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TITLE **PRECISE METHODS FOR ESTIMATING PAVEMENT CLASSIFICATION NUMBER**

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# Abstract

This document presents methods that can be used by an airport authority to determine Pavement Classification Numbers for both flexible and rigid pavements. The techniques that are recommended are based on the ICAO ACN/PCN method as published in Annex 14. This includes simplified procedures based on using aircraft, as well as a more complex technical analysis that embody pavement characteristics and the traffic mix. The comprehensive methods described in this document are presented in a step-by-step approach, and many examples are included to help explain the processes. Discussion of aircraft loading in excess of the published PCN is based on an extension of the basic ICAO ACN/PCN method of pavement overloading. These procedures will allow the airport authority to assess the impact of individual aircraft overloads, as well as continuous overloading by a fleet of aircraft. Methods are presented that can be used to convert common rating systems such as FAA, LCN, and LCG to a PCN. A complete description of the ACN/PCN procedure as presented in the ICAO Annex 14 is provided.

## Acknowledgments

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## Key Words

Aircraft Classification Number (ACN)
Pavement Classification Number (PCN)
flexible pavement
rigid pavement
asphalt
concrete
International Civil Aviation Organization (ICAO)
pavement overloads
pavement analysis
pavement rating
technical analysis
using aircraft analysis

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# References


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# 1. Introduction

The ACN/PCN system of rating airport pavements is designated by the International Civil Aviation Organization (ICAO) as the only approved method for reporting strength. Although there is a great amount of material published on how an ACN is computed (References 1 and 2), ICAO has not specified regulatory guidance as to how an airport authority is to arrive at a PCN, but has left it up to the authority as to how to perform this task. This is a result of member states reluctance to agree on an international standardized method of pavement evaluation, but rather to rely on their own internally developed procedures. Acceptance of the ACN/PCN method itself resulted only from the omission of a uniform evaluation standard in that many states felt that their method was superior, and a change to another method would be costly in terms of study, research, development, field training, staff familiarity, and all other attendant concerns.

As a consequence, it has been discovered through our work and correspondence with airport authorities, engineering consultants, and airlines that there is a great amount of uncertainty among many states that do not have well-established evaluation methodology as to exactly how to arrive at a PCN and still be within the boundaries of whatever ICAO guidelines might exist. Most organizations attempt to follow regulatory guidelines in their operations, but without a specific guidance procedure this uncertainty has developed. Additionally, without published ICAO standard recommendations on this subject, the determination of PCN has most certainly been anywhere from inconsistent to erroneous.

The principal objective of this document is to explain the rating process by suggesting straightforward, standardized methods for determining PCN for those airport authorities that have not yet developed their own. It is recognized that others already have appropriate evaluation procedures in place, and the methods proposed herein can be treated as supplementary information.

In the most fundamental terms, the determination of a rating in terms of PCN is a process of deciding on the maximum allowable gross weight of a selected critical airplane for a pavement, and knowing its ACN at that weight, reporting it as PCN. This process can be as simple as knowing the operational gross weight of each aircraft that is currently using the pavement and looking up its ACN (referred to as the *Using* aircraft method). This method can be applied with limited knowledge of the existing traffic and pavement characteristics. The second method is more complex and is referred to as *Technical* evaluation. In order to be successfully implemented, *Technical* evaluation requires an intimate knowledge of the pavement and its traffic, as well as a basic understanding of engineering methods that are utilized in pavement design. In either of these cases, accuracy is improved with greater knowledge of the pavement and traffic characteristics.

The purpose of an airfield *pavement* is to provide a surface on which aircraft takeoffs, landings, and other operations may be safely conducted. The purpose of a *pavement rating* is to allow for adequate pavement utilization at a reasonable cost, with the optimization of pavement economics that vary with local operational conditions. For example, a heavily used runway should have greater strength, and a correspondingly greater rating, than a lightly used runway, even though they both may have been designed to be served by the same aircraft. Although the PCN does not indicate anything about actual traffic and pavement characteristics, these components are necessary in order to determine the allowable gross weight for a critical airplane, which is then turned into a relative rating called PCN.

There are no precise pavement strength requirements for a given airplane or fleet of airplanes, even though the various design systems in use today can be very accurate in their computational abilities. Pavement structural capability is best determined through a combination of on-site inspection, load-bearing tests, and engineering judgment. Each of these is of importance, and it is for this reason that pavement ratings should not be viewed in precise terms, but rather as nominal estimations of a representative value. The end result of a valid rating process is that an assignment of PCN is enabled which considers the effects of all significant traffic on the pavement.

The strength rating of airport pavements is commonly thought of in terms of conventional structural concepts in which limiting loads are determined based on ultimate strength or failure criteria. However, pavements do not generally experience a loss in serviceability from instantaneous structural failure, but rather from an increase in roughness or deterioration resulting from the accumulated effects of traffic. Structural failure is most often recognized in terms of common pavement distresses such as rutting, cracking, and noticeably intolerable roughness that both pilots and passengers experience. Analysis of the adequacy of a pavement for the intended service, therefore, requires that a pavement rating be assigned that not only considers the significance of load magnitude, but the effects of the traffic volume over the intended life of the pavement.

It is important that the PCN rating process not be related to the pavement design process. Pavement design cannot be determined from a PCN rating in that the PCN is a relative rating of pavement strength in terms of ACN. The PCN does not indicate anything about traffic volume, design loads, or pavement thickness, which are major components in pavement design. Flexible pavement ACN is no more than the weight of a standard single wheel at a standard tire pressure that has the same thickness requirements as the airplane in question at an arbitrary 10,000 coverages. Rigid pavement ACN is likewise the weight of a standard single wheel load that has the same thickness requirements as the airplane in question at an arbitrary 400 psi concrete working stress. (The values of 10,000 coverages and 400 psi working stress were chosen in the ACN/PCN development process as representative values of typical airfield pavements). The ACN is therefore a relative number based on chosen pavement design parameters, and the PCN is the ACN of the critical airplane. It is for these reasons that conversions of other rating methods to PCN, such as LCN, cannot be developed based on simplified formulas.

The steps outlined in this document can be used by a pavement engineer to determine the rating of a runway pavement in terms of PCN. These steps can also be utilized for taxiways, but evaluation of parking aprons is somewhat more difficult due to the lack of detailed traffic pattern information. Both rigid (concrete) and flexible (asphalt) runway types are included. Additionally, methods that go beyond the simplified methods presented in Reference 1 are given that will allow the assignment of a PCN in overload conditions where the pavement is not strong enough to handle current or future traffic.

# 2. The ICAO ACN/PCN Method

## 2.1 Description

ICAO requires that the bearing strength of pavements for aircraft with mass greater than 12,500 lb (5,700 kg) be made available using the Aircraft Classification Number - Pavement Classification Number (ACN/PCN) method by reporting all of the following information (Reference 1):

- Pavement Classification Number (PCN)
- Pavement type
- Subgrade strength category
- Maximum allowable tire pressure category or maximum allowable tire pressure value
- Evaluation method

If desired, PCNs may be published to an accuracy of 1/10th of a whole number; however, as discussed in the introduction of this document, the wisdom of relying on absolute pavement ratings even to a whole number is questionable in that much judgment is required in obtaining a rating due to the many variables involved.

The PCN reported indicates that any aircraft with an ACN number less than or equal to the reported PCN can operate on the pavement, subject to any limitation of the tire pressure or all-up mass for specified aircraft types.

The ACN of an aircraft is determined in accordance with the standard procedures associated with the ICAO ACN/PCN method. These standard procedures are given in the Aerodrome Design Manual, Part 3 (Reference 2). For convenience, this manual lists the ACNs of many aircraft currently in use for both rigid and flexible pavement types.

Table 2-1 lists the pavement type for the purposes of determining the ACN. For the purposes of this rating, pavements are classified as having either a flexible or rigid construction. If the pavement is of composite construction, the rating should be the type that most accurately reflects the structural behavior of the pavements - either rigid or flexible. It is permissible to add a note stating that the pavement is composite, but in application only the rating type (*R* or *F*) is utilized in the assessment of the pavement capability. Pavements having gravel, compacted earth, laterite, coral, etc. surfaces are classified as flexible for reporting, and therefore should be rated with a PCN having a pavement type code *F*. Military landing mat and membrane surfaced fields should also be classified as flexible for reporting. (See special notes regarding unsurfaced pavements in Section 6 of this report).

**Table 2-1. Pavement Type Codes**

| Pavement Type | Code |
|---|---|
| Rigid | R |
| Flexible | F |

Subgrade code categories for flexible pavements are shown in Table 2-2, and subgrade code categories for rigid pavements are shown in Table 2-3. The letter categories for each pavement type are the same, and while not necessarily identical, the subgrade strength is nominally the same or similar. The determination of subgrade strength is conducted in a different manner and with different equipment in field-testing for each pavement type. It can be seen in a comparison of the tables that the manner of strength characterization is completely different, including the units. A CBR number represents a ratio to a standard material, while the k-value represents a pressure per vertical inch of deflection of a loaded standard plate.

**Table 2-2. Flexible Pavement Subgrade Codes and Strength Categories**

| Category | Code | Characterization | Subgrade CBR Range |
|---|---|---|---|
| High | A | CBR 15 | Above 13 |
| Medium | B | CBR 10 | From above 8 to 13 |
| Low | C | CBR 6 | From 4 to 8 |
| Ultra Low | D | CBR 3 | Below 4 |

**Table 2-3. Rigid Pavement Subgrade Codes and Strength Categories**

| Category | Code | Characterization | Subgrade k-value Range |
|---|---|---|---|
| High | A | k = 150 MN/m$^3$ (553 pci) | Above 120 MN/m$^3$ (442 pci) |
| Medium | B | k = 80 MF/m$^3$ (295 pci) | From 60 to 120 MN/m$^3$ (221 to 442 pci) |
| Low | C | k = 40 MN/m$^3$ (147 pci) | From 25 to 60 MN/m$^3$ (92 to 220 pci) |
| Ultra Low | D | k = 20 MN/m$^3$ (74 pci) | Below 25 MN/m$^3$ (92 pci) |

Table 2-4 lists the maximum allowable tire pressures categories. They have the same ranges for both pavement types in that these categories represent an airplane characterization, rather than pavement. However, in application, the allowable tire pressures differ substantially for asphalt and concrete pavements.

**Table 2-4. Maximum Tire Pressure Codes and Categories**

| Category | Code | Tire Pressure Range |
|---|---|---|
| High | W | No pressure limit |
| Medium | X | Pressure limited to 1.50 Mpa (218 psi) |
| Low | Y | Pressure limited to 1.00 Mpa (145 psi) |
| Very Low | Z | Pressure limited to 0.50 Mpa (73 psi) |

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. The principal concern in resisting tire pressure effects is with stability or shear resistance of lower quality mixes. A very good mix can withstand substantial tire pressure in excess of 218 psi, while casual or poor mixes will show distress under tire pressures of 100 psi or less. Although these effects are independent of the asphalt layer thickness, pavements with well-placed asphalt of 4 to 5 inches in thickness can generally be rated with Code *X* or *W*, while thinner pavements of poorer quality asphalt should not be rated above Code *Y*. Concrete pavements are inherently strong enough to resist much higher tire pressures that are currently in use, and except for marginally thin pavements, can usually be rated as Code *W*.

Exceptions to the tire pressure categories are published by other airport authorities, such as in Australia. Rather than using the broadly based codes of Table 2-4, the actual maximum tire pressure is shown in the PCN.

The reporting of PCN by either the *Using* aircraft experience or *Technical* evaluation method is shown in Table 2-5. As stated in the table, a *U* code indicates that the pavement is being rated primarily on the traffic that is operating at the airport. In this case, small attention is paid to the structural strength of the pavement, except as to a precursory view of the surface condition. PCNs containing a *T* code have typically been derived with an engineering analysis of the pavement as it relates to the operating traffic.

**Table 2-5. Evaluation Method Categories and Codes**

| Category | Code |
| --- | --- |
| *Technical* evaluation, representing a specific study of the pavement characteristics and application of pavement behavior technology. | T |
| *Using* aircraft experience, representing a knowledge of the specific type and mass of aircraft that are satisfactorily being supported under regular use. | U |

## 2.2 Overload Operations

ICAO presents a method of reporting pavement strength for overload operations in Reference 1, which 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 aircraft 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 aircraft 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 aircraft 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 aircraft traffic cycles.
- Overloads should not normally be permitted on pavements exhibiting signs of distress or failure, during any 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.

ICAO has published descriptions of more detailed procedures for evaluation of pavements and their suitability for restricted overload operations in Reference 2, while Section 5 of this document outlines a more comprehensive and detailed method of accounting for pavement overloading.

## 2.3 ACNs of Common Aircraft

ACNs of many of today's aircraft may be found in a number of different sources. One of the most comprehensive and up-to-date is in the Airport Directory section of Jeppesen flight manual books (Reference 3). Another extensive source is found in the ICAO publication, Part 3, Pavements (Reference 2). However, this source is not as current as is the Jeppesen publication. A third source of ACNs is in the *Airplane Characteristics for Airport Planning* manuals, as published by the major aircraft manufacturers. This data is generally the most current, and it is normally presented in graphical form.

## 2.4 ICAO ACN Computer Programs

The ICAO ACN pavement computer programs are subsets of two different previously existing programs. For flexible pavement, the S-77-1 method (Reference 4) is utilized in which the variable traffic term of passes is replaced by a constant standard coverages value. Likewise, rigid pavement ACN is calculated by a subset program of the PCA pavement computer program (Reference 5), except the variable term of working stress is replaced by a constant standard value.

## 2.5 Examples of PCN Reporting

The following examples illustrate how pavement strength data are reported under the ACN/PCN method.

Example 1

The bearing strength of a rigid pavement resting on a subgrade with a medium subgrade has been assessed by technical evaluation to be PCN 80. There is no tire pressure limitation. The reported information would be PCN 80 RBWT.

Example 2

The bearing strength of a composite pavement, which behaves like a flexible pavement and resting on a high-strength subgrade, has been assessed by using aircraft experience to be PCN 50. The tire pressure limitation is stated as 145 psi (1.00 Mpa). The reported information would be PCN 50 FAYU.

Example 3

The bearing strength of a flexible pavement resting on a low strength subgrade has been assessed by technical evaluation to be PCN 40. The maximum allowable tire pressure is 116 psi (0.80 Mpa). The reported information would be PCN 40 FC / 116 psi / T or PCN 40 FC / 0.80 Mpa / T.

Example 4

If a pavement were subject to a B747-400 all-up mass limitation of 873,000 lb (396,000 kg), then the reported information would include a note stating that deviation.

# 3. Equivalent Traffic

A detailed method, based on the procedures outlined in Reference 6, is presented in this section that will allow the calculation of the combined effect of multiple aircraft 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 ICAO computer programs that are used to calculate ACN allow 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 herein has been developed and utilized over a period of years by a recognized airport authority - the U. S. FAA. For the purposes of this document, it was not considered efficient or prudent to deviate from a procedure that has been already accepted as having validity. Regardless of how equivalent traffic is determined, the principles presented of arriving at a PCN for an airport with a mix of traffic are still relevant.

The assessment of equivalent traffic, as described in this section, is needed only in the process of determining PCN using the *Technical* method, and it may be disregarded when the *Using* aircraft method will be 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. This in turn requires that the pavement design and aircraft loading characteristics be examined in detail. Consequently, the information presented in this section 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.

## 3.1 Equivalent Traffic Terminology

In order to determine a PCN, as based on the *Technical* evaluation method, it is first necessary to define some of the terms used in aircraft traffic and pavement loading. Once the terms are understood, at least in the context of this document, then application may be made to the determination of a critical airplane and the eventual calculation of a PCN. The terms *arrival, departure, pass, coverage, load repetition, operation,* and traffic *cycle* are often used interchangeably by different organizations when determining the effect of traffic operating on a runway. It is not only important 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 purposes of this document, they are differentiated as follows:

- Arrival or Landing and Departure or Takeoff

  Typically, aircraft arrive at an airport with a lower amount of fuel than is used for 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. Many engineers will therefore only count departures and ignore the arrival traffic count in pavement design. However, if the aircraft do not receive any 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 it should be counted the same as a takeoff for pavement stress loading cycles. The effect of this latter scenario is that there are two equal load stresses on the pavement for each traffic count, 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 aircraft, subject to a further refinement of the definition in the following text.

- 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 3-1 shows typical traffic patterns for runways having either parallel taxiways or central taxiways. A parallel taxiway is defined as one in which none (or mostly none) of the runway is used as part of the taxi, while a central taxiway is a condition where all (or nearly all) of the runway is used during taxi.

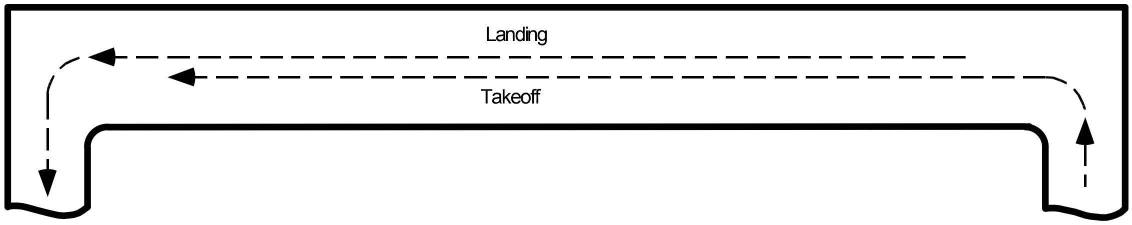


Figure 3-1a. Runways With a Parallel Taxiway

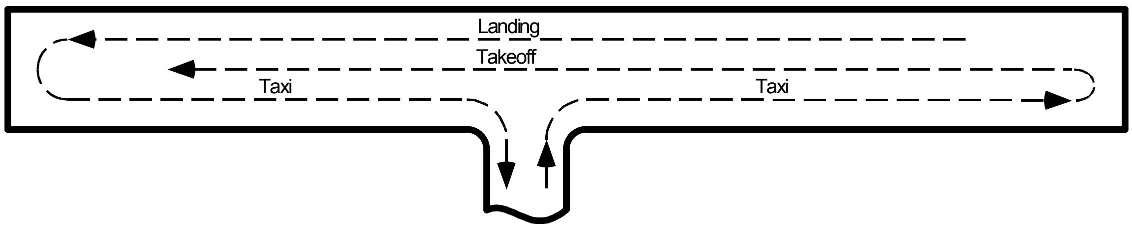


Figure 3-1b. Runways With a Central Taxiway

**Figure 3-1. Traffic Load Distribution Patterns**

In the case of the parallel taxiway, as shown in Figure 3-1a, there are two possible loading situations that 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.

In the case of the central taxiway, as shown in Figure 3-1b, there also are two possible loading situations that can occur. In a similar manner 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 this results 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.

Notwithstanding the previous discussion on the magnitude of the P/TC ratio for the different runway and taxiway conditions, an alternate procedure would be to consider the P/TC ratio to be 1 for all situations. Since landing and takeoff only apply full load to perhaps the end 1/3 of the runway (opposite ends for no shift in wind direction), a less conservative approach would be to count one pass for both landing and takeoff. However, it has been the practice at Boeing to conduct airport evaluations on the conservative side, which is to consider that the entire runway has been covered during any one of the passes.

- Coverage or Load Repetition

  When an airplane traverses on 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 or load repetition occurs when a unit area of the runway has been traversed by an aircraft wheel on the main gear (Reference 4). Due to the 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 related to either the pass-to-coverage (P/C) ratio for flexible pavements or the pass-to-load repetition (P/LR) ratio for rigid pavements.

  Although the terms *coverage* and *P/C* ratio have commonly been applied to both flexible and rigid pavements, they have been used by Boeing only when referring to flexible pavements, while *load repetition* and *P/LR* have been used when referring to rigid pavements. This is due partially to the manner in which flexible and rigid pavements are considered to react to aircraft loadings having the various types of gear configurations. For gear configurations of more than two wheels, such as dual tandem and tridem, the ratios are different for flexible and rigid pavements, and it was felt that using the same term for both types of pavements might be confusing. However, regardless of the terminology, the effect is the same.

While coverages are used by the S-77-1 flexible pavement program, only passes can be determined (counted) by observation. The P/C ratio converts passes to coverages for use in the program. Typical values shown in Table 3-1 are sufficient for the purposes of determining traffic coverages for flexible pavements. This ratio is different for each airplane due to the different number of wheels, main gear configurations, tire contact areas, and load on the gear. The ratio will change slightly for each airplane when the tire contact area varies due to changes in applied load.

**Table 3-1. Flexible Pavement Pass-to-Coverage Ratios**

| Airplane | P/C Ratio | Airplane | P/C Ratio | Airplane | P/C Ratio |
|---|---|---|---|---|---|
| 707-320C | 1.70 | DC8-63 | 1.66 | A300 B2 | 1.77 |
| 717-200 | 3.58 | DC9-15 | 3.63 | A300 B4 | 1.81 |
| 727-200 | 2.89 | DC9-51 | 3.64 | A300-600R | 1.73 |
| 737-200 | 3.82 | DC10-10 | 1.88 | A310-200 | 1.87 |
| 737-300 | 3.87 | DC10-30 | 1.77 | A310-300 | 1.69 |
| 737-400 | 3.52 | MD-11 | 1.81 | A319-100 | 3.70 |
| 737-500 | 3.85 | MD-81 | 3.39 | A320-100 | 3.78 |
| 737-600 | 3.76 | MD-82,-88 | 3.42 | A320-200 Dual | 3.72 |
| 737-700 | 3.75 | MD-83 | 3.41 | A320-200 DT | 2.34 |
| 737-800 | 3.60 | MD-87 | 3.43 | A321-100 | 3.42 |
| 747-200 | 1.74 | MD-90 | 3.47 | A321-200 | 3.45 |
| 747-400 | 1.72 | L1011-100 | 1.71 | A330-300 | 1.84 |
| 747SP | 1.99 | L1011-500 | 1.72 | A340-200 | 1.86 |
| 757-200 | 1.98 | BAC111-500 | 3.60 | A340-300 | 1.85 |
| 757-300 | 1.97 | BAe146-300 | 3.72 | FAA Single | 5.18 |
| 767-200 | 2.01 | F-27 | 3.86 | FAA Dual | 3.48 |
| 767-200 ER | 1.81 | F28 | 3.55 | FAA DT | 1.84 |
| 767-300 | 1.93 | F100 | 3.58 | C130 | 2.29 |
| 767-300 ER | 1.82 | IL62M | 1.47 | C141 | 1.72 |
| 777-200 | 1.39 | IL86 | 1.19 | C-5A | 0.79 |
| 777-200 IGW | 1.39 | TU-134A | 2.90 | | |
| 777-300 | 1.35 | TU-154B | 1.74 | | |

For aircraft not shown, P/C ratios may be calculated using Equation 3-1, which is based on data from Reference 4. This equation applies to aircraft with dual wheel main gear, with dual tandem and tridem gears being accounted for by the factor *n*. Landing gear with other arrangements, such as the C-17, C-5A and C-130, must be analyzed separately in that their gear patterns do not fit this equation. The constants a, b, and c are from a fit of a curve in Figure 10 of Reference 4.

$$P/C = \frac{1}{n * Xoc * W_t} \quad \text{(dimensionless)} \qquad \textbf{(3-1)}$$

where:

- n = Number of dual gear sets in the landing gear configuration. *n* is 1 for dual gears, 2 for dual tandem, and 3 for tridem.
- Xoc = $a + b * (\text{dual spacing}) + c * (\text{dual spacing})^2$
  Units of dual spacing are inches. The range of validity for this equation is from dual gear spacings of about 24 to 60 inches.
- a = 0.02776
- b = -0.00009893
- c = -0.0000014176
- $W_t$ = Tire contact width in inches. A good representation is: $0.878 * (\text{tire contact area in square inches})^{1/2}$

Table 3-2 shows similar P/LR ratio information for rigid pavements. Load repetitions are not used directly by the PCA computer program (Reference 5), but are used to indirectly determine the allowable working stress of the pavement. Application of this process is discussed in detail in Section 4.

- Note that the ratios of Table 3-2 are different than in Table 3-1 for dual tandem and tridem gear arrangements. This difference occurs due to the method in which the flexible and rigid pavements are assumed to handle stress. It is considered that the flexible pavement loading pattern has a series of stress peaks, depending on the number of wheel sets, while a rigid pavement acts as a single deflecting plate, with only one stress peak per set of wheels. Generally, a single or dual gear arrangement will provide only one load stress per pass, regardless of the pavement type, in that there is only one set of wheels traversing a given place on the pavement. However, a dual-tandem gear stresses a flexible pavement twice in that 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 set of wheels. Likewise, a tridem gear stresses the flexible pavement three times to one time for rigid pavement.

- 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.

- Traffic Cycle and Traffic Cycle Ratio

  As has been discussed, a traffic cycle can include a landing pass, a takeoff pass, a taxi

**Table 3-2. Rigid Pavement Pass-to-Load Repetition Ratios**

| Airplane | P/LR Ratio | Airplane | P/LR Ratio | Airplane | P/LR Ratio |
|---|---|---|---|---|---|
| 707-320C | 3.40 | DC8-63 | 3.32 | A300 B2 | 3.54 |
| 717-200 | 3.58 | DC9-15 | 3.63 | A300 B4 | 3.62 |
| 727-200 | 2.89 | DC9-51 | 3.64 | A300-600R | 3.46 |
| 737-200 | 3.82 | DC10-10 | 3.76 | A310-200 | 3.74 |
| 737-300 | 3.87 | DC10-30 | 3.74 | A310-300 | 3.38 |
| 737-400 | 3.52 | MD-11 | 3.62 | A319-100 | 3.70 |
| 737-500 | 3.85 | MD-81 | 3.39 | A320-100 | 3.78 |
| 737-600 | 3.76 | MD-82,-88 | 3.42 | A320-200 Dual | 3.72 |
| 737-700 | 3.75 | MD-83 | 3.41 | A320-200 DT | 2.34 |
| 737-800 | 3.60 | MD-87 | 3.43 | A321-100 | 3.42 |
| 747-200 | 3.48 | MD-90 | 3.47 | A321-200 | 3.45 |
| 747-400 | 3.44 | L1011-100 | 3.42 | A330-300 | 3.68 |
| 747SP | 3.98 | L1011-500 | 3.44 | A340-200 | 3.72 |
| 757-200 | 3.96 | BAC111-500 | 3.60 | A340-300 | 3.70 |
| 757-300 | 3.94 | BAe146-300 | 3.72 | FAA Single | 5.18 |
| 767-200 | 4.02 | F27 | 3.86 | FAA Dual | 3.48 |
| 767-200 ER | 3.62 | F28 | 3.55 | FAA DT | 3.68 |
| 767-300 | 3.86 | F100 | 3.58 | C130 | 4.58 |
| 767-300 ER | 3.84 | IL62M | 2.94 | C141 | 3.44 |
| 777-200 | 4.17 | IL86 | 3.57 | C-5A | 3.16 |
| 777-200 IGW | 4.17 | TU-134A | 5.80 | | |
| 777-300 | 4.05 | TU-154B | 5.22 | | |

pass or all three. For pavement design or evaluation, the ratio of traffic cycles to coverages 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 3-2 translates the P/C ratio to the TC/C ratio for flexible pavements by including the previously described ratio of passes to traffic cycles (P/TC):

$$TC/C = P/C \div P/TC \qquad \textbf{(3-2)}$$

where:

TC = Traffic Cycles
C = Coverages
P = Passes

Likewise, for rigid pavements, Equation 3-3 is used to convert passes to determine the TC/LR ratio for rigid pavements:

$$TC/LR = P/LR \div P/TC \qquad \textbf{(3-3)}$$

where:

TC = Traffic Cycles
LR = Load Repetitions
P = Passes

Determination of the TC/C ratio can best be illustrated by examples. Table 3-3 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 aircraft. Refer to Figure 3-1 and Table 3-1 for guidance in determining the number of passes utilized 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 3-3. TC/C Ratio for Flexible Pavements - Additional Fuel Not Obtained**

| Taxiway Type | Typical Dual Gear | Typical Dual Tandem Gear | Typical Tridem Gear |
|---|---|---|---|
| **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 3-4 shows the same information for a situation in which additional fuel is obtained at the airport. From a comparison of theses two tables, it can be seen that for a runway having a central taxiway and 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 in Table 3-3 is 1.2 compared with that of 3.6 for the parallel taxiway in Table 3-4, 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 3-4. TC/C Ratio for Flexible Pavements - Additional Fuel Obtained**

| Taxiway Type | Typical Dual Gear | Typical Dual Tandem Gear | Typical Tridem Gear |
|---|---|---|---|
| **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 3-5 shows typical ratios for rigid pavements for situations in which fuel is not obtained at the airport, while Table 3-6 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, from Tables 3-5 and 3-6, both the dual and dual-tandem gears have the same TC/LR ratio, while the tridem 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 3-5. TC/LR Ratio for Rigid Pavements - Additional Fuel Not Obtained**

| Taxiway Type | Typical Dual Gear | Typical Dual Tandem Gear | Typical Tridem Gear |
|---|---|---|---|
| **P/LR** | 3.6 | 3.6 | 4.2 |
| **P/TC - Parallel** | 2 | 2 | 2 |
| **P/TC - Central** | 3 | 3 | 3 |
| **TC/LR - Parallel** | 1.8 | 1.8 | 2.1 |
| **TC/LR - Central** | 1.2 | 1.2 | 1.3 |

**Table 3-6. TC/LR Ratio for Rigid Pavements - Additional Fuel Obtained**

| Taxiway Type | Typical Dual Gear | Typical Dual Tandem Gear | Typical Tridem Gear |
|---|---|---|---|
| **P/LR** | 3.6 | 3.6 | 4.2 |
| **P/TC - Parallel** | 1 | 1 | 1 |
| **P/TC - Central** | 2 | 2 | 2 |
| **TC/LR - Parallel** | 3.6 | 3.6 | 4.2 |
| **TC/LR - Central** | 1.8 | 1.8 | 2.1 |

## 3.2 Equivalent Traffic Based on Gear Type

In order complete the equivalent traffic calculation, all other significant aircraft in the traffic mix must be first converted to a critical airplane in terms of gear type and traffic cycles in that this other traffic also must be accounted for in the overall pavement design life. Secondly, the converted gear types must be in turn converted to a critical airplane equivalent in terms of load magnitude.

