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**M.Sc. in Civil Engineering**

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**REPUBLIC OF TÜRKİYE  
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GRADUATE SCHOOL OF NATURAL & APPLIED SCIENCES**

**COMPARISON OF RIGID PAVEMENT DESIGNS FOR  
AIRPORT RUNWAYS UNDER STRONG AND WEAK GROUND  
CONDITIONS AT LOW AND HIGH TRAFFIC AIRPORTS**

**M.Sc. THESIS  
IN  
CIVIL ENGINEERING**

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LOW AND HIGH TRAFFIC AIRPORTS**

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**Dilan UZUNKODALAK AKSOY**

## **ABSTRACT**

### **COMPARISON OF RIGID PAVEMENT DESIGNS FOR AIRPORT RUNWAYS UNDER STRONG AND WEAK GROUND CONDITIONS AT LOW AND HIGH TRAFFIC AIRPORTS**

**UZUNKODALAK AKSOY, Dilan**  
**M.Sc. in Civil Engineering**  
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The evaluation and design of runway pavements under service loads is of great importance for the operation of airports. For this purpose, in addition to pavement properties, soil capacity under service loads is of great importance. In this thesis, the FAARFIELD program was used to evaluate the construction of rigid pavements for the airport under different soil conditions under aircraft type and annual traffic loads (number of take-offs). This is because take-off movements are important parameters for runway strength in design. In addition, gross weight values for each aircraft type were entered into the system and obtained from the system with annual tariff growth rates. For pavement life, 20-year periods were considered. The study includes 2 different traffic loads: low and high traffic. The high traffic study is an example of 1 year of flight operations (1 year of total departures for each aircraft type) at a hub airport with +50 million passengers per year. Low traffic is total departure ATMs for 1 year at a local/regional airport. The California Bearing Ratio (CBR) value was taken as 5 for low strength soil and CBR=15 for good soil. CDF (Cumulative Damage Factor) and P/C (pass-to-coverage ratio) values were examined in the results of the data obtained from the analysis of rigid pavement designs for airport runways under strong and weak soil conditions for low and high traffic airports with FAARFIELD program.

**Key Words:** Cumulative damage factor, Runway pavement, Airport

## ÖZET

### DÜŞÜK VE YÜKSEK TRAFİKLİ HAVALİMANLARINDA GÜÇLÜ VE ZAYIF ZEMİN KOŞULLARI ALTINDA HAVALİMANI PİSTLERİ İÇİN RİJİT KAPLAMA TASARIMLARININ KARŞILAŞTIRILMASI

**UZUNKODALAK AKSOY, Dilan**  
**Yüksek Lisans Tezi, İnşaat Mühendisliği**  
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Pist kaplamalarının servis yükleri altında değerlendirilmesi ve tasarımı, havalimanlarının işletilmesi için büyük önem taşımaktadır. Bu amaçla, kaplama özelliklerinin yanı sıra, servis yükleri altında zemin kapasitesi de büyük önem taşımaktadır. Bu tezde, FAARFIELD programı, uçak tipi ve yıllık trafik yükleri (kalkış sayısı) altında farklı zemin koşulları altında havaalanı için rijit kaplamaların yapımını değerlendirmek için kullanılmıştır. Bunun nedeni, kalkış hareketlerinin tasarımda pist mukavemeti için önemli parametreler olmasıdır. Ayrıca, her bir uçak tipi için brüt ağırlık değerleri sisteme girilmiş ve yıllık tarife büyüme oranları ile sistemden elde edilmiştir. Kaplama ömrü için 20 yıllık periyotlar dikkate alınmıştır. Çalışma düşük ve yüksek trafik olmak üzere 2 farklı trafik yükünü içermektedir. Yüksek trafik çalışması, yılda +50 milyon yolcuya sahip bir merkez havalimanındaki 1 yıllık uçuş operasyonlarına (her bir uçak tipi için 1 yıllık toplam kalkış) bir örnektir. Düşük trafik, küçük bir yerel/bölgesel havalimanındaki 1 yıllık toplam kalkışlar için Hava Trafik Yönetimi (ATM) trafiğidir. CBR (Kaliforniya Taşıma Oranı) değeri düşük mukavemetli zemin için 5 ve iyi zemin için CBR=15 olarak alınmıştır. FAARFIELD programı ile düşük ve yüksek trafikli havalimanları için güçlü ve zayıf zemin koşulları altında havalimanı pistleri için rijit kaplama tasarımlarının analizinden elde edilen veriler sonucunda CDF (Kümülatif Hasar Faktörü) ve P/C (birim alanı kaplamak için gereken geçiş sayısı) değerleri incelenmiştir.

**Anahtar Kelimeler:** Kümülatif hasar faktörü, Pist kaplaması, Havaalanı



*"Dedicated to My One and Only Son"*

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## LIST OF SYMBOLS

**k** Coefficient used in the FAARFIELD program



## **LIST OF ABBREVIATIONS**

<b>ATM</b>	Air Traffic Movement
<b>CBR</b>	California Bearing Ratio
<b>CDF</b>	Cumulative Damage Factor
<b>CRCP</b>	Continuously reinforced concrete pavements
<b>FAA</b>	US Civil Federal Aviation Administration
<b>FAARFIELD</b>	Federal Aviation Administration Rigid and Flexible Iterative Elastic Layered Design
<b>ICAO</b>	International Civil Aviation Organization
<b>JCP</b>	Joint concrete pavements
<b>JRCP</b>	Joint reinforced concrete pavements
<b>LCN</b>	The Load Classification Number
<b>PAT</b>	Runway, apron and taxiway
<b>PCA</b>	Positive Control Airspace
<b>PCC</b>	Portland cement concrete
<b>PCI</b>	Pavement Condition Index
<b>PCP</b>	Prestressed concrete pavements
<b>SCI</b>	Structural Condition Index
<b>PCR</b>	Pavement Classification Rating

## **CHAPTER 1 INTRODUCTION**

### **1.1 General**

In addition to being the most important sector that facilitates human life, the transportation sector is also the most important parameter in increasing the level of livability. Technological developments in the transportation sector have contributed greatly to the development of countries at the level of modern civilizations. Transportation is one of the leading sectors that contribute to economic growth, national income increase, social order, industry, and trade development for every country. Aviation is one of the transportation systems where parameters such as speed, comfort, safety, and technology come to the fore with technological developments in transportation systems. Although it is only a century old, air transportation is the locomotive of the system in terms of socio-economic globalization. Today, thanks to aviation, it takes no more than 5-10 hours to cross oceans and continents. From a systemic approach, aviation is also composed of subsystems. Among these systems, airports are the most important and fundamental system. Airports, which were obtained by modifying football stadiums in the early 1900s, today provide employment for tens of thousands of people and have the appearance of a techno-city, which is the economic development parameter of the region where they are located (Bingöl, 2000).

One of the sub-sectors of the systems used for transportation purposes is air transportation, which has gained importance in the last century, and airports, which are an important infrastructure element of this system. Airports, which have a very important place in air transportation, have an important place for every country as a gateway to the world. From the point of view of airports, it is possible to mention many important contributions, including the promotion of the country among the purposes of use. In addition to this important function of the airport, airports are also known to contribute to the economic, social, and cultural development of the region in which they are located (Doganis, 2005).

The concept of quality, which is one of the main objectives of civil engineering, is important in airports as in every structure. Maintenance costs, which are seen as one of the main elements in the construction and operation costs of airports, are directly related to the quality of the structures and the extent to which they can meet scientific needs. The quality and selection criteria of the pavements, which are considered as the basic structure of airports and the most important element of the service they provide, are also one of the important factors that will affect this service. The selection of the type of pavement to be used on the airport superstructure should be based on scientific facts and the appropriate type of pavement should be selected.

Air transport plays a vital role in inter-regional transportation. The past century has seen tremendous growth in air traffic. The failure or loss of serviceability of a pavement at an airport and the closure of a runway, especially a major runway, can affect the operations of the entire airport system. Therefore, the reliability of pavements on runways is critical for air transportation. There is a growing need for reliable pavement design at airports. It has long been recognized that pavements are integral to the smooth operation of airports. However, this is the exception rather than the rule for airport pavements, which by their original design complete their service life without extensive maintenance. One of the most common problems in the design of airport pavements has been the underestimation of air traffic growth rates and the consequent under-design of pavement characteristics.

Considering the design characteristics of pavements, it can be said that they are one of the most difficult design problems faced by civil engineers during design. Superstructures are constructed with the use of low-cost materials depending on highly variable usage and design characteristics as well as environmental and loading conditions. Due to the modernization and globalization of the world, the increase in air traffic often exceeds expectations. Traffic loads are difficult to predict as a result of new aircraft entering airports as they are needed. It can be assessed on a probabilistic basis based on environmental conditions and historical trends; however, the specific environment at a given time can have a dramatic impact on the performance of the superstructure.

One of the most difficult aspects of pavement analysis is the determination of pavement damage. Excessive stresses in the pavement structure cause the material to crack. However, the development of cracking alone does not necessarily indicate a failure of the superstructure surface. Airplanes can fly over defective pavements. On the highway, field pavement failure is defined in terms of the functional properties of the pavement surface, primarily in relation to ride quality. There is no comparable definition of failure for airport pavements. On airport pavements, the cumulative effect of different types of distress is a major concern for the pavement engineer.

Due to the difficulty of the airport superstructure analysis process, design methods have been developed empirically. Although these methods have produced feasible designs, they have some shortcomings. Significant progress has been made in the fields of engineering mechanics and materials evaluation that can provide the basis for the development of improved airfield pavement design procedures. The purpose of this report is to summarize the state of the art in airport pavement analysis models. There is no clear limit to this task. There are models for superstructure design that have been used for many years. There are models that have been applied only by engineers at the forefront of technology in the design of superstructure structures. Other models have been proposed by researchers but have not been widely used for airport pavement analysis. Finally, there are models developed in other engineering fields that can be applied to the analysis of airport pavements. This report attempts to cover all these levels of development (Zaniewski & others, 1991).

## **1.2 Research Significance**

The service life of the runways where the main activities are carried out at airports is of great importance. The evaluation and design of runway pavements under the service loads to which they are exposed according to the aircraft operating on them is of great importance for the operation of airports. For this purpose, it is of great importance not only to evaluate the pavement properties but also to evaluate the ground capacity under service loads. The evaluation of this situation can be evaluated with software with current technological developments. FAARFIELD program was used within the scope of the thesis study. Annual traffic loads (number of take-offs) are evaluated by considering the aircraft type and airport operating capacity and characteristics into the program and the evaluation of the construction of rigid pavements for the airport under

different ground conditions in the construction of runway pavements is carried out with this program. The reflection of runway pavement life on the design as load distribution of take-off movements is considered as an important parameter in terms of runway pavement and embankment strength and its effects are evaluated in detail within the scope of the thesis. In addition, gross weight values for each aircraft type were entered into the system and obtained from the system with annual tariff growth rates. Within the scope of the study, 20-year periods were considered for runway pavement service life. In addition, two different traffic loads, defined as low and high traffic, were evaluated. The high traffic load study is an example of 1 year flight operations (1 year total departures for each aircraft type) at a hub airport with +50 million passengers per year. Low traffic load is considered as total departure ATM number for 1-year at a local/regional airport. Another parameter, the soil bearing capacity, is considered with CBR (California Bearing Ratio). CBR value is taken as 5 for low strength soil sample and CBR=15 for good soil. As a result, 4 different case studies were conducted and the change in runway pavement properties within the airport traffic load and soil properties were evaluated with the FAARFIELD program. The 4 different case studies can be summarized as follows: Case-I with low traffic load and low soil capacity, Case-II with high traffic load and low soil capacity, Case-III with low traffic load and high soil capacity, and finally Case-IV for airport runways with high traffic load and high soil capacity. As a result of the data obtained, CDF (Cumulative Damage Factor) and P/C (pass-to-coverage ratio) values were analyzed.

### **1.3 Outline of the Thesis**

**Chapter 1** This chapter consists of general introduction and the significance of the thesis.

**Chapter 2** This chapter focuses on the historical background on the applications, for rigid pavement design properties for airlines.

**Chapter 3** This chapter covers general characteristics of focused study.

**Chapter 4** The properties of the program characteristics.

**Chapter 5** The results obtained from analysis are presented in detail.

**Chapter 6** According to the results of analysis, conclusions are presented.



## **CHAPTER 2**

### **LITERATURE REVIEW**

#### **2.1 Introduction**

In this part of the study, the concept of airport, which has become an important part of the world economy and is developing, and literature studies on the creation of airport systems in general are discussed. The aviation sector, which has shown a continuous rapid development from past to present, has manifested itself with airports, which are among the most important elements of the air transportation sector. For this purpose, in this study, first of all, a literature review of the studies on airport concepts and their creation forms has been made.

#### **2.2 Previous Studies Survey**

In general, airports can be defined as large and complex organizations where several different activities are carried out. If we talk about the main function of airports, it can be said that it is aimed to facilitate the basic activities related to the transition of passengers and cargo from the land transportation system to the air transportation system. In addition, it is of great importance to provide easy access to stations and structural systems for all facilities and services that can be used by aircraft operators at airports. It is also possible to define an airport as a functional area specially designed for the buildings necessary for the regulation of passenger and aircraft traffic and the infrastructure and facilities necessary for the preparation of aircraft for flight and the landing and take-off of aircraft (Doganis, 2005; ICAO, 1996; Tatlı, 2004).

With the acceleration of industrial and technological developments, air transportation has a very special position among transportation types due to the speed and comfort features it provides to passengers and logistics companies. In the globalizing world, air transportation continues its development with a rapid acceleration in parallel with the increasing population and the increase in trade volume and is expected to become even more special. In the Turkish Civil Aviation Law No. 2920, an airport is defined as “an area on land or water, together with its buildings, facilities, and equipment,

allocated partially or completely for the use of aircraft for landing, take-off and ground movements” (Erol, 2022; Tatlı, 2004). Airports are the most important link in the air transportation chain. It is the place where transfers are exchanged between air and ground transportation for passenger and freight transportation. It plays a role in the harmonious execution of a wide range of activities from different sectors. Airports are systems that are constantly changing and developing in line with usage and needs. Airports are becoming much more complex building systems that require business management competence and skills, rather than being areas with advanced technical capacity and features. Therefore, an airport is not only about providing infrastructure for air transportation. Beyond providing a service, it is also a way for the airport to ensure that the various needs of its users are met in response to the ever-increasing demand for airports. In this respect, airports are characterized by large physical areas, fixed operational facilities requiring large investments, complex and highly sophisticated mechanical, electrical and electronic systems, and a highly mobile structure that is rapidly moving away from structural systems (Doganis, 2005; Kaya & Başar, 2005; Tatlı, 2004).

The definition of airport includes runways or runways established on land or water systems in order to perform landing and take-off activities of aircraft; navigation aids to be used by aircraft in navigation, landing and take-off; areas required for the movements of aircraft on the ground, passenger, baggage and cargo loading and unloading, maintenance and control of passengers and cargo; facilities and conveniences necessary to ensure passage between land transportation systems and air transportation systems; hangars for the accommodation and maintenance of aircraft, places where all kinds of measures are taken and services are provided for aviation safety and security (Kaya & Başar, 2005; Korul & Küçükönel, 2003).

## **CHAPTER 3**

### **AIRPORT SUPERSTRUCTURE AND PAVEMENT TYPES**

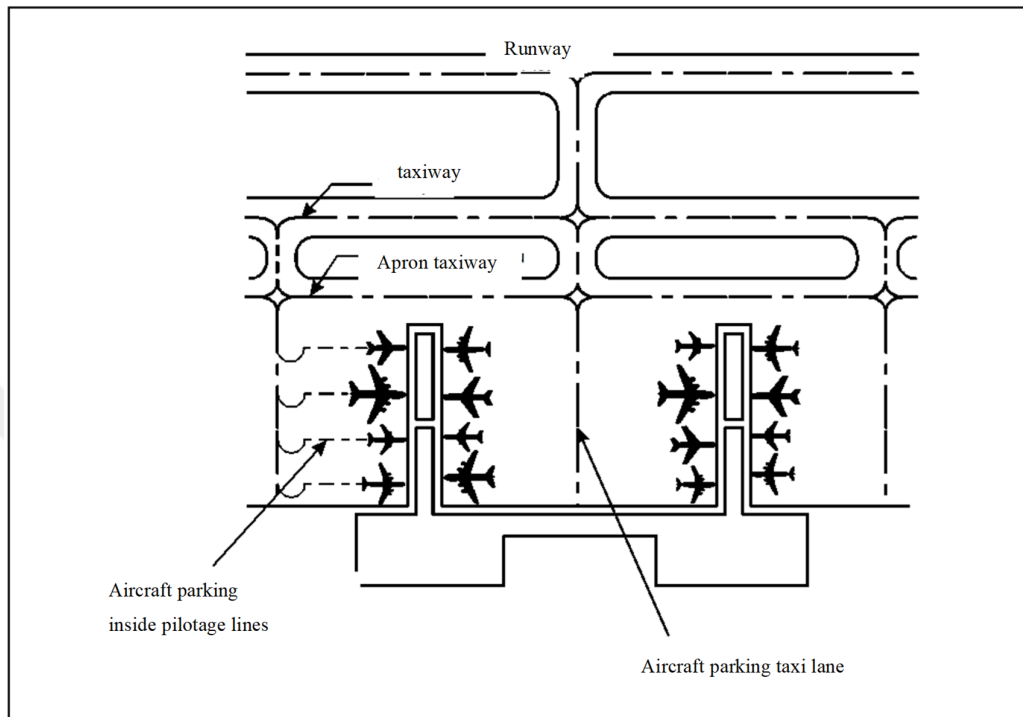
#### **3.1 Airport Description**

In the definition of airport, it can be expressed as specially designed and prepared areas where buildings for the regulation of air and passenger vehicle traffic are located, infrastructure systems and necessary facilities for flight preparations, landing and take-off of aircraft. Airports are defined in the Turkish Civil Aviation Law No. 2920 as places on land or water specially designed and prepared for the landing and take-off movements of aircraft, equipped with facilities suitable for the transportation of passengers and cargo, where maintenance and other technical needs of aircraft are met. Airports are one of the most important transportation systems that provide convenience and speed in transportation. Airports, which take the leading role in air transportation, are the gateway of a country to any point in the world and have made great contributions to countries in the economic context as they are among the structures that enable countries to grow economically, socially, and culturally. It has become possible to systematically carry out many activities at airports at the same time. These structures, which enable the transfer of land transportation to air transportation, contain all units that can be used in passenger and freight transportation. An airport is a special area that includes runways on land or water for the landing and take-off of motorized aircraft, connection roads between these runways, places reserved for aircraft to wait in a fixed state, a terminal building where passengers in this area can meet their basic needs and where all personnel responsible for controlling air traffic are located, and sections where maintenance, repair and refuelling of aircraft can be provided (Doganis, 2005; ICAO, 1996; Seferoğlu, 2014).

#### **3.2 Airport Layout Structure**

If airports are functionally classified and segmented, they are basically divided into two parts: air facility and ground facility. The air facility consists of the airspace near the terminal, runway, taxiway, and apron, which are allocated for different purposes. The ground facility section includes the passenger terminal or cargo terminal, parking

lot, airport access roads, which are reserved for passenger, baggage, or cargo operations as shown in Figure 3.1.



