CE 452
Transportation Engineering Sessional II
(Manual)

Department of Civil Engineering
Ahsanullah University of Science and Technology
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Preface

This manual covers traffic studies, reinforcement detailing of rigid pavement by road pavement design manual-2021 of Local Government Engineering Department (LGED) according to Road Note 29 developed by Transportation Research Laboratory (TRL) of UK, flexible pavement design by catalogue method of LGED according to Road Note 31 developed by TRL and design of airfield pavement by AC 150/5320-6D developed by Federal Aviation Administration (FAA) of US Department of Transportation (DoT). The road traffic studies are based on collecting field data and in this process students will learn to design, organize and conduct a traffic survey work and also to conduct work simultaneously and quickly.

While preparing the lab manual, different graphs, charts and images are collected from manual developed by LGED, TRL and Federal Aviation Administration (FAA) of US Department of Transportation (DoT).

Prepared By

Md. Minhajul Islam Khan
Assistant Professor
Department of Civil Engineering
Ahsanullah University of Science and Technology

Updated By

Md. Yusuf Ali
Assistant Professor
Department of Civil Engineering
Ahsanullah University of Science and Technology

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1. Traffic Volume Study

Data Collection

- ☐ Observation- Classified Vehicle Counts
- ☐ Method- Manual
- ☐ Equipment- Hand counter, Tally Sheet, Clip board etc.
- ☐ Location- Mid-block
- ☐ Duration- 30 minute (short count)
- ☐ Sampling- Count all vehicles
- ☐ Enumerators- 6 nos.
- ☐ Group activity- Each enumerator would count a specific vehicle (s) type

Survey Tips

Before data collection

- ☐ Find the suitable site for observation i.e. at what location of the road and from which position (at/above ground)
- ☐ Check/calibrate the counters (hand tally)
- ☐ Perform a trial survey to familiarize with the job and to find any problem in vehicle counting

Table: Sample Data Sheet for Volume Study

Survey Purpose or Project name																
Name of Enumerator								Location				Northing				
Date of Survey												Easting				
Weather Condition												Starting Time				
Vehicle type		**Motorized Vehicles**												**Non-motorized vehicles**		
		Single Unit Truck			4-Wheeler (4-WL)				3-WL				Non-Standard			
Vehicle class		Heavy 3 XL 10 WL	Medium 2 XL 6 WL	Mini 2 XL 4 WL	Large Bus >40 Seats 11 m	Mini bus 16-39 seats	Microbus/ Jeep/Pickup < 16 seats	Car/Taxi Station Wagon	Easy Bike/ CNG	Agricul-tural Tractor	Agricul-tural Trailer	Motor-cycle	Korimon/ Nosimon	Bicycle	Cycle Rickshaw/ Van	Push Cart
PCU Factor																
Time																
00.00-15.00	L															
	T															
	R															
15.00-30.00	L															
	T															
	R															
30.00-45.00	L															
	T															
	R															
45.00-60.00	L															
	T															
	R															

Data Analysis

- For each direction
  - Determine vehicle composition of traffic stream and show in a Pie-chart
  - Determine service flow rate in PCU/PCE unit
  - Determine directional distribution (DD)
  - Peak hour flow (PHF)
- For whole width of the road
  - Estimate average annual daily traffic AADT based on expansion factors

$$\text{HEF} = \frac{\text{Total volume for 24 hour period}}{\text{Volume for particular hour}}$$

$$\text{DEF} = \frac{\text{Average total volume for a week}}{\text{Average volume for particular day}}$$

$$\text{MEF} = \frac{\text{AADT}}{\text{ADT for particular month}}$$

  - Draw flow-fluctuation curve (sharing other groups data)

The required expansion factor is provided in Appendix 3

2. Traffic Speed Study

Data Collection

Spot Speed

- ☐ Observation- Travel time between 88 ft strip (Speed= 60/time in second = speed in mph)
- ☐ Method- Manual (Strip Method)
- ☐ Equipment- Ranging rods for strip marking, stopwatch, data sheet etc.
- ☐ Location- Mid-block (free from obstructions)
- ☐ Duration- 30 minutes (at least 50 observations for each group)
- ☐ Sampling- Random, only free flow vehicles, matching vehicle proportion in the traffic stream
- ☐ Enumerators- 6 numbers
- ☐ Group activity- Each enumerator would record travel time of a specific vehicle(s) type

Travel Speed

- ☐ Observation- Travel time between two widely separated sections
- ☐ Method- Matching registration plate
- ☐ Equipment- Ranging rods for marking terminal points, watch, speed recorder etc.
- ☐ Location- Suitable points would be where vehicle approach0\-speed is low (near junctions, speed breaker etc)
- ☐ Duration- 30 minutes
- ☐ Sampling- Record as many vehicle as possible
- ☐ Enumerators- 12 numbers (6 numbers at upstream and 6 numbers at downstream)
- ☐ Gr. Activity- Each enumerator would record type of vehicle, registration no. and entry/exit time of a specific vehicle(s) type.

Survey Tips

Before start of the work

- ☐ Prepare a data sheet to enter vehicle type, registration number, entry/exit time
- ☐ For quick entry
    - o Assign vehicle abbreviations
    - o Record only the numeric part of registration plate
- ☐ Use digital wrest watch to measure travel time in second
- ☐ Synchronize enumerators’ wrest watches
- ☐ To fix starting and ending time of data recording at up & downstream, estimate off-set time between up & downstream points
- ☐ To go to the downstream position quickly, rickshaws can be used

Analysis

Spot speed

- ☐ Calculate speeds
- ☐ Present data in a tabular form for statistical analysis
- ☐ Plot histogram, Frequency Curve and Cumulative frequency curve
- ☐ Determine weighted average speed, Pace, modal speed, speed limits, design speed limits, design speed
- ☐ Check the speed distribution pattern by a normal distribution curve

Travel Speed

- ☐ Find time mean speed and space mean speeds
- ☐ Prove that:
    - The space mean speed is lower than the time mean speed (usually $V_s<V_t$)
    - The Wardrop relationship between time mean speed and space mean speed is $\bar{V}_t = \bar{V}_s + \delta_s^2/V_s$;

      δ_s = Standard deviation of V_s

      δ_s^2 is the variance about the space mean speed
- ☐ Delay for each type of vehicle (assuming free flow spot-speed as the travel speed)
- ☐ Find the cost of delay based on present users' value of travel time (VOT), vehicle occupancy rate and vehicles operating cost (VOC)

Speed Flow

- ☐ Draw speed (space-mean)-Flow curve based on observed data

3. Roadway Condition Survey

Data collection

Geometric condition

- ☐ Observations
  - Geometric layout of the roadway (road length, width, no. of lanes, median height, width, shoulder height, width etc.)
  - Geometric layout of intersections (geometric measurement and position of channels/islands, corner radius, dimension and location of pedestrian refuge)
  - Surface condition
    - ✓ By skid resistance tester of sand-patch method (near high speed location, Zebra crossing, intersection)
    - ✓ By qualitative observation of potholes, elevated/depressed manholes, speed breakers etc.
  - Equipment – Tape, Odometer etc.

Operating condition

- ☐ Observations
  - Location and width of side roads
  - Road side land-use pattern
  - Loss of road width due to parking, passenger loading/unloading, presence of dustbin/construction materials etc.
  - Pedestrian crossing facilities
  - Location and type of control devices
    - ✓ Road signs, markings
    - ✓ Signal (per approach no. of signal, type of signal heads, special filter signal)
    - ✓ Speed breakers
  - Layout of street lighting system (spacing, pattern etc.)

Analysis

- Draw the detailed layout of roadway and intersection
- Show the location of bottlenecks (side road, parking, pedestrian concentrations, dust bins, speed breakers etc.), street light arrangement, control devices etc.
- Determine
  - ✓ Loss of effective width at different locations of road
  - ✓ Average skid resistance value at different locations of road
  - ✓ Density of side roads (access control)
- Identify road traffic problems and suggest improvement measures

4. Joint Details of Rigid Pavement

Main Causes of Failure of Rigid Pavement

- ☐ Fatigue
- ☐ Rutting
- ☐ Differential swelling of sub-grade
- ☐ Pore pressure due to poor surface & sub-surface drainage
- ☐ Long time submergence
- ☐ Construction and design faults etc.

Stress Inducing Factors of Rigid Pavement

Besides fatigue, rigid pavement slab fails due to distresses caused by:

- ☐ Uniform temperature along thickness — which causes
  - **Contraction**
    - Immediately after construction
    - At night especially during winter season
    - Causes
      - at the slab - shrinkage/distributed(random) cracks because of
        - volume change along with frictions developed at the soil-slab interface (due to self-wt. of slab)
        - concrete is weaker in tension (about 1/100 of compressive strength)
      - at the edge of expansion joints - excessive stress due to widening of gaps
    - Solutions
      - to minimize immediate shrinkage cracks
        - construction of work should be carried out during winter season
        - should not be constructed when ambient temperature is more than 31°C
        - use of retarder admixture (slow setting)/ice water etc.
        - use of short panel and stabilized subbase
      - to minimize contraction cracks
        - for larger panel size, use of temperature/distributed reinforcement - to hold the crack tightly
        - use of contraction joint (pre-formed crack) - to concentrate random cracks into intended location
        - use of tie bars to prevent construction joints from opening
  - **Expansion**
    - During daytime
    - Causes blowup problems at the slab edges
    - Solution - provision of expansion joints and to reduce load transfer related problems at joints
      - use of skewed joints or
      - use of Dowel bars

- ☐ Differential temperature/temp. gradient along thickness of slab — which causes
    - **Warping**
        - During transition of day to night and night to day
        - Causes cracks due to warping of slab
        - Solution - use of distributed reinforcement
- ☐ Moisture change — which causes
        - Pumping problems at joints (due to losses of sub-surface materials with water)
        - Solution - use of Dowel bars

Joint types

- ☐ Direction-wise
    - **Longitudinal joints**
    - **Transverse joints**
- ☐ Function-wise
    - **Contraction joints**
        - are used to prevent irregular shrinkage cracks
        - are used to make sure that cracking will occur at a predetermined desired location
        - are used to relieve tensile stress resulting from contraction and warping of the concrete
        - constructed by cutting a groove at the pavement surface; groove may be formed by sawing or by placing a metal strip
        - dowel bars are used to transfer load across the joints
        - to permit freedom of movement dowel should be lubricated plain bars
    - **Expansion joints**
        - are used to permit thermal expansion of slab and to prevent blowup at the slab edges
        - are used to relieve compressive stress resulting from expansion of the concrete
        - constructed with a clean break throughout the depth of the slab
        - usually joint opening of l9mm (3/4") to 25mm (1") is used
        - dowel bars are used to transfer load across the joints
        - to permit freedom of movement, dowel bars must be smooth and lubricated on at least one side
        - an expansion cap must also be provided to allow space for dowel bar to move during the expansion process
        - filler (cork/plastic/rubber) and sealant materials are needed to concealed the Joints to reduce infiltration of water or pumping effect and to reduce clogging of joint with hard material or chance of blowup problem
        - expansion joints are susceptible to pumping action
        - periodic maintenance is required

- **Construction joints**
  - are used at the transition from old to new construction, such as at the end of a day's pour or at longitudinal joints
  - instead of dowel bars, usually key form is used to act as load transferring device and
  - deformed or hooked tie bars are used to hold/anchored two adjacent segments firmly to prevent movement

- Layout-wise - w.r.t. direction of travel
  - **Perpendicular joints**
  - **Skewed joints**

Types of Reinforcement

- Temperature/distributed reinforcements
  - used to control the width of the crack opening and not to prohibit the formation of cracks
  - not to increase structural capability of the pavements
  - smaller in sizes
  - applied in the slab, usually in both directions in the form of welded wire-mesh or bar-mat
  - amount depend on length of panel & thickness of slab
- Dowel bars
  - used as a load transferring device (with high shearing strength i.e. with large x-sectional area)
  - used to reduce deflection of slab edge and to control pumping effect
  - 25mm (#8) or 32mm (#10) in size, 600mm (2') long and spaced @200mm (8") to 300mm (12") c/c
  - applied only in longitudinal direction and across the expansion & contraction joints
  - to allow freedom of movement of the slab, dowel bars must be smooth and lubricated
  - become necessary for longer span i.e. >12m or 40' (due to excessive movements of expansion joints)
  - they are placed at mid-depth of the slab
- Tie bars
  - are used to tie two adjacent slabs together
  - the bars are not so heavy and are smaller than dowel bars & spaced at greater intervals
  - usually 12mm (114) - 19mm (#5) bars are used
  - length of tie bars are determined from bond criterion
  - must be deformed or hooked and must be firmly anchored into the concrete to function properly

According to the reinforcement and joints, rigid pavement can be mainly classified in to as follows-

- <u>Jointed reinforced concrete pavement (JRCP)</u>: JRCP uses contraction joints and reinforcing steel to control cracking. Transverse joint spacing typically ranges from about 7.6 m (25 ft.) to 15.2 m (50 ft.). Temperature and moisture stresses are expected to cause cracking between joints, hence reinforcing steel or a steel mesh is used to hold these cracks tightly together. Dowel bars are typically used at transverse joints to assist in load transfer while the reinforcing steel/wire mesh assists in load transfer across cracks.

