Transportation Engineering – II
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Lecture - 32
Runway Length

Dear students, I welcome you back to the lecture series on course material of Transportation Engineering – II. From the previous some of lectures, we have started with the airport engineering part and we have already discussed some of the important factors or aspects related to airport engineering. This covers not only the site selection or the size of the airport, but also the obstructions and the flight rules. We have also looked at that how we can fix up the orientation of the runway and what may be the different type of configurations of runways and how they create an effect in terms of the capacity which can be handled by any of the airport.

In continuation of the runway design, in today's lecture we will be looking at the runway length.

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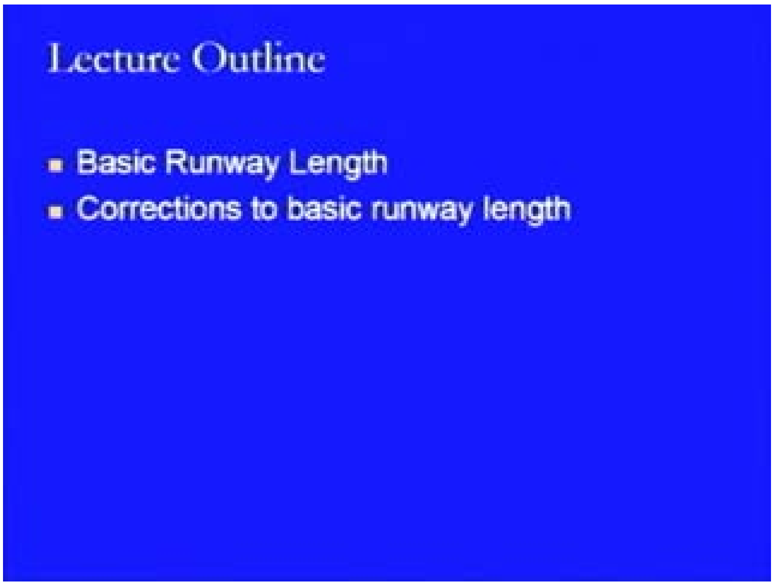

In this lecture, it is being outlined in two parts that is the basic runway length and the corrections to basic runway length. We will be starting with the first one that is the basic runway length and we will try to look at the various factors which create its effect on basic runway length.

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In the case of basic runway length, the length is calculated under the following conditions or by making the assumptions like, there is no wind blowing on the runway. This is the very first assumption, so as to take into consideration the effect of the wind, because if there is no wind, then whatever the stopping distance is required on the runway will be the normal stopping distance. But, if the wind is there and that is from the head side, then obviously it is going to reduce it, whereas if it is from the tail end side, then it will increase the length of the runway. So, the assumption here is that there is no wind and in that condition, we will try to compute the value of runway and then make corrections related to it.

Then, another assumption is that the aircraft is loaded with full loading capacity. This is another assumption, because it has its effect not only on the speed with which the aircraft will be moving with respect to the propulsive power which is being provided on that aircraft, but at the same time it will also be having its effect on the thickness of the pavement being provided. Another assumption is that the airport is provided at the sea level, because at the sea level, the meteorological conditions are at their standard. So, with respect to those standard values, then whatever variations are there we will be considering those variations by calculating the length of the runway strip, so this is another assumption and no wind is blowing on the way to the destination is another thing, so that we know that at what particular point the aircrafts will be landing or how they have to take-off. So, this is another aspect which is taken into consideration.

Then, another is related to the terrain or related to the topography. That is the runway is levelled and it is provided with zero effective gradient. We will be looking at what this effective gradient is in the due course of time, but this is one assumption. Then, the standard temperature is 15 degrees centigrade at the airport. This is the temperature which is taken with respect to the sea level. So, that is why, when we are assuming if the airport is at the sea level, then the standard temperature is being taken with respect to that and it is 15 degrees centigrade and the standard temperature exists along the way that is along the pathway also. This is another assumption.

So, based on these assumptions, then we try to calculate the length of the runway and if there is any variation from these assumptions, then a correction have to be provided, so that the length of the runway can be increased or decreased accordingly. So, these are the things which otherwise will also be creating an effect on the length of the runway and its computation and that is what we will be looking at, when we will go to the computation of the runway length based on different correction factors.

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Now, in this case, when we look at the various factors which are going to create its effect on the runway length, then they can be categorized under the three broad heading. The headings may be or the major factors may be aircraft characteristics, the safety requirements and the airport environment. Now, we will be discussing about the various aspects related to these broad categories of the factors.

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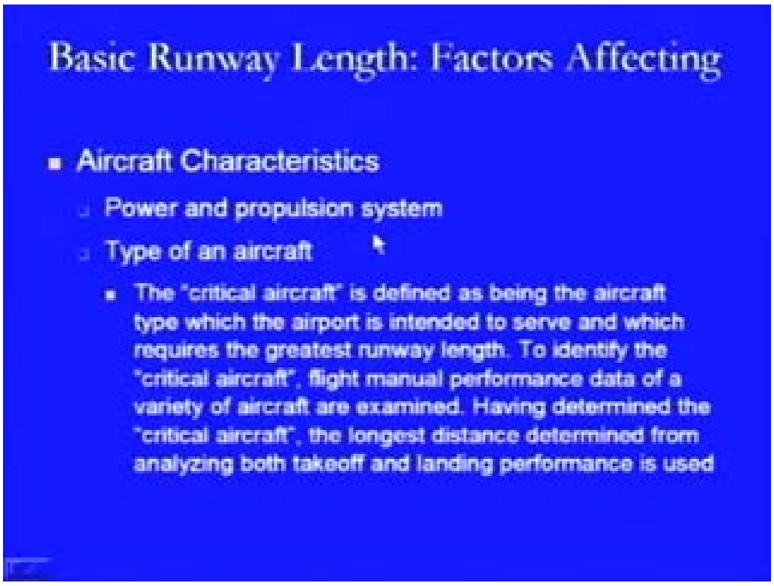

In the case aircraft characteristics, the very first thing which is going to create an effect is the power and the prolusion system. Now, as we have seen that in the case of an aircraft which is landing or which is taking off, the power is one of the important aspects which create its effect or the propulsion system which is being provided is the one which finally gets transformed into the power. So, here what we are understanding is that if the power is more, then the aircraft requires a longer length so as to stop, because it has, there is a certain rate of de-acceleration and with that rate of de-acceleration, the vehicle or the aircraft will be going to stop.

Similarly, when there is a take-off condition, in the case of take-off condition if the power is more, then the lift can be generated early and therefore, it can move into the air much earlier, but then at the same time, if the load is more, then it takes a little more distance. Whereas, in the case of smaller aircrafts, we have to see that in this case the length of the runway strip which is required because of the propulsion system or because of the power which is much lesser as compared to the bigger aircrafts that length of the runway may be also lesser. So, we have to look at that what are the effects of the power which is being provided on any of the aircraft and then with respect to that the length of the runway is to be examined.

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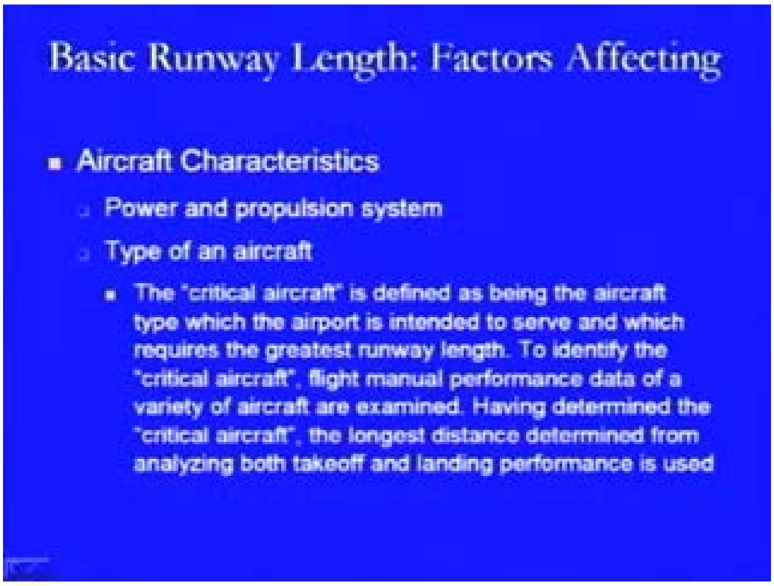

Now, another effect is the type of an aircraft. Now, in this case, when we are talking about the type of the aircraft there is one technical word, technical notation which is used and that is critical aircraft. The critical aircraft is defined as being the aircraft type which the airport is intended to serve and which requires the greatest runway length. So, this is what is the definition of the critical aircraft and the definition itself tries to define that we have to look at that particular aircraft which requires the maximum length and obviously, in the case of the propulsive power or in the case of the power which is available with the aircraft, it comes out to be the biggest type of the aircraft which will be using that airport.

So as to identify this critical aircraft, what we do is that we have flight manual performance data of the variety of aircrafts are examined and this is the one type of data which we have already seen, when we tried to see the characteristics of aircrafts and then, we have compared the characteristics of different types of the aircrafts, like the air buses, different categories of airbuses, similarly the Boeing’s and there we have seen that the performances data is related to the weight characteristics, to the fuel characteristics, to the range, to the seating capacity, to the total load which can be taken up, to the structural loading condition in terms of take-offs or in terms of landings or the fuel, etc. So, on the basis of that, then we can examine that which is going to be the critical aircraft that is the one aircraft which requires the greatest runway length.

Now, having determined this critical aircraft, the longest distance is determined from analysing both take-off and landing performance. So, that is the thing like we have to analyse both of the conditions. If the aircraft is landing, then how much length is required and if the aircraft is taking off, then in that case what is the length required. Now, out of these two lengths which have been computed, the maximum required will be taken up as the length of the runway. Therefore, this is another important thing which is to be done so as to identify, so as to compute the length of the runway as far as the aircraft characteristics is concerned.

Then, within the aircraft characteristics, another important thing is the gross take-off and landing weights of aircraft.

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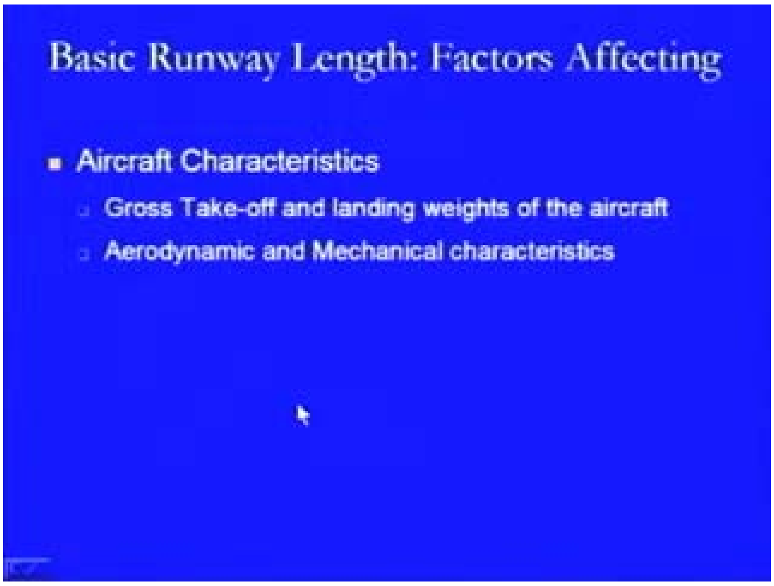

Now, these gross take-off or gross landing weight of the aircraft has its effect at the time when the aircraft is taking off or it is landing, respectively. Now, in this case what happens is that, if there is a heavy take-off load, then obviously the aircraft will require more of the power and so as to get more of this power, it has to run more distance and by running that particular more distance, it will be reaching that velocity at which there will be a possibility of attaining the lift or the lift becomes more than the weight, which is otherwise acting in the downward direction. So, if that condition is achieved, then only the aircraft will be going into air. So, that is the effect of the take-off load for the aircraft and in case of runway length, there will be more length required if there is a higher take-off gross weight.

In the case of the landing weight, this is another condition, where we are looking at the effect of this weight where it acts again in the downward direction, but then due to the effect of this weight, what we can see is that again that there will be a change in the length of the runway strip, because of the velocity with which it will be moving.

Another characteristic of the aircraft which can create its effect is the two types of the things one is the structure which is being provided another one is the mechanical characteristics which have been provided within that aircraft. Now, in the case of their structure, if it has aerodynamic structure, then obviously the frictions are lesser and then, the effect of the resistance being offered by the air mask in the front direction will become lesser. So, in that case, it will be going to move more distance as compared to another condition where the structure is not aerodynamic and it is a blunt sort of a situation.

Similarly, in the case of mechanical characteristics, we have to look at the various types of the mechanical components and their effects. It may be in terms of, say the landing system being provided at a time of the landing that is the wheel bases and the way these wheel bases moves in or moves out of the structure of an aircraft. So, that is one thing which is being governed by the velocity with which it is going to touch the ground at the time of the landing. So, that particular system should be supportive enough without having any failure at the time of the landing.

So, because at the time of landing the speeds are so high that it creates a very heavy thermal stress condition. So, due to that thermal stress or due to that energy which is getting dissipated at the point of contact of the aircraft with the pavement surface, these mechanical devices may get damaged and that is where we have to look at these different types of systems.

