Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2023/2024

COURSE NAME	:	HIGHWAY ENGINEERING
COURSE CODE	:	BFC 31802
PROGRAMME CODE	:	BFF
EXAMINATION DATE	:	JULY 2024
DURATION	:	2 HOURS 30 MINUTES
INSTRUCTIONS	:	1. ANSWER ALL QUESTIONS 2. THIS FINAL EXAMINATION IS CONDUCTED VIA ☐ Open book ☒ Closed book 3. STUDENTS ARE **PROHIBITED** TO CONSULT THEIR OWN MATERIAL OR ANY EXTERNAL RESOURCES DURING THE EXAMINATION CONDUCTED VIA CLOSED BOOK

THIS QUESTION PAPER CONSISTS OF **THIRTEEN (13)** PAGES

Q1 (a) Briefly explain **THREE (3)** factors considered in pavement design.

(6 marks)

(b) Differentiate structural component and material between flexible and rigid pavement.

(7 marks)

(c) A two lane flexible pavement will be constructed on a flat terrain. By assuming loading are from the following daily traffic: CV1=130, CV2=900, CV3=1500, CV4=20, CV5=4000 and CV8=200. The traffic growth rate is 4% and mean of subgrade CBR is 19% with the standard deviation 4.4%. By referring to **Table APPENDIX A.1** to **Table APPENDIX A.5** and **Figure APPENDIX A.1** to **Figure APPENDIX A.5**

(i) Determine the design traffic for 20 years, traffic category and subgrade category.

(6 marks)

(ii) Propose the pavement thickness and materials.

(2 marks)

(iii) Give your justification if a full depth asphalt pavement will be applied for this project.

(2 marks)

(iv) Suggest a method to improve the road foundation if the subgrade having value CBR value as low as 8%.

(2 marks)

Q2 (a) State the main purpose of site investigation and survey in highway construction projects, and briefly discuss how it contributes to the successful implementation of infrastructure projects.

(5 marks)

(b) A preparation of formation level for construction has been conducted on the site with laterite soil. Prior to the placement of the sub-base layer, the density of the soil need to be carried out by conducting compaction and sand cone replacement test. The results are shown in **Table Q2.1.**

Table Q2.1 Results of site density test

Parameter	Results
Maximum Dry Density (MDD)	1766 kg/m^3
Bulk density	1835 kg/m^3
Water content	9.1%

(i) Calculate the degree of compaction of the soil.

(8 marks)

(ii) Based on the answer **Q2(b)(i),** give your justification on done if the requirement for degree of compaction according to the JKR specification is at least 95%.

(2 marks)

(c) Compaction of base layer, in pavement structure is a densification of aggregate by removal of air from the voids of the aggregate. Discuss the term of relative compaction and factors which affect the compaction of the base layer.

(5 marks)

(d) The main function of drainage is to divert and removes water from the pavement surface. Illustrate and describe **TWO (2)** system for surface drainage.

(5 marks)

Q3 (a) A pavement condition survey has been conducted from KM 2 to KM 3 at Jalan Parit Botak to Rengit. A sample unit 1 with 6m width and 100 m length was analysed. From the survey, sample unit 1 had two blocks cracking. Based on the analysis, density of the block cracking distress is 1.98%. If the first block cracking area was 7.8 m^2, determine the area and length of the second block cracking if it's width is 0.8 m.

(5 marks)

(b) From the analysis of the pavement condition survey data, the selected deduct values are 50, 34, 11, 6. Based on this selected deduct values and **Figure APPENDIX B.1**, determine the Pavement Condition Index (PCI) of this sample unit and suggest your

(i) Determine the Pavement Condition Index (PCI) of this sample unit.

(8 marks)

(ii) Suggest the recommendation of the maintenance for this road.

(2 marks)

(c) Waste hierarchy is a tool that has been used to evaluate the processes which protect the environment alongside resource and energy consumption from most favorable to least favorable actions. The European waste hierarchy refers to the five steps which included in the article 4 of the Waste Framework Directive. Briefly explain about these **FIVE (5)** steps of managing the waste.

(5 marks)

(d) Describe cold in-place recycling of asphalt concrete and its benefit of using this technique in road maintenance.