**Figure 3.1** Airport schematic representation (Havaalanları Daire Başkanlığı, 2011)

The terms mentioned above can be defined in detail as follows. An airport is a place that can be built on land or water, which allows various aircraft to land, take off and maneuver (taxi), as well as meeting the maintenance and other needs of these vehicles, and has various facilities for loading and unloading cargo and passengers. Runway is a rectangular area on the airport superstructure prepared for take-off and landing of aircrafts. Apron is an area designated for parking, loading, and unloading passengers and cargo, refueling, maintenance, etc. Taxiway is a roadway prepared for the passage of aircraft and designated to provide a connection between one part of the airport and another part of the airport.

### 3.3 Airport Superstructure Types

Operationally, airport tarmac areas are the most important of airport facilities. If any of the PAT (Runway-Apron-Taxiway) areas remain closed for a long time while a flight is in progress, it will adversely affect the flight and cause delays. This will cause risks in terms of flight and ground safety. The main requirement for the design of the

superstructures of these areas is to withstand the high wheel loads and tire pressures of the aircraft. In the design of areas such as refueling and maintenance areas, adequate resistance to the wheel loads of aircraft and maintenance vehicles as well as resistance to the adverse effects of chemical, oil and fuel leaks are also considered (Havaalanları Daire Başkanlığı, 2011; Heymsfield & Tingle, 2019; Özdemir, 2010).

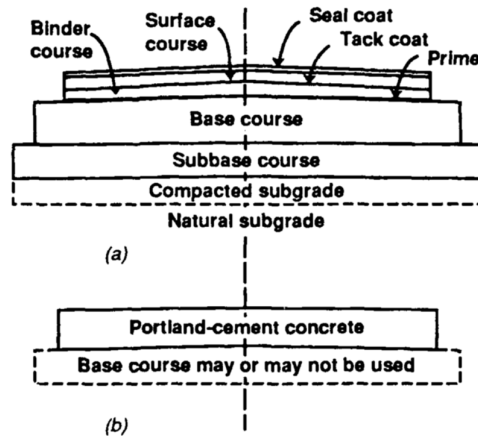
In a rapidly changing and developing world with industrial and technological developments, time, the most valuable resource in human life, has become even more precious. The fact that air transportation is faster, more comfortable, and safer than other modes of transportation bring the reason for preference and development to the forefront. However, since the economic parameter of air transportation is not low enough, the demand for other modes of transportation is higher. The year 1970 was a turning point in air transportation in the world and since then it has become a rapidly increasing preference and a developing technology. In our country, passenger demand has increased by 100% in the last decade. This rate of increase shows the socioeconomic development in our country and the change in people's transportation habits. Competition in air transportation and the decrease in aircraft and operating costs also play an important role in this development (Kuloğlu et al., 2007; Tunç, 2003).

With the developments in air transportation, the study of pavements used in airports has gained great importance. The functional characteristics of airport pavements are defined as surfaces that carry aircraft loads, are constructed in indoor and outdoor areas, and cover all layers on natural and/or reclaimed ground. These surfaces are often referred to as paved areas. Horon jeff (Horonjeff et al., 1962) states in his research that the pavement should be smooth and of sufficient thickness to allow safe driving in all weather conditions. The thickness of each layer in the runway road section should be designed and manufactured with sufficient thickness to prevent possible rupture and breakage due to the loads applied in the same layer or in different layers under service. As with road pavements, airport pavements are classified as rigid, composite, and flexible pavements according to the methods and materials used in their construction (Horonjeff et al., 1962; Kuloğlu et al., 2007; Tunç, 2003)

Rigid pavement constructions consist of concrete or reinforced concrete slabs. The main structural elements are concrete slab, drainage layer, separation layer and compacted soil. The definition of a flexible pavement is a pavement that can exhibit flexibility in accordance with the definition of elastic behavior at the moment of surface contact with the load and allows the load to be carried on it with small-scale deformations. A flexible pavement is a structural system consisting of a bituminous surface layer with flexibility between structural elements and a foundation layer, drainage layer, separator layer, sub-base layer, and compacted soil. The definition of a composite pavement is a pavement formed by laying bituminous hot asphalt over concrete slabs that deteriorate over time due to service and weather conditions, or by building concrete slabs over a deteriorated asphalt layer. The design and pavement properties of rigid, composite, and flexible pavements for PAT areas and other areas where aircraft ground handling services are provided is a complex engineering problem similar to the design of highway pavements. However, flexible pavements at airports are subjected to much higher loads than flexible pavements on highways due to the characteristics of the transportation vehicles they serve. In addition, mix proportions vary in asphalt production. Therefore, the idea that the properties of asphalt concrete used for highways and asphalt concrete to be used in airports can be the same can be considered as a big mistake in terms of basic engineering (Horonjeff et al., 1962; Kuloğlu et al., 2007; Martin et al., 1973; Özdemir, 2010; Tunç, 2003).

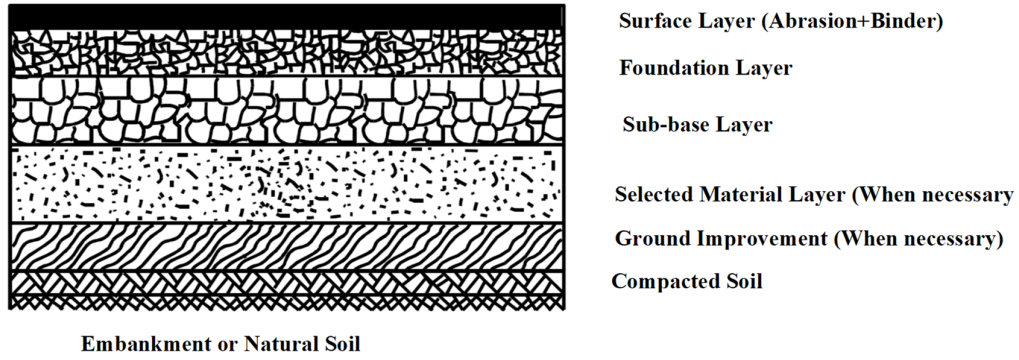
In pavements, pavements are generally classified as rigid or flexible according to the pavement properties used according to the application methods to distribute the load to the subgrade. In rigid pavements, as described above, the system is formed by a rigid surface on which the service load is carried. It is known that during flexural loading applied as a service load, most of the structural capacity is provided by the surface coating. In flexible pavements, a lower modulus is used. In distributing this load, the stresses generated by the service loads on the pavement should not exceed the strength of the subbase along the surfacing structure on the foundation and subbase materials as shown in Figure 3.2. In general, Portland cement concrete surfaces are preferred for rigid pavements, while flexible behaviour is achieved by flexible pavements, i.e. asphalt concrete surfaces. A third type of pavement has been introduced or discussed among some authors. This type of pavement has an asphalt concrete surface over surfaces formed with Portland cement slabs. This is called

composite pavement. Functionally, the composite pavement behaves like a rigid pavement due to the predominance of the concrete part (Zaniewski & others, 1991).



**Figure 3.2** Pavement types: (a) flexible and (b) rigid (Yoder & Witczak, 1991; Zaniewski & others, 1991)

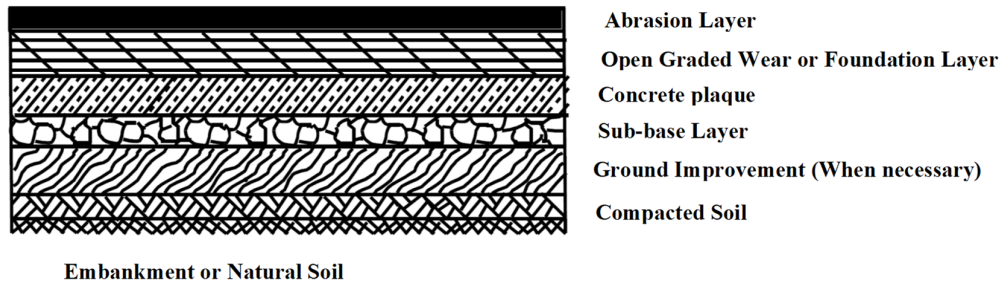
There are rigid (concrete), flexible (flexible) and composite (mixed) types of airport pavements used in our country (Figure 3.3). Rigid pavements on roads built for heavy and high traffic volume transportation vehicles also have a granular sub-base. They are concrete pavement slabs produced with a layer of concrete built on this foundation. Flexible pavements use a multi-layered structural system. Granular materials with high drainage capability are used in the lower layers of the system, while asphalt mixtures with high stability and the capacity to provide good driving comfort are used in the upper layers. Composite pavements are used to replace concrete pavements that deteriorate over time. In this case, they are pavements obtained by applying a reinforcement layer of hot asphalt mixture or concrete pavement layer on top of deteriorated flexible pavements (Figure 3.3).



**a.Flexible Pavements**



**b.Rigid Pavements**



**c.Flexible Pavements**

**Figure 3.3** Airport pavement types and their characteristics (Kaya & Başar, 2005; Kazda & Caves, 2015; Seferoğlu, 2014; Tunç, 2003; Yoder & Witczak, 1991)

One of the most important factors considered in the thickness design of airport pavements is the service traffic of the aircraft that will use the pavement. Depending on the capacity of an aircraft with certain characteristics, the amount of damage that the tire will cause to the pavement according to the position of the aircraft tire depends on various factors. Some of these factors can be listed as follows;

- a.Landing gear geometry
- b.Wheel load

- c. Tire contact pressure
- d. The position of the aircraft on the pavement
- e. Previous installation status of the coating

Determining the pavement thickness at airports as well as on highways is a very complex task. The reason for this is that the pavement serves under very different loads as well as very variable climatic and environmental conditions. The variables affecting the pavement thickness both influence each other and cannot be measured quantitatively (Horonjeff et al., 1962; Kazda & Caves, 2015; Martin et al., 1973; Seferoğlu, 2014; Tunç, 2003; Yoder & Witczak, 1991; Zaniewski & others, 1991).

During its service life, airfield pavement functions under very different loads and in highly variable climatic and environmental conditions. Pavement type and thickness can be influenced by numerous factors (Table 3.1). Many of these factors cannot be measured (Kuloğlu et al., 2007; Tunç, 2003; Zaniewski & others, 1991).

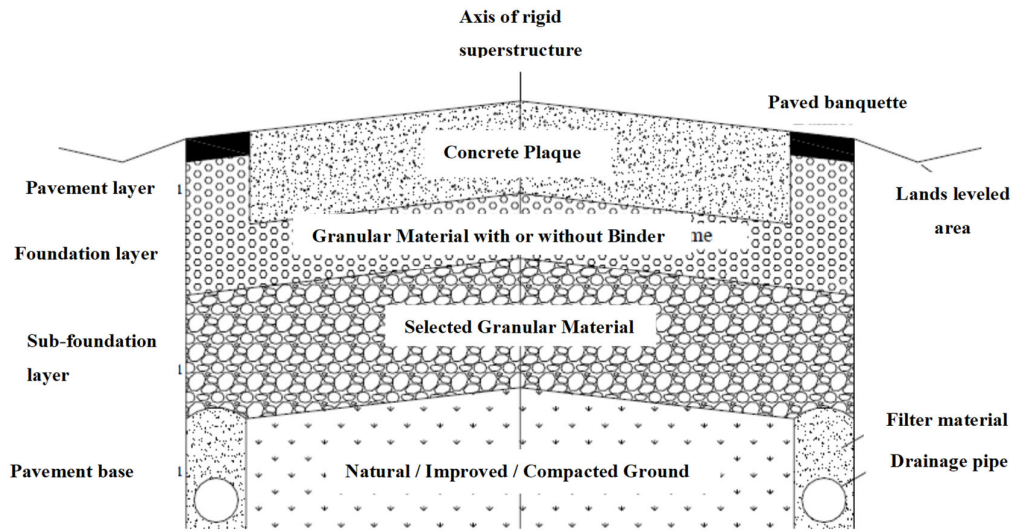
**Table 3.1** Main factors and variables affecting pavement type and thickness  
(Kuloğlu et al., 2007).

Main Factors	Variables
Traffic and Load	Current traffic volume, estimated future traffic volume, traffic distribution, wheel load, wheel arrangement, tire pressure, contact patch, number of load repetitions, load application time
Climate and Environment	Temperature changes, rainfall, frost depth, drainage conditions, soil properties, freeze-thaw, consolidation
Material	Material properties (asphalt, concrete, aggregates, and the materials they contain), mechanical properties of the layers such as load distribution and strength
Construction and Maintenance	Pavement detection, layer thickness, layer type, build quality and grade control level, periodic and condition-based maintenance services

### 3.3.1 Rigid Pavements

A rigid pavement system consists of pavement surfaces made of concrete or reinforced concrete slabs. They are systems consisting of a concrete slab, foundation layer and

compacted soil as the main structural elements. Concrete pavements were first constructed as runway pavements at the Ford Terminal in Dearborn, Michigan in 1927-1928. Since then, concrete pavements have been widely used on airport runways and aprons (Figure 3.4) (Kuloğlu et al., 2007).



**Figure 3.4** Rigid pavement section view (Salgin, 2015)

In general, concrete pavement types at airports can be classified according to their reinforcement content. Basically, they can be divided into 4 main classes. These classes can be listed as follows:

- Joint concrete pavements (JCP): Designed without reinforcement in the slab. While the values determined for joint spacing are taken into consideration, they are selected in accordance with the working and cracking strength of concrete because of curing and temperature stresses. Due to the slab discontinuity between joints, load transfer elements are rarely, if ever, used in JCP, usually in the form of dowel bars.
- Joint reinforced concrete pavements (JRCP): designed with a wider spacing between joints to reduce discontinuities caused by joints between slabs. However, due to the wider spacing between joints, cracks in the slabs are inevitable. Reinforcing steel is used to combat these cracks and limit their propagation. This ensures both load transfer and interlocking of the aggregates along the crack. Depending on the amount of steel, the slab is designed to

control the crack width by limiting it, rather than being an element involved in carrying the traffic load. Considering the distance between the joints formed in production, the joint movement in JRCP will be greater than in JCP. Therefore, mechanical load transfer elements defined as dowel bars are needed.

- Continuously Reinforced Concrete Pavements (CRCP): Designed and implemented to eliminate the need for joints. As with JRCP, the amount of steel reinforcement is primarily selected to limit and control crack movement and to provide aggregate interlocking along cracking surfaces.
- Prestressed Concrete Pavements (PCP): are designed to effectively exploit the high compressive strength after the development of low flexural strength, which is a natural deficiency of concrete. Thanks to the prestressing process, the compressive stresses and flexural strength generated at the pavement surface become cumulative and cause an increase in the stress range in the flexural zone. The wider stress ranges allowed by this process in the flexural zone can allow PCP to be produced thinner than other types of concrete pavement. Prestressing is usually accomplished by post-tensioning applied to steel wires. The plate size of the prestressed pavement is limited by the post-tensioning capacity created in the steel wires (Zaniewski & others, 1991).

### **3.3.1.1 Airport Rigid Pavement Design with FAA Method**

There are many methods for airport concrete pavement design such as Federal Aviation Administration (FAA), Corps of Eng., The Load Classification Number (LCN) and Positive Control Airspace (PCA). In our study, we will focus on the design of concrete pavement at airports considering the FAA method. In the design of concrete pavements and determination of pavement thickness; parameters such as strength of concrete, characteristics of the base soil, estimated number of annual take-offs and aircraft weight are needed.

The thickness of concrete pavements is calculated based on the strength of the existing concrete. The use of concrete pavements during the construction of airport roads is an example of pavement construction. Since the main property of pavement layers is resistance to tensile stress, it is necessary to know the flexural strength of the concrete to be used in pavement construction. The design of the pavement thickness starts with selecting these parameters and investigating their suitability.

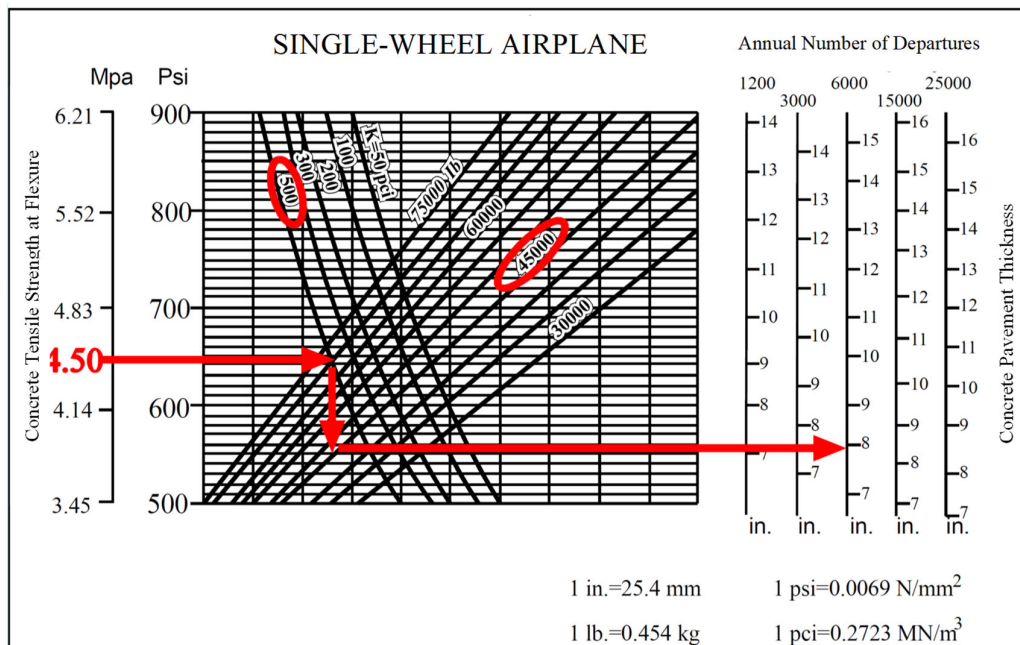
For the design, which is the first stage during the construction of airport pavements, the bearing coefficient ( $k$ ) of the soil in the area to be constructed should be evaluated by finding the CBR value. In CBR value calculations, the force required to immerse the sample to a certain depth is calculated for a sample prepared by considering the standard conditions for a piston that can be applied at a constant diameter and loading rate. In the comparison of sample samples, it is defined as the value obtained by proportioning the force that can provide the same amount of immersion depth on a sample prepared with a limestone-derived crushed stone material with a continuous gradation selected with a maximum grain diameter of 1 inch (25.4 mm). This value is given as a percentage expression. The previously obtained relationship between the coefficient value ( $k$ ) calculated for the soil bed and the CBR value can be determined using Table 3.2. If the CBR value obtained because of the test results is between 0 and 3, they are very weak soils and need to be rehabilitated. Soils with a CBR value between 3 and 7 are considered weak-medium soils, and soils with a CBR value greater than 10 are considered strong soils. Whether additional measures should be taken for medium soils depends on other characteristics of the soil (Seferoğlu, 2014; Yoder & Witezak, 1991)

**Table 3.2** Relationship between bed coefficient and CBR value (Tunç, 2002).

CBR (%)	$k, 10^3 \text{ kN/m}^3$
5	13.7
8	27.5
10	34.3
12	43.2
15	52
20	60.8
25	70.6
30	78.5
50	103
90	131.4

The FAA uses the flexural tensile strength of concrete, the bearing coefficient value of the soil, the design aircraft weight and the estimated number of annual take-offs to determine the pavement thickness at airports. According to Figure 3.5, starting from the flexural tensile strength of the concrete, an arrow is drawn with a horizontal projection to the bearing coefficient value of the soil. The vertical projection of this point is extended to the design airplane weight curve. Then the horizontal projection

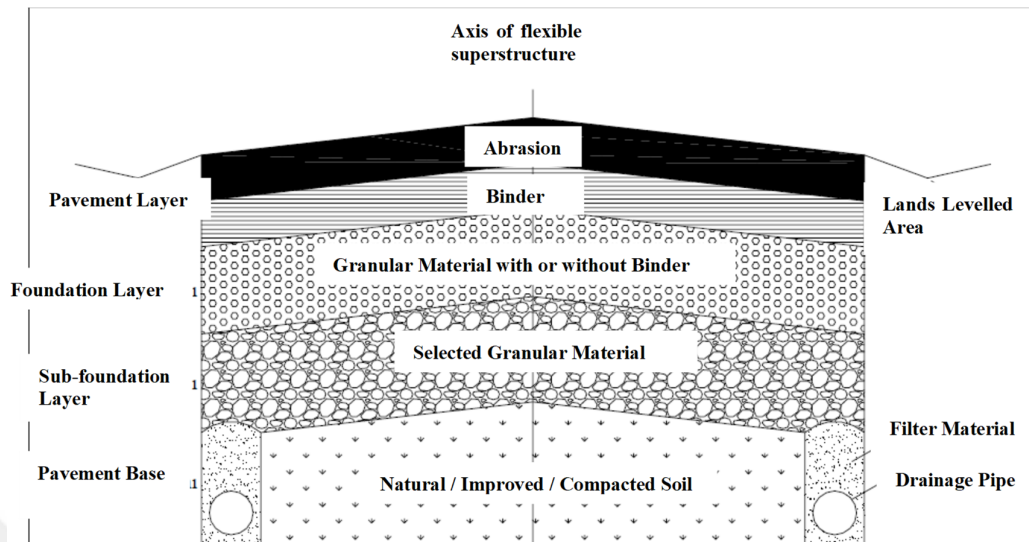
is taken again from the last point and the pavement thickness is extended to the reference lines and the pavement thickness can be determined by stopping at the desired estimated number of annual take-offs. FAA no longer uses this method but instead uses a finite element calculation program called FAARFIELD (Federal Aviation Administration Rigid and Flexible Iterative Elastic Layered Design). However, the basic inputs are as mentioned above. FAARFIELD (Brill & Kawa, 2017) recommends a minimum concrete pavement thickness of 6 in (15.24 cm). The FAA also recommends a concrete flexural tensile strength of 600 to 700 psi (4.14 to 4.83 MPa) for most airport applications (Brill & Kawa, 2017b; Osman, 2015; Salgın, 2015; Tamagusko, 2020; Tunç, 2002).



