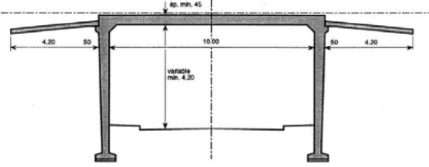
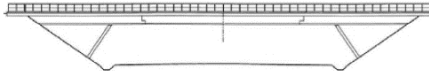
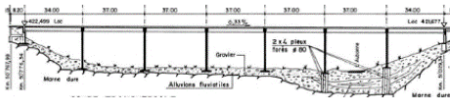


## Exercise 13: Proportionality of maintenance operations

### Background

The aim of this application is to evaluate the proportionality of maintenance interventions. The required safety level was determined for 3 accidental situations involving freeway bridges; the results are given in the following table, with  $\beta_{t0}$  or  $P_{t0}$  describing the required safety level. On the basis of a risk analysis, it was then demonstrated that all three situations of danger have insufficient safety, namely:  $p_f > p_{t0}$ . (with the annual probability of ruin (see following table for "estimated"  $p_f$  for hazard situation). The table in Appendix (next page) gives estimates of the Loss of use and Rehabilitation costs following failure, for the three cases.

Examination situation	Bridge type	$\beta_{t0}$ or $p_{t0}$	$p_f$ [per year].	$C_{int}$ [Mio CHF.]
A. Collapse of the slab following the impact of a truck under the underpass; 3 deaths		$4.2 / 10^{-5}$	$5 \cdot 10^{-4}$	3.0
B. Loss of strength due to corrosion of prestressing tendons (spontaneous collapse) of the deck under the load of a truck; 5 deaths		$4.0 / 5 \cdot 10^{-5}$	$8 \cdot 10^{-3}$	2.7
C. Freeway bridge. Vehicle impact and ruin of barrier; 50 deaths		$4.4 / 5 \cdot 10^{-6}$	$10^{-3}$	0.8

As a result, intervention projects (linked to construction) have been drawn up to restore safety (to achieve the required level of safety):

- A: to improve visibility for the road user and reduce the danger of a truck hitting the underpass slab, the underpass gauge (current height = 4.2 m) is widened by two inclined walls (with crutches to obtain a trapezoidal-shaped opening) and raised by 0.6 m.
- B: the bridge is reinforced (reinforcement with R-UPFRC and bonded CFRP strips, repassivation of reinforcement, new waterproofing with R-UHPFRC, external prestressing, etc.).
- C: the barriers are replaced by new ones with the required strength.

The estimated construction cost for each  $C_{int}$  intervention is also given in the table. This intervention cost is made up of safety costs (which can be attributed to the effective protection of the load-bearing structure) and the costs of restoring durability and structural safety.

**Question:** are these interventions "proportionate"?

## Appendix

Estimated loss of use and rehabilitation costs following failure.

	Loss of use cost  [Mio]	Rehabilitation cost, following failure  $C_w$  [Mio.]
A. Underpass	1.4  (one lane closed for 14 days)	1.2
B. Overpass	1.0  (5 days total closure of highway)	3.5
C. Viaduct	0.05  (traffic restrictions for 1 day)	0.8

**Note: this document is an adapted/amended translation of the exercise 13, lecture notes Prof. Eugen Brühwiler “Structures existantes I : Examen et interventions – Bases”, 2022 edition, course CIVIL-436, courtesy of Prof. Brühwiler.**

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