# I-11 Serviceability Condition Evaluation of Highway Bridges using Structural Reliability Theory.

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## 1. Introduction

The evaluation of lifetime risk is quite important to ensure a satisfactory safety or serviceability level throughout the life of structures, (Hitoshi Furuta, 1998). Use of structural reliability theory in this manner has been increased during the past decades. The objective of this paper is to describe how structural reliability theory can be utilized in the serviceability condition evaluation of reinforced concrete deck bridges.

Corrosion of the reinforcement is a well-known factor that directly influences the deterioration of the reinforced concrete deck bridges. The chemical and physical phenomena that occur during corrosion are really important to understand in detail, as shown in the work done by Thoft-Christensen (2001). Even though many formulations and models have been introduced or proposed, how it really affects is not much understood yet.

## 2. Methodology

When considering corrosion, numbers of factors are involved, such as when is the corrosion initiated? What types of corrosion products are produced? How much corrosion is needed to form a corrosion crack? What kind of crack size may be accepted? But here in this study it has been considered only reduction in area of the reinforcement.

### 2.1 Reliability Model

The reliability based expression for reinforced concrete deck bridges can be expressed in the following way.

$$M = (A_s)_{current} - (A_s)_{required} \quad (1)$$

In this equation, M is called as the safety margin, $(A_s)_{current}$ is the steel area currently available at the time of consideration and $(A_s)_{required}$ is the steel area required to carry the prescribed load effect on the bridge. This expression can be graphically interpreted as in the Fig. 1 in a 2D plane.

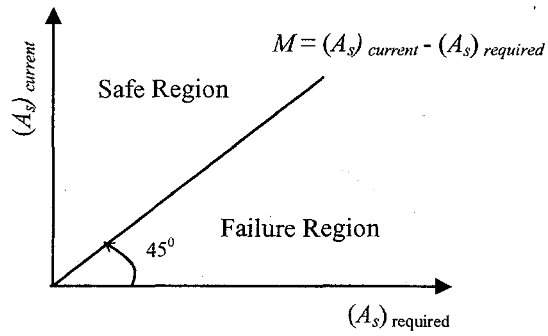


Figure 1. Graphical interpretation of failure and safe region

By considering both random variables as normally distributed, following expression can be presented. This was clearly elucidated by Christensen and Murotsu (1985).

$$(A_s)_{current} \sim N(\mu_{(As)\,current}, \sigma_{(As)\,current})$$

$$(A_s)_{required} \sim N(\mu_{(As)\,required}, \sigma_{(As)\,required})$$

The reliability index ($\beta$) is used as a measure of bridge safety (Ghosn and Frangopol, 1999). It can be found as follows,

$$\beta = \mu_M / \sigma_M$$

It is a measure of number of standard deviations ($\sigma_M$) from mean value ($\mu_M$) to the failure point.

Here, $\beta$ has been expressed by a relationship of reinforcement area. As $M$ is a linearly independent combination of $(A_s)_{current}$ and $(A_s)_{required}$, the above parameters can be taken as,

$$\mu_M = \mu_{(As)\,current} - \mu_{(As)\,required}$$

$$\sigma^2_M = \sigma^2_{(As)\,current} + \sigma^2_{(As)\,required}$$

And there by,

$$\beta = (\mu_{(As)\,current} - \mu_{(As)\,required}) / (\sigma^2_{(As)\,current} + \sigma^2_{(As)\,required})^{0.5}$$

Failure probability $P_f$, which is a measure of to the closeness the failure at a selected time, can be expressed as,

$$P_f = P\ (M \leq 0)$$

Having converted $M$ in to the standard normally distributed variable, a relationship with failure probability with reliability index can be found as in Eq.2 as shown in the work of Christensen and Baker (1982)..

$$P_f = \phi\ (-\beta) \quad (2)$$

### 2.2 Probabilistic parameters for $(A_s)_{current}$

In the determination of probabilistic parameters, $(A_s)_{current}$ at times was found from corrosion measurements of the damaged bridge. However, the modeling of $(A_s)_{current}$ has to be done in a probabilistic way because of it is not a deterministic quantity. Therefore, the exact behavior can fairly be modeled with random variable assumption.

### 2.3 Probabilistic parameters for $(A_s)_{required}$

The $(A_s)_{required}$ represents the actual steel area needed to carry the load effect exerted to the bridge. This can be calculated with the measurements of the actual axle load on the selected bridge site. In measurement of the axle load, pneumatic tube was employed at the bridge site for a period of week and from the data accumulated steel area needed to carry the load effect $(A_s)_{required}$ was deduced. Here, design procedures are mostly based on assumptions. Therefore, the quantity of steel $(A_s)_{required}$ has a fair amount of uncertainty. Fortunately, this uncertainty of steel area $(A_s)_{required}$, could be represented by the parameter called Coefficient of Variation (*COV*).

## 3.Case Study

Single spanned reinforced bridge was selected to apply the failure model presented in this paper.

### 3.1 Considered Bridge

The selected bridge is situated in Naula–Elhera-Kalugaga road (B312) in the national road network of Sri Lanka. The span of the bridge is 9.7 m, the width of the bridge is 6.5 m and with a slab height of 0.15 m. This was constructed in 1975 and the first sign of corrosion appeared to the public in 1995.

### 3.2 Results

From the corrosion measurement, it can be found that $(A_s)_{current}$ has a mean value of $445.71mm^2$ and standard deviation of $40.65mm^2$. With the axle load measurements and using the design codes and guidelines $(A_s)_{required}$ has found to be $277.29mm^2$. To consider the uncertainty *COV* values have been deduced. Generally, *COV* cannot have a large variation and as these procedures are generally accepted guidelines, a maximum *COV* of 0.1 is assumed in this case. Hence, taking three values for *COV* as 0, 0.05 and 0.1, the reliability index and the failure probability have been calculated as shown in table 1.

Table 1. Reliability index and failure probability *COV*

| Coefficient of variation (*COV*) | Reliability Index/( $\beta$ ) | Failure Probability/ ($P_f$) |
|---|---|---|
| 0 | 4.14 | $1.5 \times 10^{-5}$ |
| 0.05 | 3.92 | $4.4 \times 10^{-5}$ |
| 0.1 | 3.42 | $3.1 \times 10^{-4}$ |

## 4. Conclusion

For the first two cases, the failure probability is in the range of $10^{-5}$. For the third case, it is higher than $10^{-5}$. Since the target failure probability for bridges taken as $10^{-5}$, the third case is out of the region. But it is one of the extreme ends to the problem. Therefore, It can be concluded in general, the selected bridge is currently safe for the design vehicle load but it is recommended for assess the condition of the bridge at suitable time intervals in future.

## References

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