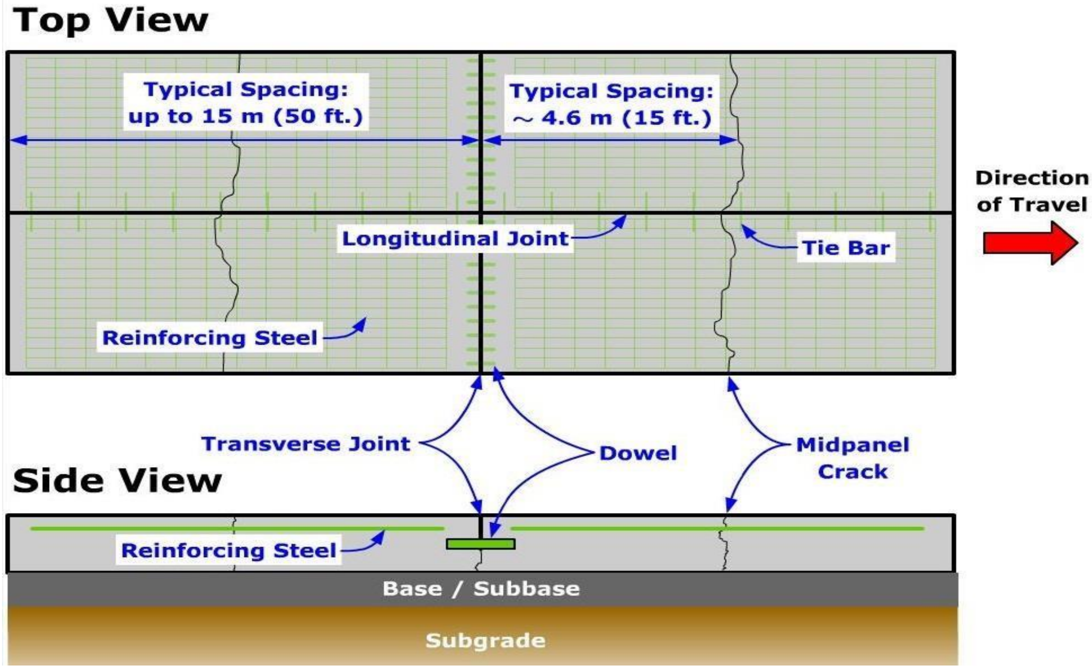

Figure 4.1 Jointed reinforced concrete pavement (JRCP)

- Continuously reinforced concrete pavement (CRCP): CRCP has no active transverse contraction joints. Continuous longitudinal reinforcement is provided that results in tight cracks in the concrete at about 2-ft to 8-ft (0.6 m to 2.4 m) spacing. Sufficient reinforcement is necessary to keep the cracks tight. Unlike dowel bars, reinforcing steel is bonded to the concrete on either side of the crack in order to hold the crack tightly together and provides load transfer across these cracks.

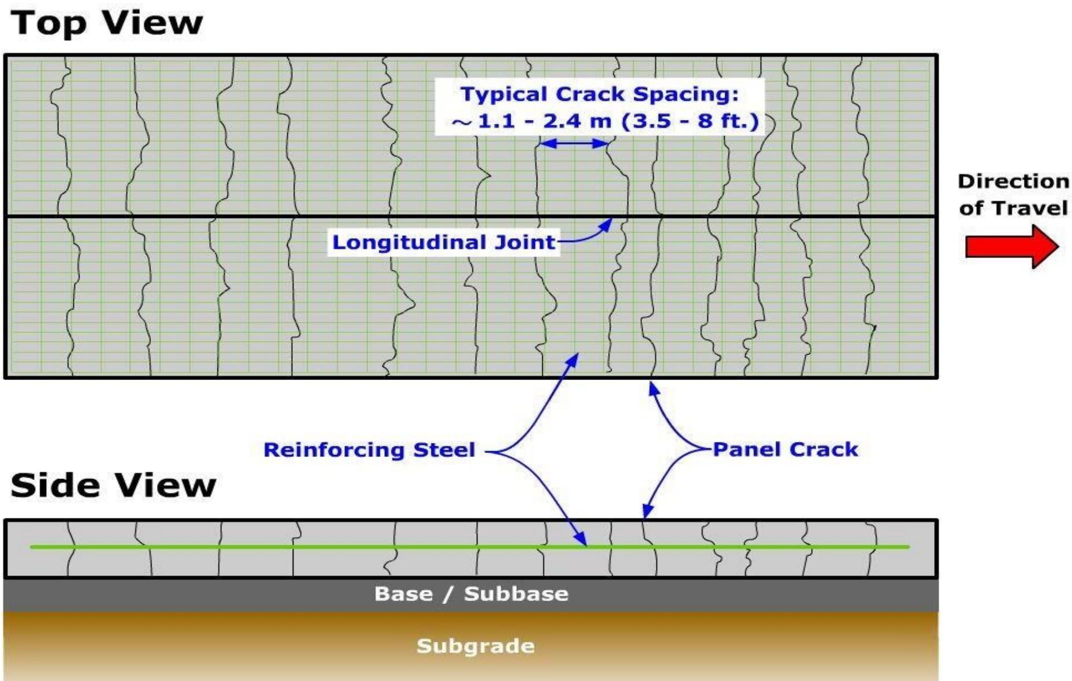

Figure 4.2. Continuously reinforced concrete pavement (CRCP)

- ☐ <u>Jointed plain concrete pavement (JPCP)</u>: JPCP uses contraction joints to control cracking and does not use any reinforcing steel. Transverse joint spacing is selected such that temperature and moisture stresses do not produce intermediate cracking between joints. This typically results in a spacing no longer than about 6.1 m (20 ft.). Dowel bars are typically used at transverse joints to assist in load transfer. Tie bars are typically used at longitudinal joints.

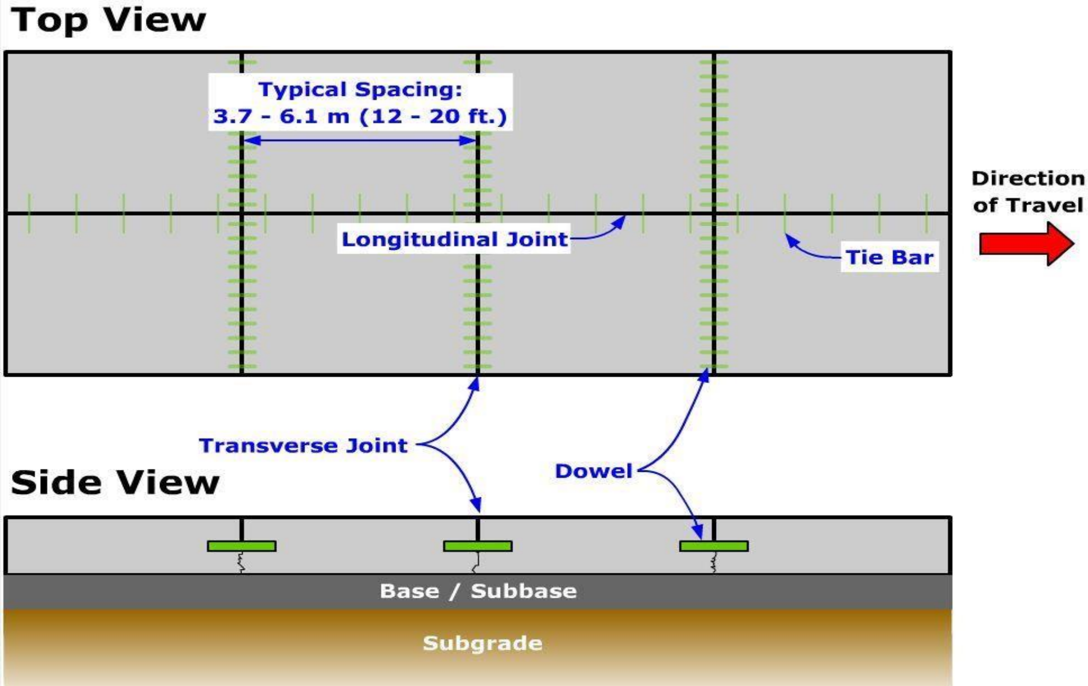

Figure 4.3. Jointed plain concrete pavement (JPCP)

To show the reinforcement and joint detailing of a rigid pavement, an example of Jointed reinforced concrete pavement (JRCP) is provided. The temperature/distribution reinforcement in a JRCP is calculated by Road pavement design manual-2021 of Local Government Engineering Department (LGED), according to Road Note 29 developed by Transportation Research Laboratory (TRL).

<u>Calculation of Temperature/Distributed Reinforcement</u> (according to Road Note 29)

- Assumption - resistance to movement of slab will be overcome by tension in steel
- $A_s = (W*f/f_s)L$
  Where A_s = steel per foot of width;
  W = weight of slab (lb/ft^2)
  f = co-efficient of resistance (generally assumed to be 1.5);
  fs = allowable stress of steel (psi)
  L = length of slab (in longitudinal direction L is L/2 and in transverse direction L is L)
- From the equation it is seen that the amount of steel is directly proportional to L, as such amount of steel can be reduced to zero by shortening the length of the slab
- On the contrary, shorter slab increases no of joints; as joints are vulnerable and costly to maintain there need to make a trade-off between slab length (cost of reinforcement) and no. of joints (cost of joint construction)

Selection Criteria of slab length and its type

a. Stabilized sub-base

- Cement treated Sub-base/base add to the structural capability of pavement &
- also assist in load transfer across joints without dowel bars
- therefore, use of short slabs (increase no of joints) and a cement-treated sub-base sometimes go hand- in hand

b. Plain Versus Reinforced Pavements

- Plain pavements:
  - no temperature reinforcement is required
  - no contraction joints
  - dowel bars at expansion joints are also omitted if stabilized sub-base is used
  - suitable for
    - pavements that will carry low volume of traffic and
    - slab length is < 6m or 20'
- Simply reinforcement pavements:
  - when slab length lies in between 6m (20') to 23m (75')
  - it became necessary to use
    - some steel for crack control as well as contraction joints
    - dowel bars at the joints to assist with load transfer
  - suitable for pavements that will carry medium volume of traffic
- Continuously reinforced pavements
  - when slab length is > 23m or 75'
  - amount of steel required to hold the cracks become excessive
  - no need for contraction joints

Reinforcement Detail of Rigid Pavement

Problem:

Design Reinforcement of the following:

Thickness of rigid pavement, t = 12 inch

No. of lanes = 2

Width of pavement, w = 24 ft

Spacing of transverse joint = 45 ft

Allowable Strength of:

Shrinkage steel (bar-mat) = 33000 psi

Tie bars = 27000 psi

Bond = 350 psi (10% compressive strength of concrete)

Draw reinforcement and joint details

Solution:

Amount of shrinkage reinforcement, A_s (in^2/ft) = ($W*f/f_s$)* Effective length

Wt. of pavement, W = 150*12/12= lb/ft^2

Coefficient of friction, f = 1.5

Distributed Temperature Reinforcement:

Longitudinal direction A_s = (*1.5/33000)*45/2 = in^2/ft

If #4 bars are used, spacing = Area of bar/A_s = 0.2/ = ft

Transverse direction, A_s= (*1.5/33000)*24/2 = in^2/ft

If #4 bars are used, spacing = Area of bar/A_s = 0.2/ = ft

Tie bars along longitudinal construction joints:

Longitudinal direction, A_s = (*1.5/27000)*24/2 = in^2/ft

If #5 bars are used, spacing = Area of bar/A_s = 0.31/ = ft

Length of tie bars is, t(in) = 0.5 ($f_s d$)/f_b + 3" = 0.5*(27000*5/8)/350 + 3 = inch

(where d=dia of tie bar in inch)

Dowel bars across transverse and contraction joints:

Bar Detail	Transverse Joints	Contraction Joints
Bar Size	No.	No.
Length	ft	ft
Spacing	in c/c	in c/c

Where part of load transferred by interlocking of aggregates

5. Design of Flexible Pavement

Catalogue Method of Flexible Pavement Design

Considering the behavior of local materials, climatic condition and construction practices, a Catalogue of Pavement Structure is developed

- To simplify design procedure
- To prevent both under design and over design and thereby
- To ensure economical design

The method is designed by LGED (Local Government Engineering Department) as per the Road Note 31 delivered by TRL (Transportation Research Laboratory) of UK Government. This design method is applicable for –

- Undivided rural road having crest width ranging from 5.6-7.3 m.
- Flexible and semi-rigid pavement (i.e. ratio of modulus between two successive layer is <5)
- Cumulative traffic 0.5-3.0 MESA (million equivalent standard axle)

This design method is established based on –

- Empirical Analysis – investigating behavior of existing pavement structure and experience gathered in other countries with similar conditions
- Experimental results – laboratory tests of local soil and road construction materials
- Theoretical knowledge – consideration of pavement mechanism i.e. elastic theory of pavement behavior under the effect of traffic
- Finally, design catalogue is prepared by checking PADMA (Pavement Design by Mathematical Analysis) software (stress and strain are calculated at the interface of the layers and compared with admissible values as function of expected maximum axle load, cumulative traffic, material characteristics)
- Structures proposed are intended to use materials and construction technique traditionally pertaining in Bangladesh.
- A balancing between geometric and structural design of pavement

<u>Problem:</u> Design flexible pavement for an undivided rural highway by using catalogue of pavement structure method for the following data and also determine the construction of a 10 km highway.

Given:

The forecast AADT for 2022 the year of opening is assessed as:

Vehicle Types	**Two-way AADT vpd**
Large Truck	450
Small Truck	90
Large Bus	400
Small Bus	30
Car	200
Auto-rickshaw	50
Motorcycle	30
Bicycle	50
Rickshaw	60
Cart	10

Assume:

Growth Rate, r =	7.5%	per annum
Design Period, n =	15	year
CBR of Subgrade =	9.0%	

<u>Solution:</u>

(A) Determination of Roadway Geometry

Vehicle Types	**Two-way ADT (vpd)**	**PCU Factors**	**PCU/day at 2022**
Large Truck			
Small Truck			
Large Bus			
Small Bus			
Car			
Auto-rickshaw			
Motorcycle			
Bicycle			
Rickshaw			
Cart			
		Total =	

Forecasted design flow in 2037 = Total PCU/day at 2022 x (1+ growth rate) $^{(\text{design period})}$

= x $(1.075)^{15}$ PCU/day

From the manuals of geometric design standards, the recommended:

Road Width = m

Shoulder Width = m

(B) Determination of Cumulative ESAL for Pavement Design

Heavy Vehicle Types	Two-way AADT (vpd)	ESAL per vehicle	Cumulative ESAL*
Large Truck			
Small Truck			
Large Bus			
Small Bus			
		Total =	

$$\text{*Cumulative ESAL} = 365 \times \text{AADT} \times \text{ESAL} \times \frac{[(1+r)^n - 1]}{r}$$

Total Cumulative ESAL in both direction =

Total Cumulative ESAL in one direction = DD= 50.0%

Determination of Channelization Factor

The proportion of non-motorized traffic to heavy vehicle is:

P = (+ +)/(+ + +) =

By interpolation Channelization factor from table 3 =

Design Cumulative Traffic = ESA

= MESA

(C) Determination of Pavement Layer Thickness

Traffic Class = for MESA

Subgrade Class = for 9% CBR

Using charts for catalogue provided in Appendix 4 to propose alternative designs of pavement with varying material types. Then evaluate alternatives based on availability of materials, construction strategy and economy.

