ANALYSIS OF LTPP CONCRETE PAVEMENT SECTIONS: JCP&CRCP

Feng Hong, PhD, PE
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LONG-TERM PAVEMENT PERFORMANCE (LTPP) PROGRAM

- Initiated in 1980’s, as part of Strategic Highway Research Program (SHRP)
- Currently under the management of Federal Highway Administration (FHWA)
- Objective: assess long-term performance of in-service pavements under various loading and environmental conditions over a period of over 20 years
- The largest comprehensive pavement database across the world
- Over 2,300 test sections across the U.S. and Canada
  - Over 200 sections in Texas
DATA SOURCE

- LTPP standard data release CD or Website
  - [http://www.infopave.com](http://www.infopave.com)
- LTPP concrete pavement sections in this study
  - 54 sections identified
    - 32 JCP: 23(TX) + 7(OK) + 1(LA) + 1(NM)
    - 22 CRCP: 19(TX) + 3 (OK)
- Data collection
  - Condition: distress, ride quality, deflection, etc.
  - Structure: thickness
  - Traffic: AADT, Loading (ESAL)
  - Environment: freeze-index
  - Maintenance: crack sealing, PDR, etc.
Sections 48-3003, built in 1975, still in service in 2007 (>32 years of life)
JOINTED CONCRETE PAVEMENT

- Section 48-3589, built in 1960, out of service in 2000 (40 years of life)
JOINTED CONCRETE PAVEMENT

- Section 48-4143, built in 1970, still in service in 2011 (>41 years of life)
CONTINUOUS REINFORCED CONCRETE PAVEMENT

- Section 48-5328, built in 1975, still in service in 2012 (>37 years of life)
CONTINUOUS REINFORCED CONCRETE PAVEMENT

- Section 48-5274, built in 1973, AC overlaid in 2000 (27 years of life)
Section 48-3779, built in 1978, still in service in 2012 (>34 years of life)
SERVICE LIFE ANALYSIS

- Determination of service life
  - Termination of service
    - Overlaid
    - Out of service per LTPP designation

- Distribution of service life
  - Observed
  - Unobserved

- Survival analysis
  - Duration models
DISTRIBUTION OF SERVICE LIFE: JCP

All Mean > 30.8 y

Mean = 27.6 y
Mean > 31.6 y

Observed
Unobserved
DISTRIBUTION OF SERVICE LIFE: CRCP

All Mean > 29.3 y

Mean = 30.0 y

Mean > 29.0 y

Life (years)
DATA STRUCTURE

- Non-censored vs. Censored data
SURVIVAL ANALYSIS: DURATION MODELS

- Statistical modeling approach to handle the mix of un- and censored data
- Pavement failure/survival as a stochastic process
  - Failure probability
  - Survival probability
- Hazard function
  - Use Weibull distribution to model hazard
  - Incorporate the affecting variables
    - Traffic: annual average k-ESALs
    - Environment: freeze-index
    - Structure: slab thickness
    - Pavement type: JCP vs. CRCP
### MODEL ESTIMATION RESULTS

<table>
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<tr>
<th>Parameters</th>
<th>Variables</th>
<th>Mean</th>
<th>Stdev</th>
<th>t-stat*</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha_0$</td>
<td>Constant</td>
<td>3.55</td>
<td>8.11E-01</td>
<td>4.38</td>
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<tr>
<td>$\alpha_1$</td>
<td>Avg. Annual ESAL</td>
<td>-5.39E-04</td>
<td>3.27E-04</td>
<td>-1.65</td>
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<td>$\alpha_2$</td>
<td>Freeze-Index</td>
<td>-8.06E-04</td>
<td>1.79E-03</td>
<td>-0.45</td>
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<tr>
<td>$\alpha_3$</td>
<td>Slab-Thickness</td>
<td>5.05-02</td>
<td>9.27E-02</td>
<td>0.55</td>
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<tr>
<td>$\alpha_4$</td>
<td>JCP(Y)</td>
<td>-4.89E-02</td>
<td>2.12E-01</td>
<td>-0.23</td>
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</tbody>
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* The critical value for t-stat is ±1.645 at a 90% confidence level.
SUMMARY

- 4 southern states LTPP concrete pavement sections investigated in this study
- Service life focused
- Statistical analysis conducted
  - In a 20 years service period, survival probability was almost 100%
  - In a 30 years service period, survival probability was approximate 90%
  - In a 40 years service period, survival probability was around 65%
  - Traffic played a significant role in pavement deterioration
  - Freeze-index did not significantly affect life
  - Slab thickness (in a range) did not significantly affect life
  - No significant difference found in lives between JCP and CRCP
- Further study
  - Including more detailed factors, more sections e.g., from PMIS
ACKNOWLEDGEMENT

- Magdy Mikhail, PhD, PE, Texas Department of Transportation
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- Long-Term Pavement Performance Program, Federal Highway Administration
THANK YOU

Contact: Feng.Hong@txdot.gov
SURVIVAL ANALYSIS: PARAMETRIC

- Cumulative density function

\[ F(t) = \text{Prob}(T \leq t) = \int_0^t f(s)ds \]

- Survival function

\[ S(t) = 1 - F(t) = \text{Prob}(T \geq t) = \int_t^{+\infty} f(s)ds \]

- Hazard function

\[ \lambda(t) = \lim_{\Delta t \to 0} \frac{\text{Prob}(t \leq T \leq t + \Delta t)}{\Delta t} = \frac{f(t)}{S(t)} \]

- Use Weibull distribution to model hazard

\[ \lambda(t) = \lambda p(\lambda t)^{p-1} \]

- Incorporating covariates

\[ \lambda = \exp(-X' \beta) \]

\[ = \exp(-(\alpha_0 + \alpha_1 Traffic + \alpha_2 Environment + \alpha_3 Structure + \alpha_4 If _ JCP)) \]
SURVIVAL ANALYSIS: NONPARAMETRIC

- Algorithm: Kaplan-Meier method (product limit formula)

\[
\hat{S}(t_j) = \hat{S}(t_{j-1})P(T > t_j | T \geq t_j) = \prod_{i=1 \text{to } j} \frac{n_i - d_i}{n_i}
\]

Where,

\(\hat{S}(t_j)\) = Survival probability estimate,

\(t_j\) = Ordered failure times,

\(d_i\) = Number of failures, and

\(n_i\) = Number of those exposed to risk
SURVIVAL CURVE: NONPARAMETRIC

[Graph showing survival curve with different durations and survival rates.]