Class – VII Semester / IV Year

Subject –Transportation Engineering

Unit –4 Pavement Design:

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Jaipur

VISION

- To become a role model in the field of Civil Engineering for the sustainable development of the society

MISSION

1) To provide outcome base education.
2) To create a learning environment conducive for achieving academic excellence.
3) To prepare civil engineers for the society with high ethical values.

PROGRAMME OUTCOMES (PO)

1. **Engineering knowledge**: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

2. **Problem analysis**: Identify, formulate, research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

3. **Design/development of solutions**: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations

4. **Conduct investigations of complex problems**: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

5. **Modern tool usage**: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

6. **The engineer and society**: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

7. **Environment and sustainability**: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

8. **Ethics**: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

9. **Individual and team work**: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

10. **Communication**: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

11. **Project management and finance**: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one’s own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

12. **Life-long learning**: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

COURSE OUTCOMES

Name of Subject – TRANSPORTATION ENGINEERING

Semester- VII **Code – 7CE4-01**

CO1:-Introduction,modes,development,classification,planning & alignment of highway in India.

CO2:-Design of highway & desirable properties, testing of material as per IRC code.

CO 3:-Method of highway construction, Equipment & design of flexible & rigid pavements as per IRC.

CO4:-Introduction of Railway,Waterways,Airways,Engineering

INTRODUCTION TO PAVEMENT

- **PAVEMENT:-** **Pavement** is the durable surface material laid down on an area intended to sustain vehicular load or foot traffic, such as a road or walkway.
- It is of two types.
- Flexible pavement or bituminous pavement or black top pavement
- Rigid pavement or cement concrete pavement or white surface pavement

• Requirements of a Pavement

- Sufficient thickness to distribute the wheel load stresses to a safe value on the sub-grade soil.
- Structurally strong to withstand all types of stresses imposed upon it.
- Adequate coefficient of friction to prevent skidding of vehicles.
- Smooth surface to provide comfort to road users even at high speed.
- Produce least noise from moving vehicles.
- Dust proof surface so that traffic safety is not impaired by reducing visibility.
- Impervious surface, so that sub-grade soil is well protected.

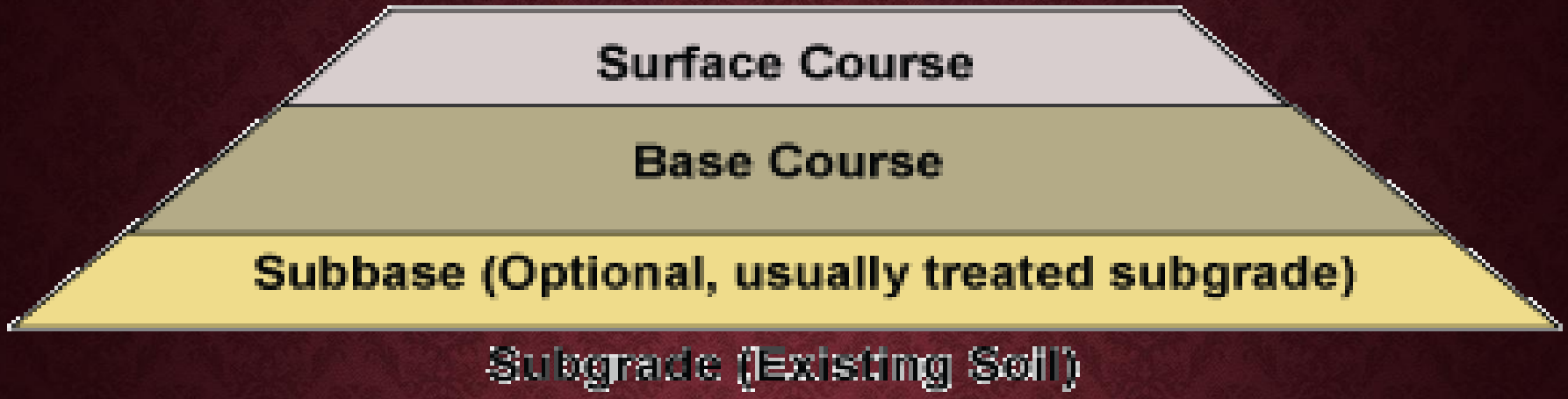
- Long design life with low maintenance cost.

COMPARISON OF FLEXIBLE PAVEMENT & RIGID PAVEMENT

- **FLEXIBLE PAVEMENT**
- Have low flexural strength
- Load is transferred by grain to grain contact
- Surfacing cannot be laid directly on the sub grade but a sub base is needed
- No thermal stresses are induced
- expansion joints are not needed
- Design life 10-15 years
- Initial cost of construction is low
- Maintenance cost is high
- Road can be used for traffic within 24 hours
- Damaged by Oils and Certain Chemicals

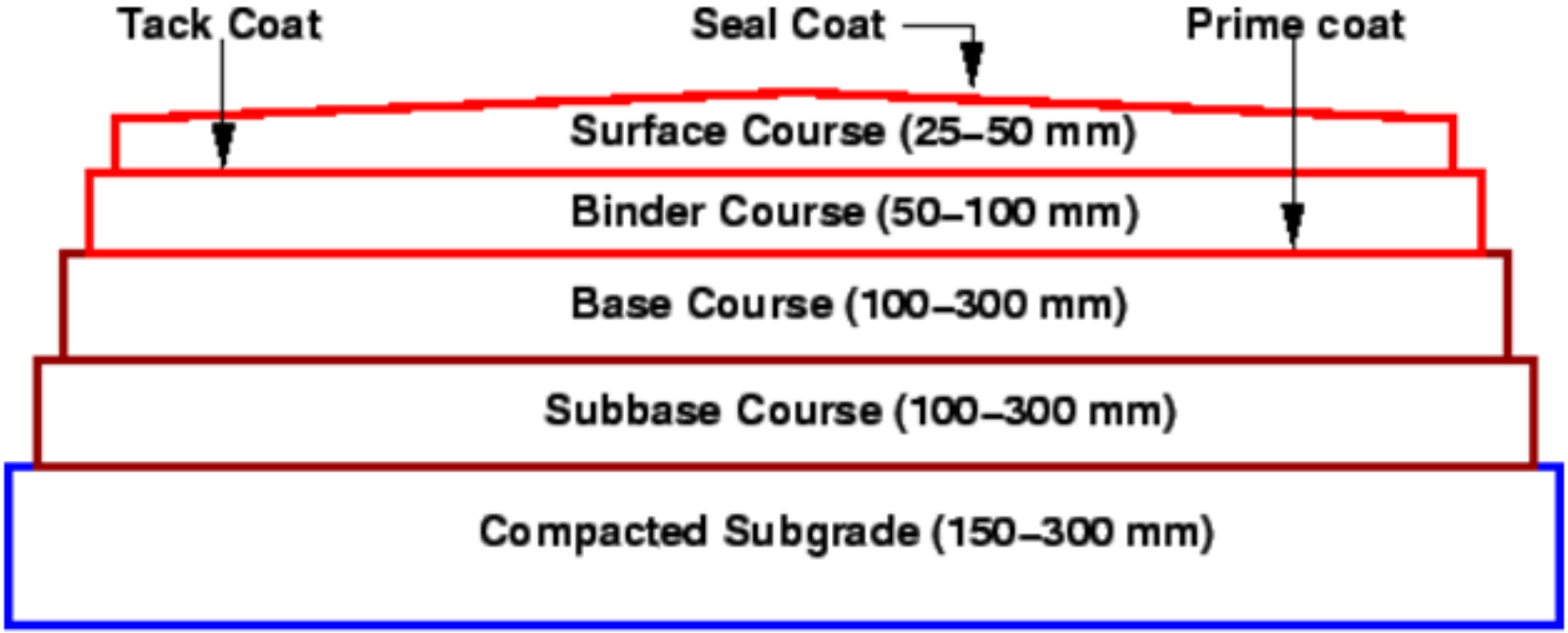
- **RIGID PAVEMENT**
- Have more flexural strength
- No such phenomenon of grain to grain load transfer exists
- Surfacing can be directly laid on
- the sub grade
- Thermal stresses are induced
- expansion joints are needed
- Design life 20-30 years
- Initial cost of construction is high
- Less maintenance cost
- Road cannot be used until 14 days of curing
- No Damage by Oils and other chemicals

- **Types of Flexible pavements**
  - Conventional layered flexible pavement
  - Full - depth asphalt pavement
  - Contained rock asphalt mat (CRAM).
  - **Conventional flexible pavements** are layered systems with high quality expensive materials are placed in the top where stresses are high, and low quality cheap materials are placed in lower layers.
  - **Full - depth asphalt pavements** are constructed by placing bituminous layers directly on the soil sub-grade. This is more suitable when there is high traffic and local materials are not available.
  - **Contained rock asphalt mats** are constructed by placing dense/open graded aggregate layers in between two asphalt layers.

