Runway Design for an International Airport

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ABSTRACT

The expansion of air transportation is one of the most remarkable technological developments of last century. The phenomenon increase in air travel as created severe congestion at the airports in large cities, needing additional facilities for rapidly growing short- haul domestic marks. As the international airports has to serve maximum traffic. For the same reason the runway design is a region specific work that aims to geometrically design the runway and orient it by considering all the factors that affect it including the environmental norms and regulations. The runway has been designed as per 'International Civil Aviation Organization' (ICAO) standards. In the present work physical characteristics of the runway and its sections have been studied in depth and designed according to the standards. CBR method is adopted for design of pavements.

Key words— **CBR, Geometrical design, ICAO, Runway Design.**

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1. Introduction

Transportation is an important factor of social and economic development for any region or country. It is very difficult to imagine society without any mode of transportation. The economic development of the nation links its direct benefits with the efficient system of transportation. The basic function that the transport system performs is by carrying passengers and goods, from one place to another. There are many modes of transportation, among them transportation by air ways is predominant. Now a day we need transportation in shorter time period for far distances. In the view of modernization of sub-urban areas into metropolitan cities are happening now there is a need to accommodate more air traffic conditions in already existed airport area. For the landing and takeoff of aeroplanes often there is a need to design a runway to accommodate repetitive loads and also for the maximum loads come from the biggest possible aeroplanes like Boeing-747-400. The development of airport needs to operate international flights like Boeings to the foreign countries. Now the existing conditions of Gannavaram airport of Andhra Pradesh state is not enough for operating bigger aircrafts. So, it requires a new parallel runway to operate international flights to various regions. From the region planning to transform into an international airport within the 3 years which includes expansion of runway and construction of terminal buildings along with aerodromes for the convenience of passengers coming from various countries. At present Spice Jet and Air India are operating from the above stated region

2. DESIGN OF THE RUNWAY

The design of the runway is done in the following order:
1) Runway orientation
2) Runway geometric design
3) Runway pavement
4) Runway marking
5) Runway lightings
The designing part is as follows:

2.1 Runway Orientation**:** The number and orientation of the runways play an important role in the overall arrangement of various components of an airport. The number of runways will depend on the volume of air traffic while its orientation will depend on the direction of wind and sometimes on the extend area available for the airport development.

Wind data*:* The wind data i.e. the direction, duration and intensity of the wind were obtained from Indian Metrological Department. Andhra Pradesh.

Direction	0.0-5.0 (m/s)	5.1-23.5 (m/s)	23.6-39.7 (m/s)	%	%	%	Total %
N	0	0	0	0	0	0	0
NNE	0	0	0	0	0	0	0
NE	0	0	0	0	0	0	0
ENE	23	8	0	6.28	2.19	0	8.47
E	0	0	0	0	0	0	0
ESE	30	0	0	8.20	0	0	8.20
SE	0	0	0	0	0	0	0
SES	0	0	0	0	0	0	0
S	0	0	0	0	0	0	0
SSW	0	0	0	0	0	0	0
SW	0	0	0	0	0	0	0
WSW	0	0	0	0	0	0	0
W	38	53	1	10.38	14.48	0.27	25.14
WNW	143	70	0	39.07	19.13	0	58.20
NW	0	0	0	0	0	0	0
NNW	0	0	0	0	0	0	0

Fig. 1: Wind Data Values

According to the obtained wind data plot the wind rose diagram to determine the suitable orientation for the runway. From the wind rose diagram the obtained orientation of runway is in the direction of 08/26. The cross wind value is taken as 20 knots.

2.2 Runway Geometric Design: The runway is designed to carry the takeoff and landing of the largest aircraft in the world A380. The categories of the runway and their corresponding length and width have defined by "International Civil Aviation Association" (ICAO). Boeing 747-400 falls under the category 4E and the minimum take off run is 2915 m and the width of the runway is 60m.

