U.S. Department
of Transportation
Federal Aviation
Administration

Advisory Circular

Subject: STANDARDIZED METHOD OF REPORTING AIRPORT PAVEMENT STRENGTH - PCN

Date: DATE, 09/28/06
Initiated by: AAS-100

AC No: 150/5335-5A
Change:

1. THE PURPOSE OF THIS ADVISORY CIRCULAR.
This advisory circular (AC) provides guidance for using the standardized International Civil Aviation Organization (ICAO) method to report airport pavement strength. The standardized method is known as the Aircraft Classification Number – Pavement Classification Number (ACN-PCN) method.

2. WHAT THIS AC CANCELS.
This AC cancels AC 150/5335-5, Standardized Method of Reporting Airport Pavement Strength – PCN, dated June 15, 1983.

3. WHO THIS AC AFFECTS.
The International Civil Aviation Organization (ICAO) requires member countries to report pavement strength information for a variety of purposes. The ACN-PCN method has been developed and adopted as an international standard and has facilitated the exchange of pavement strength rating information. This AC provides specific guidance on how to report airport pavement strength using the standardized method.

4. RELATED READING MATERIAL. The publications listed in Appendix 4 provide further information on the development and use of the ACN-PCN method.

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CHAPTER 1. INTRODUCTION

1.0 BACKGROUND. The United States is a member of the International Civil Aviation Organization (ICAO) and is bound by treaty agreements to comply with the requirements of ICAO to the maximum extent practical (see Federal Aviation Administration (FAA) Order 2100.13, FAA Rulemaking Policies, Chapter 11). Annex 14 to the Convention of International Civil Aviation-Aerodromes requires that each member country publish information on the strengths of all public airport pavements in its own Aeronautical Information Publication (AIP). FAA reports pavement strength information to the National Airspace System Resources (NASR) database and published pavement strength information in the Airport Master Record (Form 5010) and the Airport/Facility Directory (AFD).

1.1 DEVELOPMENT OF A STANDARDIZED METHOD. In 1977, ICAO established a Study Group to develop a single international method of reporting pavement strengths. The study group developed and ICAO adopted the Aircraft Classification Number - Pavement Classification Number (ACN-PCN) method. Using this method, it is possible to express the effect of an individual airplane on different pavements by a single unique number that varies according to airplane weight and configuration (e.g. tire pressure, gear geometry, etc.), pavement type, and subgrade strength. This number is the Aircraft Classification Number (ACN). Conversely, the load-carrying capacity of a pavement can be expressed by a single unique number, without specifying a particular airplane or detailed information about the pavement structure. This number is the Pavement Classification Number (PCN).

a. Definition of ACN. ACN is defined as a number that expresses the relative effect of an airplane at a given weight on a pavement structure for a specified standard subgrade strength.

b. Definition of PCN. PCN is a number that expresses the load-carrying capacity of a pavement for unrestricted operations.

c. System Methodology. The ACN-PCN system is structured so a pavement with a particular PCN value can support, without weight restrictions, an airplane that has an ACN value equal to or less than the pavement's PCN value. This is possible because ACN and PCN values are computed using the same technical basis.

1.2 APPLICATION. The use of the standardized method of reporting pavement strength applies only to pavements with bearing strengths of 12,500 pounds (5 700 kg) or greater. The method of reporting pavement strength for pavements of less than 12,500 pounds (5 700 kg) bearing strength remains unchanged.

1.3 LIMITATIONS OF THE ACN-PCN SYSTEM. The ACN-PCN system is only intended as a method of reporting relative pavement strength so airport operators can evaluate acceptable operations of airplanes. It is not intended as a pavement design or pavement evaluation procedure, nor does it restrict the methodology used to design or evaluate a pavement structure.

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CHAPTER 2. DETERMINATION OF AIRCRAFT CLASSIFICATION NUMBER

2.0 DETERMINATION OF THE ACN. The airplane manufacturer provides the official computation of an ACN value. Computation of the ACN requires detailed information on the operational characteristics of the airplane such as maximum aft center of gravity, maximum ramp weight, wheel spacing, tire pressure, and other factors.

2.1 SUBGRADE CATEGORY. The ACN-PCN method adopts four standard levels of subgrade strength for rigid pavements and four levels of subgrade strength for flexible pavements. These standard support conditions are used to represent a range of subgrade conditions as shown in Tables 2-1 and 2-2.

Table 2-1. Standard Subgrade Support Conditions for Rigid Pavement ACN Calculation

Subgrade Strength Category	Subgrade Support k-Value pci (MN/m^3)	Represents pci (MN/m^3)	Code Designation
High	552.6 (150)	k ≥ 442 (≥120)	A
Medium	294.7 (80)	221<k<442 (60<k<120)	B
Low	147.4 (40)	92<k≤221 (25<k≤60)	C
Ultra Low	73.7 (20)	k≤92 (≤25)	D

Table 2-2. Standard Subgrade Support Conditions for Flexible Pavement ACN Calculation

Subgrade Strength Category	Subgrade Support CBR-Value	Represents	Code Designation
High	15	CBR ≥ 13	A
Medium	10	8<CBR<13	B
Low	6	4<CBR≤8	C
Ultra Low	3	CBR≤4	D

2.2 OPERATIONAL FREQUENCY. Operational frequency is defined in terms of coverages that represent a full-load application on a point in the pavement. Coverages must not be confused with other common terminology used to reference movement of airplanes. As an airplane moves along a pavement section it seldom travels in a perfectly straight path or along the exact same path as before. This movement is known as airplane wander and is assumed to be modeled by a statistically normal distribution. As the airplane moves along a taxiway or runway, it may take several trips or passes along the pavement for a specific point on the pavement to receive a full-load application. It is easy to observe the number of passes an airplane may make on a given pavement, but the number of coverages must be mathematically derived based upon the established pass-to-coverage ratio for each airplane.

2.3 RIGID PAVEMENT ACN. For rigid pavements, the airplane landing gear flotation requirements are determined by the Westergaard solution for a loaded elastic plate on a Winkler foundation (interior load case), assuming a concrete working stress of 399 psi (2.75 MPa).

2.4 FLEXIBLE PAVEMENT ACN. For flexible pavements, airplane landing gear flotation requirements are determined by the California Bearing Ratio (CBR) method for each subgrade support category. The CBR method employees a Boussinesq solution for stresses and displacements in a homogeneous, isotropic elastic half-space. To standardize the ACN calculation and to remove operational frequency from the relative rating scale, the ACN-PCN method specifies that ACN values be determined at a frequency of 10,000 coverages.

2.5 ACN CALCULATION. Using the parameters defined for each type of pavement section, a mathematically derived single wheel load is calculated to define the landing gear/pavement interaction. The derived single wheel load implies equal stress to the pavement structure and eliminates the need to specify pavement thickness for comparative purposes. This is achieved by equating the thickness derived for a given airplane landing gear to the thickness derived for a single wheel load at a standard tire pressure of 18l psi (1.25 MPa). The ACN is defined as two times the derived single wheel load (expressed in thousands of kilograms).

2.6 VARIABLES INVOLVED IN DETERMINATION OF ACN VALUES. Because airplanes can be operated at various weight and center of gravity combinations, ICAO adopted standard operating conditions for determining ACN values. The ACN is to be determined at the weight and center of gravity combination that creates the maximum ACN value. Tire pressures are assumed to be those recommended by the manufacturer for the noted conditions. Airplane manufacturers publish maximum weight and center of gravity information in their Airplane Characteristics for Airport Planning (ACAP) manuals.

CHAPTER 3. DETERMINATION OF ACN VALUES USING COMFAA

3.0 ANNOUNCEMENT OF COMFAA SOFTWARE APPLICATION. To facilitate the use of the ACN-PCN system, FAA developed a software application that calculates ACN values using the procedures and conditions specified by ICAO. The software is called COMFAA and it may be downloaded along with its source code and supporting documentation from the FAA website. The program is useful for determining an ACN value under various conditions however, the user should remember that official ACN values are provided by the airplane manufacturer.

3.1 ORIGIN OF THE COMFAA PROGRAM. Appendix 2 of the ICAO Aerodrome Design Manual, Part 3, Pavements, provides procedures for determining the Aircraft Classification Number (ACN). The appendix provides program code for two FORTRAN software applications capable of calculating the ACN for various airplanes on rigid and flexible pavement systems. The computer program listings in Appendix 2 of the ICAO manual were optically scanned and the FORTRAN code translated into Visual Basic 6.0 for incorporation into COMFAA.

3.2 COMFAA PROGRAM. The COMFAA software is a general purpose program that operates in two computational modes: ACN Computation Mode and Pavement Thickness Mode.

a. ACN Computation Mode:

- Calculates the ACN number for airplanes on flexible pavements.
- Calculates the ACN number for airplanes on rigid pavements.
- Calculates flexible pavement thickness based on the ICAO procedure (CBR method) for default values of CBR (15, 10, 6, and 3).
- Calculates rigid pavement slab thickness based on the ICAO procedures (Portland Cement Association method, interior load case) for default values of k (552.6, 294.7, 147.4, and 73.7 lb/in3 [150, 80, 40, and 20 MN/m3]).

  Note: Thickness calculation in the ACN mode is for specific conditions identified by ICAO for determination of ACN. For flexible pavements a standard tire pressure of 181 psi (1.25 MPa) and 10,000 coverages is specified. For rigid pavements an allowable stress level of 399 psi is identified by ICAO. These parameters seldom represent actual design criteria used for pavement design. The thickness calculated in ACN mode has little meaning to pavement design requirements and should not be used for determining allowable pavement loading.

b. Pavement Thickness Mode:

- Calculates total flexible pavement thickness based on the FAA CBR method specified in AC 150/5320-6D, Airport Pavement Design and Evaluation, for CBR values and coverage levels specified by the user.
- Calculates rigid pavement slab thickness based on the FAA Westergaard method (edge load analysis) specified in AC 150/5320-6D for k values and coverage levels specified by the user.

3.3 INTERNAL AIRPLANE LIBRARY. COMFAA contains an internal library of airplanes covering most large commercial and US military airplanes currently in operation. The internal library is based on airplane information provided directly by airplane manufacturers or obtained from ACAP Manuals. The default characteristics of airplanes in the internal library represent the ICAO standard conditions for calculation of ACN. These characteristics include center of gravity at the maximum aft position for each airplane in the ACN mode, whereas the pavement thickness mode center of gravity is fixed to distribute 95 percent of the max gross load to the main landing gear for all airplanes.

3.4 EXTERNAL AIRPLANE LIBRARY. COMFAA allows for an external airplane library where characteristics of the airplane can be changed and additional airplanes added as desired. Functions permit users to modify the characteristics of an airplane and save the modified airplane in the external library. There are no safeguards in the COMFAA program to assure that airplane parameters in the external library are feasible or appropriate. The user is responsible for assuring all data is correct.

When saving an airplane from the internal library to the external library, the COMFAA program will calculate the tire contact area based upon the gross load, maximum aft center of gravity, and tire pressure. This value is recorded in the external library and is used for calculating the pass-to-coverage (P/C) ratio in the pavement thickness mode. Since the tire contact area is constant, the P/C ratio is also constant in the pavement thickness mode. This fixed P/C ratio should be used for converting passes to coverages for pavement thickness determination and equivalent airplane operations.

3.5 USING THE COMFAA PROGRAM. Using the COMFAA program to calculate ACN values is visually interactive and intuitive. The user selects the desired airplane, confirms the physical properties of the airplane, and clicks on the ACN Flexible or ACN Rigid button to determine the ACN for the four standard subgrade conditions. The program includes a help file assist the user. Figures 3-1 and 3-2 detail the operation of the COMFAA program.

