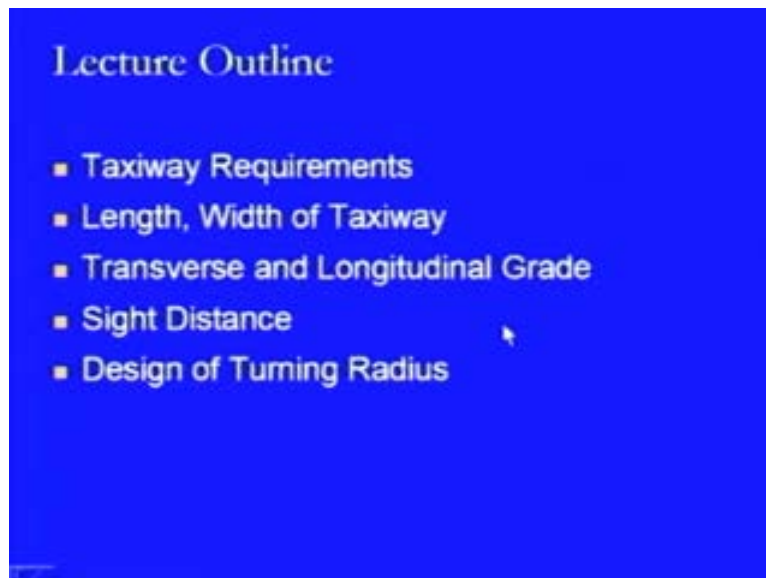


**Transportation Engineering – II**  
**Dr. Rajat Rastogi**  
**Department of Civil Engineering**  
**Indian Institute of Technology - Roorkee**

**Lecture - 34**  
**Taxiway**

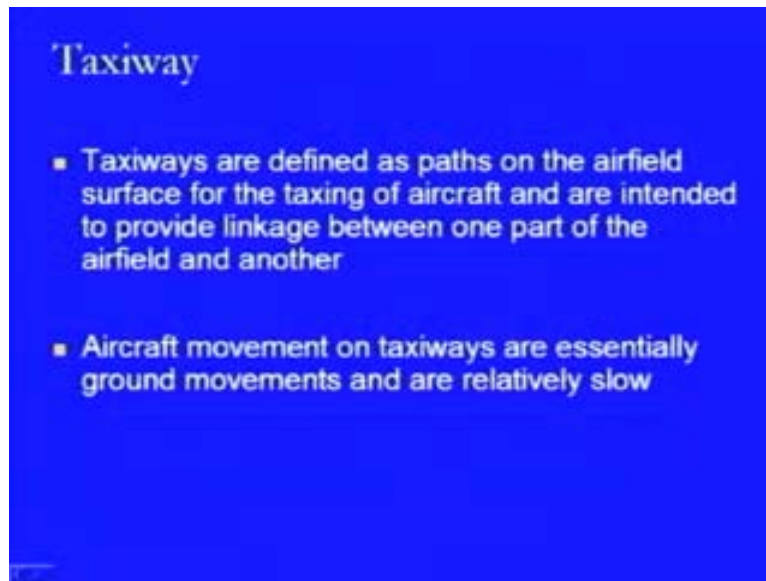
Dear students, I welcome you back to another lecture under the lecture series on course material of Transportation Engineering – II. In the previous lectures, we have already discussed about one of the important components of any airport that is runways. We discussed about the various features of the runways in terms of the orientation of runways, the configuration of runways, the length of runway strips and the geometric features of the runways. In continuation of the same, in today's lecture we will be discussing about another important component of any airport which is termed as taxiway.

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In the case of taxiway, we will be discussing about the taxiway requirements, we talk about the length and the width of the taxiway, the transverse and the longitudinal grades, the sight distance and the design of the turning radius.

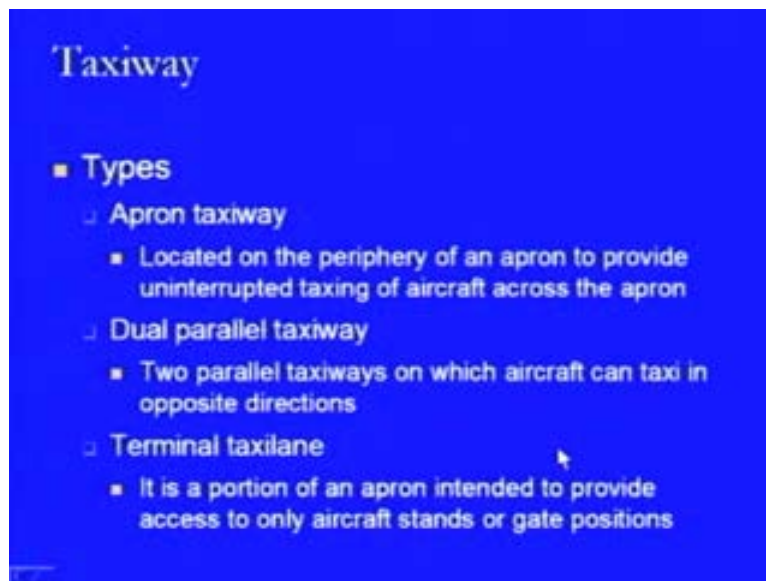
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So, we start with the taxiway and try to define that what is taxiway. Taxiways are defined as paths on the airfield surface for the taxing of the aircraft and are intended to provide linkage between one part of the airfield and another part of the airfield. What it wants to say is that we are trying to provide the connectivity for those aircrafts, which are reaching or arriving on any of the airport, so that they can taxi on this particular lane away from the active runway strip on which the continuous movements are going on and in that sense it provides a connectivity between the different locations or different parts of any airport and all those such connectivities are termed as taxiways.

These taxiways have the aircraft movement which are essentially ground movements. There is no air movement associated with these and the movements are relatively slow. They are much, much slower as compared to the speeds at which the aircrafts have landed or at which they are going to take-off.

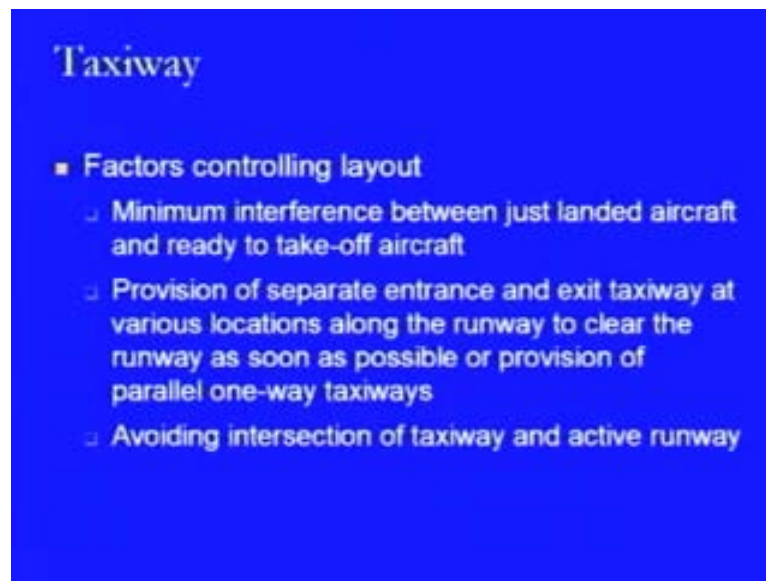
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There are different types of taxiways. There is one type which is termed as the apron taxiway. The word itself defines that they are provided very near to the apron, so as to provide the storage of the aircrafts somewhere at the periphery of the apron, so that there is no interruption to the other movements of the aircrafts on the apron. So, that is what is the apron taxiway. Another type of taxiway is the dual parallel taxiway. Again, this name itself shows that there are two taxiways which are laid parallel to each other and in this case, there is one functional condition which is **there is** that the taxiways can be exclusively used for a single directional operation. That is on two taxiways we have two opposite directional movements or the aircraft will be taxiing in opposite directions.

Then, the third type of taxiway is known as the terminal taxilane and this terminal taxilane is provided very near to the terminal building and it provides access to the terminal in terms of the access to the gate positions or to the stands where the aircrafts can stand, so as to take the passengers or so as to just have the passengers who will be coming out of the aircraft. So, at that particular location, in between those locations, whatever the lane is being provided that lane is known as terminal taxilane.

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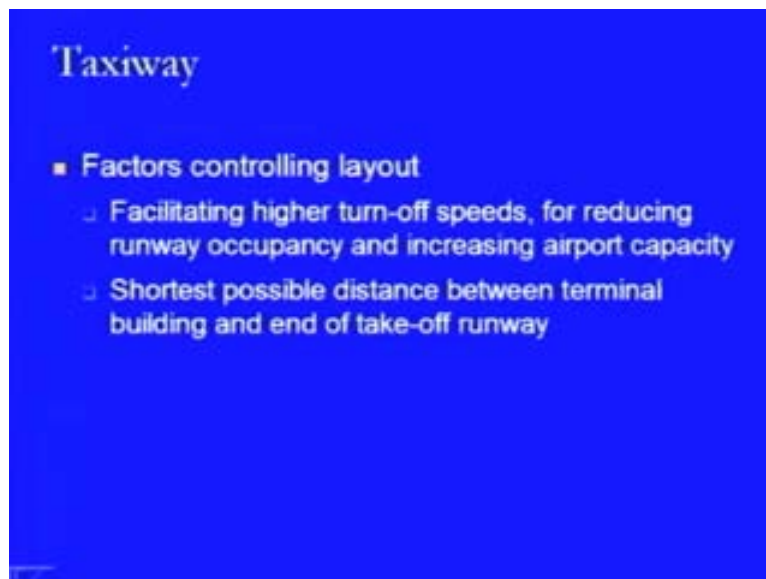
We now look at some of the factors which control the layout of any taxiway or layout of any taxiway. The factors are that there should be minimum interference between the just landed aircraft on a runway strip and the ready to take-off aircraft which is coming towards the runway strip. So, it means there are two simultaneous operations which are going on. There is one aircraft which is landing; at the same time, there is another aircraft which is ready to take-off. So, a connectivity is to be provided in such sense that there is minimum interference between these two type of operations and they cross each other with minimum hindrance.