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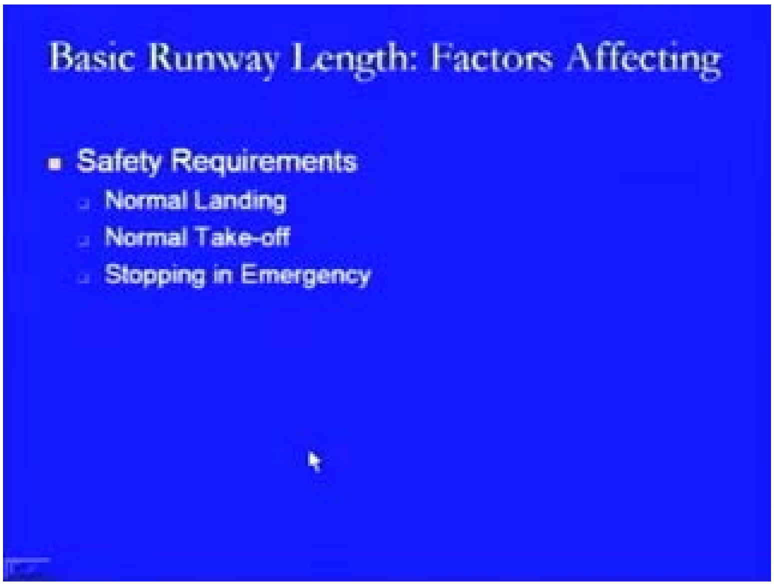

Then, apart from the characteristics of the aircraft, another requirement is maintaining the safety. Now, in this case, when we are trying to maintain the safety, then we have to look again at the two conditions that is the aircraft may take-off or the aircraft maybe landing. Apart from these two conditions, another condition is the emergency condition where the aircraft while taking-off found that there is a snag in the aircraft and therefore, the aircraft has to be stopped or it has started taking off and then, it is being observed that there is some problem on the aircraft, maybe there is a problem with the engine or there is some malfunctioning of any of the equipment on board of the aircraft, then the aircraft has to return.

So, in those two conditions, then we require certain length and we have to look at that whether there is a requirement of increasing the length or if it is so, how far, by how much value that is to be done. So, therefore the three conditions needs to be examined - for the normal landing condition, for the normal take-off condition and for stopping under emergency conditions.

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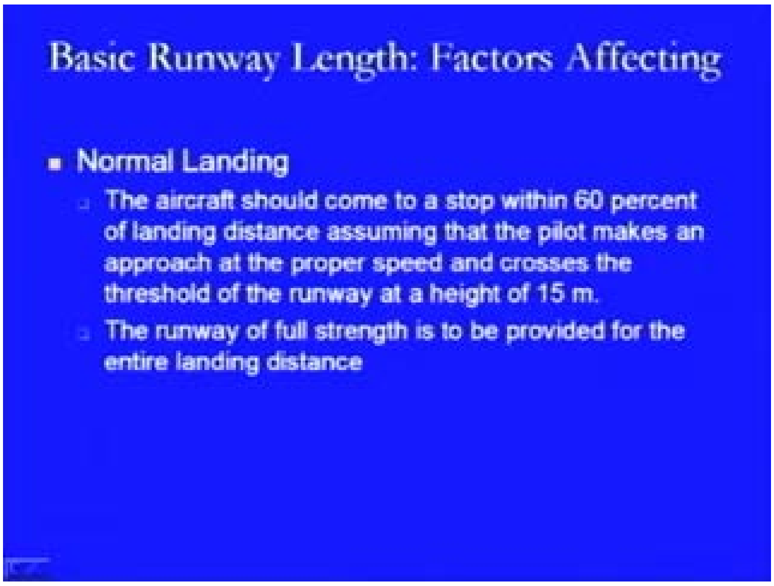

Now, in the case of normal landing condition, the aircraft should come to a stop within 60% of the landing distance assuming that the pilot makes an approach at the proper speed and crosses the threshold of the runway at a height of 15 metres. So, there is an assumption being made that the pilot knows what to do and what the pilot is supposed to do is that if the pilot has to cross …. aircraft, the threshold of the runway that is the end of the runway at a height of 15 metres, so that should be the height of the aircraft and then, there is a certain speed at which it has to cross and approach the landing strip. So, that is being done.

Then, in that case, the aircraft is going to stop within 60% of the overall landing distance to be provided otherwise and in this case, because the landing is being done with complete loading, therefore the pavement is to be provided with the full strength on the entire length of the landing runway strip. So, that is the way how we try to compute the value of the runway length in the case of the normal landing condition.

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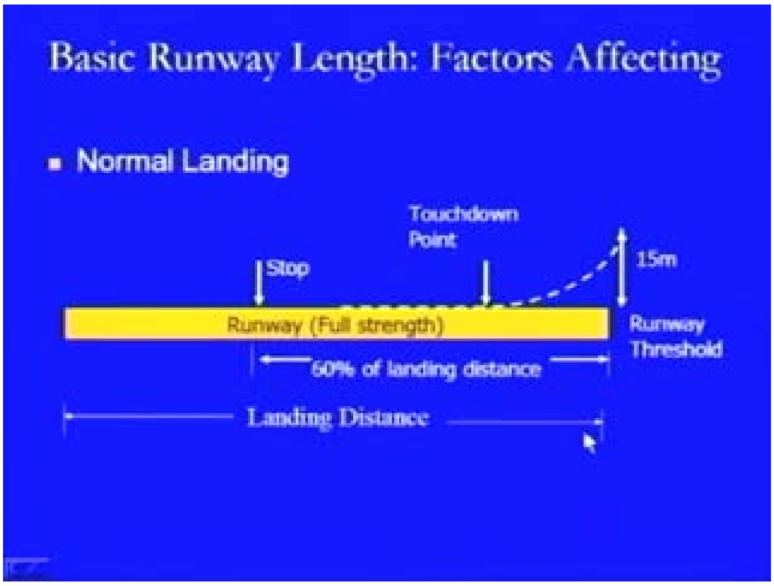

Now, we will try to look at the same aspect in this figure. This is the runway strip being provided and this is somewhere here is the runway threshold. In the case of the marking, this threshold will be at some distance away from the end of the runway strip, but just we assume in this diagram that suppose the threshold is somewhere here, then the aircraft has to come at this threshold and cross the threshold at a height of 15 metres and then, it will be coming down and will be touching this runway strip at some point and that point is known as touchdown point and that is also generally defined by crossing up to this value, then at what distance the aircraft should touchdown and then, after that it will start reducing the speed, initially by using the flaps and then slowly and slowly, it will come to a very lesser value and it is going to get stopped at this location.

So, if this is the condition, then this is, this particular distance being moved from this end to the stopping point, this is termed as 60% of the landing distance. So, in that case, this is going to be the overall landing distance and this overall strip of the runway which is used for landing is to be provided in complete full strength, means it should be able to take up from this point to this point the load which is designated for any of the big aircraft at the time of landing.

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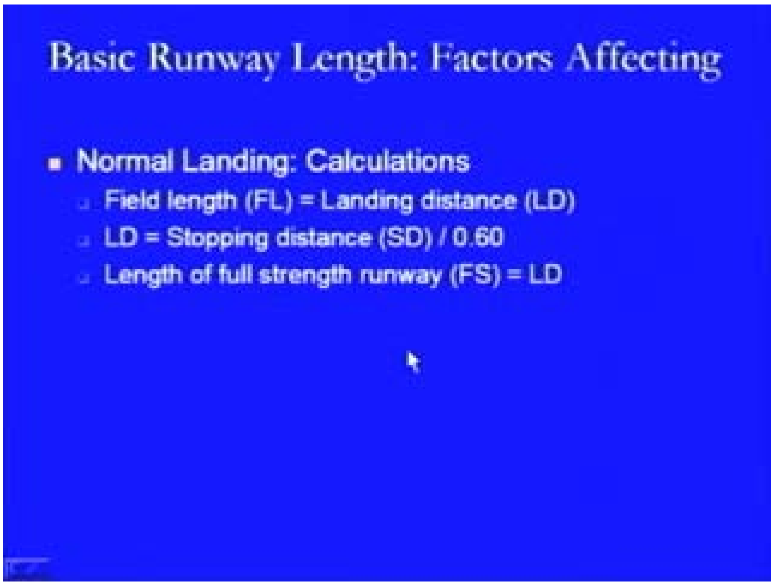

Therefore, the field length as we try to calculate the length of the runway strip is that the field length will be nothing but the landing distance LD that is we are talking about this landing distance. Landing distance is this LD, so the field length will be the same as that one and this landing distance is stopping distance divided by 0.60, because this is 60% and another thing as we have discussed is that, the length of the full strength runway will remain the same as equals to the landing distance that is LD.

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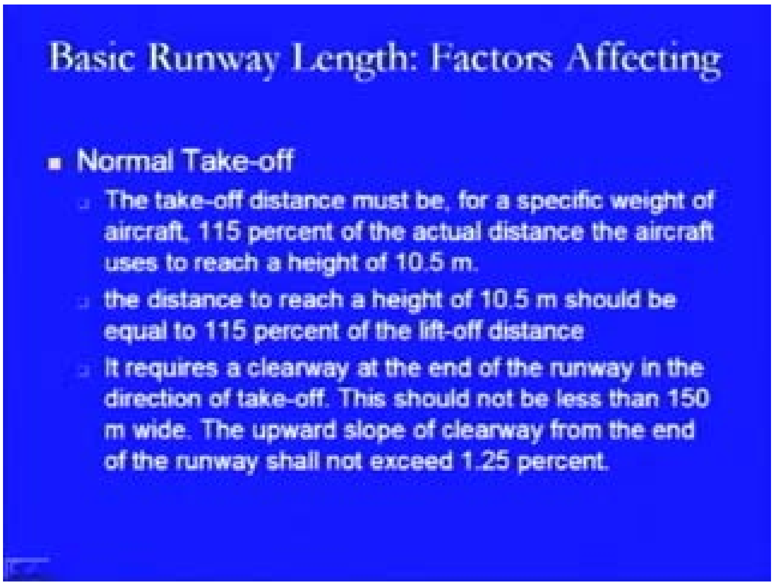

Now, we will look at another condition that is normal take-off condition. In the case of normal take-off condition, the take-off distance must be for a specific weight of the aircraft. 115% of the actual distance the aircraft uses to reach a height of 10.5 metres that is how it tries to define the requirement of the length. Here, what it says is that when the aircraft is taking off, then it should attain a height of 10.5 metres and whatever is the distance being moved, so as to attain the height of 10.5 metres, the length of the runway strip should be 115% of that actual distance and the distance to reach a height of this 10.5 metres should be equal to 115% of the lift off distance and it requires a clearway at the end of the runway in the direction of take-off, because we are moving away from the runway strip and therefore, in this case, if there is an emergency or the aircraft is not being able to take up this distance just at the end of the runway strip, then this clearway will help in the form that it will maintain the safety. That is why this clearway has to be provided in that direction where the take-off is going on. But, in the direction where the landing is going on, there is no need of providing these clearways and this should not be less than 150 metre wide. The upper slope of the clearway from the end of the runway shall not exceed 1.25%. That is the sort of the specification which is required for any clearway being provided.

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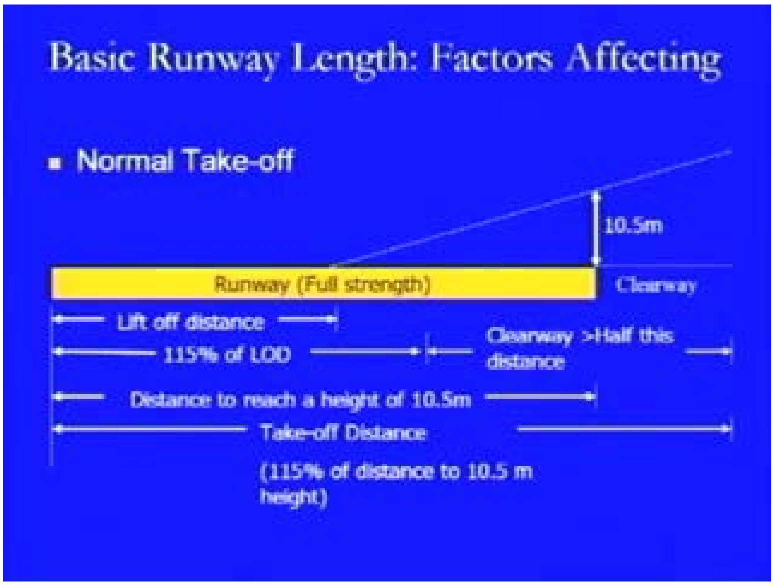

Now, this is a diagram which tries to depict the same condition that the aircraft is starting from this direction and then it is starting moving in this direction and then, at this particular point it just moves into the air. So, that is the, this is the point after moving this much distance it attains the lift and it is moving like this and it should be able to take a height of 10.5 metres at the end and here the clearway is being provided after the end of the runway strip. So, here this distance up to which it has moved on the ground is known as lift off distance. That is the distance after which there is a lift. Then, 100% of this, 115% of this lift off distance is supposed to come to this particular position and this is the distance which is to be moved, so as to attain a height of 10.5 metres as being shown here.

Then, the take-off distance is going to be the 115% of the distance which is required to move a height of 10.5 metres. That is if this is 10.5 metres, then the take-off distance is going to be 115% of that. So, we come up to this value. Then, from this value we go back in terms of the, this length of the clearway which is again being specified and the distance between this 115% of the lift off distance that is this point and this point being provided, this is the clearway distance, this should be half of this distance. So, this clearway should be half of this total distance. So, that is how we try to fix up the various distances in this normal take-off condition and we compute the value of the runway strip.

