

# **BRAGANÇA REGIONAL AIRPORT MASTER PLAN EVALUATION**

## **Geometrical and Structural Characteristics**

**Mayela Cecilia González Lalyre**

Final Report submitted to the

**Escola Superior de Tecnologia e Gestão**

**Instituto Politécnico de Bragança**

To obtain the Master Degree of

**Construction Engineering**

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Advisor:

**Prof. Dr. Manuel Joaquim da Costa Minhoto**

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*“The impulse to travel is one of the hopeful symptoms of life. ” — Agnes Repplier*

*to my grandmother Maria Luisa.*



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Initially I would like to thank God, that gave me the opportunity to carry out this outstanding experience, where I grew professionally and personally. Always giving me the strength necessary and accompanying me along the way through the completion of this stage of my studies.

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# Abstract

Regional airports are important for the development of a European network of integrated air transport. The Bragança Regional Airport is not an exception to this statement and as it looks to increase its capacity and flexibility of aircraft operations the cost of developing the infrastructure becomes highly elevated hindering expansion projects. Regardless, an effort to enhance the actual service level is made where this document aims to provide an evaluation to the Airport Master Plan, focusing on the structural and geometrical characteristics of the airfield facilities. Further, to obtain lower grade improvements that will still promote its present situation with reduced costs.

To support the assessment a series of international aviation standards and airport design recommendations were reviewed, highlighting those of the Federal Aviation Administration (FAA) and the International Civil Aviation Organization (ICAO), to ensure the compliance of necessary requirements. A variety of airport design software was used to calculate adequate pavement thickness, also other parameters as the runway orientation which made possible to elaborate the proposed development alternatives.

Keywords:

Airport Master Plan

ICAO

FAA

Pavement thickness

Aircraft Classification Number

Pavement Classification Number

Wind Analysis

Runway orientation



# Resumo

Os aeroportos regionais são importantes para o desenvolvimento de uma rede europeia de transporte aéreo integrado. O Aeroporto Regional de Bragança não é exceção e a perspetiva de aumento da sua capacidade e flexibilidade, em termos de operação de aeronaves, implica um custo muito elevado no que diz respeito ao desenvolvimento e concretização de projetos de expansão da infraestrutura. Apesar disso, neste trabalho é realizado um esforço no sentido de melhorar o nível atual de serviço, tendo este trabalho como objetivo propor uma evolução do Plano Diretor do Aeroporto, com foco nas características estruturais e geométricas das instalações do lado ar do aeródromo. Pretende-se, acima de tudo, propor uma melhoria das atuais condições com custos o mais reduzidos possível.

Neste sentido, foi realizada uma avaliação baseada na pesquisa de uma série de normas internacionais de aviação e recomendações de projeto de aeroportos, destacando-se as da Federal Aviation Administration (FAA) e da Organização da Aviação Civil Internacional (ICAO), de forma a permitir a garantia do cumprimento dos requisitos necessários ao estudo. Neste contexto, foi usada uma variedade de software de projeto de aeroportos, em particular para o cálculo das espessuras do pavimento adequadas e também outros parâmetros, tais como a orientação da pista, o que tornou possível a elaboração das alternativas de desenvolvimento propostas.

Palavras-chave:

Plano Diretor de um Aeroporto

ICAO

FAA

Espessura do pavimento

Número de Classificação de Aeronaves

Número de classificação de pavimentos

Análise de ventos

Orientação da pista



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# Abbreviations

AAC	Aircraft Approach Category
AC	Advisory Circular
ADG	Airplane Design Group
AFIS	Aerodrome Flight Information Service
AIS	Aeronautical Information Services
AMSL	Above Mean Sea Level
APCH	Approach
ASPH	Asphalt
ASV	Annual Service Volume
CDF	Cumulative Damage Factor
CWY	Clearway
DGAC	Direcção Geral de Aeronáutica Civil / General Direction of Civil Aeronautics
FAA	Federal Aviation Administration
HMA	Hot mix asphalt
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
INAC	National Institute of Civil Aviation / Instituto Nacional de Aviação Civil
INE	Instituto Nacional de Estatística / National Institute of Statistics

ISA	International Standard Atmosphere
LDI	Landing Direction Indicator
MLW	Maximum Landing Weight
MTOW	Maximum Takeoff Weight
PAPI	Precision Approach Path Indicator
PCC	Portland cement concrete
RCL	Runway Centerline
RESA	Runway End Safety Area
RFF	Rescue and Firefighting Facilities
RTIL	Runway Threshold Identification Lights
RWY	Runway
SL	Sea Level
SWY	Stopway
TDZ	Touchdown Zone
THR	Threshold
VFR	Visual Flight Rules
WDI	Wind Direction Indicator

# 1. Introduction

Airports are constituted by a complex set of elements where the airfield infrastructure plays a vital role to conduct aircraft operations in complete safety and effectiveness. As its fundamental mission is to facilitate the landing, takeoff, taxiing and parking of aircraft is imperative to carry out preventive and corrective maintenance of this infrastructure.

As the Bragança Airport foresees in the future, operations of companies whose fleet is characterized by C-type aircraft with an average capacity of 150 passengers, it becomes necessary not only the expansion of the runway but also the improvement of the pavement infrastructure and its bearing capacity.

## 1.1. Background

The Airport of Bragança, with IATA code (*BGC*) and ICAO code (*LPBG*), was built between the years of 1965 and 1972 by the City Council of Bragança (Câmara Municipal de Bragança), accordingly the airport sponsor who owns it entirely. Since then, there has been carried out various actions aimed at expanding and improving the provided services and its capacity. From 1972 to 1975, the General Direction of Civil Aeronautics (DGAC) promoted the construction of a primary phase on the airfield. At the time this phase was completed, the airport had available a runway with 1200 m of length and a platform of 80 x 60 m as well as a taxiway linking directly the apron parking platform to the runway [CCoB08]. The image shown in **Figure 1.1** presents an aerial view from the east side of the aerodrome with the 1200 m runway.

In 1976 it was approved the first Master Plan of Bragança Regional Airport. Later in 1989, it was installed the night lighting allowing to operate at night, however this installation was not certified until many years later. Between the years of 1997 and 1998 it was carried out a reinforcement of the runway with a layer of 5 cm of bituminous concrete [CCoB08].

Then in 2000 the consulting firm GIBB Portugal elaborated the document “Review of the Development Master Plan”, which included the “Project for the Runway Expansion”.

In January of 2003, with the night lighting already installed over a decade ago, it was certified by the Portuguese Air Force and became operational for the night activities in



**Figure 1.1.:** Aerial view of Bragança Airport

(Source: [http://jsulm.no.sapo.pt/ulmphotos/aerodromo\\_braganca.jpg](http://jsulm.no.sapo.pt/ulmphotos/aerodromo_braganca.jpg))

visual flight conditions. In 2005, the length of the runway was increased by 500 meters, reaching a total length of 1700 meters paved. The runway was expanded to the South, moving the threshold of Runway 02 by a distance of 500 meters. Also paved shoulders of 7,5 meters were added on each side of the runway axis along the whole length. In summary, with all this actions, the airport was equipped with a 30 meters wide runway (15 m each side of the axis) and with 7,5 meters wide shoulders for a total width of 45 meters along the total length, the actual configuration [CCoB08].

Further in 2006, the City Council of Bragança issued a tender to comply with studies for the revision of the Master Plan for the Development of the Bragança Regional Airport. The contract was awarded later in 2007 to the company SENER, Ingeniería y Sistemas, S.A. The object of this new Master Plan was to delimitate the area of service, defining and ordering the different subsystems that integrate and structure the airport according to its interdependent functionality, seeking a harmonious balance and efficient overall airport activity and ensuring its development and future expansion.

The reference code of the current Airport is 3-C, according to the Annex 14 “Aerodromes” to the Convention on International Civil Aviation and consistently with the established for the aircraft to which the airport is intended.

## 1.2. Purpose and Scope of Study

The purpose of this study is to conduct an examination to the Bragança Regional Airport, according to the International Civil Aviation Organization (ICAO) and the Federal

Aviation Administration (FAA) standards and regulations, focusing at both geometric and structural level.

It is also to review and update data regarding climatic and meteorological conditions around the study area, contemplating a wind analysis to determine optimal runway orientation.

Furthermore the aim is to develop a rehabilitation and improvement proposal for the analyzed infrastructure. Pursuing to condense the original planned upgrades, seeking to reduce costs in the current project.

### **1.3. Methodology**

In order to achieve the objectives mentioned above, the proceedings started with a bibliographic research about the geometric and structural measures applicable to aerodrome and airport infrastructure that included the ICAO, FAA and other existing standards together with manuals and guidelines to airport engineering and design.

The data collection regarding the airport operations and facilities as well as the characteristics of the area of study was conducted through the analysis of existing reports and studies. Undertaking a revision and updating the information within possibility.

Following this research, it was carried out an examination of the applicability of these standards to evaluate the case of study and trials with software developed to calculate pavement thickness.

### **1.4. Structure of Content**

The completion of this study is structured into five chapters, which are briefly described next.

The *first chapter* consists of an introduction that presents the background of the subject matter, outlines the objectives and methodology of the study conducted and finally summarizes the contents of each chapter.

Next, the *second chapter* defines the study area and shows the climatic and meteorological conditions, topographic features and soil characteristics. Also includes an inventory and description of the existing facilities at the airport.

Continues the *third chapter* with an analysis of the airfield capacity, following the facility requirements based on the previous analysis executed.

Later the *fourth chapter* addresses the structural part of the study, illustrating the method developed for reporting pavement strength and exemplifying through different software applications the calculations of the thickness needed for the pavement design.

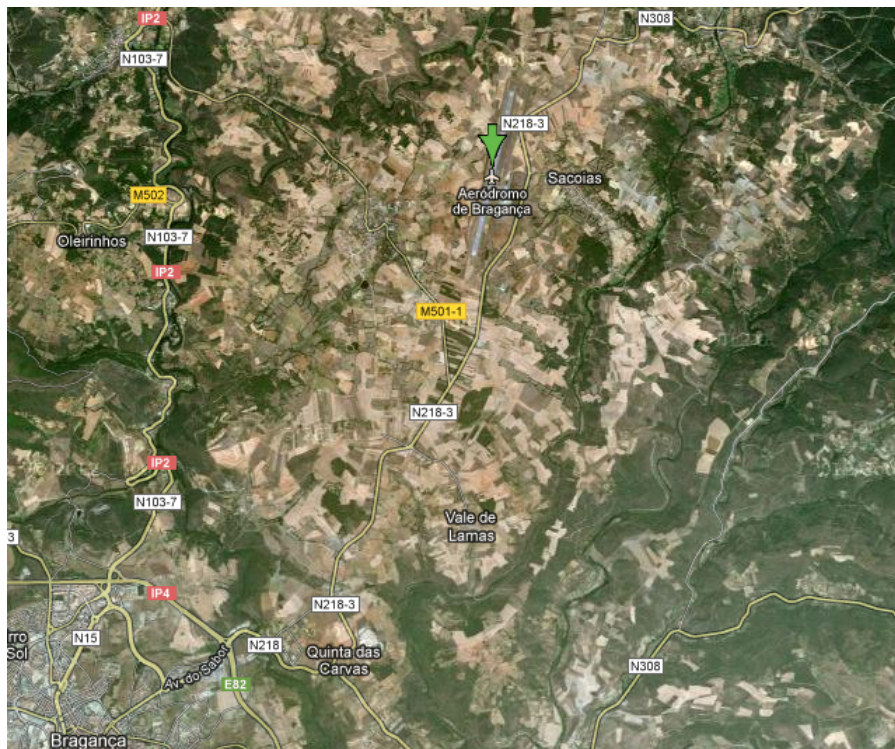
Subsequently the *fifth chapter* exposes the analysis of the wind rose study for determining the orientation of the runway and explains the results of the pavement design calculations obtained on the preceding chapter.

## 2. Existing Conditions

An essential part of the planning and assessment process is the development of a thorough inventory of existing conditions at the Bragança Airport and the area it serves. For this analysis the inventory incorporates information such as the weather conditions, topography and soils characteristics and an overview of airside and landside facilities.

### 2.1. Area of Study

Bragança Airport is situated in the Municipality of Bragança and therefore the district of the same name. The location of the airport can be seen in a satellite image in **Figure 2.1**.



**Figure 2.1.:** Location of the Airport of Bragança  
(Source: Google Maps® 2012)

The Bragança Municipality being part of Alto Tras-os-Montes Region, in the northeast end of Portugal, makes border with Spain. On the Portuguese side, is bounded by the

municipalities of Vinhais, Macedo de Cavaleiros and Vimioso and, on the Spanish side, by counties of Aliste and Sanabria, belonging to the province of Zamora. It lies 520 km from Lisbon, 252 km from Porto, 90 km from Zamora and 330 km from Madrid [CCoB08].

Furthermore is located approximately 10 km northeast of the city of Bragança, the district capital, and between the villages of Baçal and Sacoias. It has an elevation of 683 m upon the northeastern mountains. Its geographic coordinates, expressed in the reference system WGS84, are 41°51'18" N, 6°42'23" W, with a magnetic declination of 3°35'W and an annual variation of -9,0° .

## 2.2. Adjacent Land Use

Bragança Airport is placed in a land considered "Agro-Forest-Pastoral Space Type II" Adjoining the current limit of the airport land in its east side, is the village of Sacoias considered a "Urbanized Space Type III", same case as Baçal, located 1 km west of the runway center line.

At 540 m from the Runway 02, in the extension of the runway center line towards the south and 150 m west of the same extension, there is a field cataloged as "Urbanized Space Type IV." And at 600 m south of the Runway 02, in the extension of the runway center line, and 300 m east of the same extension, there is a land considered "Industrial Space"[CCoB08].

## 2.3. Socioeconomic Conditions

According to the National Institute of Statistics (INE) the Bragança District has a population of 136.252 inhabitants (2011). This represents a decrease of 8,3% compared to the previous census of 2001. Nevertheless the Bragança Municipality increased its population to a total of 35,341 inhabitants in an area of 1.173,5 km<sup>2</sup>, thereby resulting in a population density of 30,1 inh/km<sup>2</sup>.

Against this the working-age population rate of the municipality consists of 43,6%, with a correspondent employment-to-population ratio of 90,1%, that is mostly distributed by the tertiary sector, followed by a considerably lower proportion in the secondary and the fewest of the workforce dedicated to the primary sector. This distribution of population by sectors in the Municipality of Bragança is similar to the distribution by sector in the rest of the country [CCoB08].

### 2.4. Climatic and Meteorological Conditions

The average values that characterize the climate of a given region, depend on the time interval used and do not present the same results when comparing one year with a decade or a century. Moreover, it is important to have long series of data to study the climate variations and trends. According to the World Meteorological Organization it is called climatological normals to the meteorological statistical results in periods of 30 years. The information shown here is part of the results of the climatological normals 1981-2000, the latest available provisory results.

#### 2.4.1. Temperature

Due to its geographical position the climate in Bragança is identified as temperate continental climate, very cold in winter and very hot and dry during the summer. The mean annual temperature is 12,7°C. The temperature range in January goes from a mean minimum of 0,2°C to a mean maximum of 8,8°C. While in July, the hottest month, from a mean minimum of 14,2°C to a mean maximum of 29,2°C, being 21,7°C the month average. The full annual record of temperatures for the previously mentioned period is shown on the next page in **Table 2.1** and represented on a chart in **Figure 2.2**.

In accordance with these data, the airport reference temperature, defined as the monthly average of maximum temperatures corresponding to the hottest month of the year (July) is 29,2°C. However, more recent information sets a reference temperature of 29,7°C, which will be taken as the reference temperature for subsequent calculations.

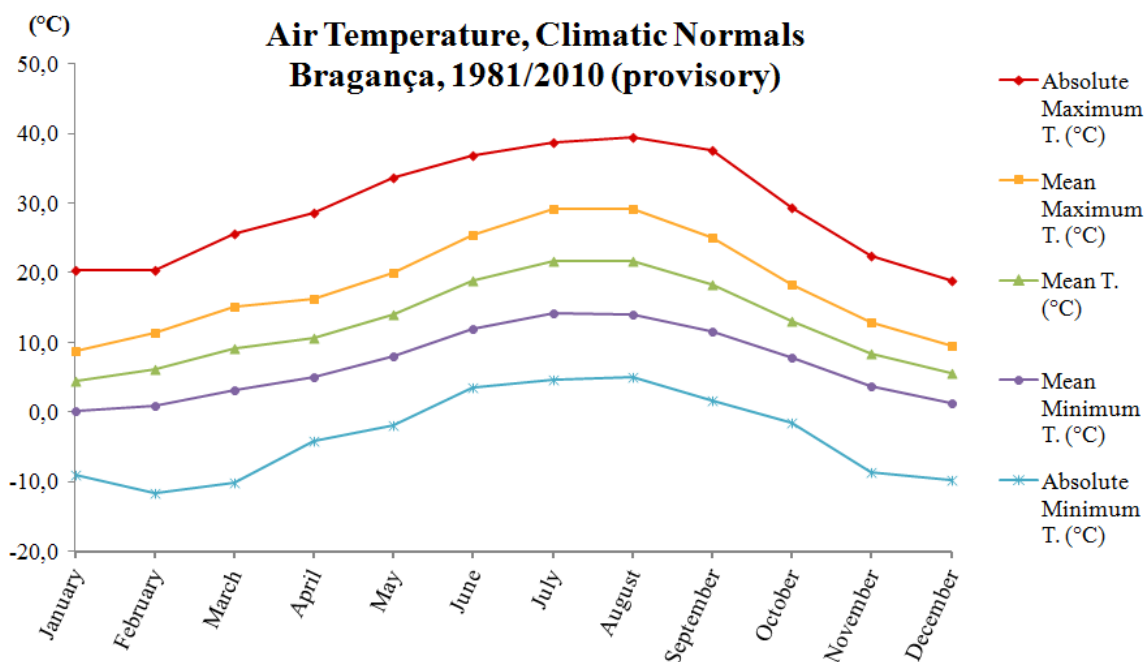
#### 2.4.2. Precipitation

The precipitation distributed throughout the year has the heaviest periods occurring from October to January, with an average annual precipitation of 772,8 mm. The precipitation data collected for a period of 30 years (1981-2010), are shown in **Table 2.2** and illustrated later in the **Figure 2.3**.

**Table 2.1.:** Temperature data registered from 1981 to 2010

Month	Absolute Maximum T. (°C)	Mean Maximum T. (°C)	Mean T. (°C)	Mean Minimum T. (°C)	Absolute Minimum T. (°C)
January	20,4	8,8	4,5	0,2	-9,0
February	20,4	11,4	6,2	0,9	-11,6
March	25,7	15,1	9,2	3,2	-10,2
April	28,6	16,3	10,7	5,1	-4,2
May	33,6	20,0	14,0	8,0	-2,0
June	36,9	25,5	18,8	12,0	3,6
July	38,8	29,2	21,7	14,2	4,6
August	39,5	29,1	21,6	14,0	5,0
September	37,7	25,1	18,4	11,6	1,7
October	29,3	18,4	13,1	7,9	-1,6
November	22,4	12,8	8,3	3,7	-8,6
December	18,8	9,5	5,5	1,3	-9,7
Annual	29,3	18,4	12,7	6,8	-3,5

(Source: Normais Climatológicas - Instituto de Meteorologia, I.P., [www.meteo.pt](http://www.meteo.pt))

**Figure 2.2.:** Air Temperature Distribution Chart

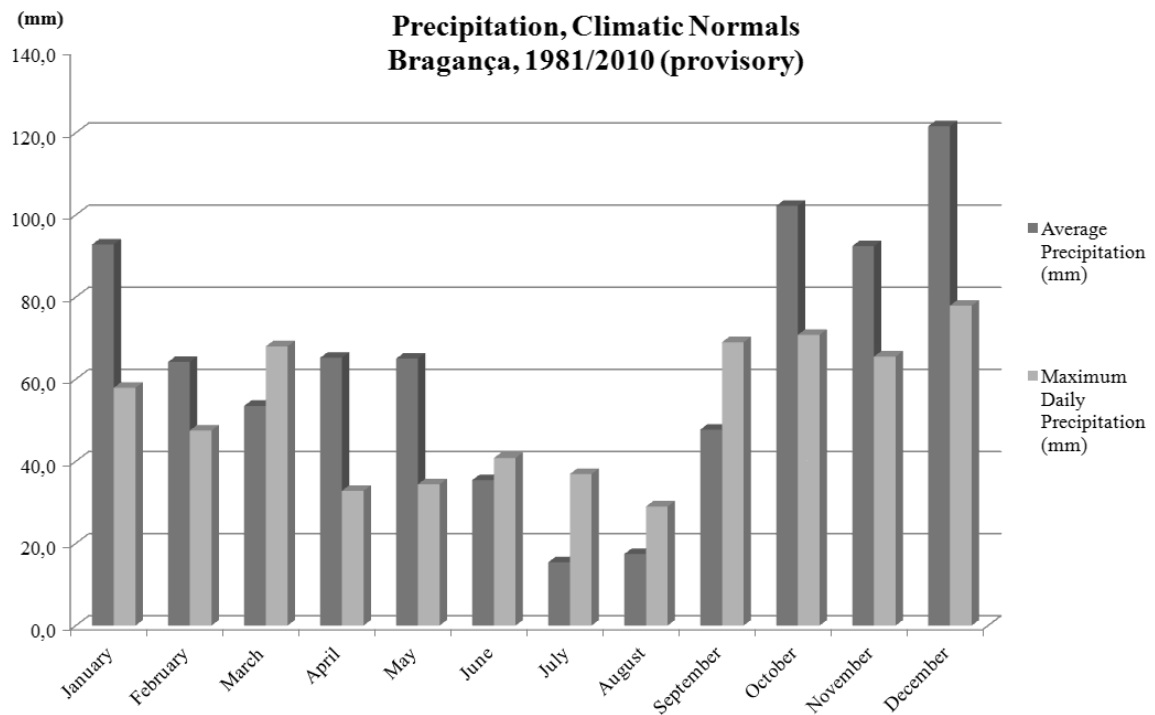
(Source: Normais Climatológicas - Instituto de Meteorologia, I.P., [www.meteo.pt](http://www.meteo.pt))

## 2.4 Climatic and Meteorological Conditions

**Table 2.2.:** Precipitation data registered from 1981 to 2010

Month	Average Precipitation (mm)	Maximum Daily Precipitation (mm)
January	92,8	57,9
February	64,2	47,5
March	53,5	68,0
April	65,2	32,8
May	65,0	34,4
June	35,4	40,8
July	15,4	36,9
August	17,4	29,0
September	47,7	69,0
October	102,2	70,8
November	92,4	65,5
December	121,6	77,9
<b>Annual</b>	<b>772,8</b>	
<b>Maximum</b>		<b>77,9</b>

(Source: Normais Climatológicas - Instituto de Meteorologia, I.P., [www.meteo.pt](http://www.meteo.pt))

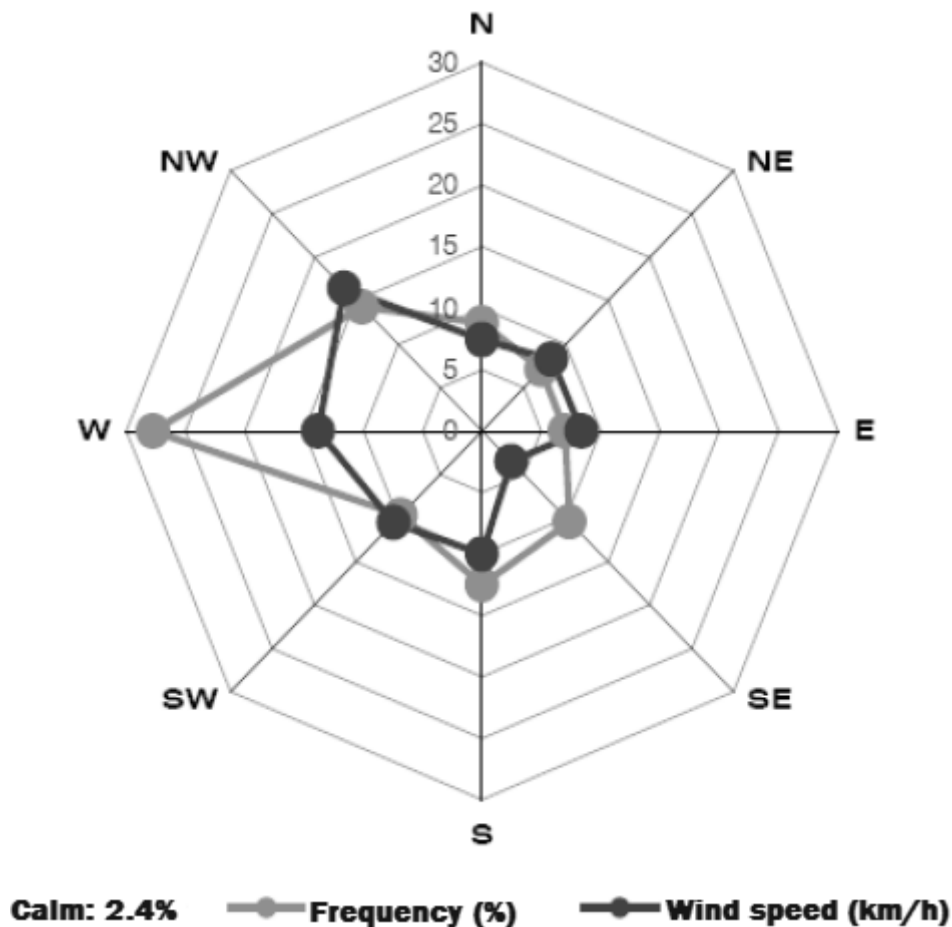


**Figure 2.3.:** Average Monthly Precipitations Distribution Chart from 1971 to 2000

(Source: Normais Climatológicas - Instituto de Meteorologia, I.P., [www.meteo.pt](http://www.meteo.pt))

### 2.4.3. Wind

In Bragança winds are predominantly blowing from the West. The average speed in any of the quadrants does not go over 20 km/h. Though occasionally, there are more intense winds associated with thunderstorms [TCG<sup>+</sup>10]. An outline of the recorded wind observations at the Meteorological Station of Bragança for the period of 1971-2000 is shown in **Figure 2.4**.