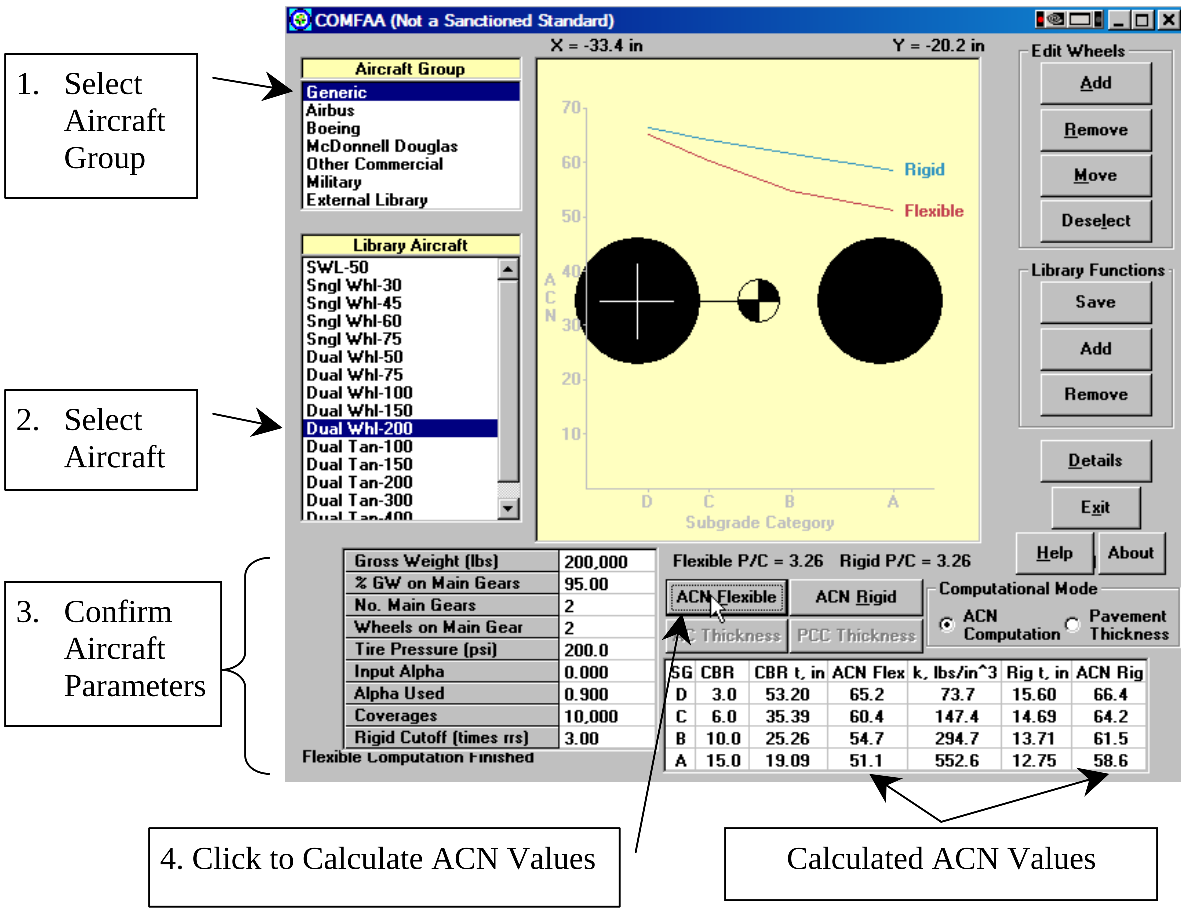

Figure 3-1. Operation of the COMFAA Program in ACN Mode

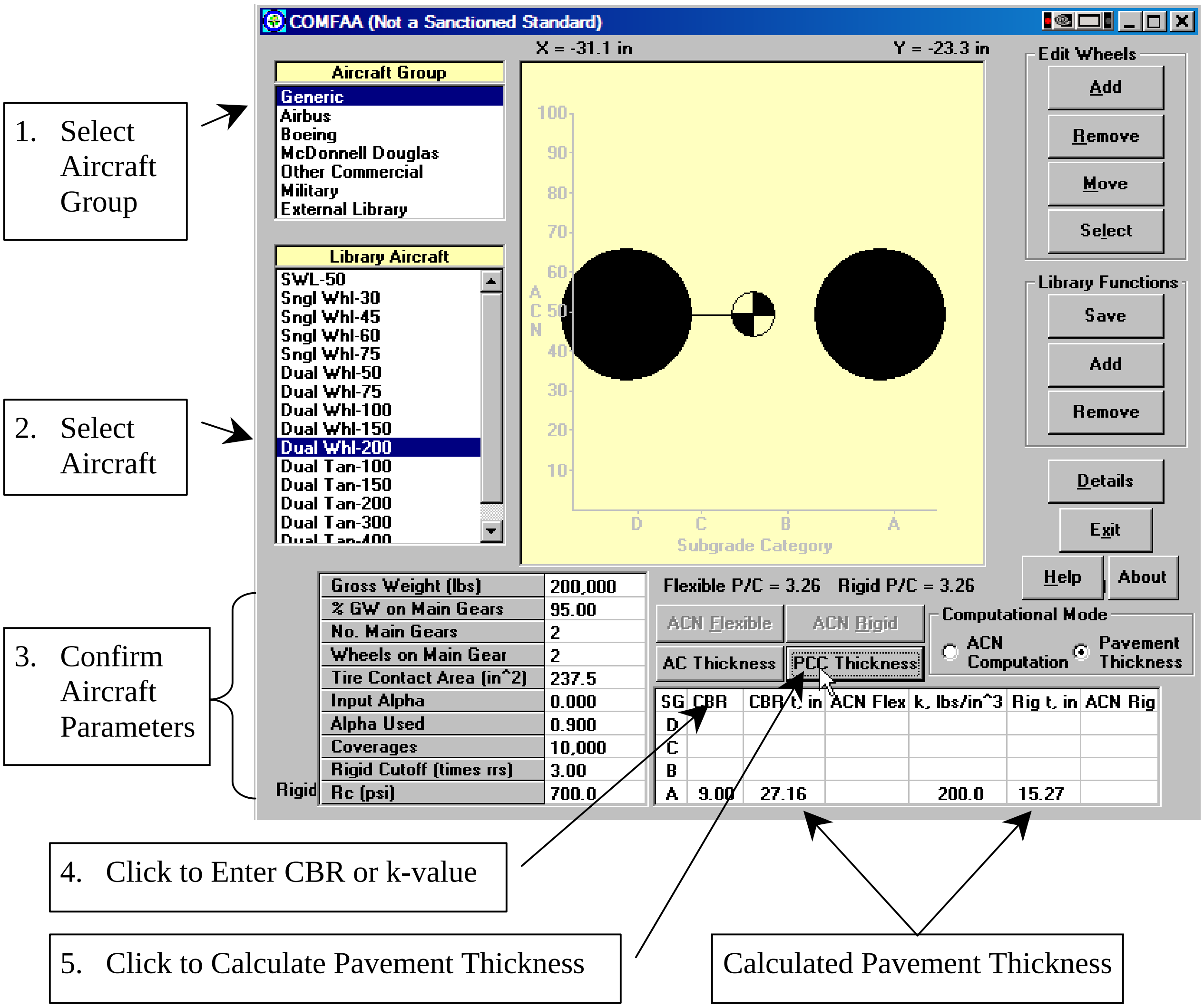

Figure 3-2. Operation of the COMFAA Program in Pavement Thickness Mode

CHAPTER 4. DETERMINATION OF PCN NUMERICAL VALUE

4.0 PCN CONCEPT. In fundamental terms, the determination of a pavement rating in terms of PCN is a process of determining the ACN for the selected critical or most demanding airplane and reporting the ACN value as the PCN for the pavement structure. Under these conditions, any airplane with an ACN equal to or less than the reported PCN value can safely operate on the pavement subject to any limitations on tire pressure.

4.1 DETERMINATION OF NUMERICAL PCN VALUE. Determination of the numerical PCN value for a particular pavement can be based upon one of two procedures. The procedures are known as the "using" airplane method and the "technical" evaluation method. ICAO procedures permit member states to determine how PCN values will be determined based upon internally developed pavement evaluation procedures. Either procedure may be used to determine a PCN, but the methodology must be reported as part of the posted rating.

4.2 USING AIRPLANE METHOD TO DETERMINE PCN. The using airplane method is a simple procedure where ACN values for all airplanes currently permitted to use the pavement facility are determined and the largest ACN value is reported as the PCN. This method is easy to apply and does not require detailed knowledge of the pavement structure.

a. Assumptions of the Using Airplane Method. An underlying assumption with the using airplane method is that the pavement structure has the structural capacity to accommodate all airplanes in the traffic mixture and that each airplane is capable of operating on the pavement structure without restriction.

b. Inaccuracies of the Using Airplane Method. The accuracy of this method is greatly improved when airplane traffic information is available. Significant over-estimation of the pavement capacity can result if an excessively damaging airplane, which uses the pavement on a very infrequent basis, is used to determine the PCN. Likewise, significant under-estimation of the pavement capacity can lead to uneconomic use of the pavement by preventing acceptable traffic from operating. Although there are no minimum limits on frequency of operation before an airplane is considered part of the normal traffic, the reporting agency must use a rational approach to avoid overstating or understating the pavement capacity. Use of the using airplane method is discouraged on a long-term basis due to the concerns listed above.

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

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

a. Determination of the PCN Value. The PCN numerical value is determined from an allowable load rating. While it is important not to confuse the PCN value with a pavement design parameter, the PCN is developed in a similar fashion. An allowable load rating is determined by applying the same principles as those used for pavement design. The process for determining the allowable load rating takes factors such as frequency of operations and permissible stress levels into account. Allowable load ratings are often stated in terms of airplane gear type and maximum gross airplane weight, as these variables are used in the pavement design procedure. Missing from the stated load rating, but just as important, is frequency of operation. In determining an allowable load rating, the evaluation must address whether the allowable load rating represents the pavement strength over a reasonable frequency of operation. Once the allowable load rating is established, the determination of the PCN value is a simple process of determining the ACN of the airplane representing the allowable load and reporting the value as the PCN.

b. Concept of Equivalent Traffic. The ACN-PCN method is based upon design procedures that establish one airplane as the critical or most demanding on the pavement structure. Calculations necessary to determine the PCN can only be performed for one airplane at a time. The ACN-PCN method does not directly address how to represent a traffic mixture as a single airplane. To address this limitation, FAA uses the equivalent airplane concept to consolidate entire traffic mixtures into one representative airplane. The procedures for establishing an equivalent airplane from a traffic mixture are provided in Appendix A1.

c. Counting Airplane Operations. When evaluating or designing a pavement section, it is important to account for the number of times the pavement will be stressed. As discussed in paragraph 2.2, an airplane may have to pass over a given section of pavement numerous times before the portion of pavement considered for evaluation receives one full stress application. While statistical procedures exist to determine the passes required for one full stress application, the evaluation of a pavement section for PCN determination must also consider how airplanes use the pavement in question. A conservative approach is used in pavement design procedures where it is assumed that each airplane using the airport must land and take off once per cycle. Since the arrival or landing weight of the airplane is usually less than the departure weight, the design procedure only counts one pass at the departure weight for analysis. These departures are usually discussed in term of departures per year or annual departures. A detailed discussion of traffic analysis is provided in Appendix 1.

4.4 LIMITATIONS OF THE PCN. The PCN value is for reporting relative pavement strength only and should not be used for pavement design or as a substitute for evaluation. Pavement design and evaluation are complex engineering problems that require detailed analyses. They cannot be reduced to a single number. The PCN rating system uses a continuous scale to compare pavement strength where higher values represent pavements with larger load capacity.

4.5 REPORTING THE PCN. The PCN system uses a coded format to maximize the amount of information contained in a minimum number of characters and to facilitate computerization. The PCN for a pavement is reported as a five-part number where the following codes are ordered and separated by forward slashes.

- Numerical PCN value
- Pavement type,
- Subgrade category,
- Allowable tire pressure, and
- Method used to determine the PCN.

An example of a PCN code is 80/R/B/W/T, which is further explained in paragraph 4.5.f.

a. Numerical PCN Value. The PCN numerical value is a relative indication of the load-carrying capacity of a pavement in terms of a standard single wheel load at a tire pressure of 181 psi (1.25 MPa). The PCN value should be reported in whole numbers, rounding off any fractional parts to the nearest whole number. For pavements of diverse strengths, the controlling PCN numerical value for the weakest segment of the pavement should normally be reported as the strength of the pavement. Engineering judgment may be required here in that if the weakest segment is not in the most heavily used part of the runway, then another representative segment may be more appropriate to determine PCN.

b. Pavement Type. For the purpose of reporting PCN values, pavement types are considered to function as either flexible or rigid structures. Table 4-1 lists the pavement codes for the purposes of reporting PCN.

Table 4-1. Pavement Codes for Reporting PCN

Pavement Type	Pavement Code
Flexible	F
Rigid	R

i) Flexible Pavement. Flexible pavements support loads through bearing rather than flexural action. They comprise several layers of selected materials designed to gradually distribute loads from the surface to the layers beneath. The design ensures that load transmitted to each successive layer does not exceed the layer's load-bearing capacity.

ii) Rigid Pavement. Rigid pavements employ a single structural layer, which is very stiff or rigid in nature, to support the pavement loads. The rigidity of the structural layer and resulting beam action enable rigid pavement to distribute loads over a large area of the subgrade. The load-carrying capacity of a rigid structure is highly dependent upon the strength of the structural layer, which relies on uniform support from the layers beneath.

iii) Composite Pavement. Various combinations of pavement types and stabilized layers can result in complex pavements that could be classified as between rigid or flexible. A pavement section may comprise multiple structural elements representative of both rigid and flexible pavements. Composite pavements are most often the result of pavement surface overlays applied at various stages in the life of the pavement structure. If a pavement is of composite construction, the pavement type should be reported as the type that most accurately reflects the structural behavior of the pavement. The method used in computing the PCN is the best guide in determining how to report the pavement type. For example, if a runway is composed of a rigid pavement with a bituminous overlay, the usual manner of determining the load-carrying capacity is to convert the pavement to an equivalent thickness of rigid pavement. In this instance, the pavement type should be reported as a rigid structure. A general guideline is that when the bituminous overlay reaches 75 to 100 percent of the rigid pavement thickness the pavement can be considered as a flexible pavement. It is permissible to include a note stating that the pavement is of composite construction but only the rating type, “R” or “F”, is used in the assessment of the pavement load capacity.

c. Subgrade Strength Category. As discussed in Paragraph 2-1, there are four standard subgrade strengths identified for calculating and reporting ACN or PCN values. The values for rigid and flexible pavements are reported in Tables 2-1 and 2-2.

d. Allowable Tire Pressure. Table 4-2 lists the allowable tire pressure categories identified by the ACN-PCN system. The tire pressure codes apply equally to rigid or flexible pavement sections; however, the application of the allowable tire pressure differs substantially for rigid and flexible pavements.

TABLE 4-2. Tire Pressure Codes for Reporting PCN

Category	Code	Tire Pressure Range
High	W	No pressure limit
Medium	X	Pressure limited to 218 psi (1.5 MPa)
Low	Y	Pressure limited to 145 psi (1.00 MPa)
Very Low	Z	Pressure limited to 73 psi (0.50 MPa)

i) Tire Pressures on Rigid Pavements. Airplane tire pressure will have little effect on pavements with Portland cement concrete surfaces. Rigid pavements are inherently strong enough to resist tire pressures higher than currently used by commercial airplanes and can usually be rated as code W.

ii) Tire Pressures on Flexible Pavements. Tire Pressures may be restricted on asphaltic concrete, depending upon the quality of the asphalt mixture and climatic conditions. Tire pressure effects on an asphalt layer relate to the stability of the mix in resisting shearing or densification. A poorly constructed asphalt pavement can be subject to rutting due to consolidation under load. The principal concern in resisting tire pressure effects is with stability or shear resistance of lower quality mixtures. A properly prepared and placed mixture that conforms to FAA specification Item P-401 can withstand substantial tire pressure in excess of 218 psi (1.5 Mpa). Item P-401, Plant Mix Bituminous Pavements, is provided in AC 150/5370-10B, Standards for Specifying Construction of Airports. Improperly prepared and placed mixtures can show distress under tire pressures of 100 psi (0.7 MPa) or less. Although these effects are independent of the asphalt layer thickness, pavements with well-placed asphalt of 4 to 5 inches (10.2 to 12.7 cm) in thickness can generally be rated with code X or W, while thinner pavement of poorer quality asphalt should not be rated above code Y.

e. Method Used to Determine PCN. Two pavement evaluation methods are recognized in the PCN system. If the evaluation represents the results of a technical study, the evaluation method should be coded T. If the evaluation is based on "using airplane" experience, the evaluation method should be coded U. Technical evaluation implies that some form of technical study and computation were involved in the determination of the PCN. Using airplane evaluation means the PCN was determined by selecting the highest ACN among the airplanes currently using the facility and not causing pavement distress. PCN values computed by the technical evaluation method should be reported to the NASR database and shown in the FAA Form 5010, Airport Master Record. Publication of a using airplane evaluation in the Airport Master Record, Form 5010, and the NASR database is permitted only by mutual agreement between the airport owner and FAA.

f. Example PCN Reporting. An example of a PCN code is 80/R/B/W/T—with 80 expressing the PCN numerical value, R for rigid pavement, B for medium strength subgrade, W for high allowable tire pressure, and T for a PCN value obtained by a technical evaluation.

g. Report PCN Values to the FAA. Once a PCN value and the coded entries are determined, the PCN code should be reported to the appropriate regional FAA Airports Division, either in writing or as part of the annual update to the Airport Master Record, FAA Form 5010-l. The regional office will forward the PCN code to FAA headquarters where it will be disseminated by the National Flight Data Center through aeronautical publications such as the Airport/Facility Directory (AFD) and the Aeronautical Information Publication (AIP). An airplane's ACN can then be compared with the published PCN to determine if the airplane can safely operate on the airport's runways, subject to any limitation on tire pressure.

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APPENDIX 1. EQUIVALENT TRAFFIC

1.0 EQUIVALENT TRAFFIC. A detailed method, based on the procedures originally introduced in AC 150/5320-6C (outdated version) is presented to allow the calculation of the combined effect of multiple airplanes in the traffic mix for an airport. This combined traffic is brought together into the equivalent traffic of a critical airplane. This is necessary in that the procedure used to calculate ACN allows only one airplane at a time. By combining all of the airplanes in the traffic mix into an equivalent critical airplane, calculation of a PCN that includes the effects of all traffic becomes possible. It is recognized that there are other methods of determining equivalent traffic. However, the method described here has been developed and used over a period of years by FAA.

The assessment of equivalent traffic, as described in this section, is needed only in the process of determining PCN using the technical method and may be disregarded when the using airplane method is employed.

