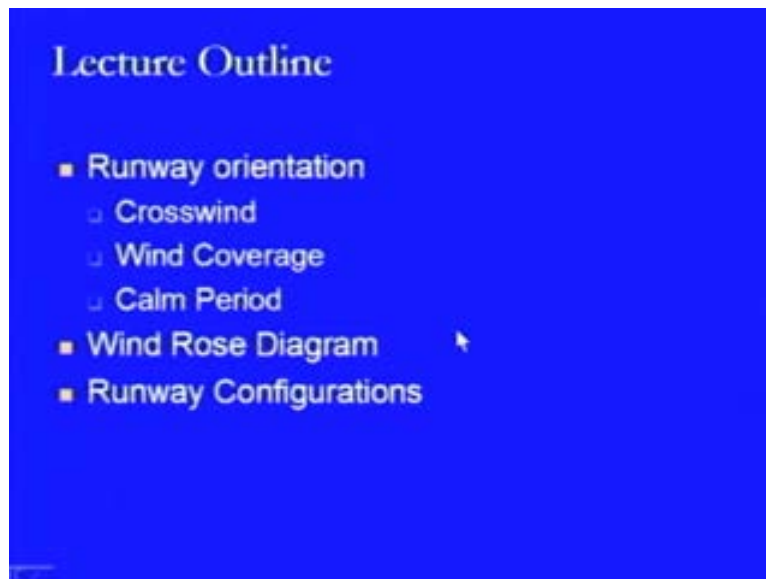


Transportation Engineering – II
Dr. Rajat Rastogi
Department of Civil Engineering
Indian Institute of Technology - Roorkee

Lecture – 31
Runway – Orientation

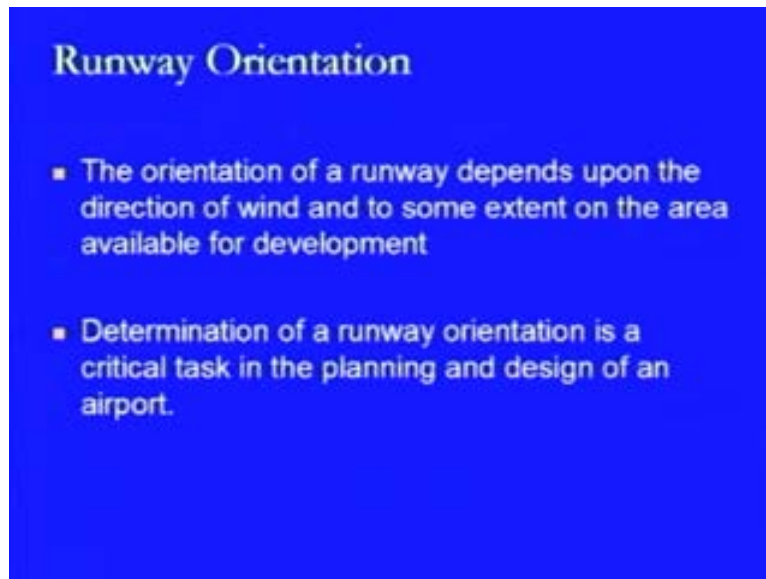
Dear students, I welcome you back to the lecture series on course material of Transportation Engineering – II. In the previous lecture we have discussed about the various fly rules and we have also discussed about the associated features of those one. In today's lecture, we will be looking at some other aspects that is related to the runways. So, what we are trying to do now is to start moving towards the design aspects of some of the components of an airport and runway is one of the major components of any airport. So, in today's lecture we are going to look at the orientation of the runways and we will, in terms we will be looking at the various associated features related to those.

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So, what we are going cover in today's lectures are the runway orientation, the cross wind effect, the wind coverage, the calm period and the wind rose diagrams and the runway configurations. So, these are the things we would like to cover in today's lecture. So, we will be starting right now with the runway orientation.

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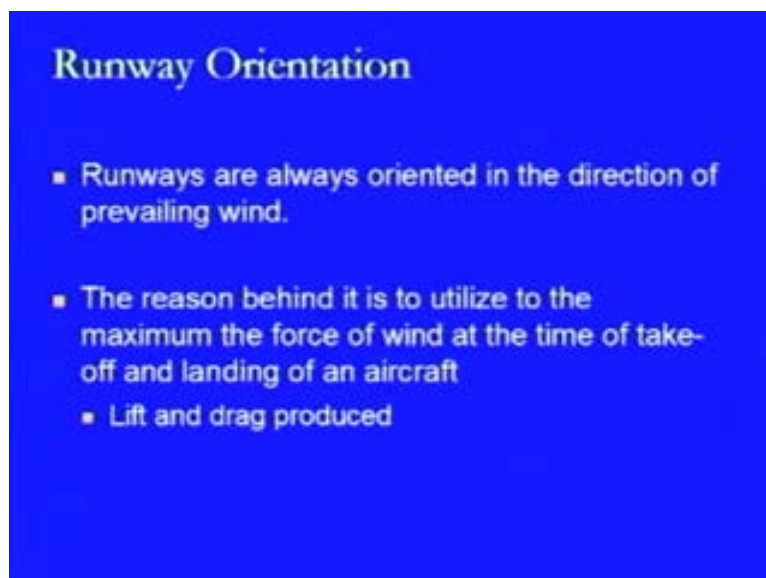


Runway Orientation

- The orientation of a runway depends upon the direction of wind and to some extent on the area available for development
- Determination of a runway orientation is a critical task in the planning and design of an airport.

In the case of runway orientation, the orientation of a runway depends upon the direction of the wind and to some extent on the area available for development. These are the two major components which creates an effect on the direction in which the runways can be oriented. The determination of a runway orientation is a critical task and we have to look at because this is one of influential things, which its effect in terms of planning and designing of an airport.

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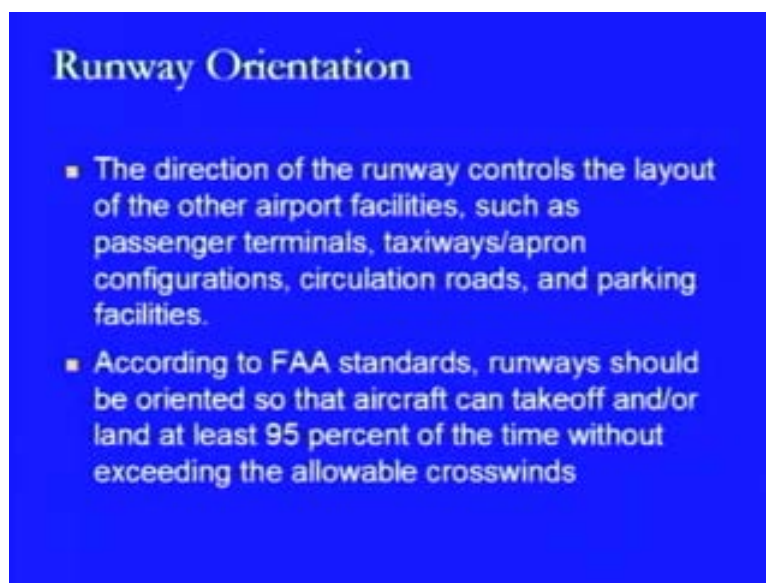


Runway Orientation

- Runways are always oriented in the direction of prevailing wind.
- The reason behind it is to utilize to the maximum the force of wind at the time of take-off and landing of an aircraft
 - Lift and drag produced

Runways are always orientated in the direction of the prevailing winds, so that we can utilize the force of the wind during take-off and landing operations. In the case of take-off operations, this wind will help us in generating the lift, whereas during the landing operations the same wind will help in generating the drag, so as to stop the landing aircraft. So, that is what is important as far as the orientation of runway is concerned. The reason behind here is that is what we are looking for is the utilizing the maximum the force of the wind at the time of take-off and landing of any aircraft. It is in terms of lift and drag produced.

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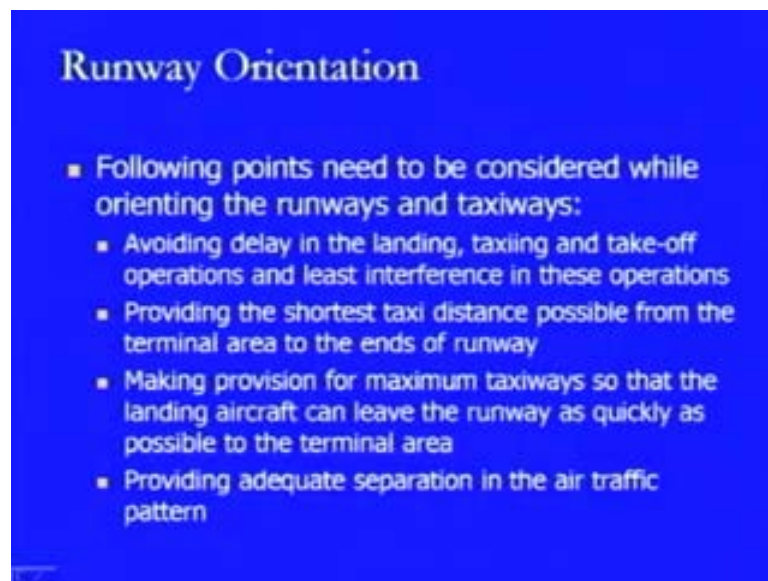


The direction of the runway controls the layout of the other airport facilities such as passenger terminals, taxiways, apron configurations, circulation roads and parking facilities - means the rest of the facilities which needs to be provided on any of the airport are governed by the orientation of the runway and with respect to that because the movements of the aircraft will be there and therefore, the facilities have to be placed in such a way, so that it takes minimum of the time so as to approach a facility or so as to operate that facility. According to FAA standards, runways should be orientated so that aircraft can take-off and or land at least 95% of the time without exceeding the allowable crosswinds. So, if there cross winds available on any of the airport, which is mostly are, then in that case, as per the FAA standard it says that for 95% of the time period, the aircraft should be able to take-off or they should be able to land, without taking an effect of the allowable crosswinds into consideration. That

is what is the orientation which needs to be taken care of and this is what becomes the principle behind the orientation of any runway strip, as you will see when we will try to compute, we will try to find out the runway orientation.

There are certain points which needs to be considered when they are orienting any runway and similarly when we are orientating the taxiways.

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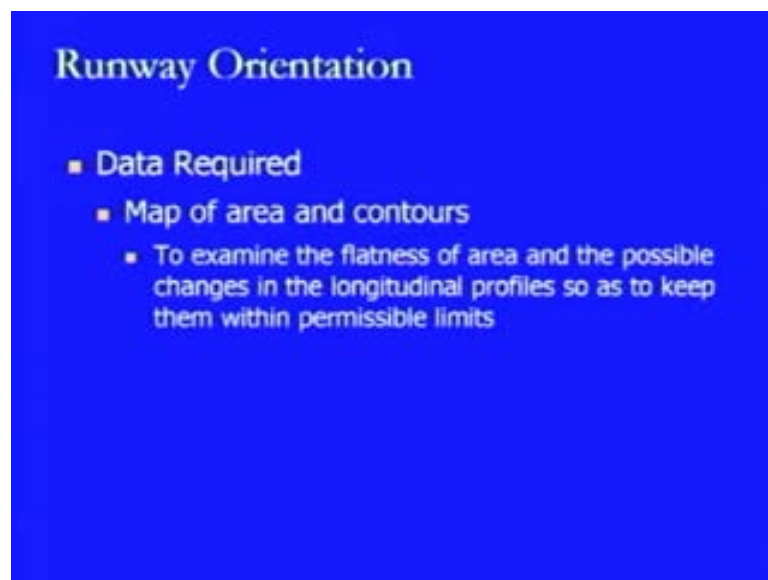
They are avoiding delay in the landing, taxing and take-off operations and least interference in these operations. This is one of the principles behind the orientations that is during landing, there should be minimum of the delay for landing and then, taxing means it is coming out of the runway strip and it is going towards the apron. So, in that point of a time, in between of that transition that is known as taxing and the aircraft will be using the taxiway during that operation.

Similarly, at the time of taking off operation also, there should be least of the delay and then, there should be least interference of the different type of operations which are simultaneously going on, on any of the busy airport. That is simultaneously there can be a landing, there can be an aircraft which is taxing and there can be an aircraft which is taking-off. So, in such conditions, no one operation should interfere with the other operation. Then, providing the shortest taxi distance possible from the terminal area to the end of the runway, this is another important thing. This is another way of

trying to economize at the same time trying to shorten the time which it takes, so as to move from the terminal building to the runway or from the runway to the terminal building.

Then, making provision for maximum taxiway, so that the landing aircraft can leave the runway as quickly as possible to the terminal area. Now, this is important in the light of the different type of aircrafts which are going to use any landing strip. Not all the aircrafts are of the same specification. If the aircrafts are of bigger size with the big amount of power available to them, then they will be moving to a larger distance on the runway strip before they start taxing, whereas if the aircraft is of the smaller size, then it will start taxing at a much earlier time frame. Therefore the taxiways should be connected from the runway at different locations, so that as soon as an aircraft comes into a position of taxing it should move quickly away from the runway, allowing the runway to be used by another aircraft. Then, we should provide adequate separation in the air traffic pattern that is another aspect related to the orientation of the runway strips.

