PAVEMENT DESIGN

Dr Andrew Collop
Reader in Civil Engineering
University of Nottingham

SCHEDULE - MONDAY

10 – 11	Introduction to pavement design
11 – 1	Functions & properties of road layers
2 – 3	Calculating pavement responses
3 – 4	Introduction to analytical pavement design
4 – 5	Examples and Discussion

SCHEDULE - TUESDAY

10 - 1	Nottingham Design Method (theory + examples)
2 - 3	Empirical design
3 - 4	Non-standard methods
4 - 5	Examples and Discussion

INTRODUCTION TO PAVEMENT DESIGN

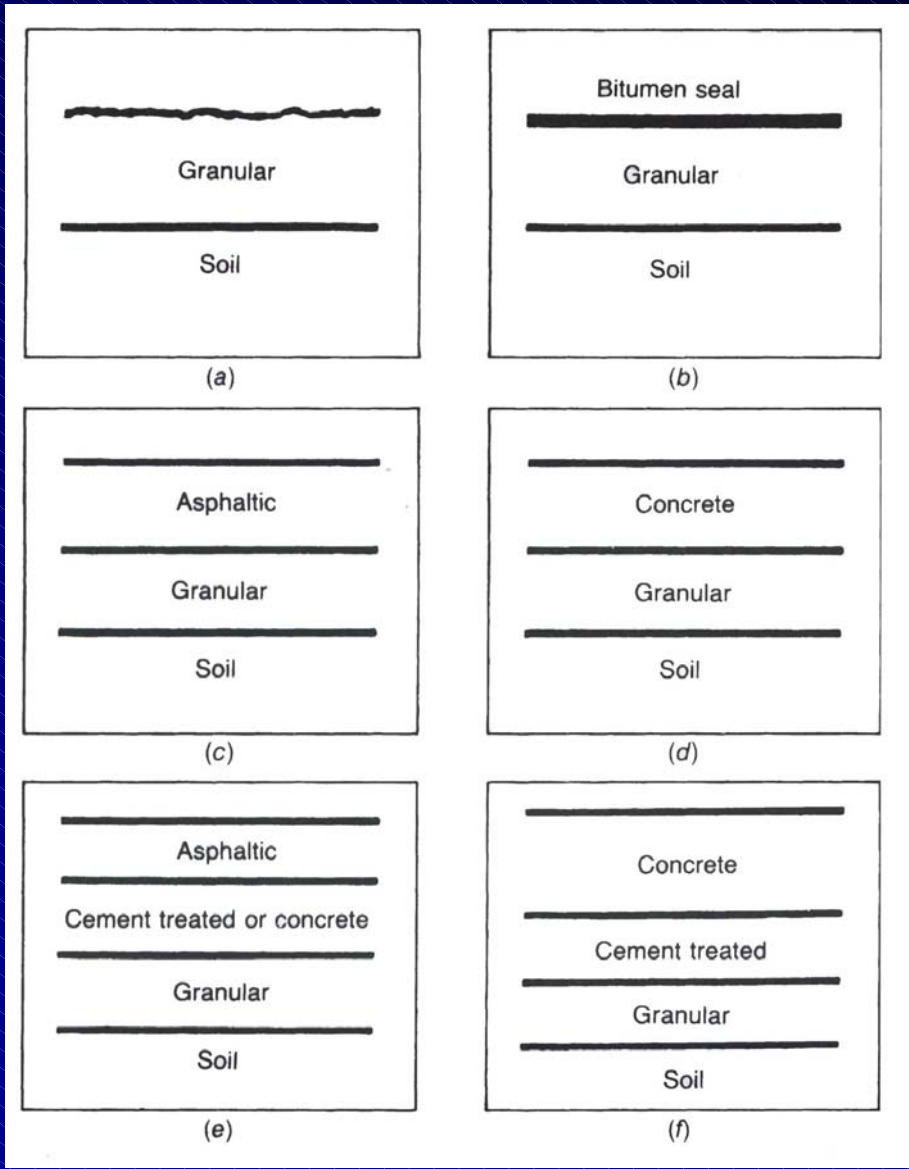
CONTENTS

- Introduction
- Failure mechanisms
- Ideal pavement
- Design concepts

INTRODUCTION

- Various combinations of layers between surface and ground
- Many different materials can be used (bound and un-bound)
- Primary function to carry traffic loading safely without damaging subgrade

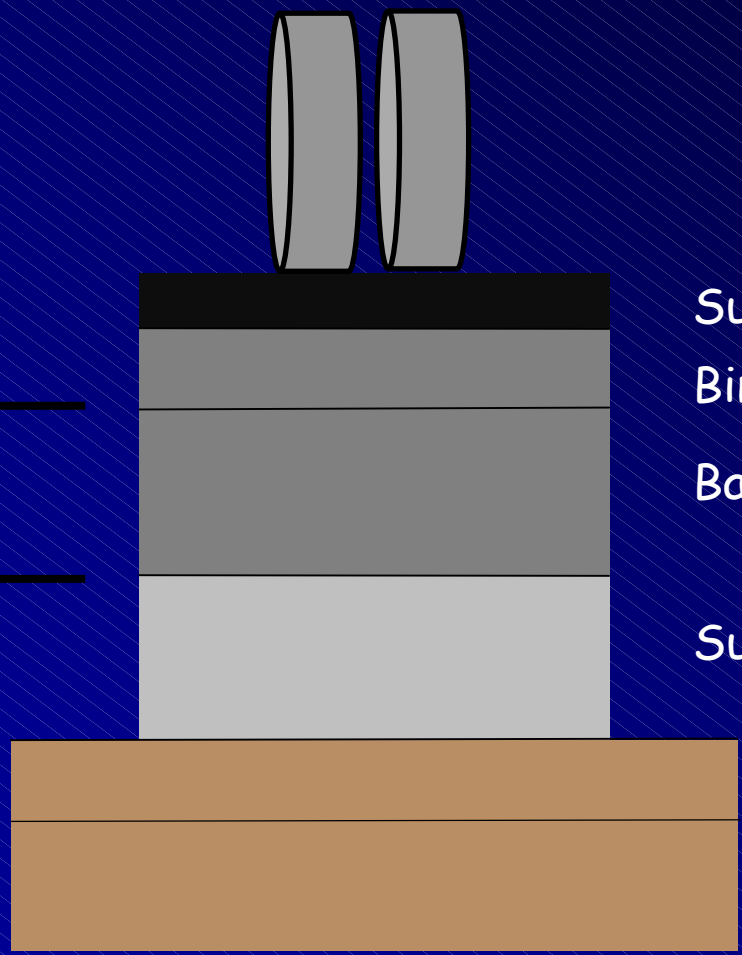
ROAD TYPES


Granular
Soil
(a)
Bitumen seal
Granular
Soil
(b)
Asphaltic
Granular
Soil
(c)
Concrete
Granular
Soil
(d)
Asphaltic
Cement treated or concrete
Granular
Soil
(e)
Concrete
Cement treated
Granular
Soil
(f)

INTRODUCTION

- Range from unsurfaced roads to thick bituminous or concrete roads
- Most common UK types
  - Flexible (asphalt + granular)
  - Flexible composite (asphalt + CBM)
  - Rigid (Concrete + CBM)
  - Rigid composite (asphalt + CRCR)
- Granular bases used overseas

FLEXIBLE CONSTRUCTION



Surfacing

Base

Foundation

Surfacing (Wearing Course)

Binder course (Basecourse)

