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DESIGN PROCEDURE OF AN AIRPORT LAYOUT ACCORDING TO INTERNATIONAL STANDARD CODES

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Abstract - *This study is intended to enable its readers to understand the procedure to design the layout of an international airport in accordance to the various codes (guidelines and recommendations) given by the 'International Civil Aviation Organization' (ICAO) on a single platform. The layout designed for explanation is for a fictitious location and is not intended to be used for any actual site. The step by step procedure for the geometric design of various runways and taxiways is stated clearly and the various safety checks are provided for the same. The information for data to be collected at an actual site is also mentioned clearly. The paper concludes with the complete design drawing of an airport layout which includes runways, taxiways, airport terminal, hangars, aircraft support facilities, etc. The code references have been specified at various related places to facilitate better understanding of the design procedure.*

Key Words: Airport Layout, International Civil Aviation Organization, ICAO Annex 14, ICAO Aerodrome Design Manual Part 1 and Part 2, Runway, Taxiway, Designing of Airport

1.INTRODUCTION

According to the International Civil Aviation Organization (ICAO) Annex 14, an aerodrome is 'A defined area on land or water (including any buildings, installations and equipment) intended to be used either wholly or in part for the arrival, departure and surface movement of aircraft.' Thus, we can define an airport as an aerodrome that is certified for commercial / military aircraft operations.

An international airport is an airport that facilitates the movement of international as well as domestic civilian and cargo airliners and is well equipped with immigration and customs facilities for the passengers.

In this paper, the location characteristics of the fictitious airport along with all the design parameters, have been assumed suitably so as to foster easier calculations for the design purpose. However, the location characteristics for an actual airport site must be compiled properly by consulting aviation professionals.

The various codes that have been used for designing purpose are given as follows-

1. ICAO Annex 14 (Sixth Edition, July 2013)
2. ICAO Aerodrome Design Manual Part 1- Runways (Third Edition, 2006)
3. ICAO Aerodrome Design Manual Part 2- Taxiways, Aprons and Holding Bays (Fourth Edition, 2005)

For detailed design of runway and taxiway intersections or intersections between two taxiways, the local ground profile must be studied carefully to provide appropriate turning radius. Also, the size of the turn must easily accommodate the design aircraft at that turn. For detailed design refer Aerodrome Design Manuals Part 1 and 2. This paper deals with the design procedure of the layout only.

1.1 DATA REQUIRED AND ASSUMPTIONS

For designing actual airports, adequate traffic forecasting, demand analysis and environmental impact assessment is to be carried out as the construction of an airport is expensive and it may also have deleterious environmental effects.

It is also necessary to obtain, verify and compile the actual site data (wind, temperature, obstruction clearance, geotechnical investigation, etc.) from reliable aviation agencies.

For this study, the airport to be designed is an international airport having **two parallel, non-staggered runways**.

The runways are assumed to be **instrumental with precision approach** and are intended for operation of aircraft using **instrumental as well as visual approach procedures**.

The various assumptions under which the airport layout is designed are given below.

1. The hypothetical location of the airport is at non-polar latitudes to neglect the effect of magnetic declination on the orientation and designation of the runways.
2. Usability factor is considered as 95% as per the ICAO guidelines with the runway end designation and runway orientation assumed as a result of a wind-rose analysis (not performed).
3. The Mean elevation of the airport is 100 m above (mean sea level) MSL and the aerodrome elevation or field elevation is 102.3 m above MSL.
4. ICAO reference code number – 4
5. ICAO reference code letter – F
6. The whole circle bearing (WCB) heading of the runway ends are 90.3^0 and 270.3^0

2.AERODROME DESIGN PROCEDURE FOR EXPLANATORY AIRPORT

2.1 ABBREVIATIONS

ICAO: International civil aviation organization
TOR: Takeoff run of an aircraft
MTOW: Maximum takeoff weight of an aircraft
TORA: Takeoff run available
TODA: Takeoff distance available
ASDA: Accelerate stop distance available
LDA: Landing distance available
RET: Rapid exit taxiway
ISA: International standard atmosphere
GSE: Ground support equipment
ARFF: Aircraft rescue and fire-fighting
DVOR/DME: Doppler VHS omni directional range/distance measuring equipment
ASR/MSSR: Airport surveillance radar/monopulse secondary surveillance radar
ADM: Aerodrome design manual

2.2 ICAO AIRPORT CLASSIFICATION

Table -1: Aerodrome Reference Code

Code Number	Aeroplane Reference Field Length	Code Letter	Wingspan	Outer Main Gear Wheel Span
1	Less than 800 m	A	Up to but not including 15 m	Up to but not including 4.5 m
2	800 m up to but not including 1200 m	B	15 m up to but not including 24 m	4.5 m up to but not including 6 m
3	1200 m up to but not including 1800 m	C	24 m up to but not including 36 m	6 m up to but not including 9 m
4	1800 m and over	D	36 m up to but not including 52 m	9 m up to but not including 14 m
		E	52 m up to but not including 65 m	9 m up to but not including 14 m
		F	65 m up to but not including 80 m	14 m up to but not including 16 m
			Greater than and including 80 m	Refer Aerodrome Design Manual Parts 1 and 2.

