CHAPTER 3. PHYSICAL CHARACTERISTICS

3.1 Introduction

This chapter contains specifications related to the physical characteristics required of aerodrome runway, taxiway, apron and related facilities.

3.2. Runways

3.2.1 Number and orientation of runways

Introductory Note: Many factors affect the determination of the orientation, siting and number of runways. One important factor is the usability factor, as determined by the wind distribution, which is specified hereunder. Another important factor is the alignment of the runway to facilitate the provision of approaches conforming to the approach surface specifications of Chapter 4 of this Manual. In Attachment B, Section 1, information is given concerning these and other factors.

When a new instrument runway is being located, particular attention needs to be given to areas over which aeroplanes will be required to fly when following instrument approach and missed approach procedures, so as to ensure that obstacles in these areas or other factors will not restrict the operation of the aeroplanes for which the runway is intended.

3.2.1.1 The number and orientation of runways at an aerodrome should be such that the usability factor of the aerodrome is not less than 95 per cent for the aeroplanes that the aerodrome is intended to serve.

3.2.1.2 The siting and orientation of runways at an aerodrome should, where possible, be such that the arrival and departure tracks minimize interference with areas approved for residential use and other noise-sensitive areas close to the aerodrome in order to avoid future noise problems.

Note. – Guidance on how to address noise problems is provided in the ICAO Airport Planning Manual (Doc 9184), Part 2, and in ICAO Guidance on the Balanced Approach to Aircraft Noise Management (Doc 9829).

3.2.1.3 Choice of maximum permissible cross-wind components

In the application of paragraph 3.2.1.1 above, it should be assumed that landing or take-off of aeroplanes is, in normal circumstances, precluded when the cross-wind component exceeds:

– 37 km/h (20 kt) in the case of aeroplanes whose reference field length is

1 500 m or over, except that when poor runway braking action owing to an insufficient longitudinal coefficient of friction is experienced with some frequency, a cross-wind component not exceeding 24 km/h (13 kt) should be assumed;

– 24 km/h (13 kt) in the case of aeroplanes whose reference field length is 1 200 m or up to but not including 1 500 m; and
– 19 km/h (10 kt) in the case of aeroplanes whose reference field length is less than 1 200 m.

Note: In Attachment B, Section 1, guidance is given on factors affecting the calculation of the estimate of the usability factor and allowances which may have to be made to take account of the effect of unusual circumstances.

3.2.1.4 Data to be used

The selection of data to be used for the calculation of the usability factor should be based on reliable wind distribution statistics that extend over as long a period as possible, preferably of not less than five years. The observations used should be made at least eight times daily and spaced at equal intervals of time.

Note — These winds are mean winds. Reference to the need for some allowance for gusty conditions is made in Attachment B, Section 1.

Location of threshold

3.2.1.5 A threshold should normally be located at the extremity of a runway unless operational considerations justify the choice of another location.

Note — Guidance on the siting of the threshold is given in Attachment B, Section 10.

3.2.1.6 When it is necessary to displace a threshold, either permanently or temporarily, from its normal location, account should be taken of the various factors which may have a bearing on the location of the threshold. Where this displacement is due to an unserviceable runway condition, a cleared and graded area of at least 60 m in length should be available between the unserviceable area and the displaced threshold. Additional distance should also be provided to meet the requirements of the runway end safety area as appropriate.

Note — Guidance on factors which may be considered in the determination of the location of a displaced threshold is given in Attachment B, Section 10.

Actual length of runways

3.2.1.7 Primary runway

Except as provided in paragraph 3.2.1.9 of this Manual, the actual runway length to be provided for a primary runway should be adequate to meet the operational requirements of the aeroplanes for which the runway is intended and should be not less than the longest length determined by applying the corrections for local conditions to the operations and performance characteristics of the relevant aeroplanes.

Note 1 — This specification does not necessarily mean providing for operations by the critical aeroplane at its maximum mass.

Note 2 — Both take-off and landing requirements need to be considered when determining the length of runway to be provided and the need for operations to be conducted in both directions of the runway.

Note 3 — Local conditions that may need to be considered include elevation, temperature, runway slope, humidity and the runway surface characteristics.

Note 4 — When performance data on aeroplanes for which the runway is intended are not known, guidance on the determination of the actual length of a primary runway by application of general correction factors is given in the ICAO Aerodrome Design Manual, Part 1.

3.2.1.8 Secondary runway

The length of a secondary runway should be determined similarly to primary runways except that it needs only to be adequate for those aeroplanes which require to use that secondary runway in addition to the other runway or runways in order to obtain a usability factor of at least 95 per cent.

3.2.1.9 Runways with stop-ways or clearways

Where a runway is associated with a stop-way or clearway, an actual runway length less than that resulting from application of paragraphs 3.2.1.7 or 3.2.1.8, as appropriate, may be considered satisfactory, but in such a case any combination of runway, stop-way and clearway provided should permit compliance with the operational requirements for take-off and landing of the aeroplanes the runway is intended to serve.

Note — Guidance on use of stop-ways and clearways is given in Attachment B, Section 2.

Width of runways

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

	Code letter					
Code number	A	B	C	D	E	F
1[a]	18 m	18 m	23 m	-	-	-
2[a]	23 m	23 m	30 m	-	-	-
3	30 m	30 m	30 m	45 m	-	-
4	-	-	45 m	45 m	45 m	60 m

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

Note 1 — The combinations of code numbers and letters for which widths are specified have been developed for typical aeroplane characteristics.

Note 2 — Factors affecting runway width are given in the ICAO Aerodrome Design Manual, Part 1.

Minimum distance between parallel runways

3.2.1.11 Where parallel non-instrument runways are intended for simultaneous use, the minimum distance between their centre lines should be:

- 210 m where the higher code number is 3 or 4;
- 150 m where the higher code number is 2; and
- 120 m where the higher code number is 1.

Note — Procedures for wake turbulence categorization of aircraft and wake turbulence separation minima are contained in the Procedures for Air Navigation Services —Air Traffic Management (PANS-ATM), Doc 4444, Chapter 4, paragraph 4.9 and Chapter 5, paragraph 5.8 respectively.

3.2.1.12 Where parallel instrument runways are intended for simultaneous use subject to conditions specified in the PANS-ATM (Doc 4444) and the PANS-OPS (Doc 8168), Volume I, the minimum distance between their centre lines shall be:

- 1 035 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.

Note — Procedures and facilities requirements for simultaneous operations on parallel or near-parallel instrument runways are contained in the PANS-ATM (Doc 4444), Chapter 6 and the PANS-OPS (Doc 8168), Volume I, Part III, Section 2, and Volume II, Part I, Section I; and Part III, Section 3, and relevant guidance is contained in the ICAO Manual of Simultaneous Operations on Parallel or Near-Parallel Instrument Runways (SOIR)(Doc 9643).

Slopes on runways

3.2.1.13 Longitudinal slopes

The slope computed by dividing the difference between the maximum and minimum elevation along the runway centre line by the runway length shall not exceed:

a) 1 per cent where the code number is 3 or 4; and

b) 2 per cent where the code number is 1 or 2.