Base course (Roadbase)

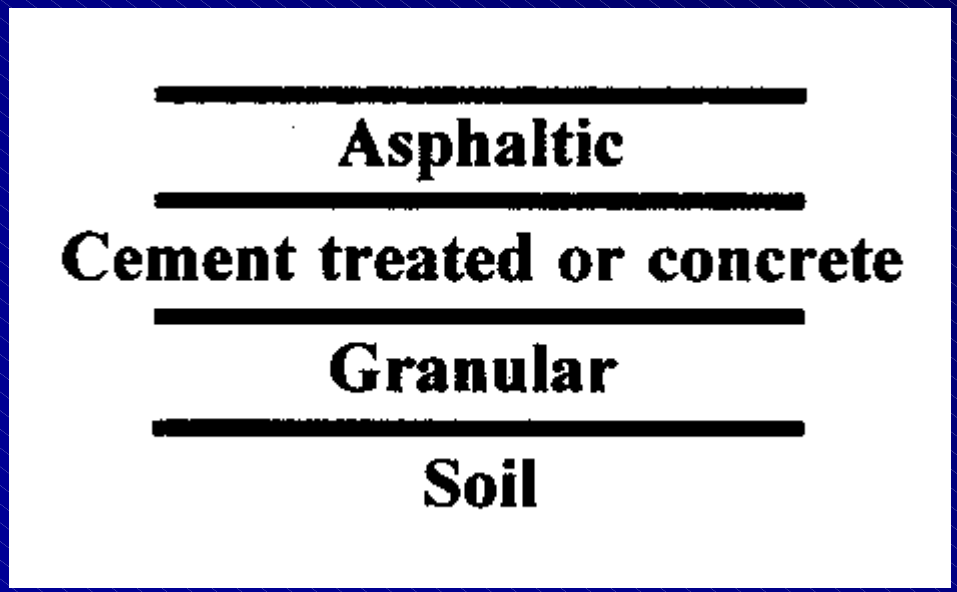
Subbase

Capping

Subgrade

FLEXIBLE CONSTRUCTION

COMPOSITE CONSTRUCTION



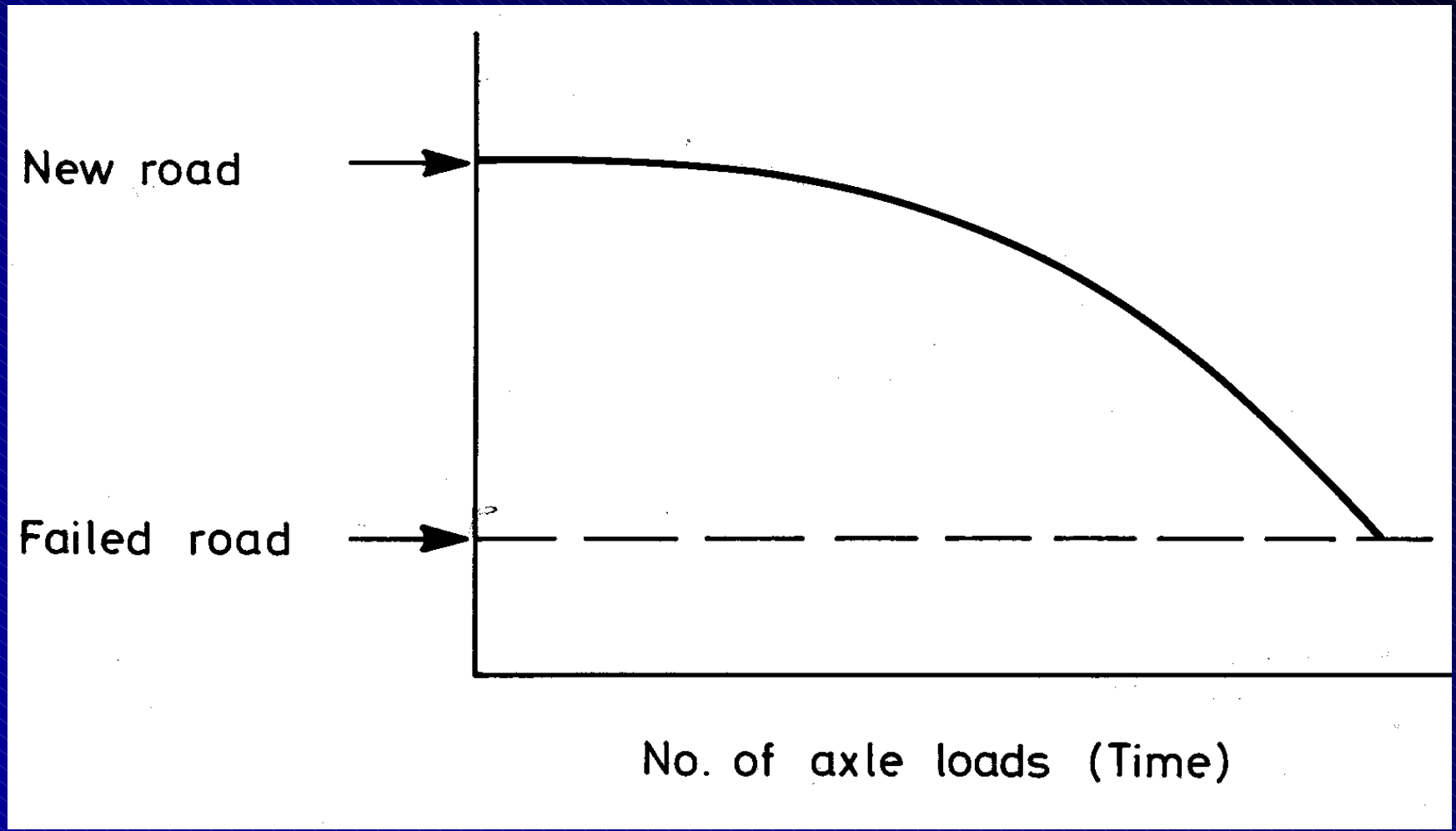
GRANULAR BASE

FAILURE MECHANISMS

FAILURE MECHANISMS

- Roads deteriorate slowly (don't suddenly fail)
- Structural failures and non-structural failures
- Concept of serviceability