In order to arrive at a technically derived PCN, it is necessary to determine the maximum allowable or commonly sustained gross weight of the critical airplane (i.e. the allowable weight on a given landing gear configuration). This in turn requires that the pavement design and airplane loading characteristics be examined in detail. Consequently, the information presented in this appendix appears at first to apply to pavement design rather than a PCN determination. However, with this knowledge in hand, an engineer will be able to arrive at a PCN that will have a solid technical foundation.

1.1 EQUIVALENT TRAFFIC TERMINOLOGY. In order to determine a PCN, as based on the technical evaluation method, it is necessary to define common terms used in airplane traffic and pavement loading. The terms arrival, departure, pass, coverage, load repetition, operation, and traffic cycle are often used interchangeably by different organizations when determining the effect of airplane traffic operating on a runway. It is important not only to determine which of the airplane movements need be counted when considering pavement stress, but how these terms apply in relation to the pavement design and evaluation process. In general, and for the purpose of this document, they are differentiated as follows:

a. Arrival (Landing) and Departure (Takeoff). Typically, airplanes arrive at an airport with a lower amount of fuel than is used at takeoff. As a consequence, the stress loading of the wheels on the runway pavement is less when landing than at takeoff due to the lower weight. This is true even at the touchdown impact in that there is still lift on the wings, which alleviates the dynamic vertical force. Because of this, the FAA pavement design procedure only considers departures and ignores the arrival traffic count. However, if the airplanes do not receive additional fuel at the airport, then the landing weight will be substantially the same as the takeoff weight (discounting the changes in passenger count and cargo), and the landing operation should be counted as a takeoff for pavement stress loading cycles. In this latter scenario, there are two equal load stresses on the pavement for each traffic count (departure), rather than just one. Regardless of the method of counting load stresses, a traffic cycle is defined as one takeoff and one landing of the same airplane, subject to a further refinement of the definition in the following text.

b. Pass. A pass is a one-time transaction of the airplane over the runway pavement. It could be an arrival, a departure, a taxi operation, or all three, depending on the loading magnitude and the location of the taxiways. Figure A1-1 shows typical traffic patterns for runways having either parallel taxiways or central taxiways. A parallel taxiway requires that none or very little of the runway be used as part of the taxi movement. A central taxiway requires that a large portion of the runway be used during the taxi movement.

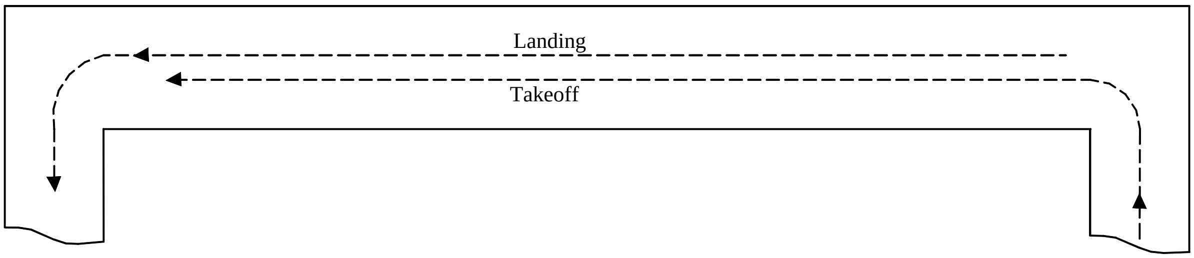

Figure A1-1a. Runway with Parallel Taxiway

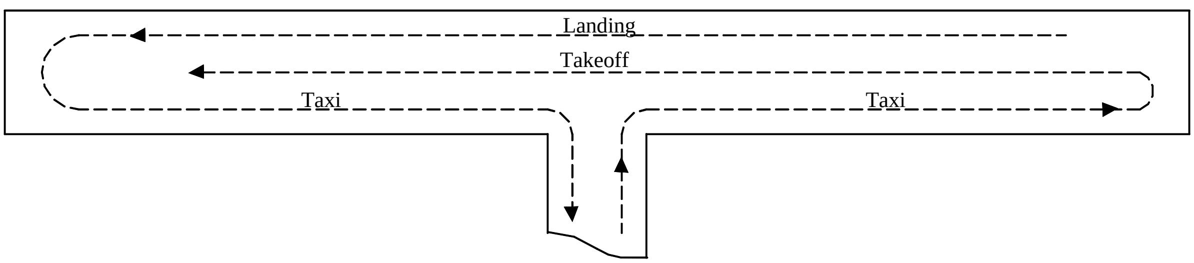

Figure A1-1b. Runway with Central Taxiway

Figure A1-1. Traffic Load Distribution Patterns

i) Parallel Taxiway Scenario. In the case of the parallel taxiway, as shown in Figure A1-1a, two possible loading situations can occur. Both of these situations assume that the passenger count and cargo payload are approximately the same for the entire landing and takeoff cycle:

1) If the airplane obtains fuel at the airport, then a traffic cycle consists of only one pass since the landing stress loading is considered at a reduced level, which is a fractional equivalence. For this condition only the takeoff pass is counted, and the ratio of passes to traffic cycles (P/TC) is 1.

2) If the airplane does not obtain fuel at the airport, then both landing and takeoff passes should be counted, and a traffic cycle consists of two passes of equal load stress. In this case, the P/TC ratio is 2.

ii) Central Taxiway Scenario. For a central taxiway configuration, as shown in Figure A1-1b, there are also two possible loading situations that can occur. As was done for the parallel taxiway condition, both of these situations assume that the payload is approximately the same for the entire landing and takeoff cycle:

1) If the airplane obtains fuel at the airport, then both the takeoff and taxi to takeoff passes should be counted since they result in a traffic cycle consisting of two passes at the maximum load stress. The landing pass can be ignored in this case. It is recognized that only part of the runway is used during some of these operations, but it is conservative to assume that the entire runway is covered each time a pass occurs. For this situation, the P/TC ratio is 2.

2) If the airplane does not obtain fuel at the airport, then both the landing and takeoff passes should be counted, along with the taxi pass, and a traffic cycle consists of three passes at loads of equal magnitude. In this case, the P/TC ratio is 3.

iii) A simplified, but less conservative, approach would be use a P/TC ratio of 1 for all situations. Since a landing and a takeoff only apply full load to perhaps the end third of the runway (opposite ends for no shift in wind direction), this less conservative approach could be used to count one pass for both landing and takeoff. However, the FAA recommends conducting airport evaluations on the conservative side, which is to assume any one of the passes covers the entire runway.

c. **Coverage.** When an airplane moves along a runway, it seldom travels in a perfectly straight line or over the exact same wheel path as before. It will wander on the runway with a statistically normal distribution. One coverage occurs when a unit area of the runway has been traversed by a wheel of the airplane main gear. Due to random wander, this unit area may not be covered by the wheel every time the airplane is on the runway. The number of passes required to statistically cover the unit area one time on the pavement is expressed by the pass to coverage (P/C).

Although the terms coverage and P/C ratio have commonly been applied to both flexible and rigid pavements, the P/C ratio has a slightly different meaning when applied to flexible pavements as opposed to rigid pavements. This is due to the manner in which flexible and rigid pavements are considered to react to various types of gear configurations. For gear configurations with wheels in tandem, such as dual tandem (2D) and triple dual tandem (3D), the ratios are different for flexible and rigid pavements, and using the same term for both types of pavements may become confusing. It is incumbent upon the user to select the proper value for flexible and rigid pavements.

Aircraft passes can be determined (counted) by observation but coverages are used by the COMFAA program. The P/C ratio is necessary to convert passes to coverages for use in the program. The P/C ratio for any airplane can be determined from the COMFAA program. This ratio is different for each airplane because of the different number of wheels, main gear configurations, tire contact areas, and load on the gear. Although the ratio will change slightly for each airplane when the tire contact area varies due to changes in applied load, for the purposes of this document, the P/C ratio will be reported as the ratio obtained from the COMFAA program in pavement thickness mode. In the pavement thickness mode the P/C is based upon the manufacturer's recommended tire deflection at 95 percent of the gross load on the main landing gear(s).

The P/C ratios for gears with wheels in tandem are different for flexible and rigid pavement. This difference occurs because of the method in which the flexible and rigid pavements are assumed to handle stress. It is assumed that the flexible pavement loading pattern has a series of stress peaks, depending on the number of wheels in tandem, while a rigid pavement acts as a single deflecting plate, with only one stress peak per group of wheels. Generally, a single- or dual-gear arrangement will provide only one load stress per pass, regardless of the pavement type, since there is only one set of wheels traversing a given place on the pavement. However, a dual tandem gear stresses a flexible pavement twice since there are two repetitions of the load on flexible pavement, and it stresses a rigid pavement once due to the effect of only one stress loading per group of wheels. Likewise, a triple dual tandem gear stresses the flexible pavement three times but only one time for rigid pavement. Gear configurations with tandem spacing exceeding 72 inches (182 cm) are treated as individual load peaks for flexible and rigid pavements in the COMFAA program.

d. Operation. The meaning of this term is unclear when used in pavement design or evaluation. It could mean a departure at full load or a landing at minimal load. It is often used interchangeably with pass or traffic cycle. When this description of an airplane activity is used, additional information should be supplied. It is usually preferable to use the more precise terms described in this section.

e. Traffic Cycle and Traffic Cycle Ratio. As has been discussed, a traffic cycle can include a landing pass, a takeoff pass, a taxi pass or all three. For pavement design or evaluation, the ratio of traffic cycles to coverages (TC/C) in flexible pavement, rather than passes to coverages, is required since there could be one or more passes per traffic cycle. When only one pass on the operating surface is assumed for each traffic count, then the P/C ratio is sufficient. However, when situations are encountered where more than one pass is considered to occur during the landing to takeoff cycle, then the TC/C ratio is necessary in order to properly account for the effects of all of the traffic. These situations occur most often when there are central taxiways or fuel is not obtained at the airport.

Equation A1-1 translates the P/C ratio to the TC/C ratio for flexible and rigid pavements by including the previously described ratio of passes to traffic cycles (P/TC):

$$TC/C = P/C \div P/TC \qquad \text{(Equation A1-1)}$$

Where:
TC = Traffic Cycles
C = Coverages
P = Passes

Determination of the TC/C ratio can best be illustrated by examples. Table A1-1 shows typical ratios for flexible pavement runways for situations in which fuel is not obtained at the airport. Typical values of the P/C ratio are shown in this table, but different ratios can be substituted for other airplanes. Refer to Figure A1-1 for guidance in determining the number of passes used for each traffic count. Note that the number of traffic cycles to complete one coverage is reduced considerably for a runway with a central taxiway, as opposed to one with a parallel taxiway. The effect of this is that a runway with a central taxiway will experience more load stresses for each traffic count than one with a parallel taxiway.

Table A1-1. TC/C Ratio for Flexible Pavements – Additional Fuel Not Obtained

Taxiway Type	Typical Dual Gear (D)	Typical Dual Tandem Gear (2D)	Typical Triple Dual Tandem Gear (3D)
P/C	3.6	1.8	1.4
P/TC - Parallel	2	2	2
P/TC - Central	3	3	3
TC/C - Parallel	1.8	0.9	0.7
TC/C - Central	1.2	0.6	0.5

Table A1-2 shows the same information for a situation in which additional fuel is obtained at the airport. From a comparison of these two tables, it is seen that for a runway having a central taxiway where fuel is not obtained at the airport, there are more traffic cycles than for a runway in which a parallel taxiway exists and fuel is obtained at the airport. For example, the typical dual gear TC/C for a central taxiway indicated in Table A1-1 is 1.2 compared with that of 3.6 for the parallel taxiway indicated in Table A1-2, resulting in three times the number of passes for each traffic count. Additionally, as the number of wheels increases, the TC/C ratio decreases, regardless of the taxiway configuration. The effect of this is that there are more loading cycles in terms of coverages per traffic count on flexible pavement with the increased number of wheels.

Table A1-2. TC/C Ratio for Flexible Pavements – Additional Fuel Obtained

Taxiway Type	Typical Dual Gear (D)	Typical Dual Tandem Gear (2D)	Typical Triple Dual Tandem Gear (3D)
P/C	3.6	1.8	1.4
P/TC - Parallel	1	1	1
P/TC - Central	2	2	2
TC/C - Parallel	3.6	1.8	1.4
TC/C - Central	1.8	0.9	0.7

Table A1-3 shows typical ratios for rigid pavements for situations in which fuel is not obtained at the airport, while Table A1-4 shows the same information for cases in which additional fuel is obtained at the airport. The same comparison as above is seen in which a different number of traffic cycles occur between the runways with differing taxiway configurations. However, unlike the flexible pavement example, the ratio of traffic cycles to load stress is not very sensitive to gear configuration. For example, in Tables A1-3 and A1-4, both the dual and dual-tandem gears have the same TC/C ratio, while the triple dual tandem gear is only slightly different. The effect of this is that for the same taxiway type and fuel-loading situation, the level of load repetitions per traffic cycle on rigid pavement is virtually the same, regardless of the gear configuration.

Table A1-3. TC/C Ratio for Rigid Pavements – Additional Fuel Not Obtained

Taxiway Type	Typical Dual Gear (D)	Typical Dual Tandem Gear (2D)	Typical Triple Dual Tandem Gear (3D)
P/C	3.6	3.6	4.2
P/TC - Parallel	2	2	2
P/TC - Central	3	3	3
TC/C - Parallel	1.8	1.8	2.1
TC/C - Central	1.2	1.2	1.4

Table A1-4. TC/C Ratio for Rigid Pavements – Additional Fuel Obtained

Taxiway Type	Typical Dual Gear (D)	Typical Dual Tandem Gear (2D)	Typical Triple Dual Tandem Gear (3D)
P/C	3.6	3.6	4.2
P/TC - Parallel	1	1	1
P/TC - Central	2	2	2
TC/C - Parallel	3.6	3.6	4.2
TC/C - Central	1.8	1.8	2.1

1.2 EQUIVALENT TRAFFIC BASED ON GEAR TYPE. In order to complete the equivalent traffic calculation, all other significant airplanes in the traffic mix must first be converted to a critical airplane in terms of gear type and traffic cycles so this other traffic is accounted for in the overall pavement design life. Then, the converted gear types must be in turn converted to a critical airplane equivalent in terms of load magnitude. The critical airplane is an airplane that regularly uses the pavement and that has the greatest thickness requirements, based on its individual operational characteristics.

Table A1-5 provides conversion factors for common gear configurations that are used to convert a given gear type to that of the critical airplane. After this conversion, each airplane in the traffic mix, and its corresponding traffic cycles, will be represented by the same gear configuration as the critical airplane.

Table A1-5. Conversion Factors to Convert from One Landing Gear Type to Another

To Convert From Gear Type (N)	To Gear Type (M)	Multiply Traffic Cycles By
S	D	0.80
S	2D	0.51
S	3D	0.33
D	S	1.25
D	2D	0.64
D	3D	0.41
2D	S	1.95
2D	D	1.56
2D	3D	0.64
3D	S	3.05
3D	D	2.44
3D	2D	1.56
2D/2D2	D	1.56
2D/2D2	2D	1.00

The general equation for this conversion is:

$$0.8^{(M-N)}$$ (Equation A1-2)

Where:

M = the number of wheels on the critical airplane main gear.
N = the number of wheels on the converted airplane gear.