Further, there should be provision of separate entrance and exit taxiway at various locations along the runway and this is required, so as to clear the traffic which is coming on the runway in terms of the landing aircraft as soon as possible and this will make them available for the other landing operation or for another take-off operation and in this case, we can also provide the parallel one way taxiway systems by which on one particular taxiway the aircrafts are coming towards the runway strip, whereas on the other taxiway, the aircrafts are coming from the runway towards the terminal area. So, that is how the parallel one way taxiways can be provided.

Another important thing at the time of fixing the layout of the taxiways within the overall airport space is that there should not be any intersection of a taxiway with the active runway. The reason behind is that these two components have different speed

conditions. The active runway is having the speed as much higher value where the taxiways are having the speed of the aircraft which is quite low. Therefore, if there is an intersection, then this movement of an aircraft on the taxiway from one side to the other side of the runway strip will cause delay or the aircrafts which are using the runway for say, take-off. At the same time if there is landing, then it may create a hazardous condition or may cause even an accident if such type of operation is going on, on an intersecting taxiway and the runway.

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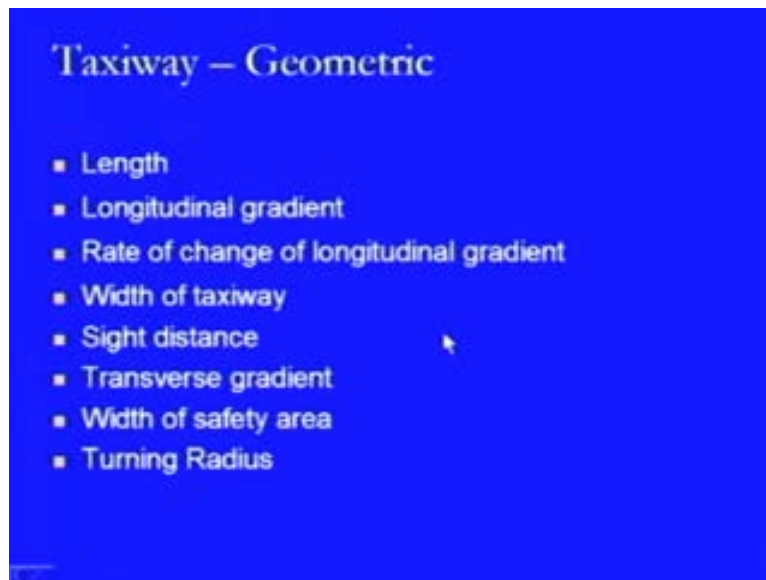


Further, there is a requirement of facilitating the higher turn-off speeds for reducing runway occupancy and thus increasing the airport capacity. What it signifies is that the design feature of the connectivity of taxiway with the runway. This design feature should help in facilitating the turn-off at a much higher speed and if this is possible, then with the little reduction in the speed of the landing, aircraft we will be able to take-off the aircraft from the runway strip and it will come to the taxiway strip. This will help in reducing the overall occupancy time of any runway strip by an aircraft and it means, now the same runway strip can be used for another operation and thus the airport capacity will increase.

Another point is that there should be a possible shortest distance between the terminal building and the end of take-off runway. That is a thing which needs to be taken care of, so as to provide the minimum travel from the terminal building to the runway strip

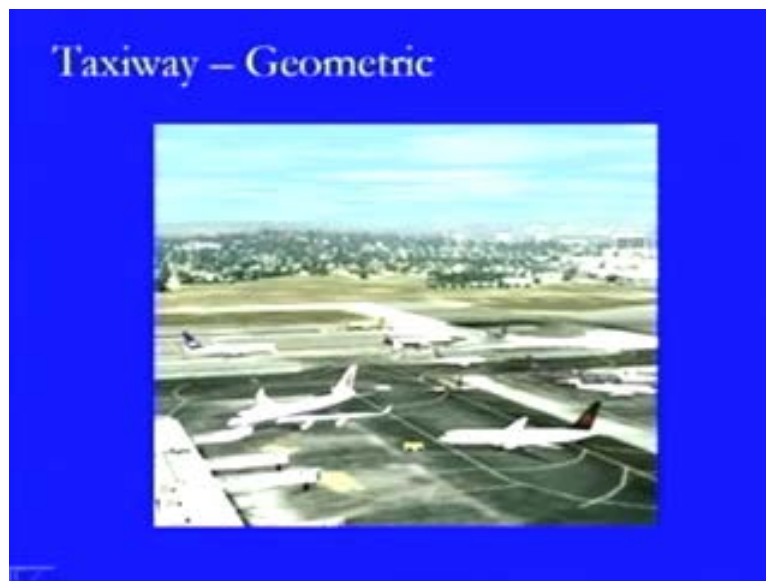
at the time of taking off. Though we also try to have the similar sort of a condition for those aircrafts which are landing and which come towards the terminal building or towards the airport stand to which they will be taken, so that the passengers can de-board.

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With this aspect in mind, now we will try to look up at the different geometric features of any taxiway. In the case of geometric features, we will be looking at the length of the taxiway, the longitudinal gradients, the rate of change of longitudinal gradients, the width of taxiway, the sight distance, the transverse gradient, the width of the safety area and the turning radius. So, these are the different geometric features which we will be looking at and it is in the similar form as we have done in the case of runway strips.

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Here in this photograph, we are looking at one of the operational area of any airport. In this photograph, we can see that there is terminal building being provided on this side. This is the part of the terminal building being shown in this photograph. Then, these are some of the extended pathways or the corridors which are coming out of this terminal building, which provides the connectivity to the aircraft that is to the door of the aircraft.

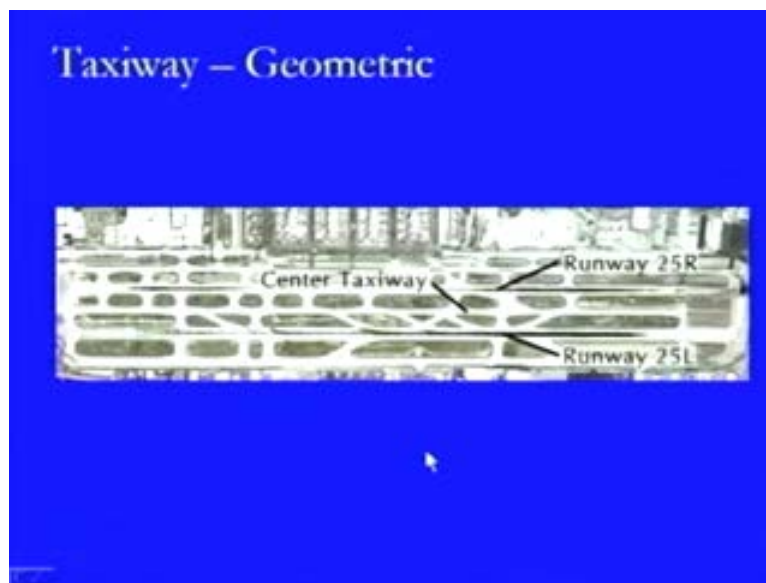
Now, this is the door of the aircraft, as a **block** this part being shown here. So, this corridor provides the connectivity directly to this level. So, the person who is coming from this terminal building, do not have to go up or down. They can straight away move in this corridor and it will come up to this point. All these corridors being provided here, they are flexible in nature means they can come, they can be stretched or they can be pulled back and will be placed up to this position, because of these wheels being provided at the bottom and they are sturdy enough so as to take the load of the passengers who will be coming from the terminal building and going to this aircraft.

In the similar [...] case, what we can see is that there are, there is a runway strip being provided on this side and with respect to this runway strip, there is a connectivity provided at this one from this side to the taxilanes. So, we have the two parallel taxilanes being provided and we can see that the aircrafts are moving in

certain direction. These aircrafts are moving in this direction, whereas these aircrafts are moving in this direction, on these parallel two runway strips.

Now, from these runway strips, these aircrafts will take a turn and they will come to this particular area and this is another connectivity being provided between these taxiways and this one and this is what is termed as the taxilane and this a terminal taxilane, because this is provided very near to the terminal and provides a connectivity to the normal taxiway and here, the aircraft can go to this direction and it can go to the other direction and we can see that there are some aircrafts being shown at this location, where they are standing with their nose in this direction, whereas in this direction here, these are standing with the nose towards the left hand direction. So, that is how they are oriented towards different directions.

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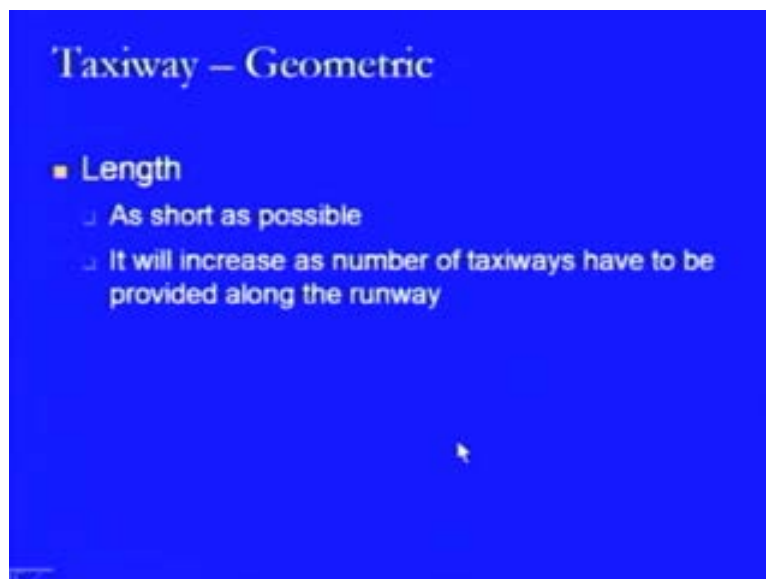
This is another photograph being taken from the top, where there is a runway strip being defined here like this. This is one runway strip and there is a parallel runway strip being provided at this location. So, we have the two parallel runway strips being designated as 25R and 25L. This 25R means for right and L means for left condition. So, this is a right runway strip and this is a left runway strip and this 25 defines the angle out of the 360 degrees at which this runway strip is being oriented. So, this is oriented at an angle of 250 degrees. This is the way it is being defined.



