Transportation Engineering – II
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Lecture - 33
Runway Geometric

Dear students, I welcome you back to the lectures on lecture series of course materials of Transportation Engineering - II. From the previous two lectures we have been discussing about runways. We have seen how the runways can be oriented. We have also discussed about the various configurations in which the runways can be laid and then, in the previous lecture we have discussed about the various factors which are considered for the calculation of the runway land to be provided at certain elevation, where some temperature is prevailing or the terrain conditions are being defined in terms of the effective gradients.

In continuation of the same, in today's lecture we will be concentrating on the various geometric features of runway strip.

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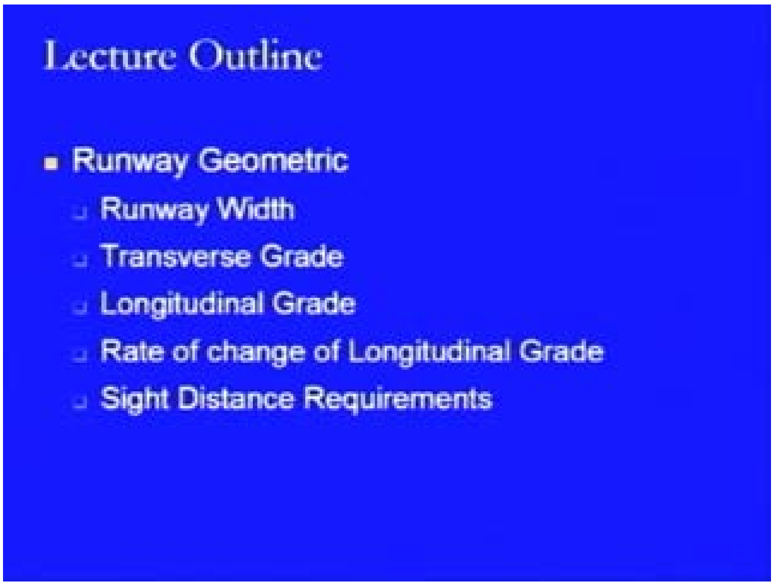

Therefore, this lecture has been outlined in the form of the runway geometric, wherein we will be discussing about the runway width, the transverse grade, the longitudinal grade, the rate of change longitudinal grade, sight distance requirements.

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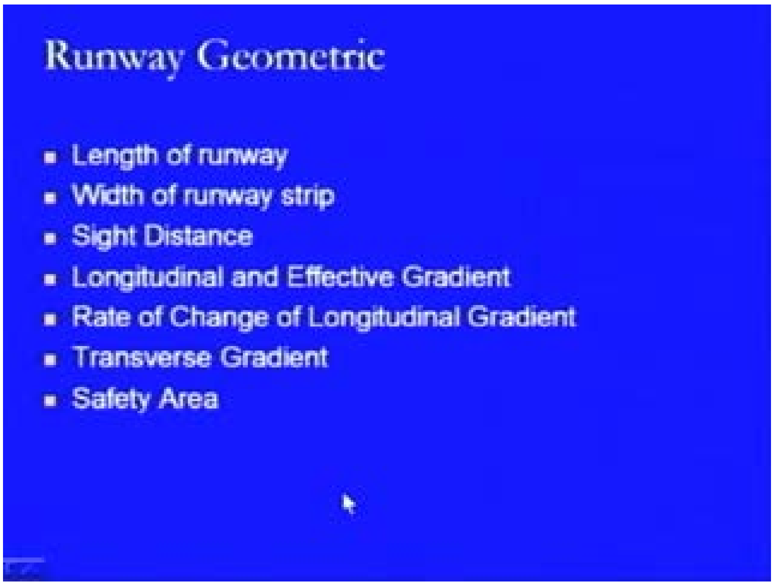

So, we start with the initial geometric condition that is the length of runway strip. Already we have seen in the previous lecture that the length of runway strip is governed by certain assumptions with respect to the mean sea level. Mean sea level is the one which has the defined metrological conditions and for that defined metrological conditions, whatever runway strip is provided is known as the basic runway length. With respect to that basic runway length, now we have to see whether it is to be increased or decreased for any other elevation, for any other site of airport being provided. If this airport is being provided at a higher altitude with respect to the mean sea level, then the correction goes in the form of a sequential form as we have seen that is for elevation, for temperature and for the effective gradients.

So, the elevation is for the condition effect, the temperature is from the metrological conditions and the gradient is from the topographical conditions. In that sequence, what we have to look at is that how this length is going to be computed. Then, another thing is the width of the runway strip. That is we have seen when we discussed about the aircraft characteristics, what are characteristics which create an effect on the width of the runway strip and that was the wing span. With respect to that we will be looking in today's lecture that how the width of the runway strip is affected and what should be the width of runway strip.

Another thing is the sight distance to be provided. That is related to the visibility and this visibility we have discussed before in terms of the flight rules, where we talked about the instrumental flight rules or the visual flight rules or the instrumental landing conditions or the non-instrumental landing conditions, where in the sstricter form the visibility is being defined in terms of the 300 meters at the minimum level. Then, the longitudinal and effective gradients - this we have just seen that we will be looking in the sequence and then, we have the rate of change, we have the transverse gradient and the safety area.

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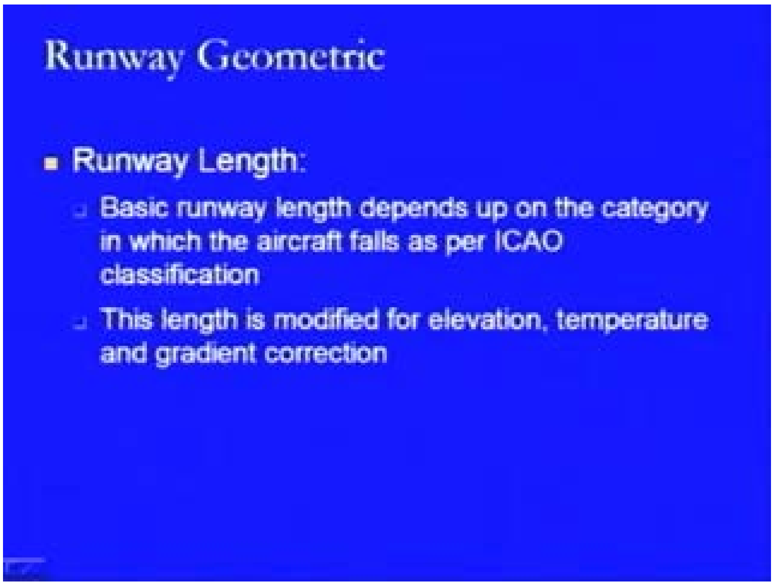

So, starting with these various geometric features, the very first one is runway length, where the basic runway length, as we have seen, depends on the category in which the aircraft falls as per ICAO classification, because what we have seen is in the case of ICAO classification where and its effect on the competition of the basic runway length in terms of take-off distance available, take-off run available or the distance required for acceleration, stopping available for the aircraft and likewise, all these distances are governed by the power which is available or the propulsion system which is available with any of the aircraft.

If the aircraft is big the power is more, therefore it will require longer distance so as to stop or so as to take-off. So, in that sense, we try to analyse it that in what particular category the aircraft falls and then for that particular category what should be the basic runway length. Now, here when we are talking about this basic runway length, then it means we are talking about the mean sea level and therefore, whatever this length is to be provided is for 15 degree centigrade temperature at a mean sea level 670 mm of the mercury and the air pressure accordingly.

Now, this length needs to be modified for the three types of the corrections that is elevation correction, temperature correction and the gradient correction taken in order and this we have seen in the previous lecture that how these corrections can be provided and at what particular rate these needs to be provided. We have seen that the elevation correction is to be provided at a rate of 7% for every 300 meter elevation, temperature is to be provided for every 1% change, for 1%, per every 1% change in the temperature between ART and the standard temperature at that elevation on the airport and the gradient correction is being provided in terms of at 20% for every 1% effective gradient. So, that is the value by which this basic runway length which is being computed gets modified and in the case of elevations, while going up, these will be increasing. So, that is the aspect which we have to take care of when we are talking about any runway length.

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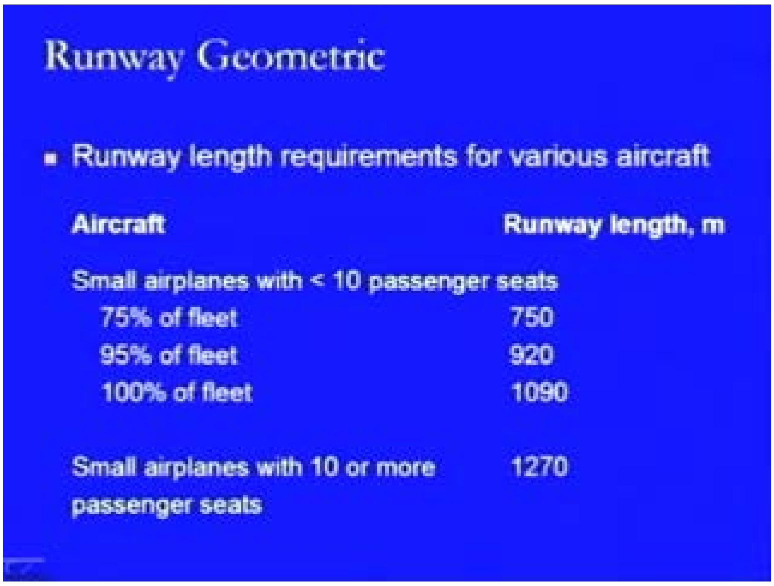

Now, the runway length requirement for various aircrafts can be seen just now in this particular analysis, where we are taking the aircraft and the runway length in meters. The aircraft has been defined based on the passenger seats available and if there is a small airplane where it is having passenger seats less than 10, then in that case it is dependent on how much fleet we are talking about. If it 75% of the fleet, then the runway length required is 750 meters, whereas if it is 95% of the fleet, means the total number of aircrafts which are available in the overall system or on that airport, then in that case it becomes 920 that is we require a little longer length of the runway strip, because here what we are assuming is that there is a queue and as the number of aircrafts increases, then the, at the time when one aircraft is taking off another starts coming towards the runway strip, so as to take position and start taking off and that is why we require a little longer length, so as to have a safety aspect and if there is 100% of the fleet being used, if the small airplane, then the runway length will be 1090 meters. That is as per ICAO.