3.2.1.14 The longitudinal slope along any portion of the runway shall not exceed:

a) 1.25 per cent 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 per cent;

b) 1.5 per cent where the code number is 3, except that for the first and last quarter of the length of a precision approach runway category II or III the longitudinal slope should not exceed 0.8 percent; and

c) 2 per cent where the code number is 1 or 2.

3.2.1.15 longitudinal slope changes

Where slope changes cannot be avoided, a slope change between two consecutive slopes shall not exceed:

a) 1.5 per cent where the code number is 3 or 4; and

b) 2 per cent where the code number is 1 or 2.

Note — Guidance on slope changes before a runway is given in Attachment B, Section 4.

3.2.1.16 The transition from one slope to another shall be accomplished by a curved surface with a rate of change not exceeding:

a) 0.1 per cent per 30 m (minimum radius of curvature of 30 000 m) where the code number is 4;

b) 0.2 per cent per 30 m (minimum radius of curvature of 15 000 m) where the code number is 3; and

c) 0.4 per cent per 30 m (minimum radius of curvature of 7 500 m) where the code number is 1 or 2.

3.2.1.17 Sight distance

Where slope changes cannot be avoided, they shall be such that there will be an unobstructed line of sight from;

a) any point 3 m above a runway to all other points 3 m above the runway within a distance of at least half the length of the runway where the code letter is C, D, E or F;

b) any point 2 m above a runway to all other points 2 m above the runway within a distance of at least half the length of the runway where the code letter is B; and

c) any point 1.5 m above a runway to all other points 1.5 m above the runway within a distance of at least half the length of the runway where the code letter is A.

Note — Consideration will have to be given to providing an unobstructed line of sight over the entire length of a single runway where a full-length parallel taxiway is not available. Where an aerodrome has intersecting runways, additional criteria on the line of sight of the intersection area would need to be considered for operational safety. See the ICAO Aerodrome Design Manual (Doc 9157), Part 1.

3.2.1.18 Distance between slope changes

Undulations or appreciable changes in slopes located close together along a runway shall be avoided. The distance between the points of intersection of two successive curves shall not be less than:

a) the sum of the absolute numerical values of the corresponding slope changes multiplied by the appropriate value as follows:

   – 30 000 m where the code number is 4;
   – 15 000 m where the code number is 3; and
   – 5 000 m where the code number is 1 or 2; or

b) 45 m;

whichever is greater.

Note — Guidance on implementing this specification is given in Attachment B, Section 4.

3.2.1.19 Transverse slopes

To promote the most rapid drainage of water, the runway surface should, if practicable, be cambered except where a single cross fall from high to low in the direction of the wind most frequently associated with rain would ensure rapid drainage. The transverse slope should ideally be:

– 1.5 per cent when the code letter is C, D, E or F; and
– 2 per cent when the code letter is A or B;

but in any event should not exceed 1.5 per cent or 2 per cent, as applicable, nor be less than 1 per cent except at runway or taxiway intersections where flatter slopes may be necessary. For a cambered surface the transverse slope on each side of the centre line should be symmetrical.

Note — On wet runways with cross-wind conditions the problem of aquaplaning from poor drainage is apt to be accentuated. Attachment B, Section 7, information is given concerning this problem and other relevant factors.

3.2.1.20 The transverse slope shall be substantially the same throughout the length of a runway except at an intersection with another runway or a taxiway where an even transition shall be provided taking account of the need for adequate drainage.

Note — Guidance on transverse slope is given in the ICAO Aerodrome Design Manual (Doc 9157), Part 3.

Strength of runways

3.2.1.21 A runway shall be capable of withstanding the traffic of aeroplanes the runway is intended to serve.

Surface of runways

3.2.1.22 The surface of a runway shall be constructed without irregularities that would result in loss in friction characteristics or otherwise adversely affect the take-off or landing of an aeroplane.

Note 1 — Surface irregularities may adversely affect the take-off or landing of an aeroplane by causing excessive bouncing, pitching, vibration, or other difficulties in the control of an aeroplane.

Note 2 — Guidance on design tolerances and other information is given in Attachment B, Section 5. Additional guidance is included in the ICAO Aerodrome Design Manual, *Part 3.*

3.2.1.23 The surface of a paved runway shall be so constructed as to provide good friction characteristics when the runway is wet.

3.2.1.24 Measurements of the friction characteristics of a new or resurfaced runway shall be made with a continuous friction measuring device using self-wetting features in order to assure that the design objectives with respect to its friction characteristics have been achieved.

Note — Guidance on friction characteristics of new runway surfaces is given in Attachment B, Section 7. Additional guidance is included in the ICAO Airport Services Manual (9137), Part 2.

3.2.1.25 The average surface texture depth of a new surface should be not less than 1.0 mm.

Note 1: — This normally requires some form of special surface treatment.

Note 2 — Guidance on methods used to measure surface texture is given in the ICAO Airport Services Manual (9137), Part 2.

3.2.1.26 When the surface is grooved or scored, the grooves or scorings should be either perpendicular to the runway centre line or parallel to non-perpendicular transverse joints, where applicable.

Note — Guidance on methods for improving the runway surface texture is given in the ICAO Aerodrome Design Manual (Doc 9157), Part3.

3.3 Runway shoulders

Note — Guidance on characteristics and treatment of runway shoulders is given in Attachment B, Section 8, and in the ICAO Aerodrome Design Manual (9157), Part 1.

3.3.1 Runway shoulders shall be provided for a runway where the code letter is D or E, and the runway width is less than 60 m.

3.3.2 Runway shoulders shall be provided for a runway where the code letter is F.

Width of runway shoulders

3.3.3 The runway shoulders should extend symmetrically on each side of the runway so that the overall width of the runway and its shoulders is not less than:

– 60 m where the code letter is D or E; and

– 75 m where the code letter is F.

Slopes on runway shoulders

3.3.4 The surface of the shoulder that abuts the runway shall be flush with the surface of the runway and its transverse slope shall not exceed 2.5 per cent.

Strength of runway shoulders

3.3.5 A runway shoulder shall be prepared or constructed so as to be capable, in the event of an aeroplane running off the runway, of supporting the aeroplane without inducing structural damage to the aeroplane and of supporting ground vehicles which may operate on the shoulder.

Note.— Guidance on strength of runway shoulders is given in the Aerodrome Design Manual *(Doc 9157), Part 1*.

3.4 Runway turn pads

3.4.1 Where the end of a runway is not served by a taxiway or a taxiway turnaround and where the code letter is D, E or F, a runway turn pad shall be provided to facilitate 180 degree turn of aeroplanes. (See figure 3-1)

3.4.2 Where the end of a runway is not served by a taxiway or a taxiway turnaround and where the code letter is A, B, C, a runway turn pad should be provided to facilitate a 180-degree turn of aeroplanes.

