

THE FLEXIBLE PAVEMENT ENGINEERING MODULE

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PREFACE

The first edition of *The Flexible Pavement Engineering Handbook* informs the basic theory of pavement engineering and provides the overview of important background information on road pavement material. This book is an ideal resource to introduce all Malaysian, particularly who is involved in road pavement engineering, regarding road pavement material.

Each chapter goes through a detailed description of the term in pavement engineering (chapter 1), bitumen and aggregate (chapter 2), flexible pavement (chapter 3), asphalt mixture (chapter 4) and asphalt mixture testing (chapter 5). With this book, readers will quickly setup-to-speed on the most recent in road material, especially in pavement engineering. This volume will be useful in giving professionals a method to evaluate the road pavement material.

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LIST OF SYMBOLS

S_{mix}	Stiffness Modulus
F	Peak Value of the Applied Vertical Load
z	Amplitude of Horizontal Deformation
h	Mean Thickness of the Test Specimen
ν	Poisson's Ratio
σ	Horizontal Tensile Stress at Specimen Centre
P	Load Applied at Centre of Sample
t	Specimen Thickness
ΔH	Horizontal Deformation
Ω	Specimen Diameter
G_{mb}	Bulk Specific Gravity
W_a	Mass of Asphalt Mixture Sample in Air
W_w	Mass of Asphalt Mixture Sample in Water
W_{sat}	Mass of Asphalt Mixture Sample in Saturated Condition
G_{mm}	Theoretical Maximum Specific Gravity of Bituminous Paving Mixtures
P_b	Bitumen Content
G_{se}	Effective Specific Gravity of Aggregate
G_b	Specific Gravity of Bitumen
G_{sb}	Bulk Specific Gravity of Aggregate
MC	Moisture Content of Sample
W	Original Wet Weight of Sample
D	Dry Weight of Sample

σ_{\max}	Maximum Tensile Stress
$\dot{\epsilon}_{\text{ini}}$	Initial Tensile Strain
S_{mix}	Stiffness Modulus
N_f	Number of Cycle to Failure
R^2	Coefficient of Determination
N_c	Number of Cycle at Critical Crack

LIST OF ABBREVIATIONS

AASTHO	American Association of State Highway and Transportation Officials
ACV	Aggregate Crushing Value
AI	Asphalt Institute
AIV	Aggregate Impact Value
ASTM	American Society for Testing and Materials
BC	Bitumen Content
BS	British Standard
HMA	Hot-Mix Asphalt
ITFT	Indirect Tensile Fatigue Test
ITSM	Indirect Tensile Stiffness Modulus Test
ITST	Indirect Tensile Strength Test
LAAB	Los Angeles Abrasion Value
OBC	Optimum Bitumen Content
PI	Penetration Index
PWD	Public Work Department
RLAT	Repeat Load Axial Test
SP	Softening Point Test
VFB	Percentage of Voids in Aggregate Filled with Bitumen
VMA	Percentage of Voids in Mineral Aggregate
VTM	Percentage of Voids in Total Asphalt Mixture

CHAPTER 1

BASIC PAVEMENT ENGINEERING TERM

This section discusses the pavement engineering term that will be widely used after this chapter. This term is also to remind or give a clear meaning to avoid any confusion and misunderstanding (Thom, 2008).

1.1 DENSITY, UNIT WEIGHT AND SPECIFIC GRAVITY

The density of material is the mass per unit volume (kg/m^3). For instance,

Water	=	1000 kg/m^3
Rock	=	2500 - 3000 kg/m^3
Soil (rock particles + water + air)	=	1500 - 2000 kg/m^3
Crush rock pavement layer	=	2200 kg/m^3
Asphalt mixture and Concrete	=	2400 kg/m^3

However, in pavement engineering, we prefer using unit weight rather than density, because most materials in pavement engineering are statics and the effect of density is to generate weight due to gravity. This is defined as the weight per unit volume and expressed in N/m^3 or more popular as kN/m^3 . For example, the pavement layers tend to have 18 to 24 kN/m^3 of unit weights.

