Aircraft Structures - I
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Module – 1
Lecture – 3
Introduction Continued

Welcome back. I am back again with the structures 1 course. Myself Anup Ghosh from Aerospace Engineering Department, IIT Kharagpur. We were in the process of introduction to the course. We have already covered 2 things in the first few minutes or say about half an hour. We have observed how the theory has progressed, not only the theory. We started with an example, an example of Leonardo da Vinci.

How he did his first experiment to find out the strength of wire and gradually, we have seen how Newton played his role in the study. Then there are many other scientists like Bernoulli, like Euler and then Hodge, Crandall. They have laid the path of the theory of elasticity. Then we ended with the discussion of the recent day's work in the shell with Donnell's work and then the lecture following that was consisting of the history of how the aircraft or aviation industry has come into the present day.

The first controllable flight was on 17th December 1903 at Kitty Hawk by Wright brothers. Then from there, we have aircraft to carry more than 600, probably more than 800 passengers and we have an aircraft to carry probably anything, maybe a few wagons of the railway. So those who have seen how the slow progress has come up, in between how rotorcraft has come in and then today what we will do, we will be again discussing a few aspects related to aircraft structures in consideration to the existing structures.

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Before we go for any analysis or understanding of any structure, I think it is better to understand what it is, how it is. So we that will have to some extent discussed about any structure, load-bearing structure which beers load and in case of aircraft how big it is, it can be and how small it can be, how much payload it is supposed to carry, all those things that are the reason we have said here that where, how, what of the aircraft structure. So if we see these things we will discuss.

We will also discuss about the concept of construction as a structure, these things will discuss. So better, we take a few examples of aircraft and try to discuss how the structure is important and where we need to pay more attention as a structure.

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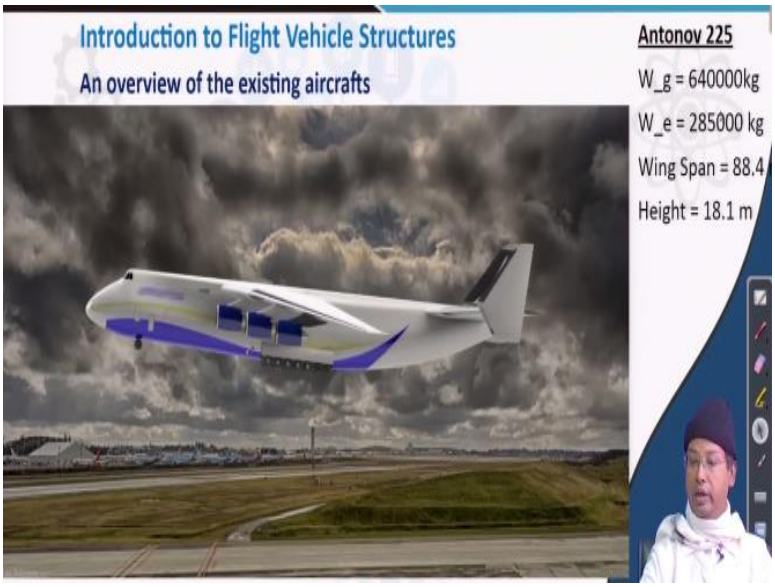

So the first example what we will consider is really a huge aircraft that is the Antonov 225,

An-225 is also known as. In this lecture, we will cover an overview of the existing aircrafts from its size consideration, structures consideration, from an external way. We would not go into detail about internal structures. So a photograph, unless we have a comparison, it is very difficult to understand how big it is.

So from here also that is missing, probably we have on the farce a few aircraft, so we have the runway scene, but that also is not very good observation to imagine the size of the aircraft.

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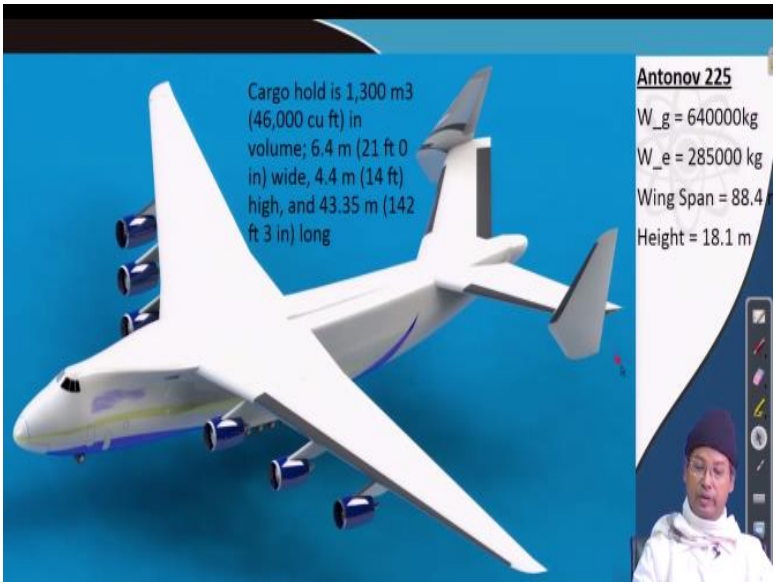

Here the gross takeoff weight if we look at that gross takeoff weight is about 640000 kg and empty weight is about 280000 kg and a wingspan that is very important, wingspan is about 88.4 meter. This gives you some idea of how big it is. If you look at how big it is, it is better to notice that a standard soccer field, a football field, is about 100 meter to 120 meter. So an aircraft, if we can imagine, is standing on that field its wingspan from here to here is covering almost the length of the football field.