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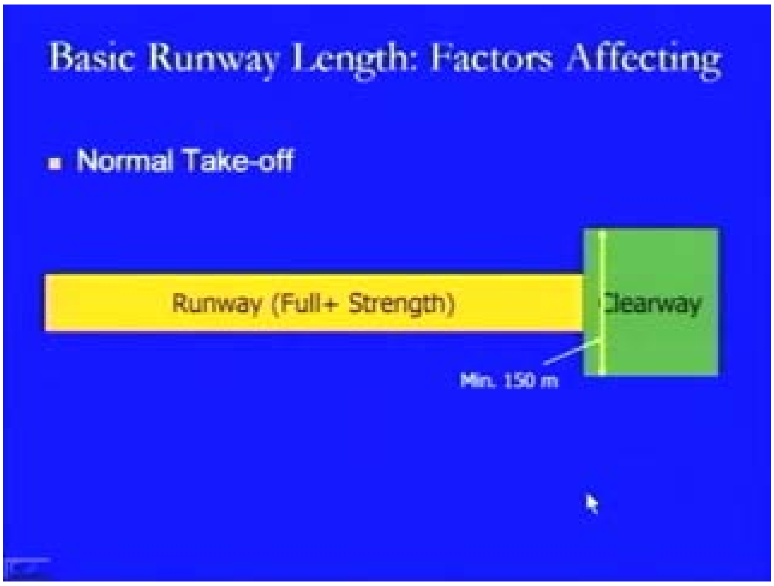

So, this is how it will look like in the plan, where this is runway strip and at the end of runway strip a clearway is being provided, where the minimum width of this clearway is 150 metres on this side and this runway strip is to be provided with full strength, means the thickness of the pavement from the start to the end should be the same, it should not differ.

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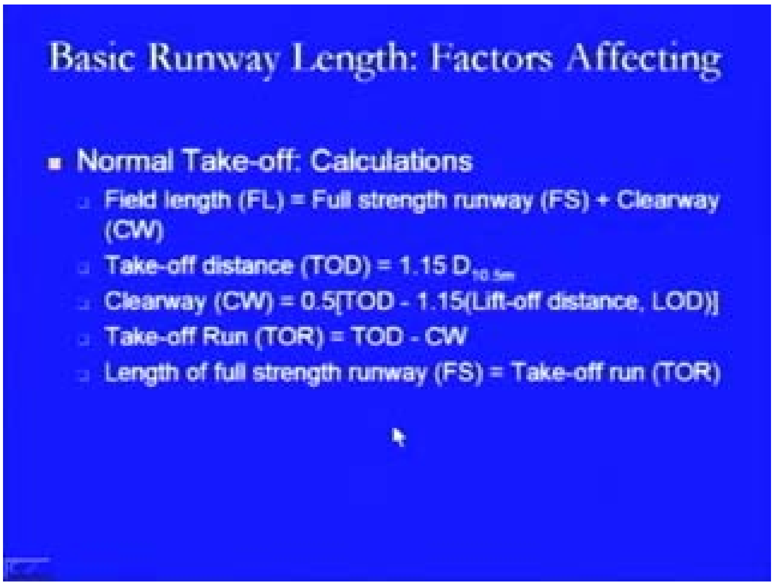

Now, as far as the calculations are concerned, here the field length will be the full strength runway plus clearway that is what is the total length of the strip and we have the take-off distance will be 1.15 times the distance required for gaining a height of 10.5 metres and the clearway will be half of the take-off distance minus 1.15 times of the lift off distance that is the LOD, whereas the take-off run, it will be the take-off distance minus the clearway length and the length of the full strength runway is going to be again the same equal to the take-off run. So, that is how the various values can be computed for normal take-off condition.

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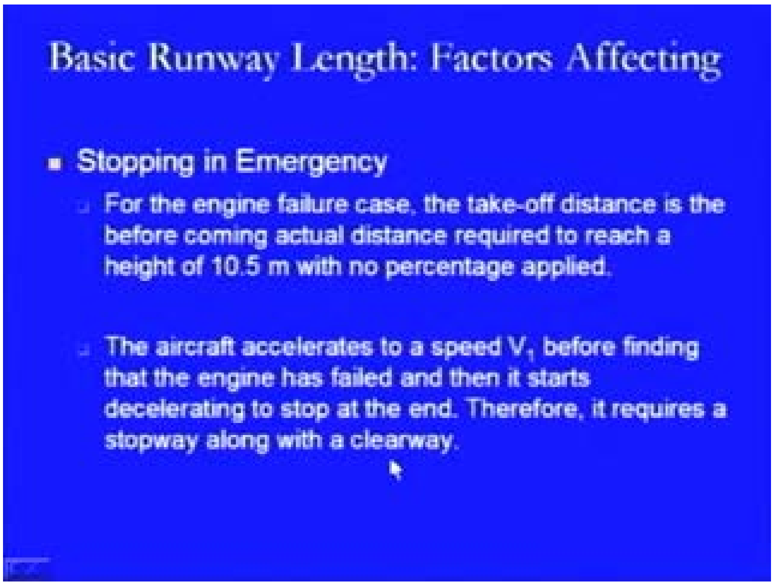

Then, another condition is the stopping in emergency. Now, what happens in this case is that, there may be an engine failure case and in this engine failure case, the take-off distance is before coming actual distance required to reach a height of 10.5 metres with no percentage applied in this case. What happens is that the aircraft is trying to attain the speed and while trying to attain the speed means it is taking accelerating. Now, after some distance, it is being moved. The pilot observes that there is some problem on the aircraft and therefore, the aircraft has to be stopped. It means after that point it will start de-accelerating and once it starts de-accelerating, then it will be requiring some distance, so as to stop the aircraft.

Another case is that, when the engine failure condition is there and it has started taking off and then it is reaching a height of 10.5 metre, then here without applying to any percentages we have to find out in the actual condition what is the overall length which needs to be provided, so as to stop the vehicle without creating any problem for the safety concerns. Now, the aircraft accelerates to a speed to V 1 before finding that the engine has failed and then, it starts de-accelerating to a stop at the end. Therefore, it requires a stop way along with the clearway. So, that is a requirement of another type of facility, another type of construction which is to be provided at the end of the runway strip in the direction of taking off.

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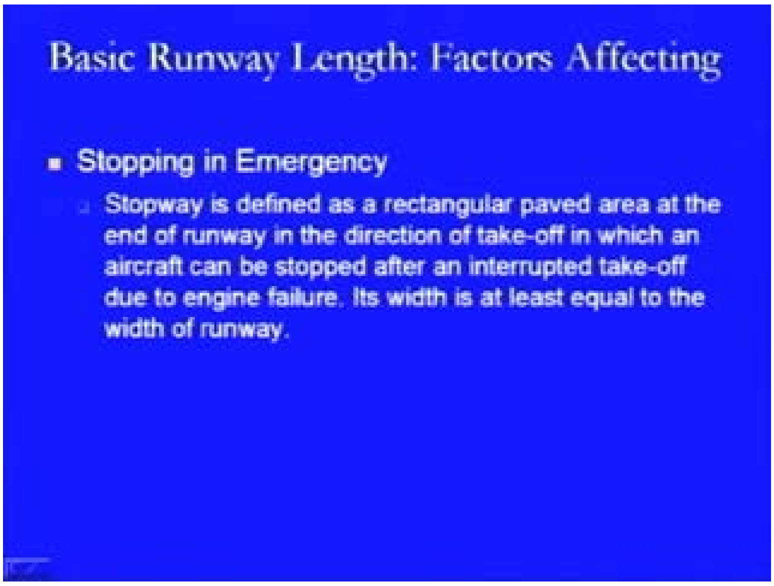

Now, this stop way is defined as a rectangular paved area at the end of the runway in the direction of take-off in which an aircraft can be stopped after an interrupted take-off due to engine failure and its width is atleast equal to the width of the runway strip or it may be more than that.

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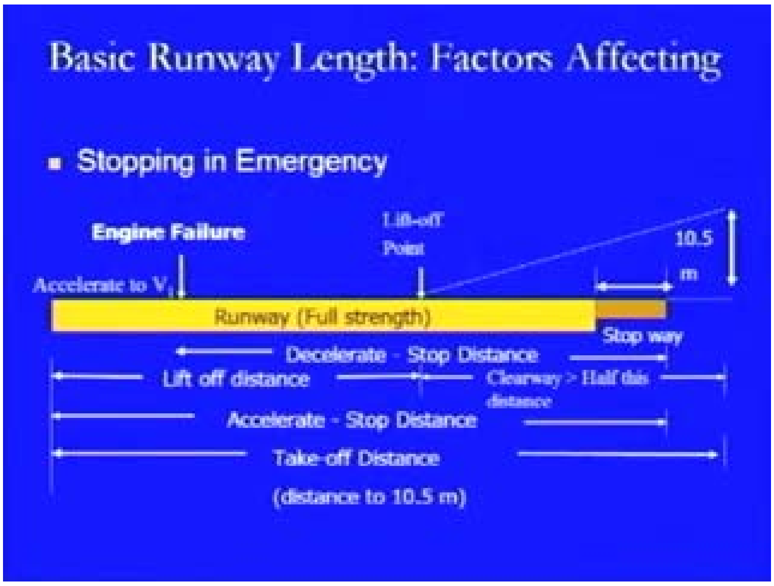

Now, this is a diagram which tries to show the same thing that the aircraft is starting from this location and then it starts accelerating. So, from zero value it is accelerating to a speed V 1 and at this point it is observed that there is a failure of engine.

Therefore, it starts de-accelerating and then, it will be going to stop. So, there is a de-acceleration stop distance to be provided and if we assume that it is going to stop by this point, then this is what is the de-accelerate stop distance which starts from this position and goes up to this point and this distance being more than the length of the runway strip we are providing a stop way at the end. In the normal condition, if the aircraft would have moved with the same rate of acceleration, then this is the point at which the aircraft would have got the lift off and then, in that case this was the flight path which the aircraft would have taken.

Now, here what we are looking at is that this take-off distance, now in this case is going to be related to a height of 10.5 metres, which is provided at some distance away and this some distance away is calculated on the basis of the length of the clearway and the distance being provided between the lift off point and the end as been done previously. So, we have the stop way and this stop way is within the clearway which comes up to this value. So, here we are having this height as 10.5 metres, so and this is accelerate. This is what is accelerate and the stop distance, so it comes up to this value.

On the basis of this lift off distance and on the basis of the take-off distance required for 10.5 metre height in this case, even if for that condition where even with the engine failure, the aircraft is going to take-off. Now, because at this particular point what happens is that as the pilot has observed that there is a failure of engine, the pilot will shift to the standby engine or if there is no requirement, then this engine will be shut off and the aircraft will be moving with the rest of the engines available on board. Therefore, there is some time being lost and due to that loss of time, this 10.5 metre, instead of having at the end of the runway strip will get displaced some distance away and that will be displaced by a distance equal to the length of the clearway.

That is why in the previous case when we have discussed about the normal take-off the 10.5 metre was here, but in this case it is at this location. Here also, this lift off point has moved away to this location, whereas in the previous case it was somewhere nearer to this end.

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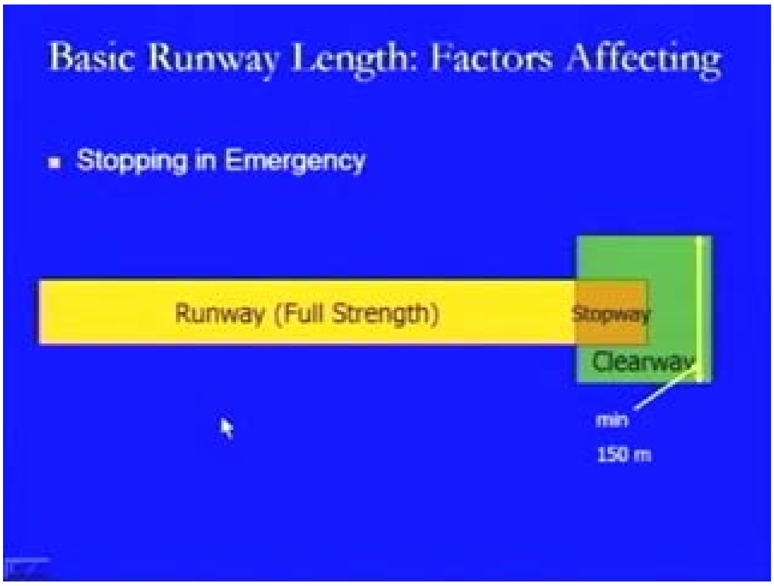

Now, this is how it looks like. This is the full strength runway strip and at the end of the runway strip a stop way is being provided and then, at the sides of this stop way and away from this one there is a clearway and this clearway again is having a minimum width of 150 meters. So, this stop way is also going to be a full strength condition.

