Development of IRC Methods of Flexible Pavement Design

1)Flexible Pavements in India are designed using Indian Roads Congress (IRC) Guidelines

2)Earliest IRC Flexible Pavement design (**1970**) was a set of curves connecting the CBR of a pavement layer with the thickness of the pavement required above it, given for traffic represented by commercial vehicles per day, 0 to 1500 vpd.

3)Later in 1984 (IRC-37-1984**)** the set of curves was revised by representing traffic in terms of Equivalent standard axles in millions (Msa) instead of vpd. The curves covered the range of CBRs 2% to 10% and traffic up to 30Msa

4)In the subsequent revision in 2001(IRC-37-2001), the method of design was radically changed from a set of curves to analytical

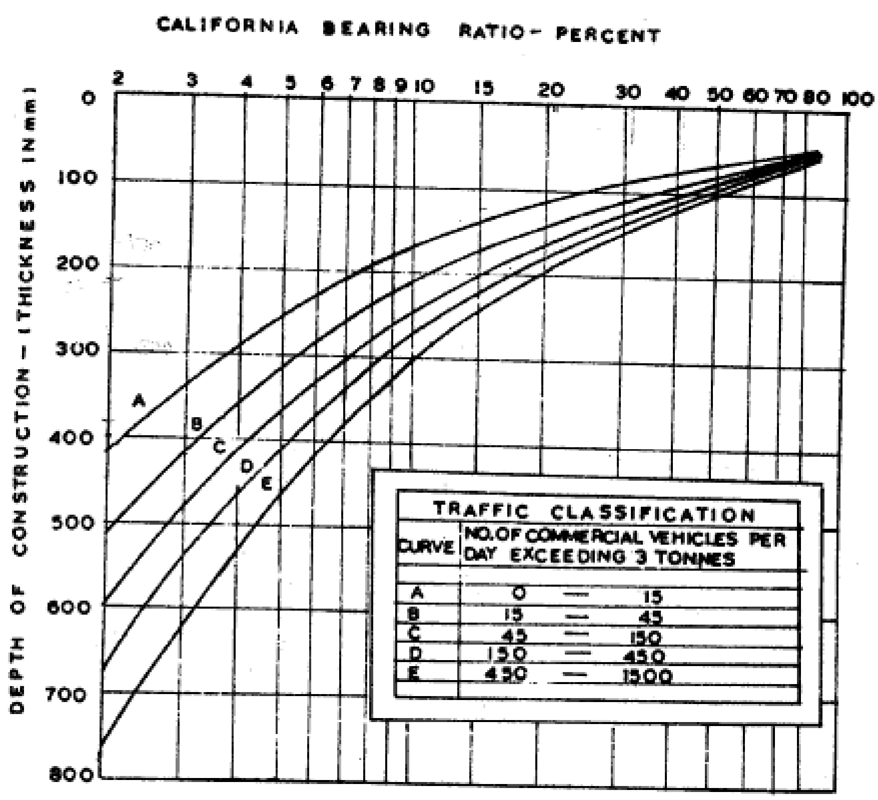


Fig. 3. C.B.R. curves for flexible pavement design

IRC Flexible Pavement Design IRC-37-2001

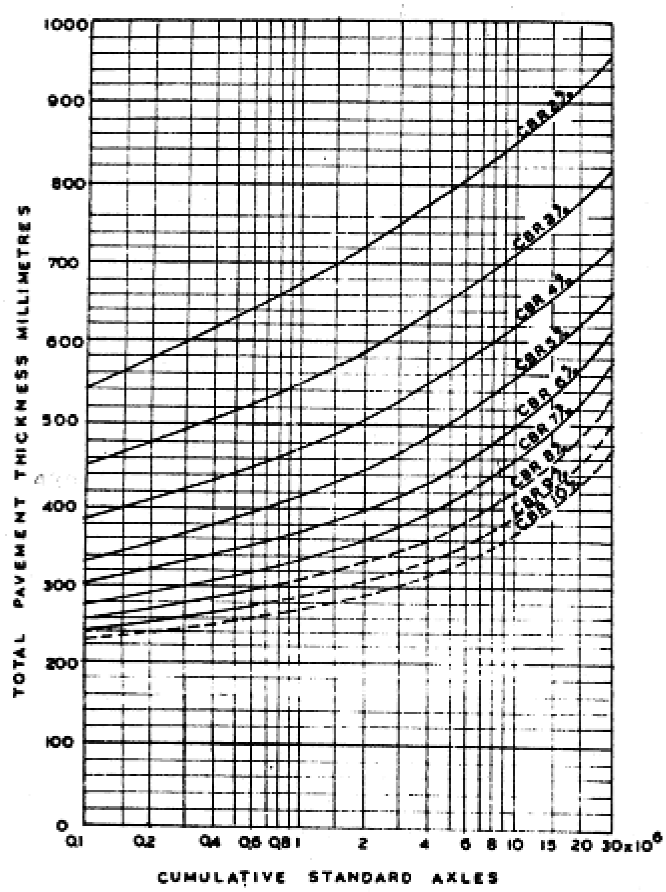


Fig. 1. Pavement thickness design chart
Note: 1. Read total pavement thickness from continuous curves
2. Use dotted curves for proportioning sub-base thickness