**Figure 2.4.:** Average wind scheme for 1971-2000 period.

(Source: *Manual de Boas Práticas em Espaços Verdes / Normais Climatológicas - Instituto de Meteorologia, I.P., www.meteo.pt*)

The orientation of an airport's runway system to the prevailing wind direction is critical to the safe operation of aircraft and the maximum utilization of the airport facilities. Crosswinds are winds perpendicular to the runway or path of an aircraft that tend to affect the flight of approaching aircraft. Generally, the lighter the aircraft, the more is affected by crosswinds. The FAA recommends 95% wind coverage on the basis of the crosswind not exceeding a particular speed for specified size of aircraft. The methodology for computing

## 2.5 Topography

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coverage is detailed in Advisory Circular 150/5300-13A, Airport Design. If a single runway alignment does not provide sufficient wind coverage, the construction of a crosswind runway may be warranted.

Further on the next chapter, to establish the runway orientation requirement, the paragraph **Runway Orientation**, presents a detailed study using more recent wind data from the Meteorological Station of the IPB.

## 2.5. Topography

The area has a landscape characterized by a rugged geomorphology, where the highest elevation reached by the Serra de Montesinho, climbs up to 1.486 m. On the surroundings we identify the mountains ranges of the Serra da Nogueira, that rises up to 1.320 meters above mean sea level, and extends over the Municipalities of Macedo de Cavaleiros, Bragança and Vinhais; the Serra de Bornes, with an elevation of 1.100 m on the Macedo de Cavaleiros Municipality; the Serra de Mogadouro, with 997 m of altitude within the Mogadouro Municipality; the Serra Coroa, with 1.273 m, on the Vinhais Municipality.

Within a 4 km radius around the airport, the maximum ground elevations are found in the north half. Among them stand out the hills of Cabeço da Cuca (743 m), Campina (746 m), Alto do Facho (784 m), Alto do Espinheiro (805 m) and Lamelas (796 m). In turn, within a wider radius of 7 km, the most prominent elevations are the hills of Coroto (1.121 m), Agra (957 m), Serro (931 m), Castro (897 m), Alto da Fonte Jungueira (919 m) and Lavradas (903 m) [CCoB08].

## 2.6. Soils

The runway is based on a thin plated material deposit of a sandy clay matrix conglomerate material (<5 m).

As for the rest of region, there is a deposit of materials from the Pliocene (1,8 million years), formed in conditions of semi-aridity. This geological formation is characterized by its constitution from conglomerate deposits with clasts of reduced erosion, predominantly quartz or quartz with some clay. The substrate upon which this deposit is based is part of the massif of Bragança, from the Precambrian (1 million years). It is formed by greatly altered muscovite mica. At the south end of the deposit appears an extension of thin amphibolites and serpentinites, oriented NW-SE, and also strongly altered [CCoB08].

## 2.7. Aircraft Fleet Mix

The current composition and main characteristics of the aircraft fleet at Bragança Airport are listed in **Table 2.3**. It is primarily distributed between small aircraft having gross weights of less than 2.000 kg for general aviation, and by aircraft for scheduled and seasonal operations. The information includes the FAA classifications Aircraft Approach Category (AAC) and Airplane Design Group (ADG).

**Table 2.3.:** Based Aircraft Characteristics, FAA Classification

Model	%	Max. Take-Off Weight (kg)	Approach Speed (knots)	Wingspan (m)	AAC	ADG
Dornier 228	30,8	13.900	101	16,97	B	II
ATR 42-300	7,7	16.700	103	24,57	B	III
Piper Seneca	15,4	1.905	79	11,86	A	I
Cessna 172	15,4	1.150	61	11,00	A	I
Morane Saulnier 893	30,8	1.050	65	9,75	A	I

100

(Source: Aircraft Specifications and Bragança Regional Airport Master Plan, City Council of Bragança)

## 2.8. Airside Facilities

Airside facilities accommodate aircraft operations and include runways, taxiways, aprons, navigational aids, and other features. An outline of the existing airside facilities is presented in the Aerodrome Chart shown in **Figure 2.5**.

The geometric and operational characteristics of this airport are according to the ones published by the Aeronautical Information Services (AIS), which depends on the National Institute of Civil Aviation of Portugal (INAC) [CCoB08].

### 2.8.1. Critical Aircraft

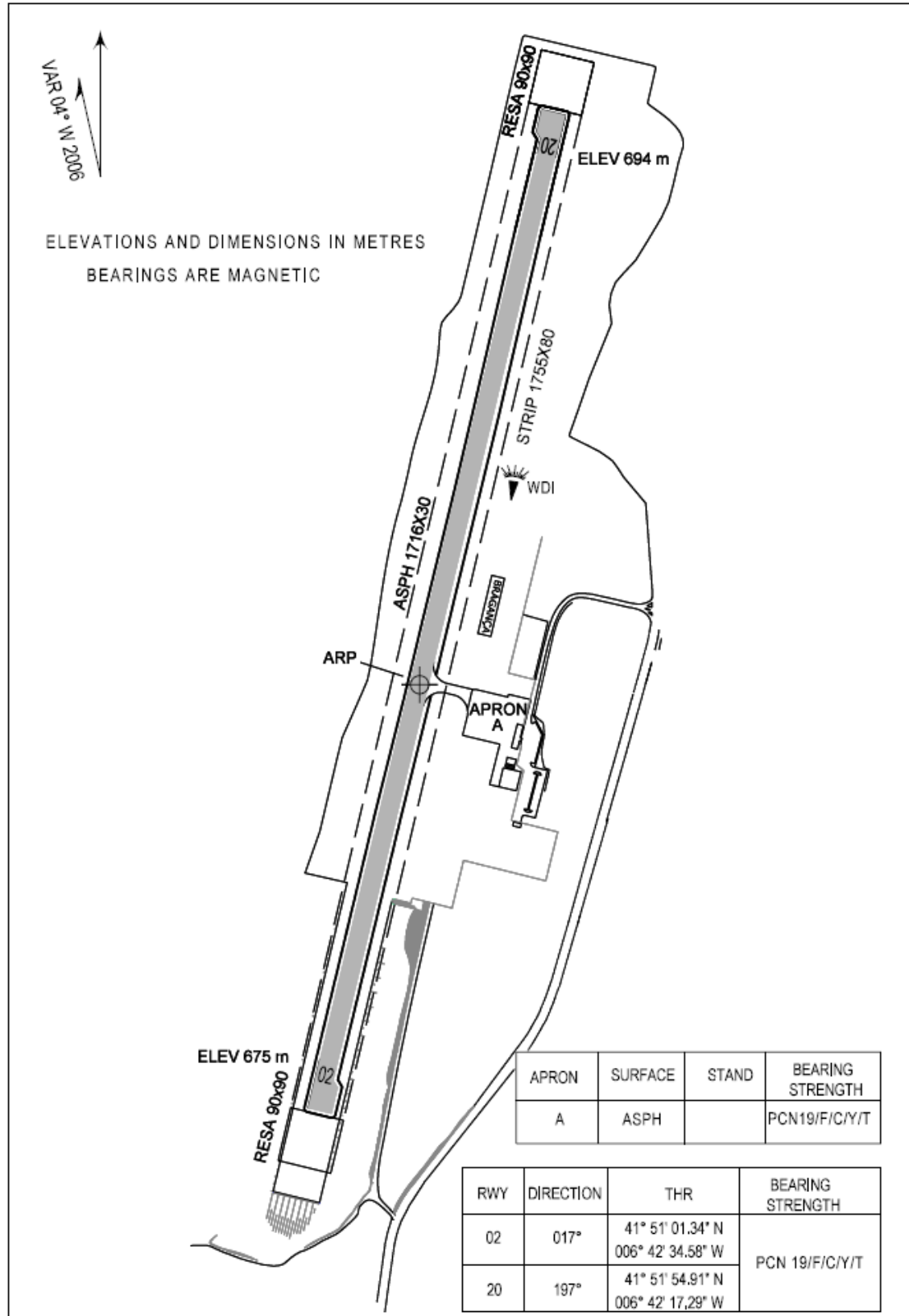
The selection of appropriate airport design criteria is based primarily upon the critical or design aircraft that will be utilizing the airport. The last revision of the Master Plan defined the Boeing 737-800 as the design aircraft; however a purpose of this study is to condense upgrades to reduce costs. Therefore it was selected a smaller airplane like the Bombardier CRJ 700 as the critical aircraft, that simultaneously lowered the runway requirements.

CARTA DE AERODROMO  
AERODROME CHART

AD ELEV 694m  
LAT 41°51'24"N  
LONG 006°42'27"W

BRAGANÇA / LPBG

AFIS 122.300 FIS 130.900



**Figure 2.5.:** Bragança Aerodrome Chart  
(Source: VFR Manual, AIS, NAV Portugal [(AI12)])

The Bombardier CRJ 700 has a wingspan of 23,24 m, a maximum takeoff weight of 34.000 kg and an approach speed of 135 knots. For design purposes, in terms of the FAA Classification the aircraft is classified as a member of Airplane Design Group II (aircraft with wingspans of 15 m up to, but not including 24 m). It is categorized under Aircraft Approach Category C (approach speed of 121 knots or more but less than 141 knots).

### **2.8.2. Runway and Taxiways**

Bragança Airport has a single runway, Runway 02-20, supported by a perpendicular taxiway that connects it to the apron. The designation “02-20” indicates that the runway is positioned an approximate compass heading of 20 degrees and 200 degrees. The asphalt runway measures 1.700 m in length and 30 m in width. It has paved shoulders on both sides of 7,5 m wide, where the thickness of the base layer has 20 cm. On each of the runway ends it exist a small platform for turning the aircraft with an area of 45 x 50 m.

The average longitudinal grade is 1,2%, and the lowest point of the runway is located at the threshold of Runway 02 with an elevation of 673,80 m. The transverse grade is 1% offset from the runway centerline to both sides, ensuring a proper drainage.

The taxiway has has a length of 74 m and a width of 15 m. It is located east of the runway. The axis of this taxiway, perpendicular to the track, is situated 734 m from the threshold of Runway 02 and 966 m from the threshold of Runway 20 [CCoB08].

### **2.8.3. Safety Areas**

The Runway End Safety Area (RESA) enhances the safety of aircraft which undershoot, overrun, or veer off the runway, and it provides greater accessibility for fire-fighting and rescue equipment during such incidents [FAA12]. At Bragança Airport, both runway ends have a RESA of 90 x 90 m [CCoB08].

### **2.8.4. Clearways and Stopways**

The airport lacks of Clearways (CWY) and Stopways (SWY) [CCoB08].

### **2.8.5. Declared Distances**

Declared distances represent the maximum distances available and suitable for meeting takeoff, rejected takeoff, and landing distances performance requirements for turbine

powered aircraft. As states in the Annex 14 to the Convention of International Civil Aviation - Aerodromes, where a runway is not provided with a stopway or clearway and the threshold is located at the extremity of the runway, the four declared distances should normally be equal to the length of the runway. Hence we have:

- a) Take-off run available (TORA) = 1.700 m
- b) Take-off distance available (TODA) = 1.700 m
- c) Accelerate-stop distance available (ASDA) = 1.700 m
- d) Landing distance available (LDA) = 1.700 m

### **2.8.6. Airfield Lighting and Markings**

As described in the Runway Expansion Project (October 2000), the Airport has light signaling devices suitable for VFR. The systems provided are:

- Simple approach lighting system at Runway 02.
- Threshold and runway end lights for both Runway ends.
- Runway side lights.
- Precision Approach Path Indicator (PAPI) system at both Runway ends.
- Taxiway side lights.
- Runway Threshold Identification Lights (RTIL) at both Runway ends.

The airfield marking comprises:

- Runway designation markings.
- Runway centerline markings.
- Threshold markings.
- Runway side strip markings.
- Runway aiming point markings.
- Taxiway centerline markings.
- Taxiway edge marking.
- Surface painted holding position signs.

### 2.8.7. Navigational Aids

According to the information included in NOTAM 440-443/07 of December 17th, published by the Aeronautical Information Service, the airport has the following aeronautical stations and radio aids:

An Aerodrome Flight Information Service (AFIS), on request. It emits on the 122.300 MHz frequency and has a coverage of 15 NM. The emission type is A3E.

A radio beacon L, running 24 hours a day. Emits in a frequency of 358.0 kHz, with a coverage of 25 MN. The type emission is NON/A2A. Its identification is "BRG" and is located at coordinates 41°47'47" N and 006°43'31" W [CCoB08].

Additionally a new DVOR/DME Station is under test. The identification for this service is "BGN", with a coverage of 60 MN. The radio aid VOR, for magnetic azimuth indication, has a frequency of 115.700 MHz and a emission type 20k0A3X. The radio aid DME, for distance indication, has a frequency of 1.191 MHz/104X and the emission type is 1M60k2k [(AI12)].

### 2.8.8. Weather Reporting Equipment

There is a lighted wind direction indicator, non frangible, located 83,3 m left from the runway centerline and 714,6 m from the threshold [(AI12)].

### 2.8.9. Airside Summary

The existing airfield facilities at the Bragança Airport are summarized in **Table 2.4**

**Table 2.4.:** Existing Bragança Airport Airfield Facilities Data

PHYSICAL CHARACTERISTICS							
RWY	Dimensions and surface	Grade %	THR Elev. (m)	Declared Distances (m)			
				TORA	TODA	ASDA	LDA
02	1700X30	+ 1,2	675	1.700	1.700	1.700	1.700
20	ASPH	- 1,2	694	1.700	1.700	1.700	1.700
APRON	80x60m ASPH						
RSA 02	90X90m						
RSA 20	90X90m						
STRIP	1755X80m						

## 2.9 Landside Facilities

(Table 2.4 continues)

<b>LIGHTING</b>							
<b>RWY</b>	<b>APCH</b>	<b>PAPI</b>	<b>THR</b>	<b>END</b>	<b>TDZ</b>	<b>RCL</b>	<b>EDGE</b>
02			X	X		X	
20			X	X		X	
Aerodrome Beacon (Ibn) green flashes Identification “BRG”							
Prior request for lighting							
<b>SURFACE MOVEMENT GUIDANCE AND MARKINGS</b>							
<b>ID SIGN</b>	<b>WDI</b>	<b>LDI</b>	<b>RWY</b>	<b>TDZ</b>	<b>RWY</b>	<b>RCL</b>	
			<b>MARKS</b>	<b>MARKS</b>	<b>DESIGNATION</b>		
X	X Lighted	X	X	X	X	X	

APCH - Approach, ASPH - Asphalt, LDI - Landing designation indicator, RCL - Runway centerline,  
 RWY - Runway, TDZ- Touchdown zone, THR - Threshold, WDI - Wind direction indicator  
 (Source: VFR Manual, AIS, NAV Portugal)

## 2.9. Landside Facilities

Lanside facilities can generally be described as supplementary components in support of airport activity, but not necessarily aircraft operations. Examples include terminal buildings, aircraft storage units, and aircraft fueling facilities.

### 2.9.1. Aircraft Parking Apron

The aircraft parking apron area is located east of the runway and comprise a dimension of 80 x 60 m of flexible pavement. At the moment it can accomodate up to four Type B aircraft.

### 2.9.2. Terminal Building

Bragança Airport has a terminal building with a total area of 317,06m<sup>2</sup>, divided in four levels as described next.

### 2.9.2.1. First Level

The ground level has  $247,06m^2$  and is divided into different areas. The respective dimensions are shown in **Table 2.5**, according to the airport's Emergency Exit Plan, provided by the City Council of Bragança.

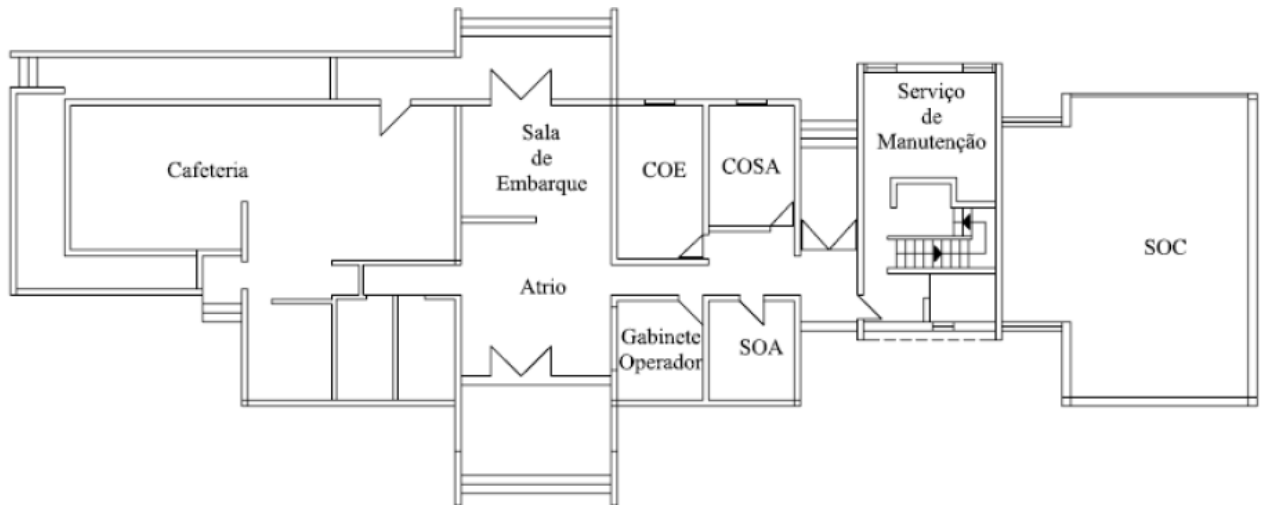
**Table 2.5.:** Ground Level surface distribution

Description	Size ( $m^2$ )
Departures Atrium	20,65
Boarding Lounge	14,98
Cafeteria	58,97
Restrooms	10,71
Office Space	15,22
Emergency Operation Center	11,77
Operation Center and Airport Security	9,23
Maintenance Zone	14,04
Airport Aid Service	59,89
Others (hallways, stairs, etc.)	31,6
<b>Total</b>	<b>247,06</b>

(Source: *Bragança Regional Airport Master Plan, City Council of Bragança*)

The **Figure 2.6** depicts the first level floor plan, where it can be seen that the departures atrium is found at the entrance of the Terminal and, forward after passing the security check point is the boarding lounge. Left to the entrance of the Terminal there is a hallway that leads to the restrooms and a door to the cafeteria, where the Airport airfield can be observed. To the right of the departures atrium there is a hallway which gives access to the technical wing of the Terminal, constituted by 4 office spaces and the stairs leading to the Control Tower. What appears in the image as Airport Service Aid (SOC) corresponds to a room that serves as the warehouse; in its interior there is a generator, a deicing device, etc [CCoB08].

**Figure 2.6.:** First Level Floor Plan



COE - Emergency Operation Center  
COSA - Operation Center and Airport Security  
SOC - Airport Aid Service.

*(Source: Bragança Regional Airport Master Plan, City Council of Bragança)*

### 2.9.2.2. Second Level

The second level has approximately 20m<sup>2</sup> of useful surface area, occupied by the Airport Director's office, as seen in the floor plan in **Figure 2.7**.

**Figure 2.7.:** Second Level Floor Plan



*(Source: Bragança Regional Airport Master Plan, City Council of Bragança)*

### 2.9.2.3. Third Level

The third level has approximately 20m<sup>2</sup> of useful surface area, taken by the Meteorology Service, shown in **Figure 2.8**.

**Figure 2.8.:** Third Level Floor Plan

(Source: Bragança Regional Airport Master Plan, City Council of Bragança)

#### 2.9.2.4. Fourth Level

The fourth level has  $30m^2$ , where the Control Tower Service is located, as seen in **Figure 2.9.**

**Figure 2.9.:** Fourth Level Floor Plan

(Source: Bragança Regional Airport Master Plan, City Council of Bragança)

#### 2.9.3. Automobile Parking

The existing parking has approximately 67 parking spaces for vehicles, with no specific area for buses. For taxis are available reserved places that are marked beside the Terminal.

#### 2.9.4. Ground Access

Access to the airport can only be done by road, by the N-218-1, which is linked to the Terminal and Automobile Parking by a roadway of 390 m.

There is no public transport service between the airport and Bragança or any of the nearby villages[CCoB08].

### **2.9.5. Hangars and Other Buildings**

As complementary buildings Bragança Airport is provided with a hangar of  $900m^2$  (30X30). The access door is approximately 7 m high and 20 m wide.

The hangar has a metallic structure formed by 30 m frames in order to accommodate therein the maximum number of aircraft without structural elements interfering with the operation of aircraft movement. Currently, the hangar is used for maintenance and storage of small aircraft such as small planes, ultralight aircraft, etc.

Enclosed to the automobile parking platform are the facilities of an Aeroclub that operates sports and private aviation activities [CCoB08].

### **2.9.6. Airport Rescue and Fire Fighting**

Under the fulfillment of public service obligations, the Airport ensures the protection level RFF category 3. Upon request, the Airport certifies the protection level RFF category 4.

For all other flights, there is a 100 kg fire extinguisher on wheels of dry powder and portable fire extinguishers distributed throughout Terminal. Medical Assistance and a Volunteer Firefighter Corps are available in Bragança [CCoB08].

### **2.9.7. Fuel Storage Facilities**

The Airport offers a fuel supply service of both AVGAS 100LL and JET A1, having reservoirs with a capacity of 10.000 l each [CCoB08].



## **3. Capacity and Facility Requirements Analysis**

The determination of airfield and airspace requirements includes an assessment of the airports ability to handle forecast activity levels, analysis of its compliance with design and safety standards, and a determination of design standards for new facilities or the improvement of existing facilities.

This chapter identifies the current airfield capacity and the requirements for airfield and general aviation areas to accommodate the forecast demand level at Bragança Airport. The FAA provides guidance for the planning and design of airport facilities through FAA Advisory Circulars that promote airport safety, economy, efficiency and longevity. Where applicable and within the scope of this study, the facility requirements recommended in this chapter incorporate FAA planning and design standards presented in Advisory Circular 150/5300-13A, Airport Design, as well as the recommendations from the ICAO Annex 14 - Aerodromes and the Aerodrome Design Manual Part 1 - Runways.

### **3.1. Definition of Airfield Capacity**

Airfield capacity is expressed in terms of the number of aircraft operations that can be conducted in a given period of time. Capacity is most often expressed as annual capacity (or annual service volume) and hourly capacity (or throughput capacity) for a particular runway and taxiway configuration [FAA07].

The methodology in FAA Advisory Circular 150/5060-5, Airport Capacity and Delay, commonly referred to as the “handbook methods”, yields hourly capacities and annual service volumes (ASV) and permits the estimation of aircraft delay levels as demand approaches and exceeds the throughput capacity of each airfield configuration [FAA07]. The calculations for the runway capacity presented on the Bragança Regional Airport Master Plan are based on this methodology. Where considering the aircraft fleet mix and starting parameters the following capacities were obtained:

- **Runway** - 53 operations/hour
- **Aircraft Parking Apron** - 24 operations/hour
- **Car Parking** - 191 passengers/hour

## 3.2. Airfield Facilities

Airfield facilities, as described in this report, include the runways, taxiways and airfield instrumentation and lighting.

### 3.2.1. Runway and Taxiways

#### 3.2.1.1. Runway Orientation

An important factor influencing runway alignment is wind, as the orientation of a runway in relation to the prevailing wind direction is critical to the safe operation of aircraft and the maximum utilization of airport facilities.

According to the previous wind rose study the existing runway alignment provided 100% wind coverage, fully complying with the minimum FAA recommendation of 95%. For comparison purposes a new study is presented, using more recent data from another meteorological station located in the Instituto Politécnico de Bragança. The first step to perform the analysis is to set an allowable crosswind component appropriate for the type of runway is considered. The FAA provides a table with the recommended values per RDC, as seen in **Table 3.1.**

**Table 3.1.:** Allowable crosswind component per Runway Design Code (RDC)

RDC	Allowable Crosswind Component
A-I and B-I *	10.5 knots
A-II and B-II	13 knots
A-III, B-III, C-I through D-III D-I through D-III	16 knots
A-IV and B-IV, C-IV through C-VI, D-IV through D-VI	20 knots
E-I through E-VI	20 knots

\* Includes A-I and B-I small aircraft.

(Source: FAA Advisory Circular 150/5300-13A, Airport Design)

Taking into account that the critical aircraft, the CRJ-700, belongs to the RDC classified as C-II, the crosswind component to consider is 16 knots.

### ***Wind Rose Analysis***

The purpose of the analysis is to determine the runway orientation which provides the greatest wind coverage within the allowable crosswind component limits. This can be readily estimated by rotating the crosswind template about the wind rose center point until the sum of the individual segment percentages appearing between the outer “crosswind limit” lines is maximized. It is accepted practice to total the percentages of the segments appearing outside the limit lines and to subtract this number from 100. For analysis purposes, winds are assumed to be uniformly distributed throughout each of the individual segments [FAA12].

There were found some limitations on assembling the wind data, due to incomplete records for the period of 2001 to 2010. It was decided to analyze only the year of 2010, which represents a much lower observational period than the recommended one, yet, still applicable to implement the method for comparison purposes.

The hourly records were classified in 6 wind classes and 16 wind directions to determine the frequency distribution. This was accomplished with the support of computer software specialized for wind analysis, called WRPLOT View.

WRPLOT View is a Windows program, from Lakes Environmental Software, that generates wind rose statistics and plots for selected meteorological stations for user-specified date and time ranges.

It was possible to import an Excel file with the hourly observations into the program to classify the data into the wind classes and directions before mentioned. The results obtained with the program demonstrate a prevailing wind direction blowing from the Southwest (SW), observed in a series of frequency distribution reports and charts described as follows:

1. Two reports about wind frequency distribution, the first presents the count of hourly observations for each wind class and wind directions considered (**Figure 5.1**) and the second the same values expressed as a percentage of the total,
2. A graphic representation of the resultant Wind Rose illustrated in **Figure 5.2** (a complete layout is found in **Attachment B.5.1**), and
3. A wind class frequency distribution chart, as seen in **Figure 5.3**.