The runway length is calculated under two constraints:
1. Basic runway length\
2. Actual runway length

2.2.1 Basic runway length: Basic runway length is the length calculated under the following assumed conditions,

- Airport altitude is at sea level
- Temperature at the airport is standard
- No wind is blowing on the runway
- Runway is leveled in the longitudinal direction
- Aircraft is loaded to its full capacity
- Enroute temperature is standard
- No wind is blowing enroute to the destination

Basic runway length is determined from the take off performance charts and is greater of the either

(a)When one of the critical engines fails, the pilot has an option to continue the run or abort the take off after attaining a certain speed called as the decision speed, if he aborts the take off then the take off run and the stop distance should be equal. If both the lengths are equal then the total length is called as the balanced field length.

Take off speed (v) = 290km\hr

The decision speed is less than or equal to the take off speed

Decision speed ≤ Take off speed

Hence decision speed, V_f = 290km/hr

Velocity= (290× 1000)/3600 = 81 m/s

The acceleration is assumed as, a=1m/s^2

Time= v/a= 81/1= 36 s

Now, actual velocity is the difference between final velocity and initial velocity.

Hence, V_a= (Vf -Vi)/2= (81-0)/2 = 40.5 m/s

Hence, Total Distance (Take off Run) = 40.5x 81= 3280m

(b) When all the engines are operating.

115% Of Take Off run = (115×2915)/ 100 = 3352 m

Taking the maximum value of case (a) and case (b),

Take off run from aircraft's performance = 3352 m

Now the loading length requirement is 2175m and hence safe.

2.2.2 Actual Runway length: Actual runway length is the length obtained after applying the corrections of temperature, elevation and slope. The actual runway length should be adequate to meet the operational requirements of the aircrafts for which the runway is designed and should not be less than the longest length determined by applying the corrections for local conditions to the operations and performance characteristics of the relevant aircraft. Local conditions that have to be considered are temperature, elevation, slope and humidity and runway surface characteristics. The length is calculated as follows,

a) The basic length selected for the runway should be increased at the rate of 7% per 300m elevation.

Runway elevation at the aerodrome= 12m.

Runway take off length corrected for elevation

= [Take off run×.07 × (runway elevation/3)]+Take off run

= [3352 × .07 × (12/300)] + 3352

= 3360m.

b) The length of the runway determined should be further increase at the rate of 1% for every 1°C in the aerodrome reference temperature exceeds over standard atmosphere for the aerodrome. If however, the total correction for elevation and temperature exceeds 35% then the required correction should be obtained by means of specific study**.**

Runway take off length corrected for elevation and temperature= [Takeoff run × (ART–Standard Temperature) ×0.01] +Takeoff run

ART= Aerodrome reference temperature

ART= Ta + ((Tm – Ta) ÷ 3)

Where,

Tm = the monthly mean of the maximum daily temperature for the hottest month of the year.

Ta = the monthly mean of the average daily temperature for the hottest month of the year.

Therefore,

Aerodrome reference temperature=35.16^{0}c

Standard temperature at 12m elevation is found out by interpolation=14.98^{0}c

Runway take off length corrected for elevation and temperature

= [3360 × (35.16 – 14.98) × .01] + 3360 = 4038m.

c) The runway length is increased at the rate of 10% for each of 1% of the runway slope, where the runway length is greater than 900m.

Runway take off length corrected for elevation, temperature and slope = [Take off run × % runway slope × .10] + Take off run

The runway length obtained from correction of elevation and temperature is divided in 4 parts. The runway slope in the first quarter and the last quarter is taken as zero. In the second quarter the slope is taken as 1.25% and in the third quarter it is taken as 0.35%.

For second quarter:

(Dy/Dx)× 100 = 1.25

(Dy/900)× 100 = 1.25

Dy = 11.25

Total elevation at the end of second quarter = 11.25

For third quarter:

(Dy/Dx0 × 100 = 0.35

(Dy/900)× 100 = 0.35

Dy= 3.15m

Total elevation at the end of the third quarter = 3.15+11.25 = 14.40m

Hence, the maximum elevation is 14.40 and the minimum elevation is 0

Therefore the average slope is given by the equation, = (Maximum elevation – Minimum elevation)/3

Slope = (14.4 – 0)/4038 = .3%

Runway take off length corrected for elevation, temperature and slope = [4038 × .3× .10] + 4038 = 4159m

So the total length of the runway is 4159m.

