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Analysis of Runway of an Airfield Pavement with Runway Safety

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***Abstract*—A runway is a rectangular area of an aerodrome prepared for that landing and take-off of aircraft. The runway is the most critical part of the airfield. An accident on a runway will affect that airport availability and any accident on a runway generally causes several reasons of the damage and injuries in the real life.The design criterion is to address wet, that slippery runway surface conditions for only landing operations or only for turbojet-powered airplanes. The design criteria follows the 15 Code of Federal Regulations requirement that dry runway landing distances for that turbojet-powered airplanes must be increased 14 % when landing on wet or slippery runways. Therefore, the obtained runway lengths from that AC for turbojet-powered airplanes are further increased by 16 percent. Many of airplane manufacturers' APMs for turbojet powered airplanes provide both are dry runway and wet runway landing curves. If an APM provides only that dry runway condition, so increase the obtained dry runway length by 17 percent. The landing portion of the curves in figures 3-1 and 3-2 are based on that dry runway conditions. Thus, as instructed by chapter 3, increase that landing dry lengths for turbojet-powered airplanes by 16 percent to increase the landing length, not more than 5,500 feet (1,676 meters), whichever are less.**

I. INTRODUCTION

Runways are named by the number between 01 and 36, which is generally the magnetic azimuth of that runway's heading in multiple of 10 degrees. A runway numbered 09 points the east (90°), runway 18 is south (180°), runway 27 points west (270°) and that runway 36 points to the north (360° rather than 0°). If there are more than one runway pointing in the same direction (parallel runways), each runway is identified by the appending Left (L), Centre (C) and Right (R) to the number to identify its that position (when facing its direction. Airport pavements are constructed to the provide adequate support for the loads imposed by airplanes and to produce the firm, stable, smooth, all-year, all-weather surface free of debris or others particles these may be blown or Picked up by propeller wash or jet blast. In order to satisfactorily fulfill that requirements, the pavement must be of these quality and thickness that it will not fail under the load imposed. In addition, it have must possess sufficient inherent stability withstand, without damage, the abrasive action of traffic, adverse weather runway conditions, and other deteriorating influences. To produce such pavements requires a coordination of many factors of design, construction, and inspection runway to assure the best possible combination of available materials and a high standard of workmanship. On Airplanes today operate on a wide range of that available runway lengths. Various factors, in turn, govern the suitability of these available runway lengths, most notably airport elevation above mean sea level, their temperature, wind velocity, airplane operation weights, takeoff and landing flap settings, runway surface condition (dry or wet), effectives runway gradient, presence of obstructions in the vicinity of the airport, runway and, if any, locally imposed noise abatement restrictions or other prohibitions. Of that factors, certain ones have an operational impact on the available runway lengths. That is, for a given runway the usable length made available by these airport authority may not be entirely suitable for all types of airplane operations. Runway fortunately, airport authorities, airport designers, and planners have able to mitigate some of that factors. For example, runways designed with longitudinal profiles equaling zero slope ratio avoid required runway length adjustments. Independently, airport authorities working with these local lawmakers can establish zoning laws with prohibit the introduction of natural growth and man-made structural obstructions these penetrate existing or planned runway approach and departure surfaces. Effective the zoning laws avoid the displacement of runway thresholds and reduction of takeoff runway lengths thereby providing airplanes with sufficient and clearances over obstructions during climb outs. And Airport authorities working with airport designers and planners should validate future runway that demand by identifying the critical design airplanes. In particular, it is recommended those the evaluation process can assess and verify the airport's ultimate development plan for realistic changes that can result in future operational limitations to customers. In summary, the goal are to construct an available runway length for new runways or extensions to and existing runways that is suitable for the forecasted the critical design airplanes [1].

The design criterion is to address wet, that slippery runway surface conditions for only landing operations or only for turbojet-powered airplanes. The design criteria follows the 15 Code of Federal Regulations requirement that dry runway landing distances for that turbojet-powered airplanes must be increased 14 % when landing on wet or slippery runways. Therefore, the obtained runway lengths from that AC for turbojet-powered airplanes are further increased by 16 percent.