An airplane, which is regularly using the pavement that has the greatest thickness requirements, based on its individual operational characteristics, is the critical airplane. The process of selecting a critical airplane differs depending on the pavement type - flexible or rigid, and these procedures are described in Section 4 of this report. The remaining discussion in this section is not necessary to obtain a critical airplane; however, the critical airplane must first be selected in order to complete the equivalency process described below. Therefore, in order to complete the determination of equivalent traffic and to provide some examples, a critical airplane will be assumed.

To accomplish the conversion of gear types to that of the critical airplane, Table 3-7 is presented which lists appropriate conversion factors for each type of gear (Reference 6). After this conversion has occurred, each airplane in the traffic mix, and its corresponding traffic cycles, will be represented by the same gear configuration as the critical airplane.

**Table 3-7. Gear Configuration Conversion Factors**

| To Convert From (N) | To (M) | Multiply Traffic Cycles By |
|---|---|---|
| Single | Dual | 0.8 |
| Single | Dual tandem (DT) | 0.5 |
| Single | Tridem (TD) | 0.3 |
| Dual | Single | 1.3 |
| Dual | Dual tandem | 0.6 |
| Dual | Tridem | 0.4 |
| Dual tandem | Single | 2.0 |
| Dual tandem | Dual | 1.7 |
| Dual tandem | Tridem | 0.6 |
| Tridem | Single | 3.3 |
| Tridem | Dual | 2.5 |
| Tridem | Dual tandem | 1.7 |

The general equation for this conversion is:

$$0.8^{(M-N)} \qquad \textbf{(3-4)}$$

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

As an example of the use of gear configuration conversion factors, and without making a judgment as to the critical airplane, Table 3-8 shows the gear equivalencies for a dual-tandem (DT) gear in a sample traffic mix, while Table 3-9 shows the same gear equivalencies for a dual gear. 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 erroneous number of equivalent traffic cycles. This is evident in Table 3-8 where the overall total of annual traffic cycles is 15,200 compared with the total equivalent dual-tandem traffic cycles of 12,370, whereas in Table 3-9, the total equivalent dual traffic cycles is 20,760.

**Table 3-8. Equivalency Conversion to a Dual Tandem Gear Type**

| Airplane | Gear Type | Annual Traffic Cycles | Conversion Factor | Equivalent DT TC |
|---|---|---|---|---|
| 727-200 | Dual | 400 | 0.6 | 240 |
| 737-300 | Dual | 6,000 | 0.6 | 3,600 |
| A319-100 | Dual | 1,200 | 0.6 | 720 |
| 747-400 | DT | 3,000 | 1.0 | 3,000 |
| 767-200ER | DT | 2,000 | 1.0 | 2,000 |
| DC8-63 | DT | 800 | 1.0 | 800 |
| MD11 | DT | 1,500 | 1.0 | 1,500 |
| 777-200 | TD | 300 | 1.7 | 510 |
| | | 15,200 | | 12,370 |

**Table 3-9. Equivalency Conversion to a Dual Gear Type**

| Airplane | Gear Type | Annual Traffic Cycles | Conversion Factor | Equivalent Dual TC |
|---|---|---|---|---|
| 727-200 | Dual | 400 | 1.0 | 400 |
| 737-300 | Dual | 6,000 | 1.0 | 6,000 |
| A319-100 | Dual | 1,200 | 1.0 | 1,200 |
| 747-400 | DT | 3,000 | 1.7 | 5,100 |
| 767-200ER | DT | 2,000 | 1.7 | 3,400 |
| DC8-63 | DT | 800 | 1.7 | 1,360 |
| MD11 | DT | 1,500 | 1.7 | 2,550 |
| 777-200 | TD | 300 | 2.5 | 750 |
| | | 15,200 | | 20,760 |

## 3.3 Equivalent Traffic Based on Load Magnitude

After the aircraft 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 was stated for the gear type conversion procedure, this step also requires that the critical airplane be previously selected.

When computing equivalent traffic cycles of the critical airplane based on load magnitude, there are several simplifying rules that can be utilized:

- For the purposes of equivalent traffic cycle calculations, it is generally sufficient to use single wheel loads at based on 95% of gross airplane weight on the main gear.
- Since it is difficult to determine current or projected operational weights, maximum taxi gross weights of each airplane may be used for this calculation, except as noted next.
- Widebody aircraft are all treated as 300,000-pound dual-tandem gear aircraft (35,625-pound single wheel load), even when the critical airplane is a widebody, for this calculation. This is due to the generally wider wheel spacing on widebody landing gears. Note that this procedure is followed only for determining traffic equivalencies, and it should not be used for pavement design or evaluation.

The above procedure to convert gear types for the aircraft of the traffic mix to that of the critical airplane accounts for the differences in gear type, whereas the effect of wheel load magnitude may be calculated by applying Equation 3-5 from Reference 6:

$$R_1 = R_2^{\ A} \qquad \textbf{(3-5)}$$

where:

$A = (W_2 / W_1)^{1/2}$
$R_1$ = Equivalent traffic cycles of the critical airplane
$R_2$ = Traffic cycles of a given airplane expressed in terms of the critical airplane landing gear
$W_1$ = Single wheel load of the critical airplane
$W_2$ = Single wheel load of the airplane in question

Table 3-10 shows how the above calculations are combined to determine the equivalent traffic cycles of the critical airplane. For this example, assume that the 747-400 is the critical airplane. It can be seen that the original 3,000 annual traffic cycles of the 747-400 have increased to an equivalent 11,250 due to the combined effect of the other aircraft in the traffic mix. The $R_2$ column is from Table 3-8.

**Table 3-10. Equivalent Traffic Cycles Based on Load Magnitude**

| Airplane | ($W_2$) Single Wheel Load, lb | | ($R_2$) DT TC | $(A)^{1/2}$ Wheel Load Ratio | ($R_1$) Equivalent 747-400 TC | |
|---|---|---|---|---|---|---|
| 727-200 | 43,940 | | 240 | 1.111 | 440 | |
| 737-300 | 30,875 | | 3,600 | 0.931 | 2,046 | |
| A319-100 | 34,440 | | 720 | 0.983 | 644 | |
| 747-400 | 35,625 | ($W_1$) | 3,000 | 1.000 | 3,000 | (Critical airplane) |
| 767-200ER | 35,625 | | 2,000 | 1.000 | 2,000 | |
| DC8-63 | 39,190 | | 800 | 1.049 | 1,110 | |
| MD11 | 35,625 | | 1,500 | 1.000 | 1,500 | |
| 777-200 | 35,625 | | 510 | 1.000 | 510 | |
| | | | 12,370 | | 11,250 | |

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 increase from 240 to 440, even though this is a relatively small airplane as compared to the 747-400. Alternately, the 737-300 equivalent traffic has reduced from 3,600 to 2,046 due to the relative magnitude of the single wheel loads.

The next section finalizes the process of PCN determination for both flexible and rigid pavements. For those situations where the PCN is not sufficient to accommodate the existing traffic, a discussion of pavement overloading effects is presented in Section 5.

# 4. Assignment of the PCN

The following steps outline the procedure that can be used by an airport authority to determine the rating of a pavement in terms of PCN. The first method discussed, known as the *Using* aircraft method, can be applied with limited knowledge of the existing traffic and runway characteristics. The terminology *Using aircraft* simply means that the PCN is based on the aircraft currently and satisfactorily using the pavement, and there are no engineering methods or technical analyses employed to arrive at this sort of PCN. The second method, known as the *Technical evaluation* method, requires a much more intimate knowledge of the pavement and its traffic, as well as a basic understanding of engineering methods that are utilized in pavement evaluation in order to be successfully implemented. All of the factors that contribute towards pavement analysis, such as existing and forecasted traffic, aircraft characteristics, pavement design parameters, and engineering experience and observation are applied in arriving at an evaluation as a basis for determining PCN based on this method.

## 4.1 The *Using* Aircraft Method

The *Using* aircraft method of determining PCN is presented in the following steps. As mentioned above, 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.

Accuracy of ratings based on *Using* aircraft is by nature less than that for a *Technical* evaluation, but PCNs can be assessed more quickly and with minimal cost. However, airport authorities should be more flexible in the application of a *Using* aircraft PCN in that the rating has not been rigorously determined.

There are two basic steps required to arrive at a *Using* aircraft PCN:

1. Determine the airplane with the highest ACN in the traffic mix currently using the runway. This is the critical airplane.
2. Assign the ACN of the critical airplane as the PCN.

The following list is an expansion of the basic steps that are necessary for determining a PCN as based on the *Using* aircraft method:

1. Assign the pavement surface type as Code *F* or *R* as shown in Table 2-1.

2. From available records, determine the average strength of the pavement subgrade. The subgrade code is the letter that falls within the range of existing subgrade values, as shown in either Table 2-2 or Table 2-3. 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 aircraft that are presently using the runway, based on the surface code from Step 1 and the subgrade code from Step 2. ACNs for common aircraft may be found in References 2 and 3. Alternatively, use ACN graphs as found in Section 7 of the manufacturer's published *Airplane Characteristics for Airport Planning* manuals. Use the same subgrade code for each of the aircraft when determining the maximum ACN. The ACNs should be based on the highest operating weight at the airport, but if not available, either uses an estimate or the published maximum allowable gross weight of the airplane in question. The airplane with the highest ACN, and which 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 needs for either restrictions of or allowances for certain aircraft, pavement conditions, or the need to reflect weight-based landing fees.

5. The tire pressure code (W, X, Y, or Z) should represent the highest tire pressure of the aircraft fleet currently using the runway. Use the values from Table 2-4 to select this code. 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, and the rigid pavement rating should normally be assigned as *W*.

6. The evaluation method for the *Using* aircraft method is *U*, as determined from Table 2-5.

### 4.1.1 *Using* Aircraft Example for Flexible Pavements

The following example illustrates the *Using* aircraft 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 4-1.

**Table 4-1. *Using* Aircraft and Traffic for a Flexible Pavement**

| Airplane | Operating Weight, lb | Tire Pressure (psi) | ACN Flexible | Annual Departures |
|---|---|---|---|---|
| 727-200 | 185,000 | 148 | 48 FB | 400 |
| 737-300 | 130,000 | 195 | 34 FB | 6,000 |
| A319-100 | 145,000 | 196 | 35 FB | 1,200 |
| 747-400 | 820,000 | 200 | 60 FB | 3,000 |
| 767-300ER | 370,000 | 190 | 52 FB | 2,000 |
| DC8-63 | 330,000 | 194 | 52 FB | 800 |
| MD-11 | 515,000 | 205 | 58 FB | 1,500 |
| 777-200 | 600,000 | 215 | 51 FB | 300 |

- Since this is a flexible pavement, the pavement type code is *F*, as found in Table 2-1.
- The subgrade strength under the pavement is CBR 9, which from Table 2-2 is in the *Medium, Code B* category.
- The highest tire pressure of any airplane in the traffic mix is 215 psi, which is in the *X* category, as found in Table 2-4.
- From the above list, the critical airplane is the 747-400, since it has the highest ACN of the group at the operational weights shown (60 FB). 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 aircraft using the runway, the evaluation code from Table 2-5 is *U*.
- Based on the results of the previous steps, the pavement should tentatively be rated as PCN 60 FBXU, assuming that the pavement is performing satisfactorily under the current traffic.

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

### 4.1.2 *Using* Aircraft Example for Rigid Pavements

The following example illustrates the *Using* aircraft 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 4-2.

**Table 4-2. *Using* Aircraft and Traffic for a Rigid Pavement**

| Airplane | Operating Weight, lb | Tire Pressure (psi) | ACN Rigid | Annual Departures |
|---|---|---|---|---|
| 727-200 | 185,000 | 148 | 55 RC | 400 |
| 737-300 | 130,000 | 201 | 41 RC | 6,000 |
| A319-100 | 150,000 | 173 | 43 RC | 1,200 |
| 747-400 | 800,000 | 200 | 67 RC | 3,000 |
| 767-300ER | 370,000 | 200 | 61 RC | 2,000 |
| DC8-63 | 330,000 | 194 | 61 RC | 800 |
| MD-11 | 550,000 | 205 | 71 RC | 1,500 |
| 777-200 | 600,000 | 215 | 76 RC | 300 |

- Since this is a rigid pavement, the pavement type code is *R*, as found in Table 2-1.
- The subgrade strength under the pavement is k=200 pci, which from Table 2-2 is in the *Low, Code C* category.
- The highest tire pressure of any airplane in the traffic mix is 215 psi, which is in the *X* category, as found in Table 2-4. However, since concrete can normally tolerate substantially higher tire pressures, the rating should be assigned as *W*.
- From the above list, the critical airplane is the 777-200, since it has the highest ACN of the group at the operational weights shown (76 RC). However, the critical airplane could also be the MD-11 at ACN 71 RC or the 747-400 at ACN 67 RC in that these aircraft have higher frequencies than the 777.

- Since there was no engineering analysis done in this example, and the rating was determined simply by examination of the current aircraft using the runway, the evaluation code from Table 2-5 is *U*.
- Based on the results of the previous steps, the pavement should tentatively be rated as PCN 76 RCWU in order to accommodate all of the current traffic.
- If the pavement shows obvious signs of distress, then this rating may have to be adjusted downward at the discretion of the airport authority. If the rating is lowered, then one or more of the aircraft will have ACNs that exceed the assigned rating. This may require a restriction in allowable gross weight for those aircraft or consideration of pavement strengthening. The rating could also be adjusted upward, depending on the performance of the pavement under the current traffic.

## 4.2 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. Accuracy of ratings based on a *Technical* evaluation is better than that based on the *Using* aircraft method, but at a greater cost in terms of financial expenditure and time. Although the accuracy of this type of rating better reflects existing conditions that does the *Using* aircraft method, the airport authority should still be somewhat flexible in its application in that there are not only many variables in the pavement structure, but also in the method of analysis itself. Pavement evaluation has never been a precise process, and ratings obtained in any manner, including the *Technical* evaluation method, should be considered as, at best, close approximations.

The technical method for the evaluation of flexible pavements is somewhat different than for rigid pavements in that traffic volume is used directly in the determination of the critical airplane allowable gross weight. For rigid pavements traffic volume is used, but only in an indirect manner. However, the objective of both methods is to arrive a critical airplane allowable gross weight in order to assess the PCN.

### 4.2.1 *Technical* Evaluation for Flexible Pavements

A summary list of the steps required for flexible pavements as based on the *Technical* evaluation method is as follows:

1. Determine the traffic volume in terms of type of aircraft and number of operations of each aircraft that the pavement will experience over its life.
2. Convert that traffic into a single critical airplane equivalent.
3. Determine the pavement characteristics, including the subgrade CBR and pavement thickness.
4. Calculate the maximum allowable gross weight of the critical airplane on that pavement.
5. Look up or calculate the ACN of the critical aircraft at its maximum allowable gross weight.
6. Assign the PCN to be the ACN of the critical aircraft.

Details of the steps required for flexible pavements as based on the *Technical* evaluation method are listed below. Although these steps appear to be quite voluminous in their application, they are very straightforward when followed to their conclusion. Several examples are presented at the end of this section that will further explain the process describe below:

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. All significant traffic, including non-scheduled, charter, and military, should be recorded as accurately as possible. This includes traffic that has occurred from the original construction or last overlay, until the next planned overlay or reconstruction. If the pavement life is unknown or undetermined, assume that it will include a reasonable period of time. Normal flexible pavement design life is 20 years. However, the expected life can vary depending on the existing pavement conditions, climatic conditions, and maintenance practices.

The aircraft information necessary for the traffic volume process is:

- Past, current, and forecasted traffic cycles of each significant aircraft.
- Operational or maximum gross weights.
- Typical aircraft weight distribution on the main and nose gear. If unknown, it is generally sufficient to use 95% 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 critical.
- Fuel loading practices of aircraft at the airport.
- Type of taxiway system - parallel or central.

2. Determine which of aircraft in the traffic mix from step 1 is critical or the most significant. This is required because the ACN computer program is able to accommodate only one airplane at a time. Since ICAO has adopted a modified version of the S-77-1 computer program of Reference 4 to determine ACN for flexible pavements, it is appropriate to use that same program to select the critical airplane. The critical airplane is the one which 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 S-77-1 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. Typical P/C ratios for a number of aircraft on flexible pavement are shown in Table 3-1, with a method to calculate the P/C ratio for other aircraft also shown. It is not necessary to determine each individual airplane's P/C ratio in the traffic mix, since it is ultimately required only for the critical airplane.
4. Using the conversion factors of Table 3-7, group 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 tridem wheel gears need to be converted into the dual tandem gear equivalent. Likewise, if the critical airplane has a dual gear arrangement, then all

single wheel, dual tandem wheel, and tridem wheel gears need to be converted into the dual 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 3-5.
6. Calculate the critical airplane TC/C ratio from Equation 3-2 for the type of taxiway and the fuel loading method. This will allow the S-77-1 computer program to determine coverages from the critical airplane equivalent traffic cycles of 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 in that 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. If the pavement has excess asphalt surface material, the excess material thickness may be increased according to the methods described in Reference 6. The pavement is considered to have excess asphalt, which can be converted to extra equivalent thickness when the asphalt thickness is greater than 4 inches for standard body jet transport aircraft or 5 inches for widebody aircraft. The pavement may also be considered to have excess base or subbase thickness when the cross section has other non-granular materials such as asphalt stabilization or imbedded concrete slabs. This allows an additional thickness adjustment for the calculation of allowable gross weight of the critical airplane. It is recognized that some airport authorities do not employ this technique of accounting for excess premium materials as is described in Reference 6, and this may require that other means be utilized to determine the total in-place equivalent pavement thickness.
9. With 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 S-77-1 pavement design

computer program or by any other means as required by the appropriate airport authority. Alternatively, consult an S-77-1 chart such as published Section 7 of the manufacturer's *Airplane Characteristics for Airport Planning* manuals.

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 ICAO ACN program. 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 vs Gross Weight* chart as published in the manufacturer's *Airplane Characteristics for Airport Planning* manuals.
12. Assign the tire pressure code based on the highest tire pressure in the traffic mix from Table 2-4. Keep in mind the quality of the asphalt surface layer, as discussed in Section 2.1, when assigning this code.
13. The evaluation method is *Technical*, with a code of *T,* as described in Table 2-5.
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 calculated allowable gross weight of Step 11 is equal to or greater than the critical aircraft 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 of Step 14 is sufficient. If the allowable gross weight from Step 11 is less than the critical aircraft gross weight required for the desired pavement life, then the pavement may be assigned a PCN equal to the ACN of the critical aircraft 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 aircraft 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 Section 5 of this document.

### 4.2.1.1 *Technical* Evaluation Examples for Flexible Pavements

Four examples are presented which help explain the *Technical* Evaluation method PCN process for flexible pavements. The first example is for an under strength pavement which has 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.

Computer runs are provided for all *Technical* evaluation method example calculations at the end of this section, with an index beginning on page 4-4.

#### 4.2.1.1.1 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, shown in Figure 4-1. 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 4-3, and it is the same as in Table 4-1, but with additional information added.

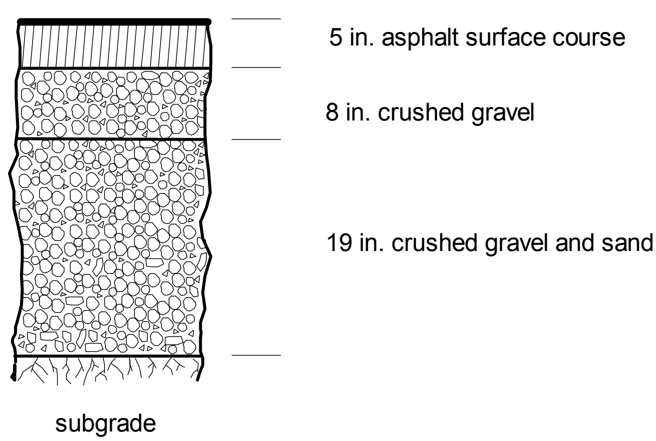


Figure 4-1. Flexible Pavement Example Cross Section

**Table 4-3. Technical Evaluation Critical Airplane Determination**

| Airplane | Operating Weight, lb | Tire Pressure (psi) | ACN | Annual Departures | P/C Ratio | Required t, (in.) |
|---|---|---|---|---|---|---|
| 727-200 | 185,000 | 148 | 48 FB | 400 | 2.92 | 22.6 |
| 737-300 | 130,000 | 195 | 34 FB | 6,000 | 3.87 | 23.2 |
| A319-100 | 145,000 | 196 | 35 FB | 1,200 | 3.56 | 21.1 |
| **747-400** | **820,000** | **200** | **60 FB** | **3,000** | **1.72** | **31.2** |
| 767-300ER | 370,000 | 190 | 52 FB | 2,000 | 1.82 | 28.2 |
| DC8-63 | 330,000 | 194 | 52 FB | 800 | 1.66 | 26.7 |
| MD-11 | 515,000 | 205 | 58 FB | 1,500 | 1.83 | 29.0 |
| 777-200 | 600,000 | 215 | 51 FB | 300 | 1.39 | 24.9 |

- The required total pavement thickness results are shown in Table 4-3 for each airplane. An examination of each airplane individually by using the S-77-1 computer program shows the required pavement thickness, with the airplane and pavement characteristics as described above. (See computer calculations on pages 4-26 to 4-33).
- It can be seen that the 747-400 airplane has the greatest individual pavement thickness requirement (31.2 inches) for its total traffic over 20 years, and it is therefore the critical airplane. Note that the thickness requirements for each individual airplane are less than the existing pavement thickness of 32.0 inches.
- Table 4-4 shows the conversion of departures of the other traffic to the critical airplane 747-400 equivalent. For the purposes of this calculation only, and as recommended in Reference 6, all widebody wheel loads were considered to be that of a 300,000-lb dual tandem airplane, or 35,625 lb, including the critical airplane. Gear configuration conversion factors from Table 3-7 were utilized to determine the equivalent dual tandem gear departures. The 747-400 equivalent annual departures were calculated by using Equation 3-5. Although the 747-400 had only 3,000 annual departures, the effect of the other traffic has increased the number to an equivalent 11,250.

  Note that the equivalent annual departure total shown would also be the same for the 767-300ER and the MD-11 because the assumed wheel loads are the same as that of the critical airplane. This would not be true, however, for the 777-200 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 in determining equivalent traffic.

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

| Airplane | Annual Departures | Gear Type | ($R_2$) Equiv. DT Departures | ($W_2$) Wheel Load | ($W_1$) 747-400 Wheel Load | ($R_1$) 747-400 Equiv. Ann. Departures |
|---|---|---|---|---|---|---|
| 727-200 | 400 | Dual | 240 | 43,940 | 35,625 | 440 |
| 737-300 | 6,000 | Dual | 3,600 | 30,875 | 35,625 | 2,045 |
| A319-100 | 1,200 | Dual | 720 | 34,440 | 35,625 | 645 |
| **747-400** | **3,000** | **DT** | **3,000** | **35,625** | **35,625** | **3,000** |
| 767-300ER | 2,000 | DT | 2,000 | 35,625 | 35,625 | 2,000 |
| DC8-63 | 800 | DT | 800 | 39,190 | 35,625 | 1,110 |
| MD-11 | 1,500 | DT | 1,500 | 35,625 | 35,625 | 1,500 |
| 777-200 | 300 | TD | 510 | 35,625 | 35,625 | 510 |
| | 15,200 | | | | | 11,250 |

- With the total equivalent traffic of the critical airplane known, the traffic cycle ratio for the taxiway and fuel situation can be calculated. Following the example shown in Table 3-4 and based on Equation 3-2, for a critical airplane P/C ratio of 1.72 and a P/TC ratio of 1 for a parallel taxiway, the traffic cycle to coverage ratio is:

$$TC/C = 1.72 \div 1 = 1.72$$

- It is now possible to calculate the maximum allowable gross weight of the 747-400 critical airplane on this pavement. The input parameters to the S-77-1 computer program are:

| | |
|---|---|
| Critical airplane | 747-400 |
| 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 % |
| TC/C ratio | 1.72 |
| Annual equivalent departures | 11,250 |
| Pavement life | 20 years |

- For these conditions, from the S-77-1 computer program, the calculated allowable gross weight of the 747-400 is 771,000 pounds. From the ICAO ACN program, the 747-400 ACN at this weight is 55.1 FB, for a recommended pavement rating of PCN 55 FBXT. (The computer calculations are on page 4-34).
- Referring to Table 4 3, it can be seen that the 747-400 and the MD-11 aircraft would be restricted in their operations on this runway due to their ACN's of 60 FB and 58 FB, respectively, being higher than the recommended PCN of 55 FB. It is apparent from this result that the pavement is not adequate to handle the existing traffic, and either the operating weights will have to be restricted or pavement life will be less than originally expected. A complete analysis of this situation and the requirements for adjustments is fully explained in Section 5 of this document.

#### 4.2.1.1.2 Example 2

This second example has the same input parameters as the first, except that the pavement cross-section is increased to 35 inches.

- The input parameters to the S-77-1 computer program for this example are:

| | |
|---|---|
| Critical airplane | 747-400 |
| Pavement thickness | 35.0 inches |
| Subgrade CBR | 9.0 (Code *B*) |
| Tire pressure | 200 psi (Code *X*) |
| Percent Weight on the main gear | 95.0 % |
| TC/C ratio | 1.72 |
| Annual equivalent departures | 11,250 |
| Pavement life | 20 years |

- For these conditions, the calculated allowable gross weight of the 747-400 is 864,000 pounds. From the ICAO ACN program, the 747-400 ACN at this weight is 64.6 FB, for a recommended rating of PCN 65 FBXT. (The computer calculations are on page 4-35).
- It can be seen from an examination of Table 4-3 that all of 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 3 inches in pavement thickness from Example 1 has resulted in a net increase in PCN of 10.

#### 4.2.1.1.3 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 shown in Figure 3-1b. Referring to Table 3-4, the P/TC ratio changes from 1 to 2. From Equation 3-2, the TC/C ratio for the critical 747-400 airplane becomes:

$$TC/C = 1.72 \div 2 = 0.86$$

- The input parameters to the S-77-1 program are:

| | |
|---|---|
| Critical airplane | 747-400 |
| Pavement thickness | 35.0 inches |
| Subgrade CBR | 9.0 (Code *B*) |
| Tire pressure | 200 psi (Code *X*) |
| Percent Weight on the main gear | 95.0 % |
| TC/C ratio | 0.86 |
| Annual equivalent departures | 11,250 |
| Pavement life | 20 years |

- For these conditions, the calculated allowable gross weight of the 747-400 is 832,000 pounds. (The computer calculations are on page 4-36).
- From the ICAO ACN program, the 747-400 ACN at this weight is 61.3 FB, for a recommended runway rating of PCN 62 FBXT. The net effect of the change in taxiway configuration from that of Example 2 is the reduction in PCN by 3.

#### 4.2.1.1.4 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 65 FBXT, which is equivalent to a 747-400 critical airplane allowable gross weight of 864,000 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 1.72 to 0.86. A similar effect would be noticed if the fuel situation were to be changed to *not* obtaining fuel at the airport, rather than as proposed in the first flexible pavement example case. These changes in pavement life would need to be acceptable to the airport authority. (The computer calculations are on page 4-37).