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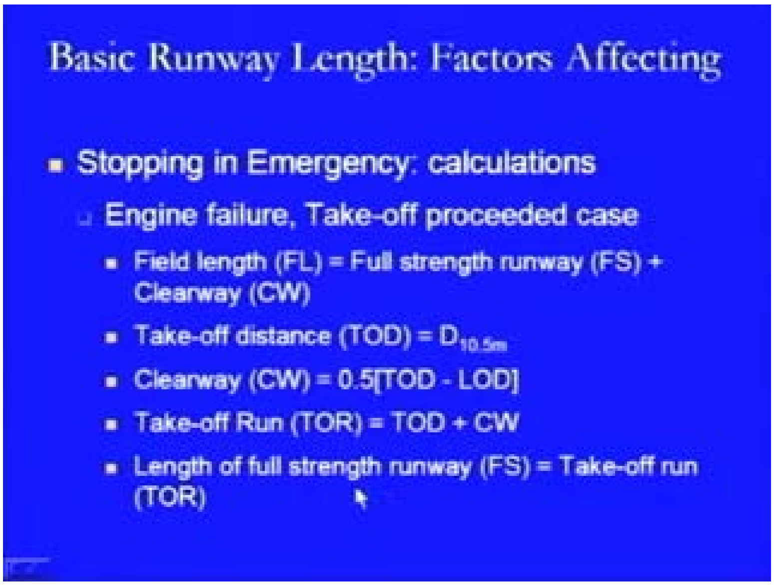

Now, here again these are the calculations. The engine failure take-off proceeded case field length is equal to full strength runway plus the clearway. Take-off distance will be equal to the distance required to attain a height of 10.5 metres, whereas here it will be half of the take-off distance minus the lift off distance, LOD and this take-off run is equal to the take-off distance plus the clearway, whereas the length of the full strength runway will be equal to the take-off run that is this particular distance.

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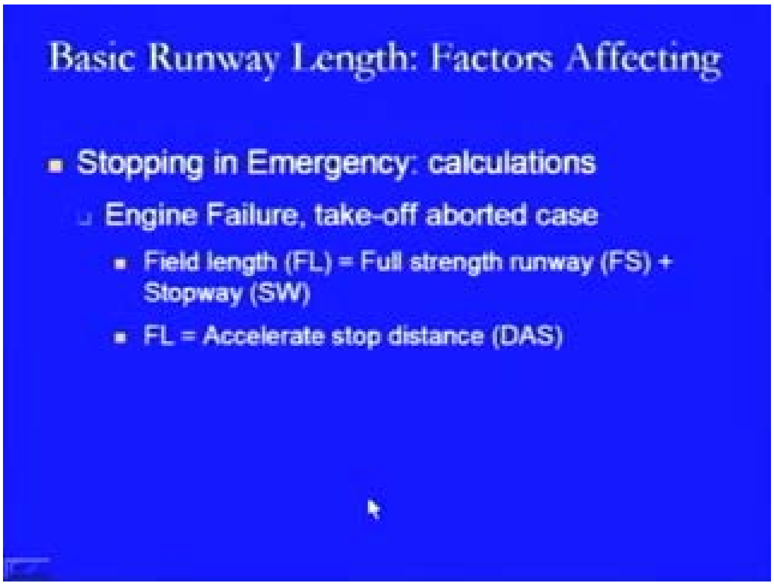

Another case is that there is an engine failure and the take-off is aborted means now we are not going to take-off. It has been decided to stop. Then in that case, the field length will be the full strength runway plus stop way. Instead of clearway, now it will be taken as stop way and this FL will be the accelerate stop distance that is for the full length condition, field length condition.

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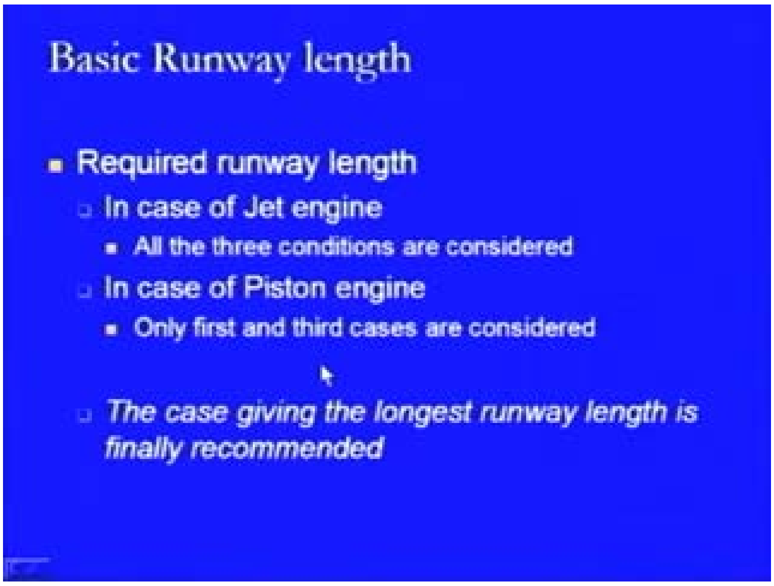

Now, another thing here which we are going to discuss is the effect of different types of the engines. If we are being provided with a jet engine or a piston engine, then we have to look at that which particular condition needs to be evaluated in these cases. Now, in the case of the jet engine, all the three conditions which we have discussed so far needs to be evaluated, whereas in the case of piston engine, only the first and the third case is evaluated, the second case of take-off is not evaluated. The case giving the longest runway length is finally recommended as the basic runway length.

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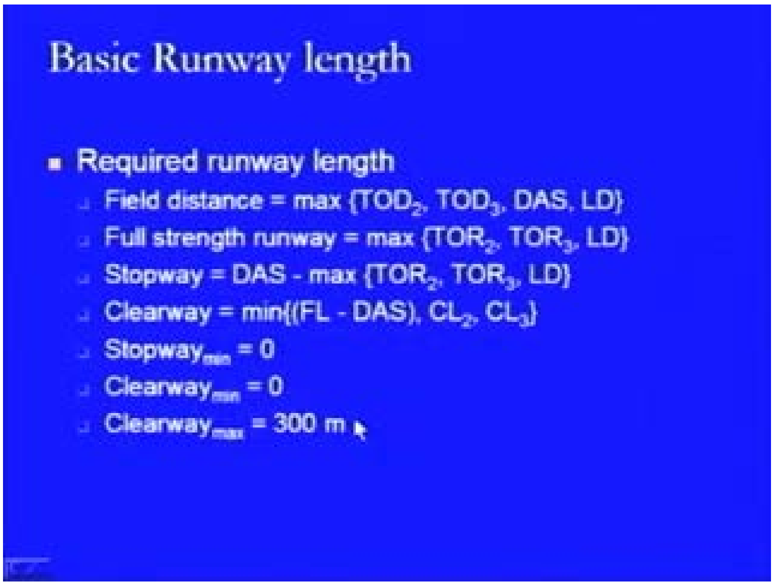

So, what we see is that the runway length required can be computed as the field distance is the maximum of the case of take-off distance in second case and third case and then, the various other values as being noted here. Similarly, the full strength runway can be the maximum of the three values. Then, stop way is computed as a difference between the values for acceleration and stopping and the maximum of the three values as computed previously, whereas similar clearway if going to be the minimum value out of the clearway length being computed in second and third case and the difference between the field length and the distance for accelerate and stopping condition. In this case, the stop way minimum will be zero, the clearway minimum will be zero, where the maximum clearway can be up to 300 metres.

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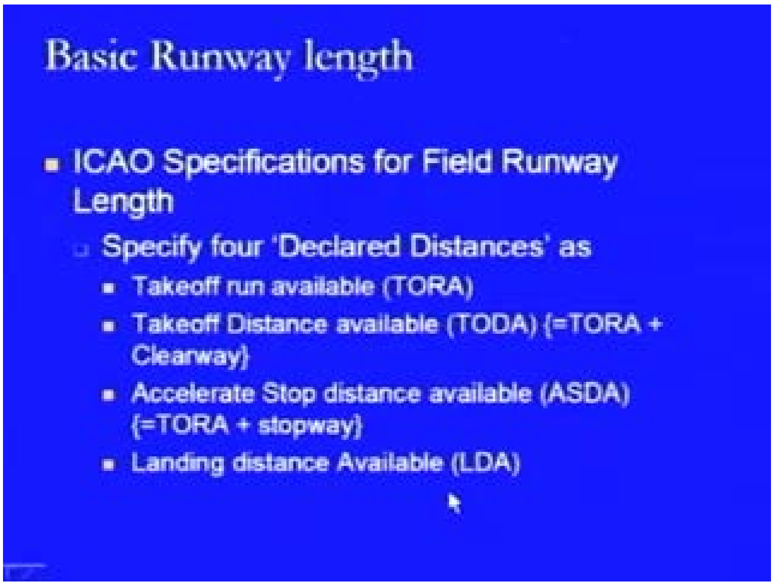

Now, we come to the ICAO specifications for field runway length and it specifies four declared distances as take-off run available known as TORA, take-off distance available that is TODA, which is TORA plus clearway that is take-off run available plus clearway, accelerate stop distance available that is ASDA, which is TORA plus stop way, TORA again for run available and landing distance available is termed as LDA.

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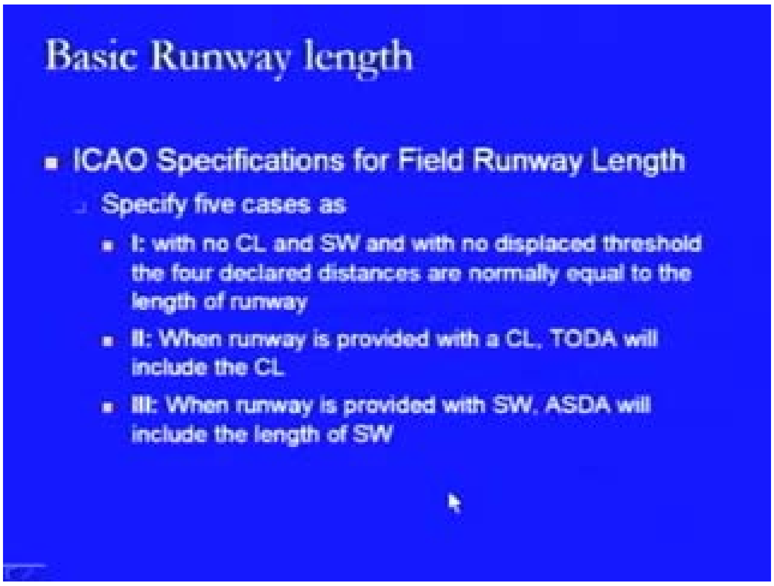

It also specifies five cases as, the first case is with no clear length and the stop way and with no displaced threshold, the four declared distances are normally equal to the length of the runway. In the second case, when the runway is provided with the clearway, then the take-off distance will be included, will include the clearway length and the third case is when the runway is provided with stop way, then ASDA will include the length of the stop way.

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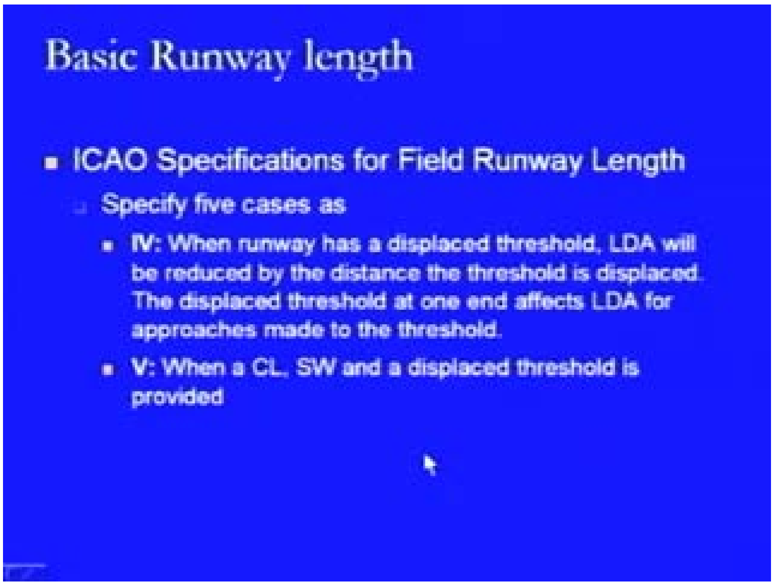

Then, the fourth case says that when the runway has a displaced threshold, then LDA will be reduced by the distance the threshold is displaced and the displaced threshold at one end will affect the LDA for approaches made to the threshold and the final case is that when the CL, SW and displaced threshold is provided, then we have to find out what is the length.

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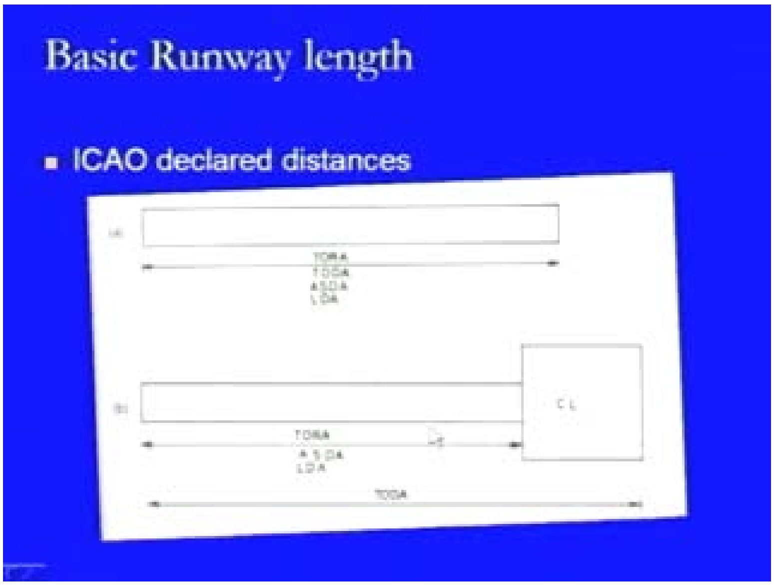

The same sort of the thing has been depicted here. Then, in this case that is a case one where it is talking about the take-off run available and take-off distance available and this is ASDA and LDA, lift off distance available, they all are same in the first case, where in the second case what we see is a clearway length has been provided at the end and therefore, take-off distance will be considering this clearway length also, whereas the take-off run available will be up to the end of the runway strip and start of the clearway length and this will also be equal to ASDA and LDA in this case.