(5 marks)

- END OF QUESTIONS -

APPENDIX A: Design Charts And Tables

Table APPENDIX A.1: Axle Configuration and Load Equivalence Factors (LEF)

Vehicles		Load Equivalent Factor (LEF)
Class Designation	**Class**	
Cars and Taxis	C	0
Rigid Vehicle (1+1) incl. Busses (2 Axle)	CV1	3.9
Rigid Vehicle (1+2) incl. Busses (3 Axle)	CV2	2.8
Rigid Vehicle (2+2) (4 Axles)	CV3	2.6
Articulated Vehicle (1+1+1)(3 Axle)	CV4	7.1
Articulated Vehicle (1+1+2)(4 Axle)	CV5	6.1
Articulated Vehicle (1+1+3)(5 Axle)	CV6	4.7
Articulated Vehicle (1+2+2)(5 Axle)	CV7	4.2
Articulated Vehicle (1+2+3)(6 Axle)	CV8	3.5
Articulated Vehicle (1+2+4)(7 Axle)	CV9	3.6
Motorcycles	MC	0

Table APPENDIX A.2: Classes of Sub-grade Strength based on CBR

Sub-Grade	CBR (%)	Elastic Modulus (MPa)	
		Range	Design Input Value
SG1	5 to 12	50 to 20	60
SG2	12.1 to 20	80 to 140	120
SG3	20.1 to 30.0	100 to 160	140
SG4	>30.0	120 to 180	180

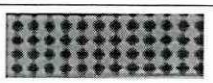
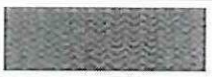
Table APPENDIX A.3: Traffic Categories

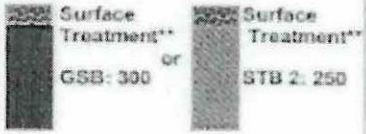
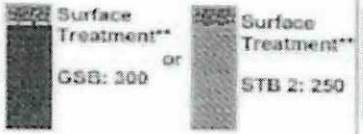
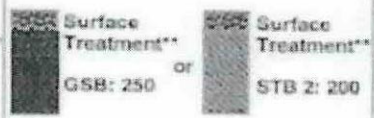
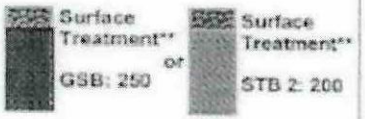
Traffic category	Design Traffic (ESAL x 10^6)	Probability (Percentile Applied to Properties of Subgrade Material
T1	≤1.0	≥60%
T2	1.1 to 2.0	≥70%
T3	2.1 to 10.0	≥85%
T4	10.1 to 30.0	≥85%
T5	>30.0	≥85%

Table APPENDIX A.4: Conceptual Outline of Pavement Structures

Pavement Structure	**Traffic Category (based on million ESALs@ 80kN)**				
	≤1	**1 to 2**	**2.1 to 10**	**10.1 to 30**	**>30**
	T1	**T2**	**T3**	**T4**	**T5**
Combined Thickness of Bituminous Layers					24 cm
				20 cm	
			18 cm		
		10 cm			
	5 cm				
Crushed Aggregate Road Base + Sub-base for Subgrade CBR of:					
o 5 to 12	23+15 cm	20+15 cm	20+20 cm	NR	NR
o 12.1 to 20	20+15 cm	20+15 cm	20+20 cm	20+20 cm	20+20 cm
o 20.1 to 30	20+10 cm	20+10 cm	20+15 cm	20+15 cm	20+15 cm
o >30	20 cm	20+10 cm	20+10 cm	20+10 cm	20+10 cm