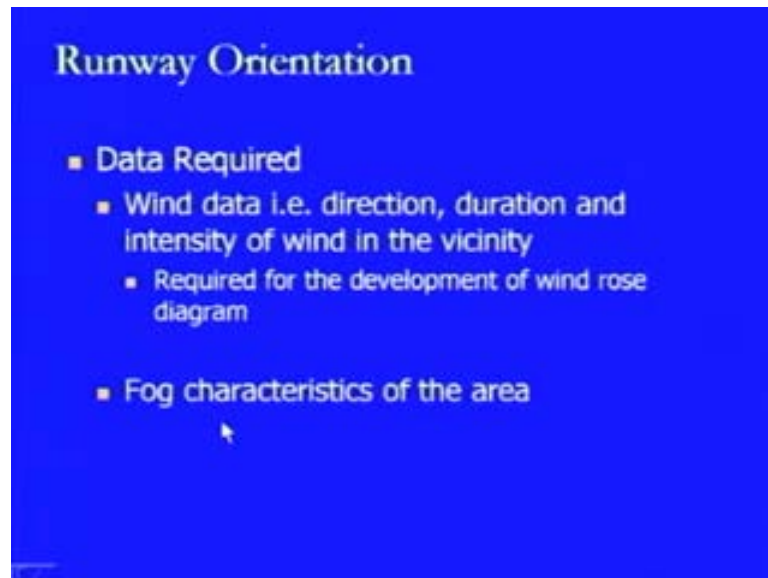
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Now, what type of data is required so as to decide about the orientation of the runway strip? We require the map of the area and contours, which is required to examine the flatness of the area and the possible changes in the longitudinal profiles, so as to keep them within permissible limits. So, we are looking at basically the contours the

topography of that area and with respect to that topography of the area, we try to maintain as far as possible, the runways should be orientated in that particular area where the flatness can be ensured, so that there are minimum changes in the grades.

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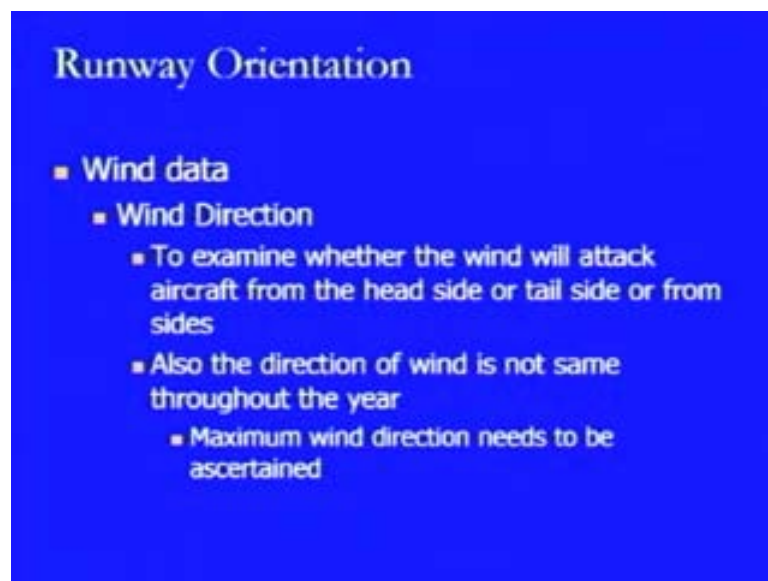
Further, another thing which is required is the wind data and the wind data is required in three dimensions. That is in terms of direction, in terms of duration and the intensity of wind in the vicinity of the airport and this is a requirement for the development of wind rose diagram, which is finally used to identify the orientation of the runway based on the wind coverage area. So, that is why this is one another important metrological data which is required, so as to find out the orientation of runways at an airport.

Another characteristic which has its effect on the orientation of runway is the fog characteristics of the area, which is governed by not only the metrological conditions, but it is also governed by the positioning of the runway strips with respect to the conditions which are going to be created in terms of whether we are providing the runway strip on the leeward side or the windward side as we have discussed in the case of site selection of an airport. That is another thing which needs to be given due consideration, because if you are on the windward side, then what happens is that we will be getting more of the wind and that means whatever are the fog which has got

created or formed at any other location which will travel towards the site of the airport or runway strip, so that should not happen.

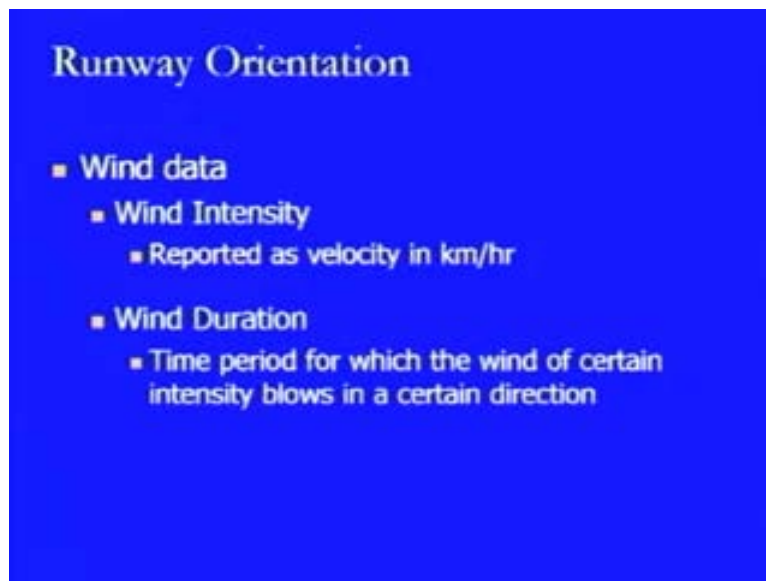
Now, in the case of wind direction, when we are looking at the wind data, what we will try to do is that we try to find out what way this wind is going to create an effect on the aircraft. That is whether it is coming from the front side or it is coming from the backside or it is going to create an effect from the sides of the aircraft.

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In that sense it will be termed as the head wind or the tail wind or the cross wind respectively. Also, the direction of wind is not necessarily the same throughout the year. It will keep on changing. Therefore, we require to find out that particular direction, where the maximum wind will remain can be ascertained throughout the year. So, that means for the maximum time period in a year they can utilize the direction for the operation of the runway; it means in terms of landings and take-off's of the aircrafts.

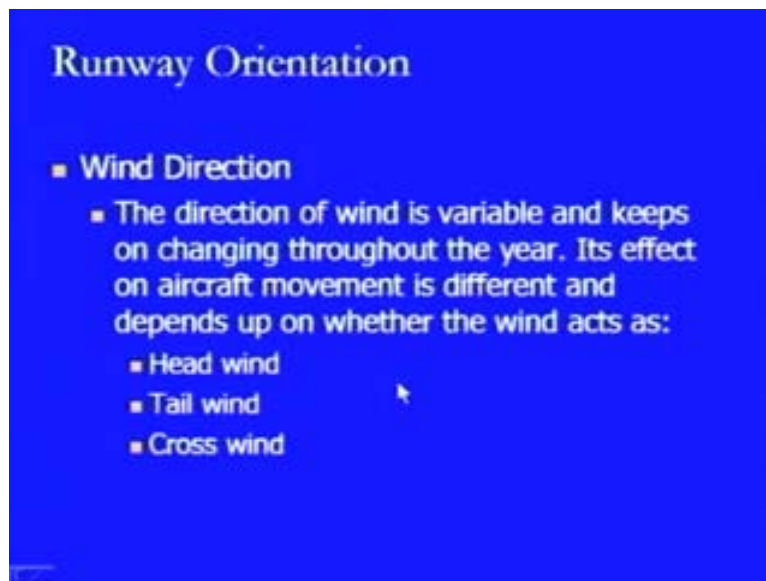
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Another data related to wind is the wind intensity, which is reported in terms of velocity in kilometers per hour and this velocity has its effect in terms of the force it is going to generate on any of the aircraft and this force, finally we use on not only during the navigation in the air, but we are going to use it during the ground movements of the aircraft. So, in that sense, we look at this wind intensity or this wind velocity or speed in terms of the ground velocity or in terms of the air velocity and the wind velocity.

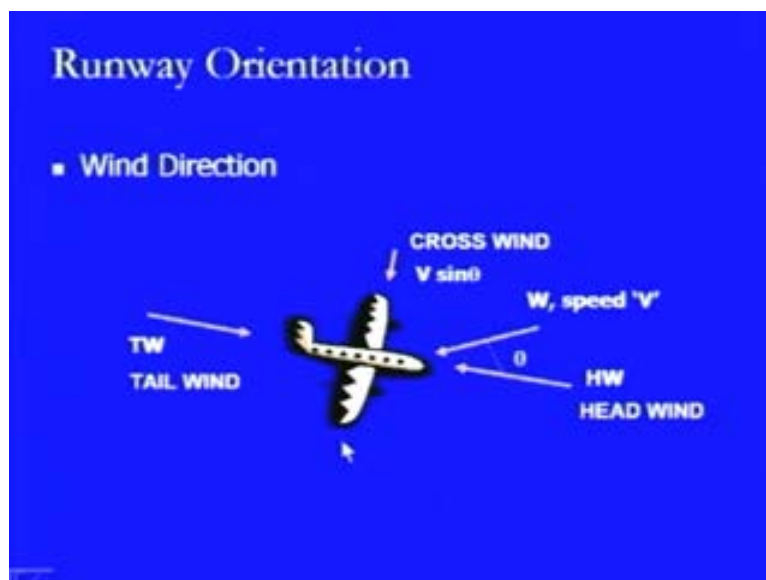
Another aspect is the duration for which the wind is available, but with certain intensity for certain directions at the airport. So, that is another aspect which needs to be taken care of and this is one of the design parameters which we use while fixing the runway orientation.

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So, in this case of wind direction, we look at the three of the components as we have just discussed, where it is varying and it depends on from which particular direction it is going to create an effect or attack on the aircraft and its effect on the aircraft movements obviously then in that sense will become different. So, we are going to look at the three wind acts that is the head wind, the tail wind and the cross wind

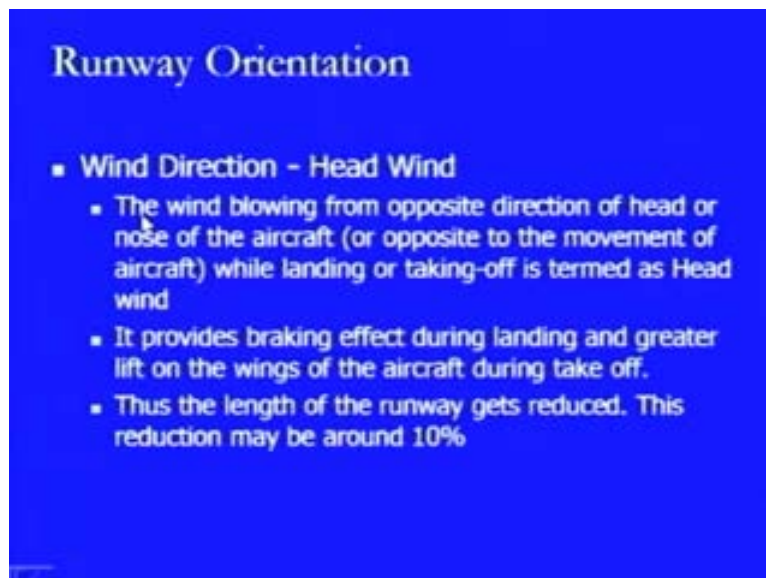
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Now, this is a diagram which tries to depict the three conditions as we have just discussed and which we are going to discuss further. Here this aircraft is moving in

this direction and there is a wind which is coming from the side of, from the front side that is just opposite to the movement of the aircraft. Then, it is known as the head wind, because it is creating its effect in the head of the aircraft, whereas if there is a wind which is coming from the tail side, then that is known as tail wind. There can be another wind which is coming at an angle of theta with respect to the longitudinal axis of the flight path of the aircraft. In that sense, it will be having two components - one component which will be longitudinally moving in the direction of the aircraft or opposite to the direction of the aircraft, depending on the angle of the theta whether it is less than 90 degrees or it is greater than 90 degrees, respectively and the other component will be at just transverse direction of the movement of the aircraft which is termed as the cross wind component and this cross wind component will be nothing but it will be $V \sin \theta$, where this V is the speed of the wind at an angle theta with respect to the flight path.

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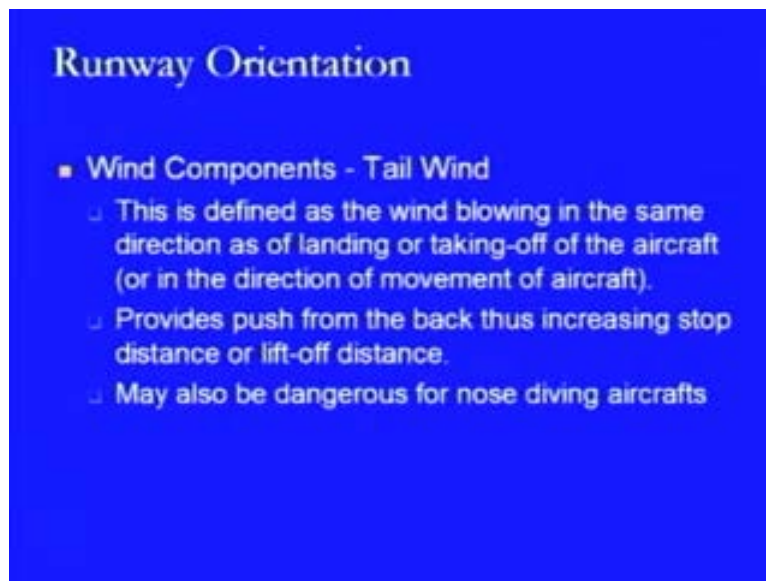
The slide has a blue background with white text. The title 'Runway Orientation' is at the top. Below it is a bullet point 'Wind Direction - Head Wind' which is further broken down into three sub-bullets.

Runway Orientation

- Wind Direction - Head Wind
 - The wind blowing from opposite direction of head or nose of the aircraft (or opposite to the movement of aircraft) while landing or taking-off is termed as Head wind
 - It provides braking effect during landing and greater lift on the wings of the aircraft during take off.
 - Thus the length of the runway gets reduced. This reduction may be around 10%

So, if you look at this head wind, then this head wind is the wind blowing from the opposite direction of head or nose of the aircraft or opposite to the movement of the aircraft while landing or taking-off and this is what is termed as head wind, which provides braking effect during landing and greater lift on the wings of the aircraft during take-off. That is what is the effect of the head wind. Thus the length of the runway gets reduced and this reduction maybe around 10% if we have the head wind on the aircraft on the airport.