250 is defined here as **two** 25. So, at the angle of 250 degrees, we have provided two runway strips on this airport and in between these two runway strips, a central taxiway strip is being provided. Now, what we have discussed previously as a requirement of the provision of the taxiway is that it should have the multiple access points to the runway strip. So, here we can see that very easily that this runway strip or this runway strip, they are being connected to the central taxiway by number of connectivities and we can see the connectivities in this direction as well as in this direction and similarly, here in this direction or in this direction or likewise.

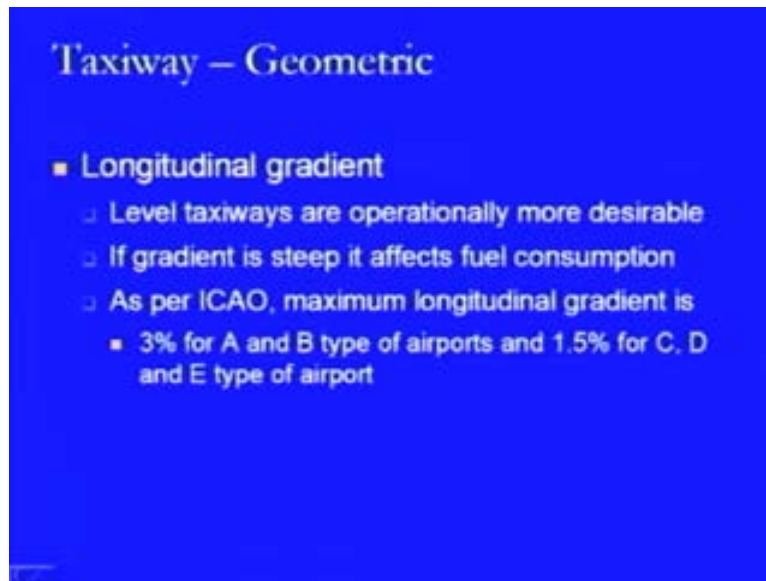
It means the aircraft which is coming from this direction has a landing can take, can go away from this point or from this point to the taxiway or if it is coming from this direction, then similarly it can go from this point or from this point or this point to the taxiway. So, it means on the basis of the propulsive power, if it is stopping in an early condition it can go away from the runway earlier or if it is going to a little further distance, then it will come out of it at a further distance and this is what is the main use of the connectivity of the taxiway with the runway strip, so that the efficiency of the runway strip and the traffic handling capacity of the runway strip can be enhanced and if this can be enhanced, then the overall traffic handling capacity of the airport will also increase.

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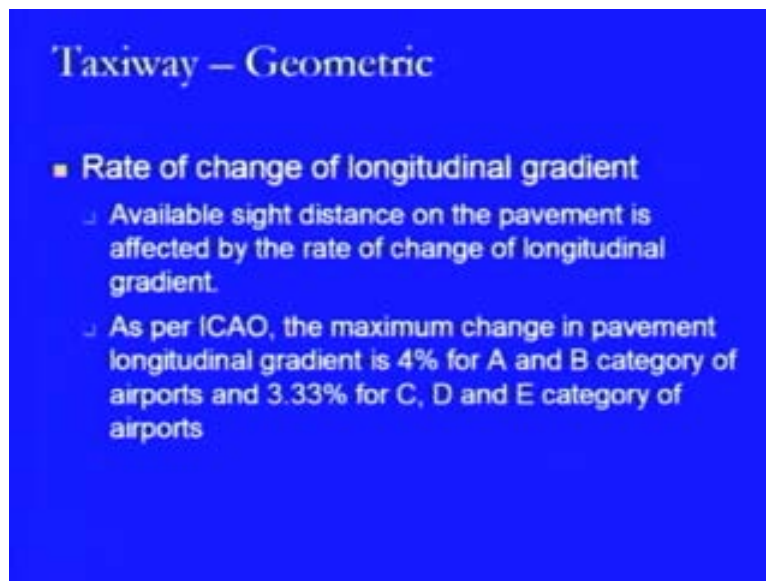
With this aspect in mind, we start with the geometric features that is the length. The length of the taxiway should be as short as possible. It will increase as the number of taxiways has to be provided along the runway, as we have seen in the previous case. There was a different connectivity, so it will increase the overall length of the taxiway.

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In the case of the longitudinal gradient, the level taxiways are operationally more desirable. That is the similar condition to the runway strips. If the gradient is steep, then it affects fuel consumption. This is again the similar sort of the condition as we have discussed for runway strips. As per ICAO, the maximum longitudinal gradient is fixed depending on the type of the airport and in the case of A and B type of the airport, it is designated as 3% maximum, whereas for C, D and E type of the airport, it is defined as 1.5% maximum.

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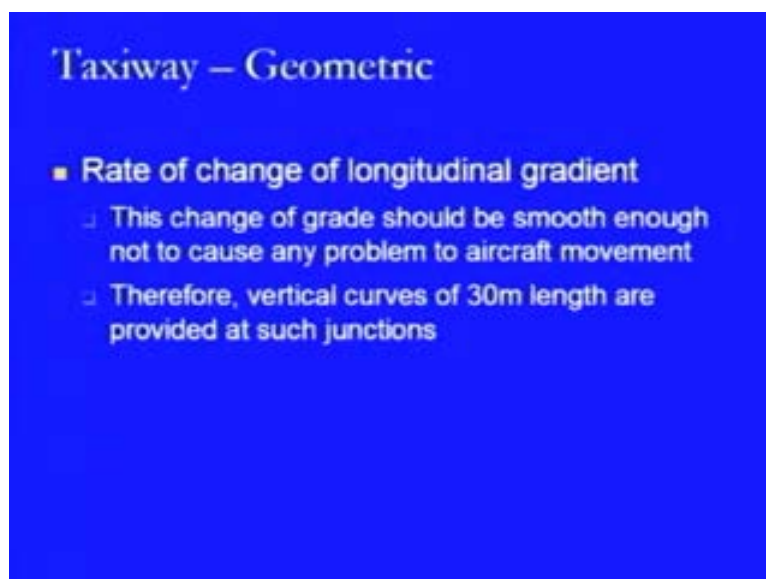


**Taxiway – Geometric**

- **Rate of change of longitudinal gradient**
  - └ Available sight distance on the pavement is affected by the rate of change of longitudinal gradient.
  - └ As per ICAO, the maximum change in pavement longitudinal gradient is 4% for A and B category of airports and 3.33% for C, D and E category of airports

Then, another specific feature related to the longitudinal gradient is the rate of change of longitudinal gradient. This rate of change of longitudinal gradient is controlled by the sight distance available and in that sense, what we can say is that the available sight distance on the pavement is affected by the rate of change of longitudinal gradient. So, it is vice versa condition between the two things. Again, as per ICAO, the maximum change in the pavement longitudinal gradient is fixed as 4% for A and B category of airports and it is fixed at 3.33% for the C, D and E category of airports. So, these are the specifications related to the rate change of longitudinal gradient.

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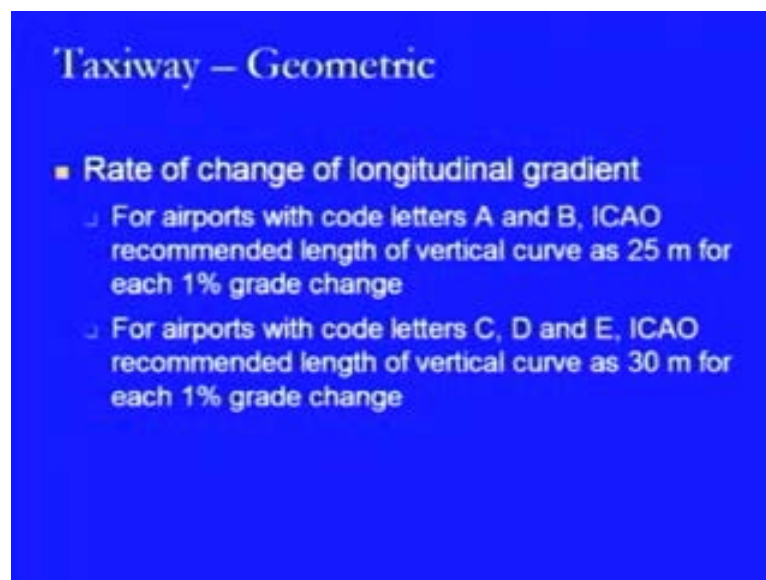


**Taxiway – Geometric**

- **Rate of change of longitudinal gradient**
  - └ This change of grade should be smooth enough not to cause any problem to aircraft movement
  - └ Therefore, vertical curves of 30m length are provided at such junctions

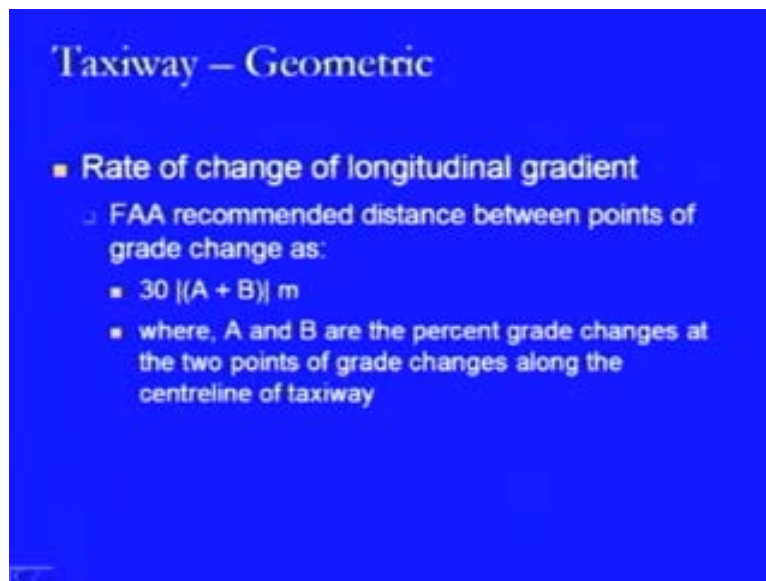
In the same case for the rate of change of longitudinal gradient, this change of grade should be smooth enough. It should not create any jerk position at the point where the connectivity is being provided and if it is being done, then it will be a problematic condition to the movement of an aircraft across that point. So, that is why, the smoothing is to be done and this smoothing obviously, can be provided by a use of the vertical curves as we have seen in the case of runways or we have also seen the same sort of conditions in the case of railways or the highways, means the concept remains the same. Therefore, the vertical curves of 30 metre length are provided at such junctions. So, that is another specification associated with this one along with the rate of change. We are talking here about the vertical curve and the length of the vertical curve is fixed at 30 metres.