Whereas, there is another category where we have the small airplane where there are 10 or more passengers seats in that case it is 1270 meters. Now, why it is increasing is that in this particular case, because it is a little bigger aircraft as compared to the previous one, then the propulsive power will also be more, the size of the aircraft will also be more and therefore, on that aspect it requires a more distance, so as to take-off or so as to stop. That is why it is 1270 meters.

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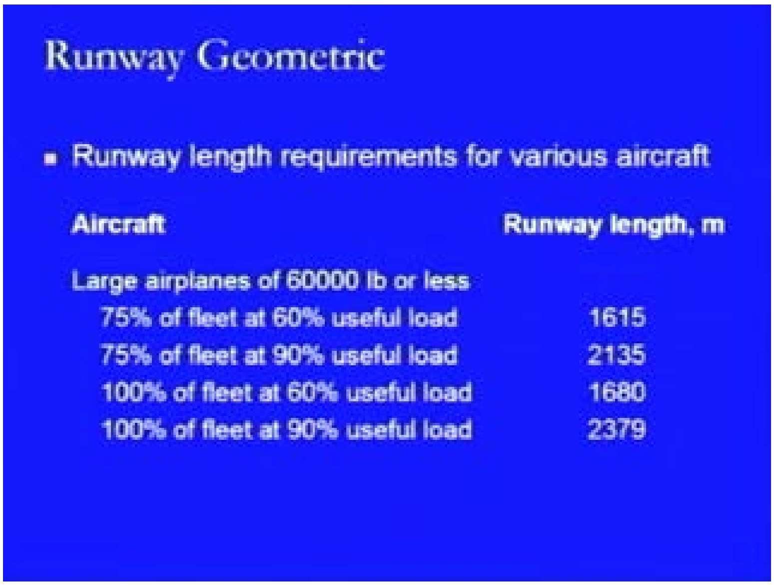

Another case in the same category is that there is a large airplane of 60,000 pounds or less. In that case, again it is dependent on the total amount of fleet which will be using at point of a time the runway strip and that is like 75% of the fleet at 60% useful load, means the total loading is 60% with respect to that 75% of the fleet, then the runway strip will be required as 1615 meters. Whereas, if it increases, the useful load increases to 90%, then this will be 2135 meters. Further, if we are increasing the fleet size from 75% to 100% and keep the useful load at 60%, then the runway length will increase from 1615 meters to 1680 zero meters. There is a small change in the length of the runway strip with respect to the size of the fleet, whereas if there is a change in the useful load, then there is a big effect. That is what is coming out from this information or data which is being presented right now. In case we have 100% of the fleet, but then the useful load has been increased to 90%, then what we find is that there is a big increase in the length of the runway strip and it is 2379 meters.

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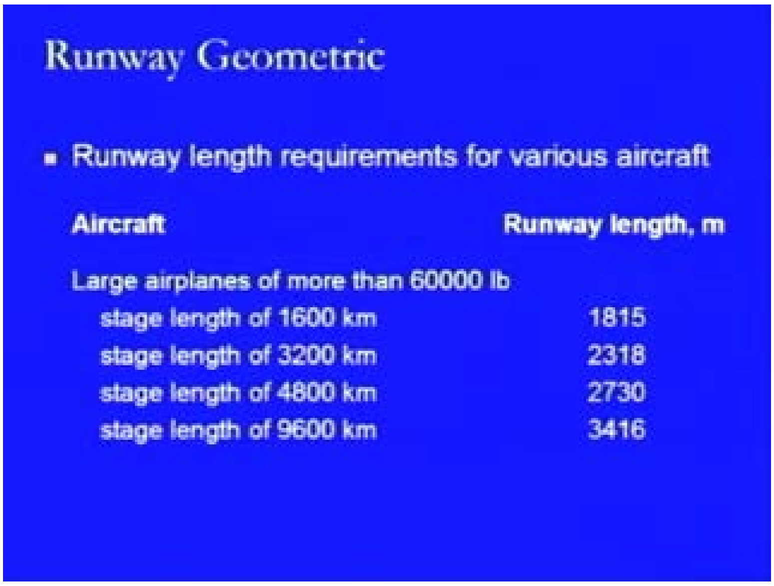

Then there is one more case here, where we talk about large aeroplanes where the weight is more than 60,000 pounds and in this case it is dependent on the stage length of ….. and this is, if it is 1600 kilometres, then the length of the runway strip is 1815 meters. If it is, stage length is 3200 kilometres, then it is 2318 meters and if it is 4800 kilometres, then it is 2730 meters. The stage length, we can say that within one particular stage length how much kilometres that particular airplane can go and that is how it is being defined, whereas if the stage length is 9600 kilometres, then this is 3416 meters.

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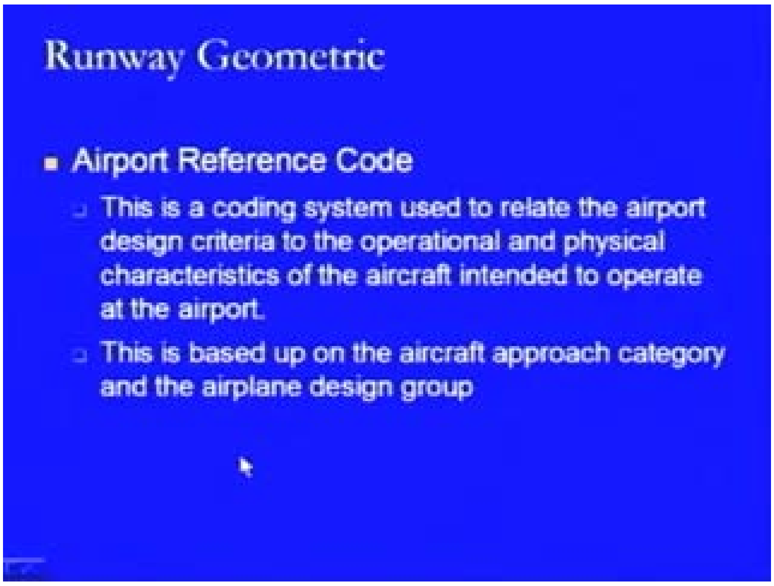

Then, apart from this length there is another characteristic, there is another feature, which needs to be just referred to. That is airport reference code. This airport reference code is a coding system which is used to relate the airport design criteria to the operational and physical characteristics of the aircraft and which are intended to operate at any of the airports. So, that is the type of the coding system which is there with respect to the use of the airport by different type of aircrafts, so and this is generally used in the design criteria conditions that as soon as an airport reference code is defined, then it simultaneously defines the type of the aircrafts or the characteristics of the aircraft which will be using the airport or the type of the aircraft on which these systems will be operating and this is based on the aircraft approach category and the airplane design group. Whatever the number of planes being designed, on the basis of their characteristics these planes are being grouped together and that is what is known as the airplane design group.

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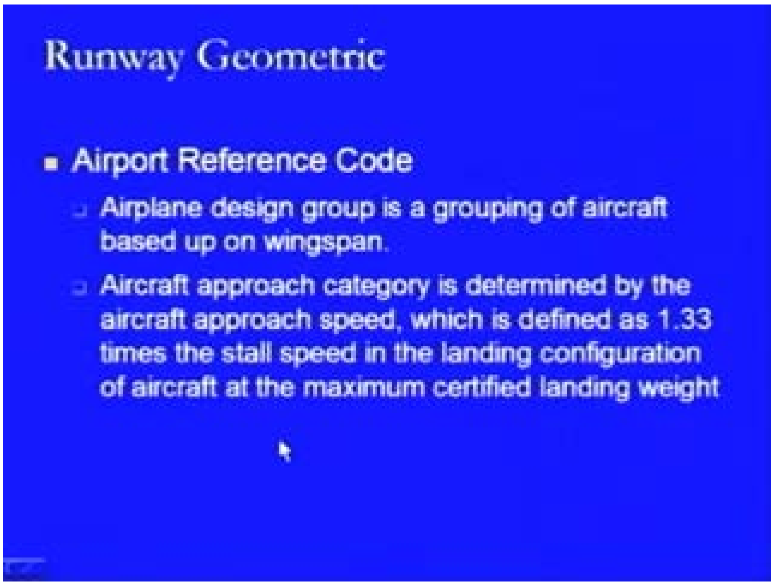

So, in this case of airport reference code, there is an airport design group as just I have said, is a grouping of aircraft and the basis for doing this grouping is the wingspan. So, on the basis of the wingspan that is the size or the distance between one point to the other point of the wings, we define that what is the airplane design group and this aircraft approach categories determined by the aircraft approach speed which is defined as 1.33 times the stall speed in the landing configuration of aircraft at the maximum certified landing weight. So, if the complete landing weight available whatever is the approach, speed is there, then with respect to that approach speed, we try to define the category of that aircraft and that is what is the aircraft approach category and this is used, so as to find out the lengths, etc of the various runway strips.

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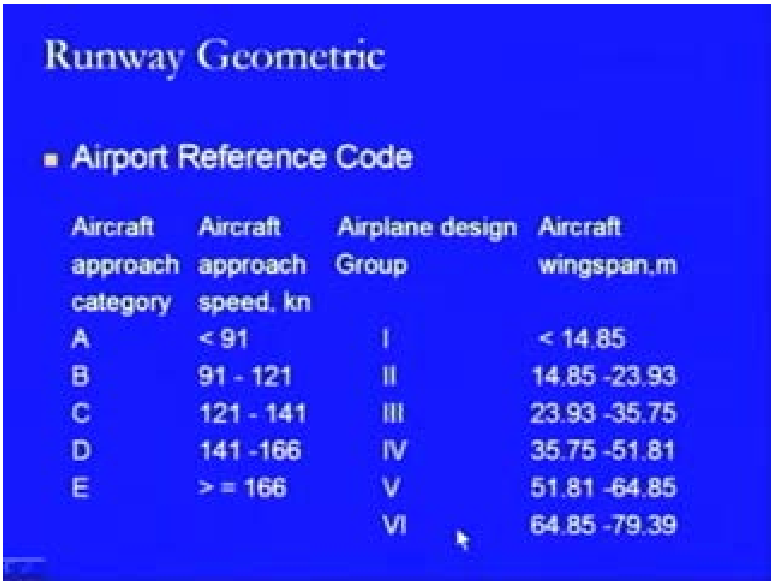

Here we are looking at how we are going to get what is the correlation between the different categories. We have the aircraft approach category, we have aircraft approach speed in kilo knots and then, there is airplane design group and then, there is aircraft wingspan in meters. So, if we talk about the A category of aircraft approach, then in this case the aircraft approach speed is less than 91 kilo knots and the airplane design group is I and the aircraft wingspan is less than 14.85 meters. In the case of B, it varies, speed varies from 91 to 121, the group is second and the wing span varies between 14.85 and 23.93.