**Figure 3.1.:** Wind Frequency Distribution Count

Station ID: 5300

Run ID:

Start Date: 01/01/2010 - 01:00

End Date: 12/31/2010 - 23:00

	Frequency Distribution (Count)						Total
	Wind Direction (Blowing From) / Wind Speed (Knots)						
	1 - 4	4 - 7	7 - 11	11 - 17	17 - 21	>= 22	
348.75-11.25	363	317	205	42	2	0	929
11.25-33.75	256	217	120	21	0	0	614
33.75-56.25	93	31	35	8	0	0	167
56.25-78.75	65	19	31	12	2	0	129
78.75-101.25	78	50	34	10	0	0	172
101.25-123.75	61	48	26	13	0	0	148
123.75-146.25	71	85	50	13	1	0	220
146.25-168.75	109	106	113	31	10	2	371
168.75-191.25	279	233	365	174	36	28	1115
191.25-213.75	527	224	454	317	86	53	1661
213.75-236.25	289	195	460	316	51	46	1357
236.25-258.75	67	49	73	56	4	7	256
258.75-281.25	38	6	7	3	0	1	55
281.25-303.75	129	134	80	18	0	0	361
303.75-326.25	45	19	16	1	0	0	81
326.25-348.75	10	23	12	0	0	0	45
Total	2480	1756	2081	1035	192	137	8745

Frequency of Calm Winds: 1064

Average Wind Speed: 6.11 Knots

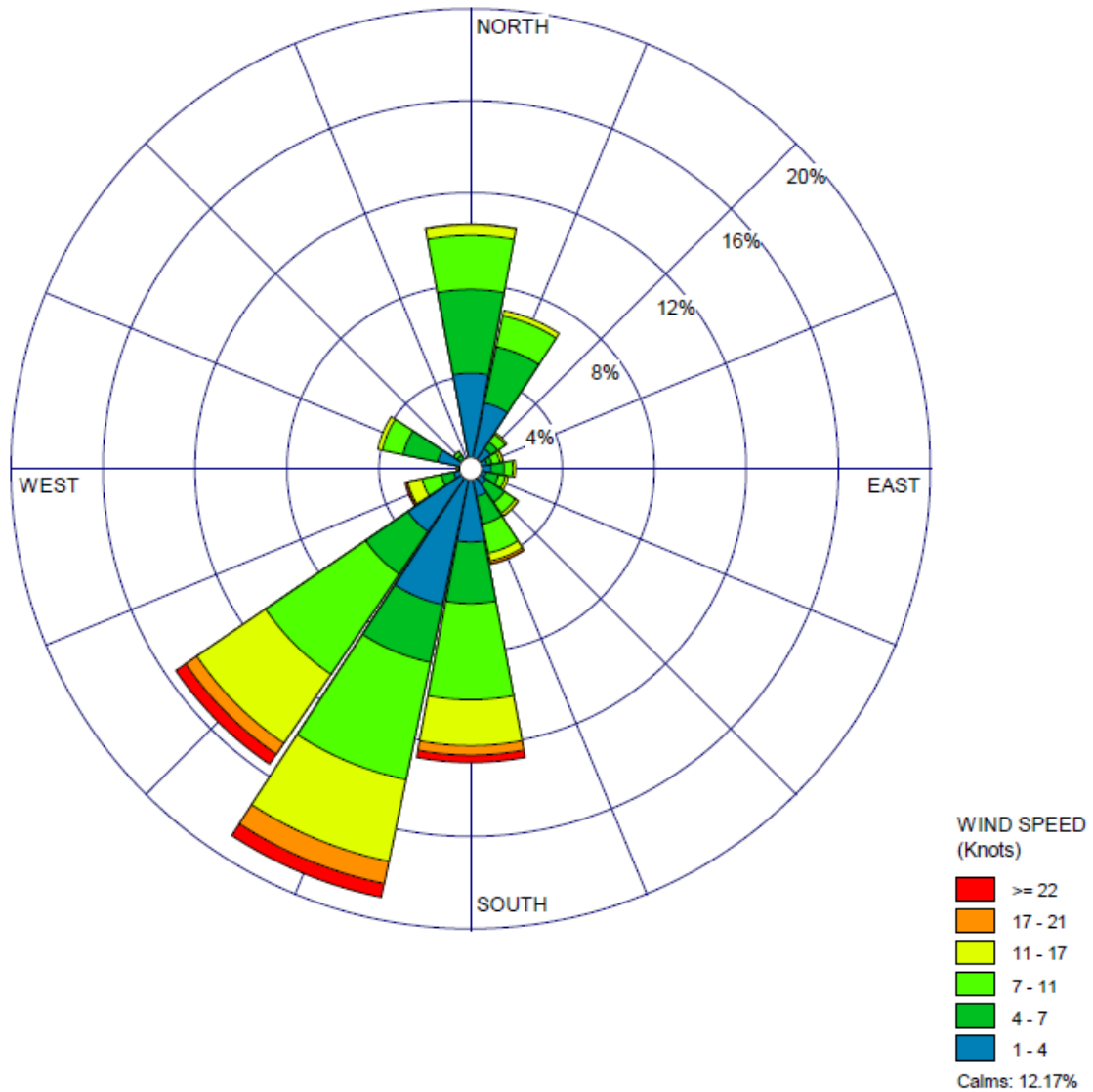
*(Source: WRPLOT View Freeware)*

The software also features the possibility to export your wind rose results to Google Earth™ at the location coordinates. This allows you to clearly envision your wind rose and its impact using the high quality images provided by Google Earth™, as observed in **Figure 5.4**.

To draw the windrose it was used the wind analysis program available on the FAA Airport Surveying – Geographic Information System (GIS) Program website: <https://airports-gis.faa.gov/public/index.html>.

Employing the frequency count calculated by the WRPLOT View, the values were approximated to introduce them into the FAA Wind Analysis Program. The results, later provided in the **Attachments B.5.2** and **B.5.3**, for the runway orientation 02-20, despite

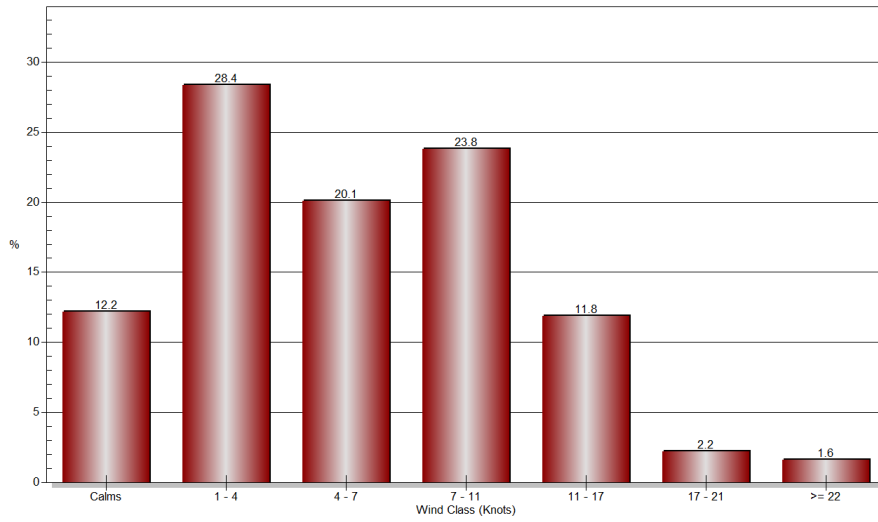
**Figure 3.2.:** Wind Rose Graphic Display



(Source: WRPLOT View Freeware)

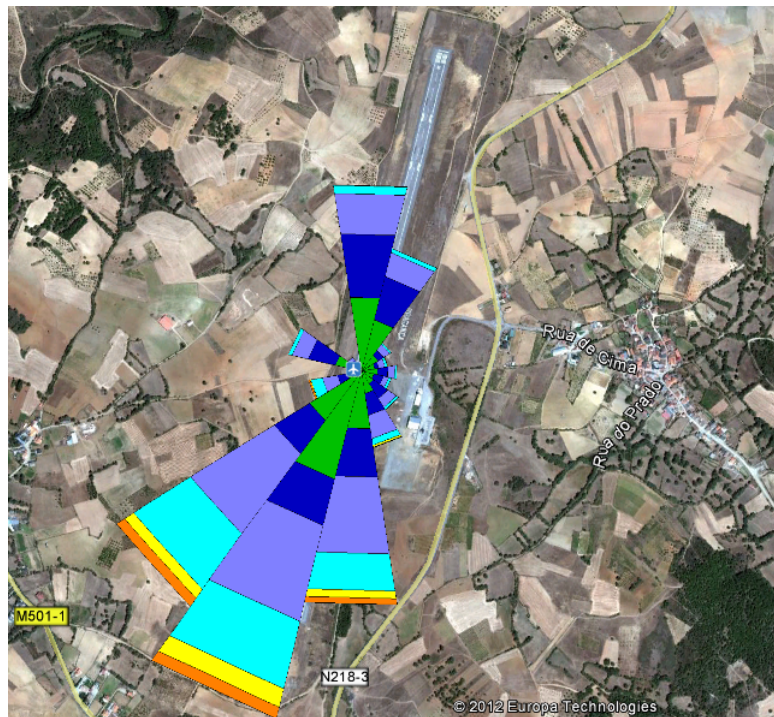
the different prevailing wind direction, exhibited a wind coverage of 99,84 % with a cross-wind component of 16 knots and a tailwind component of 60 knots (to indicate that the runway is bi-directional) and a calm winds percentage of 12,17. Since the FAA minimum recommendation of 95 % of wind coverage is well complied, it is concluded that the current runway orientation does not need realignment. The resultant Wind Rose is presented in **Figure 5.5**.

**Figure 3.3.: Wind Class Frequency Distribution Chart**



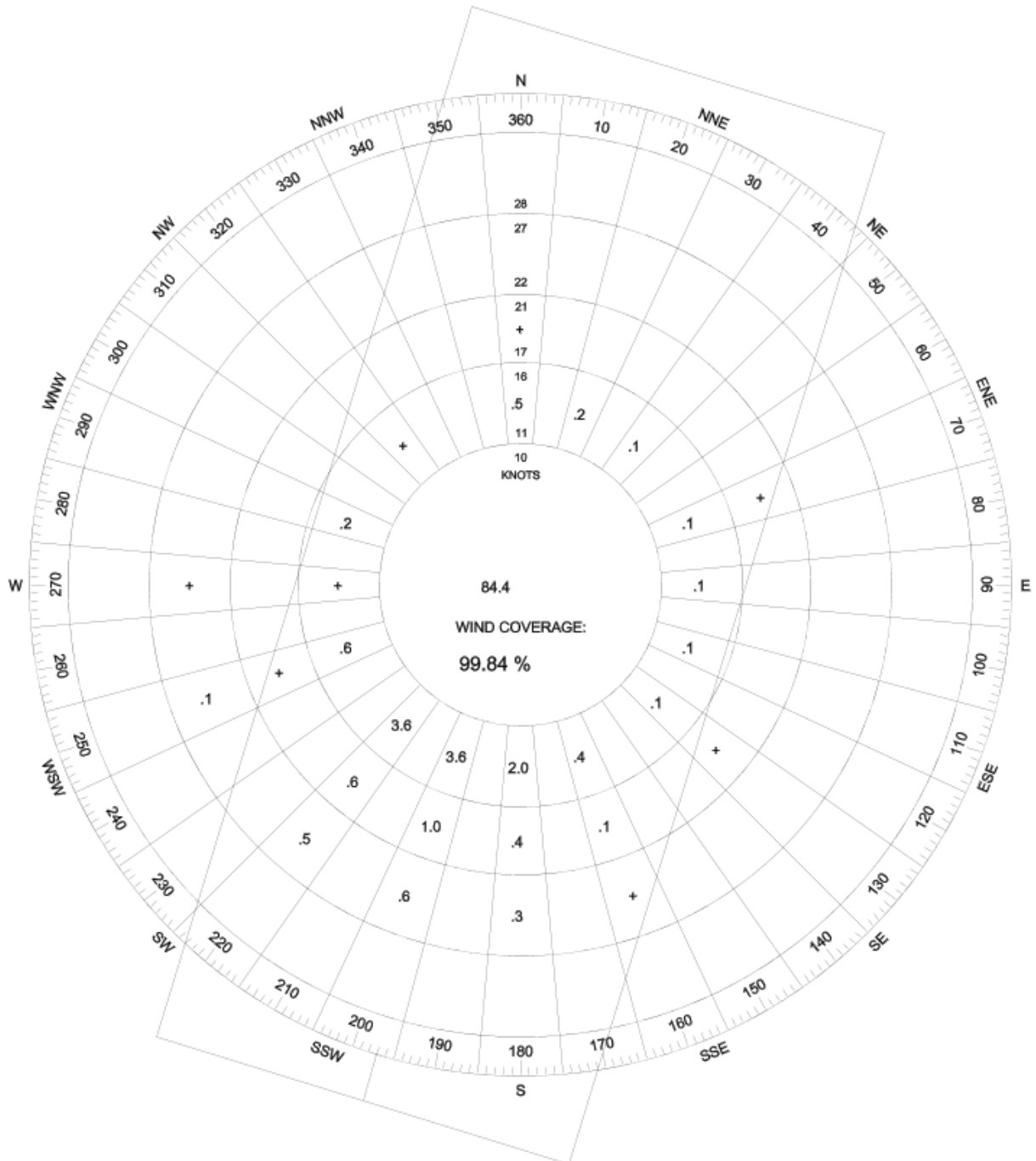
*(Source: WRPLOT View Freeware)*

**Figure 3.4.: Google Earth™ satellite view of Wind Rose**



*(Source: WRPLOT View Freeware and Google Earth™)*

Figure 3.5.: Wind Rose Analysis with FAA Program



(Source: <https://airports-gis.faa.gov/airportgis/publicToolbox/windroseForm.jsp?windroseId=null&requestToken=1355828326847>)

### 3.2.1.2. Runway Length Analysis

The selection of appropriate design criteria to be used for future development at Bragança Airport is based primarily upon performance characteristics and operating masses of design aircraft, which will be utilizing the airport. Still, other important factors have a bearing on the runway length to be provided like weather, particularly surface wind and temperature; runway characteristics such as slope and surface condition; and aerodrome location factors, for example aerodrome elevation which affects the barometric pressure and topographical constraints [Int06].

The analysis considered the takeoff field length and landing field length requirements of the aircraft at maximum takeoff weight (MTOW). Additionally a runway elevation of 683 m above mean sea level (AMSL), a runway grade of 1,2%, and a reference temperature of 29,7°C. Balanced field length requirements were adjusted to reflect these local conditions in accordance with guidance provided in Aerodrome Design Manual, Part 1, Runways, published by ICAO. This guidance advises the following adjustments:

- Increasing runway length requirements by 7% for every 300 meters the runway elevation exceeds sea level. The altitude of the Airport is 683 m AMSL, therefore the balanced field length requirements for standard conditions were increased by 15,9% to account for the altitude.
- Increasing runway length requirements by 1% for every 1° Centigrade (C) that the aerodrome reference temperature exceeds the temperature in the standard atmosphere for the aerodrome elevation. Temperature at the Airport will significantly affect runway length requirements. The aerodrome reference temperature of the Airport is 29,7°C and the standard temperature at the airport elevation is 10,56°C. As specified in the aforementioned criteria, balanced field length requirements for standard conditions were increased by 19,1% to account for temperature effects.
- Increasing runway length requirements by 10% for each 1% of positive (e.g., uphill) runway slope in the direction of takeoff. The runway grade is 1,2%, hence an increase of 12% of the standard balanced field length requirements to account for the runway slope.

The corresponding lengths of the Bombardier CRJ700 are:

1. Takeoff field length @ MTOW, ISA, SL 5,130 ft 1,564 m
2. Landing field length @ MLW, ISA, SL 5,090 ft 1,551 m

Consequently the required Runway Length would be approximately 2.420 m.

### 3.2.1.3. Runway Width

With the implement of the FAA Runway Design Code provided in the AC 150/5300-13A, based on Aircraft Approach Category (AAC) and approach visibility minimums, the appropriate runway width for a category C-II aircraft is 30 m (100 ft), as seen in **Table 3.2**. However, taking into account the ICAO Standards due to the required runway length of 2400 m, the Airport falls under Category number 4, with a minimum runway width of 45 m, as observed in **Table 3.3**.

**Table 3.2.:** Runway design standards, RDC C/D/E - II

<i>Runway Design Code (RDC)</i>		<i>C/D/E - II</i>			
ITEM	DIM <sup>1</sup>	VISIBILITY MINIMUMS			
		Visual	Not Lower than 1 mile	Not Lower than 3/4 mile	Lower than 3/4 mile
<b>RUNWAY DESIGN</b>					
Runway Length	A	<i>Refer to paragraphs 302 and 304</i>			
Runway Width	B	100 ft	100 ft	100 ft	100 ft
Shoulder Width		10 ft	10 ft	10 ft	10 ft
Blast Pad Width		120 ft	120 ft	120 ft	120 ft
Blast Pad Length		150 ft	150 ft	150 ft	150 ft
Crosswind Component		16 knots	16 knots	16 knots	16 knots

(Source: FAA Advisory Circular 150/5300-13A, Airport Design)

**Table 3.3.:** Runway widths, ICAO

Code Number	Code Letter					
	A	B	C	D	E	F
1 <sup>a</sup>	18 m	18 m	23 m	—	—	—
2 <sup>a</sup>	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.

(Source: Aerodrome Design Manual, Part 1, Runways, ICAO Doc 9157-AN/901)

### 3.2.1.4. Runway Grades

It is always recommended to keep the longitudinal grades and grade changes to a minimum. Following FAA longitudinal gradient standards for the centerline of runways on Approach Category C:

- The maximum longitudinal grade is  $\pm 1,50\%$ ; however, longitudinal grades may not exceed  $\pm 0,80\%$  in the first and last quarter of the runway length.

- The maximum allowable grade change is  $\pm 1,50\%$ , still, no grade changes are allowed in the first and last quarter of the runway length.
- Vertical curves for longitudinal grade changes are parabolic. The length of the vertical curve is a minimum of 305 m for each 1,0% of change.
- The minimum allowable distance between the points of intersection of vertical curves is 305 m multiplied by the sum of the grade changes (in percent) associated with the two vertical curves.

Respectively the ICAO standards reduce it to a maximum of  $\pm 1\%$  where the code number is 3 or 4; in this instance the current runway grade is 1,2% is within the FAA ranges. Nonetheless is recommended to reduce it to 1% as it states in the Bragança Regional Airport Master Plan.

### 3.2.1.5. Runway Safety Area

The values recommended for the FAA Runway Design Code C-II to have runway protection, respectively Runway Safety Area, are shown in **Table 3.4**.

**Table 3.4.:** Runway protection standards, RDC C/D/E - II

<i>Runway Design Code (RDC)</i>		<i>C/D/E - II</i>			
ITEM	DIM <sup>1</sup>	VISIBILITY MINIMUMS			
		Visual	Not Lower than 1 mile	Not Lower than 3/4 mile	Lower than 3/4 mile
<b>RUNWAY PROTECTION</b>					
Runway Safety Area (RSA)					
Length beyond departure end <sup>10,11</sup>	R	1,000 ft	1,000 ft	1,000 ft	1,000 ft
Length prior to threshold <sup>12</sup>	P	600 ft	600 ft	600 ft	600 ft
Width <sup>14</sup>	C	500 ft	500 ft	500 ft	500 ft

(Source: FAA Advisory Circular 150/5300-13A, Airport Design)

- Length beyond departure end - 304,8 m (1000 ft)
- Length prior to threshold - 182,9 m (600 ft)
- Width - 152, 4 m (500 ft)

For the ICAO Standards the length beyond departure end reduce to 240 m.

### 3.2.1.6. Taxiways

The values selected for the minimum taxiway widths are based on adding clearance distance from wheel to pavement edge to the maximum outer main gear wheel span for the selected code letter [Int05].

### 3.3 Landside Facilities

The 15 m width of the existing taxiway complies with the recommendation of ICAO Annex 14, but limits its use to aircraft with a wheel base of less than 18 m. As recommended by ICAO Annex 14 airports in the letter C key, in order to make possible the use of the taxiway by aircraft whose wheel base is equal or greater than 18 m, the width of the taxiway should be 18 m [CCoB08]. A new taxiway perpendicular to the runway will be required to connect it with a new aircraft parking platform. The recommended values by ICAO are shown in **Table 3.5**.

**Table 3.5.:** Design criteria for a taxiway

Physical characteristics	Code letter					
	A	B	C	D	E	F
Minimum width of:						
taxiway pavement	7.5 m	10.5 m	18 m <sup>a</sup> 15 m <sup>b</sup>	23 m <sup>c</sup> 18 m <sup>d</sup>	23 m	25 m
taxiway pavement and shoulder	—	—	25 m	38 m	44 m	60 m
taxiway strip	32.5 m	43 m	52 m	81 m	95 m	115 m
graded portion of taxiway strip	22 m	25 m	25 m	38 m	44 m	60 m

(Source: *Aerodrome Design Manual, Part 2, Taxiways, Aprons and Holding Bays, ICAO Doc 9157-AN/901*)

### 3.2.2. Airfield Instrumentation and Lighting

Instrumentation and lighting at an airport is a prime importance of all pilots and residents concerned. Determining the suitable instrumentation and lighting standards has a prominent influence on airside and landside development.

As discussed in Chapter 2, the Runway 02-20 is equipped with a simple approach lighting system, threshold and runway end lights, runway side lights, taxiway side lights, PAPIs and RTILs. These facilities are sufficient to accommodate the exiting and projected operating fleet at the Airport, but may require relocation based on the characteristic of the recommended development alternative.

### 3.3. Landside Facilities

For the purpose of this study, from the Landside Facilities, only the aircraft apron area requirements will be evaluated.

### 3.3.1. Apron Area Requirements

The function of an apron is to accommodate aircraft during loading and unloading of passengers and or cargo. Activities such as fueling, maintenance and short/long-term parking take place on an apron. Apron layout depends on aircraft gate positions; aircraft and ground vehicle circulation needs; and aircraft clearance requirements [FAA12].

Currently there is a total of  $4.800m^2$  (80X60 m) of paved apron space, limiting the number of parking spaces to 4 type B aircraft, which are now functioning at the Airport. In the matter of aircraft type C, it should have a single parking station together with another type B [CCoB08].

The pavement of the apron is flexible, this type of pavement is not resistant to hydrocarbons. At these platforms fuel supply operations are carried out and fuel spills are very likely to happen. These oil spills deteriorate the surface and reduce its strength, causing the service life to decrease significantly. Therefore it is recommended to eliminate this pavement and replace by a rigid type, adequate to the requirements [CCoB08].

A typically constructed apron is of either asphalt concrete or portland cement concrete pavement. Apron pavement design considerations include the following: pavement useful life, surface damage resistance to fuel spills, pavement maintenance requirements, the effects of aircraft static load, and the effects of any aircraft support equipment including passenger boarding bridges and ARFF equipment.

It is also required that the apron design must at all times allow aircraft to maintain specified clearances during apron movement activities. From the earlier Runway Design Code mentioned it is possible to get the clearance distance between the runway centerline and the Aircraft parking area, that for a design code C-II is approximately 121,92 m (400 ft).

## **4. Pavement Design Concepts and Condition Analysis**

The choice of the kind of pavement depends on the characteristics of the aeroplanes which are intended to use the aerodrome or the respective runway, operational requirements (particularly with respect to reconstruction of the runway) and geological conditions. Requirements for pavement bearing strength, longitudinal and transverse slopes of runways and other movement areas, pavement texture and braking action are all specified by Annex-14, Aerodromes, Volume I and amplified in the Aerodrome Design Manual, Part 3, Pavements. Operational regulations of individual airport administrations complement these requirements and offer guidance on the occasional excessive loading of pavements [KC07].

Furthermore, the FAA developed the Advisory Circular AC 150/5320-6E Airport Pavement Design and Evaluation, providing guidance on the structural design and evaluation of airport pavements. This chapter gives an overview about pavement design considerations and methods, the pavement design made for the different areas of Bragança Airport is explained in the next chapter.

### **4.1. Function and Purposes of Airport Pavements**

Overall airport pavements are constructed to provide adequate support for the loads imposed by airplanes and to produce a firm, stable, smooth, all-year, all-weather surface free of debris or other particles that may be blown or picked up by propeller wash or jet blast. In order to satisfactorily fulfill these requirements, the pavement must be of such quality and thickness that it will not fail under the load imposed. In addition, it must possess sufficient inherent stability to withstand, without damage, the abrasive action of traffic, adverse weather conditions, and other deteriorating influences. To produce such pavements requires a coordination of many factors of design, construction, and inspection to assure the best possible combination of available materials and a high standard of workmanship [FAA09].

All the criterias regarding the construction, geometrical characteristics and texture of the pavement are fundamental and complement one another. Important factors that influence the selection of the pavement type are:

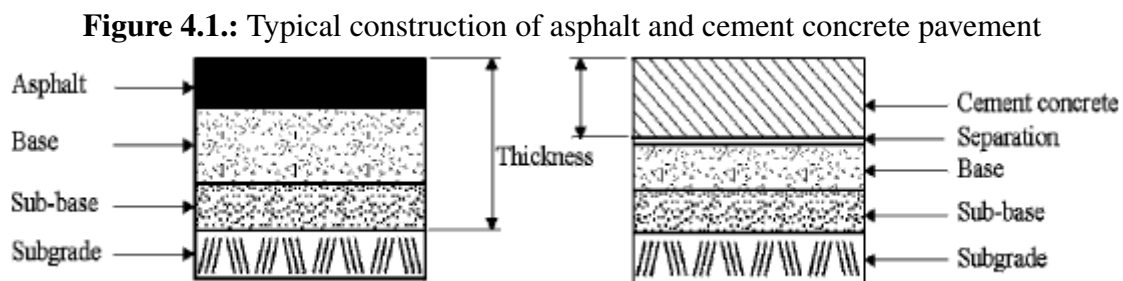
- types of aeroplanes from the viewpoint of the maximum point load for which the aerodrome is intended, and other operational requirements,
- availability and price of suppliers, materials and works,
- geological conditions,
- prevailing climatic conditions [KC07].