The IRC-37-2001 Flexible Pavement Design approach. It is an analytical approach *in which* stresses caused by traffic loads in the pavement layers are considered. Pavement composition is selected such that these stresses are not excessive to cause failure of the pavement during the design period. *Three modes of failure are identified for design.*

The IRC Method (Design approach)

The three modes of Pavement failure

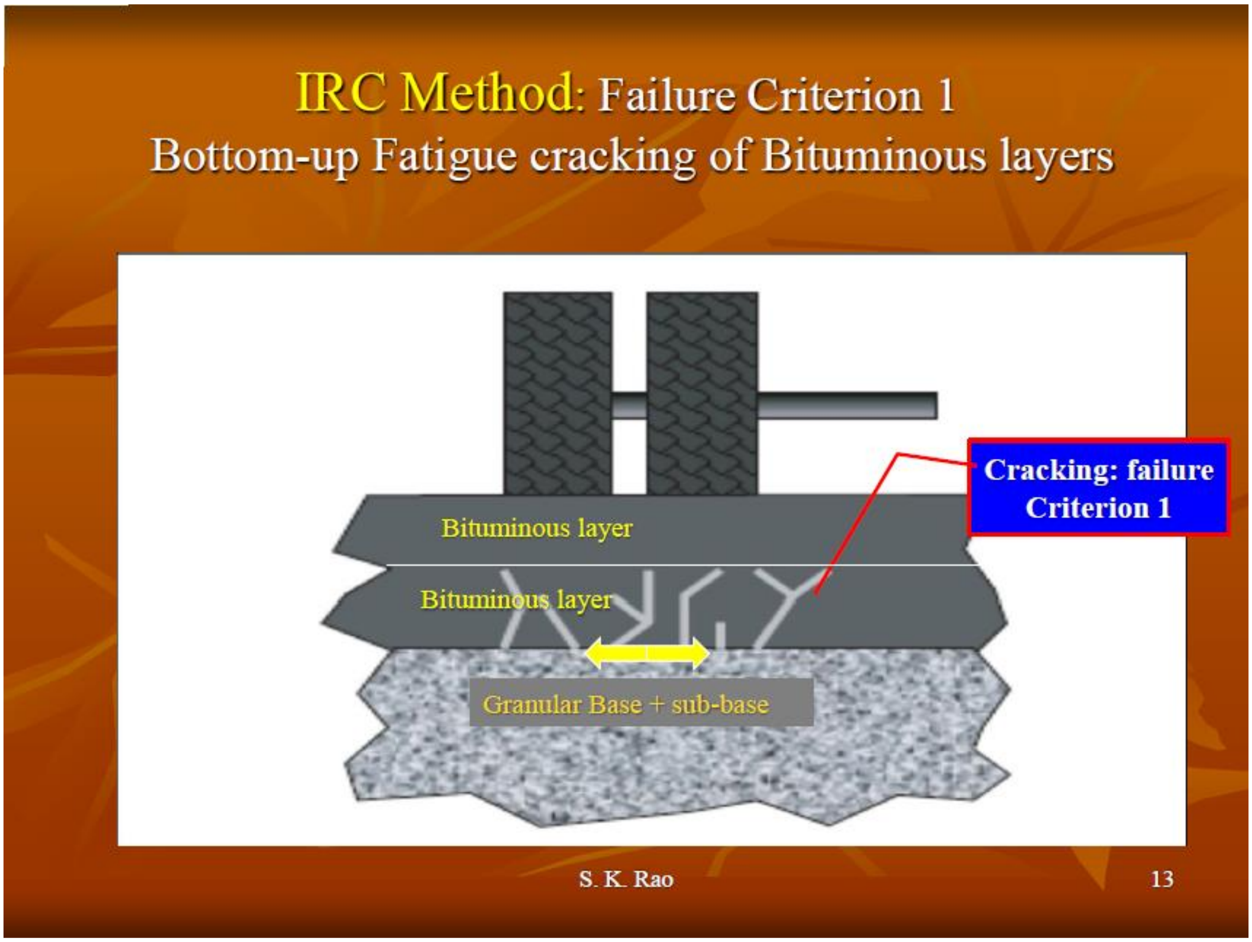
1. Fatigue cracking of bituminous layers, due to high horizontal tensile strains occurring at the bottom of bituminous layers

2. permanent deformation or rutting, caused by high vertical compressive strains on subgrade.