For C category of aircraft, we have the aircraft approach speed ranging between 121 and 141 for the design group as III and the wing span will be between 23.93 and 35.75 meters. Then, for D category, it is 141 to 166 with the fourth category of design group and the wingspan varies between 35.75 and 51.81 meters. Then, for finally for E category that is for fifth category, its approach speed is greater than or it is equal to 166 kilo knots in this category the design group is fifth and the wingspan is 51.81 to 64.85 meters. It means that as we are going below that is we are going from A to E, the wingspan is increasing means the size of the aircraft is increasing and that is why the approach speed in also increasing. It means this particular aircraft will be approaching the runway strip at a speed of 166 kilo knot that's the amount of speed.

Apart from these, in the list E category we have another case of the airplane design group, which is the sixth group, where we have the values ranging from 64.85 to 79.39 meters.

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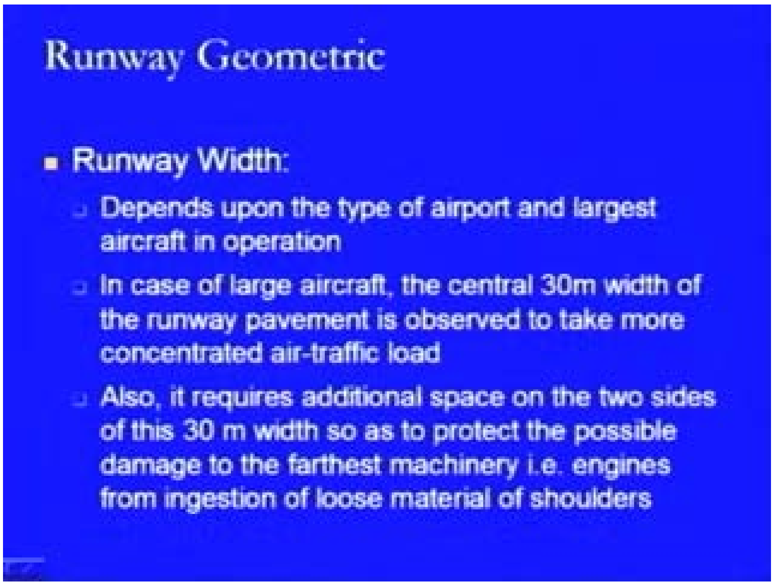

Now, we come to another runway geometric and this is runway width. We have to see that what should be the width which needs to be provided and this depends on the type of the airport as well as the biggest aircraft which will be using that airport. Now, when we say that there is a biggest aircraft or largest aircraft which will be using the airport, then this is basically in terms of the wingspan and as we have seen, there is one aircraft which is used for cargo movement and that cargo movement aircraft is having the wingspan of such size that if it is, if we take the distance from one side of the wing to the other side of the wing, then the total size is equivalent to the size of a football ground.

Now, there is only single aircraft in the world which is being manufactured and it is mostly used for delivering cargo from one location to another. It is available with Russia. Now, in case of a large aircraft, the central 30 meter width of the runway pavement is observed to take more concentrated air-traffic load. That is the lateral displacement of the aircrafts with respect to the pavement. So, within the central 30 meter width most of the loads are coming, whereas out of that, the loads will be reducing. Further, it also requires additional space on the two sides of this 30 meter width, so as to protect the possible damage to the farthest machinery that is engines, from ingestion of loose material of shoulders. That is another problematic and important thing, because if the wings are going away from this runway strip, then on these wings we are providing the engines and if there are more engines, more than a set of one engine on each wing, then the second engine will be going away from the width of the runway strip.

In that case, as soon as the engine starts working and there is propulsion condition, then it will start sucking the loose materials which are lying on the pavement surface or if it is not a pavement surface, it is a ground, then it will be sucking the grass or the loose material in terms of dust, etc., and that is a very harmful condition for the machinery of that engine or for the propulsion or for the turbine, because it will damage it and therefore, that engine will become non-operational. So, that is why it is required to provide some more space on the two sides of the runway strip of equivalent to 30 meter width. So, that particular area can be termed as the shoulder area and that should also be paved.

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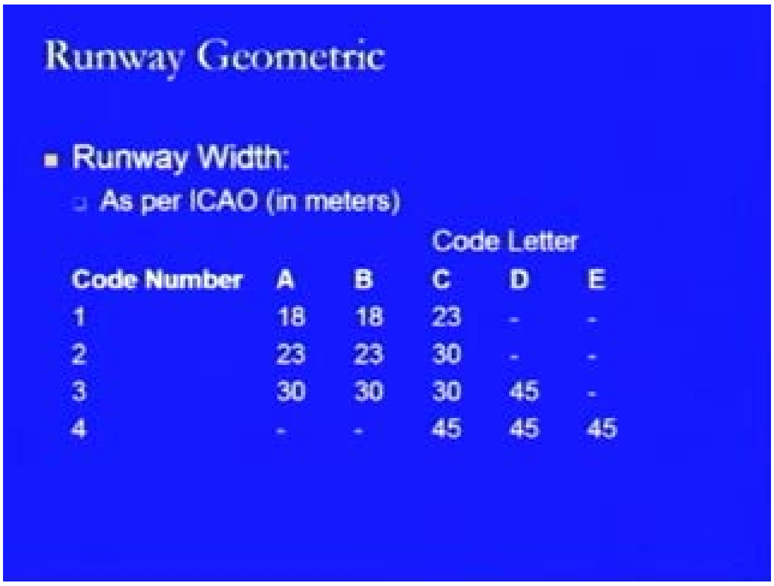

Now, in this case if we look at the specifications which have been given by ICAO, then this runway width is being defined in terms of meters and it depends on the what is the code number and what are the code letter for that airport. That is it ranges from A to E and in that case if we have code number 1 says that the width of the runway strip can be 18 meters if it is a category A airport and it can be 23 meters if it is C category of airport and the second code 2, this value will be 23 meters for A and B category, whereas 30 meters for C category. In the third code condition, it will be 30 meters for A to C category, whereas 45 meters for D category and then, in fourth code number condition, it is 45 meters for C, D and E category, whereas for A and B, this is not valid. So, this how we can find or we can provide the width of a runway strip and then, apart from that width of the runway strip, we have to provide shoulders also.

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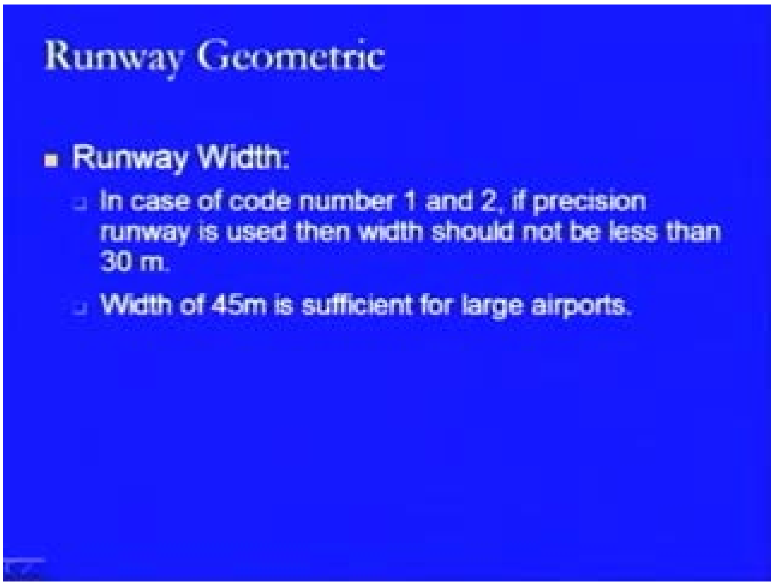

Then, further in the case of this code number 1 and 2, if precision runway is used, then the width should not be less than 30 meters. That is we are trying to define the runway in terms of the instrumentation condition, then the minimum width of the runway has to be 30 meters and in the case of large airports, the width of 45 meters is found to be sufficient.

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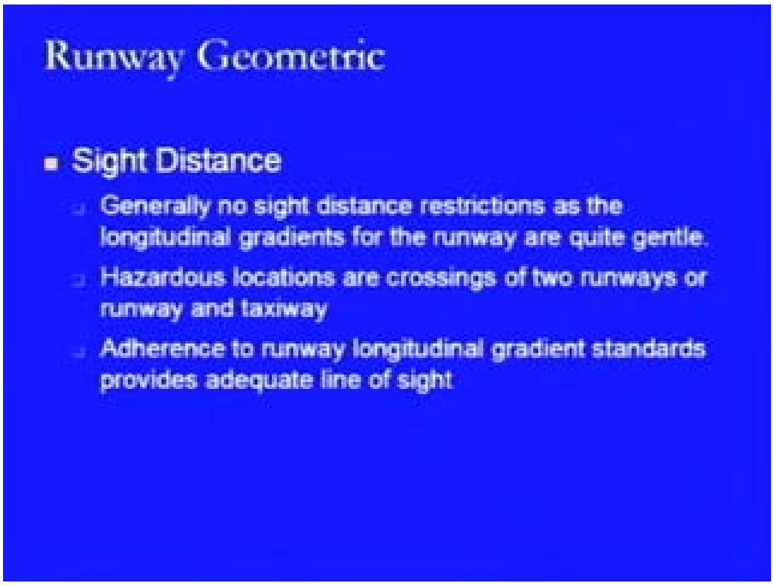

Now, we look at another geometric feature that is sight distance. In the case of sight distance, basically there is generally no sight distance restriction, as the longitudinal gradients for the runways are quite gentle, because there is not much difference going on in the elevations along the runway length and that is why there is not going to be a problem as far as the visibility is concerned for the pilot who is sitting at a sufficiently high location with respect to the elevation of the pavement. So that is why, this should not be in general conditions, in the normal conditions problem should not be there.