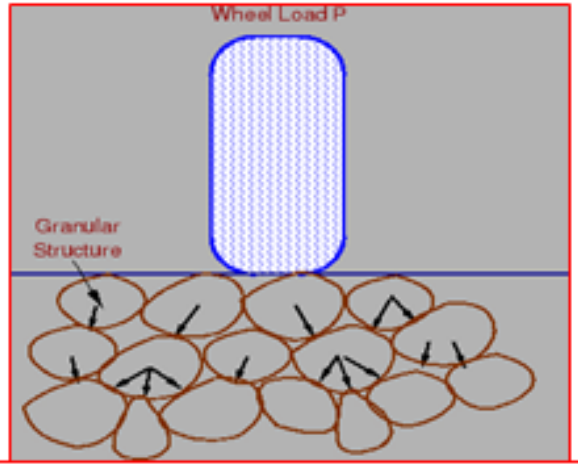


C/S OF FLEXIBLE PAVEMENT

C/S OF RIGID PAVEMENT



c/s of flexible pavement



Load is transferred by grain to grain contact

Typical layers of a flexible pavement

Seal Coat: Seal coat is a thin surface treatment used to water- proof the surface and to provide skid resistance and to seal the surfacing against the ingress of water.

Tack Coat: Tack coat is a very light application of asphalt, usually asphalt emulsion diluted with water. It provides proper bonding between two layer of binder course.it is generally applied on impervious surface.

Prime Coat: Prime coat is an application of low viscous liquide bituminous material over an existing porous or absorbent pavement surface like WBM.

- Prime objective is to plug the capillary voids of the porous surface and to bond the loose materials on the existing surface like granular bases on which binder layer is placed. It provides bonding between two layers.


Prim
e
coat
Seal coat

Surface course:

- Surface course is the layer directly in contact with traffic loads and generally contains superior quality materials. They are usually constructed with dense graded asphalt concrete(AC).
- It provides characteristics such as friction, smoothness, drainage, etc. Also it will prevent the entrance of excessive quantities of surface water into the underlying base, sub-base and sub-grade,
- It provide a smooth and skid- resistant riding surface,
- It must be water proof to protect the entire base and sub-grade from the weakening effect of water.

Binder course:

- This layer provides the bulk of the asphalt concrete structure. It's chief purpose is to distribute load to the base course.
- The binder course generally consists of aggregates having less asphalt and doesn't require quality as high as the surface course, so replacing a part of the surface course by the binder course results in more economical design.

Base course:

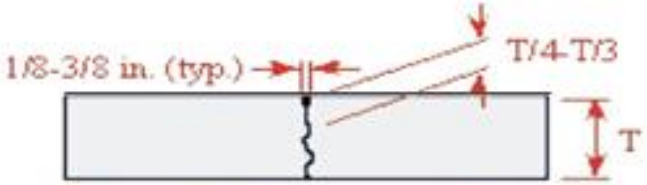
- The base course is the layer of material immediately beneath the surface of binder course and it provides additional load distribution and contributes to the sub-surface drainage It may be composed of crushed stone and other untreated or stabilized materials.

- **Sub-Base course:** The sub-base course is the layer of material beneath the base course and the primary functions are to provide structural support, improve drainage.
- It may WBM or WMM
- A sub-base course is not always needed or used. For example, a pavement constructed over a high quality.
- **Sub-grade:** The top soil or sub-grade is a layer of natural soil prepared to receive the stresses from the layers above. It is essential that at no time soil sub-grade is overstressed.
- It should be compacted to the desirable density, near the optimum moisture content.

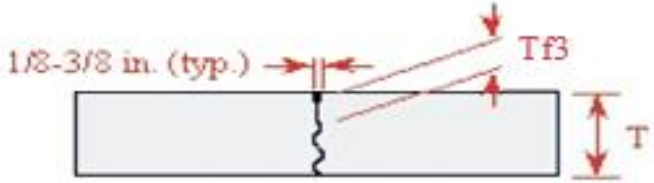
TYPES OF RIGID PAVEMENTS

- Jointed plain concrete pavement (JPCP),
- Jointed reinforced concrete pavement (JRCP),
- Continuous reinforced concrete pavement (CRCP)
- Pre-stressed concrete pavement (PCP).

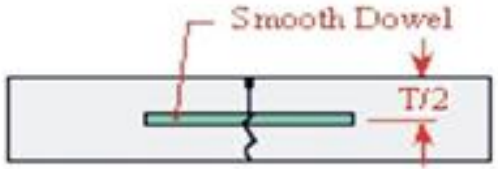
- **Jointed Plain Concrete Pavement:** constructed with closely spaced contraction joints. Dowel bars or aggregate interlocks are normally used for load transfer across joints. They normally has a joint spacing of 5 to 10m.
- **Jointed Reinforced Concrete Pavement:** reinforcements do not improve the structural capacity significantly but they can drastically increase the joint spacing to 10 to 30m. Dowel bars are required for load transfer. Reinforcements help to keep the slab together even after cracks.
- **Continuous Reinforced Concrete Pavement:** Complete elimination of joints are achieved by reinforcement.



Undoweled - Transverse (Type A-1)

