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RUNWAY ORIENTATION AND DESIGNING

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Abstract- Transportation plays a major role in Socio-economic development of any nation. In the present day scenario the need for transportation to any place is deeply concerned and it is very difficult to imagine any society without any mode of transportation. There are basically four modes of transportation namely Roadways, Railways, Waterways and Airways. Each and every mode has its own advantages and disadvantages. Due to rapid industrialization and urbanization, change in the growing standards of the people and the increasing demand for the exchange of science and technology, goods and services across the nations of the globe has intensified the importance and usage of Airways. The technical issues of airways are connected with the design and construction of the Runways where the aeroplanes have to move on the runway as like vehicles on the Road. In this context the orientation and alignment of the runway is the key component in the design. As the planes move in the higher altitudes the intensity and direction of wind plays a vital role in the movement, safe landing and take-off of them. The alignment of the runway is based on wind data of the region presented in the form of a diagram popularly known as Wind Rose Diagram. Preparation of the Wind Rose Diagram is a time taking process and also, search for the direction of maximum wind coverage is difficult manually. As a result several softwares have been developed with the advancement of software technology. Different kinds of software are being developed in different regions and are being successfully used.

In the present research work, simple computer programs are developed in 'C' language to search the wind direction where maximum wind coverage is present and the necessary corrections for temperature, elevation and gradients are done. Just if we give input data related to wind and the basic requirement of runway length, we will get output data of Runway Orientation, Corrections for runway and the Geometric standards of runway.

Keywords - Alignment, Correction, Maximum Wind coverage, Runway, Runway Orientation, and Wind Rose Diagram.

I. Introduction

According to the International Civil Aviation Organization (ICAO) [3] a runway is a "defined rectangular area on a land aerodrome prepared for the landing and takeoff operations of aircrafts". The efficiency and safety in the movement of crafts depends on the orientation of the runway in the airports. Always a runway is oriented in the direction of prevailing wind. Ideally, all the aircraft operations on a runway should be conducted against the wind. But wind conditions vary from hour to hour thus requiring a careful examination of prevailing wind conditions at airport site. This is a major challenge for designers of airport.

The head wind i.e. direction of wind opposite to the direction of landing and take-off, provides greater lift on the wings of the aircraft when it is taking-off. As such the air craft rises above the ground much earlier and in a short length of runway. During landing, the head wind provides a breaking effect and the aircraft comes to a stop in a smaller length of runway, landing and take-off operations, if done along the wind direction, would require longer runway[10].

The factors that should be considered while orienting the runway are Wind i. e, Cross Wind Component (CWC), Wind Coverage (WC) s, availability of Air space, Environmental factors like noise, air and quality of water, Obstructions to navigation, Terrain and soil considerations, natural and man-made obstructions etc.

II. Objective

The main objective of the present research work is to propose an easy method for finding out the wind direction by developing an algorithm and the same is implemented by a simple program in 'C' language.

III. Literature Review

Falls and Brown (1972) [2] prepared a report in which two methods were mentioned in obtaining optimum runway orientation. This report was prepared for NASA. The two methods were theoretical methods and empirical methods. In the theoretical method, the bivariate normal elliptical distribution is applied to the wind data and wind statistics are then computed. In the empirical method manual hand calculations were used on normal wind rose.

FAA AC (2000)[9] According to this the runways should be oriented in such a direction that the crafts can make any action of landing or take-off with minimum exposure to cross wind. Generally the wind coverage should be 95% for the runway system. This means for 95% of time the CWC should be smaller than the maximum.

Mosa and Mumayiz (2000) [6] presented a computer model which involves mathematical formulations. In this model the radial line and circles of the wind rose were transformed into points with numerical coordinates. The model then calculates the areas of sectors covered fully, partially and determines an adjustment factor for the wind

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data of the covered sections. The optimum orientation is achieved through an "exhaustive search".

Jia et al (2004) [4] developed a method which uses GIS and other data based management tools for determining the runway orientation.

IV. Background

Earlier manual analysis was implemented through Wind Rose Diagrams. Now-a-days software like Windrose PRO and FAA Airport design are being used.

A. Windrose Diagrams

It is a graphical representation which helps us in identifying the wind speed and direction in a particular location. A sample wind rose graph is shown below in Figure 1. The area is divided into 16 parts with each part being 22.5° angle (Fig. 1). 5 to 10 years average wind data is required for preparing this diagram [7]. There are two types of wind rose diagrams (WRD). They are- Wind Rose Diagram type-I and Wind Rose diagram Type- II. The Type- I diagram shows the direction and duration of wind (Fig. 2).