The hazardous location in the case of any runway strip is the crossing of two runways or the crossing of a runway with the taxiway. So, at that particular location the sight distance becomes very important, because if there are two runways which are crossing each other, as we have seen in the case of intersecting runway strips in one of the previous lectures or in that case, then what may happen is that if there are two simultaneous operations going on these two intersecting strips, then there are all chances of an accident taking place at the point of intersection, if the sight distance is not proper. So, that is why this is quite important in this case.

Similarly, in the case of runway and taxiway connectivity, if there is a landing aircraft, then this landing aircraft will be coming from a runway to the taxiway, whereas there can be taking off aircraft which will be coming from the taxiway to the runway and if both the things are happening simultaneously at that point of a time, then in that case what we will find is that this is another hazardous condition if the sight distance is not proper. Then, adherence to runway longitudinal gradient standards provides adequate line of sight. That is what it is possible that if we can provide the longitudinal gradients as per the standards, then there will not be any problem of line of sight or the line of sight will not get disturbed or obstructed.

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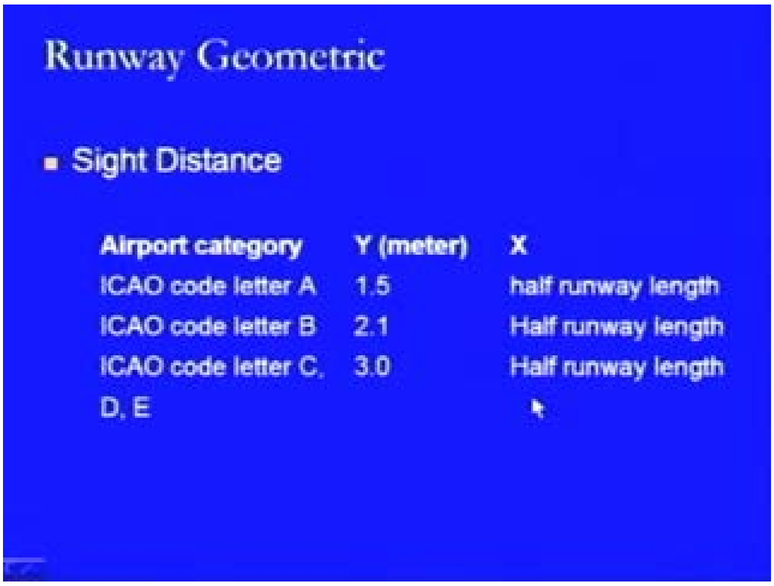

Here, we are looking at the sight distance condition with respect to the airport category and we have two values as Y and X in meters and as far as the ICAO code letter of A is concerned for the airport category, then Y is 1.5 meters and X is half of the runway length. Then, for code letter B, it is 2.1 meters, where X is half of runway length and for code letter C it is 3 meters, X remains the same and for these are the conditions for C and D and E also.

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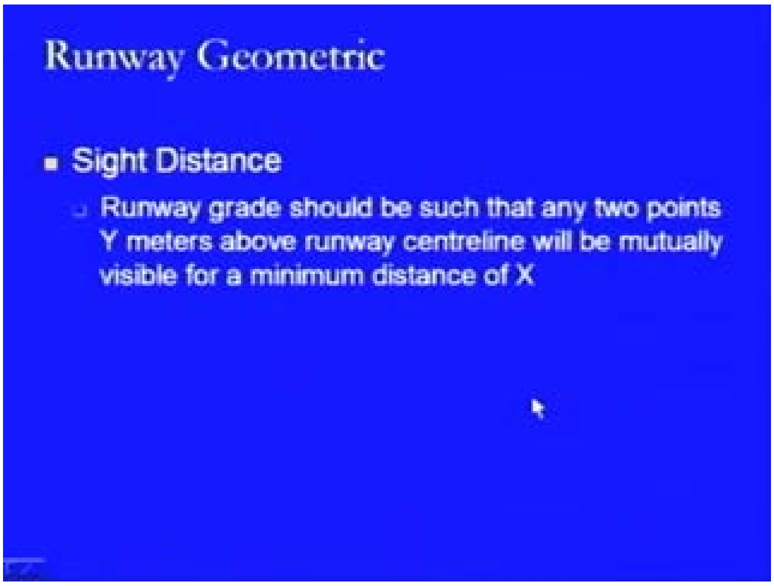

Now, here the runway grade is such that if there are two points Y meters above the runway centreline, then they will be mutually visible for a minimum distance of X. That is how this Y and X values are defined. That is the similar condition which we talked in the case of roads, where there is a vehicle and there is an obstruction, then we take the height of the eyesight of the driver and the height of the obstruction that is what is Y and then, we take the minimum distance between the two, so that there is no collision taking place and that is what is minimum distance of X.

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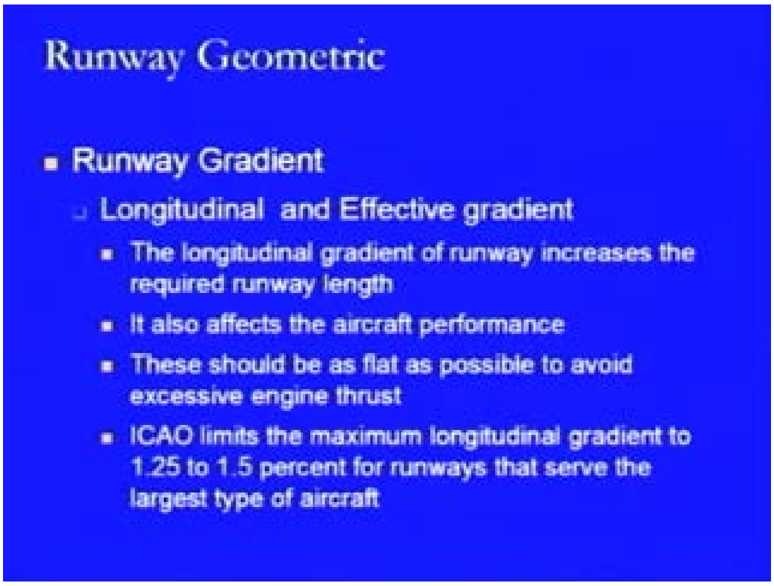

Now, we will come to another geometric feature that is runway gradient. Now, in the case of runway gradient we have different types of the gradients which need to be discussed. We have the longitudinal gradients, we have the transverse gradients and we have the effective gradients. In case of the longitudinal gradient, this longitudinal gradient also gets transformed into the effective gradient, which is used as a design parameter for finding out the length of any runway strip. So, therefore we are taking these two things together here and what we found is that the longitudinal gradient of a runway increases the required runway length. That is the one thing if it is a ….. and it is a zero gradient condition, then there is no change in the length of the runway strip.

But, as soon as there is a longitudinal gradient, then the length of the runway strip will change. It also affects the aircraft performance in the sense that if there are number of gradients being provided, then at the point where the two gradients are meeting each other there is kink being formed and as the aircraft traverses this kink, there are chances of a structural disability, deformation coming within the aircraft. So, this particular amount by which the two longitudinal gradients have been connected with each other that is what is the steepness of those two longitudinal gradients will define that amount of damage which may be caused to any aircraft.

Then, these should be flat as far as possible, so that we can avoid excessive engine thrust, because if it is downward direction and the aircraft is going in the upward direction, then the engine thrust will be towards the pavement side, whereas if it is going in the downward direction after traversing this point of connectivity of the two gradients, then the thrust will be in the upward direction and may cause problem with some other feature on the airport. Now, ICAO has limitized the maximum longitudinal gradient to 1.25% to 1.5% of runways that serve the largest type of aircraft. So, that is the limited value being provided by the ICAO.

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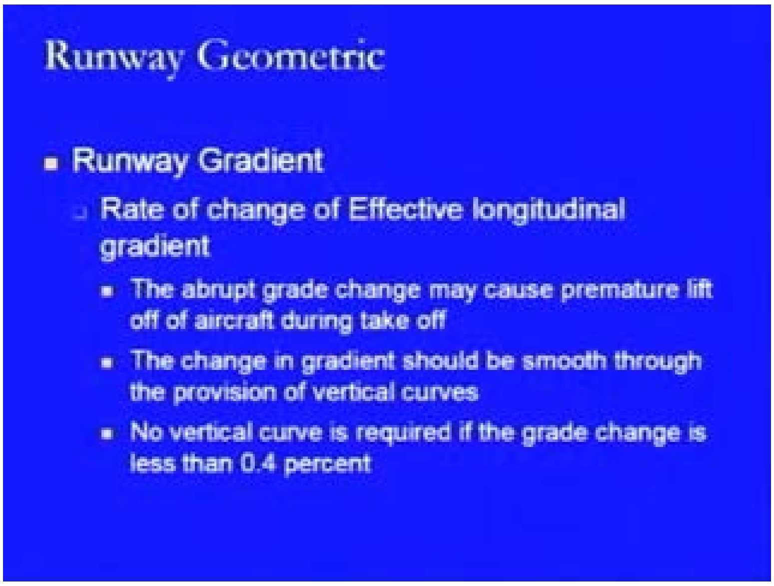

Now, when we talk about this longitudinal gradient, then we can also talk about the rate of change of effective longitudinal gradient. In this case, what we have to look at is that at what particular rate the effective longitudinal gradient is changing, then that should not be abrupt. If it is abrupt, then this abrupt grade change will cause premature lift off of the aircraft during taking off, because if it is abrupt and as soon as there is an upgrade being followed by a downgrade, we will find that there will be a lift which will be induced on the aircraft and this lift will be premature lift instead of the designated point from where the lift should have taken place, this lift will be taking place before that.