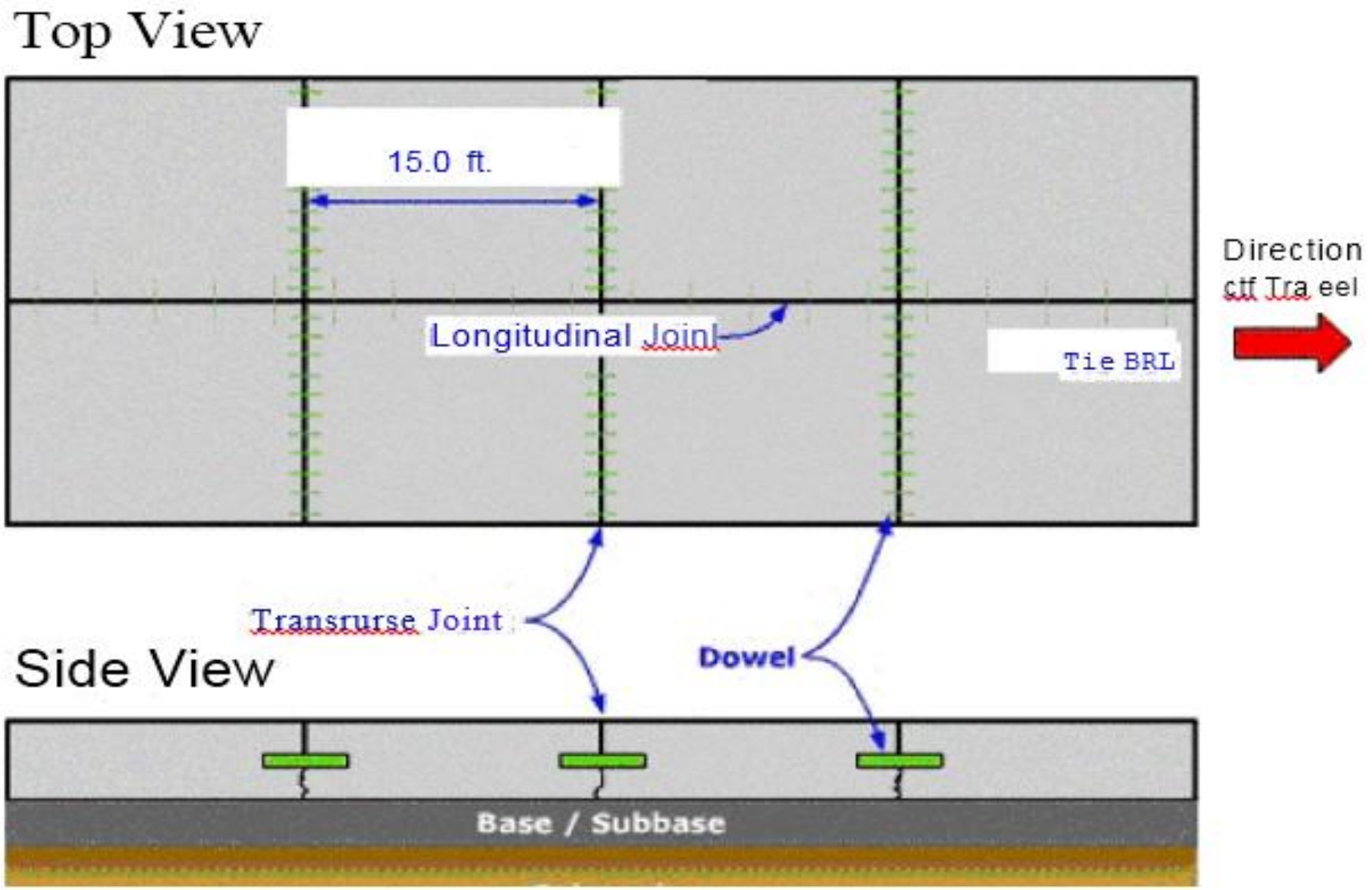


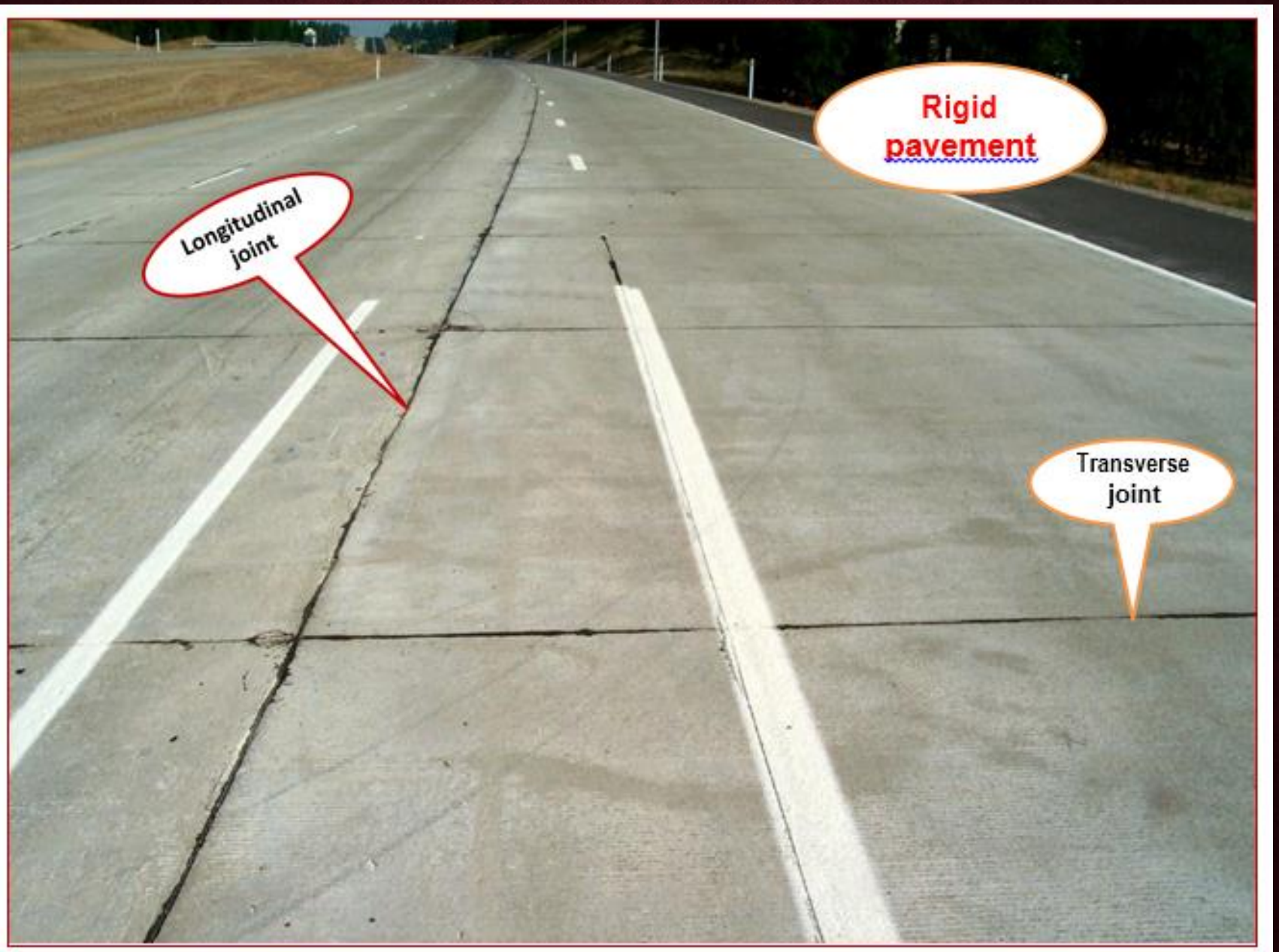
Untied - Longitudinal (Type A-3)



Tied - Longitudinal (Type A-4)

Note : T = Thickness of Concrete Slab


Top View
15.0 ft.
Longitudinal Joint
Tie BRL
Direction
ctf Tra eel
Transrurse Joint
Dowel
Side View
Base / Subbase