Probably if somebody wants to play here, a small soccer game probably maybe played on this portion, that gives us how big the aircraft is, okay, that is about the span. We understand it is so big at about the height of 18.1 meter. 18.1 meter in the standard way if we look at in our surrounding if we see, we generally compare with our known objects as generally, we consider that a single storey of a house is about 3 meters, sometimes it is less, sometimes it is more, but it is about 3 meter.

So if I divide it, this number it comes about 6 storey building. So you just try to imagine you are just at the foot of a multi-storied building and the height of this aircraft is about six storey, so it is so huge inside, some other ideas if we have all these views will come into slowly cargo-hold capacity. This is particularly a cargo aircraft. So cargo hold capacity if we look at it is 1,300 meter cube, sorry for this mistake or say 46,000 cubic feet and its width is about 6.4 meter.

Again 6.4 meter means about how much, about say two table tennis board if you keep side by side it is little more than that. So it may be about the width of your classroom generally where you sit for a class and the height is about 4.4 meter. That means inside it is about one and half storey height and long it is about 43.35 meters that means almost about half of the football field. So it is better to notice it is so huge.

If it is so huge, it has to be light also to carry all those cargo. Cargo weight is not directly a subtraction from the gross weight to empty weight because this includes also the weight of the fuel and that determines the range of the aircraft. So it is generally a compromise between the range and the payload. So accordingly according to the assignment, generally this aircraft is hired.

According to the payload capacity the range is decided according to the requirement of range in general, the fuel is filled and it is used for that particular range.

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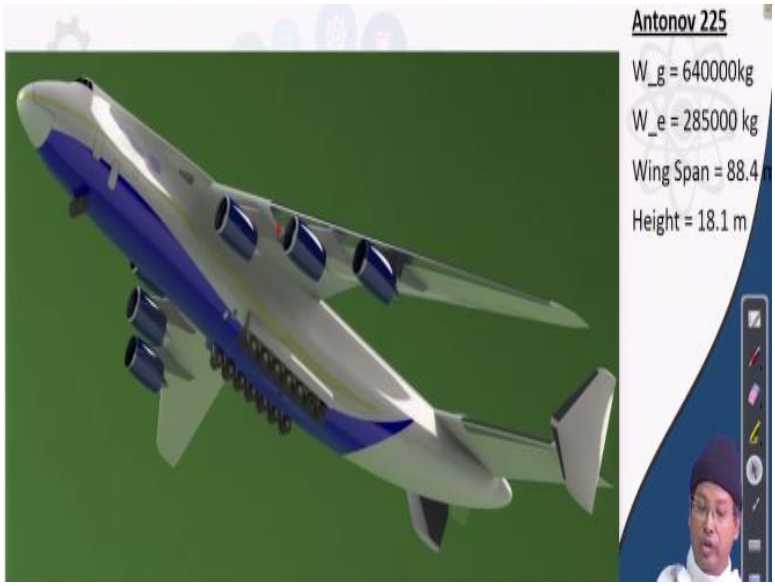

This is another view, this is the top view if we say, not top that way it is a kind of skew view

from top, it is a skew view from bottom if we look at. There are 6 engines, this particular type of configuration of the aircraft is known as 2 vertical tail and high wing configuration with bogie type of landing here, you see these are the 2 bogie type of landing here and because this tail has come on this side.

The vertical tail has come on this side that increases the load on the structure because see it is increasing the air load which is coming horizontally on this vertical tail plane as a moment component on this horizontal tail plane. So that increases the size sectional dimensions or weight of the horizontal tail plane, but because of some other design requirements probably they have used this type of configuration.

Generally all cargo aircrafts are high wing configuration because the most important thing to remember in cargo aircraft is that how to load the cargo. In this case generally, the front portion gets lifted, there is a hinge here, you can find many videos in website in YouTube to see how the cargo is loaded from front. This bogie type of landing gear we need many landing gear to distribute the weight while it is landing.

Because it has to be very soft landing because it carries sensitive things, probably it was used to carry a few space shuttle. So, all those things are sensitive things, so a shock is not at all desirable. It is not at all desirable in another view also, other requirements are also there. So keeping in mind all these things generally a bogie type of landing gear and a high wing configuration is considered.