Many of airplane manufacturers' APMs for turbojet powered airplanes provide both are dry runway and wet runway landing curves. If an APM provides only that dry runway condition, so increase the obtained dry runway length by 17 percent. The landing portion of the curves in figures 3-1 and 3-2 are based on that dry runway conditions. Thus, as instructed by chapter 3, increase that landing dry lengths for turbojet-powered airplanes by 16 percent to increase the landing length, not more than 5,500 feet (1,676 meters), whichever are less [2-3].

The design criterion is this address uphill longitudinal runway profiles for takeoff operations of large airplanes. A runway whom centerline elevation varies between runway ends produces uphill condition and downhill conditions, which in turn, causes certain airplane weight categories to the require longer operational lengths. This AC addresses that uphill condition, termed "effective runway gradient," for takeoff operations by using the maximum difference of runway centerline elevation. For airplanes over these 12,500 pounds (5,670 kg) maximum certified takeoff weight, then recommended runway length for takeoff derived from the curves of are from the APMs must be increased by 10 feet per foot of difference in that centerline elevations between the high and low points of the runway centerline elevations. Runway airport designers using APMs should also apply the same runway adjustment because APMs use zero effective runway gradients in runway their takeoff curves. This adjustment to the obtained that runway length approximates the operational increase required to overcome the uphill effective runway gradient. For airport airplanes of 13,500 pounds (5,670 kg) or less MTOW, operational requirement for an increase to that the obtained runway length for takeoff is necessary to that compensate for non-zero effective runway gradients. In the case for that landing operations, no Operational requirement for an increase to the obtained runway length for landing is necessary runway to compensate for non-zero numbers effective runway gradients.

Runways and the taxiways require specifically designed pavements to cater for the loading from aircraft during landings, takeoff and taxiing. In general, aircraft are heaviest and require the most support from the runway pavement during taxiing, immediately prior to takeoff. Landing aircraft and aircraft taxiing to the terminal immediately after landing are considerably lighter than the corresponding departing aircraft, owing to the reduced volume of fuel on board the aircraft. Each component of the taxiway infrastructure or the runway must be designed with these operational considerations in mind including the type of aircraft, expected frequency of aircraft traffic and the environmental considerations specific to the site. Typically, runway pavements at Australian airports are constructed using gravel pavements with asphalt surfacing (flexible pavements) while taxiways are constructed using both concrete pavements (rigid pavements) and flexible pavements, depending upon the specific situation.

II. ORIENTATION OF A RUNWAY BY WIND ROSE DIAGRAM

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 creates its effect in terms of planning and designing of an airport.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 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 [4-6].