**Figure 3.5** FAA rigid pavement thickness calculation chart (Brill & Kawa, 2017b; Osman, 2015; Salgın, 2015; Tamagusko, 2020; Tunç, 2002)

### 3.3.2 Flexible Pavements

A flexible pavement is a type of pavement that allows small-scale deformations and elastic behavior to occur under the service wheel loads of vehicles and transmits these service loads to the foundation soil through the bituminous binder pavement layer (asphalt concrete), foundation and sub-base layers (Figure 3.6).



**Figure 3.6** Flexible pavement section view (Salgın, 2015)

There are several methods for designing flexible pavements for airports, called FAA, Corps of Eng., LCN, Asphalt Institute, French and Canadian Practices. FAA (US Civil Aviation Administration) and Corps of Eng. methods are almost identical. On the other hand, ICAO (International Civil Aviation Organization) recommends the FAA method. The stability of asphalt pavements is defined as their resistance to compression, shrinkage, shear and crumbling under sustained and prolonged static loads from vehicles, accelerating or decelerating vehicle wheel impacts. The term stability can be briefly defined as the ability to withstand traffic loads in translation and to exhibit the capacity to deform in service without rutting. Stability should be at a value that will withstand traffic loads. However, too high stability means a mixture that is too stiff to withstand deformation under traffic loads and will crack. Therefore, like low stability, too high stability is also harmful (Seferoğlu, 2014).

The FAA method, also called the CBR method, allows pavement thickness to be determined using empirically developed design graphs. Using this method, values can be determined for the full thickness of the pavement and for the thickness of each layer of the system. For factors affecting the choice of pavement thickness;

- Aircraft weight and characteristic wheel arrangement (configuration)
- Traffic volume
- Mode of operation (traffic density and speed on the sidewalk)
- Strength of the floor
- It is the characteristic feature of the material.

In addition, the characteristics of the airplanes that will use the pavement in airport flexible and rigid pavement design are as follows;

- Load distribution of the airplane
- Aircraft wheel configuration and geometry
- Traffic volume
- Determination of the design aircraft (Seferoğlu, 2014; Tunç, 2001)



## CHAPTER 4

### AIRPORT PAVEMENT ANALYSIS SOFTWARE PROGRAM

The design of rigid airport pavements under different soil conditions is the focus of this study. Such problems constitute an extremely complex engineering problem involving many interacting variables. The calculation of the design method for an airport pavement is very computationally intensive, so the FAA has designed a computer program called FAARFIELD to assist pavement engineers. FAARFIELD is offered as a user-friendly and completely free software. As far as the design procedure is concerned, it provides a design method based on structural analysis based on layered elastic and three-dimensional finite element method developed for use in calculating design thicknesses for airfield pavements. Layered elastic and three-dimensional finite element-based design theories are adopted within the software to address the impact of new complex gear and wheel arrangements.

#### 4.1 FAARFIELD program usage

The FAARFIELD program also requires information on the fleet of aircraft that the airport will acquire in Figure 4.1 (Bhalla et al., 2013).

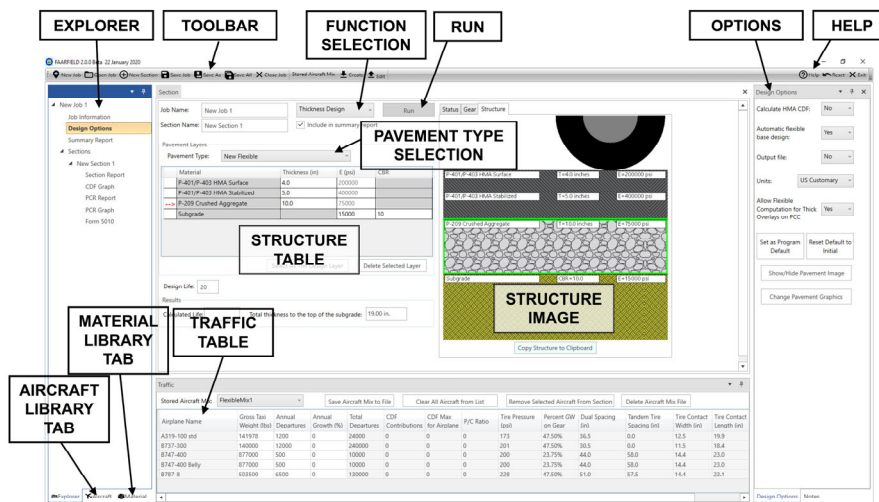


Figure 4.1 Example view of FAARFIELD program (Bhalla et al., 2013).

The FAARFIELD program includes four functions (Figure 4.2) (Brill, 2021).

- Thickness Design: Compute required thickness per AC 150/5320-6 (Office of Airport Safety & Standards - Airport Engineering Division, 2021).
- Life: The structural life for a given structural system is calculated for the traffic it will be exposed to during its service life
- Compaction: Compute subgrade compaction requirements per AC 150/5320-6 (Office of Airport Safety & Standards - Airport Engineering Division, 2021). for a given structure and traffic mix. (Applies to completed designs.)
- PCR: Compute Pavement Classification Rating (PCR) for the structure and traffic mix.

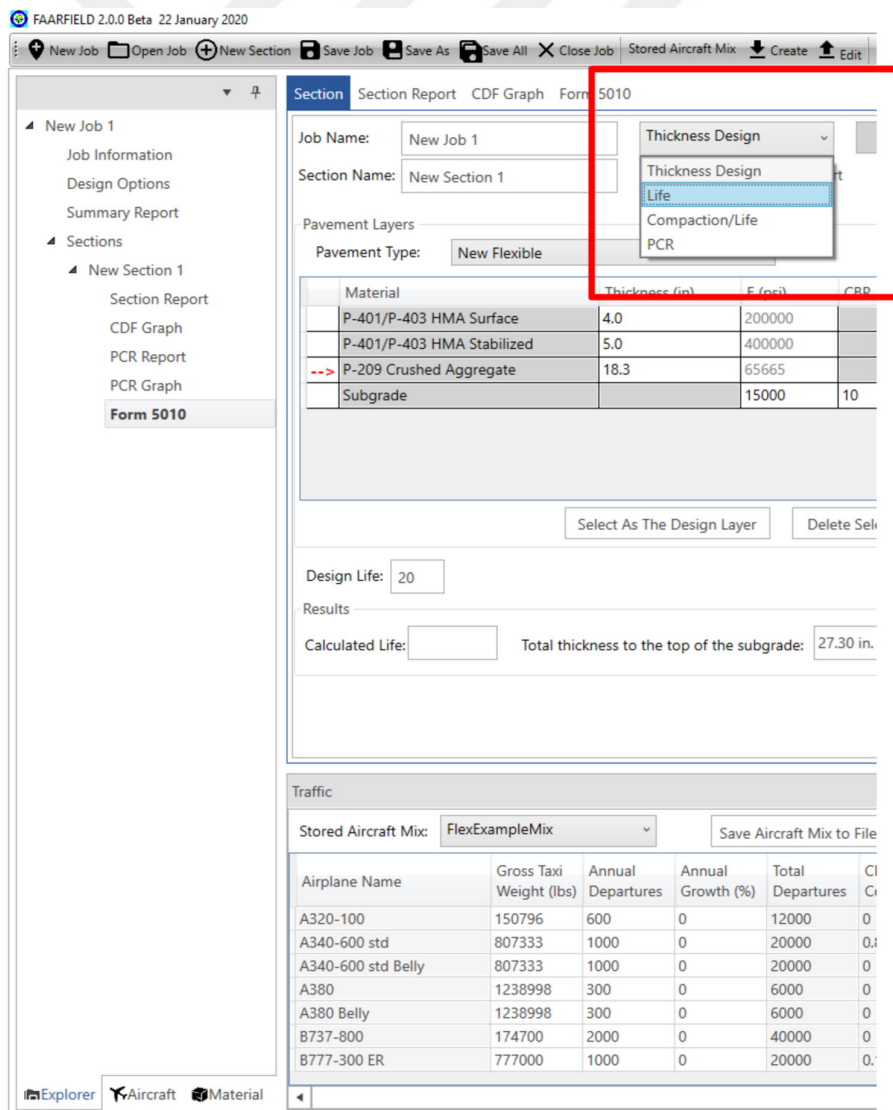
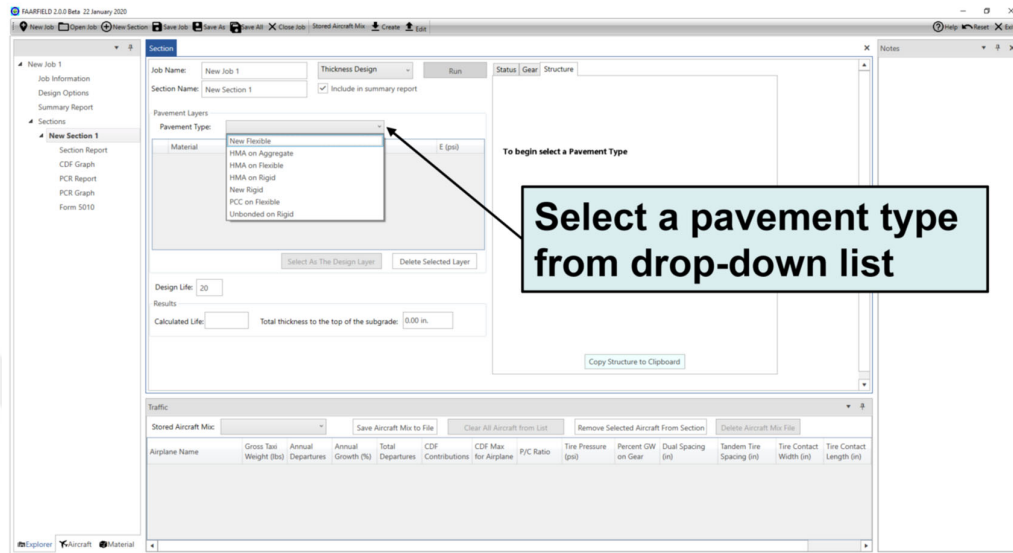
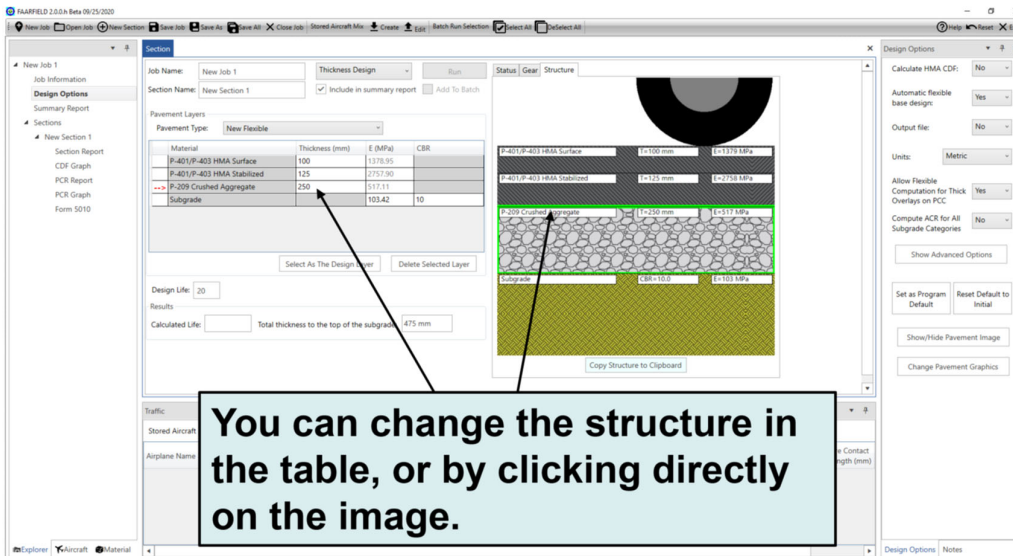


Figure 4.2 Example view of FAARFIELD program menu (Brill, 2021)

In the next step, the pavement type is selected from the program (Figure 4.3). After that, the pavement structure is selected from the program (Figure 4.4).



**Figure 4.3** Example view for pavement type from FAARFIELD program menu (Brill, 2021)



**Figure 4.4** Example view for pavement structure from FAARFIELD program menu (Brill, 2021)

Go to Aircraft Selection and select the relevant values, Aircraft Group, Library Aircraft and Traffic List (Figure 4.5). The landing gear information and data are displayed on the screen (changed by applying the mouse over the wheel to display the coordinates) and the loading phases are defined by selecting the aircraft handling characteristics (Figure 4.6).

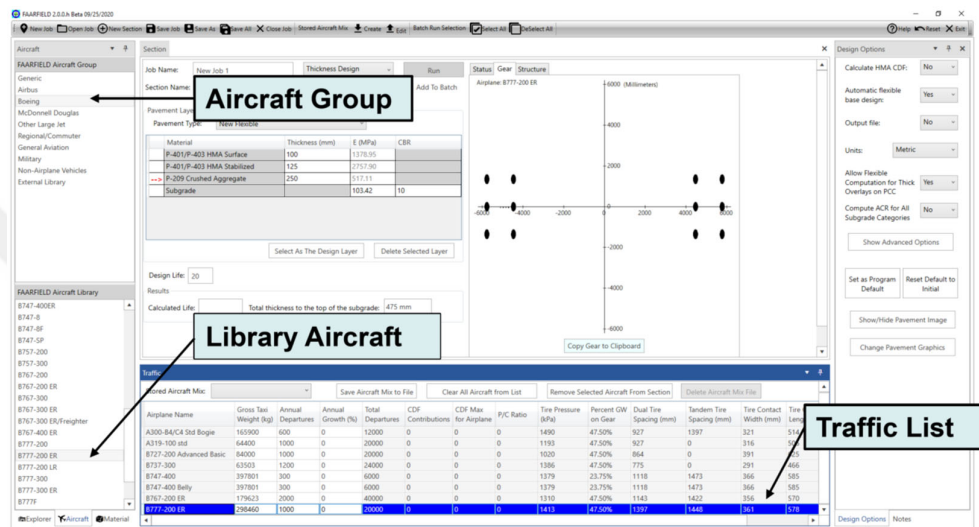


Figure 4.5 Example view for aircraft selection from FAARFIELD program menu (Brill, 2021)

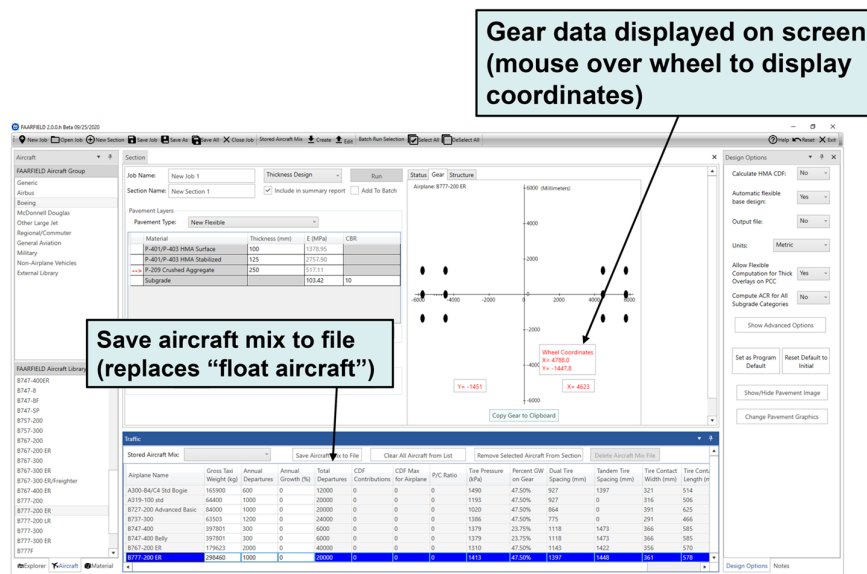


Figure 4.6 Example view for aircraft gear and wheel data from FAARFIELD program menu (Brill, 2021)

After the operations for the loading details are completed, the relevant command is executed to determine the coating thickness details (Figure 4.7). The result screen is accessed and the calculated P/C ratio that defines the relationship between the number of passes needed to apply one coverage and the unit area of the pavement and CDF results for each aircraft value are interpreted, and design safety is analyzed (Figure 4.8).

