SIMPLIFIED STRESS ANALYSIS PROCEDURES FOR JOINTED CONCRETE PAVEMENTS

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OBJECTIVES

- Develop an Alternative Procedure to Instantly Calculate Critical Stresses
- Develop a User-friendly TKUPAV Program for Automatic Stress Calculation
- May Encourage Use by Practitioners

RESEARCH APPROACH

- Westergaard / ILLI-SLAB F.E. Solutions
- Results of Actual Field Measurements
- Identification of Mechanistic Variables (Using Dimensional Analysis)
- Development of Stress Prediction Models
- Development of TKUPAV Program
- Conclusions and Recommendations

CLOSED-FORM SOLUTIONS / ILLI-SLAB F. E. MODEL

- Westergaard/Bradbury
  - Loading Only
  - Thermal Curling
  - Loading Plus Curling
- ILLI-SLAB F. E. Model
  - Dimensional Analysis
  - Identification of Mechanistic Variables
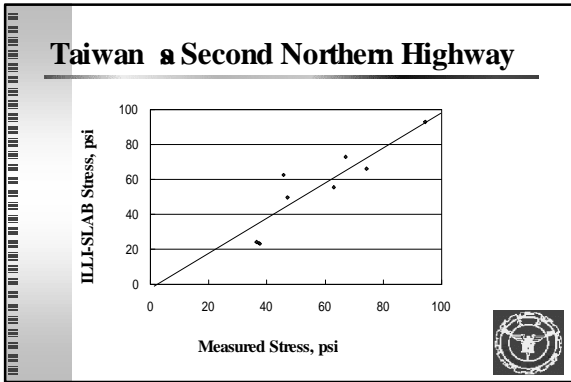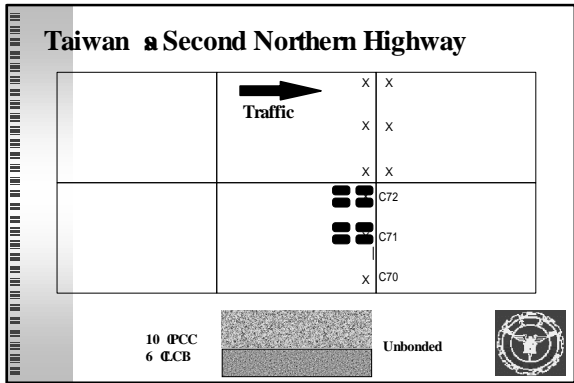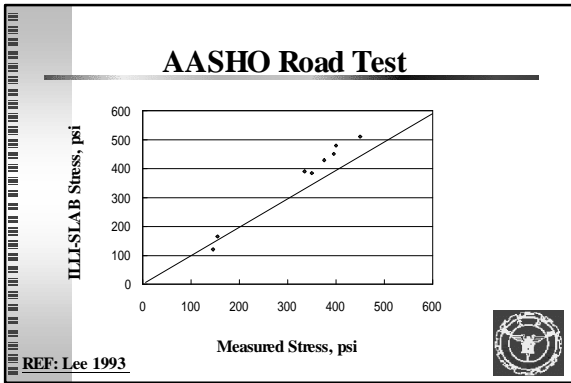

ILLI-SLAB Program

- Originally Developed by Tabatabaie, 1977
- Continuously Revised by Wong, Conroyd, Ioannides, 1980-1985
- Included Curling Analysis by Korovesis, 1986-1989
- Re-Compiled by Lee, 1995 (Microsoft FORTRAN PowerStation)

RESULTS OF ACTUAL FIELD MEASUREMENTS

- AASHO Road Test
  - Edge Stress (Loading + Curling)
- Taiwan s Second Northern Highway
  - Corner Stress (Loading + Curling)
- Compared to ILLI-SLAB Results
- Validated Its Applicability