Table 1: PCU factors for rural road

Vehicle Types	PCU factors
Large Truck	3.0
Small Truck	2.0
Large Bus	2.5
Small Bus	1.5
Car	1.0
Auto-rickshaw	0.8
Motorcycle	0.5
Bicycle	0.3
Rickshaw	2.0
Other	4.0

Table 2: ESAL per vehicle

Vehicle Types	ESAL per veh.
Large Truck	1.5
Small Truck	0.5
Large Bus	0.5
Small Bus	0.2

Table 3: Channelization Factor

Road Width		Channelization factor depending on the ratio of NMV to be applied to one way flow	
m	**ft**	**Low (<0.5)**	**High (>= 0.5)**
5.6	18.4	2.0	2.0
6.8	22.3	1.0	1.8
7.3	23.9	1.0	1.6

Table 4: Traffic Definition

Class	MSA
T0	< 0.5
T1	0.5-1.5
T2	1.5-3.0
T3	3.0-7.5
T4	7.5-20.0
T5	20.0-30.0

Table 5: Subgrade Definition

Class	CBR
S1	3-5
S2	5-7
S3	7-10
S4	10-15
S5	>15

6. Airport Pavement Design

SCOPE

All the methodology, charts and table presented below are as per **AC 150/5320-6D** of Federal Aviation Administration (FAA) of US Department of Transportation (DoT). This method covers pavement design for airports serving aircraft with gross weights of 30,000 pounds (13 000 kg) or more.

BACKGROUND

An airfield pavement and the operating aircraft represent an interactive system which must be addressed in the pavement design process. Design considerations associated with both the aircraft and the pavement must be recognized in order to produce a satisfactory design. Careful construction control and some degree of maintenance will be required to produce a pavement which will achieve the intended design life. Pavements are designed to provide a finite life and fatigue limits are anticipated. Poor construction and lack of preventative maintenance will usually shorten the service life of even the best designed pavement.

a. Variables.

The determination of pavement thickness requirements is a complex engineering problem. Pavements are subject to a wide variety of loadings and climatic effects. The design process involves a large number of interacting variables which are often difficult to quantify. Although a great deal of research work has been completed and more is underway, it has been impossible to arrive at a direct mathematical solution of thickness requirements. For this reason, the determination of pavement thickness must be based on the theoretical analysis of load distribution through pavements and soils, the analysis of experimental pavement data, and a study of the performance of pavements under actual service conditions. Pavement thickness curves presented here have been developed through correlation of the data obtained from these sources. Pavements designed in accordance with these standards are intended to provide a structural life of 20 years that is free of major maintenance if no major changes in forecast traffic are encountered. It is likely that rehabilitation of surface grades and renewal of skid resistant properties will be needed before 20 years due to destructive climatic effects and deteriorating effects of normal usage.

b. Structural Design

The structural design of airport pavements consists of determining both the overall pavement thickness and the thickness of the component parts of the pavement. There are a number of factors which influence the thickness of pavement required to provide satisfactory service. These include the magnitude and character of the aircraft loads to be supported, the volume of traffic, the concentration of traffic in certain areas, and the quality of the subgrade soil and materials comprising the pavement structure.

AIRCRAFT CONSIDERATIONS

a. Load

The pavement design method is based on the gross weight of the aircraft. For design purposes the pavement should be designed for the maximum anticipated takeoff weight of the aircraft. The design procedure assumes 95 percent of the gross weight is carried by the main landing gears and 5 percent is carried by the nose gear. AC 150/5300-13, Airport Design, lists the weight of nearly all civil aircraft. Use of the maximum anticipated takeoff weight is recommended to provide some degree of conservatism in the design and is justified by the fact that changes in operational use can often occur and recognition of the fact that forecast traffic is approximate at best. By ignoring arriving traffic some of the conservatism is offset.

b. Landing Gear Type and Geometry

The gear type and configuration dictate how the aircraft weight is distributed to the pavement and determine pavement response to aircraft loadings. It would have been impractical to develop design curves for each type of aircraft. However, since the thickness of both rigid and flexible pavements is dependent upon the gear dimensions and the type of gear, separate design curves would be necessary unless some valid assumptions could be made to reduce the number of variables. Examination of gear configuration, tire contact areas, and tire pressure in common use indicated that these follow a definite trend related to aircraft gross weight. Reasonable assumptions could therefore be made and design curves constructed from the assumed data. These assumed data are as follows:

(1) Single Gear Aircraft: No special assumptions needed.

(2) Dual Gear Aircraft: A study of the spacing between dual wheels for these aircraft indicated that a dimension of 20 inches (0.5 1 m) between the centerline of the tires appeared reasonable for the lighter aircraft and a dimension of 34 inches (0.86 m) between the centerline of the tires appeared reasonable for the heavier aircraft.

(3) Dual Tandem Gear Aircraft: The study indicated a dual wheel spacing of 20 inches (0.51m) and a tandem spacing of 45 inches (1.14 m) for lighter aircraft, and a dual wheel spacing of 30 inches (0.76 m) and a tandem spacing of 55 inches (1.40 m) for the heavier aircraft are appropriate design values.

(4) Wide Body Aircraft: Wide body aircraft; i.e., B-747, DC-l0, and L-1011 represent a radical departure from the geometry assumed for dual tandem aircraft described in paragraph above. Due to the large differences in gross weights and gear geometries, separate design curves have been prepared for the wide body aircraft.

c. Tire Pressure

Tire pressure varies between 75 and 200 Psi (516 to 1380 kPa) depending on gear configuration and gross weight. It should be noted that tire pressure asserts less influence on pavement stresses as gross weight increases, and the assumed maximum of 200 Psi (1380 kPa) may be safely exceeded if other parameters are not exceeded and a high stability surface course is used.

d. Traffic Volume

Forecasts of annual departures by aircraft type are needed for pavement design.

Information on aircraft operations is available from Airport Master Plans, Terminal Area Forecasts, and the National Plan of Integrated Airport Systems.

DETERMINATION OF DESIGN AIRCRAFT

The forecast of annual departures by aircraft type will result in a list of a number of different aircraft. The design aircraft should be selected on the basis of the one requiring the greatest pavement thickness. Each aircraft type in the forecast should be checked to determine the pavement thickness required by using the appropriate design curve with the forecast number of annual departures for that aircraft. The aircraft type which produces the greatest pavement thickness is the design aircraft. The design aircraft is not necessarily the heaviest aircraft in the forecast.

DETERMINATION OF EQUIVALENT ANNUAL DEPARTURES BY THE DESIGN AIRCRAFT

a. Conversions

Since the traffic forecast is a mixture of a variety of aircraft having different landing gear types and different weights, the effects of all traffic must be accounted for in terms of the design aircraft. First, all aircraft must be converted to the same landing gear type as the design aircraft. Factors have been established to accomplish this conversion. These factors are constant and apply to both flexible and rigid pavements. They represent an approximation of the relative fatigue effects of different gear types. Much more precise and theoretically rigorous factors could be developed for different types and thicknesses of pavement. However, such precision would be impractical for hand calculation as numerous iterations and adjustments would be required as the design evolved. At this stage of the design process such precision is not warranted. The following conversion factors should be used to convert from one landing gear type to another:

Table 6.1: Airport Landing Gear-Configuration Conversion Factors

To Convert from	To	Multiply Departures by
Single wheel	Dual wheel	0.8
Single wheel	Dual tandem	0.5
Dual wheel	Dual tandem	0.6
Double dual tandem	Dual tandem	1.0
Dual tandem	Single wheel	2.0
Dual tandem	Dual wheel	1.7
Dual wheel	Single wheel	1.3
Double dual tandem	Dual wheel	1.7

Source: Federal Aviation Administration

Secondly, after the aircraft have been grouped into the same landing gear configuration, the conversion to equivalent annual departures of the design aircraft should be determined by the following formula:

$\log R_1 = \log R_2 * (W_2/W_1)^{1/2}$

where

R_1 =equivalent annual departures by the design aircraft

R_2=annual departures expressed in design aircraft landing gear
W_1=wheel load of the design aircraft
W_2=wheel load of the aircraft in question
For this computation 95 percent of the gross weight of the aircraft is assumed to be carried by the main landing gears.
Wide body aircraft require special attention in this calculation. The procedure discussed above is a relative rating which compares different aircraft to a common design aircraft. Since wide body aircraft have significantly different landing gear assembly spacing than other aircraft, special considerations are needed to maintain the relative effects. This is done by treating each wide body as a 300,000-pound (136100 kg) dual tandem aircraft when computing equivalent annual departures. This should be done in every instance even when the design aircraft is a wide body. After the equivalent annual departures are determined, the design should proceed using the appropriate design curve for the design aircraft.
For example, if a wide body is the design aircraft, all equivalent departures should be calculated as described above; then the design curve for the wide body should be used with the calculated equivalent annual departures.

b. Example:

Assume an airport pavement is to be designed for the following forecast traffic:

Aircraft	Gear Type	Average Annual Departures	Maximum Takeoff Weight Lbs.	(kg)
727-100	Dual	3760	160,000	(72600)
727-200	Dual	9080	190,500	(86500)
707-320B	Dual tandem	3050	327,000	(148500)
DC-g-30	Dual	5800	108,000	(49000)
cv-880	Dual tandem	400	184,500	(83948)
737-200	Dual	2650	115,500	(52440)
L-101 I-100	Dual tandem	1710	450,000	(204120)
747-100	Double dual tandem	85	700,000	(317800)

(1) **Determine Design Aircraft:** A pavement thickness is determined for each aircraft in the forecast using the appropriate design curves. The pavement input data, CBR, K value, flexural strength, etc., should be the same for all aircraft. Aircraft weights and departure levels must correspond to the particular aircraft in the forecast.

In this example the 727-200 requires the greatest pavement thickness and is thus the design aircraft.

(2) **Group Forecast Traffic into Landing Gear of Design Aircraft:** In this example the design aircraft is equipped with a dual wheel landing gear so all traffic must be grouped into the dual wheel configuration.

(3) **Convert Aircraft to Equivalent Annual Departures of the Design Aircraft:** After the aircraft mixture has been grouped into a common landing gear configuration, the equivalent annual departures of the design aircraft can be calculated.

Aircraft	Equivalent Dual Gear Departures	Wheel load		Wheel load of design aircraft		Equivalent Annual Departs Design Aircraft
		lbs	(kg)	lbs	(kg)	
727-100	3760	38000	(17240)	45240	(20520)	1891
727-200	9080	45240	(20520)	45240	(20520)	9080
707-320B	5185	38830	(17610)	45240	(20520)	2764
DC-g-30	5800	25650	(11630)	45240	(20520)	682
cv-880	680	21910	(9940)	45240	(20520)	94
737-200	2650	27430	(12440)	45240	(20520)	463
L-101 I-100	145	35625*	(16160)	45240	(20520)	83
747-100	2907	35625*	(16160)	45240	(20520)	1184

Total= 16241

(4) **Final Result:** For this example, the pavement would be designed for 16,000 annual departures of a dual wheel aircraft weighing 190,500 pounds (86 500 kg). The design should, however, provide for the heaviest aircraft in the traffic mixture, B747-100, when considering depth of compaction, thickness of asphalt surface, drainage structures, etc.

Problem

Design a flexible pavement for airport using FAA method for following data:

Forecast Aircraft Traffic Data for a Typical Airport

Aircraft Type	Forecast Annual Departures	Main Landing Gear Configuration	Gross Take-off Weight, kip
B-727-100	3,000	Dual	160
B-727-200	4,000	Dual	185
B-707-320B	3,000	Dual tandem	327
CV-880	1,000	Dual tandem	185
DC-9-30	1,200	Dual	108
B-737-200	900	Dual	100
L-1011-100	1,300	Dual tandem	510
B-747-100	1,200	Double dual tandem	710
A-340-200	1,000	Dual tandem & Dual	559

Design Pavement Life = 20 years

Solution:

A. Determination of Design Aircraft

Thickness requirement for each aircraft is determined by using design curves (Fig- A1.1 to Fig- A1.14, Appendix 1), considering same input data (CBR, k value, etc.) for all aircraft. Gross weights and no. of departures must correspond to the particular aircraft in the forecast list.