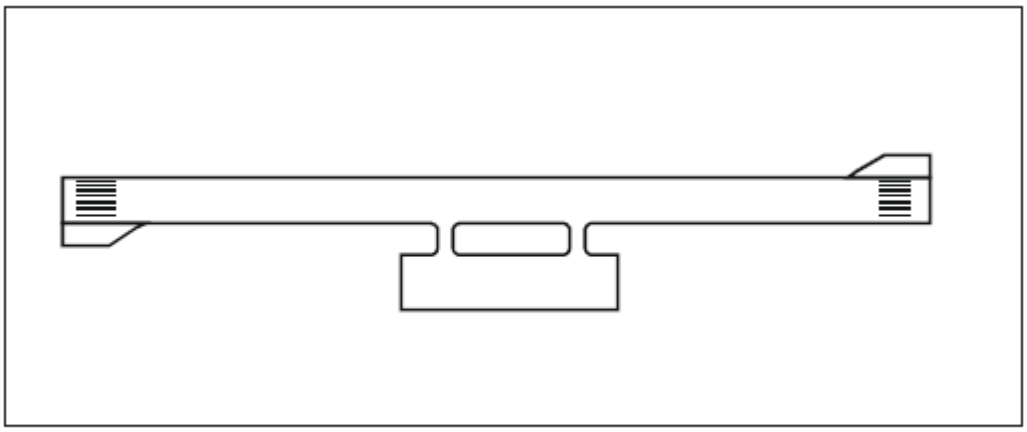

Figure 3-1. Typical turn pad layout

Note 1.— Such areas may also be useful if provided along a runway to reduce taxiing time and distance for aeroplanes which may not require the full length of the runway.

Note 2.— Guidance on the design of the runway turn pads is available in the Aerodrome Design Manual (Doc 9157), Part 1. Guidance on taxiway turnaround as an alternate facility is available in the Aerodrome Design Manual(Doc 9157), Part 2.

3.4.3 The runway turn pad may be located on either the left or right side of the runway and adjoining the runway pavement at both ends of the runway and at some intermediate locations where deemed necessary.

Note.— The initiation of the turn would be facilitated by locating the turn pad on the left side of the runway, since the left seat is the normal position of the pilot-in-command.

3.4.4 The intersection angle of the runway turn pad with the runway should not exceed 30 degrees.

3.4.5 The nose wheel steering angle to be used in the design of the runway turn pad should not exceed 45 degrees.

3.4.6 The design of a runway turn pad shall be such that, where the cockpit of the aeroplane for which the turn pad is intended over the turn pad marking, the clearance distance between any wheels of the aeroplane landing gears and the edge of the turn pad shall not be less than that given by the following tabulation:

Code letter	Clearance
A	1.5 m
B	2.25 m
C	3 m if the turn pad is intended to be used by aeroplane with a wheel base less than 18 m; 4.5 m if the turn pad is intended to be used by aeroplanes with a wheelbase equal to or greater than 18 m;
D	4.5 m
E	4.5 m
F	4.5 m

Note. – Wheelbase means the distance from the nose gear to the geometric centre of the main gear.

3.4.7 Where severe weather conditions and resultant lowering of surface friction characteristics prevail, a larger wheel-to-edge clearance of 6 m should be provided where the code letter is E or F.

Slopes on runway turn pads

3.4.8 The longitudinal and transverse slopes on a runway turn pad should be sufficient to prevent the accumulation of water on the surface and facilitate rapid drainage of surface water. The slopes should be the same as those on the adjacent runway pavement surface.

Strength of runway turn pads

3.4.9 The strength of a runway turn pad should be at least equal to that of the adjoining runway which it serves, due consideration being given to the fact that the turn pad will be subjected to slow-moving traffic making hard turns and consequent higher stresses on the pavement.

Note.— Where a runway turn pad is provided with flexible pavement, the surface would need to be capable of withstanding the horizontal shear forces exerted by the main landing gear tires during turning manoeuvres.

Surface of runway turn pads

3.4.10 The surface of a runway turn pad shall not have surface irregularities that may cause damage to an aeroplane using the turn pad.

3.4.11 The surface of a runway turn pad should be so constructed as to provide good friction characteristics for aeroplanes using the facility when the surface is wet.

Shoulders for runway turn pads

3.4.12 The runway turn pads should be provided with shoulders of such width as is necessary to prevent surface erosion by the jet blast of the most demanding aeroplane for which the turn pad is intended, and any possible foreign object damage to the aeroplane engines.

Note.— As a minimum, the width of the shoulders would need to cover the outer engine of the most demanding aeroplane and thus may be wider than the associated runway shoulders.

3.4.13 The strength of runway turn pad shoulders should be capable of withstanding the occasional passage of the aeroplane it is designed to serve without inducing structural damage to the aeroplane and to the supporting ground vehicles that may operate on the shoulder.

3.5 Runway strips

3.5.1 A runway and any associated stop-ways shall be included in a strip.

Length of runway strips

3.5.2 A strip shall extend before the threshold and beyond the end of the runway or stop-way for a distance of at least:

- 60 m where the code number is 2, 3 or 4;
- 60 m where the code number is 1 and the runway is an instrument one; and
- 30 m where the code number is 1 and the runway is a non-instrument one.

Width of runway strips

3.5.3 A strip including a precision approach runway shall extend laterally to a distance of at least:

— 150 m where the code number is 3 or 4; and
— 75 m where the code number is 1 or 2;

on each side of the centre line of the runway and its extended centre line throughout the length of the strip.

3.5.4 A strip including a non-precision approach runway shall extend laterally to a distance of at least:

— 150 m where the code number is 3 or 4; and
— 75 m where the code number is 1 or 2;

on each side of the centre line of the runway and its extended centre line throughout the length of the strip.

3.5.5 A strip including a non-instrument runway shall extend on each side of the centre line of the runway and its extended centre line throughout the length of the strip, to a distance of at least:

— 75 m where the code number is 3 or 4;
— 40 m where the code number is 2; and
— 30 m where the code number is 1.

Objects on runway strips

Note — See paragraph 9.10 of this Manual for information regarding siting and construction of equipment and installations on runway strips.

3.5.6 An object situated on a runway strip, which may endanger aeroplanes shall be regarded as an obstacle and shall be removed.

3.5.7 No fixed object, other than visual aids required for air navigation purposes and satisfying the relevant frangibility requirement in Para 9.10 of this Manual, shall be permitted on a runway strip:

a) within 77.5 m of the runway centre line of a precision approach runway category I or II where the code number is 4 and the code letter is F; or

b) within 60 m of the runway centre line of a precision approach runway category I or II where the code number is 3 or 4; or

c) within 45 m of the runway centre line of a precision approach runway category I where the code number is 1 or 2.

No mobile object shall be permitted on this part of the runway strip during the use of the runway for landing or take-off.

Grading of runway strips

3.5.8 That portion of a strip of an instrument runway within a distance of at least:

— 75 m where the code number is 3 or 4; and
— 40 m where the code number is 1 or 2;

from the centre line of the runway and its extended centre line shall provide a graded area for aeroplanes, which the runway is intended to serve in the event of an aeroplane running off the runway.