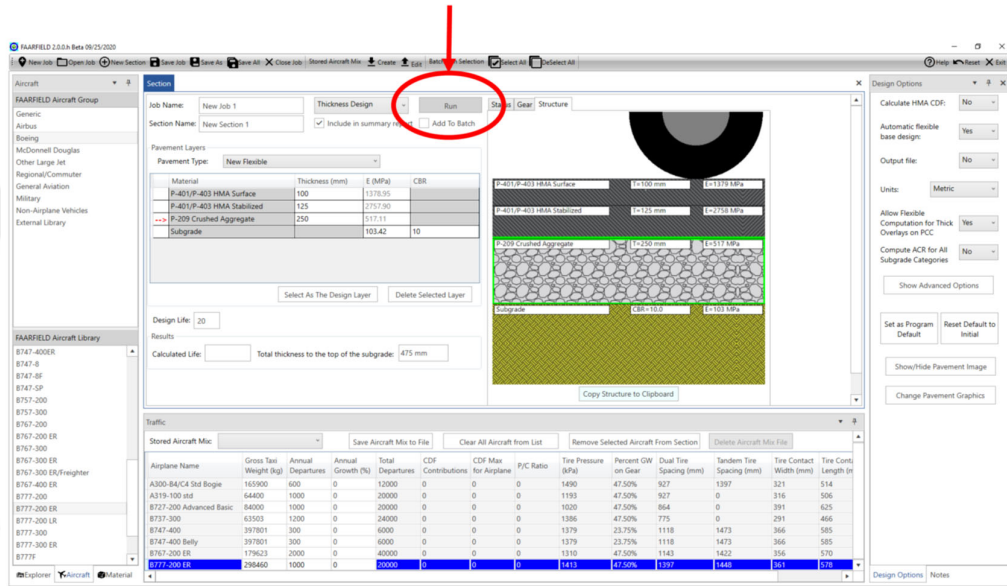


Figure 4.7 Example view for pavement thickness calculation from FAARFIELD program menu (Brill, 2021)

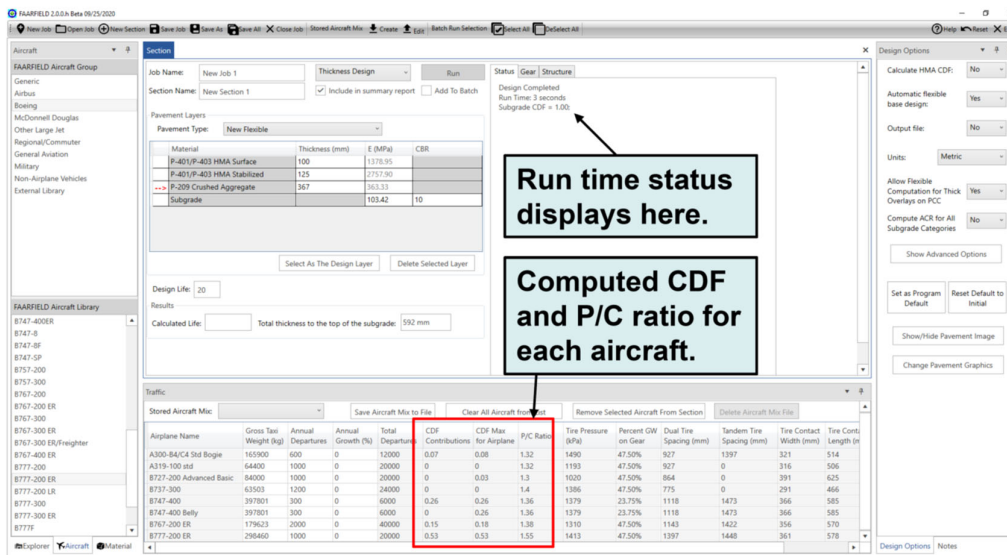


Figure 4.8 Example view for CDF and P/C ratio from FAARFIELD program menu (Brill, 2021)

## 4.2 FAARFIELD software

FAA Advisory Circular AC-150/5320-6E is used for the design of new airport pavements and rehabilitation of damaged old pavements. This AC uses a finite element method for rigid and flexible elements. pavements: together with software called FAARFIELD to facilitate calculations for its users (Bhalla et al., 2013).

The FAARFIELD program is easy to use. In the case of flexible pavement, the user enters the thickness of the flexible pavement. The available layers are concrete slabs, cement treated base layers and granular layers and the modulus of each of them. Likewise, there are some parameters in the program that indicate the structural state of the pavement to be treated. There are two parameters (Bhalla et al., 2013).

CDF: Cumulative Damage Factor used; the amount of structural life used by this factor is subtracted up to the coating time (Bhalla et al., 2013).

SCI: Structural Condition Index, derived from the following data Pavement Condition Index (PCI), using only 6 distress modes: corner breakage; longitudinal, transverse, and diagonal cracking; fragmented pavement; shrinkage cracks; joint spalling; and corner spalling. An SCI of 80% is the FAA's definition of structural failure of a hard pavement and is consistent with 50% of pavements in the traffic area exhibiting structural cracks (Bhalla et al., 2013).

The FAARFIELD program also requires information on the fleet of aircraft that the airport will acquire in Figure 4.9. To facilitate the introduction of the fleet, the program provides a library from which the most common aircraft models can be selected, together with the frequency of departures and the projected annual growth rate. For each model, the number of annual take-offs and the expected annual growth in the coming years are introduced. Finally, the design life of the project should be introduced; this is usually set in the coming years. Finally, the design life of the project, which is usually set at 20 years, should be specified. Based on this data and the modulus of the layer, the program calculates the required thickness of the pavement in successive iterations (Bhalla et al., 2013).

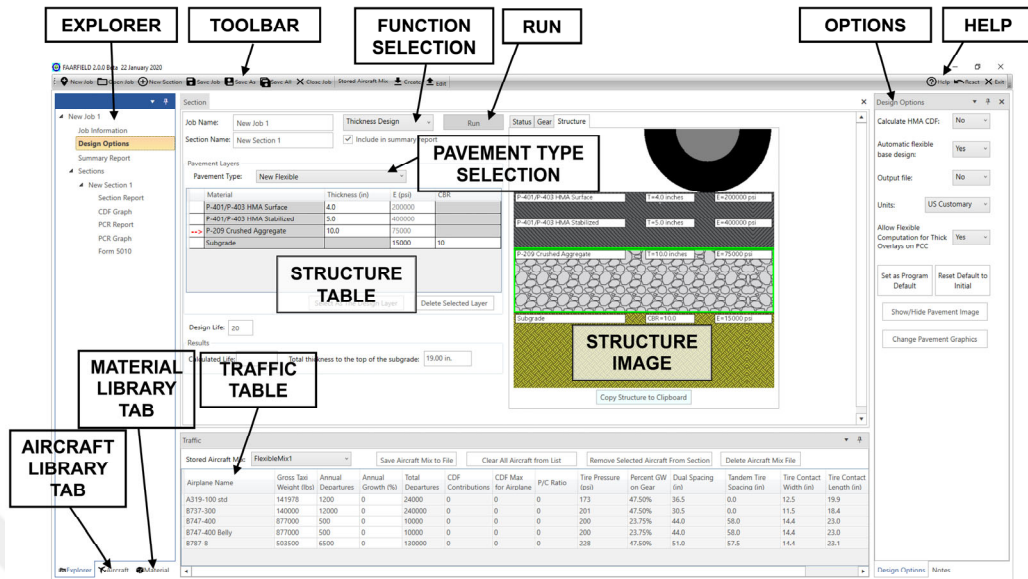


Figure 4.9 Example view of FAARFIELD program (Bhalla et al., 2013).

## CHAPTER 5 PAVEMENT ANALYSIS RESULT

### 5.1 Case studies

This thesis presents a comparison of rigid pavement designs for airport runways under strong and weak soil conditions for low and high traffic airports. Within the scope of this thesis, analyses were performed with the FAARFIELD program provided by FAA. During the analyses, firstly, the design type of the airport pavement was determined as flexible or rigid. Annual traffic loads (number of take-offs) for each airport and aircraft type should be entered into the program, the main reason for this is that take-off movements are important for runway strength in design. The gross weight values and the annual tariff growth rate for each aircraft type were also specified in the program. The service life information and all inputs for the superstructure design analysis were entered. Afterwards, separate analyses such as runway pavement design and service life are performed.

The 4 different case studies can be summarized as follows: Case-I with low traffic load and low soil capacity, Case-II with high traffic load and low soil capacity, Case-III with low traffic load and high soil capacity, and finally Case-IV for airport runways with high traffic load and high soil capacity as given in Table 5.1. As a result of the data obtained, CDF and P/C ratio values were analyzed.

**Table 5.1** Definition of all cases.

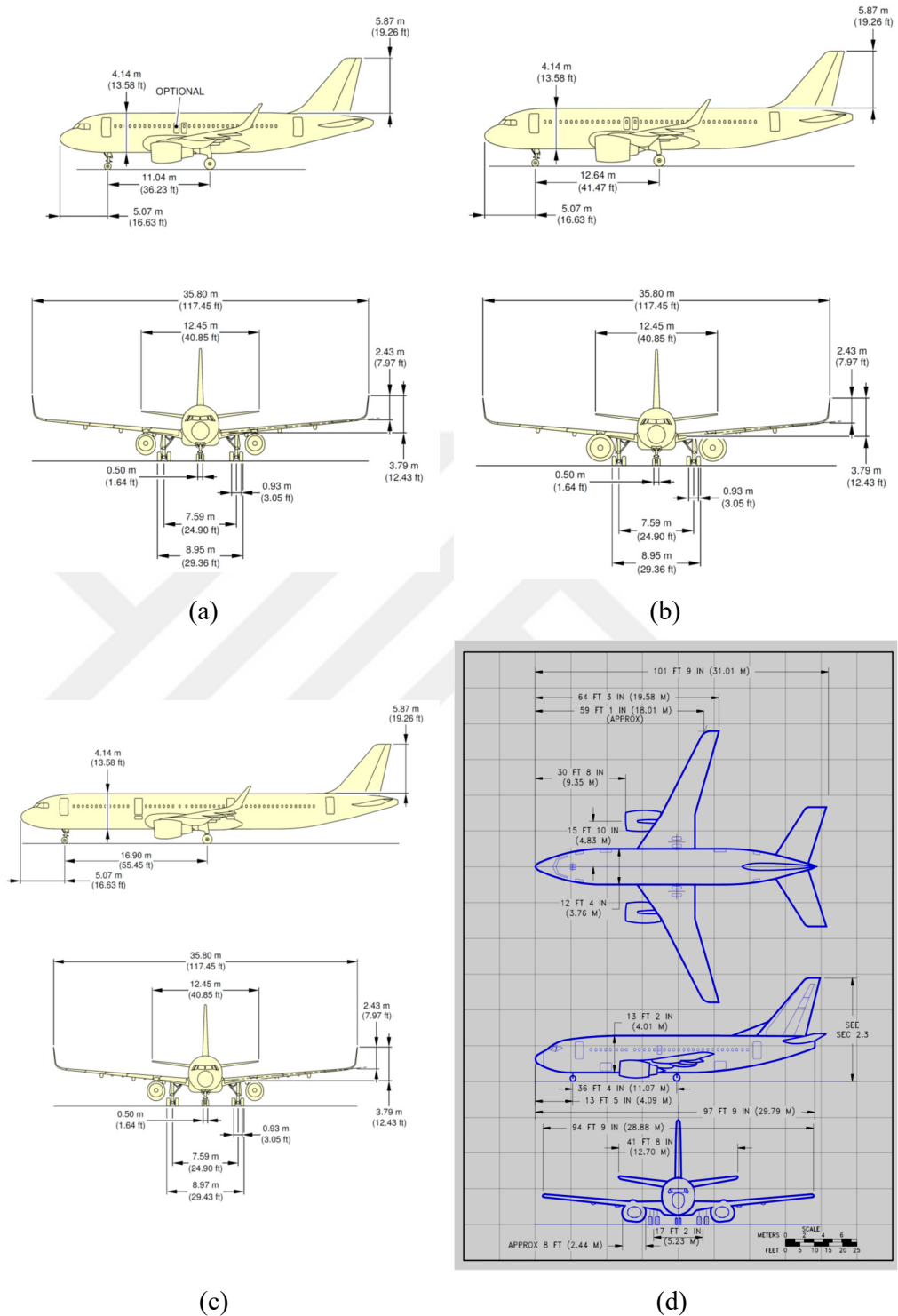
Case no.	traffic load	soil capacity	CBR
Case-I	low	low	5
Case-II	high	low	5
Case-III	low	high	15
Case-IV	high	high	15

The reflection of runway pavement life on the design as load distribution of take-off movements is considered as an important parameter in terms of runway pavement and embankment strength and its effects are evaluated in detail within the scope of the

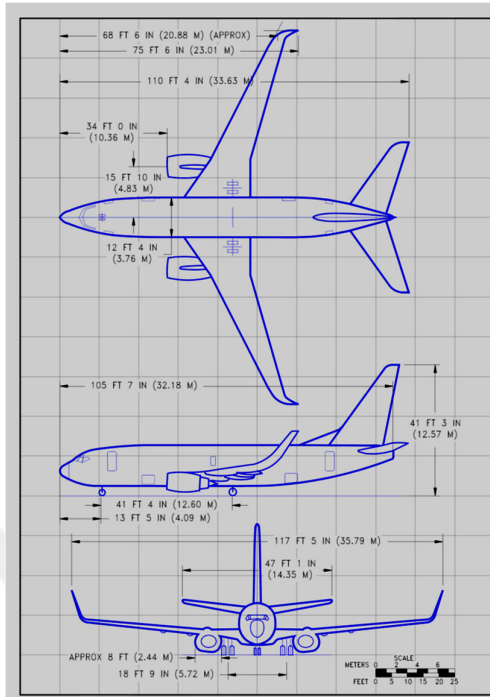
thesis. In addition, gross weight values for each aircraft type were entered into the system and obtained from the system with annual tariff growth rates. Within the scope of the study, 20-year periods were considered for runway pavement service life. In addition, two different traffic loads, defined as low and high traffic, were evaluated. The high traffic load study is an example of 1 year flight operations (1-year total departures for each aircraft type) at a hub airport with +50 million passengers per year. Low traffic load is considered as total departure ATMs for 1-year at a local/regional airport. Another parameter, the soil bearing capacity, is considered with CBR. CBR value is taken as 5 for low strength soil sample and CBR=15 for good soil. As a result, 4 different case studies were conducted and the change in runway pavement properties within the airport traffic load and soil properties were evaluated with the FAARFIELD program. The 4 different case studies can be summarized as follows: Case-I with low traffic load and low soil capacity, Case-II with high traffic load and low soil capacity, Case-III with low traffic load and high soil capacity, and finally Case-IV for airport runways with high traffic load and high soil capacity. Although the value selected for low soil strength is CBR value 5, the k coefficient used in the FAARFIELD program was calculated for this CBR value with the help of the formula given as Equation 5.1 and entered the FAARFIELD program.

$$k = 28.6926 \times [CBR]^{0.7788} \times 0.271447138 \left(\frac{MPa}{m}\right) \quad (4.1)$$

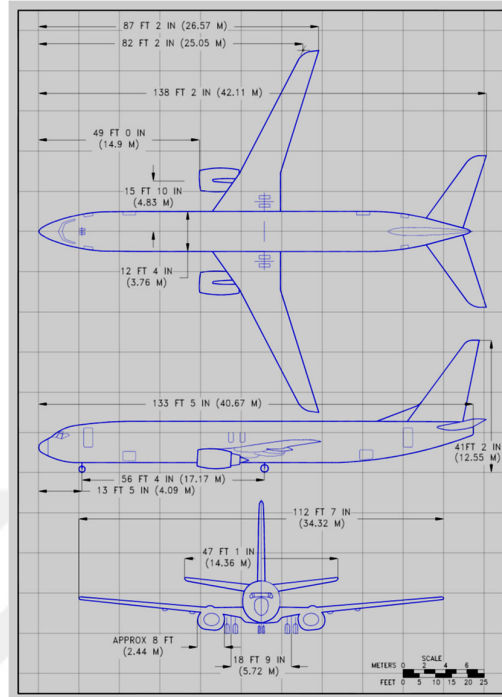
In addition, detailed views of the aircraft characteristics of the wheel loads used in the calculations are presented for low traffic condition in Figures 5.1 to 5.3.



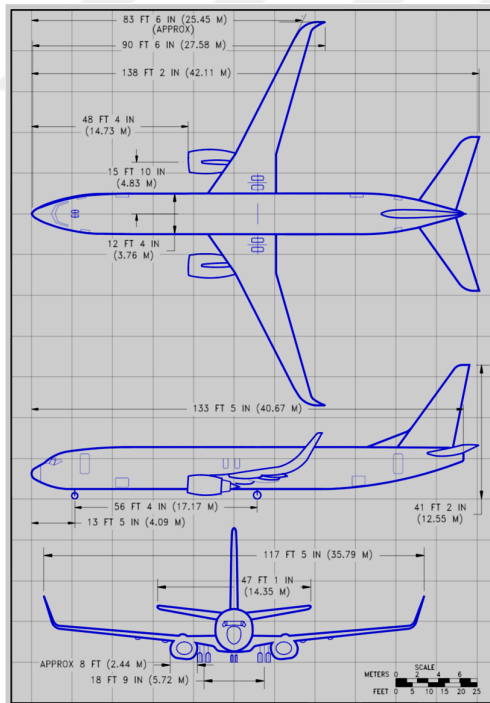
**Figure 5.1** Characteristic properties of planes for low traffic condition (Part-I): a) A319-100 opt, b) A320-200 std, c) A321neo and d) B737-400



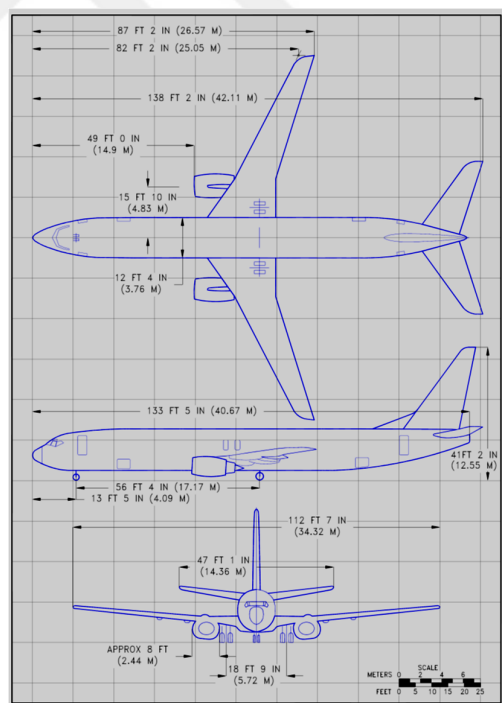
(a)