(ICAO Annex 14, Table 1-1, and page 1-12)

In order to accommodate the movement of the largest passenger aircraft, the Airbus A380, the airport classification of the airport is to be taken as 4F.

Selected Code Number – 4 (Aeroplane reference field length is 1800 m and above).

Selected Code Letter – F (Wingspan 80 m and above) {Must refer Aerodrome Design Manual Parts 1 and 2}.

2.3 GEOMETRIC DESIGN OF RUNWAY

Width of each runway assumed = 60 m (excluding runway shoulders)

Width of runway shoulders assumed = 12 m each

Therefore, Overall width of each runway including shoulders = 12+60+12 = 84 m.

The width of the runway shall not be less than the appropriate dimension specified in the following tabulation-

Table -2: Code Letters for Runway Width

Code Number	A	B	C	D	E	F
1	18 m	18 m	23 m	-	-	-
2	23 m	23 m	30 m	-	-	-
3	30 m	30 m	30 m	45 m	-	-
4	-	-	45 m	45 m	45 m	60 m

Table referred from ICAO Annex 14, page 3-3

The length of precision approach runway shall be not less than 30 m where the code number is 1 or 2.

For Code 4 F runways, the minimum width of runway to be provided is 60 m.

Width of runway provided = 60 m

Hence, the check is satisfied.

As per clause 3.2.3 of ICAO Annex 14, the runway shoulders shall extend symmetrically on each side of the runway so that the overall width of runway and its shoulders is not less than 75 m where the code letter is F.

Overall width of each runway including shoulders provided = 84 m which is greater than 75 m

Hence, the check is satisfied.

The lengths of runway are calculated as follows-

Step 1- Determining the Takeoff run (TOR) of an aircraft at Maximum takeoff weight (MTOW) at standard temperature with no wind blowing on the runway to calculate the **Basic Runway Length.**

Table -3: Takeoff run at max. takeoff weight at ISA

Aircraft Type	Approx. TOR at MTOW (in meter)
Airbus A380 – 800/800 F	2880
Boeing 747 Series	3300 (maximum among variants)
Airbus A340 Corporate	3180
Airbus A350 – 900	2670
Airbus A330 Series	2770 (maximum among variants)
Boeing 777 Series	3380 (maximum among variants)
Boeing 787 Series	3100 (maximum among variants)

The Aircraft Types in the above table are selected on the basis of their body size (narrow or wide), the frequency of their movements and the probability for their use on long haul flights.

The above table is not conclusive of the fact that the above-mentioned aircrafts will only give the maximum TOR at MTOW. The values of TOR at MTOW are eclectic.

From above table, we can safely conclude **that large size of the aircraft may not always give us the maximum TOR at MTOW.** The large size of an aircraft especially the wing span, **influences the classification of the airport in case of geometric design.**

The basic runway length can also be calculated using the concept of balanced field length and can be only applied to min. TOR of an aircraft. However, if this concept is applied to TOR at MTOW, the design becomes uneconomical due to excess length of runway which is practically found to be unnecessary.

Therefore, the TOR selected for design check is 3380 m (highest value observed from Table 3)

Step 2- Designating the runways and calculating the **Actual Length of each runway**-

Runways are designated on the basis of their magnetic bearing of the runways heading in decadegrees. These numbers vary from 01 to 36 but are never in a decimal. If the magnetic bearing of a runway is in decimal, then it is rounded off to the nearest whole number. E.g. heading of 140^0 implies a designation of 14. In case of multiple parallel runways in the same direction, the designation number is followed by the letters L(left), R(right) or C(center).

While designing the layout of an airport that has to be practically implemented, a wind rose analysis has to be performed to determine the orientation of the runways. The whole circle bearing thus obtained must be converted into

decadegrees and must be rounded off to the nearest whole number.

Also, the Aerodrome Reference Temperature must be calculated by the following formula,

Aerodrome Reference Temperature = $T_a + \frac{Tm - Ta}{3}$

Where, T_m = Monthly mean of the maximum daily temperature for the hottest month of the year.