SERVICEABILITY



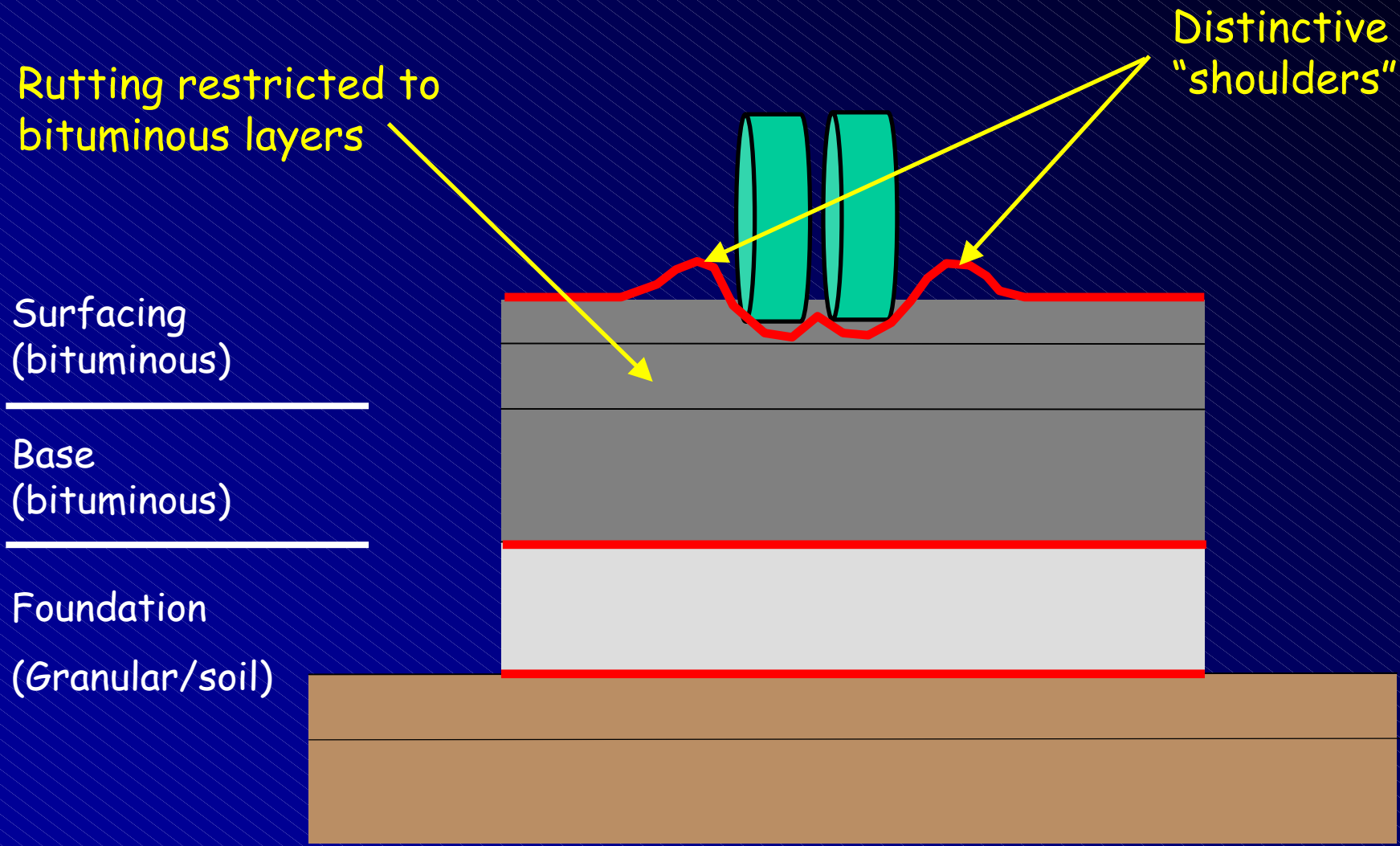
FAILURE MECHANISMS

- Design life determined by economics
- Typical design life 20 years (flexible pavements) 40 years (rigid pavement)
- Long-life pavements (40 years)
- Main structural failure mechanisms are rutting and fatigue cracking

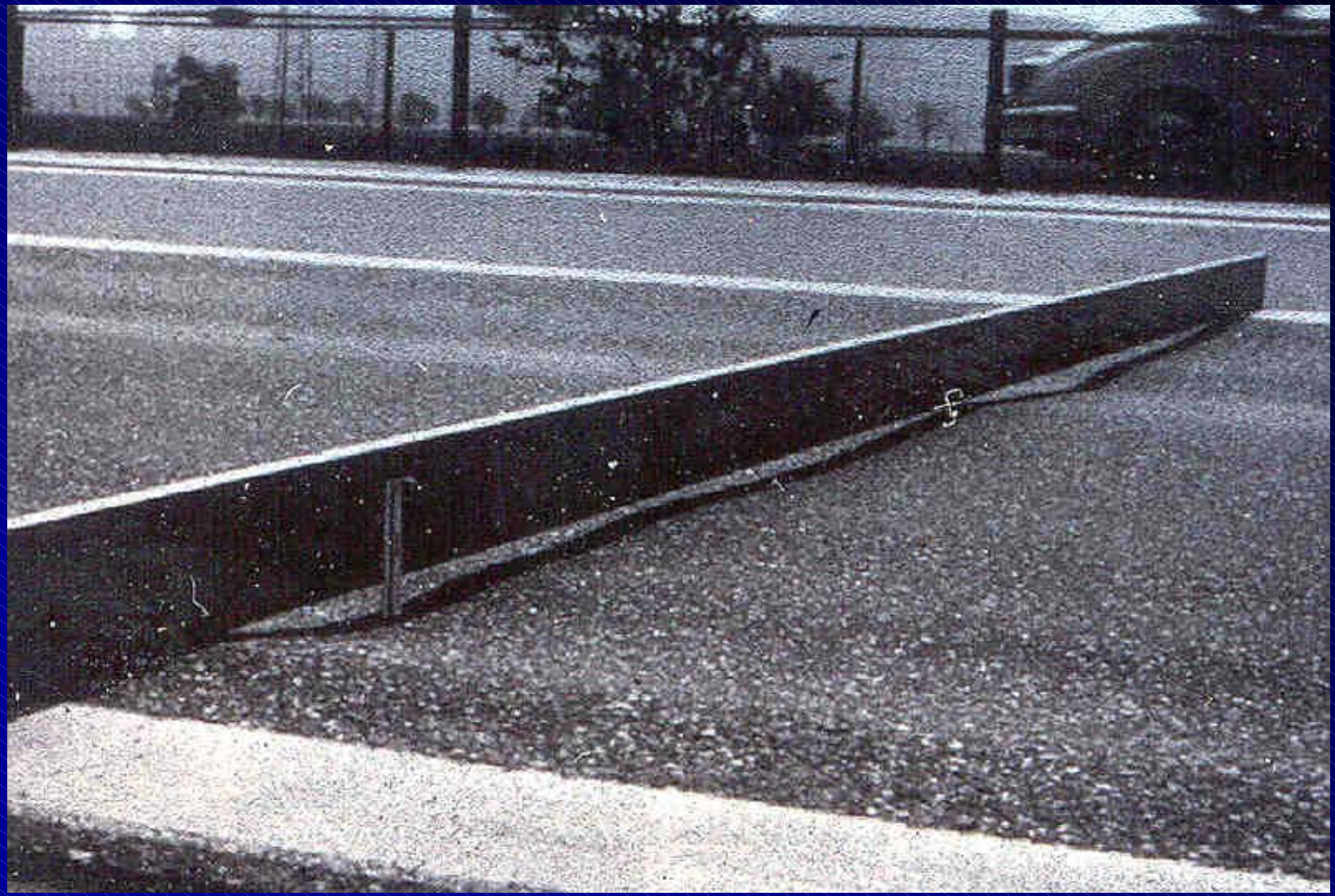
RUTTING

- Accumulated permanent vertical strain due to traffic loading
- Can be confined to the bituminous layers (non-structural rutting)