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Now, in the case of airports which are designated as, led by letter A and B, again ICAO recommends the length of the vertical curve as 25 metres for each 1% in the grade change. So, if there is more percent of the grade change, then with respect to that we multiply with 25 metres, so as to get the length of the vertical curve. Whereas, in the case of the airports where they are being designated by the code letters as C, D and E, then ICAO again recommends the length of the vertical curve as 30 metres for each 1% change in the grade. So, these are the specifications with respect to the type of the airport and the value which is recommend as the rate of change along with the length of the vertical curve and the overall value which is to be provided in this case.

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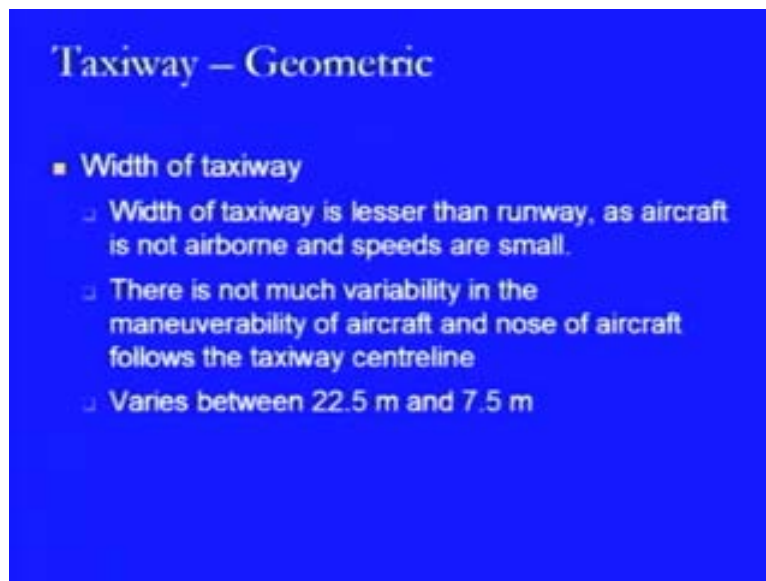
**Taxiway – Geometric**

- **Rate of change of longitudinal gradient**
  - FAA recommended distance between points of grade change as:
    - $30 |A + B| \text{ m}$
    - where, A and B are the percent grade changes at the two points of grade changes along the centreline of taxiway

Then, similar conditions are there with respect to FAA. FAA recommends the distance between the points of grade changes. This is what we have seen and we have seen a diagram of the change of grade from x to y to z that is plus x to minus y to plus z and then, there was a change in the gradient from x to y designated by A and then, there was a change in gradient from y to z designated by B. In the similar sort of condition, for the taxiways, the FAA defines that this value can be 30 times of A plus B and this A plus B is being taken in the absolute form, where the effect of the positive or the negative value is being taken away.

So, these A and B they are percent grade changes at the two points of grade changes along the centreline of the taxiway. So, this is another recommendation and the guideline being provided for the provision of the different grades and then, at the same time so as to maintain a distance between those changes of the grades.

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Now, we come to another geometric feature of the taxiway and that is the width of the taxiway. The width of the taxiway is lesser than the width of the runway. The reason behind is that the aircrafts are not air borne and the speeds are small in this case. Therefore, we can control the movement of the aircraft as compared to the movement on the runway, because with the small change in the controlling feature of the aircraft when it is coming on the runway and moving at a higher speed, then it may be a disastrous condition whereas in the case of the taxiway, because the speeds are very less the steering of the .... aircraft will not create very big effect in the case the width of the taxiway is being provided lower.

Further, there is not much variability in the manoeuvrability of the aircraft that is a thing which I was just discussing is that it is a sort of a normal movement of the aircraft from the taxiway in a certain direction, so as to reach the destination that is the terminal or the runway and in this case, the nose of the aircraft mostly follows the taxiway centreline and that is the one type of the guideline which is being provided that the pilot may follow the centreline of the taxiway and the nose will keep on moving along that one and in that case whatever is the width that is required that width is to be provided. Generally, this width of the taxiway varies between 22.5 metres and 7.5 metres.

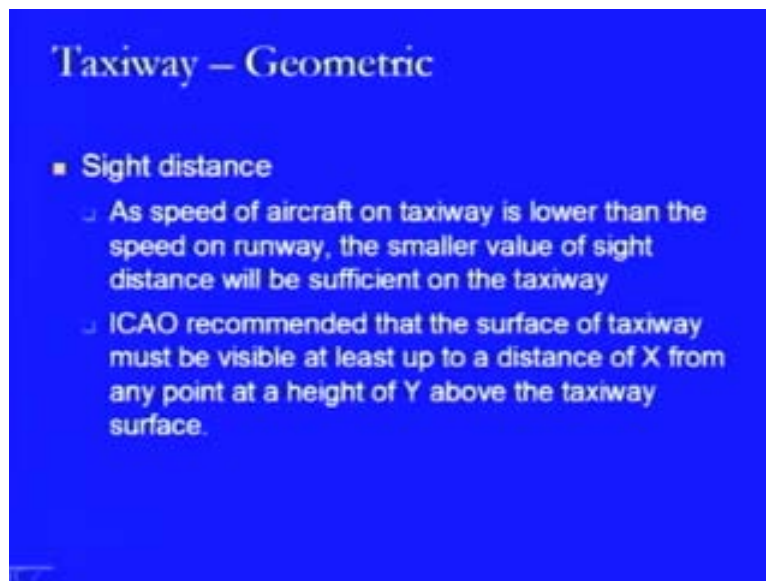
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Taxiway – Geometric	
■ Width of taxiway (ICAO)	
Airport Code	Taxiway width
A	7.5 m
B	10.5 m
C	15 m (18 m if the taxiway is used by aircraft with a wheelbase equal to or greater than 18 m)
D	18 m (23 m if used by aircraft with an outer main gear wheel span equal to or greater than 9 m)
E	23 m

Then, as far as the ICAO recommendations are concerned for the width of the taxiway, what we look is that it is defined in terms of the airport category and if the airport code is A then the taxiway width is 7.5 metres, if it is B then it is 10.5 metres, if it is C then it is 15 metres and it is at times provided as 18 metres if the taxiway is used by aircraft with a wheelbase equal to or greater than 18 metres. In case of D category of the airport, the value is 18 metres and similarly here also it is enhanced to 23 metres if it is used by an aircraft with an outer main gear wheel span equal to or greater than 9 metres. In the case of category E, this value is 23 metres. So, these are the various categories of the airports for which the taxiway widths have been defined and these vary from 7.5 metres to 23 metres.



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Now, another specific geometric feature of taxiway is the sight distance. As we have discussed, the sight distance is more important than the connectivities. As the speed of the aircraft on taxiway is lower than the speed on the runway, the smaller value of sight distance is sufficient on the taxiway. We know that, as we have computed the value of the sight distances from very starting when we have read highway engineering and there we have seen that as the speed keeps on increasing, the sight distance keeps on increasing and it becomes something like 180 metres at a speed of 100 kilometres per hour speed, whereas at a speed of 40 kilometres per hour, the sight distance requirement is around 50 metres.

So, in the similar form, here when we are looking at, the taxiways are being governed by the lower speed of the aircrafts and therefore, the requirement of the sight distance is also lower. ICAO recommends that surface of taxiway must be visible at least up to a distance of X from any point at a height of Y above the taxiway surface. That is what ICAO recommends that if we are at any point and we are at a height of Y above the surface, then we should be able to see up to a distance X and how these X and Y are being defined by ICAO we will look at those values.



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Taxiway – Geometric		
■ Sight distance		
Airport code	Y	X
A	1.5 m	150 m
B	2 m	200 m
C,D and E	3 m	300 m

They have been defined with respect to the airport code that is the categorization of the airports and here for the airport code of A, the Y value that is the height above the pavement surface is 1.5 metres and in this case, the sight distance should be 150 metres, whereas in the case of airport code B, the height is 2 metres and the distance is 200 metres. For C, D and E category of the airports, the height is 3 metres, whereas the distance is 300 metres.

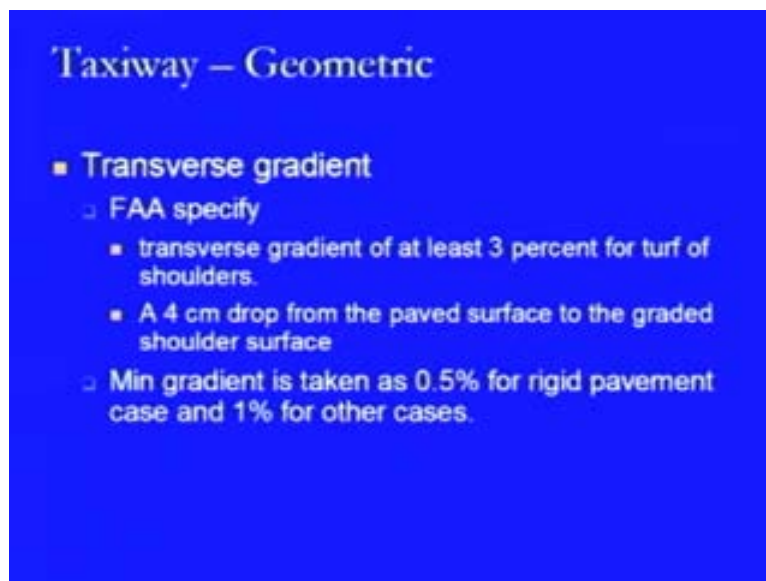
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Taxiway – Geometric	
■ Transverse gradient	
□	Adopted same as recommended for runways
□	ICAO recommended maximum pavement transverse gradients of 2% for A and B and 1.5% for airports with code C, D and E type of airport.