### 4.2.2 *Technical* Evaluation for Rigid Pavements

A summary list of the steps required for rigid pavements as based on the *Technical* evaluation method is as follows:

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

Details of the steps for rigid pavements as based on the *Technical* evaluation method are:

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. All significant traffic, including non-scheduled, charter, and military, should be included as accurately as possible. This includes traffic that has occurred from the original construction or last overlay, until the next planned overlay or reconstruction. If the pavement life is unknown or undetermined, assume that it will include a reasonable time period based on climatic conditions. Typical concrete pavement design life is 20 years. However, the expected life can vary depending on the existing pavement conditions and maintenance practices.

   The aircraft information necessary for the traffic volume process is:

   - Past, current, and forecasted traffic cycles of each significant aircraft.
   - Operational or maximum gross weights.
   - Typical weight distribution of the main and nose gear. If unknown, it is generally sufficient to use 95% weight on the main gear.
   - Main gear types (dual, dual tandem, etc.).
   - Main gear tire pressure.

- Pass-to-load repetition (P/LR) ratio of each airplane that might be considered as critical.
- Fuel loading practices of aircraft at the airport.
- Type of taxiway system - parallel or central.

2. Determine which of aircraft in the traffic mix from step 1 is critical or the most significant. This is required because the ACN computer program is able to accommodate only one airplane at a time. Since ICAO has adopted a modified version of the PCA computer program of Reference 5 to determine ACN for rigid pavements, it is appropriate to use that same program to select the critical airplane. The critical airplane is the one that has the greatest pavement thickness requirements based on individual gross weight, traffic volume, P/LR ratio, and tire pressure, and it is not necessarily the one with the highest ACN or the highest gross weight.
3. The PCA program calculates pavement thickness requirements based on the concrete working 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. Typical P/LR ratios for a number of aircraft on rigid pavement are shown in Table 3-2. It is not necessary to determine each individual airplane's P/LR ratio in the traffic mix, since it is ultimately required only for the critical airplane.
4. Using the conversion factors of Table 3-7, group 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 tridem wheel gears need to be converted into the dual tandem gear equivalent. Likewise, if the critical airplane has a tridem gear arrangement, then all single wheel, dual wheel, and dual tandem wheel gears need to be converted into the tridem gear equivalent.
5. Determine the critical airplane equivalent traffic cycles based on the single wheel loads of each airplane in the traffic mix. These calculations should be based on Equation 3-5.

6. Calculate the critical airplane TC/LR ratio from Equation 3-3 for the type of taxiway and the fuel loading method.
7. Using the critical airplane equivalent traffic cycles from Step 5 and the TC/LR 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. Unless more precise information is available, it is generally assumed that the value of concrete elastic modulus is 4,000,000 psi and Poisson's ratio is 0.15. 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, then the subgrade modulus can be adjusted upwards to an equivalent value in order to account for the improvement in support.
9. Enter Figure 4-2 with the number of equivalent load repetitions of the critical airplane from Step 7 in order to determine the stress ratio (SR). Multiply the modulus of rupture from Step 8 by the stress ratio to find the limiting (working) concrete tensile stress.
10. With the allowable working stress, slab thickness, and subgrade modulus, compute the maximum allowable gross weight of the critical airplane using the PCA pavement design computer program or by any other means as required by the appropriate airport authority. Alternately, consult a PCA chart as published in Section 7 of the manufacturer's *Airplane Characteristics for Airport Planning* manuals.
11. Assign the subgrade modulus (k-value) to the nearest standard ACN/PCN subgrade code. The k-value to be used is that found in Step 8. Subgrade codes for k-value ranges are found in Table 2-2.
12. The ACN of the critical airplane may now be determined from the ICAO ACN program. Enter the allowable gross weight of the critical airplane from Step 10, and calculate the ACN for the standard subgrade code of Step 11. Alternatively, consult

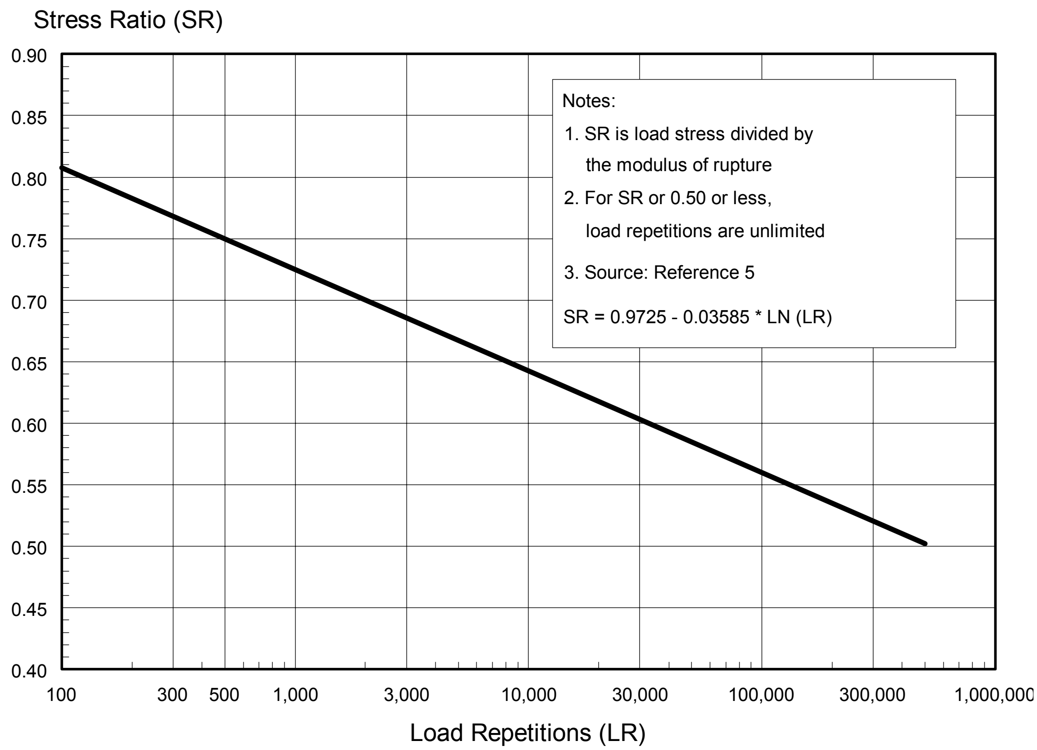


**Figure 4-2. Stress Ratio Variation with Load Repetitions**

an *ACN vs Gross Weight* chart as published in the manufacturer's *Airplane Characteristics for Airport Planning* manuals.

13. Assign the tire pressure code based on the highest tire pressure in the traffic mix from Table 2-4. As discussed previously, rigid pavements are typically able to handle high tire pressures, and usually Code W can be assigned.
14. The evaluation method is *Technical*, with a code of *T*, as described in Table 2-5.
15. The numerical value of the PCN is the same as the numerical value of the ACN of the critical airplane just calculated in Step 12.
16. If the allowable gross weight of Step 12 is equal to or greater than the critical aircraft 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 of Step 13 is sufficient. If the allowable gross weight from Step 12 is less than the critical aircraft gross weight required for the desired pavement life, then the pavement may be assigned a PCN equal to the ACN of

the critical aircraft 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. Procedures on how to relate pavement life and gross weight for rigid pavements in terms of PCN are found in Section 5 of this document. Any overload should be treated in terms of ACN and equivalent critical aircraft 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 rigid pavements are found in Section 5 of this document.

### 4.2.2.1 *Technical* Evaluation Examples for Rigid Pavements

Three examples are presented which help explain the *Technical* Evaluation method PCN process for rigid pavements. The first example pavement is under designed in that 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 the second, except that the aircraft generally do not obtain fuel at the airport.

Computer runs are provided for all *Technical* evaluation method example calculations at the end of this section, with an index beginning on page 4-24.

#### 4.2.2.1.1 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 4-3. The concrete has a modulus of rupture is 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 4-5 is the same as in Table 4-1, but with P/LR ratios and annual departures added.

- The critical airplane will be the one with the highest required thickness for its load magnitude and frequency. It is determined by first finding the working stress as calculated from the stress ratio, which is the ratio of load stress to modulus of rupture,

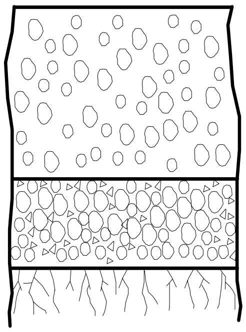


**Figure 4-3. Rigid Pavement Example Cross Section**

and then running the PCA program. In order to determine the stress ratio, the lifetime load repetitions must first be calculated for each airplane by using Equation 3-3. Since additional fuel is generally obtained at the airport, and there is a parallel taxiway, then:

P/TC = 1
TC/LR = P/LR
Lifetime load repetitions = annual departures ∗ 20 years ÷ TC/LR

The resulting lifetime load repetitions are listed for each airplane in Table 4-5. The relationship of stress ratio with load repetitions is shown in Figure 4-2. By entering the load repetitions into this figure, the stress ratios shown in Table 4-5 can be determined. (The computer calculations are on pages 4-38 to 4-41).

**Table 4-5. Rigid Pavement *Technical* Evaluation Traffic**

| Airplane | Operating Weight, lb | Tire Press. (psi) | ACN Rigid | P/LR Ratio | Annual Departures | Life Load Repetitions | Stress Ratio |
|---|---|---|---|---|---|---|---|
| 727-200 | 185,000 | 148 | 55 RC | 2.92 | 400 | 2,740 | 0.689 |
| 737-300 | 130,000 | 201 | 41 RC | 3.87 | 6,000 | 31,010 | 0.602 |
| A319-100 | 150,000 | 173 | 43 RC | 3.56 | 1,200 | 6,740 | 0.656 |
| 747-400 | 800,000 | 200 | 67 RC | 3.44 | 3,000 | 17,440 | 0.622 |
| 767-300ER | 370,000 | 200 | 61 RC | 3.64 | 2,000 | 10,990 | 0.639 |
| DC8-63 | 330,000 | 194 | 61 RC | 3.32 | 800 | 4,820 | 0.668 |
| MD-11 | 550,000 | 205 | 71 RC | 3.66 | 1,500 | 8,200 | 0.649 |
| 777-200 | 600,000 | 215 | 76 RC | 4.17 | 300 | 1,440 | 0.712 |

- It is now necessary to calculate the required slab thickness of each airplane by utilizing the PCA program. The inputs to the program are concrete elastic modulus, Poisson's ratio, and the airplane parameters of weight, tire pressure, and allowable working stress as calculated from the stress ratio. The allowable stress is calculated from:

Allowable stress = stress ratio ∗ modulus of rupture

- Table 4-6 shows that the critical airplane is the 747-400, based on its required thickness. However, the MD-11 should also be given consideration as critical in that its required thickness is very close to that of the 747-400. In this example, the 777-200 is not the critical airplane, even though it has the highest ACN. (The computer calculations are on pages 4-42 to 4-45).

**Table 4-6. *Technical* Evaluation Critical Airplane Determination**

| Airplane | Operating Weight, lb | Tire Pressure (psi) | Stress Ratio | Allowable Stress (psi) | Required Thickness (in.) |
|---|---|---|---|---|---|
| 727-200 | 185,000 | 148 | 0.689 | 482 | 11.6 |
| 737-300 | 130,000 | 201 | 0.602 | 421 | 11.1 |
| A319-100 | 150,000 | 173 | 0.656 | 459 | 10.8 |
| **747-400** | **800,000** | **200** | **0.622** | **435** | **13.3** |
| 767-300ER | 370,000 | 200 | 0.639 | 447 | 12.4 |
| DC8-63 | 330,000 | 194 | 0.668 | 468 | 12.1 |
| MD-11 | 550,000 | 205 | 0.649 | 454 | 13.1 |
| 777-200 | 600,000 | 215 | 0.712 | 498 | 12.2 |

- All departures of the other traffic must be converted to the 747-400 equivalent as shown in Table 4-7. For the purposes of this calculation, all widebody wheel loads are

**Table 4-7. Equivalent Annual Departures of the Critical Airplane**

| Airplane | Annual Departures | Gear Type | ($R_2$) Equiv. DT Departures | ($W_2$) Wheel Load | ($W_1$) 747-400 Wheel Load | ($R_1$) 747-400 Equiv. Ann. Departures |
|---|---|---|---|---|---|---|
| 727-200 | 400 | Dual | 240 | 43,940 | 35,625 | 440 |
| 737-300 | 6,000 | Dual | 3,600 | 30,875 | 35,625 | 2,045 |
| A319-100 | 1,200 | Dual | 720 | 34,440 | 35,625 | 645 |
| **747-400** | **3,000** | **DT** | **3,000** | **35,625** | **35,625** | **3,000** |
| 767-200ER | 2,000 | DT | 2,000 | 35,625 | 35,625 | 2,000 |
| DC8-63 | 800 | DT | 800 | 39,190 | 35,625 | 1,110 |
| MD-11 | 1,500 | DT | 1,500 | 35,625 | 35,625 | 1,500 |
| 777-200 | 300 | TD | 510 | 35,625 | 35,625 | 510 |
| | 15,200 | | | | | 11,250 |

considered to be 35,625 lb, including the critical airplane. Note that this table is identical to Table 4-3 for the flexible pavement examples.

- Before the maximum allowable gross weight of the critical airplane can be determined, the effect of all the traffic must be considered in terms of the stress ratio and the maximum working stress of the critical airplane. The allowable stress is calculated as

  P/TC = 1
  P/LR = 3.44
  TC/LR = 3.44

  Lifetime load repetitions = 11,250 ∗ 20 years ÷ 3.44 = 65,400
  Stress ratio = 0.575

  Allowable working stress = 700 ∗ 0.575 = 403 psi

- The input parameters to the PCA computer program are:

| | |
|---|---|
| Critical airplane | 747-400 |
| Percent weight on the main gear | 95.0 % |
| Tire pressure | 200 psi (Code *X*) |
| Slab thickness | 14.0 inches |
| Subgrade k-value | 200 (Code *C*) |
| Working stress | 403 psi |

- For these conditions, the calculated allowable gross weight of the 747-400 is 792,000 pounds. The 747-400 ACN is 66.0 RC, for a recommended runway rating of PCN 66 RCWT. As mentioned in Section 2, even though none of the aircraft in this example have tire pressures that exceed the limits of Code *X*, the code for rigid pavement should normally be *W*. (The computer calculations are on page 4-46).
- Referring to Table 4-5, it can be seen that the 747-400, the MD-11, and the 777-200 aircraft would be restricted in their operations on this runway due to their ACN's of 67 RC, 69 RC and 75 RC, respectively, being higher than the derived PCN of 66 RC. It is apparent from this result that the pavement is not adequate to handle the existing traffic, and either the operating weights will have to be restricted or pavement life will be less than originally expected. A complete analysis of this situation and the requirements for adjustments is explained in Section 5 of this document.

### 4.2.2.1.2 Example 2

This second example has the same input parameters as the first, except that the slab thickness is increased to 15 inches.

- The input parameters to the PCA computer program are:

| | |
|---|---|
| Critical airplane | 747-400 |
| Percent weight on the main gear | 95.0 % |
| Tire pressure | 200 psi (Code *X*) |
| Slab thickness | 15.0 inches |
| Subgrade k-value | 200 (Code *C*) |
| Working stress | 403 psi |

- For these conditions, the calculated allowable gross weight of the 747-400 is 880,000 pounds. The 747-400 ACN is 76.4 RC, for a recommended runway rating of PCN 77 RCWT. (The computer calculations are on page 4-47).
- It can be seen from Table 4-5 that all of 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.

### 4.2.2.1.3 Example 3

The only change in this example from the second example is that the aircraft generally do not obtain fuel at the airport. Referring to Table 3-5, the P/TC ratio changes from 1 to 2. From Equation 3-3, the TC/LR ratio for the critical 747-400 airplane becomes:

$$TC/LR = 3.44 \div 2 = 1.72$$

and the allowable working stress is:

P/TC = 2
P/LR = 3.44
TC/LR = 1.72
Lifetime load repetitions = 11,250 ∗ 20 years ÷ 1.72 = 130,800
Stress ratio = 0.550
Allowable working stress = 700 ∗ 0.511 = 385 psi

- The input parameters to the PCA computer program are:

| | |
|---|---|
| Critical airplane | 747-400 |
| Percent weight on the main gear | 95.0 % |
| Tire pressure | 200 psi (Code *X*) |
| Slab thickness | 15.0 inches |
| Subgrade k-value | 200 (Code *C*) |
| Working stress | 385 psi |

- For these conditions, the calculated allowable gross weight of the 747-400 is 834,000 pounds. The 747-400 ACN is 70.9 RC, for a recommended runway rating of PCN 71 RCWT. (The computer calculations are on page 4-48).

## 4.3 Computer Calculations

The next 23 pages show the pavement calculations and ACNs that were included in the *Technical* evaluation flexible and rigid pavement examples of this section. These listings are in order of the example presentation.

<u>Flexible pavement first example</u>



<u>Flexible pavement second example</u>



<u>Flexible pavement third example</u>



<u>Flexible pavement fourth example</u>

*******FLEXIBLE PAVEMENT ANALYSIS - S-77-1*******

**B727-200 pavement thickness requirements**

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | RADIUS (IN.) |
|---|---|---|---|---|---|
| 185000. | 47.50 | 43938. | 148.00 | 296.88 | 9.72 |

| NWL | X | Y | GRID | X | Y |
|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | START | 0.00 | 0.00 |
| 2 | 0.00 | 34.00 | END | 0.00 | 17.00 |
| | | | INCR | 0.00 | 1.89 |

| DEPARTURES (PASSES) | P/C RATIO | PVMT LIFE (YRS) | COVERAGES | ALPHA FACTOR |
|---|---|---|---|---|
| 400. | 2.92 | 20.0 | 2740. | 0.820 |

| THICKNESS (IN.) | ESWL (LB) | REQUIRED CBR FOR DEPARTURES OF: 400. |
|---|---|---|
| 22.50 | 62726. | 9.06 |
| 22.60 | 62809. | 9.00 |
| 22.70 | 62893. | 8.95 |

*******FLEXIBLE PAVEMENT ANALYSIS - ACN*******

**B727-200**

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | RADIUS (IN.) |
|---|---|---|---|---|---|
| 185000. | 47.50 | 43938. | 148.00 | 296.88 | 9.72 |

| NWL | X | Y | GRID | X | Y | ALPHA |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | START | 0.00 | 0.00 | 0.900 |
| 2 | 0.00 | 34.00 | END | 0.00 | 17.00 | |
| | | | INCR | 0.00 | 1.89 | |

| SUBGRADE CBR | SUBGRADE CODE | ESWL (LB) | X-LOC (IN.) | Y-LOC (IN.) | THICKNESS (IN.) | ACN |
|---|---|---|---|---|---|---|
| 10. | B (MEDIUM) | 63641. | 0.00 | 7.56 | 23.55 | 47.5 |

*****FLEXIBLE PAVEMENT ANALYSIS - S-77-1*****

B737-300 pavement thickness requirements

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | RADIUS (IN.) |
|---|---|---|---|---|---|
| 130000. | 47.50 | 30875. | 195.00 | 158.33 | 7.10 |

| NWL | X | Y |
|---|---|---|
| 1 | 0.00 | 0.00 |
| 2 | 0.00 | 30.50 |

| GRID | X | Y |
|---|---|---|
| START | 0.00 | 0.00 |
| END | 0.00 | 15.25 |
| INCR | 0.00 | 1.69 |

| DEPARTURES (PASSES) | P/C RATIO | PVMT LIFE (YRS) | COVERAGES | ALPHA FACTOR |
|---|---|---|---|---|
| 6000. | 3.87 | 20.0 | 31008. | 0.966 |

| THICKNESS (IN.) | ESWL (LB) | REQUIRED CBR FOR DEPARTURES OF: 6000. |
|---|---|---|
| 23.00 | 45465. | 9.09 |
| 23.10 | 45533. | 9.04 |
| 23.20 | 45602. | 8.98 |

*****FLEXIBLE PAVEMENT ANALYSIS - ACN*****

B737-300

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | RADIUS (IN.) |
|---|---|---|---|---|---|
| 130000. | 47.50 | 30875. | 195.00 | 158.33 | 7.10 |

| NWL | X | Y |
|---|---|---|
| 1 | 0.00 | 0.00 |
| 2 | 0.00 | 30.50 |

| GRID | X | Y | ALPHA |
|---|---|---|---|
| START | 0.00 | 0.00 | 0.900 |
| END | 0.00 | 15.25 | |
| INCR | 0.00 | 1.69 | |

| CBR | SUBGRADE CODE | ESWL (LB) | X-LOC (IN.) | Y-LOC (IN.) | THICKNESS (IN.) | ACN |
|---|---|---|---|---|---|---|
| 10. | B (MEDIUM) | 43199. | 0.00 | 3.39 | 19.71 | 33.3 |

*******FLEXIBLE PAVEMENT ANALYSIS - S-77-1*******

**A319-100 pavement thickness requirements**

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | RADIUS (IN.) |
|---|---|---|---|---|---|
| 145000. | 47.50 | 34438. | 196.00 | 175.70 | 7.48 |

| NWL | X | Y | GRID | X | Y |
|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | START | 0.00 | 0.00 |
| 2 | 0.00 | 36.50 | END | 0.00 | 18.25 |
| | | | INCR | 0.00 | 2.03 |

| DEPARTURES (PASSES) | P/C RATIO | PVMT LIFE (YRS) | COVERAGES | ALPHA FACTOR |
|---|---|---|---|---|
| 1200. | 3.56 | 20.0 | 6742. | 0.877 |

| THICKNESS (IN.) | ESWL (LB) | REQUIRED CBR FOR DEPARTURES OF: 1200. |
|---|---|---|
| 21.00 | 46356. | 9.09 |
| 21.10 | 46419. | 9.02 |
| 21.20 | 46482. | 8.96 |

*******FLEXIBLE PAVEMENT ANALYSIS - ACN*******

**A319-100**

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | RADIUS (IN.) |
|---|---|---|---|---|---|
| 145000. | 47.50 | 34438. | 196.00 | 175.70 | 7.48 |

| NWL | X | Y | GRID | X | Y | ALPHA |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | START | 0.00 | 0.00 | 0.900 |
| 2 | 0.00 | 36.50 | END | 0.00 | 18.25 | |
| | | | INCR | 0.00 | 2.03 | |

| SUBGRADE CBR | SUBGRADE CODE | ESWL (LB) | X-LOC (IN.) | Y-LOC (IN.) | THICKNESS (IN.) | ACN |
|---|---|---|---|---|---|---|
| 10. | B (MEDIUM) | 45941. | 0.00 | 2.03 | 20.30 | 35.3 |

*******FLEXIBLE PAVEMENT ANALYSIS - S-77-1*******

**B747-400 pavement thickness requirements**

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | RADIUS (IN.) |
|---|---|---|---|---|---|
| 820000. | 23.75 | 48688. | 200.00 | 243.44 | 8.80 |

| NWL | X | Y | GRID | X | Y |
|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | START | 0.00 | 0.00 |
| 2 | 0.00 | 44.00 | END | 29.00 | 22.00 |
| 3 | 58.00 | 44.00 | INCR | 3.22 | 2.44 |
| 4 | 58.00 | 0.00 | | | |

| DEPARTURES (PASSES) | P/C RATIO | PVMT LIFE (YRS) | COVERAGES | ALPHA FACTOR |
|---|---|---|---|---|
| 3000. | 1.72 | 20.0 | 34884. | 0.878 |

| THICKNESS (IN.) | ESWL (LB) | REQUIRED CBR FOR DEPARTURES OF: 3000. |
|---|---|---|
| 31.10 | 97719. | 9.05 |
| 31.20 | 97904. | 9.01 |
| 31.30 | 98088. | 8.97 |

*******FLEXIBLE PAVEMENT ANALYSIS - ACN*******

**B747-400**

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | RADIUS (IN.) |
|---|---|---|---|---|---|
| 820000. | 23.75 | 48688. | 200.00 | 243.44 | 8.80 |

| NWL | X | Y | GRID | X | Y | ALPHA |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | START | 0.00 | 0.00 | 0.825 |
| 2 | 0.00 | 44.00 | END | 29.00 | 22.00 | |
| 3 | 58.00 | 44.00 | INCR | 3.22 | 2.44 | |
| 4 | 58.00 | 0.00 | | | | |

| SUBGRADE CBR | SUBGRADE CODE | ESWL (LB) | X-LOC (IN.) | Y-LOC (IN.) | THICKNESS (IN.) | ACN |
|---|---|---|---|---|---|---|
| 10. | B (MEDIUM) | 89611. | 3.22 | 4.89 | 26.47 | 60.0 |

*******FLEXIBLE PAVEMENT ANALYSIS - S-77-1*******

**B767-300ER pavement thickness requirements**

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | RADIUS (IN.) |
|---|---|---|---|---|---|
| 370000. | 47.50 | 43938. | 190.00 | 231.25 | 8.58 |

| NWL | X | Y | GRID | X | Y |
|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | START | 0.00 | 0.00 |
| 2 | 0.00 | 45.00 | END | 28.00 | 22.50 |
| 3 | 56.00 | 45.00 | INCR | 3.11 | 2.50 |
| 4 | 56.00 | 0.00 | | | |

| DEPARTURES (PASSES) | P/C RATIO | PVMT LIFE (YRS) | COVERAGES | ALPHA FACTOR |
|---|---|---|---|---|
| 2000. | 1.82 | 20.0 | 21978. | 0.860 |

| THICKNESS (IN.) | ESWL (LB) | REQUIRED CBR FOR DEPARTURES OF: 2000. |
|---|---|---|
| 28.00 | 83263. | 9.07 |
| 28.10 | 83411. | 9.02 |
| 28.20 | 83563. | 8.98 |

*******FLEXIBLE PAVEMENT ANALYSIS - ACN*******

**B767-300ER**

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | RADIUS (IN.) |
|---|---|---|---|---|---|
| 370000. | 47.50 | 43938. | 200.00 | 219.69 | 8.36 |

| NWL | X | Y | GRID | X | Y | ALPHA |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | START | 0.00 | 0.00 | 0.825 |
| 2 | 0.00 | 45.00 | END | 28.00 | 22.50 | |
| 3 | 56.00 | 45.00 | INCR | 3.11 | 2.50 | |
| 4 | 56.00 | 0.00 | | | | |

| SUBGRADE CBR | SUBGRADE CODE | ESWL (LB) | X-LOC (IN.) | Y-LOC (IN.) | THICKNESS (IN.) | ACN |
|---|---|---|---|---|---|---|
| 10. | B (MEDIUM) | 78153. | 3.11 | 5.00 | 24.69 | 52.2 |

*****FLEXIBLE PAVEMENT ANALYSIS - S-77-1*****

DC8-63/73 pavement thickness requirements

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | RADIUS (IN.) |
|---|---|---|---|---|---|
| 330000. | 47.50 | 39188. | 194.00 | 202.00 | 8.02 |

| NWL | X | Y |
|---|---|---|
| 1 | 0.00 | 0.00 |
| 2 | 0.00 | 32.00 |
| 3 | 55.00 | 32.00 |
| 4 | 55.00 | 0.00 |

| GRID | X | Y |
|---|---|---|
| START | 0.00 | 0.00 |
| END | 27.50 | 16.00 |
| INCR | 3.06 | 1.78 |

| DEPARTURES (PASSES) | P/C RATIO | PVMT LIFE (YRS) | COVERAGES | ALPHA FACTOR |
|---|---|---|---|---|
| 800. | 1.66 | 20.0 | 9639. | 0.825 |

| THICKNESS (IN.) | ESWL (LB) | REQUIRED CBR FOR DEPARTURES OF: 800. |
|---|---|---|
| 26.60 | 81059. | 9.06 |
| 26.70 | 81231. | 9.01 |
| 26.80 | 81402. | 8.96 |

*****FLEXIBLE PAVEMENT ANALYSIS - ACN*****

DC8-63/73

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | RADIUS (IN.) |
|---|---|---|---|---|---|
| 330000. | 47.50 | 39188. | 194.00 | 202.00 | 8.02 |

| NWL | X | Y |
|---|---|---|
| 1 | 0.00 | 0.00 |
| 2 | 0.00 | 32.00 |
| 3 | 55.00 | 32.00 |
| 4 | 55.00 | 0.00 |

| GRID | X | Y | ALPHA |
|---|---|---|---|
| START | 0.00 | 0.00 | 0.825 |
| END | 27.50 | 16.00 | |
| INCR | 3.06 | 1.78 | |

| SUBGRADE CBR | SUBGRADE CODE | ESWL (LB) | X-LOC (IN.) | Y-LOC (IN.) | THICKNESS (IN.) | ACN |
|---|---|---|---|---|---|---|
| 10. | B (MEDIUM) | 77704. | 3.06 | 10.67 | 24.69 | 52.2 |