Tables A1-6 and A1-7 provide examples of the use of gear configuration conversion factors Table A1-6 shows the gear equivalencies for a dual tandem (2D) gear in a sample traffic mix, while Table A1-7 shows the same gear equivalencies for a dual gear (D). The equivalent traffic cycles totals are shown for comparison purposes only and are not necessary for critical airplane calculations. It can be seen from a comparison of these totals that the selection of the critical airplane is very important for the overall evaluation process in that an incorrect selection leads to an erroneous number of equivalent traffic cycles. This is evident in Table A1-6 where the overall total of annual traffic cycles is 15,200, compared with the total equivalent dual tandem traffic cycles of 12,632, whereas in Table A1-7, the total equivalent dual traffic cycles is 19,720.

Table A1-6. Equivalency Conversion to a Dual Tandem (2D) Gear Type

Airplane	Gear Type	Annual Traffic Cycles (TC)	Conversion Factor	Total Equivalent (2D) TC
727-200	D	400	0.64	256
737-300	D	6,000	0.64	3840
A319-100	D	1,200	0.64	768
B747-400	2D/2D2	3,000	1.0	3,000
B767-200ER	2D	2,000	1.0	2,000
DC8-63	2D	800	1.0	800
A300-B4	2D	1,500	1.0	1,500
B777-200	3D	300	1.56	468
		15,200		12,632

Table A1-7. Equivalency Conversion to a Dual Gear (D) Type

Airplane	Gear Type	Annual Traffic Cycles (TC)	Conversion Factor	Total Equivalent (D) TC
727-200	D	400	1.0	400
737-300	D	6,000	1.0	6,000
A319-100	D	1,200	1.0	1,200
B747-400	2D/2D2	3,000	1.56	4,680
B767-200ER	2D	2,000	1.56	3,120
DC8-63	2D	800	1.56	1,248
A300-B4	2D	1,500	1.56	2,340
B777-200	3D	300	2.44	732
		15,200		19,720

1.3 EQUIVALENT TRAFFIC BASED ON LOAD MAGNITUDE. After the airplanes have been grouped into the same gear configuration, it is necessary to determine the total equivalent traffic cycles of each airplane in terms of the critical airplane as based on the relative load magnitude. As for the gear type conversion procedure (Paragraph 1.2), this step requires a previously selected critical airplane.

When computing equivalent traffic cycles of the critical airplane based on load magnitude, there are several simplifying rules to use:

- For the purpose of equivalent traffic cycle calculations, it is generally sufficient to use single wheel loads based on 95 percent of gross airplane weight on the main gear.

- Since it is difficult to determine current or projected operational weights, the FAA recommends using maximum taxiing gross weights of each airplane for this calculation.

After gear types for the airplanes of the traffic mix are converted to that of the critical airplane (Paragraph 1.2), the traffic cycles of each airplane must be converted to equivalent traffic cycles of the critical airplane. This conversion addresses the effect of wheel load magnitude and may be calculated by applying Equation A1-3:

$$\text{Log } R_1 = \text{Log } R_2 \times \sqrt{\frac{W_2}{W_1}} \quad \text{or} \quad R_1 = (R_2)^{\sqrt{W_2/W_1}} \qquad \text{(Equation A1-3)}$$

Where:

R_1 = Equivalent traffic cycles of the critical airplane
R_2 = Traffic cycles of a given airplane expressed in terms of the critical airplane landing gear
W_1 = Wheel load of the critical airplane
W_2 = Wheel load of the airplane in question

Table A1-8 shows how the above calculations are combined to determine the equivalent traffic cycles of the critical airplane. For this example, assume that the B747-400 is the critical airplane. It can be seen that the original 3,000 annual traffic cycles of the B747-400 have increased to an equivalent 7,692 due to the combined effect of the other airplanes in the traffic mix. The R_2 column is from Table A1-6.

Table A1-8. Equivalent Traffic Cycles Based on Load Magnitude

Airplane	Operating Weight lb	(W_2) Single Wheel Load, lb	(R_2) (2D) TC	$(W_2/W_1)^{1/2}$ Wheel Load Ratio	(R_1) Equivalent B747-400 TC	
727-200	185,000	43,938	256	0.95	194	
737-300	130,000	30,875	3,840	0.796	716	
A319-100	145,000	34,438	768	0.841	268	
B747-400	820,000	48,688 (W1)	3,000	1.000	3,000	(Critical Airplane)
B767-200ER	370,000	43,938	2,000	0.950	1,368	
DC8-63	330,000	39,188	800	0.897	403	
A300-B4	370,000	43,938	1,500	0.950	1,041	
B777-200	600,000	47,500	468	0.988	434	
			12,632		7,424	

Note that a sensitive factor in this table is the single wheel load and its ratio to the critical airplane single wheel load. Any changes in the single wheel load magnitude are reflected in the wheel load ratio, which is used as an exponent in the calculation of equivalent traffic cycles. For example, the 727-200 equivalent traffic is shown to decrease from 256 to 194. Alternately, the B777-200 equivalent traffic decreases from 468 to 434 due to the relative magnitude of the single wheel loads.

APPENDIX 2. PCN DETERMINATION EXAMPLES

1.0. THE USING AIRPLANE METHOD. The using airplane method of determining PCN is presented in the following steps. This procedure can be used when there is limited knowledge of the existing traffic and runway characteristics. It is also useful when engineering analysis is neither possible nor desired. Airport authorities should be more careful in the application of a using airplane PCN in that the rating has not been rigorously determined.

There are two basic steps required to arrive at a using airplane PCN:

- Determine the airplane with the highest ACN in the traffic mix currently using the runway. This is the critical airplane.

- Assign the ACN of the critical airplane as the PCN.

These steps are explained in greater detail:

1. Assign the pavement surface type as code F or R.

2. From available records, determine the average strength of the pavement subgrade. If the subgrade strength is not known, make a judgment of High, Medium, Low, or Ultra Low.

3. Determine which airplane has the highest ACN from a list of airplanes that are presently using the runway, based on the surface type code assigned in Step 1 and the subgrade code in Step 2. ACN values may be determined from the COMFAA program or from ACN graphs found in the manufacturer's published ACAP manuals. Use the same subgrade code for each of the airplanes when determining the maximum ACN. Base ACNs on the highest operating weight of the airplanes at the airport if the data is available; otherwise, use an estimate or the published maximum allowable gross weight of the airplane in question. The airplane with the highest ACN that regularly uses the pavement, is the critical airplane.

4. The PCN is simply the ACN of the critical airplane, with appropriate tire pressure and evaluation codes added. The numerical value of the PCN may be adjusted up or down at the preference of the airport authority. Reasons for adjustment include local restrictions, allowances for certain airplanes, or pavement conditions.

5. The tire pressure code (W, X, Y, or Z) should represent the highest tire pressure of the airplane fleet currently using the runway. For flexible pavements, code X should be used if no higher tire pressure is evident from among the existing traffic. It is commonly understood that concrete can tolerate substantially higher tire pressures, so the rigid pavement rating should normally be given as W.

6. The evaluation method for the using airplane method is reported as U.

1.1 USING AIRPLANE EXAMPLE FOR FLEXIBLE PAVEMENTS. The following example illustrates the using airplane PCN process for flexible pavements:

An airport has a flexible (asphalt-surfaced) pavement runway with a subgrade strength of CBR 9 and traffic having the operating gross weights and ACNs shown in Table A2-1.

Table A2-1. Using Airplane and Traffic for a Flexible Pavement

Airplane	Operating Weight, lbs	Tire Pressure (psi)	% Gross Weight on Main Gear for ACN	ACN F/B	Annual Departures
B727-200	185,000	148	96.00	48	400
B737-300	130,000	195	90.86	32	6,000
A319-100	145,000	196	92.60	34	1,200
B747-400	820,000	200	93.32	59	3,000
B767-300ER	370,000	190	92.40	50	2,000
DC8-63	330,000	194	96.12	53	800
A300-B4	370,000	205	94.00	57	1,500
B777-200	600,000	215	95.42	52	300

- Since this is a flexible pavement, the pavement type code is F, (Table 4-1).
- The subgrade strength under the pavement is CBR 9, or Medium category, so the appropriate code is B (Table 2-2).
- The highest tire pressure of any airplane in the traffic mix is 215 psi, so the tire pressure code is X (Table 4-2).
- From the above list, the critical airplane is the B747-400, because it has the highest ACN of the group at the operational weights shown (59/F/B). Additionally, it has regular service as compared to the rest of the traffic, which qualifies it as a possible critical airplane.
- Since there was no engineering analysis done in this example, and the rating was determined simply by examination of the current airplanes using the runway, the evaluation code from Paragraph 4.5e is U.
- Based on the results of the previous steps, the pavement should tentatively be rated as PCN 59/F/B/X/U, assuming that the pavement is performing satisfactorily under the current traffic.

If the pavement shows obvious signs of distress, this rating may need to be adjusted downward at the discretion of the airport authority. If the rating is lowered, then one or more of the airplanes will have ACNs that exceed the assigned rating. This may require the airport to restrict the allowable gross weight for those airplanes or consider pavement strengthening. The rating could also be adjusted upward, depending on the performance of the pavement under the current traffic.

1.2 USING AIRPLANE EXAMPLE FOR RIGID PAVEMENTS. The following example illustrates the using airplane PCN process for rigid pavements:

An airport has a rigid (concrete-surfaced) pavement runway with a subgrade modulus strength of k=200 pci and traffic having the operating gross weights and ACNs shown in Table A2-2.

Table A2-2. Using Airplane and Traffic for a Rigid Pavement

Airplane	Operating Weight, lbs	Tire Pressure (psi)	% Gross Weight on Main Gear for ACN	ACN R/C	Annual Departures
B727-200	185,000	148	96.00	56	400
B737-300	130,000	195	90.86	38	6,000
A319-100	145,000	196	92.60	42	1,200
B747-400	820,000	200	93.32	68	3,000
B767-300ER	370,000	190	92.40	58	2,000
DC8-63	330,000	194	96.12	62	800
A300-B4	370,000	205	94.00	67	1,500
B777-200	600,000	215	95.42	77	300

- Since this is a rigid pavement, the pavement type code is *R*, (Table 4-1).
- The subgrade strength under the pavement is k=200 pci, which is Low category, so the appropriate code is C (Table 2-1).
- The highest tire pressure of any airplane in the traffic mix is 215 psi, so the tire pressure code is X, as found in Table 4-2. However, since concrete can normally tolerate substantially higher tire pressures, the code W should be assigned.
- From the above list, the critical airplane is the B777-200, because it has the highest ACN of the group at the operational weights shown (77/R/C). However, the critical airplane could also be the A300-B4 at ACN 67/R/C or the B747-400 at ACN 68/R/C since these airplanes have higher frequencies than the B777-200.
- Since there was no engineering analysis done in this example, and the rating was determined simply by examination of the current airplanes using the runway, the evaluation code from Paragraph 4.5e is U.
- Based on these steps, the pavement should tentatively be rated as PCN 77/R/C/W/U in order to accommodate all of the current traffic.

- If the pavement shows obvious signs of distress, this rating may need to be adjusted downward at the discretion of the airport authority. If the rating is lowered, then one or more of the airplanes will have ACNs that exceed the assigned rating. This may require the airport to restrict the allowable gross weight for those airplanes or consideration of pavement strengthening. The rating could also be adjusted upward, depending on the performance of the pavement under the current traffic.

2.0 THE TECHNICAL EVALUATION METHOD. The technical evaluation method of determining PCN should be used when there is reliable knowledge of the existing traffic and pavement characteristics. Although the technical evaluation provides a good representation of existing conditions, the airport authority should still be somewhat flexible in its application since there are many variables in the pavement structure as well as the method of analysis itself. The objective of the technical method is to determine a critical airplane allowable gross weight in order to assess the PCN.

2.1 TECHNICAL EVALUATION FOR FLEXIBLE PAVEMENTS. The following list summarizes the steps for using the technical evaluation method for flexible pavements:

- Determine the traffic volume in terms of type of airplane and number of operations of each airplane that the pavement will experience over its life.
- Convert that traffic into a single critical airplane equivalent.
- Determine pavement characteristics, including the subgrade CBR and pavement thickness.
- Calculate the maximum allowable gross weight of the critical airplane on that pavement.
- Calculate the ACN of the critical airplane at its maximum allowable gross weight.
- Assign the PCN to be the ACN of the critical airplane.

These steps are explained in greater detail below. Several examples at the end of this section further illustrate the process.

1. Determine the traffic volume in terms of traffic cycles for each airplane that has used or is planned to use the airport during the pavement life period. Record all significant traffic, including non-scheduled, charter, and military, as accurately as possible. This includes traffic that has occurred since the original construction or last overlay and traffic that will occur before the next planned overlay or reconstruction. If the pavement life is unknown or undetermined, assume that it will include a reasonable period of time. The normal design life for pavement is 20 years. However, the expected life can vary depending on the existing pavement conditions, climatic conditions, and maintenance practices.

   The information necessary for the traffic volume process is—
   - Past, current, and forecasted traffic cycles of each significant airplane.
   - Operational or maximum gross weights.

- Typical airplane weight distribution on the main and nose gear. If unknown, AC 150/5320-6 assumes 95 percent weight on the main gear.
- Main gear type (dual, dual tandem, etc.).
- Main gear tire pressure.
- The pass-to-coverage (P/C) ratio of each airplane that might be considered as the critical airplane.
- Fuel-loading practices of airplanes at the airport.
- Type of taxiway system – parallel or central.

2. Determine which airplane in the traffic mix from step 1 is critical or the most significant. This is required because the ACN procedure implemented in the COMFAA program is able to accommodate only one airplane at a time. The critical airplane is the one that has the greatest pavement thickness requirements based on its individual gross weight, traffic volume, P/C ratio, and tire pressure; and it is not necessarily the one with the highest ACN or the highest gross weight.

3. The COMFAA program calculates pavement thickness requirements based on coverages rather than traffic cycles or passes. It is therefore a requirement to convert these types of frequencies to coverages by using a pass-to-coverage ratio. Airplane-specific P/C ratios on flexible pavement can be calculated in the COMFAA program.

4. Using the conversion factors in Table A1-5, convert the traffic volume of each airplane in the traffic mix to the critical airplane equivalent based on gear configuration differences. For example, if the critical airplane has a dual tandem gear, then all single wheel, dual wheel, and triple dual tandem wheel gears need to be converted into the dual tandem gear equivalent.

5. Determine the critical airplane equivalent traffic cycles based on the single wheel load magnitude of each airplane in the traffic mix. These calculations should be based on Equation A1-3.

6. Calculate the critical airplane TC/C ratio from Equation A1-1 for the type of taxiway and the fuel-loading method. This will allow the COMFAA program to determine coverages from the critical airplane equivalent traffic cycles determined in Step 5.

7. From field data or construction drawings, document the average CBR of the subgrade soil. Alternatively, conduct field or laboratory tests of the subgrade soil in order to determine the CBR. Accurate portrayal of the subgrade CBR value is vital to the technical method because a small variation in CBR could result in a disproportionately large variation in the critical airplane allowable gross weight and the corresponding PCN.