Note — Guidance on grading of a greater area of a strip including a precision approach runway where the code number is 3 or 4 is given in Attachment B, Section 8.

3.5.9 That portion of a strip of a non-instrument runway within a distance of at least:

— 75 m where the code number is 3 or 4;
— 40 m where the code number is 2; and
— 30 m where the code number is 1;

from the centre line of the runway and its extended centre line shall provide a graded area for aeroplanes, which the run-way is intended to serve in the event of an aeroplane running off the runway.

3.5.10 The surface of that portion of a strip that abuts a runway, shoulder or Stop-way shall be flush with the surface of the runway, shoulder or Stop-way.

3.5.11 That portion of a strip to at least 30 m before a threshold shall be prepared against blast erosion in order to protect a landing aeroplane from the danger of an exposed edge.

Slopes on runway strips

3.5.12 **Longitudinal slopes**

A longitudinal slope along that portion of a strip to be graded shall not exceed:

— 1.5 per cent where the code number is 4;
— 1.75 per cent where the code number is 3; and
— 2 per cent where the code number is 1 or 2.

3.5.13 **Longitudinal slope changes**

Slope changes on that portion of a strip to be graded shall be as gradual as practicable and abrupt changes or sudden reversals of slopes avoided.

3.5.14 **Transverse slopes**

Transverse slopes on that portion of a strip to be graded shall be adequate to prevent the accumulation of water on the surface but should not exceed:

— 2.5 per cent where the code number is 3 or 4; and
— 3 per cent where the code number is 1 or 2;

except that to facilitate drainage the slope for the first 3 m outward from the runway, shoulder or stop-way edge shall be negative as measured in the direction away from the runway and may be as great as 5 per cent.

3.5.15 The transverse slopes of any portion of a strip beyond that to be graded shall not exceed an upward slope of 5 per cent as measured in the direction away from the runway.

Strength of runway strips

3.5.16 That portion of a strip of an instrument runway within a distance of at least:

— 75 m where the code number is 3 or 4; and

— 40 m where the code number is 1 or 2

from the centre line of the runway and its extended centre line shall be so prepared or constructed as to minimize hazards arising from differences in load bearing capacity to aeroplanes, which the runway is intended to serve in the event of an aeroplane running off the runway.

Note — Guidance on preparation of runway strips is given in the ICAO Aerodrome Design Manual (Doc 9157), Part 1.

3.5.17 That portion of a strip containing a non-instrument runway within a distance of at least:

— 75 m where the code number is 3 or 4;

— 40 m where the code number is 2; and

— 30 m where the code number is 1;

from the centre line of the runway and its extended centre line shall be so prepared or constructed as to minimize hazards arising from differences in load bearing capacity to aeroplanes, which the runway is intended to serve in the event of an aeroplane running off the runway.

3.6 Runway end safety areas

General

3.6.1 A runway end safety area shall be provided at each end of a runway strip where:

— the code number is 3 or 4; and

— the code number is 1 or 2 and the runway is an instrument one.

Note — Guidance on runway end safety areas is given in Attachment B, Section 9.

Dimensions of runway end safety areas

3.6.2 A runway end safety area shall extend from the end of a runway strip to a distance of at least 90 m.

3.6.3 A runway end safety area should, as far as practicable, extend from the end of a runway strip to a distance of at least:

— 240 m where the code number is 3 or 4; and

— 120 m where the code number is 1 or 2.

3.6.4 The width of a runway end safety area shall be at least twice that of the associated runway.

3.6.5 The width of a runway end safety area should, wherever practicable, be equal to that of the graded portion of the associated runway strip.

Objects on runway end safety areas

Note — See paragraph 9.10 of this Manual for information regarding siting and construction of equipment and installations on runway end safety areas.

3.6.6 An object situated on a runway end safety area, which may endanger aeroplanes shall be regarded as an obstacle and shall be removed.

Clearing and grading of runway end safety areas

3.6.7 A runway end safety area shall provide a cleared and graded area for aeroplanes which the runway is intended to serve in the event of an aeroplane undershooting or overrunning the runway.

Note: — The surface of the ground in the runway end safety area does not need to be prepared to the same quality as the runway strip. See, paragraph 3.6.11 of this Manual.

Slopes on runway end safety areas

3.6.8 General

The slopes of a runway end safety area shall be such that no part of the runway end safety area penetrates the approach or take-off climb surface.

3.6.9 Longitudinal slopes

The longitudinal slopes of a runway end safety area shall not exceed a downward slope of 5 per cent. Longitudinal slope changes shall be as gradual as practicable and abrupt changes or sudden reversals of slopes avoided.

3.6.10 Transverse slopes

The transverse slopes of a runway end safety area shall not exceed an upward or downward slope of 5 per cent. Transitions between differing slopes should be as gradual as practicable.

Strength of runway end safety areas

3.6.11 A runway end safety area shall be so prepared or constructed as to reduce the risk of damage to an aeroplane undershooting or overrunning the runway, enhance aeroplane deceleration and facilitate the movement of rescue and fire fighting vehicles as required in paragraphs 9.3.26 to 9.3.28 of this Manual.

Note — Guidance on strength of a runway end safety area is given in the ICAO Aerodrome Design Manual (Doc 9157), Part 1.

3.7 Clearways

Note — The inclusion of detailed specifications for clearways in this section is not intended to imply that a clearway has to be provided. Attachment B, Section 2 provides information on the use of clearways.

Location of clearways

3.7.1 The origin of a clearway shall be at the end of the take-off run available.

Length of clearways

3.7.2 The length of a clearway shall not exceed half the length of the take-off run available.

Width of clearways

3.7.3 A clearway should extend laterally to a distance of at least 75 m on each side of the extended centre line of the runway.

Slopes on clearways

3.7.4 The ground in a clearway shall not project above a plane having an upward slope of 1.25 per cent, the lower limit of this plane being a horizontal line which:

a) is perpendicular to the vertical plane containing the runway centre line; and

b) passes through a point located on the runway centre line at the end of the take-off run available.

Note — Because of transverse or longitudinal slopes on a runway, shoulder or strip, in certain cases the lower limit of the clearway plane specified above may be below the corresponding elevation of the runway, shoulder or strip. It is not intended that these surfaces be graded to conform with the lower limit of the clearway plane nor is it intended that terrain or objects which are above the clearway plane beyond the end of the strip but below the level of the strip be removed unless it is considered they may endanger aeroplanes.

3.7.5 Abrupt upward changes in slope shall be avoided when the slope on the ground in a clearway is relatively small or when the mean slope is upward. In such situations, in that portion of the clearway within a distance of 22.5 m or half the runway width whichever is greater on each side of the extended centre line, the slopes, slope changes and the transition from runway to clearway shall conform with those of the runway with which the clearway is associated.

Objects on clearways

Note — See paragraph 9.10 of this Manual for information regarding siting and construction of equipment and installations on clearways.