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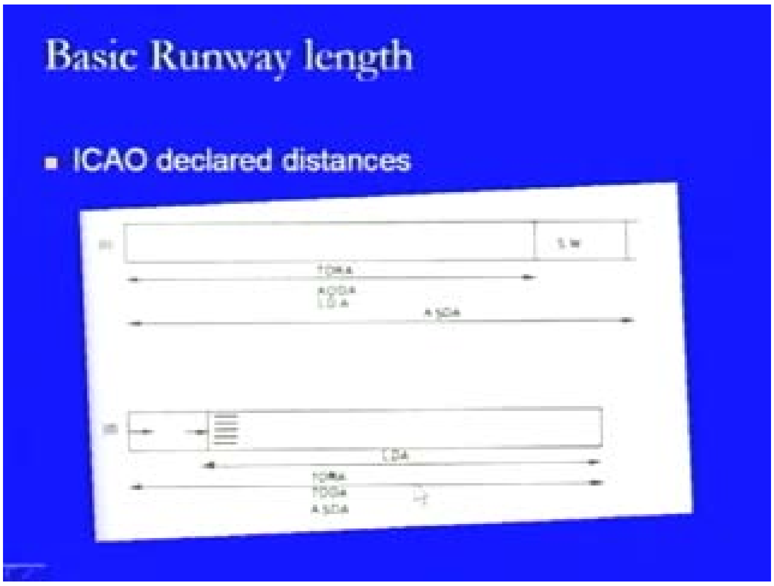

Then in the third case which we have discussed, here the stop way is being provided and this stop way means it is the ASDA, accelerating stopping distance available will be equal to this TORA plus the stop way and this TORA, the take-off run available, will be close to AOD and LDA. In the case of the fourth one which we just discussed, there is a displaced threshold being provided, means instead of starting from this point, this runway is assumed to start from this point and therefore, lift off distance available will be computed from this point onwards instead of this point onwards, whereas the take-off run available will be assumed from the initial location only and that is going to be again equivalent to TODA and ASDA.

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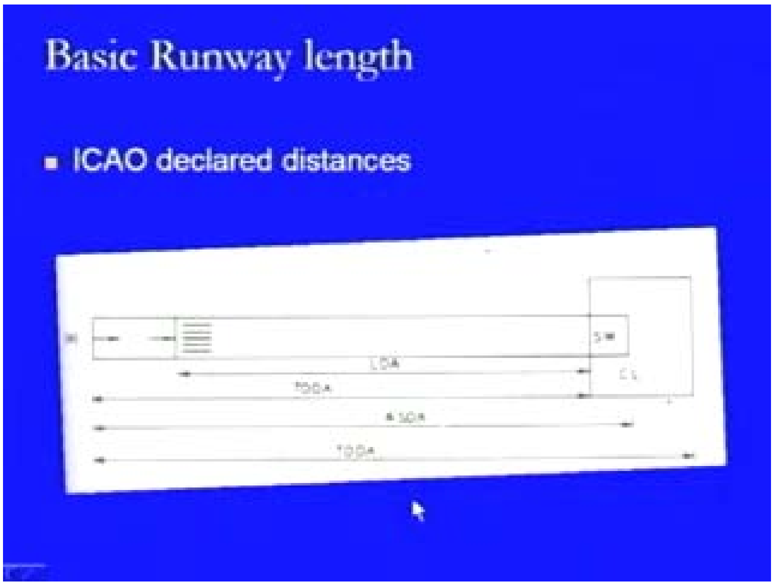

This is the final case which we have discussed along with the displace threshold and here in this case, the stop way is also provided and clearway is also being provided along with this and therefore the various distances will be, the lift off distance available will be calculated from the threshold distance up to the start of the stop way, whereas the take-off distance available will be the overall length of the runway strip and the accelerating stop distance available will be up to the centre point of the clearway being provided, whereas the take-off distance available in this case finally will be this final value also. So, this is how the ICAO declares the various types of the runway strips.

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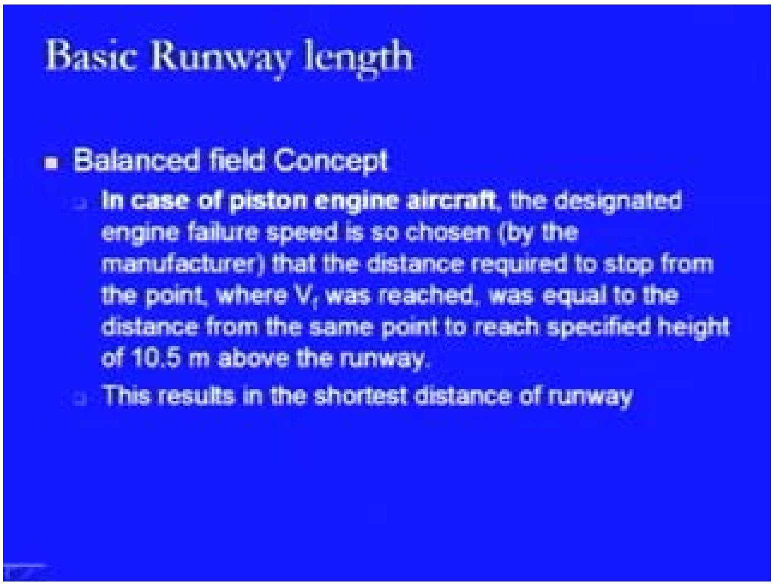

Now, another concept while finding out the runway length is the balanced field concept. In the case of this balanced field concept, in the case of a piston engine aircraft, the designated engine failure speed is so chosen by the manufacturer that the distance required to stop from the point where the V f was reached that is the failure speed was reached, final speed was reached was equal to the distance from the same point to reach a specified height of 10.5 metre above the runway.

That is the concept by which it is being defined that how we can compute or how we can find out this value of V f in the case there is an engine failure, means what it tries to say is that the distance which is being moved and at which the failure is being observed is going to be the … and then after that it is going to stop. They are going to be the same distance and equivalent to the half of the distance required to attain a height of 10.5 metre above the runway strip and in this case, the result is that, it provides the shortest distance of the runway.

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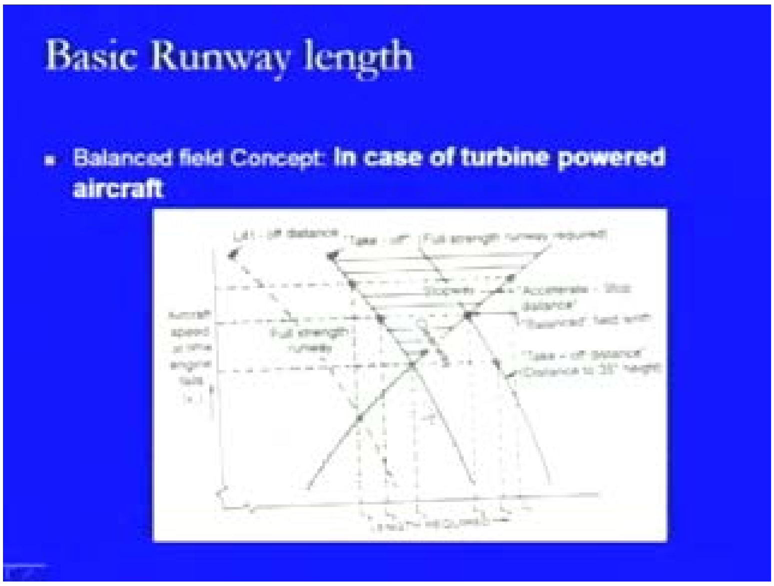

So, this is a diagram which is being provided for the turbine powered aircrafts which depicts the aircraft speeds at the time the engine fails and this is the length which is required of the runway strip and then it is dependent on various aspects like this graph shows the lift off distance at different speeds. So, we can find out the lift off distance at different speeds like if we are talking about this one, then this much is the length which is required so as to stop, so as to get a lift at this speed. So, this is how the things can be correlated, where this is the take-off full strength runway required condition. So, take-off distance can be computed with respect to this line and this is another graph which tries to define the take-off distance to attain a height of 10.5 metres. So that is another one and then there is this one.

This is defining, trying to define the accelerate stop distance and wherever this is cutting another one, that provides the balanced field length. So, this balanced field length, LD is basically required. So, there are different lengths which can be computed like the length LA, which is related to the take-off with full strength length, LB which is a condition equivalent to the balanced field condition, but at the take-off condition where there is a distance of stop way being provided and then LD is related to this curve, where this is a take-off distance curve being provided and this L e and L f they are the other two values on the same these two curves.

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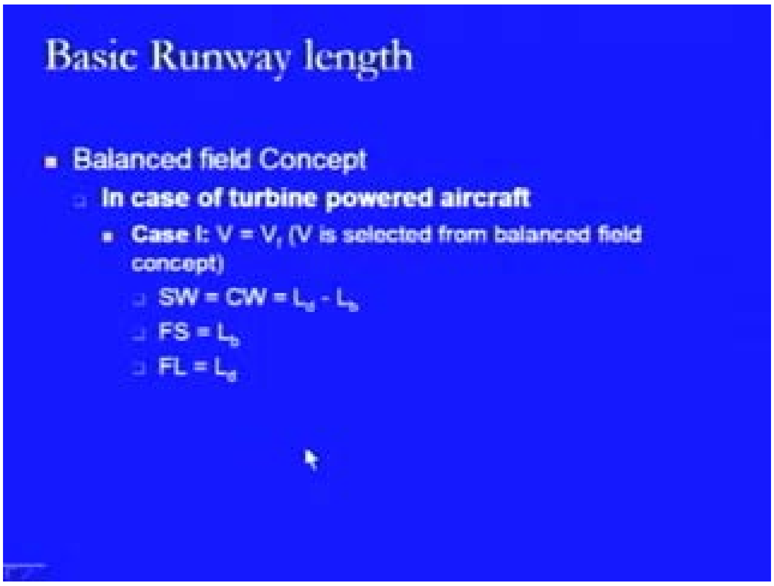

So, we have to look at, on the basis of this one the computations can be done and there is one case, where we assume that this velocity V is equivalent to the velocity V f and this velocity V f is dependent on this V, which is selected from the graph which we have seen just now and then on the basis of that, the length of the stop way or the clearway will be computed on the basis of the two values which we have found out that is L d minus L b and field length of the stop way and the complete field length will be computed as L b and L d respectively.

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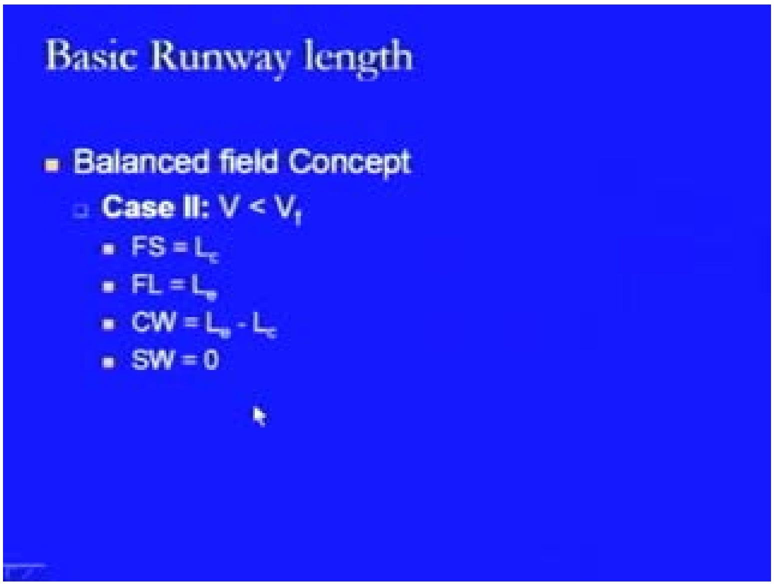

Whereas, there can be another case II, where the speed is less than the failure speed. In that case, the values of the full strength runway strip, the field length of the runway or the clearway or the stop way will be given as being shown here in terms of, as L c, L e or the difference between L e and L c respectively, whereas for stop way, it will be a zero value.