Now, we look at transverse gradient. This is another type of the gradient which needs to be provided, which needs to be considered, when any of the geometrics have to be taken up and the conditions remains the same as we have talked about the runways. They are adopted on the same recommended conditions like runways. Basic thing is that they are provided, so as to drain of the water, so as to bring the taxiways again to the dry condition, so that there is no slipping, there is no ponding of water on the taxiways and which may be detrimental or which may be hazardous for the movement of the aircraft on the taxiways.

ICAO again recommends the maximum pavement transverse gradient of 2% for A and B category of airports, whereas in the case of C, D and E category of airports, it is being defined and designated as 1.5% again by ICAO.

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**Taxiway – Geometric**

- **Transverse gradient**
  - FAA specify
    - transverse gradient of at least 3 percent for turf of shoulders.
    - A 4 cm drop from the paved surface to the graded shoulder surface
  - Min gradient is taken as 0.5% for rigid pavement case and 1% for other cases.

Then, there are some recommendations which have been given by FAA and FAA says that the transverse gradient of atleast 3% is to be provided for shoulders which have been turfed, being provided with some fixed objects and also a 4 centimetre drop from the paved surface to the graded shoulder surface should be provided. That is another recommendation being given by FAA. The minimum gradient in the case is being taken as 0.5% for the rigid pavements and 1% for the other pavements. This remains the same as in the case of the runway strips, because here as well as there the concept remains the same and that is the drainage of water.

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Taxiway – Geometric					
■ Transverse gradient (ICAO)					
Strip	Aerodrom Code				
Maximum transverse	A	B	C	D	E
Graded portion					
Upward	3.0	3.0	2.5	2.5	2.5
Downward	5.0	5.0	5.0	5.0	5.0
Un-graded portion					
Upward	5.0	5.0	5.0	5.0	5.0

Now, further there is a value being defined by ICAO, where the **minimum transverse graded portion is being defined for**, maximum transverse value is being defined for the various aerodrome code ranging from A to E and in this case, if the graded portion is in the upward direction, then the values ranges from 3% to 2.5% starting from A to E. If it is in the downward direction, then we find that it is being provided in a constant form as at a rate of 5%. Similarly, in the case of un-graded portion, if it is in the upward direction, the value remains as 5%.

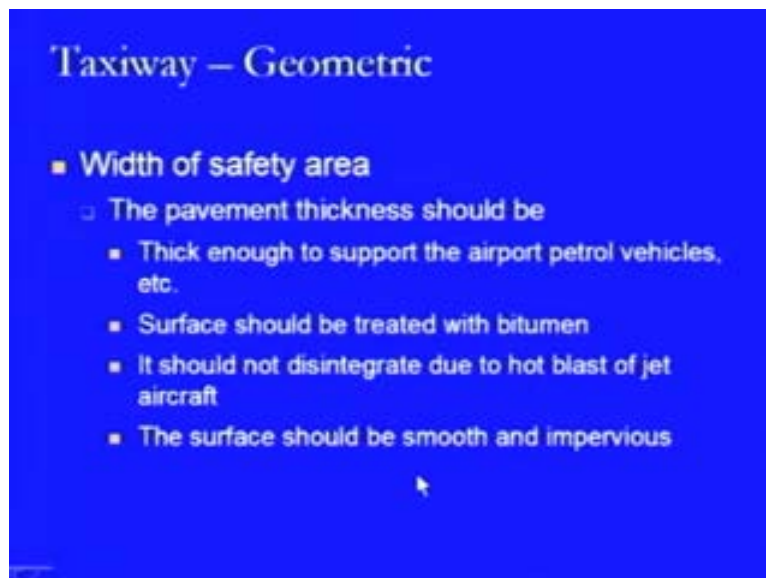
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Taxiway – Geometric	
■ Width of safety area	
□	Safety area is made up of partially paved shoulders on either side plus the area which is graded and drained
□	In case of jet aircraft, a paved surface of light strength material on either side of taxiway edge with min width of 7.5 m on both sides of pavement edge is provided.

Another thing which we have to look at is the safety area and the width of the total space which is to be provided for the safety area. Now, safety area here is made up of partially paved shoulders on either side plus the area which is graded and drained and in this case, as we have seen in the case of runways also that we have to look at the area which is provided on the two sides as well as the area which is to be provided on the ends. In the case of the jet aircraft, a paved surface of a light strength material on either side of taxiway edge with the minimum width of 7.5 metres is to be provided on both sides of the pavement edge.

Therefore, whatever is the width of the taxiway lane that is defined in terms of varying between 7.5 metres and 23 metres. Then, on the side of that 23 metre taxiway lane, we can provide 7.5 metres on one side and 7.5 metres on the other side. That means 15 metres more and that is what becomes the overall safety area.

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Now, we look at the width of the safety area that is another geometric feature. In this case, the pavement thickness should be thick enough to support the airport petrol vehicles, etc., that is one thing. Another thing is that the surface should be treated with bitumen and it should not disintegrate due to the hot blast of jet aircrafts and the surface should be smooth and impervious. We have already seen that what should be the size of the width of the taxi safety area, but apart from that there are certain things

which need to be taken care of with respect to pavement thickness as has been enumerated at this point.

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Taxiway – Geometric					
■ Width of safety area					
□ As per ICAO					
	Aerodrome code				
	A	B	C	D	E
Pavement and shoulders -	-	-	25m	38m	44m
Edge safety margin	1.5m	2.25m	3*m	4.5m	4.5m
Graded portion of strip	22m	25m	25m	38m	44m
* 4.5m if intended to be used by an airplane with a wheel base equal to or greater than 18m					

Then, as per ICAO, we have some of these values like the pavement and shoulders. They should be 25 metres wide in the case of category C, 38 metres for category D and 44 metres in the category E, whereas the edge safety margins they should be 1.5 metres for category A, 2.25 metres for B, 3 metres for C, 4.5 metres for D and 4.5 metres again for E. In the case of graded portion of the strip, the values are 22 metres for A category, 25 metres for B category, again 25 metres for C, 38 metres for D and 44 metres for E category of aerodromes.

Now, here this value of 3 metres being provided for the edge safety margins in the case of C category of the aerodromes, this maybe 4.5 metres if it is intended to be used by an airplane with the wheel base equal to or greater than 18 metres, means it will become similar to the category of D and E.

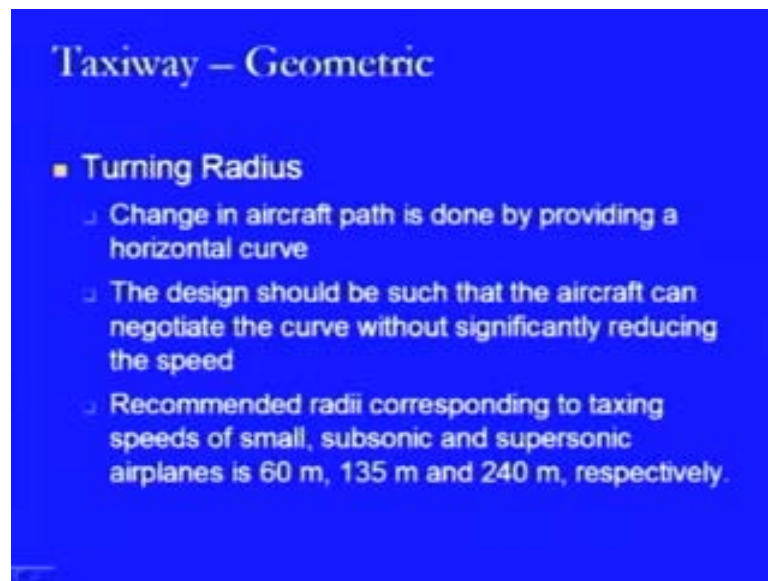
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Taxiway – Geometric						
■ Width of safety area						
□ As per FAA						
	Airplane Design Group					
	I	II	III	IV	V	VI
Width of safety area	15m	24m	36m	52m	59m	79m
Edge safety margin	1.5m	2.5m	3m	4.5m	4.5m	6m
Shoulder width	3m	3m	6m	7.5m	10.5m	12m

Whereas, as per the guidelines given by FAA, it is being defined on the basis of the airplane design group which ranges from I to VI and here the width of the safety area will be 15 metres for category I and it is 24 metres, then 36 metres subsequently, to 52 metres, 59 metres and 79 metres in the design group category VI. Then, in the case of edge safety it is 1.5 metres for the first case, 2.5 for the second category, 3 metres for the third category, 4.5 metres for the fourth category, again 4.5 metres for the fifth category and 6 metres for the sixth category.

The, we have the shoulder width, which is 3 metres for the first and second categories, 6 metres for the third category, 7.5 metres for fourth category and 10.5 metres for fifth category and 12 metres for sixth category.

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Now, we come to another important aspect of the features of taxiway that is turning radius. This turning radius is the thing which provides the transformation or the movement from the runway to the taxiway that is from a high speed to a low speed condition and therefore, we have to adjust the turning radius in such a way that it provides or it makes it possible, so that the aircrafts can take a turn at a higher speed to the taxiway and come to a lower speed condition.

So, in that sense, we have to see that the change in the aircraft path is done by providing a smooth horizontal curve and the design should be such that the aircraft can negotiate the curve without significantly reducing the speed, because at the time of the change from the runway to this taxiway through the connectivity, that is the circular curve being provided, at that point of a time, there should not be a much change in the speed. Whatever is the speed with which it is coming, the aircraft is coming, it should be able to negotiate.

The recommended radii corresponding to the taxing speeds of small subsonic and supersonic airplanes are 60 metres, 135 metres and 240 metres respectively. If we have the planes which are having speed less than 1 Mach, then it is 135 metres, but if the speed of the plane is more than the Mach number, then it is 240 metres.