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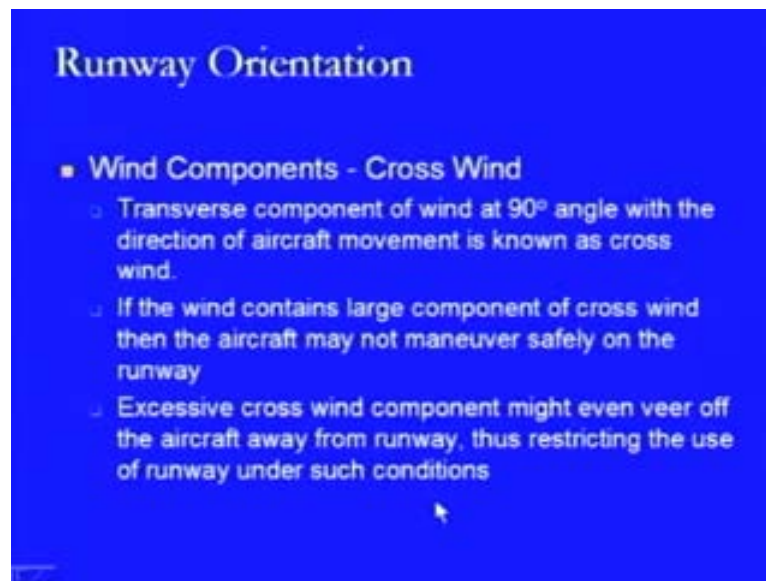
Runway Orientation

- Wind Components - Tail Wind
 - This is defined as the wind blowing in the same direction as of landing or taking-off of the aircraft (or in the direction of movement of aircraft).
 - Provides push from the back thus increasing stop distance or lift-off distance.
 - May also be dangerous for nose diving aircrafts

In case of tail wind, this is defined as the wind which is blowing in the same direction as of landing or taking-off of the aircraft or in the other words it can be defined as it is moving in the direction of the movement of the aircraft. That is what we have discussed that is coming from the tail side is moving towards the nose side and the effect of this tail wind is that it provides a push from the back, thus increasing the stop distance or it may increase the lift-off distance also. So, that is the effect of the tail wind and in that sense, it is going to be dangerous for the nose diving aircrafts.

This is the case, where the nose of the aircraft is going towards a downward elevation as compared to the tail of the aircraft and if that type of aircraft is standing on the apron or in the parking area or bay, then in that case what will happen is that the tail wind which is coming from the tail direction will create an effect of a sort of a lift from the back side and the nose will go further down and will hit the ground. So, that is a dangerous condition for that aircraft, because then the aircraft will become un-operational in this sense.

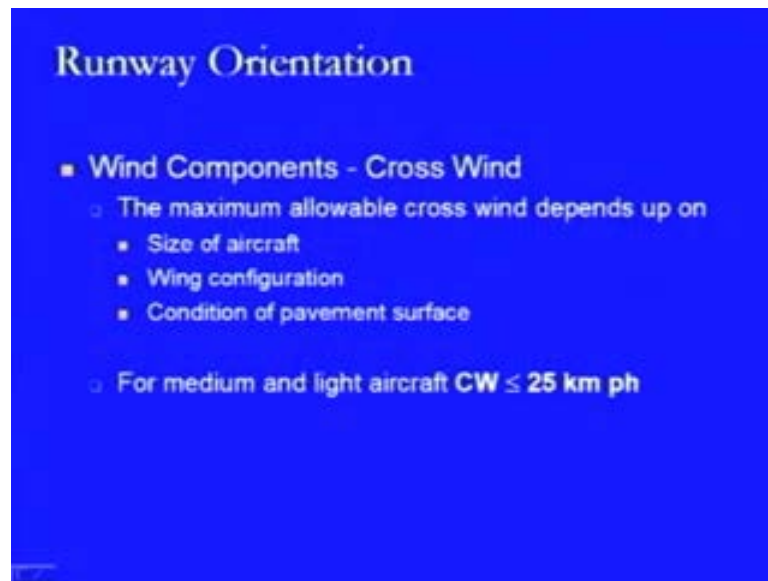
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The third component which we are looking at is the cross wind component and in this cross wind component, this is the transverse component of the wind, which is taken at 90 degree angles may be it is in the form of that **one or** being reduced to that with the direction of the aircraft movement and that is what is a cross wind component and if the wind contains large component of cross wind, then the chances are that that during the manoeuver of that aircraft, there will be drifting effect.

Drifting effect means the aircraft will be moving towards the, in the lateral direction away from the runway strip and if the cross wind component is very, very large, then in that case, there are all chances that **.....** take-off or landing, the aircraft may move towards the shoulder area or even away from that which is hazardous condition for the movement of an aircraft, so and that way we have to look at that what is the cross wind component and this cross wind component is to be specified and has to remain below that one, so that we have the safe and smooth operation of the aircrafts. The excessive cross wind component might even **veer** off the aircraft. That is what I have just said, away from runway thus restricting the use of the runway under such conditions.

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We are looking again at the cross wind component, where the maximum allowable cross wind component will depend on three factors like the size of the aircraft, the wing configuration and the condition of the pavement surface. So, the amount of the cross wind which can be allowed is going to be a cumulative effect of these three cases. If the size of the aircraft is big, then the higher value of the cross wind component can be taken up, whereas the wing configuration again is such that it can take up more of the wind and the surface area is larger, then also effect of higher cross wind component can be eliminated or reduced.

But, in the case of the condition of the pavement surface, if there are more of depths and rises, then this cross wind component may create its effect. Now, for medium and light aircraft conditions, then this cross wind component is usually taken as less than or equals to 25 kilometers per hour. So, the velocity of the wind in terms of at 90 degrees to the flight path or in 90 degrees to the landing or taking-off of the aircraft is restricted to a value of 25 kilometers per hour.

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Runway Orientation	
■ Wind Components - Cross Wind	
▫ The ICAO recommends maximum allowable cross wind component as	
Reference Field Length	Maximum Crosswind Component
1500 m or over	37 km/hr
1200 m to 1499 m	24 km/hr
< 1200 m	19 km/hr

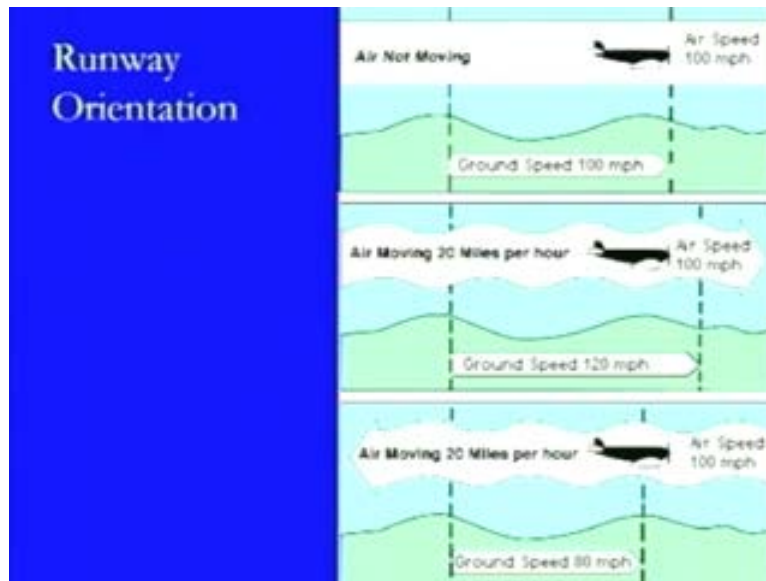
Another thing related to cross wind is the ICAO recommendation which has a maximum allowable cross wind component as defined for the different field lengths, reference field lengths and on the basis of that, like if the value of the reference field length is 1500 metres or over, that is more than that, then in that case, the maximum cross wind component can be 37 kilometers per hour, whereas if it is between 1200 metres and 1499 metres, then this is taken as 24 kilometers per hour and if it is less than 1200 metres, it is taken as 19 kilometers per hour.

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Runway Orientation	
■ Wind Components - Cross Wind	
▫ The FAA recommends as follows	
Airport Reference Code	Allowable Crosswind
A-I, B-I	19 km/hr
A-II, B-II	24 km/hr
A-III, B-III, C-I, C-II, C-III, C-IV	30 km/hr
A-IVM D-VI	37 km/hr

Further, if we look at the FAA recommendations, then what it gives is that in the case of airport reference code like A-I and B-I, then it is 19 kilometers per hour. For A-II and B-II, it is 24 kilometers per hour. For category of A-III, B-III and C-I, C-II, C-III and C-IV, it is 30 kilometers per hour. For a category of A-IVM and D-VI, it is 37 kilometers per hour.

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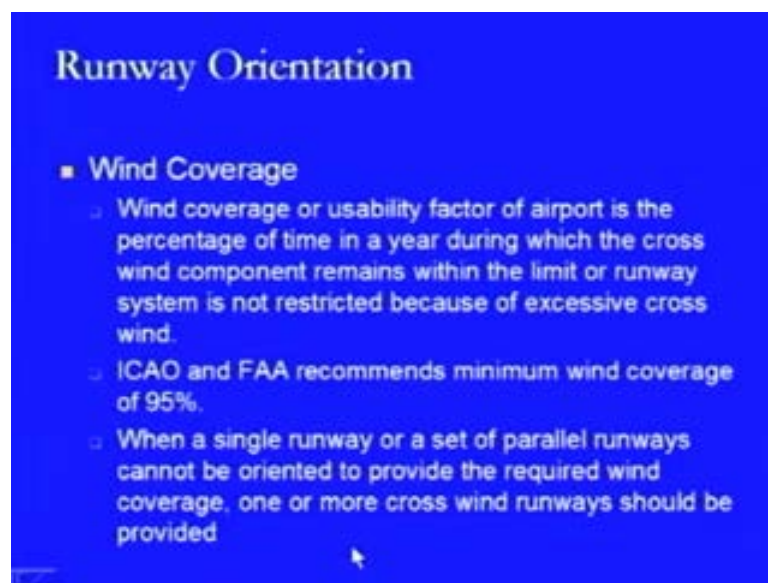
Now, here the effect of the air speed with respect to the aircraft speed has been shown and this is one aspect which we have discussed previously, where we try to correlate the value of the ground with the air speed given the wind speed to us. In this diagram, in the top most there is no air moving and therefore, whatever is the speed of the aircraft in the air remains the speed of that aircraft on the ground. So, there is no difference in the value in this case. Whereas, if there is air which is moving at 20 miles per hour and it is in the same direction in which the aircraft is moving with the speed of some like 100 miles per hour, then the ground speed will be depicted as 120 miles per hour. So, that is the variation in the value between air speed and the ground speed of an aircraft.

Similarly, when the air is moving at the same 20 miles per hour, but opposite to the value to the direction of the movement of the aircraft, then the ground speed will be coming as 80 miles per hour. This is because of the relative phenomena of the velocity which is being considered here, so as to find out the velocity. So, that is the

case, that is how the ground speed or the air speed can be computed given the two other values to us and this has its significance in the terms that we have to look at what value the aircraft is going to navigate in the air or at the same time at the time of say landing, at what speed it will be landing. So, that is where these values have their own significance. So, we have looked at the surface wind, we have looked at the ground speed, in that.

Now, we come to another important aspect that is wind coverage.

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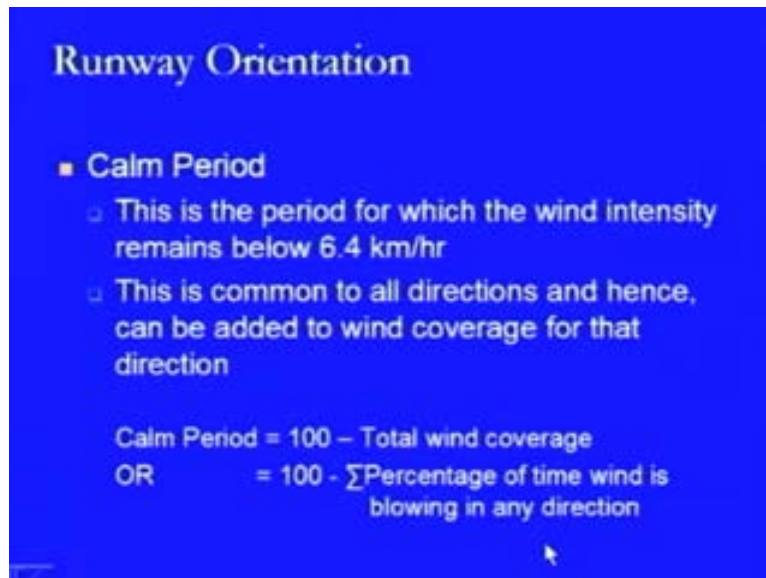
- Wind Coverage
 - Wind coverage or usability factor of airport is the percentage of time in a year during which the cross wind component remains within the limit or runway system is not restricted because of excessive cross wind.
 - ICAO and FAA recommends minimum wind coverage of 95%.
 - When a single runway or a set of parallel runways cannot be oriented to provide the required wind coverage, one or more cross wind runways should be provided

This wind coverage is also termed as sometimes as a usability factor of airport and this is defined as a percentage of time in a year, during which the cross wind component remains within the limit or runway system in not restricted, because of the excessive cross wind component. So, we have seen previously that what is the cross wind component being defined on the basis of the type of the airport by ICAO and by FAA. Now, based on the type of airport and the selected cross wind component, we have to look at the maximum percentage of time in a year for which the cross wind component will remain below that value and that is what is the wind coverage being defined. ICAO and FAA both recommends the minimum wind coverage area of 95% and this is what is being globally generally accepted by the other countries. A single runway or a set of parallel runways cannot be oriented to provide the required wind coverage of 95% as defined by ICAO, FAA. Then, one or more than one runways

needs to be provided in that case and the combined value of those two or more runways will come out as more than 95%. So, that is the value which needs to be provided while selecting the orientation of the runways.

Another aspect in the orientation of runways is the calm period.

