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Factors of Safety for Structural Design

Coefficients de sécurité pour le calcul des constructions

Sicherheitsfaktoren für den Entwurf

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Introduction

Sufficient statistic information on the probability of deviations from mean values of both stress and strength still lacking for the next future, the structural engineer needs a clear and simple method of evaluating adequate factors of safety in design practice.

Factors of Safety Composed of Partial Coefficients

As outlined earlier /1/ the factor of safety has to prevent actual stress from becoming equal to actual strength. Possible deviations from the mean values of both stress and strength assumed in the design calculations can be accounted for by partial coefficients /2/ considering all influences of any importance.

1. Influences on stress:

- (a) loads,
- (b) design calculations,
- (c) adaptability of structure,
- (d) type of failure.

2. Influences on strength:

- (a) strength of construction material,
- (b) workmanship,
- (c) section-size of member,
- (d) type of load.

The partial coefficient characterizing the uniformity of a value has been defined as the possible deviation from the mean for a certain probability $/1/$.

Table I: Partial Coefficients for Structural Design

Group No.	Influence group	Partial coefficient
1(a)	Loads	
	Standardized (dead, live, snow load; wind and water pressure; temperature changes; earth quake acceleration) Non-standardized (earth and ice pressure; air-blast from weapons)	1,0 1,2
1(b)	Design calculations	
	Interpolated from measurements	1,1* (1,0)
	Extrapolated from measurements	1,2* (1,1)
	Not based on measurements	1,3* (1,2)
*) valid for the probable loading combination only, to be reduced for the most unfavorable loading combination to values in brackets		
1(c)	Adaptability of structure	
	Linear systems (1) statically determinate (2) statically indeterminate	1,1 1,0
	Plane and spatial systems	0,9
1(d)	Type of failure	
	With warning (preceding deformations) Without warning (brittle failure or instability)	1,0 1,1

Table I: continued

	Progressive failure	1,2
	Catastrophic consequences	1,3 to 1,5
2(a)	Construction material	
	Steel and aluminum	0,9
	Timber and plastics	0,8
	Concrete	
	(1) ready-mixed	0,7
	(2) mixed-in-place	0,6
2(b)	Workmanship	
	Excellent	1,0
	Average	0,9
	Poor or unknown	0,8
2(c)	Section-size of member	
	Big	1,1
	Average	1,0
	Small	0,9
2(d)	Type of load	
	Static	Introduced as reference or response strength
	Dynamic	
	Vibration	
	Impact	
	Fatigue	
	Effect of (1) time	
	(2) temperature	

With the above values for the partial coefficients K the factor of safety is calculated with formula

$$S = \frac{K_{1a} \times K_{1b} \times K_{1c} \times K_{1d}}{K_{2a} \times K_{2b} \times K_{2c}} \dots\dots\dots (1)$$

Numerical Example

A completely worked example for the reinforced concrete skeleton of a multi-story office-building will explain how the factor of safety is calculated from partial coefficients.

Loads standardized	$K_{1a} = 1,0$
Design calculations extrapolated from measurements	$K_{1b} = 1,2$
Linear system statically determinate (columns)	$K_{1c} = 1,1$
Plane system (flat slab)	$K_{1c} = 0,9$
Failure with warning deformations (flat slab)	$K_{1d} = 1,0$
Progressive failure (columns)	$K_{1d} = 1,2$
Strength of ready-mixed concrete	$K_{2a} = 0,7$
Strength of reinforcement	$K_{2a} = 0,9$
Workmanship average	$K_{2b} = 0,9$
Section-size average	$K_{2c} = 1,0$

(a) Members mainly in bending stress (flat slab)

$$S = \frac{1,0 \times 1,2 \times 0,9 \times 1,0}{0,7 \times 0,9 \times 1,0} = 1,7 \text{ for concrete}$$

$$S = \frac{1,0 \times 1,2 \times 0,9 \times 1,0}{0,9 \times 0,9 \times 1,0} = 1,3 \text{ for reinforcement,}$$

(b) Members mainly in direct stress (columns)

$$S = \frac{1,0 \times 1,2 \times 1,1 \times 1,2}{0,7 \times 0,9 \times 1,0} = 2,5 \text{ for concrete}$$

$$S = \frac{1,0 \times 1,2 \times 1,1 \times 1,2}{0,9 \times 0,9 \times 1,0} = 2,0 \text{ for reinforcement.}$$

References

- /1/ Herzog, M.: Load Factors (Discussion of a paper by E. Torroja) Journal of the American Concrete Institute (Detroit), V. 30, No. 12, June 1959, p. 1390-1392.
- /2/ Herzog, M.: Die praktische Berechnung des Sicherheitskoeffizienten für Baukonstruktionen. Schweizerische Bauzeitung (Zürich), V. 83, No. 12, 25 March 1965, p. 185-187.

SUMMARY

Departing from a definition of its mission the factor of safety is composed of partial coefficients taking into account all possible influences on both stress and strength. Numerical values of the partial coefficients are given for design purposes. The method described is illustrated with a typical numerical example.

RESUME

Partant de la définition de sa mission, le facteur de sécurité est composé de coefficients partiels prenant en considération toutes les influences possibles aussi bien sur les contraintes que sur les résistances. Des valeurs numériques sont données pour les coefficients partiels applicables dans la pratique. La méthode décrite est illustrée par un exemple numérique caractéristique.

ZUSAMMENFASSUNG

Von der Definition seiner Aufgabe ausgehend, wird der Sicherheitsfaktor aus Partialkoeffizienten zusammengesetzt, die alle möglichen Einflüsse sowohl auf die Beanspruchungen als auch auf die Festigkeiten berücksichtigen. Zahlenwerte der Partialkoeffizienten für Entwurfszwecke werden mitgeteilt. Die beschriebene Methode wird mit einem typischen Zahlenbeispiel erläutert.

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