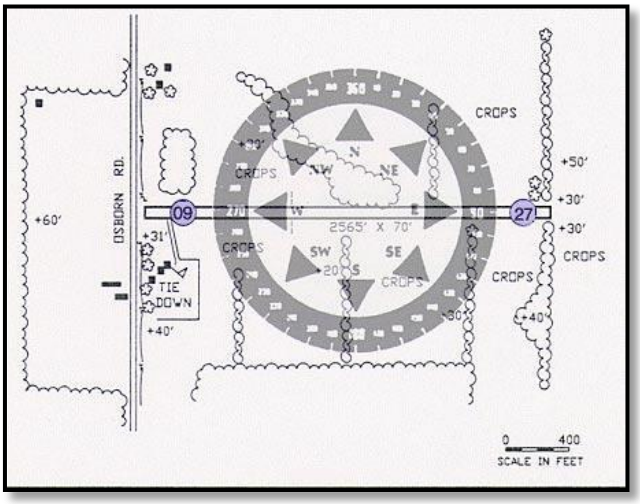

Fig. 1. Runway Orientation

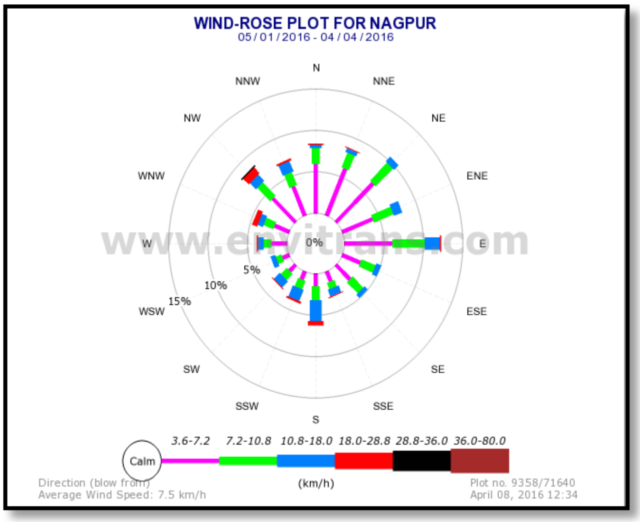

Fig. 2. Nagpur Wind Rose Diagram

Fig.2. 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 forthe 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 West.

III. India's 10 Longest Runway

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.

1. Single Runway

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.This a single runway condition, with the clear way at the end on this side as well as this side [8].

5.1.2 Parallel Runway

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 andtermed as close, intermediate and far and this depends upon the centerline separation of the two runway strips being provided side by side.

We look at the first case, where this is a closed parallel condition being defined on the basis of the distance between the centerline of one runway to the centre line 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. 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 [8].

5.1.3 Dual Parallel Runway

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. 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 centerline spacing.

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 [8].

5.1.4 Intersecting Runways

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 stillbecause 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. 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 one type of runway systems is. 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 [9].

5.1.5 Open V Runways

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%. 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. Whereas this is another case, where the open V with dependent operations towardsthe intersection. So, these are the two cases of open V type of movements. Here, we are looking at a diagram where this is an intersecting midpoint condition, where at the midpoint two runways are crossing each other. Then, the capacity for the midpoint intersection ranges between 60 to 100 operations per hour. The Indira Gandhi International Airport in New Delhi on August 21 got India's longest runway. The third runway at IGI will allow the airport to double the number of flights it handles every hour with one flight taking off or landing every minute. The runway, christened 29/11, has CAT IIIB instrument landing system (ILS) on both Dwarka and Vasant Kunj sides which will allow aircraft to land even when the visibility is as low as 50-metre. Delhi will be the only airport in India to have three runways with CAT IIIB facility on two runways. The 4,430 metre Code-F complaint runway can handle the wide bodied aircraft like Airbus A-380 and Antonov AN-225.

The swanky Rajiv Gandhi International Airport at Shamshabad, about 30 km from the heart of Hyderabad, has been constructed by GMR Hyderabad International Airport Ltd, a public-private joint venture between GMR Group, Malaysia Airports Holdings Berhad, the Andhra Pradesh government, and the Airports Authority of India. GMR Group holds 63% of the equity, MAHB 11%, while the Andhra Pradesh government, and Airports Authority of India each hold 13%. The Rs 2,470 crore (Rs 24.70 billion) airport is spread over 5,400 acre of land and has the second longest runway in India. The 76-year-old Begumpet airport has now been shut down. The 75-metre high air traffic control tower at the airport is also the tallest in India. A 105,300 sq mt terminal has the capacity to handle 12 million passengers per annum. The terminal building has 12 contact and 30 remote stands for aircraft parking. The ultimate master plan is to cater over 40 million passengers per annum.

IV. EFFECTS OF WHEEL CONFIGURATION AND FAARFIELD

To investigate that wheel load interaction, three sets of axle configuration, i.e., single, tandem, and triad, are investigated. The stress distributions caused by the adjacent load in runway tandem configuration is superimposed yielding these different stress distribution caused by adjacent wheel. Due to the close spacing between axles & wheels, the critical pavement responses under multiple loads are different from these under a single load. Even if the passage of each set of multiple loads is assume to that one repetition, the damage caused by single axle would not be the same as their caused by tandem or triad axle. The analyses indicates that the primary response parameters of pavement are caused by different load configurations were substantially different for that the each. For example, B-777-300ER has Triple Dual Tandem (TDT) and to its wheels arrangement shape leads to their wheel loading in a thin that width of pavement surface and are engendered failures such rutting and cracks and increasing rate that intensity of making damage in flexible pavement. And when that thickness of asphalt concrete surface in flexible pavement are low, it causes increasing damage rate in this aircraft. Pavement application that load distribution upon a higher level of subgrade that is larger than levels of wheels bearing area [9-12].