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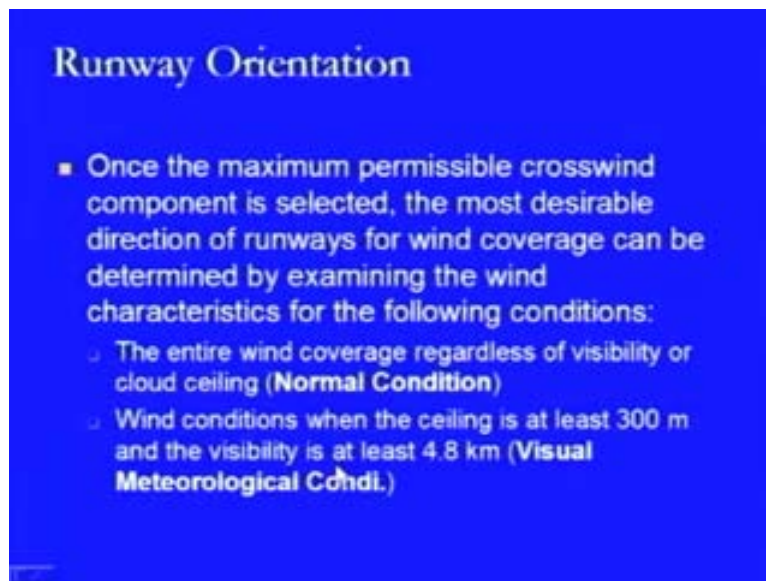
Runway Orientation

- **Calm Period**
 - This is the period for which the wind intensity remains below 6.4 km/hr
 - This is common to all directions and hence, can be added to wind coverage for that direction

Calm Period = 100 – Total wind coverage
OR = 100 - \sum Percentage of time wind is blowing in any direction

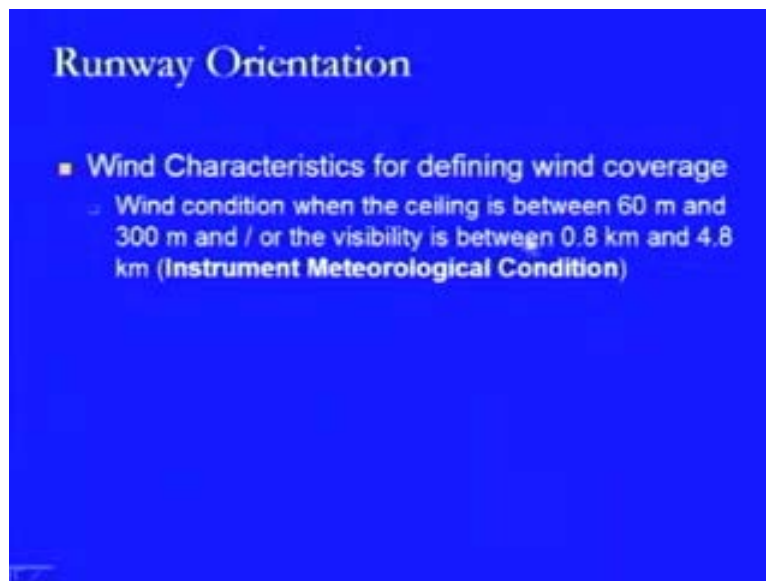
Calm period is the one when the wind intensity remains below 6.4 kilometers per hour and this is common to all directions and hence can be added to wind coverage for that direction. So, we are looking at the wind coverage data and we are trying to find out the wind coverage value, then this is the one which can be taken and added to the overall wind coverage information. So, the calm period is equal to 100 minus the total wind coverage or it is 100 minus the percentage of time wind is blowing in any direction, with any speed. So, if we take a total summation of all those percentages with respect to time, with respect to direction and with respect to duration, then and we subtract it from 100, what we are going to get is calm period.

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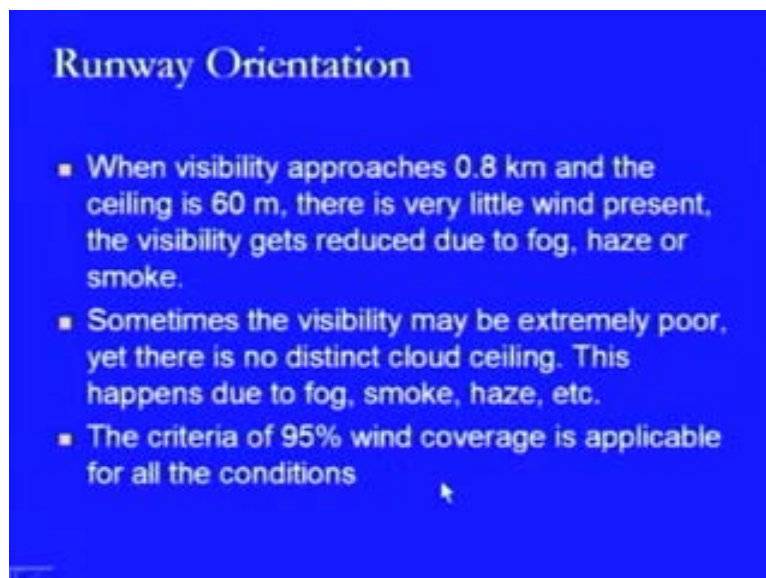
Once the maximum permissible cross wind component is selected, the most desirable direction of runway for cross wind coverage can be determined by examining the wind characteristics for the following conditions: that the entire wind coverage regardless of visibility or cloud ceiling which is termed as the normal condition, that we can provide the overall whole of the wind coverage condition there is no problem of visibility. There is a visual metrological condition as we have discussed previously during the fly rules that the wind condition when the ceiling is at least 300 metres that is what I have discussed previously too and the visibility is at least 4.8 kilometers and this value during the concession period, where the concession fees was also levied on the airlines and that was charged by the passengers during the flights at different airports in India, this value is being requested to be lessened out, because this is a little more stringent as compared to the other countries and the request was to bring it to as low as 50 metres during the worst visual metrological conditions.

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Further, in the case of the instrument metrological conditions, it defines that the wind condition when the ceiling is between 60 metre and 300 metre and or the visibility is between 0.8 kilometer and 4.8 kilometer, so that is the way it is defined in terms of the instrument metrological condition.

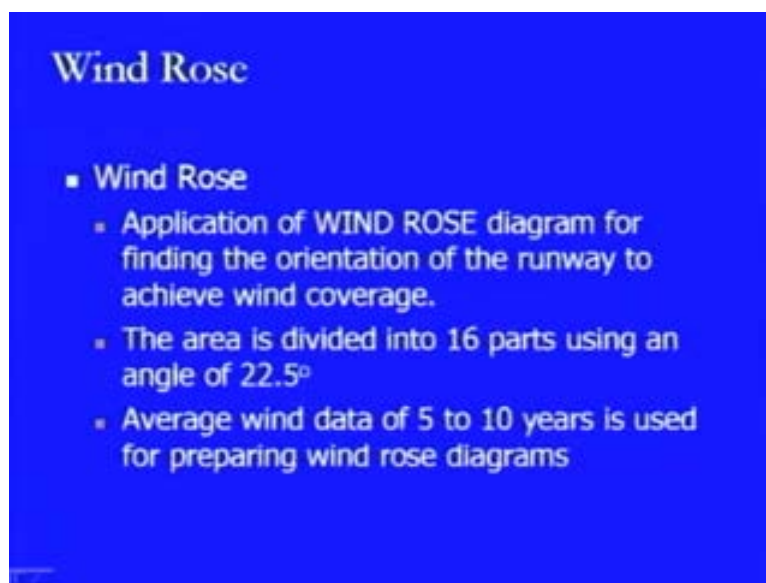
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Now, when visibility approaches 0.8 kilometers and the ceiling is 60 metres, there is very little wind present, the visibility gets reduced due to fog, haze or smoke. So, this is the minimum value which remains and the visibility is hampered, because of

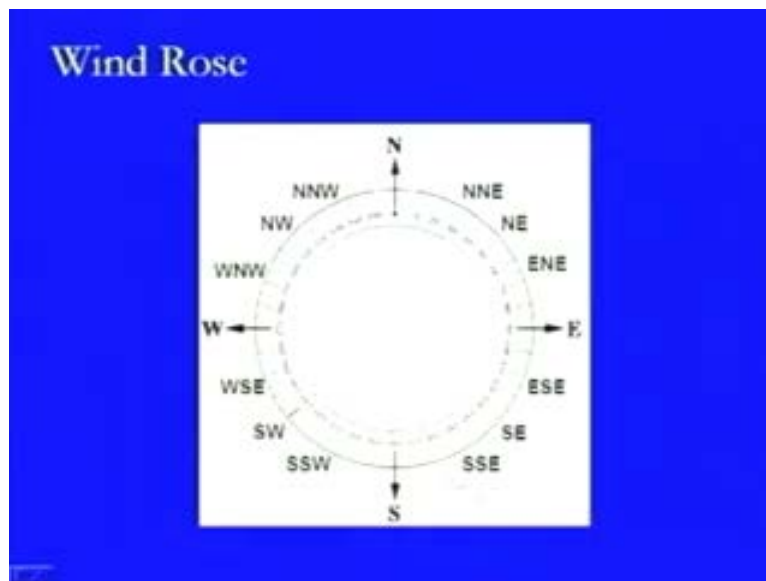
various types of metrological conditions. Sometimes, the visibility may be extremely poor, yet there is no distinct cloud ceiling. This happens due to fog or smoke or haze or similar conditions and the criteria of 95% wind coverage is applicable to all the conditions. Whatever are the conditions this cannot be removed or restricted. So, once we have the idea of the wind and its components in terms of its intensity, direction and duration and the effects of those winds, then now we can think of discussing about the wind rose diagrams and this wind rose diagrams are the tools which we use for finding out the orientation of the runways.

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So the application of the wind rose diagram is for finding the orientation of the runway to achieve the desired wind coverage and the area is divided in the case of the wind rose diagram into 16 parts using an angle of 22.5 degrees. So, whatever is the overall area on which the airport is being provided, we just divide it into 16 equal parts and obviously, this will be on the basis of equal angle of 22.5 degrees and the average wind data of 5 to 10 years is used for preparing such type of wind rose diagrams. So, we will be taking the information available to us for say 10 years, in terms of wind intensity, wind duration and wind direction and then we analyse that and then, on the basis of that analysis we draw the wind rose diagrams.

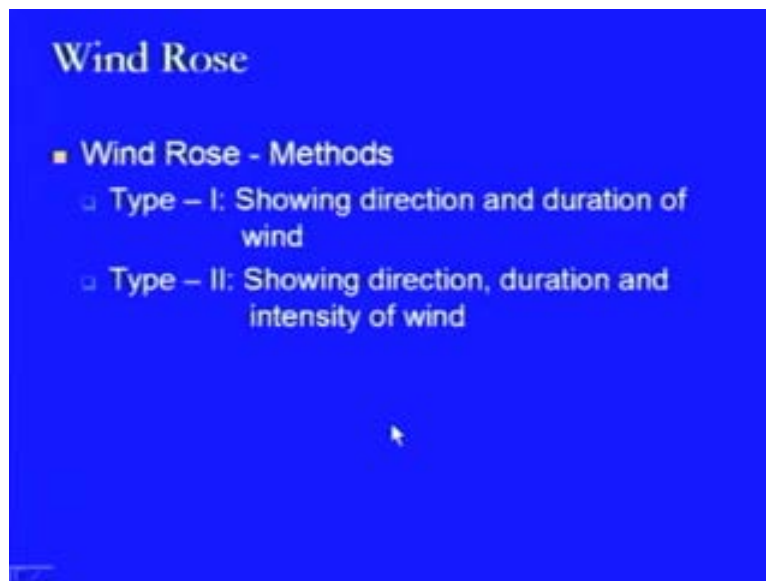
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This is a typical wind rose diagram, where what we are trying to do is that it shows those directions in which it is being divided. This is the 360 degree circular curve condition, where it shows the North, South, East and West directions and then it is further being divided into, each quadrant is being divided into 4 parts using 22.5 degree angle and that is how at 45 degree angle, we have the North East and then at the centre of that one, we have the North North East and on this side, it is the East North East, because it is from the East side.

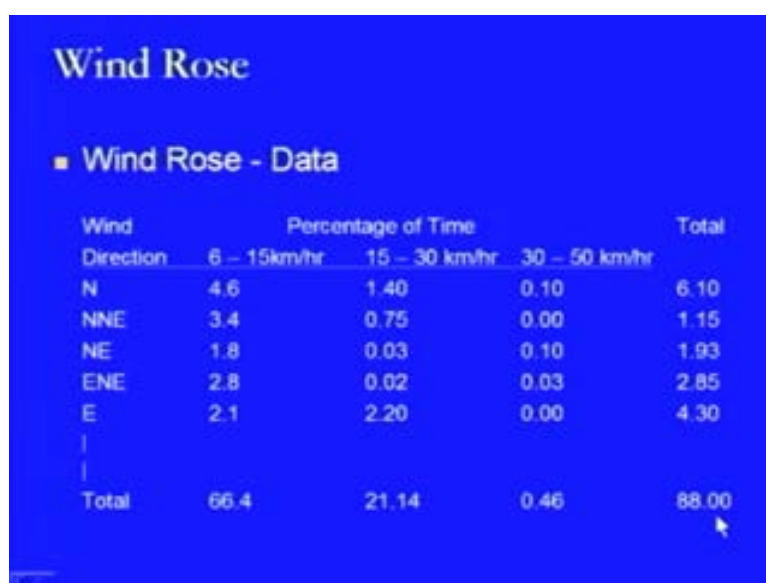
Similarly, when we look from the South side, at the centre it is the South East, whereas on this side, it will be East South East and here it will be South South East and this is the same way it is been defined on the other side for the West direction as North North West, North West and West North West. Similarly for the South, it is the West South East; this is the West South West basically, it is not East, let us make the rectification here and this is the South West and this is South South West.