8. Determine the total pavement thickness and cross-sectional properties. The thickness of the pavement section under consideration must be referenced to a standard pavement section for evaluation purposes. The standard section is the total thickness requirement calculated by the COMFAA program assuming minimum layer thickness for the asphalt surface, minimum base layer thickness of material with a CBR 80 or higher, and a variable subbase layer with a CBR 20 or greater. If the pavement has excess material or improved materials, the total pavement thickness may be increased according to the

methods described in paragraph 321 of AC 150/5320-6D. The pavement is considered to have excess asphalt, which can be converted to extra equivalent thickness, when the asphalt thickness is greater than the minimum thickness of asphalt surfaced required for the critical airplane. Minimum asphalt surface course thickness requirements are 4 inches for standard body jet transport airplanes and 5 inches for widebody airplanes. The pavement may also be considered to have excess base thickness when the cross-section has a base thickness greater than the minimum specified in Table 3-4 of AC 150/5320-6D or when other improved materials such as asphalt stabilization or cement treated materials, are present. Likewise, additional subbase thickness or improved subbase materials may also be converted to additional total pavement thickness.

9. Using the equivalent traffic and TC/C ratio of the critical airplane, the equivalent pavement thickness, and the average CBR of the subgrade, compute the maximum allowable gross weight of the critical airplane using the COMFAA program in the pavement design mode.

10. Assign the subgrade CBR strength found in Step 7 to the appropriate standard ACN-PCN subgrade code as given in Table 2-2.

11. The ACN of the critical airplane may now be determined from the COMFAA program using the ACN mode. Enter the allowable gross weight of the critical airplane, and calculate the ACN based on the standard subgrade code of Step 10. Alternatively, consult an "ACN versus Gross Weight" chart as published in the manufacturer's ACAP manuals.

12. Assign the tire pressure code based on the highest tire pressure in the traffic mix from Table 4-2. Keep in mind the quality of the asphalt surface layer, as discussed in Section 2.1, when assigning this code.

13. As the evaluation method is technical, assign the code of *T*, as described in paragraph 4.5e.

14. The numerical value of the PCN is the same as the numerical value of the ACN of the critical airplane calculated in Step 11.

15. If the calculated allowable gross weight of Step 11 is equal to or greater than the critical airplane operational gross weight required for the desired pavement life, then the pavement is capable of handling the predicted traffic for the time period established in the traffic forecast. Accordingly, the assigned PCN determined in Step 14 is sufficient. If the allowable gross weight from Step 11 is less than the critical airplane gross weight required for the desired pavement life, then the pavement may be assigned a PCN equal to the ACN of the critical airplane at that gross weight, but with a lower expected pavement life. Additionally, it may then be necessary to develop a relationship of allowable gross weight based on the assigned PCN versus pavement life. Any overload should be treated in terms of ACN and equivalent critical airplane operations per individual operation. Allowance for the overload should be negotiated with the airport authority since pre-approval cannot be assumed. Specific procedures on how to relate pavement life and gross weight for flexible pavements are found in Appendix 3 of this document.

2.2 TECHNICAL EVALUATION EXAMPLES FOR FLEXIBLE PAVEMENTS. The following four examples help demonstrate the technical evaluation method of determining a PCN for flexible pavements. The first example is for an under-strength pavement with a traffic volume that has increased to such a level that pavement life is reduced from the original design. The second example pavement has more than adequate strength to handle the forecasted traffic. The third example pavement is the same as the second, except that the runway has a central rather than a parallel taxiway. Example 4 discusses the effect on pavement life of a higher PCN rather than a reduced allowable gross weight.

a. Flexible Pavement Example 1. An airport has a flexible (asphalt-surfaced) runway pavement with a subgrade CBR of 9 and a total thickness of 32.0 inches, as shown in Figure A2-1 (5 inch minimum asphalt surface layer, 8 minimum base layer and variable subbase layer). Additional fuel is generally obtained at the airport before departure, and the runway has a parallel taxiway. The pavement was designed for a life of 20 years. It is assumed for the purposes of this example that the traffic level is constant over the 20-year time period. The traffic is shown in Table A2-3, which is similar to Table A2-1 but with additional information added.

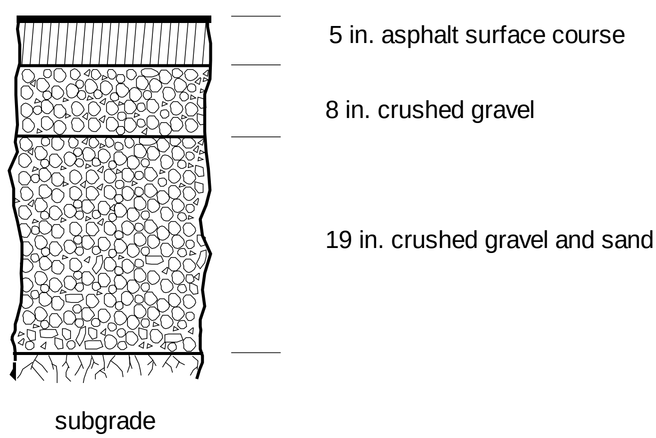

Figure A2-1. Flexible Pavement Example Cross-Section

Table A2-3. Technical Evaluation Critical Airplane Determination

Airplane	Operating Weight, (lbs)	Tire Pressure (psi)	ACN F/B	Annual Departures	Flexible **P/C	Required Thickness, (in.)
B727-200	185,000	148	48	400	2.92	22.6
B737-300	130,000	195	35	6,000	3.79	22.7
A319-100	145,000	196	35	1,200	3.18	20.3
B747-400	820,000	200	59	3,000	1.73	30.9
B767-300ER	370,000	190	52	2,000	1.80	27.9
DC8-63	330,000	194	52	800	1.68	26.6
A300-B4	370,000	205	57	1,500	1.75	29.1
B777-200	600,000	215	51	300	1.42	28.0

** P/C determined at 95 percent of gross load on main gear

The required total pavement thickness results are shown in Table A2-3 for each airplane. The B747-400 airplane has the greatest individual pavement thickness requirement (30.9 inches) for its total traffic over 20 years; it is therefore the critical airplane. Note the thickness requirements for each individual airplane are less than the existing pavement thickness of 32 inches.

Table A2-4 shows the conversion of departures of the other traffic to the critical airplane (B747-400) equivalent. Gear configuration conversion factors from Table A1-5 were used to determine the equivalent dual tandem gear departures. The B747-400 equivalent annual departures were calculated by using Equation A1-3. Although the B747-400 had only 3,000 annual departures, the effect of the other traffic has increased the number to an equivalent 7,424.

Note the equivalent annual departure total shown would also be the same for the B767-300ER and the A300-B4 because the assumed wheel loads are the same as that of the critical airplane. This would not be true, however, for the B777-200 because of the different gear configuration. Note also the effect of wheel load on the critical airplane equivalent annual departures. Wheel loads of the individual airplanes that are greater than the critical airplane wheel load add to the critical airplane equivalent departures by a factor greater than one, while wheel loads that are less add by a factor less than one. This relationship indicates the need to carefully consider the loading of each airplane in the traffic mix when determining equivalent traffic.

Table A2-4. Equivalent Annual Departures of the Critical Airplane

Airplane	Annual Depart-ures	Gear Type	Gear Type Factor	(R_2) Equiv. (2D) Depart-ures	(W_2) Wheel Load (lbs)	(W_1) B747-400 Wheel Load (lbs)	(R_1) B747-400 Equiv. Ann. Departures
B727-200	400	D	0.64	256	43,938	48,688	194
B737-300	6,000	D	0.64	3,840	30,875	48,688	716
A319-100	1,200	D	0.64	768	34,438	48,688	268
B747-400	3,000	2D/2D2	1.00	3,000	48,688	48,688	3,000
B767-300ER	2,000	2D	1.00	2,000	43,938	48,688	1368
DC8-63	800	2D	1.00	800	39,188	48,688	403
A300-B4	1,500	2D	1.00	1,500	43,938	48,688	1,041
B777-200	300	3D	1.56	468	47,500	48,688	434
	15,200						7,424

With the total equivalent traffic of the critical airplane known, the traffic cycle ratio for the taxiway and fuel situation can be calculated. Using a critical airplane P/C ratio of 1.73 (Table A2-3) and a P/TC ratio of 1 for a parallel taxiway (Table A1-2), the traffic cycle to coverage ratio can be calculated with Equation A1-1:

$$TC/C = 1.73 \div 1 = 1.73$$

It is now possible to calculate the maximum allowable gross weight of the B747-400 critical airplane on this pavement. The input parameters to the COMFAA program are as follows:

Critical airplane	B747-400
Pavement thickness	32.0 inches
Subgrade CBR	9.0 (code B)
Tire pressure	200 psi (code X)
Percent weight on the main gear	95.0 percent
TC/C ratio	1.73
Pavement life	20 years
Annual equivalent departures	7,424
Total coverages (TC/1.73) x 20	85,827

For these conditions, the COMFAA program calculates an allowable gross weight for the B747-400 of 797,500 pounds. Further, the program determines the B747-400 ACN at this weight to be 56.4/F/B, for a recommended pavement rating of PCN 56/F/B/X/T.

Referring to Table A2-3, it can be seen that the B747-400 and the A300-B4 airplanes would be restricted in their operations on this runway due to their ACNs of 59/F/B and 57/F/B, respectively—both of which are higher than the recommended PCN of 56/F/B. It is apparent the pavement is not adequate to accommodate the existing traffic, and either the operating weights will have to be restricted or pavement life will be less than originally expected. An analysis of this situation and the requirements for adjustments is provided in Appendix 3.

b. Flexible Pavement Example 2. This second example has the same input parameters as the first, except the pavement cross-section is increased to 36 inches.

The input parameters to the COMFAA program for this example are:

Critical airplane	B747-400
Pavement thickness	36.0 inches
Subgrade CBR	9.0 (code B)
Tire pressure	200 psi (code X)
Percent weight on the main gear	95.0 percent
TC/C ratio	1.73
Pavement life	20 years
Annual equivalent departures	7,424
Total coverages (TC/1.73) x 20	85,827

For these conditions, the calculated allowable gross weight of the B747-400 is 923,000 pounds. The COMFAA program determines the B747-400 ACN at this weight is 69.3/F/B, for a recommended rating of PCN 69/F/B/X/T.

An examination of Table A2-3 shows that the traffic has ACNs that are less than the recommended PCN. It can therefore be safely assumed that the pavement will adequately handle the existing traffic within its design life, and no adjustments to the pavement cross-section or life will have to be made. Note that the addition of 4 inches in pavement thickness from Example 1 has resulted in a net increase in PCN of 13.0.

c. Flexible Pavement Example 3. The only change in this example from the second example is that the taxiway is a central configuration rather than parallel, such as that shown in Figure A1-1b. Using data from Table A1-2, the P/TC ratio changes from 1 to 2. From Equation A1-1, the TC/C ratio for the critical B747-400 airplane becomes—

$$TC/C = 1.73 \div 2 = 0.865$$

The input parameters to the COMFAA program are:

Critical airplane	B747-400
Pavement thickness	36.0 inches
Subgrade CBR	9.0 (code B)
Tire pressure	200 psi (code X)
Percent weight on the main gear	95.0 percent
TC/C ratio	0.86
Pavement life	20 years
Annual equivalent departures	7,424
Total coverages (TC/0.865) x 20	171,653

For these conditions, the calculated allowable gross weight of the B747-400 is 875,000 pounds. The COMFAA program determines the B747-400 ACN at this weight to be 64.2/F/B, for a recommended runway rating of PCN 64/F/B/X/T. The net effect of the change in taxiway configuration from that of Example 2 is the reduction in PCN by 5.

d. Flexible Pavement Example 4. As an alternate way of looking at the effect of a parallel versus central taxiway effects, consider how the pavement life would change instead of the PCN. If the PCN from Example 2 were to remain at 69/F/B/X/T, which is equivalent to a B747-400 critical airplane allowable gross weight of 923,000 pounds, then the pavement life would be reduced from 20 to 10 years. This is due to the change in the TC/C ratio from 1.73 to 0.86. A similar effect would be noticed if fuel was not obtained at the airport, (it was obtained in the first flexible pavement example case).

2.3 TECHNICAL EVALUATION FOR RIGID PAVEMENTS. The following list summarizes the steps for using the technical evaluation method for rigid pavements:

- Determine the traffic volume in terms of type of airplane and number of operations of each airplane that the pavement will experience over its life.
- Convert that traffic into a single critical (design) airplane equivalent.
- Determine the pavement characteristics; including subgrade soil modulus, k, and the concrete thickness and elastic modulus.
- Calculate the maximum allowable gross weight of the critical airplane on that pavement.
- Look up or calculate the ACN of the critical airplane at its maximum allowable gross weight, as determined in the previous step.
- Assign the PCN to be the ACN just calculated.

The above steps are explained in greater detail:

1. Determine the traffic volume in the same fashion as noted in paragraph A2-2.1 for flexible pavements
2. Determine which airplane in the traffic mix from step 1 is critical or the most significant. The critical airplane is the one that has the greatest pavement thickness requirements based on its individual gross weight, traffic volume, P/C ratio, and tire pressure; it is not necessarily the one with the highest ACN or the highest gross weight.
3. The rigid design procedure implemented in the COMFAA program calculates pavement thickness requirements based on the concrete edge stress, which is in turn dependent on load repetitions of the total traffic mix. It is therefore a requirement to convert traffic cycles or passes to load repetitions by using a pass-to-load repetition

ratio. P/C ratios for any airplane on rigid pavement are calculated in the COMFAA program.

4. Using the conversion factors in Table A1-5, convert the traffic volume of each airplane in the traffic mix to the critical airplane equivalent based on gear configuration differences.

5. Determine the critical airplane equivalent traffic cycles based on the single wheel loads of each airplane in the traffic mix using Equation A1-3.

6. Calculate the critical airplane TC/C ratio from Equation A1-1 for the type of taxiway and the fuel-loading method.

7. Using the critical airplane equivalent traffic cycles from Step 5 and the TC/C ratio from Step 6, calculate the equivalent load repetitions of the critical airplane based on the life expectation of the pavement.

8. Obtain the pavement characteristics including the concrete slab thickness, the concrete modulus of rupture, and average modulus, k, of the subgrade. Concrete elastic modulus is set at 4,000,000 psi and Poisson's ratio is set at 0.15 in the COMFAA program. Accurate subgrade modulus determination is important to the technical method, but small variations in the modulus will not affect the PCN results in a disproportionate manner. This is in contrast to flexible pavement subgrade modulus in which strength variations have a significant effect on PCN. If the pavement has a subbase course and/or stabilized subbase layers, then the subgrade modulus is adjusted upwards in the rigid design procedure to an equivalent value in order to account for the improvement in support. Subgrade modulus adjustments are made from Figures 2-4 and 3-16 of AC 150/5320-6D.

9. Using the known slab thickness, subgrade modulus, and airplane parameters compute the maximum allowable gross weight of the critical airplane using the COMFAA program in the pavement design mode. By setting the airplane total coverages, gross airplane weight can be adjusted until the known pavement thickness is achieved.

10. Assign the subgrade modulus (k-value) to the nearest standard ACN-PCN subgrade code. The k-value to be reported for PCN purposes is the improved k-value seen at the top of all improved layers. Subgrade codes for k-value ranges are found in Table 2-1.

11. The ACN of the critical airplane may now be determined from the COMFAA program. Enter the allowable gross weight of the critical airplane from Step 9, and calculate the ACN for the standard subgrade code of Step 10. Alternatively, consult an "ACN versus Gross Weight" chart as published in the manufacturer's ACAP manual.