Design Aircraft[1] Data	
Aircraft Type	
Gear Type	
Gross Wt., W_g (kip)	
Wheel Load, W_1 (kip)	

B. Determination of Equivalent Departures of Design Aircraft

Aircraft Type	Forecast Annual Departures (R)	Gross Wt. on main landing gears (W^2)	Total No. of wheels[3]	Load/ Wheel (W_2)[4]	Gear Conversion Factor, GCF[5]	Equivalent Departures of	
						Design Gear (R_2)[5]	Design Wheel Load (R_1)[7]
B-727-100	3,000						
B-727-200	4,000						
B-707-320B	3,000						
CV-880	1,000						
DC-9-30	1,200						
B-737-200	900						
L-1011-100	1,300						
B-747-100	1,200						
A-340-200	1,000						

Total Equivalent Annual Departures of Design Aircraft=

Notes:

1. The aircraft which requires greatest pavement thickness
2. 95% of the gross take-off weight is assumed to be carried by the main landing gears. Wide body aircraft is considered as a 300-kip Dual tandem aircraft
3. See Fig 6.1: Landing Gear Configuration
4. Load per wheel= W/Total no. of wheels
5. For Gear Conversion Factor (GCF) see Table 6.1
6. R_2= R*GCF

Design Aircraft Data		Design CBR Values	
Aircraft Type		Subgrade	5
Gear Type		Subbase	20
Gross gear wt. (kip)			
Total Equivalent Departures			

Determination of Pavement Layer Thicknesses for Critical Areas

Thicknesses from the appropriate design curve	**Inputs/Calculations**	**inch**
T_1= Total thickness above subgrade (i.e. Surface+Base+Subbase)	App 2, Fig: 2 ; CBR= 5	
T_2= Total thickness above subbase (i.e. Surface+Base)	App 2, Fig: 2 ; CBR= 20	
T_3= Minimum thickness of untreated base course		
T_4= Minimum thickness of Surface course	App 2, Fig: 2	
Calculated Thickness of Base and Subbase Course		
T_5= thickness of untreated subbase	T_1-T_2	
T_6= thickness of untreated base course	T_2-T_4	
Check for minimum base course	As T_6<T_3, use T_3 instead of T_6	
Adjusted base and subbase course thicknesses		
T_7= Due to minimum criterion, the extra thickness of base course would be T_7 This extra thickness need be deducted from the subbase thickness, T_5 instead of adding with the total pavement thickness, T_1	T_3-T_6	
T_8= So the pavement thickness becomes T_8	T_5-T_7	
Stabilized Subbase and Base Courses		
As the design aircraft Wt.>100 kip, stabilized subbase/base needs to be used		
If soil cement base course materials are used for subbase stabilization then the thickness of stabilized subbase would be	App 3, Table:1 T_8/Stabilization Factor	
If cement base course materials are used for base stabilization then the thickness of stabilized base would be	App 3, Table:1 T_3/Stabilization Factor	
Thicknesses for Non-critical areas		
Surface Course The minimum thickness of stabilized base would be	App 2; Fig:2	
Base and Subbase Courses At high speed areas: The thickness of subbase course would be The thickness of base course would be	0.9 of Critical Thickness 0.9 of Critical Thickness	
At pavement edges: The thickness of base would be	0.7 of critical thickness	
The subbase is not reduced to allow for transverse drainage.		

The final design thickness would be as follows

Pavement Layer	Thickness requirements (rounded to even increments)		
	Critical Areas (in)	Non-critical (in)	
		High Speed Areas	Pavement Edges
Bituminous Surface			
Base Course			
Subbase Course			

Appendix 1

Design Curves for Flexible Pavements (Fig: A1.1 through Fig: A1.14)

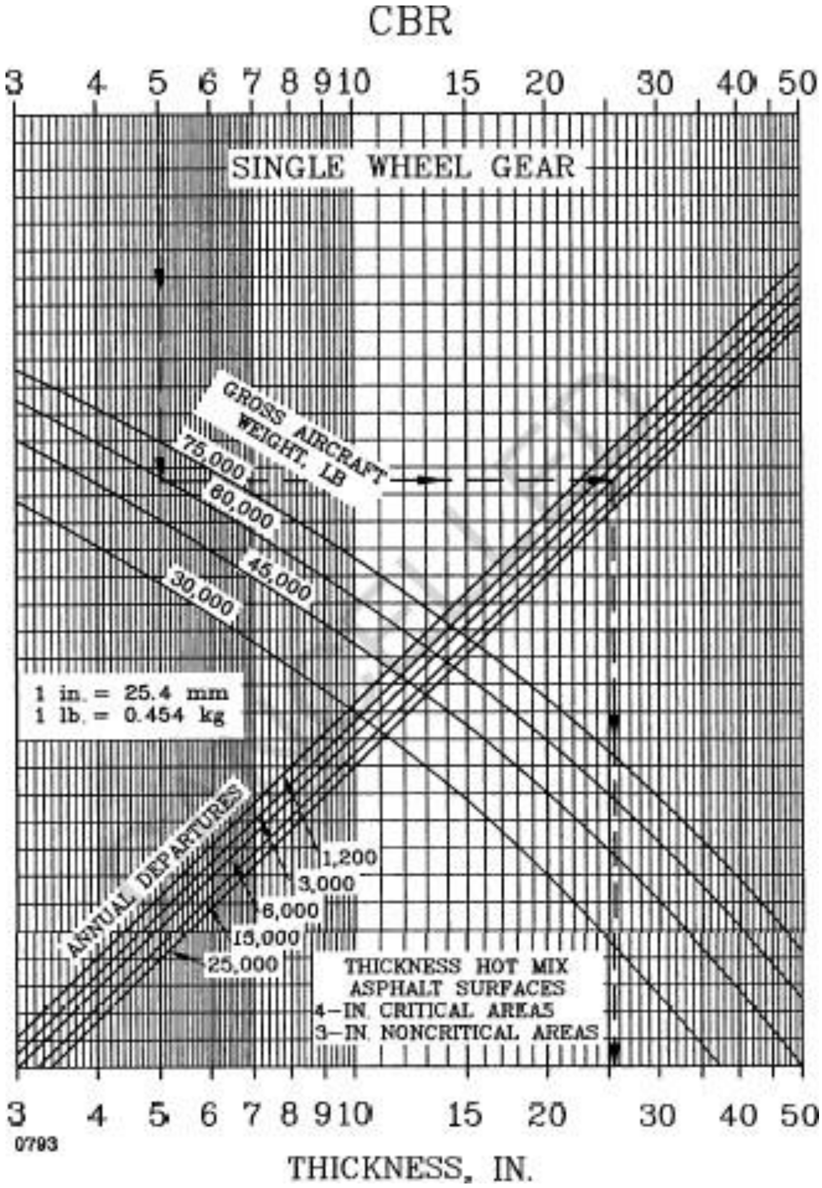

Figure A1.1. Flexible pavement design curves, single wheel gear (Source: FAA)

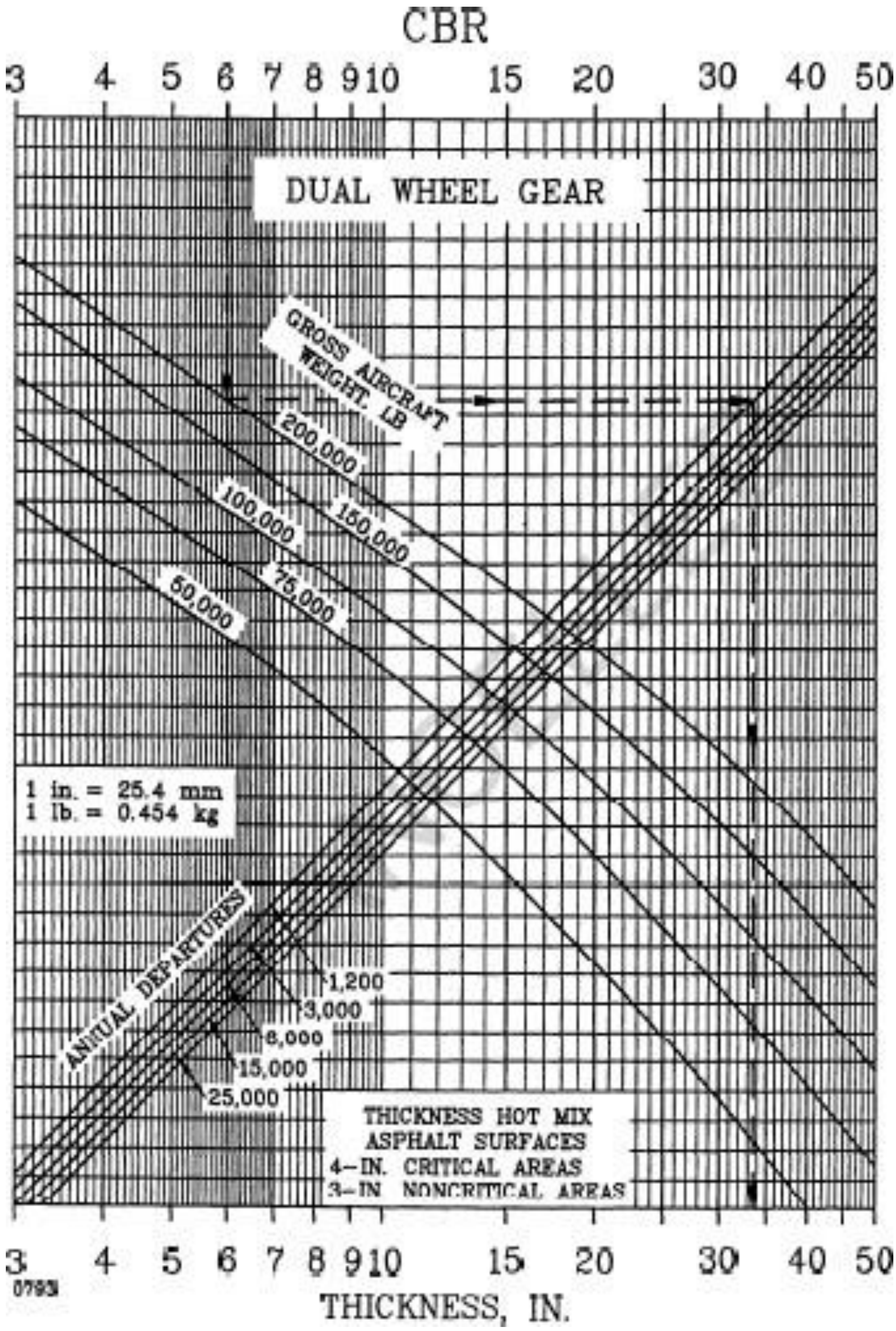

Figure A1.2. Flexible pavement design curves, dual wheel gear (Source: FAA)

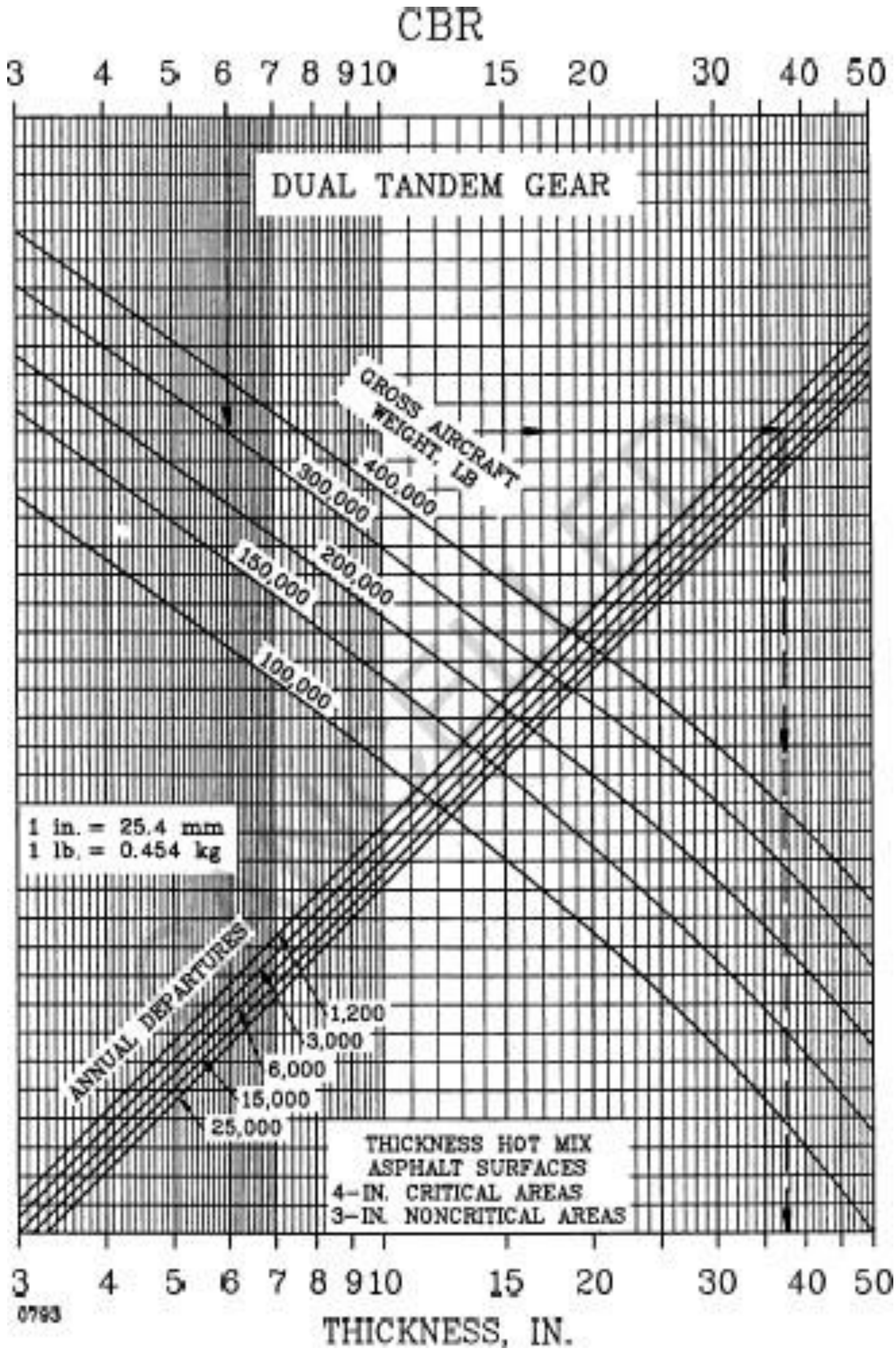

Figure A1.3. Flexible pavement design curves, dual tandem gear (Source: FAA)