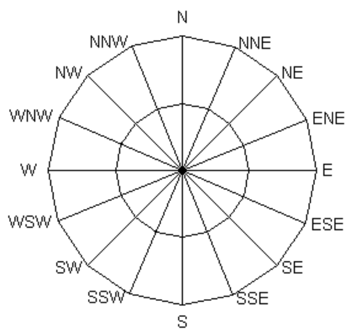

Fig.1.Sample Windrose Diagram

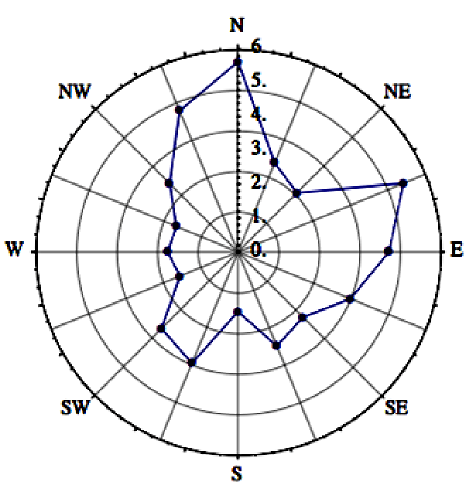

Fig.2.Type-I Wind Rose Diagram (Source: https://i.stack.imgur.com/cUVeQ.pn)

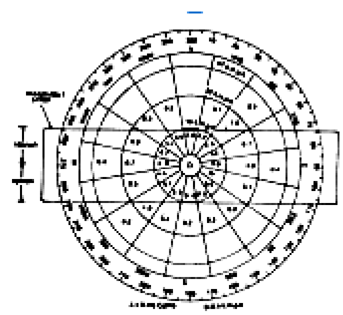

Fig.3. Type-II Wind Rose Diagram (Source: http://images.slideplayer.com/7/1704998/slides/slide_12.jpg)

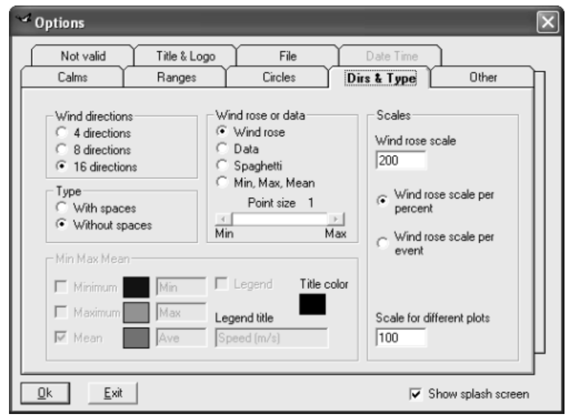

Fig.4. Tab from Software showing Wind directions and data (Source:[1]https://www.enviroware.com)

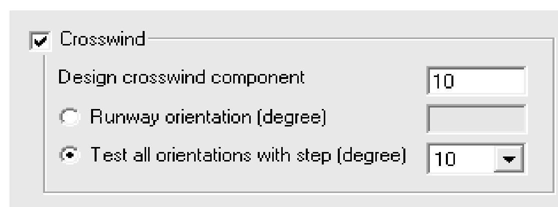

Fig.5. Tab showing CWC (Source: [1] https://www.enviroware.com)

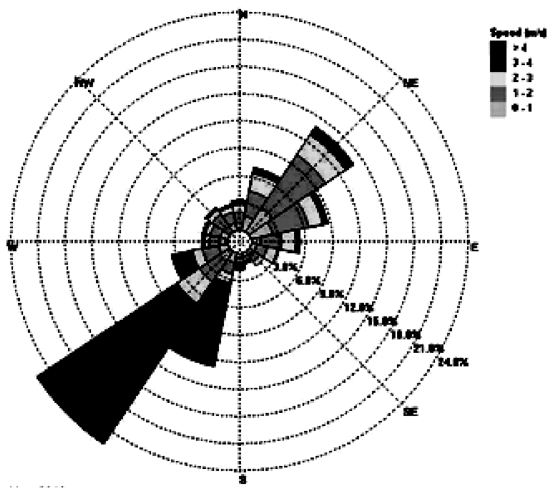

Fig.6. Classic Wind Rose (Source[1]: https://www.enviroware.com/create-your-wind-roses-on-line/windrosepro.jpg)

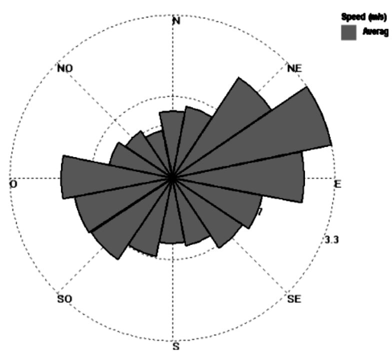

Fig.7. Wind rose through raw data (Source;[1] https://www.enviroware.com)

The radial lines indicate the direction of wind and each circle represents the wind duration. The Type- II diagram shows the direction, duration and intensity of wind (Fig. 3). Each circle represents the intensity of wind to some scale.