Rigid pavement
Longitudinal joint
Transverse joint

Granular materials

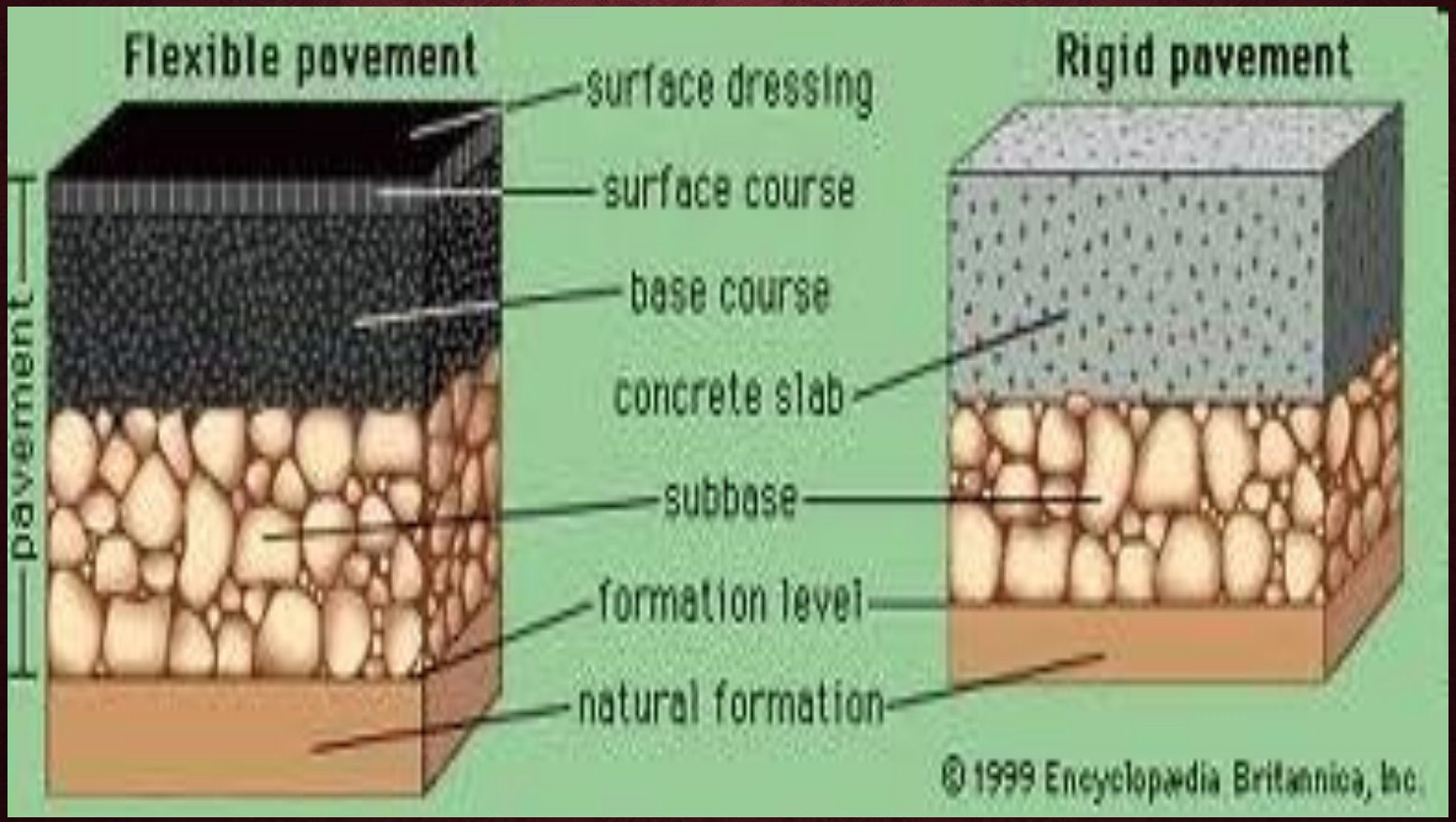
Design of Flexible Pavement

IRC-37:2001

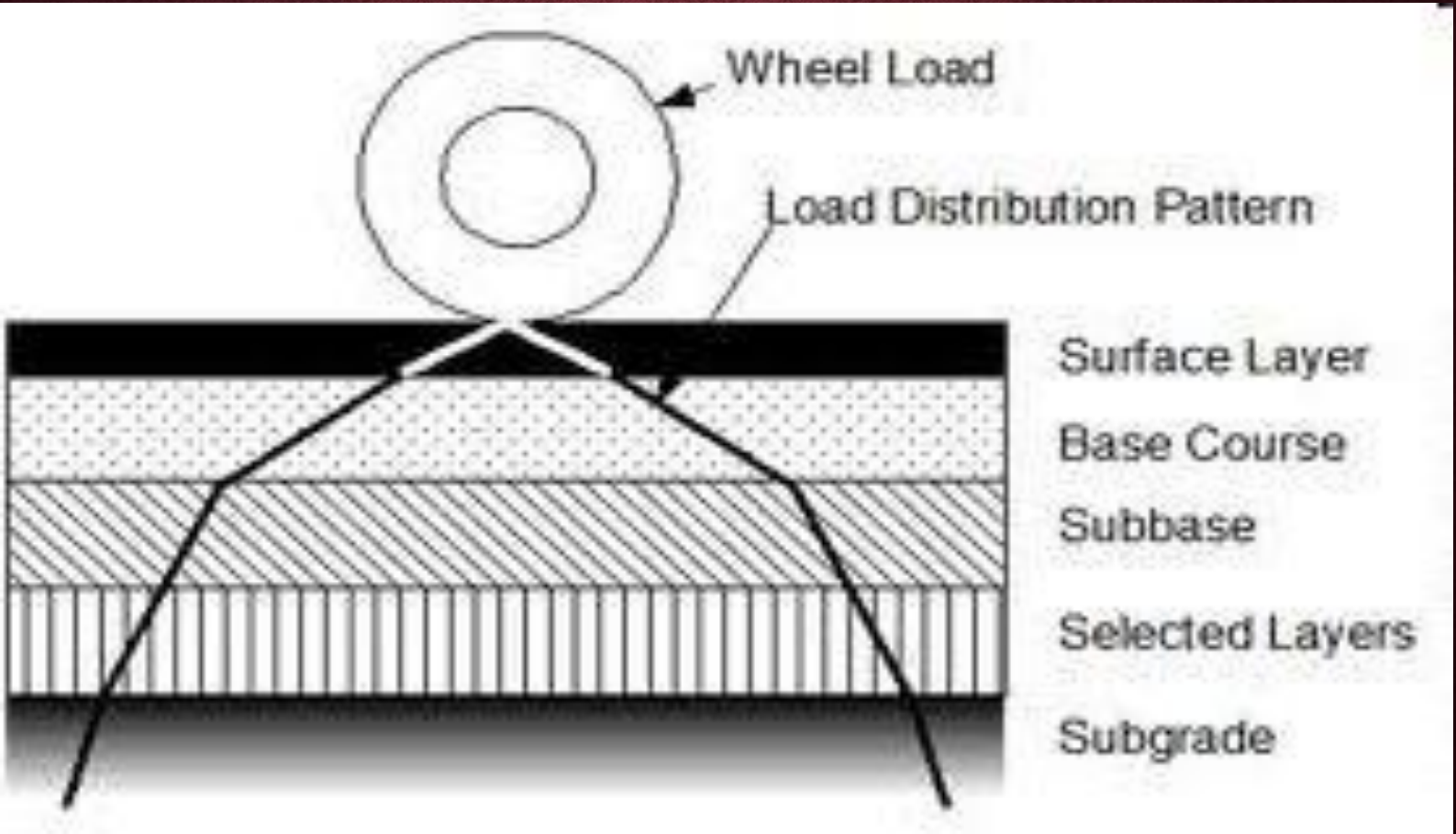
FLEXIBLE PAVEMENT

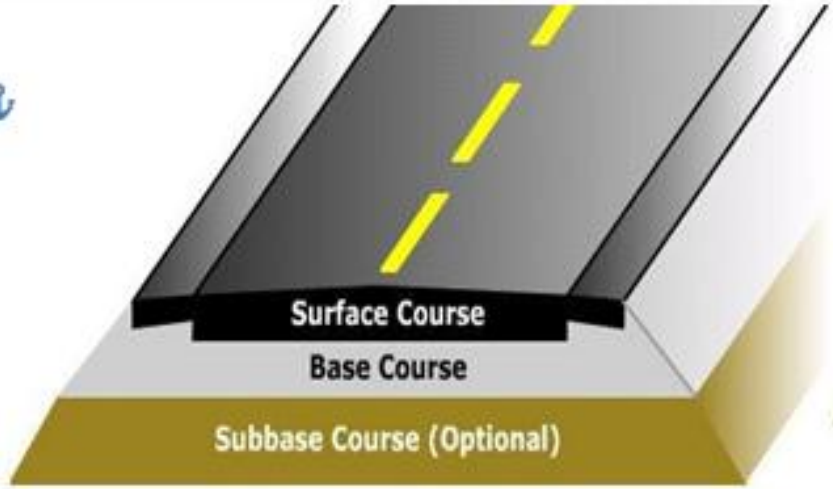
RIGID PAVEMENT

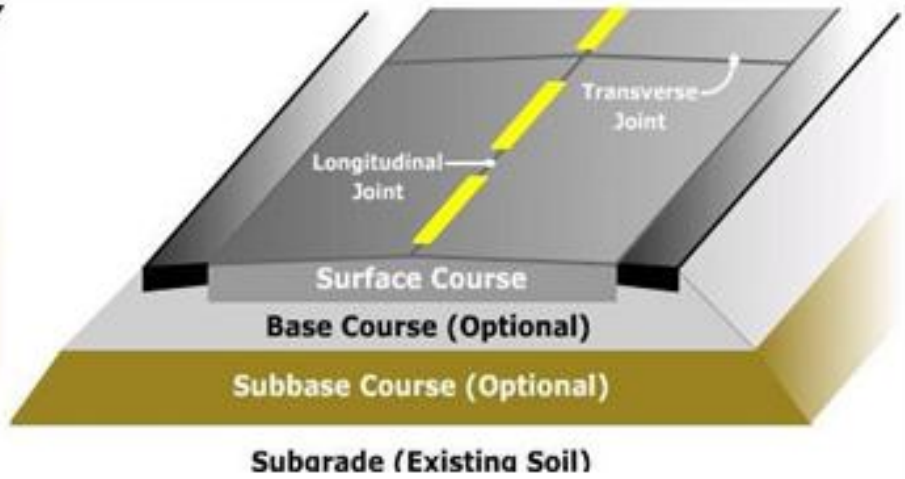
TYPES OF PAVEMENTS

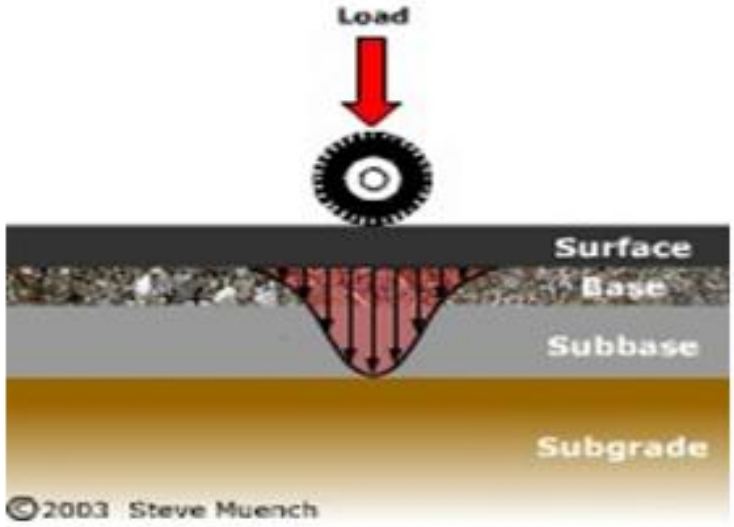


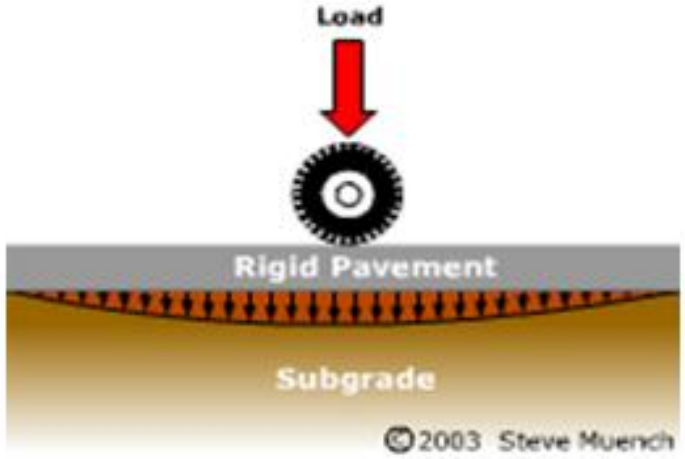
WHEEL LOAD DISTRIBUTION