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This is another view of that particular aircraft to give you the size. So probably if we stand beside this aircraft, our height will be somewhere here, up to this much, so one human height, 2, 3, 4, 5, 6, 7, 8, up to this probably, human height is much less than the height of a storey, so our height probably will be something like this.

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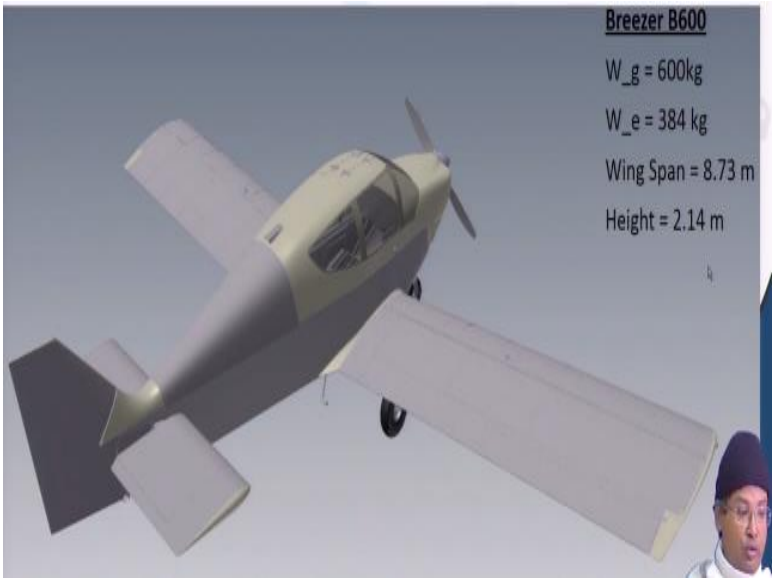

So with this let us move to some smaller aircraft. Basically the structures requirement remains same in smaller aircraft also. This is also a very famous aircraft Breezer B600 which is having a gross takeoff weight of 600 kg and empty weight of 384 kg. So this is one thing to notice here. We will discuss many other things, but weight is very important parameter while we talk about aircraft structure. So this is about 400 kg, so just to give you some comparison about weight of a general car.

A 5 seater car which is the most popular in our society that comes with thousand CC capacity that comes about 1000 kg around, but this particular at its takeoff weight is about 600 kg and this 384 kg this weight is probably equal to some big bikes, nowadays that has become a fashion. So it is probably equivalent almost same to that those big bikes, weight of those big bikes, but this is able to carry about 4 people including pilot.

So there is the mileage, there is the advantage, there is the efficiency required for aircraft structure design, so that is what we need to study, we will have to study, and the wingspan wise if we look at about it is about 9 meter. Again this is here if you see it is 9 meter, this is about the span of your classroom maybe. So if we try if you open one wall of your classroom, probably we can fit in one such aircraft, it would not be much difficult.

So, from here to here if we look at, it will come into your classroom and height is definitely less than a storey height, it is 2.14. So just try to imagine you are in a classroom and just beside that there is an aircraft by which you can fly for a few 100 kilometers, so it is so small. So these type of aircrafts are generally built abroad in US and Europe at home these are known as a kind of home-built aircraft also, but we do not have.

Our government does not give that type of permission, so we cannot build it. Anyway, let us progress probably in future government will permit, so it is your scope you learn it and probably you will be able to fabricate in flight on your own.

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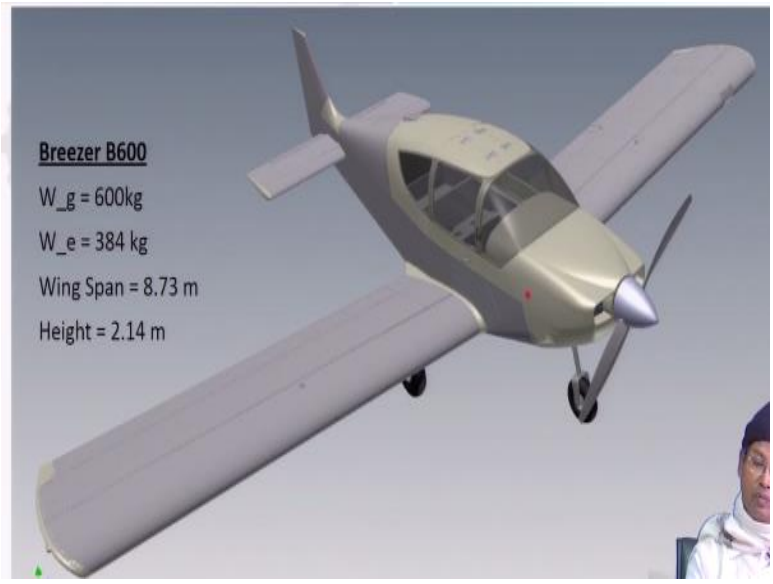

Next it is a different view. About the configuration if we look at, this engine is something different. The previous engine was a mainly turbofan engine, this is a piston prop engine. Piston prop engine means it is similar to the engine what you use in your car or in your motorbike, only it has a different configuration inside, its orientation is different so that it can exert that much power.