3.7.6 An object situated on a clear-way, which may endanger aeroplanes in the air shall be regarded as an obstacle and shall be removed.

3.8 Stop-ways

Note — The inclusion of detailed specifications for stop-ways in this section is not intended to imply that a stop-way has to be provided. Attachment B, Section 2 provides information on the use of stop-ways.

Width of stop-ways

3.8.1 A stop-way shall have the same width as the runway with which it is associated.

Slopes on stop-ways

3.8.2 Slopes and changes in slope on a stop-way, and the transition from a runway to a stop-way, shall comply with the specifications of paragraphs 3.2.1.13 to 3.2.1.19 of this Manual for the runway with which the stop-way is associated except that:

a) the limitation in paragraph 3.2.1.14 of this Manual of a 0.8 per cent slope for the first and last quarter of the length of a runway need not be applied to the stop-way; and

b) at the junction of the stop-way and runway and along the stop-way the maximum rate of slope change may be 0.3per cent per 30 m (minimum radius of curvature of 10 000 m) for a runway where the code number is 3 or 4.

Strength of stop-ways

3.8.3 A stop-way shall be prepared or constructed so as to be capable, in the event of an abandoned take-off, of supporting the aeroplane which the stop-way is intended to serve without inducing structural damage to the aeroplane.

Note —Attachment B, Section 2 presents guidance relative to the support capability of a stop-way.

Surface of stop-ways

3.8.4 The surface of a paved stop-way shall be so constructed as to provide a good coefficient of friction to be compatible with that of the associated runway when the stop-way is wet.

3.8.5 The friction characteristics of an unpaved stop-way shall not be substantially less than that of the runway with which the stop-way is associated.

3.9 Radio altimeter operating area

General

3.9.1 A radio altimeter operating area should be established in the pre-threshold area of a precision approach runway.

Length of the area

3.9.2 A radio altimeter operating area should extend before the threshold for a distance of at least 300 m.

Width of the area

3.9.3 A radio altimeter operating area should extend laterally, on each side of the extended centre line of the runway, to a distance of 60 m, except that, when special circumstances so warrant, the distance may be reduced to no less than 30 m if an aeronautical study indicates that such reduction would not affect the safety of operations of aircraft.

Longitudinal slope changes

3.9.4 On a radio altimeter operating area, slope changes should be avoided or kept to a minimum. Where slope changes cannot be avoided, the slope changes should be as gradual as practicable and abrupt changes or sudden reversals of slopes avoided. The rate of change between two consecutive slopes should not exceed 2per cent per 30 m.

Note — Guidance on radio altimeter operating area is given in Attachment B, Section 4.3 and in the ICAO Manual of All-Weather Operations, (Doc 9365), Section 5.2. Guidance on the use of radio altimeter is given in the PANS-OPS, Volume II, Part II, Section I.

3.10 Taxiways

Note: Unless otherwise indicated the requirements in this section are applicable to all types of taxiways.

General

3.10.1 Taxiways shall be provided to permit the safe and expeditious surface movement of aircraft.

Note — Guidance on layout of taxiways is given in the ICAO Aerodrome Design Manual, Part 2.

3.10.2 Sufficient entrance and exit taxiways for a runway should be provided to expedite the movement of aeroplanes to and from the runway and provision of rapid exit taxiways considered when traffic volumes are high.

3.10.3 The design of a taxiway should be such that, when the cockpit of the aeroplane for which the taxiway is intended remains over the taxiway centre line markings, the clearance distance between the outer main wheel of the aeroplane and the edge of the taxiway should be not less than that given by the following tabulation:

Code letter	**Clearance**
A	1.5 m
B	2.25 m
C	3 m if the taxiway is intended to be used by aeroplanes with a wheel base less than 18 m;
D	4.5 m
E	4.5 m
F	4.5 m

Note 1 — Wheel base means the distance from the nose gear to the geometric centre of the main gear.

Note 2 — Where the code letter is F and the traffic density is high, a wheel-to-edge clearance greater than 4.5 m may be provided to permit higher taxiing speeds.

3.10.4 As of 20 November 2008, the design of a taxiway shall be such that, when the cockpit of the aeroplane for which the taxiway is intended remains over the taxiway centre line markings, the clearance distance between the outer main wheel of the aeroplane and the edge of the taxiway shall be not less than that given by the following tabulation:

Code letter	*Clearance*
A	1.5 m
B	2.25 m
C	3 m if the taxiway is intended to be used by aeroplanes with a wheel base less than 18 m; 4.5 m if the taxiway is intended to be used by aeroplanes with a wheel base equal to or greater than 18 m.
D	4.5 m
E	4.5 m
F	4.5 m

Note 1.— Wheel base means the distance from the nose gear to the geometric centre of the main gear.

Note 2.— Where the code letter is F and the traffic density is high, a wheel-to-edge clearance greater than 4.5 m may be provided to permit higher taxiing speeds.

Note 3.— This provision applies to taxiways first put into service on or after 20 November 2008.

Width of taxiways

3.10.5 A straight portion of a taxi-way shall have a width of not less than that given by the following tabulation:

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

Note — Guidance on width of taxiways is given in the ICAO Aerodrome Design Manual (DOC 9157), Part 2.

Taxiway curves

3.10.6 Changes in direction of taxiways should be as few and small as possible. The radii of the curves should be compatible with the manoeuvring capability and normal taxiing speeds of the aeroplanes for which the taxiway is intended. The design of the curve should be such that, when the cockpit of the aeroplane remains over the taxiway centre line markings, the clearance distance between the outer main wheels of the aeroplane and the edge of the taxiway should not be less than those specified in 3.10.3.of this Manual.

Note 1 — An example of widening taxiways to achieve the wheel clearance specified is illustrated in Figure 3-2. Guidance on the values of suitable dimensions is given in the ICAO Aerodrome Design Manual, Part 2.

Note 2 — The location of taxiway centre line markings and lights is specified in paragraphs 5.2.2.8.4 and 5.2.3.15.10 of this Manual.

Note 3 — Compound curves may reduce or eliminate the need for extra taxiway width.