Flexible

Rigid

LOAD DISTRIBUTION

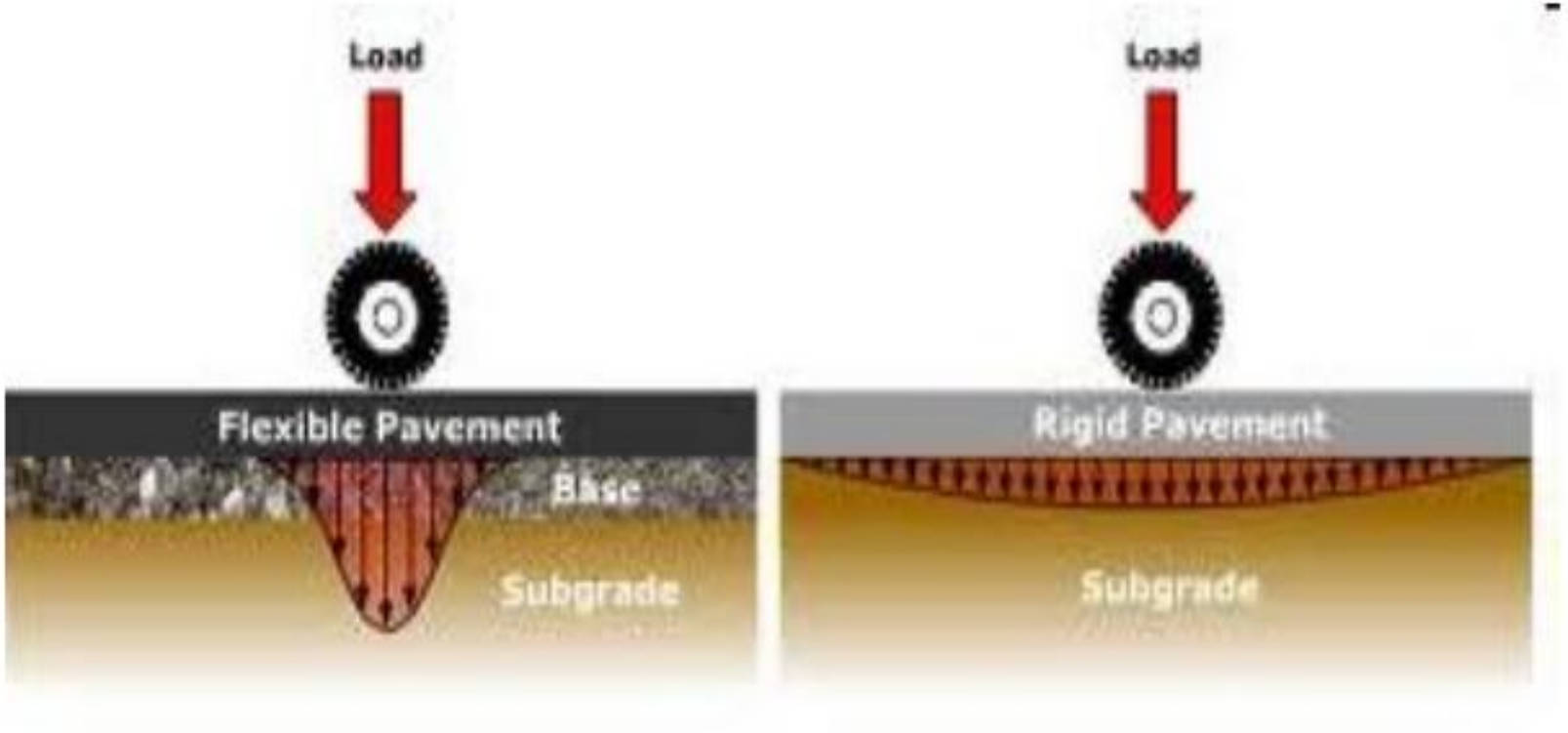
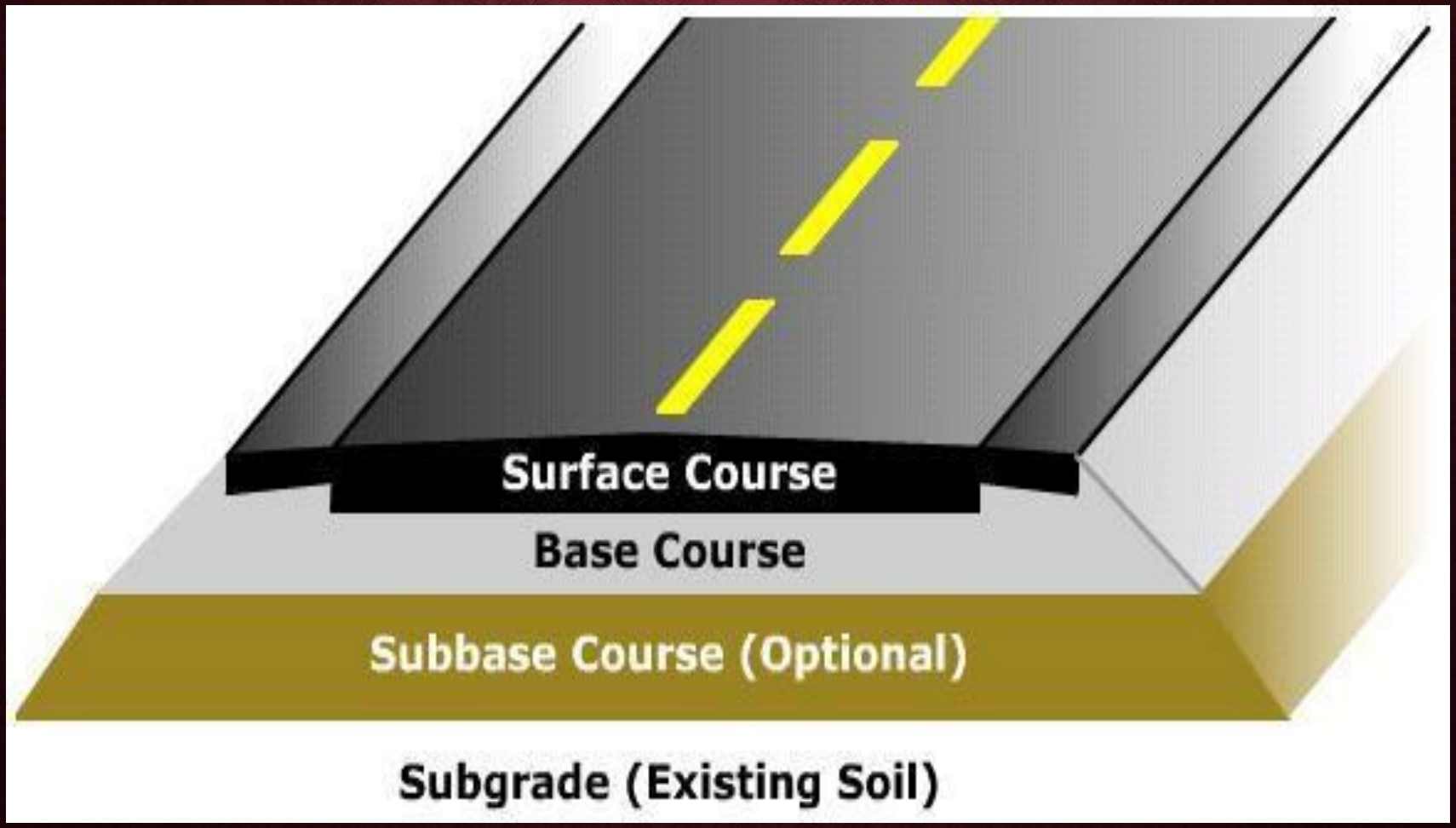


Figure 1: Rigid and Flexible Pavement Load Distribution

COMPONENTS OF FLEXIBLE PAVEMENT



FUNCTION AND SIGNIFICANCE OF SUBGRADE PROPERTIES

- Basement soil of road bed.
- Important for structural and pavement life.
- Should not deflect excessively due to dynamic loading.
- May be in fill or embankment.