*******FLEXIBLE PAVEMENT ANALYSIS - S-77-1*******

**MD-11 pavement thickness requirements**

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | RADIUS (IN.) |
|---|---|---|---|---|---|
| 515000. | 40.00 | 51500. | 205.00 | 251.22 | 8.94 |

| NWL | X | Y | GRID | X | Y |
|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | START | 0.00 | 0.00 |
| 2 | 0.00 | 54.00 | END | 32.00 | 27.00 |
| 3 | 64.00 | 54.00 | INCR | 3.56 | 3.00 |
| 4 | 64.00 | 0.00 | | | |

| DEPARTURES (PASSES) | P/C RATIO | PVMT LIFE (YRS) | COVERAGES | ALPHA FACTOR |
|---|---|---|---|---|
| 1500. | 1.83 | 20.0 | 16393. | 0.848 |

| THICKNESS (IN.) | ESWL (LB) | REQUIRED CBR FOR DEPARTURES OF: 1500. |
|---|---|---|
| 29.00 | 91243. | 9.01 |
| 29.10 | 91389. | 8.97 |
| 29.20 | 91543. | 8.93 |

*******FLEXIBLE PAVEMENT ANALYSIS - ACN*******

**MD-11**

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | RADIUS (IN.) |
|---|---|---|---|---|---|
| 515000. | 40.00 | 51500. | 205.00 | 251.22 | 8.94 |

| NWL | X | Y | GRID | X | Y | ALPHA |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | START | 0.00 | 0.00 | 0.825 |
| 2 | 0.00 | 54.00 | END | 32.00 | 27.00 | |
| 3 | 64.00 | 54.00 | INCR | 3.56 | 3.00 | |
| 4 | 64.00 | 0.00 | | | | |

| SUBGRADE CBR | SUBGRADE CODE | ESWL (LB) | X-LOC (IN.) | Y-LOC (IN.) | THICKNESS (IN.) | ACN |
|---|---|---|---|---|---|---|
| 10. | B (MEDIUM) | 86915. | 3.56 | 3.00 | 26.01 | 57.9 |

*****FLEXIBLE PAVEMENT ANALYSIS - S-77-1*****

B777-200 pavement thickness requirements

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | RADIUS (IN.) |
|---|---|---|---|---|---|
| 600000. | 47.50 | 47500. | 215.00 | 220.93 | 8.39 |

| NWL | X | Y |
|---|---|---|
| 1 | 0.00 | 0.00 |
| 2 | 0.00 | 55.00 |
| 3 | 57.00 | 0.00 |
| 4 | 57.00 | 55.00 |
| 5 | 114.00 | 0.00 |
| 6 | 114.00 | 55.00 |

| GRID | X | Y |
|---|---|---|
| START | 57.00 | 0.00 |
| END | 85.50 | 27.50 |
| INCR | 3.17 | 3.06 |

| DEPARTURES (PASSES) | P/C RATIO | PVMT LIFE (YRS) | COVERAGES | ALPHA FACTOR |
|---|---|---|---|---|
| 300. | 1.39 | 20.0 | 4317. | 0.691 |

| THICKNESS (IN.) | ESWL (LB) | REQUIRED CBR FOR DEPARTURES OF: 300. |
|---|---|---|
| 24.90 | 100017. | 9.02 |
| 25.00 | 100226. | 8.97 |

*****FLEXIBLE PAVEMENT ANALYSIS - ACN*****

B777-200

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | RADIUS (IN.) |
|---|---|---|---|---|---|
| 600000. | 47.50 | 47500. | 215.00 | 220.93 | 8.39 |

| NWL | X | Y |
|---|---|---|
| 1 | 0.00 | 0.00 |
| 2 | 0.00 | 55.00 |
| 3 | 57.00 | 0.00 |
| 4 | 57.00 | 55.00 |
| 5 | 114.00 | 0.00 |
| 6 | 114.00 | 55.00 |

| GRID | X | Y | ALPHA |
|---|---|---|---|
| START | 57.00 | 0.00 | 0.720 |
| END | 85.50 | 27.50 | |
| INCR | 3.17 | 3.06 | |

THE FOLLOWING FLEXIBLE PAVEMENT ACNs ARE CALCULATED USING ALPHA FACTORS DESIGNATED **PRELIMINARY** BY ICAO

| SUBGRADE CBR | CODE | ESWL (LB) | X-LOC (IN.) | Y-LOC (IN.) | THICKNESS (IN.) | ACN |
|---|---|---|---|---|---|---|
| 10. | B (MEDIUM) | 98968. | 57.00 | 3.06 | 24.42 | 51.1 |

*****FLEXIBLE PAVEMENT ANALYSIS - S-77-1*****

B747-400 critical airplane allowable gross weight

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | RADIUS (IN.) |
|---|---|---|---|---|---|
| 771000. | 23.75 | 45778. | 200.00 | 228.89 | 8.54 |

| NWL | X | Y | GRID | X | Y |
|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | START | 0.00 | 0.00 |
| 2 | 0.00 | 44.00 | END | 29.00 | 22.00 |
| 3 | 58.00 | 44.00 | INCR | 3.22 | 2.44 |
| 4 | 58.00 | 0.00 | | | |

| DEPARTURES (PASSES) | P/C RATIO | PVMT LIFE (YRS) | COVERAGES | ALPHA FACTOR |
|---|---|---|---|---|
| 11250. | 1.72 | 20.0 | 130814. | 0.922 |

| THICKNESS (IN.) | ESWL (LB) | REQUIRED CBR FOR DEPARTURES OF: 11250. |
|---|---|---|
| 32.00 | 93288. | 9.00 |

*****FLEXIBLE PAVEMENT ANALYSIS - ACN*****

B747-400

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | RADIUS (IN.) |
|---|---|---|---|---|---|
| 771000. | 23.75 | 45778. | 200.00 | 228.89 | 8.54 |

| NWL | X | Y | GRID | X | Y | ALPHA |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | START | 0.00 | 0.00 | 0.825 |
| 2 | 0.00 | 44.00 | END | 29.00 | 22.00 | |
| 3 | 58.00 | 44.00 | INCR | 3.22 | 2.44 | |
| 4 | 58.00 | 0.00 | | | | |

| CBR | SUBGRADE CODE | ESWL (LB) | X-LOC (IN.) | Y-LOC (IN.) | THICKNESS (IN.) | ACN |
|---|---|---|---|---|---|---|
| 10. | B (MEDIUM) | 82385. | 3.22 | 4.89 | 25.36 | 55.1 |

*******FLEXIBLE PAVEMENT ANALYSIS - S-77-1*******

**B747-400  allowable gw for increased thickness**

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | RADIUS (IN.) |
|---|---|---|---|---|---|
| 864000. | 23.75 | 51300. | 200.00 | 256.50 | 9.04 |

| NWL | X | Y | GRID | X | Y |
|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | START | 0.00 | 0.00 |
| 2 | 0.00 | 44.00 | END | 29.00 | 22.00 |
| 3 | 58.00 | 44.00 | INCR | 3.22 | 2.44 |
| 4 | 58.00 | 0.00 | | | |

| DEPARTURES (PASSES) | P/C RATIO | PVMT LIFE (YRS) | COVERAGES | ALPHA FACTOR |
|---|---|---|---|---|
| 11250. | 1.72 | 20.0 | 130814. | 0.922 |

| THICKNESS (IN.) | ESWL (LB) | REQUIRED CBR FOR DEPARTURES OF: 11250. |
|---|---|---|
| 35.00 | 110979. | 9.00 |

*******FLEXIBLE PAVEMENT ANALYSIS - ACN*******

**B747-400**

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | RADIUS (IN.) |
|---|---|---|---|---|---|
| 864000. | 23.75 | 51300. | 200.00 | 256.50 | 9.04 |

| NWL | X | Y | GRID | X | Y | ALPHA |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | START | 0.00 | 0.00 | 0.825 |
| 2 | 0.00 | 44.00 | END | 29.00 | 22.00 | |
| 3 | 58.00 | 44.00 | INCR | 3.22 | 2.44 | |
| 4 | 58.00 | 0.00 | | | | |

| SUBGRADE CBR | SUBGRADE CODE | ESWL (LB) | X-LOC (IN.) | Y-LOC (IN.) | THICKNESS (IN.) | ACN |
|---|---|---|---|---|---|---|
| 10. | B (MEDIUM) | 96270. | 3.22 | 7.33 | 27.46 | 64.6 |

*******FLEXIBLE PAVEMENT ANALYSIS - S-77-1*******

**B747-400 central taxiway**

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | RADIUS (IN.) |
|---|---|---|---|---|---|
| 832000. | 23.75 | 49400. | 200.00 | 247.00 | 8.87 |

| NWL | X | Y | GRID | X | Y |
|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | START | 0.00 | 0.00 |
| 2 | 0.00 | 44.00 | END | 29.00 | 22.00 |
| 3 | 58.00 | 44.00 | INCR | 3.22 | 2.44 |
| 4 | 58.00 | 0.00 | | | |

| DEPARTURES (PASSES) | P/C RATIO | PVMT LIFE (YRS) | COVERAGES | ALPHA FACTOR |
|---|---|---|---|---|
| 11250. | 0.86 | 20.0 | 261628. | 0.940 |

| THICKNESS (IN.) | ESWL (LB) | REQUIRED CBR FOR DEPARTURES OF: 11250. |
|---|---|---|
| 35.00 | 106759. | 9.00 |

*******FLEXIBLE PAVEMENT ANALYSIS - ACN*******

**B747-400**

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | RADIUS (IN.) |
|---|---|---|---|---|---|
| 832000. | 23.75 | 49400. | 200.00 | 247.00 | 8.87 |

| NWL | X | Y | GRID | X | Y | ALPHA |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | START | 0.00 | 0.00 | 0.825 |
| 2 | 0.00 | 44.00 | END | 29.00 | 22.00 | |
| 3 | 58.00 | 44.00 | INCR | 3.22 | 2.44 | |
| 4 | 58.00 | 0.00 | | | | |

| SUBGRADE CBR | SUBGRADE CODE | ESWL (LB) | X-LOC (IN.) | Y-LOC (IN.) | THICKNESS (IN.) | ACN |
|---|---|---|---|---|---|---|
| 10. | B (MEDIUM) | 91408. | 3.22 | 4.89 | 26.74 | 61.3 |

*******FLEXIBLE PAVEMENT ANALYSIS - S-77-1*******

**B747-400 reduced pavement life**

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | RADIUS (IN.) |
|---|---|---|---|---|---|
| 864000. | 23.75 | 51300. | 200.00 | 256.50 | 9.04 |

| NWL | X | Y | GRID | X | Y |
|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | START | 0.00 | 0.00 |
| 2 | 0.00 | 44.00 | END | 29.00 | 22.00 |
| 3 | 58.00 | 44.00 | INCR | 3.22 | 2.44 |
| 4 | 58.00 | 0.00 | | | |

| DEPARTURES (PASSES) | P/C RATIO | PVMT LIFE (YRS) | COVERAGES | ALPHA FACTOR |
|---|---|---|---|---|
| 11250. | 0.86 | 10.0 | 130814. | 0.922 |

| THICKNESS (IN.) | ESWL (LB) | REQUIRED CBR FOR DEPARTURES OF: 11250. |
|---|---|---|
| 35.00 | 110979. | 9.00 |

*******FLEXIBLE PAVEMENT ANALYSIS - ACN*******

**B747-400**

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | RADIUS (IN.) |
|---|---|---|---|---|---|
| 864000. | 23.75 | 51300. | 200.00 | 256.50 | 9.04 |

| NWL | X | Y | GRID | X | Y | ALPHA |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | START | 0.00 | 0.00 | 0.825 |
| 2 | 0.00 | 44.00 | END | 29.00 | 22.00 | |
| 3 | 58.00 | 44.00 | INCR | 3.22 | 2.44 | |
| 4 | 58.00 | 0.00 | | | | |

| SUBGRADE CBR | SUBGRADE CODE | ESWL (LB) | X-LOC (IN.) | Y-LOC (IN.) | THICKNESS (IN.) | ACN |
|---|---|---|---|---|---|---|
| 10. | B (MEDIUM) | 96270. | 3.22 | 7.33 | 27.46 | 64.6 |

*****RIGID PAVEMENT ANALYSIS - ACN*****

B727-200

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | ELLIPSE RADII A | B |
|---|---|---|---|---|---|---|
| 185000. | 47.50 | 43938. | 148.00 | 296.88 | 11.92 | 7.93 |

| NWL | X | Y |
|---|---|---|
| 1 | 0.00 | 0.00 |
| 2 | 0.00 | 34.00 |

| SUBGRADE MODULUS | CODE | X-LOC (IN.) | Y-LOC (IN.) | THICKNESS (IN.) | ACN RIGID |
|---|---|---|---|---|---|
| 150. | C (LOW) | 0.00 | 4.03 | 13.61 | 54.9 |

*****RIGID PAVEMENT ANALYSIS - ACN*****

B737-300

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | ELLIPSE RADII A | B |
|---|---|---|---|---|---|---|
| 130000. | 47.50 | 30875. | 201.00 | 153.61 | 8.57 | 5.70 |

| NWL | X | Y |
|---|---|---|
| 1 | 0.00 | 0.00 |
| 2 | 0.00 | 30.50 |

| SUBGRADE MODULUS | CODE | X-LOC (IN.) | Y-LOC (IN.) | THICKNESS (IN.) | ACN RIGID |
|---|---|---|---|---|---|
| 150. | C (LOW) | 0.00 | 2.25 | 11.80 | 40.5 |

*****RIGID PAVEMENT ANALYSIS - ACN*****

A319-100

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | ELLIPSE RADII A | B |
|---|---|---|---|---|---|---|
| 150000. | 47.50 | 35625. | 200.00 | 178.13 | 9.23 | 6.14 |

| NWL | X | Y |
|---|---|---|
| 1 | 0.00 | 0.00 |
| 2 | 0.00 | 36.50 |

| SUBGRADE MODULUS | CODE | X-LOC (IN.) | Y-LOC (IN.) | THICKNESS (IN.) | ACN RIGID |
|---|---|---|---|---|---|
| 150. | C (LOW) | 0.02 | 2.10 | 12.33 | 44.5 |

*****RIGID PAVEMENT ANALYSIS - ACN*****

B747-400

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | ELLIPSE RADII A | B |
|---|---|---|---|---|---|---|
| 800000. | 23.75 | 47500. | 200.00 | 237.50 | 10.66 | 7.09 |

| NWL | X | Y |
|---|---|---|
| 1 | 0.00 | 0.00 |
| 2 | 0.00 | 44.00 |
| 3 | 58.00 | 44.00 |
| 4 | 58.00 | 0.00 |

| SUBGRADE MODULUS | CODE | X-LOC (IN.) | Y-LOC (IN.) | THICKNESS (IN.) | ACN RIGID |
|---|---|---|---|---|---|
| 150. | C (LOW) | 1.04 | 0.99 | 14.92 | 66.9 |

*****RIGID PAVEMENT ANALYSIS - ACN*****

B767-300ER

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | ELLIPSE RADII A | B |
|---|---|---|---|---|---|---|
| 370000. | 47.50 | 43938. | 200.00 | 219.69 | 10.25 | 6.82 |

| NWL | X | Y |
|---|---|---|
| 1 | 0.00 | 0.00 |
| 2 | 0.00 | 45.00 |
| 3 | 56.00 | 45.00 |
| 4 | 56.00 | 0.00 |

| SUBGRADE MODULUS | CODE | X-LOC (IN.) | Y-LOC (IN.) | THICKNESS (IN.) | ACN RIGID |
|---|---|---|---|---|---|
| 150. | C (LOW) | 1.03 | 0.87 | 14.22 | 60.4 |

*****RIGID PAVEMENT ANALYSIS - ACN*****

DC8-63/73

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | ELLIPSE RADII A | B |
|---|---|---|---|---|---|---|
| 330000. | 47.50 | 39188. | 194.00 | 202.00 | 9.83 | 6.54 |

| NWL | X | Y |
|---|---|---|
| 1 | 0.00 | 0.00 |
| 2 | 0.00 | 32.00 |
| 3 | 55.00 | 32.00 |
| 4 | 55.00 | 0.00 |

| SUBGRADE MODULUS | CODE | X-LOC (IN.) | Y-LOC (IN.) | THICKNESS (IN.) | ACN RIGID |
|---|---|---|---|---|---|
| 150. | C (LOW) | 1.16 | 1.26 | 14.28 | 60.9 |

*****RIGID PAVEMENT ANALYSIS - ACN*****

MD-11

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | ELLIPSE RADII A | B |
|---|---|---|---|---|---|---|
| 550000. | 40.00 | 55000. | 205.00 | 268.29 | 11.33 | 7.54 |

| NWL | X | Y |
|---|---|---|
| 1 | 0.00 | 0.00 |
| 2 | 0.00 | 54.00 |
| 3 | 64.00 | 54.00 |
| 4 | 64.00 | 0.00 |

| SUBGRADE MODULUS | CODE | X-LOC (IN.) | Y-LOC (IN.) | THICKNESS (IN.) | ACN RIGID |
|---|---|---|---|---|---|
| 150. | C (LOW) | 0.92 | 0.75 | 15.31 | 70.7 |

*****RIGID PAVEMENT ANALYSIS - ACN*****

B777-200

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | ELLIPSE RADII A | B |
|---|---|---|---|---|---|---|
| 600000. | 47.50 | 47500. | 215.00 | 220.93 | 10.28 | 6.84 |

| NWL | X | Y |
|---|---|---|
| 1 | 0.00 | 0.00 |
| 2 | 0.00 | 55.00 |
| 3 | 57.00 | 0.00 |
| 4 | 57.00 | 55.00 |
| 5 | 114.00 | 0.00 |
| 6 | 114.00 | 55.00 |

THE FOLLOWING FLEXIBLE PAVEMENT ACNs ARE CALCULATED USING ALPHA FACTORS DESIGNATED **PRELIMINARY** BY ICAO

| SUBGRADE MODULUS | CODE | X-LOC (IN.) | Y-LOC (IN.) | THICKNESS (IN.) | ACN RIGID |
|---|---|---|---|---|---|
| 150. | C (LOW) | 57.06 | 1.15 | 15.80 | 75.6 |

*****RIGID PAVEMENT ANALYSIS - PCA*****

B727-200 pavement thickness requirements

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | ELLIPSE RADII A | B |
|---|---|---|---|---|---|---|
| 185000. | 47.50 | 43938. | 148.00 | 296.88 | 11.92 | 7.93 |

| SUBGRADE MODULUS | POISSON'S RATIO | ELASTIC MODULUS |
|---|---|---|
| 200. | 0.15 | 0.40E+07 |

| NWL | X | Y |
|---|---|---|
| 1 | 0.00 | 0.00 |
| 2 | 0.00 | 34.00 |

***SEARCH FOR MAXIMUM STRESS POINT***

| PAVEMENT THICKNESS | RAD. REL. STIFFNESS | MAX STRESS PT-ANGLE X | Y | BETA | MAXIMUM STRESS |
|---|---|---|---|---|---|
| 11.60 | 40.39 | 0.02 | 3.88 | 0.01 | 485.8 |
| 11.70 | 40.65 | -0.01 | 3.88 | -0.01 | 479.7 |

*****RIGID PAVEMENT ANALYSIS - PCA*****

B737-300 pavement thickness requirements

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | ELLIPSE RADII A | B |
|---|---|---|---|---|---|---|
| 130000. | 47.50 | 30875. | 201.00 | 153.61 | 8.57 | 5.70 |

| SUBGRADE MODULUS | POISSON'S RATIO | ELASTIC MODULUS |
|---|---|---|
| 200. | 0.15 | 0.40E+07 |

| NWL | X | Y |
|---|---|---|
| 1 | 0.00 | 0.00 |
| 2 | 0.00 | 30.50 |

***SEARCH FOR MAXIMUM STRESS POINT***

| PAVEMENT THICKNESS | RAD. REL. STIFFNESS | MAX STRESS PT-ANGLE X | Y | BETA | MAXIMUM STRESS |
|---|---|---|---|---|---|
| 11.00 | 38.81 | 0.00 | 2.20 | 0.00 | 427.1 |
| 11.10 | 39.08 | 0.00 | 2.19 | 0.00 | 421.2 |
| 11.20 | 39.34 | 0.00 | 2.19 | 0.00 | 415.4 |

*****RIGID PAVEMENT ANALYSIS - PCA*****

A319-100 pavement thickness requirements

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | ELLIPSE RADII A | ELLIPSE RADII B |
|---|---|---|---|---|---|---|
| 150000. | 47.50 | 35625. | 173.00 | 205.92 | 9.92 | 6.60 |

| SUBGRADE MODULUS | POISSON'S RATIO | ELASTIC MODULUS |
|---|---|---|
| 200. | 0.15 | 0.40E+07 |

| NWL | X | Y |
|---|---|---|
| 1 | 0.00 | 0.00 |
| 2 | 0.00 | 36.50 |

***SEARCH FOR MAXIMUM STRESS POINT***

| PAVEMENT THICKNESS | RAD. REL. STIFFNESS | MAX STRESS PT-ANGLE X | Y | BETA | MAXIMUM STRESS |
|---|---|---|---|---|---|
| 10.70 | 38.02 | -0.04 | 2.30 | -0.02 | 463.3 |
| 10.80 | 38.28 | -0.04 | 2.30 | -0.02 | 456.8 |
| 10.90 | 38.55 | -0.04 | 2.30 | -0.02 | 450.6 |

*****RIGID PAVEMENT ANALYSIS - PCA*****

B747-400 pavement thickness requirements

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | ELLIPSE RADII A | ELLIPSE RADII B |
|---|---|---|---|---|---|---|
| 800000. | 23.75 | 47500. | 200.00 | 237.50 | 10.66 | 7.09 |

| SUBGRADE MODULUS | POISSON'S RATIO | ELASTIC MODULUS |
|---|---|---|
| 200. | 0.15 | 0.40E+07 |

| NWL | X | Y |
|---|---|---|
| 1 | 0.00 | 0.00 |
| 2 | 0.00 | 44.00 |
| 3 | 58.00 | 44.00 |
| 4 | 58.00 | 0.00 |

***SEARCH FOR MAXIMUM STRESS POINT***

| PAVEMENT THICKNESS | RAD. REL. STIFFNESS | MAX STRESS PT-ANGLE X | Y | BETA | MAXIMUM STRESS |
|---|---|---|---|---|---|
| 13.20 | 44.50 | 0.86 | 0.85 | -58.64 | 438.1 |
| 13.30 | 44.75 | 0.86 | 0.85 | -58.65 | 433.9 |
| 13.40 | 45.01 | 0.86 | 0.85 | -58.65 | 429.8 |

*****RIGID PAVEMENT ANALYSIS - PCA*****

B767-300ER pavement thickness requirements

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | ELLIPSE RADII A | B |
|---|---|---|---|---|---|---|
| 370000. | 47.50 | 43938. | 200.00 | 219.69 | 10.25 | 6.82 |

| SUBGRADE MODULUS | POISSON'S RATIO | ELASTIC MODULUS |
|---|---|---|
| 200. | 0.15 | 0.40E+07 |

| NWL | X | Y |
|---|---|---|
| 1 | 0.00 | 0.00 |
| 2 | 0.00 | 45.00 |
| 3 | 56.00 | 45.00 |
| 4 | 56.00 | 0.00 |

***SEARCH FOR MAXIMUM STRESS POINT***

| PAVEMENT THICKNESS | RAD. REL. STIFFNESS | MAX STRESS PT-ANGLE X | Y | BETA | MAXIMUM STRESS |
|---|---|---|---|---|---|
| 12.20 | 41.95 | 0.48 | 0.70 | -57.46 | 455.7 |
| 12.30 | 42.20 | 0.70 | 0.68 | -57.57 | 451.0 |
| 12.40 | 42.46 | 0.72 | 0.68 | -57.58 | 446.4 |
| 12.50 | 42.72 | 0.72 | 0.68 | -57.58 | 441.9 |

*****RIGID PAVEMENT ANALYSIS - PCA*****

DC8-63/73 pavement thickness requirements

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | ELLIPSE RADII A | B |
|---|---|---|---|---|---|---|
| 330000. | 47.50 | 39188. | 194.00 | 202.00 | 9.83 | 6.54 |

| SUBGRADE MODULUS | POISSON'S RATIO | ELASTIC MODULUS |
|---|---|---|
| 200. | 0.15 | 0.40E+07 |

| NWL | X | Y |
|---|---|---|
| 1 | 0.00 | 0.00 |
| 2 | 0.00 | 32.00 |
| 3 | 55.00 | 32.00 |
| 4 | 55.00 | 0.00 |

***SEARCH FOR MAXIMUM STRESS POINT***

| PAVEMENT THICKNESS | RAD. REL. STIFFNESS | MAX STRESS PT-ANGLE X | Y | BETA | MAXIMUM STRESS |
|---|---|---|---|---|---|
| 12.00 | 41.43 | 0.36 | 1.04 | -63.65 | 471.1 |
| 12.10 | 41.69 | 0.89 | 1.10 | -64.28 | 466.2 |
| 12.20 | 41.95 | 0.89 | 1.10 | -64.32 | 461.3 |

*****RIGID PAVEMENT ANALYSIS - PCA*****

MD-11 required pavement thickness

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | ELLIPSE RADII A | B |
|---|---|---|---|---|---|---|
| 550000. | 40.00 | 55000. | 205.00 | 268.29 | 11.33 | 7.54 |

| SUBGRADE MODULUS | POISSON'S RATIO | ELASTIC MODULUS |
|---|---|---|
| 200. | 0.15 | 0.40E+07 |

| NWL | X | Y |
|---|---|---|
| 1 | 0.00 | 0.00 |
| 2 | 0.00 | 54.00 |
| 3 | 64.00 | 54.00 |
| 4 | 64.00 | 0.00 |

***SEARCH FOR MAXIMUM STRESS POINT***

| PAVEMENT THICKNESS | RAD. REL. STIFFNESS | MAX STRESS PT-ANGLE X | Y | BETA | MAXIMUM STRESS |
|---|---|---|---|---|---|
| 13.00 | 43.99 | 0.60 | 0.57 | -56.94 | 460.6 |
| 13.10 | 44.25 | 0.60 | 0.57 | -56.93 | 456.1 |
| 13.20 | 44.50 | 0.60 | 0.57 | -56.91 | 451.8 |

*****RIGID PAVEMENT ANALYSIS - PCA*****

B777-200 required pavement thickness

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | ELLIPSE RADII A | B |
|---|---|---|---|---|---|---|
| 600000. | 47.50 | 47500. | 215.00 | 220.93 | 10.28 | 6.84 |

| SUBGRADE MODULUS | POISSON'S RATIO | ELASTIC MODULUS |
|---|---|---|
| 200. | 0.15 | 0.40E+07 |

| NWL | X | Y |
|---|---|---|
| 1 | 0.00 | 0.00 |
| 2 | 0.00 | 55.00 |
| 3 | 57.00 | 0.00 |
| 4 | 57.00 | 55.00 |
| 5 | 114.00 | 0.00 |
| 6 | 114.00 | 55.00 |

***SEARCH FOR MAXIMUM STRESS POINT***

| PAVEMENT THICKNESS | RAD. REL. STIFFNESS | MAX STRESS PT-ANGLE X | Y | BETA | MAXIMUM STRESS |
|---|---|---|---|---|---|
| 12.10 | 41.69 | 57.02 | 0.77 | 90.00 | 502.3 |
| 12.20 | 41.95 | 57.02 | 0.77 | 90.00 | 497.7 |
| 12.30 | 42.20 | 57.02 | 0.77 | 90.00 | 493.1 |

*****RIGID PAVEMENT ANALYSIS - PCA*****

B747-400 allowable gross weight

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | ELLIPSE RADII A | B |
|---|---|---|---|---|---|---|
| 792000. | 23.75 | 47025. | 200.00 | 235.13 | 10.60 | 7.06 |

| SUBGRADE MODULUS | POISSON'S RATIO | ELASTIC MODULUS |
|---|---|---|
| 200. | 0.15 | 0.40E+07 |

| NWL | X | Y |
|---|---|---|
| 1 | 0.00 | 0.00 |
| 2 | 0.00 | 44.00 |
| 3 | 58.00 | 44.00 |
| 4 | 58.00 | 0.00 |

***SEARCH FOR MAXIMUM STRESS POINT***

| PAVEMENT THICKNESS | RAD. REL. STIFFNESS | MAX STRESS X | Y | PT-ANGLE BETA | MAXIMUM STRESS |
|---|---|---|---|---|---|
| 14.00 | 46.51 | 0.90 | 0.87 | -58.71 | 402.9 |