Another case is that if this change in the gradient if it is not smooth, then it is going to create a problem. So, therefore what we need to do is we have to provide the vertical curves as we have done in the case of railways or as we do in the case of highways also. So, the provision of vertical curves is one way by which we can try to reduce these types of effects. No vertical curve is required in case the grade change is less than 0.4%. That is another specification being provided which defines the provision of requirement of providing the vertical curve or not.

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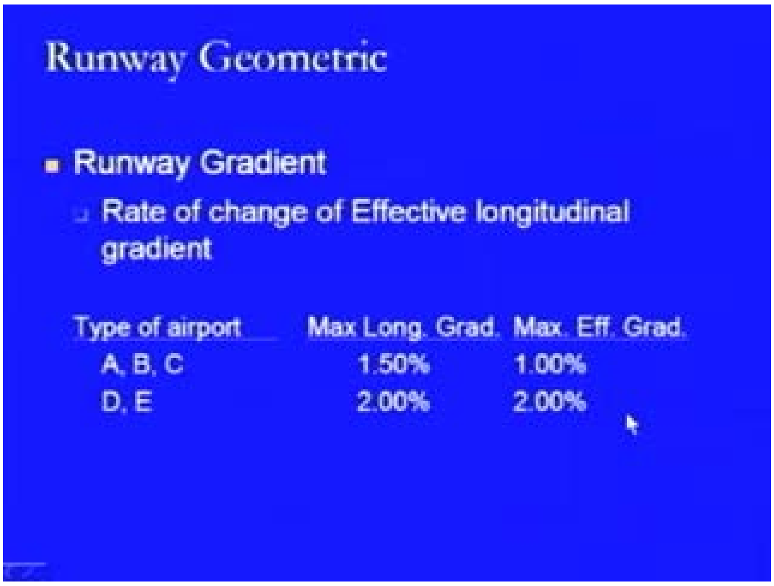

Then, in the case of runway gradient, another thing is the rate of change of effective gradient here which we are talking about and we try to look at the values which are dependent on the type of the airport. In the case of A, B and C type of the airport, then this maximum longitudinal gradient can be 1.5%, whereas the maximum effective gradient can be 1%. For D and E type of the airport, this maximum longitudinal gradient can be 2% and the same is the value for maximum effective gradient.

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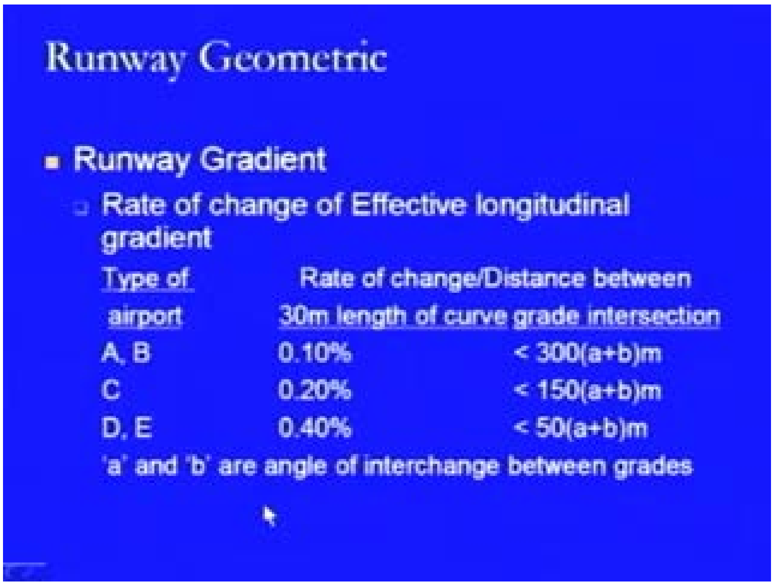

Then, further this value for how we are going to make this change over in the case of the effective gradient is in the case of various type of airports, we have to look at this rate of change and the distance between the 30 metre length of curve grade intersection and this is how it is defined. For A and B type of airport this is 0.1% and the distance between the 30 metre of curve grade intersection should be less than 300 times of a plus b in metres. Whereas for the C category of the airport, this is 0.2% as the rate of change and this value of distance between these should be less 150 times of a plus b in metres and whereas for D and E type of airport this value is 0.4% and should be less than 50 times of a and b in metres. Now, we will try to look at what is this a and b and how this is working and this a and b are angle of interchange between grades and that is defined in this case.

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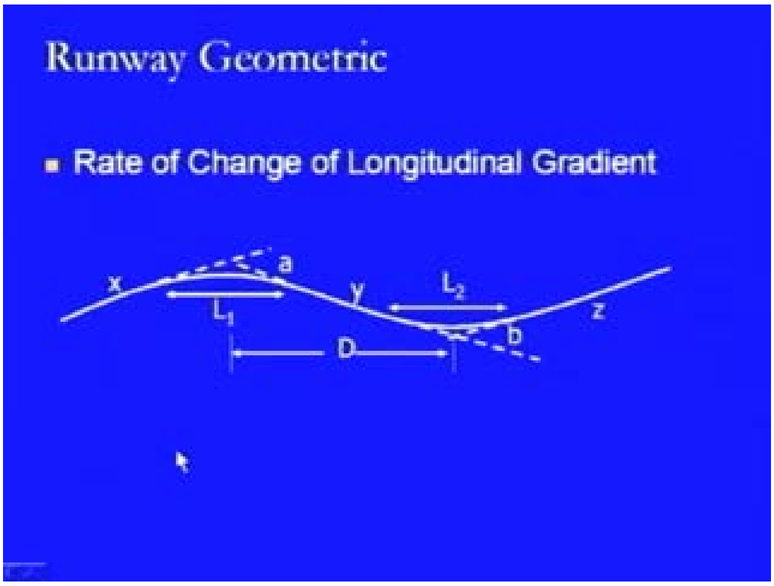

Here what we see is that there is an x gradient which is going up and there is a down gradient y and again …… there is an up gradient, Z and this is what is the profile of the runway strip. Now, in this profile of the runway strip, this a is defined as the change in the gradient at this position from x to y. Similarly from y to z there is a change b. So, this a and b which we have seen in this case like as 300 times of a plus b and 150 times of a plus b or 50 times of a plus b, are being found out from those conditions.

Then there is a, this length of the curve which is to be provided, so as to connect the two gradients that is x and y and this is L 1 on this side or say this is L 2 on this side. Another thing in this case is what is the distance between the two intersections? This is one intersection of the two grades and this is another intersection of the two grades and the distance between these two intersections is being defined as capital D.

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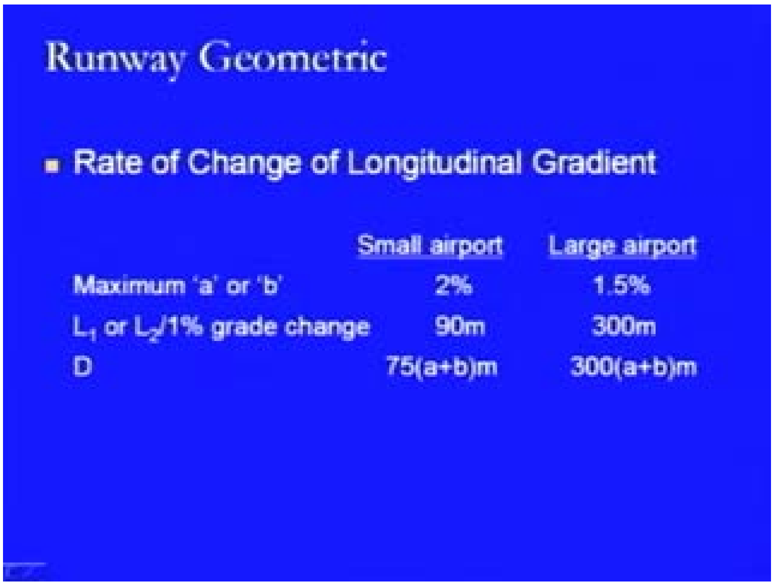

Now, in this case if we look at the values of all these a, b, etc., then what we find is that it is defined in terms of size of the airport. If the size of the airport is small or big, then this maximum value of a or b is 2% for small airport and 1.5% for large airport, whereas for this value of length of the curve that is L 1 or L 2 is defined with respect to 1% change in the grade and this is 90 metres for small airport and 300 metres for large airports. Similarly, the distance between the two successive point of intersections of the gradient, this is defined as 75 times of a plus b for small airport and 300 times of a plus b for large airport, where a and b are these rates already being defined.

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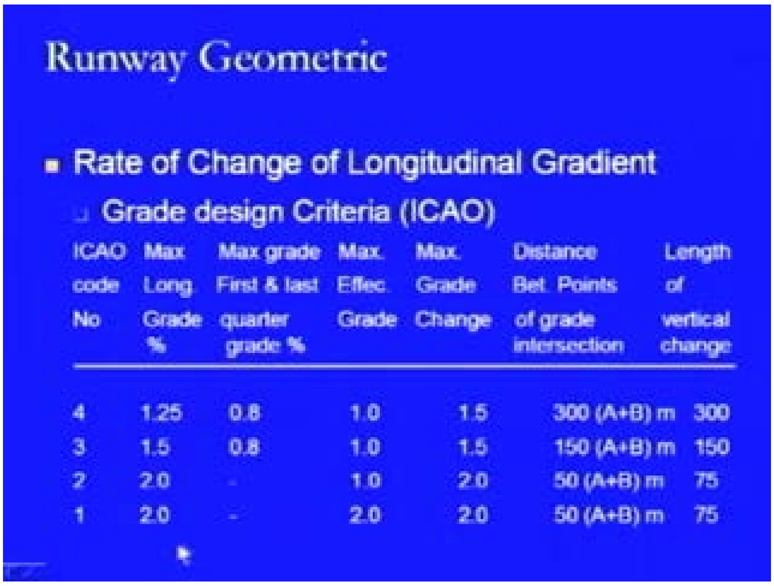

Now, we look at further in the same category of the rate of change of longitudinal gradients on the specifications being given by ICAO, in terms of the grade design criteria and this grade design criteria is being looked at in terms of ICAO code number, then the maximum longitudinal gradient percent, maximum grade and first and last quarter grade percent and then the maximum effective grade, maximum grade change, then the distance between points of grade intersection and the length of the vertical change. So, these are the various values which have been defined by ICAO as a design criteria for the grades and it says that if ICAO code number is 4, the maximum longitudinal gradient percent can be 1.25%, maximum grade quarter percent is 0.8%, maximum effective grade is 1% and this maximum grade change is 1.5% percent and then, the distance is 300 times of a plus b and the length of the vertical change is 300 metres.