3. Permanent deformation within the bituminous layers (viscous deformation of bituminous mix)

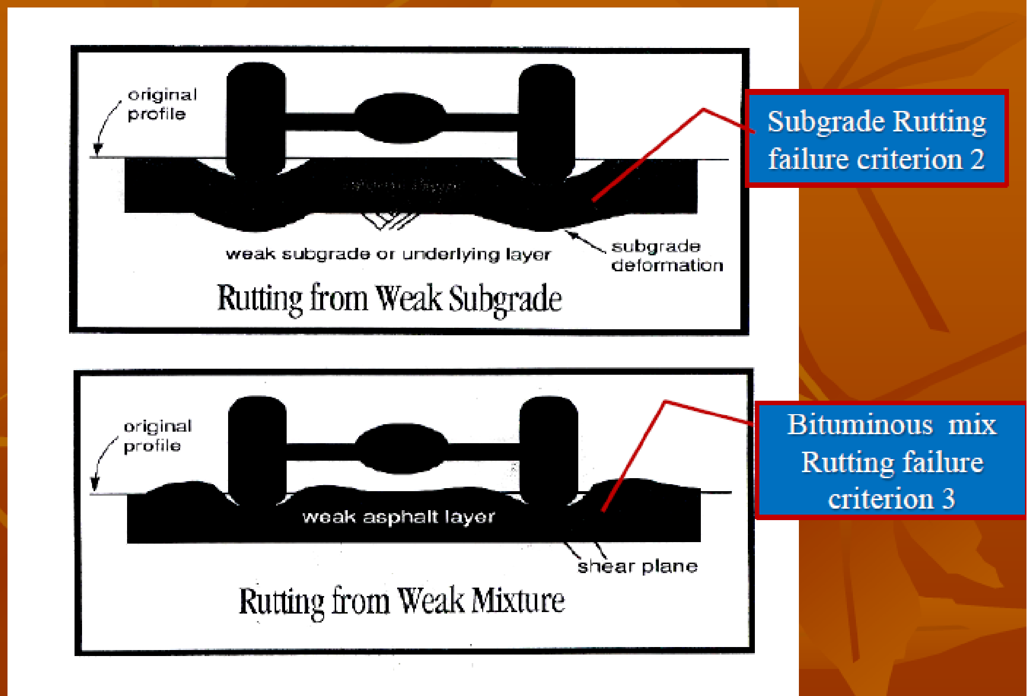
These failure modes are shown pictorially in the next two slides

IRC Method: Failure Criterion 1 Bottom-up Fatigue cracking of Bituminous layers



IRC Method: Failure Criteria 2 & 3

Subgrade Rutting and Asphalt Mix Rutting



The IRC Method (Design approach)