The basic pavement types are flexible, rigid, hot mix asphalt overlays, and rigid overlays. Various combinations of pavement types and stabilized layers result in complex pavements classified between flexible and rigid. Generally the flexible pavements are used for the movement areas such as runways, taxiways, shoulders, etc. While rigid pavements are found at parking platforms.

The pavement design normally include the following layers above the subgrade:

1. Surface - Portland cement concrete (PCC), hot mix asphalt (HMA), sand-bituminous mixture, and sprayed bituminous surface treatments.
2. Base - Untreated materials such as crushed and uncrushed aggregates. And treated materials like crushed or uncrushed aggregate mixed with a stabilizer such as cement, bitumen, etc.
3. Subbase - Granular material, stabilized granular material or stabilized soil.
4. Geosynthetics - Manufactured synthetic products use to address geotechnical problems [FAA09].

A typical profile for flexible and rigid pavement types can be seen in **Figure 4.1**.



(Source: *Aerodrome Design Manual, Part 3, Pavements, ICAO Doc 9157-AN/901*)

Providing the proper foundation and drainage facilities in the first stage of pavement construction is mandatory, as the underlying layers will not be readily accessible for upgrading in the future [FAA09].

### **4.2. Soil Investigations and Evaluation**

To provide essential information on the various types of soils, investigations should be made to determine their distribution and physical properties. This information combined with data on site topography and area climatic records, provides basic planning material essential to the logical and effective development of the airport [FAA09].

The importance of correct identification and evaluation of pavement bases can not be underestimated, although not addressed in this study. However, is important to indicate that from the existing geotechnical study was concluded that the subgrade where the Airport is located has a low bearing capacity estimating a CBR value of 5. As it was considered in the Bragança Regional Airport Master Plan, for pavement calculation purposes, the CBR value of the subgrade for the entire area to be paved or already paved will be of 5.

### **4.3. Reporting Pavement Strength**

The bearing strength of the pavement area in ideal conditions is a very important aspect for its conservation. Consequently, the International Civil Aviation Organization (ICAO) requires that each of its members publish the pavements strengths of all public airport pavements, as is stated in the Annex 14 to the Convention of International Civil Aviation - Aerodromes. Hence, a standardized method was developed for this matter, designated as the Aircraft Classification Number – Pavement Classification Number (ACN-PCN) method. It concentrates on classifying the relative damage of aircraft by defining and comparing two values in order to conduct weight unrestricted operations of an airplane.

#### **4.3.1. Description of ACN-PCN Method**

Through the use of this method is achieved a way to express the effect of an individual airplane on different pavements by a single unique number that varies according to airplane weight and configuration, pavement type, and subgrade strength. This number is the Aircraft Classification Number (ACN). Conversely, the load-carrying capacity of a pavement can be expressed by a single unique number, without specifying a particular aircraft or detailed information about the pavement structure. This number is the Pavement Classification Number (PCN) [FAA11].

### 4.3.1.1. Concepts

ACN is defined as a number that expresses the relative effect of an airplane at a given weight on a pavement structure for a specified standard subgrade strength. Whilst, PCN is a number that expresses the load-carrying capacity of a pavement for unrestricted operations [FAA06].

ACN consists of a number on a continuous scale, ranging from 0 on the lower end and with no upper limit, that is computed between two pavement types (rigid or flexible), and the subgrade support strength category. ACN values for civil aircraft have been published in ICAO's Aerodrome Design Manual and in FAA Circular 150/5335-5.

### 4.3.1.2. Application and Limitations of the system

The use of the standardized method of reporting pavement strength applies only to pavements with bearing strengths of 12,500 pounds (5 700 kg) or greater and shall be made available by reporting all of the following information [FAA06, ICA99]:

- the pavement classification number (PCN);
- pavement type for ACN-PCN determination;
- subgrade strength category;
- maximum allowable tire pressure category or maximum allowable tire pressure value; and
- evaluation method.

Whenever necessary, PCNs may be published to an accuracy of one-tenth of a whole number. The PCN reported indicates that aircraft with an ACN number less than or equal to the reported PCN could operate on the pavement, subject to any limitation of the tire pressure or all-up mass for specified aircraft types. It is possible to report different PCNs if the strength of the pavement is subject to significant seasonal variation.

It must be noted that the ACN/PCN method is not a design or evaluation method, but purely a classification system. The ICAO documentation makes it very clear that the PCN is simply the ACN of the most damaging aircraft that can use the pavement on a regular basis (regular being defined by the operator). It is not intended as a pavement design or pavement evaluation procedure, nor does it restrict the methodology used to design or evaluate a pavement structure.

### 4.3.1.3. Code Format

The PCN is actually expressed as a five part code, separated by forward-slashes, describing the piece of pavement concerned. The first part is the PCN numerical value, indicating the load-carrying capacity of the pavement. This is always reported as a whole number, rounded from the determined capacity. The value is calculated based on a number of factors, such as aircraft geometry and a pavement’s traffic patterns, and is not necessarily the direct bearing strength of the pavement.

The other four parts include pavement type, subgrade category, allowable tire pressure, and method used to determine the PCN, all shown in **Table 4.1**. There is no need to report the actual subgrade strength or the maximum tire pressure allowable [CWT07]. The subgrade strengths and tire pressures have been grouped into categories as indicated in **Table 4.2**, and the subgrade strengths and tire pressures within the range of each category could be represented by the character of that category.

**Table 4.1.:** PCN Code

PCN	Pavement Type	Subgrade Strength Category	Allowable Tire Pressure	Method of PCN Determination
Numerical Value	R – Rigid F – Flexible	A – High B – Medium C – Low D – Ultra low	W – No limit X – to 1,5 MPa (217 psi) Y – to 1,0 MPa (145 psi) Z – to 0,5 MPa (73 psi)	T – Technical U – Using aircraft

(Source: Aerodrome Design Manual, Part 3, Pavements, ICAO Doc 9157-AN/901)

**Table 4.2.:** Subgrade Support Strength Category

Subgrade Category	Designation	Pavement type	Characteristic Subgrade Strength	Range of Subgrade Strengths
High	A	Rigid	150 MN/m2/m	All k values above 120 MN/m2/m
		Flexible	CBR 15 %	All CBR values above 13 %
Medium	B	Rigid	80 MN/m2/m	60 to 120 MN/m2/m
		Flexible	CBR 10 %	CBR 8 % to CBR 13 %
Low	C	Rigid	40 MN/m2/m	25 to 60 MN/m2/m
		Flexible	CBR 6 %	CBR 4 % to CBR 8 %
Ultra Low	D	Rigid	20 MN/m2/m	All k values below 25 MN/m2/m
		Flexible	CBR 3 %	All CBR values below 4 %

(Source: Aerodrome Design Manual, Part 3, Pavements, ICAO Doc 9157-AN/901)

An example of a PCN code is 50/F/C/W/T—with 50 expressing the PCN numerical value, F for flexible pavement, C for low strength subgrade, W for high allowable tire pressure, and T for a PCN value obtained by a technical evaluation.

#### 4.3.1.4. Overload Operations

As it happens with road pavements, the overloading of airport pavements result in the shortening of the design life. However, due to the structural behavior of pavements, excepting massive overloading, they are not subject to a particular limiting load above which the suddenly or catastrophically fail. Therefore occasional minor overloading is acceptable and for those operations with a magnitude of overload it exists a criteria that relates the ACN number with the PCN [ICA99].

The suggested criteria is described by Annex–14, Aerodromes, Volume I, stating for both flexible and rigid pavements the percentages of ACN's exceeding the airports PCN's and the annual number of overload movements compared to the total of aircraft movements.

#### 4.3.2. Determination of ACN Values

The official computation value of an ACN has to be provided by the airplane manufacturer. For the calculation of the ACN is required detailed information on the operational characteristics of the airplane such as maximum aft of gravity, maximum ramp weight, wheel spacing, tire pressure, and other factors.

There are diverse ways to calculate the ACN. A well known calculation method is stated in Aerodrome Design Manual Part 3. Depending on the taxiing condition of the aircraft, two masses are selected for the ACN calculation, i.e. maximum apron mass and a representative operating mass empty (OME). Both are static loads [CWT07]. The ACN of an aircraft is numerically defined as two times the derived single wheel load (DSWL) expressed in 1,000 kg. The concept of a mathematically DSWL has been employed as a means to define the landing gear/pavement interaction without specifying pavement thickness. The DSWL is obtained by equating the thickness (reference thickness) given by the mathematical model for an aircraft landing gear to the thickness for a single wheel (DSWL) at a standard tire pressure of 1.25 MPa (181psi). For flexible pavements, the extended CBR design method for airfields is used to calculate the reference thickness, and the number of coverage is set at 10,000. For rigid pavements, the reference thickness is the thickness of the concrete slab which will give a maximum flexural working stress of 2.75 MPa (399 psi) by using Westergaard equation when loaded with one main gear

at slab center. These calculations are derived using the program developed by Mr. R. G. Packard for rigid pavements, and by the S-77-1 method for flexible pavements [CWT07]. In addition to the method used in the Aerodrome Design Manual Part 3, the aircraft manufacturers also provide charts to obtain the ACN value solely by inputting the aircraft gross weight and subgrade category. An example of these type of charts can be found in the **Attachment B.3**.

### **4.3.2.1. ACN calculation through software application COMFAA**

In order to facilitate the use of the ACN-PCN system, the FAA, developed a software application called COMFAA to calculate ACN values using the procedures and conditions specified by ICAO. This software may be obtained downloading it from the FAA website along with its source code and supporting documentation. Despite the program is useful to determine ACN values under several numerous conditions it is reminded that the official ACN values are provided by the airplane manufacturer. The COMFAA program presents a visually interactive and intuitive interface. Through the selection of the desired airplane, confirmation of the physical properties of the airplane and choice of ACN Flexible or ACN Rigid buttons is possible to determine the ACN for the four standard subgrade conditions. The **Figure 4.2** displays the interface of the program, indicating the steps to follow.

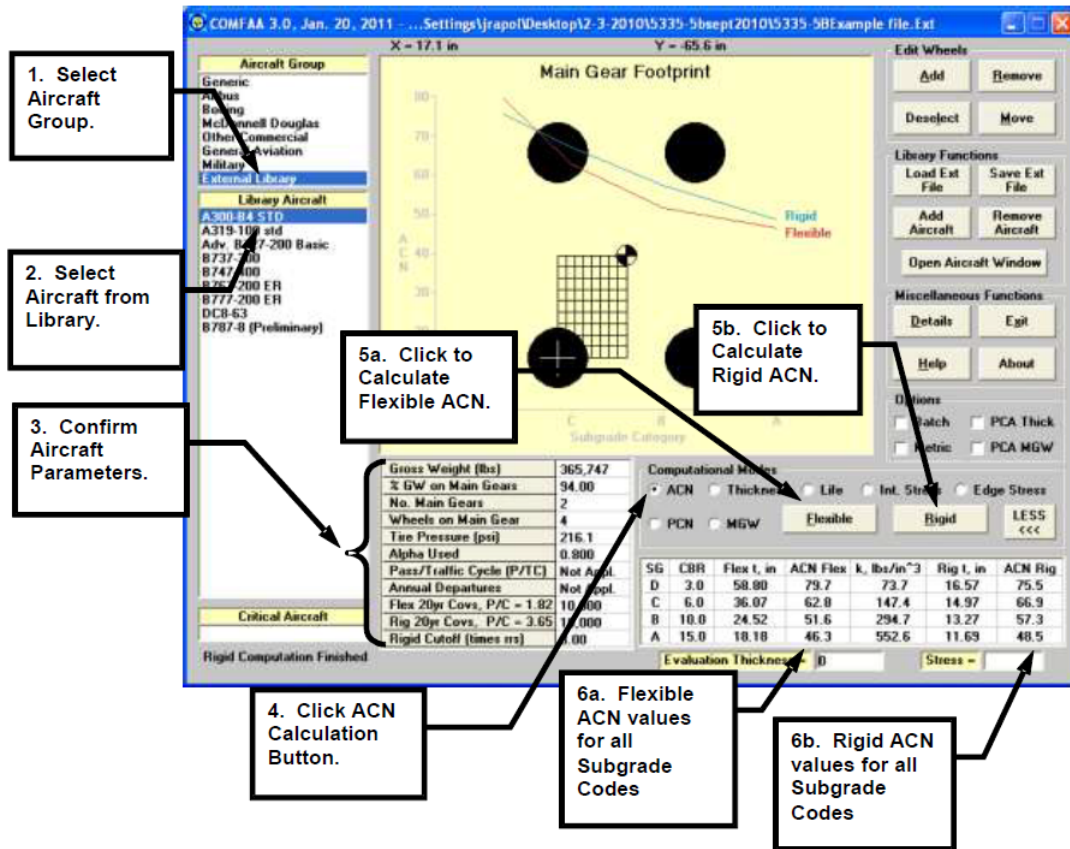
Introducing the Aircraft Mix for Bragança Airport in the COMFAA program the following results are shown in **Figure 4.3**

### **4.3.3. Determination of PCN Numerical Value**

Although there is a great amount of material published on how an ACN is computed, ICAO has not specified regulatory guidance as to how an airport authority is to arrive at a PCN, but has left it up to the authority as to how to perform this task [ICA99]. As shown before in the PCN Code Format, there are two evaluation methods to determine the PCN value, the Technical method (T) and the empirical method Using aircraft experience (U).

#### **4.3.3.1. Using aircraft experience (U)**

It represents a knowledge of the specific type and mass of aircraft satisfactorily being supported under regular use [ICA99]. The U method adopts the highest ACN value of the aircraft in the mixed traffic as the PCN value. Once the runway adopts this ACN value as the PCN and signs of distress operating are observed, the rating must be adjusted



**Figure 4.2.:** Operation of the COMFAA Program in ACN Mode.

(Source: FAA Advisory Circular 150/5335-5B, Standardized Method of Reporting Airport Pavement Strength - PCN)

**Results Table 3. Flexible ACN at Indicated Gross Weight and Strength**

No.	Aircraft Name	Gross Weight	% GW on Main Gear	Tire Pressure	A(15)	B(10)	C(6)	D(3)
1	Dornier 228	13.900	95.00	862	11.4	12.3	12.4	12.8
2	Skyhawk-172	1.150	95.00	345	0.5	0.6	0.8	1.0
3	Morane Saulnier 893	1.050	95.00	310	0.7	1.0	1.4	1.7
4	Seneca-II	1.905	95.00	379	0.8	1.1	1.4	1.6
5	RegionalJet-700	34.019	95.00	1,262	18.6	19.9	22.2	24.2

**Results Table 3. Rigid ACN at Indicated Gross Weight and Strength**

No.	Aircraft Name	Gross Weight	% GW on Main Gear	Tire Pressure	A(552)	B(295)	C(147)	D(74)
1	Dornier 228	13.900	95.00	862	11.7	11.8	12.0	12.0
2	Skyhawk-172	1.150	95.00	345	0.7	0.7	0.8	0.6
3	Morane Saulnier 893	1.050	95.00	310	1.2	1.3	1.4	1.2
4	Seneca-II	1.905	95.00	379	1.2	1.3	1.3	1.1
5	RegionalJet-700	34.019	95.00	1,262	22.0	23.0	23.9	24.7

**Figure 4.3.:** COMFAA Flexible and Rigid ACN Values for Aircraft Mix

(Source: COMFAA 3.0 Software)

downward in order to maintain normal airport operations. If one or more aircraft have ACNs that exceed the lowered PCN, then the allowable gross weight for those aircraft may need to be restricted [CWT07].

#### **4.3.3.2. Technical method (T)**

This method represents a specific study of the pavement characteristics and application of pavement behavior technology [ICAO, 1999].

The strength of a pavement section is difficult to summarize in a precise manner and will vary depending on the unique combination of aircraft loading conditions, frequency of operation, and pavement support conditions. The technical evaluation method attempts to address these and other site-specific variables to determine reasonable pavement strength. In general terms, for a given pavement structure and given aircraft, the allowable number of operations (traffic) will decrease as the intensity of pavement loading increases (increase in aircraft weight). It is entirely possible that two pavement structures with different cross-sections will report similar strength. However, the permissible aircraft operations will be considerably different. This discrepancy must be acknowledged by the airport operator and may require operational limitations administered outside of the ACN-PCN system. All of the factors involved in determining a pavement rating are important, and it is for this reason that pavement ratings should not be viewed in absolute terms, but rather as estimations of a representative value. A successful pavement evaluation is one that assigns a pavement strength rating that considers the effects of all variables on the pavement [FAA11].

Different concepts have been developed for performing the technical evaluation method, such as the ICAO method, the BOEING method, the cumulative Damage method, the FAA method using COMFAA software, and other research studies have proposed a methodology of applying Heavy Weight Deflectometer to determine pavement material properties for the calculation of the runway PCN.

The accuracy of a technical evaluation is better than that produced with the Using aircraft procedure but requires a considerable increase in time and resources. Pavement evaluation may require a combination of on-site inspections, load-bearing tests, and engineering judgment. It is common to think of pavement strength rating in terms of ultimate strength or immediate failure criteria. However, pavements are rarely removed from service due to instantaneous structural failure. A decrease in the serviceability of a pavement is commonly attributed to increases in surface roughness or localized distress, such as rutting or cracking. Determination of the adequacy of a pavement structure must not only con-

sider the magnitude of pavement loads but the impact of the accumulated effect of traffic volume over the intended life of the pavement [FAA11].

The COMFAA program provides a technical method to calculate the PCN of a pavement for a determined aircraft mix. The data of the proposed aircraft mix for Bragança Airport was introduced obtaining the results included in **Attachment B.4**.

The highest value for the subgrade category is selected. The accordingly PCN for a flexible pavement is:

*PCN 21/F/C/X/T.*

#### 4.4. Pavement Design using FAARFIELD

FAARFIELD, which stands for FAA Rigid and Flexible Iterative Elastic Layered Design, is a computer program for airport pavement thickness design. It implements both layered elastic based and three-dimensional finite element-based design procedures developed by the Federal Aviation Administration (FAA) for new and overlay design of flexible and rigid pavements. The thickness design procedures implemented in the program are the FAA airport pavement thickness design standards referenced in Advisory Circular (AC) 150/5320-6E [FAA10].

FAARFIELD is based on the cumulative damage factor (CDF) concept, in which the contribution of each airplane in a given traffic mix to total damage is separately analyzed. This replaces the design method contained in previous versions of the AC mentioned that are based on the “design aircraft concept”.

##### 4.4.1. Cumulative Damage Factor

The cumulative damage factor (CDF) is the amount of the structural fatigue life of a pavement which has been used up. It is expressed as the ratio of applied load repetitions to allowable load repetitions to failure, or, for one airplane and constant annual departures:

$$CDF = \frac{\text{number of applied load repetitions}}{\text{number of allowable repetitions to failure}} \quad (4.1)$$

$$CDF = \frac{(\text{annual departures}) (\text{life in years})}{(\text{pass/coverage ratio}) \times (\text{coverage to failure})} \quad (4.2)$$

$$CDF = \frac{\text{applied coverages}}{\text{coverages to failure}} \quad (4.3)$$

#### 4.4 Pavement Design using FAARFIELD

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When CDF = 1,	the pavement will have used up all of its fatigue life.
When CDF < 1,	the pavement will have some life remaining, and the value of CDF will give the fraction of the life used.
When CDF > 1,	all of the fatigue life will have been used up and the pavement will have failed.

(Source: FAARFIELD - Airport Pavement Design (V 1.305) User's Manual)

Note: In these definitions, failure means failure in a particular structural failure mode according to the assumptions and definitions on which the design procedures are based. A value of CDF greater than one does not necessarily mean that the pavement will no longer support traffic, but that it will have failed according to the definition of failure used in the design procedure, and within the constraints of uncertainties in material property assumptions, etc. Nevertheless, the thickness design is based on the assumption that failure occurs when CDF = 1.

Multiple airplane types are accounted for by using Miner's Rule instead of the "design airplane" concept as in the current procedures, or:

$$CDF = CDF_1 + CDF_2 + \dots CDF_N \quad (4.4)$$

Where  $CDF_1$  is the CDF for each airplane type in the mix and N is the number of airplane types in the mix [FAA10].

#### 4.4.2. New Flexible and HMA Overlay on Flexible

The design criteria for both pavement types, new flexible and HMA overlay on flexible, are the subgrade vertical strain and horizontal strain at the bottom of the top layer. The FAA defines a default asphalt modulus value of 1.380 MPa (200,000 psi), conservatively chosen to correspond to a pavement temperature of approximately 32°C. This value cannot be modified in the program, consequently, horizontal strain only becomes the dominant criterion when the structure is very deep and is heavily loaded. Overlap of the CDFs can therefore occur and a proper design never realized. For these reasons, and to save run time, the subgrade strain is used to iterate to a subgrade CDF of one. Only one evaluation depth needs to be sent to LEAF and the run time is approximately halved for deep, many layered, structures (compared to computing subgrade and asphalt strain each time). When

the subgrade criterion has been satisfied, a final calculation is made to find the asphalt CDF (again using only one evaluation depth) [FAA10].

For new flexible design, the thickness of the layer next to the subgrade is adjusted to make the subgrade CDF approximately equal to one. The default error control is that the design will terminate when CDF is in the range 0.995 to 1.005. This tolerance can be temporarily changed from the Options window. If the layer next to the subgrade becomes thinner than its specified minimum thickness, the thickness of the layer above is halved, or set at its minimum thickness, and the procedure continued. If the CDF is less than one with both of the adjusted layers at their minimum thicknesses, the CDF is displayed and the design terminated. This procedure is not intended to “optimize” a design. It is intended only to protect from inappropriate input data [FAA10].

For overlay design, the top layer is always the design layer. The thickness of the top layer is automatically adjusted to make the subgrade strain CDF equal to one. The procedure is terminated, with a message, if the top layer becomes thinner than its minimum thickness. The failure model used to find the number of coverages to failure for a given vertical strain at the top of the subgrade is:

$$C = \left( \frac{0,004}{\varepsilon_v} \right)^{8,1} \text{ when } C \leq 12,100 \quad (4.5)$$

$$C = \left( \frac{0,002428}{\varepsilon_v} \right)^{14,21} \text{ when } C > 12,100 \quad (4.6)$$

where:

$C$ = number of coverages to failure

$\varepsilon_v$ = vertical strain at the top of the subgrade

The failure model used to find the number of coverages to failure for a given horizontal strain at the bottom of the surface asphalt layer is:

$$\log_{10}(C) = 2,68 - 5 \times \log_{10}(\varepsilon_h) - 2,665 \times \log_{10}(E_A) \quad (4.7)$$

where:

$C$ = number of coverages to failure

$E_A$ = asphalt modulus, psi

$\varepsilon_h$ = horizontal strain at the bottom of the surface asphalt layer

### 4.4.3. New Rigid Failure Model

The failure model is the component of the overall design procedure that relates a computed response (vertical strain in the case of flexible pavements; horizontal PCC stress for rigid pavements) to the number of predicted coverages to failure. The failure model is empirical in that it is derived from analysis of full-scale traffic tests on test items with known loading and properties. In FAARFIELD 1.0, the rigid pavement failure model has been substantially revised based on analysis of full-scale tests at the National Airport Pavement Test Facility (NAPTF) and re-analysis of historical rigid pavement test data [?].

The rigid pavement failure model used in FAARFIELD has the general form:

$$DF = \left[ \frac{F'_s bd}{(1 - \alpha)(d - b) + F'_s b} \right] \times \log C + \left[ \frac{(1 - \alpha)(ad - bc) + F'_s bc}{(1 - \alpha)(d - b) + F'_s b} \right] \quad (4.8)$$

where:

SCI = Structural Condition Index

$\alpha = SCI/100$

DF = design factor defined as  $R/\alpha$ , where R is the concrete flexural strength and  $\alpha$  is the computed concrete tensile strength

FCAL = stress calibration factor, FCAL = 1.13

F's = stabilized base compensation factor (see below)

Parameters: a = 0.5878, b = 0.2523, c = 0.7409, d = 0.2465.

Failure for a rigid pavement in FAARFIELD is defined as SCI= 80. For a new rigid pavement, the program iterates on the thickness of the PCC layer (the design layer) until the failure model predicts a value of SCI=80 at the end of the design life (20 years for standard designs). The number of coverages to failure (C) is therefore the number of coverages for SCI = 80 at any given value of R/s [FAA10].

## 4.5. Flexible and Rigid Pavement Design using FAA Spreadsheets

The design method to determine pavement thickness as described in AC 150/5320-6D uses two programs (spreadsheets). Program F805FAA.XLS determines pavement thickness requirements for flexible pavement sections and bituminous overlays on existing flexible pavement sections. Program R805FAA.XLS determines pavement thickness requirements

for rigid pavement sections and bituminous or Portland cement concrete overlays on existing rigid or flexible pavement sections [FAA09].

The spreadsheets will produce thickness designs consistent with the nomographs used in AC 150/5320-6D.

## 5. Pavement Design Results and Development Alternatives

After establishing the requirements in Chapter 3 and reviewing designs concepts in Chapter 4, it was carried out the design for different pavement types necessary throughout the various zones of the Airport, subsequently:

1. Existing runway area: reinforcement of the flexible pavement with asphalt overlays.
2. New runway area: new flexible pavement structure for the expansion of the runway.
3. Aircraft Parking Apron area: rigid pavement structure for the parking platforms.

### 5.1. Pavement Thickness Design with FAA Software

The software employed to calculate the pavement thickness for the required areas is the one discussed at the Appendix 5 - Airfield Pavement Design Software of the AC 150/5320-6E, respectively, FAARFIELD and Flexible and Rigid Pavement Design Excel Spreadsheets. The procedure for calculating each thickness is explained next.

The Aircraft Traffic Mix used for all calculations is shown in **Table 5.1**.