Now, similarly for ICAO code number 3, the values have been defined and there is a reduction in the values at this location, whereas in the case of the maximum longitudinal grade percent, it is increasing. Further, when we go to the category 2, then the maximum longitudinal gradient is increased further to 2% and the maximum grade change also increases to 2%, whereas the distance between the points of grade change reduces to 50 times a plus b and the length of vertical change reduces to 75 that is the distance between the two successive change overs in the gradients. In case of category 1, then these grades are same that is 2%, whereas the distance remains 50 times of a plus b and 75 is the length of the vertical change being provided at any of the one location.

Now, we look at another geometric feature that is transverse gradient.

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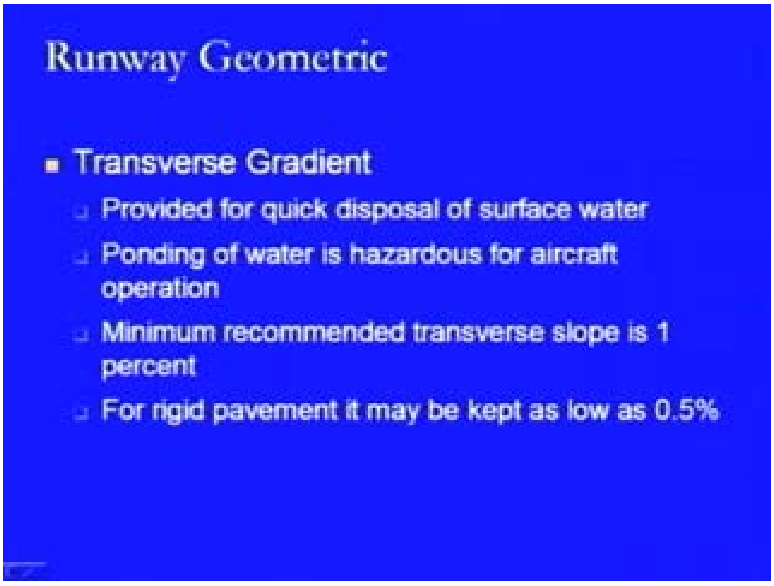

This transverse gradient, as we have discussed previously too, is provided for quick disposal of surface water and as soon as the water is being disposed off, it will become dry soon and therefore, the chances of any hazardous condition will remove and the minimum recommended transverse slope is 1% and which is provided on the basis of the minimum requirement of a grade which can drain off the water from the surface. So, that is the criteria of fixing this value. For rigid pavements, it can be kept as low as 0.5%. The 1% may be taken for the high bituminous concrete pavements being provided on the runway strips.

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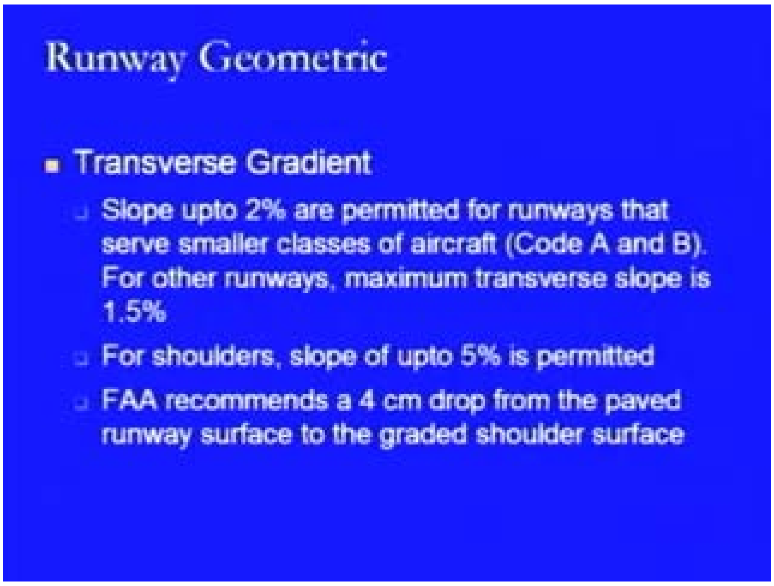

Then, a slope of up to 2% are permitted for the runways that serve smaller classes of aircrafts which are coded A or B, whereas for other runways the maximum transverse slope is fixed as 1.5%. In the case of shoulders, the slope of up to 5% is permitted. Federal Aviation Administration of US recommends a 4 centimetre drop from the paved runway surface to the graded shoulder surface. That is the specification by FAA.

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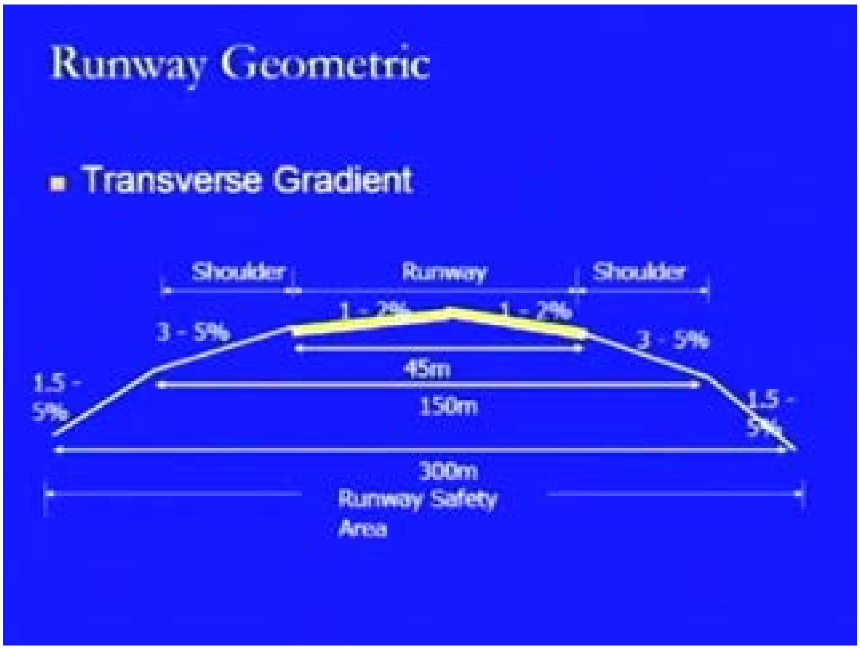

In this diagram, we look at the transverse gradients which have been specified. We have the runway strip being provided here along with some chamber at the centre, so that the water drains from to this side or to this side and the transverse slope being specified for this one is ranges between 1 and 2% and here, we are showing that this is having a width of 45 metres in the case of large airports, where the large aircrafts may be using the runway strip.

Then, we have the shoulder and in this case of the shoulder, the slope being provided as a little steeper as compared to the runway strip and varies between 3 and 5% and by this time the width of the runway strip becomes 150 metres is being shown here and this is sufficient for general categories of the aircrafts which will be using that airstrip and then finally in this embankment condition, this transverse slope can vary between 1.5 to 5% and the final value at the bottom, the width which will be there will be 300 metres. This is the runway safety area. So, this is what is to be provided in the longitudinal direction as far as the width is considered for any runway strip.

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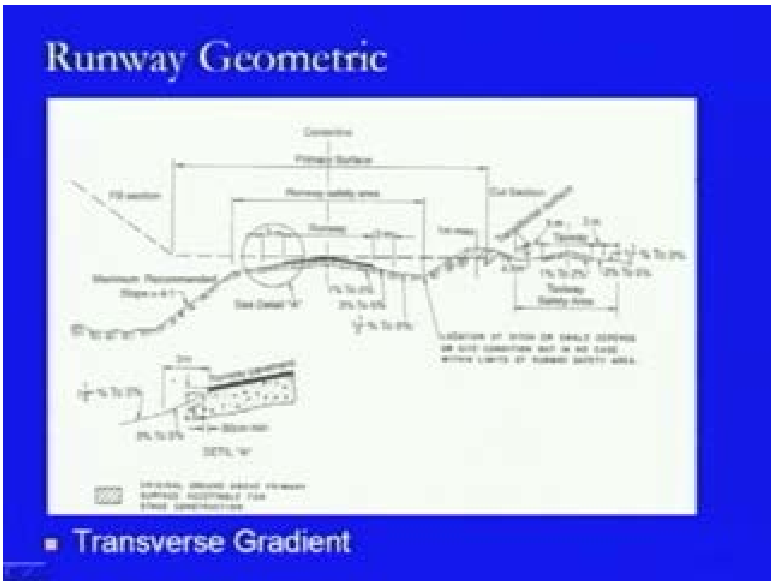

Here we are looking at another diagram, where we try to show the same sort of a condition where the runway is being provided here as a thicker black line and this runway strip is provided with 1 to 2% of grades on the two directions with respect to the centre line and then we have the shoulder on this side, where the shoulder is having the gradient as 3 to 5% and then after this shoulder, we have 1.5 to 5% of the grade being provided. So, these are the things being shown and then, this is runway, this is runway safety area from this point to this point and this is the primary surface being taken for the movement of any aircraft on this runway strip. That is the approach area generally considered and this is a normal terrain condition which is being shown here and with respect to this normal terrain condition, after this point of approach condition the transition service will start as we have seen in the case of obstructions on any airport and these transition surface will then transform into a horizontal surface after this.

Here in this diagram another thing which is being shown is position of any one taxiway on the side. This is what is another important feature of any airport and in this case of this taxiway which is being provided on this location here, this taxiway is having the width from this location to this location and it is also provided with the transverse gradient of 1 to 2% with the 3 to 5% of the shoulder conditions. So, we have this 3 metres and 3 metres from the two sides and then, this is the overall safety area being provided and this is with respect to the 4.5 metre distance from this side and 4.5 metres distance from this side. In this 4.5 metre distance area, the slope remains one and half to 3%.