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There are different methods by which these wind rose diagrams can be drawn, because in the previous diagram we have only shown the directions. Then, what is the use of those directions and how that is being done? There are different ways and most of time we are using two types of the wind rose diagram. The Type - I shows direction and duration of wind, whereas Type - II shows the direction, duration and intensity of wind. That is all the three parameters are shown in the second case. So, we will be looking at both the type of the wind rose diagrams now.

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A blue slide titled "Wind Rose" with a white bullet point "■ Wind Rose - Data". Below it is a table showing wind direction data. A mouse cursor is visible near the bottom right.

Wind Direction	Percentage of Time			Total
	6 – 15km/hr	15 – 30 km/hr	30 – 50 km/hr	
N	4.6	1.40	0.10	6.10
NNE	3.4	0.75	0.00	1.15
NE	1.8	0.03	0.10	1.93
ENE	2.8	0.02	0.03	2.85
E	2.1	2.20	0.00	4.30
Total	66.4	21.14	0.46	88.00

We look at the wind rose diagram. What type of data we are taking, just have a look at the data, say we have the wind direction data we have the time period that is being provided in terms of the percentage of time for which the wind is moving with the speed of or the velocity of 6 to 15 kilometers per hour that is what how we have segregated on the basis of the minimum value and maximum value here and another category being taken as 15 to 30 kilometers per hour and the third category is taken as 30 to 50 kilometers per hour and this we have done on the basis of the metrological data which was available to us and then, we are making a total of that. So, this will be the total time duration for which the wind is blowing in the certain direction.

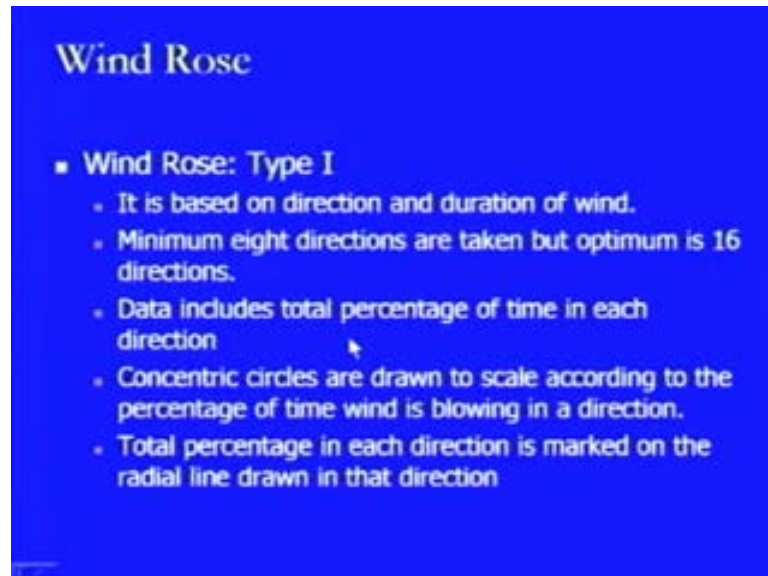
So, like this example wind is blowing in the direction North and for 4.6% of the time period it has been moving with the velocity range between 6 and 15 kilometers per hour, whereas 1.4% of the time period it was moving within a range 15 to 30 kilometers per hour and for 0.01% of the time period, it was moving in a range of 30 to 50 kilometers per hour and the summation of this time period is 6.1%, showing that out of the total 100%, the wind was blowing for a value of 6.1% in the direction North. So, that is how we have the composite data being available in this form, which can be used either to draw Type - I diagram of the wind rose, where we are using only the direction and the duration that is the total duration or we can draw the Type – II diagram, where we are using direction, duration and the speed. That is the intensity being defined here in this form.

Further, we take the example for a North North East direction and similarly we can have the way for each and every direction in which the wind is moving, we can take the values. Finally, what we do is that we take the total of for the different percentages of times being related to the various speed categories and we get this value as like 66.4% of the time period it is moving within a range 6 to 15 kilometer per hour, for 21.14 time period, percent time period, it is moving in a range of 15 to 30 kilometer per hour and for 0.46%, of the time period it is moving in a range of 30 to 50 kilometer per hour and the overall value of this comes out to be 88%.

It means for 88% time period, the speed of the wind has been more than 6 kilometers per hour, whereas for the rest of the 12% of the time period, it has been less than 6 kilometers per hour and therefore, the calm period is 12%. So, this 12% value can be

added to the wind coverage area as we find out further and then that will become, that will help us in identifying the direction of the runways.

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So, in the case of the Type - I wind rose diagram, what we do is that it is based on the direction and duration of the wind and the minimum 8 directions are taken and optimum 16 directions are taken as we have seen at an angle of 22.5 degrees. Here, the data will include the total percentage of time in each direction as being done in the final column of the previous data chart. The concentric circles are drawn to scale according to the percentage of time wind is blowing in a direction. So, based on the value, we will be drawing the concentric circle. So, this is based on the time period, whatever is the minimum or the maximum time period is available in this case.

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Wind Rose				
■ Wind Rose - Data				
Wind	Percentage of Time			Total
Direction	6 – 15km/hr	15 – 30 km/hr	30 – 50 km/hr	
N	4.6	1.40	0.10	6.10
NNE	3.4	0.75	0.00	1.15
NE	1.8	0.03	0.10	1.93
ENE	2.8	0.02	0.03	2.85
E	2.1	2.20	0.00	4.30
Total	66.4	21.14	0.46	88.00

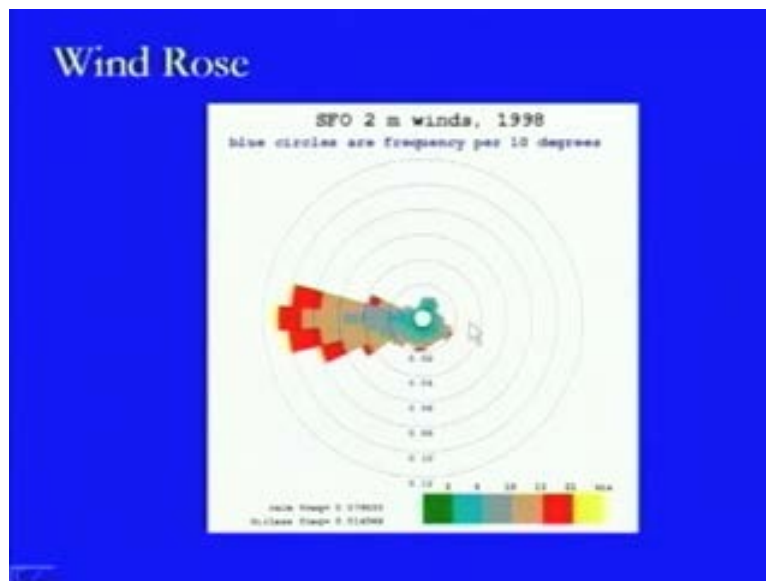
So, if you look at this diagram, the minimum is 1.15 and say the maximum is 6.10. So, on the basis of this value, we will be drawing the concentric circles, say for every 2% we are drawing it. So, it will be 2, 4 and 6. Then, there is a total percentage in each direction marked on the radial line drawn in that direction.

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Wind Rose	
■ Wind Rose: Type I	
•	These points on radial lines are joined together to form a duration map.
•	Best direction of runway is indicated along the direction of the longest line on the Wind Rose diagram

Then, these points on radial lines are joined together to form a duration map and the best direction of runway is indicated along that direction of the longest line on the wind rose diagram.

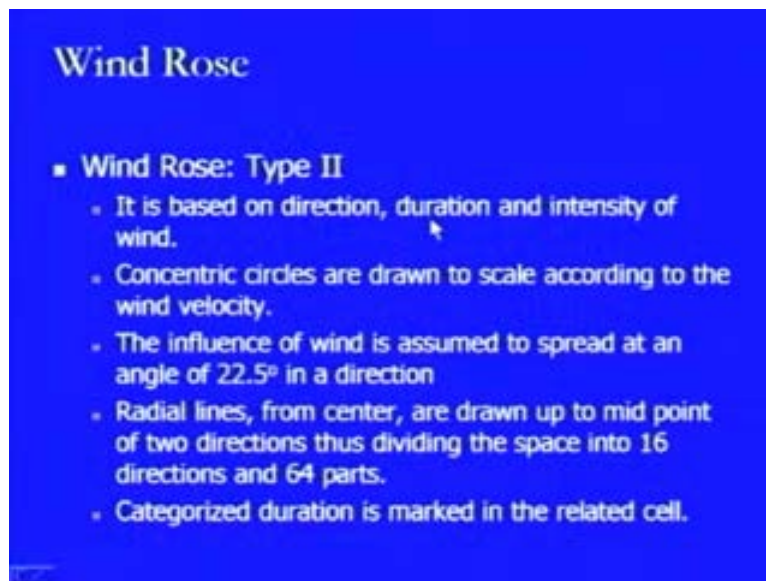
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That is how we find out the orientation of the runway and this is what we are trying to do is on the basis of the time periods, we are dividing it into the concentric circles. Now, for more accuracy we can have more of the circles or we can go for lesser number of circles. So, if we have some circles, then there will be direction, like for this there maybe the West direction, East direction and similarly for the other directions and then for that direction, for that concentric circle, we will be taking the value. In that direction what is the value of the percentage of time as we have seen in the last column of the data chart. So, we will just put that value and we will draw or put a mark on this concentric circle.

Similarly for North, if the value comes here, we will mark here or for other directions if the value comes here or here or likewise in a haphazard form, we will keep on marking all those dots in those directions on the concentric circle, far away from the concentric circles, because it is to be between the concentric circles and then once those dots have been drawn in all the directions and they are joined with each other starting from one direction going in the circular or the anticlockwise condition and coming back to the same direction, so we will be having a graph and then, within that graph we will try to find out the maximum longest line which can be drawn starting from one direction to the opposite direction and that particular line will tell that this is going to be the orientation of the runway on the basis of the first type of wind rose diagram.

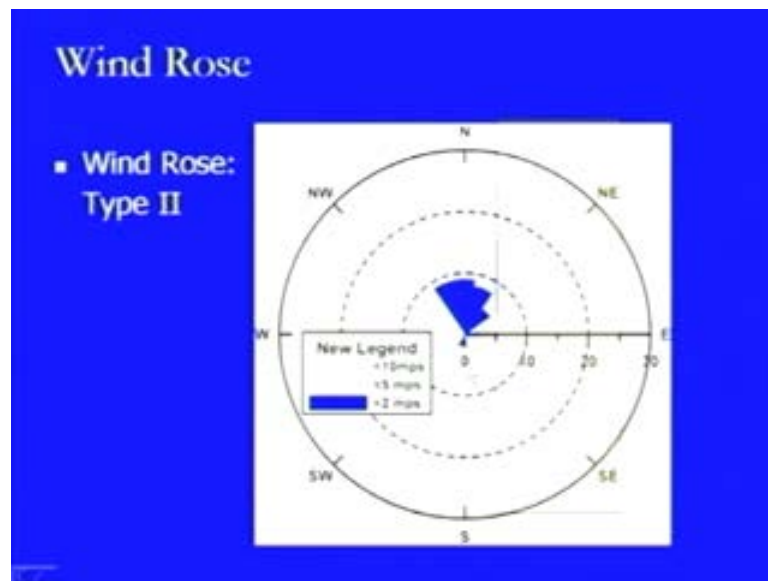
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Then, when we look at the second type of the wind rose diagram, then this is based on direction, duration and intensity of wind. The concentric circles are drawn to scale according to the wind velocity and not on the basis of the percentage time as taken in Type – I. So, here we are using wind velocity. The influence of wind is assumed to spread at an angle of 22.5 degrees in a direction and the radial lines from the centre are drawn up to the midpoint of the two directions, thus dividing the space into 16 directions and 64 parts.

So, what we are doing is that we are drawing the radial lines from the centre of the concentric circles and they will go towards the centre of the direction. So, if we have this as North, and then this as a North East and then, whatever is the centre of this one, that will be North North East in this side. So, this will be the line which will be drawn. So, it will divide this total part into two segments. So, as we are going for 16 directions, then we will be having 16 such segments based on such orientation and the categorized duration is marked in the related cell. So, whatever duration we have found out for that direction, that we can write down in the cell related to that one.

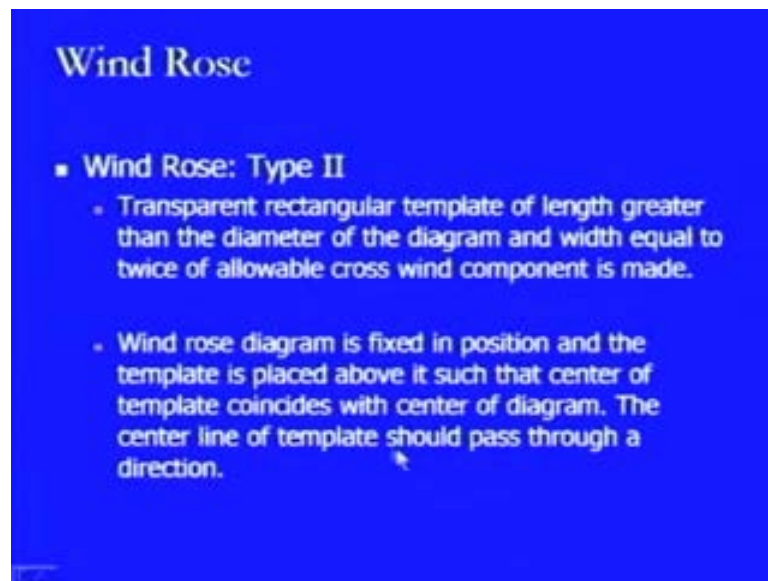
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So, here what we are doing, this is the speed of the wind 0, 10, 20, 30. So, the concentric circles have been drawn accordingly. Now, once it is being drawn, this is one direction, this is another direction or say there is one direction in the centre also here as North North East. So, this is twenty two and a half degree, this is twenty two and a half degree. Now, the line which will be drawn will be from the centre of this North and North North East. That is from this point it will be joined as a centre of the concentric circles.