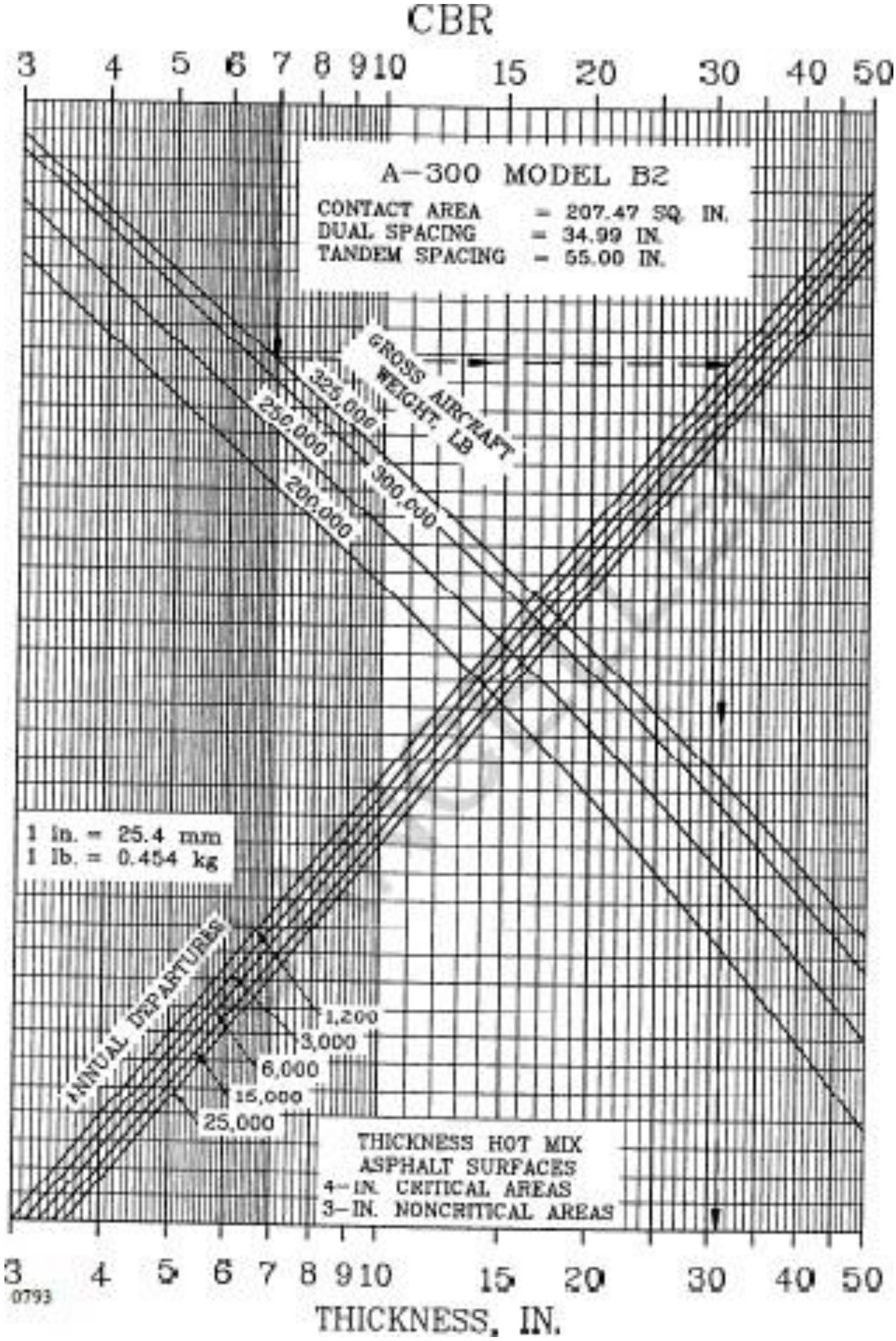

Figure A1.4. Flexible pavement design curves, a-300 model b2 (Source: FAA)

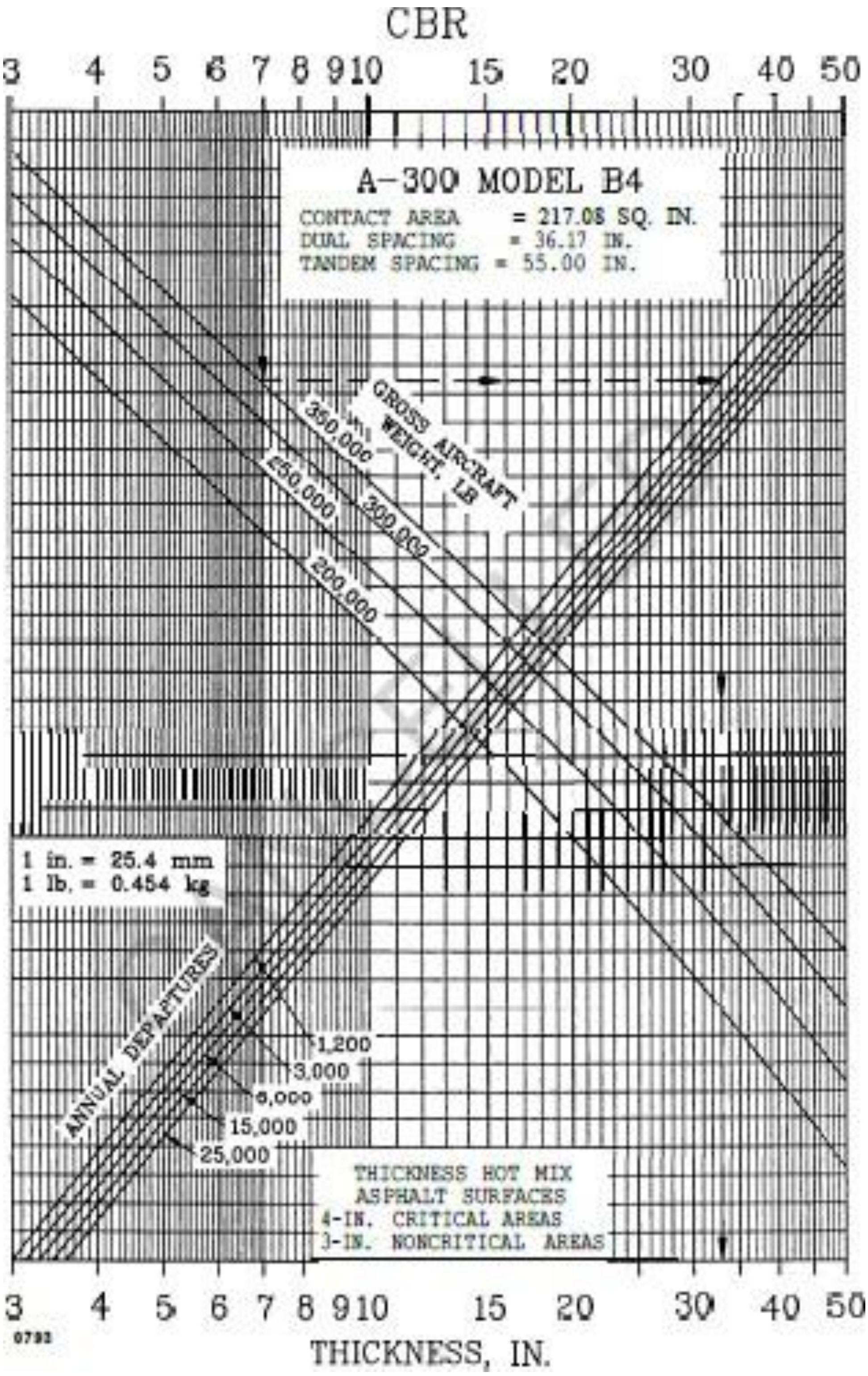

Figure A1.5. Flexible pavement design curves, a-300 model b4 (Source: FAA)

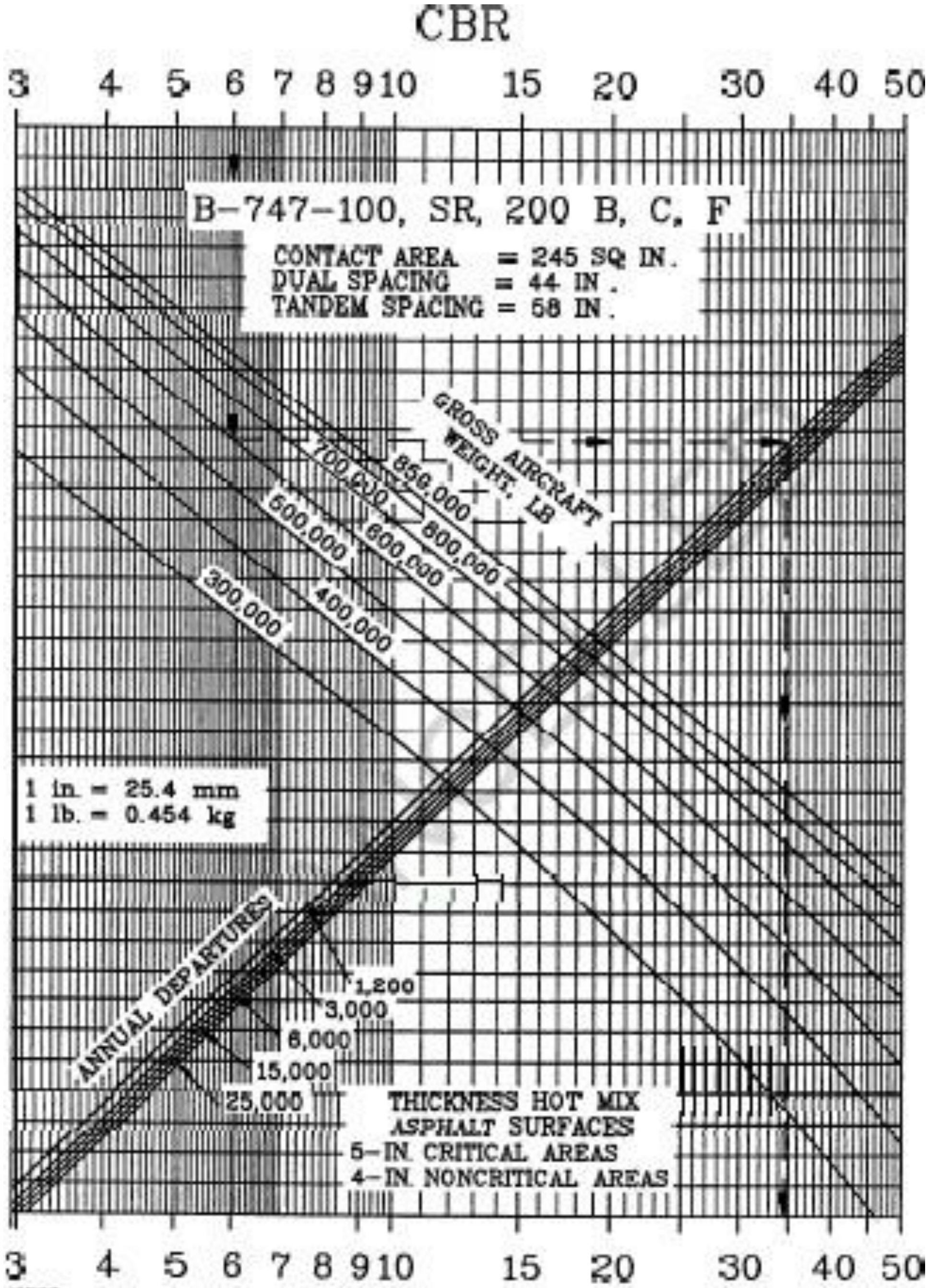

Figure A1.6. Flexible pavement design curves, b-747-100, SR, 200 B, C, F (Source: FAA)

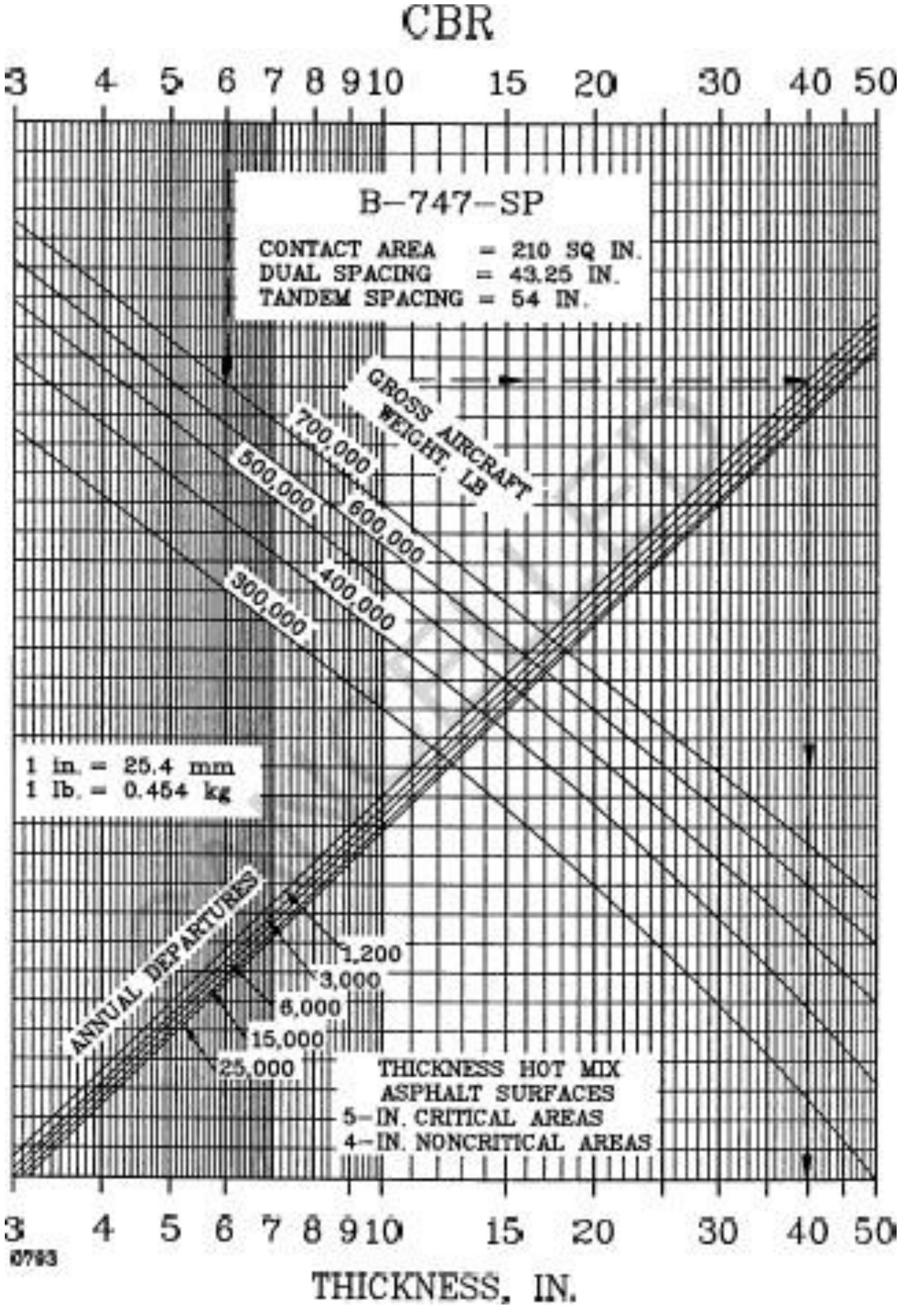

Figure A1.7. Flexible pavement design curves, b-747-sp (Source: FAA)