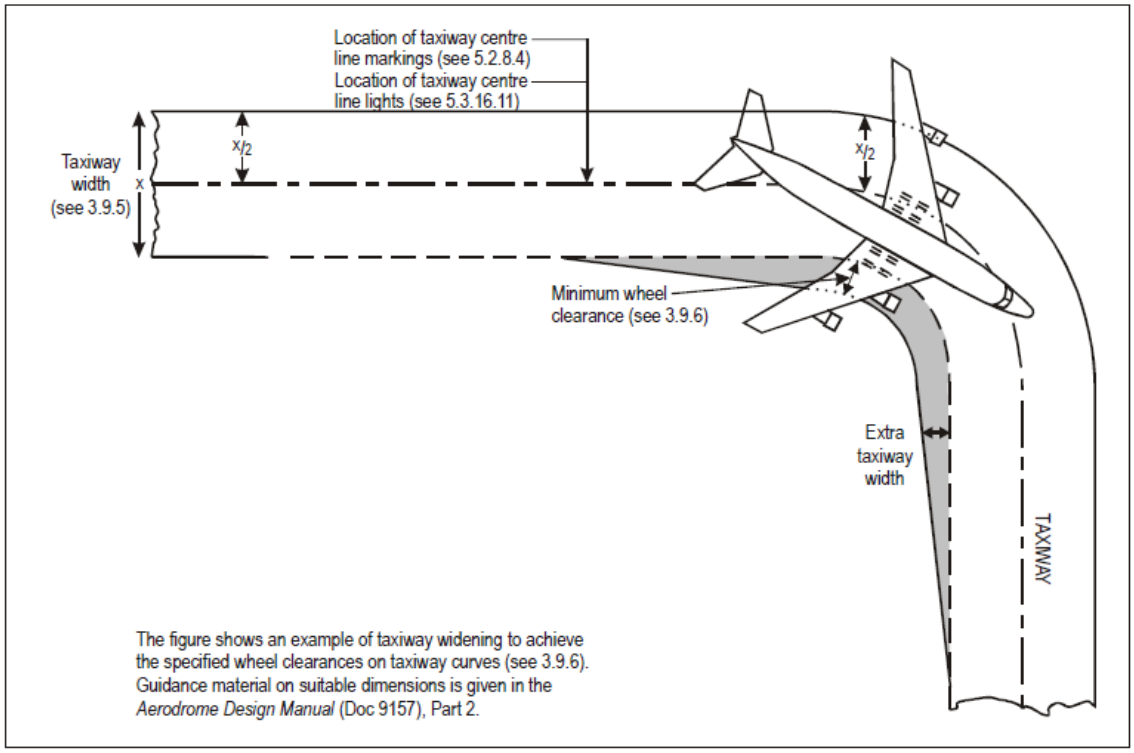

Figure 3-2. Taxiway curve

Junctions and intersections

3.10.7 To facilitate the movement of aeroplanes, fillets should be provided at junctions and intersections of taxiways with runways, aprons and other taxiways.

The design of the fillets should ensure that the minimum wheel clearances specified in 3.10.3 of this Manual are maintained when aeroplanes are manoeuvring through the junctions or intersections.

Note — Consideration will have to be given to the aeroplane datum length when designing fillets. Guidance on the design of fillets and the definition of the term aeroplane datum length are given in the ICAO Aerodrome Design Manual, Part 2.

Taxiway minimum separation distances

3.10.8The separation distance between the centre line of a taxiway and the centre line of a runway, the centre line of a parallel taxiway or an object shall not be less than the appropriate dimension specified in Table 3-1 of this chapter, except that it may be permissible to operate with lower separation distances at an existing aerodrome if an aeronautical study indicates that such lower separation distances would not adversely affect the safety or significantly affect the regularity of operations of aeroplanes.

Note 1 — Guidance on factors, which may be considered in the aeronautical study, is given in the ICAO Aerodrome Design Manual (DOC 9157), Part 2.

Note 2 — ILS and MLS installations may also influence the location of taxiways due to interferences to ILS and MLS signals by a taxiing or stopped aircraft. Information on critical and sensitive areas surrounding ILS and MLS installations is contained in ICAO Annex 10, Volume I, Attachments C and G (respectively).

Note 3 — The separation distances of Table 3-1, column 10, do not necessarily provide the capability of making a normal turn from one taxiway to another parallel taxiway. Guidance for this condition is given in the ICAO Aerodrome Design Manual (DOC 9157), Part 2.

Note 4 — The separation distance between the centre line of an aircraft stand taxi lane and an object shown in Table 3-1, column 12, may need to be increased when jet exhaust wake velocity may cause hazardous conditions for ground servicing.

Table 3-1 – Taxiway minimum separation distances

Code letter	Distance between taxiway centreline and runway centre line (metres)								Taxiway centre line to taxiway centre line (metres)	Taxiway other than aircraft stand taxilane centre line to object (metres)	Aircraft stand taxilane centre line to object (metres)
	Instrument runways Code number				Non-instrument runways Code number						
	1	2	3	4	1	2	3	4			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
A	82.5	82.5	-	-	37.5	47.5	-	-	23.75	16.25	12
B	87	87	-	-	42	52	-	-	33.5	21.5	16.5
C	-	-	168	-	-	-	93	-	44	26	24.5
D	-	-	176	176	-	-	101	101	66.5	40.5	36
E	-	-	-	182.5	-	-	-	107.5	80	47.5	42.5
F	-	-	-	190	-	-	-	115	97.5	57.5	50.5
Note 1 – The separation distances shown in columns (2) to (9) represent ordinary combinations of runways and taxiways. The basis for development of these distances is given in the ICAO Aerodrome Design Manual (DOC 9157), Part2.											
Note 2 – The distances in columns (2) to (9) do not guarantee sufficient clearance behind a holding aeroplane to permit the passing of another aeroplane on a parallel taxiway. See ICAO Aerodrome Design Manual (DOC 9157, Part 2.											

Slopes on taxiways

3.10.9 Longitudinal slopes

The longitudinal slope of a taxiway shall not exceed:

— 1.5 per cent where the code letter is C, D, E or F; and

— 3 per cent where the code letter is A or B.

3.10.10 Longitudinal slope changes

Where slope changes on a taxiway cannot be avoided, the transition from one slope to another slope shall be accomplished by a curved surface with a rate of change not exceeding:

— 1 per cent per 30 m (minimum radius of curvature of 3 000 m) where the code letter is C, D, E or F; and

— 1 per cent per 25 m (minimum radius of curvature of 2 500 m) where the code letter is A or B.

3.10.11 Sight distance

Where a change in slope on a taxiway cannot be avoided, the change shall be such that, from any point:

a) 3 m above the taxiway, it will be possible to see the whole surface of the taxiway for a distance of at least 300 m from that point, where the code letter is C, D, E or F;

b) 2 m above the taxiway, it will be possible to see the whole surface of the taxiway for a distance of at least 200 m from that point, where the code letter is B; and

c) 1.5 m above the taxiway, it will be possible to see the whole surface of the taxiway for a distance of at least 150 m from that point, where the code

d) letter is A.

3.10.12 Transverse slopes

The transverse slopes of a taxiway shall be sufficient to prevent the accumulation of water on the surface of the taxiway but should not exceed:

— 1.5 per cent where the code letter is C, D, E or F; and

— 2 per cent where the code letter is A or B.

Note — See paragraph 3.2.13.4 of this Manual regarding transverse slopes on an aircraft stand taxi lane.

Strength of taxiways

3.10.13 The strength of a taxiway shall be at least equal to that of the runway it serves, due consideration being given to the fact that a taxiway will be subjected to a greater density of traffic and, as a result of slow moving and stationary aeroplanes, to higher stresses than the runway it serves.

Note — Guidance on the relation of the strength of taxiways to the strength of runways is given in the ICAO Aerodrome Design Manual (DOC 9157, Part 3.