12. Assign the tire pressure code based on the highest tire pressure in the traffic mix from Table 4-2. As discussed previously, rigid pavements are typically able to handle high tire pressures, so code W can usually be assigned.

13. The evaluation method is technical, so the code T will be used as discussed in paragraph 4.5e.

14. The numerical value of the PCN is the same as the numerical value of the ACN of the critical airplane just calculated in Step 11.

15. If the allowable gross weight of Step 11 is equal to or greater than the critical airplane operational gross weight required for the desired pavement life, then the pavement is capable of handling the predicted traffic for the time period established in the traffic forecast. Accordingly, the assigned PCN determined in Step 12 is sufficient. If the allowable gross weight from Step 11 is less than the critical airplane gross weight required for the desired pavement life, then the pavement may be assigned a PCN equal to the ACN of the critical airplane at that gross weight, but with a reduced pavement life. Additionally, it may then be necessary to develop a relationship of allowable gross weight based on the assigned PCN versus pavement life. Appendix 3 provides procedures on how to relate pavement life and gross weight for rigid pavements in terms of PCN. Any overload should be treated in terms of ACN and equivalent critical airplane operations per individual operation. Allowance for the overload should be negotiated with the airport authority, since pre-approval cannot be assumed. Appendix 3 provides specific procedures on how to relate pavement life and gross weight for rigid pavements.

2.4 TECHNICAL EVALUATION EXAMPLES FOR RIGID PAVEMENTS. The following three examples help explain the technical evaluation method of determining a PCN for rigid pavements. The first example pavement is under-designed and the traffic volume has increased to such a level that pavement life is reduced from the original design. The second pavement has more than adequate strength to handle the forecasted traffic. The third example pavement is the same as number two, except that the airplanes generally do not obtain fuel at the airport.

a. Rigid Pavement Example 1. An airport has a rigid (concrete-surfaced) runway pavement with an effective subgrade k-value of 200 pci and a slab thickness of 14 inches, as shown in Figure A2-2. The concrete has a modulus of rupture of 700 psi, an elastic modulus of 4,000,000 psi, and a Poisson’s ratio of 0.15. The runway has a parallel taxiway, and additional fuel is generally obtained at the airport before departure. The pavement life is estimated to be 20 years from the original construction. The traffic shown in Table A2-5 is basically the same as in Table A2-1, but with P/C ratios and life-load repetitions added.

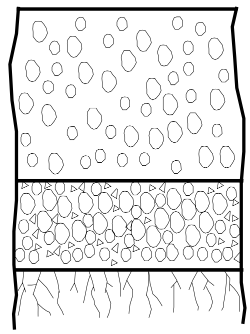

Figure A2-2. Rigid Pavement Example Cross-Section

The critical airplane will be the one with the highest required thickness for its load magnitude and frequency. The thickness required for each airplane is determined with the COMFAA program in the pavement design mode. The load repetitions must first be calculated for each airplane by using Equation A1-1 and then converted to coverages for use in the COMFAA program. Since additional fuel is generally obtained at the airport, and there is a parallel taxiway, so—

P/TC = 1
TC/C = P/C
Coverages (C) = annual departures * 20 years ÷ TC/C

The resulting coverages are listed for each airplane in Table A2-5. The thickness of rigid pavement required for each airplane at the operating weight and frequency are shown in Table A2-6.

Table A2-5. Rigid Pavement Technical Evaluation Traffic

Airplane	Operating Weight, lbs	Tire Pressure (psi)	ACN (R/C)	** P/C	Annual Departures	Coverages
B727-200	185,000	148	55	2.92	400	2,740
B737-300	130,000	195	38	3.79	6,000	31,662
A319-100	145,000	173	42	3.18	1,200	7,547
B747-400	820,000	200	68	3.46	3,000	17,341
B767-300ER	370,000	190	58	3.60	2,000	11,111
DC8-63	330,000	194	62	3.35	800	4,776
A300-B4	370,000	205	67	3.49	1,500	8,595
B777-200	600,000	215	77	4.25	300	1,412

** Rigid P/C determined at 95 percent of gross load on main gear

Table A2-6 shows that the critical airplane is the B747-400, based on its required thickness. However, the A300-B4 should also be given consideration as critical in that its required thickness is very close to that of the B747-400. In this example, the B777-200 is not the critical airplane, even though it has the highest ACN, because of the comparatively low number of coverages.

Table A2-6. Technical Evaluation Critical Airplane Determination

Airplane	Operating Weight, lb	Required Thickness (in.)
B727-200	185,000	13.0
B737-300	130,000	13.2
A319-100	145,000	11.1
B747-400	820,000	14.1
B767-300ER	370,000	12.8
DC8-63	330,000	12.5
A300-B4	370,000	13.6
B777-200	600,000	11.5

Table A2-7. Equivalent Annual Departures of the Critical Airplane

Airplane	Annual Departures	Gear Type	(R_2) Equiv. (2D) Departures	(W_2) Wheel Load	(W_1) B747-400 Wheel Load	(R_1) B747-400 Equiv.Ann. Departures
B727-200	400	D	256	43,938	48,688	194
B737-300	6,000	D	3,840	30,875	48,688	716
A319-100	1,200	D	768	34,438	48,688	268
B747-400	3,000	2D/2D2	3,000	48,688	48,688	3,000
B767-200ER	2,000	2D	2,000	43,938	48,688	1,368
DC8-63	800	2D	800	39,188	48,688	403
A300-B4	1,500	2D	1,500	43,938	48,688	1,041
B777-200	300	3D	468	47,500	48,688	434
	15,200					7,424

All departures of the other traffic must be converted to the B747-400 equivalent as shown in Table A2-7. Note that this table is identical to Table A2-4 for the flexible pavement examples.

Before the maximum allowable gross weight of the critical airplane can be determined from the COMFAA program, the anticipated traffic reported in annual departures must be converted to total coverages (lifetime coverages). As stated previously, since additional fuel is generally obtained at the airport, and there is a parallel taxiway, the following should be used:

P/TC = 1
P/C = 3.46
TC/C = 3.46

Coverages = 7,424 * 20 years ÷ 3.46 = 42,913

The input parameters to the COMFAA program (pavement design mode) are—

Critical airplane	B747-400
Coverages	42,913
Percent weight on the main gear	95.0 percent
Tire pressure	200 psi (code X) tire contact area 260.4 sq. in.
Slab thickness	14.0 inches
Slab flexural strength	700 psi
Effective subgrade k-value	200 pci (code C)

For these conditions, the COMFAA program can be used to iterate to a solution by adjusting the gross airplane weight until the known pavement thickness is obtained. For this example, the calculated allowable gross weight of the B747-400 is 762,000 pounds. By switching the COMFAA program back to the ACN mode and entering in the allowable gross weight, an ACN of 61.3/R/C is obtained for the B747-400. The final recommended runway rating is PCN 61/R/C/W/T. As mentioned in Paragraph 4.5d(i), even though none of the airplanes in this example have tire pressures that exceed the limits of code X, the code for rigid pavement should normally be W.

Based on the ACNs in Table A2-5, it can be seen that the B747-400, the DC8-63, the A300-B4, and the B777-200 airplane would be restricted in their operations on this runway due to their respective ACNs of 68/R/C, 62/R/C, 67/R/C and 77/R/C; all of which are higher than the derived PCN of 61/R/C. It is apparent the pavement is not adequate to accommodate the existing traffic, and either the operating weights will have to be restricted or pavement life will be less than originally expected. An analysis of this situation and the requirements for adjustments are discussed in Appendix 3.

b. Rigid Pavement Example 2. This second example has the same input parameters as the first, except the slab thickness is increased to 16 inches. The input parameters to the COMFAA program are—

Critical airplane	B747-400
Coverages	42,913
Percent weight on the main gear	95.0 percent
Tire pressure	200 psi (code *X*) tire contact area 260.4 sq. in.
Slab thickness	16.0 inches
Effective subgrade k-value	200 pci (code *C*)
Concrete flexural strength	700 psi

For these conditions, the calculated allowable gross weight of the B747-400 is 890,000 pounds. The B747-400 ACN is 76.2/R/C, for a recommended runway rating of PCN 76/R/C/W/T.

It can be seen from Table A2-5 that all of the traffic have ACNs that are less than the recommended PCN. It can therefore be safely assumed that the pavement will adequately accommodate the existing traffic within its design life, and no adjustments to the pavement cross-section or life will have to be made.

c. Rigid Pavement Example 3. The only change in this example from the second example is that the airplanes generally do not obtain fuel at the airport. Using Table A1-3, the P/TC ratio changes from 1 to 2. Using Equation A1-2, the TC/C ratio for the critical B747-400 airplane becomes—

$$TC/C = 3.46 \div 2 = 1.73$$

Where:

P/TC = 2
P/C = 3.46

Therefore, lifetime coverages = 7,424 * 20 years ÷ 1.73 = 85,827

The input parameters to the COMFAA program in pavement thickness mode are—

Critical airplane	B747-400
Coverages	85,827
Percent weight on the main gear	95.0 percent
Tire pressure	200 psi (code *X*) tire contact area 260.4 sq. in.
Slab thickness	16.0 inches
Subgrade k-value	200 (code *C*)
Concrete flexural strength	700 psi

For these conditions, the calculated allowable gross weight of the B747-400 is 851,000 pounds. The B747-400 ACN is 71.6/R/C, for a recommended runway rating of PCN 72/R/C/W/T. This rating would require small weight restrictions on the B777 airplane. However since additional fuel is not obtained, the landing weight is most likely already below the possible restriction.

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APPENDIX 3. PAVEMENT OVERLOAD EVALUATION BY THE ACN-PCN SYSTEM

1.0 ICAO PAVEMENT OVERLOAD EVALUATION GUIDANCE. In the life of a pavement, it is possible that either the current or the future traffic will load the pavement in such a manner that the assigned pavement rating is exceeded. ICAO provides a simplified method to account for minor pavement overloading in which the overloading may be adjusted by applying a fixed percentage to the existing PCN.

The ICAO procedure for overload operations is based on minor or limited traffic having ACNs that exceed the reported PCN. Loads that are larger than the defined PCN will shorten the pavement design life, while smaller loads will use up the life at a reduced rate. With the exception of massive overloading, pavements in their structural behavior do not suddenly or catastrophically fail. As a result, occasional minor airplane overloading is acceptable with only limited loss of pavement life expectancy and relatively small acceleration of pavement deterioration. For those operations in which the magnitude of overload and/or frequency does not justify a detailed (technical) analysis, the following criteria are suggested.

- For flexible pavements, occasional traffic cycles by airplanes with an ACN not exceeding 10 percent above the reported PCN should not adversely affect the pavement.
- For rigid or composite pavements, occasional traffic cycles by airplanes with an ACN not exceeding 5 percent above the reported PCN should not adversely affect the pavement.
- The annual number of overload traffic cycles should not exceed approximately 5 percent of the total annual airplane traffic cycles.
- Overloads should not normally be permitted on pavements exhibiting signs of distress, during periods of thaw following frost penetration, or when the strength of the pavement or its subgrade could be weakened by water.
- Where overload operations are conducted, the airport authority should review the relevant pavement condition on a regular basis and should also review the criteria for overload operations periodically, since excessive repetition of overloads can cause severe shortening of pavement life or require major rehabilitation of the pavement.

However, these criteria give little guidance to the airport authority as to the impact of these overload operations on the pavement in terms of pavement life reduction or increased maintenance requirements. This appendix discusses methods for making overload allowances for both flexible and rigid pavements that will clearly indicate these effects and will give the authority the ability to determine the impact both economically and in terms of pavement life.

1.1 OVERLOAD GUIDANCE. The overload evaluation guidance in this appendix applies primarily to flexible and rigid pavements that have PCN values that were established by the technical method. Pavements that have ratings determined by the using airplane method can use the overload guidelines provided by ICAO. The procedures presented here rely on the COMFAA program.

The adjustments for pavement overloads start with the assumption that some of the airplanes in the traffic mix have ACNs that exceed the PCN. If the steps outlined in Appendix 2 have been followed for the technical method, then most of the necessary data already exists to perform an examination of overloading.

For flexible pavement, it was found in the first example of Appendix 2 that the B747-400 and A300-B4 airplanes have ACNs that exceed the recommended runway rating. Likewise, for the first rigid pavement example, the ACNs of the B747-400, A300B4, DC8-63, and B777-200 exceed the recommended runway rating. Individually, none of the airplanes in the traffic mix have requirements that exceed the existing pavement thickness requirements. However, even though each of these airplanes were included in the derivation of the allowable gross weight of the critical airplane, the recommended PCN is not adequate for the larger airplanes. To resolve these kinds of problems the airport authority has three options when making a pavement strength rating selection:

1. Let the PCN remain as derived from the technical evaluation method, but retain local knowledge that there are some airplanes in the traffic mix that can be allowed to operate with ACNs that exceed the published PCN or at a reduced weight to not exceed the PCN.

2. Provide for an increased PCN by either adding an overlay or by reconstructing to accommodate airplanes with the higher ACNs.

3. Adjust the PCN upward to that of the airplane with the highest ACN, but recognize the need to expect possible severe maintenance. This will result in earlier than planned reconstruction or overlay due to reduced pavement life.

The first option requires that the airport authority be constantly aware of the composition of the entire traffic mix in terms of operating gross weights and loading frequency. If the traffic mix has changes that affect the factors involved in developing a technically based PCN, then the PCN will need to be adjusted to reflect the changes. The airport authority will also have to internally make allowance for or prevent airplane operations that exceed the PCN. The difficulty in doing this is that the magnitude of the PCN is out of step with the ACNs of some of the traffic.

The second option alleviates the problems discussed for the first option, but it does require additional expense to bring the pavement up to the strength required by the combination of airplanes in the traffic mix. However, providing the pavement strengthening will allow operations at the required strength and for the desired pavement life.

The third option has the benefit of allowing all airplanes in the traffic mix to operate as necessary. However, by increasing the PCN, which implies higher pavement strength, the pavement life will be reduced unless an increase in thickness is provided.

Each of these options is considered in the following discussion on pavement overloading—first for flexible pavement and then for rigid pavement.

1.2 ADJUSTMENTS FOR FLEXIBLE PAVEMENT OVERLOADS. It is most efficient to describe the procedures for flexible pavement overloading by referencing flexible pavement technical evaluation example 1 in Appendix 2 (Paragraph 2.2a). In this example, two airplanes of the traffic mix were found to exceed the pavement capability. The derived rating was found to be PCN 56/F/B/X/T, with the traffic of Table A2-3 operating on the runway.

a. Flexible Pavement Overload Illustration 1. Table A2-3 indicates that the B747-400 was operating at a gross weight of 820,000 pounds, with an ACN of 59/F/B. Likewise, the A300-B4 had a gross weight of 370,000 pounds and an ACN of 57/F/B. Reduction of the gross weights to the rated PCN of 56/F/B/X/T would result in a gross weight for the B747-400 of 797,500 pounds and a gross weight of 366,500 pounds for the A300-B4. Although these limited operating weights would solve the problem of pavement loading, they have the disadvantage of restricting airline operations. Additionally, new traffic with airplanes having ACNs exceeding the PCN would also have to be restricted.

b. Flexible Pavement Overload Illustration 2. Rather than restricting operating weights, the airport could refurbish the pavement by adding an overlay. The computer steps for determining such a flexible pavement overlay are as follows:

- Construct an ACN versus gross weight diagram, such as that shown in Figure A3-1, for the B747-400 critical airplane at the subgrade code previously determined. Data for this chart may be obtained from the COMFAA program by calculating ACN at various gross weights. Note in this figure that the relationship of ACN and gross weight is not a straight line, but is slightly curved because the line was derived by calculating the ACN at a series of gross weights, rather than just connecting the minimum and maximum values.