Table APPENDIX A.5: Summary of material use in pavement structure in Malaysia

NEW PAVEMENT DESIGN AND CONSTRUCTION		
DESIGNATION	**DESCRIPTION**	**ABBREVIATION/ SYMBOL**
DRAINAGE LAYER	Primarily functional granular layer with load distribution capability similar to the Sub-Base	DL 
SUB-BASE COURSE	Crush or natural granular material with maximum 10% fines	GSB 
ROAD BASE COURSE		
Crushed Aggregate	Crushed granular material with maximum 10% fines	CAB 
Wet Mix	Crushed granular material with maximum 10% fines	WMB 
Bituminous	Coarse bituminous mix (AC28)	BB 
STB1	Stabilises base with at least 3% Portland cement	STB1 
STB2	Stabilised base with bituminous emulsion and maximum of 2% Portland cement	STB2 
BINDER COURSE		
Binder Course	Coarse bituminous mix (AC28)	BC 
WEARING COURSE		
Asphaltic Concrete	Medium to fine bituminous mix (AC 10 or AC 14)	BSC 
Polymer Modified Asphalt (PMA)	Medium to fine bituminous mix (AC 10 or AC 14) incorporated with polymer modified bitumen.	PMA 
Stone Mastic Asphalt (SMA)	Stone mastic asphalt (SMA 14 or SMA 20)	SMA 
Porous Asphalt	Primarily functional porous asphalt (PA 10 or PA 14)	PA 
Gap-Graded Asphalt	Gap Graded Asphalt GPA 1 or GPA 11	FC 

Pavement Type	Sub-Grade Category			
	SG 1: CBR 5 to 12	SG 2: CBR 12.1 to 20	SG 3: CBR 20.1 to 30	SG 4: CBR > 30
Conventional Flexible: Granular Base	 BSC: 50 CAB: 250 GSB: 150	 BSC: 50 CAB: 200 GSB: 150	 BSC: 50 CAB: 200 GSB: 100	 BSC: 50 CAB: 100 GSB: 100
Deep Strength: Stabilised Base	 BSC: 50 STB 2: 100 GSB: 200	 BSC: 50 STB 2: 100 GSB: 150	 BSC: 50 STB 2: 100 GSB: 100	 BSC: 50 STB 2: 100 GSB: 100
Stabilised Base with Surface Treatment*	 Surface Treatment** GSB: 300 or Surface Treatment** STB 2: 250	 Surface Treatment** GSB: 300 or Surface Treatment** STB 2: 250	 Surface Treatment** GSB: 250 or Surface Treatment** STB 2: 200	 Surface Treatment** GSB: 250 or Surface Treatment** STB 2: 200

Notes:

* *Full Depth Asphalt Concrete Pavement is not recommended for this Traffic Category.*

** *Single or Double Layer Chip Seal or Micro-Surfacing.*

Figure APPENDIX A.1: Pavement structure for traffic category T1: <1 million ESALs (80kN)

Pavement Type	Sub-Grade Category			
	SG 1: CBR 5 to 12	SG 2: CBR 12.1 to 20	SG 3: CBR 20.1 to 30	SG 4: CBR > 30
Conventional Flexible: Granular Base	 BSC: 140 CAB: 200 GSB: 150	 BSC: 140 CAB: 200 GSB: 150	 BSC: 120 CAB: 200 GSB: 100	 BSC: 100 CAB: 200 GSB: 100
Deep Strength: Stabilised Base	 BSC: 120 STB 2: 150 GSB: 200	 BSC: 120 STB 2: 150 GSB: 150	 BSC: 100 STB 2: 120 GSB: 150	 BSC: 100 STB 2: 120 GSB: 150
Full Depth: Asphalt Concrete Base	 BSC: 50 BB: 100 GSB: 250	 BSC: 50 BB: 100 GSB: 200	 BSC: 50 BB: 100 GSB: 150	 BSC: 50 BB: 80 GSB: 150

Figure APPENDIX A.2: Pavement structure for traffic category T2: 1.0 to 2.0 million ESALs

Pavement Type	Sub-Grade Category			
	SG 1: CBR 5 to 12	SG 2: CBR 12.1 to 20	SG 3: CBR 20.1 to 30	SG 4: CBR > 30
Conventional Flexible: Granular Base	 BSC: 50 BC: 130 CAB: 200 GSB: 200	 BSC: 50 BC: 130 CAB: 200 GSB: 200	 BSC: 50 BC: 130 CAB: 200 GSB: 150	 BSC: 50 BC: 130 CAB: 200 GSB: 100
Deep Strength: Stabilised Base	 BSC: 50 BC: 100 STB 1: 150 GSB: 200	 BSC: 50 BC: 100 STB 1: 150 GSB: 150	 BSC: 50 BC: 100 STB 1: 100 GSB: 150	 BSC: 50 BC: 100 STB 1: 100 GSB: 100
Full Depth: Asphalt Concrete Base	 BSC: 50 BC/BB: 160 GSB: 200	 BSC: 50 BC/BB: 150 GSB: 150	 BSC: 50 BC/BB: 130 GSB: 150	 BSC: 50 BC/BB: 130 GSB: 100