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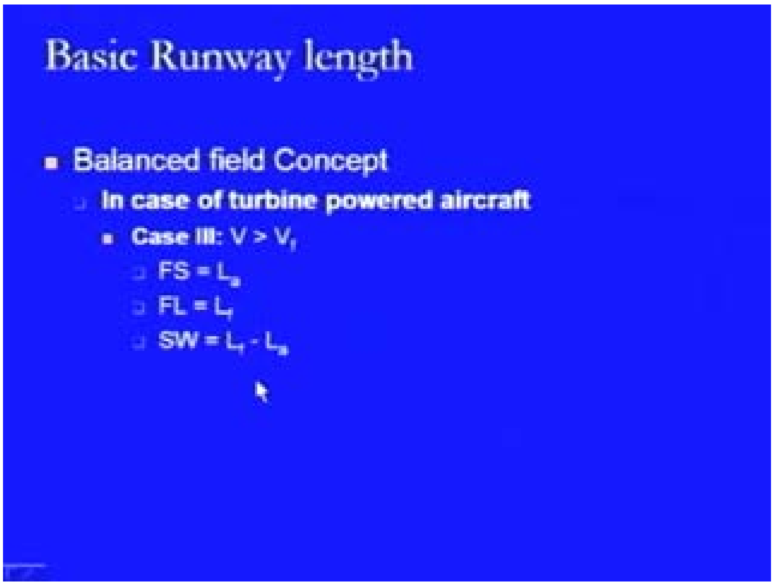

Now, in the case of the turbine powered aircraft, in the case III where this speed is greater than the failure speed, designated failure speed which can be there, then in that case, for this full strength one it is given by L a, whereas for the field length it is given by L f and for stop way it is given L f minus L a. So, because the speed is more here, therefore the stop way is to be provided and it is the part of the clearway.

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Now, we come to some of the other factors which are quite important, so as to find out the basic runway length and that is the airport environment. Airport environment comprises of atmosphere, where the temperature and surface wind is to be considered and the effect of this temperature and surface wind is to be taken into consideration. We will look at these things while we discuss further, whereas another thing is the location and condition of the runway, where it is to be considered in terms of two factors that is altitude and the runway gradient.

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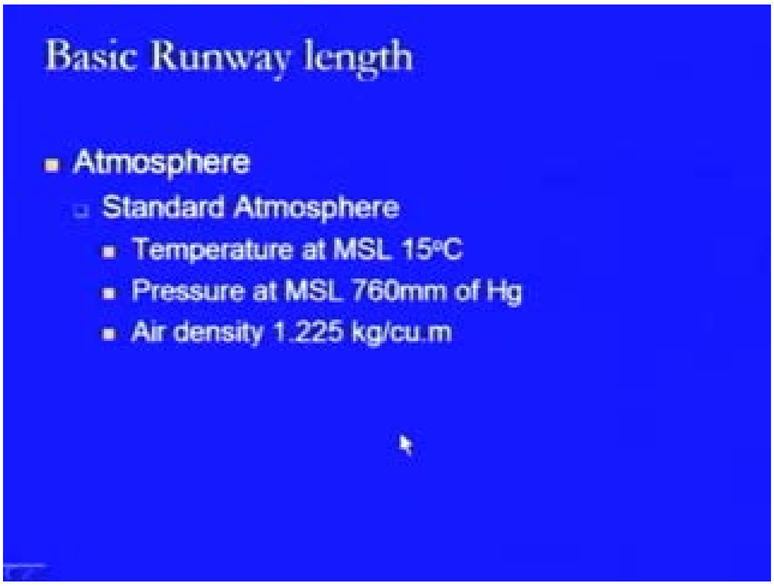

In the case of the atmosphere, the standard atmosphere is defined as the temperature at mean sea level of 15 degree centigrade, pressure at mean sea level as 760 mm of mercury, air density as 1.225 kg per cubic metre. So, if there is a variation with respect to these values, then the basic runway length has to be adjusted.

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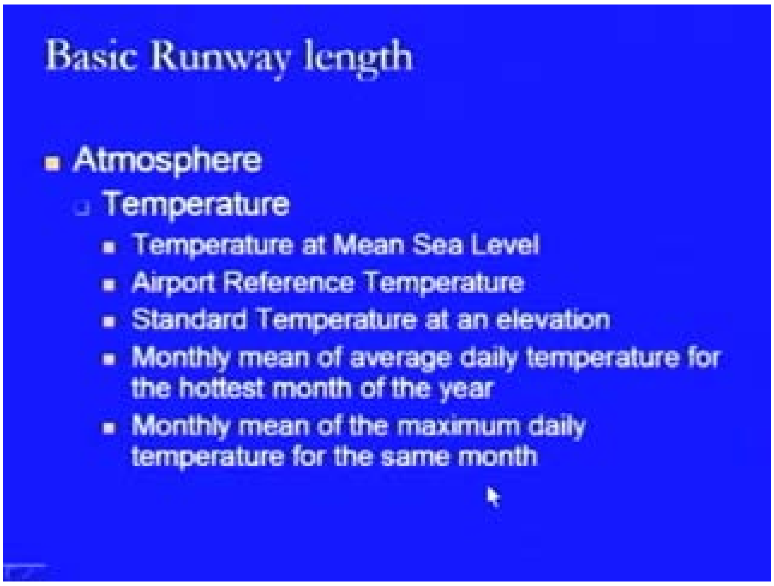

In the case of temperature, it is taken as the temperature at mean sea level. Then, there is another temperature which is to be computed that is termed as the airport reference temperature, which is dependent on the altitude with respect to the mean sea level. Then, there is a standard temperature at an elevation. So, we have to compute this one also and then there is a monthly mean of average daily temperature for the hottest month of the year. Whatever is the hottest month of the year we take the average of that and similarly, for the same month we also take the value of maximum daily temperature of the same month. So, that is the mean of …

The two type of the means have to be taken up - average and the maximum value of the hottest month. Now, these two values we will be using, so as to compute the value of airport reference temperature and the standard temperature with respect to elevation will also be computed.

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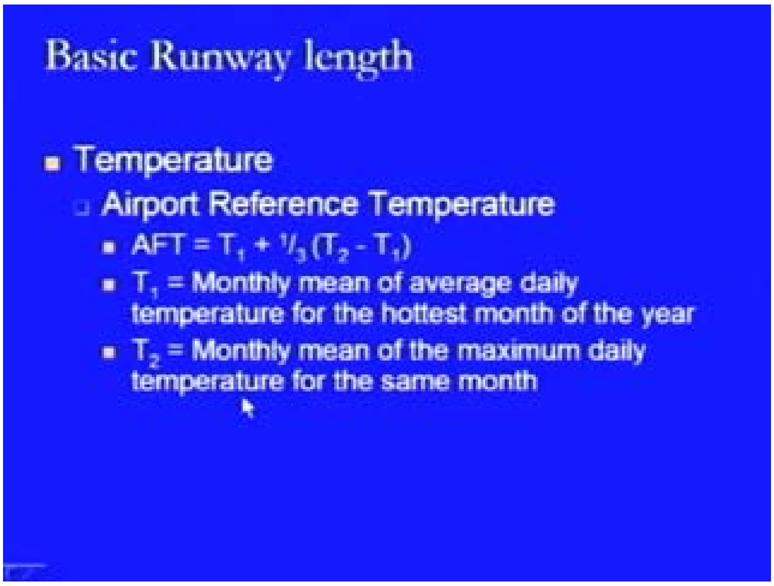

This is how we will be doing. Now, here in this case of the airport reference temperature that is AFT, it will be T 1 plus one third of the difference between T 2 and T 1, where T 2 and T 1 are what? They are, T 1 is monthly mean of average daily temperature for the hottest month of the year, whereas T 2 is the monthly mean of the maximum daily temperature of the same month. So, this is how we define the T 1 and T 2. So, we have got the mean values of average and mean value of the maximum and then we use them, so as to compute the value of AFT.

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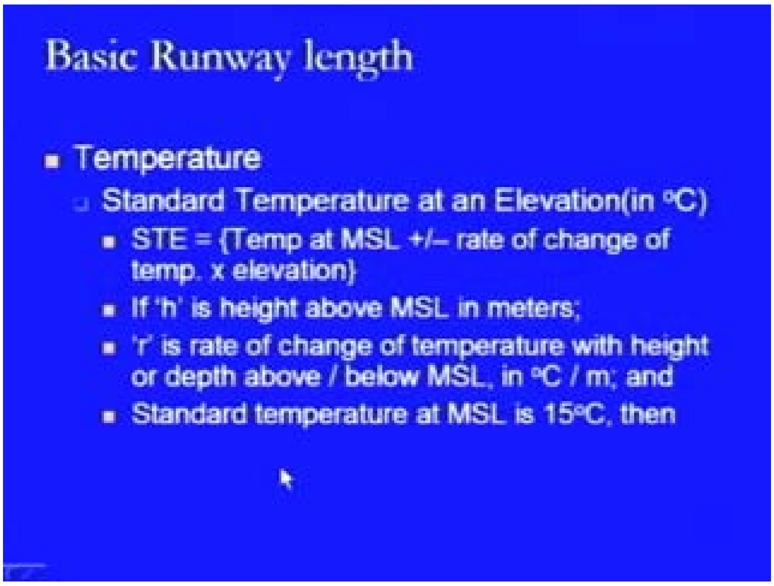

Similarly, this standard temperature at an elevation can be computed as temperature at mean sea level plus oblique minus the rate of change of temperature multiplied with elevation. So, we have to look at what particular rate as we go above mean sea level the temperature changes, whether it is increasing or it is decreasing. So, on the basis of that, we will be taking up plus or a minus value. So, temperature at mean sea level is 15 degree centigrade and whatever rate is being provided with respect to the height then it is multiplied with height will give us the standard temperature which will be available at the sight of the airport. So, here the r is the rate of change of temperature with height or depth above or below mean sea level and this is generally given as degree centigrade per metre.

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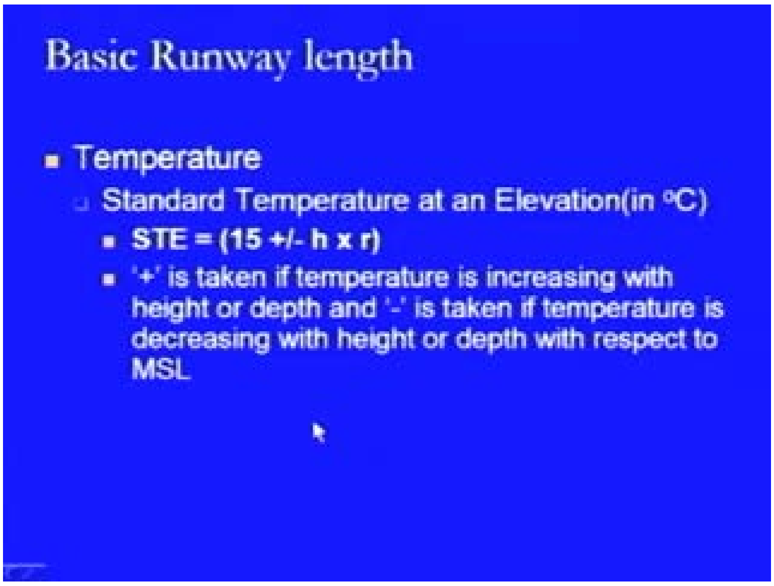

So, if in that case, if height is the h and r is the rate, then it will be as 15 plus or minus h multiplied by r. So, plus is taken if the temperature is increasing with the height or depth and negative is taken if the temperature is decreasing with the height or depth with respect to the mean sea level.

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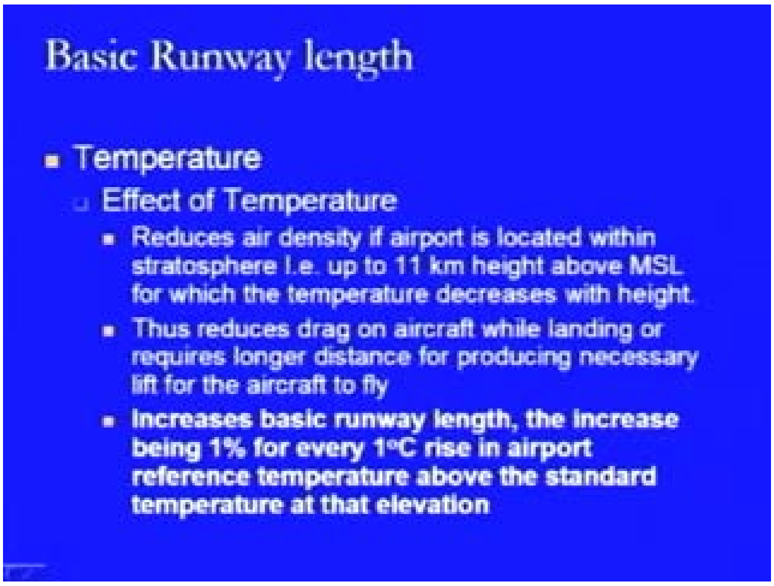

Now, what is the effect of temperature that needs to be examined. What happens is the temperature reduces the air density and the airport is located within the stratosphere that is up to 11 kilometre height above mean sea level. In this particular sphere, what happens is the temperature decreases with height. Now, as the temperature is decreasing with the height, therefore what we found is that there is an effect of the change in the air density and that air density creates an effect in terms of the resistance being offered to the movement of the aircraft at that elevation. What will be the effect is that it will reduce the drag on the aircraft while landing, but it will require longer distance for producing necessary lift for the aircraft to fly. So, that is the effect which will be there in this case.

It means we are going to have a bigger size of the airport as compared to the normal condition. So, increase basically in the runway length is at the rate of being 1% for every 1 degree centigrade rise in airport reference temperature above the standard temperature at that elevation. So, the airport reference temperature, we have computed with respect to the two means. That is mean for average and mean for the maximum and the standard temperature we have computed on the basis of rate of change of temperature with height. So, if we take the difference of these two, then for every 1 degree centigrade rise, the length is to be increased by 1%.