T_a = Monthly mean of the average daily temperature for the hottest month of the year.

Let the two parallel, non-staggered runways be designated as **Runway 27L – 09R** and **Runway 27R – 09L**

Assuming the runway headings are 90.3^0 and 270.3^0.

Corrections of elevations, temperature and gradient are applied respectively to the basic runway length to calculate the actual runway length.

Step 3- Calculations for runway 27 L – 09 R

Assumptions-

1. Maximum Reduced Level along Runway Centerline = 101.2 m (assumed at runway end)
2. Minimum Reduced Level along Runway Centerline = 93.5 m (assumed at runway end)
3. Airport Reference Temperature = 25 ^{0}C

ICAO ADM Part1 has recommended that the basic length selected for the runway should be increased at the rate of 7 % per 300 m rise in elevation.

Let C_e be the correction for elevation.

Therefore, $C_e = \frac{3380 \text{ X } 0.07 \text{ X } 100}{300}$ = 78.86 m

Let C_e = 80 m

Therefore, Corrected Length = 3380 m + 80 m = 3460 m

ICAO ADM Part 1 recommends that the length corrected for elevation, should further be increased at the rate of 1 % for every 1 ^{0}C by which the 'Airport Reference Temperature' exceeds the temperature in the 'Standard Atmosphere' for the airport elevation.

Standard Temperature- Standard temperature at site can be determined by reducing the standard sea level temperature of 15 ^{0}C at the rate of 6.5 ^{0}C per 1000 m rise in elevation.

Standard Temperature at airport to be designed = 15 ^{0}C - $\frac{6.5}{1000}$ X 100 = 14.35 ^{0}C

Let C_t be the correction for temperature.

Therefore, C_t = Corrected Length X (Airport Reference Temperature – 14.35) X 0.01

= 3460 X (25 – 14.35) X 0.01

= 368.49 m

Let C_t = 370 m

Therefore, Revised Corrected Length = 3460 + 370 = 3830 m

According to the ICAO, if the total correction for elevation and temperature exceeds 35%, the required correction should be obtained by means by a specific study.

For the above case, the total correction for elevation and temperature is 13.31%

Hence, the check is satisfied.

According to clause 3.1.13 and 3.1.14 of ICAO Annex 14,

1. **The slope computed by dividing the difference between maximum and minimum elevation along the runway centerline by the runway length should not exceed 1 % where the code number is 3 or 4.**
2. **Along no portion of a runway should the longitudinal slope exceed 1.25 % where the code number is 4, except that for the first and last quarter of the length of the runway the longitudinal slope should not exceed 0.8 %.**

$$\text{Effective runway gradient} = \frac{\textit{Maximum difference in runway centreline elevation}}{\textit{Length of runway (final length)}}$$

$$= \frac{101.2 - 93.5}{4000 \text{ (assuming final length)}} \text{ X } 100$$

= 0.19 %

approx. = 0.2 % (assumed constant throughout the length)

which is less than 1% and 0.8%

Hence, the check is satisfied.

Where the basic length determined by take-off requirement is 900 m or more, that length should be further increased at the rate of 10 % for each 1 % of the runway effective gradient.

Let C_s be the correction for slope.

Therefore, C_s = 3830 X 0.2 X 0.1

= 76.6 m

Let C_s = 80 m

Therefore, Revised Corrected Length = 3830 + 80 = 3910 m

Step 4- Calculations for runway 27 R – 09 L

Assumptions-

1. Maximum Reduced Level along Runway Centerline = 102.3 m (assumed at runway end)
2. Minimum Reduced Level along Runway Centerline = 92.2 m (assumed at runway end)
3. Airport Reference Temperature = 25 ^{0}C

After applying corrections for temperature and elevation as per runway 28 L – 10 R, the length of the runway becomes 3830 m.

$$\text{Effective runway gradient} = \frac{\textit{Maximum difference in runway centreline elevation}}{\textit{Length of runway (final length)}}$$

$$= \frac{102.3-92.2}{4000\ (\textit{assuming final length})} \text{ X } 100$$

= 0.25 % (assumed constant throughout the length)

which is less than 1% and 0.8%

Hence, the check is satisfied.

Where the basic length determined by take-off requirement is 900 m or more, that length should be further increased at the rate of 10 % for each 1 % of the runway effective gradient.

Let C_s be the correction for slope.

Therefore, C_s = 3830 X 0.25 X 0.1

= 95.75 m

Let C_s = 100 m

Therefore, Revised Corrected Length = 3830 + 100 = 3930 m

Increasing the lengths of both the runways by about 7% to 8%, as length after gradient correction is less than assumed length for gradient (4000), let the total length be 4220 m.