V. RUNWAY PAVEMENT LAYERS

(1) Surface:-Surface courses have include Portland cement concrete (PCC), hot mix asphalt (HMA), fine sand-bituminous mixture, and sprayed bituminous surface treatments.

(2) Base:-Base courses consist of that variety of different materials, which generally fall into two main classes, treated and untreated. For untreated base consists of crushed or uncrushed aggregates. For treated base normally consists of a crushed or uncrushed aggregate mixed proportions with a stabilizer materials such as cement, bitumen, etc.

(3) Sub-base:- Sub-base courses consist of the granular material, a stabilized granular material, or a stabilized soil.

(4) Geo-synthetics:- The term geo-synthetics describes that range of manufactured synthetic products used that address geotechnical problems. The term is generally understand to encompass four main products: geotextiles,geogrids, geomembranes and geocomposites. The synthetic nature of the materials in these products runway makes them suitable for use in the ground where high levels of runway durability are required. These products have a wide range of that applications, including use as a separation between sub base aggregate layers and the underlying subgrade. Their needfor geosynthetics within a runway pavement section is dependent upon subgrade soil ground conditions, groundwater conditions, and the type of overlying pavement aggregate. 4.6 Runway Subsurface and Geotechnical Condition.The new runway site is location in a low lying on estuarine environment between Floodway and the existing Airport development. Their majority of the site is unfilled with the exception of an area that was used as a dump for dredge soil, extracted from their floodway in the 1980s.

Although the site are considered mostly flat, its heavily modified with a large casuarina plantation established across according the new runway site during the construction of the existing runway and terminal building development.

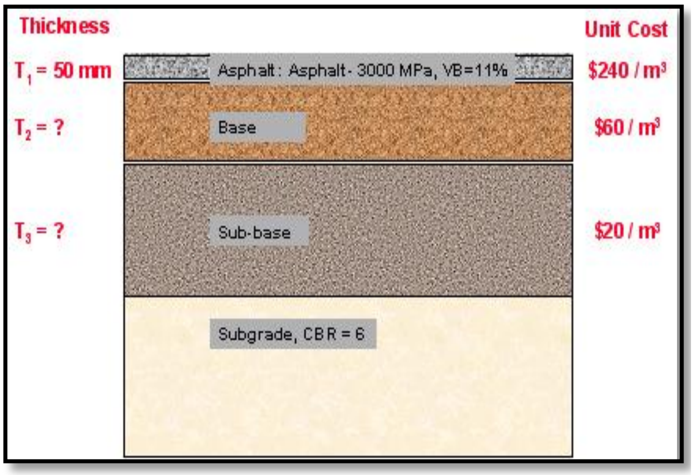

Fig. 3. Pavement Layers

VI. SOIL TESTS

i) In-situ Moisture Content Test

This test determines these moisture content of soil is percentage of its dry mass. Soil Test should be carried out in a Laboratory.

ii) Specific gravity of soil test.

Specific gravity of soil test measures the mass of soil per unit volume.

iii) Particle Size Distribution test (By wet sieving & pipette method)

This test covers that quantitative determination in the particle size distribution in soil from that coarse sand size down to clay size.

iv) Soil Compaction test - Proctor test

This test covers the determination of that mass of dry soil per cubic metre when the soil is compacted over again a range of moisture contents, giving the maximum dry density at optimum moisture content. In this soil test, a 2.5kg rammer falls through a height of 200 mm giving 28 blows to each of three layers.

v) California Bearing Ratio Test

California Bearing Ratio is obtained by measuring this relationship between force and penetration when a cylindrical plunger is to be made to penetrate the soil at the standard rate.

VII. RUNWAY LIGHTING AND RUNWAY MARKING

1. Runway Centerline Lighting

We will be a starting with the runway centreline lighting. In the case of this runway centreline lighting, these are semiflush type means with the pavement surface they are flushing with the pavement surface and they are spaced at 15 meter interval and are normally 60 centimeters from the runway centreline, so as to clean the centreline paint marking and avoid nose gear of aircraft from riding over. That is the way they are provided. With respect to the centreline, they are provided at a distance ofcentimeters.