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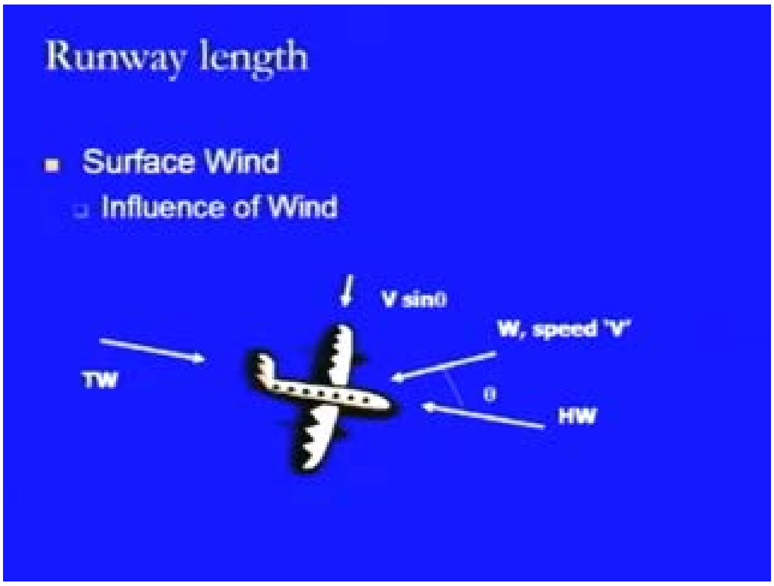

Then, another case is the surface wind. Of course, in the previous lectures we have discussed about the surface wind and we know that there is a head wind, there is a tail wind and there is a cross wind component.

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So, the effect of all these components are there and we have to look at what is the effect of that in the case of head wind component. It creates a breaking effect during landing, because it is coming from the opposite direction, whereas in the case of the take-off, it will create greater lift and there is a premature lift just before the lift off point, the aircraft will go into the air. Therefore, in this case, there will be a reduction in the overall runway length required at that elevation.

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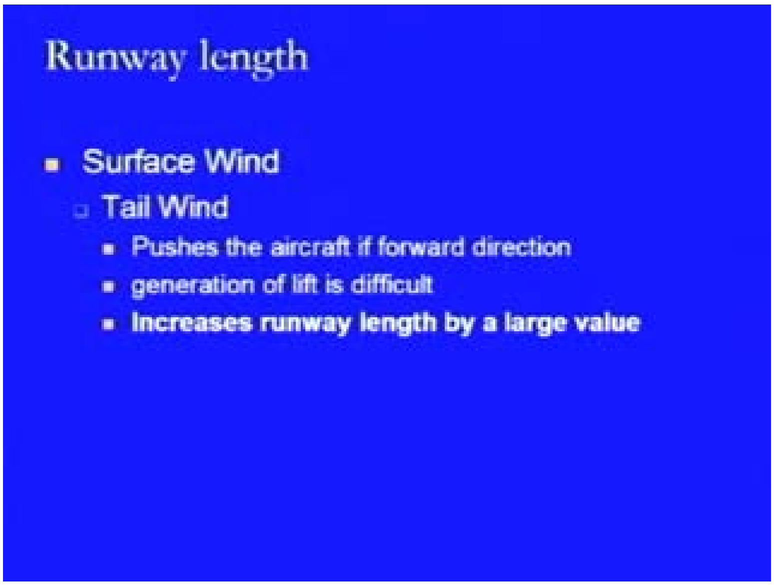

Whereas, if we look at the effect of the tail wind, then the tail wind will be having its effect in terms of pushing the aircraft in the forward direction and another problem is that there is difficulty in the generation of lift required, so as to attain height and in this case, the runway length increases by a very large value.

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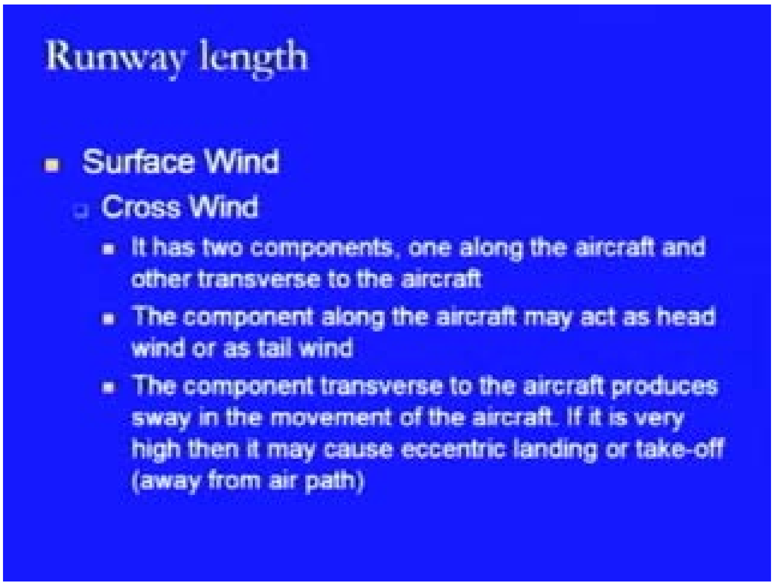

Similarly, we have to understand the effect of the crosswind. In this case it has two components one along the aircraft and another transverse to the aircraft and the component which is along the aircraft may act as a head wind or as tail wind depending on the angle at which that wind is attacking the aircraft or the flight path of that aircraft. Accordingly there will be the effect that what we have seen as a head wind or a tail wind. In the case of that component which is transverse to the aircraft movement that will always create a sway or drift in the movement of the aircraft, means it will, the aircraft will be moving in the transverse direction away from the flight path and if this component is very, very high, then it may cause eccentric landing or take-off condition on the landing strips of the runway. At the same it may also cause a drift of the aircraft away from the flight path and which may be dangerous, because there maybe another flight path moving in the adjoining area in the space and there maybe another aircraft which is using that flight path and may cause collision at that point.

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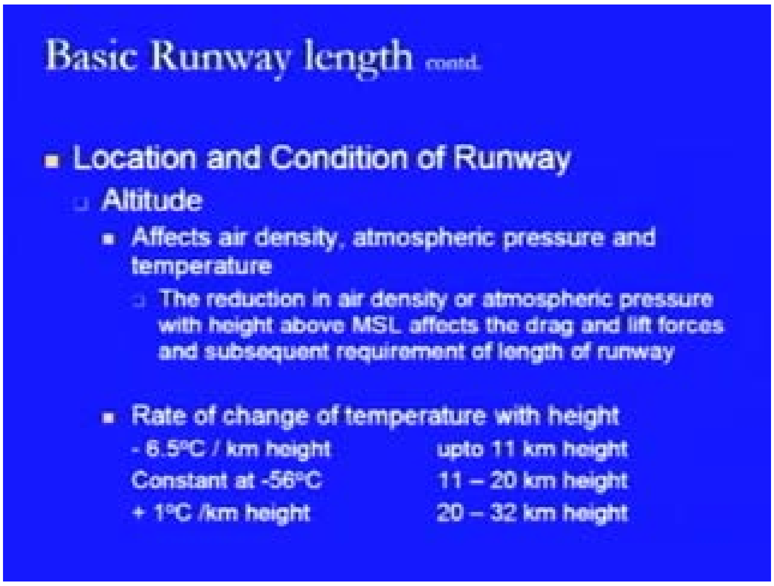

Then, another factor which we have to look at is the location and condition of the runway and this is the one factor which we have to look is altitude that is the height and it creates an effect on air density, on atmospheric pressure and on temperature. The effect is in terms of that if the reduction in air density, air atmospheric pressure is there with height above the mean sea level, then it affects the drag and lift forces and therefore, there is longer runways required at that location and this rate of change of temperature with height, because these are the two things which are correlated with each other, it is at a rate of 6.5 degree centigrade per kilometre height up to a height of 11 kilometre from the mean sea level; so, this is and it decreasing at this rate. That is why minus is being taken.

Then, if we are moving from a height of 11 to 20 kilometres above the mean sea level, then the temperature remains constant at a value of minus 56 degree centigrade.11 kilometres means we can say that we have crossed the height of Everest by something like around two point some kilometres, around 2.2 kilometres or so. Then, in this, in the case when we are moving away further from 20 kilometres that is we have already crossed after 11 kilometres stratosphere and we are in another sphere, troposphere, so in this case, if we are moving from 20 to 32 kilometre height, then the temperature again starts rising with height at a rate of 1 degree centigrade per kilometre. So, these are the rates at which the rate temperature is changing, as we go above mean sea level.

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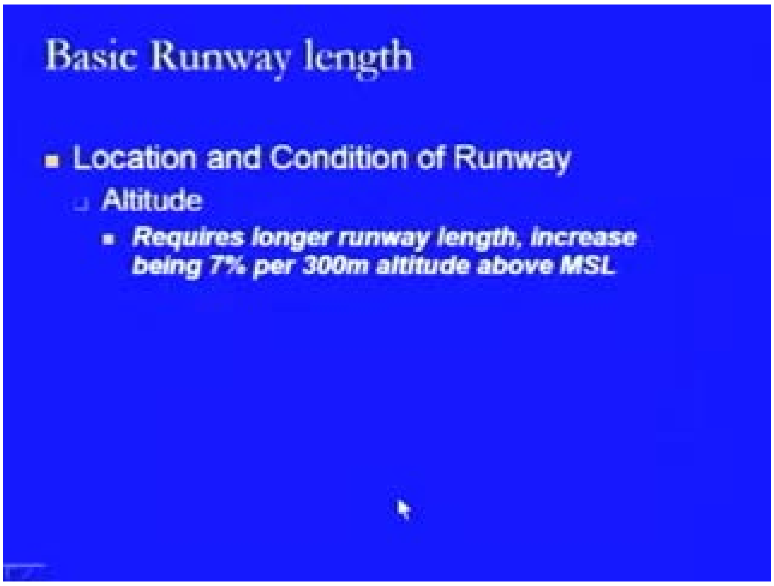

So, the altitude requires what? It requires longer runway length at an increase being taken at 7% per 300 metre altitude above mean sea level. That is how the value of the runway length will increase. Every 300 metre rise will increase the length of the runway by 7%.

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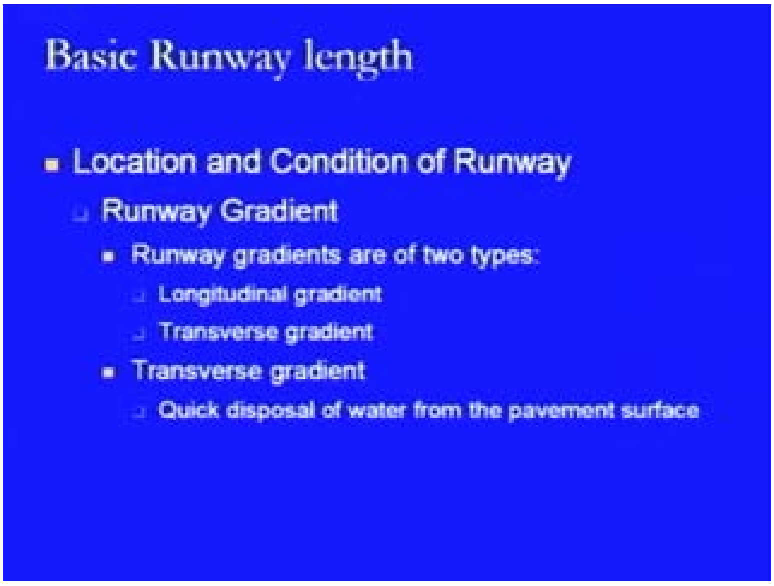

Now, another case is of the runway gradient where the runway gradients are of two types, longitudinal gradients and transverse gradients and in the case of transverse gradients, these are provided, so that there is quick disposal of water from the pavement surface and it becomes dry as soon as possible, so that there is no slippery condition on the pavement surface for the aircraft.

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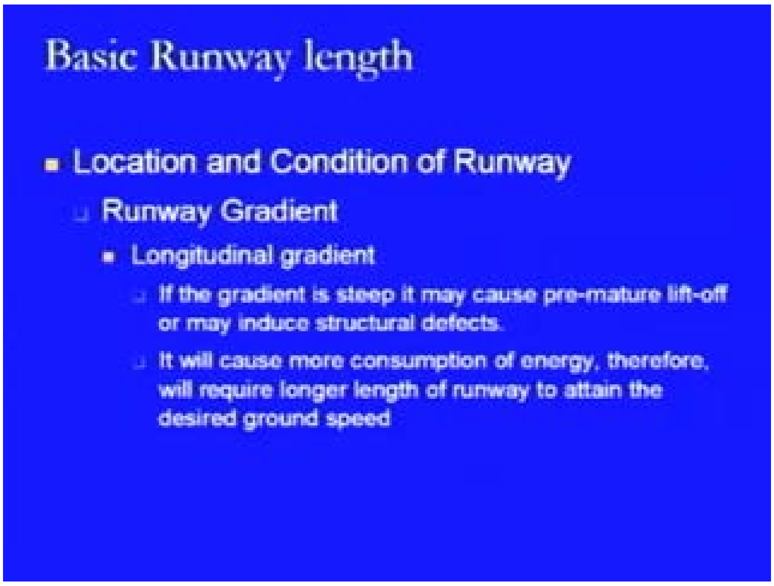

In the case of longitudinal gradient, if the gradient is steep, then it may cause premature lift off or it may induce structural defects. So, that is why there is a requirement of having more smoothened longitudinal gradients. Then, it will also cause more consumption of energy and it will therefore require longer length of runway to attain the desired ground speed. So, that what is the effect of more of longitudinal gradient being provided along the runway length. That is why flatter runways should be provided and they are desirable.