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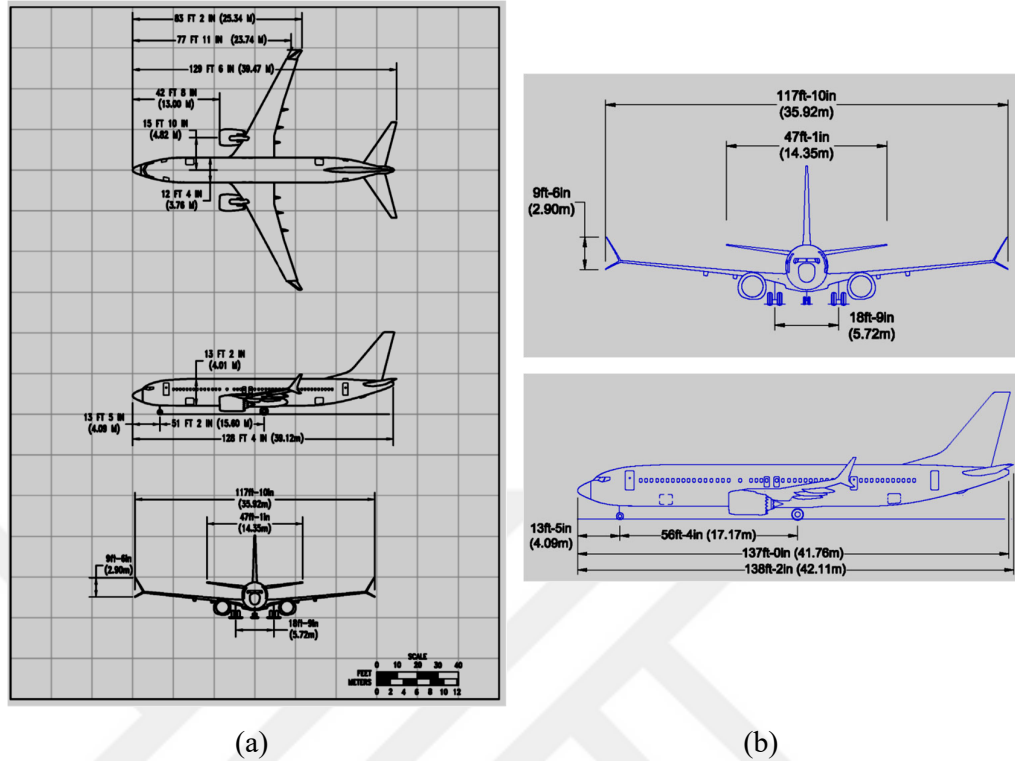


(c)



(d)

**Figure 5.2** Characteristic properties of planes for low traffic condition (Part-II): a) B737-700, b) B737-800, c) B737-900 and d) B737-BBJ2



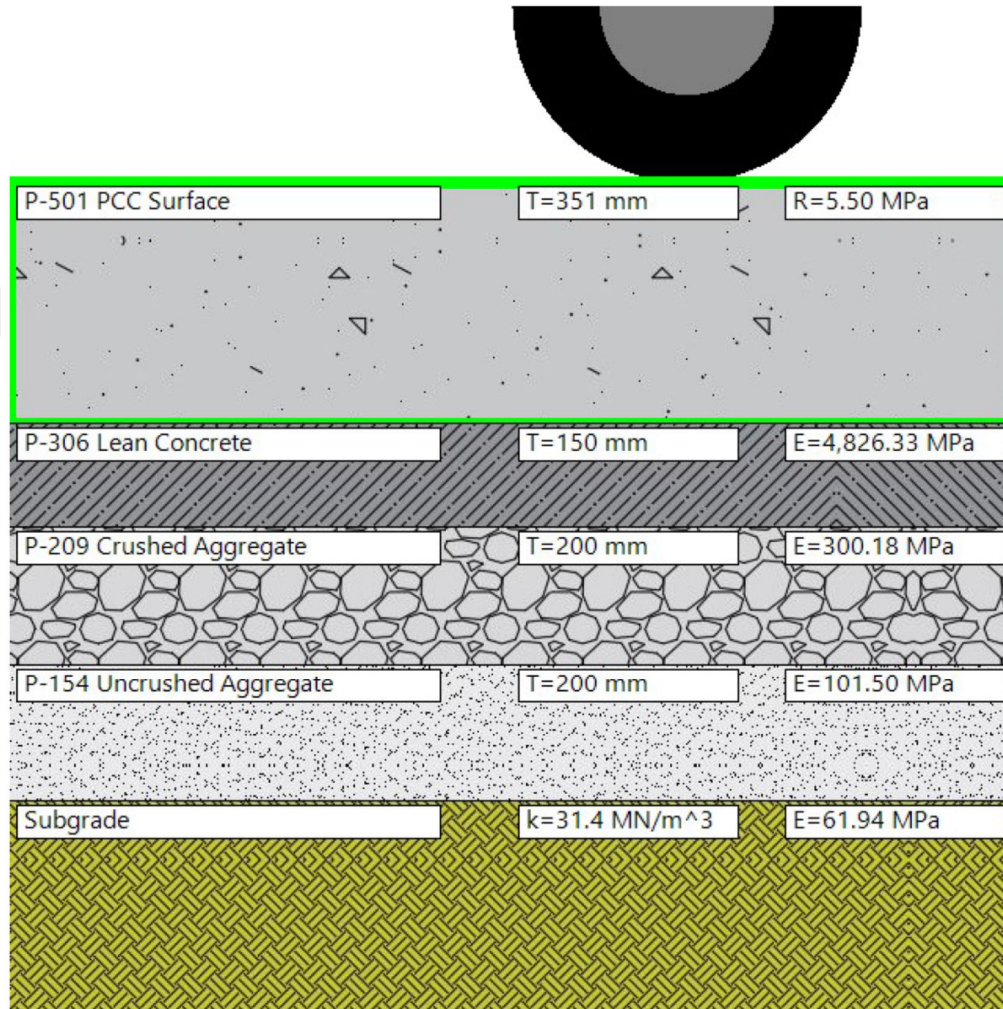
**Figure 5.3** Characteristic properties of planes for low traffic condition (Part-III): a) B737-8/8-200/BBJ MAX 8, and b) B737-9 MAX

### 5.1.1 Case study I (low traffic-low soil capacity)

Within the scope of the study, 4 case studies were conducted. Under this heading, the results of the analyses performed with the FAARFIELD program for low soil strength and low air traffic are presented. In the content of these results, the changes in CDF values and P/C ratios according to the FAARFIELD program are presented separately for each aircraft traffic.

The total thickness value up to the top of the subgrade is defined as 901 mm in total. The layers that make up this value are PCC (Portland cement concrete) Surface, Lean Concrete, Crushed Aggregate, Uncrushed Aggregate and Subgrade. PCC Surface, Lean Concrete, Crushed Aggregate, Uncrushed Aggregate layer thicknesses are 351, 150, 200 and 200 mm respectively. Although the service life defined in the system is 20 years, the coating type is defined as rigid as defined in Figure 5.1. Modulus of elasticity values for PCC Surface, Lean Concrete, Crushed Aggregate, Uncrushed Aggregate layers were defined as 27,579.04, 4,826.33, 300.18 and 101.50 MPa respectively. Poisson's ratio values of PCC Surface, Lean Concrete, Crushed

Aggregate, Uncrushed Aggregate layers were determined as 0.15, 0.2, 0.35 and 0.35 MPa respectively. Subgrade modulus of elasticity and Poisson's ratio values were defined as 61.94 and 0.4 respectively as defined in Figure 5.4.



**Figure 5.4** Case-I pavement structure information by layer view of FAARFIELD program

Aircraft weights and number of departures used in the coatings during the analysis are given in the table. The table also shows the estimated annual growth rates of 10% for the annual departure values. Furthermore, maximum values for contribution ratios and CDF values for each aircraft are presented (Table 5.2). On the other hand, P/C ratios for each aircraft type were obtained through analysis and calculated by the software. The A321neo with the highest weight of 97.4 t is considered in the analysis. The CDF

contribution value for this aircraft was calculated as 0.86 and 0.04 for 783 and 39 annual departures, respectively (Table 5.2 and Table 5.3).

**Table 5.2** Airplane information used in Case-I.

No.	Name	Gross Wt. (kg)	Annual Departures	% Annual Growth
1	A319-100 opt	68,400	56	10
2	A320-200 std	73,900	1,164	10
3	A321neo	97,400	783	10
4	A321neo	97,400	39	10
5	B737-400	68,266	5	10
6	B737-800	79,242	742	10
7	B737-700	70,307	1	10
8	B737 BBJ2	79,250	3,134	10
9	B737-900	79,242	593	10
10	B737-8/8-200/BBJ MAX 8	82,417	941	10
11	B737-9 MAX	88,541	42	10

On the other hand, the same values were obtained for CDF max for this aircraft. The P/C ratio values are 3.36 for both number of departures for this aircraft. A320-200std and B737-BBJ2 aircraft with the highest departure values were included in the calculations as 73.9 and 79.25 t, respectively. CDF contribution values are calculated as 0 and 0.04 for A320-200std and B737-BBJ2 aircraft, respectively. Moreover, CDF max contribution values are calculated as 0 and 0.07 for A320-200std and B737-BBJ2 aircraft, respectively. P/C ratios values are calculated as 3.7 and 3.53 for A320-200std and B737-BBJ2 aircraft, respectively (Table 5.2 and Table 5.3).

**Table 5.3** Airplane departure CDF and P/C ratio results in Case-I.

No.	Name	CDF Contribution	CDF Max for Airplane	P/C Ratio
1	A319-100 opt	0.00	0.00	3.66
2	A320-200 std	0.00	0.00	3.7
3	A321neo	0.86	0.86	3.36
4	A321neo	0.04	0.04	3.36
5	B737-400	0.00	0.00	3.52
6	B737-800	0.01	0.02	3.53
7	B737-700	0.00	0.00	3.68
8	B737 BBJ2	0.04	0.07	3.53
9	B737-900	0.01	0.01	3.53
10	B737-8/8-200/BBJ MAX 8	0.03	0.05	3.47
11	B737-9 MAX	0.01	0.01	3.39

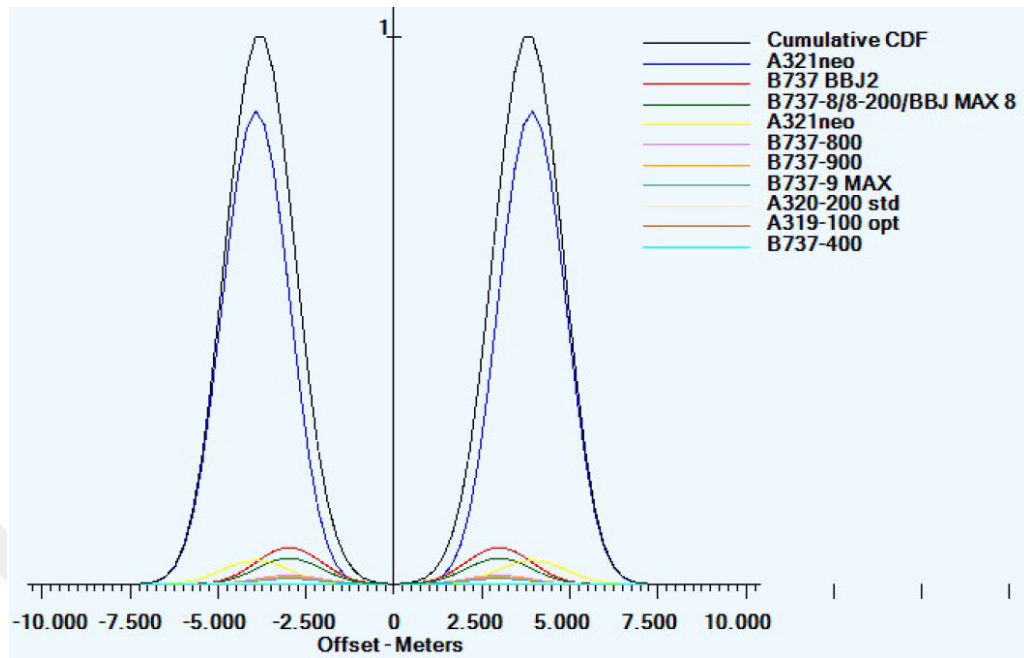
Details of the subgrade compaction requirements for noncohesive soil are presented in the Table 5.4. shows the compaction values and depths of the superstructure and subgrade layers for noncohesive soil. For Case-I, the critical aircraft mobility was observed for the A321neo aircraft. For this aircraft, compaction depths of 0-358, 358-494, 494-1277 and 1277-2552 mm should be achieved for maximum dry density values of 100, 95, 90 and 85 percent from the pavement surface. For compaction depth from the top of the subgrade, maximum dry density values of 90 and 85 percent should be achieved at 0-375 and 375-1651 mm respectively (Table 5.5).

**Table 5.4** Subgrade compaction requirements for noncohesive soil used in Case-I.

Percent Maximum Dry Density(%)	Depth of compaction from pavement surface (mm)	Depth of compaction from top of subgrade (mm)	Critical Airplane for Compaction
100	0 - 358	--	A321neo
95	358 - 494	--	A321neo
90	494 - 1277	0 - 375	A321neo
85	1277 - 2552	375 - 1651	A321neo

**Table 5.5** Subgrade compaction requirements for cohesive soil used in Case-I.

Percent Maximum Dry Density(%)	Depth of compaction from pavement surface (mm)	Depth of compaction from top of subgrade (mm)	Critical Airplane for Compaction
95	0 - 349	--	A321neo
90	349 - 442	--	A321neo
85	442 - 616	--	A321neo
80	616 - 1229	0 - 327	A321neo



**Figure 5.5** CDF values in Case-I

For Case-I, the critical aircraft mobility was observed for the A321neo aircraft for cohesive soil. For this aircraft, compaction depths of 0-349, 349-442, 442-616 and 616-1229 mm should be achieved for maximum dry density values of 95, 90, 85 and 80 percent from the pavement surface. For compaction depth from the top of the subgrade, maximum dry density values of 80 percent should be achieved at 0-327 mm respectively (Table 4.4).

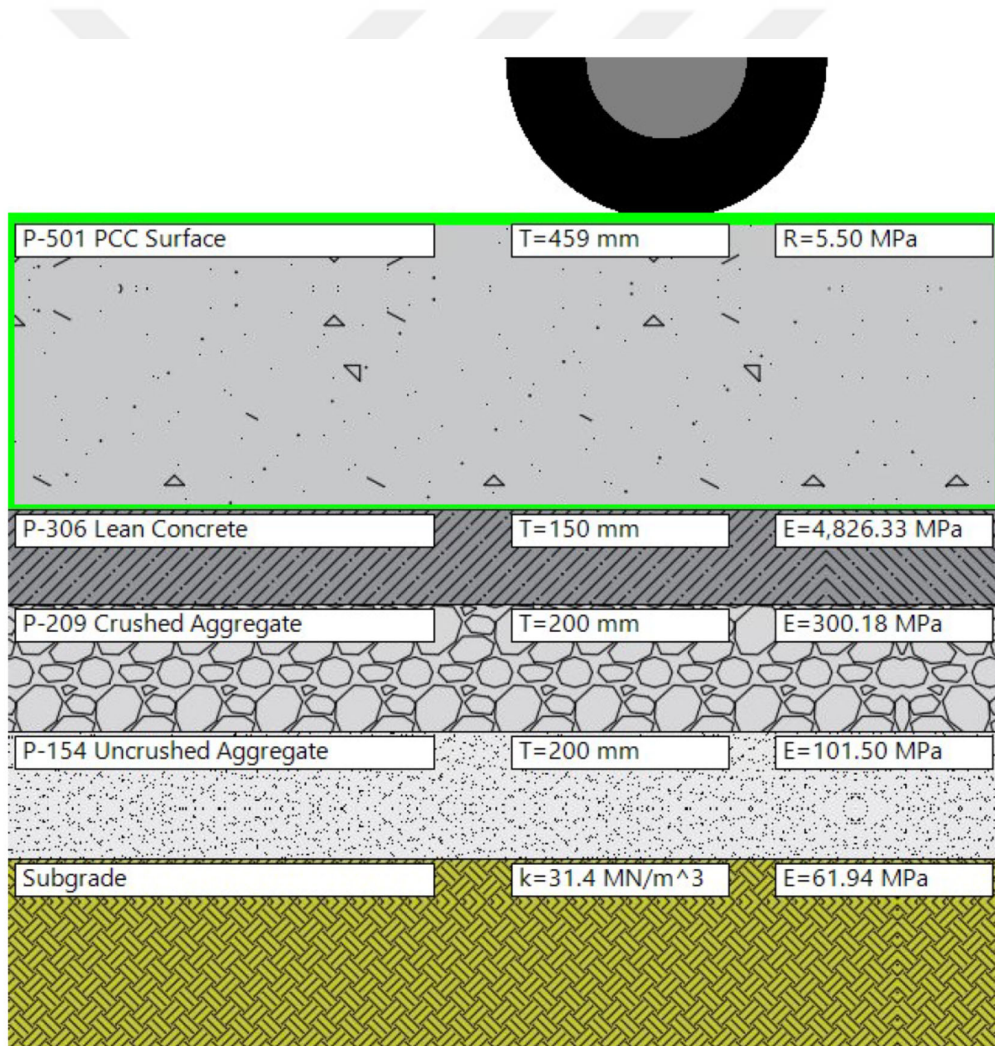
The CDF plot for Case-I is presented in the study as in Figure 5.5. From this graph, the fatigue effects of the aircraft on the runway pavement can be easily evaluated. When this situation is evaluated for Case-I, the highest fatigue effect will be observed with the A321neo aircraft, while the lowest fatigue effect will occur with the landing and take-off effect of the B737-400 aircraft (Figure 5.5).

### **5.1.2 Case study II (high traffic-low soil capacity)**

Within the scope of the study, for second case, the analyses performed with the FAARFIELD program for low soil strength and high traffic are presented. In the content of these results, the changes in CDF values and P/C ratios according to the FAARFIELD program are presented separately for each aircraft traffic. Although the value selected for low soil strength is CBR value 5, the k coefficient used in the

FAARFIELD program was calculated for this CBR value with the help of the formula given as Equation 4.1 and entered the FAARFIELD program.

The total thickness value up to the top of the subgrade is defined as 1009 mm in total. The layers that make up this value are PCC (Portland cement concrete) Surface, Lean Concrete, Crushed Aggregate, Uncrushed Aggregate and Subgrade. PCC Surface, Lean Concrete, Crushed Aggregate, Uncrushed Aggregate layer thicknesses are 459, 150, 200 and 200 mm respectively. Although the service life defined in the system is 20 years, the coating type is defined as rigid as defined in Figure 5.6.



**Figure 5.6** Case-II pavement structure information by layer view of FAARFIELD program

Modulus of elasticity values for PCC Surface, Lean Concrete, Crushed Aggregate, Uncrushed Aggregate layers were defined as 27,579.04, 4,826.33, 300.18 and 101.50 MPa respectively. Poisson's ratio values of PCC Surface, Lean Concrete, Crushed Aggregate, Uncrushed Aggregate layers were determined as 0.15, 0.2, 0.35 and 0.35 MPa respectively. Subgrade modulus of elasticity and Poisson's ratio values were defined as 61.94 and 0.4 respectively as defined in Figure 5.6.

Aircraft weights and number of departures used in the coatings during the analysis are given in the table. The table also shows the estimated annual growth rates of 10% for the annual departure values. Furthermore, maximum values for contribution ratios and CDF values for each aircraft are presented (Table 5.7).

