Module 1-2

PAVEMENT ANALYSIS AND DESIGN CONCEPTS

This module provides an introduction to some concepts which are central to the course.

These concepts are applicable to both AC and PCC pavements and overlays.

Module Contents

- Pavement performance
- Model development
- Pavement responses
- Sensitivity analysis
- Overall concept

The contents of this module also correspond to the main objectives of this course.

Pavement Performance

- Measurable adequacy of the structural and functional performance over a specified design period
- Structural performance refers to ability to carry traffic loads
- Functional performance relates to ride quality and safety issues
- Pavement performance is a key element in pavement design

Measures of structural performance include distresses and deflections.

Measures of functional performance include skid resistance and roughness.

What are indicators of structural performance - both good and bad? Functional performance?

Objective in improving design is to improve performance.

Sample Faulting Model

$$FAULT = ESAL^{0.144} \{ - 0.2980 + 0.2671\ THICK^{-0.3184} - 0.0285\ BASETYP + 0.0406\ (FI + 1)^{0.3598} - 0.0462\ EDGESUP + 0.2384\ (PUMP + 1)^{0.0109} - 0.0340\ DOW^{2.0587} \}$$

This is an example of a typical performance model. This particular model is the JPCP joint faulting model developed as part of the COPES study.

Models are a means to predict performance (in this case, transverse joint faulting) based on known conditions.

They can be used to relate design parameters to performance.

Establishing the Experiment

- Identify variables that effect the development of distresses (e.g. thickness, joint spacing, ESALs)
- May also need to include environmental factors
- Set up a matrix of candidate sections that cover the range of variables

How is a model, such as that shown previously, developed?

See example matrix on page 1-2.4. What's the difference between a full and a partial factorial? It is difficult to fill all cells with existing projects.

Ideally, construct test sections encompassing a range of design criteria. However, this is usually too expensive and time-consuming. Thus, as-built sections are usually used.

Data Collection

- Uniform and consistent measurement system (e.g., if national model is developed from State data, how is traffic reported?)
- Work from same definitions
- Are distresses being measured or recorded from supplied data?

For example, how distresses will be labeled or identified, and how they will be measured or quantified (see *Distress Identification Manual for the Long-Term Pavement Performance Project*).

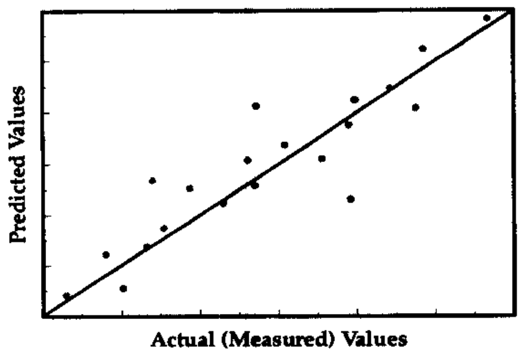
Model Development

- Dependent vs. independent variables
- Selecting the independent variables
- Perform regression analysis
- What do the statistics mean?
  - R^2, SEE, n

Dependent
- Faulting
- Rutting

Independent
- Traffic
- Material properties
- Environmental factors

SEE is sometimes reported as logarithms and can appear to be deceptively small.



Statistics are often provided for models:
- R^2- Measure of the variance of the actual data from the equation (0.0-1.0, with 1.0 best).
- SEE - Standard error of the estimate, a measure of the standard deviation of the data (the lower the better, 0 is best).
- n - Number of samples that were used to develop the model (generally, the higher the n, the more reliable the model).

Inference Space

- Limits of the variables used to develop the model
- Models should not be used to predict performance of sections outside these limits

For example, Figure 1-2.1 (page 1-2.4) uses transverse joint spacings of 4.6 and 9.1 (15 and 30 ft).

A joint spacing of 12.2 m (40 ft) would be outside the limits (inference space) of the model.

The models resulting from the AASHO Road Test were based on limited data. The extrapolation of these models beyond the inference space is a major shortcoming.

Pavement Responses

- Reaction to applied loads
  - Stresses
  - Strains
  - Deflections
- Loads can come from vehicles or environment (moisture or temperature gradients)

Pavement responses are an important component of this course.

Performance has pavement responses implied in it.

Generally, only interested in the critical responses in the pavement system, which can vary depending on the type of pavement and layer configuration.

Stress (σ)

- Force per unit area

$$\sigma = \frac{P}{A}$$

- Units: MPa, psi, ksi
- Types: bearing, shearing, axial

Stresses are generally a concern for PCC pavements, usually the tensile stress since it is much weaker in tension.