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## Taxiway – Geometric

- Turning Radius
  - Relationship between exit speed and radius of curve

$$\text{Radius} = V^2/125f \text{ (m)}$$

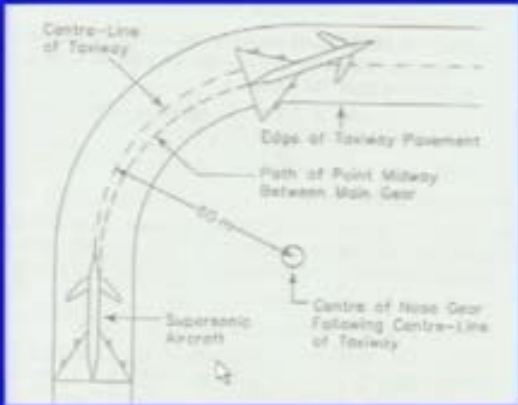
where, 'V' is in km ph and 'f' is coefficient of friction and is equal to 0.13

The relationship between the exit speed and the radius of the curve is ascertained and this value can be computed by this formula. The radius is V square divided 125 f and this value will come out in metres. Here, V is in kilometres per hour and f is the coefficient of friction and is equals to 0.13 that is it is being fixed. So, we have the fixed value of f, this is another constant as 125. Therefore, there is only one variable, which governs the radius and this is the speed at which the aircraft is taking a turn. So, this is a turning speed, not the speed at which it is moving on the runway.

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## Taxiway – Geometric

- Turning Radius

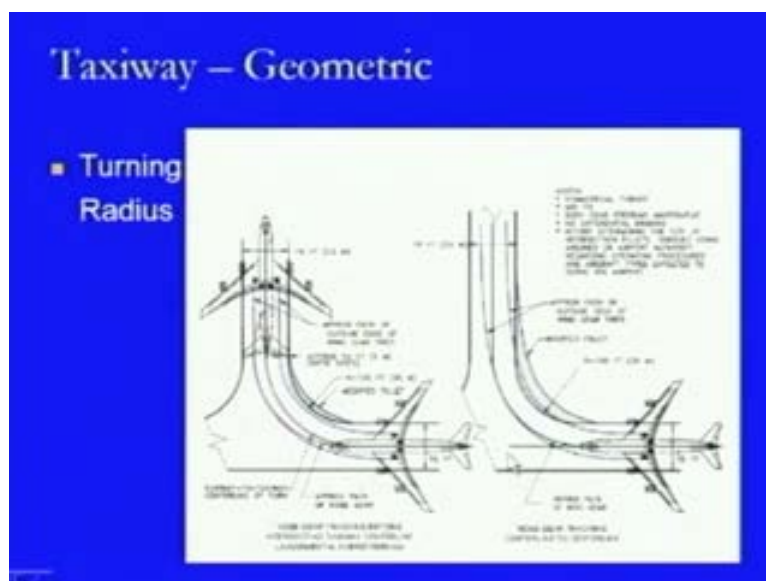




So, this turning radius, this is how we define it. Here in this diagram, there is say, supersonic aircraft means an aircraft which is coming at a much larger speed as compared to the normal conditions and we have the centreline condition. So, what happens is that in this case, if this is the 60 metre radius at which it is being provided and this is the centre of the nose gear following the centreline of the taxiway, means this nose gear is trying to follow the centreline of the taxiway being provided like this. So, this is what is the condition and then, there is another pathway being shown on this side and this pathway is the path of a point midway between the main gears.

So, the nose, what happens is when the pilot is trying to maintain the nose along the centreline, then the two gears which have been provided, one on this side and one on this side, they will be trying to maintain adjusting themselves in this one and this will be the centreline of those two main gears, means there will be one wheel which will be moving somewhere here and there will be another wheel which will be moving somewhere here and that is how they will keep on moving on the two sides of this particular centreline. So, there is such sort of orientation which will be there and therefore, we have to provide this curve in accordance, so that this aircraft is not going away from the edge of the taxiway pavement. So, that is the main thing which is to be maintained and this type of condition should not get created.

(Refer Slide Time: 38:45)



We will also look at some more diagrams. Here, this is another diagram, where we can see a plane which is coming on this side and this is the runway strip on this direction and this runway strip means the aircraft is coming along the centreline of this runway strip. So, this axis of the aircraft is just superimposing on the centreline of the runway strip and then, as this connectivity is being provided, so we have the centreline like this. So, this is the centreline of the curve, this one and then, this is a position which is being taken by the aircraft after taking the turn on the taxiway and again it is aligned with the centreline on this taxiway with the wings coming out in the safety area.

So, what is happening here is that this nose gear it tries to track beyond the intersecting taxiway centreline. That is this a condition where what it is trying to do is that this is a judgemental approach of the pilot. The pilot is trying to move the nose of aircraft along this pathway, the red pathway being shown here. This is on the basis of the judgement of the pilot. What he is trying to do is that this particular gear which is on the inner side of the curve, it is having, this is moving like this and while this particular movement, it should remain clear of the edge of this connectivity. That is what is the basis of this particular judgemental over steering method or judgemental over steering **being done** adopted by the pilot.

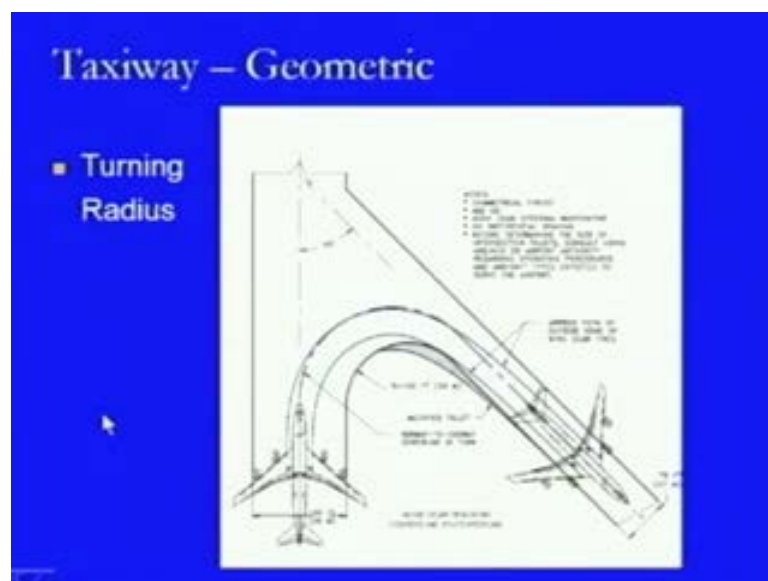
So, in this case what will happen is that if this nose will go away from the centreline like this. This is the centreline, so this is going away from the centreline and then, after negotiating this curve, this will come back to the centreline and the aircraft will get oriented again with respect to the centreline. So, only part here to emphasize is that, because this gear is not going away from the edge, therefore the smaller **side**, smaller size of the fillet may help us in this particular location. So, we have this particular hashed portion being shown. This is what is termed as the fillet and this is the fillet means this is the extra area which is being filled, so that if there is any emergency, then this can be utilized by the moving aircraft.

This is another diagram, where again this is a runway strip and this is the connectivity and this is the taxiway. So, this is the centreline of the taxiway, this is the centreline of the runway and here it is being provided or it is being connected by this circular centreline of this curve. Now, in this case, here this is tracking where the pilot is

trying to keep the nose along the centreline of the connectivity. So, it means that nose will be taking the same profile as been provided by the connectivity of the centreline that is this particular **path**. So, the nose is coming in this form. This is coming along this one. Whereas in this case, this is one wheel and this is another wheel being provided on the two sides of the wings. So, this is going in this pathway like this, whereas **another path**, another wheel will take a path like this and here it will, in this particular portion this is superimposing with the nose gear pathway and again it is going away from this one, so that it becomes a central position in this location.

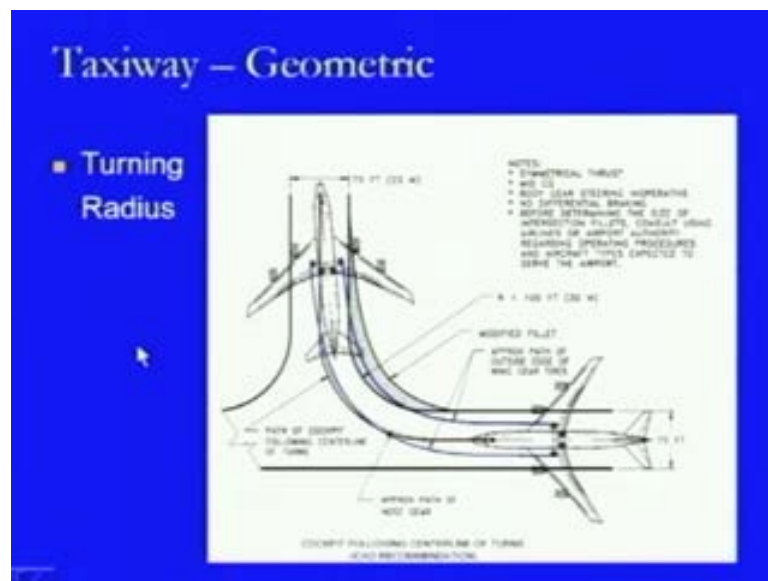
The main thing to see here is that this particular wheel is making a, making a change from in this direction like this and here this is the edge of the curve, whereas the pathway of this particular wheel or this particular gear is going away from this edge like this. So, this line is showing the pathway of this particular gear. It means it is going away from the edge. So, that is the disadvantage in this particular method, where if we are following the centreline profile along the nose, then the inner side gear may go away from the edge of the curve and therefore, we require a much wider fillet to be provided in this case as compared to a very smaller fillet, which has been required in this case. So, that is the differentiation between the type of the turning radiuses and the type of the movements on those turning radiuses, which can be there when aircraft moves from the runway strip to the taxiway strip.