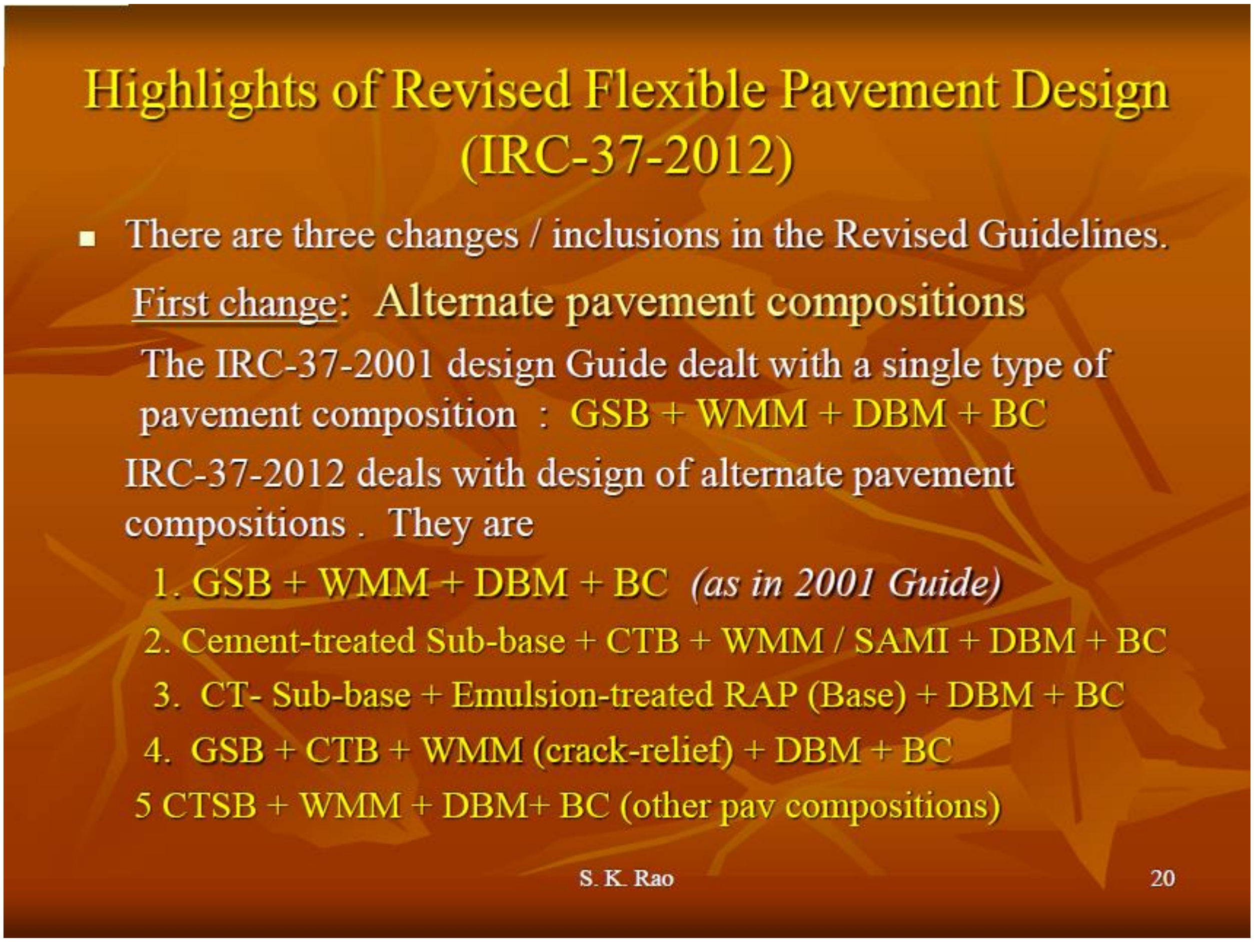
The first two modes of failure are only considered for pavement design

The third mode of failure is required to be taken care of by appropriate asphalt mix design.

The two Failure criteria are quantified further for design as

1. Tensile cracking of bituminous layers as reflected on the pavement surface, not to exceed 20% of surface area.

2. Permanent deformation of Subgrade, reflected on the pavement surface as rutting, not to exceed 20 mm



PAVEMENT DESIGN BY IRC: 37-2012

VEHCLE DAMAGE FACTOT

It is a converting factor to mixed traffic to Standard Axle load Repetitions on a highway
The Standard Axle loads for Different Axle load configurations are as follows:
Single Axle Single Wheel on either side = 65kN=6500kgs=6.5 tonnes
Single axle with Dual wheels on Either side= 80kN=8000kgs=8 tonnes
Tandem Axles (Two) with Dual wheels on either side= 148kN=14800kgs=14.8 tonnes

Tridem Axle (Three) with Dual wheels on either side= 224kN=22400Kgs=22.4 tonnes

$$VDF = \frac{\sum_{i}^{n} (Wi/Ws)^4 \, F_i}{\sum_{i}^{n} Fi}$$

Where

VDF= Vehicle Damage Factor

W_i = i^{th} Vehicle Axle load weighed

W_s = Weight of Standard Axle

Lane distribution factor, D

The transverse distribution of heavy vehicles across the width of the carriageway along both the directions (in the case of two-way traffic movement) is to be taken into account. In case this cannot be assessed from actual field studies, the following recommended guidelines on lane distribution factors, D may be followed:

(a) On undivided roads with single lane carriageway the total number of heavy vehicles along both the directions are taken or the lane distribution factor D = 1.0.

(b) On undivided roads with two-lane carriageway, D = 0.75 and the total number of heavy vehicles along both the directions is to be considered

(c) On undivided roads with four-lane carriageway, D = 0.40 and the total number of heavy vehicles along both the directions is to be considered

(d) On roads with divided carriageway with two lanes each, D = 0.75 and the number of heavy vehicles along each direction is considered

(e) On roads with divided carriageway with three lanes each, D = 0.60 and the number of heavy vehicles along each direction is considered

(f) On roads with divided carriageway with four lanes each, D = 0.45 and the number of heavy vehicles along each direction is considered.

