Safety Standard for Existing Structures

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Summary

A safety philosophy for evaluating and upgrading existing structures is of great value. For a large part of the existing infrastructure and buildings the design life has been reached or will be reached in the near future. These structures need to be reassessed in order to find out whether the safety requirements are met. Not only for new structures but also for the existing stock the Eurocodes are starting point for the assessment of the safety. However, it would be uneconomical to require all existing buildings and civil engineering works like bridges to comply fully with these new codes and corresponding safety levels. The assessment of existing structures differs from the design situation on three main points. Increasing safety levels usually involves more costs for an existing structure than for structures that are still in the design phase. The remaining lifetime of an existing structure is often less than the standard reference period of 50 or 100 years that applies to new structures. For an existing building or bridge structure actual measurements with respect to geometry, material properties and behaviour under normal or design circumstances may be made in order to reduce uncertainty. In the design philosophy both economic arguments and limits for individual human safety play a role. This paper gives guidelines for establishing reliability indices for existing structures.

Keywords: Reliability index; safety, existing, structures.

1. Reliability index for existing structures

β values are derived for two types of decisions: the safety level below which the structure is unfit for use and the safety level for repair. Economic arguments and limits for human safety play a role.

1.1 Economic arguments

ISO 13822 (2003) and ISO 2394 (1998) indicate that the target level of reliability should depend on a balance between the consequences of failure and the costs of safety measures. From an economic point of view the objective is to minimize the total working-life cost. This is shown in Fig. 1.

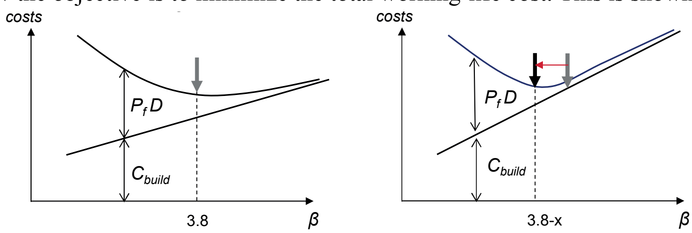

Figure 1: Model for the determination of the reliability from total life costs minimisation, new (left) and existing (right)

The optimum strategy should aim at the target reliability corresponding to the minimum of the sum of the building costs C_{build} and the involved risk $P_f{*}D$ (probability of failure * damage). A linear relation is assumed between the building costs and the reliability index. No discount rate is assumed. The building costs are assumed to consist out of a constant part C_c and a part C_s which is a function of the safety level β. Based on this model, from an economic point of view, the

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difference between the optimum level for the design of new structures and the repair level of existing structures becomes:

$$\Delta\beta_{repair} = \log(C_{s,rep} / C_{s,new}) \quad (1)$$

Depending on the ratio $C_{s,rep} / C_{s,new}$ the possible reduction can be different. Increasing safety levels usually involves more costs for an existing structure than for structures that are still in the design phase; this is the reason that from an economical point of view the required safety level for existing structures can be lower than for new structures. In Fig. 2, the reduction $\Delta\beta_{repair}$ is plotted.

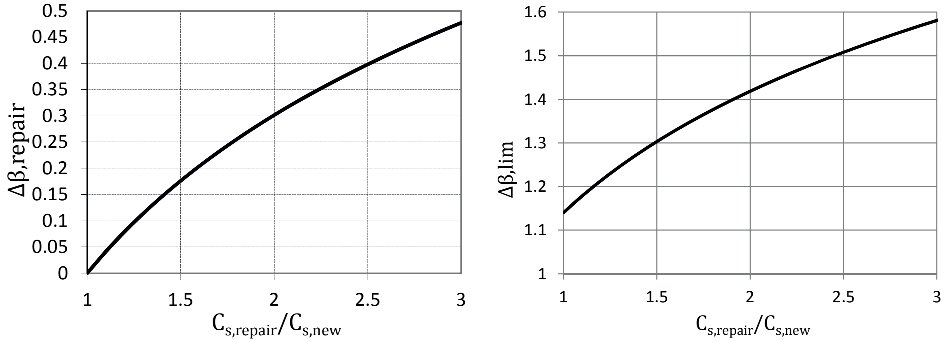

Figure 2: Reduction of the reliability index for the repair-level (left)and the unfit for use level (right)

From an economical point of view, for the lowest allowable reliability index β_{lim} is found:

$$\beta_{new,T} - \beta_{lim,T} = \log\left(2.3\, C_{s,rep} / C_{s,new} * \{ \beta_{new,T} + \log[(C_{s,new} / C_{s,rep}) * T_{rep}] \} \right) \quad (2)$$

Below this level, the structure is unfit for use. The reduction for $\beta_{lim,T}$ is written is terms of the ratio $C_{s,rep} / C_{s,new}$; the reliability index for new structures in the life time $\beta_{new,T}$ and the remaining lifetime after the repair, T_{rep}. It appears that the influence of $\beta_{new,T}$ and T_{rep} is very small. In Fig. 2, as a function of $C_{s,rep} / C_{s,new}$ the reduction $\beta_{new,T} - \beta_{lim,T} = \Delta\beta_{lim}$ is plotted for $\beta_{new,T} = 3.8$ and $T_{rep} = 30$ year. From Fig. 2 it can be seen that independently of the choice of the parameters it holds:

$$\beta_{new,T} - \beta_{lim,T} > 1.0 \quad (3)$$

A conservative and easy rule could therefore be: $\beta_{lim,T} = \beta_{new,T} - 1.0$; in that case no study is needed to establish the ratio between the costs needed for new and existing structures to increase the safety.

1.2 Human safety

Limits for human safety play a role because of the maximum allowable annual probability of failure, which may not exceed the limits for human safety (ISO 2394, Annex E.4). In Fig. 3 the reliability index for human safety is plotted as a function of the life time and the consequence class.

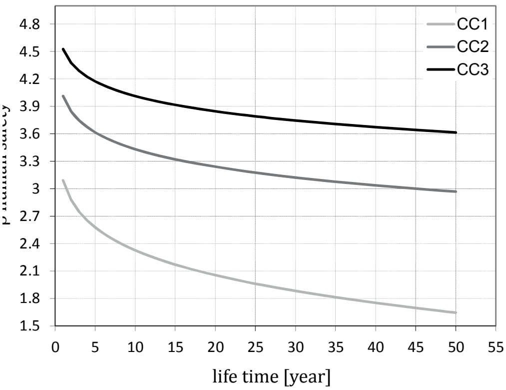

Figure 3: Limits for human safety.

2. Conclusions

For existing structures, lower target reliability levels can be used if justified on the basis of economical considerations. Two target reliability levels have been derived - the minimum level below which the structure should be upgraded (β_{lim}), and the level indicating an optimum repair strategy (β_{rep}). The maximum value from a) the economical optimization (Fig. 2) and b) the requirements for human safety (Fig. 3) should be taken for the assessment of an existing structure.