NON-STRUCTURAL RUTTING



NON-STRUCTURAL RUTTING

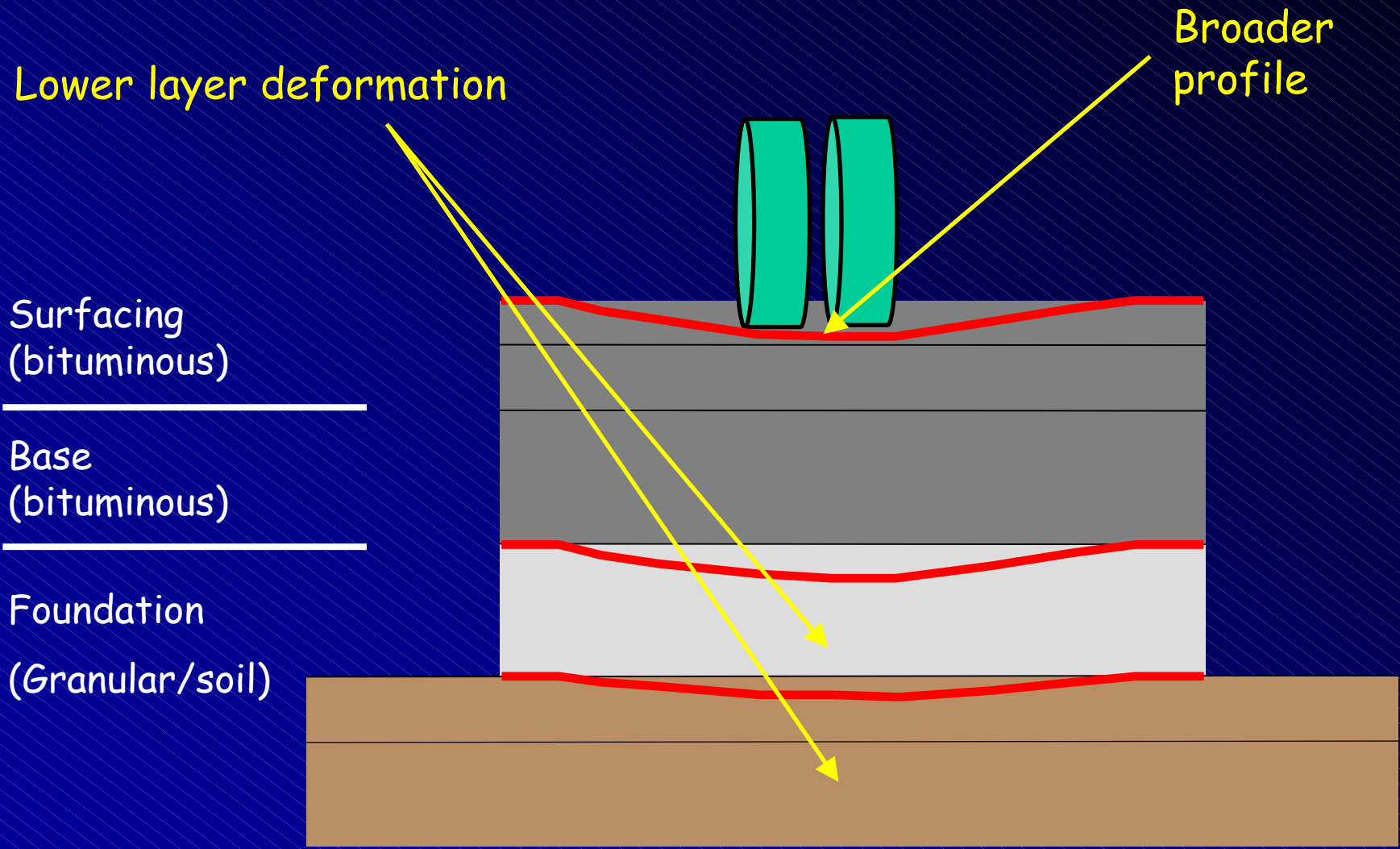


NON-STRUCTURAL RUTTING

STRUCTURAL RUTTING

- Can be due to permanent deformations lower in the structure (structural rutting)

STRUCTURAL RUTTING



STRUCTURAL RUTTING

LOAD ASSOCIATED FATIGUE

- Base of bound materials (thinner pavements)
- Surface of bound material (thicker pavements)
- Traditionally divided into initiation and propagation
- Complex mechanism
- Tends to be longitudinal

LOAD ASSOCIATED FATIGUE

LOAD ASSOCIATED FATIGUE

THERMAL CRACKING

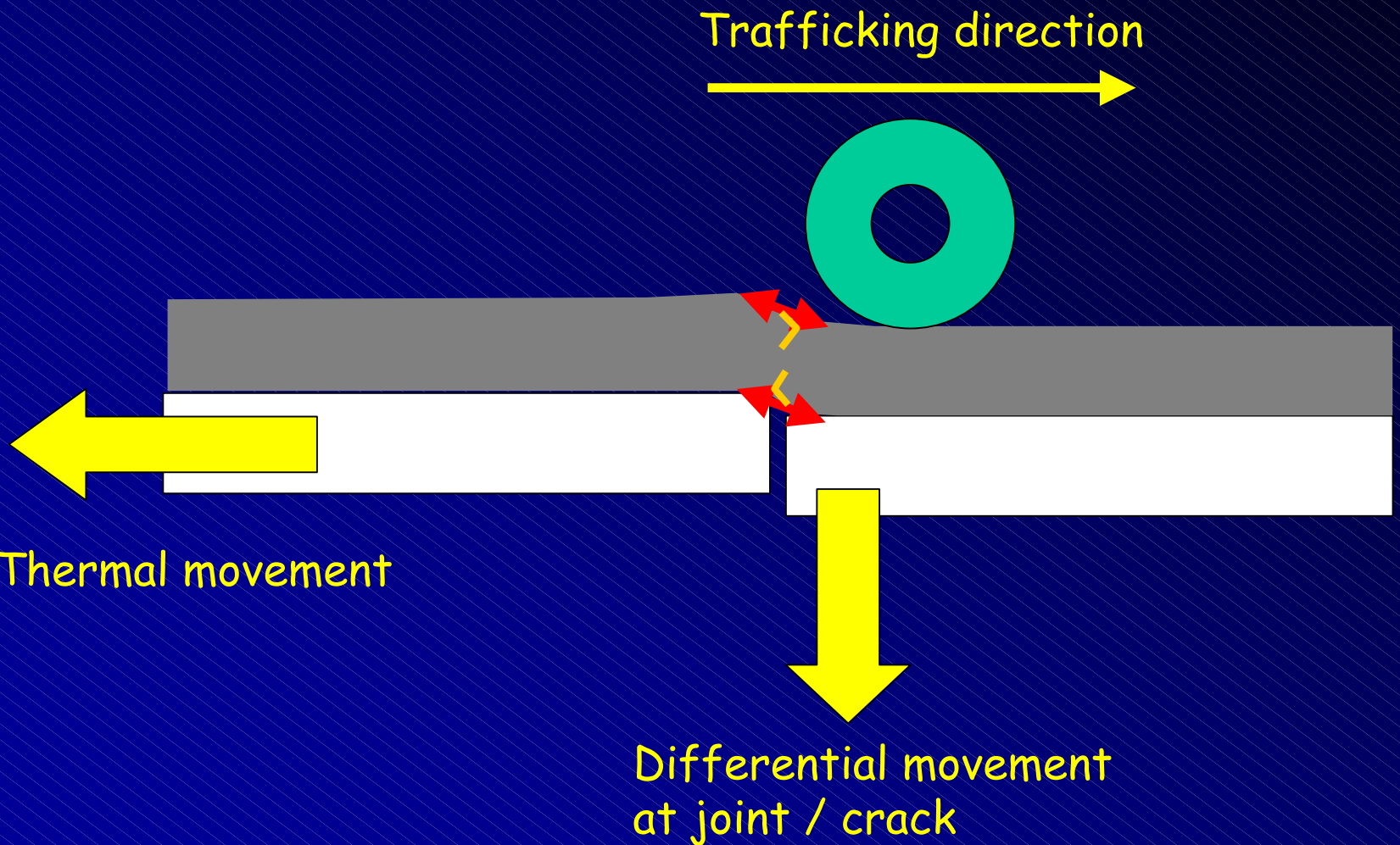
- Particularly in CBMs and concrete
- Can also occur in asphalt
- Tends to be transverse