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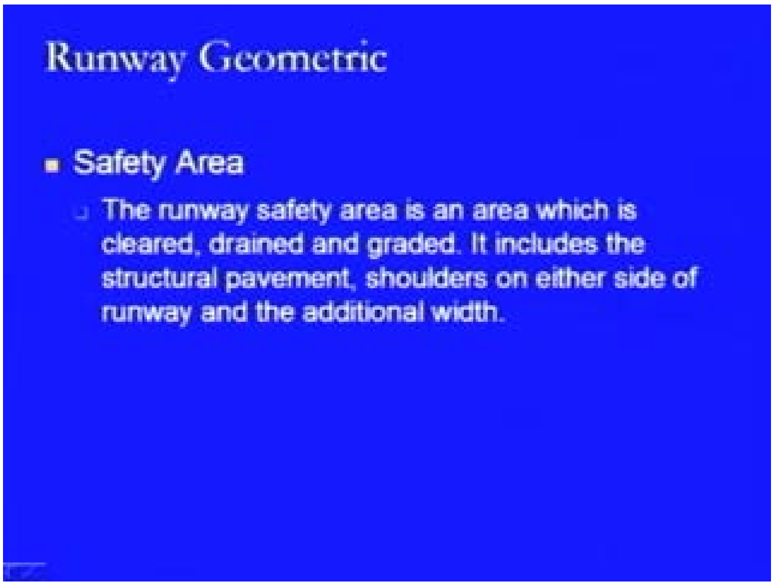

Now, we come to the safety area. The safety area is an area which is cleared, drained and graded. It includes the structural pavement shoulders on either side of the runway and additional width to be provided for the safety of the movement of the aircrafts.

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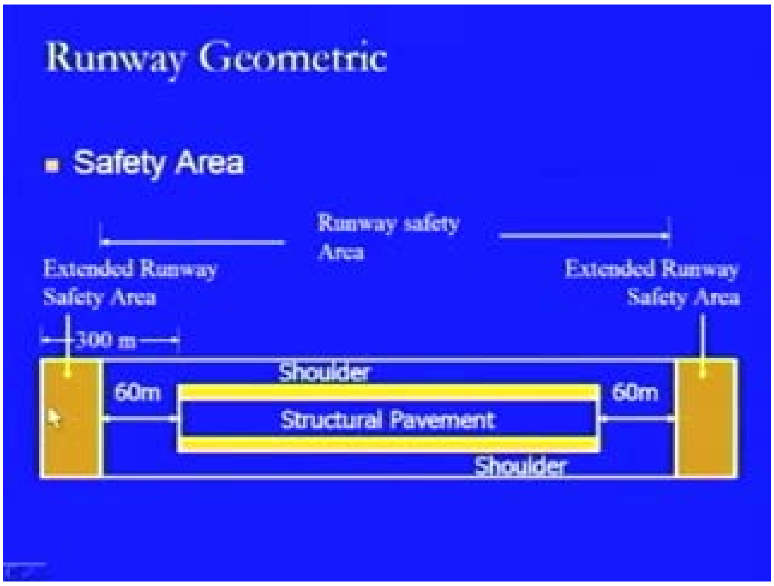

In this diagram, we are looking at the safety area. This is the pavement, this is the runway strip being provided. This runway strip is provided with the shoulder on this side and with the shoulder on the other side also and then after a distance of 60 metres from the end of the runway strip on either of the side, you provide another area which is having the same width as the width being provided in this section and this is what is known as the safety area. This is the standard safety area being provided on this side as well as on this side. The length of this safety area will be at the maximum of around 240 metres as the final value, final distance of this safety area with respect to the end of the runway strip is 300 metres. So, this is what we find is that this is the overall normal safety area being provided in this case and then, it is further extended, so that this becomes the total safety area which will be available for the movement of the aircrafts, looking at the emergencies which may be caused.

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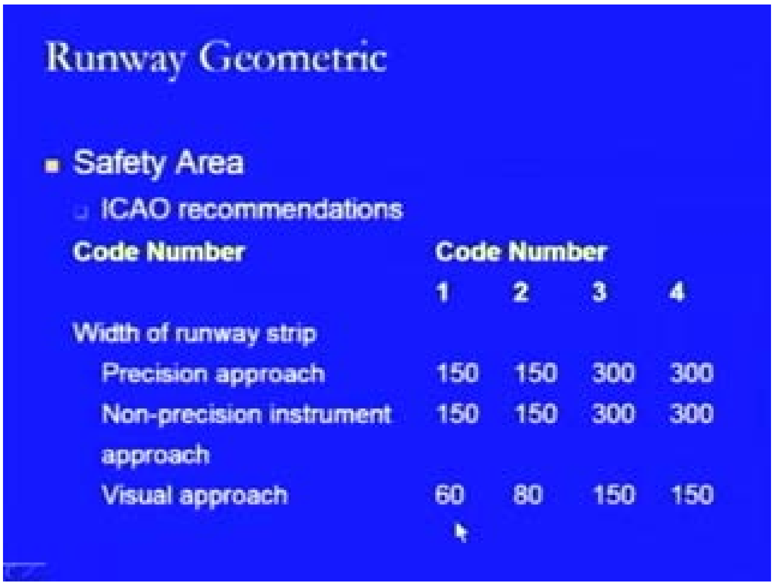

There are certain recommendations which have been given by ICAO and these recommendations are again in terms of the various code numbers being designated. This code number is in terms of like, here we are talking about the width of the runway strip, where the width of the runway strip with respect to the precision approach and if we have the categories of the airports as 1, 2, 3, 4, then this value is being provided as 150 metres, 150 metres, 300 metres and 300 metres. In the case of non-precision instrument, then it remains the same in this case and then, for usual approach the values decreases and they become 60 metres, 80 metres, 150 metres and 150 metres.

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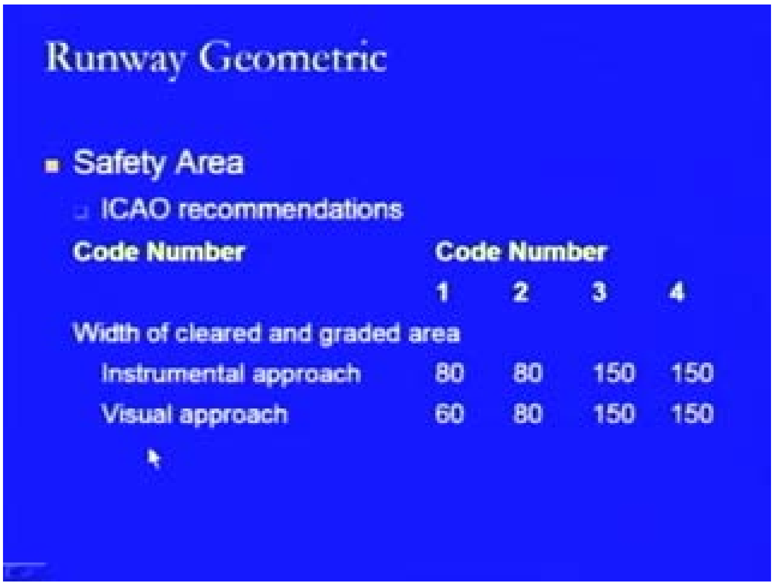

Further, there are some more recommendations associated with the ICAO and it is in terms of the width of the cleared and the graded area which is provided on the sides as well as the ends of the runway strips and in the case of instrumental approach, this is 80 metres, 80 metres, 150 metres and 150 metres for the code categories of 1 to 4. In the case of visual approach, this value is again 60, 80, 150 and 150.

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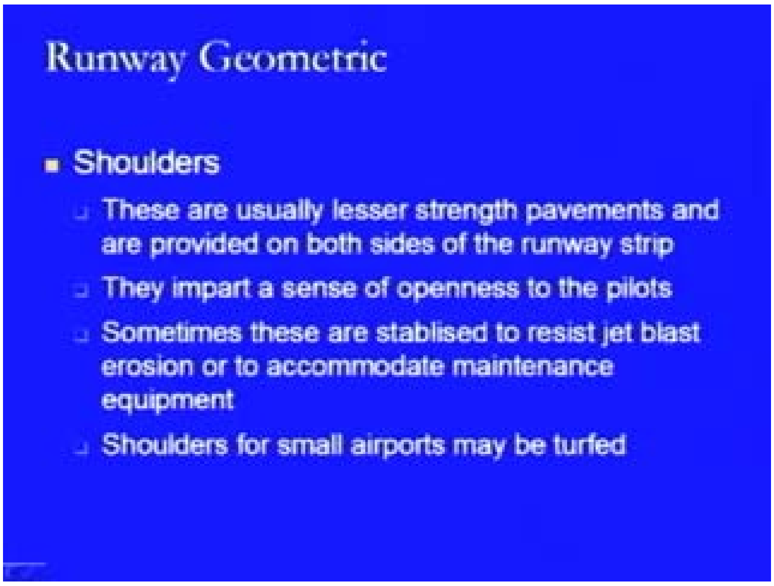

Then, we come to the aspect, as we have been discussing again and again, shoulders. In the case of shoulders, these are usually provided with lesser strength pavements, because the loads are not directly coming on the shoulders. This is remote condition when the load may come to the shoulder and these are provided on both sides of the runway strip and these impart a sense of openness to the pilot, because that is sort of a psychological clearance which is being provided on the two sides of the runway strip which otherwise may not be required as far as the width of runway strip is concerned. Sometimes these are stabilized to resist jet blast erosion or to accommodate maintenance equipment that is on the basis of the requirements. If the maintenance equipment has to move, then they have to be stabilized or at times they have to be made a little in the form of a pavement, not may be having the full strength as being provided in the case of the runway strip. The shoulders for small airports they maybe turfed. That is they are provided with some material at the top.