**Table 5.6** Airplane information used in Case-II.

No.	Name	Gross Wt. (kg)	Annual Departures	% Annual Growth
1	A319-100 opt	68,400	10,684	10
2	A320-200 opt	78,400	35,967	10
3	A321-200 opt	93,900	31,365	10
4	A300-600 Std Bogie	172,600	1,702	10
5	A310-200	142,900	1,926	10
6	A318-100 opt	68,400	626	10
7	A330-200 WV057	236,900	2,850	10
8	A330-300 WV022	233,900	1,066	10
9	A330-300 std	230,900	3,109	10
10	A340-300 opt	277,400	2,328	10
11	A340-300 opt Belly	277,400	2,328	10
12	B737-800	79,242	38,894	10
13	B737-300	63,503	1,525	10
14	B737-400	68,266	3,849	10
15	B737-500	60,781	1,095	10
16	B737-700	70,307	4,621	10
17	B757-200	116,100	1,693	10
18	B767-300 ER	175,994	1,072	10
19	B777-200 LR	348,358	880	10
20	B777-300 ER	352,441	997	10
21	B777F	348,722	1,720	10
22	B777-300 ER	352,441	686	10
23	A380-800 WV006	575,000	5,000	10
24	A380-800 WV006 Belly	575,000	5,000	10
25	MD-83	73,016	13,954	10

On the other hand, P/C ratios for each aircraft type were obtained through analysis and calculated by the software. The A380-800 WV006 and A380-800 WV006 Belly are

the highest weight of 575 t is considered in the analysis. The CDF contribution value for these aircrafts were calculated as 0 for 5000 annual departures both airplanes, respectively (Table 5.6). On the other hand, the CDF max values were obtained as 0 and 0.03 for CDF max for this aircraft. The P/C ratio values are 3.78 and 4.2 for both A380-800 WV006 and A380-800 WV006 Belly airplanes and number of 5000 departures. A320-200opt and B737-800 aircraft with the highest departure with values 35967 and 38894 were included in the calculations as 78.4 and 79.242 t, respectively.

CDF contribution values are calculated as 0 for A320-200opt and B737-800 aircraft, respectively. Moreover, CDF max contribution values are calculated as 0 for A320-200opt and B737-800 aircraft, respectively. P/C ratios values are calculated as 3.67 and 3.53 for A320-200opt and B737-800 aircraft, respectively (Table 5.7).

**Table 5.7** Airplane departure CDF and P/C ratio results in Case-II.

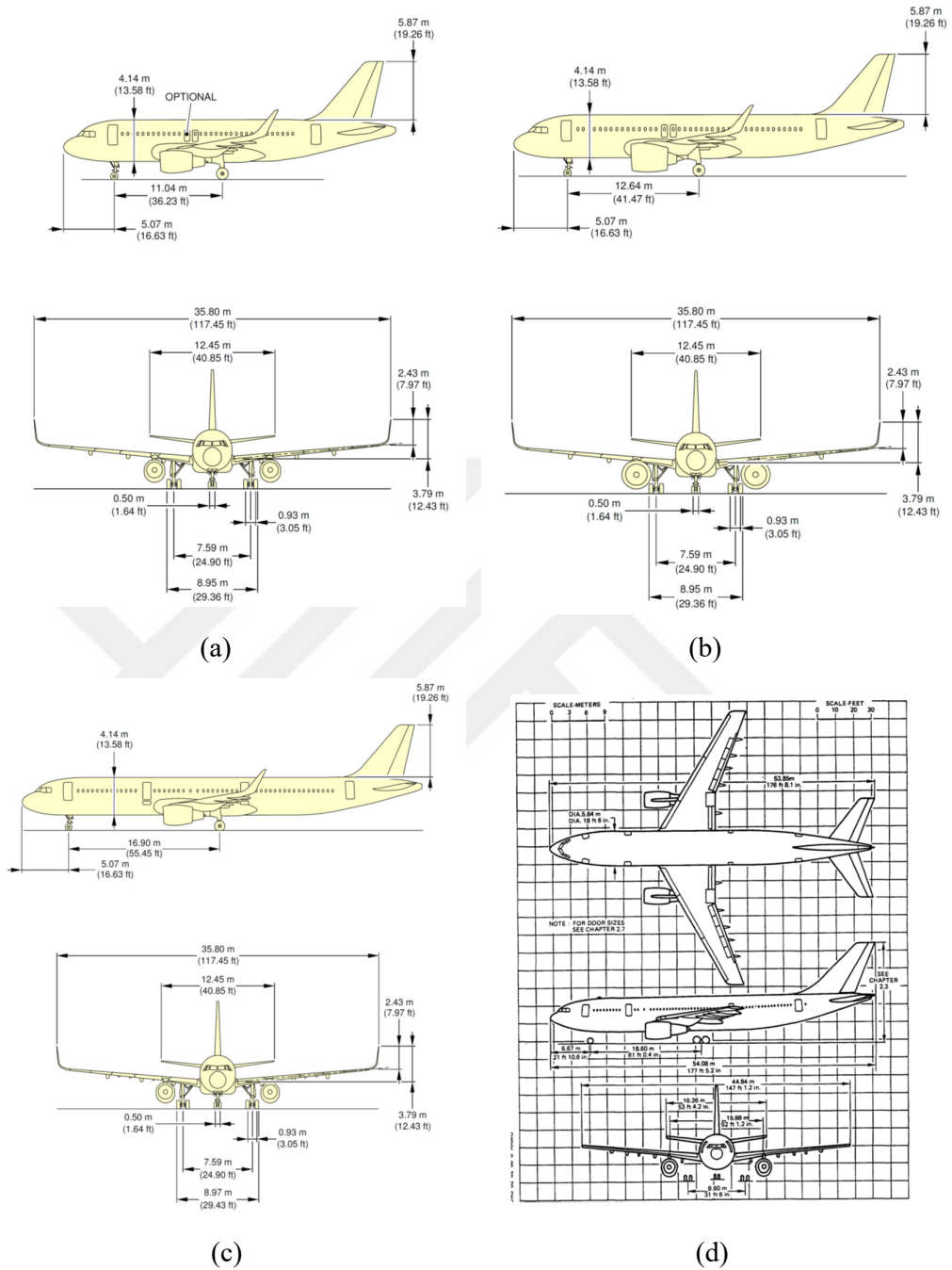
<b>No.</b>	<b>Name</b>	<b>CDF Contribution</b>	<b>CDF Max for Airplane</b>	<b>P/C Ratio</b>
1	A319-100 opt	0.00	0.00	3.66
2	A320-200 opt	0.00	0.00	3.67
3	A321-200 opt	0.00	0.00	3.42
4	A300-600 Std Bogie	0.00	0.00	3.38
5	A310-200	0.00	0.00	3.69
6	A318-100 opt	0.00	0.00	3.65
7	A330-200 WV057	0.00	0.00	1.86
8	A330-300 WV022	0.00	0.00	1.87
9	A330-300 std	0.00	0.00	1.88
10	A340-300 opt	0.00	0.00	1.81
11	A340-300 opt Belly	0.00	0.00	3.78
12	B737-800	0.00	0.00	3.53
13	B737-300	0.00	0.00	3.8
14	B737-400	0.00	0.00	3.52
15	B737-500	0.00	0.00	3.82
16	B737-700	0.00	0.00	3.68
17	B757-200	0.00	0.00	3.92
18	B767-300 ER	0.00	0.00	3.63
19	B777-200 LR	0.09	0.09	3.86
20	B777-300 ER	0.13	0.13	3.84
21	B777F	0.70	0.70	3.86
22	B777-300 ER	0.09	0.09	3.84
23	A380-800 WV006	0.00	0.00	3.78
24	A380-800 WV006 Belly	0.00	0.03	4.2
25	MD-83	0.00	0.00	3.42

Details of the subgrade compaction requirements for noncohesive soil defined in Case-II are presented in the Table 5.8. shows the compaction values and depths of the superstructure and subgrade layers for noncohesive soil. For Case-II, the critical aircraft mobility was observed for the B777-300ER aircraft under the condition of noncohesive soil. For this aircraft, compaction depths of 0-417, 417-1109, 1109-3517 and 3517-5882 mm should be achieved for maximum dry density values of 100, 95, 90 and 85 percent from the pavement surface. For compaction depth from the top of the subgrade, maximum dry density values of 95, 90 and 85 percent should be achieved at 0-99, 99-2527 and 2527-4872 mm respectively (Table 5.8).

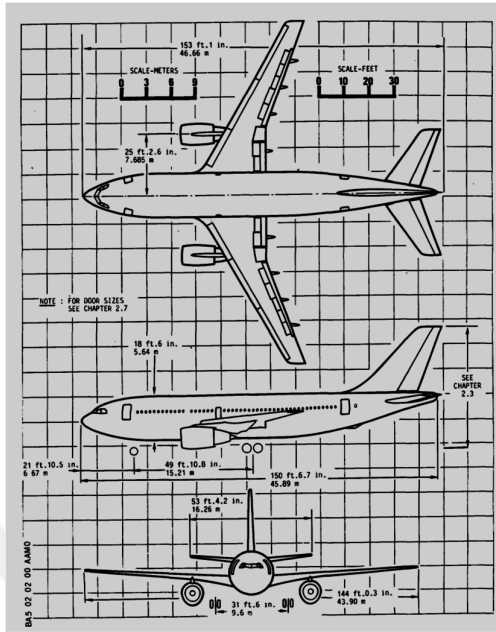
**Table 5.8** Subgrade compaction requirements for noncohesive soil used in Case-II.

Percent Maximum Dry Density(%)	Depth of compaction from pavement surface (mm)	Depth of compaction from top of subgrade (mm)	Critical Airplane for Compaction
100	0 - 417	--	B777-300 ER
95	417 - 1109	0 - 99	B777-300 ER
90	1109 - 3537	99 - 2527	B777-300 ER
85	3537 - 5882	2527 - 4872	B777-300 ER

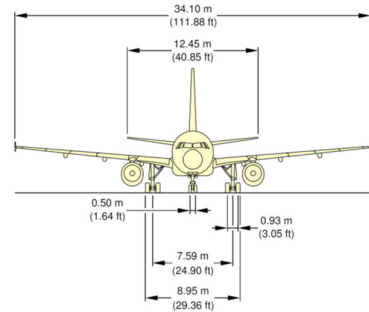
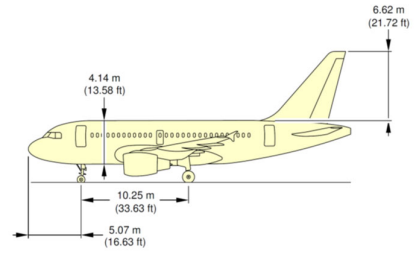
In addition, detailed views of the aircraft characteristics of the wheel loads used in the calculations are presented for high traffic condition in Figures 5.7 to 5.9.



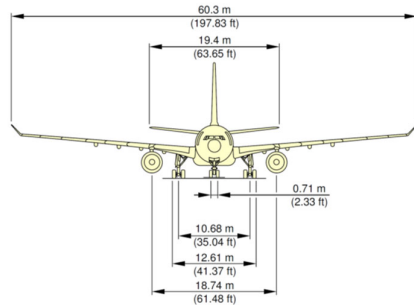
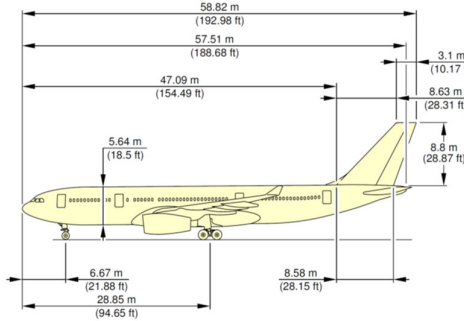
**Figure 5.7** Characteristic properties of planes for high traffic condition (Part-I): a) A319-100 opt, b) A320-200 std, c) A321-200 opt, and d) A300-600 Std Bogie



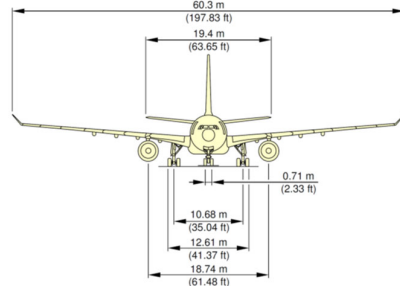
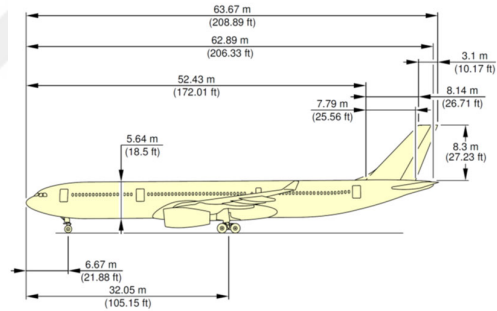
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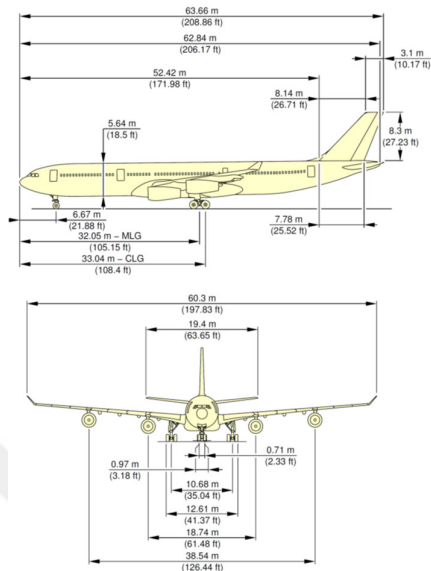


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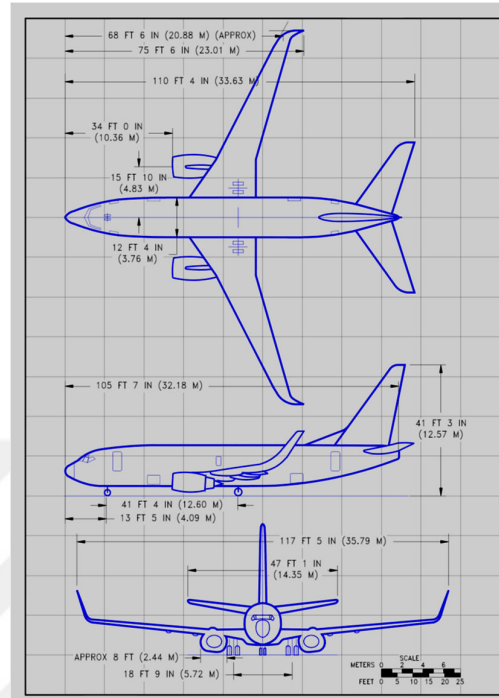


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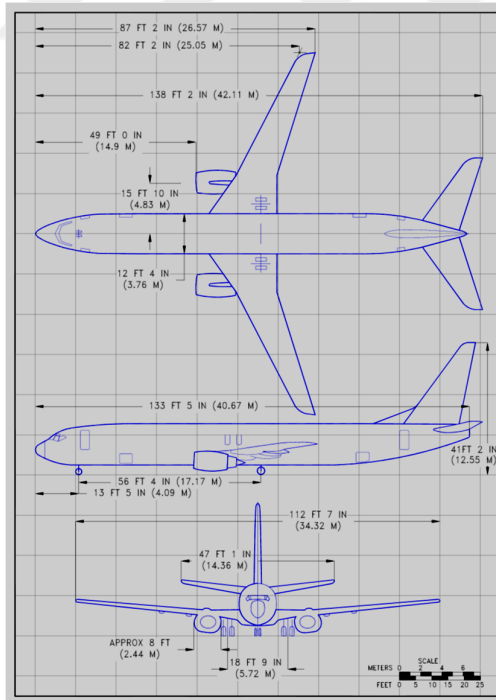
**Figure 5.8** Characteristic properties of planes for high traffic condition (Part-III): a) A310-200, b) A318-100 opt, c) A330-200 WV057, and d) A330-300 WV022



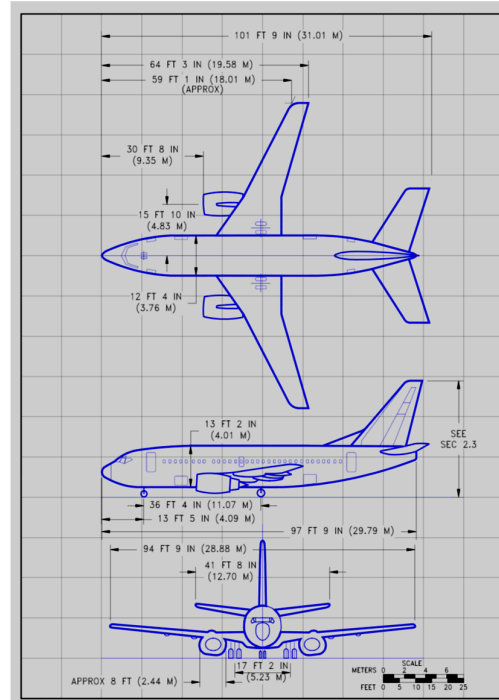
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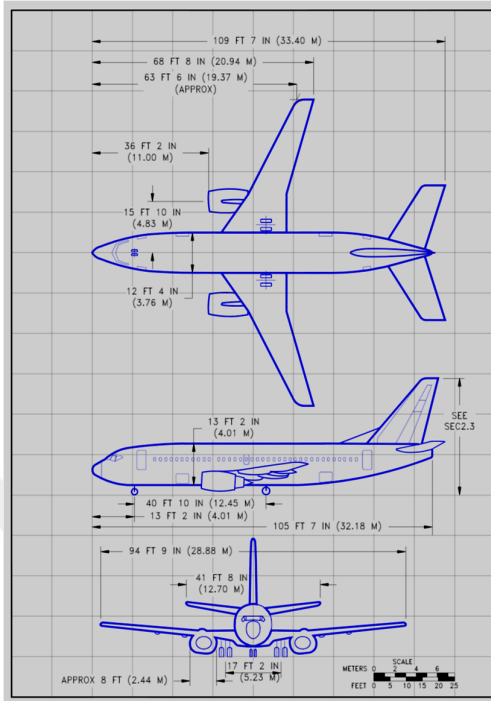


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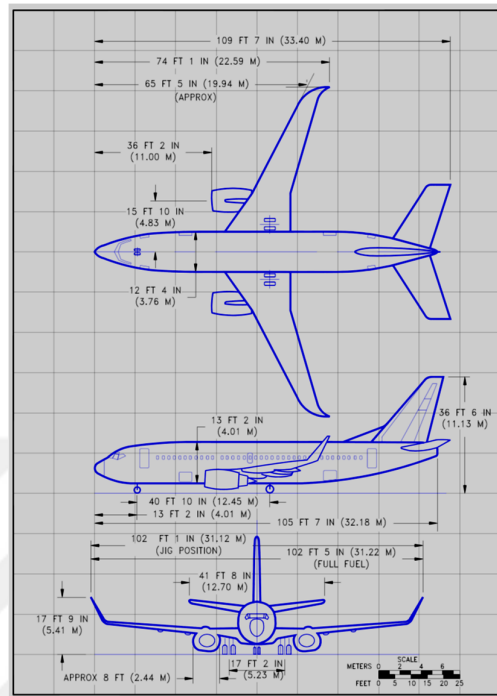