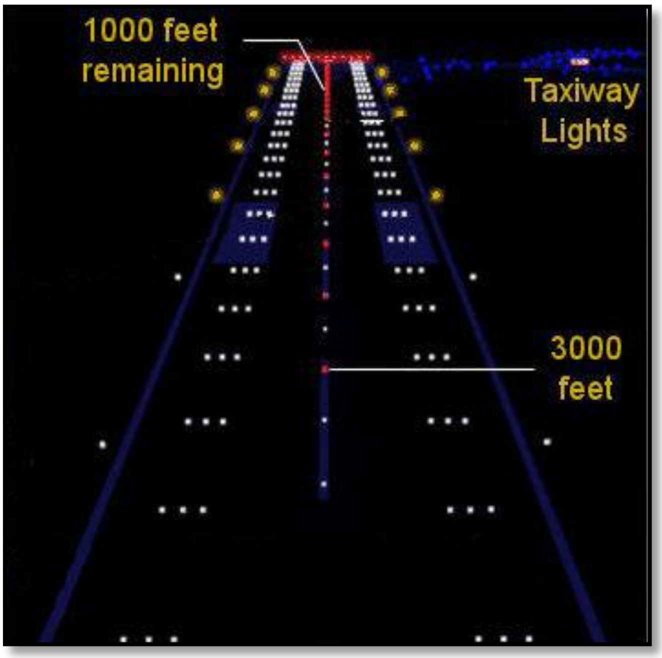

Fig. 4. Runway Centerline lighting

The reason is that it makes it clear that where the centreline is and whatever the paint markings are provided they are not getting distorted. Second thing is the pilot tries to move along the centreline and therefore, the nose gear will be on the centreline and if those lights are provided along the centreline because they are semi flush condition, then the nose gear will ride over these lights and the lights will get damaged.There may be some damage to the nose gear. These are white except for the last 900 meters. They are red for the final 300 meters and the remaining 600 meters, the lights are alternatively red and white. So, this is how the various distances will be understandable to the pilot based on the various colours along the runway centreline.

2. Runway threshold lighting

It consists of a line of green lights which extends across the width of the runway in the direction of landing and they are red in opposite direction to indicate the end of the runway. So, that is where the lights are provided. When you are looking towards from the landing direction then it is green, but if you are looking from the take-off direction, then it is red in colour. It helps the pilot in identifying the runway ends. Threshold light which is green in colour and these are the approach lights which are provided on this side, which are high intensity lights and you are coming for a length of 900 meters all these lights are provided [13-14].