Similarly, from the centre of the North North East and North East that is from here, a line will be joined here. It means now this is, this area which is being provided for this North North East is starting from half of the distance from this side and half of the distance from this side. Similarly for North East, we have half of the distance from this side and half of the distance from this side. So, we will be having a line segments line this way. So, once we have the line segments this way, then we will be having the cells, the cell between these two lines and the cells being created because of the concentric circles. So, whatever is the duration that duration will be written in that cell. So, if it is North North East, then within this cell that is between 10 and 20 kilometers per hour whatever was the duration will be written here. Then, whatever was the duration for 20 to 30 will be written here. So, that is how the total chart will be prepared.

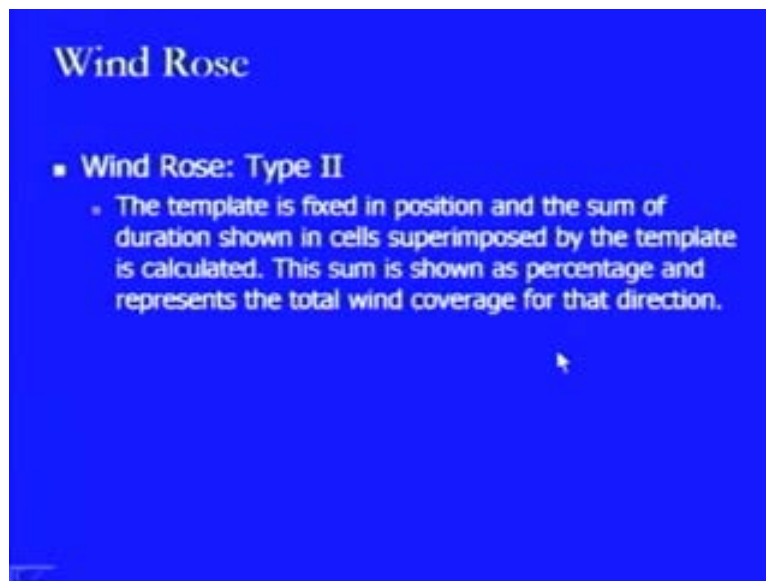
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Now, once this is being done, the next step is to prepare a transparent rectangular template of length greater than the diameter of the diagram. So, whatever the diameter of this diagram is, we prepare a template like this. This template is having a size which is greater than the diameter. This is the diameter of this one, so it is greater than this. So this is the length. Similarly, we have to decide the width of this one. So, what we are doing is ... and the width is equal to the twice of allowable cross wind component. So, whatever is the cross wind component, say if it is 24 kilometers per hour, then the twice of that means 48 kilometers per hour. So, whatever is the scale we have taken, so as to find out these speeds, here as 10, 20 and 30, using the same scale you will decide this width as 48 kilometers per hour. So, that is how the size of the template is decided.

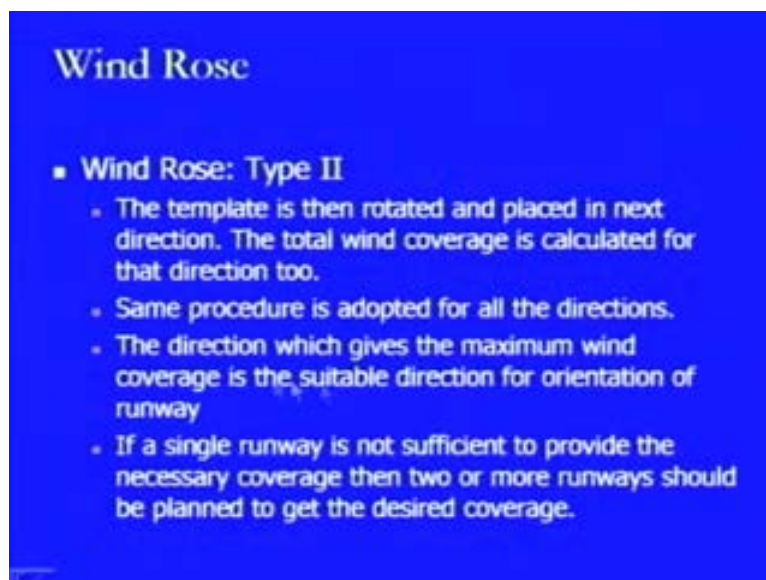
Now, wind rose diagram is fixed in position and the template is placed above it, such that the centre of the template coincides with the centre of diagram and the centre line of template should pass through the direction. So, whatever is the centre of this template will come at the centre of this line diagram which we have drawn and the centre of the template here will be at this location. This is how now we place our template over this diagram and we start locating our template.

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The template is fixed in position and the sum of the duration shown in cells superimposed by the template is calculated. So, whatever is the area being covered by the template, we will find out the area in terms of the values being written in the cells and then, we take the sum of all those values and that sum will become the percentage and will represent the total wind coverage for that direction.

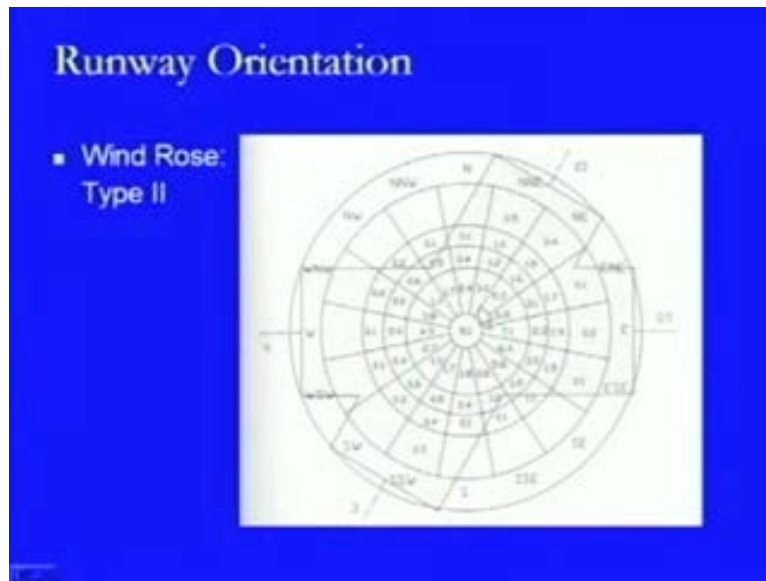
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So, once we have got the total wind coverage for that direction, similarly we will be doing the same exercise for the rest of the 16 other directions and if we do it for all the

directions, then the direction which gives the maximum wind coverage is the suitable direction for orientation of runway. In case, a single runway is not in a position to provide the necessary coverage that is 95% of the wind coverage, then two or more runways should be planned, so as to get the desired coverage area. That is how it works.

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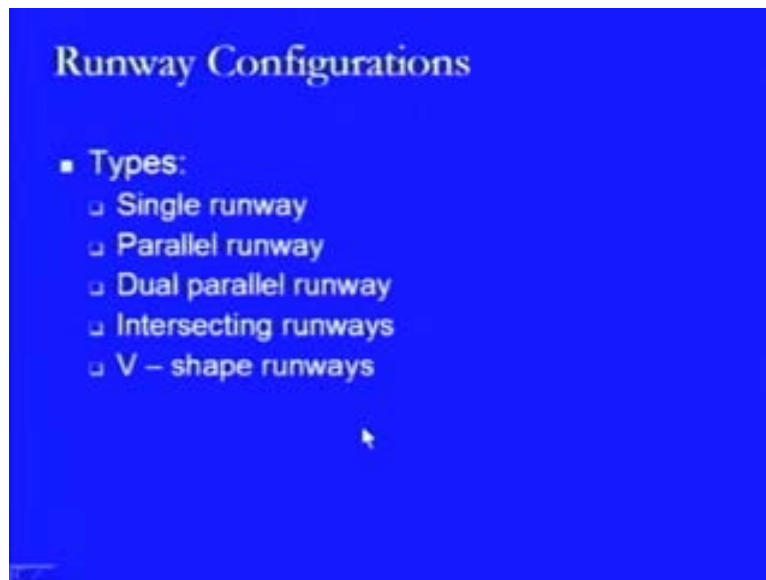


This is one of the typical diagrams, where we are having this North and these radial lines are drawn from the centre of this direction and the other direction that is North and North East, so this is the centre, likewise and because these concentric circles are related to their speeds, so we have the cells. So, this is one cell, this is another cell, this is another cell, this is another cell, likewise. So, whatever was the value related to North, for the first category, then for the second category or for the third category has been noted.

Similarly, it has been done for the rest of the cells. Now, once we have done this, then we will keep on orientating our template and on the basis of that, what we found that if we keep our template in the direction of North North East and South South West that is this direction in this way and we take the summation of all the values which are coming like this and then, we are also putting the value in this direction in this form and taking the summation of all these values which are coming in this direction that is in West and East, then the total value of these two directions is providing us a 95% of

the coverage area and that means in this particular airport, we have to provide two runway strips which are placed like this. In case only a single strip is providing 95% of the coverage area, then there is no need of providing any such other strip which is crossing it.

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Now, we come to the various types of the runway configurations and these are single runways, parallel runways, dual parallel runways and intersecting runways and V - shaped runways. These are the 5 categories of the runway configurations which can be there on the basis of the orientations which we have found out. So, we will be discussing about these now.

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Runway Configurations

- **Single Runway:**
 - Simplest of the 4 basic configurations.
 - Optimally positioned for prevailing winds, noise, land use and other determining factors.
 - During VFR (visual flight rules) conditions, the hourly capacity is between 50 and 100 operations per hour.
 - Under IFR (instrument flight rules) conditions, this capacity is reduced to 50 to 70 operations per hour.
 - Capacity depends upon aircraft mix and navigational aids available

In the case of single runway, this is one of the simplest of the basic configurations and optimally positioned for prevailing winds, noise, land uses and other determining factors which determine the position of the runway strip and during VFR conditions, the hour capacity of this type of a runway is between 50 and 100 operations per hour, whereas in the case of IFR condition, it is reduced to 50 to 70 operations per hour. The capacity depends upon aircraft mix as well as navigational aids being provided.

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Runway Configurations



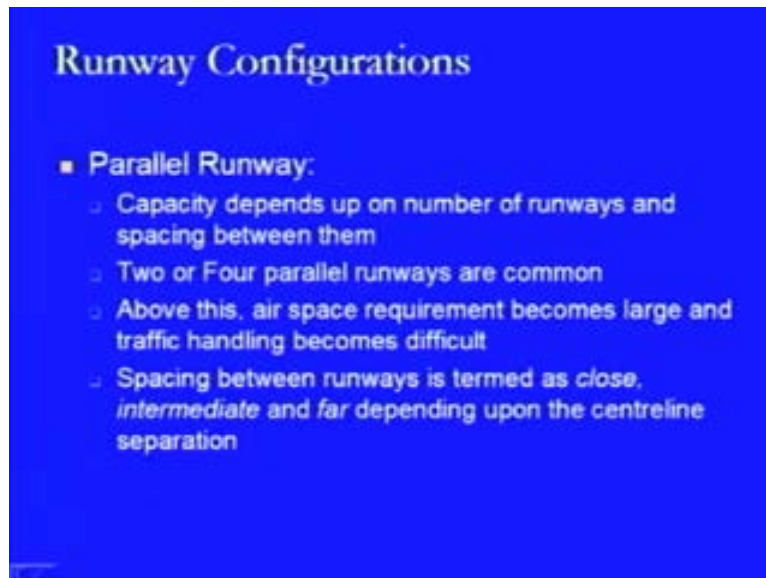
The diagram shows a single runway strip, represented by a thick black line, oriented diagonally from the top-left to the bottom-right. At each end of the runway, there are small rectangular structures representing taxiways or aprons. Below the runway strip, the text "Single runway" is written in a small font. Below the entire diagram, the text "SINGLE RUNWAY" is written in a larger, bold, all-caps font.

Single runway

SINGLE RUNWAY

This a single runway condition, with the clear way at the end on this side as well as this side. So, this single clear way will look like this way. This is a particular orientation on the basis of the orientation we found out from the wind rose diagram.

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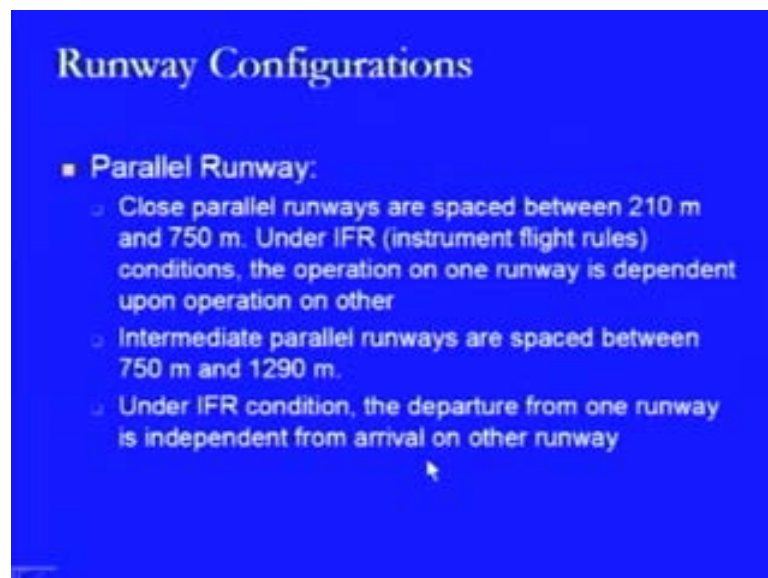
Then, there is a parallel runway condition where the capacity depends upon the number of runways and the spacing between them. Two or four parallel runways are the common type of configurations. Above this, the air space requirement becomes large and the traffic handling becomes difficult. That is why most of the time, we are providing only up to four parallel runways and not more than four parallel runways. The spacing between the runways is termed as close, intermediate and far and this depends upon the centreline separation of the two runway strips being provided side by side.