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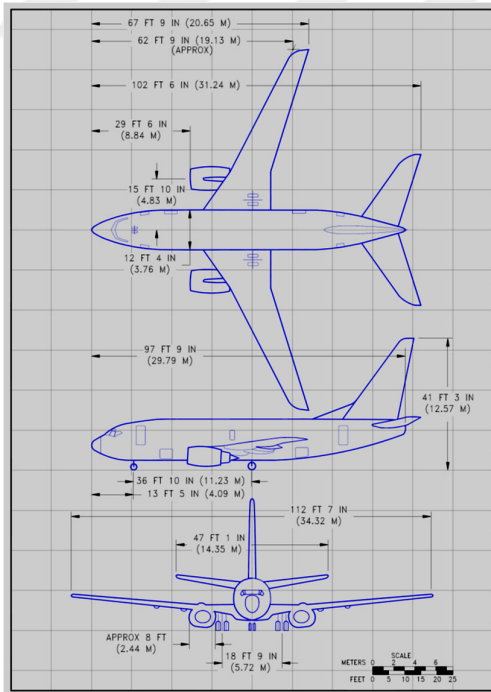
**Figure 5.9** Characteristic properties of planes for high traffic condition (Part-IV): a) A340-300 opt, b) B737-700, c) B737-800, and d) B737-400



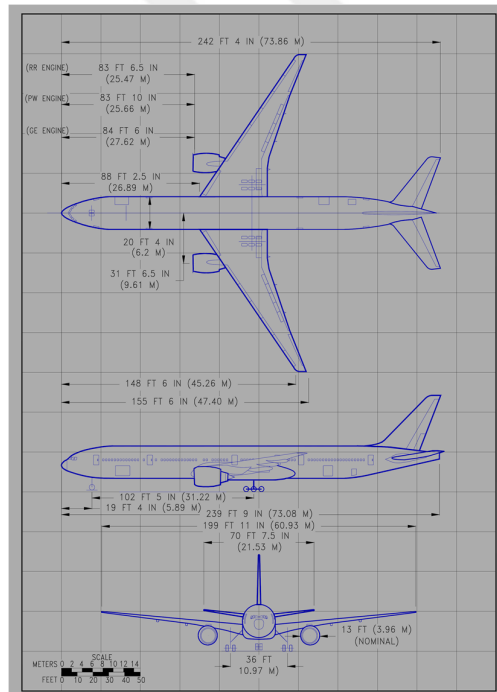
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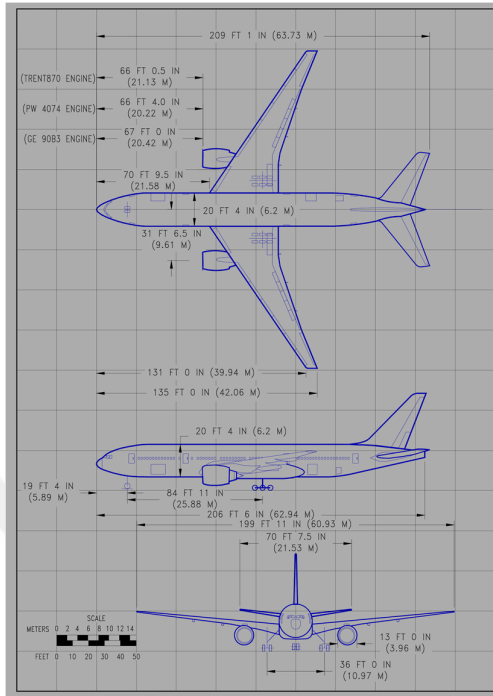


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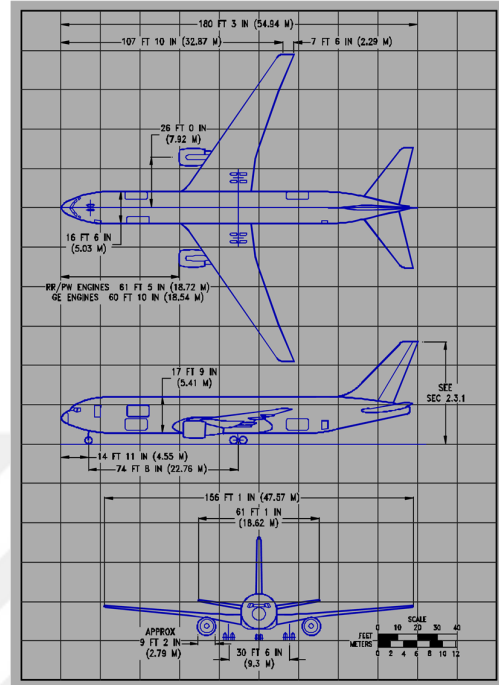


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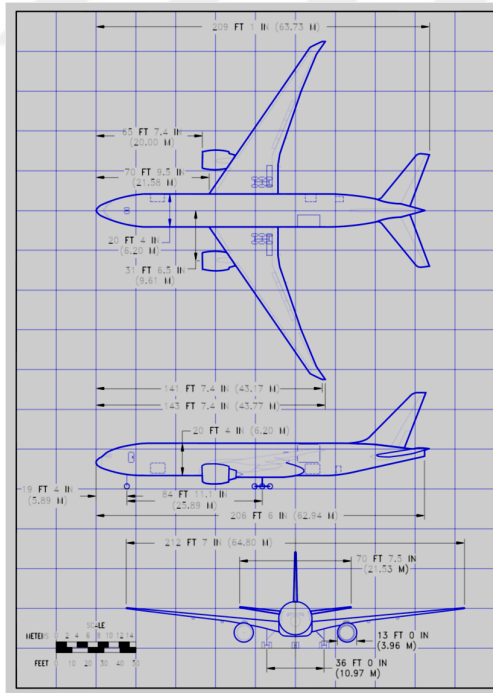
**Figure 5.10** Characteristic properties of planes for high traffic condition (Part-V): a) B737-200, b) B737-300, c) B737-500, and d) B777-200



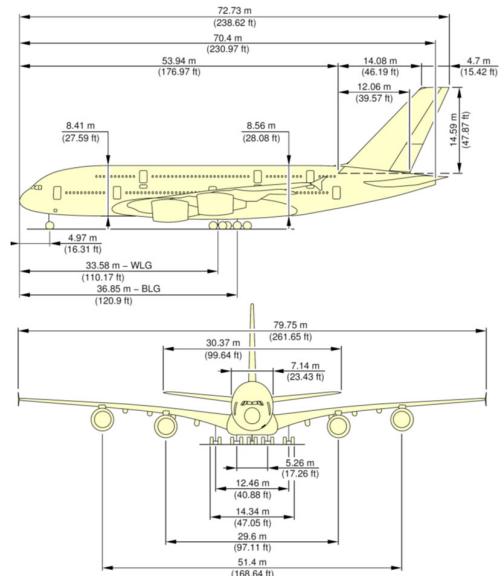
(a)



(b)



(c)



(d)

**Figure 5.11** Characteristic properties of planes for high traffic condition (Part-VI): a) B777-300, b) B767-300ER, c) B777F, and d) A380-800 WV006

Details of the subgrade compaction requirements for cohesive soil are presented in the Table 5.9. Table 5.9 shows the compaction values and depths of the superstructure and subgrade layers for cohesive soil. For Case-II, the critical aircraft mobility was observed for the B777-300ER aircraft for cohesive soil. For this aircraft, compaction depths of 0-407, 407-577, 577-1943 and 1943-3447 mm should be achieved for maximum dry density values of 95, 90, 85 and 80 percent from the pavement surface. For compaction depth from the top of the subgrade, maximum dry density values of 85 and 80 percent should be achieved at 0-934 and 934-2348 mm respectively (Table 5.9).

**Table 5.9** Subgrade compaction requirements for cohesive soil used in Case-II.

Percent Maximum Dry Density(%)	Depth of compaction from pavement surface (mm)	Depth of compaction from top of subgrade (mm)	Critical Airplane for Compaction
95	0 - 407	--	B777-300 ER
90	407 - 577	--	B777-300 ER
85	577 - 1943	0 - 934	B777-300 ER
80	1943 - 3447	934 - 2438	B777-300 ER

The CDF plot for Case-II is presented in the study as in Figure 5.12. From this graph, the fatigue effects of the aircraft on the runway pavement can be easily evaluated. When this situation is evaluated for Case-II, the highest fatigue effect will be observed with the B737F aircraft, while the lowest fatigue effect will occur with the landing and take-off effect of the A330-300std aircraft (Figure 5.12).

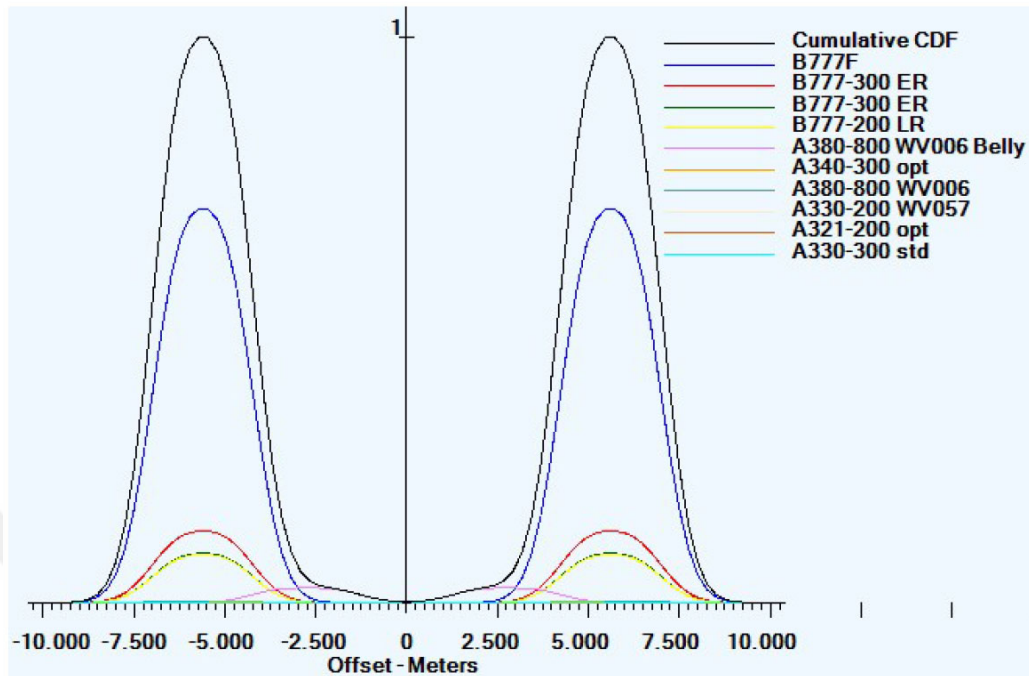


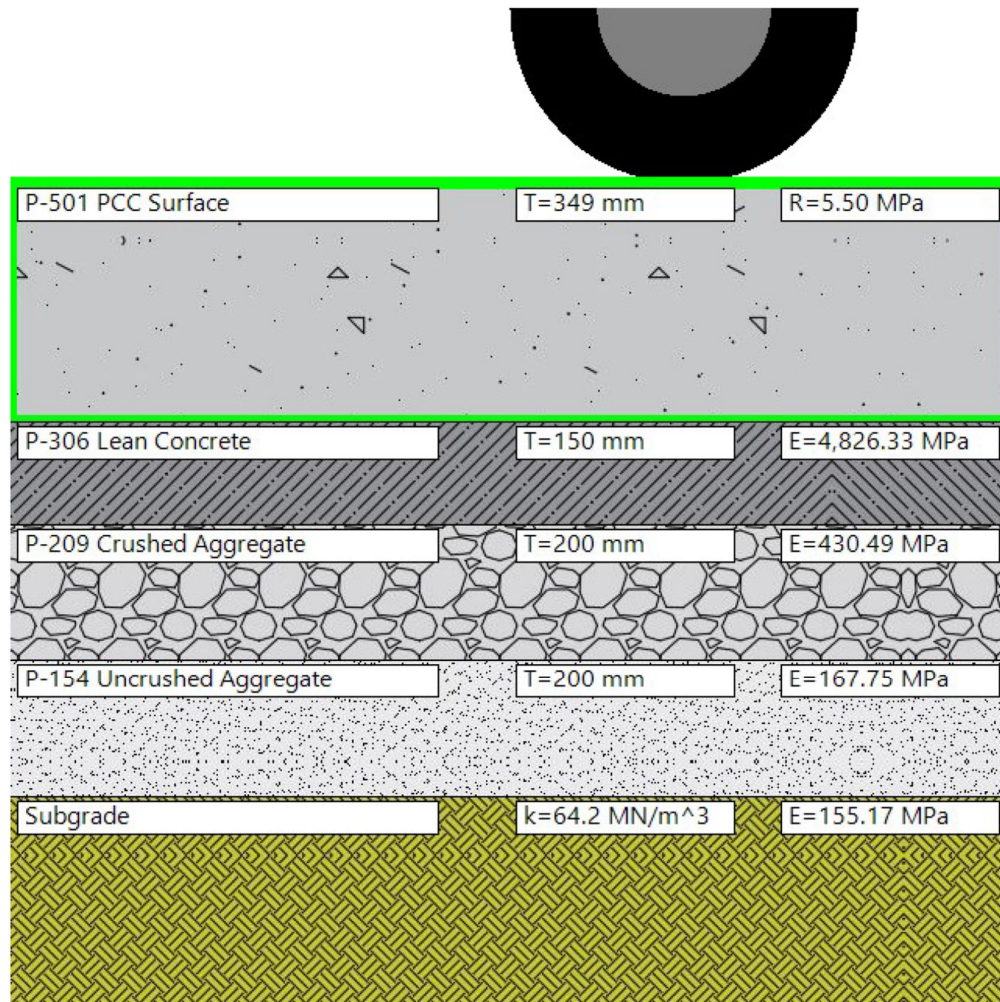
Figure 5.12 CDF values in Case-II

### 5.1.3 Case study III (low traffic-high soil capacity)

Within the scope of the study, for third case, the analyses performed with the FAARFIELD program for high soil strength and low traffic are presented. In the content of these results, the changes in CDF values and P/C ratios according to the FAARFIELD program are presented separately for each aircraft traffic. Although the value selected for high soil strength is CBR value 15, the k coefficient used in the FAARFIELD program was calculated for this CBR value with the help of the formula given as Equation 4.1 and entered the FAARFIELD program.

The total thickness value up to the top of the subgrade is defined as 899 mm in total. The layers that make up this value are PCC (Portland cement concrete) Surface, Lean Concrete, Crushed Aggregate, Uncrushed Aggregate and Subgrade. PCC Surface, Lean Concrete, Crushed Aggregate, Uncrushed Aggregate layer thicknesses are 349, 150, 200 and 200 mm respectively. Although the service life defined in the system is 20 years, the coating type is defined as rigid as defined in Figure 5.13. Modulus of elasticity values for PCC Surface, Lean Concrete, Crushed Aggregate, Uncrushed Aggregate layers were defined as 27,579.04, 4,826.33, 430.49 and 167.75 MPa respectively. Poisson's ratio values of PCC Surface, Lean Concrete, Crushed

Aggregate, Uncrushed Aggregate layers were determined as 0.15, 0.2, 0.35 and 0.35 MPa respectively. Subgrade modulus of elasticity and Poisson's ratio values were defined as 155.17 and 0.4 respectively as defined in Figure 5.13.



**Figure 5.13** Case-III pavement structure information by layer view of FAARFIELD program

Aircraft weights, annual growth rates, and number of departures used in the coatings during the analysis are given in the Table 5.2 as in Case-I. Furthermore, maximum values for contribution ratios and CDF values for each aircraft are presented (Table 5.10). On the other hand, P/C ratios for each aircraft type were obtained through analysis and calculated by the software. The A321neo with the highest weight of 97.4 t is considered in the analysis. The CDF contribution value for this aircraft was

calculated as 0.91 and 0.05 for 783 and 39 annual departures, respectively (Table 5.10). On the other hand, the same values were obtained for CDF max for this aircraft. The P/C ratio values are 3.36 for both number of departures. A320-200std and B737-BBJ2 aircraft with the highest departure values were included in the calculations as 73.9 and 79.25 t, respectively. CDF contribution values are calculated as 0 and 0.02 for A320-200std and B737-BBJ2 aircraft, respectively. Moreover, CDF max contribution values are calculated as 0 and 0.02 for A320-200std and B737-BBJ2 aircraft, respectively. P/C ratios values are calculated as 3.7 and 3.53 for A320-200std and B737-BBJ2 aircraft, respectively (Table 5.10).

**Table 5.10** Airplane departure CDF and P/C ratio results in Case-III.

No.	Name	CDF Contribution	CDF Max for Airplane	P/C Ratio
1	A319-100 opt	0.00	0.00	3.66
2	A320-200 std	0.00	0.00	3.7
3	A321neo	0.91	0.91	3.36
4	A321neo	0.05	0.05	3.36
5	B737-400	0.00	0.00	3.52
6	B737-800	0.00	0.01	3.53
7	B737-700	0.00	0.00	3.68
8	B737 BBJ2	0.02	0.03	3.53
9	B737-900	0.00	0.01	3.53
10	B737-8/8-200/BBJ MAX 8	0.02	0.03	3.47
11	B737-9 MAX	0.00	0.01	3.39

Details of the subgrade compaction requirements for noncohesive soil are presented in the Table 5.11. Table 5.11 shows the compaction values and depths of the superstructure and subgrade layers for noncohesive soil. For Case-III, the critical aircraft mobility was observed for the A321neo aircraft under the condition of noncohesive soil. For this aircraft, compaction depths of 0-406, 406-928, 928-2041 and 2041-3250 mm should be achieved for maximum dry density values of 100, 95, 90 and 85 percent from the pavement surface. For compaction depth from the top of the subgrade, maximum dry density values of 95, 90 and 85 percent should be achieved at 0-29, 29-1142 and 1142-2352 mm respectively (Table 5.11).

**Table 5.11** Subgrade compaction requirements for noncohesive soil used in Case-III.

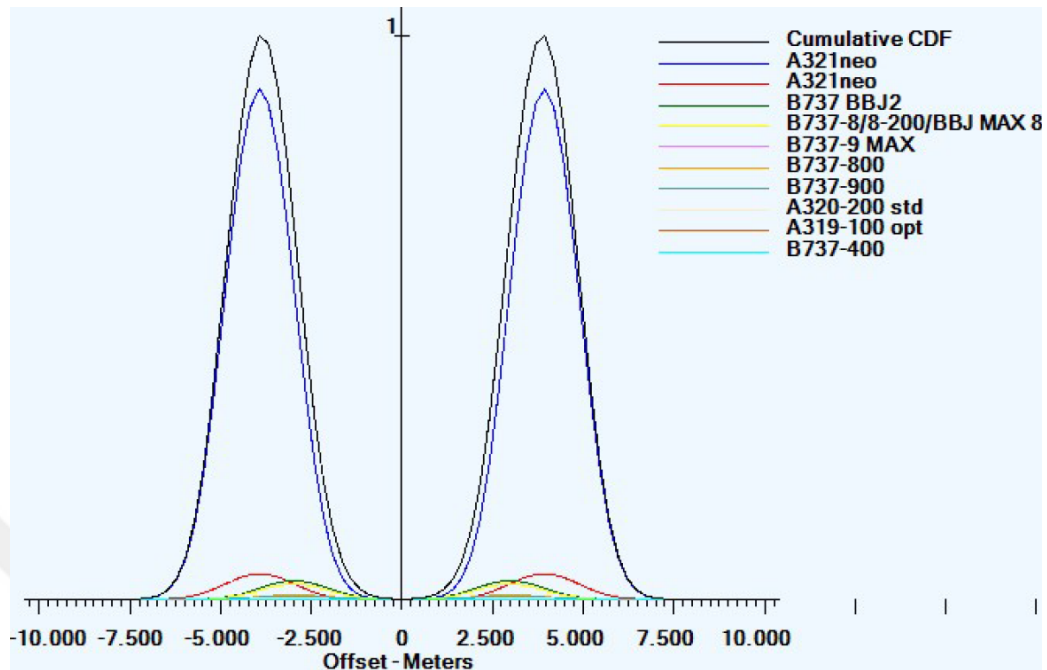
Percent Maximum Dry Density(%)	Depth of compaction from pavement surface (mm)	Depth of compaction from top of subgrade (mm)	Critical Airplane for Compaction
100	0 - 406	--	A321neo
95	406 - 928	0 - 29	A321neo
90	928 - 2041	29 - 1142	A321neo
85	2041 - 3250	1142 - 2352	A321neo

Details of the subgrade compaction requirements for cohesive soil are presented in the Table 5.12. Table 5.12 shows the compaction values and depths of the superstructure and subgrade layers for cohesive soil. For Case-III, the critical aircraft mobility was observed for the A321neo aircraft for cohesive soil. For this aircraft, compaction depths of 0-393, 393-577, 577-1273 and 1273-1996 mm should be achieved for maximum dry density values of 95, 90, 85 and 80 percent from the pavement surface. For compaction depth from the top of the subgrade, maximum dry density values of 85 and 80 percent should be achieved at 0-374 and 374-1097 mm respectively (Table 5.12).