Definition of declared distances as per ICAO Annex 14 Page 1-4 –

1. **Take-off run available (TORA)**: The length of runway declared available and suitable for the ground run of an aeroplane taking off.
2. **Take-off distance available (TODA)**: The length of the take-off run available plus the length of clearway, if provided.
3. **Accelerate stop distance available (ASDA)**: The length of take-off run available plus the length of stop way, if provided.
4. **Landing distance available (LDA)**: The length of runway which is declared available and suitable for the ground run of an aeroplane landing.

SUMMARY-

Thus, the final dimensions of the runways after applying relevant corrections are as follows-

Width of both runways = 60 m

Width of both runways including shoulders = 84 m

Actual length of both runways by take-off requirements = 4220 m

Table -4: Declared distances

Runway Designation Ends	TORA (m)	ASDA (m)	TODA (m)	LDA (m)
09 L	4070	4070	4070	4070
27 R	4220	4220	4220	4070
09 R	4070	4070	4070	4070
27 L	4220	4220	4220	4070

Effective runway gradient of runway 27 L – 09 R = 0.2 %

Effective runway gradient of runway 27 R – 09 L = 0.25 %

2.4 GEOMETRIC DESIGN OF TAXIWAY

General Taxiway and Rapid Exit Taxiway-

Width of taxiway = 28 m

Width of taxiway shoulders = 21 m

Therefore, Overall width of taxiway including shoulders = 21+28+21 = 70 m.

As per clause 3.9.5 of ICAO Annex 14, a straight portion of a taxiway should have a width of not less than that given by the following tabulation –

Table -5: Minimum Width of Taxiways

Code Letter	Taxiway Width
A	7.5 m
B	10.5 m
C	15 m if the taxiway is intended to be used by aeroplanes with a wheel base less than 18 m. 18 m if the taxiway is intended to be used by aeroplanes with a wheel base equal to or greater than 18 m.
D	18 m if the taxiway is intended to be used by aeroplanes with an outer main gear wheel span of less than 9 m. 23 m if the taxiway is intended to be used by aeroplanes with an outer main gear wheel span equal to or greater than 9 m.
E	23 m
F	25 m

Referred from ICAO Annex 14, page 3-19

For code F airports, minimum width of taxiways = 25 m

The minimum width of taxiways provided in the airport to be designed in the above-mentioned cases = 28 m

Hence, the check is satisfied.

For code F airports, overall width of taxiways required = 60 m (as per ICAO Annex 14)

For code F airports, overall width of taxiways provided is 70 m and is greater than 60 m in the above-mentioned cases.

Hence, the check is satisfied.

The exact location of the taxiways is at the discretion of the airport layout designer and his/her attempts to ease surface movement congestion.

As per clause 3.9.16, a rapid exit taxiway should be designed with a radius of turn-off curve of at least 550 m where the code number is 3 or 4 to enable exit speeds under wet conditions of 93 km/hr where the code number is 3 or 4.

As per clause 3.9.19, the intersection and of a rapid exit taxiway with the runway should not be greater than 45^0 nor less than 25^0 and preferably should be 30^0.

For the airport to be designed, Angle of Intersection of RET and Runway = 30^0

The radius of turn-off curve is 550 m and radius of inside fillet curve is 488 m for all the rapid exit taxiways in accordance with ICAO Aerodrome Design Manual Part 2.

Hence, the check is satisfied.

The rapid exit taxiways are provided at a suitable distance from the runway ends to facilitate smooth and quick exit of the aircraft from the runway.

Like general taxiways, the precise location of the rapid exit taxiways is at the discretion of the airport layout designer; however, care must be taken to ensure minimum runway occupancy time.

2.5 DIMENSIONS OF VARIOUS BUILDINGS AND INSTALLATIONS

It must be noted that the areas and size of the buildings may be subjected to local bye-laws. The dimensions of the buildings given below are suggestive of the general dimensions of various buildings at an airport.

