Load combination

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Summary

A universal theory on combining loads in structural design is missing. The current codes include three methods: dependent, semi-dependent and independent. These methods are mutually contradicting and inconsistently applied: The paper presents arguments that the structural loads must always be combined dependently. The current load combination is unsafe in comparison with the target reliability. In the Eurocodes for instance the safety factors are up to 20 % too low. Before the load combination, the load distributions must be set up to the appropriate design state. In the Eurocodes, the permanent load distribution is set up correctly. However, the variable load is set up wrongly for one-year loads but should be set up for 50-year loads. Therefore the safety factor for the variable load is too low. 50-year failure probability of the Eurocodes should be 1/15000 but it is 1/1000 assuming that the uncertainty is 10 % and the variable load factor is increased ca 10 %.

Keywords: Load combination, code, reliability.

1. Introduction

The load combination is the key issue in the safety factor γ_G, γ_Q, γ_M and the combination factor ψ_0 calculation. The dominant hypothesis is that the loads are combined independently if the loads are independent, dependently if the loads are dependent and other loads are combined semi-dependently. However, the permanent loads are independent but combined always dependently. The permanent load and the variable load are combined sometimes independently and sometimes dependently in the failure state but combined always dependently in the serviceability state. Variable loads are combined usually semi-dependently but sometimes dependently.
An explanation is missing why different combination methods are used. A uniform theory on the load combination is missing.

1.1 Current theory

The basic load combination theory is revealed by MADSEN [1], MADSEN ET AL [2] and TURKSTRA [3]. Much theoretical research is paid to find out how variable loads are combined and how the load configuration impacts on the load combination. The current variable load combination is based on Turkstra's method TURKSTRA [3]. The combination load is the higher load which is obtained when one load is constant and the other load has a random value. In this load combination, the load configuration has no effect.
The theoretical references [1, 2, 3] and references [4, 5, 6, 7, 8] explaining the actual load combination in the code, describe that the loads are stochastic and combined independently. However, this concept is not consistently applied.
No reference explains why permanent loads are combined dependently although these loads are independent?
If there are many loads, e.g. imposed loads of a multi storey house or many permanent loads, the independent load combination results in an unrealistic outcome, as the reliability vanishes. The unrealistic outcome of the independent load combination is recognized in an Eurocode background document: *Imposed loads on floors and roofs* (1990) "The storey-dependent reduction formulas of the code-draft are not scientifically derived…". The current load combination theory does not address this contradiction either.
The references [1, 2, 3, 4, 5, 6, 7, 8] do not address several other significant issues of the load combination:

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