THERMAL CRACKING

REFLECTION CRACKING

- Occurs when cracks in CBM base "reflect" through the asphalt layer above
- Can be driven by both thermal and traffic loading
- CBM bases typically pre-cracked to control crack movement and limit reflection cracking (difficult to eliminate)

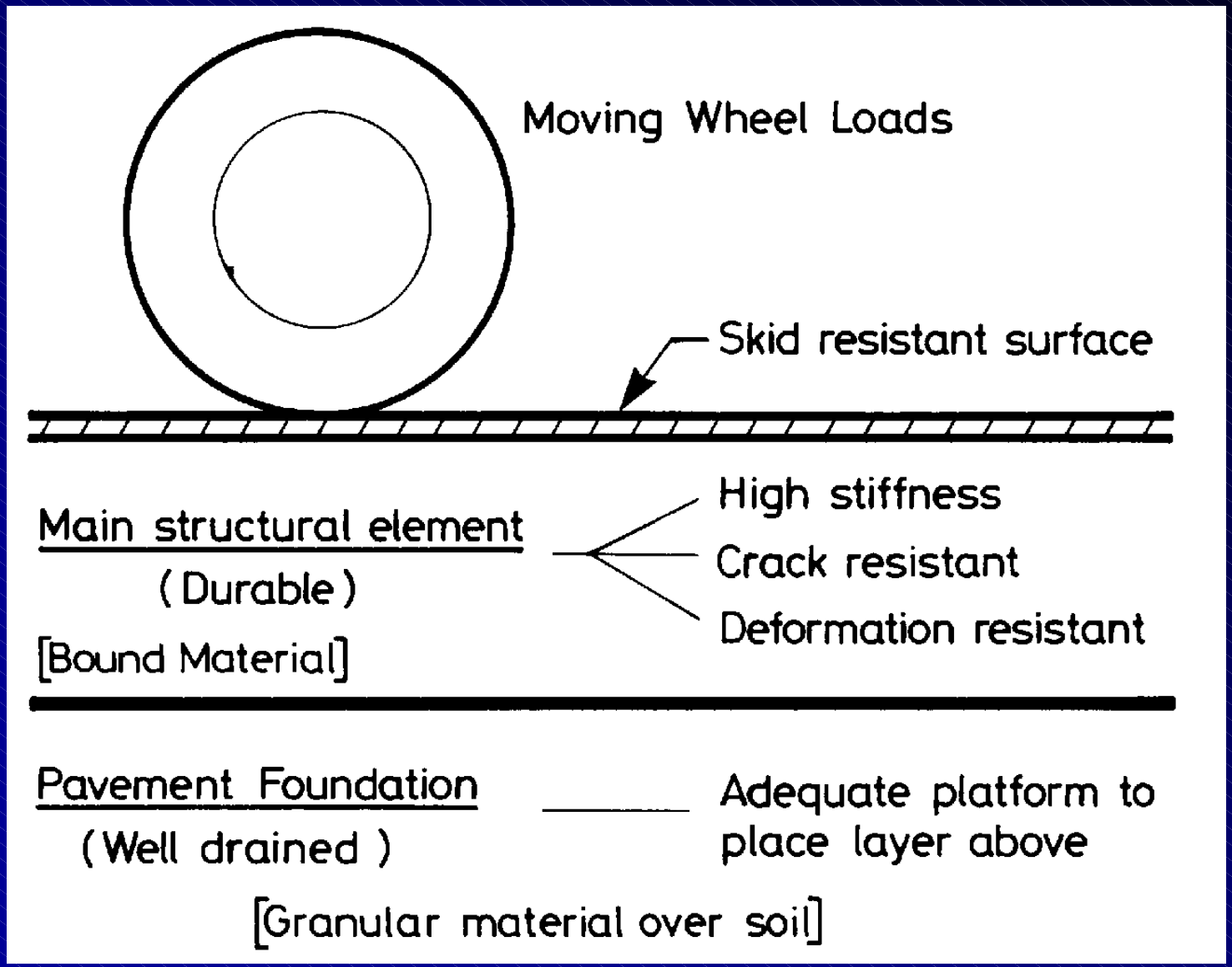
REFLECTION CRACKING



REFLECTION CRACKING

IDEAL PAVEMENT

IDEAL PAVEMENT



IDEAL PAVEMENT

Surface Course

- Essentially cosmetic (little structural role)
- Must provide safe and comfortable contact with vehicle tyres
- Waterproofing function

IDEAL PAVEMENT

Base

- Main structural layer
- Binder course covering base
- Spread wheel load so underlying layers not overstressed
- Resist damage (cracking and permanent deformation)

IDEAL PAVEMENT

Foundation

- Must be adequate to carry construction traffic
- Principles of soil mechanics apply
- Good drainage is essential

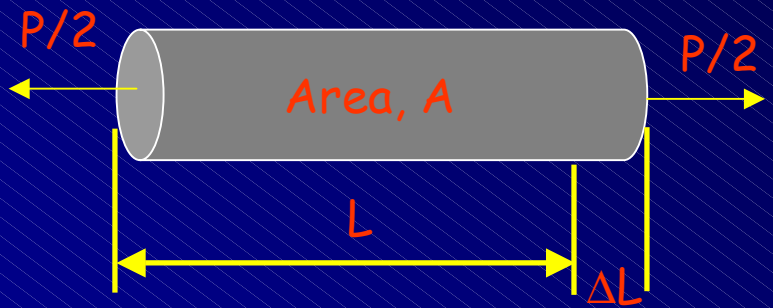
DESIGN CONCEPTS

DESIGN CONCEPTS

Load spreading ability

- Main function of pavement structure is to protect lower pavement layers from high stresses
- Higher quality materials used nearer the surface
- Material stiffness modulus and thickness determines load spreading ability (ability to protect subgrade)