Engine capacity is also probably more than those and this is a low wing configuration. This also gives us that this is a semi-monocoque type configuration. That means it is not only the skin which is bearing the load, there are some frames like this, like these frames which also bears load.

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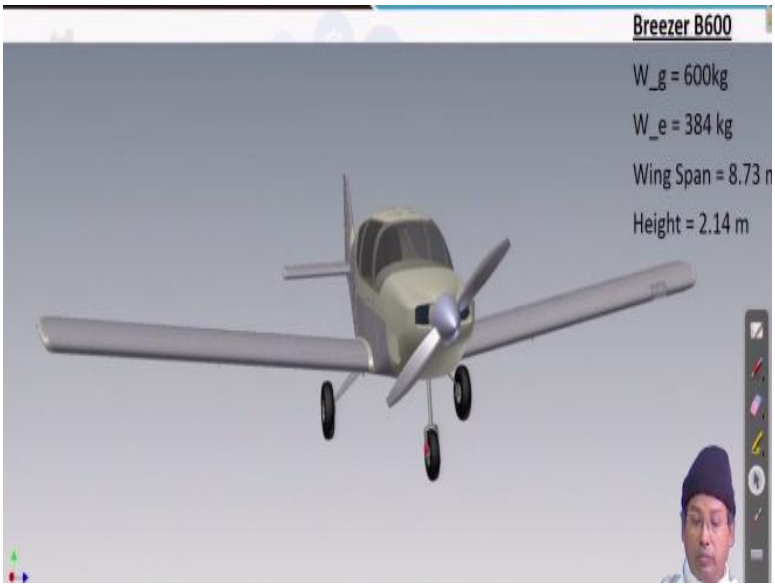

This has 3 landing gears and these landing gears are fixed, these are not retractable landing gear. Retractable landing gears increase the weight because that needs hydraulics to do, so these types of aircrafts are generally does not come with retractable landing gear. So along with this concept, we will see, we will go forward.

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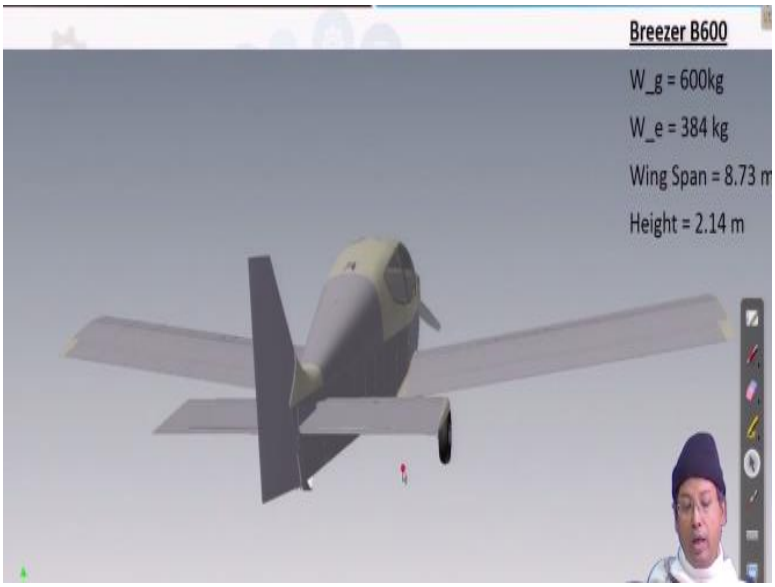

This is another view, it is almost from the front and this type of tail plane configuration is very common. Tail plane also withstands the load to control the aircraft. The wing is on which the total portion hangs while it is on air. So the wing root is very important structure in that sense. There is a wing box structure, wing joining structure inside which joins the wing with the fuselage and while it is on the ground, the load comes from the landing gear and that landing gear has to be.

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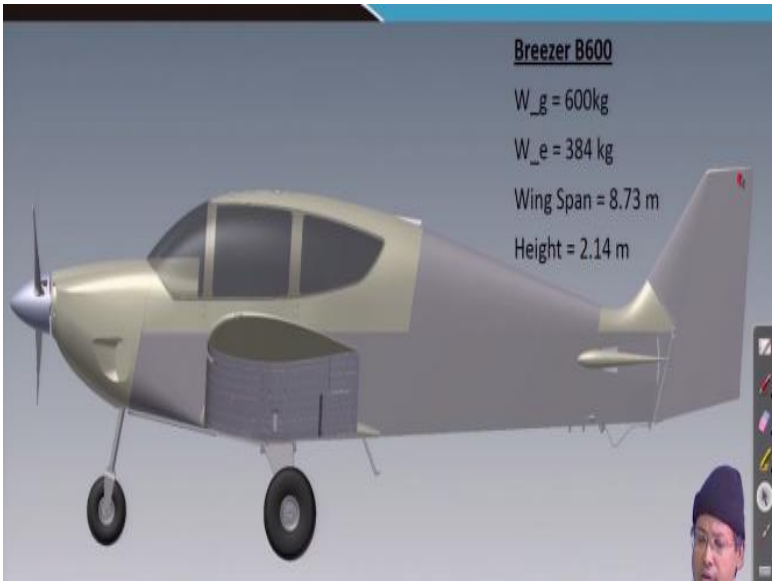

This is another view. We see here there is a dihedral, this is the wing root and it goes up, so this much is the dihedral. On the other view also you can see, but where the tail plane is not having any dihedral, the 3 landing gears we see. This is the portion of rudder.