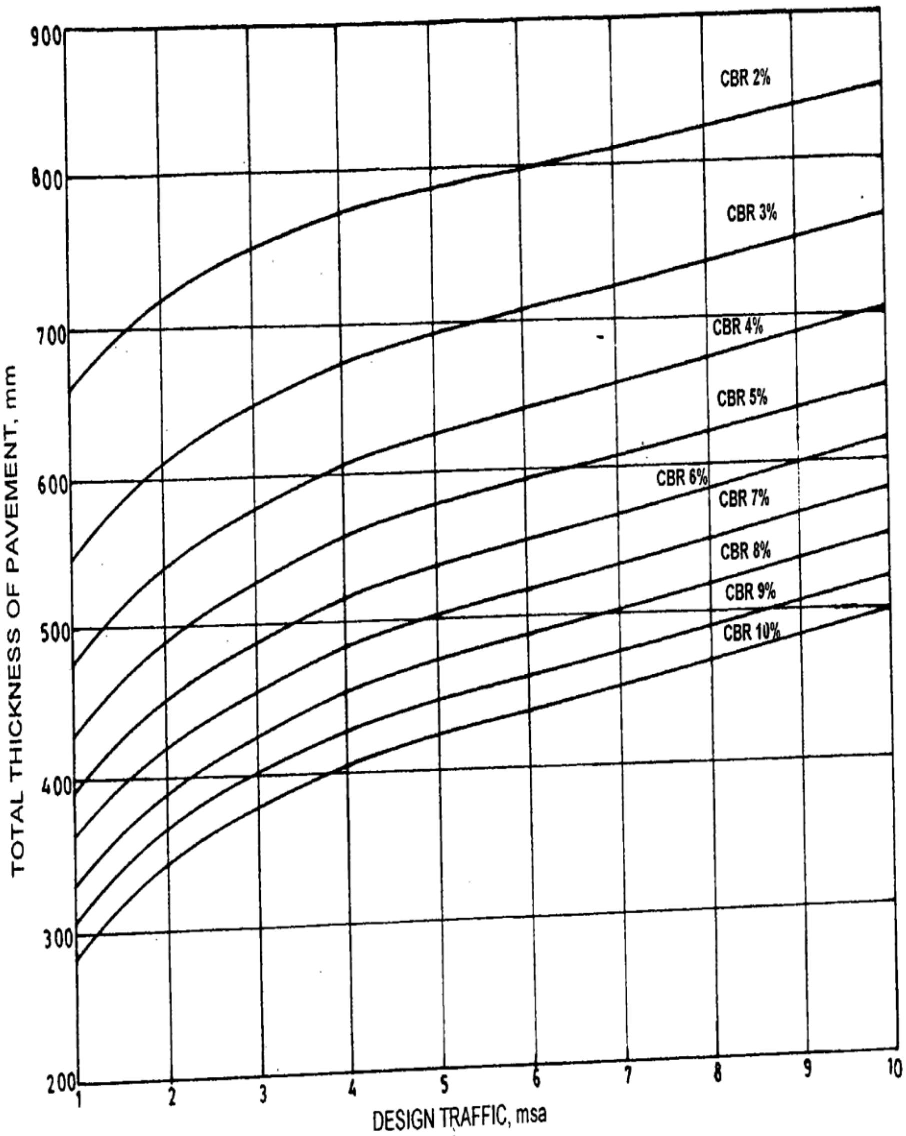


Fig. 1. Pavement Thickness Design Chart for Traffic 1-10 msa

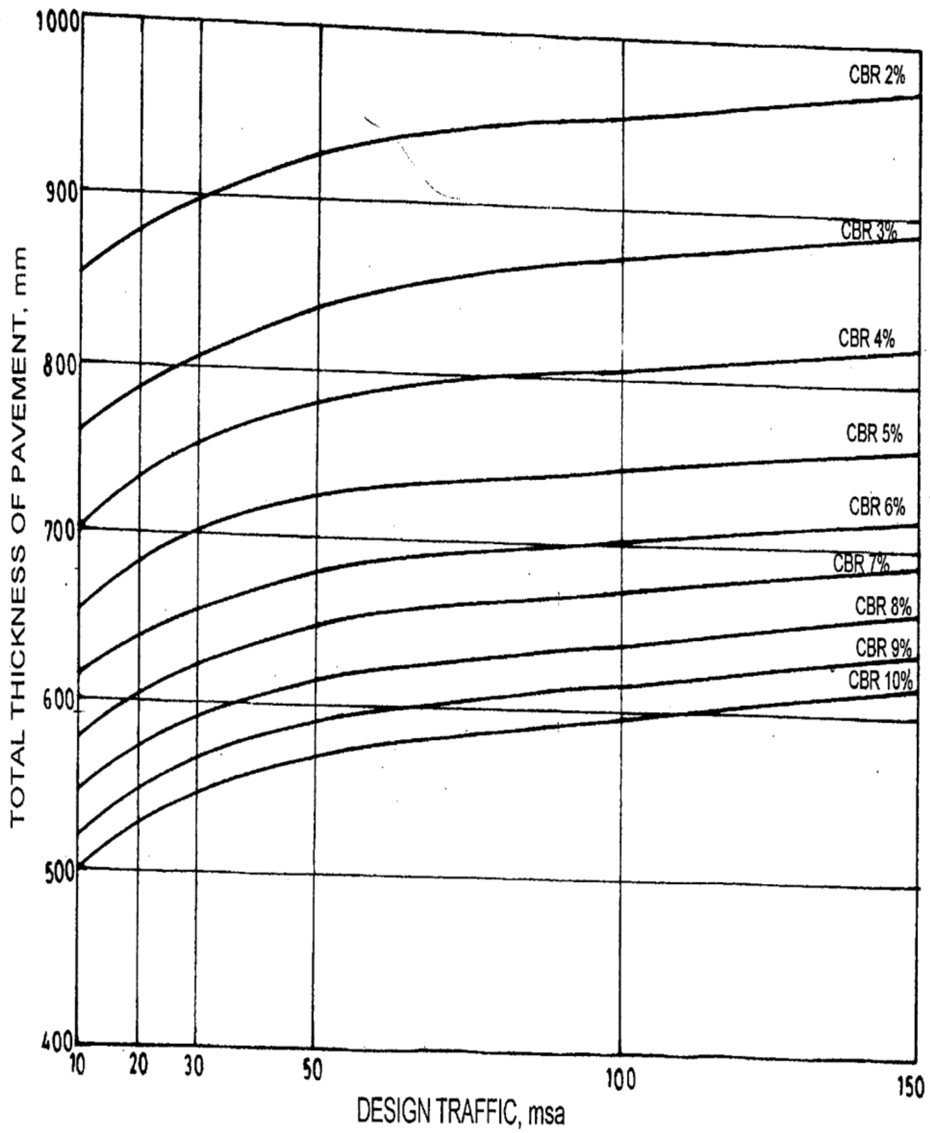


Fig. 2. Pavement Thickness Design Chart for Traffic 10-150 msa

Table 7.3, Pavement design with recommended component layers for cumulative traffic range 1 to 10 msa

CBR, %	CSA, msa	Total pavement thickness, mm	Granular sub-base course, mm	Granular base course, mm	Binder course, mm	Surface course, mm
3	1	550	435	225		20 PC
	2	610	335	225	50 BM	20 PC
	3	645	335	250	60 BM	20 PC
	5	690	335	250	60 DBM	25 SDBC
	10	760	335	250	90DBM	40 BC
4	1	480	255	225		20 PC
	2	540	265	225	50 BM	20 PC
	3	580	280	250	50 BM	20 PC
	5	620	285	250	60 BM	25 SDBC
	10	700	330	250	80 BM	40 BC
6	1	390	165	225		20 PC
	2	450	175	225	50 BM	20 PC
	3	490	190	250	50 BM	20 PC
	5	535	210	250	50 BM	25 SDBC
	10	615	260	250	65 BM	40 BC
8	1	375	150	225		20 PC
	2	425	150	225	50 BM	20 PC
	3	450	150	250	50 BM	20 PC
	5	475	150	250	50 DBM	25 SDBC
	10	550	200	250	60 DBM	40 BC
10	1	375	150	225		20 PC
	2	425	150	225	50 BM	20 PC
	3	450	150	250	50 BM	20 PC
	5	475	150	250	50 DBM	25 SDBC
	10	540	200	250	50 DBM	40 BC

Table 7.4, Pavement design with recommended component layers for cumulative traffic range 10 to 150 msa