Commercial Aircraft Apron = 420 X 181.5 m

Passenger Terminal (Plan Area) = 234776.52 m^2

Vehicle Parking Lot

1. Near Primary Passenger Terminal = 170 X 749.9 m
2. Near Low Cost Terminal = 180 X 580.1 m

Control Tower (Tentative Plan Area) = 50 m^2

Long Term Parking Apron = 960 X 180 m

Cargo Aircraft Apron = 480 X 120 m

International Cargo Building = 420 X 80 m

Air Freight Cargo Building = 480 X 80 m

Maintenance Apron = 720 X 180 m

Maintenance Hangars (Total Plan Area Allotted) = 720 X 240 m

General Aviation Apron = 200 X 180 m

General Aviation Building = 200 X 80 m

Aircraft Rescue and Fire Fighting (ARFF) = 168 X 168.1 m

GSE Maintenance = 150 X 150 m

Heavy Airfield Maintenance (inclusive of GSE Maintenance) = 300 X 300 m

Sewage Treatment Plant (may vary according to capacity) = 200 X 150 m

Fuel Farm = 360 X 180 m

Catering (Tentative Area) = 84.5 m^2

Support Facilities Area = 400.3 X 165.2 m

Low Cost Terminal (Plan Area)

1. Direct Access Terminal = 93925.98 m^2
2. Internal Terminal = 54432 m^2

2.6 CHECKS FOR CENTER TO CENTER DISTANCES

These checks are carried out after the entire layout of the airport is almost finalized especially after the introduction on the terminal buildings, hangars, parking bays or any other structure/area which will cause the center to center dimensions of adjacent taxiways/runways to change.

The table specifying the minimum center to center separation distances for instrumental runways is given below-

Table -6: Distance between Taxiway Centerline and Runway Centerline (meter)

Code Letter	Instrument Runways Code Number			
	1	**2**	**3**	**4**
A	82.5	82.5	-	-
B	87	87	-	-
C	-	-	168	-
D	-	-	176	176
E	-	-	-	182.5
F	-	-	-	190

Referred from ICAO Annex 14, Table 3-1, page 3-22

Center to center distance between each runway and taxiways (in a direction parallel to that of the runways) required = 190 m for type 4 F runways.

For the airport designed, center to center distance between each runway and taxiways (in a direction parallel to that of the runways) = 200 m

Hence, the check is satisfied.

The table specifying the minimum center to center separation distances between parallel taxiways is given below-

Table -7: Distance between Taxiway Centerlines (parallel)

Code Letter	Taxiway Centerline to Taxiway Centerline
A	23.75
B	33.5
C	44
D	66.5
E	80
F	97.5

Referred from ICAO Annex 14, Table 3-1, page 3-22

Center to center distance between taxiways (parallel) required = 97.5 m for type F airports.

For the airport designed, center to center distance between taxiways (parallel) provided is greater than 97.5 m in all cases.

Hence, the check is satisfied.

As per clause 3.1.12, where parallel instrument runways are intended for simultaneous use subject to conditions specified in PANS-ATM (Doc 4444) and the PANS-OPS (Doc 8168), Volume 1, the minimum distances between their centerlines should be:

- 1035 m for independent parallel approaches

- 915 m for dependent parallel approaches
- 760 m for independent parallel departures
- 760 m for segregated parallel operations

except that:

a) for segregated parallel operations, the specified minimum distance:

1) may be decreased by 30 m for each 150 m that the arrival runway is staggered toward the arriving aircraft, to a minimum of 300 m; and

2) should be increased by 30 m for each 150 m that the arrival runway is staggered away from the arriving aircraft;

b) for independent parallel approaches, combinations of minimum distances and associated conditions other than those specified in the PANS-ATM (Doc 4444) may be applied when it is determined that such combinations would not adversely affect the safety of aircraft operations.

The airport to be designed has two parallel, independent and non-staggered runways.

The minimum center to center distance to be provided between the two runways as per above clause = 1979.9 m

The center to center distance provided between the two runways = 1979.9 m which is greater than 1035 m

Hence, the check is satisfied.

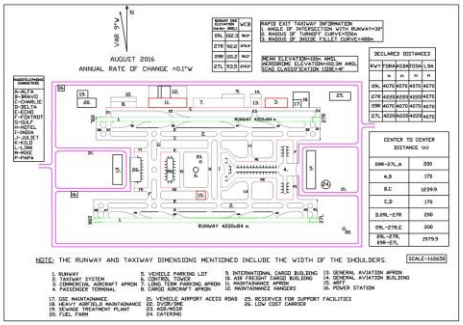

Fig -1: Airport Layout Design (Zoom for details)

Note: The aerobridges shown are for representative purpose only. The exact number of aerobridges depends upon the demand and the discretion of the airport operator.

3. CONCLUSIONS

The geometric design of the layout plan of an airport in accordance to the various ICAO codes can thus be carried out by following the steps given in this paper. With the help of the explanatory model, the reader can comprehend the various calculations and criteria that are necessary for planning and designing the layout of an airport on a single platform rather than referring the individual codes separately.

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