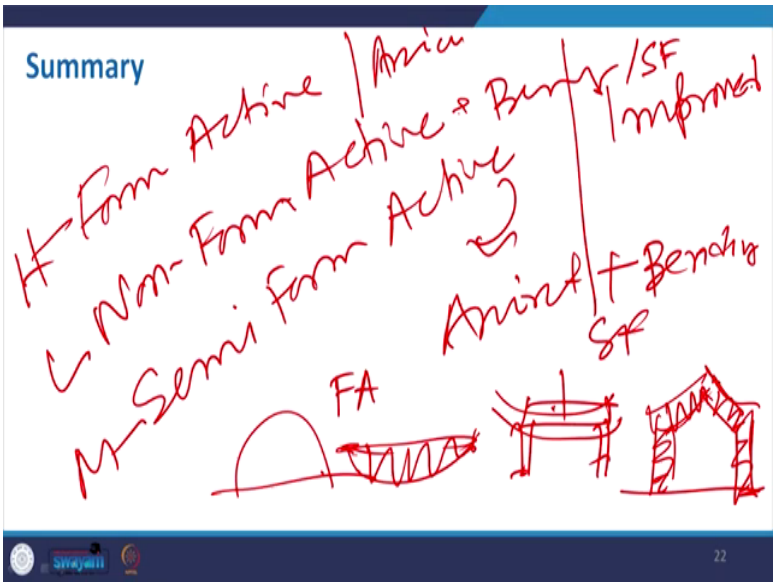

And, then in summary so, what we learn form active, the other is your form non form active and one is your semi form active. So, these are three different thing and one other thing is the improvement in their cross section and longitudinal profile to improve the efficiency. In terms of efficiency if you go like this is the highest, this is the medium and this is the low efficiency. And, in this form active your basical internal load will be axial in nature and when non form active bending and shear force will be the picture and here it is a combination of axial thrust plus bending plus your shear force. So, that is the overall thing.

In short if I just tried to draw a picture and or may be suspension bridge these are all of like you know structure of the form active. In the non form active it is just the pillar that is you know tends to bending, so, that is non form active. And, semi form active is the frame that we

can use and in order to improve it we can reduce it, we can replace it with the stress and all. So, that way we can improve the efficiency that is a relation.

In this lecture we learn that the relations efficiency of the structural element to be used depending on the form selection and how you can improve that with some you know analysis. So, with this I conclude here.

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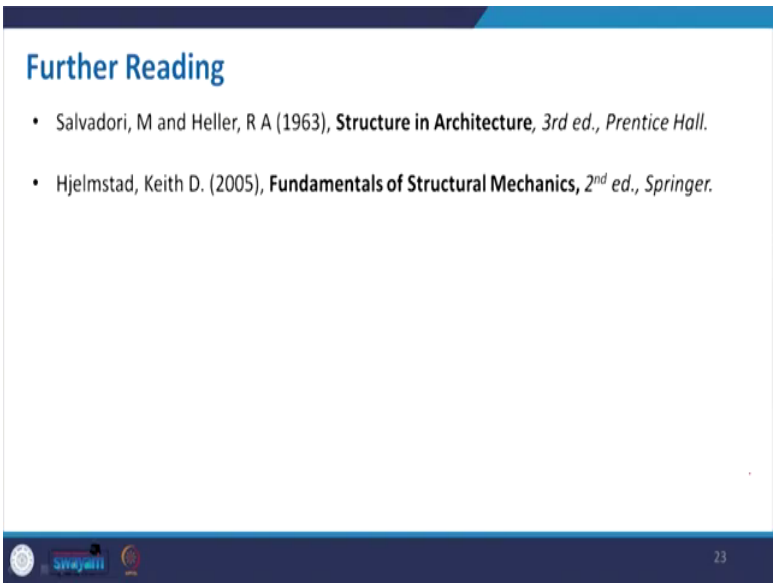

And, these are the few books that I also referred in previous lectures. So, go through it and with that we conclude and next so far we are we mentioned about the structural material so many times. So, we will focus on that in the next lecture. So, till then I again thank you all to take part in this course.

Thank you.