*****RIGID PAVEMENT ANALYSIS - ACN*****

B747-400

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | ELLIPSE RADII A | B |
|---|---|---|---|---|---|---|
| 792000. | 23.75 | 47025. | 200.00 | 235.13 | 10.60 | 7.06 |

| NWL | X | Y |
|---|---|---|
| 1 | 0.00 | 0.00 |
| 2 | 0.00 | 44.00 |
| 3 | 58.00 | 44.00 |
| 4 | 58.00 | 0.00 |

| SUBGRADE MODULUS | CODE | X-LOC (IN.) | Y-LOC (IN.) | THICKNESS (IN.) | ACN RIGID |
|---|---|---|---|---|---|
| 150. | C (LOW) | 1.09 | 0.99 | 14.82 | 66.0 |

*******RIGID PAVEMENT ANALYSIS - PCA*******

**B747-400 increased pavement thickness**

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | ELLIPSE RADII A | B |
|---|---|---|---|---|---|---|
| 880000. | 23.75 | 52250. | 200.00 | 261.25 | 11.18 | 7.44 |

| SUBGRADE MODULUS | POISSON'S RATIO | ELASTIC MODULUS |
|---|---|---|
| 200. | 0.15 | 0.40E+07 |

| NWL | X | Y |
|---|---|---|
| 1 | 0.00 | 0.00 |
| 2 | 0.00 | 44.00 |
| 3 | 58.00 | 44.00 |
| 4 | 58.00 | 0.00 |

*****SEARCH FOR MAXIMUM STRESS POINT*****

| PAVEMENT THICKNESS | RAD. REL. STIFFNESS | MAX STRESS X | Y | PT-ANGLE BETA | MAXIMUM STRESS |
|---|---|---|---|---|---|
| 15.00 | 48.98 | 1.10 | 1.02 | -59.00 | 403.0 |

*******RIGID PAVEMENT ANALYSIS - ACN*******

**B747-400**

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | ELLIPSE RADII A | B |
|---|---|---|---|---|---|---|
| 880000. | 23.75 | 52250. | 200.00 | 261.25 | 11.18 | 7.44 |

| NWL | X | Y |
|---|---|---|
| 1 | 0.00 | 0.00 |
| 2 | 0.00 | 44.00 |
| 3 | 58.00 | 44.00 |
| 4 | 58.00 | 0.00 |

| SUBGRADE MODULUS | CODE | X-LOC (IN.) | Y-LOC (IN.) | THICKNESS (IN.) | ACN RIGID |
|---|---|---|---|---|---|
| 150. | C (LOW) | 1.32 | 1.14 | 15.87 | 76.4 |

*****RIGID PAVEMENT ANALYSIS - PCA*****

B747-400 fuel not obtained at the airport

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | ELLIPSE RADII A | B |
|---|---|---|---|---|---|---|
| 834000. | 23.75 | 49519. | 200.00 | 247.59 | 10.88 | 7.24 |

| SUBGRADE MODULUS | POISSON'S RATIO | ELASTIC MODULUS |
|---|---|---|
| 200. | 0.15 | 0.40E+07 |

***SEARCH FOR MAXIMUM STRESS POINT***

| NWL | X | Y |
|---|---|---|
| 1 | 0.00 | 0.00 |
| 2 | 0.00 | 44.00 |
| 3 | 58.00 | 44.00 |
| 4 | 58.00 | 0.00 |

| PAVEMENT THICKNESS | RAD. REL. STIFFNESS | MAX STRESS X | Y | PT-ANGLE BETA | MAXIMUM STRESS |
|---|---|---|---|---|---|
| 15.00 | 48.98 | 1.00 | 0.94 | -58.89 | 385.0 |

*****RIGID PAVEMENT ANALYSIS - ACN*****

B747-400

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | ELLIPSE RADII A | B |
|---|---|---|---|---|---|---|
| 834000. | 23.75 | 49519. | 200.00 | 247.59 | 10.88 | 7.24 |

| NWL | X | Y |
|---|---|---|
| 1 | 0.00 | 0.00 |
| 2 | 0.00 | 44.00 |
| 3 | 58.00 | 44.00 |
| 4 | 58.00 | 0.00 |

| SUBGRADE MODULUS | CODE | X-LOC (IN.) | Y-LOC (IN.) | THICKNESS (IN.) | ACN RIGID |
|---|---|---|---|---|---|
| 150. | C (LOW) | 1.18 | 42.91 | 15.33 | 70.9 |

# 5. Pavement Overloads

In the life of a pavement, it is possible that either the current or future traffic will load the pavement in such a manner that the assigned pavement rating is exceeded. As mentioned in Section 2, ICAO presents 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. This is subject to a limitation on the number of operations that the overloading airplane will have. However, this gives little guidance to the airport authority as to the impact of these adjustments on the pavement in terms of pavement life reduction or increased maintenance requirements. This section will present methods for making these adjustments 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. As stated in previous sections, allowances for overloads should be negotiated with the appropriate airport authority.

This section applies primarily to pavements that have been evaluated by using the *Technical* method. Pavements that have ratings determined by the *Using* aircraft method can still use the overload guidelines of Reference 2.

The procedures in this section to make these adjustments rely on the same pavement programs as were used to arrive at the PCNs – the S-77-1 method for flexible pavements and the PCA method for rigid pavements. The flexible pavement method is more direct in that pavement life is incorporated in the S-77-1 computer program. The rigid pavement method, however, requires that pavement life be examined outside the PCA computer program before the adjustments can be made. Both of these procedures are discussed fully, with examples given.

The adjustments for pavement overloads starts with the assumption that some of the aircraft in the traffic mix have ACNs that exceed the PCN. If the steps outlined in Section 4 have been followed for the *Technical* method, then most of the data already exists that is required to extend those results to an examination of overloading.

For flexible pavement, referring the first example of Section 4.2.1.1.1, it was found that the 747-400 and MD-11 aircraft have ACNs that exceed the recommended runway rating. Likewise, for rigid pavements, referring to Section 4.2.2.1.1, the ACNs of the 747-400, the MD-11 and the 777-200 exceed the recommended runway rating. Individually, none of the aircraft in the traffic mix have requirements that exceed the existing pavement thickness requirements. However, an anomaly is created in that each of these aircraft were included in the derivation of the allowable gross weight of the critical airplane. This, in turn, led to the recommendation of a PCN that was not adequate for the larger aircraft. To resolve these kinds of problems the airport authority will have three options on their pavement strength rating selection:

1. Let the PCN remain as derived from the *Technical* evaluation method, but retain local knowledge that there are some aircraft 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 by adding an overlay or by reconstruction in order to accommodate aircraft 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 constantly be aware of the composure 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 aircraft operations that exceed the PCN. The difficulty in doing so 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 aircraft in the traffic mix. Doing so will, however, allow operations at the required strength and for the desired pavement life.

The third option has the benefit of allowing all aircraft in the traffic mix to operate as necessary. However, by increasing the PCN, which implies a 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.

## 5.1 Adjustments for Flexible Pavement Overloads

It is most efficient to describe the procedures for flexible pavement overloading by continuing the first flexible pavement *Technical* evaluation example of Section 4.2.1.1.1 in which two aircraft of the traffic mix were found to exceed the pavement capability. In this example the derived rating was found to be PCN 55 FBXT, with the traffic of Table 4-3 operating on the runway.

### 5.1.1 Example 1

Examination of Table 4-3 indicates that the 747-400 was operating at a gross weight of 820,000 pounds, with an ACN of 60 FB. Likewise, the MD-11 had a gross weight of 515,000 pounds and an ACN of 58 FB. Reduction of the gross weights to the rated PCN of 55 FBXT would result in a gross weight for the 747-400 of 770,000 pounds and a gross weight of 495,000 pounds for the MD-11. Although these new operating weights would solve the problem of pavement loading for the airport authority, it would have the disadvantage of penalizing their customer - the airline. Additionally, new traffic with aircraft having ACNs exceeding the PCN would also have to be restricted. (The computer calculations are on page 5-17).

### 5.1.2 Example 2

Rather than penalizing airline customers by restricting operating weights, the airport authority could refurbish the pavement by the addition of an overlay. The computer steps for determining such a flexible pavement overlay are as follows:

1. Construct an ACN versus gross weight diagram such as shown in Figure 5-1 for the 747-400 critical airplane at the subgrade code previously determined. These charts are readily available in Section 7 of the manufacturer's *Airplane Characteristics for Airport Planning*. Note in this figure that the relationship of ACN and gross weight is

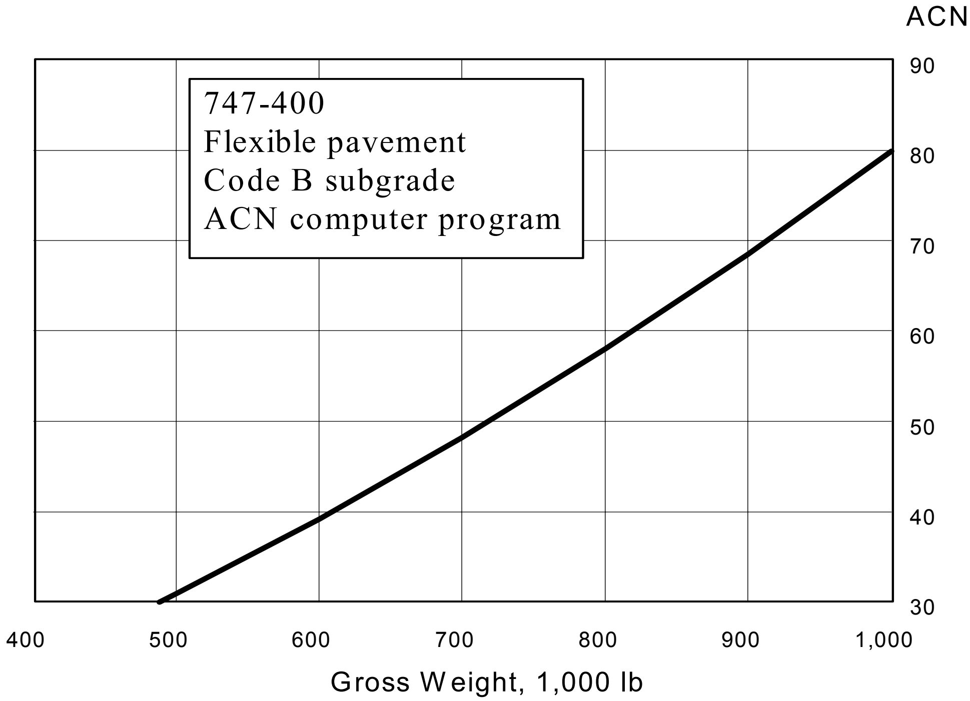


**Figure 5-1. 747-400 Flexible Pavement ACN versus Gross Weight**

not a straight line, but is slightly curved in that the line was derived by calculating the ACN at a series of gross weights, rather than just connecting the minimum and maximum values.

2. Use the S-77-1 computer program to develop data of pavement life versus ACN, such as shown in Figure 5-2. This chart is similar to that found in Section 7 of the manufacturer's *Airplane Characteristics for Airport Planning* manuals and that from the FAA Advisory Circular of Reference 6, except that subgrade CBR and pavement thickness are not shown in that 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 5-1), ACN can be substituted on the abscissa of Figure 5-2. For each pavement life number, a gross

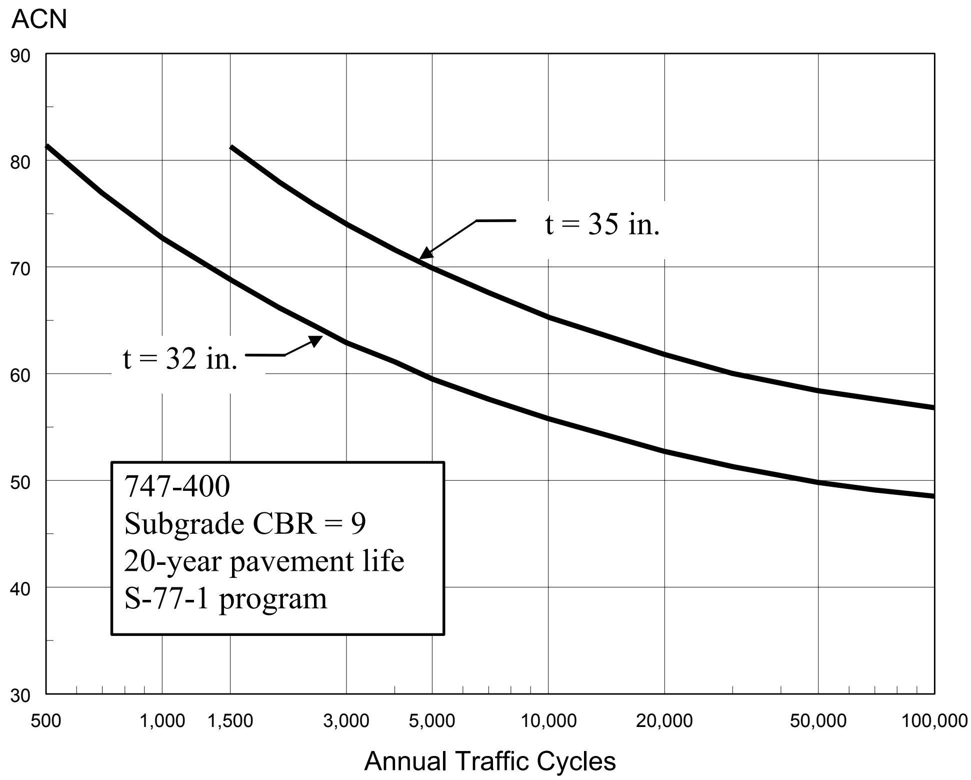


Figure 5-2: 747-400 Flexible Pavement Life vs ACN

weight is found that satisfies the subgrade CBR and pavement thickness, which is then converted to ACN. Table 5-1 contains part of the data used in the S-77-1 program to construct the curves of Figure 5-2 for a 747-400 airplane with a subgrade CBR of 9.0. (Sample computer calculations are on page 5-18)

**Table 5-1. Data for Constructing Flexible Pavement Life Curves**

| 747-400 Annual Departures | t = 32 in. Gross wt (1,000 lb) | ACN | t = 35 in. Gross wt (1,000 lb) | ACN |
|---|---|---|---|---|
| 1,500 | 903 | 72.7 | 1,012 | 81.3 |
| 2,400 | 864 | 64.6 | 969 | 76.2 |
| 3,000 | 848 | 62.9 | 950 | 74.0 |
| 5,000 | 815 | 59.5 | 913 | 69.9 |
| 11,250 | 771 | 55.1 | 864 | 64.6 |
| 20,000 | 747 | 52.7 | 837 | 61.8 |
| 50,000 | 717 | 49.8 | 804 | 58.4 |

3. It is now possible to relate the effects of gross weight, ACN, and pavement life by combining the two charts, as shown in Figure 5-3. The left hand side of this figure is the chart of Figure 5-1, while the right hand chart is that of Figure 5-2. It can now be seen how the critical airplane gross weight of 771,000 pounds (PCN 55 FBXT) equates to 11,250 equivalent 747-400 traffic cycles per year for 20 years. If the PCN were increased to 65 FBXT to accommodate the higher gross weights, the allowable traffic cycles of the critical airplane at 864,000 pounds gross weight would decrease to 2,400 per year for the 20-year time period. This effectively reduces the pavement life from 20 years to just over 4 years. (2,400 x 20 ÷ 11,250 = 4.3). (The computer calculations are on page 5-19).
4. This example shows that the 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 35 inches will be required if the pavement is to last for the required 11,250 annual departures for 20 years. This can be seen graphically in Figure 5-3.
5. Also from Figure 5-3 it can also be seen 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 of the current traffic, the required pavement overlay can be determined. Furthermore, the impact of the higher ACN aircraft can be determined in the requirements for overlay thickness. It may be necessary to repeat this process if new aircraft are added to the traffic mix in that 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.

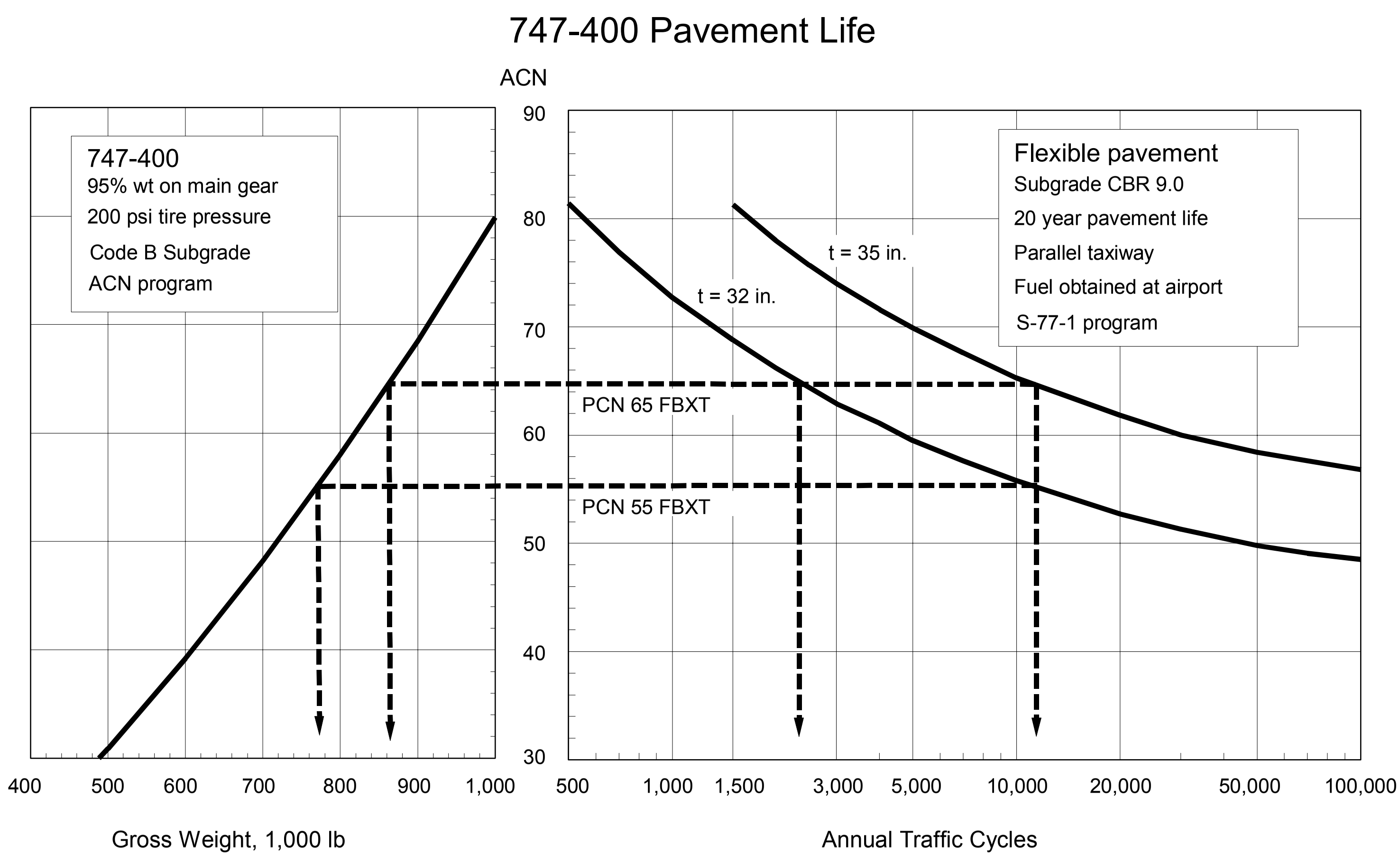


**Figure 5-3. 747-400 Flexible Pavement Life**

### 5.1.3 Example 3

This example will illustrate the effect of ICAO allowable overloading in which the ACN is no more than 10% above and PCN and the number of traffic cycles does not exceed 5% of the total annual traffic.

Table 4-3 is repeated here as Table 5-2, but with a new airplane added to the traffic mix with an ACN that is 10% above the rated PCN of 55 FBXT. The total annual departures, as shown in Table 4-4, is 15,200, of which 760 is 5% of the total. This amount is shown in Table 5-3. Normally in a calculation of critical airplane equivalent departures the $W_2$ wheel load would be listed as 35,625 pounds for a widebody airplane, but for the sake of illustration, the new airplane actual single wheel load is shown.

**Table 5-2. Flexible Pavement Overload Airplane Added**

| Airplane | Operating Weight, lb | Tire Pressure (psi) | ACN | Annual Departures | P/C Ratio | Required t, (in.) |
|---|---|---|---|---|---|---|
| 727-200 | 185,000 | 148 | 48 FB | 400 | 2.92 | 22.6 |
| 737-300 | 130,000 | 195 | 34 FB | 6,000 | 3.87 | 23.2 |
| A319-100 | 145,000 | 196 | 35 FB | 1,200 | 3.56 | 21.1 |
| 747-400 | 820,000 | 200 | 60 FB | 3,000 | 1.72 | 31.2 |
| 767-300ER | 370,000 | 190 | 52 FB | 2,000 | 1.82 | 28.4 |
| DC8-63 | 330,000 | 194 | 52 FB | 800 | 1.66 | 27.6 |
| MD-11 | 515,000 | 205 | 58 FB | 1,500 | 1.83 | 29.0 |
| 777-200 | 600,000 | 215 | 51 FB | 300 | 1.39 | 24.9 |
| **L1011-500** | **456,000** | **184** | **60 FB** | **760** | **1.72** | **28.5** |

The end result on the critical airplane calculation is that for an equivalent annual departure level of 14,810, the allowable gross weight is reduced from 771,000 to 758,000 pounds for an ACN of 53.8 FB. Alternately, for the same allowable gross weight of 771,000 pounds and an ACN of 55.1 FB, the pavement thickness would have to be increased to 32.4 inches from the current 32.0 inches. (The computer calculations are shown on pages 5-20 to 5-22).

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% overload and no more than 5% traffic increase. With this type of knowledge as to the impact of new aircraft 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 5-3. Flexible Pavement New Airplane Equivalent Traffic**

| Airplane | Annual Departures | Gear Type | ($R_2$) Equiv. DT Departures | ($W_2$) Wheel Load | ($W_1$) 747-400 Wheel Load | ($R_1$) 747-400 Equiv. Ann. Departures |
|---|---|---|---|---|---|---|
| 727-200 | 400 | Dual | 240 | 43,940 | 35,625 | 440 |
| 737-300 | 6,000 | Dual | 3,600 | 30,875 | 35,625 | 2,045 |
| A319-100 | 1,200 | Dual | 720 | 34,440 | 35,625 | 645 |
| 747-400 | 3,000 | DT | 3,000 | 35,625 | 35,625 | 3,000 |
| 767-300ER | 2,000 | DT | 2,000 | 35,625 | 35,625 | 2,000 |
| DC8-63 | 800 | DT | 800 | 39,190 | 35,625 | 1,110 |
| MD-11 | 1,500 | DT | 1,500 | 35,625 | 35,625 | 1,500 |
| 777-200 | 300 | TD | 510 | 35,625 | 35,625 | 510 |
| **L1011-500** | **760** | **DT** | **760** | **54,150** | **35,625** | **3,560** |
| | 15,960 | | | | | 14,810 |

## 5.2 Adjustments for Rigid Pavement Overloads

As was done for the flexible pavement overload example, the procedures for rigid pavement overloading can best be explained by continuing the first rigid pavement *Technical* evaluation example of Section 4.2.2.1.1. In this example, for which the derived PCN was 66 RCWT, the 747-400, 777-200, and MD-11 were found to exceed the pavement capability, as shown in Table 4-5. This requires that adjustments be made to allow these aircraft to operate at its desired gross weight. These adjustments can be in the form of either a reduced pavement life or an overlay to increase the pavement strength.

A second overload example is also presented that examines the effect of occasional traffic of aircraft having an ACN that exceeds the PCN.

### 5.2.1 Example 1

Although the end result of determining the effects of rigid pavement overloads is the similar to what was done for the flexible pavement case, the steps to arrive at the final charts are different due to the PCA program not having pavement life as an input. It is necessary to develop the pavement life variables first, and then examine the results with the PCA program. A complete listing of steps to be followed to determine rigid pavement overloading effects are:

1. Construct an ACN versus gross weight diagram such as shown in Figure 5-4 for the 747-400 critical airplane at the subgrade code previously determined. These charts are readily available in Section 7 of the manufacturer's *Airplane Characteristics for Airport Planning*. It is necessary to only show the ACN line for the subgrade code in consideration, rather than all four codes. Note that the line relating ACN and gross weight is not straight in that it was constructed by using a selection of many points rather than just connecting the minimum and maximum values.

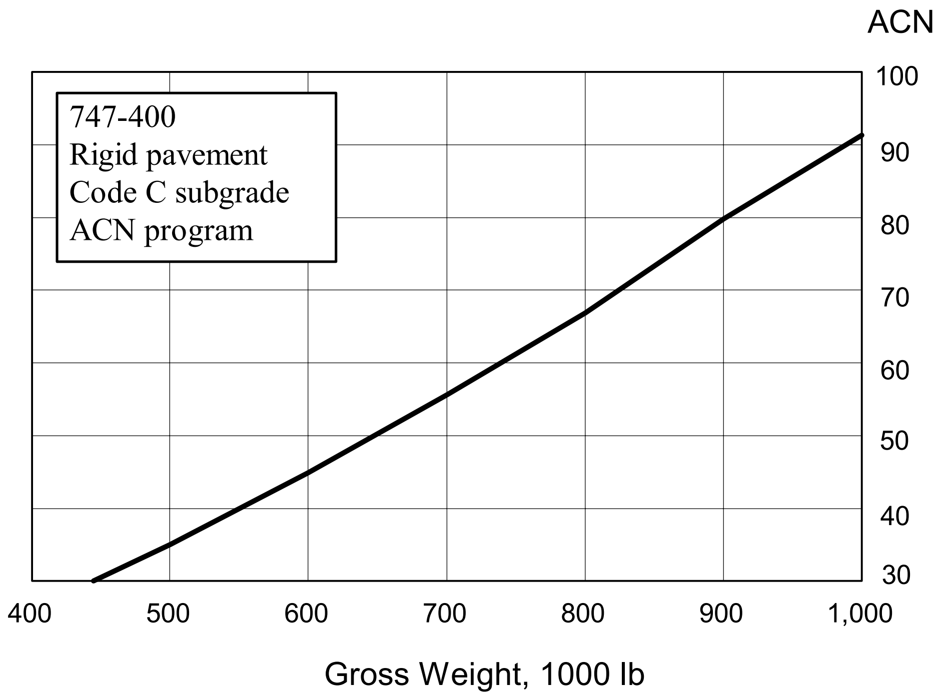


**Figure 5-4. 747-400 Rigid Pavement ACN vs Gross Weight**

2. The next series of steps are to develop the data required to construct an ACN versus pavement life chart, as shown in Figure 5-5. It is possible to develop a chart such as this 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 5-4, ACN can be utilized in place of gross weight on the abscissa of the Figure 5-5 chart. Each of

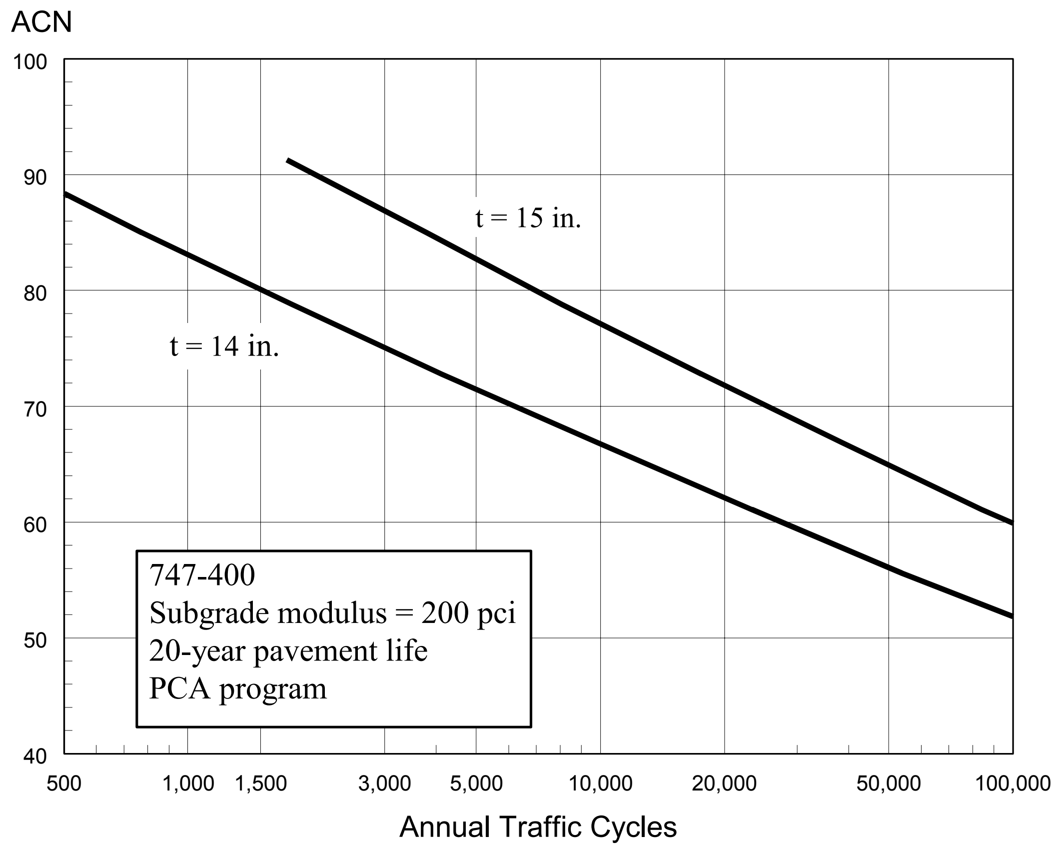


**Figure 5-5. 747-400 Rigid Pavement Life vs ACN**

these steps will be illustrated by utilizing data from the first rigid pavement example of Section 4.

a) For the actual pavement thickness and actual subgrade modulus, k, determine the working stress of the critical airplane at a range of representative gross weights by using the PCA program.

b) Divide the working stress values by the modulus of rupture to calculate the stress ratio.

c) Enter Figure 4-2 with the stress ratio values and determine the corresponding load repetitions. Multiply the load repetitions by the TC/LR ratio to obtain traffic cycles.

d) Plot the resulting traffic cycles as a function of gross weight. Knowing that ACN is related to gross weight, use ACN on the abscissa of the chart, such as shown in Figure 5-5.