CBR, %	CSA, msa	Total pavement thickness, mm	Granular sub-base, mm	Granular base, mm	Dense bituminous Macadam binder course, mm	Bituminous concrete surface course, mm
3	10	760	380	250	90	40
	20	790			120	40
	30	810			140	40
	50	830			160	40
	100	860			180	50
	150	890			210	50
4	10	700	330	250	80	40
	20	730			110	40
	30	750			130	40
	50	780			160	40
	100	800			170	50
	150	820			190	50
6	10	615	260	250	65	40
	20	640			90	40
	30	655			105	40
	50	675			125	40
	100	700			140	50
	150	720			160	50
8	10	550	200	250	60	40
	20	575			85	40
	30	590			100	40
	50	610			120	40
	100	640			140	50
	150	660			160	50
10	10	540	200	250	50	40
	20	565			75	40
	30	580			90	40
	50	600			110	40.
	100	630			130	50
	150	650			150	50

Notes:

<u>Problem 1</u>

Design a Flexible Pavement for a two lane undivided carriageway using the following Data:

Subgrade CBR=6%

Initial Traffic on Completion of Construction=300 CVPD

Traffic Growth rate6%

Design Life=10 Years

VDF value=2.5

SOLUTION

N_s = 365x CVPDx $\frac{[(1+r)^n-1]}{r}$ x VDF X LDF

=365 x 300 x $\frac{[(1+0.06)^{10}-1]}{0.06}$ x 2.5 X 0.75

=3 mSA

From Figure 1 CBR=5%, Msa=3 Total Thickness =530

PREMIX CARPET =20mm
BITUMINOUS MACADAM=50mm
GRANULAR BASE (WBM/WMM)=250mm
GRANULAR SUB GRADE=190mm
SUB GRADE CBR=6%

Problem 2

Design Four Lane Divided Highway for the following Data:

Initial Traffic after completion of road=3500 CVPD

Life of the Pavement=15Years

Growth Rate of Traffic=6.5%

SUBGRDAE CBR=8%

Vehicle Damage Factor=4.0

SOLUTION:

$N_s =$ 365x CVPDx $\frac{[(1+r)^n-1]}{r}$ x VDF X LDF

$N_s =$ 365x 3500x $\frac{[(1+0.065)^{15}-1]}{0.065}$ x 4.0X 0.75

=93mSA   Equal to 100 mSA

Design For 100mSA CBR=8%

Total Thickness=640mm

BITUMINOUS CONCRETE=50mm
DENSE BITUMINOUS CONCRETE=140mm
GRNULAR BASE(WBM/WMM)=250mm
GRANULAR SUB BASE=200mm
SUBGRADE CBR=8.0%

PROBLEM 3: Design a Flexible Pavement as per IRC-37:2012 for the Following Data:

The Subgrade CBR=5%

Number of commercial vehicles per day=1500

Growth Rate of Traffic=7.5%

Life of Pavement=15 Years

Time Lapse between Last Traffic count and Commencement of Pavement=3 Years

Number of Traffic Lanes =2

The Axle data collected on existing road

Single Axle Dual Wheel			**Tandem Axle Dual Wheel**		
Load Class(tones)	Mid Point (tones)	% of Axle loads	Load Class(tones)	Mid Point (tones)	% of Axle loads
19-21	20	0.6	34-38	36	0.30
17-19	18	1.5	30-34	32	0.30
15-17	16	4.8	26-30	28	0.60
13-15	14	10.8	22-26	24	1.80
11-13	12	22.0	18-22	20	1.50
9-11	10	23.3	14-18	16	0.50
7-9	8	30.0	10-14	12	2.0
Sum		**93.0**			**7.0**
Standard Axle Load=8.0tonnes			**Standard Axle Load=14.8 tonnes**		

SOLUTION

The cumulative number of stand axle load repetitions by IRC 37:-2012

$$N_s = 365x\ CVPDx\ \frac{[(1+r)^n - 1]}{r}\ x\ VDF\ X\ LDF$$

Where

N_s = Cumulative number of standard axle load repetetions

CVPD = Commercial vehicles per day(laden Weight>3 tonnes)