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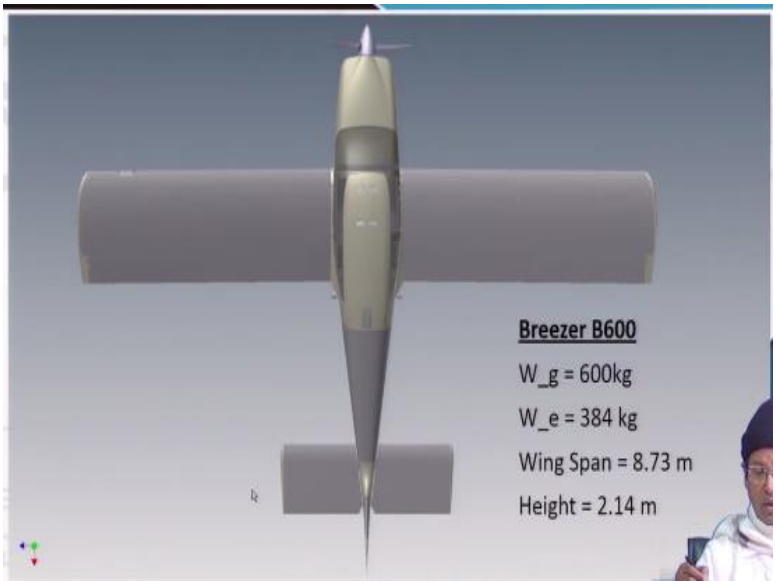

This is the top view. From this view we see a different way how does it look like. So let us go move forward to some other aircraft.

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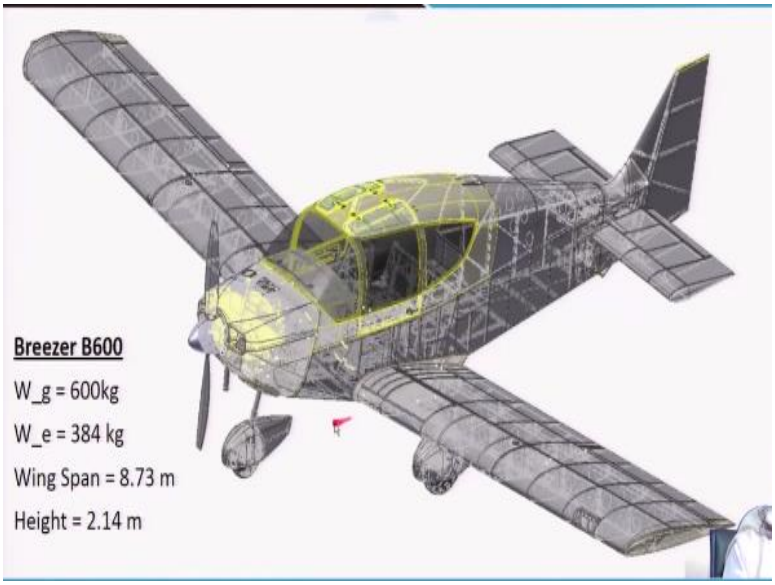

Okay before we move forward to some other aircrafts, see getting details of internal structures is a really difficult task because nobody gives it because they are doing business and they do not want somebody else to do it to create competition. Fortunately, this drawing I got it from some open forum shows in a very hybrid mode the internals also. Here we see the ribs, here we see frames.

These frames work as kind of bulkhead and then those total fuselage is fabricated on that and landing gear is fixed. All other components and equipments are inside and this construction, please notice that construction of wing and the tail plane and the vertical tail plane is almost same. The basic thing is that there are ribs, there are spars. We will come into detail in the next lecture how does a rib is constructed, how does a spar is constructed and those details will come.

So, internally there are so many structural components and on that there is a skin which gives the aerodynamics shape and it transfers the loads to internal structures and as a result we fly. It has to be very smooth to reduce the drag that these transitions are made as smooth as possible. This is as I told you it is a kind of home built that portion is not that smooth, but if you look at the commercial aircrafts or the previous in Antonov also you have seen.

In the future aircraft whatever we will see there also you will see those are made very small to reduce the drag.

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This is another wonder of aviation industry A380. So one point I would like to mention here that if you remember in case of An-225 or Antonov 225, this was 88.4 I think, yes it is 88.4 and here it is 79.75. This point is very noticeable because the cargo aircrafts are not always used in all international airports runways because it depends on the requirement, but all international runways are generally permitted to fly aircraft with 80 meter wing span.