AASHO Road Test

ILLI-SLAB Stress, psi vs Measured Stress, psi

REF: Lee 1993

Taiwan s Second Northern Highway

Traffic

X X
X X
X X
C72
C71
X C70

10 PCC
6 CB   Unbonded

Taiwan s Second Northern Highway

ILLI-SLAB Stress, psi vs Measured Stress, psi

IDENTIFICATION OF MECHANISTIC VARIABLES

- **Loading Only**
  - Finite slabs Sizes
  - Gear Configurations
  - Concrete Shoulder & Widened Outer Lane
  - Layer Bonded or UnBonded
- **Loading Plus Curling**
  - Positive / Negative Temperature Differentials

Identification of Mechanistic Variables (Loading Only)

Identification of Mechanistic Variables (Loading + Curling)

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DEVELOPMENT OF STRESS PREDICTION MODELS

- **Factorial F.E. Runs Based on the Dimensionless Mechanistic Variables**
- **Two-Step Modeling Approach**
  - **Projection Pursuit Regression (PPR)**
  - **Piece-wise Linear Regression**
- **S-PLUS Statistical Package**
- **Lee & Darter (TRR 1449)**

Proposed Stress Prediction Models

$$\sigma_{cr} = \sigma_w \cdot R_1 \cdot R_2 \cdot R_3 \cdot R_4 \cdot R_5 + R_T \cdot \sigma_c$$

$$\sigma_w = \frac{P}{h^2} \times f_1\left(\frac{a}{\ell}\right)$$

$$\sigma_c = \frac{1}{2} E r \Delta T \times f_2\left(\frac{W}{\ell}\right)$$

$$R_1 \sim R_5, R_T = \text{Prediction Models}$$

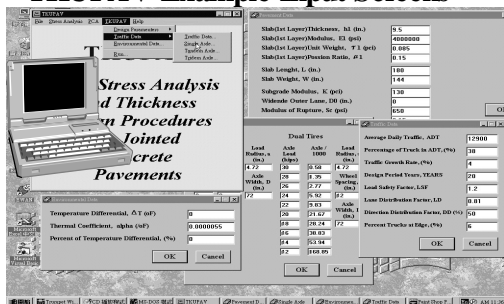## DEVELOPMENT OF TKUPAV PROGRAM

- **Using Visual Basic Program (Ver. 4.0)**
- **Highly User-Friendly Interfaces**
- **Basic Features of TKUPAV Program**
  - **Different Slab Size, Axle Configurations, Material Properties, Temperature Differentials**
  - **Metric and English Systems**
  - **English & Chinese Versions**

TKUPAV Example Input Screens

TKUPAV Example Input Screens

PCA CFatigue Analysis

$$\begin{cases} \log N_f = 11.737 - 12.077 \times SR & SR \geq 0.55 \\[4pt] N_f = \left(\dfrac{4.2577}{SR - 0.4325}\right)^{3.268} & 0.45 < SR < 0.55 \\[4pt] N_f = \text{Unlimited} & SR \leq 0.45 \end{cases}$$

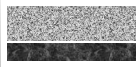$$SR = \sigma / S_c, \quad N_f = \text{Allowable Load Repetitions}$$

Modified PCA Stress Analysis & Thickness Design Procedures (I)

- Calculate Expected Load Repetitions (ni)
- Calculate Modified Equivalent Stress (σ_{eq})

  $\sigma_{eq} = \sigma_{cr} * f_3 * f_4$
  - Loading Only
  - Loading + Curling ($\Delta T > 0$)
- Calculate Stress Ratio (σ_{eq} /Sc)

Modified PCA Stress Analysis & Thickness Design Procedures (II)

- Determine Max. Allowable Load Repetitions (Ni)
- Check Cumulated Fatigue Damage
  Σ (ni/Ni) < 100%
- Repeat Previous Steps, If Necessary

$$D_r = \sum_{i=1}^{m} \frac{n_i}{N_i}$$

CONCLUSIONS AND RECOMMENDATIONS

- **Developed an Alternative Procedure for Critical Stress Estimation**
- **Developed a Highly User-Friendly TKUPAV Program**
- **Modified PCA s Equivalent Stress Calculation & Thickness Design Procedures**
- **Further Verifications & Trial Applications**

ACKNOWLEDGMENTS

THANKS FOR YOUR ATTENTION!

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