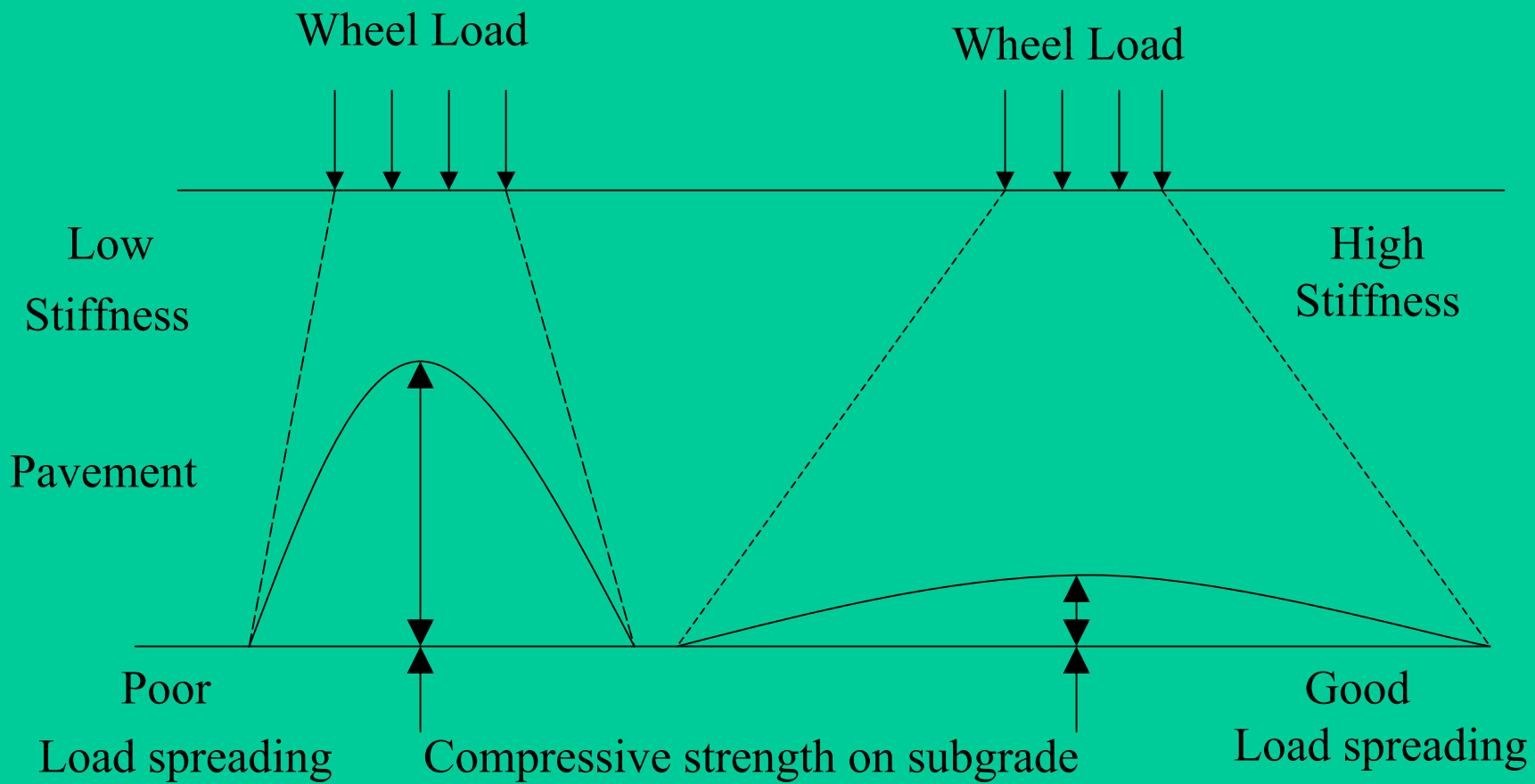
STIFFNESS MODULUS



$$\text{Stiffness Modulus} = \frac{\text{Stress}}{\text{Strain}} = \frac{P / A}{\Delta L / L}$$

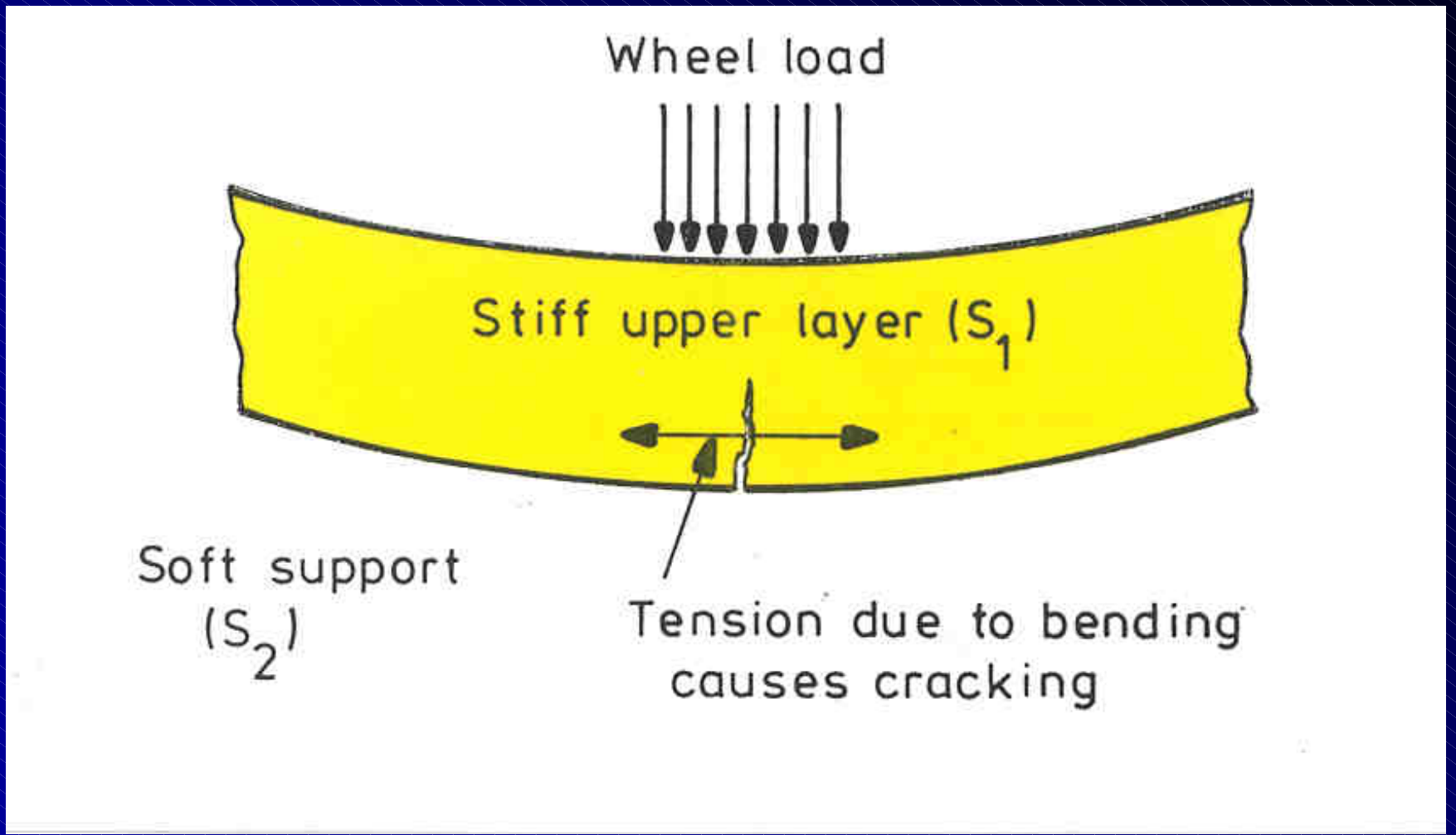
- Equivalent to Young's modulus (E) for metals
- Stiffness modulus (S) depends on loading time and temperature for bituminous mixtures