Width of the runway: The width of the runway = 60m

Runway shoulders: Runway shoulders must be provided to ensure transition from the full strength pavement to the unpaved strip of the runway. The paved shoulders protect the edge of the runway pavement, contribute to the prevention of soil erosion by jet blast and mitigate foreign object damage to the jet engines. Width of the runway shoulders = 7.5m on either side of the runway.

2.3 *Runway pavements:* The pavements in general are classified as flexible and rigid pavements according to their structural action. The black top pavement including gravel and water bound macadam follow the flexible group and the cement concrete pavement is the popular example of rigid pavement. Flexible pavements may consist of a relatively thin wearing surface built over a base course and sub base course, and they rest upon the compacted sub grade. Rigid pavements are made up of Portland cement concrete and may or may not have a base course between the pavement and sub grade. The runway pavement designed is flexible pavement and the "California Bearing Ratio"(CBR) Method has been used. The wheel load of the design aircraft is 27000kg and the CBR value of the sub grade soil is 3.8%. According to these wheel load and CBR values the thickness which is obtained is uneconomical and it is unable to resist the gross weight of the design aircraft. So that, the sub grade soil is stabilized with moorum stabilizing material then the CBR value is increased to 10%. The total thickness of the pavement is determined for the 5,000 coverage's and then the thickness is determined for the 15,000 coverage's it is increased to 11%.

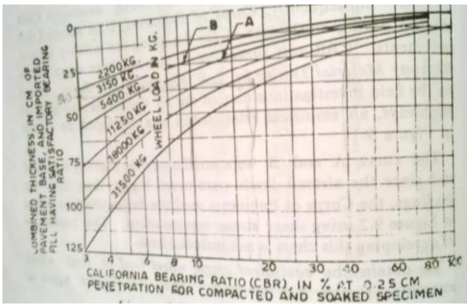

Fig. 2. CBR thickness design chart

The thickness is determined for the 5000 coverage's (Without stabilization)

Total thickness of the pavement for sub grade CBR value is 10% is 93.75 cm.

The thickness of the sub base ungraded gravel of CBR 18% is 76.875 cm.

The thickness of the base graded gravel of CBR 40% is 9.35 cm

The thickness of the bituminous concrete surfacing is usually taken as 7.5 cm as per the ICAO recommendations.

Hence, or 15000 coverage's the thickness value of pavement has increased 11%

The total thickness of the flexible pavement with stabilized CBR 10 is obtained as follows:

From the graph of CBR design chart, we found the total thickness value as 68.75 cm.

For 5000 coverage's, the pavement thickness is as follows:

TABLE I. THICKNESS RESULTS FOR 5000 COVERAGE'S (WITH STABILIZATION)

Pavement layers	CBR value	Thickness
Sub grade soil	10%	68.5cm
Ungraded gravel	18%	45cm
Graded gravel	40%	16.25cm
Bituminous dense concrete surface	-	7.5cm

TABLE II. THICKNESS FOR 15,000 COVERAGE'S

Pavement layers	CBR value	Thickness
Sub grade soil	10%	79.5cm
Ungraded gravel	18%	15cm
Graded gravel	40%	180cm
Bituminous dense concrete surface	-	80cm

2.4 Runway Markings

The markings on the runway help the pilot during the aircraft operations

i) Threshold Markings:

Commence 6m from both sides of runway ends 2.1m from either side of edge of runway.