**Table 5.1.:** Proposed Aircraft Traffic Mix

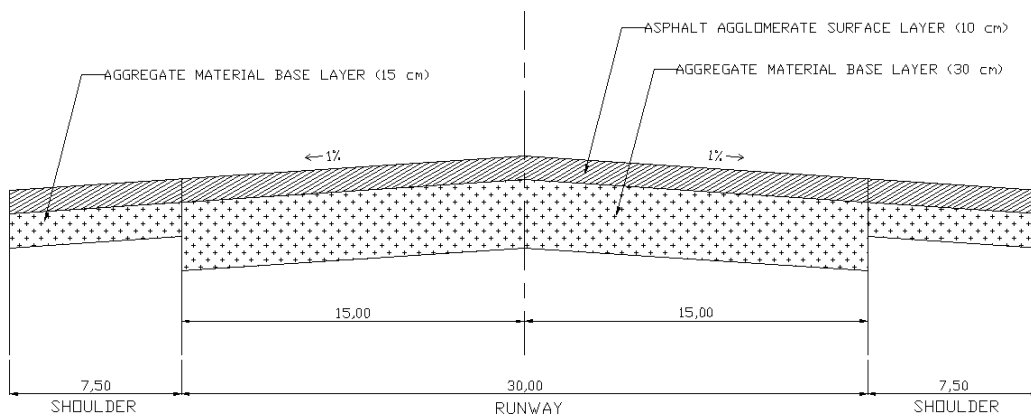
<b>Model</b>	<b>Max. Take-Off Weight (kg)</b>	<b>Max. Take-Off Weight (lb)</b>	<b>Annual Departures</b>
Dornier 228 (BGC-LIS)	13.900	30.644	1456
Piper Seneca	1.905	4.200	495
Cessna 172	1.150	2.535	495
Morane Saulnier 893	1.050	2.315	495
Regional Jet 700 (BGC-PAR)	34.000	75.000	252

*(Source: Aircraft Specifications and Bragança Regional Airport Master Plan, City Council of Bragança)*

The annual departure values are based in approximate forecasts for the aircraft found at the Bragança Regional Airport Master Plan, where the route Bragança-Lisbon, performed by the Dornier 228 has 1456 annual operations, the route Bragança-Paris, that would be made by the Bombardier CRJ 700, consist of 252 movements. The remaining operations corresponding to general aviation were estimated in a total of 1485, which was distributed in equal percentages between the rest of the aircraft composing the mix.

### 5.1.1. Flexible pavement design with FAARFIELD

The existing runway was initially conformed by flexible pavement constituted by two layers over the subgrade. A base layer of aggregate material with 300 mm thickness on top of the subgrade and surface layer with 50 mm of asphalt agglomerate above the base layer. After the expansion of the runway was carried out from 1.200 m to 1.700 m, the thickness of the surface layer was increased with 50 additional millimeters reaching a total of 100 mm, as it can be seen in the existing pavement cross section in **Figure 5.1**. The CBR for the subgrade was considered to be 5 and the standard design life 20 years. No annual growth was considered.



**Figure 5.1.:** Existing runway pavement cross section

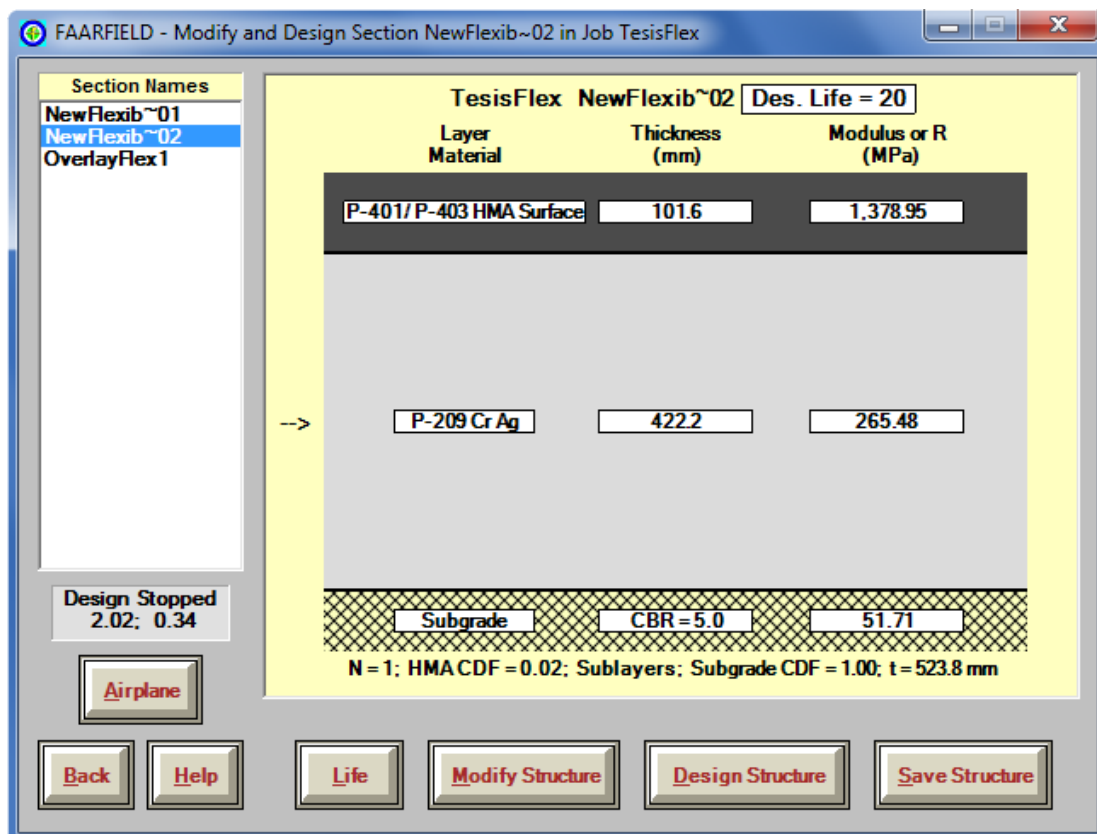
After creating the job file and selecting a new flexible pavement section, the values for the aircraft established above were introduced. Some of the aircraft were not found on the airplane lists of the program's library, still it was possible to emulate them by selecting the appropriate landing gear configuration and modifying the aircraft Gross Taxi Weight, proceeding next to modify the structure. All the material modulus were set automatically in the program and could not be adjusted.

### 5.1.1.1. Required Structure Section and Reinforcement Overlay

Before calculating the reinforcement needed to withstand the proposed traffic mix it was calculated the section that would be required, with the current configuration of two layers (surface+base), to support this same traffic mix in a new flexible pavement. For this subgrade, section configuration and aircraft traffic mix, the required thickness determined, as seen in **Figure 5.2**, is 523,8 mm, distributed in:

Standard Base (Item P - 209 Crushed Aggregate ): 422,2 mm

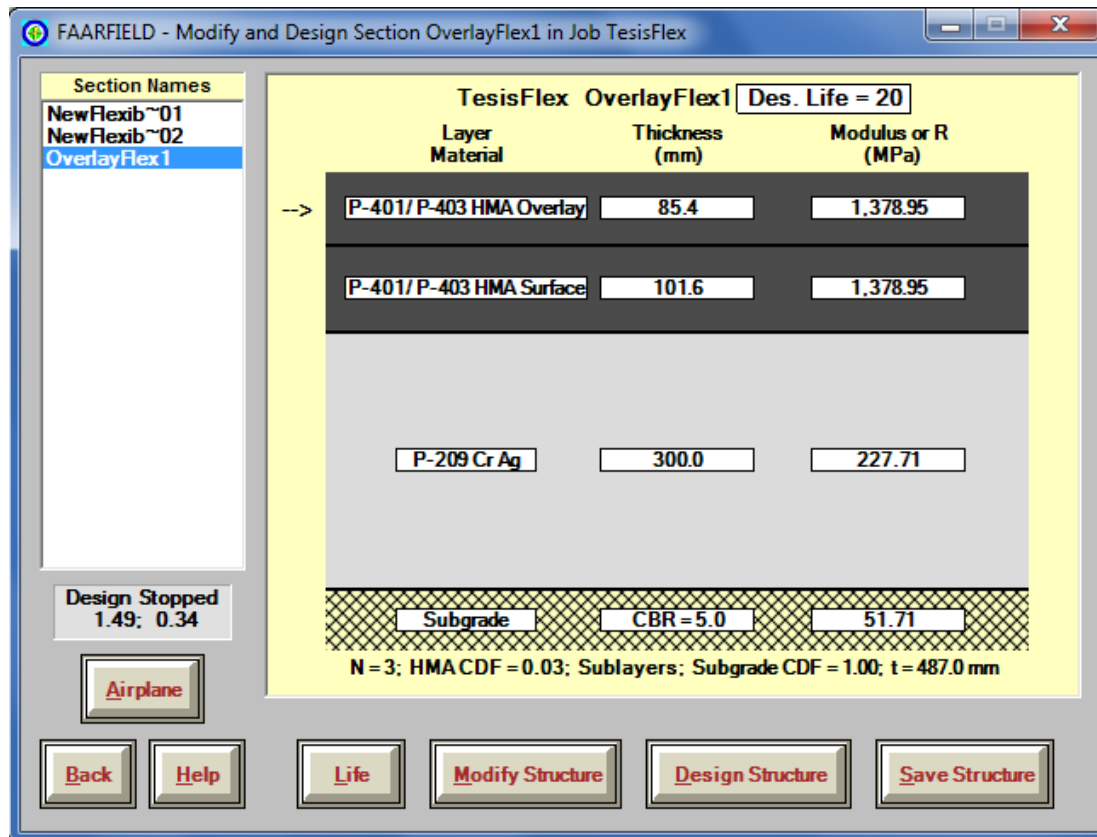
Asphalt Surface (Item P-401 - Plant Mix Bituminous): 101,6 mm



**Figure 5.2.:** Flexible Pavement Design for Two Layer Section (Surface+Base)  
 (Source: Pavement thickness calculations performed with FAARFIELD - Airport Pavement Design V 1.305)

Since the current operative structure is 122,2 mm deficient in the base layer, it was necessary to calculate an overlay that strengthens the pavement so it is able to serve the new traffic mix. With the selection of a Hot Mix Asphalt Overlay of Existing Flexible Pavement, the calculations threw the following thickness results, observed in **Figure 5.3**:

Asphalt	Overlay (Item P-401 - Plant Mix Bituminous): 85,4 mm
Asphalt	Surface (Item P-401 - Plant Mix Bituminous): 101,6 mm
Standard	Base (Item P - 209 Crushed Aggregate ): 300 mm
Total	thickness: 487 mm



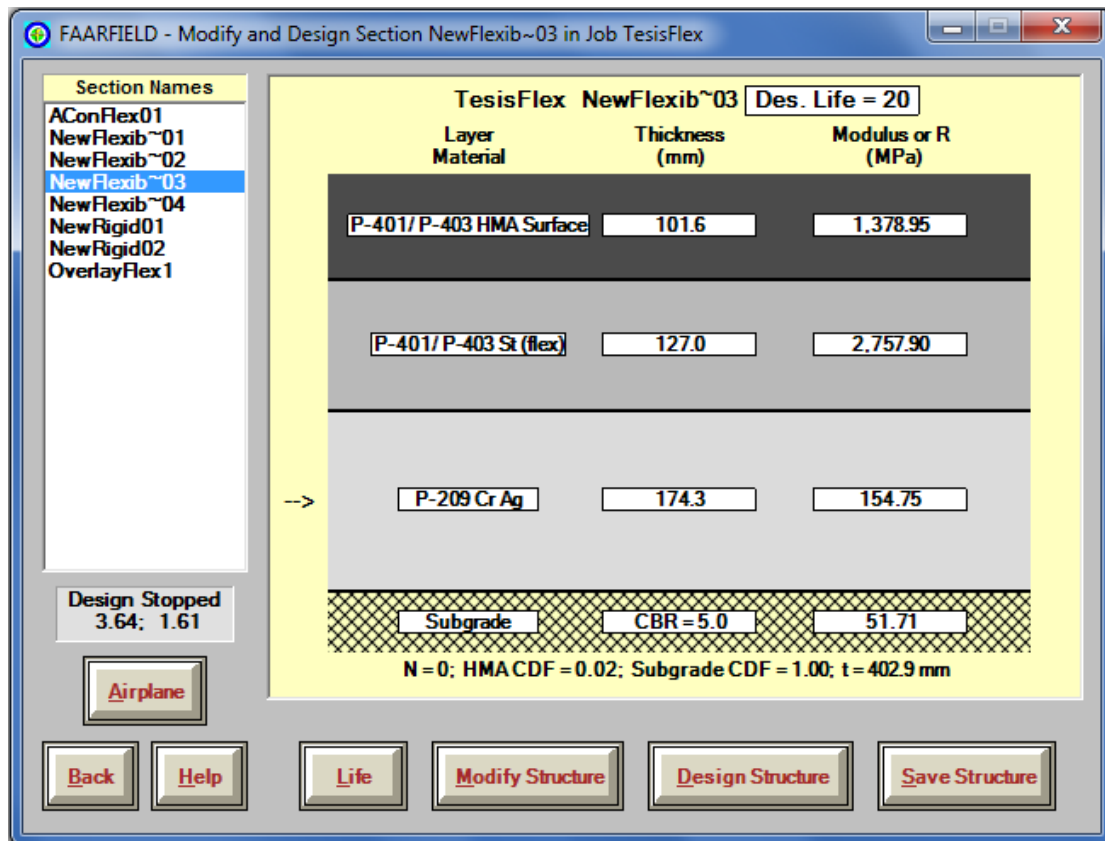
**Figure 5.3.:** Flexible Pavement Section for HMA Overlay Design

(Source: Pavement thickness calculations performed with FAARFIELD - Airport Pavement Design V 1.305)

### 5.1.1.2. Required New Runway Section

For the runway expansion fragment a new structure was calculated comprehending 3 layers, including a stabilized base course, shown in **Figure 5.4:**

Asphalt	Surface (Item P-401 - Plant Mix Bituminous): 101,6 mm
Stabilized	Base (Item P-401/P-403-HMA flex ): 127 mm
Standard	Subbase (Item P - 209 Crushed Aggregate ): 174,3 mm
Total	thickness: 402,9 mm



**Figure 5.4.:** Flexible Pavement Design for Three Layer Section (Surface+St. Base+Subbase)

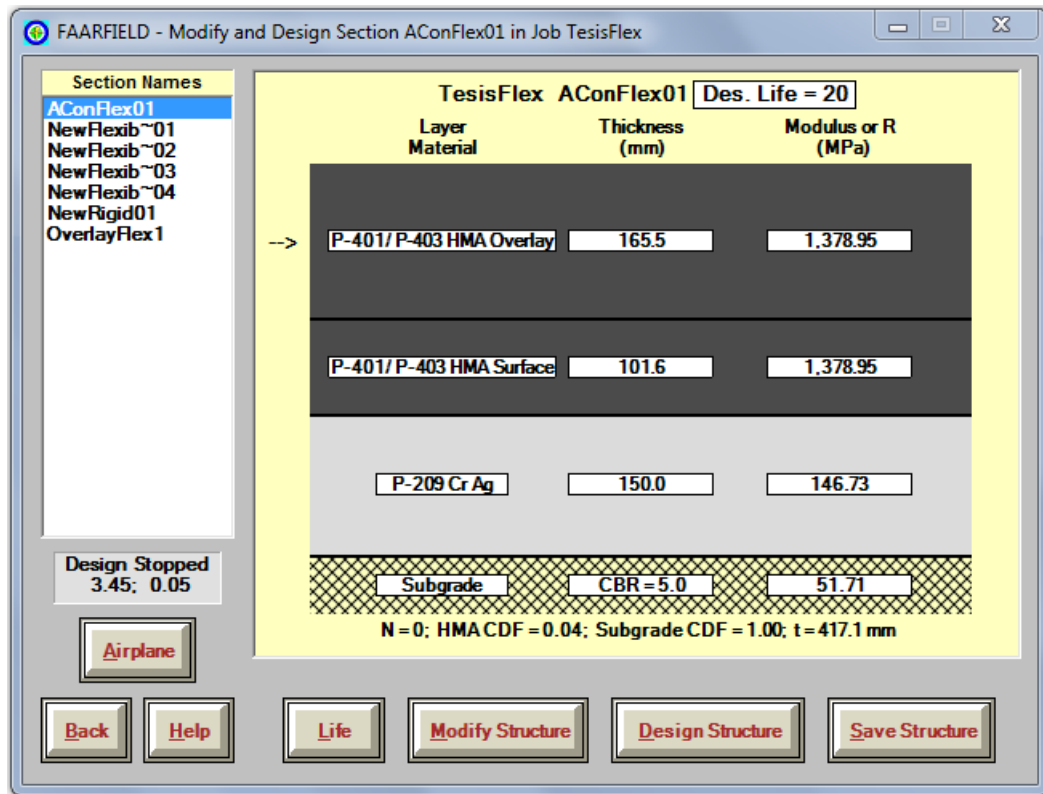
(Source: Pavement thickness calculations performed with FAARFIELD - Airport Pavement Design V 1.305)

### 5.1.1.3. Required Shoulder Overlay

In the case of selecting to expand the runway width from 30 m to 45 m. It becomes necessary to calculate the overlay thickness appropriate to reinforce not only the structure of the existing runway, but also the structure of the shoulders that would become part of the runway. The results were the following, depicted in **Figure 5.5:**

- Asphalt Overlay (Item P-401 - Plant Mix Bituminous): 165,5 mm
- Asphalt Surface (Item P-401 - Plant Mix Bituminous): 101,6 mm
- Standard Base (Item P - 209 Crushed Aggregate ): 150 mm
- Total thickness: 417,1 mm

This asphalt overlay is to be applied over the entire width of the existing runway and existing shoulders. An outline of this configuration is shown further in the Design Alternatives Proposals, as part of the proposed Alternative 2.



**Figure 5.5.:** Flexible Pavement Section for HMA Overlay Design over Runway Shoulders

(Source: Pavement thickness calculations performed with FAARFIELD - Airport Pavement Design V 1.305)

### 5.1.2. Rigid pavement design with FAARFIELD

In addition to the soils survey and analysis and classification of subgrade conditions, the determination of the foundation modulus is required for rigid pavement design. The foundation modulus should be assigned to the subgrade layer; i.e., the layer below all structural layers. The foundation modulus can be expressed as the modulus of subgrade reaction  $k$  or as the elastic (Young's) modulus  $E$  and can be input into the program directly in either form. However, all structural computations are performed using the elastic modulus  $E$ . If the foundation modulus is input as a  $k$ -value it is automatically converted to the equivalent  $E$  value using the following equation [FAA09]:

$$E_{SG} = 26k^{1.284} \quad (5.1)$$

where,

$E_{SG}$  = Foundation modulus of the subgrade

$k$  = Resilient modulus of the subgrade

For existing pavements the E modulus can be determined in the field from non-destructive testing (NDT) such as falling-weight deflectometer (FWD) tests and this may be necessary if direct testing of the subgrade is impractical. If the subgrade is accessible then the  $k$ -value can be determined directly by plate-load testing. If the  $k$ -modulus can be determined by plate load testing, or is otherwise available, then the  $k$ -value should be input directly into the FAARFIELD program without first converting to E modulus.

The preferred method of determining the subgrade modulus is by testing a limited section of representative subgrade, which has been constructed to the required specifications. The plate bearing test procedures are given in AASHTO T 222, Nonrepetitive Static Plate Load Test of Soils and Flexible Pavement Components, for Use in Evaluation and Design of Airport and Highway Pavements. If the construction and testing of a test section of embankment is impractical, the conversion from CBR to  $k$ -value for the subgrade can be achieved using the following formula [FAA09]:

$$k = \left[ \frac{1500 \times CBR}{26} \right]^{-0,7788}, (k \text{ in pci}) \quad (5.2)$$

$$k = \left[ \frac{1500 \times 5}{26} \right]^{-0,7788}$$

$$k = 82,4 \text{ pci} = 22,4 \text{ MN/m}^3$$

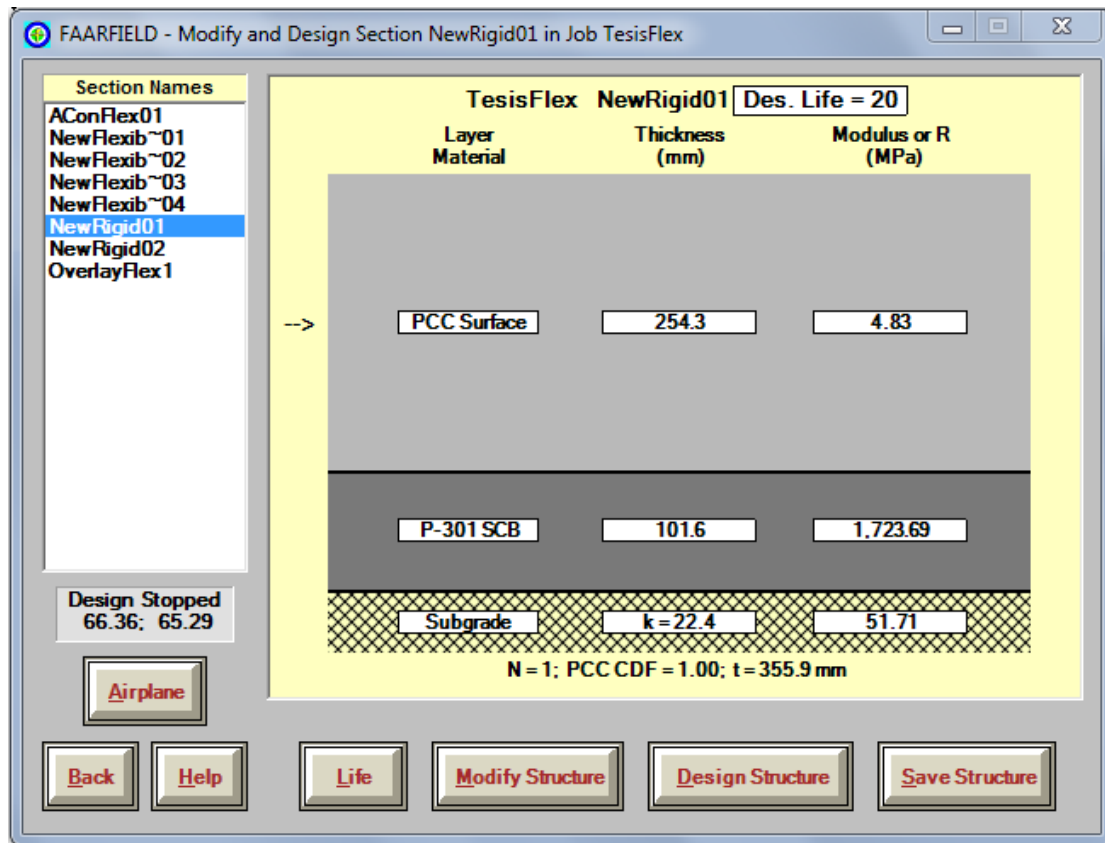
### 5.1.2.1. New Aircraft Parking Apron

After introducing the same input data as in the flexible pavement design and the calculated value of the resilient modulus of the subgrade, the required thickness of the PCC Slab resulted, seen in **Figure 5.6**:

PCC	Surface: 254,3 mm
Stabilized	Subbase (P-301 Soil Cement Base): 101,6 mm
Total	thickness: 355,9 mm

### 5.1.3. Flexible pavement design with FAA Spreadsheet F805FAA.XLS

For the flexible pavement design the spreadsheet goes through 10 steps, prompting the user for design input parameters during each step. In the manual of the spreadsheet it is



**Figure 5.6.:** Rigid Pavement Design for Two Layer Section (Concrete Slab+Subbase)  
 (Source: Pavement thickness calculations performed with FAARFIELD - Airport Pavement Design V 1.305)

warned that it is important to complete the design by following the individual steps in numerical order to assure the proper values are being assigned to the respective variables. But after completing all the steps it is possible to go back and modify the input values of any step, then skip directly to step 10 to see the results of the variable change.

- STEP 1 - General Airport/Project Information: Airport name, location, project number and designer engineer.
- STEP 2 - Subgrade CBR: For the subgrade non frost conditions and a CBR value of 5 were considered.
- STEP 3 - Number of Subbases: 1 Subbase layer.
- STEP 4 - Default Aggregate Base Material: P-209 Crushed Aggregate Base Course
- STEP 5 - Frost Penetration: since it does not affect the thickness calculation, default values were kept.
- STEP 6 - Enter Aircraft Data: values taken from **Table 5.1** of this chapter

- STEP 7 - Find Required Thickness for Each Aircraft: the maximum thickness calculated was 19,64 in for the Bombardier CRJ 700.
- STEP 8 - Accept Critical Aircraft: Bombardier CRJ 700.
- STEP 9 - Compute for Stabilized Layers: Stabilized Base with P-401 and Equivalency Factor recommended of 1,6. For the subbase stabilization was not desired.
- STEP 10 - Go to Design Summary: Results (Found in **Attachment B.7.1**)

### 5.1.3.1. Initial Pavement Cross Section

Figure 5.7.: Initial Pavement Cross Section

Initial Pavement Cross Section	
4"	Pavement Surface Layer (P-401)
6" (3,88)	Base Layer (P-209)
12"	Subbase #1 (P-154) CBR= 20
0"	Subbase #2 CBR= 0
0"	Subbase #3 CBR= 0

(Source: F805FAA.XLS Spreadsheet)

Total Thickness Required (inches) is 22" = 558,8 mm

### 5.1.3.2. Stabilized or Modified Cross Section

Figure 5.8.: Stabilized or Modified Cross Section

Stabilized or Modified Cross Section		Factors
4"	P-401 Plant Mix Bituminous Pavements	
4"	P-401, Plant Mix Bituminous Pavements	1,6
12"	Not stabilized -- P-154	1
0"	Material as defined by user	
0"	Material as defined by user	

(Source: F805FAA.XLS Spreadsheet)

Total Thickness Required (inches) is 20" = 508 mm

Besides the Design Summary it was obtained two graphic charts comparing the Thickness with the Annual Departures and the CBR value.

### 5.1.4. Rigid pavement design with FAA Spreadsheet R805FAA.XLS

For the rigid pavement design the spreadsheet goes through 8 steps, prompting the user for design input parameters during each step. In the manual of the spreadsheet it is warned that it is important to complete the design by following the individual steps in numerical order to assure the proper values are being assigned to the respective variables. But after completing all the steps it is possible to go back and modify the input values of any step, then skip directly to step 8 to see the results of the variable change.