**Table 5.12** Subgrade compaction requirements for cohesive soil used in Case-III.

Percent Maximum Dry Density(%)	Depth of compaction from pavement surface (mm)	Depth of compaction from top of subgrade (mm)	Critical Airplane for Compaction
95	0 - 393	--	A321neo
90	393 - 577	--	A321neo
85	577 - 1273	0 - 374	A321neo
80	1273 - 1996	374 - 1097	A321neo

The CDF plot for Case-III is presented in the study as in Figure 5.14. From this graph, the fatigue effects of the aircraft on the runway pavement can be easily evaluated. When this situation is evaluated for Case-III, the highest fatigue effect will be observed with the A321neo aircraft, while the lowest fatigue effect will occur with the landing and take-off effect of the B737-400 aircraft (Figure 5.14).



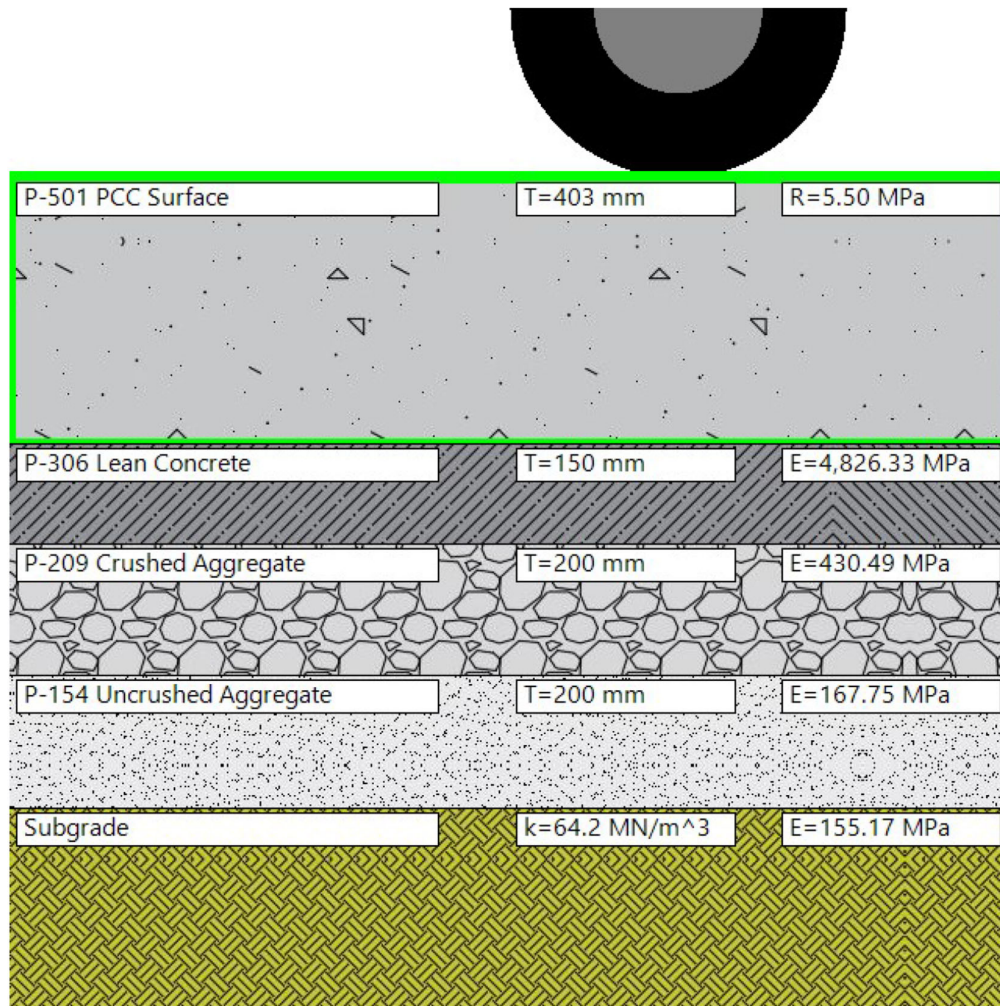
**Figure 5.14** CDF values in Case-III

#### 5.1.4 Case study IV (high traffic-high soil capacity)

Within the scope of the study, for fourth case, the analyses performed with the FAARFIELD program for high soil strength and high traffic are presented. In the content of these results, the changes in CDF values and P/C ratios according to the FAARFIELD program are presented separately for each aircraft traffic. Although the value selected for high soil strength is CBR value 15, the k coefficient used in the FAARFIELD program was calculated for this CBR value with the help of the formula given as Equation 4.1 and entered the FAARFIELD program.

The total thickness value up to the top of the subgrade is defined as 953 mm in total. The layers that make up this value are PCC (Portland cement concrete) Surface, Lean Concrete, Crushed Aggregate, Uncrushed Aggregate and Subgrade. PCC Surface, Lean Concrete, Crushed Aggregate, Uncrushed Aggregate layer thicknesses are 403, 150, 200 and 200 mm respectively. Although the service life defined in the system is 20 years, the coating type is defined as rigid as defined in Figure 5.15. Modulus of elasticity values for PCC Surface, Lean Concrete, Crushed Aggregate, Uncrushed Aggregate layers were defined as 27,579.04, 4,826.33, 430.49 and 167.75 MPa respectively. Poisson's ratio values of PCC Surface, Lean Concrete, Crushed Aggregate, Uncrushed Aggregate layers were determined as 0.15, 0.2, 0.35 and 0.35

MPa respectively. Subgrade modulus of elasticity and Poisson's ratio values were defined as 155.17 and 0.4 respectively as defined in Figure 5.15.



**Figure 5.15** Case-IV pavement structure information by layer view of FAARFIELD program

Aircraft weights, annual growth rates, and number of departures used in the coatings during the analysis are given in the Table 5.6 as in Case-IV. Furthermore, maximum values for contribution ratios and CDF values for each aircraft are presented (Table 5.13). On the other hand, P/C ratios for each aircraft type were obtained through analysis and calculated by the software. The A380-800 WV006 and A380-800 WV006 Belly are the highest weight of 575 t is considered in the analysis. The CDF contribution value for these aircrafts were calculated as 0 for 5000 annual departures

both airplanes, respectively (Table 5.13). On the other hand, the same values were obtained for CDF max for this aircraft. The P/C ratio values are 3.36 for both number of departures. A320-200std and B737-800 aircraft with the highest departure values were included in the calculations as 78.4 and 79.242 t, respectively. CDF contribution values are calculated as 0 and 0.02 for A320-200std and B737-800 aircraft, respectively. Moreover, CDF max values are calculated as 0 for A320-200std and B737-800 aircraft, respectively. P/C ratios values are calculated as 3.67 and 3.53 for A320-200std and B737-800 aircraft, respectively (Table 5.13).

**Table 5.13** Airplane departure CDF and P/C ratio results in Case-IV

No.	Name	CDF Contribution	CDF Max for Airplane	P/C Ratio
1	A319-100 opt	0.00	0.00	3.66
2	A320-200 opt	0.00	0.00	3.67
3	A321-200 opt	0.03	0.11	3.42
4	A300-600 Std Bogie	0.00	0.00	3.38
5	A310-200	0.00	0.00	3.69
6	A318-100 opt	0.00	0.00	3.65
7	A330-200 WV057	0.00	0.00	1.86
8	A330-300 WV022	0.00	0.00	1.87
9	A330-300 std	0.00	0.00	1.88
10	A340-300 opt	0.01	0.01	1.81
11	A340-300 opt Belly	0.00	0.00	3.78
12	B737-800	0.00	0.00	3.53
13	B737-300	0.00	0.00	3.8
14	B737-400	0.00	0.00	3.52
15	B737-500	0.00	0.00	3.82
16	B737-700	0.00	0.00	3.68
17	B757-200	0.00	0.00	3.92
18	B767-300 ER	0.00	0.00	3.63
19	B777-200 LR	0.11	0.11	3.86
20	B777-300 ER	0.17	0.17	3.84
21	B777F	0.55	0.55	3.86
22	B777-300 ER	0.12	0.12	3.84
23	A380-800 WV006	0.00	0.01	3.78
24	A380-800 WV006 Belly	0.00	0.02	4.2
25	MD-83	0.00	0.00	3.42

Details of the subgrade compaction requirements for noncohesive soil are presented in the Table 5.14. Table 5.14 shows the compaction values and depths of the superstructure and subgrade layers for noncohesive soil. For Case-IV, the critical aircraft mobility was observed for the B777-300ER aircraft under the condition of noncohesive soil. For this aircraft, compaction depths of 0-486, 486-2618, and 2618-

4597 mm should be achieved for maximum dry density values of 100, 95 and 90 percent from the pavement surface. For compaction depth from the top of the subgrade, maximum dry density values of 95 and 90 percent should be achieved at 0-1664, and 1664-3644 mm respectively (Table 5.14).

**Table 5.14** Subgrade compaction requirements for noncohesive soil used in Case-IV.

Percent Maximum Dry Density(%)	Depth of compaction from pavement surface (mm)	Depth of compaction from top of subgrade (mm)	Critical Airplane for Compaction
100	0 - 486	--	B777-300 ER
95	486 - 2618	0 - 1664	B777-300 ER
90	2618 - 4597	1664 - 3644	B777-300 ER

Details of the subgrade compaction requirements for cohesive soil are presented in the Table 5.15. Table 5.15 shows the compaction values and depths of the superstructure and subgrade layers for cohesive soil. For Case-IV, the critical aircraft mobility was observed for the B777-300ER aircraft for cohesive soil. For this aircraft, compaction depths of 0-467, 467-1795, 1795-3220 and 3220-4517 mm should be achieved for maximum dry density values of 95, 90, 85 and 80 percent from the pavement surface. For compaction depth from the top of the subgrade, maximum dry density values of 85 and 80 percent should be achieved at 0-842, 842-2267 and 2267-3653 mm respectively (Table 5.15).

**Table 5.15** Subgrade compaction requirements for cohesive soil used in Case-IV.

Percent Maximum Dry Density(%)	Depth of compaction from pavement surface (mm)	Depth of compaction from top of subgrade (mm)	Critical Airplane for Compaction
95	0 - 467	--	B777-300 ER
90	467 - 1795	0 - 842	B777-300 ER
85	1795 - 3220	842 - 2267	B777-300 ER
80	3220 - 4517	2267 - 3563	B777-300 ER

The CDF plot for Case-IV is presented in the study as in Figure 5.16. From this graph, the fatigue effects of the aircraft on the runway pavement can be easily evaluated. When this situation is evaluated for Case-IV, the highest fatigue effect will be observed

with the B777F, while the lowest fatigue effect will occur with the landing and take-off effect of the A330-300std aircraft (Figure 5.16).

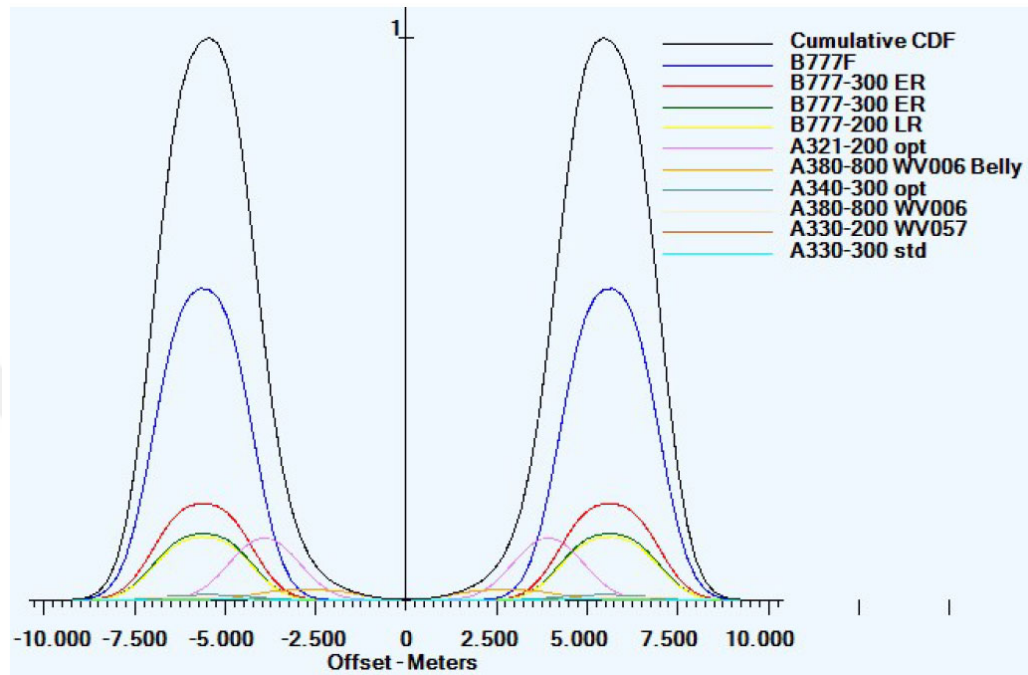


Figure 5.16 CDF values in Case-IV

All cases results were given in Table 5.16.

Table 5.16 All case results.

Case No.	Max CDF Contribution	Airplane	Min CDF Contribution	CDF Max	CDF Min	P/C Ratio max	P/C Ratio min
Case-I	0.86	A321 neo	0	0.86	0	3.68	3.36
Case-II	0.7	B777F	0	0.7	0	3.92	1.81
Case-III	0.91	A321 neo	0	0.91	0	3.68	3.36
Case-IV	0.55	B777F	0	0.55	0	4.2	1.81

In this thesis, the FAARFIELD program was used to evaluate the rigid pavements for the airport under aircraft type and annual traffic loads (number of departures). Because departure movements are important parameters for runway strength in design. In addition, gross weight values for each aircraft type were entered into the system and obtained from the system with annual tariff growth rates. For pavement life, 20-year periods were taken into consideration. FAARFIELD software was used as the software. There are 2 different traffic loads in the study, low and high traffic. The high traffic study is an example of a 1-year flight operation at a hub airport with +50 million passengers per year (1-year total number of departures for each aircraft type). Low traffic is total departure ATMs for 1 year at a local/regional airport. In the study, CBR=5 for low strength soil and CBR=15 for good soil. For the correlation of the k factor and CBR for rigid pavement, the formulation in document 150-5320-6G-Pavement-Design was used.

In Case-I (low traffic-low soil), P/C ratios for each aircraft type were obtained through analysis and calculated by the software. The A321neo with the highest weight of 97.4 t is considered in the analysis. The CDF contribution value for this aircraft was calculated as 0.86 and 0.04 for 783 and 39 annual departures, respectively. In Case-II (low traffic-high soil capacity), CDF contribution values are calculated as 0 for A320-200opt and B737-800 aircraft, respectively. Moreover, CDF max contribution values are calculated as 0 for A320-200opt and B737-800 aircraft, respectively. P/C ratios values are calculated as 3.67 and 3.53 for A320-200opt and B737-800 aircraft, respectively. In Case-III (low traffic-high soil capacity), the CDF contribution value for this aircraft was calculated as 0.91 and 0.05 for 783 and 39 annual departures, respectively. On the other hand, the same values were obtained for CDF max for this aircraft. The P/C ratio values are 3.36 for both number of departures. A320-200std and B737-BBJ2 aircraft with the highest departure values were included in the calculations as 73.9 and 79.25 t, respectively. CDF contribution values are calculated as 0 and 0.02 for A320-200std and B737-BBJ2 aircraft, respectively. Moreover, CDF max contribution values are calculated as 0 and 0.02 for A320-200std and B737-BBJ2 aircraft, respectively. P/C ratios values are calculated as 3.7 and 3.53 for A320-200std and B737-BBJ2 aircraft, respectively. In Case-IV (high traffic-high soil capacity), the P/C ratio values are 3.36 for both number of departures. A320-200std and B737-800 aircraft with the highest departure values were included in the calculations as 78.4 and

79.242 t, respectively. CDF contribution values are calculated as 0 and 0.02 for A320-200std and B737-800 aircraft, respectively. Moreover, CDF max values are calculated as 0 for A320-200std and B737-800 aircraft, respectively. P/C ratios values are calculated as 3.67 and 3.53 for A320-200std and B737-800 aircraft, respectively.



## **CHAPTER 6**

### **CONCLUSIONS**

A summary of the results of the data obtained from the analysis of rigid pavement designs for airport runways under strong and weak soil conditions for low and high traffic airports with the FAARFIELD program is given below.

- For the low and high air traffic runway operating conditions examined in the study, the rigid pavement thickness for low traffic-low ground capacity is 351 mm, while the pavement thicknesses for high traffic-low ground capacity, low traffic-high ground capacity and high traffic-high ground capacity are 459, 349 and 403 mm, respectively.
- Under low air traffic runway operating conditions, the CDF values obtained for the highest number of departures were calculated as 0.07 for the low soil strength condition.
- Under high density air traffic runway operating conditions, the CDF values obtained for the highest number of take-offs were calculated as 0 for the low soil strength condition.
- Under low air traffic runway operating conditions, the CDF values obtained for the highest number of take-offs were calculated as 0.03 for the high ground strength condition.
- Under runway operating conditions characterized by high air traffic, the CDF values obtained for the highest number of take-offs were calculated as 0 for the high soil strength condition.
- For low soil strength, the highest CDF values were 0.86 and 0.70 for runways operated with low and high air traffic, respectively.
- For high soil strength, the highest CDF values were 0.91 and 0.55 for runways operated with low and high air traffic, respectively

As a result of this thesis study;

Four different pavement designs were analyzed with the same materials while examining changes in thickness; when comparing the results obtained under high and low soil capacity for low traffic demand (Case-I and Case-III), a difference of 2 mm was observed in the thickness of the surface layer. Based on this result, it is believed that increasing the thickness of the pavement instead of soil improvement would be an efficient solution for pavement serving low traffic demand.

When comparing pavement designs under high and low soil capacity for high traffic demand (Case-II and Case-IV), a difference of 56 mm was found between the thicknesses of the pavements. From this comparison, it is considered more appropriate to improve soil capacity rather than increase the thickness of the pavement in pavement designs serving high traff

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