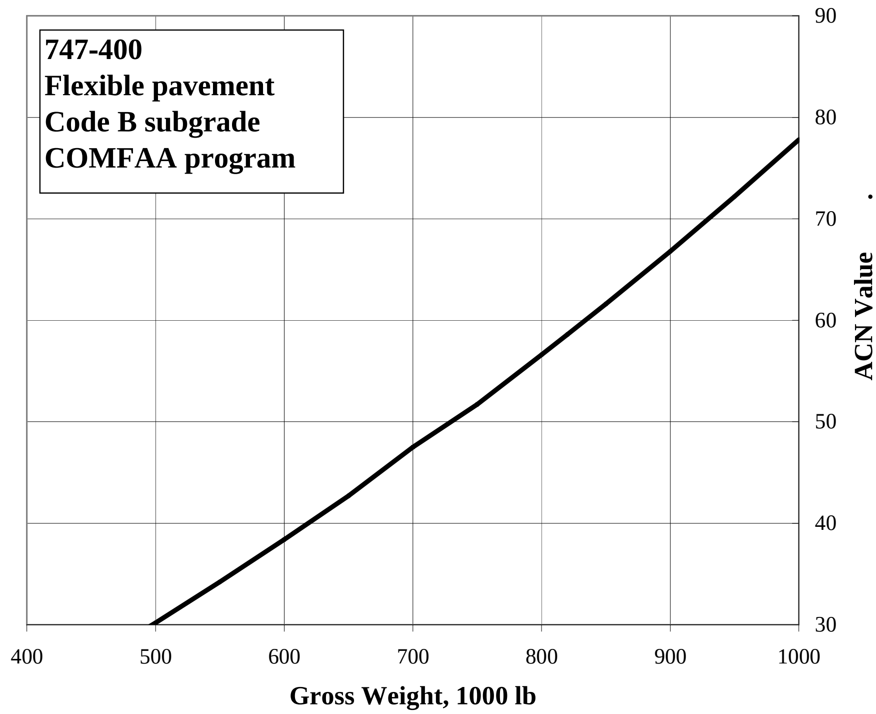

Figure A3-1. B747-400 Flexible Pavement ACN Versus Gross Weight

- Use the COMFAA program to develop data of pavement life versus ACN, such as shown in Figure A3-2. This chart is similar to that found in Section 7 of the manufacturer's ACAP manuals, except that subgrade CBR and pavement thickness are not shown because they are already fixed. For example, there are four basic parameters involved in pavement design:

  - Subgrade CBR
  - Pavement thickness
  - Airplane gross weight
  - Traffic volume and pavement life

Of these four, the only variables are gross weight and pavement life in terms of annual traffic cycles. By relating gross weight to ACN (as was done in Figure A3-1), ACN can be substituted on the abscissa of Figure A3-2. For each pavement life number, a gross weight is found that satisfies the subgrade CBR and pavement thickness, which is then converted to ACN. Table A3-1 contains part of the data used in the COMFAA program to construct the curves of Figure A3-2 for a B747-400 airplane with a subgrade CBR of 9.0.

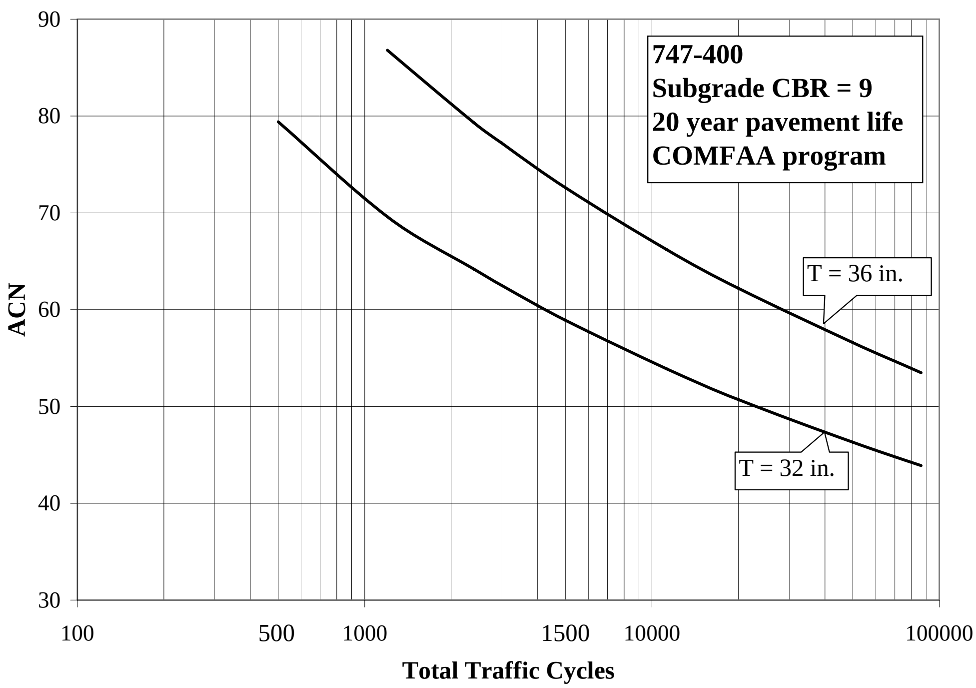

Figure A3-2. B747-400 Flexible Pavement Life Versus ACN

Table A3-1. Data for Constructing Flexible Pavement Life Curves for B747-400

B747-400 Annual Departures	Coverages at (P/C = 1.73)	T=32 Gross Weight	T=32 ACN	T-36 Gross Weight	T=36 ACN
500	5,780	1,014,000	79.4	--	--
1,200	13,873	926,000	69.6	1,075,000	86.8
2,400	27,746	875,000	64.2	1,013,000	79.3
3,000	34,682	858,000	62.5	994,500	77.2
5,000	57,803	822,500	58.9	953,400	72.6
7,424	85,827	797,500	56.4	923,000	69.3
20,000	231,214	738,500	50.7	855,000	62.2
50,000	578,035	690,400	46.3	800,000	56.6
86,500	1,000,000	664,000	43.9	768,000	53.5

Note: Pass-to-coverage ratio determined for airplane configurations reported by airplane manufacturers when calculating ACN value (gross load, center of gravity, tire pressure).

It is now possible to relate the effects of gross weight, ACN, and pavement life by combining the two charts, as shown in Figure A3-3. The left-hand side of this figure is the chart of Figure A3-1, while the right-hand chart is that of Figure A3-2. It can now be seen how the critical airplane gross weight of 797,500 pounds (PCN 56/F/B/X/T) equates to 7,424 equivalent B747-400 traffic cycles per year for 20 years. If the PCN were increased to 69/F/B/X/T to accommodate the higher gross weights, the allowable traffic cycles of the critical airplane at 923,000 pounds gross weight would decrease to 1,254 per year for the 20-year time period. This effectively reduces the pavement life from 20 years to just over 3 years (1,254 x 20 ÷ 7,424 = 3.38).

This example shows that a pavement with a thickness of 32 inches is under-designed for the traffic expected over the next 20 years. It is therefore reasonable to expect that an overlay to bring the effective thickness to 36 inches will be required if the pavement is to last for the required 7,424 annual departures for 20 years. This can be seen graphically in Figure A3-3. Figure A3-3 also shows that for any combination of critical airplane gross weight in terms of ACN, the pavement life is known. Thus, the airport authority can determine from this type of chart the allowances to be made for traffic overloading. The airport authority also now has the information necessary to make a decision on the assignment of a PCN. If the PCN is raised to a level to permit all current traffic, the required pavement overlay can be determined. Furthermore, the impact of the higher ACN airplane can be determined in the requirements for overlay thickness. It may be necessary to repeat this process if new airplanes are added to the traffic mix since their effects are not accounted for in the above calculations. Likewise, if there are any other significant changes in the traffic mix, the rating should be reviewed.

This example is only intended to illustrate the effect of pavement thickness on the PCN rating. Overlay thickness requirements for pavement design purposes should be determined using AC 150/5320-6.

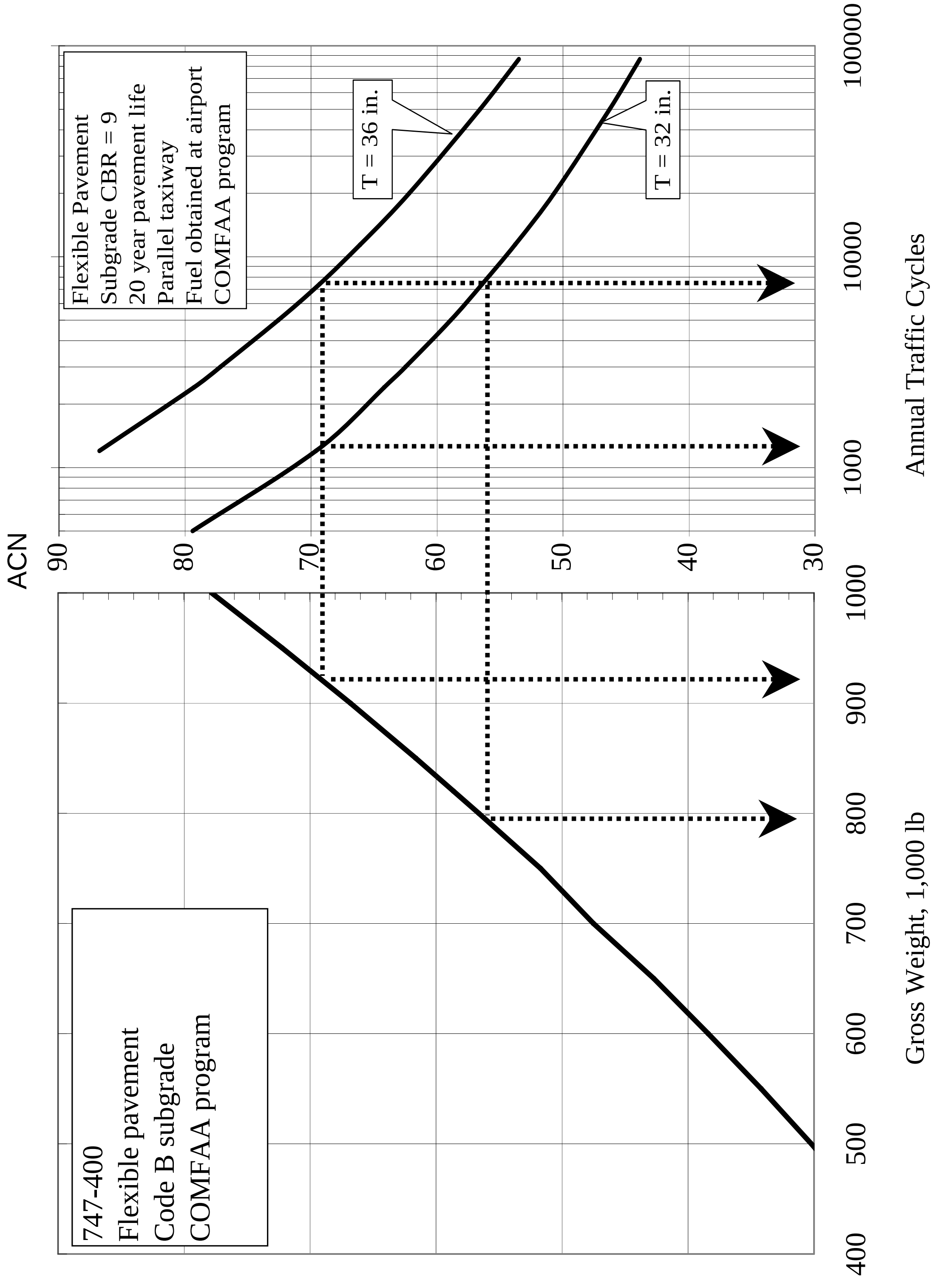

Figure A3-3. B747-400 Flexible Pavement Life

c. Flexible Pavement Overload Illustration 3. This example will illustrate the effect of ICAO allowable overloading in which the ACN is no more than 10 percent above the PCN and the number of traffic cycles does not exceed 5 percent of the total annual traffic.

Table A2-3 is repeated here as Table A3-2, but with a new airplane added to the traffic mix with an ACN that is 10 percent above the rated PCN of 56/F/B/X/T. The total annual departures, as shown in Table A2-4, is 15,200, of which 760 is 5 percent of the total. This amount is shown in Table A3-3.

Table A3-2. Flexible Pavement Overload Airplane Added

Airplane	Operating Weight, (lbs)	Tire Pressure (psi)	ACN F/B	Annual Departures	Flexible **P/C	Required t, (in.)
B727-200	185,000	148	48	400	2.92	22.6
B737-300	130,000	195	35	6,000	3.79	22.7
A319-100	145,000	196	35	1,200	3.18	20.3
B747-400	820,000	200	59	3,000	1.73	30.9
B767-300ER	370,000	190	52	2,000	1.80	27.9
DC8-63	330,000	194	52	800	1.68	26.6
A300-B4	370,000	205	57	1,500	1.75	29.3
B777-200	600,000	215	51	300	1.42	28.0
L1011-500	463,000	184	62	760	1.80	28.6

** Flexible P/C determined at 95 percent of gross load on main gear

The end result on the critical airplane calculation is that for an equivalent annual departure level of 7,934, the allowable gross weight is reduced from 797,500 to 793,500 pounds for an ACN of 56.0/F/B. Alternately, for the same allowable gross weight of 797,500 pounds and an ACN of 56.4/F/B, the pavement thickness would have to be increased to 32.13 inches from the current 32.0 inches.

This example shows the impact both on required pavement thickness and on PCN of a new airplane that is within the ICAO guidelines of no more than 10 percent overload and no more than 5 percent traffic increase. Knowing the impact of new airplanes on pavement thickness requirements, the airport authority can make a decision as to the relative effects.

Although these examples were for specific conditions as described, the methods can also be applied to any other traffic overloading condition.

Table A3-3. Flexible Pavement New Airplane Equivalent Traffic

Airplane	Annual Departures	Gear Type	(R_2) Equiv. (2D) Departures	(W_2) Wheel Load (lbs)	(W_1) B747-400 Wheel Load (lbs)	(R_1) B747-400 Equiv. Ann. Departures
B727-200	400	D	256	43,938	48,688	194
B737-300	6,000	D	3,840	30,875	48,688	716
A319-100	1,200	D	768	34,438	48,688	268
B747-400	3,000	2D/2D2	3,000	48,688	48,688	3,000
B767-300ER	2,000	2D	2,000	43,938	48,688	1,368
DC8-63	800	2D	800	39,188	48,688	403
A300-B4	1,500	2D	1,500	43,938	48,688	1,041
B777-200	300	3D	468	47,500	48,688	434
L1011-500	760	2D	760	54,981	48,688	510
	15,960					7,934

1.3 ADJUSTMENTS FOR RIGID PAVEMENT OVERLOADS. As was done for the flexible pavement overload illustration, the procedures for rigid pavement overloading can best be explained by continuing the first rigid pavement technical evaluation example in Appendix 2 (Paragraph 2.4a). In this example, for which the derived PCN was 61/R/C/W/T, the B747-400, A300-B4, B777-200, and DC863 were found to exceed the pavement capability, as shown in Table A2-5. This requires that adjustments be made to allow these airplanes to operate at their desired gross weight. These adjustments take the form of either a reduced pavement life or an overlay to increase the pavement strength.