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We look at the first case, where this is a closed parallel condition being defined on the basis of the distance between the centreline of one runway to the centreline of another runway and here it is being defined in terms of less than 2,500 feet between runways. If that is the case of the distance, then that is known as close parallels.

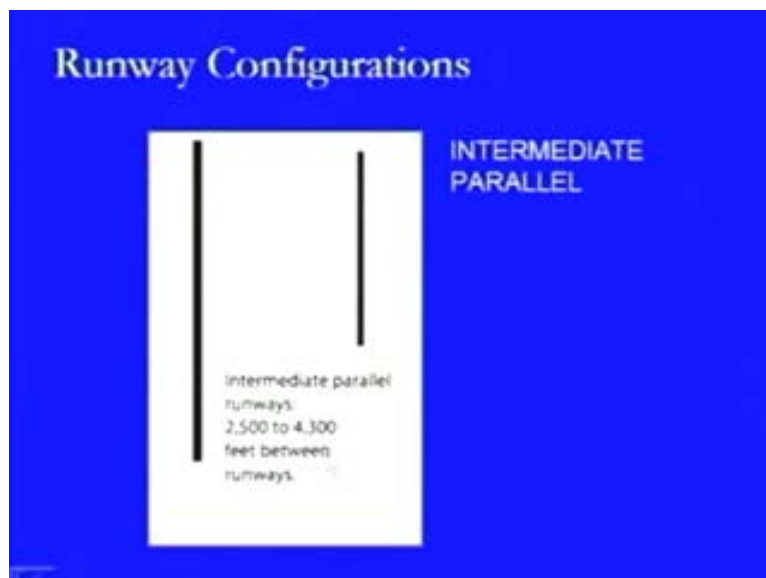
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Then, in the case of close parallel runways, if they are spaced between like 210 metre and 750 metre, under IFR conditions, the operations on one runway will become dependent upon the operation on another runway. That is the problem in the case of

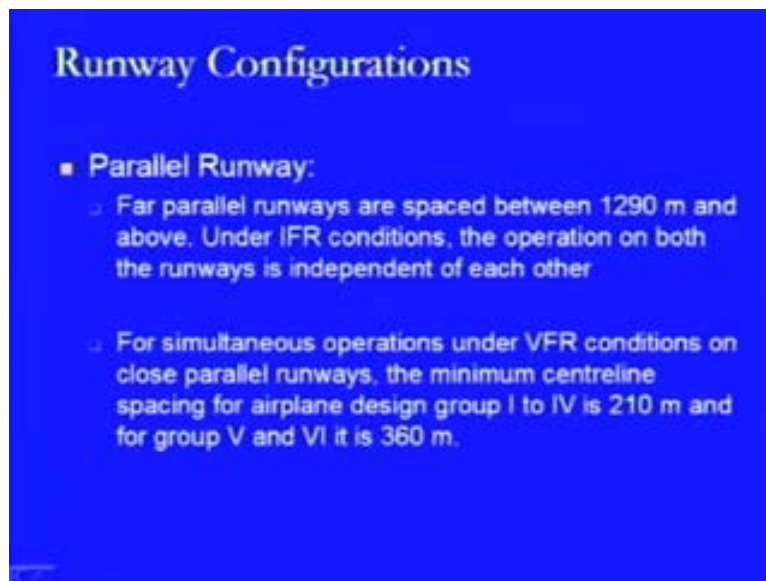
close parallel runways. In the case of intermediate parallel runways, generally these are spaced between 750 metres and 1290 metres, in the diagrams being shown in the form of feet and under IFR conditions, the departure from one runway is independent from the arrival on the other runway. That is what it tries to define is that the two runways which are being provided in the intermediate condition are used for different specific type of operations. One is used for departure and another maybe is used for say the landing and in such cases, they are independent of each other. Therefore, there is no effect of one operation on another one and the airport capacity will not be reduced. It will rather improve.

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This is the case of intermediate parallel, where again the distance between the two is being defined in terms of feet. It is 2,500 to 4,300 feet.

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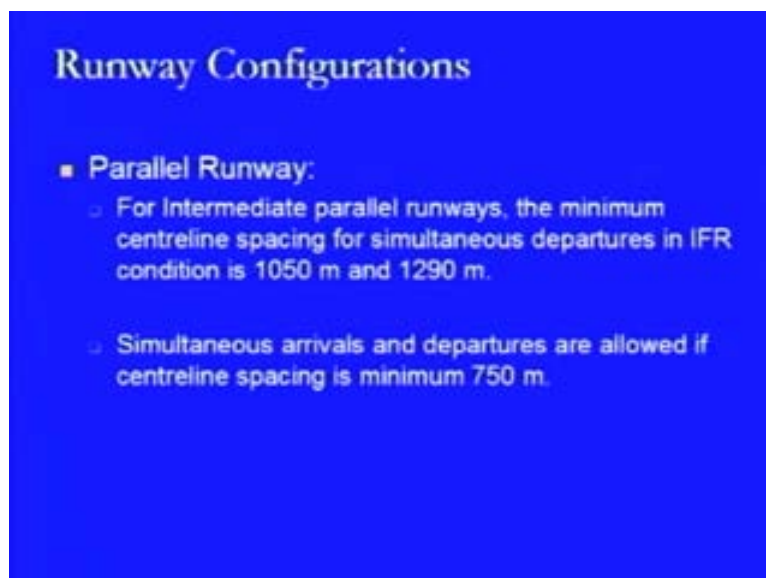


Runway Configurations

- **Parallel Runway:**
 - Far parallel runways are spaced between 1290 m and above. Under IFR conditions, the operation on both the runways is independent of each other
 - For simultaneous operations under VFR conditions on close parallel runways, the minimum centreline spacing for airplane design group I to IV is 210 m and for group V and VI it is 360 m.

Further, in the case of parallel runways, there is another case where the runways may be spaced between 1290 metres and above and under IFR conditions, the operation on the both runways becomes independent of each other and for simultaneous operations under VFR conditions on the close parallel runways, the minimum centreline spacing has to be made as 210 metres in the group I to IV cases and has to be made 360 metres for group IV to VI type of airplane design group.

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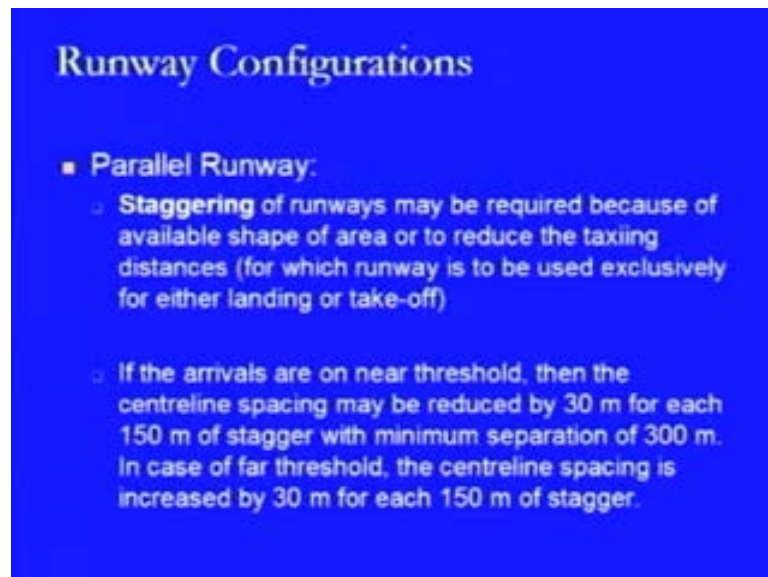


Runway Configurations

- **Parallel Runway:**
 - For Intermediate parallel runways, the minimum centreline spacing for simultaneous departures in IFR condition is 1050 m and 1290 m.
 - Simultaneous arrivals and departures are allowed if centreline spacing is minimum 750 m.

In the case of intermediate parallel runway, the minimum centreline spacing for simultaneous departures in IFR condition has to be made as 1050 metres and 1290 metres. Simultaneous arrivals and departures are allowed if the centreline spacing is minimum 750 metres, because at that case, it will become independent of each other.

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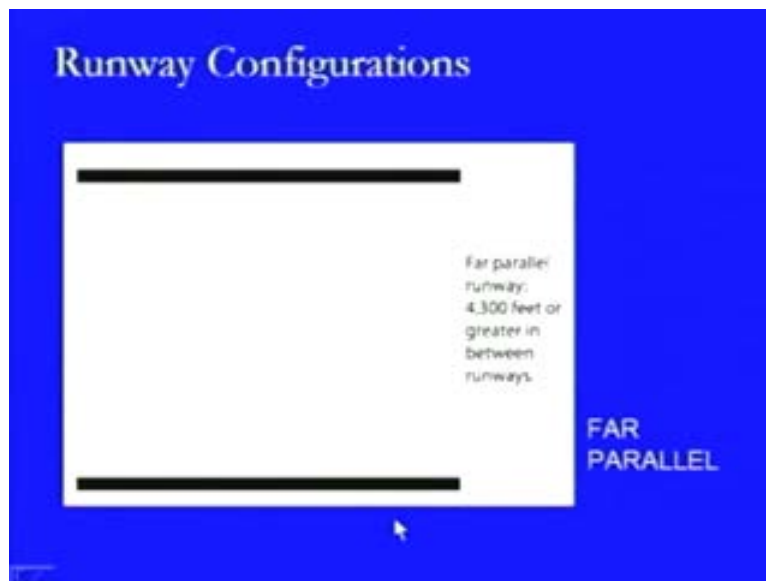


Runway Configurations

- **Parallel Runway:**
 - **Staggering** of runways may be required because of available shape of area or to reduce the taxiing distances (for which runway is to be used exclusively for either landing or take-off)
 - If the arrivals are on near threshold, then the centreline spacing may be reduced by 30 m for each 150 m of stagger with minimum separation of 300 m. In case of far threshold, the centreline spacing is increased by 30 m for each 150 m of stagger.

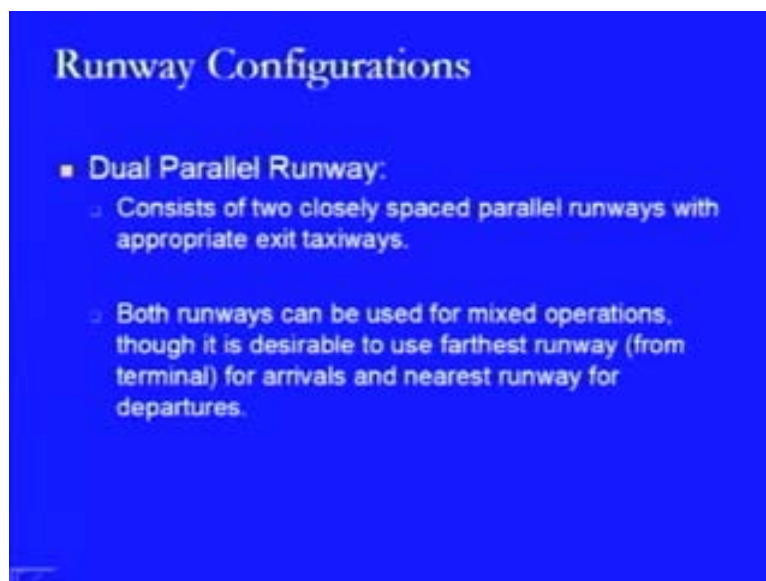
Then, a staggering of runways is also required sometimes, because the available shape of the area is such or at times we are interested in reducing the taxiing distance that is the distance by which the aircraft is coming away from the runway towards the apron area and that is the case, why we go for the staggering condition. In the case of the arrivals are on near threshold, then the centreline spacing may be reduced by 30 metre for each 150 metre of stagger with minimum separation of 300 metres. So, the minimum separation remains 300 metres, but if we are staggering it for 150 metres, then in that case, the centreline spacing can be reduced by 30 metres. In case of the far threshold movements, then the centreline spacing is increased by 50 metres for every 150 metre of staggering.

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We look at, this is a far parallel condition, where the far runway strips are at a distance 4,300 feet or more. A larger area is being provided in the centre of these two.

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Then, another case is the dual parallel runway case, where it consists of two closely spaced parallel runways with the appropriate exit taxiway. That is a dual parallel runway. Both runways can be used for mixed operations, though it is desirable to use farthest runway on the terminal for arrivals and the nearest runway for departures. That is for economizing the time.

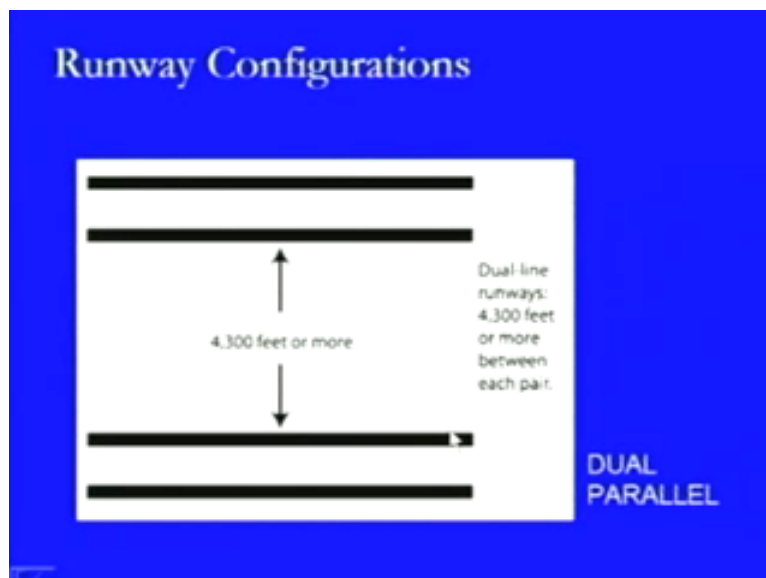
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Runway Configurations

- **Dual Parallel Runway:**
 - The dual runway can handle 70% more traffic than single runway in VFR condition and 60% more traffic in IFR condition.
 - If spaced at 300 m or more then capacity becomes insensitive to centreline spacing

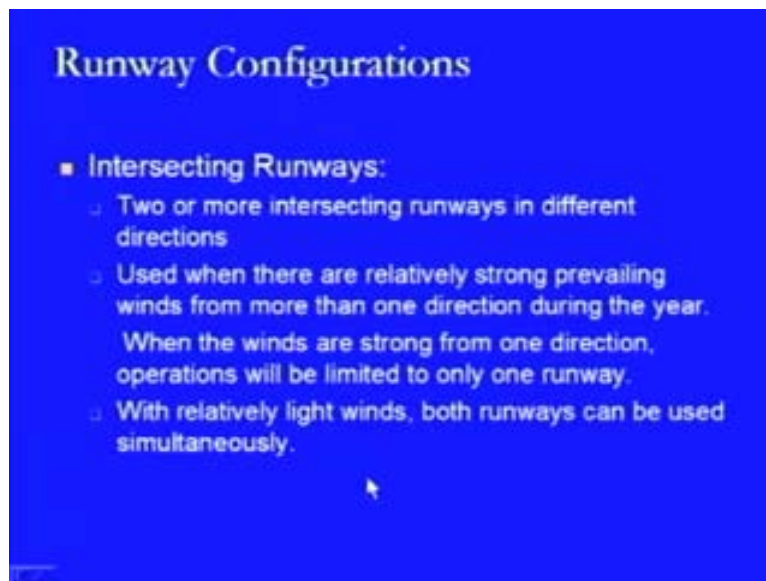
Capacity, as far as this is concerned, then it can handle 70% more traffic as compared to the single runway under VFR conditions and 60% more traffic than the single runway in case of IFR conditions and if spaced at 300 metres or more, then the capacity becomes insensitive to centreline spacing.