4. The following table contains part of the data used to construct the curves of Figure 5-5 for a 747-400 airplane operating on a pavement with a slab thickness of 14.0 inches, a subgrade modulus of 200 pci, and a pavement life of 20 years.

**Table 5-4. Data for Constructing Rigid Pavement Life Curves**

| Gross Weight 1,000 lb | ACN | Working Stress (psi) | Stress Ratio | Lifetime Load Repetitions | Lifetime Traffic Cycles | Annual Traffic Cycles |
|---|---|---|---|---|---|---|
| for t = 14 inches: | | | | | | |
| 1,000 | 91.3 | 490 | 0.700 | 2,000 | 6,680 | 344 |
| 900 | 78.8 | 449 | 0.641 | 10,372 | 35,680 | 1,784 |
| 800 | 66.9 | 406 | 0.580 | 56,862 | 195,605 | 9,780 |
| 792 | 66.0 | 403 | 0.575 | 65,400 | 225,000 | 11,250 |
| 700 | 55.6 | 363 | 0.519 | 135,011 | 1,072,390 | 53,620 |
| for t = 15 inches: | | | | | | |
| 792 | 66.0 | 369 | 0.527 | 249,390 | 857,900 | 42,895 |
| 880 | 76.4 | 403 | 0.575 | 65,400 | 225,000 | 11,250 |

4. It is now possible to relate the effects of gross weight, ACN, and pavement life by combining these two charts, as shown in Figure 5-6. The left hand side of this figure is the chart of Figure 5-4, while the right had chart is that of Figure 5-5. It can now be seen that the rating of PCN 66 RCWT equates to 11,250 traffic cycles per year.
5. The line for a thickness of 15 inches in Figures 5-5 and 5-6 shows how pavement life is increased by the addition of one inch of concrete. This line is included, not to imply that an overlay of one inch is recommended, but to only show the effect of increased thickness. It can be seen that the 15-inch pavement will accommodate a 747-400 with a gross weight of 880,000 pounds. Alternately, at a gross weight of 792,000 pounds, the 747-400 can be accommodated on the thicker pavement to about 43,000 traffic cycles. (The computer calculations are on pages 5-23 and 5-24).

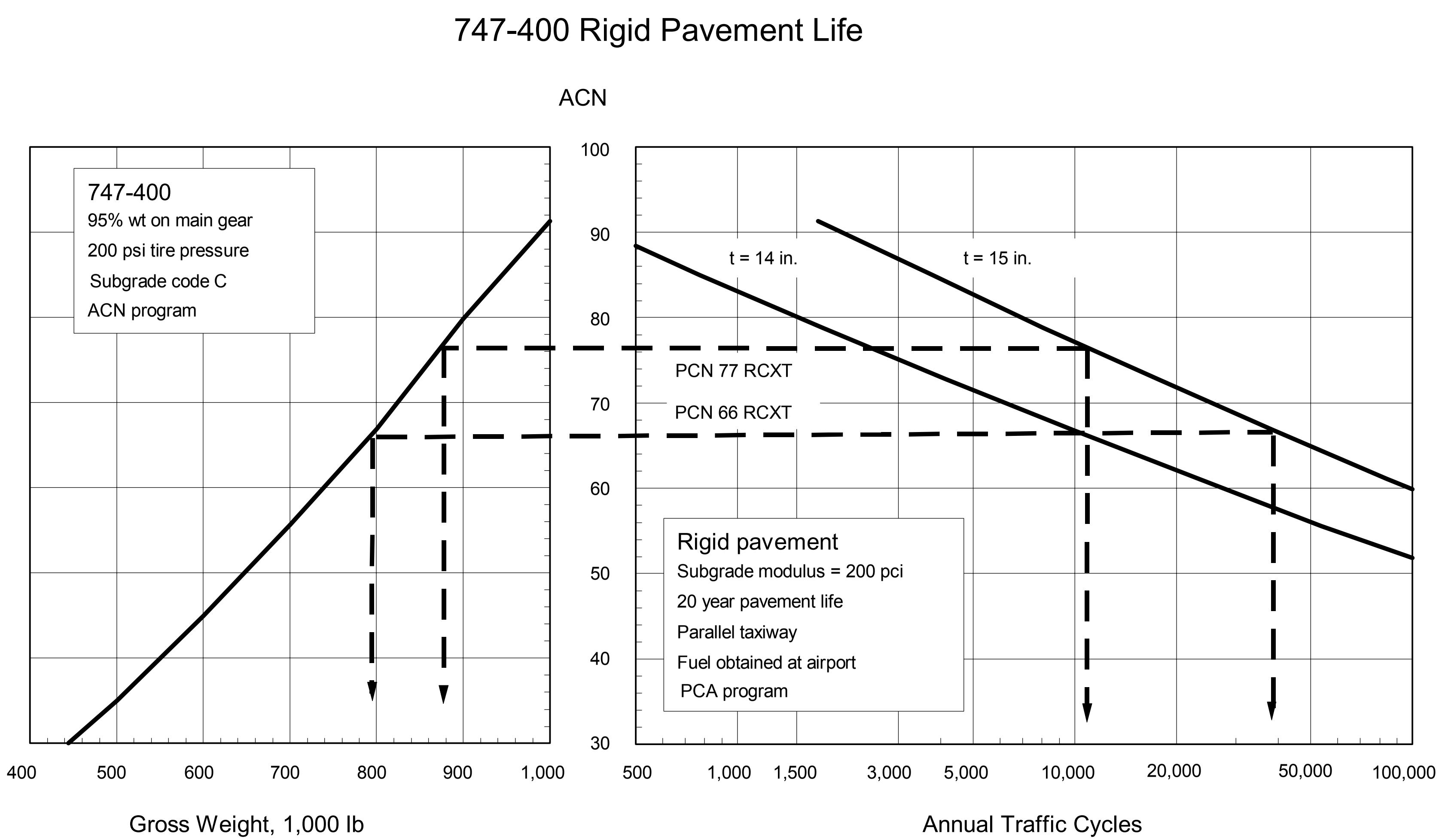


**Figure 5-6. 747-400 Rigid Pavement Life**

### 5.2.2 Example 2

This example will illustrate the effect of ICAO allowable overloading in which the ACN is no more than 5% above and PCN and the number of traffic cycles does not exceed 5% of the total annual traffic.

Table 4-5 is repeated here as Table 5-5, but with a new airplane added to the traffic mix with an ACN that is 5% above the rated PCN of 66 RCWT. The total annual departures, as shown in Table 4-4, is 15,200, of which 760 is 5% of the total. This amount is shown in Table 5-5. Normally in a calculation of critical airplane equivalent departures the $W_2$ wheel load would be listed as 35,625 pounds for a widebody airplane, but for the sake of illustration, the new airplane actual single wheel load is shown. (The computer calculations are on page 5-25).

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

| Airplane | Operating Weight, lb | Tire Press. (psi) | ACN Rigid | P/LR Ratio | Annual Departures | Life Load Repetitions | Stress Ratio |
|---|---|---|---|---|---|---|---|
| 727-200 | 185,000 | 148 | 55 RC | 2.92 | 400 | 2,740 | 0.689 |
| 737-300 | 130,000 | 201 | 41 RC | 3.87 | 6,000 | 31,010 | 0.602 |
| A319-100 | 150,000 | 173 | 43 RC | 3.56 | 1,200 | 6,740 | 0.656 |
| 747-400 | 800,000 | 200 | 67 RC | 3.44 | 3,000 | 17,440 | 0.622 |
| 767-300ER | 370,000 | 200 | 61 RC | 3.64 | 2,000 | 10,990 | 0.639 |
| DC8-63 | 330,000 | 194 | 61 RC | 3.32 | 800 | 4,820 | 0.668 |
| MD-11 | 550,000 | 205 | 71 RC | 3.66 | 1,500 | 8,200 | 0.649 |
| 777-200 | 600,000 | 215 | 76 RC | 4.17 | 300 | 1,440 | 0.712 |
| **A300-600R** | **378,500** | **196** | **69 RC** | **3.44** | **760** | **2,614** | **0.690** |

It is next necessary to determine the new total departures of the critical 747-400 airplane. To do so, Table 4-7 is shown here as Table 5-6 with the new A300-600R airplane included. As can be seen from this table, the number of 747-400 equivalent annual departures has increased to 12,960 from 11,250. The new equivalent departures are 12,960, which convert to 75,350 lifetime load repetitions. (12,960 * 20 ÷3.44 = 75,350). This results in a revised stress ratio of 0.570 from Table 4-2 and a working stress of 399 psi. (0.570 * 700 psi = 399 psi). From the PCA computer program, the new allowable 747-400 gross weight is 783,000 lb, and the ACN at this weight is 64.9 RC.

**Table 5-6. Equivalent Annual Departures of the Critical Airplane**

| Airplane | Annual Departures | Gear Type | ($R_2$) Equiv. DT Departures | ($W_2$) Wheel Load | ($W_1$) 747-400 Wheel Load | ($R_1$) 747-400 Equiv. Ann. Departures |
|---|---|---|---|---|---|---|
| 727-200 | 400 | Dual | 240 | 43,940 | 35,625 | 440 |
| 737-300 | 6,000 | Dual | 3,600 | 30,875 | 35,625 | 2,045 |
| A319-100 | 1,200 | Dual | 720 | 34,440 | 35,625 | 645 |
| **747-400** | **3,000** | **DT** | **3,000** | **35,625** | **35,625** | **3,000** |
| 767-200ER | 2,000 | DT | 2,000 | 35,625 | 35,625 | 2,000 |
| DC8-63 | 800 | DT | 800 | 39,190 | 35,625 | 1,110 |
| MD-11 | 1,500 | DT | 1,500 | 35,625 | 35,625 | 1,500 |
| 777-200 | 300 | TD | 510 | 35,625 | 35,625 | 510 |
| A300-600R | 760 | DT | 760 | 44,852 | 35,325 | 1710 |
| | 15,960 | | | | | 12,960 |

The new recommended PCN would then be 65 RCWT. (The computer calculations are on page 5-26).

Alternatively, the effect on pavement thickness can be seen by keeping the critical airplane gross weight the same at 792,000 pounds and an allowable working stress of 399 psi. The resulting required concrete slab thickness is 14.1 inches, which is a 0.1 inch increase. (The computer calculations are on page 5-27).

## 5.3 Computer Calculations

The next 11 pages show the pavement calculations and ACNs that were included in the *Technical* evaluation flexible and rigid pavement examples of this section. These listings are in order of the example presentation.

<u>Rigid pavement first example</u>



<u>Rigid pavement second example</u>

*****FLEXIBLE PAVEMENT ANALYSIS - ACN*****

B747-400 reduced allowable gross weight

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | RADIUS (IN.) |
|---|---|---|---|---|---|
| 770000. | 23.75 | 45719. | 200.00 | 228.59 | 8.53 |

| NWL | X | Y | GRID | X | Y | ALPHA |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | START | 0.00 | 0.00 | 0.825 |
| 2 | 0.00 | 44.00 | END | 29.00 | 22.00 | |
| 3 | 58.00 | 44.00 | INCR | 3.22 | 2.44 | |
| 4 | 58.00 | 0.00 | | | | |

| SUBGRADE CBR | SUBGRADE CODE | ESWL (LB) | X-LOC (IN.) | Y-LOC (IN.) | THICKNESS (IN.) | ACN |
|---|---|---|---|---|---|---|
| 10. | B (MEDIUM) | 82239. | 3.22 | 4.89 | 25.34 | 55.0 |

*****FLEXIBLE PAVEMENT ANALYSIS - ACN*****

MD-11 reduced allowable gross weight

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | RADIUS (IN.) |
|---|---|---|---|---|---|
| 495000. | 40.00 | 49500. | 205.00 | 241.46 | 8.77 |

| NWL | X | Y | GRID | X | Y | ALPHA |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | START | 0.00 | 0.00 | 0.825 |
| 2 | 0.00 | 54.00 | END | 32.00 | 27.00 | |
| 3 | 64.00 | 54.00 | INCR | 3.56 | 3.00 | |
| 4 | 64.00 | 0.00 | | | | |

| SUBGRADE CBR | SUBGRADE CODE | ESWL (LB) | X-LOC (IN.) | Y-LOC (IN.) | THICKNESS (IN.) | ACN |
|---|---|---|---|---|---|---|
| 10. | B (MEDIUM) | 82519. | 3.56 | 3.00 | 25.33 | 55.0 |

*****FLEXIBLE PAVEMENT ANALYSIS - S-77-1*****

B747-400 construction of pavement life curves

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | RADIUS (IN.) |
|---|---|---|---|---|---|
| 864000. | 23.75 | 51300. | 200.00 | 256.50 | 9.04 |

| NWL | X | Y |
|---|---|---|
| 1 | 0.00 | 0.00 |
| 2 | 0.00 | 44.00 |
| 3 | 58.00 | 44.00 |
| 4 | 58.00 | 0.00 |

| GRID | X | Y |
|---|---|---|
| START | 0.00 | 0.00 |
| END | 29.00 | 22.00 |
| INCR | 3.22 | 2.44 |

| DEPARTURES (PASSES) | P/C RATIO | PVMT LIFE (YRS) | COVERAGES | ALPHA FACTOR |
|---|---|---|---|---|
| 2400. | 1.72 | 20.0 | 27907. | 0.869 |

| THICKNESS (IN.) | ESWL (LB) | REQUIRED CBR FOR DEPARTURES OF: 2400. |
|---|---|---|
| 32.00 | 104871. | 8.99 |

*****FLEXIBLE PAVEMENT ANALYSIS - S-77-1*****

B747-400 construction of pavement life curves

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | RADIUS (IN.) |
|---|---|---|---|---|---|
| 864000. | 23.75 | 51300. | 200.00 | 256.50 | 9.04 |

| NWL | X | Y |
|---|---|---|
| 1 | 0.00 | 0.00 |
| 2 | 0.00 | 44.00 |
| 3 | 58.00 | 44.00 |
| 4 | 58.00 | 0.00 |

| GRID | X | Y |
|---|---|---|
| START | 0.00 | 0.00 |
| END | 29.00 | 22.00 |
| INCR | 3.22 | 2.44 |

| DEPARTURES (PASSES) | P/C RATIO | PVMT LIFE (YRS) | COVERAGES | ALPHA FACTOR |
|---|---|---|---|---|
| 11250. | 1.72 | 20.0 | 130814. | 0.922 |

| THICKNESS (IN.) | ESWL (LB) | REQUIRED CBR FOR DEPARTURES OF: 11250. |
|---|---|---|
| 35.00 | 110979. | 9.00 |

*******FLEXIBLE PAVEMENT ANALYSIS - S-77-1*******

**B747-400 reduced pavement life**

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | RADIUS (IN.) |
|---|---|---|---|---|---|
| 864000. | 23.75 | 51300. | 200.00 | 256.50 | 9.04 |

| NWL | X | Y | GRID | X | Y |
|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | START | 0.00 | 0.00 |
| 2 | 0.00 | 44.00 | END | 29.00 | 22.00 |
| 3 | 58.00 | 44.00 | INCR | 3.22 | 2.44 |
| 4 | 58.00 | 0.00 | | | |

| DEPARTURES (PASSES) | P/C RATIO | PVMT LIFE (YRS) | COVERAGES | ALPHA FACTOR |
|---|---|---|---|---|
| 11250. | 1.72 | 4.3 | 28125. | 0.869 |

| THICKNESS (IN.) | ESWL (LB) | REQUIRED CBR FOR DEPARTURES OF: 11250. |
|---|---|---|
| 32.00 | 104871. | 8.99 |

*******FLEXIBLE PAVEMENT ANALYSIS - S-77-1*******

**B747-400 reduced pavement life**

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | RADIUS (IN.) |
|---|---|---|---|---|---|
| 864000. | 23.75 | 51300. | 200.00 | 256.50 | 9.04 |

| NWL | X | Y | GRID | X | Y |
|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | START | 0.00 | 0.00 |
| 2 | 0.00 | 44.00 | END | 29.00 | 22.00 |
| 3 | 58.00 | 44.00 | INCR | 3.22 | 2.44 |
| 4 | 58.00 | 0.00 | | | |

| DEPARTURES (PASSES) | P/C RATIO | PVMT LIFE (YRS) | COVERAGES | ALPHA FACTOR |
|---|---|---|---|---|
| 2400. | 1.72 | 20.0 | 27907. | 0.869 |

| THICKNESS (IN.) | ESWL (LB) | REQUIRED CBR FOR DEPARTURES OF: 2400. |
|---|---|---|
| 32.00 | 104871. | 8.99 |

*****FLEXIBLE PAVEMENT ANALYSIS - ACN*****

L1011-500 new airplane

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | RADIUS (IN.) |
|---|---|---|---|---|---|
| 456000. | 47.50 | 54150. | 184.00 | 294.29 | 9.68 |

| NWL | X | Y | GRID | X | Y | ALPHA |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | START | 0.00 | 0.00 | 0.825 |
| 2 | 0.00 | 52.00 | END | 35.00 | 26.00 | |
| 3 | 70.00 | 52.00 | INCR | 3.89 | 2.89 | |
| 4 | 70.00 | 0.00 | | | | |

| SUBGRADE CBR | SUBGRADE CODE | ESWL (LB) | X-LOC (IN.) | Y-LOC (IN.) | THICKNESS (IN.) | ACN |
|---|---|---|---|---|---|---|
| 10. | B (MEDIUM) | 91492. | 3.89 | 2.89 | 26.55 | 60.4 |

*****FLEXIBLE PAVEMENT ANALYSIS - S-77-1*****

L1011-500

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | RADIUS (IN.) |
|---|---|---|---|---|---|
| 456000. | 47.50 | 54150. | 184.00 | 294.29 | 9.68 |

| NWL | X | Y | GRID | X | Y |
|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | START | 0.00 | 0.00 |
| 2 | 0.00 | 52.00 | END | 35.00 | 26.00 |
| 3 | 70.00 | 52.00 | INCR | 3.89 | 2.89 |
| 4 | 70.00 | 0.00 | | | |

| DEPARTURES (PASSES) | P/C RATIO | PVMT LIFE (YRS) | COVERAGES | ALPHA FACTOR |
|---|---|---|---|---|
| 760. | 1.72 | 20.0 | 8837. | 0.821 |

| THICKNESS (IN.) | ESWL (LB) | REQUIRED CBR FOR DEPARTURES OF: 760. |
|---|---|---|
| 28.40 | 94291. | 9.03 |
| 28.50 | 94448. | 8.98 |

*****FLEXIBLE PAVEMENT ANALYSIS - S-77-1*****

B747-400 reduced allowable gross weight

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | RADIUS (IN.) |
|---|---|---|---|---|---|
| 758000. | 23.75 | 45006. | 200.00 | 225.03 | 8.46 |

| NWL | X | Y |
|---|---|---|
| 1 | 0.00 | 0.00 |
| 2 | 0.00 | 44.00 |
| 3 | 58.00 | 44.00 |
| 4 | 58.00 | 0.00 |

| GRID | X | Y |
|---|---|---|
| START | 0.00 | 0.00 |
| END | 29.00 | 22.00 |
| INCR | 3.22 | 2.44 |

| DEPARTURES (PASSES) | P/C RATIO | PVMT LIFE (YRS) | COVERAGES | ALPHA FACTOR |
|---|---|---|---|---|
| 14810. | 1.72 | 20.0 | 172209. | 0.930 |

| THICKNESS (IN.) | ESWL (LB) | REQUIRED CBR FOR DEPARTURES OF: 14810. |
|---|---|---|
| 32.00 | 91674. | 9.00 |

*****FLEXIBLE PAVEMENT ANALYSIS - ACN*****

B747-400

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | RADIUS (IN.) |
|---|---|---|---|---|---|
| 758000. | 23.75 | 45006. | 200.00 | 225.03 | 8.46 |

| NWL | X | Y |
|---|---|---|
| 1 | 0.00 | 0.00 |
| 2 | 0.00 | 44.00 |
| 3 | 58.00 | 44.00 |
| 4 | 58.00 | 0.00 |

| GRID | X | Y | ALPHA |
|---|---|---|---|
| START | 0.00 | 0.00 | 0.825 |
| END | 29.00 | 22.00 | |
| INCR | 3.22 | 2.44 | |

| SUBGRADE CBR | SUBGRADE CODE | ESWL (LB) | X-LOC (IN.) | Y-LOC (IN.) | THICKNESS (IN.) | ACN |
|---|---|---|---|---|---|---|
| 10. | B (MEDIUM) | 80498. | 3.22 | 4.89 | 25.06 | 53.8 |

*******FLEXIBLE PAVEMENT ANALYSIS - S-77-1*******

**B747-400 increased thickness requirement**

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | RADIUS (IN.) |
|---|---|---|---|---|---|
| 771000. | 23.75 | 45778. | 200.00 | 228.89 | 8.54 |

| NWL | X | Y |
|---|---|---|
| 1 | 0.00 | 0.00 |
| 2 | 0.00 | 44.00 |
| 3 | 58.00 | 44.00 |
| 4 | 58.00 | 0.00 |

| GRID | X | Y |
|---|---|---|
| START | 0.00 | 0.00 |
| END | 29.00 | 22.00 |
| INCR | 3.22 | 2.44 |

| DEPARTURES (PASSES) | P/C RATIO | PVMT LIFE (YRS) | COVERAGES | ALPHA FACTOR |
|---|---|---|---|---|
| 14810. | 1.72 | 20.0 | 172209. | 0.930 |

| THICKNESS (IN.) | ESWL (LB) | REQUIRED CBR FOR DEPARTURES OF: 14810. |
|---|---|---|
| 32.00 | 93288. | 9.15 |
| 32.40 | 94000. | 9.00 |

*******RIGID PAVEMENT ANALYSIS - PCA*******

**B747-400 construction of pavement life curves**

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | ELLIPSE RADII A | B |
|---|---|---|---|---|---|---|
| 792000. | 23.75 | 47025. | 200.00 | 235.13 | 10.60 | 7.06 |

| SUBGRADE MODULUS | POISSON'S RATIO | ELASTIC MODULUS |
|---|---|---|
| 200. | 0.15 | 0.40E+07 |

| NWL | X | Y |
|---|---|---|
| 1 | 0.00 | 0.00 |
| 2 | 0.00 | 44.00 |
| 3 | 58.00 | 44.00 |
| 4 | 58.00 | 0.00 |

*****SEARCH FOR MAXIMUM STRESS POINT*****

| PAVEMENT THICKNESS | RAD. REL. STIFFNESS | MAX STRESS X | Y | PT-ANGLE BETA | MAXIMUM STRESS |
|---|---|---|---|---|---|
| 14.00 | 46.51 | 0.92 | 0.87 | -58.72 | 402.9 |
| 15.00 | 48.98 | 0.92 | 0.90 | -58.78 | 368.5 |

*******RIGID PAVEMENT ANALYSIS - ACN*******

**B747-400**

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | ELLIPSE RADII A | B |
|---|---|---|---|---|---|---|
| 792000. | 23.75 | 47025. | 200.00 | 235.13 | 10.60 | 7.06 |

| NWL | X | Y |
|---|---|---|
| 1 | 0.00 | 0.00 |
| 2 | 0.00 | 44.00 |
| 3 | 58.00 | 44.00 |
| 4 | 58.00 | 0.00 |

| SUBGRADE MODULUS | CODE | X-LOC (IN.) | Y-LOC (IN.) | THICKNESS (IN.) | ACN RIGID |
|---|---|---|---|---|---|
| 150. | C (LOW) | 1.06 | 0.96 | 14.82 | 66.0 |

*****RIGID PAVEMENT ANALYSIS - PCA*****

B747-400 increased thickness

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | ELLIPSE RADII A | B |
|---|---|---|---|---|---|---|
| 880000. | 23.75 | 52250. | 200.00 | 261.25 | 11.18 | 7.44 |

| SUBGRADE MODULUS | POISSON'S RATIO | ELASTIC MODULUS |
|---|---|---|
| 200. | 0.15 | 0.40E+07 |

| NWL | X | Y |
|---|---|---|
| 1 | 0.00 | 0.00 |
| 2 | 0.00 | 44.00 |
| 3 | 58.00 | 44.00 |
| 4 | 58.00 | 0.00 |

***SEARCH FOR MAXIMUM STRESS POINT***

| PAVEMENT THICKNESS | RAD. REL. STIFFNESS | MAX STRESS X | Y | PT-ANGLE BETA | MAXIMUM STRESS |
|---|---|---|---|---|---|
| 15.00 | 48.98 | 1.08 | 1.02 | -58.99 | 403.0 |

*****RIGID PAVEMENT ANALYSIS - ACN*****

B747-400

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | ELLIPSE RADII A | B |
|---|---|---|---|---|---|---|
| 880000. | 23.75 | 52250. | 200.00 | 261.25 | 11.18 | 7.44 |

| NWL | X | Y |
|---|---|---|
| 1 | 0.00 | 0.00 |
| 2 | 0.00 | 44.00 |
| 3 | 58.00 | 44.00 |
| 4 | 58.00 | 0.00 |

| SUBGRADE MODULUS | CODE | X-LOC (IN.) | Y-LOC (IN.) | THICKNESS (IN.) | ACN RIGID |
|---|---|---|---|---|---|
| 150. | C (LOW) | 1.32 | 1.14 | 15.87 | 76.4 |

*****RIGID PAVEMENT ANALYSIS - ACN*****

A300-600R new airplane

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | ELLIPSE RADII A | B |
|---|---|---|---|---|---|---|
| 378500. | 47.40 | 44852. | 196.00 | 228.84 | 10.46 | 6.96 |

| NWL | X | Y |
|---|---|---|
| 1 | 0.00 | 0.00 |
| 2 | 0.00 | 36.50 |
| 3 | 55.00 | 36.50 |
| 4 | 55.00 | 0.00 |

| SUBGRADE MODULUS | CODE | X-LOC (IN.) | Y-LOC (IN.) | THICKNESS (IN.) | ACN RIGID |
|---|---|---|---|---|---|
| 150. | C (LOW) | 1.44 | 1.27 | 15.16 | 69.2 |

*****RIGID PAVEMENT ANALYSIS - PCA*****

A300-600R

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | ELLIPSE RADII A | B |
|---|---|---|---|---|---|---|
| 378500. | 47.40 | 44852. | 196.00 | 228.84 | 10.46 | 6.96 |

| SUBGRADE MODULUS | POISSON'S RATIO | ELASTIC MODULUS |
|---|---|---|
| 200. | 0.15 | 0.40E+07 |

| NWL | X | Y |
|---|---|---|
| 1 | 0.00 | 0.00 |
| 2 | 0.00 | 36.50 |
| 3 | 55.00 | 36.50 |
| 4 | 55.00 | 0.00 |

***SEARCH FOR MAXIMUM STRESS POINT***

| PAVEMENT THICKNESS | RAD. REL. STIFFNESS | MAX STRESS X | Y | PT-ANGLE BETA | MAXIMUM STRESS |
|---|---|---|---|---|---|
| 14.00 | 46.51 | 1.15 | 1.16 | -62.09 | 416.4 |

*****RIGID PAVEMENT ANALYSIS - PCA*****

B747-400 effects of new airplane

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | ELLIPSE RADII A | B |
|---|---|---|---|---|---|---|
| 783000. | 23.75 | 46491. | 200.00 | 232.45 | 10.54 | 7.02 |

| SUBGRADE MODULUS | POISSON'S RATIO | ELASTIC MODULUS |
|---|---|---|
| 200. | 0.15 | 0.40E+07 |

| NWL | X | Y |
|---|---|---|
| 1 | 0.00 | 0.00 |
| 2 | 0.00 | 44.00 |
| 3 | 58.00 | 44.00 |
| 4 | 58.00 | 0.00 |

***SEARCH FOR MAXIMUM STRESS POINT***

| PAVEMENT THICKNESS | RAD. REL. STIFFNESS | MAX STRESS X | Y | PT-ANGLE BETA | MAXIMUM STRESS |
|---|---|---|---|---|---|
| 14.00 | 46.51 | 0.88 | 0.84 | -58.68 | 399.1 |

*****RIGID PAVEMENT ANALYSIS - ACN*****

B747-400

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | ELLIPSE RADII A | B |
|---|---|---|---|---|---|---|
| 783000. | 23.75 | 46491. | 200.00 | 232.45 | 10.54 | 7.02 |

| NWL | X | Y |
|---|---|---|
| 1 | 0.00 | 0.00 |
| 2 | 0.00 | 44.00 |
| 3 | 58.00 | 44.00 |
| 4 | 58.00 | 0.00 |

| SUBGRADE MODULUS | CODE | X-LOC (IN.) | Y-LOC (IN.) | THICKNESS (IN.) | ACN RIGID |
|---|---|---|---|---|---|
| 150. | C (LOW) | 1.11 | 0.99 | 14.71 | 64.9 |

*******RIGID PAVEMENT ANALYSIS - PCA*******

**B747-400 increased thickness requirements**

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | ELLIPSE RADII A | B |
|---|---|---|---|---|---|---|
| 792000. | 23.75 | 47025. | 200.00 | 235.13 | 10.60 | 7.06 |

| SUBGRADE MODULUS | POISSON'S RATIO | ELASTIC MODULUS |
|---|---|---|
| 200. | 0.15 | 0.40E+07 |

| NWL | X | Y |
|---|---|---|
| 1 | 0.00 | 0.00 |
| 2 | 0.00 | 44.00 |
| 3 | 58.00 | 44.00 |
| 4 | 58.00 | 0.00 |

*****SEARCH FOR MAXIMUM STRESS POINT*****

| PAVEMENT THICKNESS | RAD. REL. STIFFNESS | MAX STRESS PT-ANGLE X | Y | BETA | MAXIMUM STRESS |
|---|---|---|---|---|---|
| 14.00 | 46.51 | 0.90 | 0.84 | -58.71 | 402.9 |
| 14.10 | 46.76 | 0.90 | 0.84 | -58.71 | 399.2 |
| 14.20 | 47.01 | 0.90 | 0.84 | -58.72 | 395.6 |

# 6. Conversion of Other Methods to PCN

There are many other systems of pavement rating as conducted by the various worldwide airport authorities. Among those are the previous ICAO standards of LCN and LCN/LCG, the FAA method, the AUW method, the Canadian ALR/PLR method, the SIWL/ESWL method, and others. Of these, the LCN, LCN/LCG, FAA, and AUW method conversions to PCN are discussed. Additionally, a section on non-paved runways is included at the end of this section.