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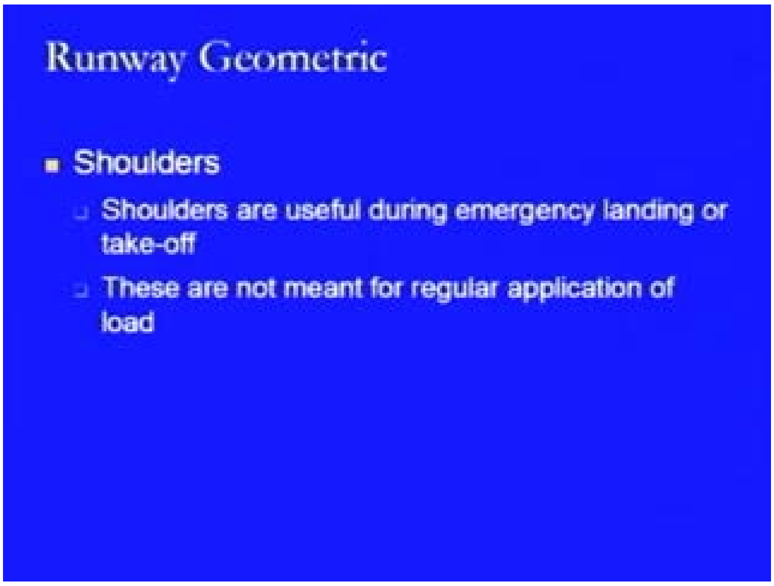

The shoulders are usually used for during the emergency landings or take-offs. That is the main specific function of the shoulders, but then they are not meant for the regular application of the load means during take-off or during landing, as on regular basis, they should not be used or otherwise they will deteriorate at a much faster rate, because they are not provided with the full strength pavement, as in the case of a runway strip.

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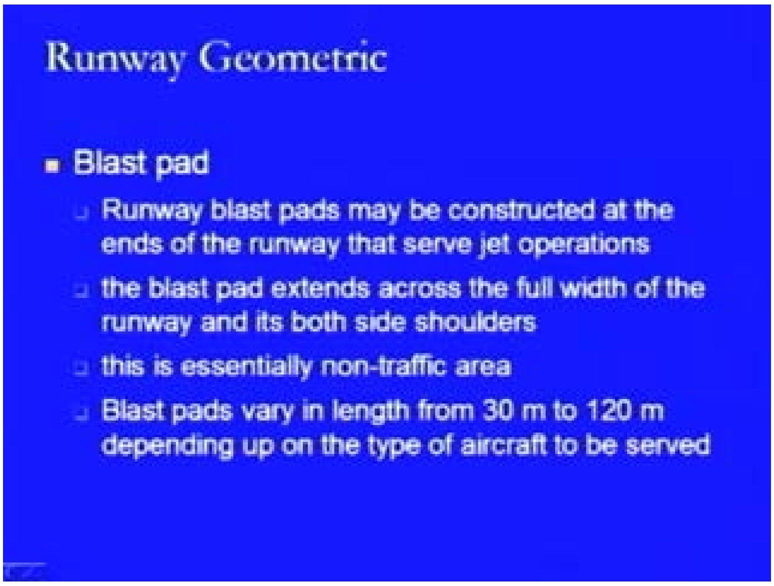

Then, the next aspect is a blast pad. In blast pad, the runway blast pad may be constructed at the ends of the runway that serve jet operations and the blast pad extends across the full width of the runway and its both side shoulders and this is essentially non-traffic area. We are not supposed to use this particular area for the movement. The blast pads vary in length and these varies from 30 metres to 120 metres depending on the type of the aircraft to be served.

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Now, we have another condition, where we have the parallel runway systems and in this case, the spacing depends on whether the operation is VMC or IMC that is visual meteorological condition or the instrument meteorological condition. In the case of IMC, it is desired to accommodate simultaneous arrivals or simultaneous arrivals and departures and in the case of airport serving both heavy and light aircraft, the simultaneous use of runways even in the VMC conditions may be dictated by separation requirements to safeguard against the wake vortices which are formed at the tail ends or which are formed at the ends of the wings.

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The recommendations here are that under VMC there are in respect to the wake vortices FAA recommends that there should be a centreline separation of 90 metres for single engine propeller aircraft, 150 metres for twin engine propeller aircraft, 210 metres for all other aircrafts and there should be a separation increased by 360 metres for airplane design group of V and VI category that is the bigger category.

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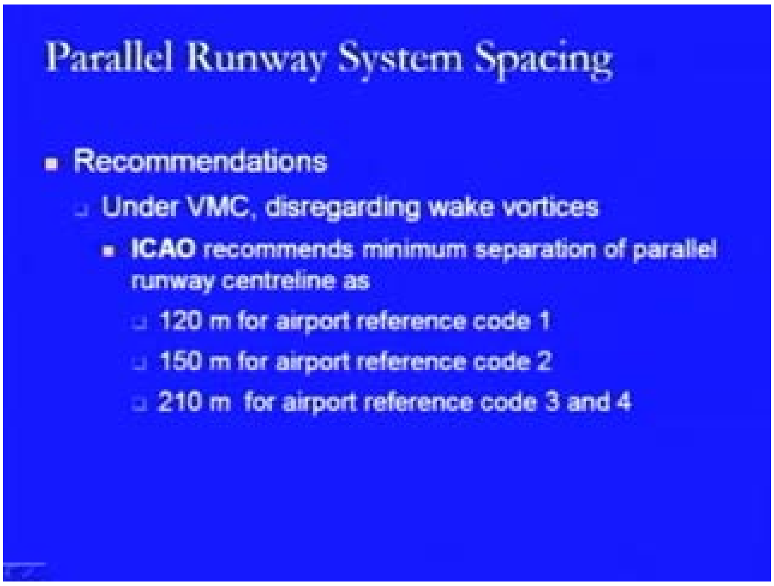

Further recommendations are that under VMC, we should disregard the wake vortices. Here, the ICAO recommendations are there which says that the minimum separation of parallel runway centreline should be as 120 metres for airport reference code 1, 150 metres for airport reference code 2 and 210 metres for airport reference code 3 and 4.

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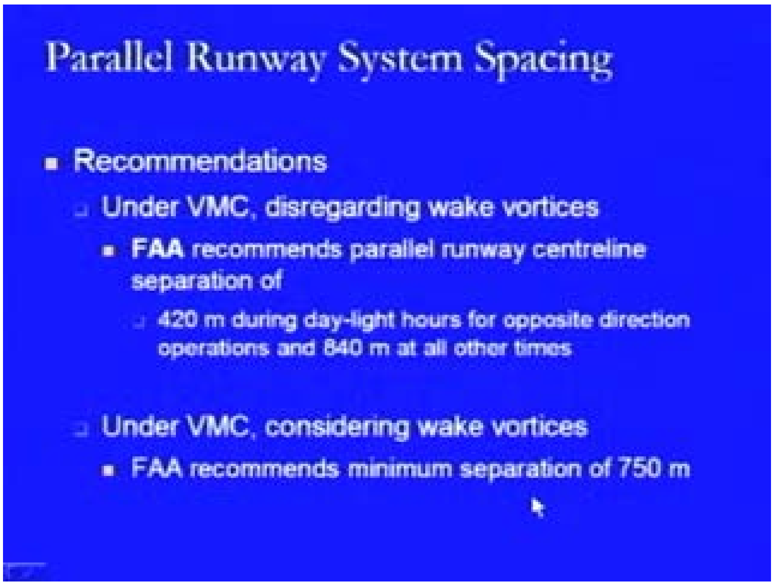

Here, in the case of VMC, the FAA recommendations are that the centreline separation should be 420 metres during day-light hours for opposite direction operations and 840 metres at all other times. Under VMC, considering the wake vortices, the FAA recommends that the minimum separation should be of 750 metres.

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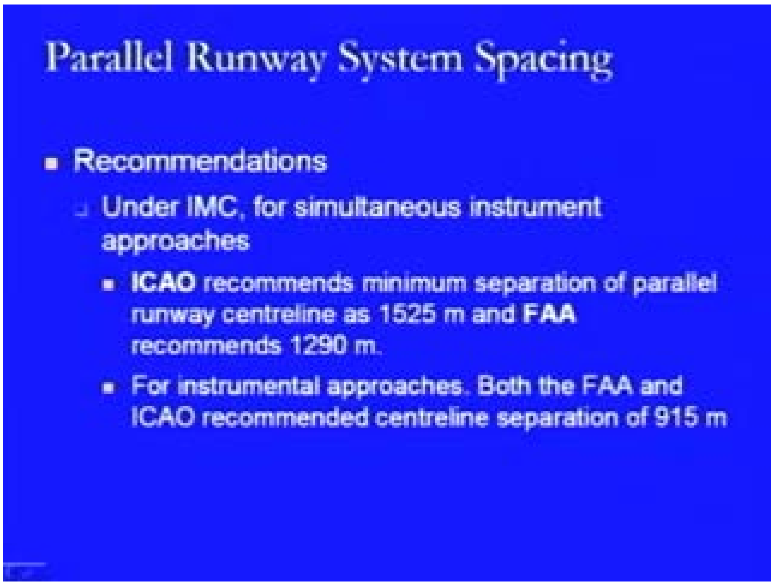

Then, in the case of IMC, for the simultaneous instrument approaches, the ICAO recommends the minimum separation of parallel runways centreline of 1525 metres, whereas the FAA recommends this distance as 1290 metres. In the case of instrumental approaches, both the FAA and ICAO recommend the centreline separation of 915 metres. So, these are certain recommendations as far as the provision of the different parallel runways are concerned.

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Then, further there are some more recommendations of Federal Aviation Administration and it speaks of that in the Simultaneous VFR conditions, for all aircraft distance or the spacing can be 210 metres, whereas for Simultaneous IFR operations under segregated conditions, it can be 760 metres. For Radar departure, it may be 760 metres. For non-radar departures, it can be 1000 metres and for dependent arrivals it can be 915 metres and for independent arrivals it may be 1300 metres.

So, this is what we have seen in this particular lecture is that what are the various geometric which needs to be provided on any of the runway strip and these varies from the length of the runway strip to width of the runway strip, to safety area to sight distance and to the different type of the gradients which needs to be provided. Alongside these things, we have also discussed about the recommendations which have been given ICAO or FAA as available.

Apart from this type of discussion, what we have tried to look at is that if two parallel runways are provided, then what is the type of this spacing which should be provided between those two runway strips? This is all about the runways and their provisions and design ns. Now, from the next lecture, we will be shift from the runways and we will be discussing about another feature like taxiway, which is one of another parallel important facility being provided on any of the airport with respect to runway strip. With that we stop at this point and I say goodbye to you and thank you to you.