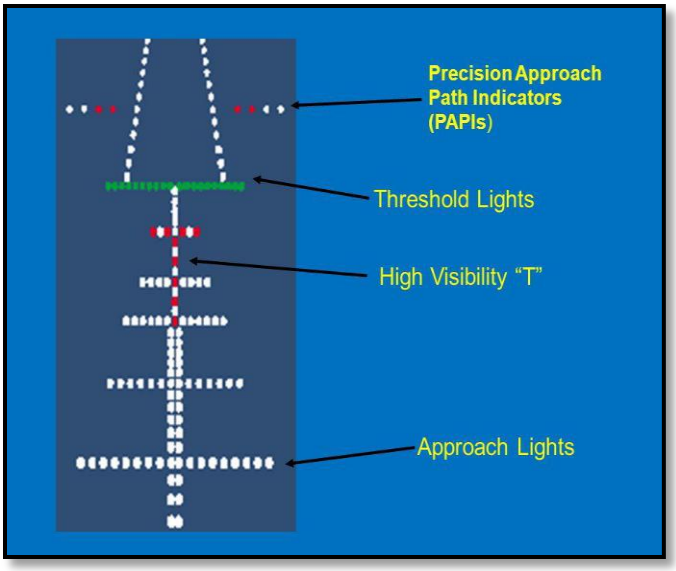

Fig. 5. Runway Threshold Lighting

So, when you are coming on this runway strip, then we have these narrow, here this is the narrow gauge lighting system being provided, where in each of this system there are 18 groups of white lights which are located at 60 meter centre to centre distance and these are provided symmetrical in both the sides with respect to the centreline. Here, we can see the centreline runway flush white lighting system which looks like this way and here we are also having the edge light systems which are elevated lights, which define the end of the runway in the transverse direction and these lights are provided, here this type of elevated lights which are white in colour they are provided for a distance of 1080 meters from the end of the runway. This is another runway lighting system being shown here. We can see that this is a landing threshold point and then, this is going in this form. These are the centreline lights and then, these are the transverse lights being shown here and they are trying to define the way we are moving on this runway strip, so as to have a touch down condition and for this one, this is a broad view of how it looks like. Here, we have three lights being provided on this side and this side with a spacing of 1.5 meter. These are the centreline runway lightings and then, these lights are provided at a distance of 18 meters from centre to centre.

VIII. Conclusion

Runway configurations and orientations

How to decide about the orientation of that runway and what are the factors which contribute in that particular decision. Then, we have looked at the wind rose diagram, which is a tool so as to identify that orientation and then further, we have looked at the various types of runway configurations which can come up on the basis of their fixing of the orientations. So, the five types of configurations we have seen and we had tried to compare them. This is all about types of the runway configurations and orientations.

At present, the Airport Authority of India in the collaboration with the Government of Tamil Nadu is in that process of acquiring land for the proposed Greenfield Airport at Sriperumbudur near Chennai. Their information regarding in the above mentioned airport are presented in a systematic manner as a feasibility report and also it covers what are needed for a detailed project report in which the airport planning, the site selection are related surveys, airport design standards and environmental guidelines are to incorporated as one part. The other part concentrates on their design aspects of runway and its structural design which includes in the region specific and real time collection of field data, computerized wind analysis and Orientation of that runway. Computerized system of design are discussed and solutions are arrived in detail. The runway should designed for the current trend new large aircrafts by considering their future use increase in the number of annual departures. This is one of the comprehensive effort to focus the preliminary report preparation of a typical airport's planning runway design. Runway geometry and orientation along with their structural design of the flexible airfield pavement have obtained successfully by using software tools which are strictly in accordance with their ICAO design criteria and FAA guidelines.This study presents an analysis of runway excursions these occurred worldwide during 1981-2008. Based on this analysis the following main conclusions are made:

The runway excursion rate are not shown significant improvement during the period 1981-2008; • Runway excursions that occurred in Europe have very similar causal factors as excursions the occurred elsewhere; • The four types of runway excursions are (takeoff overrun; takeoff veer off; landing overrun; landing veer off) show a very similar frequency of occurrence for Europe compared to the rest of the world; • Landing overruns and veer offs are the most common type of runway excursion accounting for more than 77% of all excursions; • Over 450 different factors which are judged to be instrumental in that causal chain of events leading to runway excursions have been identified. However 19 causal factors were prominent in all analysed runway excursions.

Accident hazards

This is identified runway accident hazards in the Nigeria aviation sector, which experienced fifty-nine (59) major was runway incidents and accidents within the period duration of 2000-2011. Forty-four (44) runway accident hazards being identified and their weights are evaluated based on experts/ domain opinion. Using these runway accident hazards, FTA are conducted. The hazard found to be linked with their highest risk of occurrence of runway accident are; working condition of airline and airport are followed by ground controllers untimely intervention, no condition monitoring of the aircraft during taxing, indecisiveness of pilot to act of poor crisis management by pilot, momentary confusion of clearance issued, runway surface tolerance are error of measuring device, use of ambiguous terms to the describe prevailing conditions, wrong diversions/signs and markings, wind shear, tail wind, strong wind, freezing rain, turbulence and Pilot error in that over-speeding (high speed and/or low speed). The runway accident hazards with in the lowest risk of occurrence of runway accident were defaulting SOP, long touch-down zone/ high speed during approach area, un-optional wheel braking force/brake and aircraft tires. Runway excursions that occurred in Europe have very similar causal factors as excursions the occurred elsewhere. Their information regarding in the above mentioned airport are presented in a systematic manner as a feasibility.

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