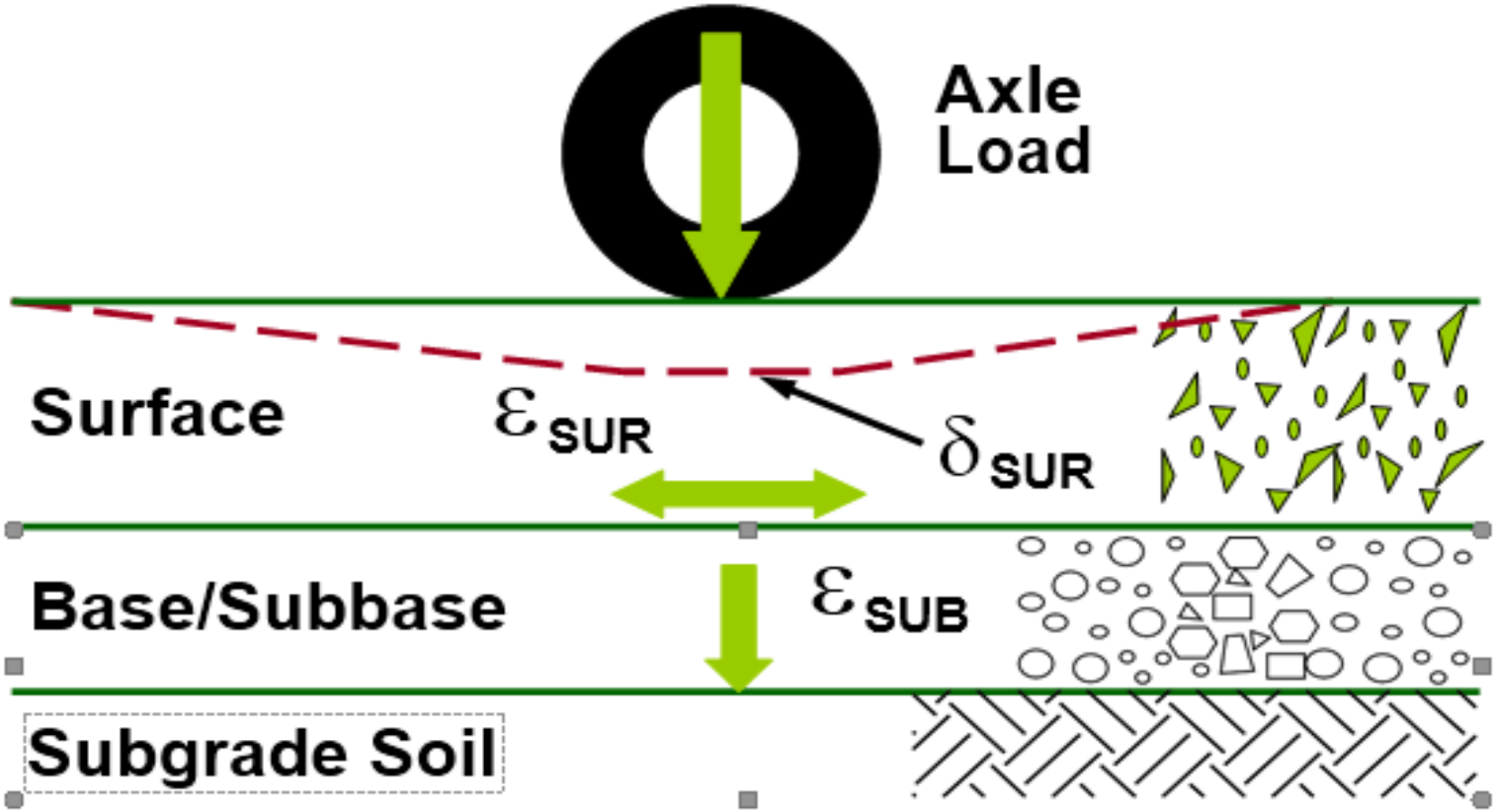
FLEXIBLE PAVEMENT DESIGN

- IRC (37-2001)
- Basic Principles
  - Vertical stress or strain on sub-grade
  - Tensile stress or strain on surface course

FACTORS FOR DESIGN OF PAVEMENTS

- Design wheel load
  - Static load on wheels
  - Contact Pressure
  - Load Repetition
- Subgrade soil
  - Thickness of pavement required
  - Stress- strain behavior under load
  - Moisture variation
- Climatic factors:(rain fall)
- Pavement component materials
- Environment factors:(height of embankment and its
- detailed)
- Traffic Characteristics
- Required Cross sectional elements of the alignment

Pavement Responses Under Load

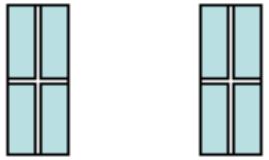


AXLE CONFIGURATIONS

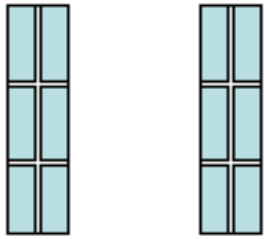
An **axle** is a central shaft for a rotating wheel or gear

Single Axle With Single Wheel
(Legal Axle Load = 6t)

Single Axle With Dual Wheel
(Legal Axle Load = 10t)



Tandem Axle
(Legal Axle Load = 18t)



Tridem Axle
(Legal Axle Load = 24t)

STANDARD AXLE

- Single axle with dual wheels carrying a load of 80 kN (8 tonnes) is defined as standard axle

Standard Axle

EVALUATION OF PAVEMENT COMPONENT LAYERS

- Sub-grade
  - To Receive Layers of Pavement Materials Placed over it
  - Plate Bearing Test
  - CBR Test
  - Triaxial Compression
- California State Highways Department Method
- Required data
  - Design Traffic in terms of cumulative number of standard
- axles(CSA)
- CBR value of subgarde

TRAFFIC DATA

- Initial data in terms of number of commercial vehicles per day (CVPD).
- Traffic growth rate during design life in %
- Design life in number of years.
- Distribution of commercial vehicles over the carriage way

Traffic – In Terms of CSA (8160 Kg) During Design Life

- **Initial Traffic**
  - **In terms of Cumulative Vehicles/day**
  - **Based on 7 days 24 hours Classified Traffic**
- **Traffic Growth Rate**
  - **7.5 % may be Assumed**

DESIGN LIFE

- National Highways – 15 Years
- Expressways and Urban Roads – 20 Years
- Other Category Roads – 10 – 15 Years

Vehicle Damage Factor (VDF)

- Multiplier to Convert No. of Commercial Vehicles of Different Axle Loads and Axle Configurations to the Number of Standard Axle Load Repetitions indicate VDF Values.

- Normally = (Axle Load/8.2)n n = 4 - 5

INDICATIVE VDF VALUES

Initial Traffic in terms of CV/PD	Terrain	
	Plain/Rolling	Hilly
0 – 150	1.5	0.5
150 – 1500	3.5	1.5
> 1500	4.5	2.5

DISTRIBUTION OF TRAFFIC

- **Single Lane Roads:**

➢ **Total No. of Commercial Vehicles in both Directions**

Two-lane Single Carriageway Roads:

➢ **75% of total No. of Commercial Vehicles in both Directions**

Four-lane Single Carriageway Roads:

➢ **40% of the total No. of Commercial Vehicles in both Directions**

Dual Carriageway Roads:

➢ **for two lane dual carriage way 75% of the No. of Commercial Vehicles in each Direction**

➢ **For three lane-60%**

➢ **For four lane-45%**

COMPUTATION OF TRAFFIC FOR USE OF PAVEMENT THICKNESS DESIGN CHART

$$N = \frac{365 \times A[(1+r)^n - 1]}{r} \times D \times F$$

N = Cumulative No. of standard axles to be catered for the design in terms of msa

D = Lane distribution factor

A = Initial traffic, in the year of completion of construction, in terms of number of commercial vehicles per day