Strain (ε)

- Ratio of deformation caused by load to the original length of material

$$\varepsilon = \frac{\Delta L}{L}$$

- Dimensionless
- In the elastic range of deformations:

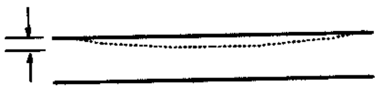
$$\sigma = E\varepsilon$$

Strain is measured as the change in length divided by original length.

Strain is generally a concern for AC pavements.

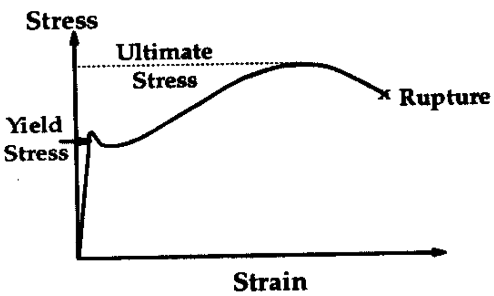
Deflection (δ)

- Change in length
- Deformation
- Units: mm, mils (0.001 in)



Deflections are used for both analyzing both AC and PCC pavements. Deflection measurements are often used to backcalculate the material properties of a pavement system.

Stress-Strain Curve



This is a typical curve for materials and is illustrated in figure 1-2.2 (page 1-2.7).

Pavements are more complex, so curve for pavement materials will look quite different.

Loads applied at less than ultimate stress will usually not cause failure in pavements.

Elastic modulus is stress divided by strain (also the slope of the stress-strain diagram to the point of yield stress).

Critical Locations

- Usually directly under the load
- Usually tension at bottom of layer
- For PCC, slab edges usually critical
- On pavements with discontinuities, must look at discontinuities
- Focusing on these locations reduces the amount of analysis

These are generally locations where distresses begin to develop.

Discontinuities refer to joints and cracks. These locations are often critical due to stress concentrations.

Looking only at the critical locations saves from analyzing every point in the pavement.

Mechanistic Analysis of AC Pavements

- **Based on multi-layer elastic layer theory**
- **Assumptions:**
  - ► Each layer is homogeneous, isotropic, and elastic
  - ► Layers are finite, except subgrade
  - ► Layers are in continuous contact
  - ► All deformations are recoverable

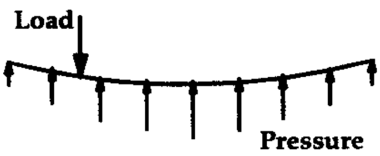
Some models use visco-elastic theory.
- Elastic - no permanent deformation after load release
- Viscous - permanent deformation after load release
- Visco-elastic - combines the two

Deformations are recoverable only in the elastic range.

How many of these assumptions actually hold? What if they are applied to PCC?

Mechanistic Analysis of PCC Pavements

- **PCC slab acts as a beam**
- **A beam on an elastic foundation bends**



Load causes some sort of deformation of the pavement.

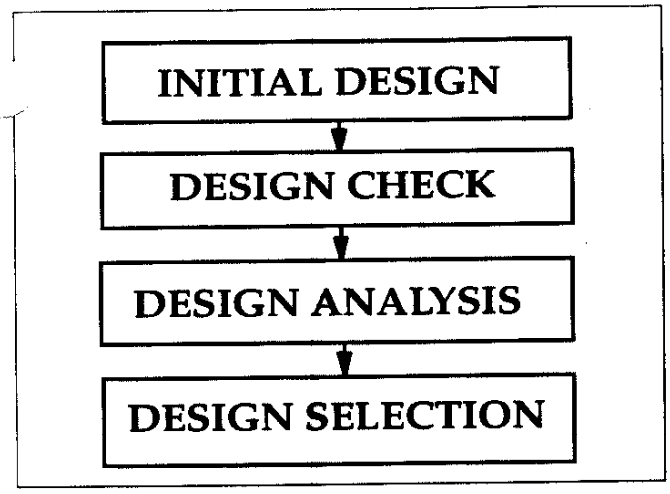
Responses of PCC to load are typically studied using some sort of finite element approach.

Sensitivity Analysis

- **Assess the effect of varying inputs on outputs (usually thickness)**
  - ► Fix all independent variables but one
  - ► Vary the one value over desired range
  - ► Look at effect on dependent variable
- **A graph of relationship is recommended**
- **Such an analysis can be used to study the importance of the inputs**

The sensitivity analysis is an important tool that will be used in this course.

For instance, what is the effect of adding 13 mm (0.5 in) to the slab thickness? Of using a stabilized base?



This is simpler version of the figure 1-2.3 (page 1-2.10). Review the detailed steps of this process with the participants.

We've looked at a number of tools that are used. This figure presents the overall concept of the course. It is an iterative process that will result in better pavement performance.

QUESTIONS?