Figure APPENDIX A.3: Pavement structure for traffic category T3: 2.0 to 10.0 million ESALs (80kN)

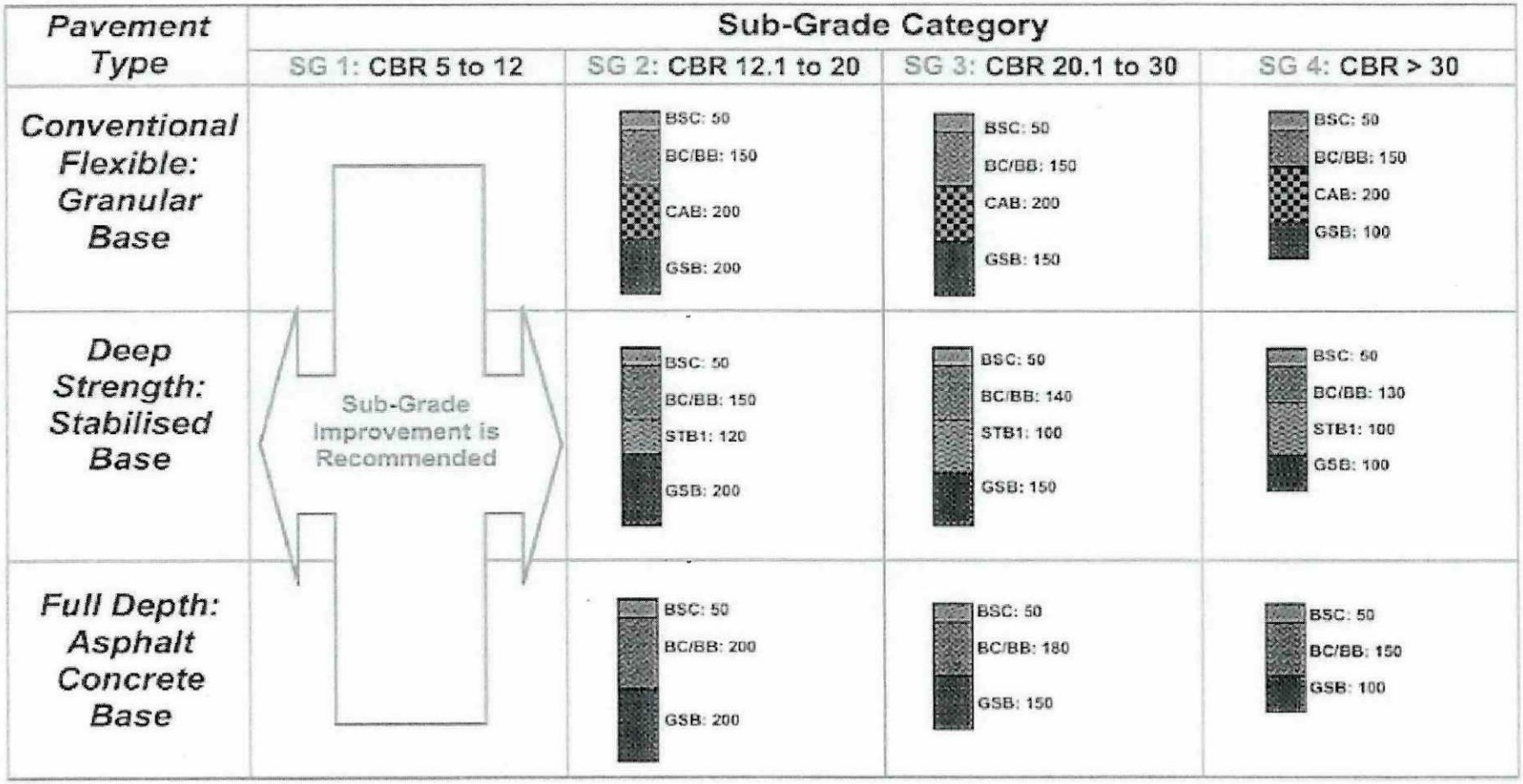


Figure APPENDIX A.4: Pavement structure for traffic category T4: 10.0 to 30.0 million ESALs (80 kN)