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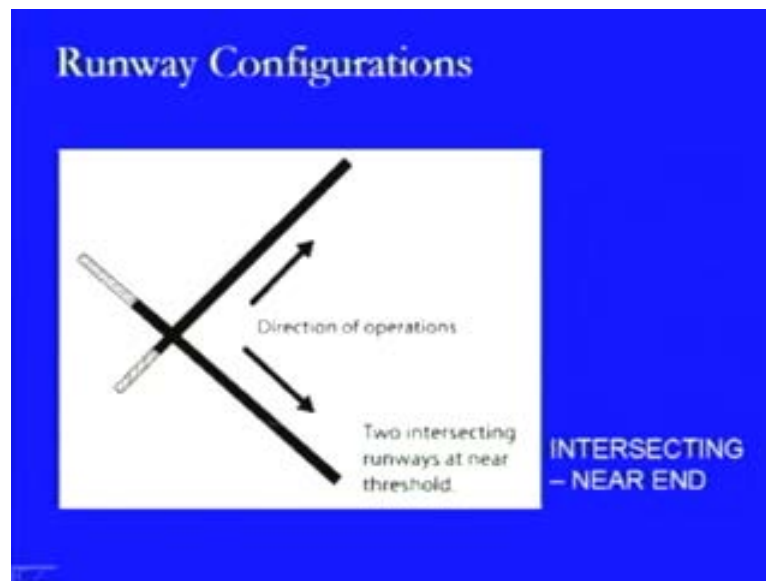
This is the case of a dual parallel condition, where the spacing in between is 4,300 feet or more, but then after that we have another parallel strip on this side as well as on the other side, so we have two pairs of parallel runways spaced at farthest spacing.

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Then, another category is the intersecting runways. In the case of intersecting runways, we have two or more intersecting runways in different directions and they are used when there are relatively strong prevailing winds from more than one direction during the year. That is the case why we go for intersecting runways and these intersecting runways may intersect each other at different positions. Now, when the winds are strong from one direction, operations will be limited to only one runway. So, that is a restrictive condition, but then still because of the intersecting runway being provided, we are in position to operate from another runway, so that the airport capacity has not reduced to zero, still some of the operations can be done. With relatively light winds, both runways can be used simultaneously, thus increasing the airport capacity.

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So, in this case of intersecting runways, we can have three conditions. Now, this is the intersecting near end runway condition, where this is the direction of operation. So, this is starting from this side, so this becomes the near end and this becomes the far end. This is the far end. So, these two runways are intersecting each other at the near end location. This is what is one type of runway systems.

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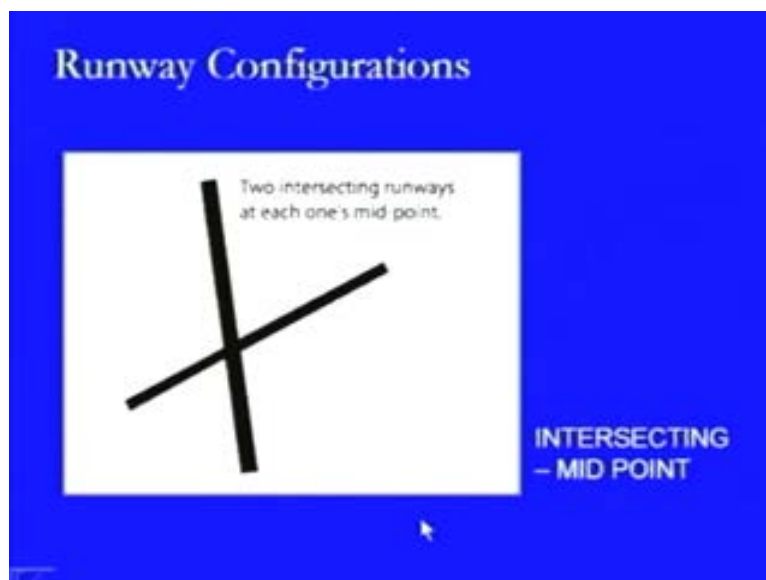
Runway Configurations

- **Intersecting Runways:**
 - The greatest capacity for operations is accomplished when the intersection is close to the takeoff end and the landing threshold.
 - Capacity is dependent up on location of intersection, runway-use strategy (for take-off and landing), and the aircraft mix
 - Capacity for near end operation ranges between 70 to 175 operations per hour in VFR condition and to 60 and 70 operations per hour in IFR condition

The greatest capacity for operation is accomplished when the intersection is close to the take-off end and the landing threshold. If that is the case, then only the maximum

capacity will be there as we have seen just in the previous photograph and capacity is dependent upon the location of intersection. That is I have said that there can be three conditions. One is very near, one is far off and one is in the case of centre point intersection and the runway-use strategy is another case that is how we are going to utilize the two runways for the two different operations that is take-off and landing and what is the type of the mix of the aircrafts on that. So, these are the factors which will create an effect on the capacity in the case of intersection runways. The capacity for near end operation ranges between 70 to 175 operations per hour in VFR condition and 60 to 70 operations per hour in IFR condition. So, under VFR conditions, we can see the capacity of the airport has increased manifolds as compared to the previous conditions.

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Here, we are looking at a diagram where this is an intersecting midpoint condition, where at the midpoint two runways are crossing each other.

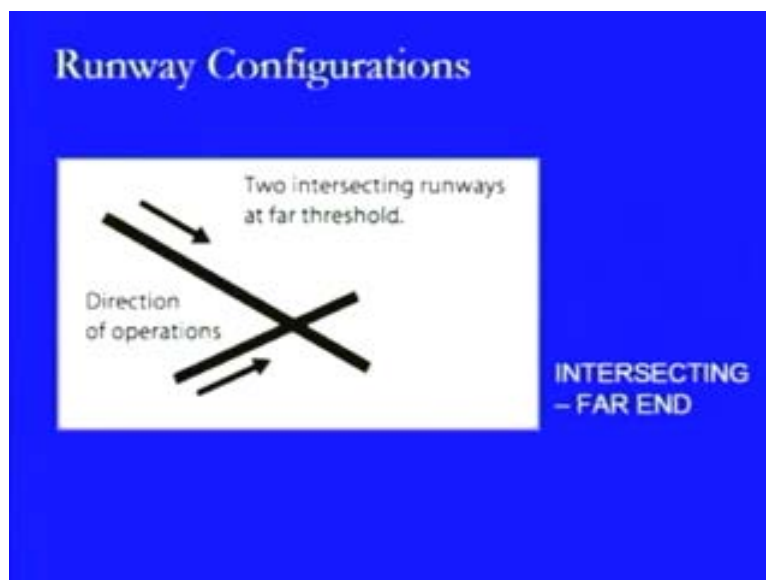
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Runway Configurations

- **Intersecting Runways:**
 - Capacity for mid point intersection ranges between 60 to 100 operations per hour in VFR condition and to 45 and 60 operations per hour in IFR condition
 - Capacity for far end operation ranges between 50 to 100 operations per hour in VFR condition and to 40 and 60 operations per hour in IFR condition

Then, the capacity for the midpoint intersection ranges between 60 to 100 operations per hour. That is as we are going away from the near end to the far end, it is changing and it is 45 to 60 operations per hour in the IFR condition. In the case of the far end operations, it ranges between 50 to 100 operations per hour in VFR condition. Further reduction is there and there is 40 to 60 operations per hour in IFR condition.

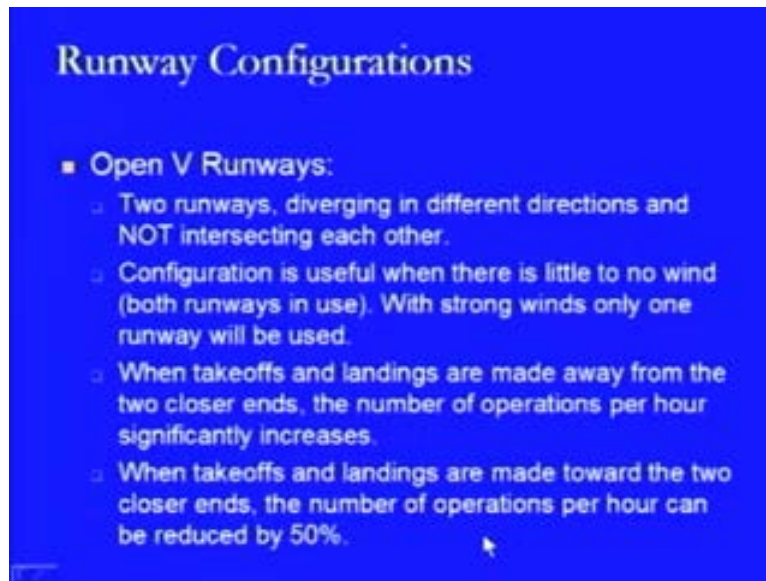
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This is a case of far end intersecting runway. Direction of operation remains like this and this is the far end. The reason is that as this is taking off or this is landing, there is

the intersection of the flight path at this location and if there is any emergency, then it is going to create a hazardous condition. That is why the intensity or the capacity of traffic handling keeps on reducing, as we go away from the near end. In the case of the near end, because they are separating from each other in the very starting that is why the capacity is more.

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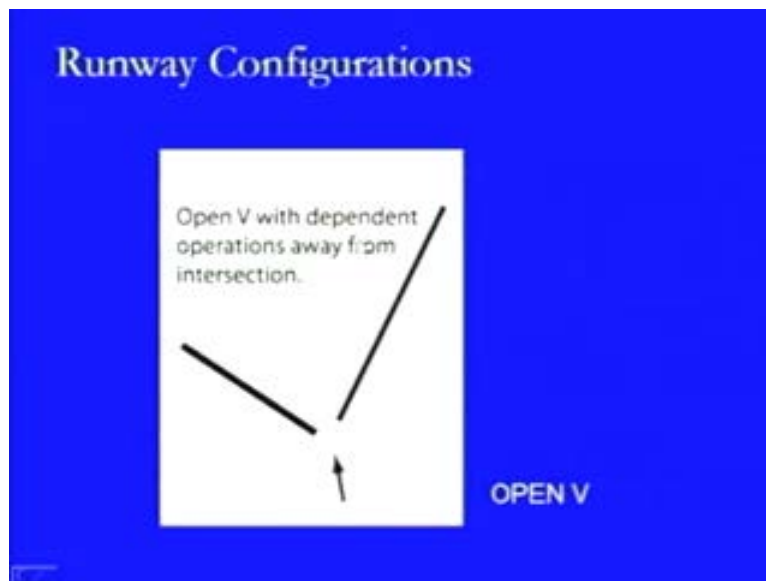
The slide has a blue background with white text. The title 'Runway Configurations' is at the top. Below it is a section header '■ Open V Runways:' followed by a list of four points, each preceded by a small square bullet.

Runway Configurations

- Open V Runways:
 - Two runways, diverging in different directions and NOT intersecting each other.
 - Configuration is useful when there is little to no wind (both runways in use). With strong winds only one runway will be used.
 - When takeoffs and landings are made away from the two closer ends, the number of operations per hour significantly increases.
 - When takeoffs and landings are made toward the two closer ends, the number of operations per hour can be reduced by 50%.

The last case is the open V runways. In this case, there are two runways which diverse in different directions and they are not intersecting with each other and the configuration is useful, when there is a little or no wind and both the runways are in use. With the strong winds only one runway can be used. When take-offs and landings are made away from the two closer ends, the number of operations per hour significantly increases. That is the case as in the case of the intersecting conditions and when the take-offs and landings are made towards the two closer ends, the number of operations per hour can be reduced by 50%.

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So, we look at this open V condition. This is open V, which is, the operations are going from this direction. So, they are going away from each other and this is dependent operations away from intersection.

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Whereas this is another case, where the open V with dependent operations towards the intersection. So, these are the two cases of open V type of movements.

So, what we have seen in today's lecture is that, how to decide about the orientation of the runway and what are the factors which contribute in this particular decision. Then, we have looked at the wind rose diagram, which is a tool so as to identify this orientation and then further, we have looked at the various types of configurations which can come up on the basis of the fixing of the orientations. So, the five types of configurations we have seen and we have tried to compare them. This is all about type of the runway configurations and orientations in today's lecture. We stop at this point and we will be meeting for some other things related to the runways in the coming lectures. Till then, good bye and thank you to you.