The following are the details of widely used software for development of Type-II WRD are briefed below:

B. Windrose PRO Software

It is application developed under Windows XP that represents directions of wind from raw data or from their frequencies and the best runway orientation can be selected from this [5]. This software [1] allows us to select the number of directions required and type of plot. Fig.4 depicts the same.

The calculation of cross wind component and correct orientation of runway is also obtained as shown in Fig.5. After the analysis of the data, the type of plot is to be selected and if classic type is selected the software will display the wind rose as shown in Figure 6.

The raw data if selected, the wind rose gets displayed like as shown in Fig.7.

C. FAA Airport design Software

This software is used to find out the optimum orientation of runway. The information regarding the wind data and cross wind component available are to be inputted in to the software and the output will be the maximum wind coverage [5].

V. Development of Program in C Language

It is difficult task to find out the direction of wind by preparing Wind Rose Diagram manually. Also it may involve errors which are unavoidable. Using software may give good results but consumes a lot of time in inputting and processing the vast data. So an attempt has been made in the present work to develop a computer program in ‘C’ language which does not require preparation of Wind Rose diagrams. Corrections for runway length is also included in the program according to ICAO standards. The algorithm is as shown below.

A. Runway Orientation

Step 1:Read Wind data from input file

Wind Velocities in kmph falling between

V1 and V2 an array (g1) for 8 consecutive directions from N-SSE

V2 and V3 an array (g2) for 8 consecutive directions from N-SSE

V3 and V4 an array (g3) for 8 consecutive directions from N-SSE

V1 and V2 an array (g4) for 8 consecutive directions from S-NNW

V2 and V3 an array (g5) for 8 consecutive directions from S-NNW

V3and V4 an array (g6) for 8 consecutive directions from S-NNW

Step 2: Find sum of g1, g2 and g3

$$\sum_{i=1}^{n} \text{Sum } 1[i] = g1\,[i] + g2\,[i] + g3\,[i]$$

where i = wind velocity direction from N to SSE (i.e., n = 8)

Find sum of g4, g5, g6

$$\sum_{i=1}^{n} \text{Sum } 1[i] = g4\,[i] + g5\,[i] + g6\,[i]$$

where i = wind velocity direction from S to NNW (i.e., n = 8)

Step 3: Add Sum 1 and Sum 2

$$\sum_{i=1}^{n} \text{Sum 3 [i]} = \text{Sum 1[i]} + \text{Sum 2[i]}$$

Step 4: Grand Sum = Sum 3[i]

Calm period = 100.0 – Grand Sum

Step 5: Find the maximum of wind velocity direction in Sum 3[i]

WRD 1 = Sum 3[i] + Sum 3[i-1]+ Sum 3[i+1]

n=16

Step 6: ∑ Sum of circle 1 = Velocities

i=1 falling in the range of velocity 1 and velocity 2 for 16 directions

Step 7: Sum of circle 2 falling in the strip = i th position of c/c of strip + 2 values before of i th position + 2 values after i th position.

Step 8: Sum of circle 3 = If centre line of runway falls on n7th position of circle 3 then add values before and after n7th position and the n7th value. Similarly add the values falling in the opposite direction, the value of this summation is stored in a variable circle 3.

Step 9: Add circle 1, circle 2, circle 3.

Strip sum = circle 1+ circle 2 + circle 3

Where Strip sum = Intensity of Wind

Step 10: Stop.

B. Corrections for Runway Length

Step 1: Start

Step 2: Read the values of standard Runway length (SRLT), Airport Reference Temperature (ART) and Standard Elevation (SE).

