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Strategies for Control of Human Errors

Stratégie pour le contrôle d'erreurs humaines

Strategien zur Reduktion menschlicher Fehler

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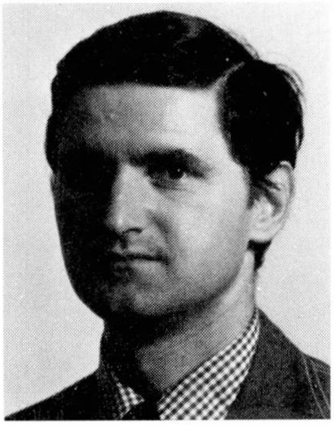

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SUMMARY
An approach to control the effect of human errors is considered. Possible consequences are identified and sensitivity analysis is performed to optimize the control of error causes. A brief numerical example is included.

RESUME
L'article propose une méthode de contrôle d'erreurs humaines. Les conséquences possibles sont évaluées et une analyse de sensibilité permet d'optimaliser le contrôle des causes d'erreurs. Un exemple numérique est présenté.

ZUSAMMENFASSUNG
Ein Vorgehen zur Erfassung der durch den Menschen verursachten Fehler wird behandelt. Mögliche Konsequenzen werden beschrieben und Sensitivitätsanalysen durchgeführt, um die Ursachen von Fehlern in den Griff zu bekommen. Ein kurzes, numerisches Beispiel ist angefügt.

1. INTRODUCTION

Human errors are the major cause of structural failures. This has been indicated by the surveys in Europe and in America. The errors include ommisions, misplacements, misinterpretations, numerical mistakes, poor inspection, etc., in planning, design, detailing, fabrication, construction, and use.

Control of errors is the principal factor determining structural safety.

The basic flowchart is as shown below:

CAUSES ---------→ ERRORS ---------→ CONSEQUENCES

Errors can be controlled through control of causes or consequences (or both). The proposed approach is to identify possible consequences, perform sensitivity analysis, and then optimize the control of causes.

2. CAUSES OF ERRORS

Observations show that errors are an inevitable part of human performance. They are made by planners, designers, manufacturers of materials, contractors, users and occupants. Each phase of the building process may be involved.

Frequency and magnitude of errors may very depending on: motivation, qualification and psychological or physiological conditions.

Most of the errors are detected within the process, in particular by self-checking. The rate of detection depends on checking and inspection systems. Cost of control is related to this rate by the economical efficiency function.

Structural safety, depends on the number and magnitude of undetected errors.

3. CONSEQUENCES OF ERRORS

Errors can be put into categories depending on the answer to the question "What goes/went wrong?". Wrong may be the whole idea (planning), design (overall or some details), construction procedure, quality of material, use or occupancy. The error may affect the structure directly or indirectly.

As in case of causes, there is an infinite number of erroneous ways to realize a structure. However, based on past experience and using engineering judgement the important error consequences can be identified. For example, in a bridge slab cast on steel girders, the possible consequences of error(s) may be deviations from intended strength of concrete, effective depth, amount and grade of reinforcing steel, thickness of concrete cover, or spacing between girders.

The relationship between consequences and structural safety is established by sensitivity functions.

4. APPROACH TO ERRORS

The suggested approach is based on the sensitivity analysis.

Let $Z = g(x_1,\dots,X_n)$ be the limit state function, and $X_1,\dots,X_n$ are the state variables (e.g. loads and resistance). $X_1,\dots,X_n$ are random variables and their distributions are usually obtained from the test data, measurements, or by engineering judgement. For given distributions the structural safety can be evaluated using available methods (reliability index, upcrossing rate, Monte Carlo simulations).

Errors may change the distributions of X_i's. Changed distributions may result in changed structural safety level. In many practical cases the relationships between the safety level and distributions of X_i's can be established.

The sensitivity functions may point to the "sensitive areas" requiring a special error control effort. This, together with the cost analysis, can be used to optimize the whole control system.

The proposed procedure includes the following steps:

1. Develop a model of the considered structure (or its part). Identify the limit state function(s) and state variables.
2. Establish the distribution and correlation functions for the variables.
3. Identify the range of possible variation for the distribution and correlation functions.
4. Develop sensitivity functions relating these distributions and correlations to structural safety.
5. Develop economical efficiency functions relating these distributions and correlations to cost of error control.
6. Distribute the error control effort using sensitivity functions and economical efficiency functions.

5. NUMERICAL EXAMPLE

Sensitivity analysis is demonstrated on a very simple case. Consider a noncomposite steel girder bridge (Fig. 1).

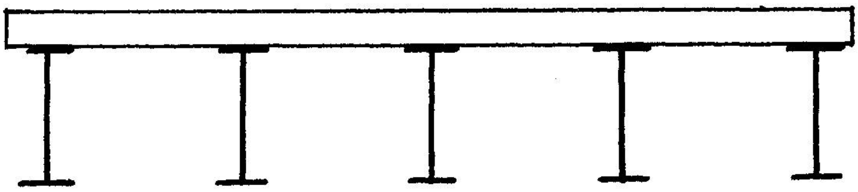

Fig. 1 Cross Section of the Considered Bridge

Girders are designed using Ontario Highway Bridge Design Code with the design equation

$$0.9R = 1.2D + 1.4\ (L + I)$$

where R = moment carrying capacity, D, L, I = moments due to dead load, live load and impact.

The distributions of these variables are given by the ratios of mean-to-nominal and the coefficients of variation, as follows:

	R	D	L	I
mean-to-nominal ratio	1.16	1.05	1.15	.74
coeff. of variation	.10	.08	.11	.45

Assume D ÷ L = 1 ÷ 1 and I = .25 L.

Safety is calculated in terms of a reliability index, β,

$$\beta = \frac{\bar{R} - \bar{D} - \bar{L} - \bar{I}}{\sqrt{\sigma_R^2 + \sigma_D^2 + \sigma_L^2 + \sigma_I^2}}$$

where $\bar{R}$, $\bar{D}$, $\bar{L}$, $\bar{I}$ are the means and σ's are the standard deviations.

Sensitivity functions were calculated for R, D, and L. The results are plotted in Fig. 2.

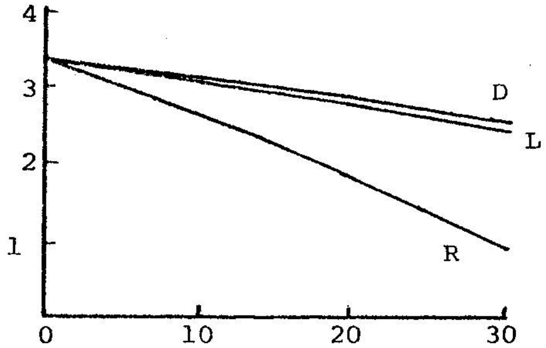

Fig. 2 Sensitivity Functions

Safety is sensitive to errors in R, however not so much to errors in live load. This also means that accuracy in transverse distribution of live load is less important than a correct R.