That is the reason I know from some reliable source that it was a big challenge for Airbus to keep this design within that 80 meter wing span limitation. You see this is very important point to notice that it is certified for up to 868 passengers. Just try to imagine this is a huge number, 868 passengers. There are 2 decks, there is division her, we will see that type of fuselage. We will get introduced to that and the gross takeoff weight is 575,000 kg.

Empty weight is 277,000 kg and wingspan is about 80 meter, height 24 meter approximately, 24.09, 24 meter means again if we bring to our comparison parameter that is the height of a storey, height of house, height of our buildings, so it is 3 meter if we get, it is about six storey building. So height wise probably it is almost same as I think this is more, point better to note that that was 18 point something this is 24 point something.

So it is about 8 storey, not 6 storey. So the height is much more than the Antonov. There the big difference comes because from the landing gear because here the landing gear is not that type of landing, unfortunately landing gear is not in the figure what I have included. Please refer to the open forum, open Internet documents you will find that it is because of the landing gear, landing gear plays a big role in this height increment.

So here the retractable landing gear, not the bogie type landing gear that requires some space. Another difference is the engine. There are 4 engines because the weight wise the payload is small here, not only that there is a progress in between on engine capacity also, so that is being utilized by Airbus.

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Another dream machine they say is Dreamliner 787 Boeing. So the wingspan is noticeable as 60 meter height is about 17 meter and typical capacity is about 242 passengers. So this is again having engine is reduced here. Again number of engine reduces because of the advance in the or progress in the engine technology, size of the engine, more latest engines are used and that way it gets reduced.

So engine thrust has to be transferred to the structure from this to the wing and then it is to push forward the aircraft, so that portion is also to be designed.

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One more segment of aircraft if we see I am putting you stress on the height and the wingspan because it is better to notice here the size what we are going to design, how big it is. So the wingspan is 22.5 meter, height is 6 meter, so it is about two storey building and span is 22 meter . This is generally a private Cessna Citation latitude, these are known as business jet aircrafts. These 2 engines, general turbofan engines are mounted at aft portion and that forces to make it a T-tail configuration.

Since it is a T-tail configuration again as we have discussed in case of Antonov that increases load in the vertical tail plane. So there the vertical tail plane was increasing load on the horizontal tail plane and here the horizontal plane is increasing load on the vertical tail plane.

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So that structure size as increases that increases weight, but this is a different type of

requirement this is a low wing, aircraft configuration is also different because it has to be very, height is supposed to be kept very low because it operates in small aircrafts also where not always the provision of ladder or staircase is present. So keeping in mind all those things, this configuration is different.

Keeping in mind the ground clearance distance also it has been made at the low wing configuration and with 22 meter wingspan and height of 6.4 meter it is able to probably fly about 20 to passengers, but it is inside is generally configured according to the requirement of business requirement.

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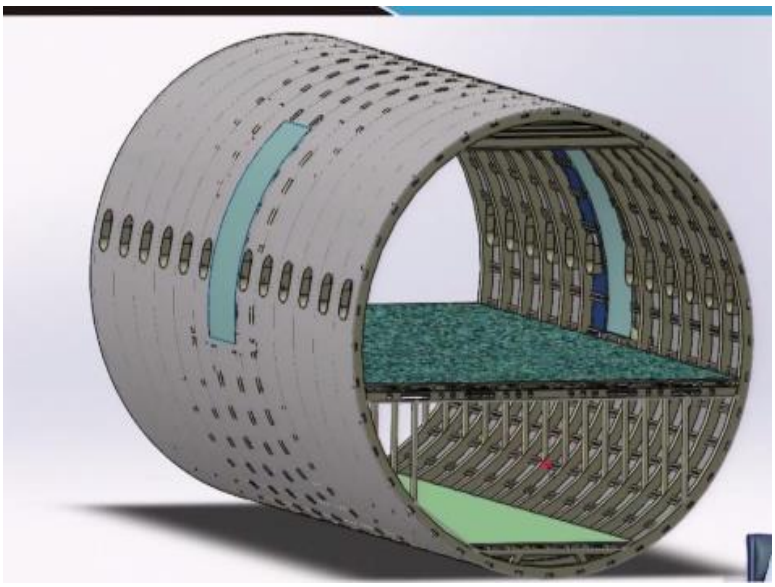

Now we come to some extent bit detail of the structure. So wing to some extent we have seen in the previous aircraft. Here is this portion, this portion is known as the cargo hold and these circular rings are the bulkheads which joins one to the other. These are the window gaps and this deck on which we generally sit. Chairs are put here from front to the back and depending on the requirement of these things, a fuselage is constructed. This is a door cut out.

This drawing is not very good, but again it is collected from some open forum. These supports are to support the deck. This is the deck beam on which the total sitting arrangement is supported. We will come at again details of those constructions, so that is why we do not want to spend much time here.