r = Growth rate of traffic

n= Design Life

VDF = Vehicle Damage Factor

LDF = Lane Distribution factor

Calculation of Vehicle Damage Factor

Single axle Dual wheel **W_s =8tonnes**

Axle Load Mid Point (tones) (W_i)	**$(w_i/w_s)^4$**	**% of axle loads observed (F_i)**	**$(w_i/w_s)^4 \times F_i$**
20	$(20/8)^4=39.06$	0.6	39.06x0.6=13.44
18	$(18/8)^4=25.63$	1.5	25.63x1.5=38.45
16	$(16/8)^4=16.00$	4.8	16.00x4.80=76.80
14	$(14/8)^4=9.38$	10.8	9.38x10.8=101.30
12	$(12/8)^4=5.06$	22.0	5.06x22=111.32
10	$(10/8)^4=2.44$	23.3	2.44x23.3=56.85
8	$(8/8)^4=1.00$	30.0	1x30=30.00
	Total F_i	93.00	
SUM1			**438.16**
Tandem Axle wheel W_s =14.8 tonnes			
Axle Load Mid Point (tones) (W_i)	**$(w_i/w_s)^4$**	**% of axle loads observed (F_i)**	**$(w_i/w_s)^4 \times F_i$**
36	$(36/14.8)^4=35.00$	0.30	35x0.30=10.50
32	$(32/14.8)^4=21.86$	0.30	21.86x0.30=6.60
28	$(28/14.8)^4=12.81$	0.60	12.81x0.60=7.70
24	$(24/14.8)^4=6.92$	1.80	6.92x1.80=12.46
20	$(20/14.8)^4=3.32$	1.50	3.32x1.50=4.98
16	$(16/14.8)^4=1.37$	0.50	1.37x0.50=0.69
12	$(12/14.8)^4=0.43$	2.00	0.43x2=0.86
	Total F_i	7.00	
SUM2			**43.79**

VDF = (SUM1+SUM2) ÷ (F_1+F_2)

= (438.16+43.79)/(93+7)

= 481.95/100

=4.8195 =4.82

Lane Distribution Facor

Single lane 100% Factor=1.00

Two Lane 75% Factor =0.75

Three Lane 40% Factor =0.40

Project of commercial vehicles from last traffic count to commencement of pavement of 3 years

$A=p(1+r)^n$

Where A= Traffic after Three years

R= growth rate of traffic =7.5%

N+ time lapse period=3 years

$A = 1500(1.075)^3$

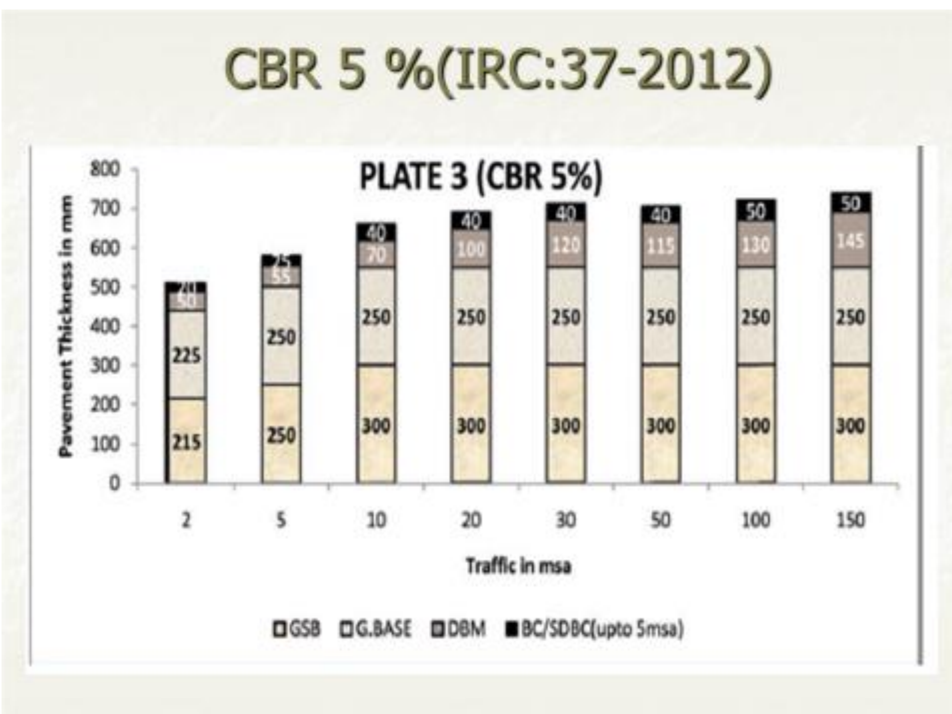
$= 1863$ CVPD

$N_s = 365 \text{x CVPDx} \frac{[(1+r)^n-1]}{r} \text{ x VDF X LDF}$

$N_S = 365 \text{ x } 1863 \text{x} \frac{[(1+0.075)^{15}-1]}{0.075} \text{ X } 4.82 \text{X} 0.75$

=65 Msa

Base on The chart Given Below



Based on the above chart for 65 mSA

Surface course =50mm Bituminous Concrete

Binder Course (Dense Bituminous Macadam= 120mm

Granular Base(Wet Mix Macadam)= 250mm

Granular Sub base= 300mm

Bituminous Concrete =50mm

De3nse Bituminous Macadam= 120mm

Granular Base = 250mm

Granular Subbase=250mm

SUBGRADE CBR=5%