## 6.1 Load Classification Number

The Load Classification System (LCN) system was developed in the 1950's and adopted as one of the ICAO standards for rating pavements in 1956. A complete description of the LCN method is contained in Reference 7. LCNs range from 1 to 100 or greater, with the higher numbers indicating greater load-carrying capacity. It was replaced by the ACN/PCN method in 1983 as the official ICAO pavement rating system (Reference 1).

The allowable gross weight of an airplane on a pavement as rated by the LCN system is such that if the airplane LCN is less than or equal to the pavement LCN, then operations are allowed. One of the difficulties in using the LCN system of pavement ratings is that quantification of allowable aircraft gross weights not only depends on the airplane characteristics, but also pavement thickness (t) for flexible pavements and radius of relative stiffness ($\ell$) for rigid pavements. A resulting effect of this feature is that the airplane LCN is dependent upon pavement factors, and consequently it changes from pavement to pavement. This requires that the airplane LCN be published only in the form of a set of charts, and not as a table as is ACN, due to the many combinations of aircraft characteristics and pavement thickness or radius of relative stiffness.

An examination of LCN charts in publications, such as in Section 7 of the manufacturer's *Airplane Characteristics for Airport Planning* document, shows that the magnitude of the equivalent single wheel load (ESWL) is also dependent on these parameters. LCN is directly dependent on ESWL and thus on the pavement $t$ or $\ell$. Unfortunately, the great majority of airport authorities who publish LCN as their pavement rating do not include $t$

or $\ell$ in their rating, thus making it virtually impossible to determine an accurate pavement strength from the published ratings as it relates to allowable gross weight of an aircraft.

Another difficulty of the LCN system is that the originators of the method have acknowledged its built-in inaccuracy by allowing the user to increase the allowable load by 10% above the published LCN for normal operations (Reference 7). This means that for whatever allowable gross weight is determined by a published LCN rating, that weight may be adjusted to a value equivalent to an LCN of 10% greater. For example, a pavement rating of LCN 80 can be adjusted to LCN 88 for the purposes of establishing an allowable aircraft gross weight.

Another system of pavement ratings, also published in Reference 7, contains a description of the United Kingdom practice, referred to as Load Classification Group (LCG). This system also contains LCN numbers that, although called the same as the ICAO standard LCN, contain values that are different due to a different method of calculation. This requires that when the LCN method is published by an airport authority as a pavement rating, it is imperative that the user distinguishes between the ICAO standard LCN and the United Kingdom LCG/LCN system. In converting LCN to PCN in this section, it will be assumed that the ICAO standard LCN will be used.

The LCN of a pavement is determined by plate loading tests, while the LCN of an airplane is determined from a standardized chart published in Reference 7 that relates LCN with tire pressure, contact area, pavement thickness, and ESWL. Airplane LCNs are also available from Section 7 of the manufacturer's *Airplane Characteristics for Airport Planning*. The effects of traffic are not included in the determination of pavement LCN in that it is determined strictly by plate bearing tests that are performed without regard to the traffic that will operate on the pavement.

The steps to convert a flexible or rigid pavement LCN to a PCN are similar to that of the *Using* aircraft method described in Section 4:

1. Multiply the pavement LCN by a factor of 1.10 to account for the presumed inaccuracies of the LCN system.

2. Accumulate a list of probable critical aircraft in the traffic mix by any means necessary. The methods introduced in Section 3 of this report can be utilized, if desired.
3. Calculate the maximum allowable gross weight of each of the probable critical aircraft by using an LCN program or the LCN charts as found in Section 7 of the *Airport Characteristics for Airport Planning* manuals. Use the existing pavement thickness for flexible pavements and the existing radius of relative thickness for rigid pavements. If the pavement thickness or radius of relative stiffness is not known, the LCN determination will be much less accurate in that the magnitude of the airplane LCN is dependent upon these factors. If this is the case, arbitrary, but realistic values must be assumed. For this situation, it is suggested that the following values be used:
    a. For flexible pavements having primarily standard body jet service, assume t = 20 inches.
    b. For flexible pavements having primarily wide body jet service, assume t = 30 inches.
    c. For rigid pavements having primarily standard body jet service, assume $\ell$ = 40 inches.
    d. For rigid pavements having primarily wide body jet service, assume $\ell$ = 50 inches.
4. The subgrade strength and code must be known in order to calculate the ACN of the critical airplane. Use the subgrade code that corresponds to the range of Table 2-2 or 2-3. If the subgrade strength is not known, make a judgment of High, Medium, Low or Ultra Low.
5. Calculate the ACNs of the probable critical aircraft from the list based on the allowable gross weights determined from Steps 2, 3 and 4.
6. The evaluation code for PCN should be *T* if the pavement LCN was determined by means of plate bearing tests. If the pavement LCN was determined by means described in Table 2-5 as corresponding to the *Using* aircraft category, the evaluation code should be *U*.

### 6.1.1 Flexible Pavement LCN Conversion Example 1

As an example, consider the first flexible pavement example of Section 4.2.1.1.1 in which the pavement has a thickness of 32.0 inches. The pavement LCN 90, as determined by plate bearing tests, and the subgrade code is B. Under the rules of LCN development, the airplane LCN for unlimited operations is 99, which is an increase of 10% over the published or rated value. For an LCN of 99 and a pavement thickness of 32 inches, the allowable gross weights of the following probable critical aircraft are shown, along with the corresponding ACNs:

| Airplane | Allowable Gross Wt, lb | LCN | ACN |
|---|---|---|---|
| 747-400 | 703,000 | 99 | 48.5 FB |
| MD-11 | 484,000 | 99 | 51.9 FB |
| 777-200 | 575,000 | 99 | 47.7 FB |

From this table, the MD-11 has the highest ACN and is the critical airplane. The assigned PCN for this pavement should then be 52 FBXT. Contrast this with the Section 4.2.1.1.1 example in which the 747-400 was the critical airplane. (The computer calculations are on pages 6-17 to 6-19).

### 6.1.2 Flexible Pavement LCN Conversion Example 2

If the pavement thickness were increased to 35.0 inches, as in the Section 4.2.1.1.2 second flexible pavement example, the 747-400 allowable gross weight appears to reduce from 703,000 to 668,000 pounds at the pavement LCN of 99. Likewise, the MD-11 and 777-200 aircraft also show apparent allowable gross weight reductions due to the increased thickness:

| Airplane | Allowable Gross Wt, lb | LCN | ACN |
|---|---|---|---|
| 747-400 | 668,000 | 99 | 45.2 FB |
| MD-11 | 449,000 | 99 | 48.3 FB |
| 777-200 | 542,000 | 99 | 43.9 FB |

From these examples, it looks as though allowable gross weight decreases as the pavement thickness increases even though a thicker pavement naturally results in a stronger pavement, and therefore, the allowable gross weight should increase. This example illustrates an incorrect application of the LCN system. The additional thickness should have been applied to the pavement LCN and not the airplane LCN. This would then result in an increase in pavement LCN, and a corresponding increase in allowable gross weight. The amount of increase would have to be determined from plate bearing tests, as was the original LCN. (The computer calculations are on page 6-20 to 6-22).

### 6.1.3 Rigid Pavement LCN Conversion Example

This LCN example is taken from the first rigid pavement example of Section 4.2.2.1.1 in which the pavement LCN is 90, as determined by plate bearing tests, and the subgrade code is C. The following pavement parameters are necessary to determine the radius of relative stiffness:

t = 14 inches

E = 4,000,000 psi

k = 200 pci

From these parameters, the radius of relative stiffness is 46.5. (A table to determine this radius may be found in Section 7 of any *Aircraft Characteristics for Airport Planning* manual). The subgrade in this example is Code C. Under the rules of LCN development, the airplane LCN for unlimited operations is 99, which is an increase of 10% over the published or rated value.

For an LCN of 99 and a pavement radius of relative stiffness of 46.5 inches, the allowable gross weights of the following probable critical aircraft are shown, along with the corresponding ACN:

| Airplane | Allowable Gross Wt, lb | LCN | ACN |
|---|---|---|---|
| 747-400 | 774,000 | 99 | 63.9 RC |
| MD-11 | 505,000 | 99 | 62.9 RC |
| 777-200 | 543,000 | 99 | 64.6 RC |

From this table, the 777-200 has the highest ACN and is the critical airplane. The assigned PCN for this pavement is then 65 RCWT. (The computer calculations are on pages 6-23 to 6-25).

## 6.2 Load Classification Group (LCN/LCG)

As mentioned previously, the LCN system was originally developed in the 1950's by the United Kingdom (UK) and adopted as one of the ICAO recommended practices for rating pavements in 1956. Since that time, the UK has developed more experience in the design and evaluation of pavements, resulting in a modification of the LCN into groups ranging from Roman numerals *I* to *VII*, with *I* being the highest strength. This new method is called LCN/LCG system. It was adopted in 1974 as one of the recommended practices of reporting pavement strength and replaced by the ACN/PCN method in 1983 as the official ICAO pavement rating system. A complete description of the LCN/LCG system is contained in Reference 7.

A significant change in this revised system was the adoption of a new method of calculating LCN, purportedly to give a better approximation to the behavior of thicker rigid pavements under load by modern heavy aircraft. The LCN values obtained under this system are not the same as those of the earlier standard LCNs because of the new method of calculation. This has caused confusion among some users because of the same LCN term being used to describe both methods. It is therefore imperative that the users of either LCN system carefully consider the source of the numerical value.

According to the description of the LCN/LCG system in Reference 7, purely flexible pavements having bases and subbases consisting wholly or partially of unbound materials are rare in the UK. This has led to the adoption by the UK of the LCN/LCG system for rigid pavements only, with the evaluation of flexible pavements being empirically based on experience in UK conditions and not supported by this system. Paradoxically, there are more airports in the world that use the LCN/LCG system for flexible pavements than for rigid. Reference is made to an Airport Classification Group method for flexible pavements, also contained in Reference 7.

Aircraft are evaluated on a standard pavement having fixed parameters, thus enabling a single LCG to be given, rather than a range of values that are dependent on the radius of relative stiffness. This allows the publication of a pavement rating without requiring that an accompanying pavement parameter be included. The standard pavement conditions are defined as:

$\ell$ = 40 inches
E = $5 \times 10^6$ psi
$\mu$ = 0.15
k = 400 pci

These values correspond to a slab thickness of 13.4 inches.

The UK considers in this method that great precision in expressing the strength of pavements is unwarranted since the materials of pavements do not have uniform properties, and in fact may vary substantially. The strength of concrete will vary with time, and the bearing capacity will also be affected by moisture and temperature variations in the subgrade and pavement. Pavement thickness is also not constant, but will vary depending upon the quality of construction. For these reasons, pavement strength is reported in the UK in terms of Load Classification Groups, such as in Table 6-1.

**Table 6-1. LCN/LCG Correlation**

| LCG | LCN* Range |
|---|---|
| I | 101 - 120 |
| II | 76 - 100 |
| III | 51 - 75 |
| IV | 31 - 50 |
| V | 16 - 30 |
| VI | 11 - 15 |
| VII | 10 and below |

* UK definition

The allowable gross weight of an airplane on a pavement as rated by the LCN/LCG system is such that if the airplane LCG is less than or equal to the pavement LCG, then operations are allowed.

One difference between the UK LCN/LCG system and the former ICAO standard LCN system is that since the pavements are grouped, the allowance for inaccuracy is built in and the 10% factor can no longer be applied for the purposes of allowable gross weight evaluation.

To convert a rigid pavement LCG to a PCN, the following steps can be used:

1. Determine a list of probable critical aircraft in the traffic mix by any means necessary. The methods introduced in Section 3 of this report can be utilized, if desired.
2. Calculate the maximum allowable gross weight of each of the probable critical aircraft by using an LCN/LCG program. Use a radius of relative thickness, $\ell$ , of 40 inches.
3. The subgrade strength and code must be known in order to calculate the ACN of the critical airplane. Use the subgrade code that corresponds to the range of Table 2-3. If the subgrade strength is not known, make a judgment of High, Medium, Low or Ultra Low.
4. Calculate the ACNs of the probable critical aircraft from the list and allowable gross weights determined in Steps 1 and 2, respectively. The critical airplane is the one with the highest ACN.
5. Assign the PCN from the ACN just determined.

### 6.2.1 Rigid Pavement LCN/LCG Conversion Example

As an example, consider the first rigid pavement example of Section 4.2.2.1.1 in which the pavement has a slab thickness of 14.0 inches, a slab elastic modulus of 4,000,000 psi, and a subgrade modulus of 200 pci, and a Poisson's ratio of 0.15. The subgrade in this example is Code C. Note that none of these pavement parameters match the standard LCN/LCG values as listed above, except for the Poisson's ratio. It is up to the airport authority to assign an LCG to the pavement based on test methods described in Reference 7. However, for this example, use an arbitrary LCG of III, giving allowable gross weights of the following probable critical aircraft, along with the corresponding ACN:

| Airplane | Allowable Gross Wt, lb | LCN | LCG | ACN |
|---|---|---|---|---|
| 747-400 | 805,000 | 76.0 | III | 67.5 RC |
| MD-11 | 531,000 | 76.0 | III | 67.4 RC |
| 777-200 | 587,000 | 76.0 | III | 73.0.RC |

From this table, the 777-200 has the highest ACN and is the critical airplane. The assigned PCN for this pavement should then be 73 RCWT. (The computer calculations are on pages 6-26 to 6-28).

## 6.3 The FAA Method

In assessing the PCN for a pavement under the U. S. Federal Aviation Administration (FAA) utilizes a method that requires factors such as frequency of operation and permissible stress levels be taken into account. Applications of these procedures have been discussed in Section 4 of this report, with the exception that the FAA uses a somewhat different method to analyze rigid pavements. Once an allowable load rating has been established, the determination of the PCN is a process of converting that rating to a standard relative value.

The FAA method uses single, dual and dual-tandem ratings as a means of describing the allowable gross weight of aircraft with these types of main gear arrangements on a pavement. Conversion of these ratings to a PCN is thoroughly described in the advisory circular of Reference 8. A summary of the procedures of this reference is contained in this section, with examples given as to the application of the method.

The FAA publishes U. S. airport pavement ratings in a format that relates the maximum allowable load to gear type. These ratings are shown in the following example format:

| | |
|---|---|
| Single-wheel gear (S) | S50 |
| Dual-wheel gear (D) | D145 |
| Dual-tandem wheel gear (DT) | DT290 |
| Double dual-tandem gear (DDT) | DDT750 |

The interpretation of these ratings is that any aircraft having that designated type of main landing gear can operate up to the allowable gross weight (in 1,000 pounds) indicated by the numerical value of the rating. For example, the rating *D145* means that each of the A319, A320, DC9, MD80, F27, F28, BAe146, B727, or B737 aircraft can operate on the rated pavement at gross weights up to 145,000 pounds, regardless of the individual airplane characteristics such as wheel spacing or tire pressure. The common and overriding factor is that these aircraft all have dual-wheel main landing gear arrangements.

A rating of *DT290* means that a DC8, B707, or B757 can operate on the pavement at gross weights up to 290,000 pounds, in that these aircraft all have dual-tandem wheel main gear assemblies. A rating of *DDT750* would allow a B747 to operate on the pavement at gross weights up to 750,000 pounds.

Other widebody aircraft, such as the L1011, MD11, B747, B767, B777, A300, and A340, require special treatment since their landing gear configurations are outside the boundaries that were used to develop DT gear ratings. These exceptions will be discussed in a later section of this report.

### 6.3.1 Conversion of FAA Ratings to PCN

The computation of PCN from FAA ratings is designed to require a minimum number of inputs. Charts have been developed and published in Reference 8 that require input for only subgrade strength category and allowable gross weight to obtain the PCN. These charts are generalized landing gear configurations and do not represent specific aircraft. In these configurations, the assumption was made that all aircraft have 95 percent of their weight on the main landing gear assembly.

The following charts originate from Reference 8 and are designed for quick assessment of a PCN from the published dual or dual-tandem ratings. Figure 6-1 applies to flexible pavements having a dual-wheel gear rating.

To convert a dual-wheel rating to a PCN, all that needs to be known is the FAA rating and the subgrade type in terms of the ICAO subgrade category of Tables 2-2 or 2-3. As an example, for a subgrade category of C, the dual wheel rating of *D145* is equivalent to an ACN of 44 FC, as shown in Figure 6-1. Assuming that the pavement can handle tire pressures up to 219 psi, the tire pressure code is *X*. Since the original dual-wheel rating was technically assessed, the PCN can be formulated as 44 FCXT. If the subgrade code was category *A*, then the PCN would be 37 FAXT, as is also shown in the figure.

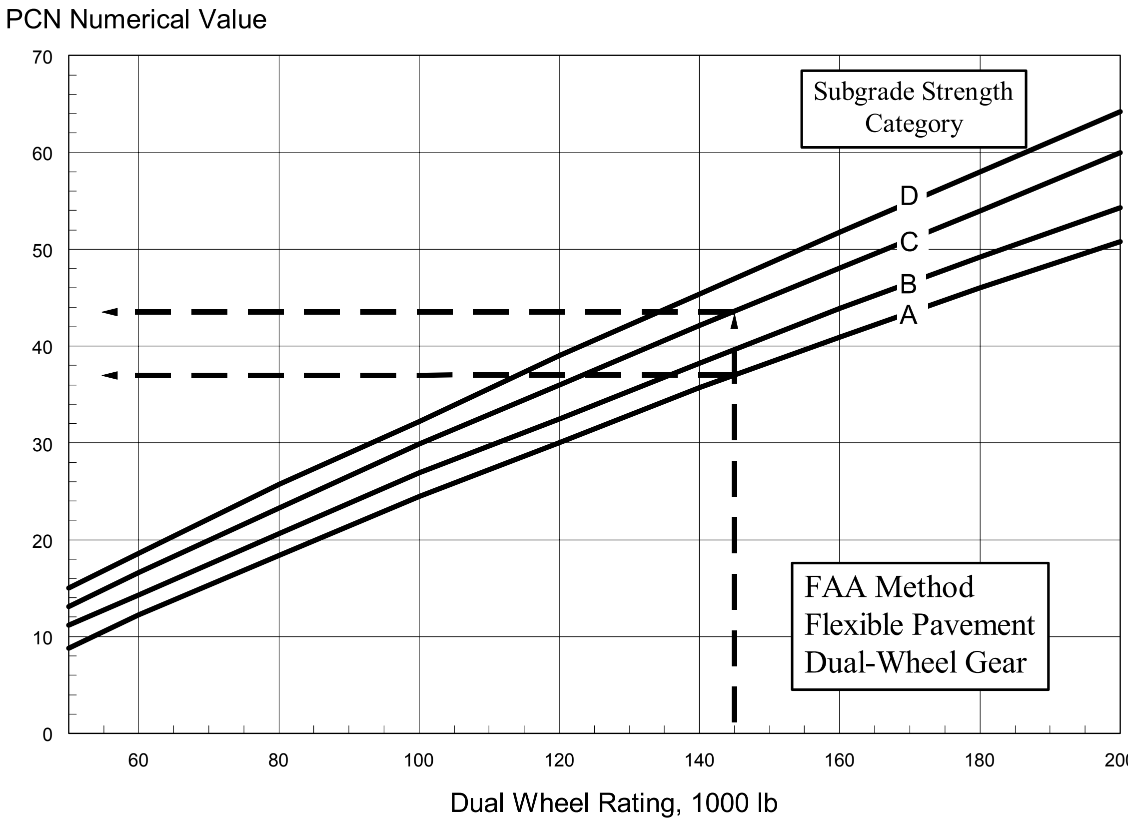


**Figure 6-1. FAA Flexible Pavement Dual-Wheel Rating**

Flexible pavements with dual-tandem wheel ratings can likewise be converted to PCN by using Figure 6-2. In this example, a dual-tandem wheel rating of *DT290* converts to an ACN of 58 FC, and with the same assumptions as before, the PCN is 58 FCXT.

The conversion of rigid pavement ratings is substantially the same as that for flexible pavements except that rigid pavement slabs can normally handle much higher tire pressures. The FAA suggests that for most rigid pavement cases the tire pressure category be assigned as code *W*.

Referring to the example of Figure 6-3, for a rigid pavement rating of *D145* the ACN is 44 RC, for a recommended PCN of 44 RCWT. Likewise, as shown in Figure 6-4, the example PCN would be 56 RCWT.

## 6.3.2 Specific Aircraft Conversion to PCN

Allowable loadings on a pavement are sometimes established for specific aircraft such as the MD11, A300, B747, B767 and others. The FAA does not consider it practical to develop charts for conversion of all of the many varieties of aircraft to PCN, and so provides an alternate method to classify pavement ratings by using the specific airplane ACN.

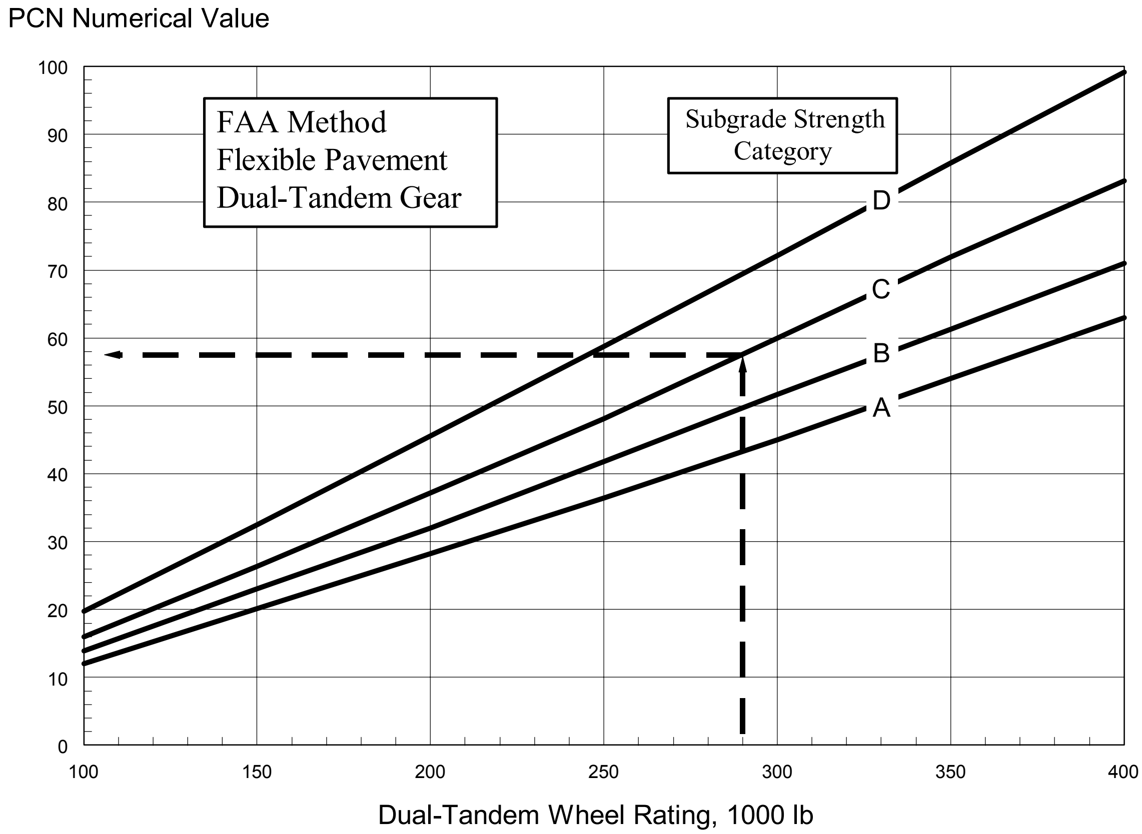


**Figure 6-2. FAA Flexible Pavement Dual-Tandem Wheel Rating**

The procedure followed by the FAA is to compute the ACN of an airplane, and providing that the pavement is performing in a satisfactory manner, converting the ACN to PCN. For example, the ACN of a 390,000-pound DC10 10 on rigid pavement having a subgrade category of B is 46 RB. From this ACN, the PCN can be assigned as 46 RBWT.

The charts presented in this section can also be used to examine the relative impact of aircraft that are not included in the generalized gear arrangements of the FAA charts of Figures 6-1 through 6-4. For example, as seen in Figure 6-4, the PCN of 46 RBWT for the DC10-10 is equivalent to an FAA rating of DT275.