- STEP 1 - General Airport/Project Information: Airport name, location, project number and designer engineer.
- STEP 2 - Subgrade Support Information:  $k=82$  psi, thickness of the stabilized sub-base layer considered 6 in. No design for Frost.
- STEP 3 - Concrete Properties: Flexural Strength of the new concrete = 650 psi.
- STEP 4 - Enter Aircraft Data: values taken from **Table 5.1** of this chapter
- STEP 5 - Calculate thickness for Each Aircraft: Maximum thickness = 6,38 in for Bombardier CRJ 700.
- STEP 6 - Accept Critical Aircraft: Bombardier CRJ 700.
- STEP 7 - Overlay Design: no overlay calculated.
- STEP 8 - Go to Design Summary: Results (Found in **Attachment B.7.2**)

#### 5.1.4.1. New Pavement Section Required

9,2 in (233,68 mm) PCC Thickness

6,0 in (152,4 mm) Stabilized Base

Total Thickness Required (inches) is  $15,2'' = 386,08$  mm

The results include two graphic charts of PCC Slab Thickness versus Annual Departures and PCC Flexural Strength.

It is necessary to conduct a Cost Analysis to compare between the different calculated pavement types, thus determine the best alternative.

## 5.2. Design Alternatives Proposals

Development alternatives were identified and evaluated to meet the projected facility requirements at the Bragança Airport. In accordance with facility requirements identified in Chapter 3, evaluations of the design alternatives focused on two facilities:

- Airfield Facilities, with specific focus on the Airport runway and taxiway system.
- Lanside facilities, with focus only on the aircraft parking apron.

### 5.2.1. Description of Alternatives

Two development options were selected for evaluation to assess the advantages and disadvantages of each. Both will be later compared within the scope of this study to the development option presented in the Bragança Regional Airport Master Plan.

#### 5.2.1.1. Alternative 1

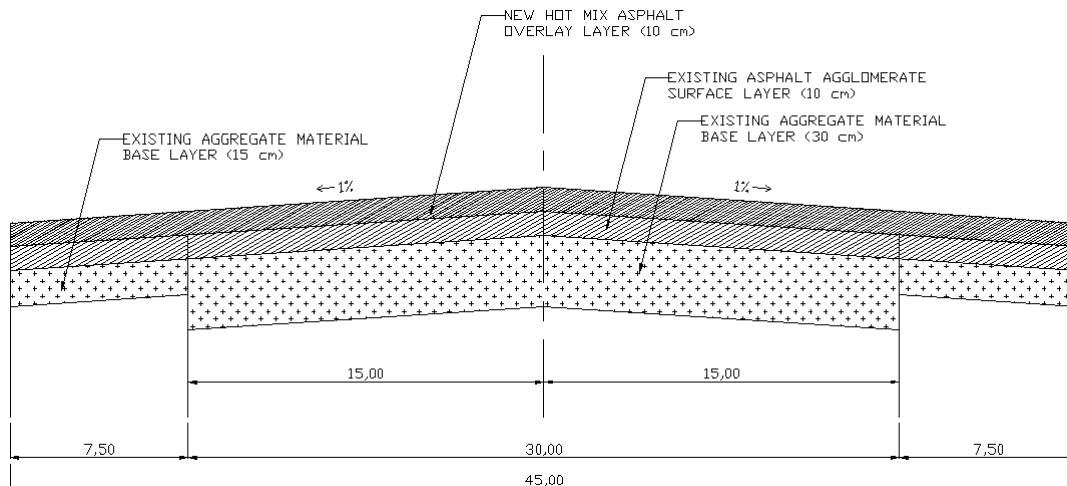
This alternative involves primarily the expansion of the runway in 700 m to reach the required length of 2400 m according with the critical aircraft needs for takeoff. Similarly to the Airport Master Plan, it is recommended this extension to be carried out at both Runway ends; 100 m for Runway 20 and 600 m for Runway 02. It will not be necessary to increase the runway width considering that the wingspan dimension of the new based aircraft fall only in FAA Design Group II, where 30 meters runway widths are acceptable. The runway shoulders will remain 7,5 m wide.

It is also envisaged the expansion of the Runway Safety Area resulting in final dimensions of 2640 m in length and 150 m of width. Complying additional requirements of clearing, grading, slopes and strength on these areas.

Conjointly to the extension of the runway, it is imperative to perform a reinforcement and improvement to pavement in order to adequate it for the operations of the design aircraft that is conceived to serve. Through the use of pavement design software the proper thickness were calculated for the zones that need either reinforcement or construction of new pavement.

For the refurbishment of the existing runway is proposed a 10 cm asphalt coating with the material designated Item P-401 - Plant Mix Bituminous, including as well the whole width of the runway shoulders, as shown in **Figure 5.9**. For new pavement is advised a three layer configuration including a 10 cm asphalt surface (P-401), 15 cm stabilized base course (P-401/P-403) and a subbase of 18 cm with crushed aggregate (P-209).

It is foreseen a new aircraft parking apron to accommodate the forecast based aircraft. Though its area was not calculated, a pavement structure was designed to implement in this platform. Correspondingly a PCC Slab of 25,5 cm above a 10 cm subbase layer of soil cement base (P-301). Consequently a new taxiway will be needed to connect the new

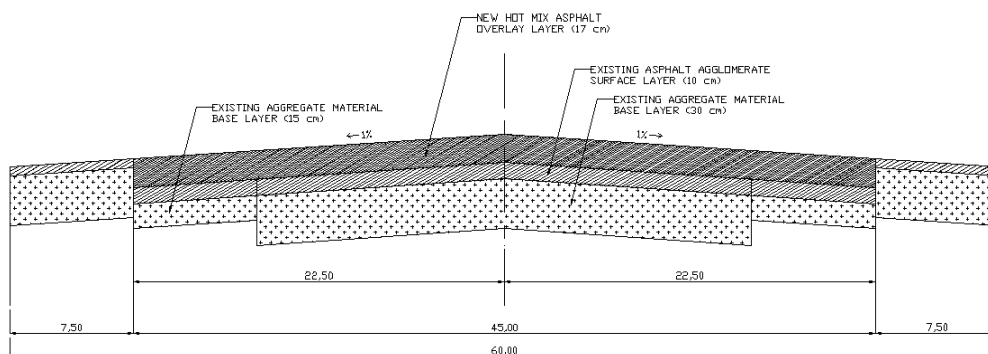


**Figure 5.9.:** Existing Runway Final Configuration, Alternative 1.

parking apron to the runway, envisioned to have the same pavement structure as the new extended runway. Perpendicular to the centerline of it and 15 m wide.

### 5.2.1.2. Alternative 2

A second alternative is considered changing practically only on increasing the width of the runway to 45 m to achieve a 4C reference code. However, for this to be performed it is necessary to alter the pavement design taking into account that the existing shoulders have a weaker pavement configuration compared to that of the runway. For this the overlay coating would have to increase from the recommended 10 cm to 17 cm using the same materials, and therefore new runway shoulders to be constructed. A cross section of the runway structure configuration is illustrated in **Figure 5.10**.



**Figure 5.10.:** Existing Runway Final Configuration, Alternative 2.

### 5.2.2. Comparison of Alternatives

The **Table 5.2** presents a comparison of the Airfield Facilities between the described alternatives and the projected in the Bragança Regional Airport Master Plan.

**Table 5.2.:** Airfield Facilities Comparison

DESCRIPTION	DEVELOPMENT ALTERNATIVES				
	REQUIREMENTS		ALTERNATIVE 1	ALTERNATIVE 2	ALTERNATIVE MP
	FAA	ICAO			
Airport Code	C-II	4C			
Design Aircraft			Bombardier CRJ 700		BOEING 737-800
<b>Runway Design</b>					
Wind Coverage (02-20)	95% Wind Coverage		99,84%	99,84%	100%
Crosswind Component	16	16	16	16	10
Length (m)		2420	2400	2400	2300
Width (m)	30	45	30	45	45
Shoulders (m)	3	7,5	7,5	7,5	7,5
Long. Grade	1,5	1	1	1	1
<b>Runway Safety Area</b>					
Width (m)	150	150	150	150	150
Length (m) (beyond runway end)	300	240	2640	2640	2420
<b>Taxiways</b>					
Width (m)	15	18	15	15	18

In terms of pavement design, since the size of the critical aircraft is significantly reduced it is explicit that the required thickness to provide the sufficient strength are lessen considerably for all the paved areas.



## **6. Conclusions and Further Works**

### **6.1. Conclusions**

The realization of this evaluation was conducted with the purpose of reducing the costs involved in the Bragança Airport Expansion Project exposed by the Master Plan. Through the analysis of existing conditions, a new proposed critical aircraft was introduced to lessen the requirements needed at the airport.

Recommended values for the new aircraft were established combining both ICAO and FAA standards and regulations. After following design procedures and recommendations several calculations were performed with the use of related software.

The results obtained were used to develop the alternatives described. Ensuing the assessment of the alternatives developed, for the accomplishment of the purpose of the evaluation is concluded that the best alternative to follow is the Alternative 1. Considering that it involves less pavement construction. Even though the resultant runway length exceeds the one proposed in the Airport Master Plan. The significant reduction in size and weight of the critical aircraft decreases most of the facility requirements.

### **6.2. Further Works**

The scope of this study was limited to the geometrical and structural characteristics focused on the air side area. So as further work is recommended to extend the reach of the evaluation and delve into all the aspects regarding the full development of the Master Plan considering the new critical aircraft.

It is advised as well to conduct a feasibility study and economic study to verify the real cost to develop the selected alternative.



# A. Appendix

## A.1. Glossary

[FAA07][FAA12]

***Aerodrome*** – 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.

***Aerodrome Reference Code (ICAO)*** – A code intended to provide a simple method for interrelating the numerous specifications concerning characteristics of aerodromes so as to provide a series of aerodrome facilities that are suitable for the aeroplanes that are intended to operate at the aerodrome. The code is composed of two elements which are related to the aeroplane performance characteristics and dimensions. Element 1 is a number based on the aeroplane reference field length and element 2 is a letter based on the aeroplane wing span and outer main gear wheel span.

***Advisory Circular*** – External publications issued by the FAA consisting of non-regulatory material providing for the recommendations relative to a policy, and guidance and information relative to a specific aviation subject.

***Aircraft Approach Category*** – An alphabetic classification of aircraft based upon 1.3 times the stall speed in a landing configuration at their maximum certified landing weight.

***Aircraft Operation*** – The landing, takeoff or touch-and-go procedure by an aircraft on a runway at an airport.

***Aircraft Rescue and Fire Fighting*** – A facility located at an airport that provides emergency vehicles, extinguishing agents, and personnel responsible for minimizing the impacts of an aircraft accident or incident.

***Airfield*** – The portion of an airport that contains the facilities necessary for the operation of aircraft.

***Airplane Design Group*** – A Roman numerical classification of aircraft based upon wingspan.

***Airport Authority*** – A quasi-governmental public organization responsible for setting the policies governing the management and operation of an airport or system of airports under its jurisdiction.

***Airport Layout Plan*** – A scaled drawing of the existing and planned land and facilities necessary for the operation and development of an airport.

***Airport Master Plan*** – The planner’s concept of the long-term development of an airport.

***Airport Reference Code (FAA)*** – A coding system used to relate airport design criteria to the operational and physical characteristics of the airplanes intended to use the airport. It is a two character code consisting of the aircraft approach category and the airplane design group.

***Airport Reference Point*** – The latitude and longitude of the geometric center of the runway system at an airport.

***Airport Sponsor*** – The entity that is legally responsible for the management and operation of an airport including the fulfillment of the requirements of laws and regulations related thereto.

***Airside*** – The portion of an airport that contains the facilities necessary for the operation of aircraft.

***Airport Traffic Control Tower*** – A facility in the terminal air traffic control system located at an airport which consists of a tower cab structure and an associated instrument flight rules room, if radar equipped, that uses ground-to-air and air-to-ground communications and radar, visual signaling, and other devices to provide for the safe and expeditious movement of terminal area air traffic in the airspace and airports within its jurisdiction.

***Annual Service Volume (ASV)*** – The number of annual operations that can reasonably be expected to occur at the airport based on a given level of delay.

***Approach Surface*** – An imaginary obstruction limiting surface defined in FAR Part 77 which is longitudinally centered on an extended runway centerline and extends outward and upward from the primary surface at each end of a runway at a designated slope and distance based upon the type of available or planned approach by aircraft to a runway.

***Apron*** – A specified portion of the airfield used for passenger, cargo or freight loading and unloading, aircraft parking, and the refueling, maintenance and servicing of aircraft.

***Based Aircraft*** – The general aviation aircraft that use a specific airport as a home base.

***Clearway (CWY)*** – A defined rectangular area beyond the end of a runway cleared or suitable for use in lieu of runway to satisfy takeoff distance requirements.

**Computer Aided Design** – Software that is commonly used for drafting architectural and engineering drawings.

**Critical (Design) Aircraft** – The most demanding aircraft with at least 500 annual operations that operates, or is expected to operate, at the airport.

**Crosswind** – A wind that is not parallel to a runway centerline or to the intended flight path of an aircraft.

**Crosswind Component** – The component of wind that is at a right angle to the runway centerline or the intended flight path of an aircraft.

**Declared Distances** – The distances the airport owner declares available for a turbine powered aircraft's takeoff run, takeoff distance, accelerate-stop distance, and landing distance requirements.

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 the clearway, if provided.
3. **Accelerate-stop distance available (ASDA)**. The length of the take-off run available plus the length of the stopway, 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.

**Displaced Threshold** – An aircraft runway landing area that begins at a point on the runway other than the designated physical end of the runway.

**Ground Access** – The transportation system on and around the airport that provides access to and from the airport by ground transportation vehicles for passengers, employees, cargo, freight, and airport services.

**Instrument Meteorological Conditions** – Meteorological conditions expressed in terms of specific visibility and ceiling conditions that are less than the minimums specified for visual meteorological conditions.

**Landing area** – That part of a movements area intended for the landing or take-off of aircraft.

**Landside** – The portion of an airport that provides the facilities necessary for the processing of passengers, cargo, freight, and ground transportation vehicles.

**Local Operations** – Aircraft operations performed by aircraft that are based at the airport and that operate in the local traffic pattern or within sight of the airport, that are known to

be departing for or arriving from flights in local practice areas within a prescribed distance from the airport, or that execute simulated instrument approaches at the airport.

**Navigational Aid** – A facility used as, available for use as, or designed for use as an aid to air navigation.

**Non-instrument Runway** – A runway intended for the operation of aircraft using visual approach procedures.

**Object Free Area (OFA)** – An area centered on the ground on a runway, taxiway, or taxilane centerline provided to enhance the safety of aircraft operations by remaining clear of objects, except for objects that need to be located in the OFA for air navigation or aircraft ground maneuvering purposes.

**Obstacle** – An existing object at a fixed geographical location or which may be expected at a fixed location within a prescribed area with reference to which vertical clearance is or must be provided during flight operation.

**Obstacle Clearance Surface (OCS)** – An evaluation surface that defines the minimum required obstruction clearance for approach or departure procedures.

**Operation** – The landing, takeoff or touch-and-go procedure by an aircraft on a runway at an airport.

**Peak Hour (PH)** – An estimate of the busiest hour in a day. This is also known as the design hour.

**Runway** – A defined rectangular area at an airport designated for the landing and taking-off of an aircraft.

**Runway End Safety Area (RESA)** – An area symmetrical about the extended runway centre line and adjacent to the end of the strip primarily intended to reduce the risk of damage to an aeroplane undershooting or overrunning the runway.

**Runway Gradient** – The ratio of the change in elevation divided by the length of the runway expressed as a percentage.

**Runway Strip** – A defined area including the runway and stopway, if provided, intended to reduce the risk of damage to aircraft running off a runway and to protect the aircraft flying over it during take-off or landing operations.

**Scope** – The document that identifies and defines the tasks, emphasis and level of effort associated with a project or study.

**Shoulder** – An area adjacent to the edge of a pavement so prepared as to provide a transition between the pavement and the adjacent surface.

**Stopway (SWY)** – An area beyond the takeoff runway, no less wide than the runway and centered upon the extended centerline of the runway, able to support the airplane during an aborted takeoff, without causing structural damage to the airplane, and designated by the airport authorities for use in decelerating the airplane during an aborted takeoff. A blast pad is not a stopway.

**Threshold** – The beginning of that portion of the runway usable for landing.

**Visual Flight Rules** – Procedures for the conduct of flight in weather conditions above Visual Flight Rules (VFR) weather minimums. The term VFR is often also used to define weather conditions and the type of flight plan under which an aircraft is operating.





**Visual Meteorological Conditions** – Meteorological conditions expressed in terms of specific visibility and ceiling conditions which are equal to or greater than the threshold values for instrument meteorological conditions.



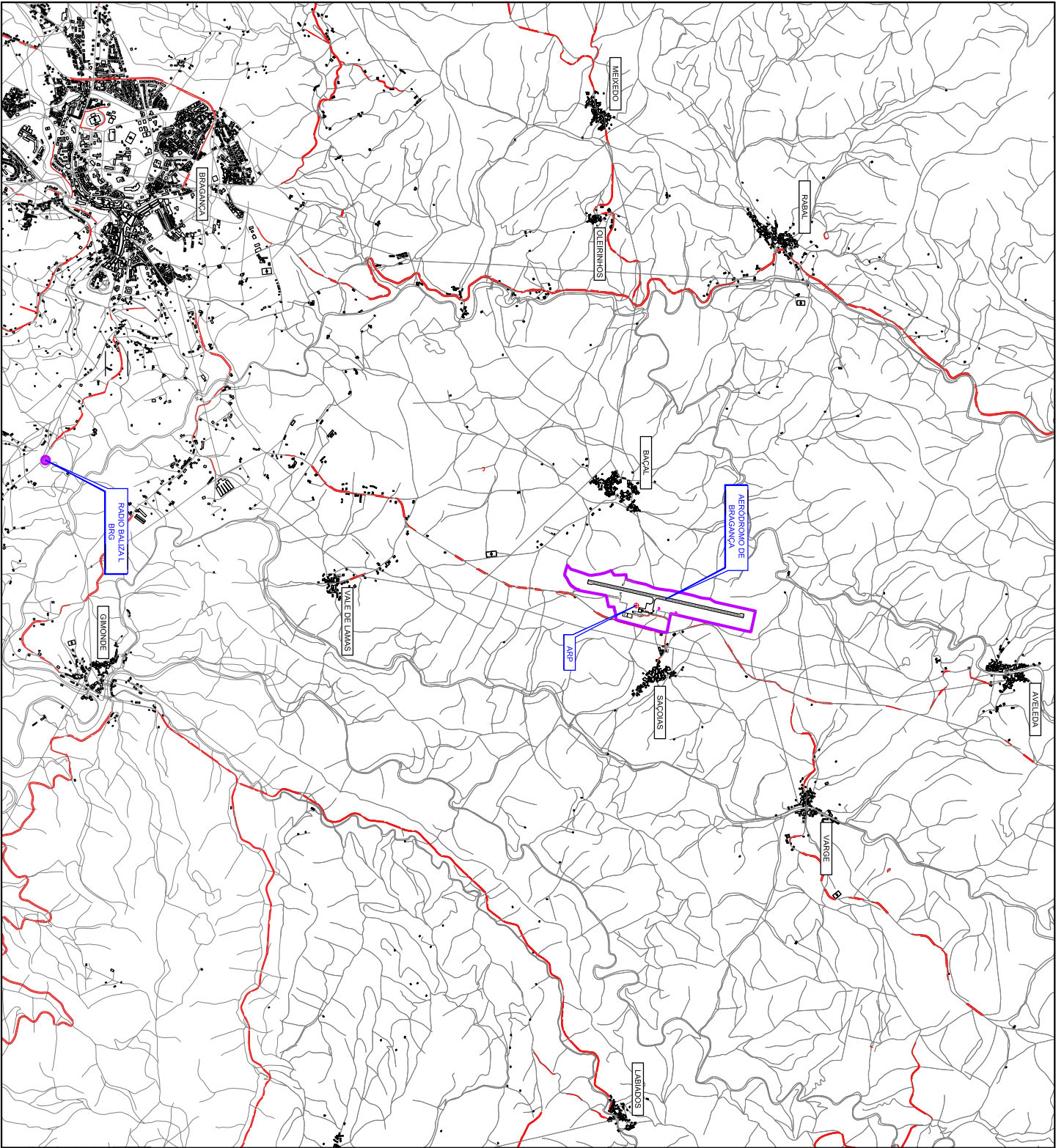
## B. Attachments

### B.1. Bragança Regional Airport Master Plan Layouts

#### B.1.1. Positioning<sup>1</sup>


LEGEND			
		EXISTING AIRPORT PROPERTY LINE	
		RAILWAY NETWORK	
SYMBOL	INSTALATION	GEOGRAPHIC COORDENATES	
	ARP	41° 51' 18" N 06° 42' 23" W	
RADIOELECTRIC INSTALATIONS			
SYMBOL	INSTALATION	ID	GEOGRAPHIC COORDENATES
	L	BRG	41° 47' 47" N 06° 43' 31" W

<sup>1</sup>Source: Bragança Regional Airport Master Plan - SENER, Ingeniería y Sistemas, S.A.



LEGENDA			
	PERÍMETRO DOS TERRENOS DO AEROPORTO		
	REDE RODoviÁRIA		
	INSTALAÇÃO	COORDENADAS GEOGRÁFICAS	
	APP	41° 51' 18" N	09° 42' 23" W
INSTALAÇÕES RADIOELÉTRICAS			
	SÍMBOLO	INSTALAÇÃO	COORDENADAS GEOGRÁFICAS
	L	BRG	41° 47' 47" N 09° 43' 31" W


**PLANO DIRECTOR DO AEROPORTO REGIONAL DE BRAGANÇA**  
**IMPLANTAÇÃO GERAL DO AEROPORTO**

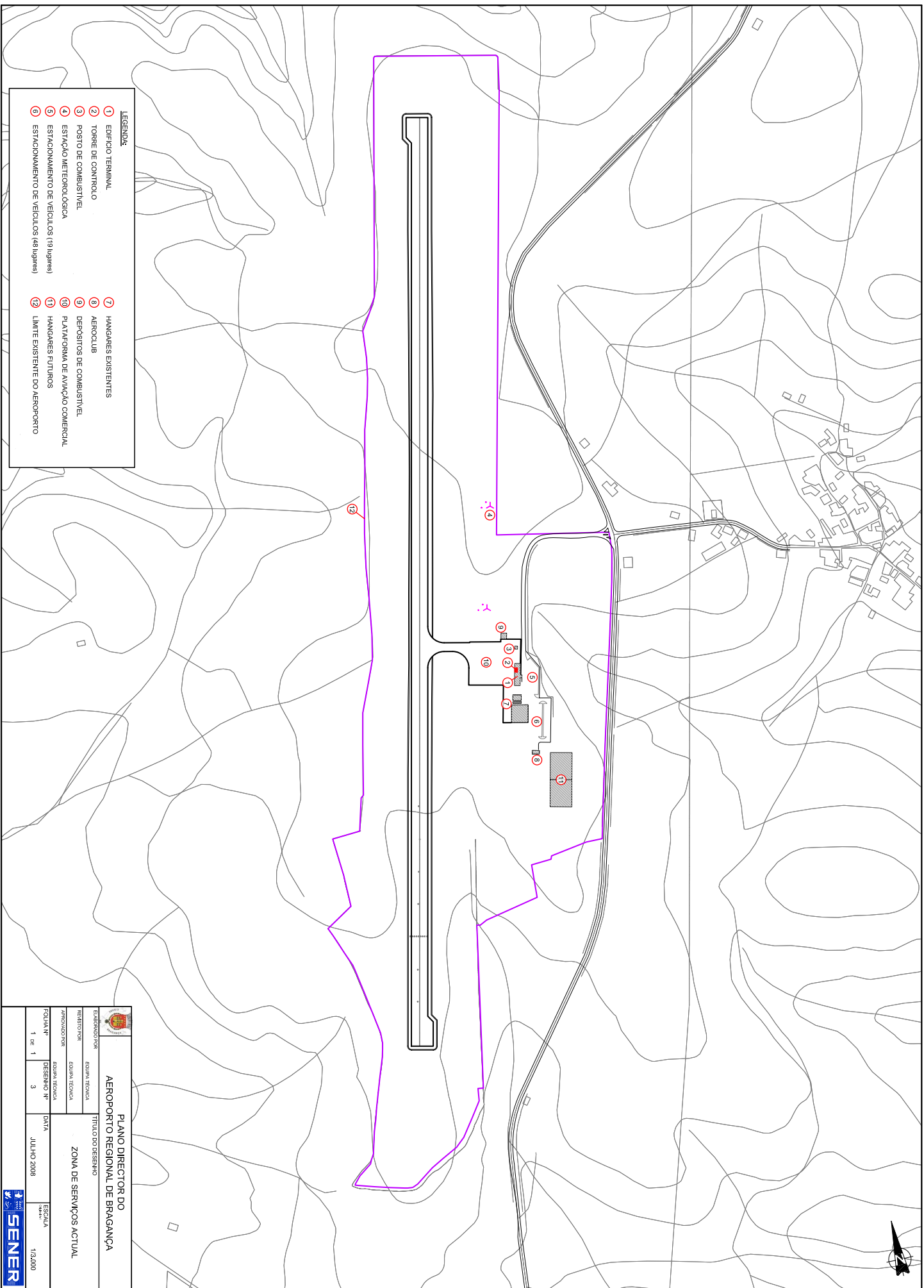
ELABORADO POR	ESQUINA TÉCNICA	TÍTULO DO DESENHO	
REVISOR POR	ESQUINA TÉCNICA		
APROVADO POR	ESQUINA TÉCNICA		
FOLHA Nº	DESENHO Nº	DATA	ESCALA
1 DE 1	2	JULHO 2008	1:20.000
			

### B.1.2. Current Property Line<sup>2</sup>



<u>LEGEND:</u>	
①	TERMINAL BUILDING
②	CONTROL TOWER
③	FUEL SUPPLY STATION
④	METEOROLOGICAL STATION
⑤	AUTOMOBILE PARKING (19 places)
⑥	AUTOMOBILE PARKING (48 places)
⑦	EXISTING HANGARS
⑧	AEROCLUB
⑨	FUEL STORAGE
⑩	COMMERCIAL AVIATION APRON
⑪	FUTURE HANGARS
⑫	EXISTING AIRPORT PROPERTY LINE

---

<sup>2</sup>Source: Bragança Regional Airport Master Plan - SENER, Ingeniería y Sistemas, S.A.