STIFFNESS MODULUS

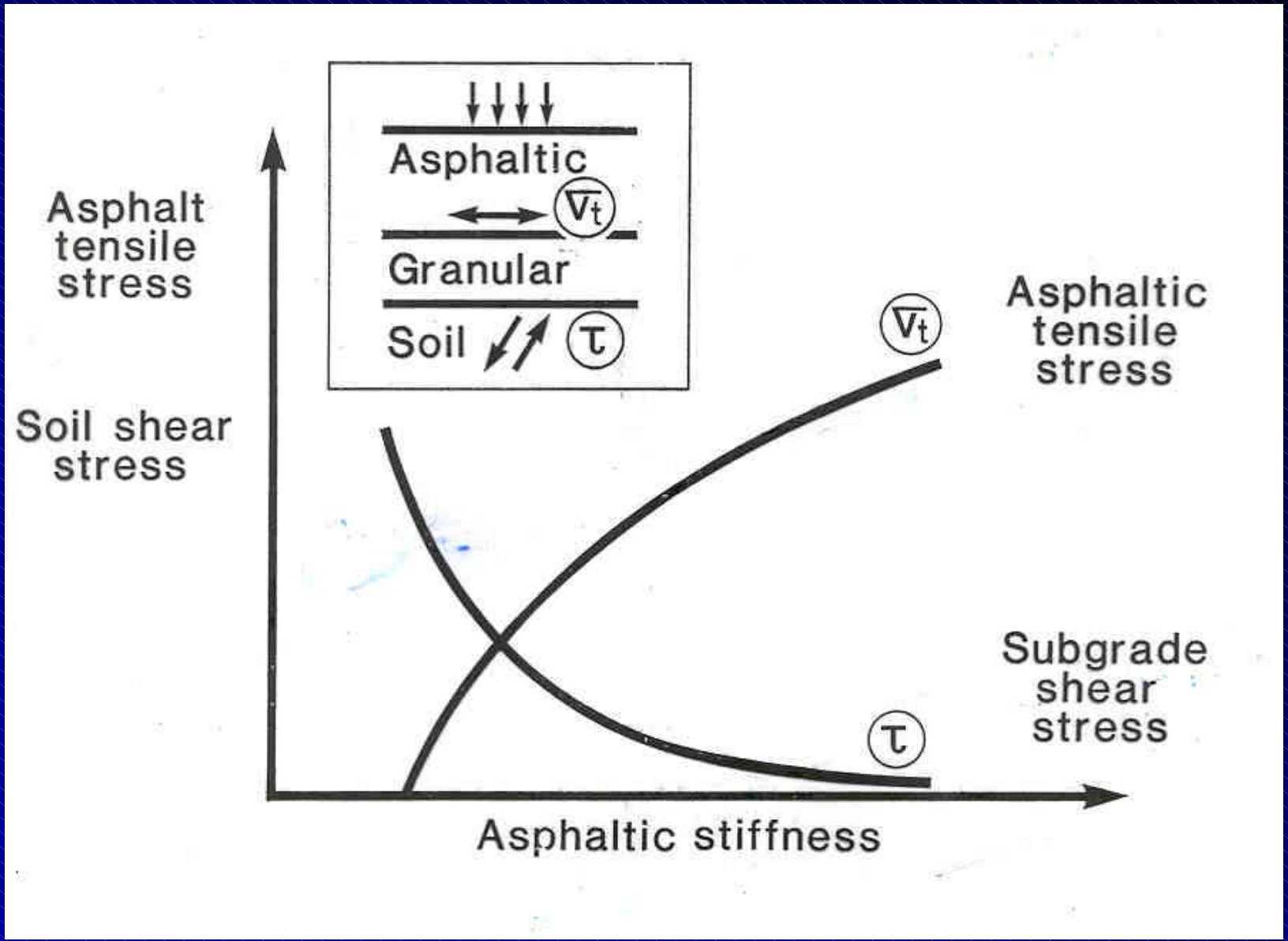


- Larger stiffness modulus / thickness spreads load over larger area

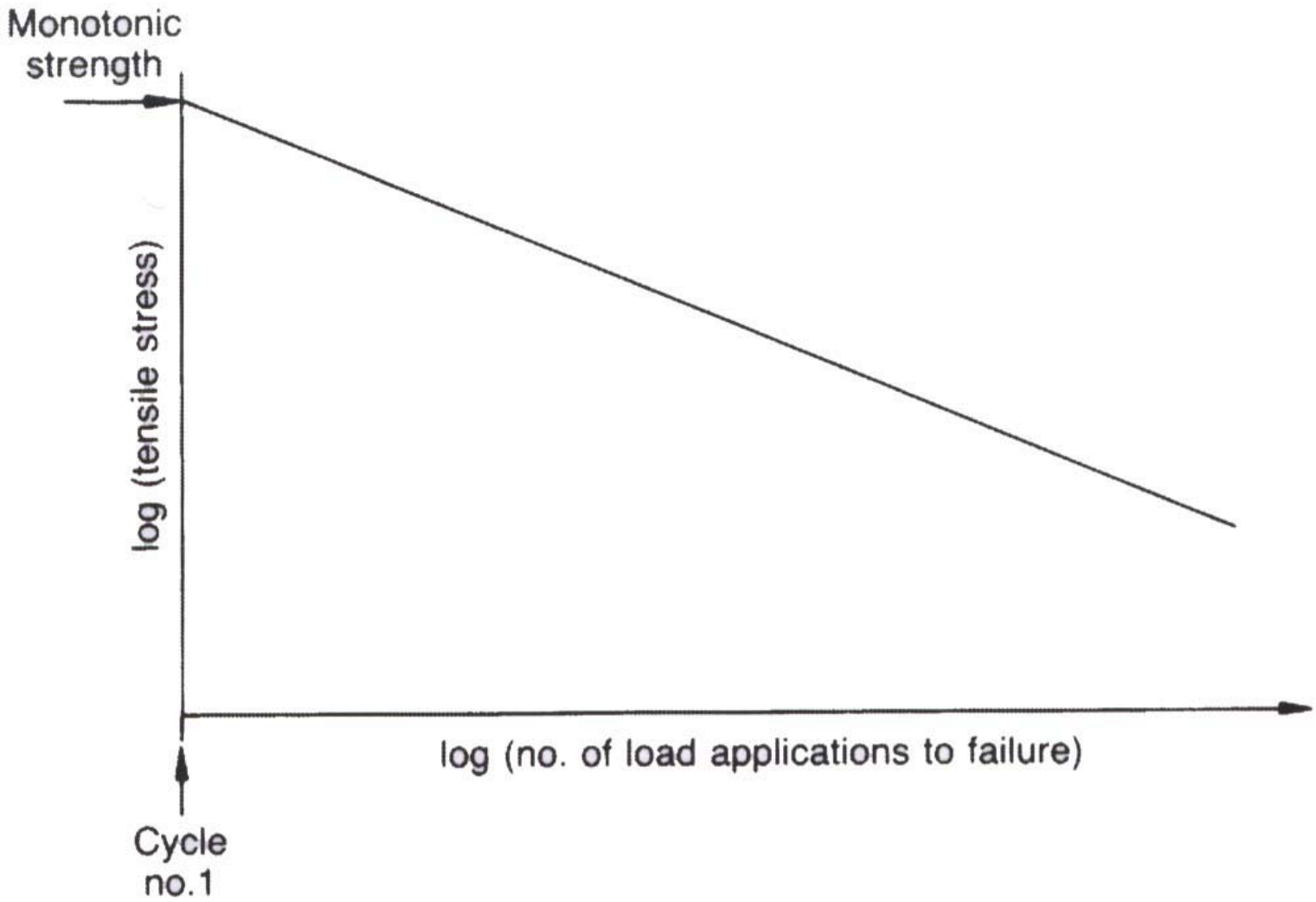
BENDING OF ASPHALT



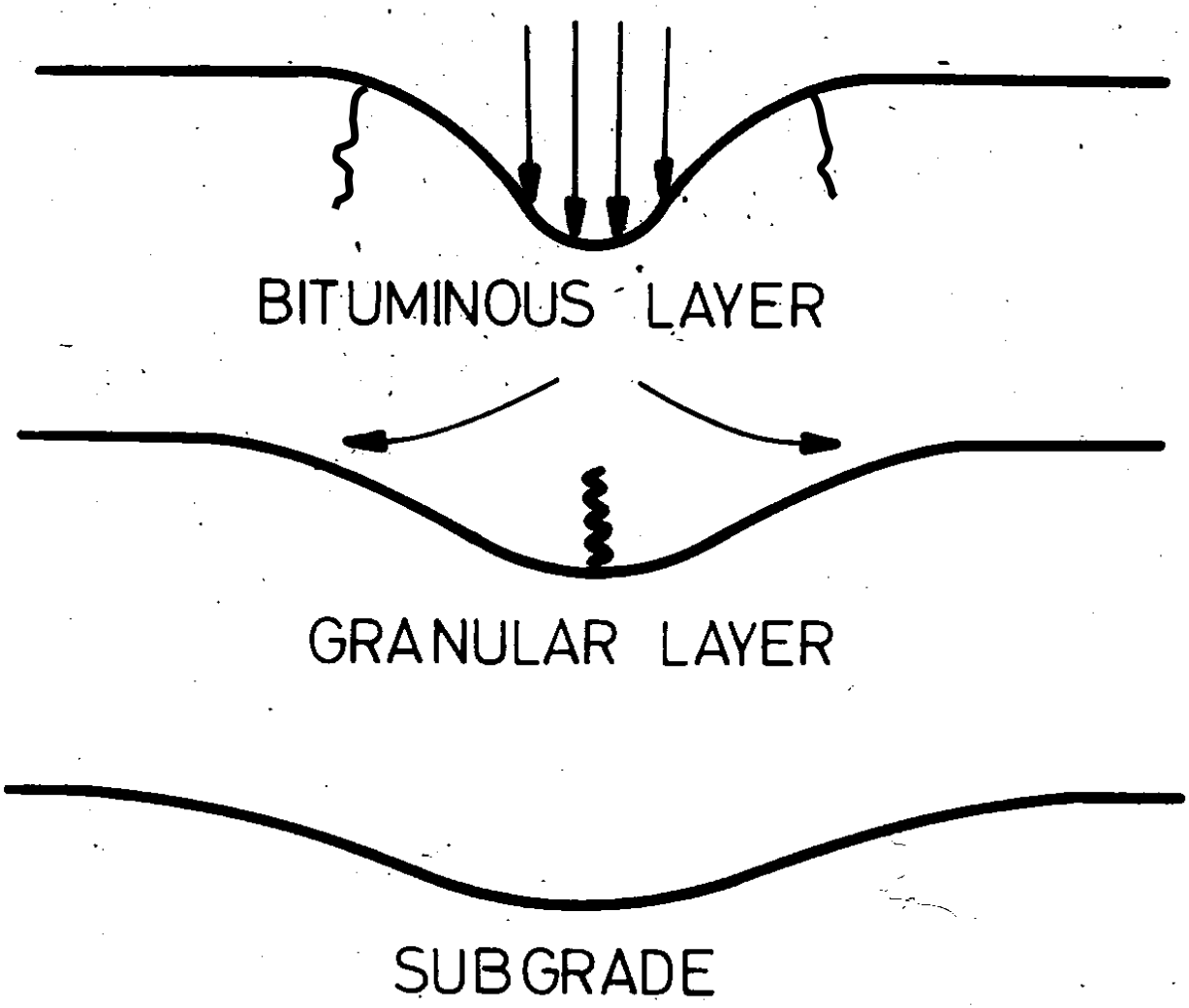
EFFECT ON STRESSES



FATIGUE


Monotonic strength
log (tensile stress)
log (no. of load applications to failure)
Cycle no.1

FATIGUE



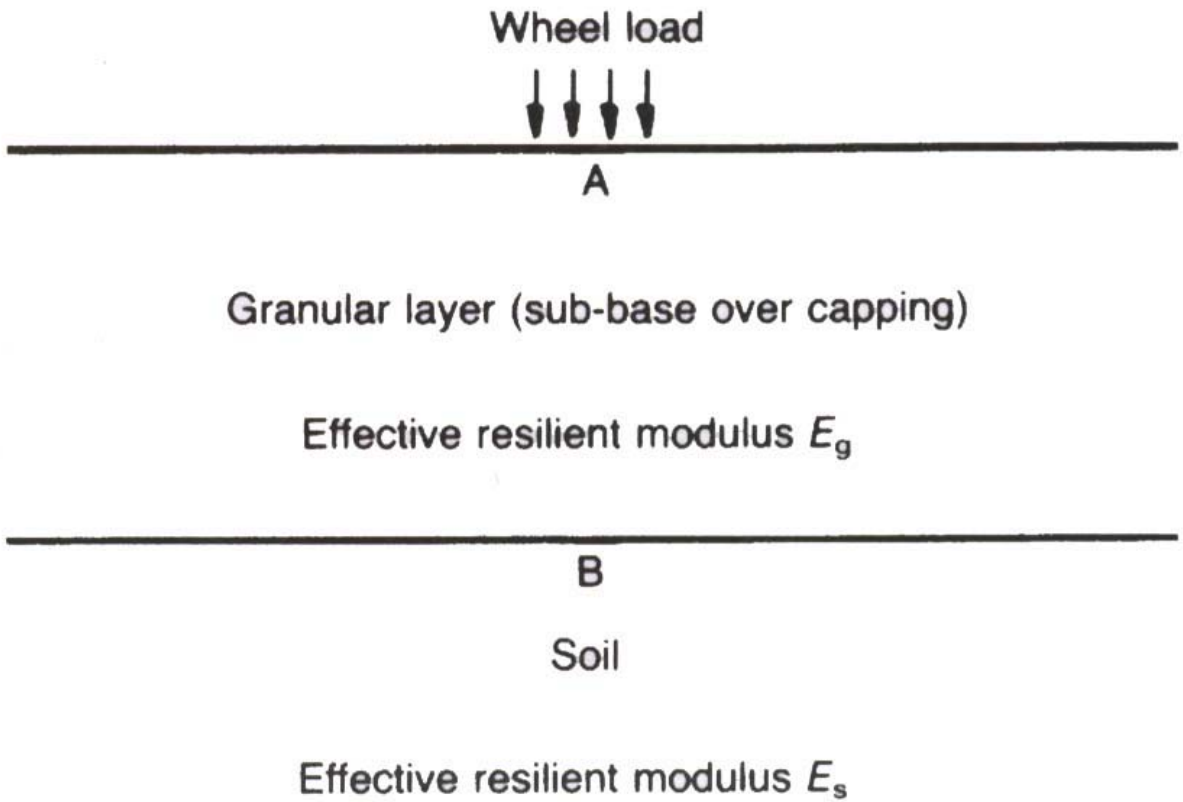
DESIGN CONCEPTS

- Two stage design process
- Pavement foundation
- Upper pavement layers

FOUNDATION

- Short-term haul road + long term support for asphalt
- 2 stage design method
- Stage 1: Designing for haul road
  - Limited number of heavy wheels
  - Essential that overstressing soil is prevented
  - Combination of thickness and stiffness
  - Capping (CBR < 15%) + crushed rock

STAGE 1: HAUL ROAD



1. Rutting to be less than 40 mm at A
2. Stress conditions at B to be below threshold level

FOUNDATION

- Stage 2: Support of asphalt
  - Correct combination of asphalt thickness and stiffness
  - Prevent overstressing of granular layer

BOUND LAYERS

- Designed to withstand traffic loading
- Protect lower layers from overstressing