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A realistic resistance deterioration model for time-dependent reliability analysis of aging bridges

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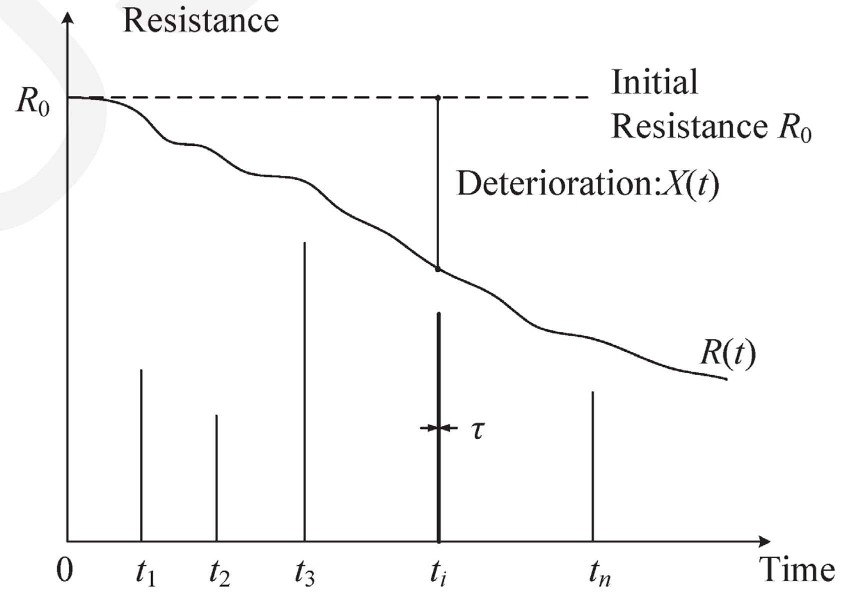
Structural deterioration

- A non-increasing process without rehabilitation or other types of strengthening
- Neither statistically independent nor fully correlated
- Modeling the resistance deterioration process as a Gamma process.



Mathematical model

$$g(t_k) = 1 - \sum_{i=1}^{k} G_i$$

$$Mean[g(t_k)] = 1 - b \times \sum_{i=1}^{k} a_i$$

$$Var[g(t_k)] = b^2 \times \sum_{i=1}^{k} a_i$$

$$\rho_{i,j} = \sqrt{\frac{\sum_{l=1}^{i} a_l}{\sum_{l=1}^{j} a_l}}$$

Notation

$g(t_k)$ is defined as the ratio of resistance at time t_k to the initial resistance R_0.

G_i is Gamma distributed with scale parameter b and shape parameter a_i

$\rho_{i,j}$ denotes the coefficient of correlation between $g(t_i)$ and $g(t_j)$.

Calibration of parameters: Method1

$$a_i = \kappa \cdot (t_i^{\alpha} - t_{i-1}^{\alpha})$$

3 unknown parameters: κ, α and b.

α is determined according to deterioration mechanism, while

$$b = \frac{v^*}{1 - m^*}$$

$$k = \frac{(1 - m^*)^2}{v^* \cdot (t^*)^{\alpha}}$$

given that the mean value and variance of $g(t^*)$ at time t^* are m^* and v^* respectively.

Calibration of parameters: Method2

Aimed at determining a common deterioration function for a specific type of bridges in similar service conditions.

3 unknown parameters:*κ*, *α* and *b*.

- *The estimate of α and bκ are obtained graphically in the coordinates with the abscissa of* $\ln(t_i^*)$ *and the ordinate of* $\ln(1-m_i)$*, where* m_i *is the deterioration function at time* t_i.

- *Then:* $$b = \frac{\sum_{i=1}^{p}(m_i - \hat{m}_i)^2}{(b\kappa)\sum_{i=1}^{p} t_k{}^{\alpha}}; k = \frac{b\kappa}{\kappa}$$

Reliability analysis with the proposed model

- If the deterioration process is treated as fully correlated, the failure probability will be underestimated.

- The square root deterioration process generates the lowest reliability compared with that associated with the linear model and the parabolic model.

- Time-dependent reliability is sensitive to the choice of deterioration type at the early stage of service life and becomes less sensitive to the deterioration type as the service period becomes longer.