- LEGENDA:**
- 1 EDIFÍCIO TERMINAL
  - 2 TORRE DE CONTROLO
  - 3 POSTO DE COMBUSTÍVEL
  - 4 ESTAÇÃO METEOROLÓGICA
  - 5 ESTACIONAMENTO DE VEÍCULOS (19 lugares)
  - 6 ESTACIONAMENTO DE VEÍCULOS (48 lugares)
  - 7 HANGARES EXISTENTES
  - 8 AEROCUB
  - 9 DEPOSITOS DE COMBUSTÍVEL
  - 10 PLATAFORMA DE AVIAÇÃO COMERCIAL
  - 11 HANGARES FUTUROS
  - 12 LIMITE EXISTENTE DO AEROPORTO

 <b>PLANO DIRECTOR DO AEROPORTO REGIONAL DE BRAGANÇA</b>		<b>ZONA DE SERVIÇOS ACTUAL</b>	
ELABORADOR	ESCALA TÉCNICA	TÍTULO DO DESENHO	
REVISOR	ESCALA TÉCNICA		
APROVADOR			
FOLHA Nº	RESERVA TÉCNICA	DATA	ESCALA
1 de 1	3	JULHO 2008	1:2.000
			

## **B.2. Bragança LPBG Visual Approach Chart<sup>3</sup>**

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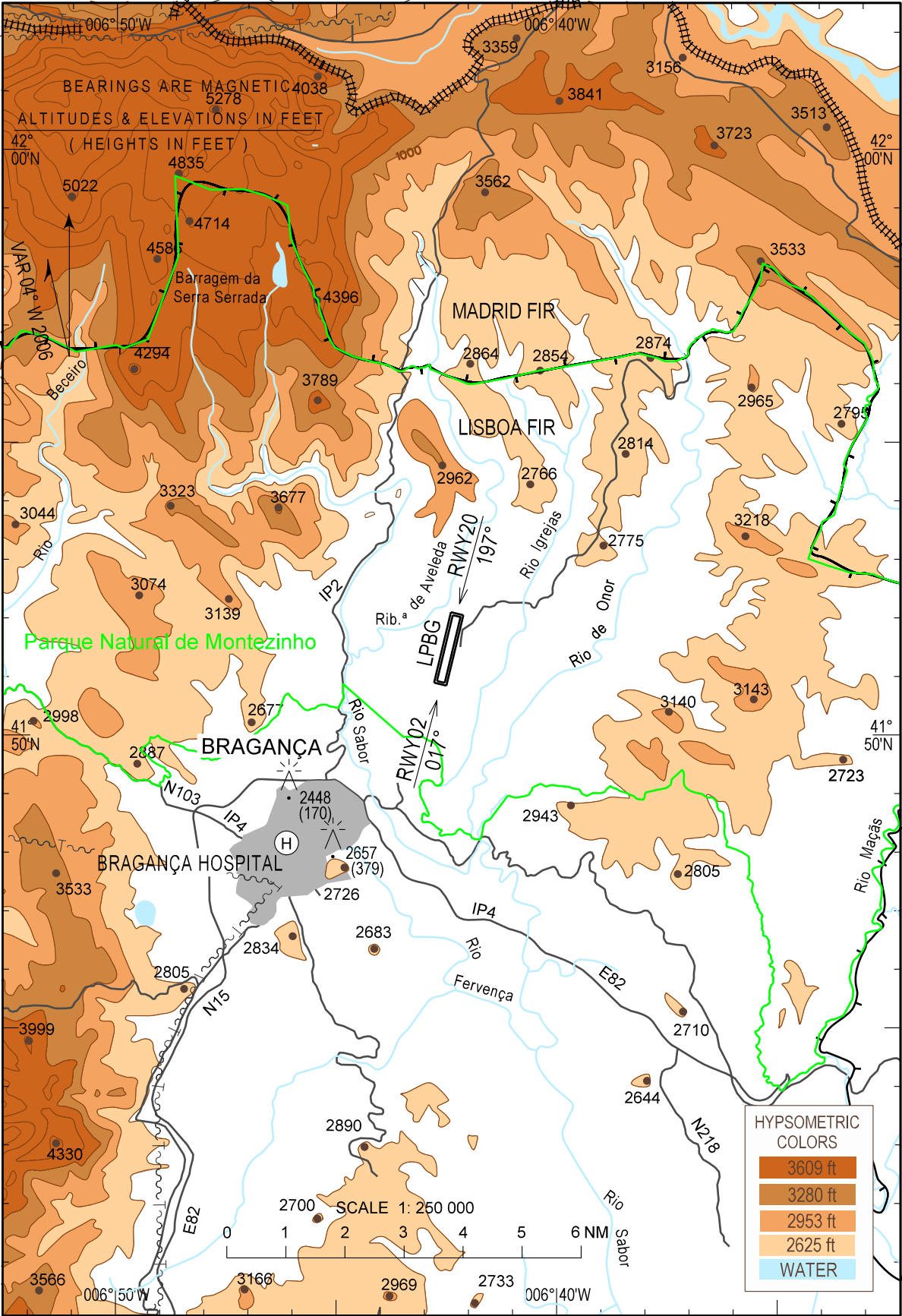
<sup>3</sup>Source: *VFR Manual, AIS, NAV Portugal 2012*

CARTA APROXIMAÇÃO VISUAL  
VISUAL APPROACH CHART

AD ELEV 2278 ft  
HEIGHTS RELATED  
TO AD ELEV

BRAGANÇA / LPBG

AFIS 122.300 FIS 130.900



### **B.3. Extract of Aircraft Classification Numbers (ACN's) Charts<sup>4</sup>**

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<sup>4</sup>Excerpt from Aircraft Classification Numbers obtained from [www.tc.gc.ca](http://www.tc.gc.ca)

## **AIRCRAFT CLASSIFICATION NUMBERS (ACN's)**

<i>Aircraft</i>	<i>Weight Max/Min (kN)</i>	<i>Tire Pressure (MPa)</i>	<i>Flexible Pavement Subgrades</i>				<i>Rigid Pavement Subgrades</i>			
			<i>CBR</i>				<i>k (MPa/m)</i>			
			<i>High A 15</i>	<i>Medium B 10</i>	<i>Low C 6</i>	<i>Vr Low D 3</i>	<i>High A 150</i>	<i>Medium B 80</i>	<i>Low C 40</i>	<i>Ult Low D 20</i>
B717-100, 200, 300	543 310	1.10	32 16	34 17	38 19	40 22	36 18	38 20	40 21	41 21
B720, 720B	1045 700	1.01	28 17	30 18	37 21	49 28	24 15	29 17	35 20	41 24
B727-100, 100C	756 450	1.14	41 23	43 23	49 25	54 30	45 24	48 26	51 28	53 29
B727-200	770 450	1.15	42 23	44 23	50 25	55 30	47 25	50 26	52 28	54 29
B727-200 (Advanced)	934 450	1.19	53 23	57 23	64 26	69 30	60 25	63 26	66 28	69 30
B727-200F (Advanced)	907 450	1.15	52 23	54 23	61 25	66 30	57 25	60 26	63 28	66 29
B737-100	445 260	1.02	23 12	23 12	26 14	30 16	25 13	26 14	28 15	29 16
B737-200, 200C, Advanced	572 300	1.26	31 15	32 15	37 16	41 19	35 17	37 18	39 19	41 20
B737-300	623 325	1.40	35 16	37 17	41 18	45 21	40 19	42 20	44 21	46 22
B737-400	670 350	1.28	38 18	40 18	45 20	49 23	43 20	45 21	47 22	49 23
B737-500	596 320	1.34	33 16	35 16	39 18	43 21	38 18	40 19	42 20	43 21
B737-600	645 357	1.30	35 18	36 18	40 19	45 22	39 20	41 21	44 22	45 23
B737-700	690 370	1.39	38 18	40 19	44 20	49 23	43 21	46 22	48 23	50 24
B737-800	777 406	1.47	44 21	46 21	51 23	56 26	51 24	53 25	56 26	57 27
B737-900	777 420	1.47	44 21	46 22	51 24	56 28	51 24	53 26	56 27	57 28
B747-100, 100B, 100SF	3350 1700	1.55	49 21	54 22	65 25	86 32	46 20	54 22	64 25	73 29

## **AIRCRAFT CLASSIFICATION NUMBERS (ACN's)**

<i>Aircraft</i>	<i>Weight Max/Min (kN)</i>	<i>Tire Pressure (MPa)</i>	<i>Flexible Pavement Subgrades</i>				<i>Rigid Pavement Subgrades</i>				
			<i>CBR</i>				<i>k (MPa/m)</i>				
			<i>High A 15</i>	<i>Medium B 10</i>	<i>Low C 6</i>	<i>Vr Low D 3</i>	<i>High A 150</i>	<i>Medium B 80</i>	<i>Low C 40</i>	<i>Ult Low D 20</i>	
Beech Queen Air 65, 70, 80 Series	40 25	0.33	----	----	----	----	----	----	----	----	----
Bombardier BD-700 (Global Express)	432 220	1.21	26 11	28 12	30 13	32 15	30 13	31 14	32 15	33 15	
C-141B Starlifter (Lockheed)	1553 600	1.31	52 15	60 16	73 18	88 24	51 14	61 16	70 19	78 22	
C-17A (Globemaster III)	2602 2000	0.95	54 38	61 42	73 50	94 65	54 41	49 38	57 40	71 48	
C-5A Galaxy (Lockheed)	3421 1500	0.73	27 10	30 11	35 12	46 15	25 10	28 11	33 12	39 13	
C123K Provider (Fairchild/Republic)	267 180	0.69	20 13	22 15	24 16	25 17	21 14	21 14	22 15	22 15	
Canadair CL-215, 415	196 130	0.55	12 8	15 10	17 11	18 12	14 9	14 10	15 10	15 10	
Canadair CL-41A (CT-114 Tutor)	49 24	0.37	----	----	----	----	----	----	----	----	
Canadair Regional Jet - 100, 200 Srs	236 135	1.12	13 7	14 7	16 8	17 9	16 8	16 9	17 9	18 9	
Canadair Regional Jet - 700 Series	335 195	1.24	18 10	19 10	21 11	24 13	21 11	22 12	23 12	24 13	
Canadair Regional Jet - 900, ER Srs	367 215	1.24	20 11	21 11	24 12	26 14	23 12	25 13	26 14	27 14	
Cessna 114B (Commander)	15 10	0.35	----	----	----	----	----	----	----	----	
Cessna 152	8 5	0.20	----	----	----	----	----	----	----	----	
Cessna 172 (Skyhawk)	11 7	0.19	----	----	----	----	----	----	----	----	
Cessna 180 (Skywagon)	13 8	0.21	----	----	----	----	----	----	----	----	
Cessna 182 (Skylane)	14 9	0.25	----	----	----	----	----	----	----	----	

### B.4. PCN Values COMFAA Results<sup>5</sup>

Evaluation pavement thickness = 500.0 mm  
 Pass to Traffic Cycle (PtoTC) Ratio = 1.00  
 Maximum number of wheels per gear = 1  
 Maximum number of gears per aircraft = 2

No aircraft have 4 or more wheels per gear. The FAA recommends a reference section assuming 76 mm of HMA and 152 mm of crushed aggregate for equivalent thickness calculations.

Results Table 1. Input Traffic Data

No.	Aircraft Name	Gross Weight	Percent Gross Wt	Tire Press	Annual Deps	20-yr Coverages	6D Thick
1	Dornier 228	13.900	95.00	862	1,456	3,659	417.8
2	Skyhawk-172	1.150	95.00	345	495	568	92.6
3	Morane Saulnier 893	1.050	95.00	310	495	808	127.7
4	Seneca-II	1.905	95.00	379	495	696	124.5
5	RegionalJet-700	34.019	95.00	1,262	252	1,089	509.5

Results Table 2. PCN Values

No.	Aircraft Name	Critical Aircraft Total		Thickness for Total Equiv. Covs.	Maximum Allowable Gross Weight	PCN at Indicated Code				CDF
		Weight	Covs.			A(15)	B(10)	C(6)	D(3)	
1	Dornier 228	67,482		506.4	13.551	11.1	12.0	12.1	12.5	0.0687
2	Skyhawk-172	>5,000,000		238.0	5.076	2.0	2.7	3.6	4.2	0.0000
3	Morane Saulnier 893	>5,000,000		316.0	2.629	1.8	2.6	3.5	4.3	0.0000
4	Seneca-II	>5,000,000		313.0	4.862	2.1	2.8	3.6	4.1	0.0000
5	RegionalJet-700	1,151		512.4	32.720	17.8	18.9	21.2	23.2	1.1984
						Total CDF =				1.2671

Results Table 3. Flexible ACN at Indicated Gross Weight and Strength

No.	Aircraft Name	Gross Weight	% GW on Main Gear	Tire Pressure	ACN			
					A(15)	B(10)	C(6)	D(3)
1	Dornier 228	13.900	95.00	862	11.4	12.3	12.4	12.8
2	Skyhawk-172	1.150	95.00	345	0.5	0.6	0.8	1.0
3	Morane Saulnier 893	1.050	95.00	310	0.7	1.0	1.4	1.7
4	Seneca-II	1.905	95.00	379	0.8	1.1	1.4	1.6
5	RegionalJet-700	34.019	95.00	1,262	18.6	19.9	22.2	24.2

Results Table 4. Summary Output for Copy and Paste Into the Support Spread Sheet

Num, Plane, GWin, ACNin, ADout, 6Dt, COV20yr, COVtoF, CDfT, GWcdf, PCNcdf, EVALt, SUBcode, KorCBR, PtoTC, FlexOrRig  
 1, Dornier 228, 13.900, 12.4, 1456, 417.78, 3.65915E+003, 5.32582E+004, 506.39, 13.551, 12.1, 500.0, C, 5.00, 1.00, F  
 2, Skyhawk-172, 1.150, 0.8, 495, 92.60, 5.67602E+002, 4.75622E+212, 237.98, 5.076, 3.6, 500.0, C, 5.00, 1.00, F  
 3, Morane Saulnier 893, 1.050, 1.4, 495, 127.70, 8.07865E+002, 1.01423E+304, 315.98, 2.629, 3.5, 500.0, C, 5.00, 1.00, F  
 4, Seneca-II, 1.905, 1.4, 495, 124.47, 6.96295E+002, 1.01423E+304, 312.98, 4.862, 3.6, 500.0, C, 5.00, 1.00, F  
 5, RegionalJet-700, 34.019, 22.2, 252, 509.47, 1.08853E+003, 9.08343E+002, 512.35, 32.720, 21.2, 500.0, C, 5.00, 1.00, F

<sup>5</sup>Source: COMFAA 3.0

## **B.5. Computer Software for Wind Analysis**

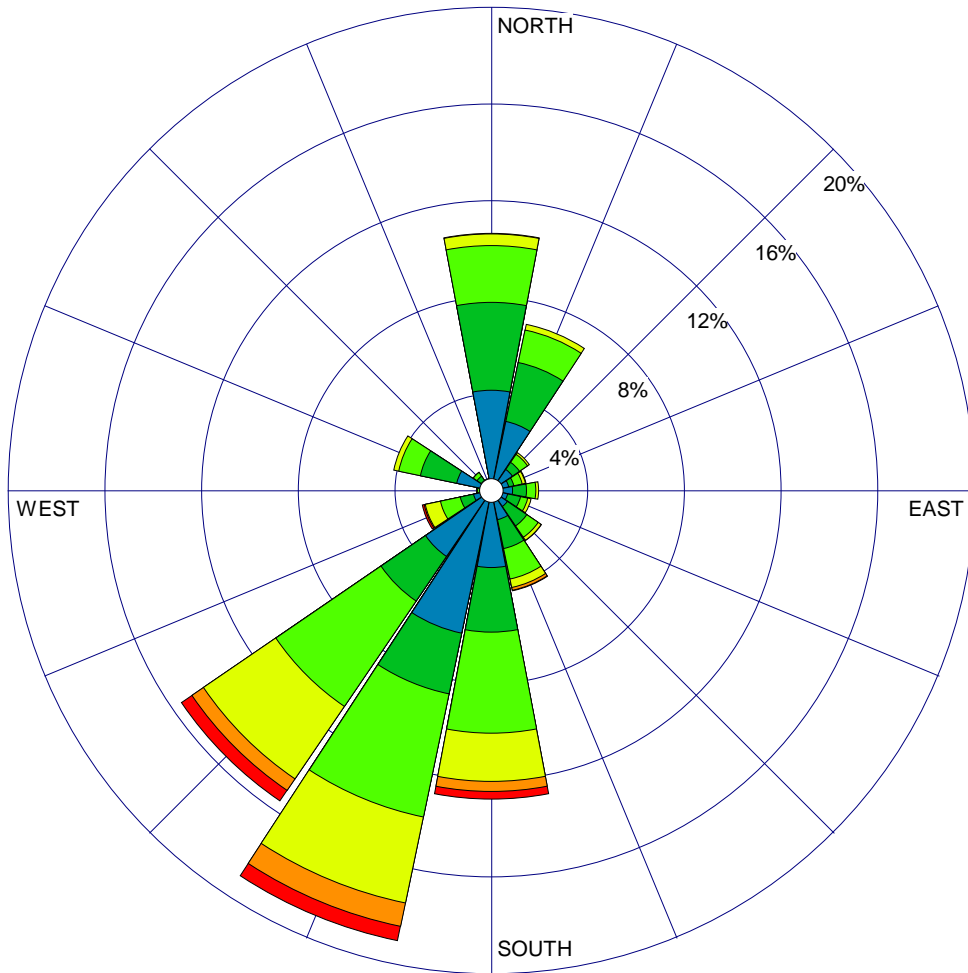
### **B.5.1. WRPLOT Wind Rose Graphic Display<sup>6</sup>**

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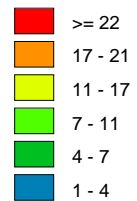
<sup>6</sup>Source: *WRPLOT View Freeware 7.0.0 - Lakes Environmental Software*

WIND ROSE PLOT:  
Station # 5300

DISPLAY:  
Wind Speed  
Direction (blowing from)



WIND SPEED  
(Knots)



Calms: 12.17%

COMMENTS:

DATA PERIOD:

Start Date: 01/01/2010 - 01:00  
End Date: 12/31/2010 - 23:00

COMPANY NAME:

Master in Construction Engineering

MODELER:

Mayela Cecilia Gonzalez  
Lalyre

CALM WINDS:

12.17%

TOTAL COUNT:

8745 hrs.

AVG. WIND SPEED:

6.11 Knots

DATE:

12/18/2012

PROJECT NO.:

26474



### B.5.2. FAA Wind Analysis Result RWY 02<sup>7</sup>

#### Standard Wind Analysis Results for ALL\_WEATHER

TITLE: Runway 02-20 Wind Analysis

RUNWAY ORIENTATION: 17.0 DEGREE  
 CROSSWIND COMPONENT: 16.0 KNOTS  
 TAILWIND COMPONENT: 60.0 KNOTS

WIND COVERAGE: 99.84 %

DIRECTION	HOURLY OBSERVATIONS OF WIND SPEED (KNOTS)									TOTAL
	0-3	4-6	7-10	11-16	17-21	22-27	28-33	34-40	> 41	
10°	0	0	0	0	0	0	0	0	0	0
20°	256	217	120	21	0	0	0	0	0	614
30°	0	0	0	0	0	0	0	0	0	0
40°	93	31	35	8	0	0	0	0	0	167
50°	0	0	0	0	0	0	0	0	0	0
60°	0	0	0	0	0	0	0	0	0	0
70°	65	19	31	12	2	0	0	0	0	129
80°	0	0	0	0	0	0	0	0	0	0
90°	78	50	34	10	0	0	0	0	0	172
100°	0	0	0	0	0	0	0	0	0	0
110°	61	48	26	13	0	0	0	0	0	148
120°	0	0	0	0	0	0	0	0	0	0
130°	71	85	50	13	1	0	0	0	0	220
140°	0	0	0	0	0	0	0	0	0	0
150°	0	0	0	0	0	0	0	0	0	0
160°	109	106	113	31	10	2	0	0	0	371
170°	0	0	0	0	0	0	0	0	0	0
180°	279	233	365	174	36	28	0	0	0	1115
190°	0	0	0	0	0	0	0	0	0	0
200°	527	224	454	317	86	53	0	0	0	1661
210°	0	0	0	0	0	0	0	0	0	0
220°	289	195	460	316	51	46	0	0	0	1357
230°	0	0	0	0	0	0	0	0	0	0
240°	0	0	0	0	0	0	0	0	0	0
250°	67	49	73	56	4	7	0	0	0	256
260°	0	0	0	0	0	0	0	0	0	0
270°	38	6	7	3	0	1	0	0	0	55
280°	0	0	0	0	0	0	0	0	0	0
290°	129	134	80	18	0	0	0	0	0	361
300°	0	0	0	0	0	0	0	0	0	0
310°	0	0	0	0	0	0	0	0	0	0
320°	45	19	16	1	0	0	0	0	0	81
330°	0	0	0	0	0	0	0	0	0	0
340°	10	23	12	0	0	0	0	0	0	45
350°	0	0	0	0	0	0	0	0	0	0
360°	363	317	205	42	2	0	0	0	0	929
Calm	1064									1064
TOTAL	3544	1756	2081	1035	192	137	0	0	0	8745

SOURCE: IPB Meteorological Station

REFERENCE: Appendix 1 of AC 150/5300-13, Airport Design, including Changes 1 through 17.

<sup>7</sup>Source: <https://airports-gis.faa.gov/airportgis/publicToolbox/windroseForm.jsp?windroseId=null&requestToken=1355828326847>

### B.5.3. FAA Wind Analysis Result RWY 20<sup>8</sup>

#### Standard Wind Analysis Results for ALL\_WEATHER

TITLE: Runway 02-20 Wind Analysis

RUNWAY ORIENTATION: 197.0 DEGREE  
 CROSSWIND COMPONENT: 16.0 KNOTS  
 TAILWIND COMPONENT: 60.0 KNOTS

WIND COVERAGE: 99.84 %

DIRECTION	HOURLY OBSERVATIONS OF WIND SPEED (KNOTS)									TOTAL
	0-3	4-6	7-10	11-16	17-21	22-27	28-33	34-40	> 41	
10°	0	0	0	0	0	0	0	0	0	0
20°	256	217	120	21	0	0	0	0	0	614
30°	0	0	0	0	0	0	0	0	0	0
40°	93	31	35	8	0	0	0	0	0	167
50°	0	0	0	0	0	0	0	0	0	0
60°	0	0	0	0	0	0	0	0	0	0
70°	65	19	31	12	2	0	0	0	0	129
80°	0	0	0	0	0	0	0	0	0	0
90°	78	50	34	10	0	0	0	0	0	172
100°	0	0	0	0	0	0	0	0	0	0
110°	61	48	26	13	0	0	0	0	0	148
120°	0	0	0	0	0	0	0	0	0	0
130°	71	85	50	13	1	0	0	0	0	220
140°	0	0	0	0	0	0	0	0	0	0
150°	0	0	0	0	0	0	0	0	0	0
160°	109	106	113	31	10	2	0	0	0	371
170°	0	0	0	0	0	0	0	0	0	0
180°	279	233	365	174	36	28	0	0	0	1115
190°	0	0	0	0	0	0	0	0	0	0
200°	527	224	454	317	86	53	0	0	0	1661
210°	0	0	0	0	0	0	0	0	0	0
220°	289	195	460	316	51	46	0	0	0	1357
230°	0	0	0	0	0	0	0	0	0	0
240°	0	0	0	0	0	0	0	0	0	0
250°	67	49	73	56	4	7	0	0	0	256
260°	0	0	0	0	0	0	0	0	0	0
270°	38	6	7	3	0	1	0	0	0	55
280°	0	0	0	0	0	0	0	0	0	0
290°	129	134	80	18	0	0	0	0	0	361
300°	0	0	0	0	0	0	0	0	0	0
310°	0	0	0	0	0	0	0	0	0	0
320°	45	19	16	1	0	0	0	0	0	81
330°	0	0	0	0	0	0	0	0	0	0
340°	10	23	12	0	0	0	0	0	0	45
350°	0	0	0	0	0	0	0	0	0	0
360°	363	317	205	42	2	0	0	0	0	929
Calm	1064									1064
TOTAL	3544	1756	2081	1035	192	137	0	0	0	8745

SOURCE: IPB Meteorological Station

REFERENCE: Appendix 1 of AC 150/5300-13, Airport Design, including Changes 1 through 17.

<sup>8</sup>Source: <https://airports-gis.faa.gov/airportsgis/publicToolbox/windroseForm.jsp?windroseId=null&requestToken=1355828326847>

**B.6. FAARFIELD Design Information Sheets**

**B.6.1. Required Two Layer Cross Section: Section NewFlexib~02**

**B.6.2. HMA Overlay Design: Section OverlayFlex1**

**B.6.3. Design for Three Layer Section: Section NewFlexib~03**

**B.6.4. HMA Overlay Design: Section AConFlex01**

**B.6.5. New Aircraft Parking Apron: Section NewRigid01**

**FAARFIELD - Airport Pavement Design (V 1.305, 9/28/10 64-bit)**

Section NewFlexib~02 in Job TesisFlex.  
Working directory is C:\Program Files\FAA\FAARFIELD\

The structure is New Flexible. Asphalt CDF = 0.0244.  
Design Life = 20 years.  
A design for this section was completed on 11/30/12 at 01:16:07.