$=p(1-r)^x$

P=no. of commercial vehicle as per last count

X=no. of year between the last count and the year of completion of construction

F = Vehicle Damage Factor

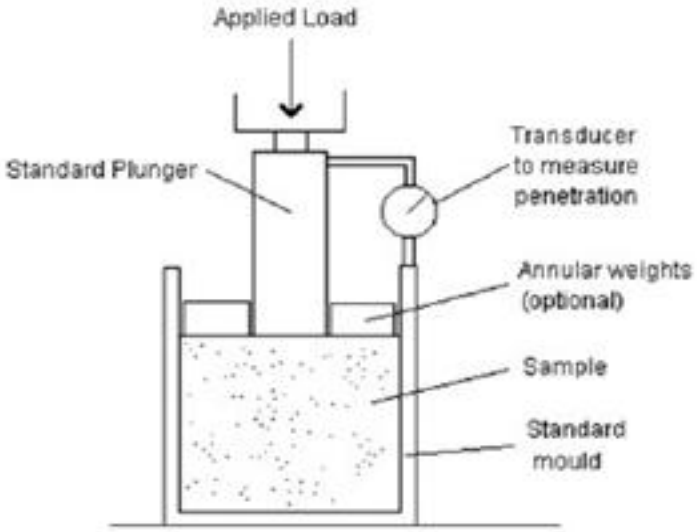
n = Design life in years

r = Annual growth rate of commercial vehicles

CBR Testing Mach

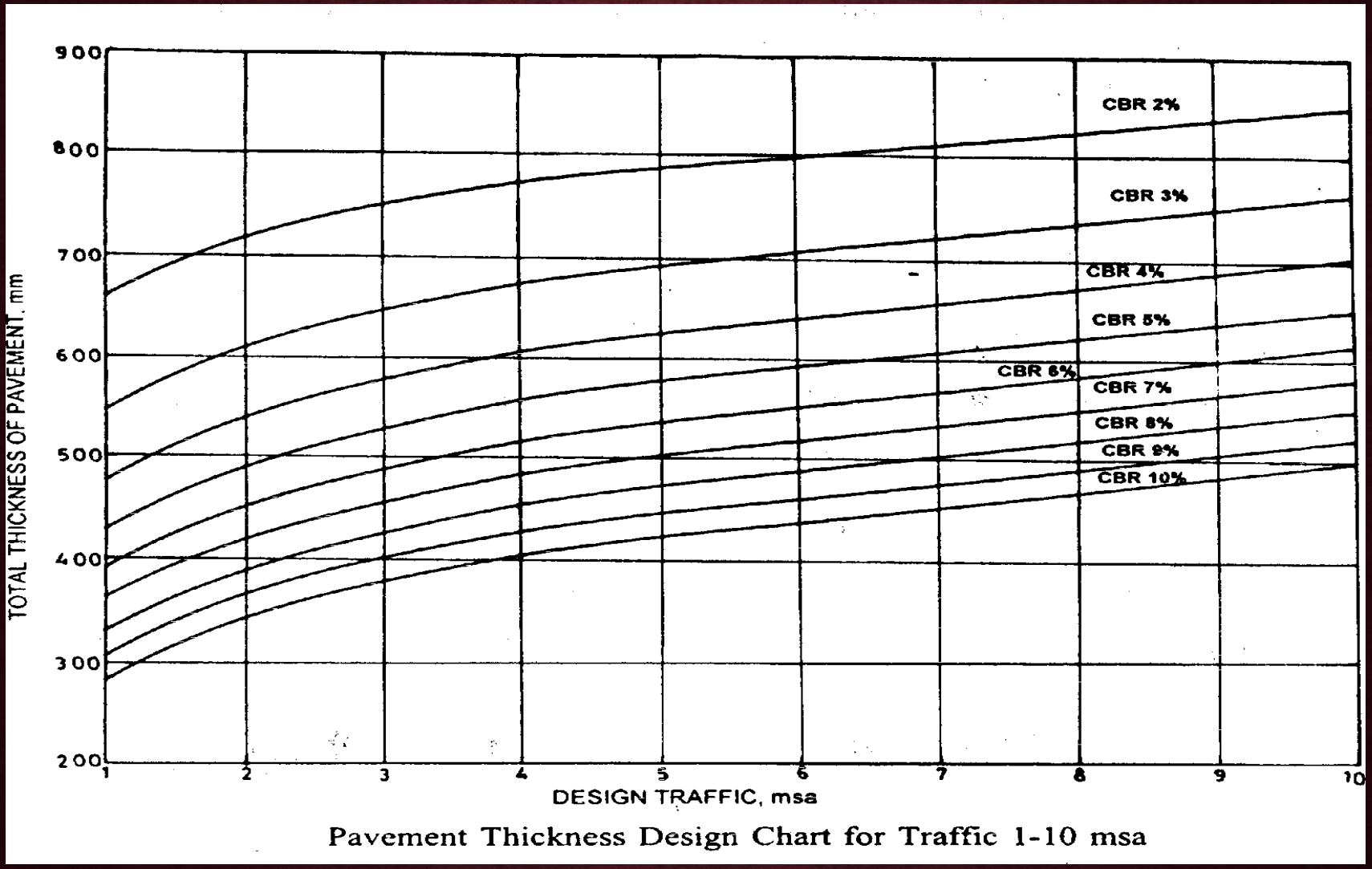
Definition:

It is the ratio of force per unit area required to penetrate a soil mass with standard circular piston at the rate of 1.25 mm/min. to that required for the corresponding penetration of a standard material.



SUBGRADE

- **Soak the Specimen in Water for FOUR days and CBR to be Determined.**
- **Use of Expansive Clays NOT to be Used as Sub-grade**
- **Non-expansive Soil to be Preferred.**
- **Subgrade to be Well Compacted to Utilize its Full Strength**
- **Top 500 mm to be Compacted to 97% of MDD (Modified Proctor).**
- **Material Should Have a Dry Density of 1.75 gm/cc.**



Pavement Thickness Design Chart for Traffic 1-10 msa

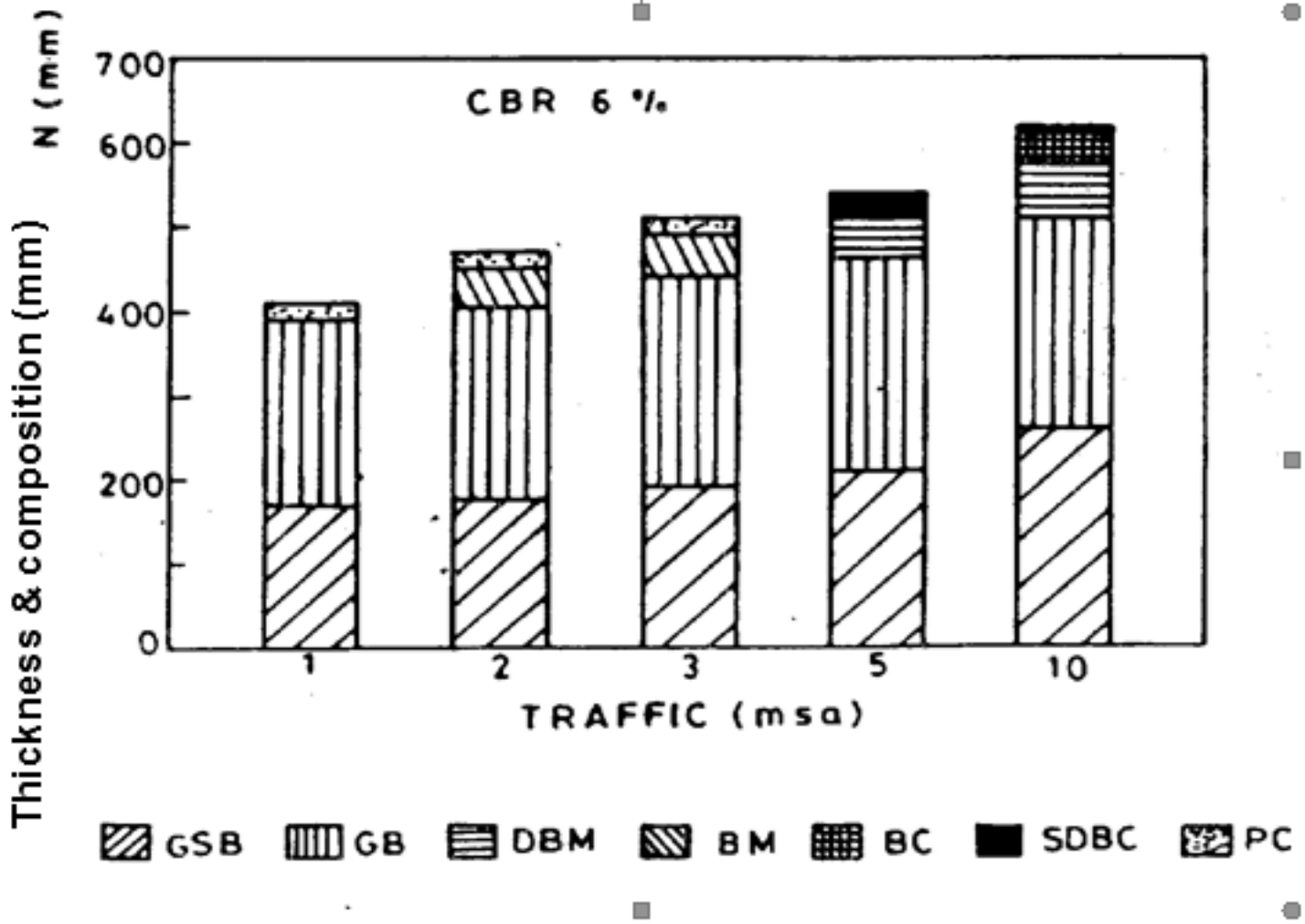
FLEXIBLE PAVEMENT DESIGN CHART (IRC) (FOR CSA< 10 MSA)