Specific gravity is a convenient relative measure. The upper and lower specific gravity are a ratio of the material densities to water i.e specific gravity of water is 1. For instance, the bitumen being marginally denser than water has a specific gravity of 1.02 to 1.03.

1.2 STRESS, PRESSURE AND STRAIN

Stress and pressure are similar, defined as force divided by area and expressed in N/m^2 or Pascal (Pa). However, in pavement engineering term, stress is more commonly used because it deals with solid but pressure usually relates to liquid and gases. Therefore, the contact stress occurs as load from the wheel applied on road surface is divided by the contact area. This will be approximately equal to the air pressure within the tyre. For example, the vertical contact stress and the tyre pressure of a typical heavy goods vehicle wheel are both around 600kPa. However, due to the way flexible pavement spreads the load from the wheel, the vertical stress at the top of the subgrade may be less than 10 kPa (Thom, 2008).

Strain describes the degree to which a material deforms. It is also defined as the change in a dimension divided by the original magnitude of that dimension and it has no units because it is a relative change. In contrast, we prefer using percentage if strains are large but we usually use microstrain ($\mu\epsilon$) if strains are very small, like strains generated within pavement under wheel load. The $1\mu\epsilon$ is a strain of 10^{-6} or a change of one millionth in the original dimension. The detail relationship between load destruction in pavement, stress and strain is shown in Figure 1.