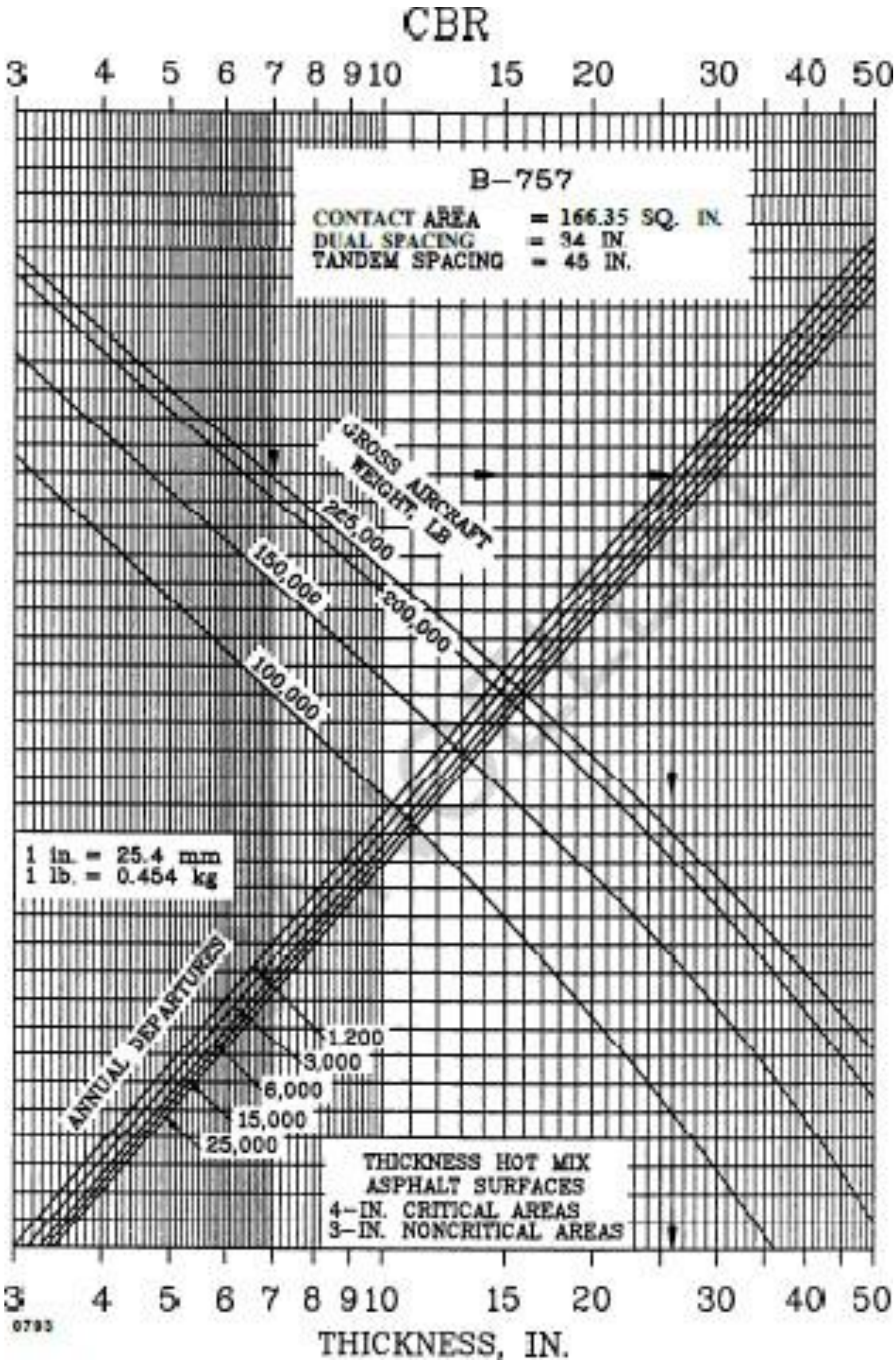

Figure A1.8. Flexible pavement design curves, B-757 (Source: FAA)

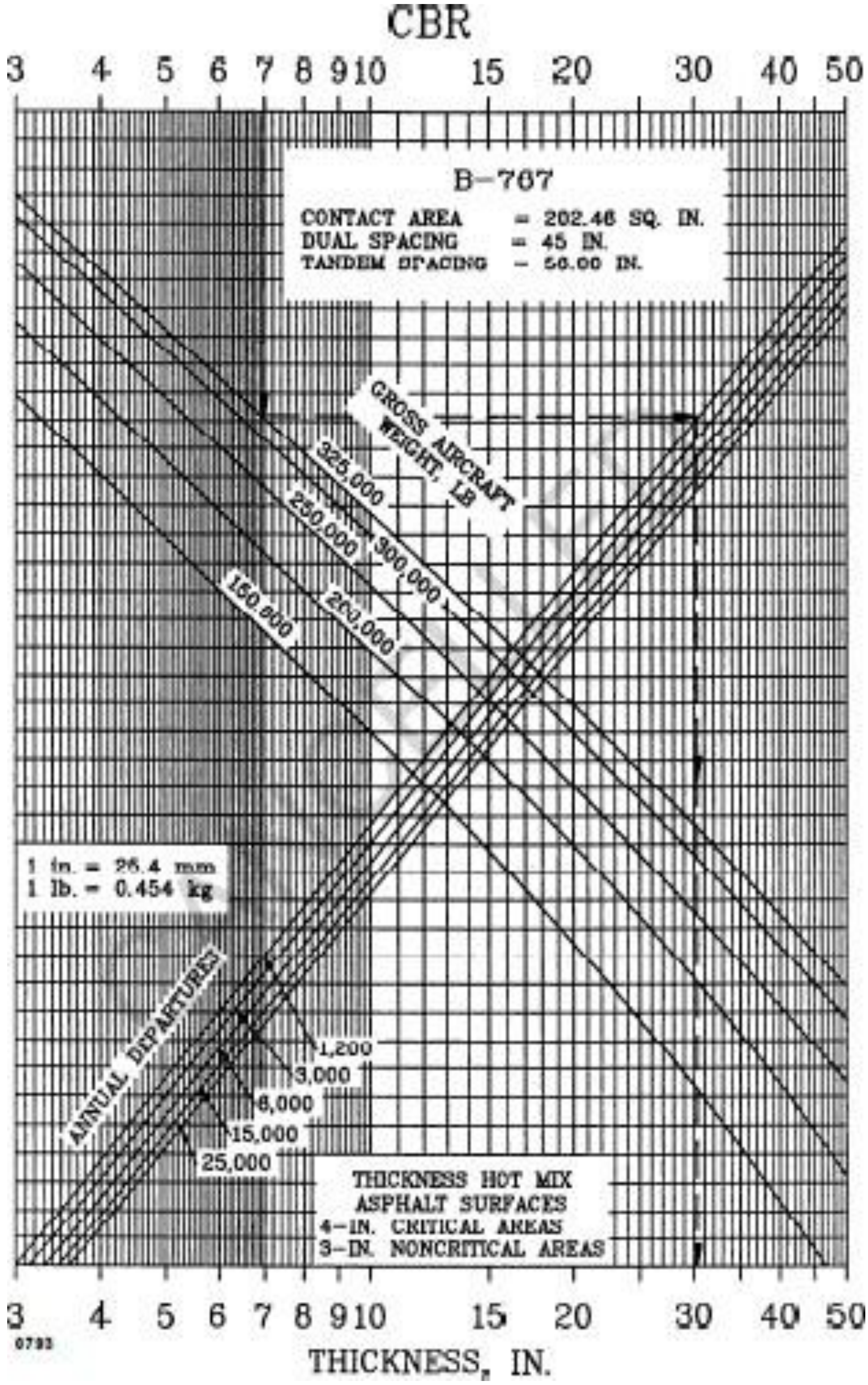

Figure A1.9. Flexible pavement design curves, B-767 (Source: FAA)

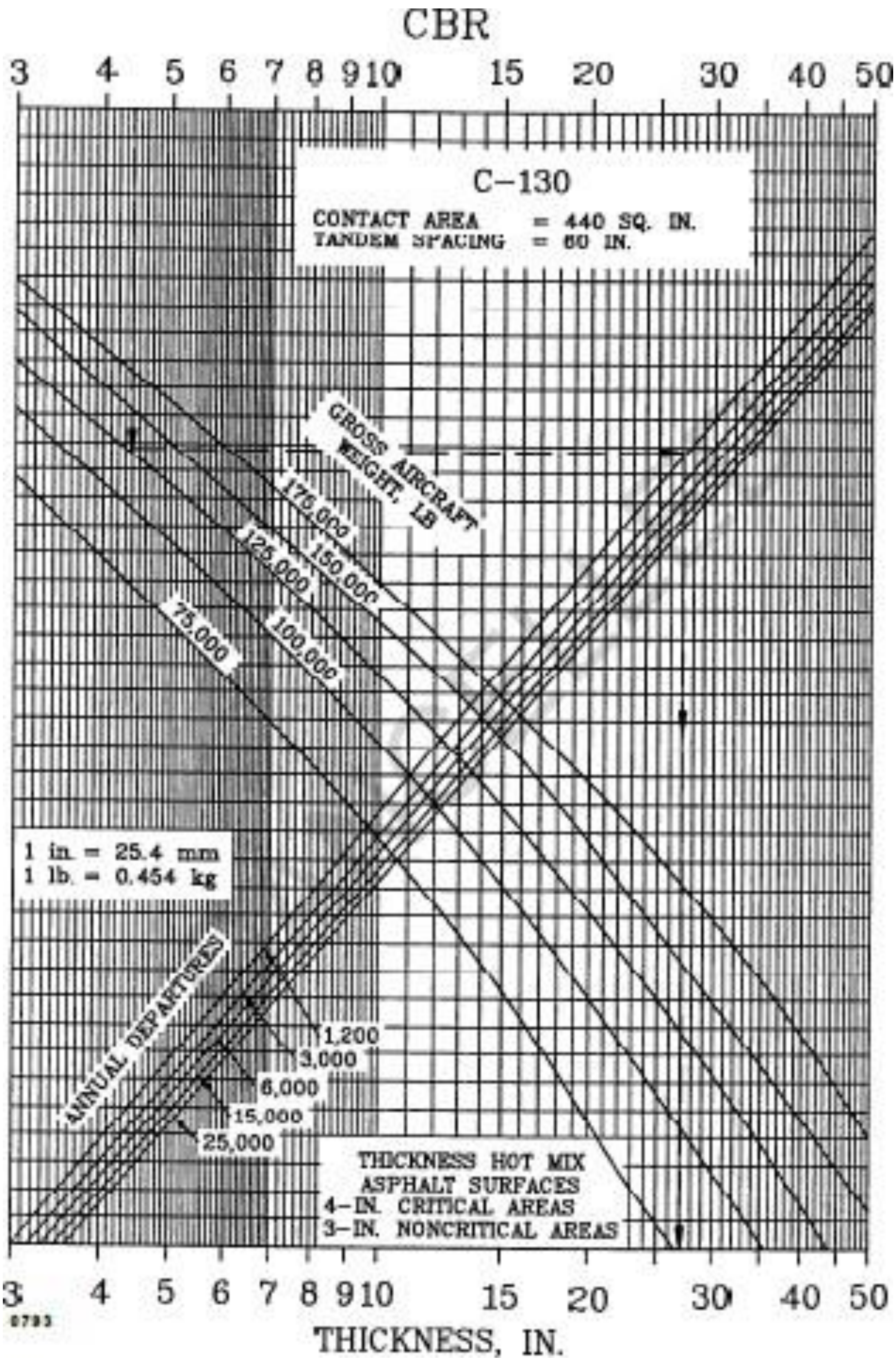

Figure A1.10. Flexible pavement design curves, C-130 (Source: FAA)