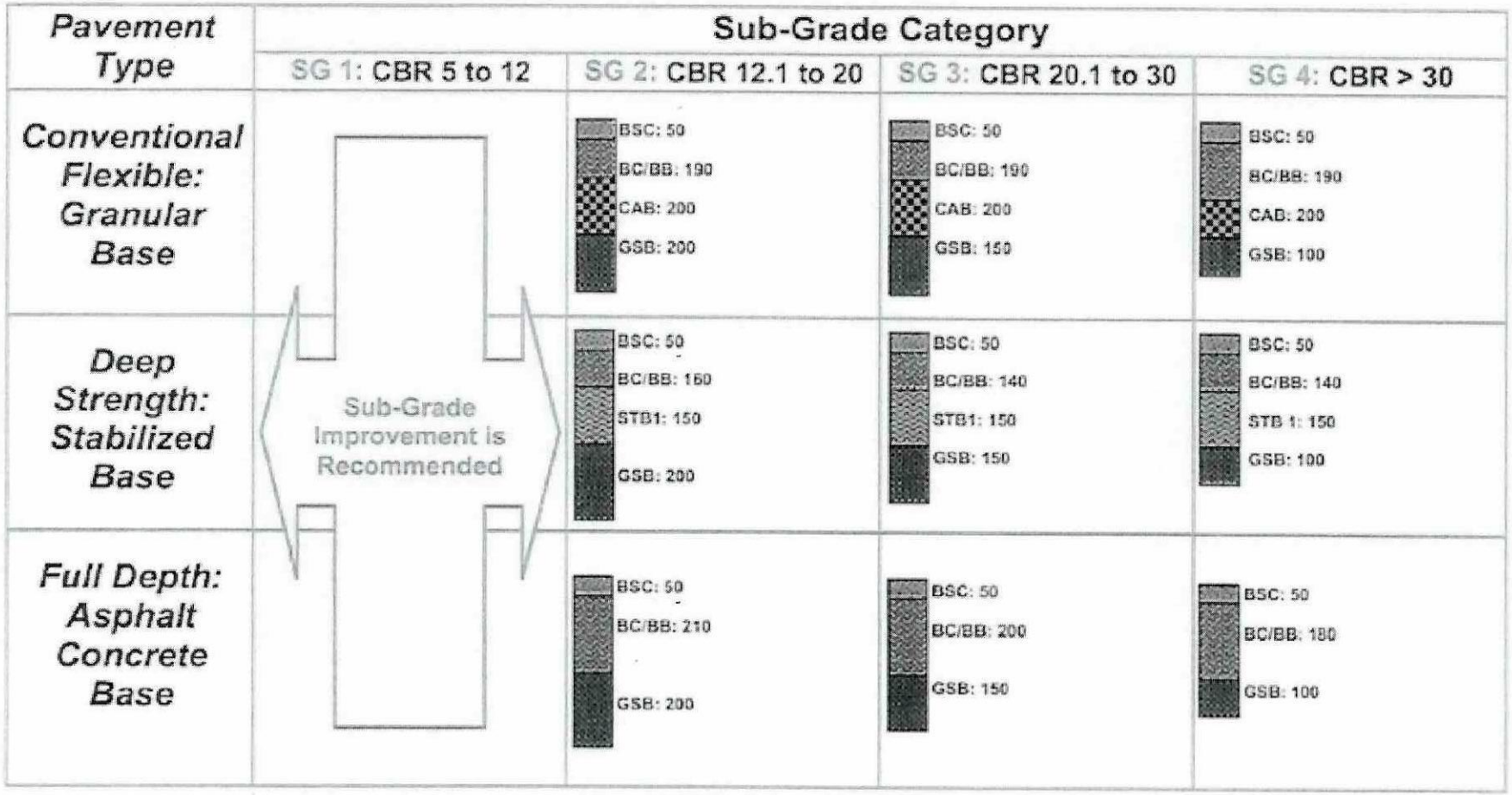


Figure APPENDIX A.5: Pavement structure for traffic category T5: > 30.0 million ESALs (80 kN)