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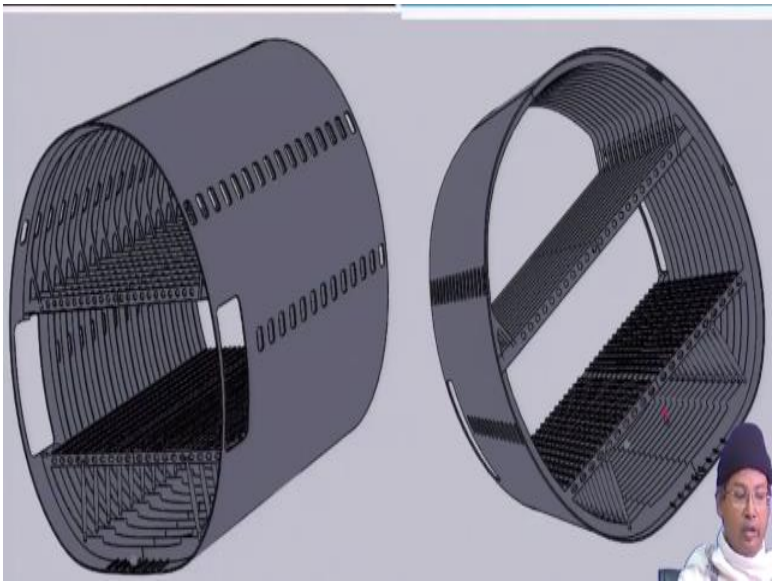

Again this is the fuselage of that A380 type of fuselage one. These cutouts are for door. There 2 decks as I mentioned and this is the cargo hold in a different view. All these things are bulkheads, circular type of semi elliptical, this is semi elliptical cross section type of things and then this is different view of that fuselage construction and we will see in detail how these things are done.

We will try to understand analysis criteria how this particular type of structure is analyzed, how torsion comes into effect for an aircraft structures, how deflection of each and every member and stress bending moments are developed in each and every member and on which how we can design a member. All those things will slowly come in our course. So before that it is better to keep in mind this type of structures we are going to design.

The examples what we will be solving are probably not exactly matching with this type of structure, but if we look at simple aircrafts, those will definitely match those examples and for more complicated aircraft like this, the advanced things are introduced and accordingly it has been carried out .

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This is another view, another SolidWorks drawing or CAD drawing I must say, previous also is a CAD drawing. This view is different. In this view, these bulkheads are quite clear. This is the beam. We always put holes in the beams to reduce weight. In this structure also you see there are holes to reduce weight and we will see why this window shape has come, what was the reason why stress is important around this hole.

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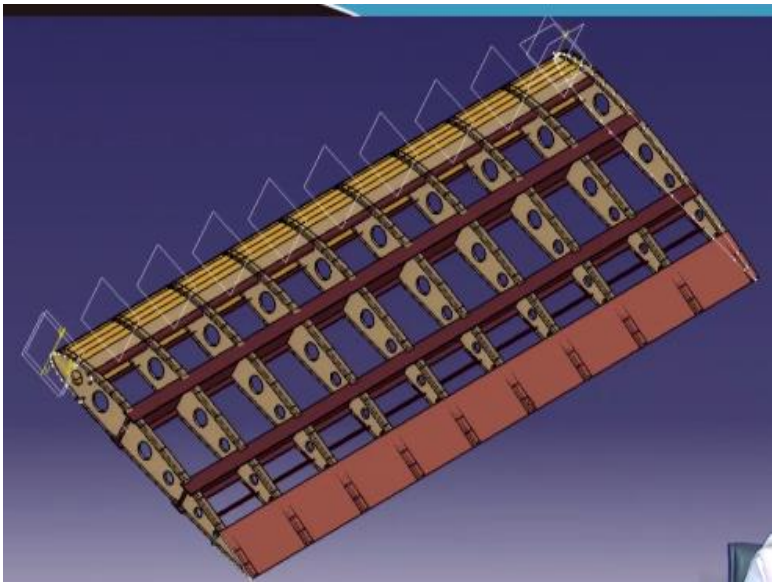

Then we come to the picture of a conventional wing structure. Here this is the spar, these two and these are the ribs. This is the leading edge cover, this is the trailing edge cover where we do not show the control surfaces. Those details are really not available. I would suggest you please go to the internet or in the book of Peery, in the book of Bruhn, in the book of Megson there are figures. We cannot reproduce directly those figures.

So this is the kind of CAD drawing. This is a CAD drawing of ideological CAD drawing, drawing which I am showing you as a representation. For more detail, I would suggest please refer those books as I mentioned. There are few photographs in the new edition. In the book of Peery you will find lot of photographs, in the book of Bruhn also you will find lot of photographs, in the book of Megson also you will find lot of photographs.

Not only that now internet is very open and there you may get many photographs and details of the structural construction.