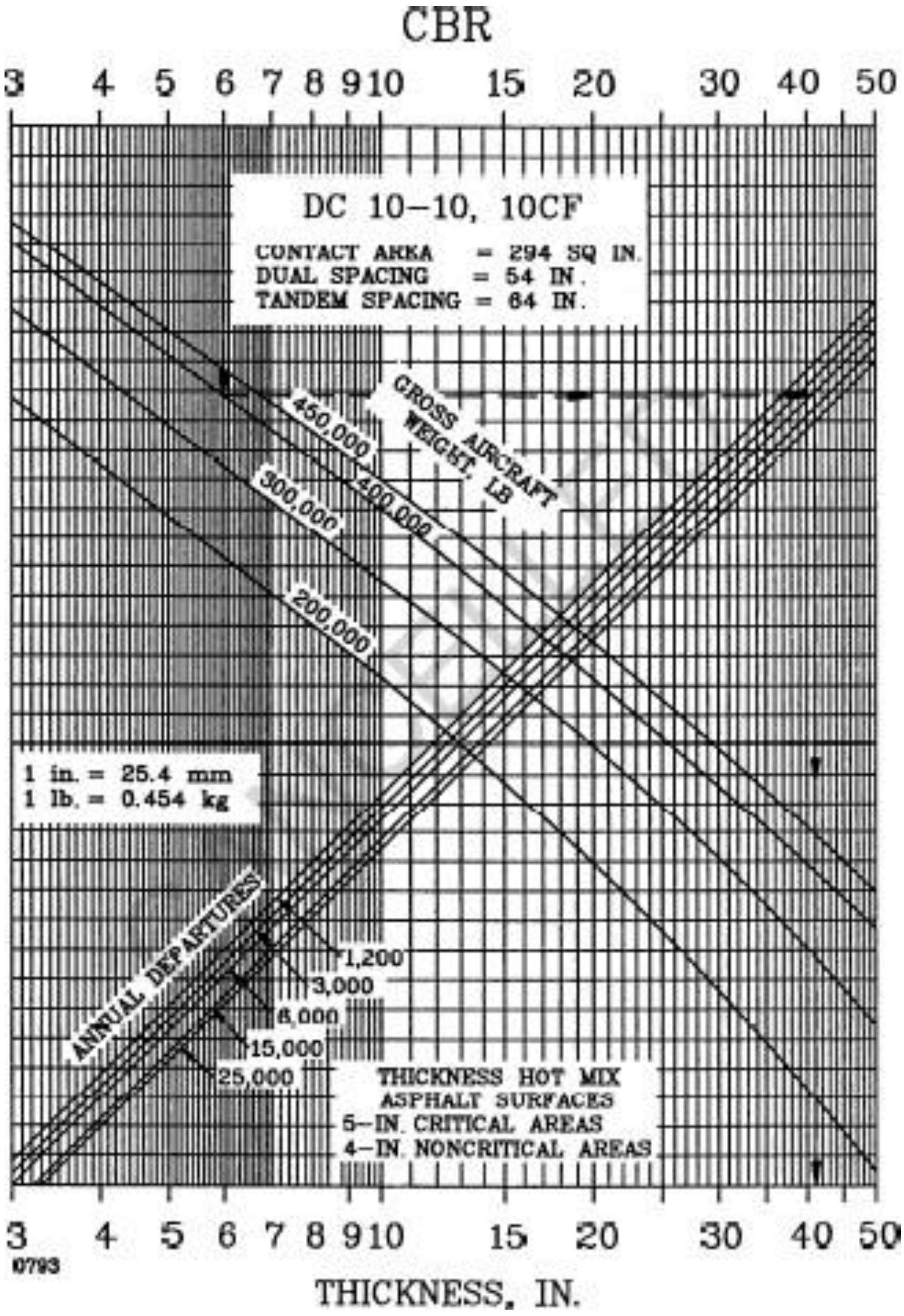

Figure A1.11. Flexible pavement design curves, DC 10-10, 1OCF (Source: FAA)

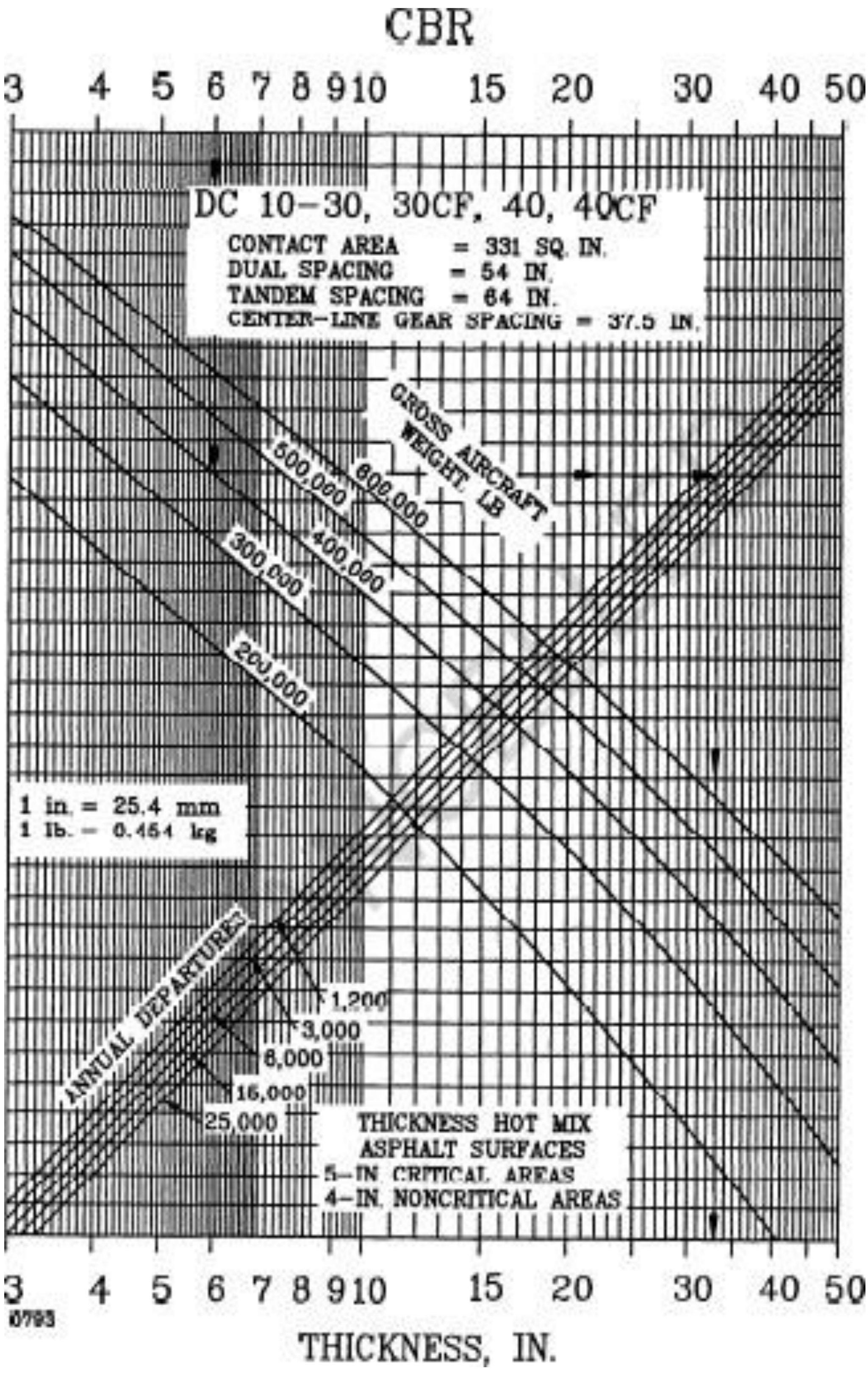

Figure A1.12. Flexible pavement design curves, DC 10-30,30CF, 40,40CF (Source: FAA)

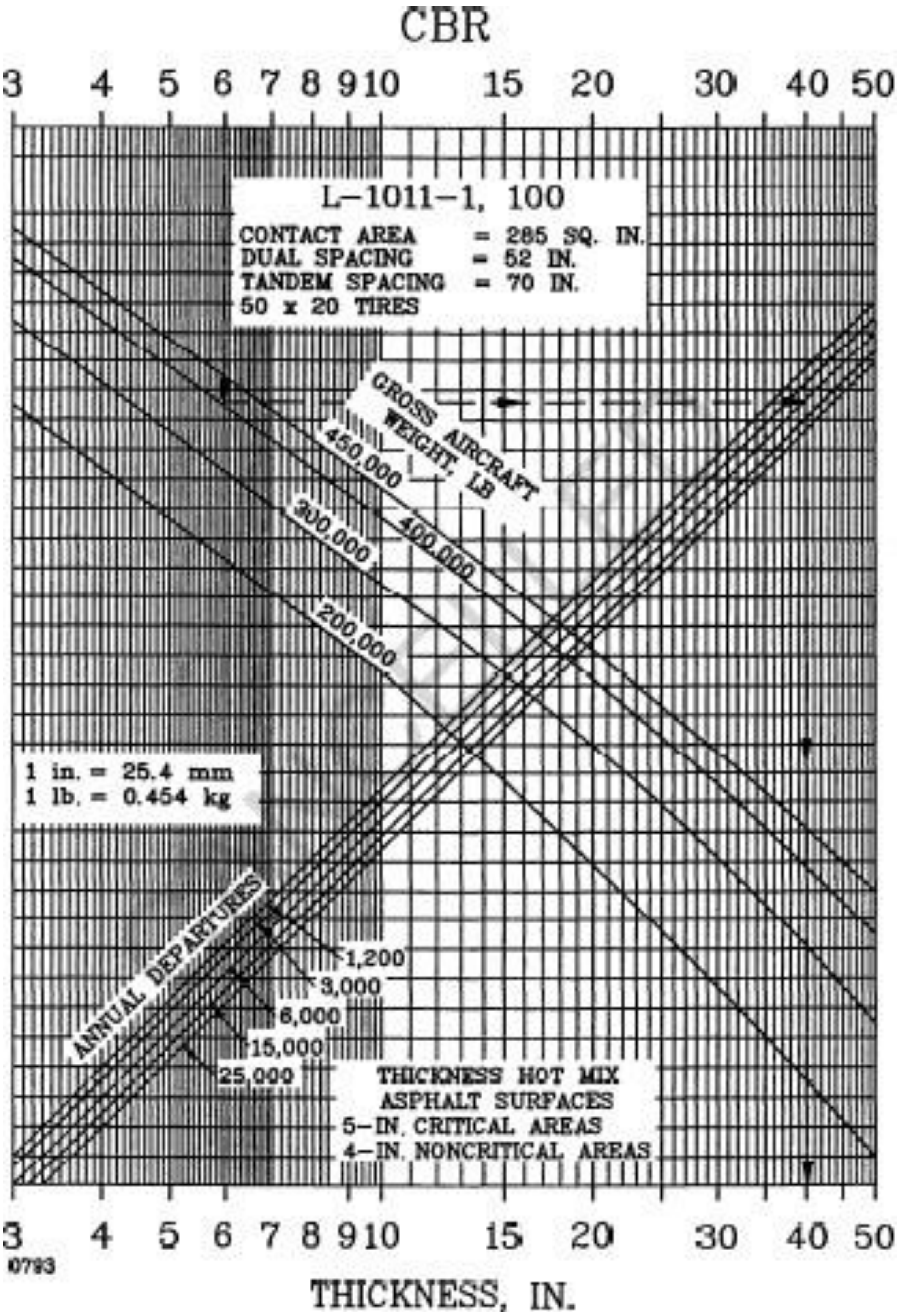

Figure A1.13. Flexible pavement design curves, L-1011-1,100 (Source: FAA)

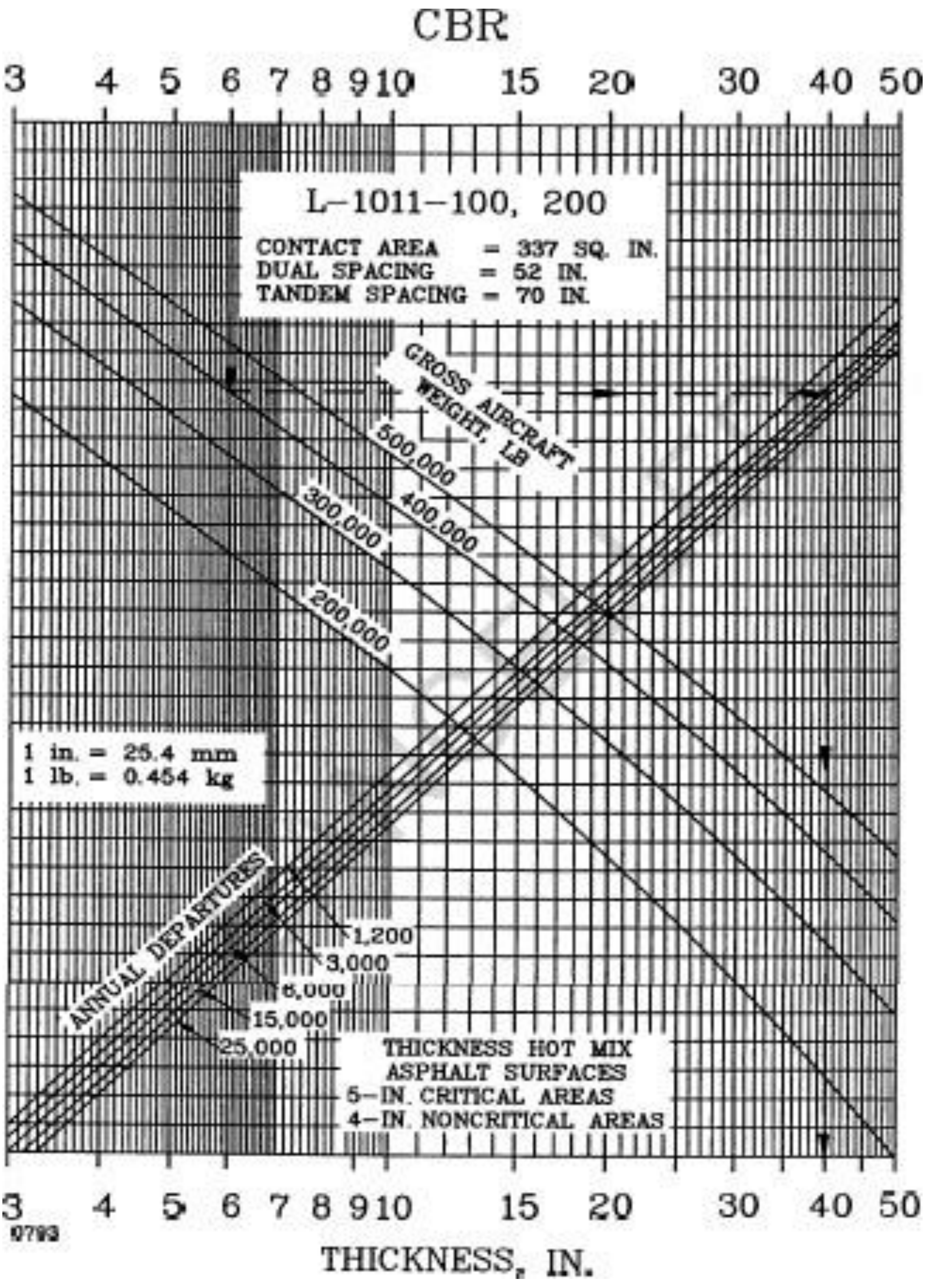

Figure A1.14. Flexible pavement design curves, L-1011-1,200 (Source: FAA)