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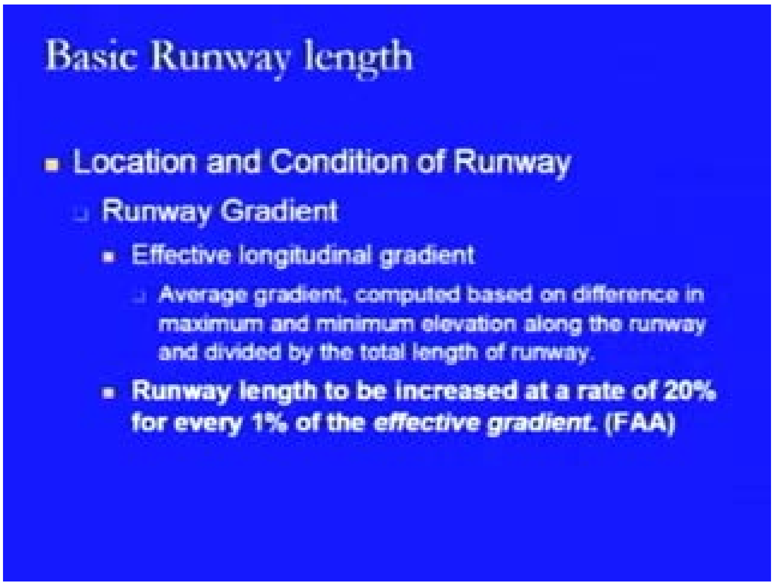

When we look at these runway gradients, one terminology which we come across and which is used in the design is the effective longitudinal gradient. This effective longitudinal gradient is the average gradient which is computed based on the difference in the maximum and minimum elevation along the runway and then this difference is divided by the total length of the runway. So, we can take the maximum point, highest point and the lowest point on the runway, take the difference of that and divide that by the length of the runway and this is what is the effective longitudinal gradient.

So, in the case of this effective longitudinal gradient, the rate at which it is creating a change on the basic runway length is the, it is to be increased at a rate of 20% for every 1% of the effective gradient. So, this is very big effect. For every 1% of effective gradient, we have to increase the length of the runway strip by 20%.

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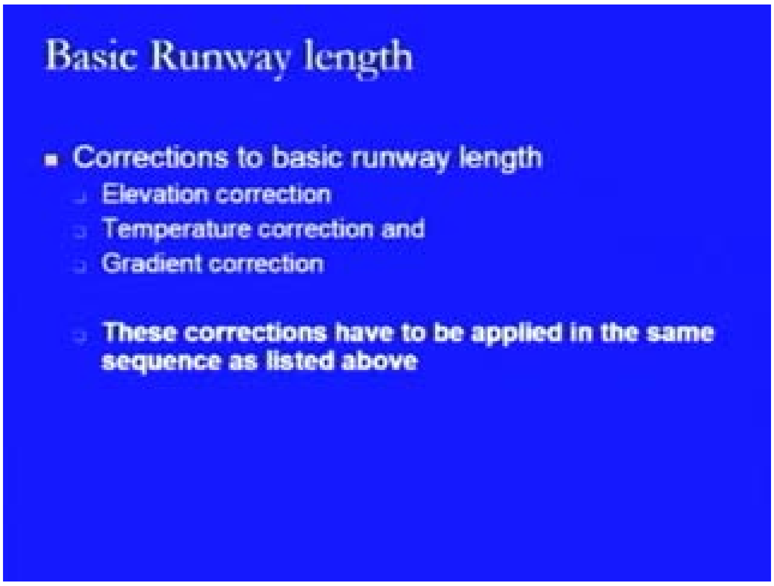

So, what we see is that there are three types of correction to be provide on the basic runway length related to the mean sea level - the correction for elevation, correction for temperature and correction for gradient and these corrections have to be applied in the sequence as they have been listed here; so, first of all elevation, then temperature, then gradient.

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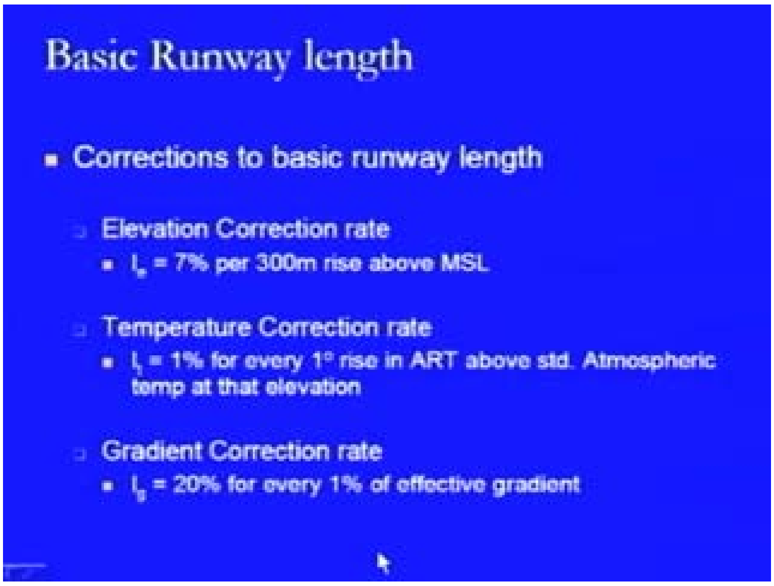

We look at how we do it. The first correction is elevation correction that is at the rate of 7% per 300 metre rise above the mean sea level. So, we will compute the value of this correction of L e. Then, there is a correction for the temperature and this is 1% for every 1 degree centigrade rise at airport reference temperature above the standard atmospheric temperature at that elevation and then, there is a gradient correction rate as L g which is 20% for every 1% of effective gradient. So, whatever the values we are computing here will go subsequently to the other correction.

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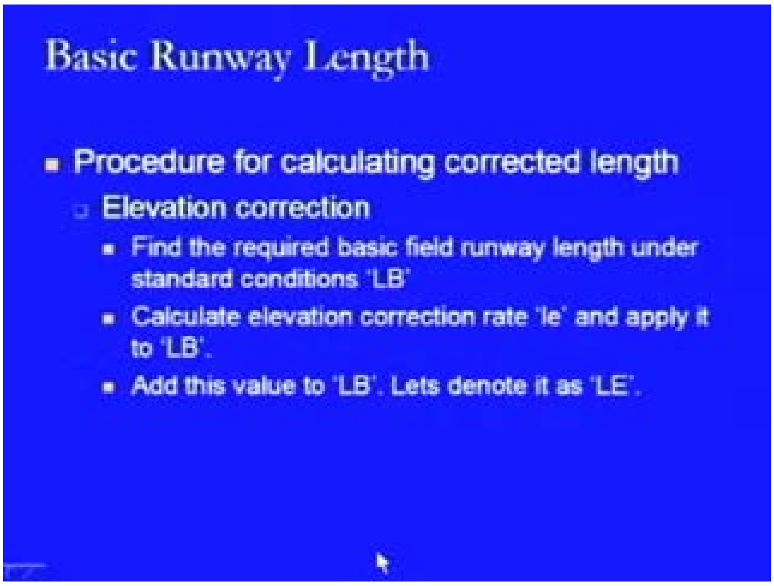

So, how we will be doing is this that first of all we have to go for the elevation correction. We find the required basic field runway length, which is required for mean sea level and under the standard conditions and say that is LB. Then, we calculate the elevation correction rate, small le and we apply it to LB and this will be the new value of the length of the runway strip and say this is LE. So, there is a, LE is nothing but LB plus small le.

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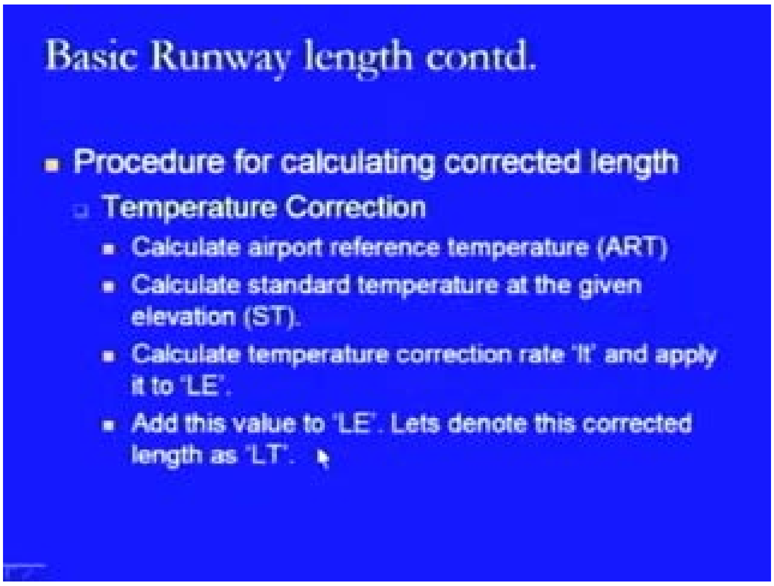

Then, we come to the temperature correction and we calculate first of all the ART that is the airport reference temperature. Then, we calculate the standard temperature at the given elevation ST, then we calculate the temperature correction rate as shown previously and suppose and this correction is to be applied to the length which we have already computed by the, after the first previous correction that is LE. Now, once we apply to this one, the new length will come as that is LT where LT is nothing but LE plus small lt.

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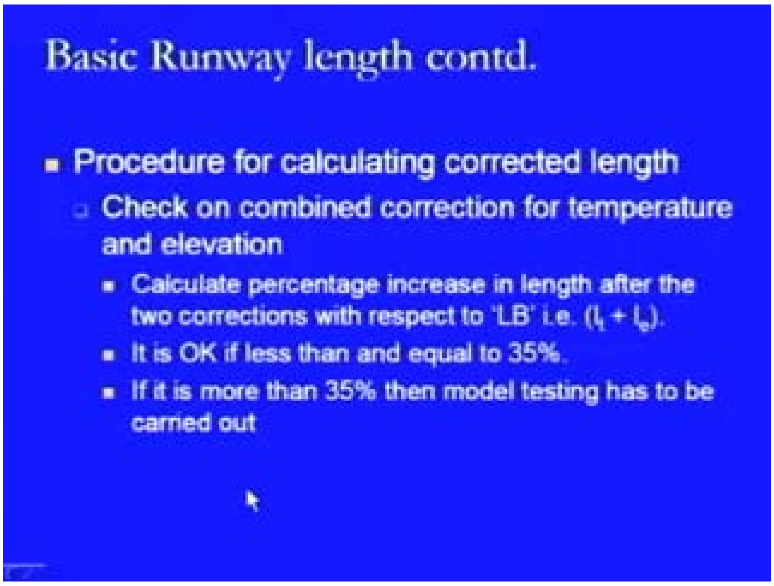

Then, we come to the checking of the combined correction for temperature and elevation. So, the combined correction is l t plus l e and this value should be, it is going to be ok if it is less than or equals to 35%, but if it is more than 35%, then we have to go for the model testing and examine whether this is right or wrong.

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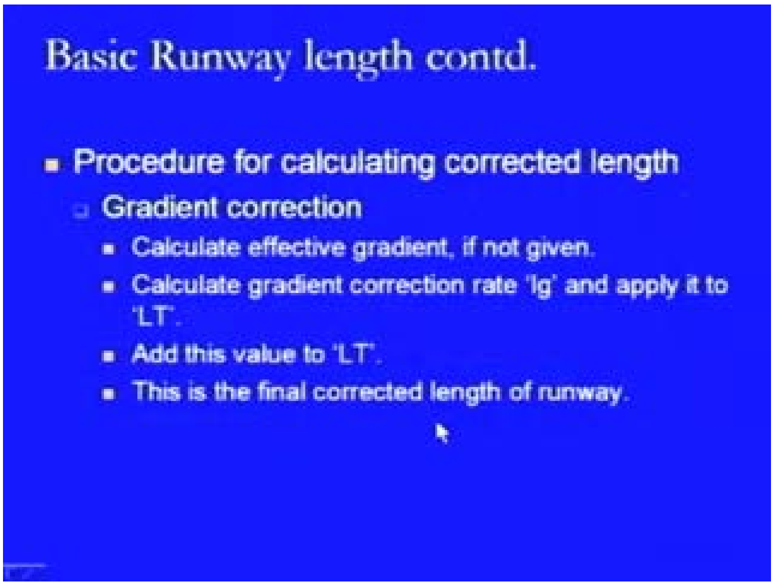

Finally, that is the gradient correction and in the case of the gradient correction, what we do is that this we calculate the effective gradient and after calculating effective gradient, the correction is find out as lg and now this lg is to be applied on the previous calculated length that is LT and therefore, now we have the final corrected length which is nothing but LT plus lg. So, this is how we can compute the length of the runway strip at any height for a given temperature and for a given topographical condition translated into the form of effective gradient.

So, this is what we have discussed today. We have, we have just tried to discuss how we can compute the length of the runway strip. Given certain scenarios, what needs to be examined? Mainly they are, it is in the form of the safety concerns for normal take-off, normal landing and for the emergency conditions of engine failure and then, during the calculation of this runway length, we have to apply three type of corrections. These are the correction for elevation, temperature and gradient. We will be looking at some more features of the runways in the next lecture and till then goodbye and thank you to you.