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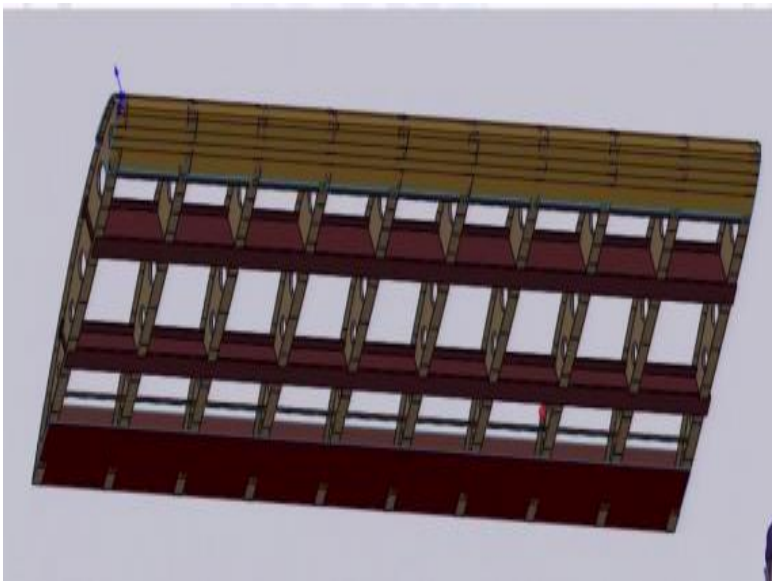

This is a different view from bottom. These are the rib construction. Skin is supposed to be put. Skin is removed here, we see the internal. Again let me mention this is an ideal construction, this is not exactly the way it is followed. We will see some more detail later how the fabrication is done.

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If we look at the references, this content is covered from some portion from Wikipedia, some portion from the Applied Elasticity by Chi-teh Wang, by Donaldson, book by Bruhn, book by Rivello, book by Megson and Peery Azar that book.

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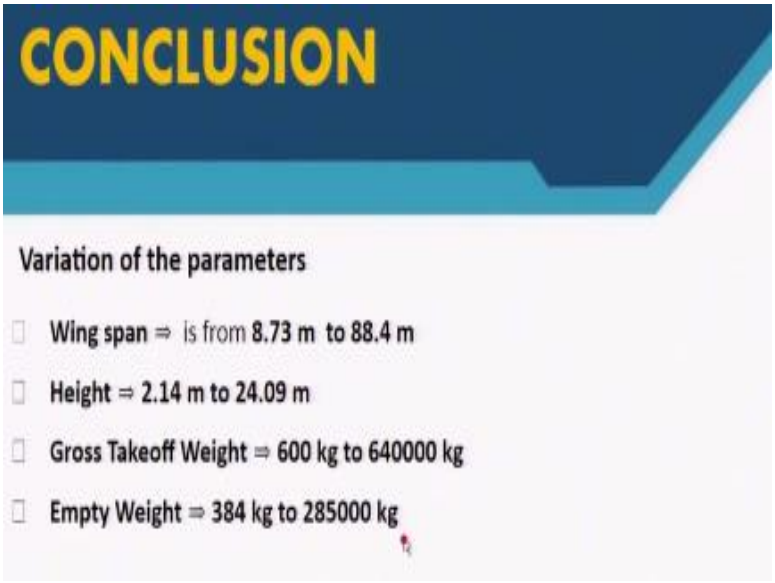

So what we have learned today is that it is to notice that there is a huge variation of the size of the structure what we are going to design, we are going to fabricate, we are going to understand, we are going to make. So in that the wing span whatever the aircraft we have discussed there it ranges from an aircraft which fits in our classroom to an aircraft which is probably as wide as a football field. So it is about 10 times probably.

So please keep in mind that it depends on how it is being operated on that the load is dependant, which it is supposed to carry and how it is supposed to carry on that the load is

dependant and on that load we are supposed to design the structure. Height is predominantly governed from the other requirements with a narrow bodied or wide bodied, it depends also on the aerodynamic considerations.

They sometimes govern decide what should be the size and how the cross-section should look like and depending upon that we try to fabricate, but point to note again that it is the approximate diameter we say, we cannot say diameter because in none of the case what we have discussed it is the section is circular, but again we say diameter because if we approximate to a circular it is the diameter of say 2.2 meter to 24 meter. So this is really huge, huge variation is there.

Depending upon the load we are carrying, we need to find out, we need to fabricate those section, find out the dimensions of those section. Gross takeoff weight varies from as I told you 600 kg may be equal to a big motorbike to something which is not imaginable at all 640,000 kg and empty weight varies from 384 to 285,000 kg. So with this, better we conclude today's lecture keeping in mind that the structure what we are going to design.

Structure what we are going to analyze is not a small one, it is huge structure. So it is as big as a football field. So if we learn the process to design the small one, we will definitely be able to design bigger one also. So with this note, let us conclude today's lecture. We will come back with the next phase of lecture again. Thank you.