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This is a condition for a U turn, where this is a runway and this is a taxiway and the aircraft is coming to the end and then, it has to take a turn, so as to go to the terminal building. So, in this case again, there is a centreline to centreline nose tracking, therefore means this nose of the aircraft keeps continuing moving along the centreline like this, whereas there is one wheel on this side and there is another wheel on this side. So, this wheel will be making a turning like this and this wheel will be making a turning like this and in between, in this particular section there is an overlapping of the outer gear with the nose gear **path**. So, this is the overlapping. So, in this case also, there will, at this particular location the inner gear is touching the edge of the taxiway and therefore, we require to provide a fillet in this orientation, at this particular location. So, this is another type of movement and another type of curving condition, which needs to be just understood.

(Refer Slide Time: 45:26)



This is another case where it is coming from say, one of this condition to this one and this is ICAO recommended condition, where it says that this is nose and this nose is going very near to the approximate path of the nose gear, remains very near to the centreline and this is, once it is being done, then again this inner side of the gear will go inside of the curve and therefore, a wider fillet is to be provided with the radius, here it is being talked of 30 metres. So, there is a modification of the fillet to be provided. This is known as cockpit following centreline of turn method as recommended by ICAO that is cockpit following centreline of turn.

(Refer Slide Time: 46:23)

## Taxiway – Geometric

- Turning Radius
  - According to Horonjeff for supersonic aircraft
    - The radius of curve should be such that a minimum distance of 6 m is maintained between the nearby main gear and the edge of pavement.

$$R = 0.388W^2/(0.5T - S),$$

So, what we find is that according to Horonjeff, for supersonic aircrafts, the radius of curve should be such that a minimum distance of 6 metre is maintained between the nearby main gear and the edge of pavement. That is the premises that is the principle of the concept, which is being taken by the Horonjeff. So, clearance is 6 metres and in this case, the radius is given by 0.388 square of W divided by the difference of 0.5 T minus S and

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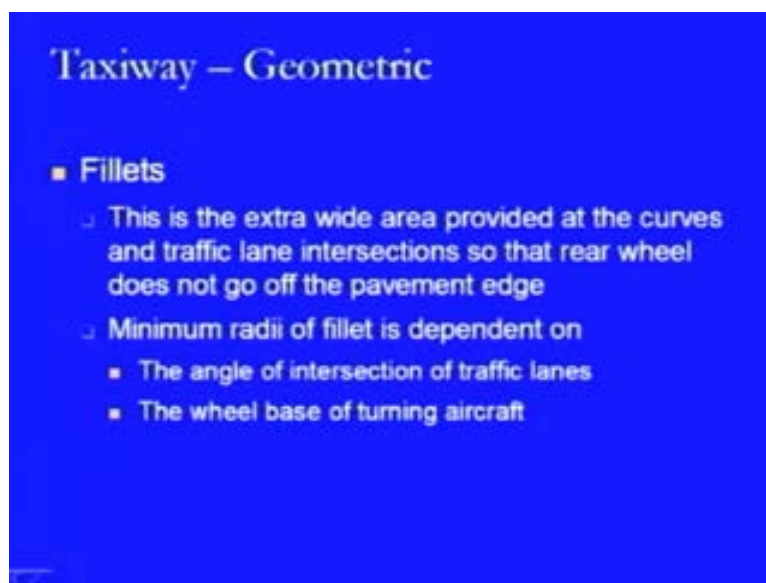
## Taxiway – Geometric

- Turning Radius
  - According to Horonjeff for supersonic aircraft
    - R = radius of center line of taxiway in meters
    - W = wheel base of aircraft in meters
    - T = Width of taxiway pavement in meters
    - S = distance between point midway of the main gear and the edge of taxiway pavement in meters

$$S = 6 + (\text{Wheel tread}/2)$$

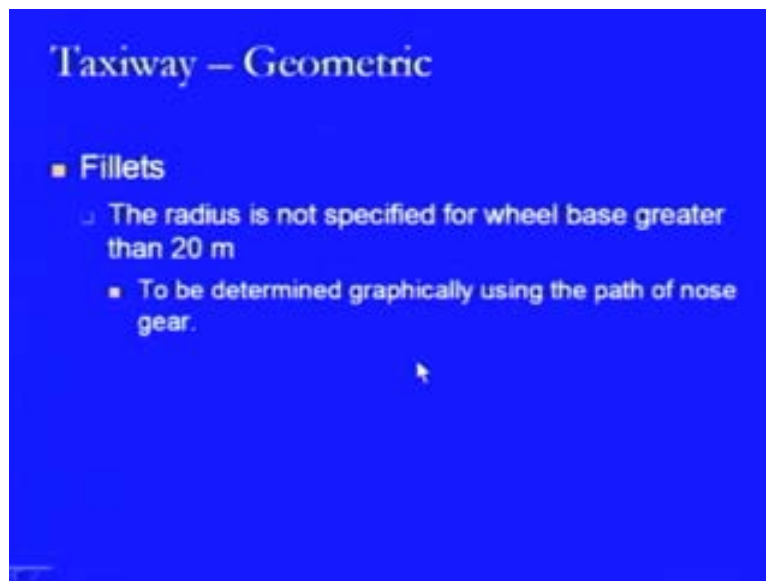
In this case, according to Horonjeff, this  $R$  is the radius of the centreline of the taxiway in metres,  $W$  is wheel base of aircraft in metres,  $T$  is the width of the taxiway pavement in metres and  $S$  is the distance between the point midway of the main gear and edge of taxiway pavement in metres again. So, this is how the values have been defined or this turning radius and this  $S$  is taken as this value of distance between the point midway of the main gear and edge of taxiway pavement is computed as 6 plus wheel tread divided by 2. This wheel tread we have already discussed, this is the distance between the two main gears being located below the wings.

(Refer Slide Time: 48:04)



Now, we come to the fillets and the fillets are the extra wide area, as we have seen already, which are provided at the curve and the traffic lane intersections, so that the rear wheel does not go off the pavement edge. So, that is what is the function of the fillet and the minimum radii of the fillet is dependent on two things. One is the angle of intersection of the traffic lanes that is the runway or the taxiway or the taxiway or the taxiway or the runway or the runway and the wheel base of the turning aircraft. If the size of the aircraft is big, the wheel base will be big and therefore, it requires a bigger turning area, where if the size of the aircraft is smaller, then the wheel base will be also smaller and it can take a turn in a very small area. So, that is why the requirement of the fillet is governed by both the things, the specification of the aircraft and the intersection of the angle.

(Refer Slide Time: 49:05)



The radius is not specified for wheel base greater than 20 metres and it is to be determined graphically using the path of nose gear.

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**Taxiway – Geometric**

- **Filletlets**

Angle of Intersection	Radii of fillet (in meters)	
	Small airport	Large airport
0 – 45°	7.50	22.50
45° - 135°	15.00	30.00
> 135°	60.00	60.00

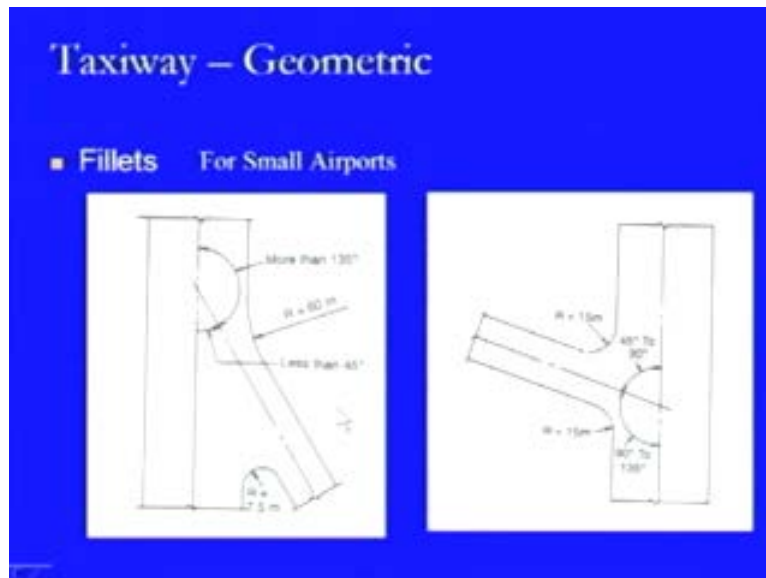
The radii of fillet should not be less than the width of taxiway

What we find is that for an angle of intersection between zero and 45 degrees, the radii of fillet in metres for a small airport is defined as 7.5 metres, for large airport it is taken as 22.5 metres, whereas if the angle of intersection varies between 45 degrees and 135 degrees, then the value for small airport is 15 metres, whereas for large airport that is 30 metres. Then, if the angle of intersection increases, it becomes more



than 135 degrees, then the radii of fillet is 60 metres for small airports and it is also 60 metres for the large airports. This radii of fillet should not be less than the width of the taxiway that is another thing which is to be considered.

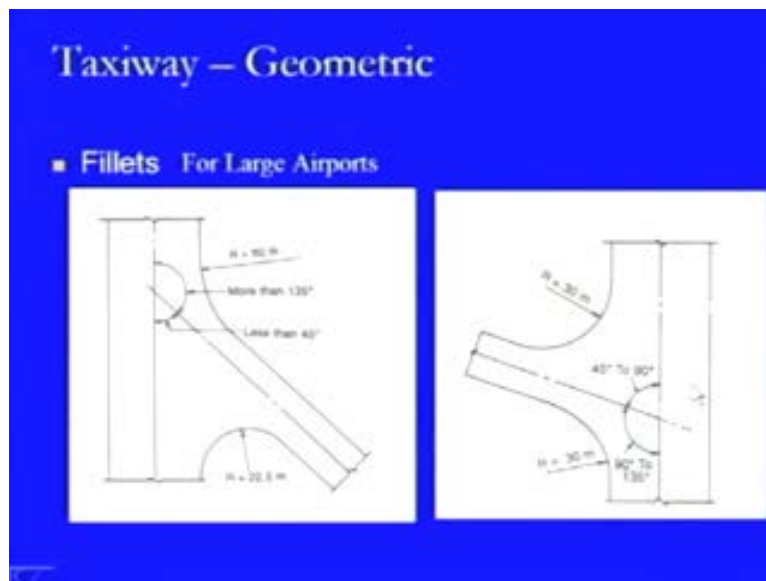
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Now, we look at the fillet for the different conditions. Here, in the case of the small airport, we have the runway strip and this is the taxiway. So, the, here what we find is that the turning is greater than, more than 135 degrees. This is the turn turning angle more than 135 degrees. In this case, the radius should be 60 metres at this particular location, where at this particular location it is governed with respect to the angle that is 45 degrees and therefore, this radius is 7.5 metres, whereas this is another condition, where we have the runway being connected with the taxiway. Here, the angle is between 45 and 90 degrees. Therefore, the radius is 15 metres and this angle is between 90 and 135 degrees. So, for that condition also, this radius remains 15 metres. So, that is for the small airport condition.