Step 3: Corrections for take-off

Calculate correction for Elevation (CEt) = 0.07 * SRLT * (SE/300)

Step 4: Corrected Elevation length for take-off (CELt)

CELt = SRLT + CEt

Step 5: Standard Atmospheric temperature (theoretical) SAT_th

SAT_th = 15.0 – (0.00065 * SE)

Step 6: If SAT_th ≤ SAT

SAT = SAT_th

Else SAT = SAT

Step 7: Calculate rise in temperature (RT)

RT = ART –SAT

Step 8: Corrected temperature length for take-off(CTLt)

CTLt = (CELt * RT)/100

Step 9:Corrected length after temperature and elevation corrections

CTLt = CTLt + CELt

Step 10: Total Length (TL)

TL = 100*(CTLt-SRLT)/SRLT

Step 11: If Total Length (TL) > 35

Write " total corrections against Elevation and Temperature are more than 35% of basic runway length, So as per ICAO further investigations are suggested".

Step 12: If Total Length (TL) ≤ 35

Write check ok. Total runway length after all corrections in meters".

Step 13: read effective gradient (eff_gr)

Calculate Correction for gradient (CGR)

CGR = 0.2 * CTLt * eff_gr

Step 14:Corrected runway length after gradient correction (CGRT)

CGRT = CGR + CTLt

Step 15: Write CGRT

Step 16: Corrections for landing

Corrections for Elevation (CEI)

Calculate CEI = 0.07 *SRLT *(SE/300)

Step 17: Calculate corrected Elevation length (CELI)

CELI = SRLT +CEI

Step 18: Write correction for Elevation (Landing)

Step 19: Read Runway length after all corrections (max_CRWL)

Read max_CRWL = 0

Step 20: If CELI ≥ CGRT

Max_CRWL = CGRT

Step 21: Else max_CRWL =CGRT

Step 22: Write runway length after all corrections in meters.

Step 23:Stop.

VI. Validation of the Program

A. Runway Orientation

The wind data to be fed as input is a huge data and the output calculations[8] are given below[8].

Grand Sum = 39.6 +49

= 88.6%

Calm Period = 100.0 – 88.6

= 11.4% …(OK)

Strip Sum = 78.7 + 6.37 + 10.1

= 95.17% > 95%

(95% is Min. Wind coverage) …(OK)

Therefore the direction of runway is along North-South. As shown in Fig 8(as).

B. Corrections for Runway length

Given [8]:-

SRLT for Take-off = 1905m

For Landing = 1433m

ART = 26.076°C, SAT = 14.09°C

SE = 140m, eff_gr = 0.48%

Correction for take-off:

CELt = 1905 + (0.07 *1905 * (140/300))

= 1971.675m

SAT_th = 15.00 – (0.00065 * 140)

= 14.909°C (> SAT = 14.09°C)

Therefore SAT = 14.09°C

RT = 26.076° - 14.09°

= 11.98°C

CTLt = 1971.675 + ((1917.675 * 11.98)/100)

= 2202m

TL = 100 * (2202 – 1905)/ 1905

= 15.6% < 35% …(OK)

The Total Runway length after all corrections is 2202m.

Considering eff_gr - (increase @ 20% for every 15 of runway slope)

CGR = 0.2 * 2202 * 0.48

= 211.39m

CRGT = 2202 + 211.39

= 2414m

The Total Runway Length after gradient correction is 2414m

Correction for landing:

CEI = (0.007 * 1433 * (140/300))

= 46.82m

CELI = 1433 + 46.82

= 1479.82m

The runway length after elevation correction is 1479.82m

Since CELI <CGRT

Therefore, the total runway length after all corrections is i.e., max_CRWL is 2414m

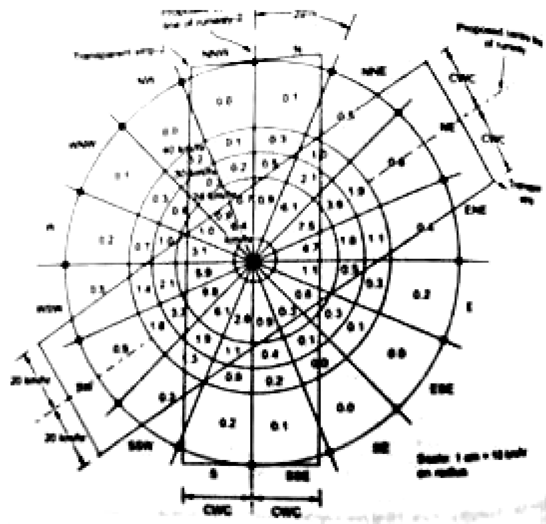

Fig.8. Windrose Strip Data,(source[8]-Srinivasa, Transportation Engineering,Universities Press)

VII. Conclusion

By using the above program, it could be concluded that it is simpler, convenient and takes very short time in obtaining the output regarding the orientation of runway and designing the runway length.

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