Number of strips=14

Length of each strip=45m

Width of strip=1.80m

Gap between each strip=1.80m

ii) Aiming Point Markings:

One rectangular strips on either side of centre line

Distance from threshold=300m

Length of each strip=50m

Width of each strip=10m

Gap between strips=20m

iii) Touchdown Zone Markings

Number of strip on both side=4

Length of each strip=25m

Width of strip=3m

Gap between each strip=1.5m

Lateral spacing between strips on either side= 20m

iv) Centre Line Markings

Length of each strip=40m

Width of strip=0.5m

Gap between each strip=35m

v) Runway Strip Markings

30m from centre line

Width = 1m

2.5 Runway Lightings

2.5.1 Runway End Identification Lights (REIL): Unidirectional (facing approach direction) or unidirectional pair of synchronized flashing lights installed at the runway threshold, one on each side.

2.5.2 Runway end lights: Pair of four lights on each side of the runway on precision instrument runways, these lights extends along the full width of the runway. These lights show green when viewed by approaching aircraft and red when seen from the runway.

2.5.3 Runway edge lights: White elevated lights that run the length of the runway on either side. On precision instrument runways, the edge-lighting becomes yellow in the last 2,000 ft (610 m) of the runway, or last third of the runway, whichever is less.

2.5.4 Runway Centre line Lighting System (RCLS); The lights embedded into the surface of the runway at 50 ft (15 m) intervals along the runway centre line on some precision instrument runways. White except the last 900 m (3,000 ft): alternate white and red for next 600 m (1,969 ft) and red for last 300 m (984 ft).

2.5.5 Touchdown Zone Lights (TDZL) : The rows of white light bar (with three in each row) at 30 or 60 m (98 or 200 ft) intervals on either side of the centre line for 900 m (3,000 ft).

3.0 TAXIWAY DESIGN

Design of an exit taxiway joining a runway and a parallel main taxiway

Turning speed of aircraft, V = 70 kmph

Wheel base, W = 25.5 m

Wheel trade = 11.02 m

Total angle of turn = 350

Turn off speed = 90 kmph

Runway width = 60 m

Taxiway width = 30 m

Turning radius, R = v^2 / 125f

= $70^2/(125x0.13)$

= 301.53 m.................... (1)

Turning radius, R = $(0.388xW^{2)} / ((0.5xT)-S)$

S = 6+ (11.02/2)

= 11.51 m

R = $(0.388x25.5^2)/ ((0.5x30)-11.51)$

=72.29 m............ (2)

The absolute minimum turning radius for supersonic aircrafts irrespective of any speed = 180 m................. (3)

Adopting the height value of the three cases mentioned above,

The turning radius of the taxiway will be 301.53 m.

1) Radius of central curve=R_2= $(90^2)/ (125\times0.13)$ = 499 m

2) Length of entrance curve=L_1= $(90^3)/ (45.5\times.39\times499)$

=83 m

3) Deflection angle of the entrance curve=D_1 =$180\times L_1/\pi\times R_1$

= $180\times83/\pi\times301.5$ = 15°46'22"

4) Deflection of the angle at central curve=D_2 =35^0- D_1

=35^0-15°46'22"

=$19^0$31'37"

5) Length of central curve=L_2=$\pi\times R_2\times D_2/180$= 167.45m

6) Sight distance S.D = V^2/25.5d = 318m

This distance is to be measured from the edge of the runway pavement along the centre line of the exit taxiway.

7) For a major airport installation with instrumental landing facilities the separation clearance as specified by the ICAO = (184+30+11.25)= 225.2m

Available length of taxiway

= [225.25/(sin 35^0)]– [(60+30)/(2sin35^0)]

= 315m

I. Conclusion

The most important points of this study can be summarised as follows:

1) From the study it can be known that the selected soil sample may be classified as (Intermediate compressibility) CI.

2) By adding moorum to this sub grade soil, the CBR value has increased to 10%.

3) From the wind data the orientation of runway is provided as 08/26 direction.

4) For the proposed airport, the field length is supposed to be 4195 m which has the reference code 'D'.

5) The total thickness of pavement with stabilized soil is 93.75 cm, where the total thickness for the stabilization soil is 68.7 cm.

6) The pavement thickness which is obtained from the stabilized soil gives 23% less than the untreated soil.

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