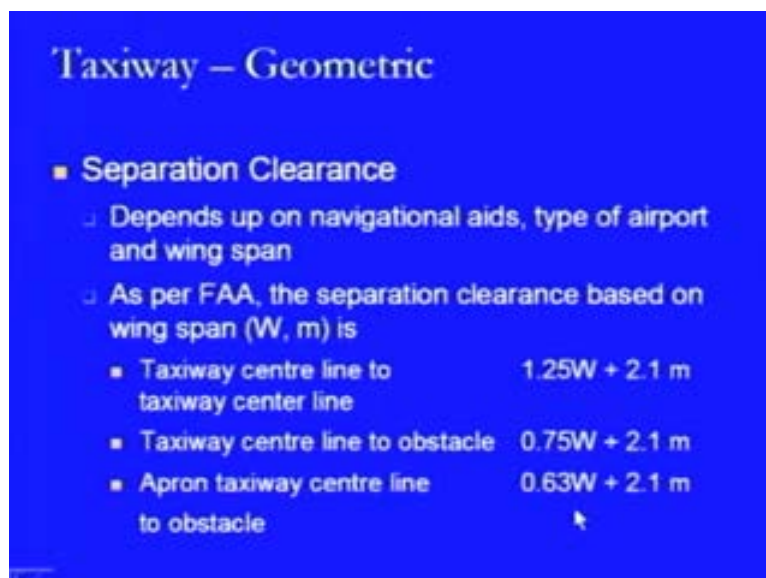


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In the case of large airports, what we see is that again it is 135 metres or remains 60. If it is less than 45 degrees, then it becomes 22.5 metres. This is another diagram. As we have seen, for the smaller airports also, it is for 45 to 90 metres the radius is 30 metres as shown here and similarly for 90 to 135 degrees, the radius again remains 30 metres. So, this is the typical diagrams or typical connectivities, which can be provided.

(Refer Slide Time: 51:49)



Now, we look at another aspect that is the separation clearance between the taxiways which needs to be provided and this depends on the navigational aids, the type of the airport and the wing span. These are the three factors which will control the separation clearance. As per FAA, the separation clearance is based on wingspan and in the case of the taxiway centreline to taxiway centreline it is taken as 1.25 times of W, where W is the wingspan plus 2.1 metres, whereas in the case of taxiway centreline to the obstacle it is taken as 0.75 times of W plus 2.1 metres. For apron taxiway centreline to obstacle it is taken as 0.63 W plus 2.1 metres. So, this is how you can compute the separation clearance based on wingspan as given by FAA.

(Refer Slide Time: 52:52)

Taxiway – Geometric						
■ Separation Clearance						
□ As per FAA, in meters						
Design Item	Airplane Design Group					
	I	II	III	IV	V	VI
Taxiway centre line to:						
Parallel taxiway c/l	21	31	46	68	75	102
Fixed or moveable object & to property line	13.5	20	28	41	46	61.5

Further, it is also being defined by FAA in terms of the design item and airplane design group and for the taxiway centreline to the parallel taxiway centreline it is 21 metres for category I and then, it is 31 metres, 46 metres, 68 metres, 75 metres and 102 metres for final category VI, whereas taxiway centreline to the fixed or the movable object, then this value is, or the property line, then this value is 13.5 metres, 20 metres, 28 metres, 41 metres, 46 metres, 61.5 metres, for airplane design group category VI.

(Refer Slide Time: 53:40)

Taxiway – Geometric						
■ Separation Clearance						
□ As per FAA, in meters						
Design item	Airplane Design Group					
	I	II	III	IV	V	VI
Taxiway centre line to:						
Fixed or immovable object	12	16	25	36	39	51
Runway centre line	120	120	120	120	vary with airport elevation	180

Further in the case that we are taking the distance from the taxiway centreline to the fixed or immovable object, then the range of the separation clearance varies from 12 metres in the case design group I to 51 metres in the case of design group VI and we have the values as 16, 25, 36 and 39 in between. For the distance between the taxiway centreline and the runway centreline, then the values for most of the cases are 120 metres. In the case of group VI, it is 180 metres, whereas in the case of group V, it varies with the airport elevation.

(Refer Slide Time: 54:35)

Taxiway – Geometric					
■ Separation Clearance					
□ As per ICAO, in meters					
Minimum Separation	Aerodrome Code				
	A	B	C	D	E
Edge safety margin	1.5	2.25	3*	4.5	4.5
Taxiway centre line to:					
taxiway centre line	21	31.5	46.5	68.5	81.5
object	13.5	19.5	28.5	42.5	49
Aircraft stand taxi lane to object	12	16.5	24.5	36	42.5

In terms of ICAO guidelines it is, the minimum separation is defined as per the aerodrome code is concerned and in the case of edge safety margin this is 1.5 metres for A, 2.2 metres for B, 3 metres for C, 4.5 metres for D and 4.5 again for E, whereas from the taxiway centreline to the taxiway centreline, it varies from 21 metres in the category A to 81.5 metres in the category E of aerodrome code, whereas if it is the distance between taxiway centreline to the object, then this varies for 13.5 metres for the aerodrome code category A to 49 metres for the aerodrome code category A with the intermediate values as 19.5, 28.5 and 42.5 metres. In case of the aircraft stand taxilane, then this value ranges from 12 to 42.5 metres with values in between as 16.5 metres, 24.5 metres and 36 metres.

(Refer Slide Time: 55:41)

Taxiway – Geometric					
■ Separation Clearance					
□ As per ICAO, in meters					
Minimum Separation	Aerodrome Code				
	A	B	C	D	E
Min wing tip clearance	3	3	4.5	7.5	7.5
Stand safety margin	1.5	1.5	2	2.5	2.5
* 4.5 m if intended to be used by the airplane with a wheel base equal to or greater than 18 m					

We have some more values here and this the minimum wing tip clearance which is 3 metres for A and B category of aerodromes, 4.5 metres for C category of aerodromes and 7.5 metres for D and E category of aerodromes. Then, in the case of stand safety margins it is 1.5 metres for A and B, 2 metres for C category and 2.5 metres for D and E category. In case we have, we are going to intend for aeroplane with a wheel base equal to or greater than 18 metres, then the value of 3 metres can be changed by 4.5 metres for category D.

(Refer Slide Time: 56:24)

**Taxiway – Geometric**

- **Separation Clearance**
  - Minimum separation between parallel taxiway centreline or taxilane centreline is given by
    - $S_{TT} = W + 2 U_1 + C_1$
  - Required separation between a taxiway centreline or an apron taxiway and a fixed or moveable object
    - $S_{TO} = 0.5W + U_1 + C_2$

The minimum separation between the parallel taxiway centreline or the taxiway centreline is given by this equation that is the separation between the taxiways is equals to the  $W$  plus  $2 U_1$  plus  $C_1$ , whereas the required separation between a taxiway centreline or an apron taxiway and the fixed or movable object is given by, this is  $T$  and  $O$  that is object, then it is  $0.5 W$  plus  $U_1$  plus  $C_2$ .

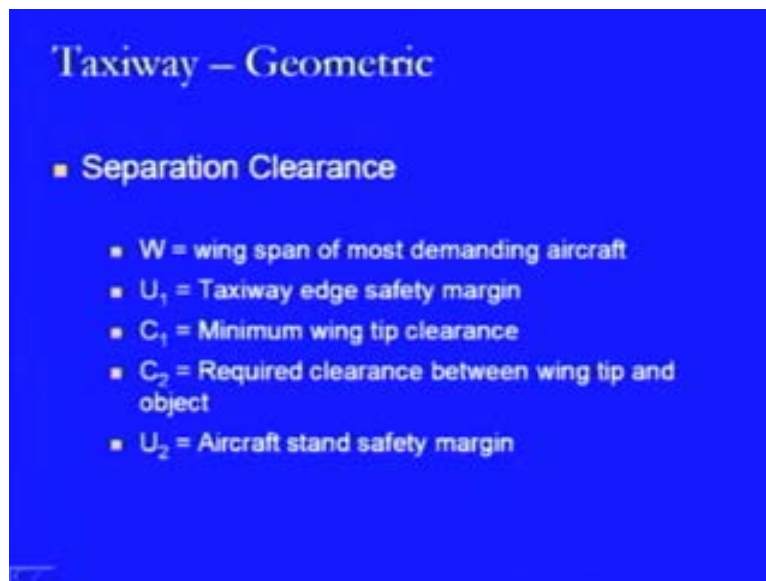
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**Taxiway – Geometric**

- **Separation Clearance**
  - Required separation between a aircraft stand taxilane and fixed or moveable object
    - $S_{ATO} = 0.5W + U_2 + C_1$

There is another one case where we have the separation between an aircraft stand taxilane and the fixed or movable object.

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In that case, it is given by  $0.5 W$  plus  $U_2$  plus  $C_1$ , where these values of  $U_2$ ,  $C_1$ , whatever abbreviations have been used are  $W$  is the wing span of most demanding aircraft,  $U_1$  is the taxiway edge safety margin,  $C_1$  is the minimum wing tip clearance,  $C_2$  is the required clearance between wing tip and object and  $U_2$  is the aircraft stand safety margin. So, this is all about the taxiways and the provision of taxiways and their requirements and their design features.

So, in today's lecture we have tried to look at the geometric features as well as we have tried to look at the connectivity of the taxiway with the runway using fillets and the radius. We have also looked at the separation clearances which need to be provided between the parallel taxiways or the taxiway and objects or the taxiway and other movable things. With this we stop in today's lecture and we will be looking at some of the other features of the taxiway in the next lecture. Till then goodbye and thank you to you.