Surface of taxiways

3.10.14 The surface of a taxiway should not have irregularities that cause damage to aeroplane structures.

3.10.15 The surface of a paved taxiway should be so constructed as to provide good friction characteristics when the taxiway is wet.

Rapid exit taxiways

Note — The following specifications detail requirements particular to rapid exit taxiways. See Figure 3-3. General requirements for taxiways also apply to this type of taxiway. Guidance on the provision, location and design of rapid exit taxiways is included in the ICAO Aerodrome Design Manual (DOC 9157, Part 2.

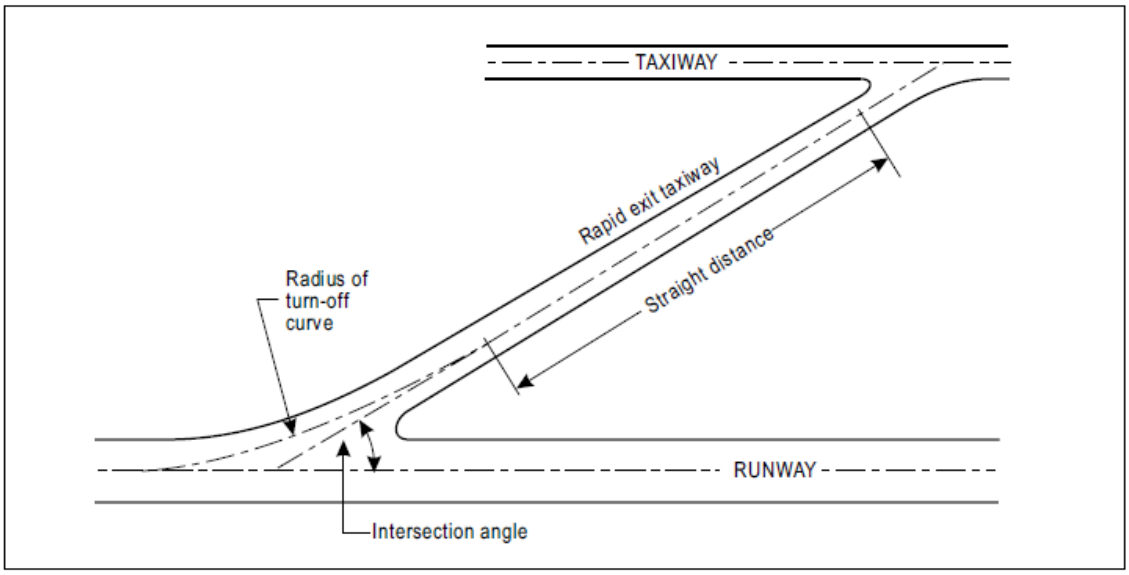

Figure 3-3. Rapid exit taxiway

3.10.16 A rapid exit taxiway shall be designed with a radius of turn-off curve of at least:

— 550 m where the code number is 3 or 4; and

— 275 m where the code number is 1 or 2;

to enable exit speeds under wet conditions of:

— 93 km/h where the code number is 3 or 4; and

— 65 km/h where the code number is 1 or 2.

Note — The locations of rapid exit taxiways along a runway are based on several criteria described in the ICAO Aerodrome Design Manual (DOC 9157, Part 2, in addition to different speed criteria.

3.10.17 The radius of the fillet on the inside of the curve at a rapid exit taxiway should be sufficient to provide a widened taxiway throat in order to facilitate early recognition of the entrance and turn-off onto the taxiway.

3.10.18 A rapid exit taxiway should include a straight distance after the turn-off curve sufficient for an exiting aircraft to come to a full stop clear of any intersecting taxiway.

3.10.19 The intersection angle of a rapid exit taxiway with the runway should not be greater than 45° nor less than 25° and preferably should be 30°.

Taxiways on bridges

3.10.20 The width of that portion of a taxiway bridge capable of supporting aeroplanes, as measured perpendicularly to the taxiway centre line, shall not be less than the width of the graded area of the strip provided for that taxiway, unless a proven method of lateral restraint is provided which shall not be hazardous for aeroplanes for which the taxiway is intended.

3.10.21 Access shall be provided to allow rescue and fire fighting vehicles to intervene in both directions within the specified response time to the largest aeroplane for which the taxiway bridge is intended.

Note — If aeroplane engines overhang the bridge structure, protection of adjacent areas below the bridge from engine blast may be required.

3.10.22 A bridge shall be constructed on a straight section of the taxiway with a straight section on both ends of the bridge to facilitate the alignment of aeroplanes approaching the bridge.

3.11 Taxiway shoulders

Note — Guidance on characteristics of taxiway shoulders and on shoulder treatment is given in the ICAO Aerodrome Design Manual (DOC 9157, Part 2.

3.11.1 Straight portions of a taxiway where the code letter is C, D, E or F should be provided with shoulders, which extend symmetrically on each side of the taxiway so that the overall width of the taxiway and its shoulders on straight portions is not less than:

— 60 m where the code letter is F;

— 44 m where the code letter is E;

— 38 m where the code letter is D; and

— 25 m where the code letter is C.

On taxiway curves and on junctions or intersections where increased pavement is provided, the shoulder width should be not less than that on the adjacent straight portions of the taxiway.

3.11.2 When a taxiway is intended to be used by turbine-engine aeroplanes, the surface of the taxiway shoulder shall be so prepared as to resist erosion and the ingestion of the surface material by aeroplane engines.

3.12 Taxiway strips

Note — Guidance on characteristics of taxiway strips is given in the ICAO Aerodrome Design Manual (DOC 9157), Part 2.

General

3.12.1 A taxiway, other than an aircraft stand taxi lane, shall be included in a strip.

Width of taxiway strips

3.12.2 A taxiway strip shall extend symmetrically on each side of the centre line of the taxiway throughout the length of the taxiway to at least the distance from the centre line given in Table 3-1, column 11 of this Manual.

Objects on taxiway strips

Note — See paragraph 9.10 of this Manual for information regarding siting and construction of equipment and installations on taxiway strips.

3.12.3 The taxiway strip shall provide an area clear of objects, which may endanger taxiing aeroplanes.

Note — Consideration will have to be given to the location and design of drains on a taxiway strip to prevent damage to an aeroplane accidentally running off a taxiway. Suitably designed drain covers may be required.

Grading of taxiway strips

3.12.4 The centre portion of a taxiway strip shall provide a graded area to a distance from the centre line of the taxiway of at least:

— 11 m where the code letter is A;

— 12.5 m where the code letter is B or C;

— 19 m where the code letter is D;

— 22 m where the code letter is E; and

— 30 m where the code letter is F.

Slopes on taxiway strips

3.12.5 The surface of the strip shall be flush at the edge of the taxiway or shoulder, if provided, and the graded portion shall not have an upward transverse slope exceeding:

— 2.5 per cent for strips where the code letter is C, D, E or F; and

— 3 per cent for strips of taxiways where the code letter is A or B;

the upward slope being measured with reference to the transverse slope of the adjacent taxiway surface and not the horizontal. The downward transverse slope shall not exceed 5 per cent measured with reference to the horizontal.