PAVEMENT DESIGN CATALOGUE

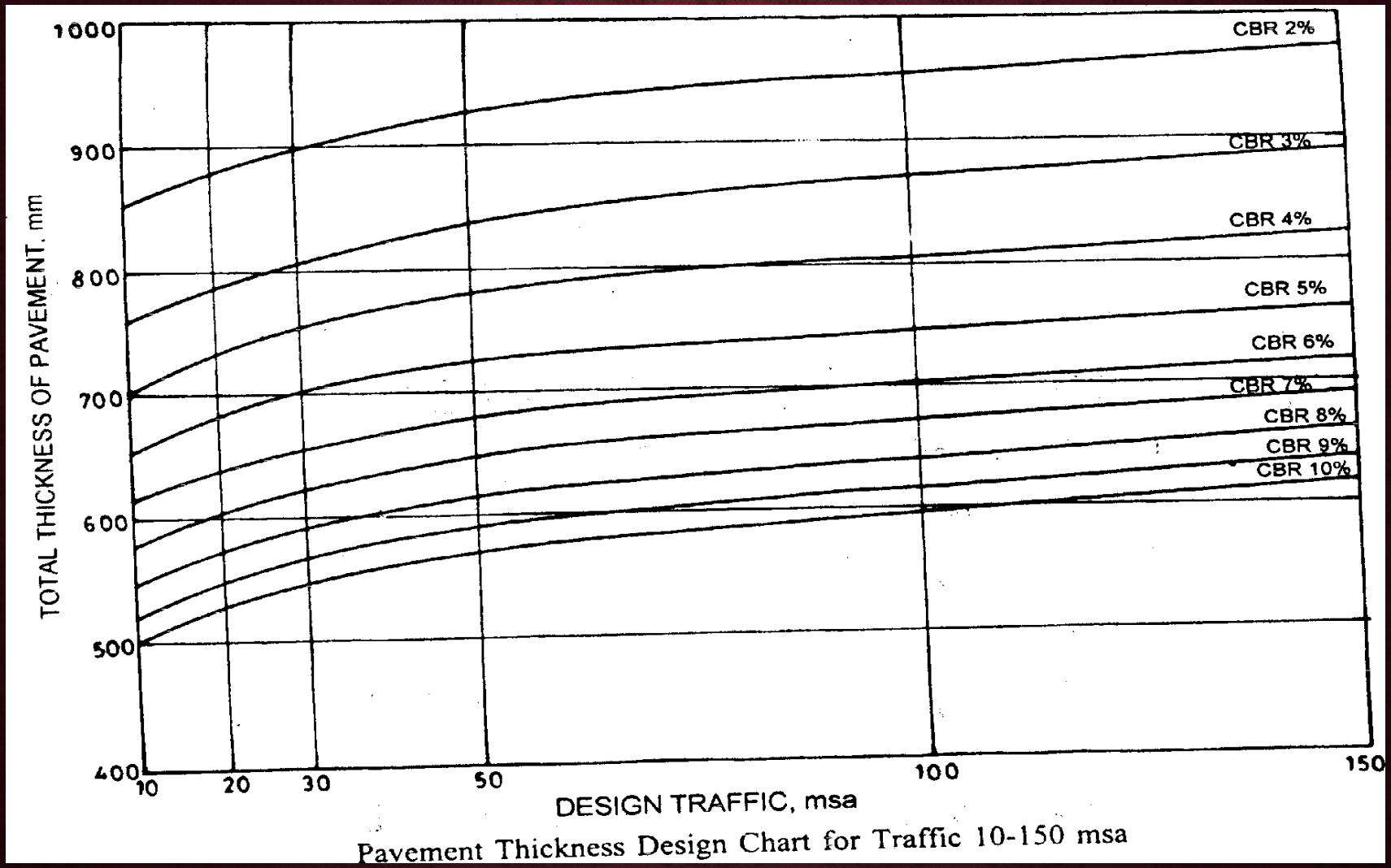
RECOMMENDED DESIGNS FOR TRAFFIC RANGE 1-10 msa

CBR 6%					
Cumulative Traffic (msa)	Total Pavement Thickness (mm)	PAVEMENT COMPOSITION			
		Bituminous Surfacing		Granular Base (mm)	Granular Sub-base (mm)
		Wearing Course (mm)	Binder Course (mm)		
1	390	20 PC		225	165
2	450	20 PC	50 BM	225	175
3	490	20 PC	50 BM	250	190
5	535	25 SDBC	50 DBM	250	210
10	615	40 BC	65 DBM	250	260

FLEXIBLE PAVEMENT LAYERS (IRC) (CSA< 10 MSA)



Flexible Pavement Layers (IRC) (CSA< 10 msa)



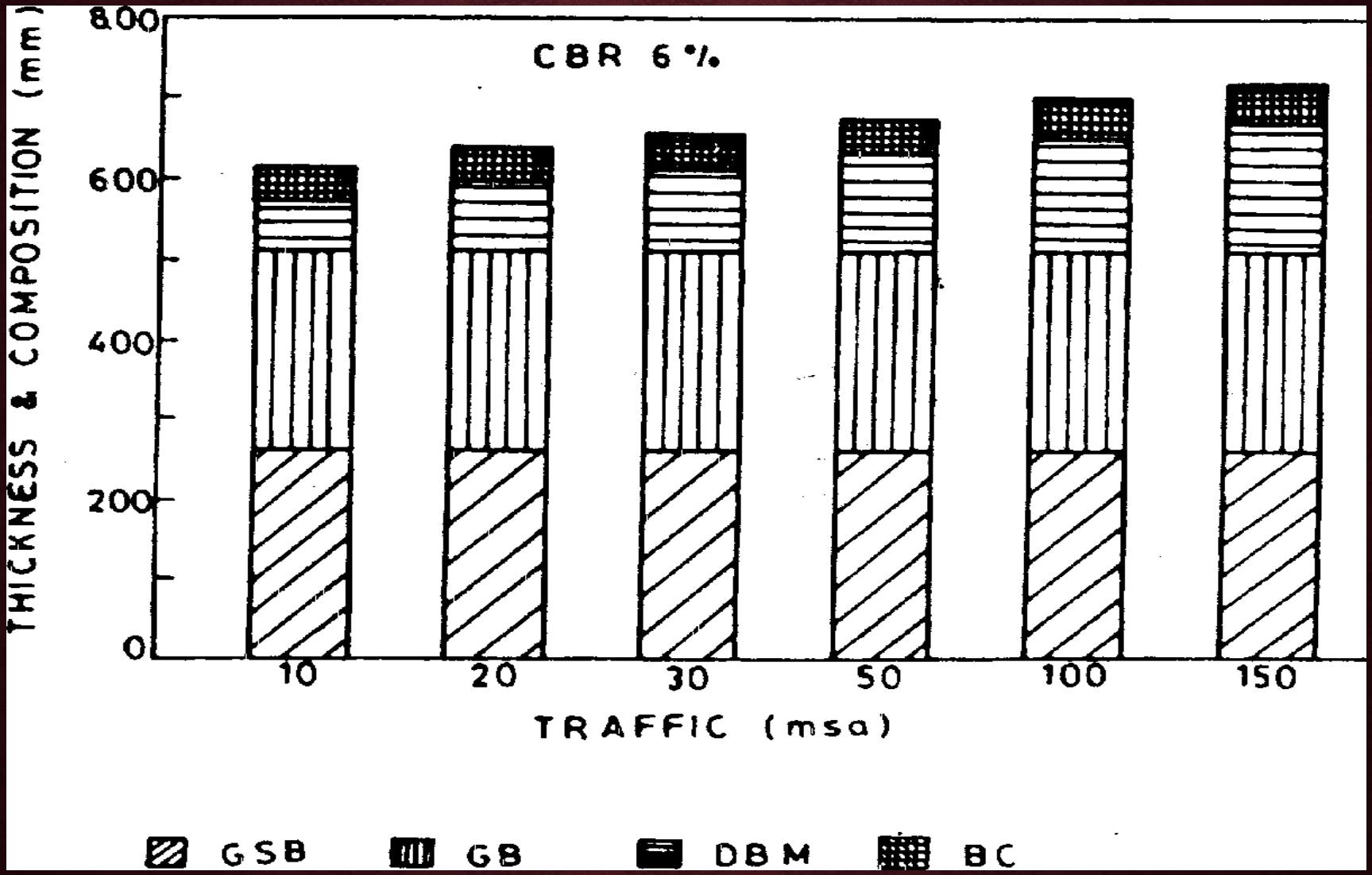
Pavement Thickness Design Chart for Traffic 10-150 msa

FLEXIBLE PAVEMENT DESIGN CHART (IRC)

PAVEMENT DESIGN CATALOGUE
RECOMMENDED DESIGNS FOR TRAFFIC RANGE 10-150 msa

CBR 6%				
Cumulative Traffic (msa)	Total Pavement Thickness (mm)	PAVEMENT COMPOSITION		
		Bituminous Surfacing		Granular Base & Sub-base (mm)
		BC (mm)	DBM (mm)	
10	615	40	65	Base = 250 Sub-base = 260
20	640	40	90	
30	655	40	105	
50	675	40	125	
100	700	50	140	
150	720	50	160	

FLEXIBLE PAVEMENT LAYERS (IRC)



FLEXIBLE PAVEMENT LAYERS (IRC)

SUBBASE

- **Material – Natural Sand, Moorum, Gravel, Laterite, Kankar, Brick Metal, Crushed Stone, Crushed Slag, Crushed Concrete**
- **GSB- Close Graded / Coarse Graded**
- **Parameters – Gradation, LL, PI, CBR**
- **Stability and Drainage Requirements**
- **Min. CBR 20 % - Traffic up-to 2 msa**
- **Min. CBR 30 %- Traffic > 2 msa**
- **If GSB is Costly, Adopt WBM, WMM**
- **Min. Thickness – 150 mm - <10 msa**
- **Min. Thickness – 200 mm - >10 msa**
- Min. CBR – 2 %
- If CBR < 2% - Pavement Thickness for 2 % CBR + Capping layer of 150 mm with Min. CBR 10% (in addition to the Sub-Base)
- In case of Stage Construction – Thickness of GSB for Full Design Life

BASE COURSE

- Unbound Granular Bases – WBM / WMM or any other Granular Construction
- Min. Thickness – 225 mm – < 2 msa
- Min. Thickness – 250 mm - > 2 msa
- WBM – Min. 300 mm (4 layers – 75mm each)

Bibliography

- Khanna, S. K., & Justo, C. E. G. "*Highway engineering". NemChand& Bros.*
- *IRC Codes.*


Thank
you