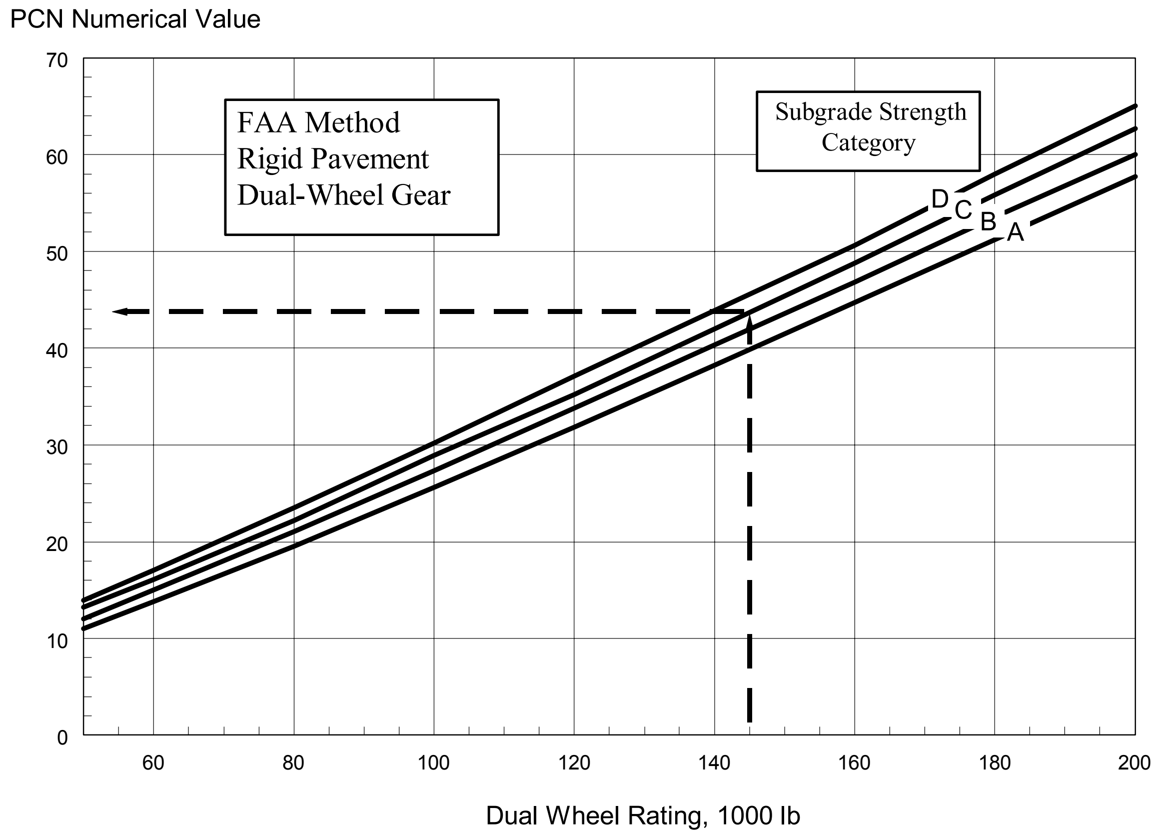


**Figure 6-3:** FAA Rigid Pavement Dual-Wheel Rating

## 6.3.3 Mixed Aircraft

A review of the examples presented in Section 4 of this report suggests that pavements are often rated for several different aircraft, but the PCN method requires that the pavement strength be reported by only one numerical value and 4-letter code. In the FAA method, a runway may have the following example ratings. Selection of the PCN is a matter of determining the ACN of each of the aircraft at the operating gross weight and selecting the highest numerical value as the PCN. In this example, for an assumed rigid pavement with a subgrade code of B, the following table shows that the dual tandem model is critical, and its ACN should be converted to the recommended PCN.

| Model | Gross Weight | ACN | Source |
|---|---|---|---|
| Dual | 145,000 lb | 42 RB | Figure 6-3 |
| Dual tandem | 290,000 | 48 RB | Figure 6-4 |
| L1011-1 | 400,000 | 46 RB | ACN tables |

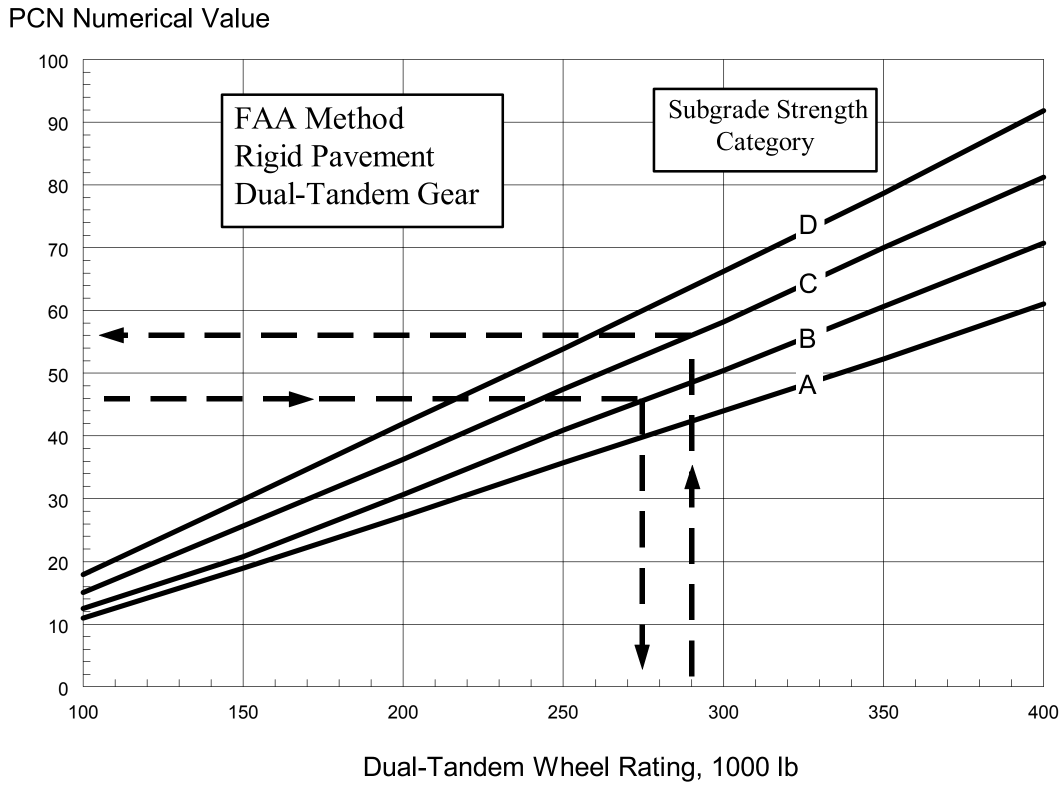


**Figure 6-4. FAA Rigid Pavement Dual-Tandem Wheel Rating**

## 6.4 All Up Weight

The All Up Weight (AUW) method of assessing allowable gross weights is somewhat nebulous in that it is a method that allows the operation of many different aircraft on the pavement without regard to its pavement loading characteristics. This method does not consider factors such as number of wheels on a main gear, differences in wheel spacing, tire pressure, or percent of weight on the main gear. For example, a 737 dual gear airplane and an A320 dual-tandem gear airplane both have the same allowed gross weight, even though the A320 has markedly superior flotation capabilities due to the gear configuration. A rating of AUW120 allows either airplane to operate at 120,000 pounds gross weight, even though the ACNs are quite different. The L1011, DC10, A300 and 767 aircraft all have an allowable gross weight of 350,000 pounds on a pavement with a rating of AUW350.

It is suggested that the airport authority take into account the mix of traffic when deciding on a conversion to PCN for these cases. The PCN should reflect the ACN of the critical aircraft, which can be determined as was done for the *Using* aircraft methods as described in Section 4 of this document.

## 6.5 Unpaved Runways

ICAO, in Reference 2, allows the publication of PCNs for other than the standard concrete and asphalt surfaced runways, even those that do not have a paved surface. These unpaved runways are to be rated with a flexible classification. Likewise, special types of pavements such as brick or block, small pre-cast slabs, and military landing mats and membrane surfaces should be classified as flexible.

Although this recommended practice may be appropriate to the types of surfaces listed above, it has been the experience at the Boeing Company that surfaces composed of gravel or dirt are very sensitive to the aircraft tire pressure and not necessarily to gross weight. With that in mind, the company has certified with the U. S. FAA two of its jet transport aircraft, the 727-100 and the 737-200 for operations on gravel runways.

Specific conditions of the certification are that each runway be examined for each gravel runway on which operation is desired. It must be shown that the runway construction is adequate to support the operational weights under the climatic conditions for the period of intended use. Additionally, the following general requirements must be met:

1. The surface and subbase strength must have minimum thickness, be well compacted, and demonstrate a minimum California Bearing Ratio (CBR). The CBR is to be measured by equipment as developed by the Boeing Company specifically for that purpose and by not the standard CBR laboratory test instruments.

2. Aircraft that are to be operated on a gravel or dirt runway shall be equipped with a gravel kit as developed specifically for that aircraft.

3. A gravel runway subjected to these Boeing models shall be maintained to insure meets minimum requirements and that it is in satisfactory condition.

As a result of Boeing Company experience and the FAA certifications, the PCN designation for gravel runways is not a satisfactory method for gravel runway strength rating. It is recommended that each runway be analyzed separately for its CBR characteristics and other required attributes.

## 6.6 Computer Calculations

The next 12 pages show the pavement calculations and ACNs that were included in the flexible and rigid pavement examples of this section. These listings are in order of the example presentation.

*****FLEXIBLE PAVEMENT ANALYSIS - LCN*****

B747-400 allowable gross weight

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | ELLIPSE RADII A | B |
|---|---|---|---|---|---|---|
| 703000. | 23.75 | 41741. | 200.00 | 208.70 | 9.64 | 6.89 |

| NWHEELS | CLSP (IN.) | AXLSP (IN.) | SMIN (IN.) | SMAX (IN.) | ORIENTATION FACTOR |
|---|---|---|---|---|---|
| 4 | 44.00 | 58.00 | 44.00 | 72.80 | 1.00 |

| THICKNESS (IN.) | ESWL (LB) | LCN |
|---|---|---|
| 15.11 | 41741. | 69.4 |
| 32.00 | 66062. | 99.0 |
| 145.60 | 166963. | 192.9 |

*****FLEXIBLE PAVEMENT ANALYSIS - ACN*****

B747-400

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | RADIUS (IN.) |
|---|---|---|---|---|---|
| 703000. | 23.75 | 41741. | 200.00 | 208.70 | 8.15 |

| NWL | X | Y | GRID | X | Y | ALPHA |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | START | 0.00 | 0.00 | 0.825 |
| 2 | 0.00 | 44.00 | END | 29.00 | 22.00 | |
| 3 | 58.00 | 44.00 | INCR | 3.22 | 2.44 | |
| 4 | 58.00 | 0.00 | | | | |

| SUBGRADE CBR | SUBGRADE CODE | ESWL (LB) | X-LOC (IN.) | Y-LOC (IN.) | THICKNESS (IN.) | ACN |
|---|---|---|---|---|---|---|
| 10. | B (MEDIUM) | 72659. | 3.22 | 4.89 | 23.79 | 48.5 |

*******FLEXIBLE PAVEMENT ANALYSIS - LCN*******

**MD-11 allowable gross weight**

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | ELLIPSE RADII A | B |
|---|---|---|---|---|---|---|
| 474000. | 40.00 | 47400. | 205.00 | 231.22 | 10.15 | 7.25 |

| NWHEELS | CLSP (IN.) | AXLSP (IN.) | SMIN (IN.) | SMAX (IN.) | ORIENTATION FACTOR |
|---|---|---|---|---|---|
| 4 | 54.00 | 64.00 | 54.00 | 83.74 | 1.00 |

| THICKNESS (IN.) | ESWL (LB) | LCN |
|---|---|---|
| 19.75 | 47400. | 77.9 |
| 32.00 | 64819. | 99.0 |
| 167.48 | 189600. | 213.2 |

*******FLEXIBLE PAVEMENT ANALYSIS - ACN*******

**MD-11**

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | RADIUS (IN.) |
|---|---|---|---|---|---|
| 474000. | 40.00 | 47400. | 205.00 | 231.22 | 8.58 |

| NWL | X | Y | GRID | X | Y | ALPHA |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | START | 0.00 | 0.00 | 0.825 |
| 2 | 0.00 | 54.00 | END | 32.00 | 27.00 | |
| 3 | 64.00 | 54.00 | INCR | 3.56 | 3.00 | |
| 4 | 64.00 | 0.00 | | | | |

| SUBGRADE CBR | SUBGRADE CODE | ESWL (LB) | X-LOC (IN.) | Y-LOC (IN.) | THICKNESS (IN.) | ACN |
|---|---|---|---|---|---|---|
| 10. | B (MEDIUM) | 77979. | 3.56 | 3.00 | 24.62 | 51.9 |

## *****FLEXIBLE PAVEMENT ANALYSIS - LCN*****

B777-200 allowable gross weight

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | ELLIPSE RADII A | B |
|---|---|---|---|---|---|---|
| 575000. | 47.50 | 45521. | 215.00 | 211.72 | 9.71 | 6.94 |

| NWHEELS | CLSP (IN.) | AXLSP (IN.) | SMIN (IN.) | SMAX (IN.) | ORIENTATION FACTOR |
|---|---|---|---|---|---|
| 6 | 55.00 | 114.00 | 55.00 | 126.57 | 1.00 |

| THICKNESS (IN.) | ESWL (LB) | LCN |
|---|---|---|
| 20.56 | 45521. | 77.7 |
| 32.00 | 62417. | 99.0 |
| 253.15 | 273125. | 278.8 |

## *****FLEXIBLE PAVEMENT ANALYSIS - ACN*****

B777-200

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | RADIUS (IN.) |
|---|---|---|---|---|---|
| 575000. | 47.50 | 45521. | 215.00 | 211.72 | 8.21 |

| NWL | X | Y | GRID | X | Y | ALPHA |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | START | 28.50 | 0.00 | 0.720 |
| 2 | 0.00 | 55.00 | END | 85.50 | 27.50 | |
| 3 | 57.00 | 0.00 | INCR | 6.33 | 3.06 | |
| 4 | 57.00 | 55.00 | | | | |
| 5 | 114.00 | 0.00 | | | | |
| 6 | 114.00 | 55.00 | | | | |

| SUBGRADE CBR | SUBGRADE CODE | ESWL (LB) | X-LOC (IN.) | Y-LOC (IN.) | THICKNESS (IN.) | ACN |
|---|---|---|---|---|---|---|
| 10. | B (MEDIUM) | 92587. | 53.83 | 3.06 | 23.61 | 47.7 |

*****FLEXIBLE PAVEMENT ANALYSIS - LCN*****

B747-400 allowable gross weight

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | ELLIPSE RADII A | B |
|---|---|---|---|---|---|---|
| 668000. | 23.75 | 39663. | 200.00 | 198.31 | 9.40 | 6.71 |

| NWHEELS | CLSP (IN.) | AXLSP (IN.) | SMIN (IN.) | SMAX (IN.) | ORIENTATION FACTOR |
|---|---|---|---|---|---|
| 4 | 44.00 | 58.00 | 44.00 | 72.80 | 1.00 |

| THICKNESS (IN.) | ESWL (LB) | LCN |
|---|---|---|
| 15.29 | 39663. | 68.3 |
| 35.00 | 66019. | 99.0 |
| 145.60 | 158650. | 186.2 |

*****FLEXIBLE PAVEMENT ANALYSIS - ACN*****

B747-400

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | RADIUS (IN.) |
|---|---|---|---|---|---|
| 668000. | 23.75 | 39663. | 200.00 | 198.31 | 7.95 |

| NWL | X | Y | GRID | X | Y | ALPHA |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | START | 0.00 | 0.00 | 0.825 |
| 2 | 0.00 | 44.00 | END | 29.00 | 22.00 | |
| 3 | 58.00 | 44.00 | INCR | 3.22 | 2.44 | |
| 4 | 58.00 | 0.00 | | | | |

| CBR | SUBGRADE CODE | ESWL (LB) | X-LOC (IN.) | Y-LOC (IN.) | THICKNESS (IN.) | ACN |
|---|---|---|---|---|---|---|
| 10. | B (MEDIUM) | 67884. | 3.22 | 2.44 | 22.98 | 45.2 |

*******FLEXIBLE PAVEMENT ANALYSIS - LCN*******

**MD-11 allowable gross weight**

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | ELLIPSE RADII A | B |
|---|---|---|---|---|---|---|
| 449000. | 40.00 | 44900. | 205.00 | 219.02 | 9.88 | 7.06 |

| NWHEELS | CLSP (IN.) | AXLSP (IN.) | SMIN (IN.) | SMAX (IN.) | ORIENTATION FACTOR |
|---|---|---|---|---|---|
| 4 | 54.00 | 64.00 | 54.00 | 83.74 | 1.00 |

| THICKNESS (IN.) | ESWL (LB) | LCN |
|---|---|---|
| 19.94 | 44900. | 74.7 |
| 35.00 | 64771. | 99.0 |
| 167.48 | 179600. | 205.5 |

*******FLEXIBLE PAVEMENT ANALYSIS - ACN*******

**MD-11**

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | RADIUS (IN.) |
|---|---|---|---|---|---|
| 449000. | 40.00 | 44900. | 205.00 | 219.02 | 8.35 |

| NWL | X | Y | GRID | X | Y | ALPHA |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | START | 0.00 | 0.00 | 0.825 |
| 2 | 0.00 | 54.00 | END | 32.00 | 27.00 | |
| 3 | 64.00 | 54.00 | INCR | 3.56 | 3.00 | |
| 4 | 64.00 | 0.00 | | | | |

| SUBGRADE CBR | SUBGRADE CODE | ESWL (LB) | X-LOC (IN.) | Y-LOC (IN.) | THICKNESS (IN.) | ACN |
|---|---|---|---|---|---|---|
| 10. | B (MEDIUM) | 72667. | 3.56 | 3.00 | 23.75 | 48.3 |

*****FLEXIBLE PAVEMENT ANALYSIS - LCN*****

B777-200 allowable gross weight

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | ELLIPSE RADII A | B |
|---|---|---|---|---|---|---|
| 575000. | 47.50 | 45521. | 215.00 | 211.72 | 9.71 | 6.94 |

| NWHEELS | CLSP (IN.) | AXLSP (IN.) | SMIN (IN.) | SMAX (IN.) | ORIENTATION FACTOR |
|---|---|---|---|---|---|
| 6 | 55.00 | 114.00 | 55.00 | 126.57 | 1.00 |

| THICKNESS (IN.) | ESWL (LB) | LCN |
|---|---|---|
| 20.56 | 45521. | 77.7 |
| 32.00 | 62417. | 99.0 |
| 253.15 | 273125. | 278.8 |

*****FLEXIBLE PAVEMENT ANALYSIS - ACN*****

B777-200

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | RADIUS (IN.) |
|---|---|---|---|---|---|
| 575000. | 47.50 | 45521. | 185.00 | 246.06 | 8.85 |

| NWL | X | Y | GRID | X | Y | ALPHA |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | START | 57.00 | 0.00 | 0.720 |
| 2 | 0.00 | 55.00 | END | 85.50 | 27.50 | |
| 3 | 57.00 | 0.00 | INCR | 3.17 | 3.06 | |
| 4 | 57.00 | 55.00 | | | | |
| 5 | 114.00 | 0.00 | | | | |
| 6 | 114.00 | 55.00 | | | | |

THE FOLLOWING FLEXIBLE PAVEMENT ACNs ARE CALCULATED USING ALPHA FACTORS DESIGNATED **PRELIMINARY** BY ICAO

| SUBGRADE CBR | SUBGRADE CODE | ESWL (LB) | X-LOC (IN.) | Y-LOC (IN.) | THICKNESS (IN.) | ACN |
|---|---|---|---|---|---|---|
| 10. | B (MEDIUM) | 93631. | 57.00 | 3.06 | 23.64 | 47.9 |

*****RIGID PAVEMENT ANALYSIS - LCN*****

B747-400 allowable gross weight

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | RADIUS (IN.) |
|---|---|---|---|---|---|
| 774000. | 23.75 | 45956. | 200.00 | 229.78 | 8.55 |

| NWL | X | Y |
|---|---|---|
| 1 | 0.00 | 0.00 |
| 2 | 0.00 | 44.00 |
| 3 | 58.00 | 44.00 |
| 4 | 58.00 | 0.00 |

***SEARCH FOR MAXIMUM STRESS POINT***

| RAD. REL. STIFFNESS | MAX STRESS PT--ANGLE X | Y | BETA | ESWL | LCN |
|---|---|---|---|---|---|
| 46.50 | 0.58 | 0.93 | -49.78 | 66088. | 99.0 |

*****RIGID PAVEMENT ANALYSIS - ACN*****

B747-400

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | ELLIPSE RADII A | B |
|---|---|---|---|---|---|---|
| 774000. | 23.75 | 45956. | 200.00 | 229.78 | 10.48 | 6.98 |

| NWL | X | Y |
|---|---|---|
| 1 | 0.00 | 0.00 |
| 2 | 0.00 | 44.00 |
| 3 | 58.00 | 44.00 |
| 4 | 58.00 | 0.00 |

| SUBGRADE MODULUS | CODE | X-LOC (IN.) | Y-LOC (IN.) | THICKNESS (IN.) | ACN RIGID |
|---|---|---|---|---|---|
| 150. | C (LOW) | 1.03 | 0.94 | 14.60 | 63.9 |

*****RIGID PAVEMENT ANALYSIS - LCN*****

MD-11 allowable gross weight

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | RADIUS (IN.) |
|---|---|---|---|---|---|
| 505000. | 40.00 | 50500. | 205.00 | 246.34 | 8.86 |

***SEARCH FOR MAXIMUM STRESS POINT***

| NWL | X | Y |
|---|---|---|
| 1 | 0.00 | 0.00 |
| 2 | 0.00 | 54.00 |
| 3 | 64.00 | 54.00 |
| 4 | 64.00 | 0.00 |

| RAD. REL. STIFFNESS | MAX STRESS PT--ANGLE X | Y | BETA | ESWL | LCN |
|---|---|---|---|---|---|
| 46.50 | 0.17 | 0.57 | -46.84 | 64801. | 99.0 |

*****RIGID PAVEMENT ANALYSIS - ACN*****

MD-11

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | ELLIPSE RADII A | B |
|---|---|---|---|---|---|---|
| 505000. | 40.00 | 50500. | 205.00 | 246.34 | 10.85 | 7.22 |

| NWL | X | Y |
|---|---|---|
| 1 | 0.00 | 0.00 |
| 2 | 0.00 | 54.00 |
| 3 | 64.00 | 54.00 |
| 4 | 64.00 | 0.00 |

| SUBGRADE MODULUS | CODE | X-LOC (IN.) | Y-LOC (IN.) | THICKNESS (IN.) | ACN RIGID |
|---|---|---|---|---|---|
| 150. | C (LOW) | 0.77 | 0.68 | 14.49 | 62.9 |

*****RIGID PAVEMENT ANALYSIS - LCN*****

B777-200 allowable gross weight

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | RADIUS (IN.) |
|---|---|---|---|---|---|
| 543000. | 47.50 | 42988. | 215.00 | 199.94 | 7.98 |

***SEARCH FOR MAXIMUM STRESS POINT***

| NWL | X | Y |
|---|---|---|
| 1 | 0.00 | 0.00 |
| 2 | 0.00 | 55.00 |
| 3 | 57.00 | 0.00 |
| 4 | 57.00 | 55.00 |
| 5 | 114.00 | 0.00 |
| 6 | 114.00 | 55.00 |

| RAD. REL. STIFFNESS | MAX STRESS PT--ANGLE X | Y | BETA | ESWL | LCN |
|---|---|---|---|---|---|
| 46.50 | 57.06 | 1.07 | 89.99 | 62407. | 99.0 |

*****RIGID PAVEMENT ANALYSIS - ACN*****

B777-200

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | ELLIPSE RADII A | B |
|---|---|---|---|---|---|---|
| 543000. | 47.50 | 42988. | 215.00 | 199.94 | 9.78 | 6.51 |

| NWL | X | Y |
|---|---|---|
| 1 | 0.00 | 0.00 |
| 2 | 0.00 | 55.00 |
| 3 | 57.00 | 0.00 |
| 4 | 57.00 | 55.00 |
| 5 | 114.00 | 0.00 |
| 6 | 114.00 | 55.00 |

THE FOLLOWING FLEXIBLE PAVEMENT ACNs ARE CALCULATED USING ALPHA FACTORS DESIGNATED **PRELIMINARY** BY ICAO

| SUBGRADE MODULUS | CODE | X-LOC (IN.) | Y-LOC (IN.) | THICKNESS (IN.) | ACN RIGID |
|---|---|---|---|---|---|
| 150. | C (LOW) | 56.9 | 0.98 | 14.68 | 64.6 |

*****RIGID PAVEMENT ANALYSIS--LCG*****

B747-400 allowable gross weight

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | ELLIPSE RADII A | B |
|---|---|---|---|---|---|---|
| 805000. | 23.75 | 47797. | 200.00 | 238.98 | 10.69 | 7.12 |

| NWL | X | Y |
|---|---|---|
| 1 | 0.00 | 0.00 |
| 2 | 0.00 | 44.00 |
| 3 | 58.00 | 44.00 |
| 4 | 58.00 | 0.00 |

***SEARCH FOR MAXIMUM STRESS POINT***

| RAD. REL. STIFFNESS | MAX STRESS PT--ANGLE X | Y | BETA | ESWL | LCN | LCG |
|---|---|---|---|---|---|---|
| 40.00 | 0.58 | 0.70 | -58.30 | 60479. | 76.0 | III |

*****RIGID PAVEMENT ANALYSIS - ACN*****

B747-400

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | ELLIPSE RADII A | B |
|---|---|---|---|---|---|---|
| 805000. | 23.75 | 47797. | 200.00 | 238.98 | 10.69 | 7.12 |

| NWL | X | Y |
|---|---|---|
| 1 | 0.00 | 0.00 |
| 2 | 0.00 | 44.00 |
| 3 | 58.00 | 44.00 |
| 4 | 58.00 | 0.00 |

| SUBGRADE MODULUS | CODE | X-LOC (IN.) | Y-LOC (IN.) | THICKNESS (IN.) | ACN RIGID |
|---|---|---|---|---|---|
| 150. | C (LOW) | 1.13 | 0.99 | 14.98 | 67.5 |

*****RIGID PAVEMENT ANALYSIS--LCG*****

MD-11 allowable gross weight

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | ELLIPSE RADII A | B |
|---|---|---|---|---|---|---|
| 531000. | 40.00 | 53100. | 205.00 | 259.02 | 11.13 | 7.41 |

| NWL | X | Y |
|---|---|---|
| 1 | 0.00 | 0.00 |
| 2 | 0.00 | 54.00 |
| 3 | 64.00 | 54.00 |
| 4 | 64.00 | 0.00 |

***SEARCH FOR MAXIMUM STRESS POINT***

| RAD. REL. STIFFNESS | MAX STRESS PT--ANGLE X | Y | BETA | ESWL | LCN | LCG |
|---|---|---|---|---|---|---|
| 40.00 | 0.35 | 0.43 | -57.08 | 59842. | 75.9 | III |

*****RIGID PAVEMENT ANALYSIS - ACN*****

MD-11

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | ELLIPSE RADII A | B |
|---|---|---|---|---|---|---|
| 531000. | 40.00 | 53100. | 205.00 | 259.02 | 11.13 | 7.41 |

| NWL | X | Y |
|---|---|---|
| 1 | 0.00 | 0.00 |
| 2 | 0.00 | 54.00 |
| 3 | 64.00 | 54.00 |
| 4 | 64.00 | 0.00 |

| SUBGRADE MODULUS | CODE | X-LOC (IN.) | Y-LOC (IN.) | THICKNESS (IN.) | ACN RIGID |
|---|---|---|---|---|---|
| 150. | C (LOW) | 0.78 | 0.71 | 14.97 | 67.4 |

*****RIGID PAVEMENT ANALYSIS--LCG*****

B777-200 allowable gross weight

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | ELLIPSE RADII A | B |
|---|---|---|---|---|---|---|
| 587000. | 47.50 | 46471. | 215.00 | 216.14 | 10.17 | 6.77 |

| NWL | X | Y |
|---|---|---|
| 1 | 0.00 | 0.00 |
| 2 | 0.00 | 55.00 |
| 3 | 57.00 | 0.00 |
| 4 | 57.00 | 55.00 |
| 5 | 114.00 | 0.00 |
| 6 | 114.00 | 55.00 |

***SEARCH FOR MAXIMUM STRESS POINT***

| RAD. REL. STIFFNESS | MAX STRESS PT--ANGLE X | Y | BETA | ESWL | LCN | LCG |
|---|---|---|---|---|---|---|
| 40.00 | 57.02 | 0.70 | 90.00 | 58902. | 76.0 | III |

*****RIGID PAVEMENT ANALYSIS - ACN*****

B777-200

| GROSS WT (LB) | PCT WT ON MG | SWL (LB) | PRESSURE (PSI) | CONTACT AREA | ELLIPSE RADII A | B |
|---|---|---|---|---|---|---|
| 587000. | 47.50 | 46471. | 215.00 | 216.14 | 10.17 | 6.77 |

| NWL | X | Y |
|---|---|---|
| 1 | 0.00 | 0.00 |
| 2 | 0.00 | 55.00 |
| 3 | 57.00 | 0.00 |
| 4 | 57.00 | 55.00 |
| 5 | 114.00 | 0.00 |
| 6 | 114.00 | 55.00 |

| SUBGRADE MODULUS | CODE | X-LOC (IN.) | Y-LOC (IN.) | THICKNESS (IN.) | ACN RIGID |
|---|---|---|---|---|---|
| 150. | C (LOW) | 57.02 | 1.10 | 15.54 | 73.0 |