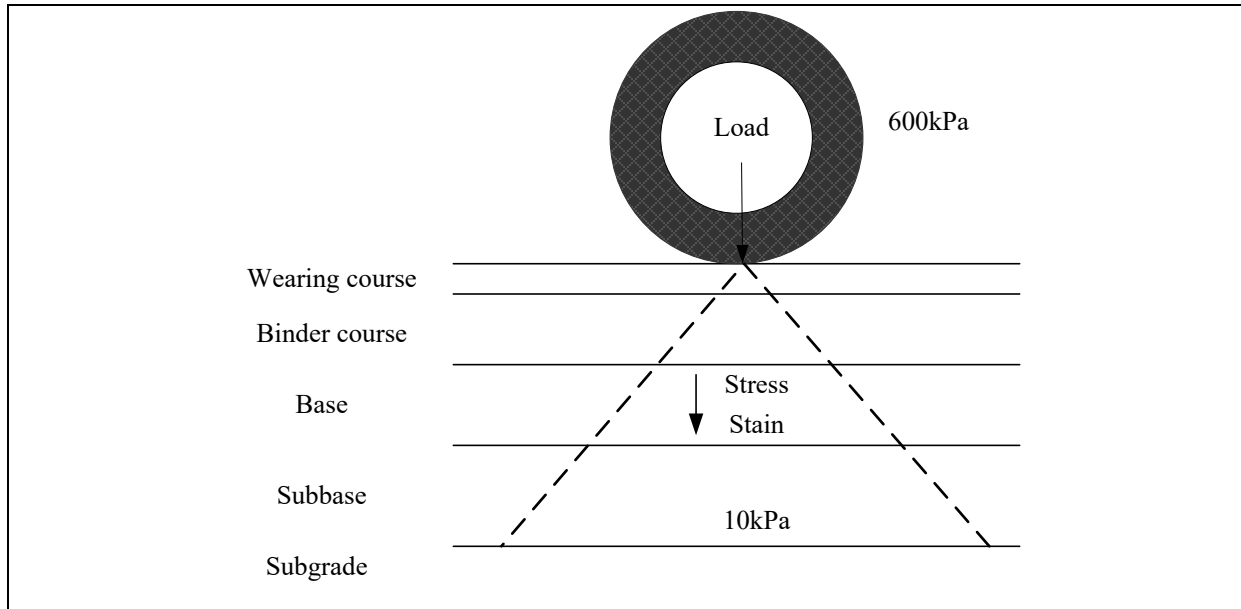


Figure 1.1: Example of load distribution in flexible pavement

1.3 ELASTIC MODULUS, RESILIENT MODULUS AND STIFFNESS MODULUS

The elasticity of civil engineering material is shown in Figure 1.2. This figure also reveals a sample of civil engineering material with length (L) and cross section area (ab), subjected to a direct normal load (P) in tension in the x direction. The civil engineering material could be applied in concrete, soil or asphalt mixture. This uniaxial loading causes a direct stress $\sigma = P/ab$ and strain $\epsilon_x = x/L$. The elastic modulus (also called Young's Modulus or resilient modulus or stiffness modulus), E , is defined as illustrated in equation 1.1.

$$E = \frac{\sigma}{\epsilon} \quad (1.1)$$

where:

E = Elastic modulus

σ = Applied stress

ϵ = Resultant strain

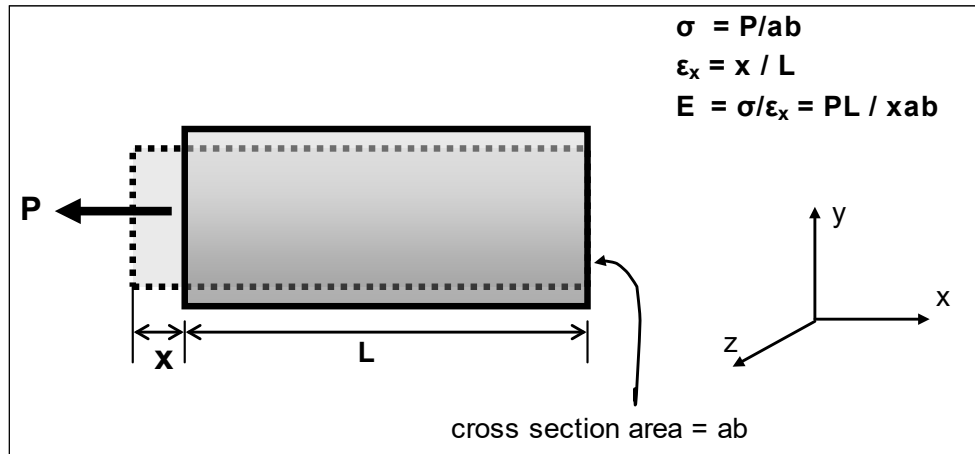


Figure 1.2: Elasticity of civil engineering material
Source: Sunarjono (2008)

The unit of stress in elastic modulus is N/m^2 or Pa. It can be seen in Figure 1.2 as the material is loaded, the civil engineering material is not only getting longer, but it also decreases its cross-sectional area. As a result, the deformations in the y and z directions occur when divided by the corresponding dimensions, a and b, and yield strain ϵ_y and ϵ_z . The ratio of these strains to ϵ_x is defined as 'Poisson's Ratio (ν)'. The Poisson's Ratio is dimensionless and generally ranges from 0.1 to 0.5. A value of 0.5 implies that no volumetric change is taking place, since increasing dimension in the x direction is compensated by decreasing dimension in the two other directions. For asphalt mixture, Poisson's Ratio is around 0.35 (Sunarjono, 2008).

In conclusion, the elastic modulus is used in concrete or steel because it is assumed that the behaviour of the concern material is linear. In contrast, the unbound material or soil is significantly non-linear and stress dependent, because it separates out elastic behaviour from plastic component where strains are non-recoverable. Therefore, for unbound material or soil, we prefer using resilient modulus. Asphalt mixture is a viscoelastic material. This material could be viscous or elastic, and it depends on temperature and loading rate. Thus, in pavement engineering, we prefer to use stiffness modulus because asphalt has non-linear behaviour, and asphalt stiffness varies depending on temperature and loading rate (Thom, 2008).

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