3.12.6 The transverse slopes on any portion of a taxiway strip beyond that to be graded shall not exceed an upward or downward slope of 5 per cent as measured in the direction away from the taxiway.

3.13 Holding bays, runway-holding positions, intermediate holding positions and road holding positions

General

3.13.1 Holding bay(s) should be provided when the traffic density is medium or heavy.

3.13.2 A runway-holding position or positions shall be established:

a) on the taxiway, at the intersection of a taxiway and a runway; and

b) at an intersection of a runway with another runway when the former runway is part of a standard taxi-route.

3.13.3 A runway-holding position shall be established on a taxiway if the location or alignment of the taxiway is such that a taxiing aircraft or vehicle can infringe an obstacle limitation surface or interfere with the operation of radio navigation aids.

3.13.4 An intermediate holding position should be established on a taxiway at any point other than a runway-holding position where it is desirable to define a specific holding limit.

3.13.5 A road-holding position shall be established at an intersection of a road with a runway.

Location

3.13.6 The distance between a holding bay, runway-holding position established at a taxiway/runway intersection or road-holding position and the centre line of a runway shall be in accordance with Table 3-2 of this Manual of this chapter and, in the case of a precision approach runway, such that a holding aircraft or vehicle will not interfere with the operation of radio navigation aids.

Table 3-2 – Minimum distance from the runway centre line to a hold bay, runway-holding position or road-holding position

	Code number			
Type of runway	1	2	3	4
Non-instrument	30 m	40 m	75 m	75 m
Non-precision	40 m	40 m	75 m	75 m
Precision approach category I	60 m [b]	60 m [b]	90 m [a,b]	90 m [a,b,c]
Precision approach category II	-	-	90 m [a,b]	90 m [a,b,c]
Take-off runway	30 m	40 m	75 m	75 m

a. If a holding bay, runway-holding position or road-holding position is at a lower elevation compared to the threshold, the distance may be decreased 5 m for every metre the bay or holding position is lower than the threshold, contingent upon not infringing the inner transitional surface.

b. This distance may need to be increased to avoid interference with radio navigation aids, particularly the glide path and localizer facilities. Information on critical and sensitive areas of ILS and MLS is contained in ICAO Annex 10, Volume I, Attachments C and G to Part I, respectively (See also paragraph 3.12.6 of this Manual).

Note 1 — The distance of 90 m for code number 3 or 4 is based on an aircraft with a tail height of 20 m, a distance from the nose to the highest part of the tail of 52.7 m and a nose height of 10 m holding at an angle of 45_ or more with respect to the runway centre line, being clear of the obstacle free zone and not accountable for the calculation of OCA/H.

Note 2 — The distance of 60 m for code number 2 is based on an aircraft with a tail height of 8 m, a distance from the nose to the highest part of the tail of 24.6 m and a nose height of 5.2 m holding at an angle of 45° or more with respect to the runway centre line, being clear of the obstacle free zone.

c. Where the code letter is F, this distance should be 107.5 m.
Note — The distance of 107.5 m for code number 4 where the code letter is F is based on an aircraft with a tail height of 24 m, a distance from the nose to the highest part of the tail of 62.2 m and a nose height of 10 m holding at an angle of 45° or more with respect to the runway centre

line, being clear of the obstacle free zone.

3.13.7 At elevations greater than 700 m (2300 ft) the distance of 90 m specified in table 3.2 of this chapter for precision approach runway code 4 should be increased as follows:

a) up to an elevation of 2000 m (6 600 ft); 1 m for every 100 m (330 ft) in exceed of 700 m (2 300 ft);

b) elevation in excess of 2 000 m (6 600 ft) and up to 4 000 m (13 320 ft); 13 m plus 1.5 m for every 100 m (330 ft) in excess of 2 000 m (6 600 ft); and

c) elevation in excess of 4 000 m plus 2 m for every 100 m (330 ft) in excess of 4 000 m (16 650 ft); 43 m plus 2 m for every 100 m (330 ft) in excess of 4000 m (13 320 ft).

3.13.8 If a holding bay, runway-holding position or road-holding position for a precision approach runway code number 4 is at a greater elevation compared to the threshold, the distance of 90 m or 107.5 m, as appropriate, specified in Table 3-2 of this chapter should be further increased 5 m for every metre the bay or position is higher than the threshold.

3.13.9 The location of a runway-holding position established in accordance with paragraph 3.13.3 of this Manual shall be such that a holding aircraft or vehicle will not infringe the obstacle free zone, approach surface, take-off climb surface or ILS/MLS critical/ sensitive area or interfere with the operation of radio navigation aids.

3.14 Aprons

General

3.14.1 Aprons shall be provided where necessary to permit the on- and off loading of passengers, cargo or mail as well as the servicing of aircraft without interfering with the aerodrome traffic.

Size of aprons

3.14.2 The total apron area should be adequate to permit expeditious handling of the aerodrome traffic at its maximum anticipated density.

Strength of aprons

3.14.3 Each part of an apron shall be capable of withstanding the traffic of the aircraft it is intended to serve, due consideration being given to the fact that some portions of the apron will be subjected to a higher density of traffic and, as a result of slow moving or stationary aircraft, to higher stresses than a runway.

Slopes on aprons

3.14.4 Slopes on an apron, including those on an aircraft stand taxi lane, should be sufficient to prevent accumulation of water on the surface of the apron but should be kept as level as drainage requirements permit.

3.14.5 On an aircraft stand the maximum slope shall not exceed 1 per cent.

Clearance distances on aircraft stands

3.14.6 An aircraft stand shall provide the following minimum clearances between an aircraft using the stand and any adjacent building, aircraft on another stand and other objects:

Code letter	Clearance
A	3 m
B	3 m
C	4.5 m
D	7.5 m
E	7.5 m
F	7.5 m

When special circumstances so warrant, these clearances may be reduced at a nose-in aircraft stand, where the code letter is D, E or F:

a) between the terminal, including any fixed passenger bridge, and the nose of an aircraft; and

b) over any portion of the stand provided with azimuth guidance by a visual docking guidance system.

Note — On aprons, consideration also has to be given to the provision of service roads and to manoeuvring and storage area for ground equipment (See the ICAO Aerodrome Design Manual, Part 2, for guidance on storage of ground equipment).

3.15 Isolated aircraft parking position

3.15.1 An isolated aircraft parking position shall be designated or the aerodrome control tower shall be advised of an area or areas suitable for the parking of an aircraft which is known or believed to be the subject of unlawful interference, or which for other reasons needs isolation from normal aerodrome activities.

3.15.2 The isolated aircraft parking position should be located at the maximum distance practicable and in any case never less than 100 m from other parking positions, buildings or public areas, etc. Care should be taken to ensure that the position is not located over underground utilities such as gas and aviation fuel and, to the extent feasible, electrical or communication cables.

Page intentionally left blank