APPENDIX B: Design Charts and Formulas

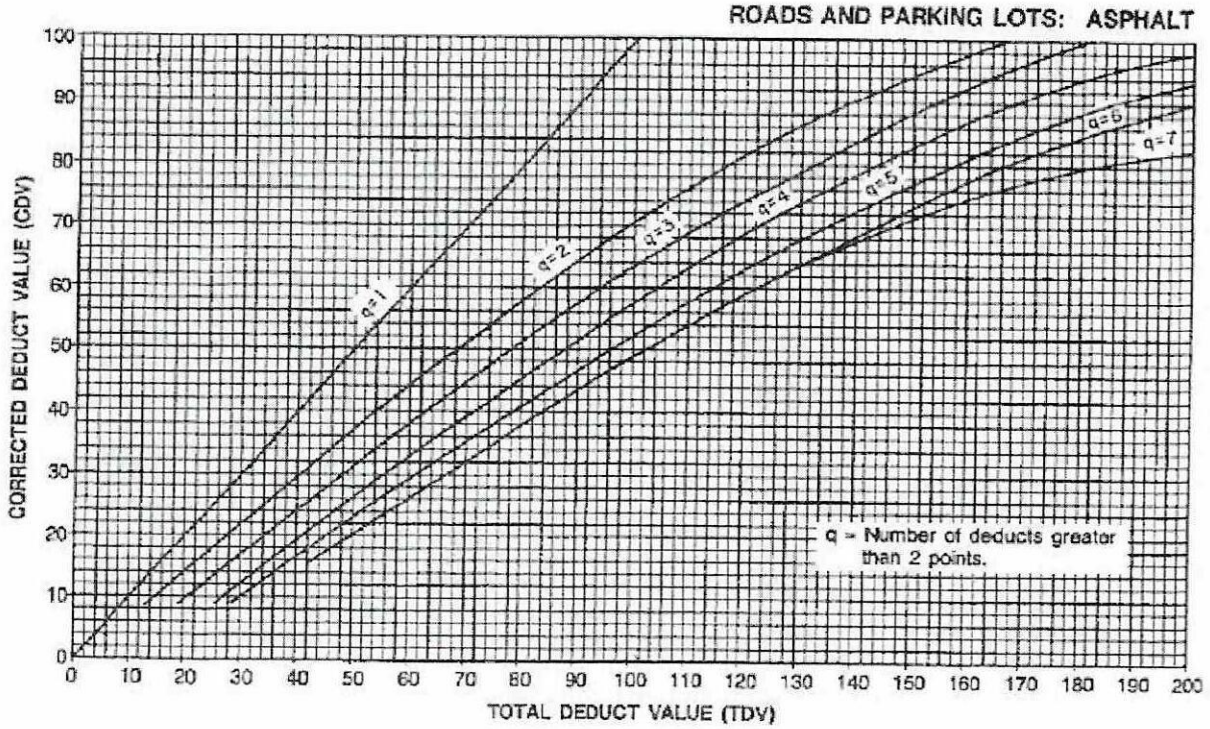


Figure APPENDIX B.1: Corrected deduct value

These fomulas may be useful to you. The symbols have their usual meaning

$$\text{ESAL}_{Y1} = [ADT_{VC1} \text{ X } LEF_1 + ADT_{VC2} \text{ X } LEF_2 + \cdots ADT_{VC9} \text{ X } LEF_9] \text{ X } 365 \text{ X } L \text{ X } T$$

$$\text{ESAL}_{DES} = ESAL_{Y1} \text{ X } \frac{[(1+r)^n - 1)]}{r}$$

$$\text{ESAL}_{DES} = \text{ESAL}_{Y1} \text{ x TGF}$$

Design input value = Mean-(Normal deviate x std. Deviation)

60% Probability: Mean-0.253 x std. Deviation

70% Probability: Mean-0.525 x std. Deviation

60% Probability: Mean-1.0 x std. Deviation