**Pavement Structure Information by Layer, Top First**

No.	Type	Thickness mm	Modulus MPa	Poisson's Ratio	Strength R,MPa
1	P-401/ P-403 HMA Surface	101.6	1,378.95	0.35	0.00
2	P-209 Cr Ag	422.2	265.48	0.35	0.00
3	Subgrade	0.0	51.71	0.35	0.00

**Total thickness to the top of the subgrade = 523.8 mm**

**Airplane Information**

No.	Name	Gross Wt. tonnes	Annual Departures	% Annual Growth
1	Sngl Whl-30	13.900	1,456	0.00
2	Skyhawk-172	1.150	495	0.00
3	Sngl Whl-3	1.050	495	0.00
4	Seneca-II	1.905	495	0.00
5	RegionalJet-700	34.000	252	0.00

**Additional Airplane Information**

**Subgrade CDF**

No.	Name	CDF Contribution	CDF Max for Airplane	P/C Ratio
1	Sngl Whl-30	0.00	0.00	2.43
2	Skyhawk-172	0.00	0.00	3.13
3	Sngl Whl-3	0.00	0.00	3.20
4	Seneca-II	0.00	0.00	3.00
5	RegionalJet-700	1.00	1.00	1.68

**HMA CDF**

No.	Name	CDF Contribution	CDF Max for Airplane	P/C Ratio
1	Sngl Whl-30	0.00	0.00	4.74
2	Skyhawk-172	0.00	0.00	9.11
3	Sngl Whl-3	0.00	0.00	9.70
4	Seneca-II	0.00	0.00	7.98
5	RegionalJet-700	0.02	0.02	3.23

**FAARFIELD - Airport Pavement Design (V 1.305, 9/28/10 64-bit)**

Section OverlayFlex1 in Job TesisFlex.  
Working directory is C:\Program Files\FAA\FAARFIELD\

The structure is AC Overlay on Flexible. Asphalt CDF = 0.0285.  
Design Life = 20 years.  
A design for this section was completed on 11/30/12 at 13:53:54.

**Pavement Structure Information by Layer, Top First**

No.	Type	Thickness mm	Modulus MPa	Poisson's Ratio	Strength R,MPa
1	P-401/ P-403 HMA Overlay	85.4	1,378.95	0.35	0.00
2	P-401/ P-403 HMA Surface	101.6	1,378.95	0.35	0.00
3	P-208 Cr Ag	300.0	227.71	0.35	0.00
4	Subgrade	0.0	51.71	0.35	0.00

**Total thickness to the top of the subgrade = 487.0 mm**

**Airplane Information**

No.	Name	Gross Wt. tonnes	Annual Departures	% Annual Growth
1	Sngl Whl-30	13.900	1,456	0.00
2	Skyhawk-172	1.150	495	0.00
3	Sngl Whl-3	1.050	495	0.00
4	Seneca-II	1.905	495	0.00
5	RegionalJet-700	34.000	252	0.00

**Additional Airplane Information**

**Subgrade CDF**

No.	Name	CDF Contribution	CDF Max for Airplane	P/C Ratio
1	Sngl Whl-30	0.00	0.00	2.53
2	Skyhawk-172	0.00	0.00	3.32
3	Sngl Whl-3	0.00	0.00	3.39
4	Seneca-II	0.00	0.00	3.16
5	RegionalJet-700	1.00	1.00	1.72

**Overlay HMA CDF**

No.	Name	CDF Contribution	CDF Max for Airplane	P/C Ratio
1	Sngl Whl-30	0.00	0.00	4.93
2	Skyhawk-172	0.00	0.00	9.87
3	Sngl Whl-3	0.00	0.00	10.56
4	Seneca-II	0.00	0.00	8.55
5	RegionalJet-700	0.00	0.00	3.40

**HMA CDF**

No.	Name	CDF Contribution	CDF Max for Airplane	P/C Ratio
1	Sngl Whl-30	0.00	0.00	3.95
2	Skyhawk-172	0.00	0.00	6.53
3	Sngl Whl-3	0.00	0.00	6.82
4	Seneca-II	0.00	0.00	5.93
5	RegionalJet-700	0.03	0.03	2.56

**FAARFIELD - Airport Pavement Design (V 1.305, 9/28/10 64-bit)**

Section NewFlexib-03 in Job TesisFlex.  
Working directory is C:\Program Files\FAA\FAARFIELD\

The structure is New Flexible. Asphalt CDF = 0.0173.  
Design Life = 20 years.  
A design for this section was completed on 12/01/12 at 00:02:31.

**Pavement Structure Information by Layer, Top First**

No.	Type	Thickness mm	Modulus MPa	Poisson's Ratio	Strength R, MPa
1	P-401/ P-403 HMA Surface	101.6	1,378.95	0.35	0.00
2	P-401/ P-403 St (flex)	127.0	2,757.90	0.35	0.00
3	P-209 Cr Ag	174.3	154.75	0.35	0.00
4	Subgrade	0.0	51.71	0.35	0.00

**Total thickness to the top of the subgrade = 402.9 mm**

**Airplane Information**

No.	Name	Gross Wt. tonnes	Annual Departures	% Annual Growth
1	Sngl Whl-30	13.900	1,456	0.00
2	Skyhawk-172	1.150	495	0.00
3	Sngl Whl-3	1.050	495	0.00
4	Seneca-II	1.905	495	0.00
5	RegionalJet-700	34.000	252	0.00

**Additional Airplane Information**

**Subgrade CDF**

No.	Name	CDF Contribution	CDF Max for Airplane	P/C Ratio
1	Sngl Whl-30	0.00	0.00	2.81
2	Skyhawk-172	0.00	0.00	3.84
3	Sngl Whl-3	0.00	0.00	3.93
4	Seneca-II	0.00	0.00	3.63
5	RegionalJet-700	1.00	1.00	1.81

**HMA CDF**

No.	Name	CDF Contribution	CDF Max for Airplane	P/C Ratio
1	Sngl Whl-30	0.00	0.00	4.74
2	Skyhawk-172	0.00	0.00	9.11
3	Sngl Whl-3	0.00	0.00	9.70
4	Seneca-II	0.00	0.00	7.98
5	RegionalJet-700	0.00	0.00	3.23

**P-401/P-403 St (flex) CDF**

No.	Name	CDF Contribution	CDF Max for Airplane	P/C Ratio
1	Sngl Whl-30	0.00	0.00	3.66
2	Skyhawk-172	0.00	0.00	5.74
3	Sngl Whl-3	0.00	0.00	5.96
4	Seneca-II	0.00	0.00	5.27
5	RegionalJet-700	0.02	0.02	2.33

**FAARFIELD - Airport Pavement Design (V 1.305, 9/28/10 64-bit)**

Section AConFlex01 in Job TesisFlex.  
Working directory is C:\Program Files\FAA\FAARFIELD\

The structure is AC Overlay on Flexible. Asphalt CDF was not computed.  
Design Life = 20 years.  
A design for this section was completed on 12/07/12 at 15:36:46.

**Pavement Structure Information by Layer, Top First**

No.	Type	Thickness mm	Modulus MPa	Poisson's Ratio	Strength R, MPa
1	P-401/ P-403 HMA Overlay	165.5	1,378.95	0.35	0.00
2	P-401/ P-403 HMA Surface	101.6	1,378.95	0.35	0.00
3	P-209 Cr Ag	150.0	146.72	0.35	0.00
4	Subgrade	0.0	51.71	0.35	0.00

**Total thickness to the top of the subgrade = 417.1 mm**

**Airplane Information**

No.	Name	Gross Wt. tonnes	Annual Departures	% Annual Growth
1	Sngl Whl-30	13.900	1,456	0.00
2	Skyhawk-172	1.150	495	0.00
3	Sngl Whl-3	1.050	495	0.00
4	Seneca-II	1.905	495	0.00
5	RegionalJet-700	34.000	252	0.00

**Additional Airplane Information**

**Subgrade CDF**

No.	Name	CDF Contribution	CDF Max for Airplane	P/C Ratio
1	Sngl Whl-30	0.00	0.00	2.76
2	Skyhawk-172	0.00	0.00	3.74
3	Sngl Whl-3	0.00	0.00	3.83
4	Seneca-II	0.00	0.00	3.54
5	RegionalJet-700	1.00	1.00	1.80

**Overlay HMA CDF**

No.	Name	CDF Contribution	CDF Max for Airplane	P/C Ratio
1	Sngl Whl-30	0.00	0.00	4.12
2	Skyhawk-172	0.00	0.00	7.03
3	Sngl Whl-3	0.00	0.00	7.38
4	Seneca-II	0.00	0.00	6.34
5	RegionalJet-700	0.00	0.00	2.71

**HMA CDF**

No.	Name	CDF Contribution	CDF Max for Airplane	P/C Ratio
1	Sngl Whl-30	0.00	0.01	3.42
2	Skyhawk-172	0.00	0.00	5.17
3	Sngl Whl-3	0.00	0.00	5.35
4	Seneca-II	0.00	0.00	4.79
5	RegionalJet-700	0.04	0.04	2.15

**FAARFIELD - Airport Pavement Design (V 1.305, 9/28/10 64-bit)**

Section NewRigid01 in Job TesisFlex.  
Working directory is C:\Program Files\FAA\FAARFIELD\

The structure is New Rigid.  
Design Life = 20 years.  
A design for this section was completed on 12/17/12 at 20:35:13.

**Pavement Structure Information by Layer, Top First**

No.	Type	Thickness mm	Modulus MPa	Poisson's Ratio	Strength R,MPa
1	PCC Surface	254.3	27,579.03	0.15	4.83
2	P-301 SCB	101.6	1,723.69	0.20	0.00
3	Subgrade	0.0	51.71	0.40	0.00

**Total thickness to the top of the subgrade = 355.9 mm**

**Airplane Information**

No.	Name	Gross Wt. tonnes	Annual Departures	% Annual Growth
1	Sngl Whl-30	13.900	1,456	0.00
2	Seneca-II	1.905	495	0.00
3	Skyhawk-172	1.150	495	0.00
4	Sngl Whl-3	1.050	495	0.00
5	RegionalJet-700	34.000	252	0.00

**Additional Airplane Information**

No.	Name	CDF Contribution	CDF Max for Airplane	P/C Ratio
1	Sngl Whl-30	0.00	0.00	3.12
2	Seneca-II	0.00	0.00	6.82
3	Skyhawk-172	0.00	0.00	8.68
4	Sngl Whl-3	0.00	0.00	9.82
5	RegionalJet-700	1.00	1.00	4.71

**B.7. FAA Spreadsheet Summary Reports**

**B.7.1. Flexible Pavement Design - Spreadsheet F805FAA.XLS**

**B.7.2. Flexible Pavement Design - t vs. Annual Departures/CBR**

**B.7.3. Rigid Pavement Design - Spreadsheet R805FAA.XLS**

**B.7.4. Rigid Pavement Design - PCC t vs. Annual Departures/PCC  
Flexural Strength**

**FLEXIBLE PAVEMENT DESIGN FOR**

10/31/2005

**Bragança Regional Airport***AC Method***Bragança, PT****Engineer -** Mayela Cecilia Gonzalez, IPB MEC Student

AIP No. 5300

MEC Final Project

**22"** **Total Thickness Required (inches)***No thickness adjustments required**Stabilized Base/Subbase Are Not Required***Initial Pavement Cross Section**

<b>4"</b>	Pavement Surface Layer (P-401)
<b>6" (3,88)</b>	Base Layer (P-209)
<b>12"</b>	Subbase #1 (P-154) CBR= 20
<b>0"</b>	Subbase #2 CBR= 0
<b>0"</b>	Subbase #3 CBR= 0

**Stabilized or Modified Cross Section**

		Factors
<b>4"</b>	P-401 Plant Mix Bituminous Pavements	
<b>4"</b>	P-401, Plant Mix Bituminous Pavements	1,6
<b>12"</b>	Not stabilized -- P-154	1
<b>0"</b>	Material as defined by user	
<b>0"</b>	Material as defined by user	

*( ) = Subminimal base thickness calculation***Frost Considerations**

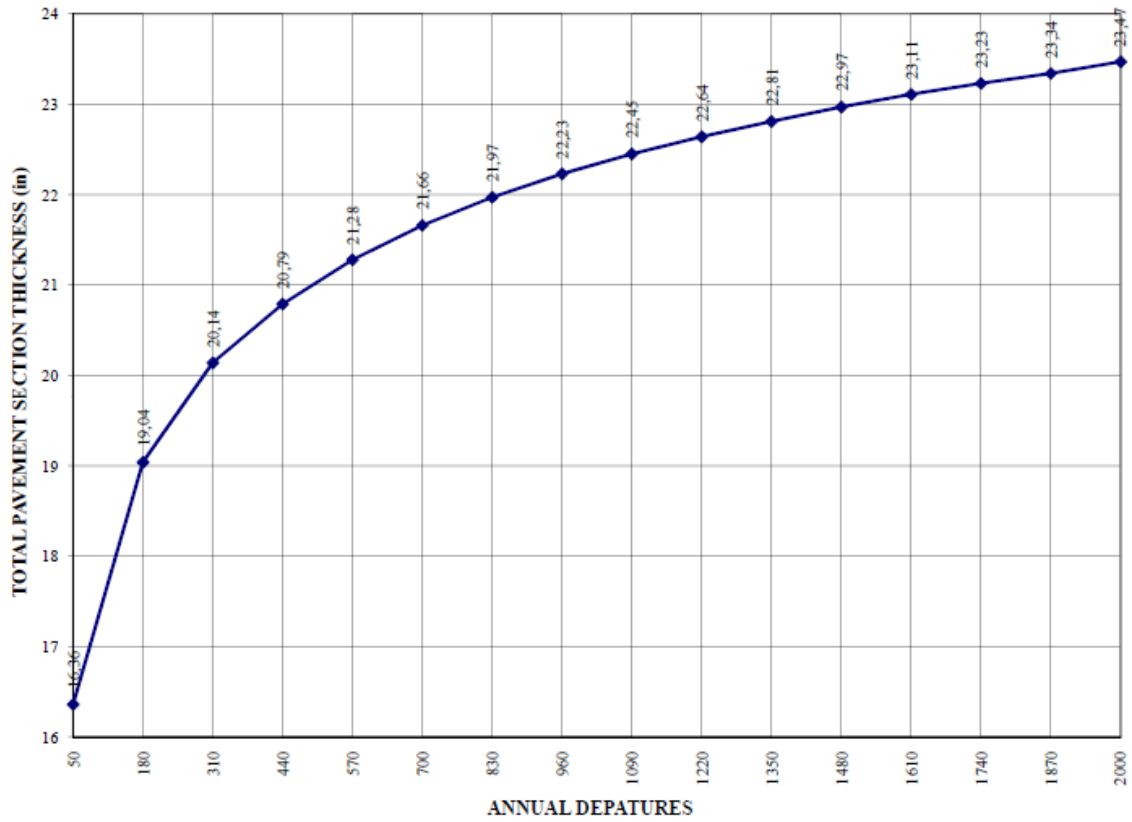
<b>100 lb/cf</b>	Dry Unit Weight of Soil	
<b>250</b>	Degree Days °F	
<b>22,53"</b>	Frost Penetration Depth	
<b>5</b>	Original CBR value of subgrade Soil	
<b>5</b>	CBR Value used for the Subgrade Soil	Non-Frost Code for Subgrade Soil
<b>20</b>	CBR Value used for subbase #1	Non-Frost code for Subbase #1
<b>0</b>	CBR Value used for subbase #2	Non-Frost code for Subbase #2
<b>0</b>	CBR Value used for subbase #3	No frost selection made for Subbase #3

**Design Aircraft Information****The Design Aircraft is a DUAL100 - 100,000 lbs -- ( )****75000 lbs** Gross Weight**20** Design Life (years)**862** Equivalent Annual Departures**Subgrade Compaction Requirements for Design Aircraft**

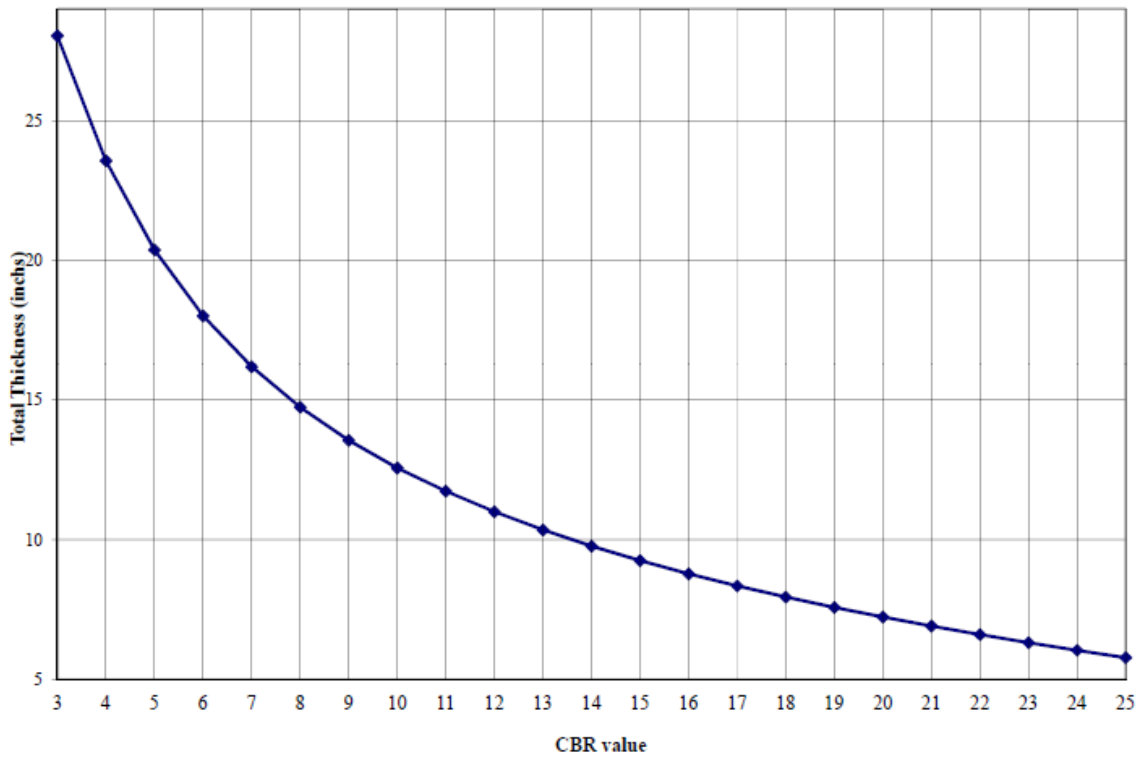
Non-Cohesive Soils		Cohesive Soils	
Compaction	Depth Required	Compaction	Depth Required
100%	0 - 14,5	95%	0 - 6"
95%	14,5 - 29"	90%	6 - 11"
90%	29 - 40"	85%	11 - 18"
85%	40 - 52,5"	80%	18 - 23,5"

See Appendix 5 to AC 150/5320-6D, Airport Design and Evaluation, for application of this software.

TOTAL THICKNESS FOR DUAL100, 75000 lbs LIFE = 20 yrs CBR = 5



TOTAL THICKNESS FOR DUAL100, 75000 lbs -- 346 Departures LIFE = 20 yrs



Program Date 04/30/04

## Rigid Pavement Design For

AC Method

Airport Name: Bragança Regional Airport

Date: 12/02/2012

Associated City: Bragança, PT

Design Firm: IPB Master in Construction Engineering

Designer: Mayela Cecilia Gonzalez, M

AIP Number: 5300

### New Pavement Section Required

*Stabilized Subbase Is Not Required*

9,2	PCC Thickness	650 psi	New Concrete Flexural Strength
6,0	Stabilized Base		
0,0	Subbase		
0,0	Non-Frost Layer (free draining material)		

*Large Aircraft Parallel to Joints (standard design)*

### Overlay Sections

N/A	Asphalt Overlay Thickness	N/A	Existing Slab Thickness
N/A	Unbonded PCC <b>without</b> leveling course	N/A	PCC needed for existing section
N/A	Unbonded PCC <b>with</b> leveling course	N/A	Existing Stabilized Subbase
N/A	Bonded PCC	N/A	Existing Aggregate Subbase
		N/A	Existing Slab Flexural Strength
		N/A	F- Factor used in design
		N/A	Cr Factor
		N/A	Cb Factor

### Frost Considerations (for new pavement section)

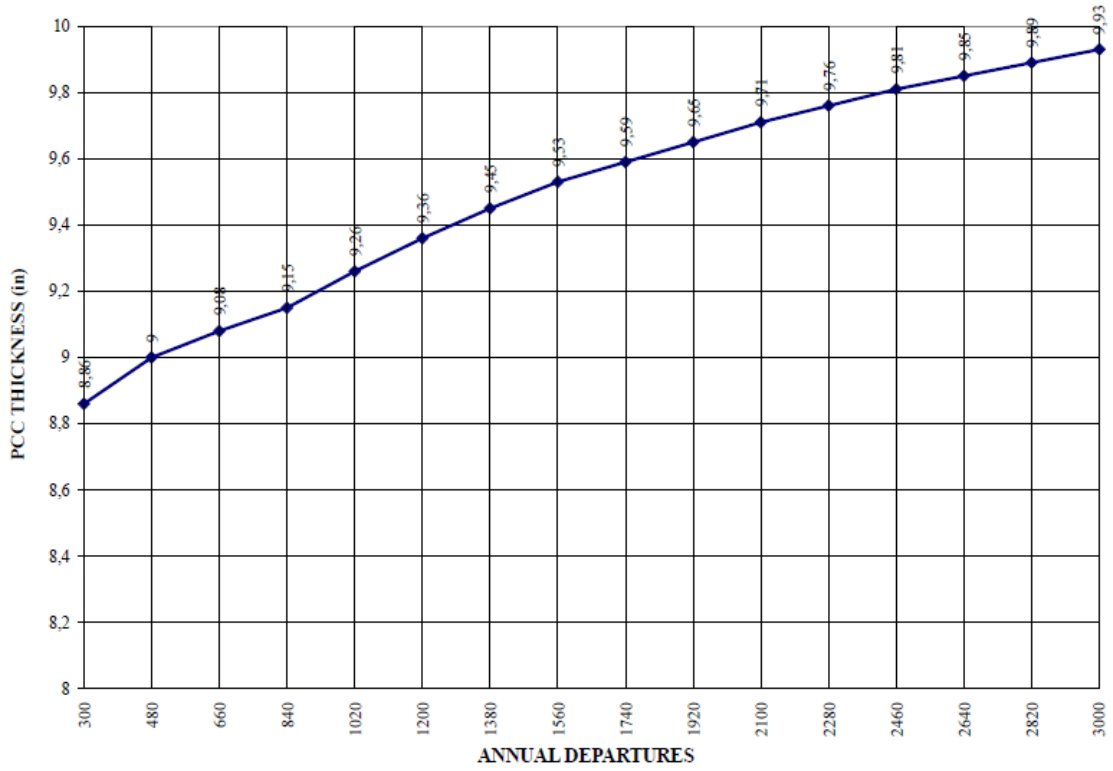
Dry Unit Weight of Soil (lb/cf)	100	
Degree Days °F	250	
Soil Frost Code	Non-Frost	Subgrade k-value was not modified for frost
Frost Depth Penetration (in)	22,53	
k value on top of stabilized layer	186	
k value on top of subbase layer	82	
Original subgrade k value	82	

### Design Aircraft Information

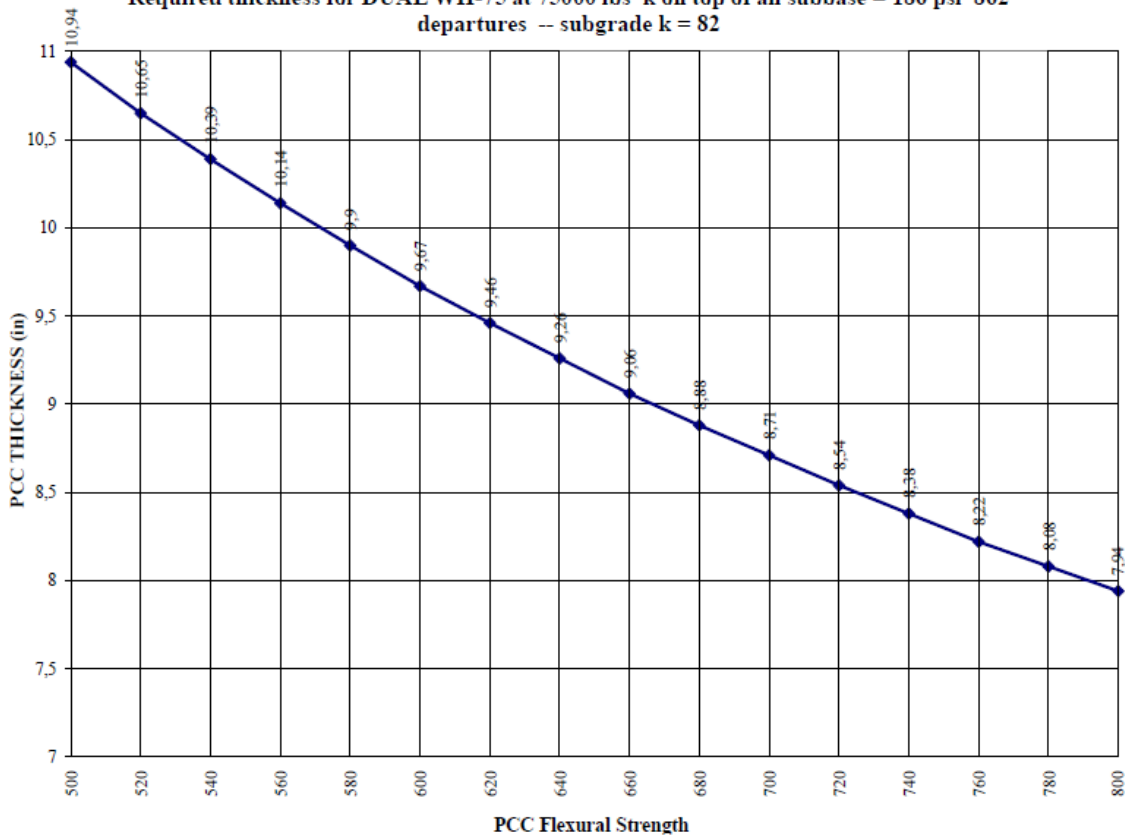
DUAL WH-75		20	Design Life (years)
75000 lbs	Gross Aircraft Weight		
862	Equivalent Annual Departures		

See Appendix 5 to AC 150/5320-6D for application of this software.
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Required thickness for DUAL WH-75 at 75000 lbs k on top of all subbase = 186 psi PCC  
 Flexural Strength = 650



Required thickness for DUAL WH-75 at 75000 lbs k on top of all subbase = 186 psi 862  
 departures -- subgrade k = 82





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