Appendix 2

Table A2.1: Recommended Equivalent Factors for Stabilized Subbase Course

Material Used	Equivalency Factor	
	Subbase	Base
Bituminous Surface Course	1.7-2.3	1.2-1.6
Bituminous base course	1.7-2.3	1.2-1.6
Cold laid bituminous base course	1.5-1.7	1.0-1.2
Mixed in-place base course	1.5-1.7	1.0-1.2
Cement treated base course	1.6-2.3	1.2-1.6
Soil cement base course	1.5-2.0	N/A
Crushed aggregate base course	1.4-2.0	1
Gravel subbase course		N/A

Appendix 3
Different Expansion Factors for a rural primary road

Table 1 Hourly Expansion Factors for a Rural Primary Road

Hour	Vol.	HEF	Hour	Vol.	HEF
6:00-7:00 a.m.	294	42.01	6:00-7:00 p.m.	743	16.6
7:00-8:00 a.m.	426	28.99	7:00-8:00 p.m.	706	17.5
8:00-9:00 a.m.	560	22.05	8:00-9:00 p.m.	606	20.4
9:00-10:00 a.m.	657	18.8	9:00-10:00 p.m.	489	25.3
10:00-11:00 a.m.	722	17.11	10:00-11:00 p.m.	396	31.2
11:00-12:00 p.m.	667	18.52	11:00-12:00 a.m.	360	34.3
12:00-1:00 p.m.	660	18.71	12:00-1:00 a.m.	241	51.2
1:00-2:00 p.m.	739	16.71	1:00-2:00 a.m.	150	82.3
2:00-3:00 p.m.	832	14.84	2:00-3:00 a.m.	100	124
3:00-4:00 p.m.	836	14.77	3:00-4:00 a.m.	90	137
4:00-5:00 p.m.	961	12.85	4:00-5:00 a.m.	86	144
5:00-6:00 p.m.	892	13.85	5:00-6:00 a.m.	137	90.2
		Total daily volume =	12350		

Table 2 Daily Expansion Factors for a Rural Primary Road

Day of Week	Volume	DEF
Sunday	7,895	9.515
Monday	10,714	7.012
Tuesday	9,722	7.727
Wednesday	11,413	6.582
Thusrday	10,714	7.012
Friday	13,125	5.724
Saturday	11,539	6.51
	Total weekly volume =	75,122

Table 3 Monthly Expansion Factors for a Rural Primary Road

Day of Week	ADT	MEF
January	1350	1.756
February	1200	1.976
March	1450	1.635
April	1600	1.482
May	1700	1.395
June	2500	0.948
July	4100	0.578
August	4550	0.521
September	3750	0.632
October	2500	0.948
November	2000	1.186
December	1750	1.355
	Total yearly ADT volume =	28450
	AADT =	2371

Appendix 4

Roadway Design Capacity and Pavement Catalogue

National Roads-Cross-Section Design Capacities

Cross-Section	Optimum Maximum Design Capacity (PCU/Hour)	Design Year Optium Demand Flow Range (PCU/Hours) (3)	Application	
			New Construction	Widening w.r.t. RHD (2)
RHD 6.7m	1000 (Daily = 14,000) (Note 3)	1 to 1000	Not applicable. New 7.4m standard always has a better overall economic performance.	No widening necessary if demand flows less than 1000 PCU/hours
4.7m + Pre-widening of embankment to 11 m standard	1900 (Daily = 27,000)	1 to 1900 (New Construction) 1001 to 1900 (Widening)	The standard new minimum width for National road with the high mobility function	If traffic demand is above 1000 PCU/Hours widening justified and can be easily carried out by re-arranging the road layout on the existing embankment crest width.
11m + Pre-widening of embanknent to 4 x 3.7m standard	(2200)	(1900 - 2200) But, optimal flow range too narrow to be usefull.	Not applicable as a final design standard but usefull as part of stage construction on way to the high level 4 x 3.7m section.	Not applicable due to narrow optimal flow range and due to practical difficulties of widening from 6.7m to 11.0m under trafficking.
4 x 3.7m + Pre-widening of embankment to 6 x 3.67m standard.	4500 (Daily = 64,000)	1901 to 4500	A very useful width for high volume roads at a future date.	An economical widening choice for the basier National roads in Bangladesh.
6 x 3.67m	7500 (Daily = 105,000)	4501 to 7500	New roads needing this capacity very unlikely to develop.	Will undoubtedly have its application on the busiest roads, or in future second round widening.

Notes : 1) Real flow Peak Hour Factor of 0.07 taken.
2) It is assumed that all widening takes place from a 6.7m RHD base.
3) This design year flow range was demonstrated by the analysis to be optimal even if traffic growth on a particular project is forcast to be other than 8%, & anywhere between 5.6% & 9.2%, (the sensitivity analysiis outer marrgins).

Regional Roads-Cross-Section Design Capacities

Cross-Section	Optimum Maximum Design Capacity (PCU/Hour)	Design year Optimum Demand Flow (PCU/Hour)	Application	
			New Construction	Widening w.r.t RHD
RHD 5.5 m	750 (Daily 8300) (Note 1)	1 to 750	Not applicable New 6.2m standard already has a better overall economic performance	No widen necessary of demand flows less than 750 PCU/Hour
6.2 m + Pre-widening of embankment to 7.4m standard	1700 (Daily = 18,500)	1 to 1700 (New Const.) 751 to 1700 (Widening)	The standard new minimum width for Regional roads	If traffic demand above 750 PCU/Hour widening can be easily carried out by re-arranging the road layout on the existing embankment width
7.4m + pre-widening of embankment to 11m standard.	(1900)	(1700-1900) But, optimal flow range too narrow to be useful	Not applicable as a find design standard but useful part of stage construction on way to the top cross-section of 11 m.	Not applicable due to various optimal flow range and due to practical difficulties of widening 5.5m to 7km under traffic.
11m	2500 (Daily = 28,000)	1701-2500	Not likely that many completely new roads would need to adopt this standard at the out set.	An economical widening choice for the bu.ie. Regional roads .n Bangladesh.

PAVEMENT CATALOGUE

MATERIAL DEFINITION

ST SURFACE TREATMENT

ASPHALT CONCRETE

GRAVEL ASPHALT

SAND BITUMEN

HAND CRUSHED BRICKS WITH 0 - 20 % LOCAL SAND

WELL GRADED PLANT CRUSHED BRICKS (0/37mm)

HAND/ PLANT CRUSHED BRICKS WITH 50 % LOCAL SAND

MIXTURE OF CRUSHED BOULDER, SHINGLES, PEA-GRAVELS & SAND (30: 30: 20: 20)

MIXTURE OF COARSE SAND & LOCAL SAND (40: 60)

HAND CRUSHED BOULDERS, PEA- GRAVELS & SAND (60:20:20)

WELL GRADED PLANT CRUSHED BOULDERS (0/37mm)

HAND/ PLANT CRUSHED BOULDERS WITH 50 % LOCAL SAND

WELL GRADED PLANT CRUSHED BRICK/ BOULDERS (0/37mm)

HAND CRUSHED BRICKS WITH 0 - 20 % LOCAL SAND OR MIXTURE OF CRUSHED BOULDER, SHINGLES, PEA-GRAVELS & SAND (30: 30: 20: 20)

SOIL STABILISED WITH 4 % LIME

LOCAL FINE RIVER SAND / MECHANICALLY STAB. SAND CLAY MIXTURE / SANDY SILT WITH PI 5 - 8

TRAFFIC DEFINITION

T_1 = MAX. 1.5 MILLION ESA

T_2 = MAX. 3.0 MILLION ESA

T_3 = MAX. 7.5 MILLION ESA

T_4 = MAX. 20.0 MILLION ESA

T_5 = MAX. 30.0 MILLION ESA

SUBGRADE DEFINITION

S_1 = MIN 3 % CBR

S_2 = MIN 5 % CBR

S_3 = MIN 7 % CBR

S_4 = MIN 10 % CBR

S_5 = MIN 15 % CBR

CATALOGUE FOR PAVEMENT TYPE - 1

(BRICKS)

	S1	S2	S3	S4	S5
T1	ST 150 275 225	ST 150 275 175	ST 150 275 150	ST 150 275 100	ST 150 275
T2	ST 150 325 250	ST 150 325 200	ST 150 325 150	ST 150 325 100	ST 150 325
T3	ST 200 275 275	ST 200 275 200	ST 200 275 150	ST 200 275 125	ST 200 275
T4	60 175 250 250	60 175 200 250	60 175 200 225	60 175 275 100	60 175 275
T5	60 200 250 250	60 200 200 250	60 200 200 225	60 200 250 125	60 200 250

CATALOGUE FOR PAVEMENT TYPE - 2

(GRAVELS & STONE)

	S1	S2	S3	S4	S5
T1	ST 150 250 225	ST 150 250 175	ST 150 250 150	ST 150 250 100	ST 150 250
T2	ST 150 300 250	ST 150 300 200	ST 150 300 150	ST 150 300 100	ST 150 300
T3	ST 200 225 250	ST 200 225 175	ST 200 225 125	ST 200 225 100	ST 200 225
T4	60 175 250 250	60 175 200 250	60 175 200 225	60 175 275 100	60 175 275
T5	60 200 250 250	60 200 200 250	60 200 200 225	60 200 250 125	60 200 250

CATALOGUE FOR PAVEMENT TYPE - 3

(GRAVEL ASPHALT BASE)

	S1	S2	S3	S4	S5
T1					
T2					
T3					
T4	40 120 175 250	40 120 150 250	40 120 150 200	40 120 175 100	40 120 175
T5	50 120 200 250	50 120 175 250	50 120 150 250	50 120 200 100	50 120 200

CATALOGUE FOR PAVEMENT TYPE – 4

(SAND BITUMEN BASE)

	S1	S2	S3	S4	S5
T1					
T2					
T3					
T4	50 115 200 250	50 115 175 250	50 115 150 250	50 115 200 100	50 115 200
T5	50 120 225 250	50 120 200 250	50 120 175 250	50 120 225 100	50 120 225

CATALOGUE FOR PAVEMENT TYPE - 5

(LIME STABILISED SUB-BASE)

	S1	S2	S3	S4	S5
T1	ST 150 275 200	ST 150 250 175	ST 150 250 125	ST 150 325	ST 150 250
T2	ST 150 300 225	ST 150 300 175	ST 150 300 125	ST 150 375	ST 150 300
T3	ST 200 300 175	ST 200 275 175	ST 200 250 150	ST 200 325	ST 200 250
T4					
T5					

CATALOGUE FOR PAVEMENT TYPE-6

(TO: ESA ≤ 0.5 MILLIONS)

	S1	S2	S3	S4	S5
ALT-1	ST 150 175 200	ST 150 175 150	ST 150 175 125	ST 150 225	ST 150 175
ALT-2	ST 125 210 225	ST 125 210 175	ST 125 210 150	ST 125 210 100	ST 125 210

MATERIAL DEFINITION

- ST SURFACE TREATMENT
- HAND CRUSHED BRICKS WITH 0 – 20% LOCAL SAND OR MIXTURE OF CRUSHED BOULDER, SHINGLES, PEA-GRAVELS & SAND (30:30:20:2
- SOIL STABILISED WITH 4% LIME
- HAND CRUSHED BRICKS WITH 50% LOCAL SAND OR MIXTURE OF SYLHET SAND + LOCAL SAND (40 : 60)
- LOCAL FINE RIVER SAND / MECHANICALLY STAB. SAND CLAY MIXTURE / SANDY SILT WITH PI 5 – 8

PER SQM COST OF DIFFERENT TYPE OF PAVEMENT

(For Rangpur Road Circle taking rates of materials from RHD Schedule 1989)

(All cost in Taka)

RANGPUR

Traffic Level	Pavt. Type	Subgrade level				
		S1	S2	S3	S4	S5
T1	1	525	520	514	504	488
	2	524	519	513	508	491
	5	455	431	422	441	407
T2	1	564	558	550	540	522
	2	562	557	548	543	526
	5	472	463	447	466	430
T3	1	672	663	655	652	628
	2	672	664	651	648	631
	5	608	591	565	583	546
T4	1	918	877	866	829	811
	2	1,065	1,008	997	985	967
	3	1,247	1,201	1,175	1,141	1,126
	4	1,280	1,227	1,184	1,174	1,159
T5	1	953	915	904	852	832
	2	1,116	1,059	1,048	1,015	995
	3	1,326	1,283	1,230	1,223	1,208
	4	1,335	1,292	1,238	1,232	1,216

Reference

1. Local Government Engineering Division, 2021. Road Pavement Design Manual.

2. Road Note 29 by Transportation Research Laboratory (TRL)

3. Lecture Material of Prof. Dr. Shamsul Hoque, CE, BUET.

4. AC 150/5320-6D, Federal Aviation Administration (FAA) of US Department of Transportation (DoT)