A second overload illustration examines the effect of occasional traffic of airplanes with ACNs that exceeds the PCN.

a. Rigid Overload Illustration 1. Evaluation of rigid pavement overload is similar to that of flexible pavement. It is necessary to develop the pavement life variables first and then examine the results with the COMFAA program. The necessary steps for determining rigid pavement overloading effects are—

1. Construct an ACN versus gross weight diagram such as that shown in Figure A3-4, for the B747-400 critical airplane at the subgrade code previously determined. Note that the line relating ACN and gross weight is not straight because it was constructed using a selection of many points rather than just connecting the minimum and maximum values. Figure A3-4 can be generated in the COMFAA program by calculating ACN values at various gross weights.

2. Construct an ACN versus pavement life chart, as shown in Figure A3-5. Data for Figure A3-5 can be generated by the COMFAA program by first entering the load repetitions (coverages) in the pavement thickness mode and adjusting the gross

weight until the desired thickness is achieved. Then switch, to the ACN mode, and enter the allowable gross weight to obtain the ACN value. It is possible to develop a chart such as Figure A3-5 because the parameters of subgrade modulus and the pavement thickness are already known. This reduces the variables to the relationship of pavement life and allowable gross weight. By relating ACN to gross weight, as in Figure A3-4, ACN can be used in place of gross weight on the ordinate of the Figure A3-5 chart. Each of these steps will be illustrated by using data from the first rigid pavement example in Appendix 2.

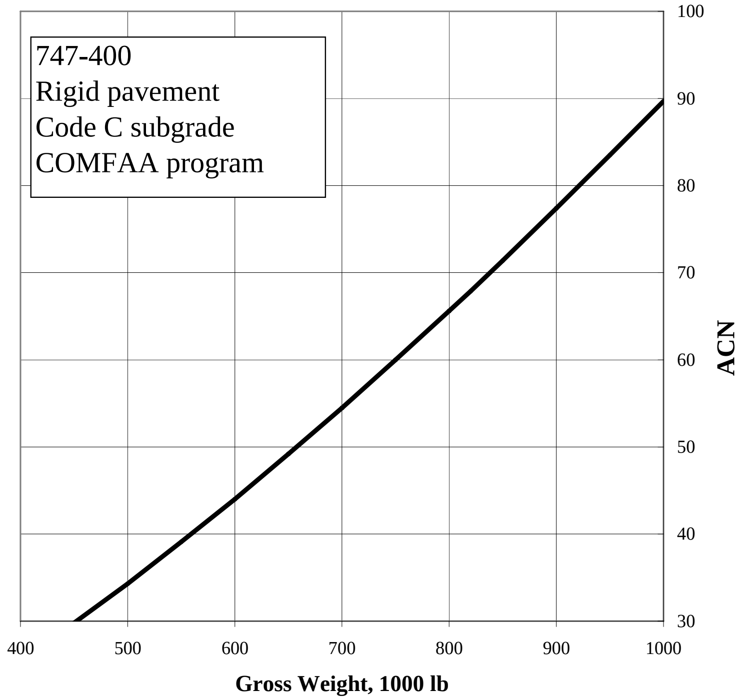

Figure A3-4. B747-400 Rigid Pavement ACN Versus Gross Weight

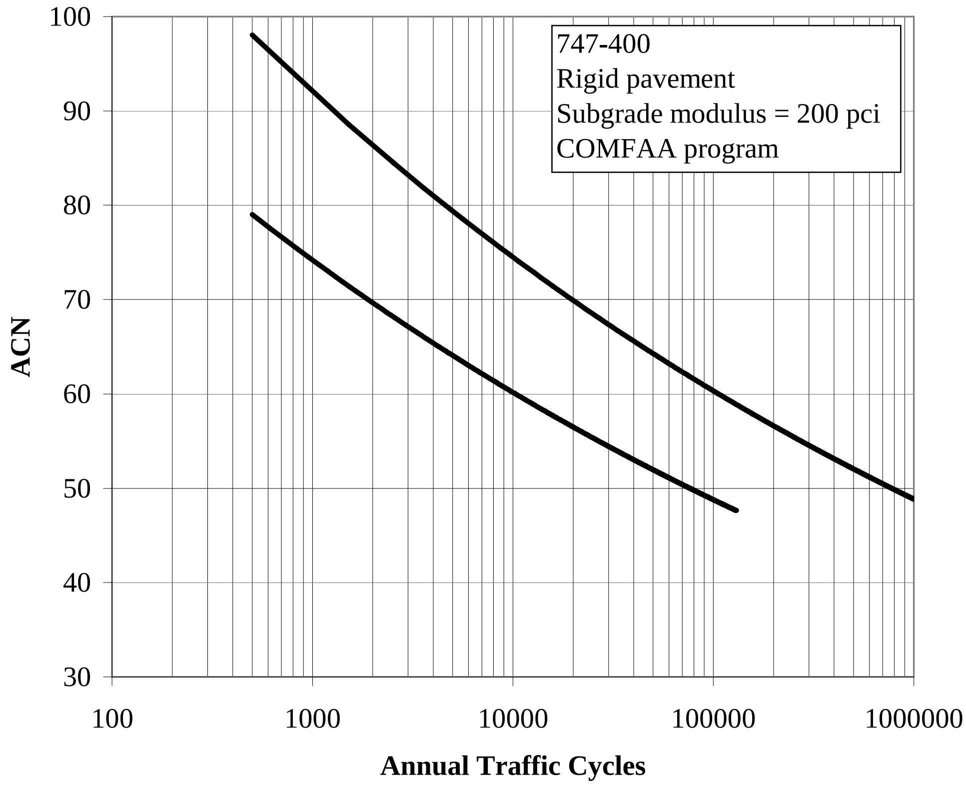

Figure A3-5. B747-400 Rigid Pavement Life Versus ACN

Table A3-4. Data for Constructing Rigid Pavement Life Curves for B747-400

Annual Traffic Cycles	Load Repetitions (coverages) (P/C = 3.46)	T=14 gross weight (lbs)	T=14 ACN	T-16 gross weight (lbs)	T=16 ACN
500	2,890	910,000	78.6	1,063,000	97.7
1,200	6,936	871,000	73.9	1,015,000	91.6
2,400	13,873	827,100	68.8	962,000	85.0
3,000	17,341	813,500	67.2	947,000	83.1
5,000	28,902	783,900	63.8	913,500	79.0
7,424	42,913	762,000	61.3	890,000	76.2
20,000	115,607	714,500	56.1	835,000	69.7
50,000	289,017	675,000	51.8	786,250	64.1
86,500	500,000	654,000	49.6	760,000	61.1
129,750	750,000	638,500	48.0	742,000	59.1

3. It is now possible to relate the effects of gross weight, ACN, and pavement life by combining these two charts, as shown in Figure A3-6. The left hand side of this figure is the chart of Figure A3-4, while the right had chart is that of Figure A3-5. It can now be seen that the rating of PCN 61/R/C/W/T on a 14-inch pavement equates to 7,424 traffic cycles per year of a B747-400 at 762,000 pounds.

4. The line for a thickness of 16 inches in Figures A3-5 and A3-6 shows how pavement life is increased by the addition of two inches of concrete. This line is included, not to imply that an overlay of two inches is recommended, but to show the effect of increased thickness. It can be seen that the 16-inch pavement will accommodate a B747-400 with a gross weight of 890,000 pounds. Alternately, at a gross weight of 762,000 pounds, the B747-400 can be accommodated on the thicker pavement to about 85,000 annual traffic cycles. Not shown directly in Figure A3-6 is that a 15-inch pavement (one additional inch) will accommodate 25,000 annual traffic cycles of a B747-400 at 762,000 pounds.

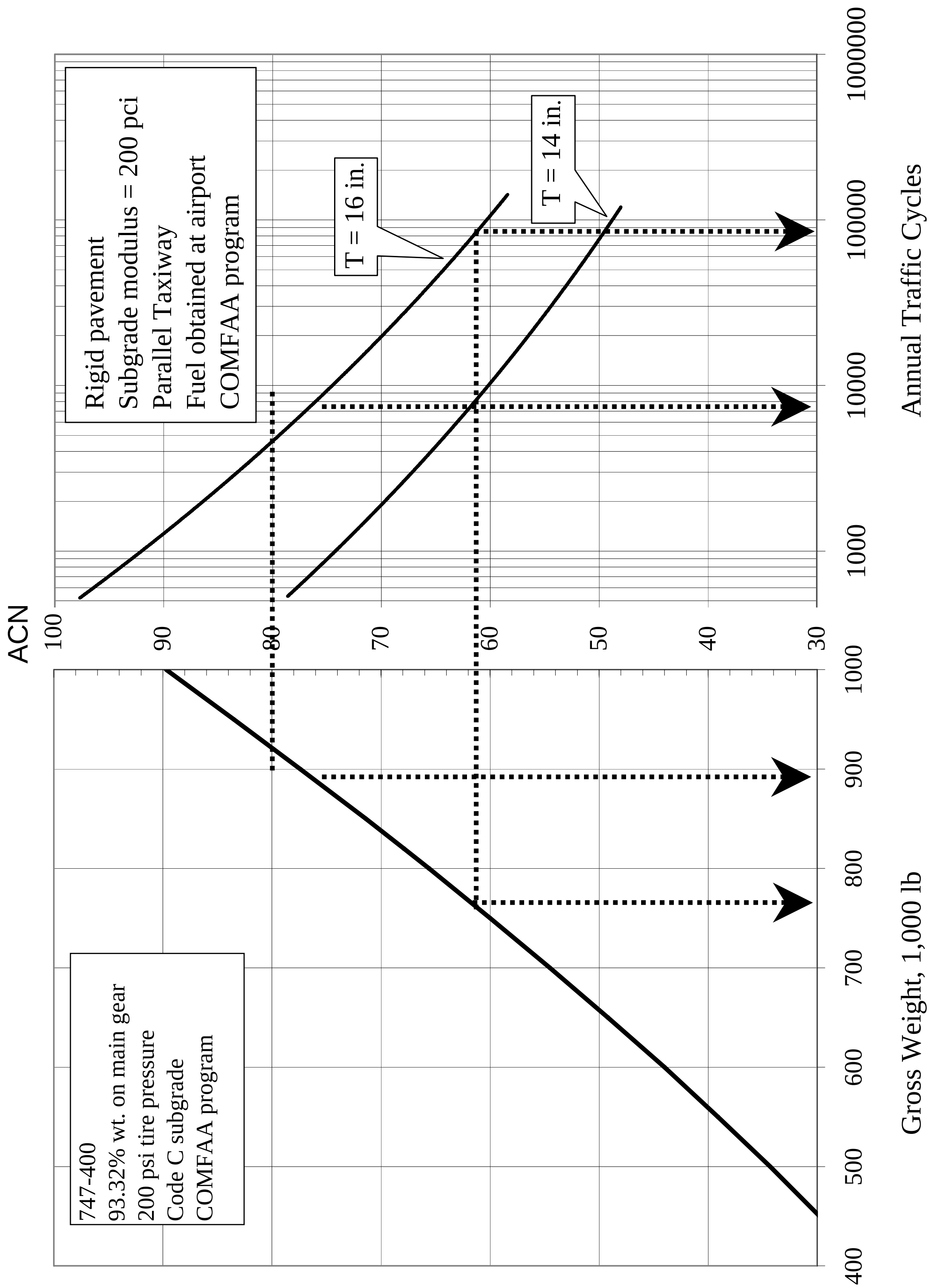

Figure A3-6. B747-400 Rigid Pavement Life

b. Rigid Pavement Overload Illustration 2. This example illustrates the effect of ICAO allowable overloading in which the ACN is no more than 5 percent above the PCN and the number of traffic cycles does not exceed 5 percent of the total annual traffic.

Table A2-5 is repeated here as Table A3-5, but with a new airplane added to the traffic mix. The ACN of the new airplane is 5 percent above the rated PCN of 61/R/C/W/T. The 760 annual departures of the new airplane represents 5 percent of the 15,200 total annual departures, as shown in Table A2-4.

Table A3-5. Rigid Pavement Overload Example with New Airplane

Airplane	Operating Weight, lbs	Tire Pressure (psi)	ACN (R/C)	** P/C	Annual Departures	Load Repetitions
B727-200	185,000	148	55	2.92	400	2,740
B737-300	130,000	195	38	3.79	6,000	31,662
A319-100	145,000	173	42	3.18	1,200	7,547
B747-400	820,000	200	68	3.46	3,000	17,341
B767-300ER	370,000	190	58	3.60	2,000	11,111
DC8-63	330,000	194	62	3.35	800	4,776
A300-B4	370,000	205	67	3.49	1,500	8,596
B777-200	600,000	215	77	4.25	300	1,412
A300-600R	362,250	231	64	3.39	760	4,484

** Rigid P/C determined at 95 percent of gross load on main gear and at manufacturer's recommended operating characteristics for ACN calculation

It is next necessary to determine the new total departures of the critical B747-400 airplane. To do so, Table A2-7 is shown here as Table A3-6 with the new A300-600R airplane included. As seen from this table, the number of B747-400 equivalent annual departures has increased to 7,934 from 7,424. The new equivalent departures are 7,934, which convert to 45,861 lifetime load repetitions (7,934 * 20 ÷3.46 = 45,861). From the COMFAA program, the new allowable B747-400 gross weight is calculated to be 758,000 pounds and the ACN at this weight is 60.9/R/C.

Table A3-6 Equivalent Annual Departures of the Critical Airplane

Airplane	Annual Departures	Gear Type	(R_2) Equiv. (2D) Departures	(W_2) Wheel Load	(W_1) B747-400 Wheel Load	(R_1) B747-400 Equiv.Ann. Departures
727-200	400	D	256	43,938	48,688	194
737-300	6,000	D	3,840	30,875	48,688	716
A319-100	1,200	D	768	34,438	48,688	268
B747-400	3,000	2D/2D2	3,000	48,688	48,688	3,000
B767-200ER	2,000	2D	2,000	43,938	48,688	1,368
DC8-63	800	2D	800	39,188	48,688	403
A300-B4	1,500	2D	1,500	43,938	48,688	1,041
B777-200	300	3D	468	47,500	48,688	434
A300-600R	760	2D	760	42,988	48,688	510
	15,960					7,934

The new recommended PCN would then be 61/R/C/W/T. Note this new PCN is the same as the existing PCN due to rounding. Alternatively, the effect on pavement thickness can be seen by keeping the critical airplane gross weight the same at 762,000 pounds. The resulting required concrete slab thickness is 14.04 inches, which is a 0.04-inch increase which not practical to measure or attempt to construct.

APPENDIX 4. RELATED READING MATERIAL

The following publications were used in the development of this AC:

a. AC 150/5320-6, Airport Pavement Design and Evaluation. This publication is available free of charge from the Department of Transportation, Section, M-442.32, Washington, DC, 20590.

c. ICAO Bulletin, Official Magazine of International Civil Aviation, Airport Technology, Volume 35, No. 1, Montreal, Quebec, Canada H3A 2R2, January l980.